The NanoProject
An assessment of nanotechnology in Denmark

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Abstract –

Nanotechnology is a new field that promises to impact the daily lives of people worldwide. However, the rapidly developing technology poses many uncertainties and may also present some risks. The Danish Consumer Council, a consumer advocacy group, is concerned with the overall lack of knowledge about nanotechnology. Our project team conducted research in Denmark centred on analysing perceptions of thought on nanotechnology including identification of risks and benefits, assessment of the European regulatory framework, and the overall public perception of nanotechnology. We conducted research on site including interviews and a nationwide survey. Results of this research will arm the Danish Consumer Council with the elements essential to inform the public and provide the foundation necessary to construct a plan of action concerning issues related to nanotechnology.

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Executive Summary –

The Danish Consumer Council (Forbrugerrådet) is the primary consumer advocacy organisation in Denmark. Created in 1947 as a housewives association, the Council has evolved into one of the most trusted non-governmental organizations (NGO) in Denmark as well as a formidable lobbying power. In order to effectively advocate for the safety and interests of the Danish public, the Council must be aware of all facets of new products and technologies. In recent years, nanotechnology has moved to the forefront of scientific research with promises of revolutionising the world. Given its myriad of possible uses, the Danish Consumer Council is very interested in this burgeoning yet virtually unknown field. The project team has been asked to identify and determine the public's perception of nanotechnology in order to help the Council more effectively represent the Danish people.

The primary focus of this project was to determine public perception and knowledge of nanotechnology in Denmark. A nationwide survey was sent to the Council's pre-existing consumer panel, and 988 members responded. The second focus of the project was to determine the opinions of individuals who are professionally involved with nanotechnology. Thirteen experts were interviewed to establish a better understanding of the risks and benefits of nanotechnology, the current state of regulation in relation to nanotechnology, and the experts' overall opinions concerning nanotechnology. The list of experts includes two Consumer Council employees, two members of Parliament, several members of academia, individuals working in industry, a representative from Danish Industries, a science journalist, and a social scientist. An interview with the social scientist, who had recently conducted a focus group study on the public perception of nanotechnology, served as a very useful supplement to our own empirical research.

All thirteen expert interviewees were asked the same core questions in addition to any necessary clarifying and probing questions. The interviewee was asked to explain his or her

background as it pertained to nanotechnology and then about possible benefits accompanying the technology. Next, the interviewee was asked to explain any risks or concerns he or she had with nanotechnology, both in general and with specific applications. To conclude the first portion of the interview, the interviewer queried the subject's overall opinions of nanotechnology and its future. The second portion of each interview focused on the regulation of nanotechnology in Europe, and specifically Denmark. Provided the subject had minimal knowledge of chemical regulation, the interviewer proceeded to ask about the adequacy of current legislation as it pertained to nanotechnology as well as how they might change the regulation in order to make it more suitable for nanotechnology. At the end of the interview, each interviewee was presented with three opinions found in scientific literature about nanotechnology regulation and then asked to select the one most akin to his or her own opinion.

The national survey consisted of thirteen questions intended to determine each respondent's opinion of technology in general and specifically nanotechnology. The survey also served to determine the public's knowledge about the benefits, risks, and applications of nanotechnology. This was achieved through questions regarding familiarity with the technology and its benefits and risks as well as a true and false section. Because nanotechnology has such a broad scope, the respondents were asked to select any and all applications of nanotechnology they would consider using given the benefits and risks.

The results of the interviews, survey, and focus group study were all very similar. The greatest concerns were with human health and the environment. Nearly all of the experts agree that free nanoparticles could serve as a great danger particularly if they were to come in direct contact with or be ingested by humans or other organisms. Therefore, nano-products with the greatest perceived risks are cosmetics and foods containing free nanoparticles. The experts' opinions are consistent with the survey results in that most respondents are not willing to use nanotechnology in

food or cosmetics based on information currently available. Experts perceive the greatest benefits resulting from nanotechnology to be in the medical, environmental, and industrial fields. The most prominent examples of beneficial applications are new cancer treatments, more effective drug delivery systems, and environmental remediation applications. In accordance with the beneficial applications of nanotechnology identified by the experts, most of the respondents said that they would likely take advantage of nanotechnology applications in medicine. Nevertheless, the most popular application of nanotechnology amongst the public is in electronics. All of the experts view nanotechnology optimistically as do a large majority of survey respondents.

While the experts are divided about the adequacy of current legislation and the likelihood of it effectively protecting the Danish public from possible nanotechnology hazards, the public seems to put a great deal of trust in the authorities. A majority of survey respondents trust the government to protect them, and the same is true for NGOs like the Consumer Council. The least trusted group are industry, companies and corporations. The public does not trust companies to use the technology safely. Some experts seem to hint at the same idea.

One overwhelming recurrence in the interviews, survey, and focus group is the lack of knowledge about nanotechnology. Several experts mentioned the need to have a clearer definition of what nanotechnology is before moving forward. These same experts also spoke of the need to establish risk assessment and detection methods specifically for nanotechnology. The lack of knowledge about nanotechnology mentioned by the experts was certainly confirmed by the survey respondents as most admitted having little familiarity with or knowledge about nanotechnology.

The first thing that must be remedied if nanotechnology is to have a future is the lack of knowledge and understanding at the expert and consumer levels.. The public should be made aware of what nanotechnology is and what can be done with it thus far. Members of Parliament and NGOs should also be made more aware of nanotechnology's applications, benefits, and risks so as

to be better prepared to engage in public discussions and debates. Additionally, more funds should be allocated to risk assessment and detection research along with development. Lastly, governments should prepare for possible gaps to appear in legislation and be ready to remedy them.

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1.0 – Introduction –

Nanotechnology has become an increasingly popular topic for worldwide scientific research in recent years. Nanotechnology, which defines an extraordinarily broad field of science and engineering, refers to the application of materials or devices that have at least one dimension measuring on the order of nanometres, or one billionth of a meter. Nanotechnology is a very new field, yet its rapid development has already resulted in numerous applications of nano-sized materials in consumer products including electronics, clothing, and health products. Some believe that nanotechnology is, "…a technology which promises to change every facet of people's lives" (Taylor 2006 pp1).

In addition to the many benefits nanotechnology brings to consumer products, there may also be risks associated with its use, many of which are not fully understood. A study done by Rahman et al. showed that when exposed to nanoparticles, rats exhibited inflammation in the lungs (Rahman 1998). Similar respiratory issues may result if humans were to inhale nanoparticles (Associated Press 2006). It may also be possible for nanoparticles to freely enter the human body through the skin because of their small size. This property of nanoparticles may provide innovative means of delivering drugs, but it also suggests that foreign, unwanted nanoparticles will be able to freely enter the human body (Oberdörster 2005).

Understanding the risks of nano-products is important in assuring consumer safety. Most consumers in developed countries expect that the goods they purchase on a day-to-day basis are safe. If there is any controversy regarding the safety of a product, most consumers are at least aware of the issues and are empowered to make a choice. When little is known about the technology integrated into a product however, the consumer loses the ability to make informed decisions and may be oblivious to the consequences the product may have on him or herself, the environment, or society as a whole. Such is the case for nanotechnology because of to its novelty and rapid

development. A study performed in March 2007 by Yale University concluded that over eighty per cent of Americans are unaware of or have heard very little about nanotechnology (Consumer Reports 2007). Nanotechnology has the potential to bring a myriad of benefits to the everyday life of the average consumer; however, if the public does not understand its potential risks or its functions, a feeling of general fear will emerge and the public will likely reject this new technology (Siegrist 2007).

Problems associated with the acceptance of nanotechnology are not new. As humans, it is in our nature to fear that which we do not know. Depending on how consumers perceive risks, nanotechnology may also face the same animosity and distrust that genetically modified (GM) foods and nuclear energy face. "…The breakdown in public trust in [GM foods] occurred not as the result of a particular health or environmental catastrophe, but from a concern that it was being promoted uncritically by governments… at the expense of wider public interest" (Wilsdon 2004 pp18). The knowledgeable public is not only concerned about the known risks of nanotechnology but also possible unpredictable effects. In addition, the public trust that companies and governments will not withhold or obfuscate important information about the risks of nanotechnology (Wilsdon 2004).

As the primary consumer advocacy organisation in Denmark, the Danish Consumer Council sets out to protect the health, safety, and interests of Danish citizens. In order for the Danish Consumer Council to perform its duties effectively, the Council must become aware of the risks and benefits associated with nanotechnology in consumer products. Gauging public knowledge and perception of nanotechnology in Denmark will be vital for the Danish Consumer Council, as will its understanding of the risks and benefits of introducing nanotechnology and nanomaterials to consumer products.

At this time, information on public perception and awareness on the topic of nanotechnology is lacking worldwide. In addition, little information is known about the views of

Danish businesspersons or researchers involved in the manufacturing or importing of nano-products toward the benefits and risks of nanotechnology.

To aid the Danish Consumer Council, we have identified key concerns and examined perceptions of the risks and benefits of nanotechnology in Denmark. This has been accomplished through interviews with researchers and businesspersons involved in the field of nanotechnology as well as government officials associated with nanotechnology regulation. We have examined public perception through the use of national surveys and focus groups. We have gauged public knowledge, identified concerns, and determined the factors that contribute to the public's overall perception of nanotechnology. This information has been compiled and analysed to inform the Danish Consumer Council of the risks, benefits, and public perceptions of nanotechnology so that it may effectively inform the public about the dangers and benefits of nanotechnology as well as advise the government in ensuring public safety.

2.0 – Background –

In order for the Danish Consumer Council (DCC) to properly inform consumers on both the risks and benefits that nanotechnology brings to consumer products, the Council itself must be made aware of how the application of nanotechnology into consumer products may benefit or harm the consumer. This chapter will cover how nanotechnology is being used in consumer goods as well as discuss some of the benefits associated with its use. Additionally, we examine the possible dangers of nanotechnology to both humans and the environment.

This chapter also provides a review of the current regulatory frameworks in both the United States and Europe as they apply to nanotechnology as well as discussion on possible changes needed in order to properly manage nanotechnology. The Danish Consumer Council's goal does not end at merely understanding the benefits, risks, and regulations that apply to nanotechnology. The DCC must pass this knowledge onto the consumer as well as to relevant persons in the government and in companies to ensure that the products people purchase are safe. Thus, we present information on consumer perception of risk, both in general and specifically about nanotechnologies.

2.1 – The History of Nanotechnology in Consumer Products –

The term nanotechnology describes the study and development of technology and materials at the nanometre scale. Nanotechnology is an extremely vast area of study containing many unique applications in diverse areas such as food, medicine, cosmetics, material science, electronics, and surface coatings, to name a few. In order to understand the fundamentals of any application, it is important to first distinguish between nanotechnology, nanomaterials, and nanoparticles. There is a strong tendency amongst the public and even, in some cases, the literature to view the terms nanotechnology and nanomaterial as synonymous with the term nanoparticle (Hansen et al 2007).

Most nanomaterials are not nanoparticles nor does nanotechnology always refer to the study of nanomaterials.

Steffen Foss Hansen et al (2007) found it useful to divide nanomaterials into three categories. The first type of nanomaterial is a bulk material with a particular nano-structure. An example of this type of material is nanocrystalline copper, the strength of which depends on the size of the nanocrystals composing the bulk material. The second is a material that has nano-structure on its surface. Examples of this type of nanomaterial include bulk materials with the same atomic composure throughout, but its surface is in a, nanocrystalline form or a thin film, on nanometres thick, applied to a substrate. The third type of nanomaterial is the free nanoparticle. Nanoparticles could be suspended in liquids, airborne, suspended in a solid, or adhered to the surface of a solid. When people think of nanotechnology or nanomaterials, it is often only this third type that is considered.

Nanomaterials have been used from as long ago as the eighth century C.E. The legendary swords of Damascus, ancient artefacts known for their keen edge and durability, have been found to contain nano-wires and carbon nanotubes that may contribute to their extraordinary properties (Inman 2006). While the weapon smiths did incorporate nanotechnology into their works, they did so unknowingly.

It was not until the twentieth century that people purposefully created nanoparticles, which gave rise to nanotechnology. Richard Feynman, in a talk given at the annual meeting of the American Physical Society at the California Institute of Technology, considered the idea of building machines on the molecular level. He said, "…I am not afraid to consider the final question as to whether… we can arrange the atoms the way we want; the very *atoms*, all the way down! What would happen if we could arrange the atoms one by one the way we want them" (Feynman 1959 pp3).

Harold Kroto, Richard Smalley, and Robert Curl (1985) were the first to observe the formation of nanoparticles. When they vaporised carbon and allowed it to condense, the three observed that the carbon atoms formed into clusters of varying sizes. A majority of the carbon clusters found consisted of sixty carbon atoms and when further analysed, Kroto, Smalley, and Curl noticed that they formed very stable ball-like shapes called fullerenes. Fullerenes are composed of carbon atoms, which form a three-dimensional lattice structure resembling that of a football (soccer ball). The C_{60} fullerene consisting of sixty carbon atoms is the most commonly studied type of fullerene and has been shown to be able to hold various other elements within its structure (Kroto 1985).

As more research was performed in this burgeoning field of science, researchers were able to manipulate carbon atoms to form different structures. By 1991, nanotubes were being fabricated in multilayer sheets and two years later, purer nanotubes one carbon sheet thick were synthesised (Sargent 2006). Nanotubes, like fullerenes, are composed of carbon atoms arranged in an explicit shape, in this case, a hollow tube. Because of the tube-like nature of these particles, the nanotubes may be used to direct or heavily influence the flow of electrons much like semiconductors (Sargent 2006).

Nanotechnology has found a place not only in the scientific community, but in the consumer world as well. Due to the small size of these particles, complexes and structures made from nanomaterials may exhibit properties and functions different from their macroscopic counterparts (Holsapple et al. 2005). The increased surface area of the particles explains the unique properties of nanoparticles. A one-centimetre cube has a surface area of six square centimetres; in contrast, one cubic centimetre of one-nanometre particles has a surface area of 6000 square metres. The enormous surface area to volume ratio of these particles makes nanoparticles highly reactive

since reactions typically occur only on the surface of solids, lending to their unique properties (Bell 2007).

Bowman and Hodge (2003) describe three generations of nanotechnology development. First generation applications, represented by the present state of nanotechnology, include the first scientific tools such as atomic force microscopes and the development of basic nano-compounds for use in electronics, clothing, cosmetics, sunscreen, coatings, and paints. In second-generation applications, many nano-structures will be assembled from nanoparticle subunits. The third generation represents the most creative and imaginative applications of nanotechnology exemplifying complete control over matter at the molecular level.

2.2 – Benefits of Nanotechnology in Consumer Products –

Since its initial discovery, scientific knowledge of the properties of nanomaterials has increased dramatically. The novel properties of nanoparticles have been incorporated as enhancements into many consumer products. The Project on Emerging Nanotechnologies (PEN), a programme established in part by the Woodrow Wilson International Centre for Scholars, has compiled a list of over 500 products currently on the market that claim to use nanotechnology. These products range from tennis balls to computer chips and from khakis to sunscreen. Companies that produce these nanoparticle infused products include popular brands such as Apple, Coppertone and Wilson ("Project on emerging nanotechnologies" 2007). The following sections will provide brief overviews of how nanotechnology has been applied to electronics, clothing, health and personal care, and medicine, as well as the food and beverage industry.

2.2.1 – Electronics –

One of the most extensive users of nanotechnology and nanoparticles is the electronics industry. Seventeen per cent of all consumer products that incorporate nanotechnology involve the use of silicon, a core component of computer chips ("Project on emerging nanotechnologies" 2007). Computer chips can be found in almost every aspect of modern society and represent a 20 billion dollar (100 billion DKK) market (CNN 2007). While seventeen per cent does not seem like a considerable portion of the nanotech market, it is important to note that this percentage does not include products that require the use of nanotechnology in their production such as memory storage and media. Additionally, nanotechnology is incorporated in capacitors, circuitry, and power storage and delivery (Rae 2005).

Since the creation of ENIAC (Electronic Numerical Integrator and Computer) the first computer in 1946, computing power has increased dramatically. A modern cell phone that can fit in the palm of one's hand has more computing power and is more efficient than the 27,000 kilogram ENIAC that took up over 450 cubic metres. The drastic miniaturisation and increase in power is due to the ability to shrink computer chips. Billions of transistors, small gates that allow or impede the flow of electrons, are etched onto silicon chips to create the brains of modern computing. Through the use of low wavelength light, transistors that are a mere 65 nanometres (nm) in size may be etched onto a silicon chip (Sargent 2006). Billions of these small transistors are etched onto a single computer chip, resulting in computers that are smaller, more powerful, and more efficient than their predecessors.

Data storage also incorporates nanotechnology into its products. Blu-Ray discs can store over 50 gigabytes worth of data on a single disc, over 10 times more than a DVD and 50 times more than a conventional CD. Storage media consist of a disc with microscopic pits etched into a substrate layer. When the discs are read, a laser is passed over the surface of the disc and the

absence or presence of a pit will return either a 1 or a 0 value. The red lasers used to read CDs and DVDs can detect pits ranging from 650-780nm. By utilising blue lasers to read media, Blu-Ray manufacturers are able to incorporate the use of pits approximately 300nm in diameter, allowing a disc to contain more pits and store more information (Blu-Ray Disc Founders 2004).

2.2.2 – Clothing –

Nanotechnology has also found uses in the textiles business. Over 64 million tons of textiles both natural, such as wool and cotton, and synthetic, such as nylon and polyester, are produced yearly, representing a 200 billion dollar (1 trillion DKK) market (Holme 2007). Nano-sized polymers have been incorporated into fabrics to give them novel properties such as stain resistance or unique moisture wicking properties (Holme 2007). The nanoparticles are not incorporated into the thread itself. Rather, the fabric is treated with the particles in such a way that they are able to self assemble onto the surface of the fibres, forming an incredibly thin layer over the surface. This monolayer is typically less than 50nm in thickness and permanently bonded to the fibres (Rodie 2007). Stain resistance is imparted onto fabric by creating an ultra hydrophobic surface on the fabric that forces the liquid to bead up and roll off the fabric rather than seep into it. Nano-Care, a stain resistant cotton fabric produced by Nano-Tex LLC is created by adhering 10nm sized molecules of fluorinated carbon monomers which are then polymerised onto the fabric (Holme 2007).

2.2.3 – Health and Personal Care –

Consumer health and personal care products have also adopted the use of nanotechnology and nanomaterials. Nanotechnology may be incorporated into sunscreens, cosmetics, as well as for medicinal purposes. Sixty-two products have been identified as health and personal care products applying nanotechnology (Maynard 2005). This number does not take into account the various

products that are still in development. Additionally, there are numerous medical applications, which we describe in the following section.

To protect against the dangers of sun overexposure, a variety of cosmetics and sunscreen lotions have begun to incorporate ultra-fine particles of zinc oxide (ZnO) and titanium oxide (TiO_2), the active ingredients in UV protection, into their products; the particles range from 80nm to 100nm in size (Morfesis 2005). The particle's size improves upon previous sunscreen products by increasing the performance of the sunscreen as it allows for more even distribution. Additionally, the sunscreen is clear when applied to the skin rather than an opaque white colour. While this aesthetic characteristic does not provide any advantageous properties to the sunscreen, it is a marketable property that would give it an advantage over older generations of sunscreen (Morfesis 2005). Similarly, nano-emulsions of either water in oil or vice versa have proven particularly useful in the formulation of cosmetics. The small particle sizes, often below 200nm, allow for a viscous, clear substance, properties that cosmetic companies find particularly attractive. The nanoparticles are more stable than their larger counterparts because they can resist sedimentation and creaming, two major problems associated with oil-water based emulsions (Solans 2005).

Silver has been found to have antimicrobial properties on the nano-scale. Because of this property, silver nanoparticles have been used to imbue products with antimicrobial characteristics. Among the products containing silver ions are bandages, clothing and keyboards. Research has shown that silver nanoparticles (Ag^+) serve as an excellent bactericide. It is thought that Ag^+ inhibits microbial replication and cellular proteins. The positively charged silver ions are attracted to the negatively charged outer membrane of bacteria. The interaction between the silver particles and the cell membrane results in damage to the cell membrane. Sondi and Sondi (2004 pp181) observed,

> …Treated bacteria show significant changes in and damage to membranes, which are recognised by the formation of "pits" on their surfaces… this morphology exhibits a significant increase in permeability, leaving the bacterial cells incapable of properly regulating transport through the plasma membrane and finally causing cell death.

Because negligible amounts of silver will be lost after continuous use, silver nanoparticles are used as a permanent method to instil antimicrobial properties to a plethora of consumer products.

2.2.4 – Medicine –

Nanoparticles are finding great potential in medicine. Surgical tools such as scalpels may be imbued with sharper cutting edges by honing the blade of the scalpel down to a few molecules in thickness. Nanotechnology may also be used as a way to administer drugs without needles. Instead of a large needle, a transdermal patch consisting of hundreds of needles a few microns in length would be used to pass the drug through the top layers of skin. No pain will be experienced because the patch does not penetrate deep enough to trigger nerve responses (Morrow 2004) Additionally, studies have been conducted on the use of nanoparticles in bio-imaging and diagnostics, drug delivery, and even as a possible new method by which to treat cancer patients.

Medical professionals, in diagnosing patients as well as in medical research, use imaging. By using fluorescently labelled bio-particles, scientists can track the movements and aggregation of these particles at possible problem sites. Nanoparticles, specifically quantum dots, may be used as a replacement for the fluorescent dyes and proteins currently used for labelling. Quantum dots are small nanoparticles that resemble semiconductors with an excited electron bound within it. When exposed to certain wavelengths of light, the quantum dot will fluoresce. What makes a quantum dot unique is the ability to vary its fluorescent absorption based on size and composition even when exposed to the same wavelength of light, making it highly versatile. Quantum dots may be used as probes by covalently attaching them to bio-molecules such as proteins and antibodies. A study done with mice fibroblasts (tumour cells) showed that nanoparticle labelling behaved better than conventional dye methods (Bruchez 1998). The quantum dots showed better resolution, stability,

and penetration. Additionally, while both conventional methods and quantum dots may be used in *in vitro* studies, only emissions from quantum dots were observed when used *in vivo*; the emission wavelengths of the quantum dots could be shifted away from the auto-fluorescence, the natural fluorescence of skin (Gao 2004).

Novel methods of drug delivery utilising nanoparticles are also being studied by scientists and doctors alike. Drugs can be encapsulated within specially designed nano-scale spheres resembling fullerenes with properties that would allow them to bypass the body's immune responses (Wilkinson 2003). Therapeutic molecules may be encapsulated, covalently attached or absorbed onto nanoparticles, which serve as carriers. These nanoparticles range in size from 2 to 250 nm in diameter, and they can serve many purposes, one of which is mentioned above. They also help increase the solubility of drugs, allowing them to more effectively dissolve in water (Moghimi 2005). Furthermore, the use of certain nanoparticles as drug carriers may provide for site specificity, allowing the drug to be delivered to where it is needed, thus improving its effectiveness (Gwinn 2006).

Cancer treatment and therapy methods may be improved by applying nanotechnology. In addition to the use of nanoparticles as carriers for drugs such as those used in chemotherapy, nanoparticles themselves may be used as a way to eradicate tumours. A current method of cancer treatment involves using hyperthermia to inactivate the tumour. By using a near infrared laser, tumours could be killed without invasive and dangerous surgeries. The problem is that with conventional methods, the laser has no way of distinguishing between healthy and cancerous tissue and success has been modest. By using gold-coated nanoparticles, the effectiveness of this approach has increased dramatically. The nano-shell is very effective at absorbing and converting the near-infrared light to heat. Compared to indocyanin green, a conventional dye, the nano-shells have an absorption cross-section six orders of magnitude larger than the dye. These particles, 60 to 400nm

in size, accumulate in tumours and convert the light to heat energy, causing irreversible heat damage to tumour cells (O'Neal 2004). While still in the earliest phases of development, nanotechnology and nanoparticles show great promise in the field of medicine.

2.2.5 – Food and Beverages –

Nanotechnology may even be applied to improve the quality and shelf life of foods and beverages. As with numerous other antimicrobial applications, silver nanoparticles may be applied to meat packaging, allowing for a longer shelf life (Siegrist, Cousin, Kastenholz, & Wiek 2007). Nanoparticles may also be used to coat fruits and vegetables to protect them from humidity and oxygen, two factors that lead to over ripening and rotting (Siegrist, Cousin, Kastenholz, & Wiek 2007). By allowing for long shelf life, fruits and vegetables may be collected when they are ripe rather than waiting for them to ripen on the shelves. Nanoparticles could be used to encapsulate vitamins and other nutrients that the body may uptake with greater ease (Siegrist, Cousin, Kastenholz, & Wiek 2007).

Water filters are yet another product group that benefits from the integration of nanotechnology (Savage 2005). Hollow carbon nanotubes may be used to fabricate extremely fine filters, shown to be very effective at removing both bacteria and viruses from water. Studies have also shown that some nanoparticles can absorb free metal ions in water while others have proven effective in neutralising organic contaminants.

2.2.6 – Other Applications –

Nanotechnology has also been applied to other consumer products. Sports equipment is one such example. Certain tennis balls and racquets produced by Wilson and Babolat, respectively, incorporate nanotechnology. To increase the durability of standard tennis balls, Wilson coats the

balls with a compound that prevents deterioration. Babolat's VS Nanotube racquets incorporate nanotubes into the head of the racquet allowing them to produce a very powerful, yet very lightweight racquet (Cronin 2004).

Batteries incorporating nanotechnology are also under development. Studies have shown that by using smaller, nano-sized particles in lithium ion batteries, the batteries will be able to sustain more recharge cycles as well as have a higher output (Panero 2004). Nanotechnology is still a rapidly developing science, and as scientists understand more about the nano-scale world, nanotechnology and nanoparticles may be applied to an increasing number of consumer products.

2.3 – Risks –

While much is known about the beneficial aspects of nanotechnology, little is known about the risks that this new technology may have on human health and the environment. Despite all the funding for nanotechnology research, over 1 billion dollars (5 billion DKK) in 2005, only a small fraction of the funds, around 11 million (55 million DKK) have been used to conduct relevant research on risks associated with nanotechnology (Maynard 2006). Nonetheless, researchers have found that certain applications of nanotechnology may pose health and/or environmental risks.

2.3.1 – Health –

One of the major causes for concern about nanotechnology is the fact that nanoparticles are extremely small (Ryman-Rasmussen et al. 2006). Their size allows certain particles to freely diffuse through the skin or cell membranes when their larger counterparts would be easily stopped. Research conducted on porcine skin showed that nanocrystals ranging from 4.6 to 12nm in diameter topically applied to the skin diffused through the epidermal layers of the skin in significant amounts over the period of an average workday (Ryman-Rasmussen et al. 2006). The tests do not definitively

show risks of nanoparticle diffusion through the skin and into pulmonary system, but the nanoparticles do have a negative effect on the skin cells.

Similarly, a decrease in human skin cell viability, its ability to survive and divide, was shown to occur in epidermal cells containing multi-walled carbon nanotubes in the cell cytoplasm (Ryman-Rasmussen et al. 2006). It has also been shown that once the particles have diffused into the skin, it is possible for the nano-scale particles to be carried throughout the body via the lymphatic system (G. Oberdörster 2005). While this might have medical applications as mentioned above, it also means that harmful nanoparticles may be able to diffuse through the skin and then spread throughout the body.

Respiratory invasion by airborne particulates is a common source of illness and due to their small size, nanoparticles, like other airborne pollutants, are expected to cause similar respiratory responses (Gwinn 2006). There is a clear correlation between increased air pollution and negative health effects within the population. Ultra fine particles, such as nanoparticles, invoked a higher inflammatory response in studies performed by Gwinn and Vallyathan. The increased stress may be attributed to the fact that the smaller particles have more surface area per unit volume, thus allowing for greater interactions between the particles and various cellular structures (Gwinn 2006). A study performed on laboratory rats showed that exposing the rats to ultra fine titanium dioxide (TiO_2), the same particles used in certain sunscreens, caused increased inflammation and stress on the lungs as well as an increase in highly dangerous reactive oxygen species which may lead to cell damage or death (Afaq 1998).

2.3.2 – Environmental –

Release of nanomaterials into the environment, either through the disposal of consumer products or through accidental release may have a serious impact on the ecosystem. For example, cerium dioxide (CeO_2), a nanoparticle that may enhance the combustion of gasoline is a very reactive oxidant; when released into the environment, it may change the chemistry of soil, water, and organisms, possibly causing serious damage to the local ecology (Guzman 2006).

Just as nanoparticles might lead to serious health problems in humans, nanoparticles may damage other organisms as well. Water pollution caused by accidental or careless release of nanoparticles may lead to disastrous effects on wildlife; because of their small size, nanoparticles are very hard to filter out of water. C_{60} fullerenes, manufactured in tons per year have been shown to cause excessive damage to aquatic wildlife. A study using largemouth bass showed the presence of fullerenes in the brain after merely two days of exposure to the C_{60} fullerenes suspended in solution. The presence of fullerenes, a strong oxidant, caused oxidative damage to the brain of the largemouth bass (E. Oberdörster 2004).

Because nanotechnology research has only recently been focused on possible health and environmental risks, little is known about the health risks that nanoparticles in consumer products may pose or the environmental impacts from their manufacture, use, and disposal. Due to the fact that nanotechnology is such a new field and the complexity of conducting ecological studies, even less is known about the possible environmental effects. The uncertainty and overall lack of knowledge of the risks involved with the use of nanotechnology has lead to heated debates over how it should be regulated.

2.4 – Public Perception –

People tend to form opinions and perceptions in subjective ways. Social scientists like Chauncey Starr, in 1969, attempted to quantify public perception, claiming that acceptability of risk could be mathematically calculated from the benefits of a given activity (Slovic 1992). However, more recently others have claimed that it is impossible to exactly quantify public perception, for humans are very complex organisms, forming opinions based on such factors as social cues, values, and bias. This section explores how certain aspects of perception may influence the public's views and acceptance of nanotechnology.

2.4.1 – Dread, Trust, and Social Amplification –

Paul Slovic has done extensive work in the field of public perception, particularly looking at public dread. In his early studies, Slovic noticed that scientists and technologists made decisions regarding risk based on facts, for example the annual death rate due to a new product or technology. Laypersons' formulation of risk perception completely juxtaposed that of the experts. Their evaluation of risk was derived from a variety of other factors, including: the ability to control the substance or product, potential of a catastrophic event resulting, as well as harm to future generations. That is not to say that the general public was not aware of facts. On the contrary, many were able to estimate the annual death rates and other such figures with surprising accuracy (Slovic 1992).

Two other factors Slovic found to greatly impact public perception are familiarity with and knowledge about the technology or event. Slovic's research shows that numerous deaths resulting from a familiar act, such as a car crash, have a less drastic effect on society than very few deaths resulting from a new technology, like an experiment with recombinant DNA (Slovic 1992). When

he probed into the reasons for this phenomenon, he discovered that most people took the few deaths or even a single death from a new technology as a sign of catastrophes and problems to come, which he classified as dread. Reputable scientists tend to view events objectively and therefore find the perceptions, particularly those involving new technologies, of most laypersons to sometimes be irrational (Slovic 1992).

Trust is paramount when the public forms opinions about technology (Slovic 1992). An interesting example of this is the public's perception of medicines versus chemicals. Most perceive very few risks with medicines because they are prescribed and controlled by medical professionals, who are generally endowed with a high level of trust. When it comes to chemicals, which are usually controlled by corporations or the government, the public perceives many risks. The public categorised chemicals as poisons; however, medicine can be just as poisonous and lethal if taken at the wrong dose (Slovic 1992). Harry Otway's research showed that the credibility of the institution handling the technology or substance is a crucial part of public perception (1992). Otway also discovered that the public consider many experts to be "overconfident and reluctant to change their views," (pp218) which has a definite effect on the acceptance of technology by the public (Otway 1992).

Roger E. Kasperson has done thorough research into the effects of social amplification on public perception. Kasperson's theory states that events dealing with hazards are not isolated events but rather interact with cultural, psychological, social, and institutional processes, thereby intensifying or lessening risk perception. It is these complex interactions that cause indirect effects such as a loss of trust and confidence in an institution, either companies or governments. According to Kasperson, these indirect effects act much like the ripples on a lake when a pebble is dropped into it, starting with the direct effects on the actual victims of a certain event and emanating out to encompass more peripheral subjects, like companies, by way of social groups and social

amplification (Kasperson 1992). These various cultural or social groups of which everyone is a member help to determine the dynamics and social processing of risk. Individuals form opinions and make decisions based on the personal beliefs as well as bias and cues presented by the group (Kasperson 1992).

2.4.2 – Current Perceptions of Nanotechnology –

Numerous psychological studies have been performed in recent years in an attempt to determine public perception of nanotechnology specifically. A number of these studies compare the American public with the European public, and the results have surprised quite a few people. One common result among the studies is the fact that Americans are generally more optimistic about science, meaning they perceive more benefits than their European counterparts despite also admitting to not following science (Siegrist, Cobb and Macoubrie 2007). When asked if they expect nanotechnology to improve their lives, 50% of Americans said yes, but only 29% of Europeans were of that opinion. Similarly, 53% of Europeans and only 35% of Americans surveyed were unsure as to whether or not nanotechnology would actually improve their lives (Gaskell 2005). While Americans seem eager to be on the forefront of this latest technology, seeing science as a means of progress, Europeans have taken a "wait and see" approach to nanotechnology in general and particularly regarding nanotechnology. These differences are due to the varying concerns of the public. Europeans are more worried about the environmental and health related risks (Gaskell 2005) whereas Americans are more concerned with "losing personal privacy to tiny new surveillance devices" (Cobb 2004 pp395).

Most studies exploring public perception of nanotechnology have dealt with nanotechnology as a whole rather than dealing with its many varied applications. Siegrist, Keller et al. (2007) found that the manner in which nanotechnology is applied likely affects public perception, that is to say

that the level of dread varied based on how nanotechnology would be used. The results coincided with Slovic's (1992) data showing differences between public perceptions of medicine versus chemicals. In general, people are wary of nanotechnology in foods or medicine or other ingestible items. Therefore, M.E. Cousin's team (2007) conducted a survey to explore public perception of nanotechnology in food and food packaging. There are already foods and nutrition products with "nanotechnology additives" available to the consumer, yet most of the people surveyed said that they would rather not buy such products (Siegrist Cousin et al. 2007).

One barrier for companies producing consumer goods with nanotechnology is the fact that their benefits are not always obvious to the consumer. This seems to be a factor that affects risk perception. Research has shown that benefits must be very clear and outweigh the risks in order for a new technology to be successful in the public eye (Siegrist Keller et al. 2007). For example, functional foods promise improvements to specific physiological functions, but consumers will not always be able to quantify these improvements. Therefore, a level of trust must be established between the consumer and food industry, a task which will not likely be easy considering the current opinions of Americans towards industry (Siegirst Cousin et al., Cobb 2007, 2004). Data from Siegrist's study showed that even if the public is made aware of the benefits of nanotechnology in food products, it might not be enough to persuade them to buy such products. The decision will also hinge on the "naturalness" of the food. This means that the more natural a food item is expected to be, the less likely the public is to buy a version that has been genetically modified or altered with nanotechnology (Gaskell 2005). "Applications in the food and health domains are most likely to become controversial topics" (Siegrist Keller et al. 2007 pp66) because they are influenced by the surrounding social, economic and political situation (Siegrist Cousin et al. 2007). It has been suggested that in order to avoid negative repercussions, "nanotechnology food industry should promote voluntary initiatives and regulations" (Siegrist Cousin et al. 2007 pp464).

Emotions and the media also play a large role in deciding nanotechnology's fate. Recent findings show that people generally depend more on what they *hear* about technology than what they actually *know* about it to make evaluations (Cobb 2004). Thus far, not much has been reported in the media concerning nanotechnology, and its applications, risks, and benefits will likely play a major role in future decision making. Gaskell performed a comparison of content in the *New York Times* and the *London Independent*. His research showed that although both newspapers have recently been reporting more information about nanotechnology, the *Independent* has reported more about the risks than the *Times*, which has consistently reported more about the benefits of nanotechnology. This information directly correlates with Gaskell's survey about public perception. Americans are more optimistic about nanotechnology than their European counterparts.

Understanding the risks and benefits, regulation, and public perception is tantamount to successfully assessing the current state of nanotechnology in Denmark. The information provided in this chapter serves as a foundation for the research we have conducted. The background research exposes key issues that need to be further explored over the course of this project. The three topics covered in the preceding sections will be further examined in relation to Danish society. The following chapter describes the methods by which this information was gathered.

2.5 – Nanotechnology Regulation –

In this section we will provide an overview of the regulatory frameworks for chemicals and consumer products in both the United States and European Union. Additionally, this section will provide some opinions on the effectiveness of current systems and ideas about how, if at all, nanotechnology could be more effectively regulated.

2.5.1 – The American Regulatory Framework –

In the United States, there is no regulation or legislation specifically geared toward nanotechnology. As it stands, the vast majority of regulation applicable to nanotechnology is implemented through the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA) (van Calster 2006). The EPA primarily focuses on the safety of specific chemicals with respect to the risks associated with each chemical's exposure to the environment and anyone who may come in contact with it, including researchers and manufacturers. The FDA focuses more on consumer products such as foods, drugs, drug delivery systems, vaccines, and cosmetics (FDA 2008). These two agencies are the chief regimes responsible for ensuring the safety of nanotechnology in consumer products in the United States.

The EPA's ability to assess the safety of nanomaterials lies primarily in the framework established by the 1976 Toxic Substance Control Act (TSCA). The TCSA is all encompassing as it defines a chemical as "any organic or inorganic substance of a particular molecular identity." Nanoparticles and materials appear to fall under the jurisdiction of the TSCA. Companies intending to manufacture a new chemical or a chemical for a "significant new use," unless that chemical qualifies for an exemption, must submit a pre-manufacture notice (PMN) to the EPA at least 90 days before the chemical is manufactured (Wardac 2006 pp13):

> The EPA takes this time to determine the safety of the chemical substance prior to its manufacture. This is done through procedures outlined by the EPA. In the PMN process, the burden of proof is on the manufacturer. They must provide the information they possess concerning the chemical's toxicity and other such data.

Based on this review, the EPA determines whether it is necessary to regulate the manufacture of a chemical. The EPA can limit and even ban the production of a chemical based on actual or potential risk (Wardac 2006).

There are four exemptions to the TSCA that would allow chemicals to bypass the EPA approval process. The first exemption is the research and development exemption. New chemicals are synthesised all of the time for research and development purposes. The research and development exemption allows companies to bypass the PMN process if they fulfil certain requirements. The two most notable requirements of the research and development exemption include five years of record keeping after a substance is developed as well as written notification to whom the substance is distributed (Wardac 2006).

There are three more exemptions for *non*-research and development manufacturers. First is the low volume exemption, whereby the chemical may be exempt if it is produced in quantities of less than 10,000 kilograms per year. Second is the low release and exposure exemption, whereby the chemical may be exempt if it does not pose the risk of dermal or respiratory exposure to workers and consumers or any potential to be released into ground water or landfills. The last case for exemption is test marketing. Test marketing involves distributing a predetermined amount of the chemical or material containing the chemical to a specified number of customers for research into market acceptability (Warduc 2006). These exemptions are mainly to keep from hindering the advancement of technology, however, no exemption should result in harm to society or the environment.

The FDA's approach to regulating the products of nanotechnology is similar to that of the EPA in that new products must be approved before they are allowed to reach the market: "The FDA paradigm for regulation of these products is based on the concepts of 'risk management', i.e. risk identification, risk analysis, and risk control" (FDA 2008). FDA regulation is conducted on a product-by-product basis. The process begins with pre-market approval wherein the manufacturer of the product must address the risks associated with the given product and how they will be minimised in the product's application. FDA staff then review the product assessment and

determine if any regulation is necessary before the product is introduced to the market. This process is also usually accompanied by an inspection of the plant where the product is manufactured. Once the product is approved, the FDA must receive notice that the product is to be marketed. The FDA then reviews the product and makes sure that all products are prepared according to existing specifications and regulations. After the first two stages are passed and the product is introduced to the market, the FDA engages in post market surveillance. The FDA states that it keeps a close watch over products under its jurisdiction and may take regulatory action if any product presents serious health risks (FDA 2008).

2.5.2 – The Regulatory Framework of the European Union –

While Denmark has its own environmental protection agency, the European Union (EU) generally handles regulation of technology to ensure that policy throughout the Union is homogenous. The Danish EPA is concerned more with implementing and enforcing EU regulations. The European Union, to date, has imposed no regulations specific to nanotechnology. The European Union does not have an FDA equivalent. Instead it carries out regulation through the many regimes operating as part of the European Commission, an organisation that handles regulation policy for the European Union. There is, however, a chemical regulation system comparable to the American Toxic Substance Control Act (van Castler 2006). Historically, the European framework for regulating new chemicals has not been as effective as the system in the United States. But Geert van Calster describes the chemical regulation system of the European Union and the proposed change, stating:

> Europe's *legislation on chemicals* is notoriously dense, and ineffective from an environmental and public health point of view. Co-ordination and improvement of the public health and environmental aspects lie at the heart of the current, longwinded drive to change the regime. The regime change goes under the acronym of REACH - Registration, Evaluation, Authorisation and restriction of Chemicals (van Calster 2006 pp242).

The new REACH directive 67/548 defines substances as "all kinds of chemical elements and their compounds in the natural state or obtained by any production process," (van Calster 2006 pp242) an even broader definition than in the TSCA. Chemical substances determined to be under regulatory jurisdiction by this definition are assessed based on "danger," which is defined by 15 categories, most notably: toxicity, harmfulness, and danger to the environment. Regulatory decisions are based on both scientific certainty as well as any strong indications of "danger" associated with the chemical.

REACH will require a new chemical registration process beginning in 2008. All chemicals and mixtures of chemicals being manufactured or imported within the European Union must be registered by the companies that are producing or importing them. Chemicals that are already registered with the pre-existing chemical registry, known as the European Inventory of Existing Commercial Chemical Substances (EINECS), will be gradually phased into REACH registration, a process that is expected to take 10 years. Deadlines have been set for all phase-in chemicals by the European Commission based on tonnage and danger. Chemicals with the greatest productions and hazards are to be registered first and all phase-in chemicals registered by the end of May in 2018. All new chemicals are expected to be registered immediately (European Commission 2007).

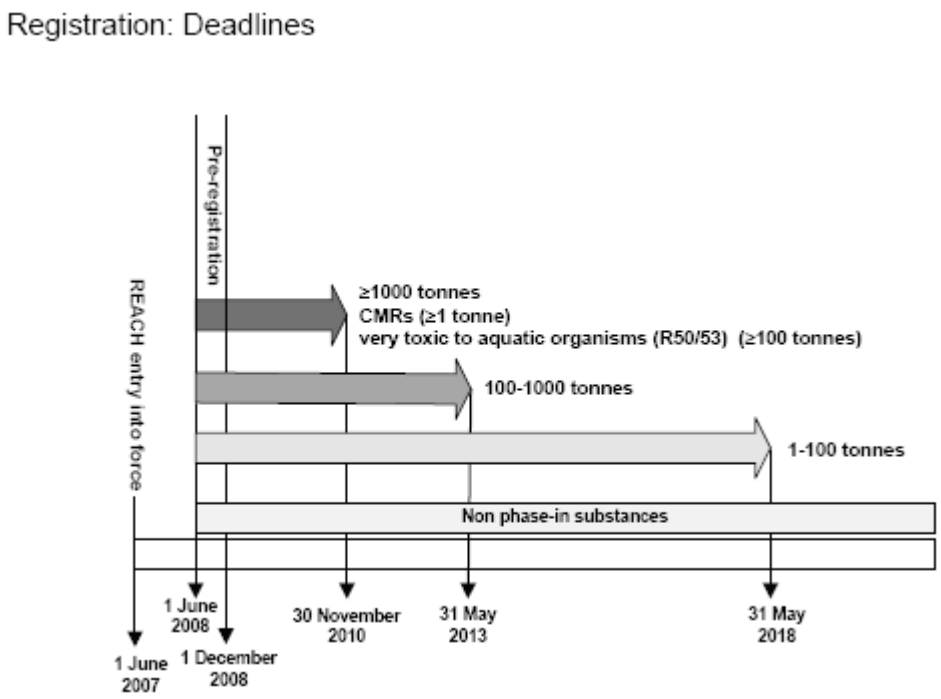

Figure 2.1 – This is the REACH timeline for chemical registration. This figure shows the deadlines for registering phase-in chemicals and production limits for each deadline (European Commission 2007).

Chemicals that are produced in quantities of at least one tonne per year per manufacturer will require a technical dossier. Chemicals that are produced in quantities of at least 10 tonnes per year per manufacturer will also require the submission of a Chemical Safety Report (CSR). A technical dossier is a comprehensive document, which provides information about a chemical's name, composition, structure, use, hazards, safety measures, and several important intrinsic properties. The greater the production tonnage, the more properties the company must report. To save on cost, companies may jointly register a chemical, but only if they share a common use for that chemical. A CSR is a more in depth look at the hazards of a chemical. The registering company must test and then report if the chemical is persistent, bio-accumulative, or toxic. The company must give a detailed life cycle of the chemical and report possible exposure scenarios. Additionally,

the company must demonstrate how it intends to control the chemical and prevent dangerous exposure to humans and the environment (European Commission 2007).

Chemical regulation under REACH will be stricter and more effective at ensuring overall chemical safety. There are still uncertainties as to how well REACH will manage nanotechnology. Some nanoparticles may still be able to bypass regulation if they are not produced in large enough quantities. Additionally, annexes VII-X of the reach legislation list the required intrinsic properties that must be reported in the technical dossier. This list does not include surface area or surface charge (Corrigendum to Regulation (EC) No 1907/2006).

Ultimately the EU hopes that REACH will provide "…the guiding principles as to how the EU may tackle nano-regulation in the future, in particular by its reliance on the precautionary principle" (van Castler 2006 pp242). The precautionary principle as defined by the European Commission is a safety model commonly employed in EU regulation. Key points from an EU statement on the precautionary principle include the idea that if there is any uncertainty about the properties of a chemical, "the safety assessment should normally be based on the evidence that gives rise to highest concern" (van Castler 2006 pp242). Also, if a company is awaiting test information about the safety of a chemical, it should assume all potential risks to be true and implement all risk management measures associated with the potential risks. Should a company wish to use a substance that raises a very high concern, it must seek authorization regardless of the risk management measures that may be in place. Finally, member states and the European Commission can suggest immediate restrictions on a chemical if there are any indications that the chemical may have severe risks associated with its use (van Castler 2006). The precautionary principle is a feature of the European regulatory system that sets it apart from the US system.

