The Canton of Zürich's Roadmap:
Smart Energy Region 2050

Interactive Qualifying Project Report completed
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Abstract

As part of the COST Action Plan, ZHAW has presented a goal of achieving a Smart Energy Region in the Canton of Zürich by the year 2050. This target is defined with milestones across 18 areas such as energy efficiency, quality of life, and renewable technologies. This report assesses those goals and develops a roadmap for the canton to achieve some of them, while recommending that other goals be re-evaluated for plausibility. The roadmap is made up of a series of recommendations that could be used by the cantonal government to reach these targets. Additionally, this report provides analyses of each of the 18 relevant areas as well as other roadmaps that have been developed in other cities, providing a strong research base for future work by ZHAW on the Smart Energy Region Project.

Acknowledgements

This project was something new to the team. We had completed projects for courses before, but our IQP presented new challenges. Our supporters provided us with valuable resources, information, and insight throughout the project. The work they invested contributed to the success of this project.

We want to extend our sincerest gratitude to Thea Weiss, Harry Spiess, Vicente Carabias, and Tobias Kuehn at ZHAW for the copious amounts of resources that they provided us with throughout the course of our project. Not many IQP groups can say that their sponsors supported them as much as our sponsors have supported us. It got to the point where we had to ask them to stop giving us resources and contacts that we utilize for the project because there simply was not enough time in the term. They trusted us to do the best that we could and gave us the opportunity to really make this project our own. Special thanks to Tobias for coming with us on some of our interviews and translating some key documents for us during the course of the project.

We also want to thank the experts that we interviewed for the project. We never would have imagined that 9 professionals in the fields relevant to our impact variables would not only be able to meet with us for interviews, but would also be excited to meet and respond to our initial correspondences within the first couple days. The information that they provided us was critical to the successful completion of our project and we had much more time to synthesize and analyze that information because they responded so quickly to setting up meetings.

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Executive Summary

This report provides an analysis of the target 2050 scenario constructed by ZHAW for the Canton of Zürich and develops an initial roadmap towards the development of the canton into a Smart Energy Region by the year 2050. The roadmap focuses on measures that would increase sustainability, decrease energy consumption, accelerate adoption of renewable technologies, and promote infrastructure developments in order to meet goals that the canton has established for 2050.

Methods used in this research have primarily been the accumulation and synthesis of data collected through online research and from interviews with experts in the various fields that the roadmap addresses.

The report concludes that a number of goals presented by ZHAW for 2050 are impractical and must be reconsidered, and that other goals may need further development. Specifically,

- Current projections for improvements in power storage indicate that it is unreasonable to expect daily load equalization of a household or community level, and unreasonable to expect yearly load equalization on a cantonal or national level.
- The target of 80% of the cantonal population living by the guidelines of a 2000-Watt society by 2050 is unlikely to be achieved given that an insignificant number of people are currently able to live in this way.

To meet desired goals and move the canton closer to a Smart Energy Region, the report recommends the following steps. The cantonal government should:

- Provide funding for the installation of smart meters for monitoring energy consumption;
- Follow through with planned ecological tax reform by 2025;
- Follow through with planned CO_2 tax increases in 2020 and continue raising the tax over time;
- Increase subsidies on installation of renewable energies;
- Begin subsidies towards development of charging stations for electrical vehicles;
- Increase grants provided towards research of efficient energy storage technologies;
- Develop a process for auditing the energy efficiency of power plants;

Additionally, the report presents a number of areas for future research that should be undertaken by ZHAW in the further development of this project. Specifically, the goals for quality of life and power storage need to be re-evaluated to create a more plausible goal for 2050.

Chapter 1: Introduction

Our Interactive Qualifying Project (IQP) team has created a roadmap that can be used to develop the Canton of Zürich into a Smart Energy Region. This project stems from increased concern for climate change and the energy crisis, which are often cited as two of the most important issues to the world's upcoming generations. While some countries have strived to alleviate both issues, few standards exists internationally to enforce or guide other countries to follow in their footsteps. Many nations now entering their own industrial revolutions, or even developed countries facing tough economic times, contribute to negative impacts on the climate without such standards in place to protect it. However, some European countries, specifically Switzerland, have often been the frontrunners in establishing cleaner energy and taking actions to prevent drastic climate change (2014 EPI, 2015). Switzerland is aiming to reduce fossil fuel dependence and Greenhouse Gas (GHG) emissions, increase energy efficiency, and combat global climate change. To achieve those goals, the country is participating in the European Cooperation of Science and Technology (COST) Action Plan: TU 1104 Smart Energy Regions (SmartER).

COST is an organization that connects scientists and researchers across countries in Europe to provide European citizens the best innovation in the technology field. The SmartER Action Plan was developed by COST to be an interdisciplinary project that aims to develop a low carbon agenda that can be translated throughout Europe, and potentially the rest of the world. The Action Plan consists of 26 participating countries aiming to create and promote alternative and renewable energy resources and reduce Carbon Dioxide (CO_2) and other GHG emissions from the atmosphere (Lang, Geyer; 2014). It calls for increased focus on energy and the environment regardless of the current financial situation, since countries tend push those issues to the side during economic crises; the energy crisis is now being identified as more imminent and pressing. The participating countries recognize the difficulty in making a change to a low carbon agenda given the individual and economic dependence on a surplus of energy provided by fossil fuels