2.5.3 – Opinions on the Existing Regulatory Framework –

Currently, the American and European governments are doing much more to promote the development of nanotechnology than to regulate it (Bowman 2006). There are several theories regarding nanotechnology regulation, and we will discuss some of them. With nanotechnology growing so rapidly, many articles have been written suggesting that governments ought to address the regulatory issue before nano-products can harm society or the environment. Some believe that nanotechnology can be adapted into the existing regulatory framework with only small changes as the technology matures. Others insist that the current framework will require extensive reforms and perhaps new regulatory regimes directed specifically toward nanotechnology.

For example, Davies (2007) reports on some of the findings made in regulatory gap reviews since 2004. Several regulatory gap reviews were prompted by a 2004 report published by The Royal Society and The Royal Academy of Engineering in the United Kingdom that attempted to set the agenda for addressing nanotechnologies. In response to this report, three agencies, the Department for Trade and Industry (DTI), the Health and Safety Executive, and the Food Standards Agency, conducted reviews of the regulatory gaps concerning nanotechnology. The reviews concluded that "the over-arching regulations in place are adequate to deal with nanotechnologies, and no cross-cutting nano-specific regulation is needed" (Davies 2007 pp100). Only gaps in specific regulations, which could be amended to better suit nanotechnology, were cited by the reports.

Bowman and Hodge (2006) claim that the current regulatory system is too reactive and does not take into account the unforeseen dangers of a new technology. They use the example of how asbestos was once widely used in many construction applications and went unregulated until many people had already been severely harmed by it. There are many dangers associated with nanotechnology that are not yet fully understood, and as a result, many products could pass through the current regulatory framework simply because there may be insufficient knowledge of the risks.

Bowman and Hodge predict "that as science advances towards second- and third-generation nanotechnology applications, the potential of nanotechnology to challenge conventional national regulatory frameworks will increase commensurately" (Bowman 2006 pp1065). It is anticipated that nano-products will encompass the scopes of multiple regulatory regimes. Currently, the regulatory frameworks are built to divide products into categories. Certain nano-products may fit into more than one category, thus causing unnecessary confusion (Taylor 2006).

In addition to the many speculative issues regarding nano-regulation, practical issues have also been identified. Many of these issues arise from the current system for regulating chemicals. For example, permissible exposure limits determined by the EPA and REACH are based on volumes and masses of substances, but nanoparticles have been shown to have reactivity based on surface area. Therefore effectively regulating nanoparticles may require a new standard for determining exposure limits as well as methods for detection. Geert van Calster uses this fact to expose a potential flaw in the EPA exemption rules. For certain applications, a company may not need to manufacture more than 10,000 kilograms of a nanomaterial per year. In theory, nanomaterials could be put into a consumer product without being assessed for safety by the EPA under current regulatory measures (van Calster 2006).

It is clear that the current system is not perfect. The real issue lies in how policy should change in order to accommodate nanotechnology. The question that surrounds this issue is: how different is nanotechnology? James Wilsdon believes that the answer to this question will ultimately determine how nano-regulation is addressed:

> Is nanotech continuous with other scientific laws and processes, or a radical departure from them? Policy responses will be framed in part by the answer to this question: novelty requires new regulations; continuity will require only incremental tweaks to those that are already in place (Wilsdon 2004 pp19).

Due to the lack of knowledge about nanotechnology, the answer to this question remains unclear. The best way to approach the regulation of nanotechnology is a hotly debated topic.

Overall, there appears to be a potential for gaps in the current regulatory framework concerning nanotechnology. There are, however, different views as to how these gaps should be addressed. Whether a framework, specific to nanotechnology, is constructed, or existing laws are revised as it becomes necessary, the overall notion from the literature suggests that regulation of nanotechnology should be proactively addressed so as to protect the consumer and the environment from the possible adverse effects of nanotechnology. The purpose of regulation should be to protect society, the public, and the environment from technology, while simultaneously fostering its benefits. By coupling careful consideration for all potential risks with acknowledgement of past regulatory mistakes, nanotechnology can be properly regulated.

3.0 – Research Methods –

The research conducted as part of this project in Denmark involved examining and reporting the views of Danes on the use of nanotechnology in consumer products. We sought to determine the public's comprehension of nanotechnology, its benefits and its risks. Also, we examined how and why people perceive risks in a certain way as well as which risks they were willing to accept for the sake of nanotechnology's benefits. Finally, we examined and gathered opinions on current regulatory measures concerning nanotechnology. Interviews, a national survey, and focus groups were used to gather the information needed to cover these gaps of knowledge. In this chapter we discuss in detail how the aforementioned activities were conducted.

3.1 – Interviews –

Interviews allowed us to obtain both quantitative and qualitative data on the perception of nanotechnology, its risks and its benefits. Using interviews we were able to ask individuals to elaborate on a particular question and explain their particular perspectives on nanotechnology. We were also able to draw references to other discussions and ask interviewees to respond to ideas and opinions that were presented by other individuals. Through interviews, we were able to ask participants open-ended questions and discuss topics outside our original line of questions, something that we could not do through surveys.

3.1.1 – The Participants –

The individuals that we chose to interview were not chosen at random from the general population. We wanted to speak with individuals who were likely to have a better understanding of nanotechnology than the general public. We refer to these individuals as "experts." Specifically, experts included individuals with any of the following backgrounds:

- Academics and researchers in the field of nanotechnology
- Persons working for nanotechnology/nanomaterial research and development in industry
- Politicians who have taken an interest in the environmental and heath issues surrounding nanotechnology
- Others who have taken a professional interest in nanotechnology Consumer advocates

We interviewed experts to gather information about the risks and benefits of nanotechnology as well as to provide insight into the current regulatory framework and how it manages nanotechnology.

3.1.2 – The Process –

We began, with help from our sponsor, by compiling a list of potential contacts, experts in each of the aforementioned categories. Several of our initial contacts referred us to others, so that we were able to fill out our full gamut of experts. Once we had identified and contacted an individual with a sufficient knowledge of nanotechnology, we scheduled an appointment for an interview. Even though the number of interviews scheduled was relatively small, the interviews were designed to gather in-depth information, which could yield very insightful findings.

Because interviews ask for personal opinions, it was important to conduct them in an unbiased manner. It was also important to promote discussion on topics that were outside the scope of our original line of questions. To do this we made sure that the questions were not asked in such a manner as to hint at the personal feelings or opinions of the interviewer. In some

instances the interviewee was asked to reflect on an idea that was presented by another expert. When doing this we made an effort not to reveal any personal bias regarding the topic.

The interviews were conducted using a recording device with the consent of the interviewee so that the conversation could be reviewed at a later point. Transcripts of each interview can be found in Appendix D. In order to encourage openness, we offered the interviewees the option of anonymity. We also informed them prior to the interview that they could choose to ignore any question or end the interview at any time.

The interviews were structured loosely around a set of predetermined questions (See Appendix B), which served to guide the interview along a set of important topics. To make the interview feel more like a dialogue, some questions were omitted or new questions added either to promote discussion or to encourage further clarification. The interview itself was split into two parts. The first set of questions was meant to gauge the participant's feelings towards nanotechnology and its benefits and risks. The second set of questions pertained to the regulation of nanotechnology.

The preliminary questions were meant to establish the name of the interviewee, if he or she wished to disclose it, and his or her occupation and position within the respective organisation or company. We asked about the participant's background and experiences with nanotechnology in order to understand the basis of their opinions. The interviewer would then query the interviewee on what he or she feels are the benefits associated with the application of nanotechnology in consumer products and how worthwhile these possible improvements are. Similar questions were then asked about their understanding and concern about possible risks of nanotechnology. Answers to these questions would not only identify the benefits and risks that the interviewee associated with the application of nanotechnology, but would also determine his or her level of concern. Then, the participants were asked about their concerns in the use of nanoparticles in various applications. It

was important to distinguish between the different applications of nanotechnology because the interviewee might have different concerns with the various applications. The interviewer would then ask the participant whether or not the benefits of nanotechnology justify the possible risks associated with its application.

Finally, the interviewee was asked for his/her opinion about how nanotechnology in consumer products would impact society in the near future. This question on benefits and risks determined the direction the interviewee saw nanotechnology to be headed. Whether or not the interviewee felt that it would impact the future in a positive way further cemented the interviewee's position concerning the incorporation of nanotechnology in consumer products.

Following the completion of the first portion of the interview, we asked the interviewee a second set of questions regarding regulation. These questions would serve to expose in detail some of the opinions on nanotechnology regulation. The first question in the regulatory set simply asked the interviewee if he or she was at all familiar with the way nanotechnology is regulated in Europe and Denmark. The second question established the interviewee's overarching opinion on the current regulatory framework's ability to protect the public from the possible risks of nanotechnology. The results from this question divided the pool of interview participants into two groups based on their positive or negative responses to this question. As a continuation to this question, the interviewee was asked to elaborate on their response so that we could understand the reasoning behind each opinion. The interview participants were then queried on how, if at all, the regulatory framework of Denmark and the European Union should be changed to ensure public safety pertaining to nanotechnology. This question allowed the interviewees to express their own recommendations regarding the regulation of nanotechnology. The answers were carefully documented, reported, and analysed to determine any correlations between the opinion and the source of the opinion. The final question allowed each interviewee to identify their opinion with one

of three approaches to regulating nanotechnology that we found in the literature. Many of the interviewees identified themselves as in between two of the proposed approaches. We took these to be acceptable responses and later summarised what the interviewees had defined as an in between or combined approach to regulating nanotechnology.

3.1.3 - Analysis of Interviews –

A transcript was made of each interview, which was then used to sort the responses based upon a number of variables including risks, benefits, level of enthusiasm and concern, and opinions on regulation and risk management. Each interview was reviewed in order to determine what each interviewee identified as benefits of nanotechnology, whether they were concerned more with health risks or environmental risks, whether they were more optimistic or pessimistic about the technology as a whole, and whether they believed the risks outweighed the benefits or the benefits outweighed the risks. Each interviewee's overall level of concern was then rated on a scale from one to five. All the data from each interview was then pooled so that the overall feelings of the experts could be determined. After the quantitative analysis was completed, a second review of the interviews was conducted to find specific qualitative information to supplement the quantitative findings.

The interviews were analysed separately for regulatory and risk management information, but similarly involved quantitative and qualitative analysis. The second and fourth questions of the regulatory portion of the interview asked for close-ended responses from the interviewee. Specifically, the second question asked the interviewee to respond with either "yes" or "no" to the question of whether they thought the regulatory framework is adequate, and the fourth question asked the interviewee to identify with one of three statements regarding how the regulation of nanotechnology should be approached. The responses to these questions were tabulated, and frequency histograms were constructed to determine the most popular responses. The interview

transcripts were also scanned in search of key points, critiques, and suggestion. We compiled a short list for each interviewee, and then scanned each for content that was common amongst multiple interviewees. The most prevalent and notable of these points are discussed in the analysis chapter of this report.

3.2 – National Survey –

The Danish Consumer Council has a panel of approximately 2000 people to whom they submit surveys an average of eight times a year. The panel forms an accurate representation of the nation's population, and usually, roughly 1000 members of the panel complete each survey. The survey questions (Appendix E) were first written in English by our team and then revised by our sponsor. Once the final set of questions was agreed upon, the survey was translated into Danish by Laura Harrison and submitted electronically to the survey panel. The survey ran for one week and once concluded, we analyzed the data by calculating statistics and searching for correlations amongst the responses to various questions. Since none of the questions were open ended, all of the survey results were in the form of numerical data and did not require translation back into English.

We constructed a survey to help establish five key points regarding the Danish public perception:

1. Their attitude toward developing technologies in general
2. Their general knowledge of nanotechnology
3. Their knowledge of and attitude toward the risks and benefits of nanotechnology
4. Their attitude toward government and industry regarding nanotechnology
5. Their overall perception of nanotechnology.

The survey was designed to test if public perception of nanotechnology is related to the overall Danish opinion on developing technologies, overall public knowledge of nanotechnology, the

perceived risks and benefits, and the degree of trust in industry and government to ensure the safe use of nanotechnology. The survey accounted for the fact that many of the respondents may not have known much about or heard of nanotechnology. Briefings were provided throughout the survey to help the respondents provide informed answers.

3.2.1 – Questions –

The first question on the survey lists six examples of developing technologies and asked the respondent to evaluate his or her attitude toward each example based on a Likert scale from one to five; one represents a very negative attitude toward the technology and five represents a very positive attitude toward the technology. The second question asked the respondent to evaluate his or her overall attitude toward developing technologies using a five-point scale similar to the one in the first question. These two questions allowed us to evaluate how Danes feel about technology in general and see if that widespread feeling reflects their feeling on nanotechnology. We have hypothesised that Danes may be apprehensive toward nanotechnology simply because they are naturally apprehensive towards certain types of technologies or developing technologies in general.

The subsequent questions deal with the public's knowledge of nanotechnology. Question 3 asked if the respondent had ever heard of nanotechnology. For those who may not have heard of nanotechnology, or have heard the term and know almost nothing about it, Question 3 is followed by a very brief and general description of nanotechnology. Question 4 determines through which sources of information the respondent has heard about nanotechnology; there are seven choices and the respondent is asked to identify all sources through which he or she has heard about nanotechnology.

Questions 5 and 6 were used to determine how familiar and knowledgeable the respondent is on the topic of nanotechnology. The sixth question on the survey was a true/false section with

seven parts. There were seven statements about nanotechnology and for each one, the respondent was asked to respond either "true" or "false." The seven true false statements were concerned with practical information and knowledge that an informed consumer might have. This section told us three pieces of information. Most importantly, it gave us an idea of how much the Danish public actually knows about nanotechnology. It also gave us an idea of how much the Danish public thinks it knows about nanotechnology. What was most interesting, however, was that this section allowed us to compare the Danish public's actual knowledge with its perceived knowledge. We have hypothesised that Danes might know more about nanotechnology than they think, or perhaps they think they know more than they actually do. It was important for us to determine if the Danish public's perception of nanotechnology was based on misconceptions. Knowledge about nanotechnology could play a major role in its overall perception and its acceptance or rejection.

The next section in the survey deals with the risks and benefits of nanotechnology. The objective of this section was to allow the respondents to choose which applications of nanotechnology they would take advantage of based on the benefits and risks. We anticipated that the respondents might know very little about the benefits and risks of nanotechnology so the section began with a briefing on some of the technology's benefits. Question 7 was used to determine if the respondent is aware of the benefits of nanotechnology. The respondent was then briefed on the possible risks of nanotechnology in a similar fashion as with the benefits and then asked if they were familiar with any nanotechnology risks in Question 8. Question 9 then determined which applications of nanotechnology the respondent would be likely to use after considering the benefits and risks. It asked the consumer to weigh both issues for a number of different applications to see whether the application affects perception.

The respondent was then asked to determine how much confidence they have in government and private companies to ensure the safe use of nanotechnology in Questions 10 and

11, respectively. The answers to these two questions served to determine the effect trust and confidence has on public perception. Questions 12 and 13 were also used to determine public perception. Question 12 asked if the respondent felt that nanotechnology would improve their lives. Question 13 resembles Question 9 in that it asked respondents to weigh the risks and benefits, but this time, on a larger scale.

The purpose of this section was to determine the applications of nanotechnology that are interesting to the consumer and for which applications of nanotechnology Danes are willing to accept risk in order to receive the benefits. This section also gave us an idea of how aware Danes are of the risks and benefits of nanotechnology. Our background research has shown us that overall, perception of risks and benefits are probably the most important factors, which will determine the overall perception of nanotechnology. Nanotechnology will not be accepted unless the benefits are clear and outweigh the risks.

3.2.2 – Analysis of Survey –

The data from the survey was collected electronically and analysed using the SPSS Software Suite, a collection of data mining and statistical analysis applications. In addition to the responses to the survey questions, demographic information was also available. These fields include: age, education level, income level, and gender. For this project, only age and education level were important. Through the analysis of the survey responses, we sought to establish correlations between understanding of nanotechnology and risk perception as well as between demographics and participants' understanding of nanotechnology. In evaluating public knowledge, familiarity in relation to both age and education level was analysed. Correlations among familiarity, quiz scores, and mean scores were established. In discussing risks and benefits, correlations between risks and benefits in terms of familiarity and education level were used. Finally, to examine public perception,

connections between public opinions and familiarity were established. Participants' confidence in both government and industry were also used in the discussion of perception.

3.3 – Focus Groups –

A recent Danish study conducted by Miljø og Sundhed employed focus groups designed to gauge public perception of nanotechnology in Denmark. Since the report was not published in English, we contacted Hanne Svenningsen, one of the primary researchers involved in the project and scheduled an interview to discuss how the focus groups were conducted and what results were obtained. We have reported on Svenningsen's findings about the general public, and also used the information she provided to help us conduct our own focus group.

Our questions for Hanne Svenningsen (Appendix C) began by asking about the details of her focus groups. We needed to know how she contacted and gathered participants and what criteria she used for choosing particular participants. We also needed to know how her focus groups were conducted, specifically what questions were asked, what if any information she used to brief the participants, and how she lead discussion toward various topics of interest. Once we had a strong sense of how her focus groups were put together and conducted, we asked about the results of Svenningsen's research. We first asked about specific results related to the questions in our national survey, like the focus groups' overall knowledge of nanotechnology, views on the risks and benefits, and trust in government and industry. Additionally we asked Svenningsen if there were any interesting or surprising results not yet mentioned. After results had been discussed we inquired about Svenningsen's conclusions, specifically what the overall perception of nanotechnology was in the group and what she thought were the main factors behind this perception. Before moving on, we asked for any additional advice that would help us hold a successful focus group of our own.

Once we were talking to Svenningsen about her focus groups, we interviewed her as an expert though she opted to keep her comments to the general interview questions off the record.

While we had initially planned to conduct a focus group with a sample of students from the Danish Technical University, a lack of response from the students as well as time constraints on our part prevented us from completing such a study. Nonetheless, the information obtained through our interview with Hanne Svenningsen proved useful in formulating our final conclusions and recommendations.

The opinions and facts gathered through the aforementioned interviews and survey will allow the Danish Consumer Council to formulate a plan of action addressing the concerns over nanotechnology. This information will imbue the concerns over nanotechnology. This information will imbue the Danish Consumer Council with the resources necessary to engage in talks and debates concerning the future of nanotechnology in consumer products. Another vital piece of information that our methods will supply the Danish Consumer Council is the baseline knowledge of nanotechnology. If a majority of the public has no knowledge of nanotechnology or is making assumptions based on rumours or popular science fiction stories, the Council could seek to remedy the situation by providing information in an issue of their newsletter, *Tænk* or through other forms of Danish Media. Because the Danish Consumer Council is a consumer advocacy group, understanding all aspects of the public attitude towards nanotechnology issues is imperative for constructing a plan of action.

4.0 – Results –

This chapter details the results of our empirical research in Denmark. We conducted several interviews and a national survey. For each interview we conducted, we provide a summary highlighting the key points and opinions presented by the interviewee. We also summarise the results of the 2007 focus groups conducted by Hanne Svenningsen, whom we interviewed. Finally, we summarise the results of the national survey that we conducted through the Danish Consumer Council's survey panel, highlighting correlations found between the general public's perception of nanotechnology and factors including knowledge of nanotechnology, opinion on emerging technologies, perception of risks and benefits, as well as trust in industry and government.

4.1 – Interviews –

Thirteen people with various connections to nanotechnology participated in interviews. The interviewees include non-governmental personnel, social scientists, researchers, and politicians, representing a broad range of people and organisations that have a background related to of nanotechnology. The persons interviewed are:

Claus Jørgensen Ulla Hansen Telcs Steen Gade

Anders Baun Lone Frank Brigitte Rasmussen

Hanne Svenningsen Robert Firkic Thomas Brock-Nelsen

Jørn Dohrmann Alexander Jensen

Sofie Krogh Holm Steffen Foss Hansen

Each interview is summarised in detail below.

4.1.1 – Claus Jørgensen –

Claus Jørgensen is the senior environmental officer at the Danish Consumer Council. His background is mainly in chemistry and the environment, and he has been working in this field for approximately ten years. The Board of the DCC believes that nanotechnology should be an area of focus for the organisation, and because of his background, Jørgensen was chosen to be primarily responsible for this area.

On the topic of consumer benefits and applications, Claus Jørgensen is very optimistic about the burgeoning technology, mentioning many applications, emphasising cancer treatment and therapy, electronics, and environmental remediation. While optimistic about the benefits, the interview quickly turned to the risks of nanotechnology. "I think the technology in itself is actually very exciting because it seems as if there's a lot of things we can do… the problem I see is not so much the technology itself, it's more the use of the technology – how we decide to use it and where to use it," (Jørgensen).

Jørgensen's concerns about nanotechnology and nanoparticles centre around human exposure. He explains that because the particle sizes are minute and when used in such products as sunscreens and cosmetics, it is very easy for the nanoparticles to enter the human body through the lips, eyes, and broken skin. Other products, such as tennis racquets, do not concern him as much when talking about risks to human health, but he does mention environmental issues such as persistency and possible problems that may arise when nanomaterials and nanoparticles end up in the environment. Currently, he is more concerned about health issues because it is a present problem. He explained that environmental damages might not reveal themselves for a long time, yet both are interrelated; "…usually health and environment are different sides of the same coin."

When asked to weigh the benefits and risks of nanotechnology, Jørgensen turned to public perception and trust. According to him, people would be willing to accept more risks if there's an obvious and substantial benefit.

> For medicine… some of them can cause very serious adverse effects… but we're willing to accept that because we'd rather be, well, alive than dead. But there's an obvious benefit right there. The problem is when you do not have the obvious benefit. When you maybe already have products that you just substitute with this [new] product… So why not just stick with the product you already have?

Trust was also brought up by Jørgensen and with that issue, the controversy behind genetically modified organisms (GMO). People are willing to accept the benefits of a new technology while the science is being explored in isolated and controlled environments, but it is when introduced to the wild, where a myriad of unknowns are introduced, that people become sceptical. Additionally, the problem with GMO's was that while scientists and officials touted the great social benefits of GMO's, such as feeding the poor and in medicines, their real intention was to make money. They have yet to feed the poor or the hungry and people are still starving. The companies were not honest and in turn, the technology, which had great potential, was shunned. According to him, for nanotechnology to have a positive effect on future society, it needs to be marketed truthfully.

On the topic of regulation, Jørgensen feels that current regulations established by the European Union are not comprehensive enough to ensure that nanotechnology and nanomaterials are properly regulated. He feels that the REACH regulations need to either be changed to include nano-specific regulations or a new set of regulatory measures should be created to control nanotechnology. Jørgensen explained that REACH allows for chemicals that are produced in low amounts (less than one tonne annually) to forego regulatory measures, which may be a problem for nanomaterials, as their effectiveness is not based upon amount, but rather surface area. He suggests that the authorities should be informed about the use of nanomaterials in products going on the market as well as how the risks have been anticipated and minimised. This information, he says,

would be useful for non-governmental organisations such as the DCC to have as well so they may inform consumers as to which products may contain nanoparticles. The underlying problem, Jørgensen believes, is that the Danes do not know enough about nanotechnology. He feels that, as part of new regulation, a new nanotechnology information centre might be formed for the sole purpose of taking technical, scientific papers and releasing them into the stream of public knowledge. "I do think that it's necessary that, well, the commission sits down and look at the regulation on nanotechnology… it could be that we could fit it into the current REACH system. I'm afraid we might need to maybe have a new nano-law, but I'm not the expert on that…" (Jørgensen). Jørgensen believes that the approach to regulating nanotechnology should involve immediate changes to the regulation, including the addition of some nano-specific legislation, as well as incremental changes over time.

4.1.2 – Anders Baun –

Anders Baun is an associate professor in the DTU Environment Department. He is also the coordinator of the nanoDTU Environment and Health network, a network that tries to coordinate actions concerning the potential risks of nanomaterials. Originally, Baun studied chemical engineering and worked in chemical risk assessment for over ten years. He shifted his focus to nanotechnology and risks three years ago after attending a seminar hosted by the United States EPA.

> Actually, I went there with that background that this was the most stupid thing I've ever heard of. So I though like, "Well let's go in and have a few laughs and then I can go home and tell you, 'Do you know what I heard about this stupid thing?'" …That's why this is sort of a revelation – they continued talking about it and I thought, "Yeah, okay, this kind of sounds like quite interesting" …Then I want back to my director here and said, "Okay I want to change my research into this."

He spent a year convincing his director on this sudden change in direction as well as setting up a network of researchers at the university, forming the nanoDTU group.

On the topic of benefits, Baun mentioned a number of scientific advancements such as in energy efficiency, catalysis and environmental remediation, all of which are studied in his department. When asked about benefits to consumer products, Baun was less than optimistic. He feels that currently the market is dominated by gadgets that provide solutions to problems that do not exist. Going through all the products with nanomaterials compiled by the Woodrow Wilson Institute, many of the products fit this description, Baun states. He explained the levels of technological development and its separation into four distinct stages, the first being the most rudimentary use and the fourth being the most advanced integration of a certain technology. Currently, he said, we are at the first generation, still trying to figure out what is going on. Of the benefits that he does acknowledge, Baun feels that advancements in the field of energy efficiency might be the greatest. He also brought up the development of medical and pharmaceutical products and the enormous impact that nanotechnology will have on the field.

When asked about the risks of nanotechnology, Anders Baun made a note to distinguish nanotechnology from nanomaterials and nanoparticles. The technology itself, he says, poses no risks. On the other hand, risks are present when referring to nanomaterials. And even at this stage, risks to human health and the environment are not from nanomaterials in general; one must narrow this down further to nanoparticles, which can either be free floating in air, suspended in liquids, embedded in matrices, or bound to a surface. Several studies have shown unexpected effects of inhaled nanoparticles travelling to the brain from the nose in animal test studies. Primarily, his concerns are over the use of nanoparticles in any application that leads to direct exposure, but this is not, he says, the fault of the nanomaterial, but how it is used. Some applications are inherently more risky than others. No one would ever consider the reading head of a DVD player as being risky, while in labs, quantum dots made from cadmium are being used. Of course, cadmium quantum dots will not be used in consumer products due to its carcinogenic properties but it is an example,

he said, on how problems might arise if people start basing new technology on known materials or techniques of high risk. Baun also mentioned medical applications such as targeted drug delivery for chemotherapy might be harmful to the environment, because it is, after all, the deliberate poisoning of the body. He raised the question of what would happen when people dispose of the chemicals, what kind of environmental issues would be raised?

Chemical risk, Baun said, may be characterised by four factors: persistency, bioaccumulation, toxicity, and mobility. Nanomaterials are, by definition persistent and have a tendency to attach to tissues and some are indeed toxic. Additionally, due to its small size, mobility is also an issue. He also presented a fifth characteristic: interaction with other toxins and contaminants. He mentioned that a couple of studies have found that in the case of some contaminants, nanoparticles do augment the negative effects of the compound.

Even with such risks, Baun does feel that the benefits outweigh the risks. There are so many applications of nanotechnology that do not involve risks concerning safety, human health, and the environment. A number of the risks concerning nanotechnology are not specific to nanotechnology. To say nanoparticles are toxic is true, but so are certain chemicals and they are still being used regardless. "What we see is sometimes very stupid use of chemicals for things we don't need so we have to learn from past experience and focus on what are the needs, what are the benefits… I think that for sure it would be a wrong use of precautionary principle to pull the plug now and say no to nanotechnology development" (Baun).

Baun spoke about public trust. Specifically, the public will be willing to accept high risk in uses as long as they recognise that it is risky. If scientists try to hide the fact that a product is risky, that is when backlash will occur. Obfuscation and the omission of these facts, in Baun's opinion, is the worst strategy because when the risks are revealed and there is backlash, the public will lose trust in the experts.

On the topic of regulation, Baun feels that while it would be best to start anew with nanotechnology regulation, for regulation to be passed, it would be more realistic to change current REACH regulations to include special criteria for products using nanomaterials. Currently the EU follows a mantra: a compound is a compound. A small "nano-flag," as he put it, could be raised when reviewing products with nanoparticles, but of course, there are not enough data from companies to properly design specific regulations concerning nanotechnology. "I think it's not stupid to say that the incremental approach is the way… because you're talking regulation. If you're talking science, because that's what I do, [starting anew] would be the best one… I would prefer something like [the incremental approach] because it means that it will actually happen."

4.1.3 – Hanne Svenningsen –

As an environmental consultant for Miljø & Sundhed (Information Centre for Environment and Health), Hanne Svenningsen has a broad experience with new technology and product safety. All of her studies, based on science and social science, have been completed in order to provide more information to consumers. In addition to looking at Miljø & Sundhed's website, consumers can call to ask specific questions about products, and the consultants will provide them with detailed and neutral information. Miljø & Sundhed publishes a newsletter and informational leaflets meant to bridge gaps in knowledge about product safety, or in the case of nanotechnology provide an overview of this new science.

In 2007, Hanne Svenningsen organised a study consisting of three focus groups intended to determine public perception of nanotechnology. The twenty four participants include: students from the Danish Technical University (DTU), the University of København, family and friends of Miljø & Sundhed employees, subscribers to the Miljø & Sundhed newsletter, and even random consumers from the street. Each participant was given a screening interview before the study began.

Each participant was asked a series of simple questions to determine their opinions of science in general, their opinions of nanotechnology specifically, and how much they knew about nanotechnology. For example, participants were asked to rank on a scale from one to ten how they felt about technological advances. Svenningsen made sure to include science enthusiasts and sceptics as well as individuals having extensive knowledge of the subject in every group. She began each session by asking what the participants thought when they heard the word nanotechnology. Although Svenningsen had a set of questions already written before the sessions began, she allowed the conversations among participants to continue relatively freely. Her questions were meant to serve only as a guide or a list of the topics Svenningsen sought to cover during the sessions. The participants were occasionally presented with unbiased information, such as which consumer products already contained nanotechnology, and then asked to react to that information. Svenningsen also asked the participants who they trusted to regulate this new technology, who they trusted to give them information, and from where they had learned most of their information thus far.

Svenningsen informed us that people get most of their information about nanotechnology from the media. However, she also found that people have little trust in the media. People do not believe that the media reports all the neutral information on a story. Instead they paint a black and white picture declaring that a technology either has no problems or big problems. Although people receive information about nanotechnology from the media, they still feel like they are missing out on some of the important facts.

According to Svenningsen's research, people are concerned the most about the inhalation of free nanoparticles. She thought this was interesting herself because many experts' main concern is with the inhalation of nanoparticles as well. Along the same lines as the nanoparticles in the air, people were also concerned about cosmetics such as sunscreens, which involve the application of

nanoparticles directly onto the skin. Although studies have shown that nanoparticles cannot penetrate completely through normal skin, Svenningsen told us that there have been studies suggesting that nanoparticles could penetrate damaged or dry skin. Aside from human health concerns, Svenningsen said that people are also concerned about nanoparticles getting into the environment. Svenningsen said that her participants mentioned the use of silver nanoparticles in laundry machines and detergent. They were worried about the effects that nano-silver might have on ecosystems after being rinsed form the laundry and into the environment.

Svenningsen told us that there is an interesting way in which people perceive risks. People are willing to accept more risk if they believe the risk is somehow in their control. Svenningsen referred to a study that she conducted a few years earlier about the risk of radiation from mobile phones. Svenningsen noted that people were more afraid of radiation from antennas on the tops of people houses than the radiation from mobile phones despite that fact that experts claim that the radiation from mobile phones is technically more dangerous.

Svenningsen believes that people perceive the risks differently than the experts because they feel like they can control mobile phones but not the antennas. She added that people would like to see labels on products that utilise nanotechnology so that they can decide for themselves if they want to use them. Svenningsen said that the issue of control often lead the discussion to a comparison of nanotechnology to GMO. The parallel between nanotechnology and the environment is ultimately our inability to control the effects of either technology on the environment.

An interesting conclusion that came from the study is that perception is very much affected by the discussion itself. As Svenningsen put it, "If in the focus group one person said, 'I know a lot about nanotechnology and there's nothing to be worried about,' I would be very affected by your statement." She believes that this is a result of the general lack of knowledge about nanotechnology

amongst the public. Perception can be easily manipulated by statements made by people or organizations that have thorough knowledge. According to Svenningsen, a statement made by an NGO, such as the Danish Consumer Council, would have a profound effect on the public's perception of nanotechnology.

When asked about whom the public trusts, Svenningsen said that people have a fair level of trust in the Danish authorities but would like to see the government make more information about nanotechnology available to the average person. She said that the people have a very low level of trust in the industries because they thought that the companies were only interested in financial gain. Reiterating, she also said that people have little trust in the media. According to Svenningsen, people have the greatest amount of trust in the NGO's.

After discussing the results of her study, we had intended to interview Svenningsen as an expert. However, she declined to answer any questions regarding her personal opinions on nanotechnology.

4.1.4 – Jørn Dohrmann –

Jørn Dohrmann is a member of the Danish Parliament and the spokesperson for the Danish People's Party on environmental and agricultural issues. In the interview, Dohrmann informed us that he has a background working as a mechanic and with electronics. Before becoming a Member of Parliament, he repaired and sold spray equipment to companies, and he said that it is through his work experience before politics that he learned about "small things" such as nanotechnology.

Dohrmann recognises nanotechnology as a big advance for science and engineering that he thinks will bring many benefits in the future. He also recognises the need for caution and believes that it is important to study the effects that nanotechnology may have on health and the environment. Dohrmann believes that there will have to be many discussions in the future

regarding the risks of nanotechnology, and that many benefits can come from nanotechnology when it is used properly.

When asked which applications of nanotechnology he thought would yield the greatest benefits, Dohrmann thought that electronics would have the most to gain. Dohrmann explained that nanotechnology would bring many benefits to electronics because people are always looking for smarter, faster, and smaller electronics. In an area such as electronics, greater benefits will come the more nanotechnology is used. Dohrmann says that because there are fields with so much to gain, it is difficult to determine whether or not people should use nanotechnology despite its possible risks.

When asked about the risks of nanotechnology, Dohrmann says that he does not see any yet, but when risks are considered, one must realise that the technology itself and how it is applied are two different entities. Nevertheless, he is most concerned about applications of nanotechnology that involve direct contact with the skin. He believes we need to understand what will happen when these nanomaterials come in contact with humans. Dohrmann cites the fact that in recent years, increasingly, Danes are having increasing difficulty conceiving children. It is not fully understood why this is happening, but he believes that incorporating nanomaterials into our lives may lead to similar problems.

Dohrmann likens nanotechnology to GMO, asbestos, or DDT and therefore believes strongly in researching the possible negative effects of nanotechnology as soon as possible. He believes that we need to research and understand what happens to a nanomaterial after we use it, if it is harmful to our health, and if it will be harmful to the environment. We need to know if nanomaterials can be recycled and how to avoid contaminating the environment. What concerns Dohrmann is the fact that it will be impossible to know all of the things that might go wrong with nanotechnology without giving the technology time to develop and time for experts to conduct their studies. Additionally he believes that companies are more concerned with their profits than

thoroughly researching the safety of their products. He also does not believe that companies reveal the entire truth regarding the safety of the technologies they are developing. Dohrmann stated that government should keep a close eye on industries and have safety research conducted by outside experts. The public should also be aware of what is in the products they use and their potential risks so that they can be careful and decide whether or not they should use a certain product.

Dohrmann could not definitively say whether he believed the benefits of technology would outweigh the risks. He believes that there will be positive and negative consequences whether nanotechnology is restricted or not. Specifically, Dohrmann cited automobiles as an example of this. If people were no longer allowed to drive their cars on the road, there would be no more deaths from car accidents, but people also would not be able to easily travel outside the local community. Dohrmann believes nanotechnology will have its risks and its benefits, but it is too soon to tell if one outweighs the other.

When asked about the regulation of nanotechnology, Dohrmann noted that there are a few things that need to be changed such as production limits and other regulatory gaps. Overall however, he believes that the current regulatory framework is sufficient to manage nanotechnology for the time being. Dohrmann said that in the future we might need new tools but it difficult to anticipate what we will learn about nanotechnology in the years to come. He believes that major changes to the regulatory framework are unnecessary and the best way to manage nanotechnology regulation is to make adjustments over time as problems with nanotechnology arise.

Overall, Dohrmann seems to be positive about the advance of nanotechnology and believes that it will bring many benefits to society in the future. He is however, concerned about the possible risks and believes experts should conduct thorough research so that the risks of nanotechnology can be understood before they are allowed to severely damage human health or the environment. Since nanotechnology is still in early stages, Dohrmann believes in letting the technology develop before

enacting any restrictions or implementing any major regulatory changes. Current regulations should be sufficient to protect the Danish public from the possible risks of nanotechnology and only gradual changes to the regulatory framework will be necessary to maintain the current level of safety.

4.1.5 – Sofie Krogh Holm –

Sofie Krogh Holm is the senior food policy officer for the Danish Consumer Council. Most of her work with nanotechnology deals with keeping track of its applications in food and risk assessment methods. She also follows how the authorities and other non-government organisations are addressing nanotechnology in food as well as what topics are being debated.

There are a few examples, according to Holm, of nanotechnology being applied in the food industry. In Denmark, scientists are researching ways to use nanotechnology to deliver vitamins and minerals to the body more efficiently. Companies have also used nanotechnology to make chewing gum that can retain its flavour for a longer period of time. She stated that it is hard to determine for sure where nanotechnology is being used in food because many companies do not want to share that information with the public. She speculates that nanotechnology might be used in food colourings and artificial flavourings. Much of Holm's job deals with finding the food applications of nanotechnology.

One of the problems with nanotechnology, according to Holm, is that no one is sure what the actual risks are. She is nevertheless, particularly concerned with the possible negative health effects of free nanoparticles coming in contact with humans. For example, when vitamins and minerals are delivered in nano-form, the body might take them up so efficiently that the recommended consumption amount is too high, which could lead to serious health problems. Holm referred to a study where large amounts of nanoparticles were fed to daphnia and scientists observed that the organism was unable to control where in the body the particles could travel. It is

very difficult to predict how nanoparticles will behave once they are allowed to enter our bodies, and many nanoparticles are known to have high reactivity and catalytic properties.

When asked if she thought people would react to nanotechnology in food the same way they reacted to GMO, she had a lot to say. Currently people are not reacting because they do not know that nanotechnology is being used in food. In the future however, it is too hard to tell. Holm believes that people should be concerned about coming in direct contact with nanoparticles, especially ingesting them. There is risk assessment and toxicology research that has not been conducted for nanoparticles. These particles could be used in foods without understanding the negative effects they may have on the body. Workers at factories where the nano-products are manufactured should be particularly concerned about inhaling, ingesting, or getting free nanoparticles on their skin.

What further concerns Holm is the fact that there is no way to detect the use of nanotechnology in food products on the market because scientific methods for detection of nanoparticles have not yet been developed. Holm also believes that companies are using nanotechnology in their food products but do not want to admit it. Since they are denying using nanotechnology in food they also are not spending the money to do risk assessment.

When asked how people perceive the risk when it comes to food, Holm could not give a definitive answer. She believes that the way consumers perceive risk is different from the way the regulators do. People are often more likely to accept a risk that they think they can control or avoid. Often, people do not perceive risks logically. She used smoking as an example. Scientists have proven that smoking causes cancer and many other health problems, but people still do it because they feel it is in their control.

Personally, Holm is concerned about the use of nanotechnology in food because there is no way to tell where exactly it is being used. Nevertheless, she is aware of some good applications of

nanotechnology in the food industry. In Denmark, companies are trying to use nanotechnology to develop a knife that is perfectly smooth so that bacteria cannot stick to it and be spread from contaminated meat to uncontaminated meat. There are many applications of nanotechnology that do not involve using free nanoparticles, and she is not particularly concerned about these types of applications.

Holm does not believe that the current regulatory system is sufficient to protect the Danish public from the possible risks of nanotechnology. The fact that we do not know how to detect nanoparticles in food and that there is no risk assessment automatically makes the regulations inadequate. She said that the European Food Safety Authorities are asking the companies to reveal what they are using so that it can be tested, but the companies just deny that there are any applications of nanotechnology in their food products. However, she said it is obvious that the companies must be using it somehow.

According to Holm, in order to properly regulate nanotechnology, there has to be an agreed upon definition and a mandatory database of all products that are using it. The proper methods of risk assessment must be developed, and companies should be required to provide methods for detecting the nanomaterials in their products. She believes that the approach to regulating nanotechnology should involve making some immediate changes to the framework and also waiting to make some adjustments in the future as we learn more about the technology. She does not believe in regulations that are specific to the entire technology, but does believe in regulation geared toward specific applications of nanotechnology such as in food and cosmetics. Holm also does not think new regulatory regimes are necessary. Regulatory expertise should remain in the currently established fields as opposed to a newly established nanotechnology regime.

4.1.6 – Robert Firkic –

Robert Firkic is a product manager with an engineering background working for the Danish company, TCnano. TCnano specialises in selling thin films and protective coatings that utilise nanotechnology. Much of the discussion with Firkic focused on the technology that TCnano works with.

Firkic noted that applying nanotechnology to surface protectants provide many new functionalities. Coatings using nanotechnology can have a wide range of functions and applications such as on automobiles, home appliances, boats, and textiles. Firkic drew attention to one of TCnano's partners in the United States, known as Dimension Polytech, a company that wants to sell clothing with UV protection and hydrophobic properties. Firkic also drew attention to one of TCnano's glass coatings, which is comparable to RainX. According to Firkic, the TCnano glass coating can last six months to a year, much longer than the RainX coating, and is also much more effective at repelling water and keeping the windshield clean. Firkic added that a lot of the products on the market that use nanotechnology are good improvements on things we already have but are not phenomenal yet.

When asked if the improvements are a result of nanoparticles, Firkic was quick to distinguish between nanoparticles and nanomaterials. He believes that nanoparticles are only a small aspect of nanotechnology. Nanoparticles are not always in nano-products. TCnano products simply incorporate some kind of nanomaterial or "nano-knowledge." Firkic believes that people's current expectations for nanotechnology are much too high. People are expecting miracles when in reality nanotechnology is only bringing improvement to old products. Despite believing that nanotechnology has matured past its very early stages, Firkic believes its applications are far from revolutionary. He hopes that one day we will be able to perfect the art of making surface coatings

but makes the analogy that what people are expecting from nanotechnology versus where it actually is, is like the difference between flying and flying to the moon.

Firkic was able to identify several risks associated with nanotechnology. His concerns rest more with the producers and the manufacturers who are working with the hazardous chemicals than the consumers. He is also slightly concerned about some applications of nanoparticles that involve direct contact with the skin such as in sunscreen. The problem with sunscreen, according to Firkic, which contains titanium dioxide nanoparticles, is that it has been used for so long and works so well that it is impossible to find alternatives despite there being some evidence, be it inconclusive, that nanoparticles may be absorbed through the skin. Firkic also mentioned nano-socks that are coated with silver nanoparticles and can wash out of the fabric and into the environment. Also, despite having great antibacterial properties, bacteria could always mutate and become resistant to silver nanoparticles.

Other specific applications of nanotechnology that concern Firkic are with aerosols that contain nanoparticles and any application that could result in free carbon nanotubes, which are very difficult to destroy, in the environment. Nanoparticles and materials constructed from nanoparticles should be given the greatest amount of caution. Overall Firkic believes that applications, which could result in free nanoparticles entering the environment or the human body, are the most concerning applications of nanotechnology in consumer products. He added that, nevertheless, many nanoparticles have been around for a very long time and are not known to have any dangers.

Concerning coatings, however, Firkic does not believe there is anything to be concerned about. He explained that the coating aggregates after it is applied to a surface, changing from nano-sized to micro-sized. Firkic said that people often believe free nanoparticles are going to somehow jump out of the coating, which is impossible because once the coating is applied there are no longer any nano-sized materials. Even as the coating wears down, the pieces are much larger than the

original nanoparticles and are as inert as bits of glass that naturally wear off of the windshield. He acknowledges that there are some uses of nanotechnology that pose some risks, but other applications such as surface coatings are no cause for concern, and he believes the benefits outweigh the risks.

Firkic then addressed what would happen if the liquid that forms the coating were to come in contact with a person's skin. He explained that the nanomaterials in the liquid are designed to self organise onto a surface as the solvent evaporates. However, the coating must be chemically designed for the substrate in order for it to bind. Since the glass coating is not designed for skin, nothing would happen. Firkic also added that he has read about several investigations, which show there is no way nanoparticles could be absorbed through all three layers of the skin. He added that there are hazards to ingesting the solution much like there would be with any chemical.

Firkic believes that it is impossible to predict what nanotechnology will be like in the future. He noted that nanotechnology is not as new as everyone is making it out to be. Nanomaterials have been around and used since ancient history. In regards to surface protection, Firkic is confident that one day, coatings will be so good that there will be no need for windshield wipers on automobiles.

Despite there being so many potential risks associated with nanotechnology, Firkic is not very concerned about nanotechnology in consumer products. He believes that the authorities will keep an eye on these products and, especially with REACH, be able to effectively manage nanomaterials. Firkic elaborated a bit on the new requirements that REACH will bring to chemical registration. REACH will require companies to report all of the components in a chemical or mixture and will also require the companies to prove that the product will be safe in its intended use. Registration for nanomaterials will require identifying information including particle size. Firkic also believes that the production triggers for regulation are low enough that nanomaterials will not be able to bypass regulation. REACH will apply to downstream producers as well, so when the

nanomaterial is mixed into a solvent the new mixture must still be less than one tonne in order to bypass registration. In the manufacturing world one tonne is a very small product volume. Firkic again referred to the glass coating as an example. He explained how the nanomaterial needs the solvent in order to function as a coating. There are few uses for nanomaterials that are not part of a larger substance. The new regulation will demand a lot from industry and many small companies may not be able to live up to it. Firkic believes that REACH is sufficient regulation to protect the Danish public from nanotechnology and should only require adjustments in the future.

4.1.7 – Steffen Foss Hansen –

Hansen is a doctoral student working under Anders Baun at the Technical University of Denmark. He has experience and knowledge in environmental planning, a combination of regulatory issues and environmental sciences. He has been involved in risk assessment of nanotechnology for approximately two and a half years. He decided to pursue this area of policy and science because he saw it as a unique opportunity to apply his knowledge in a proactive manner towards technology. Hansen's aim is to contribute to the safe and sustainable development of technology. By sustainable, he means, "fulfilling the needs of the current and future generations without compromising the environment and the possibility for future generations to fulfil their needs" (Hansen).

When asked about the benefits of nanotechnology, Hansen mentioned economical benefits, environmental as well as food security. Additionally he mentioned benefits to materials such as stronger, lighter and more environmentally friendly materials. When asked about consumer products, Hansen referred back to some of the benefits he mentioned before such as better materials. However, aside from that, he doesn't feel that the consumer directly benefits very much from the products currently on the market. He does make an exception for sunscreen, which he

feels is more effective now that titanium dioxide nanoparticles are being used. For the most part, when looking at the 600 products catalogued by the Woodrow Wilson Centre, Hansen feels none of them are products that people could not live without.

According to Hansen, the biggest risk he currently associates with nanotechnology and nanomaterials is that towards worker health and safety. Those working closely with nanoparticles will have a higher level of exposure and the risks and potential problems that are linked with exposure are not completely understood; this lack of understanding is a big issue. "We're using something where we don't know whether there's a problem, which I kind of think is a problem in itself." Hansen is more concerned about free floating nanoparticles than films and coatings, though, he says, people should understand that risks linked to nanoparticles are not shared by nanotechnology as a whole. Sharing the same views as his professor, Anders Baun, Hansen agrees that it is still too early to tell how nanotechnology will affect the environment. He is, though, concerned about how nanotechnology will affect behaviour patterns of lower level and higher level organisms. Overall, Hansen is more concerned about human health and safety than about environmental risks because the effects of human exposure are more readily visible compared to the environment. But, Hansen stated, "When it comes to it, it doesn't really matter how concerned I am; it's the not know what really makes me concerned."

Overall, Hansen is very optimistic about the direction that nanotechnology is heading but at the same time, very pessimistic about how the state will go about regulating and assessing the risk of nanotechnology. The current policies that are in effect are inadequate and Hansen feels that not enough initiative is being taken to fill the gaps in regulation. "We've been discussing it for ten years now… people have been raising the red flag ten years ago and we still have not done what needs to be done and I find that very discouraging, I must admit," (Hansen). Under current European Union regulations, production volume is used to determine the level of regulation and testing that needs to

be done. Also, no distinction is being made between bulk materials and the same material in a nano-form, which Hansen feels needs to be changed due to the change in material properties that occur on the nanometre scale. Currently, Hansen said, certain products containing nanoparticles are going through to the market untested and unregulated. In response to Firkic's claims on regulation, Hansen pointed out a difference between registration and regulation. All the products must be registered but testing may not necessarily be performed, unlike if a product were to be regulated. In order to fill in this gap in testing, Hansen proposes that the Union adapt current regulation to temporarily regulate nanomaterials. During this time, a new framework specific to nanotechnology would be drafted and then put into effect. "I'm just saying that for nanoparticles, we can't just use the tonnage requirement. We just have to figure out something else," (Hansen).

4.1.8 – Alexander Jensen –

Alexander Jensen is a third year student at the University of Copenhagen studying nanotechnology with a focus in bio-applications. Benefits that Jensen has seen include mechanical limbs controlled by nerve impulses, and surface coatings for glass. He also noted that through nanotechnology we could make incredibly small circuits, which will be very beneficial for the electronics industry. Additionally, proteins could be adhered to the surface of a carbon nanotube to give the proteins algorithmic properties.

On addressing the risks of nanotechnology, Jensen noted how nanomaterials do not behave like the chemicals we are used to. Tests are needed to determine how nanomaterials will react in the human body, particularly with proteins and biological pathways. Nevertheless, Jensen does not see a need for concern as long as the necessary tests are conducted properly. Because the technology is still in its early stages however, Jensen could not say for sure but hopes the benefits will outweigh the risks.

Jensen believes that, with nanotechnology, the scientists know what they are doing, which is why he is not too concerned about the possible risks. Although we have historically made mistakes with new technology such as asbestos, Jensen noted that there are so many products made with new technology that do not cause negative health effects. There will always be harmful products that come out, but compared to the good ones, products like asbestos are "one in a million." He also hopes that good procedures for keeping nanotechnology safe are developed to further avoid products with severe health hazards.

Jenson does not believe that the current regulatory framework is adequate to protect the Danish public from the possible risks of nanotechnology. He believes that because nanomaterials do not behave the way traditional chemicals do, the chemical regulation will not be able to handle them properly. A few laws need to be changed, and the companies making the nanomaterials should have to prove that they are safe instead of putting the burden of proof on the authorities. Jensen believes that the best way to regulate nanotechnology would be to set up a new regulatory framework. It should also be required to report surface area, surface charge, and the ability to permeate membranes for nanomaterials.

4.1.9 – Lone Frank –

Lone Frank is a science journalist for the Danish periodical, *Weekend Avisen*, and has a PhD in neurobiology. Frank is interested in analyzing how technology impacts society and has written extensively on biotechnology and society. She has recently taken an interest in nanotechnology because she sees it as the next big wave of technology and recognises that it has the potential to face many of the same problems that biotechnology has in the past. Her experience with nanotechnology includes reviews of the literature as well as attendance at several conferences on

nanotechnology and regulation. Frank has written articles on nanotechnology in the past, but we were unable to read them because they are only published in Danish.

Frank views nanotechnology as a very broad field that has the potential to bring many benefits to society. Benefits that Frank specifically identified include cancer treatment, coatings, food technology, cleaning products, and cosmetics. There are many benefits that can come from the ability to produce materials with tailor made properties using nanotechnology.

Regarding the risks of nanotechnology, Frank believes that some people get a little carried away with their fear of nanotechnology. Nanotechnology is simply the technology of nano-sized things. The field is so broad that it does not make sense to think about the risks of nanotechnology as a whole. Frank recognises that nanomaterials do carry the possibility of being harmful to both the environment and human health. The main problem as of now is the fact that we do not know enough about nanomaterials and what risks they truly carry. Frank believes that it is due to this lack of knowledge that people often associate nanotechnology with asbestos.

Frank noted that most people do not understand that nanomaterials have been around for a while. Products such as sunscreen and paints have been using nanoparticles for a long time; only recently have people outside of research and development become aware of this. Despite the fact that these common nanoparticle-containing products have yet to pose any serious health or environmental risks, concern surrounding these products has risen as a result of the greater attention being given to the possible risks of nanotechnology. Overall, Frank is not concerned about nanotechnology so long as it is applied responsibly with proper safety testing. She believes that nanotechnology is, on the whole, an interesting and positive technology with many benefits.

In the future Frank predicts that nanotechnology will bring many benefits to medicine with new ways to treat diseases. She also believes that the material science and electronics industries will take off. Many people have speculated about the possibility of nano-robots but Frank is unsure

about this technology and believes it to be mostly a fantasy. Many people have also likened nanotechnology to GMO, but she does not believe nanotechnology will have the same fate. Companies seem willing to cooperate and experts are already doing a lot to make sure nanotechnology is a success by promoting discussion and debate. Frank also believes that the term nanotechnology has a more positive and fascinating ring to it than "genetically modified organisms." People could not see many of the benefits with GMO, but if they can see the benefits with nanotechnology it shouldn't suffer the same fate. Frank stated that in general Europeans are sceptical about new technologies, especially compared to Americans, but a recent study surprisingly reported that most Europeans were comfortable letting the scientists decide what to do with nanotechnology, a very different attitude amongst the public than with GMO.

With regard to regulation, Frank does not believe that the legislation is lacking so much as the scientific methods for measuring, evaluating, and assessing the risks of nanomaterials. Nevertheless, she does believe that regulation should evolve and change if necessary. There is always the chance that scientists will find something unexpected that could require a change or adjustment of the regulation.

4.1.10 – Ulla Hansen Telcs –

Ulla Hansen Telcs is educated as a chemical engineer but has spent much of her career working with the authorities and more recently with Danish Industries. She began working with the Food Stuffs Agency and later worked in Brussels with EU legislation. When she began working with Danish Industries, she again worked with foodstuffs and food regulation but later changed her focus to environmental issues. Today she focuses both on environmental issues mainly dealing with chemicals and nanotechnology, and serves as the leader of one of Danish Industries' Branch Associations dealing with process industries. Danish Industries is an organization, which represents

thousands of Danish companies, by offering advice on how to deal with legislation and also speaks on behalf of the industries' interests.

Telcs was placed in charge of environmental issues surrounding nanotechnology because of her background with chemicals. She follows the various action plans presented by the EU and by Denmark and also recently helped organise a conference on the risks and possibilities of nanotechnology. She does not have any technical expertise but follows closely the many issues that surround the technology. She believes that there is a broad range of benefits but also many risks that need to be considered. Telcs believes it is important to remember how broad nanotechnology really is, stating: "nanotechnology is not just one technology, it's a pallet of technologies … you would not say centimetre technology."

Telcs sees several possible benefits that may come out of nanotechnology development. She mentioned that one of the companies that Danish Industries represents is trying to use nanotechnology to make industrial catalysts. Nanotechnology may provide many new ways to save energy and other vital resources. She also noted that medical equipment might be improved through the use of nanotechnology.

Telcs sees many dangers with nanotechnology as well. Her foremost concern is with the fact that there are no developed methods for assessing the risks of nanomaterials. In many applications, nanomaterials can neither be detected nor measured. Methods need to be developed for detecting nanoparticles and accurately measuring their effects on human health and the environment. Telcs believes that fortunately for the technology, there is more overall caution surrounding it than with other technologies in the past. Nevertheless, it may be some time before the proper assessment methods are developed and pressure for the technology to be applied is building.

Telcs believes that it is important that the risks are balanced by benefits and also that the public does not fear nanotechnology the same way it did with gene technology. There is no way to

ensure that nanotechnology does not suffer the same fate as GMO but one thing industry can do is be open with the public and explain that there are risks as well as great benefits. It is important not to let nanotechnology gain a negative reputation. Telcs recounted how companies never wanted their products to be connected to GMO, which probably lead to even more fear amongst the public. GMO was nevertheless a difficult technology to sell in the first place because people often thought of it as "playing God." Also, GMO's main application was with food, and many people are very concerned about what they eat.

Telcs was unable to weigh the risks against the benefits. She believes that because almost nothing is known about the risks of nanotechnology it is impossible to determine how they rate compared to the benefits. Nevertheless, if the risks are known and can be controlled, then the benefits will prevail. Telcs was also unable to determine if the current regulatory framework is sufficient to protect the Danish public from the possible risks of nanotechnology because so many of the risks are still unknown. There is really now way to determine if the regulation will be effective if it is unknown what it will be up against. Telcs does believe that it is important to get the detection and assessment methods figured out and that whatever the regulation on nanotechnology turns out to be, it should be international legislation. Telcs informed us that there are teams both with the EU as well as in Denmark reviewing the legislation, trying to determine if it can manage nanotechnology and if there are any gaps. Overall she believes that the approach to regulating nanotechnology should involve some incremental changes as well as some immediate changes and adjustments to the existing framework.

4.1.11 – Steen Gade –

Steen Gade is a Member of Parliament representing the Socialist People's Party. In the 1990s, Gade was chairman of the Environmental Committee in Parliament. For a while, Gade left Parliament and served as the Director General of the Danish EPA. Today, Steen Gade is back in Parliament and is a key speaker on environmental issues. Although he has no technical background, nanotechnology has been a common topic for discussion regarding environmental issues.

The problem that Gade sees with nanotechnology is that it seems nanoparticles may have a different way of interacting with each other than regular chemicals do. Consequently, he believes that more work should be done to assess the risks of nanomaterials. Gade admitted that it is difficult for him to form many opinions on nanotechnology because he lacks the technical expertise, but what he has noticed is that there are many experts on both sides of the issues surrounding nanotechnology. Some experts say that nanotechnology brings many new dangers and others say that there is no reason to be more concerned about nanotechnology than any other technology.

Gade commented on how in Denmark, nanotechnology is very much a buzzword. There is a positive connotation that goes along with term, and it is easier for research projects to get funded if they are related to nanotechnology. In fact, Gade stated, "And sometimes I hear from scientists, now we are applying for money for this and that, and now we're calling it nanotechnology and before we didn't call it nanotechnology but it was the same thing." Gade worries that if more effort is not put toward figuring out the risks now, then it might be too late before something really bad comes out of nanotechnology.

Gade is aware that there are many benefits associated with nanotechnology, but admits that he is not very familiar with them. It is his role to be more focused on the risks than the benefits of nanotechnology, he said. Nevertheless, Gade hopes that putting pressure on nanotechnology will only help it to excel in the future. He explained how strict regulation could be a good thing for

technology. To illustrate this he used Denmark's policy on gene technology. Denmark had the first legislation on gene technology in Europe. At first industry was against the legislation, but later found that it was easier to use the new technology because they did not face scrutiny from environmental agencies and the media, as well as apprehension by the public. Gade noted that today Denmark is home to the two largest companies in enzyme manufacturing in the world.

Gade believes that regulation is what made gene technology a success in Denmark and thinks that regulation could do the same for nanotechnology. However, because nanotechnology is so broad, especially compared to gene technology, he is not sure if nano-specific regulation is the right way to go. Ultimately the goal is simply to put pressure on industry to ensure the safety of their products so that they do not have to face scrutiny and apprehension when they want to sell their products. Gade believes that many, but of course not all, European companies are beginning to accept this point of view, and have developed a "let's make a deal," attitude toward regulation. At the end of the day everyone should be a winner. He drew attention to the new REACH regulation as an example and explained how in the beginning it was probably the strongest chemical regulation in the world. It took some time and weakening to finally get it passed, but even now, industry has accepted a great responsibility in ensuring that the chemicals are being used in a safe way.

Overall, Gade does not believe that regulation, including REACH, is sufficient to ensure the safety of the Danish public from the possible risks of nanotechnology. However, he does not yet know where or how the regulation should be changed, but he believes that a focus should be placed on health safety. Gade believes that the ideal way to regulate nanotechnology is with immediate changes and perhaps a new framework. However, because he does not know what areas of the regulation need to be changed, the most practical way to regulate nanotechnology would be a combination of immediate changes and incremental changes as the areas for regulatory improvement become clear.

4.1.12 – Brigitte Rasmussen –

Brigitte Rasmussen is the senior scientist for the management engineering program at the Danish Technical University. She was educated as a chemical engineer and has a PhD in risk assessment. In recent years Rasmussen has been working with what is called technology scenarios, or technology foresight, which is concerned with bridging the gap between developing technologies and society. Recently she was working to develop an action plan for nanotechnology and nanoscience in Denmark. She has also conducted a study on green technology related to nanotechnology. Finally, she has worked with the Technology Board in Denmark on a study regarding nanotechnology and regulation trying to determine how nanotechnology should be regulated.

Rasmussen believes there are things to be excited about with nanotechnology. On the whole however, she could not form an optimistic or pessimistic opinion. She thinks that there are so many different applications of nanotechnology that is it difficult to talk about them all as one entity. Nevertheless, she is enthusiastic about the advancements in medicine, specifically cancer treatment and drug delivery systems.

Rasmussen found it difficult to address the general risks of nanotechnology but did have a few things to say about nanoparticles. Her main concern was with free nanoparticles. It is known that nanoparticles exhibit a different chemistry than we are used to with traditional chemistries. The active sites on the nanoparticles may cause damage if they come in contact with the skin, are ingested, or inhaled. The problem is that it is not yet clear what information is important when assessing nanomaterials and there is also an issue with finding funding for all of the testing. Additionally, there is not yet a means to detect nanoparticles. There is no way to find them if they

are somehow released into the environment. The novelty of these new chemicals is very concerning and there has been a history of new chemicals causing serious harm and even death to its users.

When asked if a scenario like asbestos could repeat itself with nanotechnology, Rasmussen could not say for sure. She recalled a story from a few years back in Denmark where a coating for windshields was marketed under the "nano" name when it actually did not use any application of nanotechnology. It turned that one of the chemicals in the product was hazardous, and the product had to be pulled from the market. Occurrences such as this could spoil the name of nanotechnology and for that reason a lot of nanotechnology companies are unsure of whether or not they should market their products with the "nano" name.

Rasmussen does see some similarities between nanotechnology and GMO but also sees some major distinctions. GMO is very specific compared to nanotechnology and is obviously defined by its name as a technology that involves working with DNA and genes. Nanotechnology is difficult to define as it encompasses so many things. Rasmussen believes that as the technology develops, the name nanotechnology will become less prevalent as companies will have more specific names for the technologies they are working with. She believes that this would also probably happen if the "nano" name ever developed a negative connotation. To Rasmussen, nanotechnology is simply a buzzword used to achieve research funding.

Rasmussen told us that when she was working on the nanotechnology action plan, she conducted a study with a group of about thirty people with no education about nanotechnology to determine their views on the risks and benefits of nanotechnology. The participants were shown two presentations, one regarding health and the other regarding the scientific aspects of nanotechnology. After the presentations, the participants were asked to fill out a questionnaire. Rasmussen recalled that the study showed people were very enthusiastic about the possible advances in medicine and most concerned about the use of nanotechnology in food. She explained that

people are willing to accept the most risk for the greatest benefits and if it is an application that does not require repeated and chronic use, such as a treatment for a disease. For applications such as nanotechnology in food, the benefits are not as great and exposure to the nanomaterials frequent.

Rasmussen believes that the framework for regulating nanotechnology is adequate. In the future adjustments may be needed, but the best thing to do is to adapt the existing framework. She believes that trying to build a new framework for nanotechnology will only lead to companies claiming their products are not nanotechnology. The technology is far too vague for a nano-specific framework to be effective. What really needs to be improved is not the regulation so much as the methods for detecting, measuring, and assessing nanomaterials. There is no way to regulate nanomaterials if there is no way to prove that they exist in a product.

4.1.13 – Thomas Broch-Nielsen –

Thomas Broch-Nielsen is the senior scientist in the personal care department of Fibertex AS of Denmark. Broch-Nielsen was originally educated in chemistry and now works on various research projects involving nanotechnology. One such project, which Broch-Nielsen began two-and-a-half years ago and ran up until last year, functions in cooperation with the Interdisciplinary Institute of Nanotechnology (INano), one of the leading nanotechnology research centres, as well as the Danish Advanced National Technology Fund.

Broch-Nielsen divided the benefits of nanotechnology for consumers into two categories. The first category consists of using nanotechnology to improve problems already existing today. Broch-Nielsen sites the recent problems with brominated compounds' presence in humans from various everyday products using brominated plastic for flame resistance, such as television sets. Nanotechnology would provide many new materials with the same retardant properties but without the hazards to human health. The second division of benefits entails imparting what Broch-Nielsen

calls a "new performance" to a product, something that cannot be done with classical methods. Research into mimicking the super-hydrophobic properties of some plants, commonly referred to as the Lotus Effect, using various compounds is seen as one such consumer benefit by Broch-Nielsen. When asked about his enthusiasm towards these benefits, Broch-Nielsen responded, "we are so enthusiastic that this is the largest and most expensive project that this company has ever undertaken in research and development." He went on to say that on a scale of one to ten, "I'd say 9.5."

Despite admitting that he believes the benefits of nanotechnology will far outweigh the risks, Broch-Nielsen also acknowledged there are some risks associated with nanotechnology. He went on to divide said risks into two categories, scientific or real risk and perceived risk. In terms of perceived risk Broch-Nielsen fears that nanotechnology as a whole could be marked as something dangerous if something bad happens with one application, thereby preventing exploration into the hundreds of other applications. As an example, Broch-Nielsen mentioned the windshield spray controversy in Germany a few years ago. The spray was intended to lessen the use of windshield wipers by increasing the hydrophobicity of the windshield, however it had toxic effects on the people applying it. Broch-Nielsen said the manufacturers marketed it as a nano-spray in order to increase the price, but in fact the spray contained a known toxic chemical not nanotechnology. However, because nano was in the name of the product, journalists wrote stories about how dangerous nanotechnology must be. Broch-Nielsen fears that public perception will be swayed by sensational stories such as this, so Fibertex tries to battle this so-called misinformation. For real or scientific risks, Broch-Nielsen mentions the nano-silver socks currently available to the consumer. The socks use nano-silver as an anti-bacterial component, which would seem to be very beneficial. However, a Swedish university study showed that bacteria become resistant to the nano-silver. When that was revealed, Fibertex stopped its research into using nano-silver as an anti-bacterial. In

terms of risks in specific applications of nanotechnology, Broch-Nielsen seems more concerned about those applications where nanoparticles are directly exposed to humans. His rationale is simple, nano-medicine does seem as risky because it is typically only taken sporadically when ill and may actually lessen already existing side-effects whereas having nano-silver in one's underwear, for example, would likely have greater risks because underwear is worn all day, every day. Broch-Nielsen does not expect problems if the nanoparticles are encased by another material, such as baseball bats whose carbon nanotube core is encased by aluminium, because there is no direct contact with humans.

The frequent comparison of nanotechnology to asbestos and GMO's is a cause for concern in the eyes of Broch-Nielsen. Broch-Nielsen points to the conflicting, and often unsubstantiated, information presently available as the source of any public anxiety regarding nanotechnology. He admits "that in a way is probably my biggest concern in terms of nanotechnology – that we might end up getting so many conflicting reports that people will end up trying to avoid it just to be safe," (Broch-Nielsen). Fibertex tries to maintain a certain level of transparency with the public by publishing their findings and attempting to correct false information they see published.

Although we are currently not very far along in terms of nanotechnology development, Broch-Nielsen predicts that in the next ten to fifteen years nanotechnology will be a part of our everyday lives.

When asked about the current regulatory framework's ability to protect the Danish public from the possible risks of nanotechnology, Broch-Nielsen answered "I believe the regulation we have already encompasses all sorts of chemicals and so on, it is simply a matter of applying it to any new areas that come up such as nanotechnology," (Broch-Nielsen). At this time, there were no changes Broch-Nielsen would make to the legislation, but he can foresee needing to make tweaks and minor changes in the future as new applications are discovered. Broch-Nielsen has a good

amount of faith in REACH's ability to "grow and become more and more encompassing," (Broch-Nielsen).

4.2 – National Survey –

The DCC sent the survey out to their list of members on Wednesday, 16 April, 2008 and the results from the national survey were received the following Friday, 25 April, 2008. Of the 1845 members to whom the survey was sent, more than half, 988 people, responded to some, or all of the survey questions. The complete survey results may be found in Appendix E. Results from the survey are presented in this section, while a full analysis of the data can be found in the following chapter.

The responses Question 1 show that green technology and transportation technology were the viewed most positively while biotechnology was viewed negatively by a majority of respondents. Nanotechnology saw fairly equal distribution between very positive and positive rankings, 35.1% and 38.2% respectively. Only 5.4% of respondents had viewed the technology negatively (Table 4.1). Overall, people had a positive opinion towards developing technologies but when asked whether or not nanotechnology will improve their lives, 45% were unsure and only 32% felt that it would improve their lives.

Question 1 Results – What is your view on new technologies?								
			Rankings					
			Very Positive	Positive	Neutral	Negative	Very Negative	Total
Field	Biotechnology	Count	50	137	286	334	181	988
		% within Field	5.1%	13.9%	28.9%	33.8%	18.3%	100.0%
	Medical Technology	Count	303	404	167	76	38	988
		% within Field	30.7%	40.9%	16.9%	7.7%	3.8%	100.0%
	Computer and Information Technology	Count	305	465	189	23	6	988
		% within Field	30.9%	47.1%	19.1%	2.3%	.6%	100.0%
	Robotics	Count	219	427	277	55	10	988
		% within Field	22.2%	43.2%	28.0%	5.6%	1.0%	100.0%
	Green Technology	Count	629	294	59	6		988
		% within Field	63.7%	29.8%	6.0%	.6%	.0%	100.0%
	Transportation Technology	Count	498	385	98	6	1	988
		% within Field	50.4%	39.0%	9.9%	.6%	.1%	100.0%
	Nanotechnology	Count	347	377	211	45	8	988
		% within Field	35.1%	38.2%	21.4%	4.6%	.8%	100.0%
	Total	Count	2351	2489	1287	545	244	6916
		% within Field	34.0%	36.0%	18.6%	7.9%	3.5%	100.0%

Table 4.1 – Question 1 Results – What is your view on new technologies?

The survey results to Question 3 showed a great percentage of people have at least heard of nanotechnology. Approximately 87.3% have heard of it while 8.1% had not and 4.6% of the people who responded were unsure. Television shows and newspapers were shown to be the most popular sources of exposure to nanotechnology (Table 4.2).

Question 4 Results – How familiar do you consider yourself with nanotechnology?			
		Responses	
		Votes	Per Cent of Cases
Sources of Information	Television Shows	603	69.9%
	Radio	202	23.4%
	Newspapers	526	61.0%
	Specialist Magazines	197	22.8%
	Advertisements	226	26.2%
	Family and Friends	170	19.7%
	Other Places	71	8.2%
	Don't Remember	28	3.2%
	Total	2023	

Table 4.2 – Question 4 Results – How familiar do you consider yourself with nanotechnology?

While the responses indicate that a majority of the population has heard of nanotechnology, it does not show how familiar people are with nanotechnology. Question 5 accounts for familiarity,

showing that about 70% of the respondents claimed to have minimal knowledge of nanotechnology. The true and false section of the survey (Question 6) supports this claim (Table 4.3). On average, the respondents answered 3.38 questions out of seven correctly.

Question 6 Results – Were you aware of any possible benefits nanotechnology may bring to consumer products?			
		Frequency	Per Cent
Number of Correct Answers	0	87	9.6
	1	24	2.6
	2	119	13.1
	3	217	23.9
	4	239	26.3
	5	147	16.2
	6	61	6.7
	7	14	1.5
	Total	908	100.0

Table 4.3 – Question 6 Results – Were you aware of any possible benefits nanotechnology may bring to consumer products?

It is important to note that while we had initially planned to include a third choice to the true and false, an "unsure" option, it was never implemented in the survey that was sent out. Therefore, the results of the true and false section should be used with caution as some respondents may have merely guessed the right answer.

Questions 7 and 8 asked the participant if they were aware of any benefits and risks, respectively, of nanotechnology. The results showed that while most people, approximately 73%, were aware of the benefits, only 32% were aware of the risks. When asked to weigh the benefits and the risks of nanotechnology, people were mainly optimistic about its use. Only a small percentage of people, 8.1%, believed that the risks outweighed the benefits and 18.8% were unsure. The remaining sample was equally divided between those who believed the benefits outweighed the risks and those who believed that the benefits and risks were equal (Table 4.4).

Question 9 Results – Based on your understanding of the risks and benefits, which applications of nanotechnology would you take advantage of?								
			Ranking					
			Very Likely	Likely	Unlikely	Very Unlikely	Unsure	Total
Area	Medicine	Count	216	405	109	33	55	818
		% within Area	26.4%	49.5%	13.3%	4.0%	6.7%	100.0%
	Personal Care	Count	21	112	371	271	43	818
		% within Area	2.6%	13.7%	45.4%	33.1%	5.3%	100.0%
	Electronics	Count	250	447	61	20	40	818
		% within Area	30.6%	54.6%	7.5%	2.4%	4.9%	100.0%
	Food	Count	45	198	317	202	56	818
		% within Area	5.5%	24.2%	38.8%	24.7%	6.8%	100.0%
	Clothing and Textiles	Count	140	367	195	76	40	818
		% within Area	17.1%	44.9%	23.8%	9.3%	4.9%	100.0%
	Leisure	Count	130	342	197	92	57	818
		% within Area	15.9%	41.8%	24.1%	11.2%	7.0%	100.0%
	Household Products	Count	129	311	220	119	39	818
		% within Area	15.8%	38.0%	26.9%	14.5%	4.8%	100.0%
	Total	Count	931	2182	1470	813	330	5726
		% within Area	16.3%	38.1%	25.7%	14.2%	5.8%	100.0%

Table 4.4 – Question 9 Results – Based on your understanding of the risks and benefits, which applications of nanotechnology would you take advantage of?

When participants were queried about the likelihood of purchasing various products based on their understanding of nanotechnology's risks and benefits, applications in the medical and electronic fields were most often chosen. Respondents were more apprehensive about purchasing food and personal care products that incorporated nanomaterials and nanoparticles.

Questions 11 and 12 gauged the public's confidence in the government and private companies. The results show that people are confident in the government's ability to regulate the use of nanomaterials and nanotechnology in consumer products; about half the respondents were confident or extremely confident in the government. The same could not be said about the public's confidence in companies. Over half of the respondents had little to no confidence in companies.

The following chapter will use the aforementioned data as well as the data gathered from the numerous interviews conducted to analyse public knowledge, benefits, risks, and public perception of nanotechnology.

5.0 – Analysis –

In this chapter, we bring all of our results together and work them through the analytical techniques described in the methods chapters. This chapter is broken up into sections similar to those in the background chapter. The goal of our analysis was to determine the Danish perspective on the key themes discussed in the background chapter: public knowledge, nanotechnology risks and benefits, public perception, and nanotechnology regulation. Results from each aspect of our empirical research are unified around these four themes. Our analysis shows how each element of our research relates to one another and gives meaning to the abundance or data collected through our work.

5.1 – Knowledge of Nanotechnology –

The national survey and interviews have shown, with certainty, that while the general public has heard of nanotechnology, they are not aware of what nanotechnology is or how it may be used in consumer applications. It should be noted that this lack of awareness and understanding is not the fault of the consumer, but rather and the newness of this burgeoning field. While research is being conducted, only a small per cent of the general public is being exposed to the results of the research and an even smaller per cent understand the technical writings published by scientists. Claus Jørgensen, our sponsor at the Danish Consumer Council, said,

> If you're a scientists, you can find [papers on nanotechnology] and you can probably understand whatever reviews and papers that are presented in scientific journals… you can always find out this published research on nanotechnology and so on but you need to be a subscriber, and for a normal consumer, they will never ever read the scientific review or anything… (Jørgensen)

Others have shared opinions similar to Jørgensen's. Brigitte Rasmussen repeatedly mentioned that the term nanotechnology is still too vague; there is no accurate definition as to what constitutes

nanotechnology. "[Does] the technology have to be small in one dimension or two dimensions or three dimensions? What is it?" (Rasmussen). The lack of a concrete definition for nanotechnology further highlights the lack of proper information and knowledge amongst not only the public but also the scientific community.

This lack of knowledge within the general public is further supported by the national survey we conducted. The survey shows that while most people have heard of nanotechnology, very few people consider themselves familiar with it. Approximately 14% of the survey pool felt they were familiar or very familiar with nanotechnology. A large majority of the survey pool, 76%, felt they were only slightly familiar, and the remaining 10% felt they were not at all familiar. When broken down by age and education, the statistics vary minutely. The following tables, Table 5.1 and Table 5.2, confirm this.

Familiarity and Age							
			Age				
			18-30	31-50	51-65	Over 65	Total
Familiarity	Very	Count	1	3	1	1	6
		% within Age	1.7%	.8%	.3%	1.1%	.7%
	Somewhat	Count	10	60	37	12	119
		% within Age	17.2%	15.6%	10.9%	13.8%	13.7%
	A Little	Count	40	287	272	65	664
		% within Age	69.0%	74.7%	79.8%	74.7%	76.3%
	Not At All	Count	7	34	31	9	81
		% within Age	12.1%	8.9%	9.1%	10.3%	9.3%
	Total	Count	58	384	341	87	870
		% within Age	100.0%	100.0%	100.0%	100.0%	100.0%

Table 5.1 – Familiarity and Age

Familiarity and Education						
			Education			
			Grade School	High School	Higher Education	Total
Familiarity	Very	Count	1	1	4	6
		% within Education	.4%	.5%	1.1%	.7%
	Somewhat	Count	32	26	60	118
		% within Education	11.9%	12.0%	15.8%	13.6%
	A Little	Count	203	165	293	661
		% within Education	75.2%	76.0%	77.3%	76.3%
	Not At All	Count	34	25	22	81
		% within Education	12.6%	11.5%	5.8%	9.4%
	Total	Count	270	217	379	866
		% within Education	100.0%	100.0%	100.0%	100.0%

Table 5.2 – Familiarity and Education

There exists a slight correlation between age and familiarity. As seen by Table 5.1 above, a higher percentage of respondents between the ages of 18 and 30 declared themselves familiar with nanotechnology, approximately 19% in the top two rows (Very, Somewhat). The percentages of respondents claiming great familiarity drop slightly as the age increases, to about 16% of adults between 31 and 50 and only 11% of adults between the ages of 51 and 65. Surprisingly, for adults over the age of 65, approximately 16% of the respondents categorised themselves as "Very" and "Somewhat" familiar with nanotechnology. A possible explanation for the increase can be seen when one examines correlations between sources of information and age (Table 5.3).

Sources of Information and Age							
			Age				
			18-30	31-50	51-65	Over 65	Total
Sources of Information	Television Shows	Count	39	259	233	48	579
		% within Age	73.6%	70.4%	71.9%	59.3%	
	Radio	Count	10	90	76	21	197
		% within Age	18.9%	24.5%	23.5%	25.9%	
	Newspapers	Count	24	217	205	62	508
		% within Age	45.3%	59.0%	63.3%	76.5%	
	Specialist Magazines	Count	11	85	67	27	190
		% within Age	20.8%	23.1%	20.7%	33.3%	
	Advertisements	Count	23	112	71	12	218
		% within Age	43.4%	30.4%	21.9%	14.8%	
	Family and Friends	Count	15	74	62	13	164
		% within Age	28.3%	20.1%	19.1%	16.0%	
	Other Places	Count	8	39	14	5	66
		% within Age	15.1%	10.6%	4.3%	6.2%	
	Don't Remember	Count	4	14	7	1	26
		% within Age	7.5%	3.8%	2.2%	1.2%	
	Total	Count	53	368	324	81	826
Percentages and totals are based on respondents.							

Table 5.3 – Source of Information and Age

A significant percentage of respondents over 65 years of age have heard about nanotechnology through newspapers and other periodicals, much more than in any other age group. Their familiarity could be attributed to the fact that newspapers and other periodicals provide more informational content than other media. Given the fact that 65 is typically the age for retirement, it seems likely that respondents of this age bracket would have more free time in which to read newspapers and periodicals.

A predictable trend occurs when familiarity is related to education level in that familiarity increases with education. The trend can be better observed in the figure below (Figure 5.1)

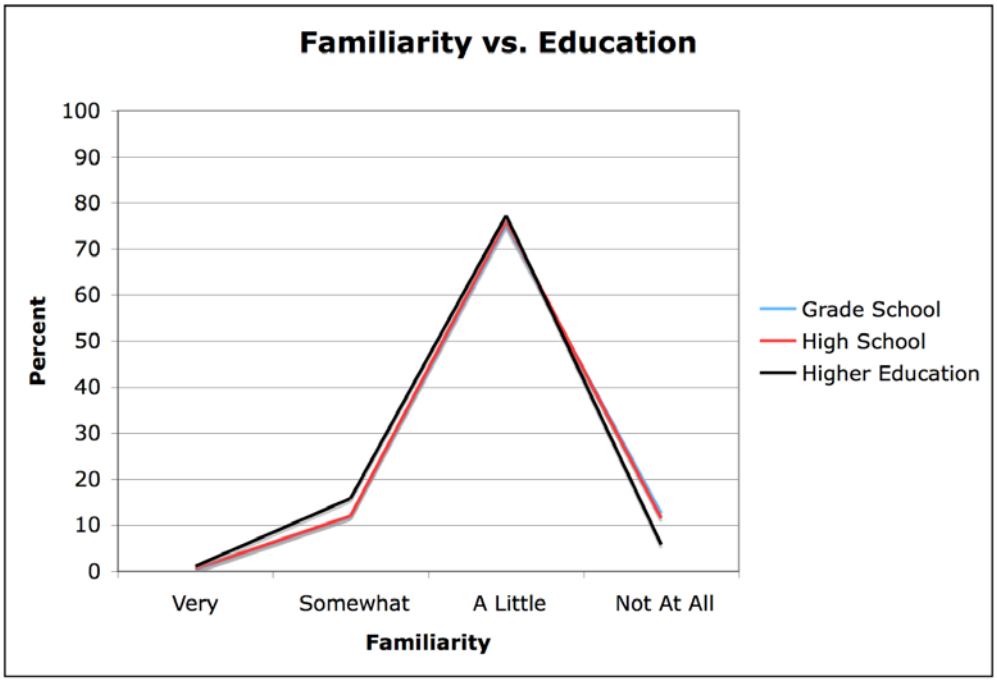

Figure 5.1 – Familiarity vs. Education

This figure is a graphical representation of the data in Table 5.2. One can see there is very little difference in familiarity between the respondents with a grade school and high school educations. About 12% of respondents in these education levels place themselves in the two upper levels of familiarity. About 75% are a little familiar and the remaining 12-13% has no familiarity with nanotechnology. There is, on the other hand, a noticeable difference between higher-level education and the other two education levels. The figure shows that more respondents with higher education are "Very" or "Somewhat" familiar with nanotechnology. While the percentage of respondents in this education level claiming to know only a little about nanotechnology is comparable to the other education levels, there is a distinct drop in the percentage of highly educated respondents claiming to know nothing about the technology. This shows that there is a slight correlation between education and familiarity.

Although we asked the survey participants to gauge their own level of understanding, we also included a true and false section meant to objectively gauge their level of knowledge concerning

nanotechnology. Table 5.4 shows relationships between the number of correct answers and the level of familiarity.

Familiarity and Scores											
			Score								
			0	1	2	3	4	5	6	7	Total
Familiarity	Very	Count			1	1	1	2	1	1	7
		% within Familiarity	.0%	.0%	14.3%	14.3%	14.3%	28.6%	14.3%	14.3%	100.0%
		% within Score	.0%	.0%	.8%	.5%	.4%	1.4%	1.6%	7.1%	.8%
	Somewhat	Count		2	10	36	30	28	16	2	124
		% within Familiarity	.0%	1.6%	8.1%	29.0%	24.2%	22.6%	12.9%	1.6%	100.0%
		% within Score	.0%	8.3%	8.4%	16.6%	12.6%	19.0%	26.2%	14.3%	13.7%
	A Little	Count	4	22	108	180	208	117	44	11	694
		% within Familiarity	.6%	3.2%	15.6%	25.9%	30.0%	16.9%	6.3%	1.6%	100.0%
		% within Score	4.6%	91.7%	90.8%	82.9%	87.0%	79.6%	72.1%	78.6%	76.4%
	Not At All	Count	83								83
		% within Familiarity	100.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	100.0%
		% within Score	95.4%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	9.1%
	Total	Count	87	24	119	217	239	147	61	14	908
		% within Familiarity	9.6%	2.6%	13.1%	23.9%	26.3%	16.2%	6.7%	1.5%	100.0%
		% within Score	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 5.4 – Familiarity and Scores

The true and false section consisted of seven questions used to determine the amount of relevant knowledge people had on nanotechnology. For the sake of this analysis, a score of zero will indicate no knowledge, a score from one to four will indicate a little knowledge, five to six will indicate some knowledge, and a score of seven indicates adequate knowledge. The range of scores corresponding to a little knowledge is very broad because we have taken to account the possibility of guessing, which would yield an average score of 3.5. Overall, the results of the familiarity question and the scores are fairly consistent. Ten per cent scored zero, about 66% scored between one and four, 23% answered five or six questions correctly and only 1.5% received a perfect score. Closer examination revealed that a majority of those who were only a little familiar with nanotechnology had scores

corresponding to the little or no knowledge category but roughly a quarter of that familiarity pool scored higher than four, which corresponds to the having some knowledge (Table 5.5); the median score for the pool was 3.65. The median score for those who claim to be somewhat familiar was 4.03 and for those who claim to be very familiar with nanotechnology, the median score was 4.57.

Mean Scores			
Familiarity	Mean Score	Cases	Std. Deviation
Very	4.5714	7	1.71825
Somewhat	4.0323	124	1.28743
A Little	3.6542	694	1.30655
Not At All	.0000	83	.00000
Total	3.3789	908	1.64945

Table 5.5 – Mean Scores

Clearly, those who are more familiar performed significantly better than those who claimed to only be a little familiar with nanotechnology. However, overall, the median score was 3.38, which is below what would be expected if one were to merely guess for all the questions. This affirms the opinions shared by the experts we interviewed, that the general public knows very little, or not enough, about nanotechnology.

5.2 – Benefits –

Interviews with experts have shown that, overall, nanotechnology is expected to provide benefits to society. While every interviewee saw nanotechnology as being beneficial, not everyone felt that nanotechnology provided significant benefits when applied to consumer products. Figure 5.2 below shows where the interviewees saw nanotechnology being most beneficial.

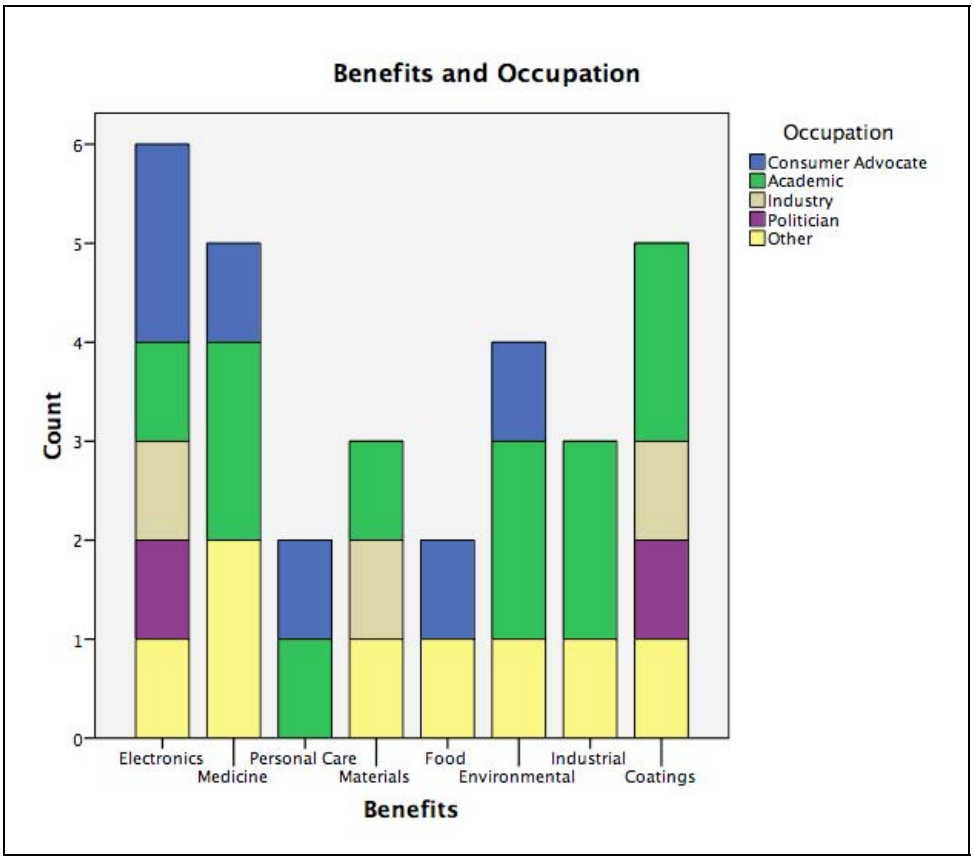

Figure 5.2 – Benefits and Occupation

Medicine was mentioned by a majority of those interviewed as a field in which nanotechnology would be beneficial. Specifically mentioned was the application of nanotechnology in the treatment of cancer. While the above graph shows that most of the people interviewed identified medicine as a major area of nanotechnology development, followed closely by environmental and industrial (by which we mean non-consumer) applications, it should be noted that those with backgrounds in academia and industry, those having the highest technical understanding of nanotechnology, saw very few viable consumer applications of the technology. For the most part, it was in environmental and industrial applications where they saw nanotechnology to be beneficial. A little less than half of the people interviewed listed electronics as an area where nanotechnology provides distinct benefits even though the electronics industry relies heavily on nanotechnology to produce computers and other various electronics that are prevalent in modern society. Additionally, only a few people saw

benefits in personal health items such as sunscreen. The graph (Figure 5.3) below describes the overall views of the interviewees towards the benefits of nanotechnology.

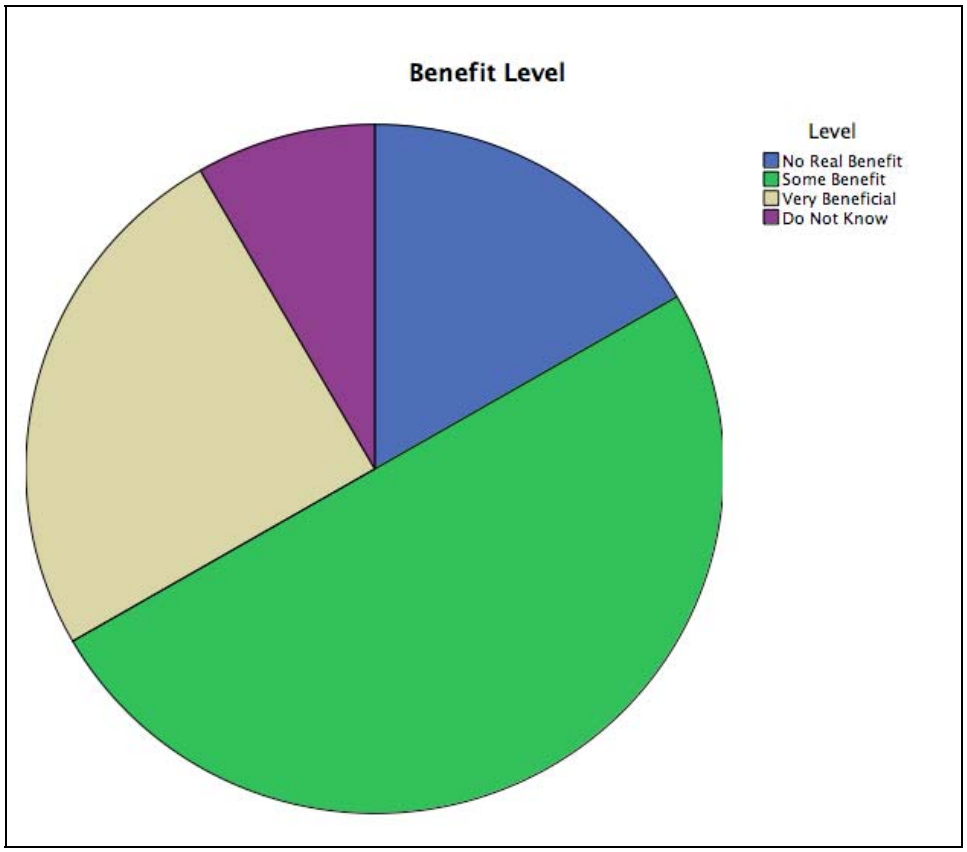

Figure 5.3 – Benefit Level

A majority of the experts saw nanotechnology as providing some sort of consumer benefit while two saw no benefits and two others were very optimistic about the benefits that nanotechnology has to offer in consumer products. It should be noted that the two participants who say no real benefits to consumer products are involved directly in risk assessment of nanotechnology. Anders Baun and Steffen Foss Hansen claim that nanotechnology does have benefits, mainly in environmental remediation, energy sciences and catalysis but in consumer products, the use of nanoparticles and nanomaterials does not provide any considerable advantages over current products. Others, such as science writer Lone Frank shares Baun and Hansen's opinion towards nanotechnology but elaborates on the issue, mentioning that nanomaterials could provide new and better solutions to

problems new and old. "Well, of course, there's no reason to use nanotechnology if you have another technology that's just as good… but if it's about, for example, coatings of things; we didn't have any technologies that are as good as nano-coating… so whenever it's a new solution to an old problem or a solution of a new problem, I think one should be positive," (Frank). In many cases, new products incorporating nanomaterials provide better solutions to existing problems such as the various surface coatings TCNano produces. Robert Firkic, product manager at the company explained that nanoparticles could adhere to surfaces better than existing compounds thus increasing the durability and lifetime of the surface coating. Nanotechnology has the potential to provide great benefits, but nanotechnology is still in its infancy. As Anders Baun explained, the development of any technology may be divided into four distinct parts or generations. In the first generation, researchers and developers are still trying to figure out how the new technology may be used. Baun believes nanotechnology is currently at this first generation. People may espouse the many applications of nanotechnology, but when one looks at what is currently on the market, not much is available. Applications, such as cancer treatment or drug delivery, environmental remediation or food, are still in the early stages of development and testing. They are still years away from being widely used in society.

The national survey revealed that the public, in general, has some awareness of the potential benefits of nanotechnology and nanomaterials. Of those who responded, 72.5% are aware of the benefits. A relationship between familiarity and awareness of benefits may be established as well (Table 5.6).

Benefit Awareness and Familiarity						
			Familiarity			
			Very	Somewhat	A Little	Total
Benefit Awareness	Yes	Count	7	118	470	595
		% within Benefit Awareness	1.2%	19.8%	79.0%	100.0%
		% within Familiarity	100.0%	95.2%	68.1%	72.5%
	No	Count		6	220	226
		% within Benefit Awareness	.0%	2.7%	97.3%	100.0%
		% within Familiarity	.0%	4.8%	31.9%	27.5%
	Total	Count	7	124	690	821
		% within Benefit Awareness	.9%	15.1%	84.0%	100.0%
		% within Familiarity	100.0%	100.0%	100.0%	100.0%

Table 5.6 – Benefit Awareness and Familiarity

Familiarity with nanotechnology has an interesting role in determining the perceptions of its overall benefits. Of all the participants who admit to having very little familiarity with nanotechnology, 32% claimed to see no benefits from nanotechnology; this 32% accounts for nearly all (97.3%) of the respondents who did not see any benefits to nanotechnology. Nearly all respondents who are somewhat familiar or very familiar felt that nanotechnology does provide some benefit to consumer products. Both interviewees and the general public are, generally, aware of some benefits associated with the application and use of nanotechnology and nanomaterials in consumer products. But, as the next section will reveal, the same cannot be said about the potential risks that nanotechnology and nanomaterials may pose.

5.3 – Risks –

Interviews show how little information is available about the risks associated with the application and use of nanotechnology and nanomaterials. When queried about what risks they believe nanotechnology poses, many replied that there is not enough information available to respond conclusively. Nevertheless, many people still revealed their concern about possible negative effects on human health. More specifically, the interviewees are concerned about the possible dangers of free nanoparticles and the consequences of coming in contact with or inhaling said particles. Thomas Broch-Nielsen, a research and development scientist, mentioned another possible

risk associated specifically with the use of nano-sized silver particles as an antimicrobial agent. He feels that while effective now, the overuse of silver may cause bacteria to evolve and inherit resistance to nano-silver's antimicrobial properties.

Most interviewees identified human health and safety as their primary concern, but several respondents could not definitively say what risks are present. In fact, several respondents felt that the greatest risk was the lack of knowledge, the uncertainty of whether or not nanomaterials could actually pose a health risk. A number of the interviewees fear that nanomaterials may emulate the rise and fall of other chemicals like DDT and asbestos. Such chemicals had great potential and were used excessively, but decades later, their use has been linked to disastrous health and environmental effects. Nanoparticles and nanomaterials are following the same path; many products are on the market or being developed that utilise these particles, yet their risks have yet to be understood or assessed. It could be that the greatest danger nanotechnology poses at this time is its novelty.

Most interviews suggest that the free nanoparticles may pose a risk to human health, but one must not neglect the possible dangers nanoparticles and nanomaterials may have on the environment. Anders Baun explained four criteria that one should examine when trying to assess environmental risks: persistency, bioaccumulation, toxicity and mobility. Nanomaterials fit all four criteria; they are by definition persistent and have been shown to accumulate in organisms. Certain types of nanomaterials may be toxic, and because of their small size, they are mobile. Nanomaterials therefore have the capacity to be hazardous to the environment. Even so, the people we interviewed are more concerned with risks to humans than to the environment. This may be explained by what Steffen Foss Hansen said, "Environmental risks might be… long term… It's definitely too early to tell. If you want hardcore evidence of harm being done, it's going to take a long while before we have that because we can't even detect them in the environment" (Hansen). Some of the studies that have been done are mentioned in the background section of this report and

were confirmed by Anders Baun. During his interview, Baun mentioned the study using largemouth bass that showed the accumulation of nanoparticles in the brain and resulting degradation of brain tissue. However, because the effects of nanoparticles on the environment will not be seen for some time, and the effects on humans are more prevalent sooner, the possible risks to human health take priority.

Nearly all the interviewees identified a possible health or environmental risk, but when asked how concerned they are about these possible risks, the majority of interviewees admitted to being only slightly concerned. Nanotechnology is a broad, all-encompassing term and the technology itself is not hazardous, nor are many of its applications. Most concerns dealt with a very narrow and specific portion of the nanotechnology field, the use of free nanoparticles. Additionally, the interviewees are confident in the government's ability to properly regulate nanotechnology and keep the public, themselves included, safe and informed. Finally, while reports have shown that the risks people identified are not without merit, the research performed is far from conclusive. As Thomas Broch-Nielsen put it, "There have been other concerns being voiced over the time but none that we have found; I have found to [be] really substantiated as of yet. I mean, there are hundreds of reports I know that exist, which some show positive and some show negative results. And I cannot help but think that because the area's so broad…" (Broch-Nielsen). Risk assessment cannot be properly performed without first understanding what risks nanotechnology actually poses on human health and the environment.

The lack of understanding concerning the potential risks of nanotechnology is reflected in the general public's lack of awareness. As Table 5.7 below shows, almost 70% of all respondents are not aware of the potential risks associated with nanotechnology.

Risk Awareness and Familiarity						
			Familiarity			
			Very	Somewhat	A Little	Total
Risk Awareness	Yes	Count	6	66	189	261
		% within Risk Awareness	2.3%	25.3%	72.4%	100.0%
		% within Familiarity	85.7%	53.2%	27.4%	31.8%
	No	Count	1	58	500	559
		% within Risk Awareness	.2%	10.4%	89.4%	100.0%
		% within Familiarity	14.3%	46.8%	72.6%	68.2%
	Total	Count	7	124	689	820
		% within Risk Awareness	.9%	15.1%	84.0%	100.0%
		% within Familiarity	100.0%	100.0%	100.0%	100.0%

Table 5.7 – Risk Awareness and Familiarity

A large majority, 72.6%, of those claiming little familiarity are unaware of risks while only 46.8% of those somewhat familiar with nanotechnology are unaware. Compared to the public's awareness of potential benefits attributed to nanotechnology, risk awareness is horribly lacking. By relating risk awareness to education (Table 5.8), one can see that risk awareness does increase as education increases, yet those who are aware of the risks still remain the minority in every education bracket.

Risk Awareness and Education						
			Education			
			Grade School	High School	Higher Education	Total
Risk Awareness	Yes	Count	59	56	137	252
		% within Education	25.3%	29.3%	38.5%	32.3%
	No	Count	174	135	219	528
		% within Education	74.7%	70.7%	61.5%	67.7%
	Total	Count	233	191	356	780
		% within Education	100.0%	100.0%	100.0%	100.0%

Table 5.8 – Risk Awareness and Education

Public awareness of both risks and benefits are important factors that play into the public perception of nanotechnology. The following section analyses the data obtained from the interviews and the national survey in terms of public perception.

5.4 – Public Perception –

The results obtained from the national survey showed that the Danish public has a fairly positive perception of nanotechnology. A majority of the population believes the benefits either outweigh or are equal to the risks presented by the application of nanotechnology in consumer products. It is important to note that nanotechnology covers a broad range of applications and therefore, public opinion on the application of nanotechnology varies depending on the intended area of use. The table below (Table 5.9) shows various applications of nanotechnology and how likely the public was to take advantage of each application after considering the benefits and risks of each.

Opinion on Specific Areas of Nanotechnology								
			Ranking					
			Very Likely	Likely	Unlikely	Very Unlikely	Unsure	Total
Area	Medicine	Count	216	405	109	33	55	818
		% within Area	26.4%	49.5%	13.3%	4.0%	6.7%	100.0%
	Personal Care	Count	21	112	371	271	43	818
		% within Area	2.6%	13.7%	45.4%	33.1%	5.3%	100.0%
	Electronics	Count	250	447	61	20	40	818
		% within Area	30.6%	54.6%	7.5%	2.4%	4.9%	100.0%
	Food	Count	45	198	317	202	56	818
		% within Area	5.5%	24.2%	38.8%	24.7%	6.8%	100.0%
	Clothing and Textiles	Count	140	367	195	76	40	818
		% within Area	17.1%	44.9%	23.8%	9.3%	4.9%	100.0%
	Leisure	Count	130	342	197	92	57	818
		% within Area	15.9%	41.8%	24.1%	11.2%	7.0%	100.0%
	Household Products	Count	129	311	220	119	39	818
		% within Area	15.8%	38.0%	26.9%	14.5%	4.8%	100.0%
	Total	Count	931	2182	1470	813	330	5726
		% within Area	16.3%	38.1%	25.7%	14.2%	5.8%	100.0%

Table 5.9 – Opinion on Specific Areas of Nanotechnology

As the table shows, most people are willing to use products in areas such as medicine and electronics, but are apprehensive about purchasing and using products in the areas of personal care and food. As Claus Jørgensen explained, people are more likely to take advantage of a product if there is a clear benefit associated with it. The degree of benefit also affects the decisions of the public. If an application shows great benefits such as a new, radical cancer treatment but also carries

considerable hazards, people will still choose the new application regardless of the hazards if it allows them to avoid death. Simply put, people will utilise nanotechnology if the benefits outweigh the risks. In other applications such as personal care items like cosmetics and sunscreen, people are less likely to use the products, as they do not show noticeable improvements over existing products. Additionally, these products are typically applied to the skin, which could add to the public's apprehension about using the products. According to a series of focus groups conducted by Hanne Svenningsen, the greatest perceived risk was coming in contact with or inhaling nanoparticles. This would also account for the apprehension towards applying nanotechnology to food.

Svenningsen's focus groups show that people are willing to accept risks once they have been identified. The data from the national survey shows a similar trend (Table 5.10, 5.7)

Perception and Familiarity						
			Familiarity			
			Very	Somewhat	A Little	Total
Perception	Benefits > Risks	Count	4	71	201	276
		% within Familiarity	57.1%	57.7%	29.3%	33.8%
	Benefits = Risks	Count		33	241	274
		% within Familiarity	.0%	26.8%	35.1%	33.6%
	Benefits < Risks	Count	1	6	73	80
		% within Familiarity	14.3%	4.9%	10.6%	9.8%
	Unsure	Count	2	13	171	186
		% within Familiarity	28.6%	10.6%	24.9%	22.8%
	Total	Count	7	123	686	816
		% within Familiarity	100.0%	100.0%	100.0%	100.0%

Table 5.10 – Perception and Familiarity

Table 5.7 of the previous section shows that more respondents who are somewhat familiar with nanotechnology have a greater awareness of the possible risks compared to those who are only a little familiar. Taking this into account, Table 5.10 shows that those who are somewhat familiar with nanotechnology still believe the benefits outweigh the risks; 57.7% of the respondents in the category share that perception. Conversely, only 29.3% of those having little familiarity with nanotechnology believe the benefits outweigh the risks and 10.6% believe the risks outweigh the benefits, which is more than double the percentage of respondents having some familiarity. As

Svenningsen put it, "It's all a question of control. For example, many people are still smoking today even through we know it's dangerous, but they choose to," (Svenningsen).

Public perception can be easily swayed by external sources like the media. This proves especially true for nanotechnology because the public has very little understanding of it. When asked if nanotechnology would improve their lives, the respondents are, for the most part, unsure (Table 5.11).

Improvement and Familiarity						
			Familiarity			
			Very	Somewhat	A Little	Total
Improvement	Yes	Count	4	68	192	264
		% within Familiarity	57.1%	55.3%	27.9%	32.3%
	No	Count	1	23	159	183
		% within Familiarity	14.3%	18.7%	23.1%	22.4%
	Unsure	Count	2	32	336	370
		% within Familiarity	28.6%	26.0%	48.9%	45.3%
	Total	Count	7	123	687	817
		% within Familiarity	100.0%	100.0%	100.0%	100.0%

Table 5.11 – Improvement and Familiarity

Those who are somewhat familiar with nanotechnology hold a definite opinion on whether or not nanotechnology would improve their lives; only 26% were unsure. On the other hand, 48.9% of those with little familiarity are unsure if nanotechnology would improve their lives. According to Thomas Broch-Nielsen, if the media associates the term nanotechnology with a negative event, the public could easily fear any product containing nanotechnology or even the term "nano" as being something dangerous due to the unfamiliarity. Broch-Nielsen mentioned once instance in particular, a spray sold in Germany that claimed to utilise nanoparticles led to respiratory problems in people who used it. Although it was later discovered the product did not contain nanoparticles, various media sources had already put a negative label on nanotechnology, which likely negatively affected the perceptions of the public towards all products claiming to incorporate nanotechnology.

Two other factors that affect public perception are confidence and trust, trust in the government to regulate and confidence that companies will utilise nanotechnology responsibly and ensure safety. About half of the respondents are confident in the government while only 40% of respondents are confident in private companies. The Danish public has a higher level of confidence in the government than they do in private industry. This point is further validated by the following data (Table 5.12).

Confidence in Government and in Industry								
			Confidence in Private Industry					
			Extremely Confident	Confident	Little Confident	No Confidence	Unsure	Total
Confidence in Government	Extremely Confident	Count	21	26	13	2		62
		% within Government	33.9%	41.9%	21.0%	3.2%	.0%	100.0%
		% within Industry	75.0%	9.6%	3.4%	1.8%	.0%	7.6%
	Confident	Count	6	188	147	10	5	356
		% within Government	1.7%	52.8%	41.3%	2.8%	1.4%	100.0%
		% within Industry	21.4%	69.4%	37.9%	8.8%	29.4%	43.6%
	Little Confident	Count		47	192	44	3	286
		% within Government	.0%	16.4%	67.1%	15.4%	1.0%	100.0%
		% within Industry	.0%	17.3%	49.5%	38.9%	17.6%	35.0%
	No Confidence	Count		7	34	57	1	99
		% within Government	.0%	7.1%	34.3%	57.6%	1.0%	100.0%
		% within Industry	.0%	2.6%	8.8%	50.4%	5.9%	12.1%
	Unsure	Count	1	3	2		8	14
		% within Government	7.1%	21.4%	14.3%	.0%	57.1%	100.0%
		% within Industry	3.6%	1.1%	.5%	.0%	47.1%	1.7%
	Total	Count	28	271	388	113	17	817
		% within Government	3.4%	33.2%	47.5%	13.8%	2.1%	100.0%
		% within Industry	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 5.12 – Confidence in Government and in Industry

Of the people who are extremely confident in the government, only 33.9% feel the same way about industry. Similarly, a large portion of the respondents who are confident in the government, 45.5%,

are less confident in industry. The results of the focus group conducted by Svenningsen correspond to these results. Her participants believe the companies are driven by monetary motives. Claus Jørgensen supports this claim. He mentioned the GMO debacle when companies made grandiose claims of feeding the world, but in reality, their goal was monetary gain. Jørgensen said, "You have to be honest on what you say you want to do and not have a different agenda when you go out and sell. If you go out and sell nanotechnology as, 'we have a new cure for cancer. We can really help a lot of people,' but what you really want to do is make a lot of products… and make a lot of money that way, then you have the same problem all over again," (Jørgensen). Trust, therefore, plays a major role in how people do and will perceive nanotechnology.

5.5 – Regulation –

Almost every person interviewed was able to offer an opinion on the current regulatory framework and its management of nanotechnology. Although we interviewed a total of thirteen experts, only twelve could be used in this analysis because Hanne Svenningsen did not wish to share her personal opinions on nanotechnology. Using various methods of content analysis we were able to illustrate the overall opinion on regulation and determine the most popular suggestions for action. The first piece of useful information we gathered from the interviews was the experts' overall opinions regarding the adequacy of the existing regulatory framework to protect public safety. We were then able to gauge the prevailing sentiment amongst the experts regarding how regulation should be changed in order to properly manage nanotechnology. The following chart shows the pooled results from the second and fourth questions in the regulatory interview.

Expert	Background	Regulation Adequacy	Approach 1-3
Anders Baun	Academic	Inadequate	2.5
Alexander Jensen	Academic	Inadequate	3
Steffen Foss Hansen	Academic	Inadequate	3
Brigitte Rasmussen	Academic	Adequate	2
Robert Firkic	Industry	Unsure	Unsure
Thomas Broch-Nielsen	Industry	Adequate	1.5
Steen Gade	Politician	Inadequate	2.5
Jørn Dohrmann	Politician	Adequate	2
Claus Jørgensen	Consumer Advocate	Inadequate	2.5
Sofie Krogh Holm	Consumer Advocate	Inadequate	2.5
Ulla Hansen Telcs	Other - Industrial Advisor	Unsure	2.5
Lone Frank	Other - Science Writer	Adequate	2
Hanne Svenningsen	Other - Social Scientist	N/A	N/A

Table 5.13 – Regulatory Opinion Pool

In Table 5.13, the experts are grouped according to their backgrounds. In this analysis it is important to note that the experts with background denoted as "other" are unrelated. Similar responses among them do not imply a characteristic of their background. For the regulatory approach responses, a one (1) refers to the opinion that regulation does not need to change in any way in order to manage nanotechnology. The number two (2) refers to gradual changes of the existing regulatory framework, also known as the incremental approach. Finally, the number three (3) refers to the opinion that a new regulatory framework is needed to manage nanotechnology. Some of the respondents identify themselves as in between two of the three options. For instance, a respondent may be very confident in the existing framework, but also recognise that unforeseen problems could arise in the future, which would require amendments to the legislation. Also, a respondent may think that there are several changes that could be made pre-emptively but did not believe in constructing a whole new framework for various reasons. In cases such as these, the experts are represented by the numbers 1.5 and 2.5.

To make better use of the tabulated data, the results were put into graphical form. The following frequency histogram illustrates the pooled results from each expert's response to the

question regarding the adequacy of the current regulatory framework. Current regulation includes the REACH directive, which officially takes effect in June 2008.

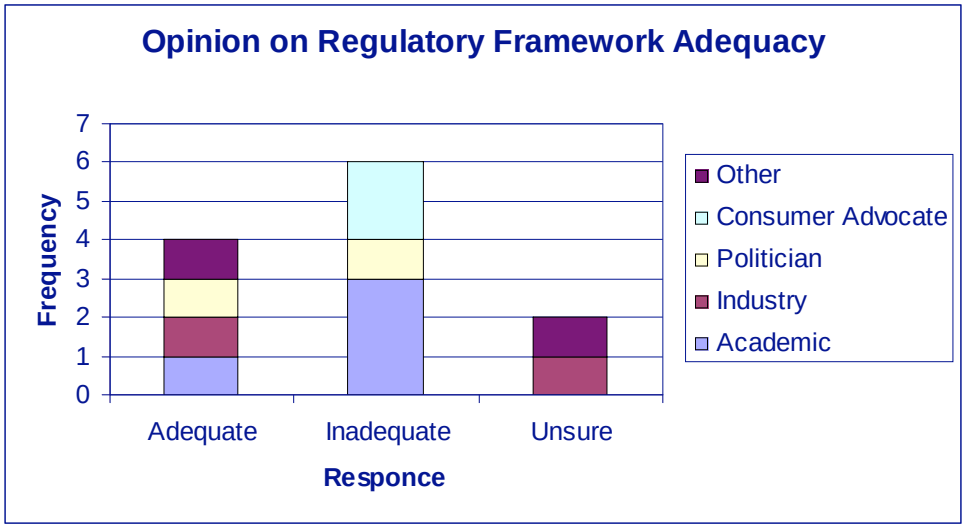

Figure 5.4 – Opinion on Regulatory Framework Adequacy

Figure 5.4 shows that there are several experts who believe that the current regulatory framework is adequate and several who do not. Although the histogram shows that more experts believe the current regulatory framework is inadequate, the difference is insubstantial. This is especially true because there are experts who are unsure either because they need to see how REACH will perform before deciding, or because they believe it is still unknown what challenges nanotechnology may present.

Most of the backgrounds are divided between two positions regarding the adequacy of current regulatory framework. Consumer advocates are the only group of experts who hold a unanimous position, that current regulatory framework is inadequate. Also, academics mostly hold the position that the current regulatory framework is inadequate. It is important to note that although the two experts from industry hold different opinions on the adequacy of the regulatory frame work, the individual who is unsure, Robert Firkic, believes that in principle the framework

including REACH should be able to manage nanotechnology, but in order to form a definitive opinion he will have to wait to see how well the regulation functions.

A histogram of the regulatory approach responses is much more revealing than the histogram for regulatory adequacy responses. The following graph illustrates the overall experts' views on how nanotechnology regulation should be approached.

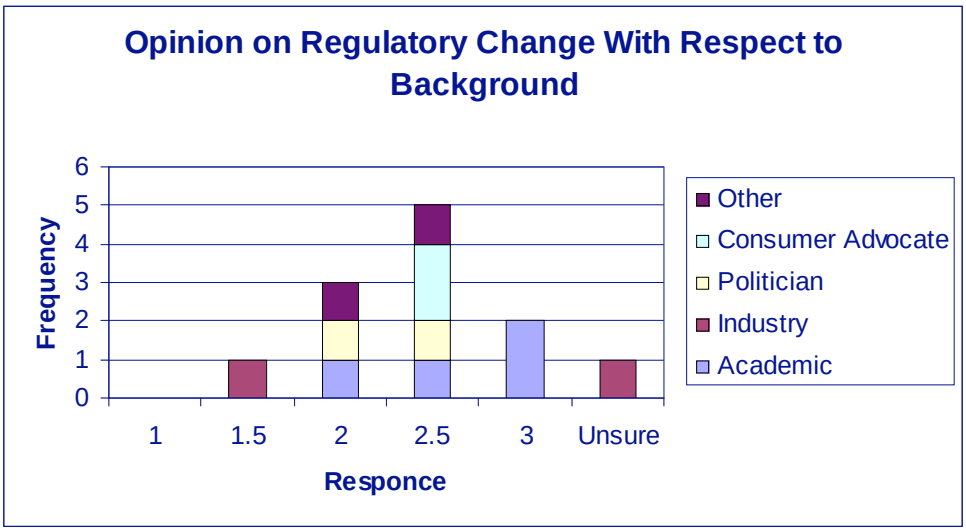

Figure 5.5 – Opinion on Regulatory Change with Respect to Background

Figure 5.5 shows that the most popular approach to regulating nanotechnology is somewhere in between the incremental approach and the development of a new framework. Most, if not all, of the experts who fall into the 2.5 category believe that there are several changes that should be made to the regulatory framework. However, they also believe that developing an entirely new framework would be impractical. Two things that the vast majority of interviewed experts can agree upon is the fact that existing regulatory framework should be kept and also that it will need to be adapted to suit nanotechnology sooner or later. No experts were positive that the current regulation would never need updating.

It is important to note that all of the experts who believe that the current regulatory framework is inadequate took either position 2.5 or three. All of these experts are able to identify

regulatory changes that could be made right away. Also, all of the experts who believe that current regulatory framework is adequate took either position 1.5 or two. Of these experts, only one, MF Jørn Dohrmann was able to identify a possible flaw in the current regulation. Dohrmann's only concern is with the tonnage requirements that trigger the registration and regulation of chemicals. Like most of the experts who believe the current framework is adequate, Robert Firkic does not identify any problems with the current regulation; Firkic is the only expert unsure as to how nanotechnology regulation should be approached.

In addition to the quantitative analysis performed on the regulatory portion of the expert interviews, a qualitative content analysis was performed. The entirety of each interview was reviewed in search of the most common regulatory critiques and general suggestions for actions that should be taken to better manage nanotechnology. There are several suggestions offered by experts who believe the current framework is adequate as well as those who do not.

The most common suggestion, which is offered by ten of the experts interviewed, is that proper risk assessment methods should be developed and the true risks of nanomaterials determined. Confident in the adequacy of the regulatory framework or not, most of the experts agree that the risks nanomaterials may pose to our health and the environment must be determined if any regulation is to be truly effective.

There are several other recurring themes amongst the many management recommendations. Many of the experts commented on the fact that nanotechnology is an incredibly vague term. A few even stress the importance of developing a standard, agreed upon definition of what nanotechnology is. If it is one day determined that legislation made specifically for nanotechnology is necessary, it will be imperative that nanotechnology is well defined, so that it is obvious to which chemicals and products the legislation applies. A few experts believe that it is important that the authorities keep a close eye on all nano-products on the market, and two of them even suggested a

mandatory registry for products containing any kind of nanomaterial. Such a provision exemplifies the importance of an agreed upon definition of nanotechnology.

Several experts have identified two regulatory gaps, which could cause trouble if they are not addressed with nanotechnology in mind. The first regulatory gap pertains to the tonnage requirements for registration. A few experts believe that many nanomaterials will not meet the ten tonne limit, which, when yearly production surpasses said limit, requires manufacturers to conduct extra risk assessment. According to these experts, it is even possible that some nanomaterials will be produced in such small volumes that they will not even need to be registered. A few of the experts also believe that the regulation will not require a distinction between the nano and bulk forms of registered chemicals. Several studies show that some nanomaterials exhibit chemical and physical properties that are very different from their bulk forms. A few of the experts claim that a manufacturer could provide the physical and chemical properties of the bulk form when they are actually using the chemical in its nano form.

There are two more recommendations, mentioned by two experts each, which were highly notable. The first recommendation stresses the need for detection methods for nanomaterials. According to these experts, there are no established methods for detecting nanomaterials. This means that there is no way to prove that a product in fact contains a nanomaterial and there is no way to find nanomaterials that may have been introduced into the environment. The second recommendation is that regulation on nanotechnology and chemicals in general should come through international legislation. The argument behind this recommendation is that globalised regulation helps promote the development and exchange of technology on a larger scale. Cooperation between countries and even continents will help lead to more benefits for more people.

Several more points and recommendations were made by the many experts interviewed in this study. The aforementioned are the most notable and prominent made by the experts. For all of

the points and recommendations made by the experts, summaries of each interview are available in the results section of this chapter, and the full transcripts are available in Appendix D.

6.0 – Conclusion –

From a careful analysis of the interviews and of the national survey, several conclusions may be drawn, the most important of which is that there is an overall lack of knowledge concerning nanotechnology, its benefits and its risks, and how it should be regulated. Both public familiarity and the scores from the true and false section of the survey confirm this conclusion. A majority, 76.4%, of the respondents identify themselves as being only a little familiar with nanotechnology. On average, the Danish public answered only 3.38 out of 7 of the true and false questions correctly. By comparison, through pure guessing, people should answer, on average, 3.5 out of the 7 questions posed correctly. Nanotechnology has only recently gained popularity in the scientific community and most information that has been gathered is contained within this community. The public hears about nanotechnology mostly from newspapers and televised media; they do not have access to the scientific journals that those in academia and in industry are privy to, let alone the background necessary to understand the technical jargon and concepts introduced in said journals.

This lack of knowledge proves particularly true when looking at the potential risks associated with the use of nanotechnology and is not limited to the Danish public. It may be concluded that not enough research has been devoted towards identifying and understanding the possible risks linked to nanotechnology. While there is research being conducted into the possible health and environmental risks associated with the use of nanotechnology, the results from the research is far from conclusive. Consequently, as the national survey shows, the majority of the Danish public is unaware of the risks associated with nanotechnology. Therefore, we recommend that in order to ensure the safe application and use of nanotechnology and nanomaterials in consumer products, more emphasis and priority should be given to research centred around the identification and understanding of potential health and environmental risks linked to nanotechnology.

Additionally, a way to inform the public of said risks should be developed. Public perception is largely dependent on what people know and what people do not know. Our research shows that people are more concerned with risks that they cannot control or understand than those that they can readily identify. A common analogy made is to that of smoking. People understand the dangers of smoking but choose to do it anyways whereas people are less inclined to purchase genetically modified foods because they do not know what kinds of effects it may have on human health. By informing the public of the risks, or even merely identifying that a product contains nanotechnology, more control is given to consumer, allowing the consumer to assess risk for him or herself.

On the topic of public perception, it may be concluded that those who are familiar with nanotechnology are optimistic about the improvements that the technology will bring to everyday life; they feel that the benefits of nanotechnology will outweigh the risks. However, overall, the Danish public is unsure as to whether or not nanotechnology will improve everyday life, though this may be attributed to the general lack of knowledge concerning nanotechnology. Because the applications of nanotechnology span several areas, public perception and opinions do vary depending on the specific application. People are willing to accept applications where the benefits are obvious and far outweigh the risks, which is why the Danish people are more likely to take advantage of nanotechnology in the areas of medicine and electronics. Additionally public perception is affected by trust. People are less likely to accept a new technology if they do not trust the companies that are promoting or manufacturing productions employing said technology. Finally, because of the lack of overall knowledge concerning nanotechnology, people are likely to associate negative reports or events in one area of application with the technology as a whole. People may hold a negative perception of any product labelled as containing nanomaterials as dangerous because of one negative event.

These conclusions lead us to recommend that the public should be more informed about nanotechnology. While they do not need to understand all of the technical aspects of nanomaterials and the technology, they should be aware of what the benefits and possible risks are so that they may base their perceptions on facts. The information needs to be presented in an unbiased manner as to not influence public perception with personal views. Through the survey, we have established newspapers and periodicals as well as televised media to be the best mediums through which this information may be spread. The Danish Consumer Council is in an excellent position to do so. Not only does the organisation publish their own magazine, *Tænk*, the Consumer Council is highly trusted by consumers, meaning the readers will likely trust the information presented in the magazine.

The experts are divided over the issue of whether or not the current regulatory framework is adequate. Nevertheless, we the vast majority of interviewed experts agree that nanotechnology should be regulated through the existing regulatory framework. We and the vast majority of the experts interviewed also believe that at some point in time, the regulation will require changes and amendment in order to manage nanotechnology. It seems as though those who believe that the current regulatory framework is adequate, do in fact recognise that nanotechnology has the propensity to present unexpected challenges that existing regulation will not prepared for. Although they have confidence for the time being that the regulatory framework will manage nanotechnology, no one can be certain that it will in the future.

The major difference between many of experts is that those who do not believe the framework is adequate could identify several regulatory gaps and had many suggestions for bettering the current regulation. Only one of the experts who believe that the current framework is adequate identify a single concern. All but one of these experts, namely Jørn Dohrmann who had an issue with the tonnage requirements, when asked what changes they would make to the regulation said

that they could not think of any. Additionally, none of the experts who believe in the current regulatory framework offered an argument defending the current regulation against the arguments made by the experts who did not believe in the current framework. We feel that many of the critiques and suggestions made by the experts who do not believe that the current regulatory framework is adequate are legitimate, as many of the arguments are commonly found in the literature. We feel that some of experts who believe in the current framework did not offer any critiques or suggestions not because they disagreed with those who did, but because they were unaware of the problems that have already been identified. It is for this reason we recommend that the existing regulatory framework should be amended pre-emptively to address many of the already identified regulatory gaps, and in general should evolve in a manner that does not react to the problems presented by nanotechnology, but instead with a bit of foresight, so that many of the technology's potential risks can be all together avoided.

It is true that the new chemical regulation under the REACH directive is a great improvement upon the old system. According to Robert Firkic, the new regulation is so demanding that many companies will not be able live up to its requirements. One might ask how we can justify strengthening a regulation that is already threatening the viability of many smaller chemical manufacturers and importers in Europe. Steen Gade believes that a demanding regulation, although difficult for some companies to manage, will actually give security to companies that can manage it. A strong regulation offers security to industry because it diminishes scrutiny by the insecure media and public.

We believe that immediate action should be taken to strengthen regulation and the overall management of nanotechnology. We specifically recommend that the initiative should be taken in developing or promoting the development of proper risk assessment methods. We also believe that this risk assessment research should include developing methods for detecting nanomaterials. A few

experts speculate that there is not a financial motivation for companies to invest in developing the risk assessment procedures. Since private industries are not likely to take the initiative themselves, we recommend that the government allocate funding for such research.

Some of the experts do not recommend any changes to the regulatory framework because they were not aware of any problems. The literature and several of our experts have identified regulatory gaps. There is a concern that the regulation does not require a distinction between the nano and the bulk form of chemicals, and also there is a concern that many nanomaterials will not meet the production requirements for required risk assessment and even registration. Robert Firkic argued that for an end product, which would usually consist of a nanomaterial and a transport material, it would be impossible for manufacturers to produce less than one tonne of the product per year. Firkic makes a good argument. We believe that since REACH applies to downstream users of nanomaterials as well as the materials' original producers, there is not an issue with the one tonne rule for registration. However, we are concerned about the ten tonne rule, which requires manufacturers to perform extra risk assessment. Because nanomaterials exhibit activities that are not analogous to ordinary chemicals, we feel manufacturers should be required to specify whether the chemical they are registering is a bulk form or a nano form and also that manufacturers should be required to conduct all risk assessment described in the REACH legislation on all nanomaterials that require registration. Both of these recommendations rely on the definition of nanotechnology and nanomaterials, therefore we also recommend the formulation of a standard and clear definition of what qualifies as a nanomaterial be written into the chemical legislation.

There are two more regulatory recommendations that we would make based on our interviews with the experts. We feel that it is a good idea, once the definition of nanomaterial is officially formulated, that all products containing a nanomaterial be registered with the authorities including a thorough list of all chemical components in the product. Experts on both sides of the

adequacy debate have stated that it is important that the authorities keep track of all the nano-products on the market. Additionally, we believe that regulation concerning nanotechnology should be implemented on an international scale. We believe that the more international cooperation that goes into assuring the safety of nano-products, the more the benefits will be available to a more global population. All of the experts we spoke with are excited about at least some of the benefits nanotechnology may be able to offer. A regulation on nanotechnology that is inconsistent from nation to nation will make it difficult for countries to share their positive developments with the world.

The development of nanotechnology has already revealed many great benefits. However, it seems as if there is a considerable level of risk accompanying these benefits. Society must find a way to maximise the benefits and minimise the risks of nanotechnology. Implementing our recommendations will aid in attaining this goal. The Danish Consumer Council has the resources and the influence necessary to put our recommendations into motion and help pave the way to a positive for nanotechnology.

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Appendix A – Gantt Chart –

	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
Meet With Sponsor														
Write Consent Form														
Test Interview/Focus Group Questions														
Finalise Interview/Focus Group Questions														
Gather List of Contacts														
Contact Interviewees														
Conduct Interviews														
Contact Focus Group Participants														
Conduct Focus Groups														
Analyse Data														
Write Report														

Appendix B – Expert Interview Questions –

Following is the general series of questions for expert interviews. All experts were asked the general series of questions as well as the general expert series of questions. Experts were also be asked the regulation series of questions if they had a knowledge of the Danish/European chemical regulation framework.

General Questions

Before we begin I would like to inform you that for our report we will only need to know your occupation. Your name will not be reported without your consent. Also, you may skip any question you do not wish to answer or end the interview at any time.

1. Shall we begin?
2. Could you please state your name?
3. Could you please state your occupation?

General Expert Questions

1. What is your experience and/or background dealing with nanotechnology?
2. What benefits, if any, do you feel nanotechnology will bring to the consumer?
3. How advantageous do you think these benefits will be for the consumer? In other words, how do you feel these benefits will improve upon previous generations of products?
4. What risks, if any, do you feel nanotechnology will bring to the consumer?
5. How concerned are you about these risks?
6. Do you think that these risks will affect the use of nanotechnology in consumer products?
7. Do you have concerns about any particular application of nanotechnology, or any other general concerns or opinions that you would like to share?

8. Which statement do you feel you best identify with, concerning the risks and benefits of nanotechnology?
    - The benefits outweigh the risks.
    - The benefits and risks are equal.
    - The risks outweigh the benefits.
9. How do you think nanotechnology will impact society, specifically the consumer, in the future?

Regulation Questions

1. Are you at all familiar with how nanotechnology is regulated in Denmark?
2. In your opinion, is policy and regulation as it currently stands sufficient to protect the Danish public from the potential risks nanotechnology now and in the future?
3. (In regards to question two) Why or why not?
4. In your opinion, what changes should be made to the regulatory framework to ensure the safety of the Danish public from the potential risks of nanotechnology?
5. Which statement best describes your opinion on regulating nanotechnology?
    - Current regulations do not need to be changed or adapted in order to fully address the risks associated with nanotechnology.
    - Current regulations should be adapted as necessary in order to fully address the risks associated with nanotechnology.
    - New nano-specific regulations and regimes need to be constructed in order to fully address the risks associated with nanotechnology.

Appendix C – Hanne Svenningsen Interview Questions

Social Scientist Questions

1. Could you please describe your study and how it was conducted?
    a. How did you go about gathering participants for this study?
    b. What criteria did you use for each focus group?
    c. What questions did you ask in the focus groups?
2. What were your results?
    d. Were there any particularly surprising or interesting results?
    e. How many people had heard of nanotechnology, and where did get their information from?
    f. What did people view as the greatest risks associated with nanotechnology?
    g. How did people prioritise their risks?
    h. What did people view as the greatest benefits associated with nanotechnology?
3. What were your conclusions?

We are planning on conducting a focus group on nanotechnology with college students in Copenhagen. Can you offer any advice?

Appendix D – Interview Transcripts –

The transcripts included in this appendix have been transcribed verbatim. Any and all grammatical errors are intentional.

Appendix D.1 –

Interivew with Claus Jørgensen
Monday, 30 March 2008

Interviewers:
Dan Carney
Linxiao Chen

DC Before we begin, I would like to inform you that for our report, we will only need to know your occupation. Your name will not be reported without your consent. Also, you may skip any question you do not wish to answer or end the interview at any time. Shall we begin?

CJ Sure, no problem.

DC Could you please state your name?

CJ My name is Claus Jørgensen.

DC And could you please state your occupation.

CJ I work as an environmental officer – senior environmental officer here at the Danish Consumer Council.

DC Alright.

CJ I think that's my English title.

LC I will begin by asking some general questions about nanotechnology. What is your experience with and/or your background dealing with nanotechnology?

CJ Well my background is actually just being the environmental officer here in the Danish Consumer Council. We have a board, which has decided that nanotechnology should be a focus area for the Danish Consumer Council. And since I work with the environment and chemicals, it was obvious that I should be working with this. My background is chemicals, which I have been working with for four – no ten years almost or so. This is where the nanotech aspect comes into play.

LC Well obviously the consumer council thinks it's an important aspect to look at. So what benefits do you feel that nanotechnology may bring to the consumer, if any?

CJ Well our view on nanotechnology is that it's an exciting technology and I think the technology in itself is actually very exciting because it seems as if there's a lot of things we can do. Benefits, which could be better treatments for people that are sick – for example they have this dream about these nanorobots, which are better at curing cancer. So instead of, you know, hitting the whole body with chemotherapy, you can aim the chemo at the cancer cells. And also I could imagine for example, you can make – I've heard something about pollution control – you can somehow clean up after spills or whatever because you

can use these different nanoparticles to eat up the pollution and so on. You can also make better conductors for electricity and so on. So there could be some environmental problems solved by using these technologies. So the problem I see is not so much the technology itself, it's more the use of the technology – how we decide to use it and where to use it.

LC So are you aware of any of the risks involved?

CJ Well, from our perspective, it's a question of whether or not we as humans are exposed to these chemicals when they are in nanoparticle shape and size because their experience with chemicals is that some of the chemicals we've used earlier on in our history which we thought were very good like DTT – there are several chemicals which we thought were very good and then all of a sudden it turns out that these chemicals are cancerous. They end up in nature because they are persistent and all of a sudden we have problems with these chemicals and now we have a ban on these chemicals. So the same things you kind of see here with nanotechnology and nanosized chemicals because maybe they can solve a lot of things that we might need but what happens when they turn up in nature, what happens if they penetrate the skin and end up in our bodies and what about it a chemical in its normal size is undangerous? What about if it's in a nanoparticle size, is it dangerous then if we get exposed? From what I hear from experts is that if the nanoparticles get into the body, they can attract each other or take other dangerous chemicals and then, you know, instead of just being nanoparticles, they can all of a sudden be bigger particles, bigger sizes. And then what happens in your body if it's in arteries or if it's in the lungs so I do see that there are some risks that we do not know enough about. This is were we kind of say, "Well let's be a little more careful," especially when we have the history of the other chemicals in our minds.

LC So how concerned are you about these risks?

CJ Well, I'm actually… sort of… I'm optimistic about the possibilities but I'm also a little bit concerned about what happens if we do not focus on what the risks are with these chemicals. Because all of a sudden it seems as if the regulation somehow also includes nanoparticles but because of the different tonnages, or the different levels of when you're supposed to register and inform the authorities about your chemicals, it's difficult to say whether or not these nanoparticles are coming into the products unnoticed or unregulated. And this is where I think there could be a problem. So now and today we do have nanoparticles in consumer goods already and we have no idea how they affect us. So already we're starting the experiment and doing what we usually do when we have a new chemical; we just put it out onto the market and then, all of a sudden, if they're dangerous then we decide to pull them back after maybe ten years because that's how long it takes before industry and authority actually do something about it. So I'm not saying that we should ban nanotechnology, but I'm thinking that we need to have methods of detecting and we need to have more control by the authorities about what is going on. One suggestion we've made is that if products are containing nanoparticles in any way, shape or form, you have to register it with the government. And then already in Denmark we do have something called the product register where most new products are to be registered so that the authorities know what's on the market. And in that you also have to describe what the chemical content is. So here it would be obvious that you just also say, "Well of course this is also nano-product. We've used this and this," so at least, the authorities can get a feel of how much is being used out there. So sceptical, but not scared.

LC Okay. So do you have any concerns about - because nanotechnology and nanoparticles can be applied to many aspects of consumer products. Do you have any specific concerns towards any specific applications?

CJ Well, the things that we've been focusing on most is maybe nanotechnology used in cosmetics because you apply it to the skin; you also put it on your lips and eyes. It's very close to places where you can get it into the body. And also, I guess, research shows that, at least if you have broken skin, it's very easy to penetrate and it comes in your body. And already, sunscreens are used with these nanoparticles – titanium oxide particles – which is good in a way because this is what the consumers want. They don't want to look white when they put on the sunscreen but it might be a problem because it goes straight into the body and what happens when it comes in there? So for now, I would say that products in which consumers are in contact with where the nanoparticles somehow have a chance of escaping the product or the fluid or whatever, so it would be sprays and things you put on your skin. While I'm not so much concerned about tennis racquets and baseball bats or… but still this can be a problem when these products go to the landfills or where ever they end up because what happens to the environment if these are persistent and end up in nature and in fish and animals and so on. So for health reasons it would probably be the sprays and what you put on your skin.

LC So is it safe to say your main concern is with health?

CJ Yes, because, well, that's the easiest thing to focus on anyways because, I mean, the environmental damages might not show for maybe 50 years or something like that. But usually health and environment are different sides of the same coin – is that what you say in America? Um… and well, when I say I'm and environmental officer here at the Consumer Council, it's basically environmental issues related to consumer products and most of the time it's health problems. But I would say that would be the present problem but in the future it could be the environmental issues.

LC So when looking at the risks and benefits of nanotechnology, do you feel that the benefits will outweigh the risks most of the time or the other way around, or perhaps they're equal?

CJ Well I hope that the technology will be used so that the benefits will outweigh the risks. When using nanotechnology, for example for medicine I'm sure that the society will be able to accept more risks if, for example, it shows that cancer treatment can have some risks of developing whatever other kind of diseases. Most people probably accept that if they can get cured from their cancer. It's the same with other chemicals they use in medicine right now. Some of them can cause very serious adverse effects and lots of medicine when it ends up in nature is also a problem, but we're willing to accept that because we'd rather be, well, alive than dead. But there's an obvious benefit right there. The problem is when you do not have the obvious benefit. When you maybe already have products that you just substitute with this product, which now contains chemicals that could be a problem. So why not just stick with the product you already have? This is what the focus groups in Denmark have shown; we are willing to take risks if the benefits are big and obvious, but we are not willing to take the risks if it's just making a windshield where water can easily flow off. It if means we have to accept nanoparticles in rivers and lakes and the fish are dying or whatever – or

maybe just the uncertainty of the fish dying. But when you look at, like here in Europe, GMO discussion, which was, as I see it, there's a huge potential in that and you see it when making medicines already now. But that's kind of easy to accept because there's so many benefits and it's also being done in closed rooms and closed systems. You know that GMOs are not out in the wild and it's better outside so people are very keen on accepting GMOs in the laboratory. But when you put it out in the field and you have no idea where they go and how they will affect the rest of nature… something different. I see the same story here with the nanotechnology; I think people accept it being used where you can make sure they're not escaping into nature but they will not accept, you know, experiments in the wildlife, for example, or on humans for that matter. And I think, generally, at least the Danes are very sceptical towards this. They really need to see the benefits to make sure that everything's in order because just uncritically using a new technology without thinking about risks and risk assessment is not something they will accept. Nanotechnology is expected to be very big and even here in Denmark, I mean I know the ministries here are also hoping Denmark will be a frontrunner, will be making a lot of money on this because they see this a s a future. But I do know that they are very serious about also making risk assessments because they have learned from the GMO experience and they know that if just one or two bad stories come out then we have a whole European population against a new technology that could do a lot of good. But the thing is that the companies have to show that they really do want to do good, not just to say with GMO, "We can feed the whole world." Sure, great, that sounds fantastic. Africa can have food and everything. But this was not their real intention. They wanted, of course – they wanted to make a lot of money and they haven't fed Africa. There are still poor people down there and they're still starving. So they have to be honest about – what do you call the thing on a product for example? – Labelling. You have to be honest on what you say you want to do and not have a different agenda when you go out and sell. If you go out and sell nanotechnology as, "We have a new cure for cancer. We can really help a lot of people," but what you really want to do is make a lot of products, which we maybe do not need and make a lot of money that way, then you have the same problem all over again.

LC So would you consider your apprehensiveness stems from a lot of the unknowns?

CJ Well I think today if we talk about the general population, they have no idea what nanotechnology is. They've heard about it and some of them know it's something small because of the "nano," but I think most people have no idea what it is. The focus groups here and what the report that was published in the fall says that people were very surprised that there were nano-products on the market. And also as soon as they were told a little bit about what nanotechnology is, what benefits there are, what risks there are, they all started to compare it with GMO. Without nobody ever mentioning GMO, they all of a sudden pulled the GMO discussion and also the asbestos, which I know you know about as well. People are very quick; they've heard about the GMO discussion and they very quickly take that discussion and bring it into a discussion about nanotechnology.

LC So how do you think nanotechnology will impact society in the future, especially the consumer?

CJ Well I hope that it has a positive effect but it all depends on how the tech is sold. Like I said, if it's sold on false pretences, I think you could have opposition towards it like GMO, but I mean, if they can – I think this is also our position here – if they can show the benefits of new products, making cars more efficient, making computers more powerful and efficient, you know, really showing what the benefits are, making sure the environment benefits and they have actually made risk assessments saying that, "Okay, we have made a nano-product, but we have checked out that this is actually safe," then I think it could work. And I think we need to have more dialogue. We need to inform the consumers what nanotechnology is. We need to tell them about the benefits; we need to tell them about the risks so they can make up their own mind because I think what happened with GMO was that the companies were, you know, too closed about what they were really doing with the GMO's and then all of a sudden you have the environmental NGOs screaming and yelling and telling about all the horrible things that could happen. Of course we haven't found out yet because nobody has made the investigations to stuff like that so I think the more open the industry can be about this, the more they work together with authorities and NGOs, the better and more outspread the use of nanotechnology will be accepted.

DC So we just want to kind of move on to a few more questions that are more regulation based. So first I'll ask, are you at all familiar with how nanotechnology is regulated in Denmark?

CJ Yes, well it's regulated right now through what's called the REACH directive, or is it a regulation – I'm not really sure. It's a new law, chemical law that came into effect last summer 2007, which regulates basically all chemicals in Europe and supposedly nanotechnology is to be regulated under that. There have been some questions especially from the environmental NGOs, who have questioned whether or not REACH will be able to have nanotechnology included and I think what I've heard so far is that the authorities think and believe that the REACH legislation actually does include nanotechnology. It just needs to be adjusted a little bit. But what could be a problem is like as I said earlier, if you market a product with chemicals, if it's below one tonne, you don't have to register it anywhere and then there's different tonnage limits where different rules of regulation apply. If you're under one tonne, you don't have to register anywhere so it means that since, of course, nanoparticles are so – and I mean you can't weigh them anyways because it's a matter of surface more than it is a matter of weight. So at least from what I heard is that the environmental NGOs are kind of critical of the Danish EPA, who are the responsible authorities on that. There have been some initiatives to try to find out whether or not the legislation is good enough so hopefully they'll get a handle on this. And I know that there is of course a lot of money set aside to research into nanotechnology and I know they have also made requirements that if you want to receive some of this funding you need to also consider whether or not there are any risks to health and environment when you do these products or research or whatever you do with nanotechnology.

DC So in your opinion, is current policy and regulation as it is now, sufficient to protect the Danish public?

CJ No, no I don't think so. I think we need to have more – a little bit more control from the authorities and like I said before, what we've suggested is that when putting a nano-product on the market, you have to inform the authorities how you have used nanotechnology and which particles are in their product and also how you have tried to minimise the risks and

how you have abated – no, anticipated what risks might there be when using or making this product. So somehow give the authorities – I mean we would love to have this information as well, but I'm not sure that companies would like to give us this information because I mean they probably have different kinds of secrecy about how they make the products, but for a consumer organisation, it would be very good because then we could tell people where you could avoid nanoparticles and so on. But I think we need some kind of tool for the authorities to make sure what nano-products are on the market so they can get a big overview of what is out there and also if some problems arise, they can quickly pinpoint, "Oh, this could be because of nanoparticles in this hairspray or this shoeshine or whatever they decide to put it in." We need a little more control and we need more information on this because what research has shown so far is that the Danes do not know what nanotechnology is. They do not know what the benefits or the risks are so we need more information on this and we hopefully will be able to make a project where we can be involved in somehow informing the public about nanotechnology.

DC So do you have any kind of thoughts or suggests ion how the regulatory framework or policies could be changed in order to better suit nanotechnology?

CJ Well, what is also needed, I think, is more cooperation – because it's an EU legislation, you need more cooperation and on and EU scale and of course transcontinentally to American and whatever else is out there. Another thing that we've suggested is to make nanotechnology information centres where the purpose is not only to, you know, inform about what research is being done and what risk assessments have been don and so on. If you're a scientist, you can find these things and you can probably understand whatever reviews and papers that are presented in scientific journals. The purpose of this information centre is to gather this information probably by having some PhDs or scientists working there but also to have people employed whose sole purpose is to translate this hard scientific data to public language so that they would be responsible for informing the population. So somehow, whatever information is out there on a scientific level gets into the public's mind so that they know what nanotechnology is. So we've suggested that they make and information centre here in Denmark because right now they do have nanotechnology centres, but this is like university based so all the universities meet and exchange information and so on. You can always find out this published research on nanotechnology and so on but you need to be a subscriber, and for a normal consumer, they will never ever read the scientific review or anything so we need somebody whose sole purpose is to inform about this. I mean this would mean that they would have to go to the press; they would have to have dialogue meetings; they have to have conferences for the normal consumers so we get this out to the public. This is also difficult because how to get boring scientific data out to the normal public is probably very strange but I think it's very necessary that the consumer find out about both the benefits which is, of course, the good things, but also they have to know about what risks are there. We do, in the Consumer Council, believe that the consumers can make a choice if they do have the information. They need the information to make a qualified choice and if they don't have the information, it's very easy for Greenpeace – or whoever wants to who are negative towards this technology – it's very easy for them to steal the agenda and to tell everybody this is unsafe and this is not something we need.

DC Alright, and just to finish things up, I have kind of three statements and I'll read them to you and I'll ask you which one you identify with best. The first statement is: current regulations do no need to be changed or adapted in order to fully address the risk associated with nanotechnology. Second: current regulations should be adapted as necessary in order to fully address the risks associated with nanotechnology. And third: new nano-specific regulations and regimes need to be constructed in order to fully address the risks associated with nanotechnology.

CJ Well, I guess it's somewhere in between the last two because, of course, depending on which way nanotechnology develops, maybe you need to have new legislation. Maybe they start using it in places where we never thought we were going to use this and so I do think that it's very necessary that, well, the commission sits down and look at the regulation on nanotechnology. For example, recently they made a code of conduct for research for nanotechnology – I should give that to you as well – but it's a voluntary code of conduct. Coming from the Consumer Council, a consumer organisation, our experience with voluntary agreements, it's not good. I mean especially on this area where we think that we need to have – if we make a code of conduct – everybody has to follow this code of conduct. It shouldn't be voluntary. So I think we definitely need better regulation and it could be that if we could fit it into the current REACH system. I'm afraid we might need to maybe have a new nano-law, but I'm not the expert on that, but I feel it's necessary that we look into it and also we need to have more openness; maybe it should be a requirement that companies supply authorities – maybe it should be in the legislation – if could probably fit within REACH that companies have to inform authorities when they use nanotechnology. So somewhere in between the last two points.

DC Alright, I think that's all we have.

Appendix D.2 –

Interview with Anders Baun
Friday, 4 April, 2008

Interviewers:
Dan Carney
Linxiao Chen

DC Just to begin with the formalities, for this interview we don't need to know your name but we do need to know your occupation and at any time you may skip any question you don't feel like answering or you may stop the interview at any time. Shall we begin?

AB Yep

DC Ok could you just state your name for the record?

AB I'm Anders Baun and I'm the associate professor at DTU Environment Department at the Technical University of Denmark and I'm the coordinator of a network that's called nanoDTU Environment and Health where we try to coordinate actions within potential risks of nanomaterials.

LC So what is your experience or background concerning nanotechnology?

AB My original background is I'm a chemical engineer and I have worked in risk assessment of chemicals for something like ten years. So I have a chemical background and I shifted my research and my research group into risks of nanotechnology from 2005 where we have tried to build up a group now consisting of 3 PhD students and myself and three other associated professors.

LC So what piqued your interest in nanotechnology?

AB Yeah it was actually kind of a revelation I got at a conference in the US in Portland Oregon where I went to a seminar made my the US EPA where they talked about their funding activities within mental health and safety concerns about nanomaterials. Actually I went in there with the background that this was the most stupid thing I've ever heard of. So I though like, "Well let's go in and have a few laughs and then I can go home and tell you, 'Do you know what I heard about this stupid thing?'" But they sort of – that's why this is sort of a revelation – they continued talking about it and I thought yeah okay this kind of sounds like quite interesting. The woman from the US EPA said if you're at a university where you have a good, strong background in environmental chemistry and eco-toxicology, you do risk assessment of chemicals, you have nanotechnology development, you have nanotechnology research at your university. If you have product forecasting and lifecycle assessment fields you should really go into this area. If you don't have all of these, you should really stay away. And I was just checking out that this was exactly the profile of my university, so I thought okay. Then I went back to my director here and said, "Okay I want to change my research into this." And he was like, "What? I never heard about this. This sounds really stupid." So

I spent, I think just about a year not only to convince him but also hook up to the network of nanotechnologists here at DTU and from that point on we formed this group of nanoDTU about the risks and now we're getting the funding. When people come in my door and ask me do I want to join this and that and I say, "Did you say nano? No? Please leave." (laugh)

LC So you're working with risk assessment – but are you aware of any of the benefits?

AB Yeah. My base here at DTU as the main place in Denmark where you develop nanotechnology solutions is focused so much on the benefits. So the energy efficiency, there's groups here working on catalysis, environmental remediation which is part of what is done here in my dept also. These topics are topics where we are also active and what we say is we would like to promote a sustainable development of nanotechnology so that we really can harvest the benefits but without being so one-eyed that we only see the great new future and forget about, "Oh there's something wrong." So we try to do this, and this is a difficult task so we always state it like we're proactive and try to be at the dinner's end table where the designers are. We have had some projects and applications where we, you could say, formed the click-on module to developing projects like, "Hey, you also need to consider these concerns." Unfortunately, these projects have not been funded – I don't know if this is my fault but sort of to balance it out. But we are very well aware of the benefits.

LC How about those that would apply to consumer products?

AB I would say it is right now in some ways damaging if you talk about the whole project of nanotechnology as a new common area because I think, I usually say it's dominated by gadget products right now so it's kind of, "Well okay, it's kind of nice but do I really need that device?" Do I really need products where I don't need to clean my bathroom every week or even once every year because I'd probably clean it anyway or that I don't have to change my underpants because they won't smell bad but well maybe I will change them. So it's sort of providing solutions that are not really solving problems. I think a lot of these products out there now are in that category. We made a survey together with the people from the Woodrow Wilson Institute and made a couple of papers with them where we tried to map what's out there. They have the large database. We tried to focus on which kinds of materials are in there and what kind of risks could come from these. And going through all these – about 500 products – a lot of it is like, "Great, we don't need it?"

DC So what do you think current, or in the future, some of the best benefits might be? In general.

AB I would think that in energy efficiency, I think, we would get really huge steps forward. I think in computer technology. Today it's not so recognised. Then I think in diagnostics, in medical diagnostics. There's a lot of attention in my university on the lab on a chip kind of thing where you can actually take a blood sample and get a lot of information. There's a lot of claims about drug delivery systems and pharmaceutical applications and I think it's gonna be huge. I think that some years down the road. Right now there's many attempts on cancer treatments. Of course the public perception of nanotechnology is going to be a huge booster for really putting focus on nanotechnology. So generally I think it's like you read in all the claims of the good stuff like energy, medical, and environmental remediation. But

contrary to the picture you may get when you read it, we're not as advanced as it says we are. So it's still a bit fumbling around and so on. So what we see – the regular citizen will see – will be these for some years these kinds of products that can perhaps in some way damage the reputation of nanotechnology because it's conceived as something that's just solving problems we didn't really have.

LC So what risks do you associate with the use of nanotechnology?

AB Usually we try to say that there is no risks with nanotechnology. You have to frame the question. The technology in itself, we don't see as causing any risks. You might say that this is just semantics, but being engineers, we would like to help frame the question saying where the risks can be is at the present, at nanomaterials. So if we talk about the human health and environmental risks we have to narrow nanotechnology down to nanomaterials because nanotechnology covers a lot of other things than just nanomaterials. And then even in the nanomaterials range we also have to narrow it down into some specific kinds which are nanoparticles which can be either free in air, suspended in liquids, they can be embedded in matrices or put on a surface. We made a paper on this that I can give you. But also, there's also sometimes forgotten the discussion about films attached to surfaces. They may also have some risks but we don't think they're as high as the risks related to free nanoparticles. So that's first of all, to frame the question and say, "Okay but it's the nanoparticles where we would see the biggest risks." If we see what has been documented about the risks, there's been seen some unexpected effects of inhaled nanoparticles going directly from the nose into the brain and causing oxidation of brain tissues and brain damage in mice and there's a controversial study about fish also where it has been seen that there is this kind of brain damage. This is an important and new kind of risk we have seen for chemicals. What we believe is that at the point being, it would be very beneficial if we start thinking of nanomaterials as a new class of chemicals. The EU regulation would say we have this mantra: A compound is a compound. So if it's a compound, it's a compound and they can keep on saying that but what we would like to push or say, "But could we raise a small nanoflag and say, 'but it's in this size range and if it's in this size range maybe we should ask some additional questions that are not asked for regular chemicals like surface are reactivity and crystal shapes and so on.'" So we sort of build up a database for addressing future risk issues because we are convinced that there will be risk issues. I'm less convinced that it will be toxic or more toxic than regular industrial chemicals. We're at the point where we don't know anything about that but I think we need to be a bit proactive and try to collect the data already now. Several studies have been made that talk about public perception of risks that the public is willing to accept even high risk in uses as long as we recognise that it's risky, but if we try to hide that they are risky then we will have the backlash. It's better to say, "Look at this pesticide. It's very toxic and so on and you should always only use it in your barn to kill flies but don't use it on your kids or children or whatever." Because it's common sense and people are used to handling risky situations, but there's been examples where you say that the researcher in the white lab coat goes out and say there's no risk. This is actually the worst kind of strategy because the public doesn't have so much trust in the white lab coats anymore.

DC Do you think this might have something to do with the GMO situation in Europe?

AB Yeah. I think there's always an analogy to GMO when you talk about nanotechnology development. I'm at the point where it's sort of saying this analogy is not very good because there many, many other factors going into the GMO debate that is neglected if you just compare it to nanotechnology. So I would always take care in this comparison. The fact is that the scepticism towards new technology is the biggest problem and I don't think GMO is the best because a lot of ethical considerations and so on. But I think you're right in this that at an early point, the risk assessment is quite blunt. It's not based in facts; there's no truth in this. At least in the European context this is very stupid because it's not accepted. It's a liability issue. If the researcher says that he does not see any risks, he is not accountable if there is any risks occurring and therefore the public loses trust in the statement. I think, I don't know, but the situation in the States could be more different because it's more based on the regulations. It is more based on scientific risk assessment being adopted in the regulations and it has a bit, I think, to do with the whole focus of liability in the US. Somebody has to pay and there's some good and some bad in this.

LC So basically you see most of the public's fear or apprehension comes from their not knowing what the risks are… or not trusting.

AB This is a very difficult question – I'm not sure if I can answer it. In nanotechnology, the public does not know it not because the public is undereducated or so on. They don't know what it is because it's very difficult actually to explain because it's so many things. Sometimes, compared to say, I don't know if this is totally valid, it's like electricity, like when electricity came, several papers and discussions said it's so dangerous. It's a crazy thing to put into a house. They could never consider this to be possible in the future to have electricity in the house because you can kill yourself by putting your finger in the socket. But we found a way to manage and we don't call your machine here an electrical device to record my voice. Right now we call a nanotechnological device anything we would find, but in the future we would not call this a chair with nanoparticles, it's just a stain resistant chair or whatever. So I think part of this public perception is it's new, and therefore it can be risky and that's one of the things that's been investigated. New things are more or less by default considered more risky than old things even though there is no scientific basis. This is what we have to address as researchers to think that we are in this area. What we are dealing with is considered as risky and that's why we say that responsible development has to take into account that. We must start talking about the risks even at the development phase. One of the frustrations of the nanotechnology developers here, when I contacted the directors of nanoDTU and said, "I have this idea," when I couldn't convince my old director, I had to convince another guy. And he said well maybe you have the answer to all our prayers because there has to be some strange questions being asked – is it risky or isn't risky. And I don't know what they mean and I say, Okay I cannot answer it but I can help you frame the questions at least because nanotechnology developers had not considered it. They were just thinking that great, I can do it. And of course we have to be like that, very innovative and ingenious. And maybe not considering that the public could have any interest in quantum mechanics of one kind of material. Why should they worry about it?

LC You mentioned a lot of applications of nanotechnology; do you have any specific concerns towards a certain application?

AB You mean which ones are more risky than others?

LC Yeah.

AB I would say any kind of application that leads to direct exposure would seem to be a bad idea and this goes for several consumer products. So if you have a product that you deliberately make into a spray that forms aerosols I would think that this would seem to be stupid. This is not that fault of the nanomaterial. You could have the same product in a spray can that you can also have in a liquid that you put using a cloth. So I think, like for regular chemicals, it's about a way how to handle exposure. That's one thing I think would be very good if we could sort of get that focus on some precautionary measures.

DC What about stain resistant pants where you have a monolayer or some kind of coating? Is there a chance that you could get particles coming off the pants and contacting the skin?

AB I think that's exactly what we say. Sometimes we say it's only the free use that would be risky. It's a bit different if it's a particle attached to a surface, which I would think could come off. Or it is the fabric in itself, it is the fibre that has been made in another way, then I would consider the risk less. We made a report to the Danish EPA about consumer products that is translated into English also, where you can see this way of thinking, that some applications are more risky or risk of likelihood of exposure whereas we think others will have a lower likelihood of exposure. The exposure part talks about more dangerous applications. Then there is, if you take on the effects sides, there are material choices made where you think, okay this is just plain stupid. It seems that the cadmium based quantum dots are actually not going to be in commercial products but it is a way to illustrate the quantum gaps and you actually can use this kind of material. But because they would emit white light therefore they could be used in diodes and so on. But for me that would be a very, very bad development if we start basing a new technology on a known persistent toxic heavy metal. This would just be plain stupid and very risky. So that's one area at least from our knowledge from regular chemicals where we can go in and say, "Hey don't base a new technology on cadmium." Another area where the risk situation will be really debatable is the pharmaceutical use for drug delivery. Some of the attempts have been made to take the chemotherapy. Compounds attach themselves to some liposome or something like that. These are poisons so it's deliberate poisoning of the body, but targeted poisoning. That's okay, you could say, if you can cure cancer but you really have to take care about the environmental issues of this because it's actually targeted poisons now going somewhere in the waste systems. This of course can be handled by saying all this waste should be collected and incinerated. But it's sometimes overlooked. We have seen from pharmaceuticals in general that it's been an area that only in the last 10-15 years have come on the agenda that it's actually a biologically active substance. That's going into the waste water system in very high amounts. Are they risky or not? So we do not want to repeat that mistake.

LC So what kind of environmental concerns – because a lot of research we've gone through cover human risks but I've only found one or two papers that actually touch upon environmental risks.

AB I think there's something like 25 papers published now where we have very few lab studies. I think it's lower than 15 and then there's several reviews going through which concerns could be there and so on. And the environmental concerns, for me, it's actually if you look at the industrial chemicals, what we would look for is persistency, bioaccumulation, toxicity and mobility. This would be like four parameters in the EU regulations - the whole regulation REACH, the new chemical law, is based on this principle. Persistence, bioaccumulation, and toxicity – these are the three governing factors, then mobility is the fourth one. But if we look at nanomaterial properties, many of the nanomaterials have exactly these kinds of profiles. They are, by definition, persistent because they are made of elements or the carbons ones are in the structures. They can be toxic, yes, because some of them are used in chemo and have high surface interactions. And the bioaccumulation, nobody knows, but they have high persistency and has a tendency to attach to tissues so it has the potential to do that. So that's the concerns – if a nanomaterial has this profile and it was a regular chemical, it would be banned in the EU. Then there's the mobility issue which is also considered for chemicals but I think it's going to be even more here because they are actually meant to be mobile because the small particles could actually be distributed to places where you don't actually expect them. So that's like the four concerns that I would say the inherent properties of nanomaterials would influence. We worry about a fifth way and it's about interaction with existing contaminants in the environment. So if you emit nanoparticles even in small amounts, how do they actually interact with the contaminants that are out there and do they influence the toxicity of other contaminants? We made a couple of studies of this and found for some chemicals they do actually seem to enhance the availability of the compound. Fortunately there are few groups – I only know of one other group in the world that is working on this issue. Unfortunately, too few groups are and it's going to be a big issue.

LC So do you think that benefits outweigh the risks or otherwise.

AB Clearly, yes to that one. I am quite sure. It depends if your talking about nanotechnology I would clearly say yes. First of all, because there's so many applications of nanotechnology that, in my opinion, do not involve risks if we talk about human health and environment and safety risks – that's what we've been talking about I would like to stress that – there are other risks of more ethical dimensions we'll talk about the social divide between north and south, rich and poor countries. There's the whole military talk about some armies being better equipped than other, so American soldiers can never be shot because they have light weight body armour and so on. There are a lot of discussions in more social sciences about other kinds of risks for humanity because of a social divide so if we turn to what I know about, which is health and environmental risks, I think that for sure it would be a wrong use of a precautionary principle to pull the plug now and say no to nanotechnology development. We really have to think actually to say that a lot of the things we already use are based on nanotechnology and of course, this is not an excuse that it could be risky but most people would not regard the reading head of the a DVD recorder to be a risky use of nanotechnology or lightweight materials where you have made the structure or changed the crystal structure of the bond. It doesn't mean anything; it just means that it has the better strength and better conductor. So there's a lot, a lot, a lot of applications of nanotechnology that we would really need in future society, a lot of the energy efficiency now are in this range where it's now based on nanoparticles I would consider risky applications so we put a strong emphasis on trying to framing the discussion. We really have to divide this. It's

equally stupid to say that nanoparticles are toxic as it is to say that chemicals are toxic or dangerous, actually, hazardous. Chemicals are hazardous. Some chemicals are very hazardous, some are not hazardous. If it wasn't for the chemicals, we would not have the society we have today. What we see is sometimes very stupid use of chemicals for things we don't need so we have to learn from past experience and focus on what are the needs what are the benefits. Soft plastic fish that our children can bite in are very nice but it will give nice plastic softness in the blood; that's a stupid use of the plastic softener but the plastic softener may be good for medical uses so you don't have to have an iron tube into your hand if your hospitalised. So it is really about not saying whether nanotechnology is good or bad but trying to frame it down to what kind of application.

LC So how do you see this tech impacting society in the future?

AB I don't know. It's a bit difficult to navigate this field because there are a lot of groups that would like to really stress the benefits so much and that it's like the next industrial revolution and all these kind of ideas and I think that if we look at what's actually possible in some of the material sciences I think it will really revolutionise like for example, textiles, not only stain resistant but intelligent textiles where you can say it's not a nanotechnological device, but nanotechnology will enable that this can be made that way. So I think we will see things that are totally new and that's a problem because it's things that we can't conceive today exactly what this is. To many, the mobile phone is sometimes mentioned as an example of what we could not foresee. Actually you could say more or less SMS is a thing, ten years ago, people would say what kind of tech is this? This is not going to be anything. Why would you want to write phone messages to each other all the time? And today we can only laugh at this kind of thing. So for me it's a problem, there's a lot – I don't know if you've seen a lot of talks about 1st 2nd 3rd 4th generation nanotechnology where the 4th generation is around self organising nanobots that can do a lot of strange things. Where we, today is at the 1st generation trying to figure out what's going on. Okay we can add some particles to fluids and see what's going on but it's not at the level it's sold at do you know what I mean. The researchers talk a lot about the future applications but when you go down to it, okay, it is a future application. We tried, for instance, to pick people at the Copenhagen University to identify some uses or some applications where we can work together to see what kind of ethical problems could there be. What kind of social, what kind of environmental and human health problems. And we actually had a bit of difficulty in finding something that is already produced as a technology and tried to assess it. We thought but okay in cancer treatment there must be some things out there but there's not. There are things that are being tried in lab animas but it's not available and it will take some time before it is. Sorry for my long answers you can just sample from it.

DC Now we're going to get to a few questions on regulation. Pretty simple stuff. First are you familiar at all with how nanotechnology or chemicals in general are regulated in Denmark?

AB Yep.

DC So basically if you think about the current state of regulation, be it in Denmark or in the EU, is the current state of regulation sufficient to ensure the safety of consumers?

AB Euuh. No

DC Why do you feel this way?

AB Because it has not been identified as a separate entity. It has not been identified as an area where you need to ask questions. It comes back to the thing that the EU says a compound is a compound so they would think that is regulated. So if we take titanium oxide, which is used in the paints to be the white pigment in the paints, they would say, "titanium oxide, okay but it's fully regulated because it has to go through the risk assessment procedures and so on." But of course the problem is that titanium oxide changes properties when it goes to a scale below 100nm.

DC Why couldn't it just be regulated as nanoscale or even nanoscale with a certain diameter titanium oxide? Why does it have to be classified as titanium oxide just because it's made of the same atoms?

AB That is exactly my criticism. Where they say they would like to use the incremental approach, which means they will use existing regulations to also risk assess new things. And I'm not against that actually, where the Danish EPA and European authorities also say that the legislation is there and it's okay. This is correct I think, but it's more from a lawyer's point of view. They say from legal terms, we have the right laws, we have the right regulations, so we don't need to make a new regulation for nano. And it took me some years to understand what they actually mean by this because as an engineer, I would say, "Yeah okay but it doesn't really have the right regulations if the underlying rules are bad." The regulators would say, "Okay, but this is a scientific problem, for us, the important this is that the regulation is there and it's going to be REACH and the regulations came through." That's okay for me now; I'm at ease with this. Okay, this is what they mean from a regulator's point. From a scientific point of view we have to then stress and say okay if you want to make a risk assessment you have to take down something that's called technical guideline. It's like a cookbook to see how should I do the risk assessment but there's nothing specifically nano in that. And this is where we have to have things such as what you outlined to say, well are there specific nano questions because of the size and diameter under 100nm or should they regulate like 50-100, 20-50 and below 20 whatever. I don't know, but I think this could be done but the problem right now is we don't know what to do with the data the company would turn in because we don't have sufficient knowledge to handle the data. In my opinion we might collect the data and when we advance our knowledge, we can actually use it.

DC Are there any other changes that you think could be made to the current framework?

AB Yeah, I think that we have seen that toxicity can be brought down to about eight characteristics that are specific for nanomaterials. Which is like chemical compositions, size and crystal structure, surface area, state of accumulation. So there are actually eight parameters. We went through the literature; I think that it's 420 studies to see in the toxicity literature what has now actually been characterised of these 8 parameters to see if we already have knowledge, which, maybe not surprising, the answer was no. It's very scarce what has actually been characterised also because there's not been focus on what are the determining characteristics, but this is a point where I would say maybe it's overkill to ask for all of these eight but it could be narrowed down to perhaps to three or four additional questions being asked if you raise the nanoflag. So the possibility if you talk in regulatory terms, there should

be open the possibility to put the nanoflag to put on specific part of the titanium oxide and for that extra questions will be asked otherwise there are no markets for you.

DC What is your feeling on production limits? I know there are a lot of loopholes or if you don't produce enough of the chemical you don't have to register it. Are you concerned at all with that?

AB Of course there's a lot of criticism about this tonnage requirement, like you only trigger regulation for ten tonnes marketed per year per producer. I think we have to invent another kind of trigger for nanomaterials. It could relate to surface. It could be how much surface do you want to put on the market – how much titanium oxide surface you want to put. I'm not quite sure where the trigger should be – this could be an alternative. But at the same time I believe there has to be this kind of divide. We have to have some kind of level where we say there is also a level of no concern where it's sometimes the developers they are very afraid of this regulation thing. Afraid like now this means I can't do anything when it has to be registered, and I try to say, "Registration legislation only comes when you want to market if comes if you want to sell." And I think that's sensible, you know? For me, it's often claimed it's a break on development if you have regulation. To me, it's simply not true. It's when you want to market it, when the public or the consumer can be exposed. This is when you have to register this is when you have to regulate. Not when the researcher is researching; of course he has to take his own precautions otherwise he will be killed. But this is regular. This is like chemicals. There is I think there's 13 million chemicals registered but there's less than 100,000 being used, so there's less than 100,000 for which any kind of regulation should be used but there's 13 million in total and the 13 million came from the lab experiments. So I think sometimes that the discussion on this is a bit biased by the fact that nano researchers don't know the regulation is only when you want to market and I think it should be like that. Then we have to find out what kind of data is triggered.

DC So just one final question. A lot of our background research reading through the literature, we found that there are three different points of views on nanotechnology regulation. That you don't need to change anything, you need to make incremental changes and tweaks as the technology develops and the change becomes necessary or we need to start making new regulations now and perhaps even new regulatory regimes and groups and statutes and stuff. Of these three categories what do you feel you best identify with.

AB I think it's somewhere between the two last ones; you'll never get me to say. Because I think it's not stupid to say that the incremental approach is the way and for me because you're talking regulation. If you're talking science because that's what I do, option number three would be the best one. To start all over and say what from a scientific point of view but it's a bit concept to say because regulation is not science so I would prefer something like two because it means that it will actually happen. I'm afraid if you say three and want all over making new, I'm afraid – I know this will take more than 20 years even though we blah, blah, blah. So from a practical point of view or like what would be in the best interest of the public and consumer I would think that number 2 is the best because it's something that could be done. With the amendments and so on that we just talked about, and we have to be aware that the incremental approach does not mean that we just take the old past off and apply it to a new area and make the same mistakes. For me, in the incremental approach it means that we have to make new technical guidelines and so on. So I'm more two than I'm

three. And maybe you should talk to my PhD students because I think they're more three than two

DC I think that's all we have. Thank you for your time.

Appendix D.3 –

Interview with Hanne Svenningsen
Wednesday 9 April, 2008

Interviewers:
Dan Carney
Kelley Murray
Linxiao Chen

DC I guess first the idea is we wanted to talk about the study with focus groups that you did to kind of get the idea of how we can do that ourselves and talk a little about the results and your conclusions. And then if we still have time, if that doesn't take too long, we have some other questions that we've kind of been asking everybody that we go see, so we'll see how long the first part takes and then we can get on to the other stuff. Kelley,

KM Ok, so how did you go about gathering participants for this study?

HS We did it in different ways. We used an email list at the university, I think it was the Technical University of Denmark…

LC DTU?

HS DTU, yes, and at the University of København for the IT, Information Technology, students and the social science students, but we also went to the street and talked to people, stopping them on the street and asking them do you know anything about nanotechnology and would you like to participate in a focus group about this subject? And finally, we sent out to our newsletter, we have a newsletter with about 10,000 users, asking if anyone wanted to participate, but we also used our own network, asking families, friends and things like that because the theory of this qualitative study is that it's ok to use the networks, the personal networks as long as it's not my mother or my sister or my best friend then you can go that way. We had three different groups: we had some people knowing a lot about this subject, it could be a person working with nanotechnology or students who knew a lot about nanotechnology; we also had a group of people who were concerned about nanotechnology and concerned about science in general; and we had a group of people we called 'technology friendly' who had positive thinking about nanotechnology and science in general…

LC So, enthusiasts?

HS Yeah, exactly. It was a way to have different people coming together talking about this area. We didn't have groups of only people who were worried about it or who were excited about it or only people who also know a lot about this area. We mixed them and had three groups in all and had 24 participants. The hard thing is to recruit these people. It's very tough job to do. So, I don't know, do you plan to do one in Denmark?

KM Yeah, we're trying to get one of mostly college students. But did you have the students from the colleges or the professors?

HS The students, only the students.

KM Ok.

HS Well that's not the whole truth because we actually had one or two professors. In the first round we thought only of the students.

KM Ok.

HS And then we also had a spread in women and men and age.

DC What's a good number of people for a focus group?

HS About seven to thirteen. I think one of the groups was six and it went all right, but the best number is eight to create a good dialogue among the members. And a focus group lasts for about 2 hours. We made a questionnaire before the meeting so we could sort of control where the talk would go, but I also found that it was important to have freedom in the discussion. I was not the controlling one. More, I had to make sure that we got around to all the subjects that I wanted to discuss. But they were talking freely. It was a good experience.

KM What sort of questions did you ask in the focus groups?

HS First of all I wanted to just have them think about nanotechnology. With a question like 'so, if I said nanotechnology, what do you think of?' And then they had a discussion about this thought or word. 'What did it make you think of?' And I didn't want to manipulate the talk. There are a couple different methods you can use: you can choose to give the people a little bit of some experts explaining things and then those groups can get more focused because they'll know more about it, but on the other hand, if you just invite people and let them talk about what they think, you'll have more open and not manipulated approaches. So that was the first question. And it was an interesting experience because they actually talked about some of the other things I had planned to ask. Then I think that the second question I asked was 'let me introduce you to some products where nanotechnology has been used and now what do you think?' Many of them were quite surprised that nanotechnology is used in so many products today. And this title (points to the report cover), it's in Danish, but it is 'Oh, I'm already a user of nanotechnology.' Because it's in the sunscreens it's in the iPod, the technology is already being used. I think some were quite surprised by it. Then I, if they didn't by themselves discuss this issue, talked about some positive things about nanotechnology. You can find medical improvements but on the other hand we don't know how it affects humans or the environment, like with unknown chemicals. Then they have the dilemma between, on the one hand, the positive benefits and the other side, we don't know much of how it effects the environment and health. And finally we discussed how to handle this dilemma. 'Who do you trust? What kind of information do you need and who's going to give that information?' So it was about who they trusted and what information they needed. That was basically what we did. But it was funny that they, by themselves, discussed many of the topics without introducing them. And I was also surprised that, as one of the conclusions, the consumers have learned very little about this issue but they are very good at discussing, what is the problem, what is the

dilemma? And they used their experiences from other areas, chemicals that are dangerous and radiation from mobile phones. They used their everyday experiences and their knowledge about environment and health issues to discuss this theme, and I thought that was interesting. I don't know if you know critic named Ulrich Beck, he's a social scientist who talks about "risk society." He says that we produce risk today ourselves and everyday we have to handle and deal with this risk. And people are actually using their experience, and information is everywhere but they can't handle it. Sometimes they get confused because one expert says one thing and another says another thing. We are an information centre, we say one thing and the authorities say another thing. So what should the people believe? They use their common sense and experience from other issues to make sense of it.

KM Where did the participants usually hear about nanotechnology? From the media or from other sources?

HS From the media mostly, but they also had little trust in the media, the know that this a quick story and the journalists just want to get it done. They know that the story is either 'oh there's no problems' or on the other side, big problems. They miss "nunst" information. So they get the knowledge from the media and from, I think all of them mentioned a sofa that had been dropped into chemicals that prevented stains – that was a commercial where they then spilled red wine and chocolate on it and it was clean. So they also get information from commercials and stories, the headlines. Yes, that was where they get most of the knowledge. But they somehow feel like they miss the information, the "nunst" information and how to handle it.

KM What did they, the participants, see as the greatest risks of nanotechnology? Which were they most afraid of?

HS The inhalation of nanoparticles. It is quite surprising that, well not surprising but as I told you before they can quickly see what's the problem and what's not the problem. If you ask some experts in the area, it is also the free nanoparticles getting into the lungs which is of greatest concern. It is also the environment. They talked about washing machines with soap that has nano-silver. What is going to happen when this nano-silver gets into the environment? Into the water and soil? We don't know, so it was also an issue. And then of course the effects on the human body. Inhalation was greatest concern,also the sunscreen. They had a discussion about whether the nanoparticles could get into the body or not. It's also a relevant issue. The experts now say that it can't get in if you have normal skin, but if you have a wound or dry skin then it might be a problem. The point is, when is the skin damaged enough that it might be penetrated by the nanoparticles? The body and the environment are the biggest concerns.

LC Are they more concerned about risks that you can't foresee? The ones that they can't expect? Are they more afraid of those ones than the known ones?

HS Yeah, it's all a question of control. For example, many people are still smoking today even though we know it's dangerous, but they choose to. We go around on our bikes without helmets and we drive our cars a little faster than we should because we think that we can control it, we choose it ourselves. There's a parallel to mobile phones. We had discussions like this one about four years ago about radiation from cell phones, looking at the risk.

People were more afraid of the antennas on top of homes than the cell phones even though experts said that if there were reason for concern it would be with the device you keep near your ear. They feared the antenna because they couldn't control it. You can control a cell phone, you can choose to use it. The parallel to this study is that a lot people want to have labels so that they can choose. If they have a label saying 'this product was made using nanotechnology,' some people might say 'thank you very much, now I know and I'm going to buy it anyway' while others would say 'oh thank God, I'll never touch it.' They also saw some benefits, especially cancer treatments and cleaner technology projects, if technology could lessen the waste and clean up the environment. They saw a dilemma between benefits and risks, those they know about and unknown.

LC Going back to what you said about them making comparisons to other things, did the controversy behind genetically modified foods come up?

HS Yes, it did. If you look at some of the other studies, GMOs comes up a lot in association with nanotechnology. The parallels were more like we are doing something new with nature that we can't definitely control. Is it all right to manipulate nature this way? And where the chemical part came into it was personal health and nature's health. Another interesting conclusion was that the perception of risk was very much affected by the discussion. If in the focus group one person said 'I know a lot about nanotechnology and there's nothing to be worried about' I would be very affected by your statement. I think it shows that our knowledge about nanotechnology is small and there hasn't been a great discussion in society about it yet, so the perception can be manipulated and changed by such things. Like if an NGO said 'this is a big problem, you will die tomorrow.' It would affect the general consumers' opinions. And that is why one of the things this is calling for is a new debate on the issue. If some experts say that there is nothing wrong with this, go ahead and buy it, people would be very affected and manipulated by that. On the other hand, if an NGO comes along and says that it's bad it's deadly, or someone in the US says that it's bad, the Danish opinion would be very affected. I can give you an example from the study. We had one guy who was saying that this was a very good technology and 'I'm not worried at all' and about an hour and a half later he was saying 'I'm very worried and you need to take action right away; the authorities are not taking responsible actions here. They have to forbid this because it's so dangerous.' He had been affected by one of the ladies, who was studying nanotechnology, the possible threats, and at the same time she was an NGO representative. It showed how quickly people can change their opinions; it was very interesting.

KM So do most people trust the government or companies? Who did most people trust?

HS In general, they had a pretty good level of trust in the Danish authority, but they also think that they should start giving the public information now. They had a very low level of trust in the industry, companies that are making nanotechnology products because they thought they are just interested in money and that they were lobbying for power in the European Union. They had little trust in the media as well. The greatest trust was definitely in NGOs like the Consumer Council and also the authorities and experts. I think that's very similar to what we found in the mobile phone discussion. Although there was actually less trust in the authorities at that time, and I think it's because there had been many discussions in society about it. But those discussions haven't happened yet about nanotechnology so I think that the trust level could quickly fall if there is a debate.

DC Do you have any other advice for us about conducting our own focus group?

HS How much time do you have left and how many resources?

LC We have two or three weeks to actually do the focus groups.

HS Then I think you need to be as focused as possible. Don't just go out to the consumers but maybe the students would be good.

LC That's what we hope to do.

HS I think it will be a good experience for you just to make a focus group, knowing what theory it's based on and what questions you can ask. It's important to know that you can't make big conclusions like 'the people think or the people say…' For that you would need a survey or something like that. But it's a good way to get under the skin of how people think and what they feel and how they talk about that. So maybe the best way to do that for you is with students who are willing to speak English because Mrs. Hensen on the street is going to say 'English? Oh, no thanks.' So the students are a good start for you.

LC How should we go about getting the students?

HS What kinds of students do you want to talk to?

KM We wanted a mix of technical students who would know something about nanotechnology and then other students, like social science majors.

LC Yeah, like liberal arts students or English, well actually Danish majors.

HS We actually have a student here from DTU and I could ask her if she has an email list you can use. I'll go get her. … She is actually a student at DTU, and she can tell you something about it.

S Well, I study biotechnology at DTU, and I can tell you that there is a message portal online that is controlled by the DTU Administration so I don't have access to it. You might be able to get in contact with them and put a message out that you are interested in getting people for this focus group to all the students.

HS How many students are there?

S Six or seven thousand. The portal is kind of a mixed forum though. It has everything from job offers to exam info and also not so official things like concerts and whatnot. You should contact the DTU Administration office and I think that they'll help you. I think we have a bachelor study of physics and nanotechnology and also the biotechnology so there are students who know about it.

LC We were actually there Friday talking to a professor.

S Oh, ok. You can also contact that professor because he'll have access to the portal.

HS And then maybe you can have the focus groups at DTU so it would be easier for the students to come.

S How long are you in Denmark?

KM A couple more weeks.

S Ok, so you can travel out to DTU? It's only about 25 minutes by bus. We also have a lot of message boards that you can leave flyers on, but I think that the portal would be the best way to get it to all the students. Do you want my email?

All Sure, that would be great.

S Ok, it's so61902@student.dtu.dk

HS So that could be a way to get the students. I would suggest you come up with a very concrete description what you're doing to put on the portal. What is it? Why are you doing it? What are you going to use it for? How long will it take? And what are the benefits for the students? Do you know exactly what it's going to be about, a look at the risks and benefits or general knowledge about it? What is your focus?

LC It's a little bit of both.

KM It's very similar to the study you did.

HS Ok, well then you should definitely come up with some questions beforehand. It's a talk between people. You're more in the background but you can also sit at the table with them as a level of trust, like a relaxed talk. The questions are more just a way to make sure that you talk about all the stuff you want to talk about. But don't stick to just those questions, let the conversation go.

LC So we'll need to get a room there.

HS Yes, that would be a good idea. But I would just stick to DTU students because you don't have much time left here. And this will also be an opportunity for you to meet other college students, and who knows maybe one day they'll visit America. Where are you from in the US?

DC Massachusetts, near Boston.

HS Oh nice.

KM I have a quick question. You gave them explanations or told them about some of the explanations…

HS Yes, very short explanations. We also had a screening interview beforehand just to make sure that we had people who knew at least a little bit about nanotechnology. We also asked questions like on a scale from one to ten, how do you feel about mobile phones? Or on a

scale from one to ten what do you think about new technology in general? Do you think that it's a very important for society or do you think that they should test it a lot before it comes onto the market? That allowed us to get a balance of worried and not worried and technology optimists and pessimists and also a balance of ages. If I were you, I wouldn't matter so much about age or what not. Maybe look at just students who are optimistic about technology and those who are a little more sceptical. And then we sent the participants a letter before just reminding them the focus group was going to happen in a few days. Remind them they agreed, where it is, and a little explanation of what nanotechnology is. Do you want to know who we are and why we did the study?

All Sure.

HS Well, we are an information centre on environment and health for the consumers. They can call us for advice like what to buy for a baby if they want to buy clothes that don't have a certain chemical, or 'what about cosmetics? What brands should I buy if I want to be careful about chemicals?' We do lots of studies like this to make some information leaflets so that we ensure that we're writing to people who need them and writing something that they want to know. Our board is made up of half industry people and half consumers and NGOs, and we have a neutral president.

LC How is your organization funded?

HS By public support, and there is also a law that the Parliament agrees on every year that allots money to different organizations. It's usually about 5 million kroner a year, which isn't too much. We aren't associated with anybody else, we're an independent organization. We give nunst information to consumers and we test a lot of products, like sunscreens. 'You know, what kind of sunscreen should you choose if you want to avoid certain chemicals? And what about tuna and fish and meat safety?' Things like that.

LC And how big is this organization?

HS We are four consultants and one leader, and some students. Right now I'm working with do-it-yourself products like painting and building materials with chemicals. What are the safest ones to pick?

DC Ok, well if you have time, we'd like to ask you some more questions that aren't really related to your study.

HS Yes, that's fine.

DC All right. This is more for a separate part of our study where we've been going around asking experts these questions. We don't need to report your name, but we'd like to report your occupation. So when we ask for your name, if you don't feel like telling us you don't have to.

HS Oh no, it's fine to print and use my name.

DC Thank you. Also, if you don't feel like answering any questions you don't have to and if you want to stop the interview at anytime that's perfectly fine too. So shall we get started?

HS Yes, sure.

DC Can you please state your name for the record?

HS Hanne Svenningsen.

DC And could you please state your occupation?

HS I work as an environment consultant for the Information Centre for Environment and Health.

LC So what is your experience or background with nanotechnology?

HS It is not so great. I mean I haven't been looking at this area for a long time because we have a lot of other projects going on too. But we have at the website something called Tema Nano which is a portal that links you to information like: what is nanotechnology? Where can I find information? What do the experts say? What do the authorities say? What information do we have today? What information are we missing today? And where can you find other kinds of information? And then of course I made this study which looks more at the perceptions of consumers rather than the expert side.

LC You've already mentioned many of the benefits and risks associated with nanotechnology that other people have talked about, but how do you feel about nanotechnology?

HS We are not like the Consumer Council where Claus is sitting telling people, well this is good and this is bad. We are an information centre so we aren't allowed to think any one thing. My job is to give nunst and detailed information to the consumers.

KM So you (as an organization) don't have any opinion, right?

HS Right, we don't have any opinion. Our approach is to give information and provide advice to the consumer so that they can do it better for the environment and their health in everyday life.

--- Begin Off the Record ---

--- End Off the Record ---

LC All right, well that's it. Thank you very much.

KM Yes, thank you very much.

HS No problem. Let me know if you need anything more.

Appendix D.4 –

Interview with Jørn Dohrmann
Thursday, 10 April, 2008

Interviewers:
Dan Carney
Linxiao Chen

JD I am the spokesman for the Danish Peoples Party about environmental issues and also agriculture and that sort of stuff. So, my interests have always been about environmental issues and also agriculture. That's the main things I would say. So you can ask any question if you want.

DC Alright, because we have been doing this interview a lot we like start of with just a few formalities. If there is any question you do not want to answer you can just skip over it or you can end the questioning at any time. That is fine. Technically we do not need your name for the report, but we do need your occupation and background. When we go through those questions, if you want to skip them, that's fine. But I don't think we have any difficult questions.

JD No no no, ask any questions. That is fine.

DC Can you please state your name and occupation for the record?

JD Yes, my name is Jørn Dohrmann, and I am a member of the Parliament in Denmark and yea. What do you want to hear more?

DC No that is fine. We have more questions about background stuff. So we will get into some general questions about nanotechnology and then a few questions at the end about regulation.

LC So what is your background or experience concerning nanotechnology?

JD Oh I have learned mechanic and also like electromechanic so I have both skills. And there you learn a lot of you can say small things like also nanotechnology. But you, you're not, as you'll never learn everything in nanotechnology. While it's very important to get schooled on, if you have your schooling then you only have your background as they say, so you have to do it afterwards. And at the time in Washington and at the Parliament I was, I did repair like spray equipment and sold that to many different customers like companies, big companies. But that's my background before I went into politics. I hope that's enough.

LC So nanotechnology, it's a booming field. It's starting to gain popularity but people still don't know much about it. Are you aware of any, if any, benefits nanotechnology may bring to society?

JD Yeah, I mean nanotechnology is a big advance. You can do a lot of things with small things and if you look forwards with nanotechnology I think you will benefit a lot in the future. I've seen that if you can, like you have seen that if you can cover a chair with nanotechnology the dirt won't get stuck on it. You can use that technology to I would say a lot of places, but you still have to be careful. Like GMO you have to study which other effects do you have on environment and what will happen if you breathe in certain things in that area. All the bad sides you have to be really careful about what will happen there. But you also have to see all of the good sides. But that will be a big discussion also in the future. But nanotechnology you can use in almost all parts I would say. So you can get a lot of smart things if you were to go to use nanotechnology in the good way.

LC So where do you think nanotechnology will benefit, which applications do you think would benefit the most do you feel?

JD I think in electronic you will use a lot of nanotechnology in the future and I think most of the people want to have a smart phone, and a small phone, and faster phone. So the more you use the nanotechnology the more benefits you will get out of it, and it is very difficult to say that you shouldn't use the nanotechnology or you should use it.

LC So are you aware of any of the risks?

JD At this state I don't see many risks, but that depends on where do you want to look. Do you want to look on the technology side or do you want to use the nano-products like the car, or the chair, and all that sort of stuff. Its two different sides I think you have to look on. But you have to see them in the environmental part. If you use the stuff, how can it disappear again? But it's hard to say which parts are the best or the baddest. I don't know it's really hard to say.

LC In other interviews we have had, we have had, people have mentioned such things as risks when we talk about risks they likened it to GMO or asbestos and DDT, and other things that were in the beginning you thought it would be good but then later on you find out there are a lot of risks in environmental and towards the health. Would you liken nanotechnology, nanomaterials, nanoparticles. Have you ever thought of them in that context?

JD Yea that is the reason why I said you have to study what effects they might have on the environmental part. Like I said, how is it you want to recycle them? How is it literally come in contact with them? If we are breathing them, what will happen there? And what will happen when you have clothes on and you come in contact with the skin all the time? You have to have some good studies, reliable information, data on it. But I, you have to have some experts who are good in the stuff. But that is in the start, and in the beginning I think the company who are selling that are more interested in selling the goods than to have the study done. That is the reason we have to be a little bit careful and say "ok if you want to use that product you first have to ensure us about don't have any bad sides, and it's good enough, don't release a lot of dust, whatever." It's a hard question while we don't get the answer on the first day it's like the other products like the GMO and the asbestos what you had before you never know what will come up in the future but we always have to be prepared to do more research on this area. But you never get all the answers on the first day. It's a hard question very complicated answer. In politic you have to be a little bit careful.

You have to say, "how do we ensure or how can we be sure it don't have any bad side?" But you can't be 100% sure.

LC So I mean, nanotechnology, as you already mentioned, can have many applications. I think you can use it in electronics, in clothing, and even in medicines are big. Even sunscreen with small nanoparticles is currently on the market. Do you have any specific concerns toward a specific application?

JD Yea I'm worried about if it's going to get in contact with people. I think our body is a sensitive and if you have too much contact it can maybe give some problem. We don't know what are the reasons for why we don't get so many babies any more. So we can see in Denmark, the sperm from the men are really bad. They are getting so you say. Before it was better and now it is really bad, and a lot of people have to have to have help to get children and that's a big problem. But what part of recent environmental? Is it the air? Is it the cars? What are we eating? We don't know really and the more things we use like nanoparticles on skin that could be one of the reasons in the long term. But they have to be careful I think, and that is the reason why factory have to search is it some bad things in this product that they are selling? But don't think they want to tell the whole truth so it's a hard question. Should we forbid it? I think we can't hold those particles away, we have to be careful and every person has to think a little about what they are using for clothes or what they are using to protect them against the sun, sunscreen.

LC So you are sceptical towards industries telling the truth or disclosing completely

JD I think you have to double check the industry. I am not sure that the industries are telling the truth or the whole truth every time. I have seen that before.

LC I guess now we have talked about benefits and we have talked about risk. So do you think the benefits overall outweigh the risks or the other way around?

JD It's hard to say now, they have to look on the future and say "what did we get from it? What did we reach with this product?" It's hard to say now but you always say "No we don't want to study things. We don't want to see what we can do." I think that we will get more problem or we didn't get all the benefits of the long term. But I think it's hard to say to the people who did work with the asbestos and talk to the people who got cancer and say that was a good benefit. I don't think they want to agree on that. But you can also say that if you use asbestos you get a good fire protector. So can you can have some good sides but you can also have some bad side but the total amount of all that you don't know in the start.

LC But personally, not as a politician but as yourself, are you more optimistic about nanotechnology or are you sceptical about it?

JD I would say you have to have advance with that product and I think you will get some benefits of it. But maybe in about ten years you will see that oh that was a big mistake but you never know. But in the start you have to control a lot to know what bad sides you get if you put it in the sunscreen how did it work on the people? You have to make a lot of tests before you can use it there. But if you always say no, we don't want to get further. We can say that at the time we let people drive in the car and they had some accident. If you didn't

allow them to drive on the car we wouldn't have so many that die on the road every day. It don't matter which decision you decide. It will have some consequence. It's a hard life to live but someone got to do it.

DC So I guess no we are going to move on to more regulation based questions. I assume you have some background knowledge of chemical regulation and how that works in Denmark and the European Union.

JD Mmhmm

DC Ok as it stands currently, the way things are without making any changes, do you think that the current regulatory system is sufficient to protect the Danish public from the possible risks of nanotechnology?

JD I didn't understand the question.

DC Is regulation with the way it's written in the book now with the REACH program. Is it good enough?

JD Yea I think in these days it's good enough. But you never know, how will it be in the future. So, maybe you have to have some other tools later on. If you see some big problems later on maybe you have to get some new regulations, but at this stage it is in now I think we will you will get some experience, and you will get further on with or in the industry to get some results and use the product. But you have to have tools that you can use if you have some problem. If there is a problem with the sunscreen, you could take it out of the market like over night. You shouldn't take the people to or in this product if they don't want to be apart of you can say the test of this product. So the regulation are useful how they are now.

DC So do you think that there are any changes or anything that they might want to improve now, before we have to wait to see if there are any problems?

JD It will always be moving the regulations. You can say that some of the chemicals I think it is 1000 litres how much it was. If you are under that amount you can do whatever you want. That's not good enough. If you have some bad things it don't matter if it is 1 Litre or 1000 Litres. If it is really bad you have to regulate it immediately. Today you have to in the chemical law, you have to get it like tested before you can send it on the market, *if* you are sending it on the market. But now you have regulation. You are using for nano-products. But like I said before you never know how will this product work on different other products. So we have to see. It's a hard question. If that one says its good enough… it will never be good enough its always moving.

DC So we just have one final question. As we were looking through the literature for critiques on the current regulatory system we kind of found that there were three main positions. One was that the current regulatory system is fine and it will handle nanotechnology just like it would handle any technology. The second one is that you know we need to be cautious but really only need to make changes as they are necessary and when we see things come up. And the third opinion is that you know we need to anticipate that nanotechnology is something new and is not like other technologies we have seen before, and we need to make

drastic changes now. Maybe set up new regulatory regimes and enact new regulations. Of these three statements, which do you feel you best identify with?

JD I think the second one.

DC The second one.

JD Yea.

DC Okay.

JD I think that just about wraps it up. We thank you very much for your time.

Appendix D.5 –

Interview with Sofie Krogh Holm
Friday, 11 April 2008

Interviewers
Dan Carney
Linxiao Chen

DC Ok, I guess before we begin we have to go through all the formalities and everything. If you want to skip a question you can just skip it, or if you want to end the questioning at anytime, that's fine you can just end it. Also, when we ask for your name you don't have to give it but we do hope that you give us your occupation. Ok?

SKH Yeah, yeah.

DC So shall we begin?

SKH Sure.

DC Ok, could you please state your name for the record?

SKH Yes, I'm Sophie Krogh Holm.

DC All right, and your occupation?

SKH I'm working here at the Danish Consumer Council and I'm a food policy officer – it's called Senior Food Policy officer in English I think.

LC All right, so what is your experience or your background with nanotechnology?

SKH With nanotechnology, I'm looking at nanotechnology but mainly from a foods perspective to see what do we know about it, what do we know about risk assessment mainly because that's my main area when I talk about foods. That would be my entrance, and then of course I also follow what the authorities and the NGOs, what the debate is like, and what they're saying.

LC So how is nanotechnology used with food?

SKH It depends a little. I know, for example, in Denmark they're looking a lot at is like vitamins and minerals and how you could use nanotechnology to make the uptake in the body greater so you take lesser amount and the uptake will be greater. I know some of the other products being talked about is like chewing gum. It can last longer, the aroma I guess. Some points I'm not sure because industry wants very little to state actually with food where they use it, so some of it is guessing. We're guessing and I'm trying to find out about food colours – the aso food colours. I think, I know, there's a technique of grinding and putting them into aso size so that will make more brilliant colours, but we don't know if that's used in foods. I'm trying to look at that. I would think that also some of the technology is used in food

flavouring and for colours where you kind of encapsulate. That would be some of them I would think could be nanotechnology. So I'm just kind of finding out and trying to find out where do we think it's used? Where do we know it's used? What kind of products do we see from the Woodrow Wilson database of what's on the market?

LC So, I guess with food, it's very controversial using chemicals because it's very risky. What are the risks involved with nanotechnology?

SKH We don't know. I mean, the straight answer is no one knows, but there's a lot of guessing going on.

LC So like what are you concerned about?

SKH What we look at is like compared to iPod or something, when there are free particles that mainly is our concern, when it gets into contact with your body that is a concern. We know some of these studies how free nanoparticles fed in huge amounts of course to daphnia and other animals how they kind of travel in your body and don't keep to certain organs and you don't really know where they're going or how they're going to hurt you. That's like what really is about the particle size as such but then of course it's increased like increased reactivity like a…

KM A catalyst?

SKH Catalyst, yeah, when it works like that. So it will be also more specific upon how do we use it? For example, vitamins and minerals when you take it for like this, it will be of a concern if there's increased uptake if you get too much for example because the way that legislation works today you have to take some many grams a day of something and then suddenly you have maybe a vitamin or something or a mineral that is taken up very different than we know; so how should legislation, how can you handle that? How can you make sure that you don't get too much? For example that it doesn't get toxic when you take it? And so in the same way, comparing it alos to other uses where you actually where it will more be dependent upon the uses now with vitamins and minerals or the taste or could it be more allergic reactions? But always depending on where from case to case it is that you use it.

LC Ok. I know that GMO in Europe, people are not so happy about it and will not eat foods that have been modified. How do you think the public will react to nanotechnology in foods?

SKH Right now, they're not reacting because they and you don't know where the products are, so right now they don't react. But in the future, it's very hard to say. I can say that I think they should be concerned at least with food and free particles getting in contact with your body – putting it on your skin or eating them. We know so little now. What we see, well what I see actually is when I look upon how do you normally do risk assessments it's like you have to do the see where is the risk; we have to see you know you have the dose and the response and where in the body does it act how does it act, you have the exposure you have the monitoring, you have a lot of data that you go through with toxicology to see what's happening, and we don't have these data with nanotechnology in food – much of this is actually missing. And still we don't know where the products are. We don't have any way of detecting them on the market actually because you cannot go out measure where do we find them. So we don't know where they are. Industry I think they use it but they won't tell.

Industry people tell me that there must be some usage but they won't tell where they use it, and you can't assess, you know, whether they are safe or not, and I don't know if they do it, but then we don't get the data. So if that would be any other food additive or food ingredient where you actually knew so little I think it would be illegal. I mean, if you think with yourself, now I want to do a new food colour a new somehow whatever additive and you want to have that one permitted and you say ah, I haven't really made a risk assessment and actually as a regulatory you can't really monitor it because we don't tell you where it is and we don't give you the methods of finding it anywhere. I mean you'd get a blank no, and that just doesn't happen. Instead people say we know so little, so we don't know what to do. So that's really perplexing to see how if you had a little more information people would actually act and the authorities would act; right now there's so little information that they just do nothing, and I think that's really, to me that's very very strange to understand how that kind of thinking can take place.

LC So how do people, I guess, perceive risk when it comes to food? Because there are some foods out there with additives that could cause cancer or could be bad for you and people eat them anyway. So how do they choose which risks they're willing to take?

SKH Wow, that's very difficult and it must also be individually. What we know is that they don't perceive risk of course in the same way as regulators because there'll be the risk they can avoid and the risk they can't avoid and the risk they think they know, so then they think they can handle it. Like smoking or something – they know they might die and they still do it, and then they might be concerned about additives you know, which is, if you do analysers on that it would be not logical. They don't handle it logical, but I think a lot of it is what is the benefit and then they want to know: can they handle it, who is actually taking care of handling the risk? It's not in a regulatory way, it's often done in a strictly scientific way and that's not the way consumers do it.

LC So are you concerned – personally concerned – about nanotechnology use?

SKH In food?

LC Yes.

SKH Yes, and in cosmetics.

LC But, I mean, you mentioned how with nanotechnology you could possibly find a more effective way of intaking vitamins and stuff, so do you feel that the benefits nanotechnology might bring to food outweigh the risks or do you think that it's too risky?

SKH How can we know when we don't even know what the products are? I mean I am aware of uses that I think are very useful now. For example, now one of the problems, for example, with the meat industry is when you have contamination from you cut one animal then the next come and the bacteria come from one ot the other. And now I know there's a research project in Denmark going on where you kind of try to, with nanotechnology, have coatings and knives that actually where bacteria don't grow or they can't actually stick to the surface because it's completely….

LC Smooth?

SKH Yeah, smooth. To me, that is a very good use so again it depends. And again, with that knife or something like that it's not free nanoparticles being fed to you or in the food or being put in on your skin. I'm not too concerned about these kinds of applications, and I think there'll be very good possibilities of good, new, and safe products that also can help us a lot. So, my concern mainly is really about the free particles I think that come in bigger doses into the body and if I was in the working environment and the people, you know, that stand in the factory where these things are handled then I would also be concerned about their health; but from a consumer side, I look at the products that come to the consumer and there I can see there will be problems there with things that you ingest or inhale or put on your skin.

DC All right, well I guess now we have a few more questions that are related to regulation and that sort of thing. Do you have any background knowledge of nanotechnology or just chemicals in general are regulated in Denmark and the EU?

LC Especially with food.

SKH Yes.

DC Ok, so in your opinion, is current policy – the way it is now – sufficient to protect the Danish public from the possible risks of nanotechnology?

SKH No, it really isn't; not so much. There's a new edition of the Novel Food Directive and there nanotechnology is mentioned but then again quite superficially and there's not like a document saying 'ok, so this is how we do the risk assessment.' Actually you cannot monitor it. You cannot go out into the market and say 'where's it used and then check it up, do they use it in the right way?' It's very hard to regulate something that you can't monitor, so we should you know ask industry to deliver some methods to go out and detect it. As long as you can't detect it then you can't really have effective regulation, so that is one of the main problems. We know that with some of the additives they might be used in a nanotech version because they've been developed for example the SAY WHAT?! And we can't know. And when the European FSA, Food Safety Authorities, ask the producers to please step up and tell us where you use it so we can have a look at, they say 'we don't use it.' But they do! I mean everyone knows somehow they must be, but they say 'no, we're not using it' because they're afraid of buuhh, you know that the public will be concerned and of course they will – how can you use something that you haven't had a safety assessment of? I don't think it's enough and I think there needs to be done a lot of work still.

DC So what changes do you think ought to be made to the current regulations?

SKH Well, first of all you have to agree on a definition – what is nanotechnology? Then you have to have like, for example, obligation of a mandatory database of the products using it, then you have to develop the methods of risk assessment. You should maybe you know take some standard substances and take them through the whole assessment, you know, from toxicology to ecotoxicology and see if we can learn something from that. Then, everyone

who uses it, they should give you the methodology of detecting it on the market, so there's a lot of issues that aren't handled now that should be.

DC Ok, so for one final question. There are basically, three kinds of points of views on nanotechnology regulation and how it should be handled that we've found in the literature. The first view is that we don't need to do anything, the current regulatory system will handle nanotechnology just fine. The second view is that we don't need to make any major changes, we can just make small changes and tweeks to the current regulatory system as necessary – when the problems arise. And, the third idea or theory is that we should start making new regulations now and start changing things on a greater scale, kind preemptively. So, of these three theories, which do you feel you most identify with?

SKH Somewhere between two and three. I mean the EU's right now looking at gaps in legislation in relation to nanotech, and in some places it will be existing legislation that you can that you'll have to adjust and then there also might be issues where you new, you have to have new legislation because there are too big gaps. But, I mean, if I were to say exactly where then I would be guessing because they're still looking for the gaps and trying to see what is lacking.

DC How about nanospecific regulations? Do you think that regulations specific to nanotechnology are really necessary?

SKH If it's for all nanotech, then you shouldn't have it, no, not for just the technology. If you say for like the use of nanotech in food then like under the food legislation you have nanotech as part of that, that makes good sense if you have a common registrar for usages of nanotech in food. That would make sense. Right now, the way it looks in the new legislation, it will be like if it's supplements or whether it is additives or whether it will be the rest that legislation is actually where it goes under. And depending upon it's actually going to handle in the food law, I'm not really sure if that's a good idea or whether it should be a nanotech in food law sort of thing, but like a common law for nanotech, all of nanotechnology, that's not an idea at all.

DC Ok, and how about new regulatory regimes? Not even. Say you have the Danish EPA, and I'm not saying to make like a Danish nanotechnology team, but what if there were or you started constructing new divisions within maybe the European Commission or the Danish EPA that dealt directly with nanotechnology, would you…?

SKH No.

DC No?

SKH I don't think so. I that the expertise must lie within the food, within the chemicals, within the you know environment and certain…

DC Fields?

SKH Yeah, fields that are already there because now it's nanotech, next time it's another technology. You know, you cannot have a new department for every new technology coming up; that just doesn't make any sense. And it's a divergent technology: you have all

kinds of makers and new things coming up. We'll just have to have, there are authorities there, and they'll just have to you know kind of upgrade so they can handle it within their field.

DC All right, well I think that just about does it. Thank you very much.

Appendix D.6 –

Interview with Robert Firkic
Monday, 14 April 2008

Interviewers
Dan Carney
Linxiao Chen

DC I guess we'll start out with the formalities since we do this interview a lot. At any point, if you wish to skip a question or not answer a question you can skip past it. For this interview, we need to know your background and occupation but we don't need to know your name.

RF Well, you've already got my name.

DC Oh no, when we write our report we don't have to put it in there.

RF There's no problem at all, just do it.

DC All right.

RF My name is Robert Firkic, you have all my data on the business card. My background is an engineer from "Olbo" University back from I'd say about five years ago. The course was something like technological…sort of I'm not chemist but the idea with this study was to integrate technology with marketing skills in some sort of combination. I've been working for TC Nano for three years or something, and the company's fairly new. We have our four or five year anniversary right now, so but in this business TC's a kind of old company.

DC So do people do research and development in this facility?

RF Not in this facility. We have our partners doing…sort of. We have some cooperation with the universities where we got some research but we also have our partners for production and research within these products, so we are sort of you know, we have tried to develop some venues of products based on nanotechnologies. So we are the guys who said 'ok, this could be interesting. What can we do about it to make products?'

DC All right, I guess we'll get into some general questions about your opinions on nanotechnology and after that maybe a few questions on regulations.

LC So what do you guys make here?

RF What do we make here?

LC Like, a lot of coatings?

RF Yeah, a lot of coatings. We are precisely working with surface protection based on nanotechnology. That means we are working with thin films in from let's say 10nm to some micrometers with different functionalities. The idea is at the end of the day to use

nanotechnology in order to enhance or to make some products be the new functionalities and that's what it's about. So we're actually working with a new way of certification along with our partners in order to have a sort of certificate for general nanotechnology products. There are some rules and some studies that need to be done on each product in order to get certification.

LC So what kind of benefits does nanotechnology bring to surface protectants?

RF The new functionalities. You know, you have some different product divisions; you have a car division with all the products for cars, you have division for home appliance, we have a division for boats, besides that we have some projects. I can tell you about one. We have a partner in US called Dimension Polytech. Dimension Polytech is the world's biggest producer of textiles for say clothes and stuff like that, and they want coating for sale for better UV protection combined with hydrophobic properties. The project was going on for this is the second year, and now as we speak we have our sails out there sailing to test the deficiencies of the coating. If you take a look at our annual products they are sort of a little bit different than everything else on the market. I'm not sure that, yo there is glass coating glass coating, you know the product from US called Raynex? This is actually good product to compare with because Raynex is a fantastic product but it is based on old technology, silicon technology where your durability of the products is, I don't know, a month or something of normal use. In this case, we have a durability of about six months up to one year. We have properties which are much better that means it works much better than the old, and that's the key question about all these products. Actually it's nothing new, you know it's nothing phenomenal, but it's better than existing products and I think that's the key word with nanotechnology.

LC So, you think the improvement is because you're using nano-sized particles rather than, or nano-films…

RF Nano-films. I think that the particle talk is a little bit…I mean you don't always use nanoparticles to make nano-products. You use some different nanomaterials in order to, and sometimes you have nanoparticles containing these nanomaterials but sometimes you have polymer chains and stuff like that where you don't have nanoparticles. So nanoparticles are sometimes a part of a product and sometimes they're not. What we are using, yeah we are using nanotechnology or nanomaterials or nanoknowledge in order to enhance or to make better products than before. I think that the main issue about nanotechnology is that the expectations about nanotechnology were too high. That means that people expecting miracles and that's not how it is. These are good products – they are much better products than we have on the market today or traditional products, but they are not like…

LC Revolutionary?

RF Yeah, that's right. They are not like you just put it on and you never going to clean your car anymore. That's what people expect of this nanotechnology.

LC So you think we're in the very early stages?

RF I'm not sure that we are in very early stages but I think that the expectations are too high.

LC Ok.

RF I hope that one day we will be able to have a coating which will work like I don't know a lotus blade when it just blows off and takes dirt and stuff with it. But I mean it's like flying versus flying to the moon that's how big gap there is. These products are good; they are working really good working much better than they used to but we are far away from products where it is like: miracle. If I may say so.

LC One of the major concerns with nanotechnology, nano-products, nanoparticles is that in contact with people it might cause harm. Do you see any risks in the use?

RF Yes and no. I see a risk some risks where producer or companies are working with these technology are not really aware of what's what's everything about. We can take some examples. Sun lotion or cream that protects against UV light, 20 years ago or 15 I'm not sure. So 15 or 20 ago they start to use titanium dioxide as a main protector within these creams. I mean you have an issue if you put in nano-sized particles and you just smear it into the skin, I mean it's like…I'm not sure I'm going to do it with my baby if I want to put some cream on her I'll try to find something else that does not contain titanium dioxide. The problem is that you actually can't find a sun lotion without it because it works so well. But…but that would an issue you know if you really have a product which is so close contact with all your body and when you know that the particles of this size are able to penetrate through the skin and blah blah blah blah blah, so there is some issues. But exactly with the coatings we are working on, the coatings are applied on a surface and once they are applied on a surface they actually material ogomerlerate, I'm not sure how you call it when it's it becomes bigger…

LC It aggragates?

RF That's right. It goes from nano-sized to micro-sized. That means when you look at the coating on the microscope afterwards, you will not actually be able to see any nano-sized material; you will have a coating with a specific thickness which is actually part of a material. And people are talking about nanoparticles jumping out of the coating or going out, you know, all this stuff, but it's not possible because there aren't nanoaprticles in the coating anymore. So I would say on one way there some areas or issues where nanotechnology is supposed to be…you have to think about where you are using it, but there are alos some other areas where it is completely, I won't say safe because if someone drinks this it's not good if someone takes a glass of petrol it's not good I mean, but there are some areas where it's quite well examined or something like that.

DC How about the environmental concerns? I mean when this coating washes away it's basically just seeping into the ground.

RF That's right because coating is a part of a material the problem is that when you have these nano-socks, you know you've heard about, where you put nano-irons into the socks, that's a problem because this actually a particle sized material which is impregnated into the sock and when you wash it you will actually wash out these nanoparticles and that could be a

problem. I mean, nano-sized silver is well known for its antibacterial properties and it's quite bad as a material. In nano-size they will be washed out into the environment and blah blah blah. But actually these products that the coating becomes part of the material of a glass; that means when you wear off the coating you actually wear off the glass and the parts which fall off will actually be big parts in of course in microscopic imagine, but big parts of a glass which don't have anything to do with nanotechnology, if you know what I mean.

DC So would they, even these small parts, do you think they're chemically inert?

RF It's glass. It's the same thing if you take sandpaper and rub it on a glass like this. It will, of course you will make some damage on the glass and some dust or some parts will fall off, but this is inorganic material where I mean there aren't any active parts there are not any parts which will react with something else further on. But yes, so like I said with nano-socks there are some materials which actually are problematic. I mean, you have some materials where the nano-sized material will be washed off or will be transformed into the water or I don't know what and can react; but on the other side, I mean, the amount of these materials is so low this stage and people are aware of it because example of nano-socks I'm talking about I've heard about US some investigation where they actually found out this can be a problem. So as soon, there are problems that I think the government will interrupt and try to find out what to do with these products. So it's very hard to talk about all nanotechnologies; I can only talk about our TCNano technology and products we are working with. Fairly thoroughly I can tell you something about other technology because I know something about it, but I can't actually, you know…

LC I notice that you have a lot of liquid based, so what happens, hypothetically, if I were to spill it on my hand? It would still be nanoparticles in liquid.

RF They'll actually react with the OH groups in the material. That means if you have a material which is…

LC The hydroxyl groups.

RF Sorry?

LC The hydroxyl groups – we're both chemists

RF Ok. That means if you have material which does not, which is made for…normally you have sticky parts and then you, if you have a substrate you have sticky parts then you have parts that actually make the thickness of the coating and again you have oxy groups which makes the stuff hydrophobic or hydrophilic, whatever you want. And if these sticky groups are not designed for your hand, you will actually you won't achieve this self-organizing process on your hand because there are not any ignition, not any reason to start up and actually it will…nothing will happen. If you take a size problem meaning that particles or nanomaterials can penetrate through the skin it's well known that skin is made of three different layers, and I have seen different investigation where they find out there's no way they can go through all three skin layers. So I think the problem would be again if you take a bottle and drink it. I mean, there are some different stuff and you will be sick but you know, your hands, there are not any investigations that actually say that it can be a problem. I think

that the best example with hands is titanium dioxide in the skin, and even then there are not any results. I don't know if you know about something else but actually this sun lotion is sold in the whole Europe and even though there are so many investigations on this subject, they didn't I mean come up here…

LC So do you believe…we have three statements here and I was wondering with which one you agree the most. They're all about benefits and risks. Do you believe the benefits outweigh the risks or they're equal or the other way around?

RF I mean I can just talk about these products because the reason why we are going these safe this safe way is that we are very aware of that there can be some risks. I mean, it's 100% that there can be some risks, but we are trying to use our common sense and knowledge about these products and picking up these products and the way how you…

LC Applications?

RF Applications, yeah, in order to go a safe way. So of couse there are some risks; of course if you I mean, if you don't think about how you sell these products, how do you…and all this stuff. Of course it will be some risks. That's why it's very hard to say on I mean for all the companies if there are more benefits than negative sides because we're also talking about I can't talk about nanotechnology because it's a huge area. I can talk about surface protection with the nanotechnology which is actually a small area and precisely this small area I can say the benefits are probably much bigger than the risks.

LC Ok, so where do you see nanotechnology – if you'd like, you can specifically down to your products – what do you think it will be like in the future? How do you think it will affect society?

RF I mean, what do you think? It's guessing. Like you know nanotechnology's not so new as they're trying to make it sound; we are just able or we are aware of that we are working with nanotechnology. You have some ancient farms that actually shows they are working with nanotechnology and they've been working ever since. If you are talking about functional coating, I think they will become much better with the time – that's just common sense. I think that you have a glass coating which will actually work at 10 or 20 km/h when you will have pearl effect just right immediately that will help the driver immediately. I hope that wind screen will eventually be just dropped because the coating will work so perfect that there not any needs for a wind screen. I hope that lock hair protection will be so efficient that you can't do any scratches on it and stuff. That's nothing, that's just…I've seen a little bit about it and I'm quite convinced that with the time it will be possible, but right now, right now where we are at this stage it's still just future plans.

DC I just want to go back, besides the nanosocks we were talking about before, are there any other particular nano-products or things that are developing that you think people should be concerned about?

RF You've seen Siemens made a washing machine you heard about…

LC Yeah, with the silver

RF Yeah, but they stopped actually production, that's one good example. Yeah there are a couple that we just discussed about it for some time. I think that antibacterial properties, no matter if they're in nanosocks or somewhere else, there are some problems with it because you actually bad side of it that make potential resistant bacteria where the bad guys aren't responding to the common...because they mutate and you can't actually kill them anymore. That's the biggest issue. It's good with the antibacterial properties but the problem is that if you keep killing them with the same materials eventually they'll mutate and then you'll have a problem. Sort of aerosols generally are bad with the nano-sized materials, but not always. I mean, if you make…you've probably heard of the case in Germany and that's really stupid strategy. They made a product for a small bathroom when you come in and go like this…the same will happen with hairspray if you just kept on doing it. There's some other materials which nanotubes, carbon nanotubes are not so good all the time. I mean, nanotubes are actually a material which is hard to destroy and if you have a tennis racket or something like that, eventually when it's got…nanotubes are able to go back to its original form. That means you can't actually destroy it. Or if you try to destroy it you could actually destroy it down to the particle size which can be problems. Nanotubes in some other I'm not sure in the computer and stuff like that they using already for as the switchers and stuff like that. I mean there's a very small size amount of it so I'm not sure if there's any concern about it, but of course there are materials I mean which we have to you have to watch out for.

DC So it seems like most of the current concern should really just be about nanoparticles and where they are or where they might end up and not so much nanotechnology or nanomaterials.

RF I would go a step farther back. I'm not saying that you should pick up the nanoparticles, I would say that you should find materials which are maybe sometimes based on nanoparticles which at this stage as a raw material can have some concerns for instance nanotubes. It's well known that they can develop cancer and stuff like that. When you know that in the early beginning so there is some you have to be concerned about it. But if you have a material like, I don't know, cesium dioxide or to a certain extent titanium dioxide these are well known materials also in nano-size, and of course it depends on where and how you are using them. As long as you're using them with the you know normal – well I wouldn't say normal – but if you're thinking about how you're using them, I can't see any concerns because these materials have been used for so many years and they didn't have any problems. I think that you have to, like everything else, it's a chemistry like you know, sometimes you need to say ok this is something about it, let's investigate it a little bit more; but in some other cases it's like I mean it's nothing to do about it because it's well known – probably is a well known, everything is more or less well known. But of course there are materials, and new materials will arrive because you have synthetically made materials which are we don't know anything about, but these materials are normally they're not sold, you can't buy them like we can buy all the stuff for these products. Really it's a regulatory level and users of these products are really limited. It's hard to speak for all the companies because I can't say that some other companies are not thinking in the same way and just like they don't know what they're dealing with and of course someone can get hurt but it's a chemistry. No matter what you do, someone can always get hurt. I mean it's like…

LC It's like any other chemical.

RF It's like any other chemicals. Of course there are some issues about the technology and we just discussed about it, but there always are. And of course we need to have someone watch all the products all the time, and we do have somebody. We have, I don't know, different government organizations and stuff who are really you know trying to investigate all the time if there's something. And now we have REACH who is going to, I think that REACH is really going to clarify everything because just suddenly you need to specify all the components, not just dangerous components. And when I say dangerous, I mean dangerous according to someone. Suddenly you have to specify, you know, all the components and you have to prove that they are not dangerous in the way that they are going to be used in, and if this going to be…when it's going to be incorporated in some years, that will help a lot. I mean, so suddenly you will have a list of the components, they way they're used and the possible…the way people are using these products are. So you will have the cycle from the beginning to the end, and I think that's going to help a lot because right now we are doing like this. Because if you're not allowed to…if you don't need to specify all the chemicals why should you?

DC Do you have any other general questions?

LC No, I'm good.

DC Ok, well we just have four more questions on kind of regulation based stuff, so are you at all familiar with how nanotechnology or chemicals in general are regulated in the EU?

RF Yeah.

DC All right, so in your opinion, is the current policy…is it good enough to protect the Danish public from nanotechnology?

RF No.

DC No?

RF But REACH will.

DC All right, I'm not fully…I don't know everything that REACH is going to put into place to help refine chemical regulation, so do you have any suggestions or things that you would change or things that you know REACH is changing to make things better?

RF Exactly what I told you before. Right now the only components you are…you should come up as dangerous components in these products are only dangerous components according to the legislation. When REACH is going to be fully integrated, you will actually…you need to expose or list all the components – not just the dangerous ones. And not even that, when you listed all the components, you need to prove that the components are not dangerous compared to the way they are going to be used. So today you have only according to someone for 10 or 15 years we said these are dangerous, that's the one you need to list in these components. We actually don't have any legislation for nanomaterials at all, but just suddenly you're going to list all of the components and that's not enough, you need to prove, not someone else but you like company needs to prove that the components that you're

using in these products are not dangerous concerning the way they want to be used. So I think that it will clarify everything just suddenly.

DC Do you think there maybe should be any regulation or policy that is directed specifically towards nanomaterials?

RF I think that the REACH is going to cover it.

DC So you think just general chemical legislation will be fine for regulating nanomaterials?

RF But this is not general, it also for regulating nanomaterials because you have to tell the government or REACH every single component. That means if you have titanium dioxide you have to tell the Danish side that in nano-size, this and this. And then they ask ok, you have titanium dioxide in particle size of I don't 20 or 50nm are there any issues about using titanium dioxide 50nm particle size concerning the use. So you'll actually have nanotechnology covered by the one legislation. It's a long way I think that the companies are going to have a hard time telling if it's dangerous or not but that's the right way to start, so eventually it will work.

DC Ok, we just have one final thing. I think we kind of got the gist of it from what we've been discussing, but we're trying to divide each of our interviewees into one of three groups. It deals with a statement on how you feel nanotechnology should be best regulated. There are three statements which do you think best describes you? The first is that current regulation is fine. Second is that current regulation should just be updated and adjusted as necessary, and the third is that new nano-specific regulations need to be constructed in order to best handle nanotechnology.

LC And by current regulation, we include REACH.

RF Ok. I mean I think that you need to be more specific because I think that if REACH as a current regulation starts, I don't know it starts now in July but only in the first part of it, but in five years – five to ten years from now – the stuff I've seen and I've heard of I think that it will cover all the necessary stuff. So I would say that the current regulation is dealing with it pretty well.

DC Do you know where we could go to find out more about the new things that REACH is going to be doing for chemical regulation? I mean, I've read a little bit about REACH myself but I actually haven't heard a lot of the things you mentioned, and I think it would be really good background information that we could use.

RF We have a fact sheet about the major points. These were done in the Danish Institution for Trade and Distribution of Chemicals, these are the guys you're supposed to contact if you want some more information but it clearly shows how everything is going to be adopted. They have something called Pre-Registration now in July, and if you do that then you have I don't know three or four years where you have time to prepare your materials for the REACH and then it goes like that. I mean I've been through the different seven hours about REACH and it's complicated, it's huge; but it's I mean it'll cover everything. Everything is going to be exposed. They have they are going to make a council or whatever

in Finland where you are…it's not like you are going to inform the general public about the components, but all the components are going to be needs to be archived, said to council in Finland. And these guys are going through the papers and stuff and these guys are the ones who saying it's ok or you have a problem with these and these components and stuff like that. And you're going back in the chain from the…that means you're actually going through the solely producer of raw material so you are not all…today you are actually just watching at the papers sent by your supplier and say ok, this and this and this; but with the new legislation, you're going to the supplier's supplier and he's going to his supplier and you're going back to the very beginning of the product.

LC I have one more question if it's all right.

RF Yeah.

LC I notice here that these only apply to products or materials produced in greater quantities than 1 ton a year, but nanoparticles, their reactivity is based on surface area. So what if nanoparticles were produced less than 1 ton a year, would they be covered?

RF It will be covered in a way because if we are buying material, finished material that is more than 1 ton then you are going backward.

LC So then it still has to be registered?

RF No matter what.
LC Ok.

RF It's a huge machinery and…

LC Yeah, it sounds complicated.

RF And it's going to be that for a lot of companies. Like I said, some are not actually going to be able to live up to these regulations especially companies who are importing materials from outside of Europe. These guys don't have a chance if they're not big enough.

DC All right, I think that's it. So you don't think there's a problem with the production limits? I mean maybe it's a chemical that – or a material that – you don't really need…there's not a huge application for it, but there's just enough that you only need to produce a small amount of but not enough to have it reach 1 ton a year. Do you think that there's a problem there?

RF What do you think? I mean a ton, I mean it's nothing.

DC Yeah, it really isn't but if there are a lot of little things, you know one chemical here one material there. I mean, I get the feeling with nanotechnology I mean for these smaller application type materials that you know you're going to start needing less and less and less and less volume or mass for certain applications. And granted maybe one material doesn't mean anything but what if there are a thousand materials that you don't need to produce a ton a year for?

RF Maybe, that's the same question as you had. Maybe for instance, we have small bottle where the main content of the material is actually ethanol and it's up to 90% of it, 10% is nanomaterial if you may say so. I mean, even though nanomaterials you don't need a huge amount big amount, you still need something to apply to the surface. You can't just, you know, apply…you need a transport material if I may say so.

LC Solvent?

RF Solvent. Solvent triggers the reaction, and when solvent starts to evaporate you start actually the self-organizing process. Otherwise you need UV. You need something to trigger the chemical reaction. Water evaporates or I don't know. So no matter…even though nanomaterials, the amounts are really small they need to be a part of something bigger in order to in these products in order to get them to work. And as soon as they are part of the something bigger, they need to go through this. So they are not going to watch as a single material but they are going to watch at the product like this where you have the 100mL and a ton of this is not really a lot. I mean it is nothing. Then you start here and go to the single producers – the guys who are mixing this – and then you are going to guys who are delivering raw products to guys who are mixing and the guys who are also buying for someone else, so you are actually going back to the same, to the very beginning of the raw material. Then you need to verify it.

LC So as long as the end product needs to be regulated, everything down the line is regulated?

RF Yes.

LC Ok.

RF In a way, I mean, no one knows how this is going to work or is it going to work out. But in theory, it covers really well almost all the aspects. I'm not so into to say what aspects can be problems but we need to start…it's a right step you know. It's a…you can't regulate this like *snap* today we're going to regulate this. This is a huge machinery and if it's going to go like they say it's going to go that is going to be fine. Maybe it won't cover 100% but it for sure will cover a lot of it – much more than today. Today we are not actually covering anything. I mean you have some issues with bar size with this and that but nanomaterials are actually not covered with any in legislation.

DC I think that's it. Thank you very much for your time. It was a great interview.

Appendix D.7 –

Interview with Steffen Foss Hansen
Tuesday, 15 April 2008

Interviewers
Linxiao Chen
Dan Carney

DC So just to begin with the formalities, if you want to skip any questions you don't want to answer, that's fine or you can end the interview at any time. And for this we need to know your occupation and your background but if you don't want to give use your name for the record that's fine.

SFH I'm fine with that; my name is Steffen Foss Hansen. Background, I'm trained in environmental planning which is kind of a combination of regulatory issues with environmental sciences but more directed towards policy than just hardcore environmental sciences. I started studying the field of risk assessment of nanotechnology two and a half years ago. Just basically trying to figure out where is the gaps of knowledge in current risk assessment frameworks and regulatory systems. That's basically what I've been doing so far. I guess that's basically my background.

LC So why did you choose nanotechnology?

SFH Because it was one of these emerging technologies that everybody seemed to be talking about and more and more attention was being drawn towards its great benefits whereas there was also some indicators that there might be some potential problems. And I saw it as a unique opportunity to kind of use everything I've learned proactively to a technology and not always be reactive. So I was kind of hoping, by contributing to a safe development or sustainable development of technology, for once. We always seem to be reactive and I saw this as an opportunity to be proactive for once. And that's why.

LC So what do you mean by sustainable development?

SFH That's a tricky question; I know there's a lot of definitions of it. For me it means fulfilling the needs of the current and future generations without compromising the environment and the possibility for future generations to fulfil their needs. And then you're going to ask me, "what do I mean by needs?" and I mean like the basic needs with housing, and food, and safety and opportunity to do with your life what you want to with it without compromising other people's opportunity to do with their lives what they want to do. That's a short definition for me.

LC So you mentioned that nanotechnology might have great benefits. What kind of benefits were you thinking of?

SFH Economical benefits that people talk about, economic growth, jobs, but also environmental benefits such as help remediation, water purification purposes. You could develop sensors to detect environmental pollutants, such kind of benefits. And also food security. There's a

lot of talk about helping food storage facilities, those kinds of benefits. Material benefits, better, stronger, lighter materials. Using less resources to develop the materials.

LC Do you see any consumer benefits?

SFH In the long term I see consumer benefits from having stronger, lighter, better materials but right now I don't see many consumer benefits from the products that are being sold on the market maybe except for sunscreens, that the sunscreens seem to be more effective if you put nano-titanium into the lotion compared to if it was micro-sized or if people don't use sunscreen because they don't want to be completely white when they use sun lotion. I see that's the only real benefits. Do you know the Woodrow Wilson Inventory for consumer products? If you look that inventory with 600 products, none of them strike me as being like really something we couldn't live without. I'm not so sure the consumers have the benefits as of yet.

LC So obviously you're working in risk assessment. So what do you see as potential risks?

SFH My biggest concern right now is for worker health and safety. That they're being exposed through handling of nanomaterials that penetrate farther into the lung than normal particles. Also the mechanism that we have for ejecting these particles again with the lung fluid, that they are not capable of dealing with the particles that have the shape or the size that nanoparticles have or some nanoparticles have. So I see that as a potential problem. And also, I'm not – one thing is that there might be a problem, the other thing is that we're using something where we don't know whether there's a problem, which I kind of think is a problem in itself. With us not knowing and production volumes going haywire is problematic. I think because we've seen what happen with chemicals in the past and it took a long time to figure out what the risks of chemicals were and I think that we should not make the same mistakes this time.

LC So what about environmental risks?

SFH Environmental risks might be a lot of long term. What I'm concerned about is that it might affect the algae and the daphnia, the animals or organisms that Anders is studying a lot. It affects their behaviour patterns; it might affect the organisms that live higher up the food chain. I think that's what I'm concerned about with environmental aspects.

LC But it's too early to tell?

SFH It's definitely too early to tell. If you want hardcore evidence of harm being done, it's going to take a long while before we have that because we can't even detect them in the environment so how are you going to know if you see some adverse effects in the environment, how are you going to know what caused it? And also there's such a long latency period with nanotechnology. With causality in many cases, it's almost impossible to establish scientifically.

LC So how concerned are you about these risks?

SFH On a scale of one to five, I would say, high being the highest, or the most concerned, for the environment I'm around three or four and with human health I'm probably about two to three.

LC So you're not too concerned about human health?

SFH I'm more concerned about human health.

LC So lower is more concerned?

SFH Yep. Yep. Because humans are exposed now and the environment is less exposed. But it's really hard to tell, because as you probably know, there's so limited number of studies on the environment so getting this number is more based on ignorance than on the knowledge that you get from reading the studies that have been done. When it comes to it, it doesn't really matter how concerned I am; it's the not knowing that really makes me concerned.

LC And do you think that's where a lot of the concern from the public is? It's because they don't know. Well it might be where a lot of the concern might arise.

SFH Yeah I think so but also the public is concerned because somebody else is gaining the benefits and it's them taking a risk, which in my perception, the public finds that problematic in general. You're adding something to a product that might be a risk to the consumer and you're the one benefiting from that. That seems… that doesn't seem right. That's my perception. It's a tricky thing, the term the public is a tricky thing because who's the public which members of the public.

LC Does your concern – I'm thinking it's not nanotechnology as a whole. You can split nanomaterials into your films and your free particles; are you more concerned with one over the other?

SFH Of course I'm more concerned about the particles. Like if you look at nanomaterials there's materials that involve materials that are structured with nanomaterials and you have the film and the coatings. I'm not so concerned about those. I'm more concerned about the ones with the particles and the free particles and the ones that are in liquids because that's also where the consumers are being exposed at the moment. And then I think that the fact that everybody is concerned about the particles or the free nanoparticles almost makes me a little bit concerned that we might be ignoring potential problems with the other kinds of nanomaterials. But that's that. Most concerned about the particles but I think we should also make sure that the films and the coatings actually stick to the materials and that they don't degrade from the materials and become free particles. But you're definitely right. I'm not out to… nanotechnology is like the whole issue of material science can have a lot of benefits and I'm not sure that just focusing on the nanoparticles… like the concern about the nanoparticles should not brought into the concern about nanotechnology as a whole.

LC So are you more optimistic than concerned about nanotechnology and where it's headed or are you about equal or the other way around?

SFH I'm very optimistic about where nanotechnology is heading but I'm very pessimistic about how we're going to risk assess it, regulate it. But also some of it is – I don't think we have the tools to do risk assessment. I think they're really inadequate at the moment and also from a policy perspective I'm just not seeing the initiative being taken that needs to be taken in order to ensure we're able to do risk assessment, to do regulation. There are obvious gaps in the current regulation and nobody's addressing them. And I think that's really… I think that makes me very pessimistic. Also we've been discussing it for ten years now. I haven't been discussing it but if you look through the literature, people have been raising the red flag ten years ago and we still have not done what needs to be done and I find that very discouraging, I must admit. But if you take a nano-science class and you hear what they're able to do and what they're trying to do with medicine, I find that very, very – I'm very optimistic. I think that's really great and I'm really fascinated by it.

DC Well on that note I guess we'll talk more about regulation. It seems that you know quite a bit about it. Our first question is usually do you feel that the current regulatory system is sufficient to protect the public from nanotechnology? And I would assume the answer's probably no to that.

SFH Yeah. Without knowing whether nanotechnology is a problem or not, I would say there's just nothing in the Danish regulation that requires you to make the distinction between nanotechnology or nanomaterials, nanoparticles and the bulk form of the substances so I don't think its adequate to protect the public.

DC Are there any other… you spoke about a number of regulatory gaps. Could you talk about a few of them that most concern you?

SFH In the European union, everything is regulated, their requirement to do testing on substances is depending on the tonnage – how much is being produced. There's no distinction between the nanoparticles and the bulk form and if you produce… okay let me rephrase that. First of all, there's no clear definition of nanoparticles. There's no distinction being made in the regulation between the bulk form and nanoparticles or the nano form of the substance, which is a problem because that means that none of the regulatory requirements are being triggered for nanomaterials even though they're clearly different, nanomaterials and their bulk form. The second issue that is a problem is that the regulation or the testing requirements to ensure safety, that they're based on tonnage production volumes, which for many nanoparticles, they will never reach the tonnage requirements which is currently ten tonnage per year per producer in the EU which means that very, very few nano-products will actually be tested for safety and I think that's a huge problem as well. And the other problem is that there's not a distinction between the bulk and the nanoparticles made in the regulation that, at least in theory, you could supply information about the bulk form of the substance and get a nanoparticle – and sell and produce nanoparticles, which I think is problem as well.

DC So what kind of changes would you feel are necessary to the regulation to ensure the safety of nanotechnology?

SFH I think you should have a clear distinction between when something is registered in its bulk form and in its nano form. And then I think you should have additional requirements for

the nanomaterials that are being produced or registered in the regulation so that we know that it's the specific products of the nanoparticle that determine their properties. So I would say that you should add, to the best of your knowledge, you should add those properties to or you should send that with your registration to the authorities. So that means that for a bulk material you have to submit certain key properties such as boiling point and W values et cetera. And for nanomaterials, I think you should have to add surface area and surface charge and some of these unique properties that we know make them different from a health and safety perspective. I think that's one thing you can do to ensure that they are at least within the scope of the regulatory system.

DC So overall, as far as handling the nanotechnology regulation would you say you are more in favour of changing and tweaking the regulation over time or kind of starting to make more major changes pre-emptively now, before we even run into problems

SFH That's a good question. I think we need to, I would say like, adapt current regulation within two or three years and then use those two or three years to develop a new framework. I think that's the approach I would use. Because we make the distinction between nanoparticles and bulk right now in the scope of current regulation and then use the two or three years to develop new regulation. I think that's the approach that I would use. But developing a new regulatory framework is not going to be easy. Like, I'm not saying it's going to be easy, but in the ideal world I think that's what we should do

DC Now yesterday we spoke with a guy from TCnano and we were talking about the regulatory issues, and a lot of things he had to say about the REACH programme that is starting to come into effect – I don't think it's fully in effect yet. That the registration system is completely changing and I'm not exactly sure where he got his information from; I'm actually looking it up myself, but I guess you do have to make, or you're going to have to make distinctions between the bulk properties – like bulk materials and nanomaterials. There's still like the production limits and I think they might be going down to one tonne instead of ten tonnes. And suppose you make a nanoparticle, and at first it doesn't get regulated because you don't produce one tonne but then maybe the next stage down the line it goes into a solvent and it could be ten per cent, so you've multiplied your mass by ten, and as it goes down the line towards when you start putting it towards applications, the likelihood that this substance or this mixture containing a nanoparticle doesn't reach one tonne or even ten tonnes is so unlikely and it will get caught up in the regulatory system before it ever reaches a consumer or an application, or at least a widespread application. I'm not sure if you've heard of this.

SFH No, there's a difference between registration and regulation. The one tonne requirement is to register a product so if you produce a substance in more than one tonne per producer per year, you have to register it, but as far as I know there are no requirements to register what kind of size the particle has in the registration. It could be microns, it could be nano, it could be whatever. But for any requirements to come into effect, that's the ten tonne. So if you produce it in more than ten tonnes, suddenly there's some safety testing you have to do. So, there's some standard. You have to do some experiments on rats you have to do some experiments looking for dermal penetration you have do some experiments on various environmental organisms. And that's the real key knowledge that we need for nanomaterials just as we do for a lot of chemicals in general but that's the information that will be really

valuable for us with nanoparticles but that's never triggered because a lot of them are not going to be produced in more than ten tonnes per producer per year. So even though you're registered, even though they might be registered as nanoparticles we're not gaining anything by having the registration. We just know that somebody has registered it. See what I'm saying? Another argument that's in the articles is that – I don't see how it can be caught up in the regulatory system. You mean that somebody's going to notice?

DC Well it can't just pass through unregulated I suppose. You could potentially put a product on the market or maybe some mixture that you use as a spray or a coating that never went through any safety testing because there's only a very small amount of nanoparticles in it because it never reached the ten tonne threshold.

SFH Oh sure you can, sure you can. That's happening today. I forget the number, but I think it's 0.1 per cent. 0.1 per cent is the threshold limit for a chemical in the product before you have to register it or do any kind of testing. So if it's less than 0.1 per cent of total amount of the particles, then you don't have to do any kind of registration or safety testing. So it could, and it does. We did a study where we looked at the application of C_{60} in oil lubrications. You don't know what the threshold is but it's just very unlikely it's going to be higher than 0.1 per cent. So it is being used and it's not being caught by the system. I'm just saying that for nanoparticles, we can't just use the tonnage requirement. We just have to figure out something else. Just say, for a ten year period until we know, we're going to require all nanoparticles to go through safety testing in order to generate the literature to ensure that's it's safe because I think going forward knowing that we don't know is really problematic. And we're not doing anything to generate the knowledge that would enable us to make informed decisions.

LC Do you think that requirements like that would make companies apprehensive about producing or developing products using nanotechnology because it costs money? They have to spend money to test it, which they might not want to do.

SFH You're right but you could have a system where it's not as costly for them to do it. There's a number of arguments, but the first one is that they're already investing like a gazillion into this so having them to put out a few hundred thousand dollars to do some health and safety testing I don't think it would be much of a problem. Second, many of them are already doing it. Many of them don't want to hurt their workers or the environment and have done all of these safety and health testing for all their normal chemicals, so of course they're doing it as well for nanoparticles. And then finally you could have a system where regulatory body or consultants are helping companies doing this. I'm not saying, for instance, small and medium sized companies, of course they need help to do this and government funds or whatever should be set up so they could definitely do that. So I think some kind of collaboration and it's done in the past with various kinds of chemicals. For instance in the state of MA they have this TURI program I don't know if you've heard of that – Toxic Use Reduction Institute – where a collaboration between UMass Lowell – they collaborate with companies to reduce their use of chemicals. I think it's 250 specific chemicals and it's a university regulatory industry collaborating to find smarter ways to use the chemicals that they use. And I think over a ten-year period they reduced the use of these chemicals by 80% or so. I'm saying something like that could be a good model for collaboration.

DC Alright. I think that's it. Thank you very much.

SFH You're very welcome.

Appendix D.8 –

Interview with Alex Jensen
Wednesday, 16 April 2008

Interviewers
Dan Carney
Linxiao Chen

DC So just to begin with the formalities since we do this interview over and over again: at any point you want to skip a question because you don't feel like answering that's fine, or if you want to end the interview at any time you can also do that. For this interview we don't need to record your name for the record but we do need to know a little information about your occupation and background, so when we get to your name if you don't wish to provide that you can skip right past it. All right, shall we begin?

AJ Yeah, sure.

DC Can you please state your name and occupation for the record?

AJ My name is Alexander Jensen and I study nanotechnology at University of Copenhagen, and I'm in my third year which is the time when I should make the bachelor project if I followed the schedule, but I'm a little behind so probably not til next year. I'm 21 years old, and that's it I think. I work at the local super markets next to the study so I can pay the rent and stuff. I live in Malmö in Sweden, it's just across…

DC We were just there for the weekend.

AJ Ah yeah, it's a nice city I think. So I also have a girlfriend living in an apartment in Malmö Central, and just like the Danish walking street, there's a mall called Triangl just 50m from where I live – it's a nice place.

LC So could you talk about your background with nanotechnology a little?

AJ My studies, which courses I have followed?

LC Or like what you've learned or what you've been doing concerning nanotechnology.

AJ I've been studying DNA technology and I've just finished a course called nano-biology, and I'm in the bio-direction. I made a project last year about some missiles that can target cancer cells with some medication, and bind to these cancer cells with high precision with folic acid I think it's called.

LC Anything else?

AJ Just the basic courses: mechanics, fusion mechanics. And we made a project first year with some cells that could induce the titatnium dioxide to create energy from the sunlight. And well just basic chemistry courses – organic and inorganic chemistry. What else?

Electrodynamics and magnetic course, quantum mechanics; I can't remember anything else. Oh, cell mechanics about how the cell works, tension, stress and pressure and how it sustains its form; and some science theory and ethics. We had a project where we were supposed to out which ethics scientists researched in weapons, like Fritz Haver during first World War. He invented some poisonous gas or something.

LC The Haver process.

AJ Sorry?
LC The Haver process with the ammonia.

AJ And we had some subject where we discussed Kiran Warrick's work in creating syphonetics where instead of some chicken's arm it could control a mechanical hand through neural signals. That was pretty exciting I think. Well, that's pretty much what I've had.

LC So after taking these courses, what benefits do you think nanotechnology provides?

AJ I think it's a wide area where you can research in all aspects of these areas. I think it's…there's a lot of technology to gain to make some products that can help us.

LC Do you have any specific examples that you know of?

AJ Well like, Kiran Warrick's work, you can make a mechanical arm if people lost their arms or some other body parts you can replace them with something mechanical. Also they made this coating for glasses so that the water won't stay on them – just stay clean. I don't know anything else about it.

LC Ok, have you like studied the risks or possible risks?

AJ There are some risks with nanotechnology because I don't think it's like normal chemicals, they're much smaller particles and it could influence in some other ways. I think it's important that you conduct research on how these particles influence on human beings and chemicals and protein pathways and such things.

LC So there are these risks, but how concerned about it are you if we use nanoparticles in consumer products?

AJ Well if they're tested properly then there should be no worries about them, but if none of these tests are conducted then I think there's some concerns about it – some risks.

LC But how concerned are you about the dangers?

AJ About dangers? Well not so concerned.

LC Not so concerned?

AJ No. I think the people developing these products know what they're doing, so I'm not concerned at all.

LC Are there specific applications that you feel nanotechnology might be more beneficial than others?

AJ Computers. Everything in these computers, electronic devices, and microchips getting smaller and smaller and perhaps nanotechnology could provide a new way of making circuits way smaller than used by normal. Perhaps by using carbon nanotubes you can make some extremely small circuits, and these carbon nanotubes could also be used for adhering proteins on the outside and make some algorithmic properties that you could use. I read about some DNA computers that can make some travels pathway or something to determine a series of steps, and by being this right-length DNA segment, you know it's the right path. So we have many options. This DNA computing is not that good at just normal computational two plus two things like that but if you have many possibilities it's faster, or it could be if developed right.

LC So you talked about a lot of these developments, how far along are we with nanotechnology development?

AJ I don't think it's very far.

LC So we're still in the early stages?

AJ Yeah, still in the early stage, I think. But it's built a lot of microtechnology and I think there could be some new discoveries in the future.

LC One last question. Do you feel the benefits that nanotechnology may bring or already brings to society outweigh the risks, or the other way around, or perhaps they're equal? Or perhaps you don't even know because some of the risks and benefits are still unknown.

AJ I think many of the benefits and risks are still unknown, but I hope that the possibilities will outweigh the risks.

LC Ok.

DC I just wanted to go back. You mentioned that you think the scientists know what they're doing so we don't have to be too concerned about the risks, and it kind of reminds me of asbestos. Are you familiar?

AJ No, I don't think.

DC It was a chemical or compound they used in construction for fire protection, and it turned out to cause cancer. I mean with so many unknown properties of nanomaterials and nanoparticles, do you think that it's possible for something like asbestos to happen again?

AJ Yeah, it's possible, but if you think of all the products that have been made without these secondary risks, health risks, then it's one out of a million I think. So there will always be something that's cause cancer or is a risk, but I don't think it's everything.

DC All right.

AJ And I hope that they will develop some good procedures to ensure that this nanotechnology stays safe.

DC Ok, so we have a couple questions about regulation. The first question is do you think current regulations are sufficient to protect the Danish public from nanotechnology's possible risks?

AJ No, I don't think so. There needs to be some new laws and stuff made because it's a whole new field than just normal chemistry. I think the current ways to make new chemicals is wrong way and a company can use chemical and the public, European Union has to prove that it's dangerous. I think it's supposed to be the other way around. The company should have to prove that it's safe in all matters, and then they can use in the food and products they made.

DC What changes do you think, other than who needs to prove that it's safe, what other changes do you think should be made to the regulatory system?

AJ I actually don't know.

DC So there are a few different approaches that we've read about in literature that they say should be taken in addressing this regulatory issue. And the first point of view is that we don't really need to do anything, that nanotechnology will be managed fine by current regulation. The second is that we only need to make changes and minor tweaks to adjust the current regulation to fit in nanotechnology when we need it, and the third is that we need to start building a new framework of regulation for nanotechnology now instead of adjusting and reacting over the course of time. Of these three, which do you think you identify with?

AJ I identify with the last one.

DC The third one? A new framework?

AJ Yeah, exactly, a new framework to be built to adjust to this new sized particles.

LC All right, well I have one more question. Are you aware of the new REACH regulation?

AJ No.

LC Ok, never mind then.

DC We've heard a lot of…we've heard mixed reviews. I was actually reading about it this morning. It seems pretty good, the registration for chemicals of if you produce a ton of any chemical in a year you have to register it. I was just going through some of the criteria that you need. It seems a lot better than what there is now, but I've noticed that certain aspects that give nanoparticles their special properties like their surface area or surface charge. Which brings me to another question. I was actually going through another template for the registration process. What do you think are the certain properties of a nanoparticle or a nanomaterial that should be taken into account when you're registering it, such as surface area?

AJ Surface area, the ability to work as a catalyst

LC So reactivity?

AJ Yeah, activity.

DC I think, yeah, the chemical activity is in there. But more like physical properties so if we don't know what a use is yet, or there might be other uses we don't know about yet; physical properties that we might be able to look at and say 'oh hey, I noticed this, maybe we can use it for something else.' For example, for any chemical you have a boiling point, a density, a vapor pressure. Are there any physical properties that are specific to nanoparticles that ought to be taken into account besides surface area?

AJ Surface charge as you mentioned it yourself. The ability to penetrate materials, small particle size I think they can penetrate cells if you touch a wall coated in nanomaterials and can penetrate the skin or something that should be taken into account. I don't have any ideas

DC Yeah, surface area and surface charge were really the only two that I had heard about from other people, but probably also permeability properties is also pretty good. So those are things I'll be looking for, to see if you have to report those. But that's all I have.

LC That's all I have.

AJ Cool.

Appendix D.9 –

Interview with Lone Frank
Thursday, 17 April 2008

Interviewers
Dan Carney
Linxiao Chen
Kelley Murray

DC Ok, so for this interview we don't need to know your, so when we ask your name you can skip over that but we do need to know a little about your occupation and background for the record. Also, at anytime you can choose to skip a question or just end the interview at anytime. So shall we begin?

LF Sure.

DC All right could you please state your name and occupation for the record?

LF Right. My name is Lone Frank. I'm a journalist at a newspaper here in Denmark called *Weekend Avisen*.

DC How's that spelled?

LC Like that <points to paper on table>

DC Oh, 'weekend'

LF And you need educational background?

DC Sure.

LF All right, well I have a PhD in neurobiology from way back but now I'm a science writer and author; so that's pretty much it.

LC So what is your background in terms of nanotechnology?

LF Well, since…

LC Or experience.

LF Yeah, well since I went from doing research to writing about science I've had an interest in how science and technology impact society, so I've written two books about biotechnology. And of course nanotechnology is like the next wave with the same kind of problems that biotechnology had, so my interest in nanotechnology is, you know, the interest of a science writer basically, so I try to follow it. I haven't had my hands in nanotechnology as such but I try to follow it; and I've been to a couple of conferences about nanotechnology and regulation and stuff like that.

DC Have you written any articles about nanotechnology?

LF Yeah. I've written some way back actually, like 2 or 3 years ago maybe.

DC Is it possible to see those articles?

LF Yeah, they should be in InfoMedia.

DC InfoMedia?

LF Yeah, and they're all in *Weekend Avisen* so you just go in and look there.

LC Yeah, but they're all in Danish.

LF Yes.

DC Oh.

LC So are you aware if any of the benefits nanotechnology brings to mainly consumer products?

LF Well…

LC Or any benefits?

LF I mean I see nanotechnology as it has great potential in all sorts of areas because it's not one kind of technology, it's a technology that just deals with size really. I mean, it's everything in nano-size, so there are tons of possible benefits for consumers in the health area, for example, and cancer treatments are being developed, stuff like that. And then there are a lot of ways to use nanoparticles in coatings and you know food technology and all sorts of stuff, cleaning products. I mean makeup products are chalk full of nanotechnology at the moment. So yeah, I mean, there are all kinds of benefits really because all sorts of materials can be tailor-made by using nanotechnology.

LC So how enthusiastic are you about these benefits? Because we've heard from, through our other interviews, that some people aren't so excited about these benefits because they seem to be solving problems that we never had to begin with.

LF Well of course, there's no reason to use nanotechnology if you have another technology that's just as good or you know, but if it's about for example coatings of things; we didn't have any technologies that are as good as nano-coating. There are tons of materials in the electronic industry and stuff like that that we didn't really have good solutions for, so whenever it's a new solution to an old problem or a solution to a new problem I think one should be positive. But of course always look at the possible downsides. So are there any dangers to the environment or to health and all this stuff? And that's when the trouble comes in of course because there aren't that many possibilities of methods to actually evaluate safety of nano-products.

LC That actually leads into the next question, which is: are you aware of any of the risks?

LF Yeah. I mean, there are a lot of…again, it's potential risks that people talk about because we don't really know them. I mean a lot of people talk about nanoparticles as this new and dangerous thing that might impact, you know, health and environment, but they don't think about the fact that there are a lot of nano stuff out there already because it's just a matter of size. But of course, the problem is that if we start using new materials that we don't really know how they impact, for example, the immune system and we don't have any methods to evaluate what they do or how they penetrate tissue or whatever, it can be tricky. But of course there can be all sorts of impacts like asbestos. A lot of people compare nanoparticles and nanotechnology to asbestos as something we don't really know what it's going to do and suddenly we'll see this health impact. The trouble is actually, at the moment, we don't really know. And if you go to the conferences where it's about safety and it's about regulation, that's always the bottom line after all the talks, 'we don't really know yet.'

LC So do you feel comfortable knowing that there are products out there already that have incorporated nanoparticles or nanotechnology even though the scientists or the companies haven't really evaluated what risks might arise?

LF Well, I'm pretty comfortable in the way that there were always nanoparticles out there, we just didn't think of them as nanoparticles. So now it's like we have a new name and a new concept for something that was always there. I mean, paint and stuff like always had nanoparticles in it, we just didn't know it; but now we talk about it and so many people get scared because they think that there's this new thing in paint or other products. But I would say that I'm not uncomfortable at the moment, but I would like scientists to come up with good methods for evaluating entirely new material decompositions, for example, that we don't know what might do. So in that way, yeah, I'm comfortable but I would like to see some solutions to possible problems. And I would like to see, of course, nanoparticles and nanomaterials being evaluated in the future.

LC Do you have any specific concerns or I guess opinions towards any specific application of nanotechnology, maybe medicine versus sport equipment versus coatings?

LF Not really. I just see it as, you know, new materials, new possibilities of solving problems. I'm, you know, basically positive about it. I see it as a new, fundamental, really great technology that can be used in great ways if we choose to use it in right ways, and you know test the safety and all this stuff. So I'm not like there isn't any area where I would say 'oh, don't use it for that!' So I just see it as across the board an interesting technology.

LC So how far along do you think the technology is right now?

LF Well, I don't think it's very far actually.

LC So in the early stages?

LF Yeah, pretty much.

LC Ok. I guess I have one final question. Where do you see nanotechnology taking us in the future? I guess, how do you see it impacting society?

LF Well I do think there will be a lot of benefits to the health area in new ways to treat diseases and new ways to diagnose diseases. I see material science taking off. I think the electronics industry will have a lot of benefit. If you think about nano-robots and all that stuff, I don't really know. It's sort of a Drexel fantasy, and I'm not really where that will go. But material science I see as sort of the first big area that we'll see take off – a lot of new really interesting materials. And the health area as well.

LC Well currently nanotechnology has been likened to GMOs in the way that it's progressing and like how scientists and companies are obfuscating the risks or the fact that they're using it – like what happened with GMOs. Do you think that the public will be…the public will be less inclined to accept nanotechnology…

LF Because of the GMO scandal?

LC Yes, and their lack of trust in the companies.

LF Well, I think that maybe people will have the GMO debates in the back of their minds but I'm sure that companies and scientists and ethicists are all over the problem because they remember GMO, so it's been very proactive. I mean scientists have been out there talking about how we need to start a debate for years, and people aren't really that interested because they don't see it anywhere, they don't really…. For most people, nanotechnology is just you know 'what is it? It sounds fascinating.' And it doesn't have the same ring to it, is my impression, as GMO had. I think that it will never develop into the same kind of debackle as GMO because there is this proactivity from companies and scientists and ethicists and also because it impacts so many areas and it's not really the same thing all over the place – yeah, it's just a matter of size. And if people can see a lot of benefits in their products, in their consumer products, which they couldn't with GMO, then that will make a difference I think.

DC So aside from these general questions about nanotechnology, we usually ask people a little bit about regulation. Are you at all familiar with chemical regulation or with the REACH Program?

LF A little bit. Not that I can go into details with it, but as far as I remember it's an EU program that covers chemicals and I think they just want to put nanotechnology in there with chemicals, as far as I know for regulation.

DC I mean they haven't been making any nano-specific regulations – that's one of the later questions. But do you think that the current regulatory framework is good enough to manage nanotechnology – keep the Danish public safe from the possible risks?

LF I think that it probably is, but what' s lacking is, again, the methods for evaluating possible damages. So it's not the regulation, it's really the scientific methods that are lacking.

DC So can you think of any changes that they ought to make to the regulation to better manage nanotechnology?

LF Not really no. I really don't think that regulation is the issue. It's about coming up with good methods to actually perform the evaluations to conform to the regulations.

DC Ok, and now just one final question because we're trying to divide all our interviewees up into three categories. Looking at the literature, there are basically three opinions on how regulation should be changed to manage nanotechnology. The first opinion is that we don't need to do anything, the regulation is fine. The second opinion is that we may need to make changes but we should make them over time as we see the risks come up and just make adjustments and tweaks to the regulation. The third is that we need to make more major changes now, changes in the regulatory framework and maybe add divisions or whatever and even nano-specific regulations. Of these three points of view, which do you think you best identify with?

LF I would definitely say that it's an area where the regulation should just evolve with what we know about the technology and the science. I don't think there's any reason to go out there and make a lot of new regulation now, but if issues come up in research and what scientists come out and say we should look at it again, so the middle category.

DC The second one?

LF Yeah.

DC Ok, then I think that's it.

KM Well I have a question, sorry. When we were doing the background research before we got here, there were some studies saying that Europeans are generally more pessimistic about technology. Do you find that to be true? Based on…because I know that you write for a paper and there was a study that said most European papers talk about risks.

LF You mean compared to Americans?

KM Yes.

LF I would definitely say so, definitely. But interestingly enough, there was a study done by EurBarometre not too long ago about nanotechnology, and people were surprisingly satisfied with leaving it to the scientists and technologists. I think it was 3 out of 4 who said 'let the scientists decide what we do with this,' and that was definitely not the case with GMO. So I think nanotechnology has a much more positive ring to it for people. But in general I would say that Europeans are a lot more sceptical.

KM Ok.

DC I think that will be it. Thank you for your time.

Appendix D.10 –

Interview with Ulla Hansen Telcs
Thursday, 17 April, 2008

Interviewers
Dan Carney
Linxiao Chen

DC All right, just to start with the formalities, for this interview we don't need to record your name for the record, but we do need to know a little bit about your background and your occupation. So when we get to your name, if you feel like skipping that's fine, we can just move right along. Also, if you want to skip any question throughout the interview or just end the interview at anytime that's also fine. So shall we begin?

UT Yes.

DC Ok, could you just please state your name and occupation for the record?

UT Yeah, fine. My name is Ulla Hansen Telcs, and my last name is spelled T-E-L-C-S, and you've got my card so you can see it there. And I have nothing against that it is published.

DC Ok.

UT As a background, I am educated as a chemical engineer at the Danish Technical University a long time ago, and I have worked with…In the beginning I worked with the authorities, the Food Stuffs Agency, and also I worked in Brussels with the EU legislation for some time. And then I have worked here in the Danish Industries, in the beginning with food stuffs also – with food stuffs legislation – and then with environmental questions as the head of the section of environment; then I worked for three years with the Branch Association we had at that time dealing with packaging and then I went back to work with environmental questions and mostly chemical questions and now I am…half of my time I'm working with environmental questions that mostly chemicals and also nanotechnology and the other half of my time I'm the manager or leader of one of our Branch Associations dealing with the processing industry, which is the nearest we come to chemical industry we come in Denmark. We have not very much chemical industry but those that are dealing with these things are gathered in the process industries which in turn…the attaché in the process industry is a member of Danish Industries, that's kind of complicated. That's a long story about my background.

DC So what exactly does Danish Industries do?

UT We do business policy. And for my turn it's environmental policy, and we do service for our members. And we are one of the leading business organizations in Denmark, and for the time being we have 7000 members, mostly industry but also service companies. For example, Tivoli is a member of Danish Industries. All those member companies are divided into several configurations and several branches, and we try to service on giving advice in some cases and doing service for them. That is to say, for instance, information about

legislation and things like that. And then with business policy, we try to influence the legislation and we speak with the politicians, authorities, media.

DC So you speak on behalf of the industries?

UT Yeah. We try to gather what they have and speak on behalf of them. And we also try think in advance, for instance, to influence the companies to do the right thing at the right moment.

LC Could you please elaborate on your experiences or background concerning nanotechnology? Like what do you do that's connected with it?

UT Yes. I would say that I'm not very experienced with nanotechnology but since it's one of the, you could say, emerging technologies and it's very much connected with chemical substances and chemicals, it's very natural that it was me to take care of that subject. And what I've done is to follow what's going with the legislation with the action plans of nanotechnology in the EU and the OCD and in Denmark. And, also, I was one the persons to plan…last year we had a one day conference on nanotechnology, the threats and the possibilities. And also I would say that in this house it's not only me dealing with nanotechnology; we have another section for research and education. There's a person there also dealing with nanotechnology. We have a branch association for food stuffs, for example, they also have some interest in nanotechnology. We have another one for IT technology there's also there an interest. So we are trying to have a cross Danish Industry group. It's not yet working but we're setting it up, and we are also just in the phase, you could say, of trying to make an action plan for what should we really do about nanotechnology. But I think the most of our…what we could do, for instance, to inform about nanotechnology, we could gather some people from our member companies that have a special interest in nanotechnology and make a group of them but we have not yet done that. So I would say that I'm not very much…I'm not a scientific specialist in nanotechnology, but I'm following it and following what's going on.

LC So, you said you held a conference where you discussed threats and possibilities?

UT Yes.

LC So what do you see as possibilities for this technology?

UT Yes, at the conference we also made book on nanotechnology – in Danish, sorry – telling about…But what I see and that's what I can gather from different reports that there are several possibilities in nanotechnology, for example, to save energy. We have one of our member companies, they make catalysts and they might also be dealing with one kind of nanotechnology. Also in medical equipment you will have possibilities. You will have the possibility to make new materials where you use less resources, so that's also a kind of environmental benefit you have there. But there was also the aim of our conference was to show that you have possibilities but there are also threats and you will have to balance the threats so that you could be able to use the possibilities. And one thing is to really find out how can we measure the threats, and how do we have the necessary methods to do that? But also to avoid what we had in the gene technology where we had the public perception of fear. And I mean, in my view that would be a bad thing because I really think that there's a

quite a whole range of possibilities with nanotechnology; and one thing more I would say is for me nanotechnology is not just one technology, it's a pallet of technologies and also you would not say centimetre technology.

LC There's a lot of applications.

UT Yes, and different tools.

LC So, I guess, what were the threats that were discussed, or that you feel that we should be concerned about?

UT Yes, that's a thing that we have to do with so small particles that we cannot use methods that we normally use to measure effects on human beings, on the environment and we need to have those methods to be sure that we're not doing the wrong thing. And one thing, I think that if we compare this new…these new technologies with former experience with new technologies, I think that we kind of we're not lagging behind that we have done in earlier times where we have done something and afterwards it is shown that we did it wrong. Now we are trying at least to be cautious. But the problem is that it is very difficult to get those methods and validated and it takes long time, and there's a pressure from the technology to be used.

LC So you mentioned the backlash that came with GMO, how do you feel…I guess what caused the fear in the public and how can you, the organisation, prevent that when talking about nanotechnology and introducing it?

UT I don't know if we can prevent it, but we can try. And I mean, the try should be to be kind of open and not say it could not be dangerous because I think that it could be dangerous, but try also to explain and to exemplify the benefits. I also think that there are two kinds of applications. There's one with all those consumer products that are sold under the 'nano,' and some of them are not even nano things, and the consumers might be afraid of them. And the other thing is the more, I would not say the business-like, but the things in the processes that could solve some of the environmental problems, but those applications of the technology are not…the consumer will not meet them so much as the other ones.

LC So like, how and why did the fear come about with GMOs, and how will…?

UT Yes, I think the fear with GMO was because firstly because GMO is something about life and you get God involved.

LC So you're playing God.

UT Yeah, and things like that. And then also because I think that industry did the mistake to be to closed about GMOs. We discussed it at that time. I dealt with the food stuffs and we discussed it with some of our member companies, I said 'be courageous. Tell them you would like to use GMOs and tell them about it,' but they wouldn't do it because they would not have their products connected with GMOs. And I think that was kind of that to withhold and not be free about it that made some of the fears of GMOs. And also because

GMOs were very much about food stuffs and food stuffs are very…people are very concerned about what they eat.

LC But with nanotechnology there also might be possible food applications.

UT Yeah, but there are also other technologies. For instance, there are with IT things and I think young people there, they don't care.

LC As you said, some of the companies in this confederation wanted to use GMOs. Are there any companies right now that are actually producing products using nanotechnology?

UT With nanotechnology, not consumer products. But I think, for instance, in these companies making catalysts they are. But there's also a report about the use of nanotechnology in Danish companies. You haven't seen that report? It's in English, so I can send you a link to that.

All That would be great.

UT But then you can have you know, were you aware that nanotechnology is used in Danish companies. Because there was a survey on consumer products with nanotechnology and they found 243 or something like that products, but I think most of those perhaps 241 were imported, they were not produced in Denmark. But the other report which is in English will help give you an idea of where is nanotechnology used in Danish companies.

LC So when you look at the possible benefits and possibilities nanotechnology may have and then you look at the risks, how, if you were to weigh them…do you think that the benefits – I know there's many applications and each application may have its own value – but do you feel that the benefits outweigh the risks, the other way around or is it just too early to tell?

UT I think that we'll have to find out what are the risks and then find ways to control the risks and then we'll not have to weigh because everything will have control of the risks and then you can benefit from the benefits.

LC That's a good answer.

DC Are there any specific like applications that you are most concerned about as far as nanotechnology goes?

UT I'm not sure I'm so much of an expert, but what we know or what there's a lot of research of nanotechnology in the workers' atmosphere I would say. And there's some projects that we're involved in now. Our paint industry is doing a project on nanotechnology in the workers' health and safety type things – I can't remember the English word for it right now. And I think there this should seen into more because if you breathe things they are going much more into your body than bigger particles so there's a point there that should be looked into and that should be looked into how we can control it. On the consumer products and the contact with people, I think that the big problem is that it takes so long time to get the methods to find out to be sure that they are safe.

DC All right, so I guess we're going to take a look at regulation – some general questions. Do you think that the current regulatory framework is sufficient to ensure the safety of the Danish people from the possible threats of nanotechnology?

UT I'm not able to answer that question because…well take it the other way around. Since we do not have the methods to measure the risks finished yet, it's very difficult to make a legislation that covers the safety. And also I think since, with all the for instance the consumer products that we get they come from outside, you could not make a Danish legislation you should have an international legislation.

DC Right. Like with the REACH.

UT Yes, and also in the REACH the EU they're trying to find out 'do we have the necessary legislation and if not, what can we do, what shall we do?' Should it be…would REACH be enough or where should REACH be amended in order to take care of nanotechnology? And the same in Denmark, there's a cross ministerial working group looking at the legislation and they're trying to find out where are the gaps or what could be done and what do we have. So I think it is necessary to look through the legislation and find where are the gaps and there might be some gaps and then you'll have to make the necessary legislation to avoid having problems for the people. The problem is that the timing, I mean nanotechnology is coming but it takes time to get the necessary legislation.

DC Well, I mean, what about…I mean they have found some gaps already. Something as simple as production limits where you need 1 ton per manufacturer per year and you have to register your chemical, but you actually have to produce 10 tons per chemical per year to actually have to submit a safety report and actually might be subject to any type of regulation, so a lot of people are saying nanotechnology, the whole idea is things are getting smaller so you're going to be producing less and less. Do you think it's necessary to amend the production limit regulations?

UT It might be, but I don't know. I have no… we have no fixed opinion on that, but it might be if it shows that we'll have to. But if you look at the REACH for instance, in REACH if you use substances for research you don't have to register. So if nanotechnology is used in research, it's outside of REACH for the first. And also, another thing in REACH, there are some annexes where some substances are listed that are exempted from the requirements of REACH and there also nanotechnology comes in because some of the substances there is carbon and they don't want to exempt them from REACH because of nanotechnology. So that's one thing and also, there's a group now in the Commission and the member states trying to find out 'how could we get nanotechnology into REACH?'

DC So just to wrap things up I guess, we're trying to take all our interviewees and kind of divide them into three groups because there are generally three opinions that we've read in the literature about how to deal with regulation and make sure it suits nanotechnology. The first is that some people believe that the current regulation is fine, nanotechnology like any other technology will be managed by the current regulation. The second is that we should just make changes and adjustments over time and progressively as we see problems arising. And the third is that we need to develop a new framework and maybe even some nano-specific regulations preemptively, now. Of these three positions, which do you most identify with?

UT I think I am somewhere between two and three.

DC Two and three?

UT Yeah, it's between two and three because I think that we should see what comes up and try to manage, but also we should push forward a little so we get the necessary background for doing it. It's not just turning back and see if you get adverse effects but push to get those methods that we can measure the risk. So we'll then have a scientific base for the legislation. Can you understand what I say?

All Yes.

UT Ok, so that's somewhere between two and three.

LC That's where a lot of the people said we should be. Because actually we had one who said that they would love three but it doesn't sound like it's possible.

UT No.

LC Just to make it possible you have to change current, you can't make new.

DC I think we're done with the questioning, thank you.

UT Ok.

LC Unless you have anything else you'd like to say?

UT No, just that I'd like to send you the link to the report and the name of a person you can contact in the Agency (Environmental Agency) because I think that you should talk to them also since they are the legislators. That would be a great idea.

KM All right, well thank you.

LC Yes, thank you very much.

Appendix D.11 –

Interview with Steen Gade
Monday, 21 April, 2008

Interviewers
Linxiao Chen
Dan Carney

SG …Environmental Committee in the Parliament back in the 90s too where this position was more powerful because my party at the same time was supporting the Social Democrat and Social Liberal government and my party was the supporting party, but today we are the opposition with the Social Democrats and the Social Liberals. So I have a long experience in this job, and I have been in the environmental discussion since I became member for the first time in Parliament in 1981. And then for…I was out of Parliament in a period when I was Director General for the EPA here in Copenhagen, and then I have had two years where I'm free, writing a book and such things. But, yes, that was my background.

DC I guess we'll get into some more specific questions that we have.

LC All right, well my first question was actually, what is your background?

SG Ok, sorry…I have no technical or scientific background, but I have such a long experience in environmental policies and of course that means also that you need to, at least in some areas, you need to have a more deep knowledge but not as a study but as a knowledge.

LC Do you have any experience during your position at the EPA did the idea of nanotechnology ever come up?

SG Yes, we discussed it at that time. I was Director General from 1999 to 2003, and in that period, normal conception was that nanotechnology was not changing from the method, the way that we should look at regulation. It is…the problems linked to nanotechnology is that at the end of the day the same as problems related to other well known…they could in many ways politically, they said in relation to political regulations, they do not play a role – nanotechnology do not play a role – that is different than other technologies. So it should be perhaps something in the regulation should be strengthened or such thing but with the same way of looking at the issues. And I think that's what you have met in Denmark, the normal…the most common way of looking at it, but it's not the only one. That was how the people in, the experts in the agency were seeing the problem.

LC So you said that most of the problems associated with nanotechnology were the same as for any other chemical. Do you see any specific problems that might arise with nanotechnology?

SG Yes, but…at that time I was 'ok, they said that,' and I could not do anything, I could not argue. I still not very good arguing that perhaps there's a need to look at in another way, perhaps in a supplementary way. I'm not capable to come with the technical arguments, but my…that's not very scientific founded point of view but I look for arguments in relation to the way these nanoparticles relate to each other perhaps could be in another have another

dimension. And I have not read very systematic on the issue so I am not very familiar with if that point of view is a strong argument, but I know that some people in the scientific society are saying something in that direction. So we need to at least be much more focused on investigations and how to find out more about the influence because the risk in the first position, that's the mainstream position, that's almost the same. The risk here is that we perhaps are not examine the potential risks as much that we should. So I'm aware that we should have much more emphasis on studies on how it function and trying to develop some scientists that could perhaps foresee where there could be areas to be aware of. But my knowledge is not big, so it's more…it's in the beginning, a feeling, an understanding and a feeling, so and then I know that some of the scientists are having the same point of views, and a few of them are saying that it's…there's a lot of new dangers. So we have this very huge range of position on nanotechnology. I was eager if you could tell me how the situation is.

LC It's, I mean, there've been studies done, but it's still very inconclusive how it affects humans. Some studies show that it can go through the skin and travel through the body, but some studies show it can't. So right now it's still up in the air, and it's even vaguer when you're talking about environmental concerns because it's just too early to tell.

SG That's also what I have in my mind, but the problem of course is that we are not trying to foresee some of the problems and we'll discover them too late if there is real problems. There is another problem in the perception of nanotechnology, at least in Denmark, I don't know about how it is in the States. But in Denmark we have this, it's a buzz word; it's much easier here to have money for universities if it's for nanotechnology. And sometimes I hear from scientists now we are applying for money for this and that, and now we're calling it nanotechnology and before we didn't call it nanotechnology but it was the same thing. I don't know.

LC So are you aware of any of the benefits nanotechnology has specifically towards the consumer?

SG My knowledge is not very specific where there is big benefits, so I'm not very much aware of the benefits, no. To be sure, I'm not very much aware of it. Perhaps I'm not focused so much on that side because I've been…what I have done is try to focus it more on the risk side because we have an experience here – a good experience I think here – in relation to gene technology.

LC Gene therapy like GMOs?

SG No, not GMOs. Gene technology, it's a technology with the DNA.

LC So like genomics?

SG Yeah, I think so. Well, we had the first legislation in the world on regulation on using the technology with gene in industries producing enzymes. Is it called gene in English?

All Yes.

SG Ok, well we call it gene technology in Denmark.

DC Just genetic technology.

SG Do you use that in relation to health or in relation to industrial processes also?

KM Everything.

SG Everything? Ok. But we have the first legislation in the world on that, and my party actually were active then. And then it had inspired the EU legislation on that. But actually it has been a good experience because in the beginning, industry was very much against it, sceptical of course because they're afraid we're giving them no chances to do anything. But when we had the legislation, then it was much easier for companies in Denmark to use it. In the rest of the world, there sometimes there's a story in the media 'ok, there's this industrial processed…that has been using this technology and it's very dangerous.' That was not the case here. So when they were producing the enzymes, as they do…we have the two biggest companies on enzymes – _____ and _____ - I think they have half the world market together, and they say today the reason it was that they had this tough regulation because then they could continue. Ok, they say to us we used too much money for this regulation but that was very good seen from today because then they have not the problem afterwards because the public was…there was no problems where it was produced in the factories they were produced, no problems with environmental organizations no problem with consumer organizations, no fault in the media; so they were in better shape to handle the production and the sale and to be a success. So I have been looking at that side, is it necessary to have a special legislation? Today I'm not sure. I could foresee that we should have it, so today my position is that I think we should have it but I don't know how to create it; I have not the knowledge to find out. And then only the answer will be to use some of the…to strengthen the mechanisms that we use today in ordinary technology but the problem is that strengthened without having very specific areas where we are looking for is not so easy to know what's the benefit, so that's my personal opinion. Perhaps others are in a better shape than I am.

LC So do you see any problems that…you said that genetic technology, because of the regulations, it didn't face problems with the public, with environmental organizations, do you think that nanotechnology will face some of these problems or what problems do you think it will face in relation to the public?

SG If we after having used nanotechnology suddenly find out some problems then…it really that industry can have problems with it because perhaps the problems are not so big as they seem at that point, so of course it's better to have the regulation as much in forehand as it's possible. And it's a benefit for the consumers or the environment or health or what it can influence, but it's also better for the companies dealing with it to have it because that gives some security for them if they know that they are being followed, that critical persons and critical groups are following them and that there is a regulation that is up to date. That's my position but I think also that in many cases it's the Danish Industries' experience and sometimes a lot of industry in Europe are looking more in the direction of the American tradition, that's also if you compare the US system with the normal Europe systems in regulation then…perhaps we have not always stronger regulation but more secure seen from

the companies. If there is a regulation then there is a regulation. A court cannot change it or something. And it gives chances also to have a stronger regulation because companies in Europe say 'ok, let's make a deal; let's take it.' Some of them are not eager and some of them are more eager, but normally, we will have companies divided…in some of the companies in Europe aiming for strong regulation and of course some of them would not have strong regulation because it's easier or something, but at the end of the day the winners of all the companies will be the companies that want to have at least stronger regulation. You have seen that on chemicals if you followed the REACH chemical in Europe. It was weakened during the process. I was not happy with that because it was really a good proposal – it was the best seen in the world – from the beginning, and a lot of industries in especially France and Germany have lowered it, but at the end of the day it can be the world's system at the end of the day because the strength in it is good and there was at least in the end a majority, also political majority but also among industry that was in favour. But I'm saying that to you because I have not studied looking at the American system but many years ago for three weeks I visited a lot of companies in the United States at that time and also some scientific institutions. So I became aware of the differences in the regulatory thinking because in your country you can be a risk, as I have understood it, that in one state can decide suddenly one thing and even in a big city they can take such a decision and then you have to go to the court and everything. At that time, actually in the big business I met people who said 'ok, I'm in favour of European legislation because it gives me more security. I know it will be harder but I'm favour if we can have that security.' So that's…if you are looking at some differences at least that's my experience perhaps it's not the whole truth but part of it as I have seen. Some of the problems in relation to global legislation on the environment too because European companies are more, there's more tradition to be in such a regulatory scheme; of course, some of them are not so eager to accept it, but much more. And some of the US owned global companies…we see in Europe the company owned by US companies often we will see that often they are not so eager to accept the regulatory systems. For example, eco-labeling, I could not understand it but when I was Director General, eco-labeling…we were promoting it as a national institution…

LC What labeling?

SG Eco-labeling. There's two systems of it in our part of the world, there's the Nordic eco-labeling system – it's not private, the state pays – and there's a European. It's a swan for the Nordic, and if you go to the supermarket you can see a swan on it then it's eco-labeled. If it's a flower then it's European, it's not so big the European because it's not so developed but the Nordic we've had for many many years. So we have this label on a lot of items but when I was Director General, an American-owned company was very very aggressive to us because we advertised and promote people to buy products using this. And of course then we are saying don't take your good because you have not this eco-labeling, so and they tried to convince me that I was wrong. And they didn't accept it. They could not understand that it was ok to use this tact, the taxpayers money to advertise. Of course, we didn't advertise against them but we advertised to eco-labeling for two months. And of course we could not advertise for private eco-labeling, but we could when the state, the country is involved in the eco-labeling system and the criteria. But the idea was that they were not willing to give information to us or another organization about what was in their detergent. Ok, it was not nanotechnology, so go on.

LC I guess, on the topic of regulation…

DC Yeah, we just want to recap on a couple of things. First, do you think that the current regulatory system, which includes REACH, which I know doesn't really start until June – June first I think…do you think that the current regulatory framework is sufficient to protect the Danish public from nanotechnology's possible risks?

SG I don't think it's sufficient but I don't know actually how to make it, if you understand. So that will not be followed of a demand immediately to have a new regulation because I don't know how to create it, but I can see that we need more…we need to know much more about the risks in relation – and perhaps the benefits, but from our side it's the risks that's the focus.

DC So do you know of anything that might be specifically inadequate or the changes in any areas that could be made?

LC Or like any gaps?

SG No, I'm not aware of the concrete gaps. In knowledge or in regulation?

DC Regulation.

SG In regulation I'm not aware of where we need to focus. That's my problem. Perhaps on health, I think. That would be my intuition. In relation to health and these small particles, but I'm not very concrete on it.

DC All right, so reading through the literature, we saw three different approaches towards attacking this nanotechnology issue with regulation. The first way is to not do anything, you think the regulatory system is fine. The second is to kind of make adjustments as time goes along and you see problem areas that you need to change, so change them when you need to. The third is to maybe reconstruct the regulatory framework and perhaps even some nanotechnology specific regulations more now than later. Of these three point of views, which do you feel you most identify with?

SG Actually I think number three in reality, but I'm not ready for it so I will be in the middle of that and two because I need more scientific knowledge about the risks to be aware, to be sure where to focus. And of course I think I could call in the persons who know it and then perhaps I could manage it. Of course I shall do it, but it's also a job for the big environmental ministry and not just for me.

DC We can always send you our report.

SG Yes, you could send me your report. That would be fine. I hoped that. If you can focus it, I'll take it and I'll read it and if it's before summer…is it?

LC Yeah, it'll be done in a few weeks.

SG Oh good, so then perhaps I can tell you how we follow your report up in Parliament. Then you can come back and say 'maybe it's not so easy to have influence in Boston, but in Denmark it's very easy.' No, no that's not the case but I'll use it if I can.

KM Sure.

DC I just have one last question. It's something about the chemical regulation that I've been trying to clear up. We've heard kind of different sides to it. As far as REACH regulation, I've heard that, or I know that, in order to register a chemical you need to produce it in 1 ton per manufacturer per year, but I've also heard from another source that in order to regulate it you need to produce it in 10 tons per manufacturer per year. But then I've read on the Danish EPA that for regulation you need to identify a certain hazard such as if it's a carcinogen or a mutagen or a teratagen, that's what we call it in the US. Do you know about this 10 ton rule to regulate? Is that true?

SG The 10 ton…if it's identified as a…the first step is to identify if the chemical is…if there is some risks. You have to do it not on your own, but it's your responsibility to put all the knowledge to be sure that this chemical is not dangerous, so it's the company that…

DC That has to do the risk assessment?

SG Yes, but also to take the decision. It's not the official system…they are not able to say yes or no. So they have not only the risk assessment but they have also to take the decision that this is not dangerous. So if it's not dangerous, ok then you can…but then you'll take all the responsibility on your own and of course it's following something, you know, you have to follow all the knowledge we know. But they have to make that…so and then I think that it's correct. If the chemical is seen as having some risks then I think you have the correct thing with this 1 ton and 10 tons as I remember it. But you have seen other things on the website?

DC I mean maybe they just left the whole tonnage thing out.

SG Have you a very close relation with the Consumer Council people?

DC Yes, we work there every day.

SG Every day? Ok. Mette is your contact?

KM Claus Jørgensen is.

SG Oh, and woman called?

KM There's a Sofie there too. We've met Mette.

SG You've met Mette…she's an expert. She's also been member of the board in my party, but she is really an expert, not just a consumer expert but an expert really. So when she had this job perhaps she has a more leading job now, perhaps it's Claus that has the job she had before, but she followed REACH very closely so she is more an expert than I am. I followed it politically but that's not the same as haven sat through many meetings and

followed it closely, so she'd knew it if you can ask her. Very concrete on how regulation is functioning.

DC Ok.

SG Ok? Is that ok?

LC That's great, thanks.

Appendix D.12 –

Interview with Brigitte Rasmussen
Monday, 21 April, 2008

Interviewers
Linxiao Chen
Dan Carney
Kelley Murray

DC Ok so just to begin with the formalities, for this interview we don't need to record your name but we do need to record a little bit about your background and occupation for the record. If at any point you want to skip a question that's fine or if you want to end the interview at any time you can do that. So shall we begin?

BR Yes.

DC Could you please state your name for the record?

BR My name is Brigit Rasmusen.

DC And your occupation?

BR Occupation? That's my job?

DC Yes.

BR I'm senior scientist at the Technical University of Denmark at an institute that was just reorganised so the institute's name is DTU Management Engineering from the first of January this year.

DC Ok.

LC So what is your experience with nanotechnology?

BR My background is in chemical engineering many years ago and I have a PhD in risk assessment twenty years ago. I've been working with the risk assessments for a long time, in risk assessments concerning chemical engineering, the factories and the industries and not the chemicals, more the installation and the facility and the operations and these kinds of things. For the last ten years I've been working with what we call technology scenarios, technology foresight, it's on the boundary of the technology and society and we're trying bridge these two fields and developing some plans for different kind of technologies. In one of these things we have been doing, we have been preparing an action plan on nanotechnology and nanoscience in Denmark, three or four years ago. And then I have prepared a study on green technologies related to nanotechnology and prepared a small study together with, I think we were eighteen in this group, on regulation for the court. Do you know the technology board?

All No.

BR Oh, well it's similar to this. It is very close to the government and very close to the normal people and they're working with how people understand technology. And we have this study on nanotechnology and regulation. Do we need special regulation for nanotechnology or do we have to work on or adapt the existing regulations to nanotechnology? I think that's the three projects I've been involved with in the last three to four years.

LC Ok.

BR I mean, they have all been Danish studies. Of course if we look for the Danish action plan, we look abroad at what is going on because we are very small country so we have to find our…

LC So in these plans have you looked at what benefits and what risks nanotechnology, in general or specific applications of nanotechnology, may have?

BR When we prepared the action plan, it was a discussion if that action plan should contain something about health hazards, environmental hazards, ethical issues, these kind of things. And that's a game or a fight about money. We have research money, are these research money going to nanoscience or is it also going to more studies on health and hazards and these kind of things and perception and…so we have of these long pages in the action plan there were one or two about remember hazards.

LC So what kind of hazards did you…?

BR We looked at hazards to environment, human beings, and a little bit about ethical issues, that was all.

LC Anything in specific that caught your eye?

BR No, because nanotechnology is so difficult to define. Are we talking about nanotechnology in medicine or nanomaterials or electronics or what are you talking about? It's so very…it's so confused, it's very difficult to define.

LC It's vague?

BR Yes, it's vague. It is easier to define gene technology because they have the DNA and that's the focus area. What is the focus area of nanotechnology? It's small, that's all you can say about it.

LC So, I mean, is there like, when focusing on a specific application, is there any specific application that you feel the risks might be considerable?

BR I think you have a big problem that the particles have an active site and this active site can cause damage if you get it on your skin or if you breathe or eat it or whatever, and it will go into a person's routes which is not known. And it's so very difficult to measure. If you want to detect it, how do you find it? You do not have the techniques to measure these very small

particles if they have left your facility. I think that's one of the main problems it is to find them. And to understand the dynamics and mechanisms on human tissues or whatever it is.

LC So, I guess because it's so hard to assess the risk, does this have an impact on public perception?

BR I think it'll have an impact because we have a history with other kind of chemicals and other kind of materials. Asbestos, you know that?

All Yes.

BR There we have one kind of particles and these particles here, they are even smaller so perhaps they are even more reactive. It's very difficult to understand, and I think that's the main influence on how people look at it. And some people see it as very fancy if you can prepare windows with a special surface so you do not need to have to clean windows, that is very attractive.

LC But, I mean, with asbestos they put it out on the market and then a few years afterwards they figured out that it was dangerous. There's some products that use nanotechnology, nanomaterials already on the market, so do you see the same kind of trend where…?

BR It's very difficult to answer yes or no to that question. You have one case in Denmark I think about two years with something you could put on the front window of your car. It was not nanotechnology but it was marked as nanotechnology and there were some problems with it. This kind of story, what will it tell normal people? First they see they are told it is nanotechnology and then it isn't nanotechnology and then there some hazards related to it because there are some other chemicals in it. And what's the difference between chemicals and nanotechnology? Some companies, they're very concerned about how to market their products. Are they going to sell it as nanotechnology or are they going to sell it as medicine or new materials or whatever?

LC I know that some people have compared nanotechnology, or the issues that may arise with public perception to that of GMOs, do you agree?

BR I think there's some similarities, but I think the GMO was easier to understand to some extent because you have this DNA as the focal point. Some people have also compared nanotechnology to nuclear power, but again nuclear power is more easier to define because you have this processors and the reactor. Then you go to nanotechnology could be nanomedicine that you put into people with cancer or whatever it is or it could be something for cleaning windows or, yeah.

DC Do you think that it's a problem that a lot of people that might not know much about nanotechnology try and relate it to GMO or nuclear power and say 'well, nanotechnology is this congible thing it's one thing that we can be afraid of' when really it should be thought of as individual applications? Do you find that a lot of people are kind of misconceiving nanotechnology and thinking that you can think about nanotechnology as this one thing, this one technology?

BR I think a lot of people are positive in case they can see an advantage in the application of the technology. If they can't see the benefit...you have to balance the benefits and the hazards. I think that's very important. In that study about the action plan, we had a small study where we invited thirty or thirty-five people and they had to answer a lot of questions about nanotechnology, people with no education in that area. It is very clear that it was benefits they were focusing, and of course they were focusing that we have to assess and investigate all the hazards very detailed.

DC Do you think that people could…if something bad happens with say maybe some specific material, and nanotechnology, because it was marketed as a nanomaterial, that could mean the downfall for the entire technology just because it's all under one name and people try and perceive it as one thing?

BR I think what you will see is that other companies will have another way of selling the products, they will not call it nanotechnology. If one goes down, you will see the others putting other names on their products.

DC Ok.

LC Do you see that as a problem that companies are hiding the fact?

BR From my point of view it's so difficult to define this nanotechnology. You have in that group – the technology board – we have a lot of discussions about regulation. Do we need a new regulation for nanotechnology? And the answer was no because it's so difficult to define it, and it's not possible to have a regulation if you can't define what is covered by the regulation. So from my point of view, nanotechnology that's very…it's a buzz word. It opens up research money.

LC Actually we've heard that a lot.

BR And do the technology have to be small in one dimension or two dimensions or three dimensions? What is it? It's just a word for impressing political people.

LC So you're talking a lot about regulation, so…

DC Actually I have one more question. I've been reading that a lot of people, when they start hearing about risks of nanotechnology and nanoparticles getting on them and there are so many applications that are already out there like paints and sunscreen that have been using nanoparticles for years and nobody really knew or cared. Are you really concerned about these products that are already on the market such as sunscreens or paints that have nanoparticles in them?

BR I told you that I'm always aware and concerned about different kinds of chemicals on the market because we have a whole lot of histories, a lot of hazards or bad histories where people have been killed or have allergic reactions. You have a lot of these kind of things.

DC Do you think there's need for any extra concern because they're nanoparticles as opposed to…

BR I think there's a need for extra concern because the particles are very small and they can go in your body and in another route than you expected it to. And they have the reactive site, so you don't know which kind of damage it can cause in different kind of your tissues or wherever it will enter into your body or into the environment. So I think the kind of hazard and the fact that it's not possible to detect it. How will you catch it or how will you get it back?

DC Right. How do you get it out of the system?

KM Did the people that you brought in to talk to, were they aware that there are already products on the market using the tiny nanoparticles?

BR I can't remember if we had products on the market. The way it was organised, we had these people and then there were two presentations, one coming from a person talking about health and one talking about the more scientific aspects, and that was their background for filling in the questionnaire about opinion about different kind of things.

KM Ok.

BR I think we were not talking specifically on products, we were more talking about possibilities in the future and new applications and they were allowed to ask questions before they were filling in the questionnaires.

DC What kind of questions did the questionnaire ask?

BR I have it at home. It was very much about which area and benefits and risks, but at a higher level it was an energy technology or materials or food technologies.

DC Can you recall which technologies people were generally more enthusiastic about?

BR I think if you go into medicine, if you can treat cancer in another way than you do today then it's very attractive for people to see in that way.

DC How about the technologies people were most concerned about?

BR I can't remember. I think there no specific, of course if you're going to eat it in food technology or GMO, if you're going to eat it.

LC So, I guess people when are weighing the benefits and risks, are they willing to take more risks if they see more benefits?

BR If you're sick, I think you're prepared to take greater risks, but if it's something you're going to eat everyday or your children are going to eat it then you're more afraid. I think it's something about energy, if the world can reduce the amount of energy we're using then we are prepared to do it. But it's so difficult because people ask 'what is it? What is nanotechnology?' How do you define it?

LC Oh, you're asking me?

BR Yes, how do you define it?

LC Uh oh. Well, I guess we define it as, it's a very general definition, any particle or the use of particles or machines on the scale of nanometers.

BR Because some people have defined it as something very small with a new functionality.

LC Oh, I see.

BR If it's only small then what's different between nanotechnology and chemistry?

LC That's a good point. I think the official, what is it the EPA, definition is any particle or machine whose scale lies on the nanoscale.

DC One dimension.

LC Yeah, so it can be a mile long but a nanometer thick, but it's a vague definition. You're right. It's still too early to really…

BR From my point of view you will see some new names in the future, and nanotechnology will get out of how we speak about it.

DC I mean, personally, I don't like the term nanotechnology and I don't like thinking about nanotechnology in general. It's too easy to think that because there's a problem, with nanoparticles might be dangerous that there's some completely different aspect of nanotechnology that you might also give a negative connotation to just because it's also called nanotechnology. Even if they're seemingly or realistically unrelated, and it could go the same way for benefits. It's almost pointless to think about nanotechnology. It makes more sense to think about nanomaterials, and even then certain nanomaterials in medicine or nanomaterials in industry which…I don't know. I personally believe that we need to get away from referring to nanotechnology as opposed to various nano-applications, I think.

BR Well what about enzymes? Are they nanotechnology or what?

DC If we could engineer an enzyme then yeah, I would call that nanotechnology. But even then, who cares? You should be thinking about engineering enzymes not is engineering enzymes nanotechnology? Who cares? The name isn't really important, but I think some people take the name and give it so much more value than it's worth.

KM Ok.

BR I think that the main problem is the free particles with nano…in some way or another containing or carrying these small particles. If you have them in a solid, I think it won't be…because then it's fixed.

LC From what we've been hearing, it's always the free particles that people are afraid of – the ones people can breathe in.

BR But I do not know. I think I've seen one or two German studies where they have analyzed the facilities producing this kind of stuff and if you have a leak from these facilities here. But the most I've seen that's more in the application area. I've not seen so much in the production of the nanoparticles, but there must be some way it can be released from these facilities.

DC Well a lot of people seem to be concerned more with the people working in these facilities and working with these particles and materials than the consumers.

BR Are you talking about the researchers or the people that work there?

DC The researchers might…I mean I worked in a lab and I know that they're always stressing safety, safety, safety do all that you can to be safe. I know they took…I don't know if you guys you Sigma Aldrich in Denmark to order chemicals…

BR Sigma what?

DC Sigma Aldrich, it's just a chemical supplying company so if you need any chemical – acetone, sodium chloride, whatever – you order it from them. And this particular company, they took sodium chloride – table salt – and said it was a carcinogen, so we had to write an SLP for it.

BR Ok.

DC That's kind of off topic, I mean, I'm not so concerned about researchers but maybe people working in chemical plants that might not even be…or just in a manufacturing facility. A lot of people seem to be concerned about them, even more so than the consumers.

BR Yeah, but the thing is, the connection can't be that they are closer to the technology they know what it is. I think if you go out into the street and ask people about nanotechnology you will not get a very clear answer. But I think another problem is what is needed in order to have a detailed or a clear assessment of the health and environmental hazards. If you look at the chemicals, at least in Europe, we have analyzed a very small part of the chemicals and there are a huge amount of chemicals still left. I think you will have similar problems with the nanotechnology. What are we going to recommend or demand for a complete analysis and who's going to pay it?

LC That's the most important question.

DC So I guess we have some more questions about regulation. Are you familiar with chemical regulation in the European Union?

BR Only from the small project we had some years ago at the Technology Board, so I know in brief what's going on but my role in that group was more to talk on principles on risk assessment and not on different kinds of regulation.

DC I mean our questions are pretty simple, nothing too specific. Do you think that the current regulatory framework system, which will include REACH since it really starts going into

effect in just a couple months now, do you think that the framework is sufficient to keep the Danish public safe from the potential risks of nanotechnology?

BR From my point of view, the normal framework of regulation is ok, but it can be necessary to develop some few areas on it in different ways to cover the nanotechnology. But we do not need a complete new regulation on nanotechnology. It will not make sense from my point of view because who is covered and if you're so unclear on who is covered then a lot of people will try to define themselves out of the area if there's a lot of trouble being inside the area from a regulation point of view. And you will see a lot of companies, researchers, laboratories saying 'oh no, that's not nanotechnology, that's not us.' So if you can't prepare a very clear definition then I think we have to keep to the framework we have. And I don't know about REACH. I haven't seen details about REACH.

DC Do you know, can you think of any changes that might need to be made or just improvements that you're aware of?

BR I think this question about detection and measuring…I think it's called metrologic, do you know this?

All No.

BR It's basically about how to measure things, how to detect things or how to measure. What is it in English?

DC I don't know.

BR In Danish, it's *metrologi*. It's a whole discipline of how do you measure things and how do you…all those kind of things, and making standards and equipment for how to do it. And two years ago I heard a presentation from a couple of guys saying it's so difficult to have a standard for how to detect it. And if you can't prove it's there how can you regulate it? How can you prove it's there?

LC So I guess the problem right now is it's really hard to measure things now, so that could be a problem.

BR Yes, if you go into court and one party saying it's there and the other party saying it's not there, how will you argue in that fight?

DC Doesn't seem like there's a way.

BR If they're another kind of chemicals or the active materials then you can measure it. You can go out there and say 'ok, so much, so high level of whatever it is.' It's more difficult with these things.

DC Just our final question, we've been trying to break up all our interviewees into three categories, but it's proving more difficult than we thought. But there are three approaches we've read about in the literature as to how to best manage nanotechnology with regulation, and the first one is that the current regulation is fine and we don't need to do anything

because nanoparticles are just like any chemical and it'll work. The second is that we'll need to make changes progressively and just tweak and change the regulation as it's necessary. And the third is to change the framework and develop maybe a new system of regulations for nanotechnology. Of these three points of view, which do you think you best identify with?

BR I think number two.

DC Number two?
BR That was having the existing framework and trying to develop it?

DC Right.

BR The first one was stay status quo and the third one was a completely new regulation?

DC Yeah.

BR I think in the middle.

LC So I have one more question just to wrap this up. Are you optimistic about the direction development is going?

BR For nanotechnology or the whole world or?

LC For nanotechnology in general, or are you sceptical?

BR From my point of view I can't see one way it's developing because it's so many different things. And I think that what you will see in the future is some different areas getting new names. I certainly hope that they find something in the medical, you know these drug delivering systems and drug targeting systems. I hope that they would be able to develop these sort of things. Because of course I can be afraid if they treat me here <points to hand> and it ends up there <points to opposite shoulder>, but I hope it's promising. I'm not working in the laboratory myself, so I have no idea if they are five or ten or twenty years from the target.

LC It's still too early to tell I guess.

BR I don't know. I think you have so many trades

LC Different applications

BR Yeah, completely different disciplines if you go to the computer and talking about quantum dots or whatever it is, it's completely different than talking about drug delivery systems. And how will you compare these two things? Or material science, how will you compare it? The only common thing is there's lots of money.

DC I think that wraps it up, thank you very much.

Appendix D.13 –

Interview with Thomas Broch-Nielsen
Tuesday 22 April, 2008

Interviewers –
Dan Carney
Kelley Murray
Linxiao Chen

DC I guess we'll start off with a few formalities. We want to let you know this interview is being recorded, if that's all right with you.

TBN No problem.

DC Ok, and also…

TBN But please never play the tape when I'm hearing my own voice.

DC All right. We'll send you a copy of our report when we're done which will include a transcript of this also. For this interview we don't need to record your name, but we do need to record a little bit about your background and your occupation just for the record. And also, if you wish to skip any question or end the interview at any time that is also fine.

TBN Ok.

DC So shall we begin?

TBN Yes please.

DC Could you please just state your name and occupation for the record?

TBN My name is Thomas Broch-Nielsen, my placement is senior scientist in the personal care division of Fibertex AS located in Denmark, the corporate headquarters.

DC Ok. Now Kelley's going to ask you a few general questions about nanotechnology.

TBN Sure.

KM Could you explain your experience of background with nanotechnology?

TBN Yes, of course I can. In Fibertex, we have for some years had a nanotechnology project running in cooperation with iNano at a university in Denmark. iNano is short for Interdisciplinary Institute of Nanotechnology, which is one of the leading nanotechnology research centers. This project has been working under the Offices of the Danish Advanced National Technology Fund I believe is their English name, in Danish it's directly translated from the High Technology Fund. That project is a relatively large project, which involves about ten people – researchers, PhDs, and people who work at Fibertex. I started up this

project about two-and-a-half years ago and managed the project for the first one-and-a-half years of its lifetime and I'm still working at some parts of this project. This project is related to several areas of nanotechnology ranging all the way from nanosurfaces to using nanoparticles.

KM Ok.

TBN Oh, and I should mention that my original background is a university education in chemistry.

KM Very good. Do you know of benefits that nanotechnology will bring to the consumer or just in general any benefits of nanotechnology?

TBN Yes. I'm just clearing my head here. The main benefits that I would envision is that we will in some cases…there are two ways you can look at it basically. One is where we take an effect that already exists today but make the effect either improved or using less toxic materials than are used today. One example would be to make a plastics flame retardant this is today very often done by using bromonated plastic. These are very efficient but unfortunately also very toxic to the environment as they tend to cast off over time. A lot of studies have shown that bromonated compounds are actually present in all human beings because it slowly evaporates away from our TV sets and everything else of plastic with bromine inside for flame retardency. And using nanotechnology, it would appear that there are several options for using less toxic material such as for instance, nano-clay and other materials which has many of the same properties but without nearly the same risks. Another area is to impart what we would call, what I would call new performance. By that I mean something that cannot be obtained using any classical methods. And one example is the super-hydrophobicity which is being done by several people with several compounds. We also have research projects in this, which is a method of mimicking the very high repellency that exists on many types of plant material – I think it's called the Lotus Effect also in English. These of course are benefits that we see to the consumer as such. Ok, next question.

KM How advantageous do you think the benefits are? How enthusiastic are you of the benefits?

TBN Well, we are so enthusiastic that this is the largest and most expensive project that this company has ever undertaken in research and development, so I would say we are very enthusiastic. If we were to rate it on a scale of one to ten I'd say 9.5, so definitely we do see many opportunities both as you say for the consumer and the greatest advantage for us as a company is that if we can make products that are better for the consumer they are generally better for us because we of course would have decreased sales.

KM Do you perceive any risks with nanotechnology or do you know of any specific risks?

TBN Yes, definitely. And again I'll have to speak broadly because of course the main challenge when discussing this area that actually also goes back to the benefits is that nanotechnology is so incredibly broad an area which of course in many ways encompasses as many different areas as using the word technology in general. I mean, the main example I usually use for nanotechnology in use today is of course any kind of computer chip used in the cell phones I'm using or computers are of course very much nanotechnology. One area that I do see the

risk is actually again a bit two-fold: one is the real risk, or you could say the scientific risk and I could say that the other one is public perception, which of course also what you talk about in your project. To take the last one very briefly, the main concern I would have is that public perception can very easily be swayed by you could say a few bad examples, so a word like nano could be known for being something dangerous even though that might only be the case for one technology out of hundreds. But the word could very quickly become something bad. For real risks it's a bit difficult to answer because there so many different ways to choose from, but one which I could mention is that for some time, we actively pursued looking into nano-silver for antibacterial effects, which I believe is quite common. I mean, I know we can buy socks and all the other stuff with nano-silver in them, but about one, two years a university in Sweden came out with some results that showed bacteria have the possibility to becoming resistant to nano-silver. And then, of course, it negates the purpose, and for that reason, we have stopped looking into that area of it.

KM So going back to public perception, is your company or are you personally afraid that people are going to equate nanotechnology to say asbestos or the GMO controversy?

TBN I would use the word 'I am concerned' because I think 'afraid' might be too strong, but I am concerned and it is something we are following actively. In the event that we see information being published that we believe to be erroneous we do try to correct it, and we do an effort, you could say, to make sure that we publish our results and our finding in a correct manner so we do not give an impression of anything that is not there and neither that we try to hide anything that is there, neither positive nor negative.

DC I just have another quick question going back to the risks. Are there any specific environmental or health concerns that you have with nanotechnology?

TBN The main issues…I mean, the only one I've heard of that is sort of active is the one with the nano-silver. There have been other concerns being voiced over the time but none that we have found, I have found to the really substantiated as of yet. I mean, there are hundreds of reports I know that exist, which some show positive and some show negative results. And I cannot help but think that because the area's so broad, I sometimes liken it a bit to the reports that often come out about the safety or positive effects of various food items. I mean it's nearly every week you find out that coffee is toxic to you and the next found out that it's an antioxidant that protects against cancer. So in the end, no consumer has a chance to actually understand anything and that often ends up in giving a negative perception because you don't understand anything you will normally try to sway from it. That in a way is probably my biggest concern in terms of nanotechnology – that we might end up getting so many conflicting reports that people will end up trying to avoid it just to be safe.

LC Hi, I'm Linxiao, I'm the third group member, and I have a question going back to you differentiated between scientific risks, I guess real risks, versus perceived risks…

TBN Yes.

LC Could you elaborate on what risks the public might perceive to be associated with nanotechnology as opposed to those that are actually existent?

TBN Oh yeah. What would be my concern is that the people, the public could become afraid of anything related to the word nano because that is actually what is happening, I see it sometimes in the newspapers and so on here in Denmark that something will become…if they find something which has a problem… I believe that if you go back about three or years ago there was a spray sold in Germany which was used, I believe it was one of those sprays you could spray on windshields to make them more like super-hydropobic so you didn't have to use your windshield wipers in the car. They found that this spray had toxic effects on the people using it. It was also quite quickly found that actually this product contained absolutely nothing that anything to do with nanotechnology, they had just put on the word nano in order to increase the price. And the agent used to release the spray was a known toxic material, so it wasn't much of a surprise in a way after looking through what was actually in there that this was a toxic material, use only in a well ventilated area and so on. But because they had called themselves nano- something, this quickly went around in various newspapers that nanotechnology is very dangerous and that word nano was also written in all capital letters. And even, often when we and other people approach these newspapers to tell there's no nanotechnology in this, this is something else, they weren't interested in doing a follow-up story because that's not where the news were. But anyway, I mean, this of course gives a very bad perception because then you have one product with the word on it in very big letters which was harmful and then people will become to fear anything with nano even if it's completely different technology.

KM So do you have concerns about any specific applications of nanotechnology, such as nanomedicines or the use in electronics or something like that?

TBN No. If I should look into a concern in a way, I would probably emphasise most on what people use the most. I may also go to the more or less logical approach, for instance, nanomedicine has been talked about a lot but in reality I don't see much problems there because even let's say they make a medicine that has a good effect, which is the reason they use it, but it might also have a slight possibility for having some side effect. In a way that is not different from today. In any kind of medical you open up, I'm personally taking a blood pressure medication and when I open it up I can see a long list of all the possible side effects that happened to either one in a hundred or one in a thousand people or even one in ten thousand people, and some of the rare ones are usually extremely serious like heart attacks or something like that. So the goal of nanomedicine would be for me at least to make this less risky. So if the medicine I take today has one chance in ten thousand of increasing my risk of heart attack, then if they could make a nanomedicine of some kind which only had a one in a million chance of doing the same, that of course would be a great benefit even if there is still a chance in a million that it will happen. Also because it will in many cases only be used sparingly, most people use medication only when they're actually sick, so it's something that you'll use for a short time only. But I suppose to, let's say that it's your I don't know, it's your underwear that has been made using some kind of nanotechnology then in theory, logically I would perceive that as a bigger risk and I would believe that had to be checked much more thoroughly because it's something that you have in close proximity to your body on a twenty-four hour basis every day. Therefore, there's a much higher risk factor.

KM All right, I'm going to give you three statements and just let me know which one you feel you identify with best with.

TBN Sure.

KM In terms of nanotechnology, the benefits will outweigh the risks, the benefits and risks are equal, or the risks outweigh the benefits.

TBN I believe the benefits will far outweigh the risks.

KM Ok. Any particular reason why?

TBN Well because I believe there are…when I look at all these papers on possibilities and so on, I see so many hundreds, close to thousands of different technologies using different areas of nanotechnology because nanotechnology is of course anything that is sufficiently small, and only a very few of those I see as having a potential for having a risk. Most of them I see as being completely risk free because the main areas of nanotechnology, at least the ones that I'm aware because they're in the general vicinity of anything I've been working with. It's very often that nanotechnology is actually they call it hidden inside a product. With many of the projects I've worked on personally, it's using nanoparticles and in many cases these nanoparticles will impart their functionality by being part of the whole structure, so actually only an extremely limited amount of the nanoparticles will be on a surface which has any possibility of being subject to a touch by someone. So, for instance, if we put it into a fiber then most of the material will actually be inside the fiber so it will stay locked into this structure made of some other material such as plastic and only very small will happen to be on the surface, which of course again means that the risk is more or less non-existent. In some cases I know where this is used actively today also is actually encased even more to improve properties. I believe I saw one company, I forget the name, has marketed a baseball bat where the center has been made of carbon fiber that has been reinforced by carbon nanotubes, and then because the material is exceedingly hard – it was actually so hard they had to encase it in a shell of aluminum to make it softer so they wouldn't destroy the balls to easily. And this of course again means that the entire nanotechnology was encased in aluminum which means that this is of course risk free.

KM All right, and just the last question, how do you think nanotechnology will impact society, specifically the consumers in the future?

TBN If you do it in a very short term, let's say the next two years, I believe the impact will be minor. I believe there might be a few products coming on the market and there'll of course be a few more but I believe the real impact on people's everyday life will be negligible. It will be like 'oh, I can get a nice, new window cleaner which is more easy and nice but yeah.' I believe if we look at it in slightly longer term like ten, fifteen years, I believe there will be so many products coming out, so many improved versions of existing products that we will actually begin to see big impact because more and more things that we use in everyday life will have changed to have new and improved properties. We'll see all this with better electronics, different systems with what they show with rollable paper, I mean electronic paper and so on will become a big part of everyday life. And then I think we'll see a big positive benefit, and of course in the longer term I can't even speculate because well thinking ahead more than twenty years is so much wishful thinking that I think it's probably not even worth doing in real life.

DC All right, oh, just one more question before we move on.

TBN Sure.

LC So I understand that nanotechnology's a very very broad area, but how far along do you think we are in terms of development?

TBN I believe we have only scratched the surface because I mean the area is in the area was first defined I don't remember when Fineman made his very famous lecture about small space at the bottom, I think it was about 1960 or something, but in many ways the technology was not really being pursued much for the next few decades. And from my understanding is the growth in nanotechnology only happened in the end 80s and early 90s and then it began to take off from there with the discovery actually of the fullerenes and the carbon nanotubes, etc. It sparked all this interest in this area. I believe if you go from 1960s to say 1980 I believe the number of scientific articles mentioning nanotechnology is quite small, but of course then suddenly spike them now there's probably thousands and thousands of them coming out each year. I can also see that in a different…we have subscriptions to different magazines and so on showing developments in both general new developments as well as specifically nanotechnology, but I can see the magazines with general developments having more and more percentage of their developments being related to nanotechnology, and the nanotechnology papers seem to have more and more developments every month, which is actually becoming more and more significant. Whereas in the beginning stage, say five years ago, many of these developments were small and incremental because they had to write about what happened for the last month, but now so many people are working that there is always something fantastic almost happening every month. Somewhere someone is coming up with something you never thought about half a year before because you hadn't even gotten the idea, so I definitely think it's going incredibly fast now and I believe it will go much much faster . I think I would like to sort of think of it about electronics about 1980 but it is already getting to be big area but it will become much much bigger.

LC Ok, very good.

DC Ok, before we wrap things up, we just have a few questions about regulation and how it relates to nanotechnology.

TBN Sure. I would like to stress though that this is a much harder topic for me because I'm not an expert on this. I've of course have some knowledge in the areas that are specifically related to where I have worked, but this also a very big area so I'm not personally an expert. I just want to stress that.

DC That's ok. Most of our interviewees are not. These are pretty simple questions.

TBN Sure.

DC Do you feel that the current regulatory framework is sufficient to protect the Danish public from the possible risks of nanotechnology?

TBN Yes, I believe so. I believe that the regulation we have already encompasses all sorts of chemicals and so on, it is simply a matter of applying it to any new areas that come up such as nanotechnology.

DC Do you think that…are there any changes or are there any part of the regulation that isn't quite good enough, that you think should be changed?

TBN No, I don't believe so.

DC Ok, and just one final question. There are kind of three points of views addressing nanotechnology regulation and how it should be approached. The first main view is that nothing needs to be done and the current regulation is fine. The second point of view is that some changes should be made over time, also known as the incremental approach. The third is that more immediate measures need to be taken to make sure that regulation is up to par with nanotechnology and this could even include reworking the actual framework. Of these three points of views or even somewhere between two of them, where do you think you best identify?

TBN I would say I'm probably somewhere in between number one and number two, so I would say slightly incremental would probably be needed eventually because I would envision that at some point something will pop up in all this nanotechnology that is not part of the current legislation. All the areas that we have worked with is actually already covered with the legislation which is why I've never come across anything that wasn't fully covered already with the legislation. But given the breadth of this, I mean eventually someone will come up with something that's not covered, so I'm sure eventually some incremental work will need to be done. I know this is already a part of REACH, the new EU legislation which is coming up as big one in terms of chemical legislation. And I know there's also a lot of talk in that area to how to best address the needs of the nanotechnology community in research and the use of their products, so I believe that area will actually be quite well addressed in that specific point of such a REACH legislation as that grows and becomes more and more encompassing.

DC Ok, I think that just about wraps it up. We thank you very much for your time, it was very helpful.

TBN You're very welcome.

DC We'll be in touch, and let you know when our report is finish and get you a copy.

TBN Ok, thank you.

Appendix E – Tentative Survey Questions

The purpose of this survey is to gauge both public knowledge and public perception of nanotechnology, its benefits and its risks. We would like to determine how familiar people think they are with nanotechnology and how knowledgeable they actually are. Additionally we would like to use this to determine if there is a correlation between knowledge and familiarity and the perception of risks and benefits. This survey will also be used to gauge public confidence and opinion on state regulation, companies and other nongovernmental organisations.

1. What is your view on new technologies? (On a scale 1 (Negative/Unenthusiastic) – 5 (Positive/Very Enthusiastic))
    a. Biotechnology
    b. Medical Technology
    c. Computer and Information Technology
    d. Robotics
    e. Green Tech
    f. Transport Tech

2. Overall, what is your view on developing technologies? (On a scale 1 (Negative/Unenthusiastic) – 5 (Positive/Very Enthusiastic))

3. Have you ever heard of nanotechnology?
    a. If so, where have you heard of it?
    b. (Family, friends, work, entertainment media, advertisements, news media, other) You may pick more than one.

Nanotechnology is the study of materials and devices whose dimensions are on the scale of one billionth of a metre. Nanotechnology may change the day-to-day lives of everyone. Currently, in the Danish market, nanotechnology has been applied to approximately 243 consumer products.

4. How familiar do you consider yourself with nanotechnology? (On a scale 1 (Not At All) – 5 (Very))

The following true/false is to gauge your knowledge on certain aspects of nanotechnology.

5. True/False/Unsure (To gauge public knowledge)

    a. Nanoparticles are used in cosmetics, such as sunscreen. (True)
    b. There are production regulations specifically targeting nanotechnology. (False)
    c. Nanoparticles may be able to freely enter the body through the skin. (True)
    d. New methods of cancer treatment utilising nanotechnology are under development. (True)

Nanotechnology brings many benefits to consumer products. These benefits include but are not limited to smaller and more powerful computers, strain resistant clothing, stronger materials, and improved medical treatment.

6. Were you aware of any possible benefits nanotechnology may bring to consumer products? (Yes/No)

7. How enthusiastic are you about these benefits? (1 – Not enthusiastic; 5 – Very enthusiastic)
    a. Medicine (Cancer Treatment, Drug Delivery Systems)
    b. Personal Care Products (Cosmetics, Sunscreen)
    c. Electronics (Computers, Storage Media)
    d. Food (Packaging, Preservatives)
    e. Clothing and Textiles (Stain Resistant, No Wrinkle Fabrics)
    f. Leisure (Sports Equipment)
    g. Other (Batteries, Self Cleaning Glass)

Not much is known about the risks associated with nanotechnology. Nanoparticles may cause respiratory inflammation when inhaled or freely enter the body due to their small size. Nanoparticles may also disrupt and cause damaged the ecosystem.

8. Were you aware of any risks associated with nanotechnology? (Yes/No)

9. Based on your understanding of the risks and benefits, which applications of nanotechnology would you take advantage of? (You make pick more than one)
    a. Medicine (Cancer Treatment, Drug Delivery Systems)
    b. Personal Care Products (Cosmetics, Sunscreen)
    c. Electonics (Computers, Storage Media)
    d. Food (Packaging, Preservatives)
    e. Clothing and Textiles (Stain Resistant, No Wrinkle Fabrics)
    f. Leisure (Sports Equipment)
    g. Other (Batteries, Self Cleaning Glass)

Although certain regulations on chemical and materials do apply to nanotechnology, there are currently no regulations geared specifically towards the application of nanotechnology in consumer products.

10. How much confidence do you have in the Danish government to regulate the use of nanoparticles in consumer products? (1 – None at all; 5 – Extremely confident)

11. How confident are you that nanotech companies will utilise the technology responsibly ensure the safety of their products? (1 – None at all; 5 – Extremely confident)

12. Do you think nanotechnology will improve your life? (Yes/No/Unsure)

13. Overall, do you think that, concerning nanotechnology:
    a. Benefits > Risks
    b. Benefits = Risks
    c. Benefits < Risks
    d. I don't know.

Appendix F – Survey Questions Results –

Demographics –
Age –

Age				
		Frequency	Per Cent	Valid Per Cent
Age Groups	18-30	64	6.5	6.8
	31-50	414	41.9	43.7
	51-65	372	37.7	39.2
	Over 65	98	9.9	10.3
	Total	948	96.0	100.0
Missing	System	40	4.0	
Total		988	100.0	

Education –

Education				
		Frequency	Per Cent	Valid Per Cent
Education Level	Grade School	310	31.4	32.9
	High School	242	24.5	25.7
	Higher Education	391	39.6	41.5
	Total	943	95.4	100.0
Missing	System	45	4.6	
Total		988	100.0	

Question Results –

Question 1 – What is your view on new technologies?

Question 1 – What is your view on new technologies?								
			Rankings					
			Very Positive	Positive	Neutral	Negative	Very Negative	Total
Field	Biotechnology	Count	50	137	286	334	181	988
		% within Field	5.1%	13.9%	28.9%	33.8%	18.3%	100.0%
	Medical Technology	Count	303	404	167	76	38	988
		% within Field	30.7%	40.9%	16.9%	7.7%	3.8%	100.0%
	Computer and Information Technology	Count	305	465	189	23	6	988
		% within Field	30.9%	47.1%	19.1%	2.3%	.6%	100.0%
	Robotics	Count	219	427	277	55	10	988
		% within Field	22.2%	43.2%	28.0%	5.6%	1.0%	100.0%
	Green Technology	Count	629	294	59	6		988
		% within Field	63.7%	29.8%	6.0%	.6%	.0%	100.0%
	Transportation Technology	Count	498	385	98	6	1	988
		% within Field	50.4%	39.0%	9.9%	.6%	.1%	100.0%
	Nanotechnology	Count	347	377	211	45	8	988
		% within Field	35.1%	38.2%	21.4%	4.6%	.8%	100.0%
	Total	Count	2351	2489	1287	545	244	6916
		% within Field	34.0%	36.0%	18.6%	7.9%	3.5%	100.0%

Question 2 – Overall, what is your view on developing technologies?

Question 2 – Overall, what is your view on developing technologies?			
		Frequency	Per Cent
Opinions	Very Positive	251	25.4
	Positive	637	64.5
	Neutral	91	9.2
	Negative	9	.9
	Total	988	100.0

Question 3 – Have you ever heard of nanotechnology?

Question 3 – Have you ever heard of nanotechnology?			
		Frequency	Per Cent
Response	Yes	863	87.3
	No	80	8.1
	Unsure	45	4.6
	Total	988	100.0

Question 4 – Where have you heard about nanotechnology?

Question 4 – Where have you heard about nanotechnology?			
		Responses	
		Number	Per Cent of Respondents
Sources of Information	Television Shows	603	69.9%
	Radio	202	23.4%
	Newspapers	526	61.0%
	Specialist Magazines	197	22.8%
	Advertisements	226	26.2%
	Family and Friends	170	19.7%
	Other Places	71	8.2%
	Don't Remember	28	3.2%
	Total	2023	

Question 5 – How familiar do you consider yourself with nanotechnology?

Question 5 – How familiar do you consider yourself with nanotechnology?				
		Frequency	Per Cent	Valid Per Cent
Familiarity	Very	7	.7	.8
	Somewhat	124	12.6	13.7
	A Little	694	70.2	76.4
	Not At All	83	8.4	9.1
	Total	908	91.9	100.0
Missing	System	80	8.1	
Total		988	100.0	

Question 6 – True/False Section

Breakdown By Question –

Question 6 – True/False Section – Breakdown By Question			
		Responses	
		Correct Answers	Per Cent of Cases
Statements	Nanoparticles are used in cosmetics.	347	42.3%
	There are production regulations specifically targeting nanotechnology.	253	30.8%
	Nanoparticles may be able to freely enter the body through the skin.	322	39.2%
	New methods of cancer treatment utilising nanotechnology are under development.	554	67.5%
	All nanomaterials contain nanoparticles.	255	31.1%
	Nanomaterials have not been used in clothing.	642	78.2%
	Nanotechnology development is still in the early stages.	695	84.7%

Breakdown By Scores –

Question 6 – True/False Section – Breakdown By Scores			
		Frequency	Per Cent
Scores	0	87	9.6
	1	24	2.6
	2	119	13.1
	3	217	23.9
	4	239	26.3
	5	147	16.2
	6	61	6.7
	7	14	1.5
	Total	908	100.0

Question 7 - Were you aware of any possible benefits nanotechnology may bring to consumer products?

Question 7 – Were you aware of any possible benefits nanotechnology may bring to consumer products?				
		Frequency	Per Cent	Valid Per Cent
Response	Yes	595	60.2	72.5
	No	226	22.9	27.5
	Total	821	83.1	100.0
Missing	System	167	16.9	
Total		988	100.0	

Question 8 - Were you aware of any risks associated with nanotechnology?

Question 8 – Were you aware of any risks associated with nanotechnology?				
		Frequency	Per Cent	Valid Per Cent
Response	Yes	261	26.4	31.8
	No	559	56.6	68.2
	Total	820	83.0	100.0
Missing	System	168	17.0	
Total		988	100.0	

Question 9 - Based on your understanding of the risks and benefits, which applications of nanotechnology would you likely buy?

Question 9 – Based on your understanding of the risks and benefits, which applications of nanotechnology would you likely buy?								
			Ranking					
			Very Likely	Likely	Unlikely	Very Unlikely	Unsure	Total
Area	Medicine	Count	216	405	109	33	55	818
		% within Area	26.4%	49.5%	13.3%	4.0%	6.7%	100.0%
	Personal Care	Count	21	112	371	271	43	818
		% within Area	2.6%	13.7%	45.4%	33.1%	5.3%	100.0%
	Electronics	Count	250	447	61	20	40	818
		% within Area	30.6%	54.6%	7.5%	2.4%	4.9%	100.0%
	Food	Count	45	198	317	202	56	818
		% within Area	5.5%	24.2%	38.8%	24.7%	6.8%	100.0%
	Clothing and Textiles	Count	140	367	195	76	40	818
		% within Area	17.1%	44.9%	23.8%	9.3%	4.9%	100.0%
	Leisure	Count	130	342	197	92	57	818
		% within Area	15.9%	41.8%	24.1%	11.2%	7.0%	100.0%
	Household Products	Count	129	311	220	119	39	818
		% within Area	15.8%	38.0%	26.9%	14.5%	4.8%	100.0%
	Total	Count	931	2182	1470	813	330	5726
		% within Area	16.3%	38.1%	25.7%	14.2%	5.8%	100.0%

Question 10 - How much confidence do you have in the Danish government to regulate the use of nanoparticles in consumer products?

Question 10 – How much confidence do you have in the Danish government to regulate the use of nanoparticles in consumer products?				
		Frequency	Per Cent	Valid Per Cent
Confidence	Extremely Confident	62	6.3	7.6
	Confident	356	36.0	43.5
	Little Confident	287	29.0	35.1
	No Confidence	99	10.0	12.1
	Unsure	14	1.4	1.7
	Total	818	82.8	100.0
Missing	System	170	17.2	
Total		988	100.0	

Question 11 - How confident are you that nanotech companies will utilise the technology responsibly and ensure the safety of their products?

Question 11 – How confident are you that nanotech companies will utilise the technology responsibly and ensure the safety of their products?				
		Frequency	Per Cent	Valid Per Cent
Confidence	Extremely Confident	28	2.8	3.4
	Confident	271	27.4	33.2
	Little Confident	388	39.3	47.5
	No Confidence	113	11.4	13.8
	Unsure	17	1.7	2.1
	Total	817	82.7	100.0
Missing	System	171	17.3	
Total		988	100.0	

Question 12 - Do you think nanotechnology will improve your life?

Question 12 – Do you think nanotechnology will improve your life?				
		Frequency	Per Cent	Valid Per Cent
Response	Yes	264	26.7	32.3
	No	183	18.5	22.4
	Unsure	370	37.4	45.3
	Total	817	82.7	100.0
Missing	System	171	17.3	
Total		988	100.0	

Question 13 – Weighing Benefits and Risks

Question 13 – Weighing Benefits and Risks				
		Frequency	Per Cent	Valid Per Cent
Response	Benefits > Risks	276	27.9	33.8
	Benefits = Risks	274	27.7	33.6
	Benefits < Risks	80	8.1	9.8
	Unsure	186	18.8	22.8
	Total	816	82.6	100.0
Missing	System	172	17.4	
Total		988	100.0	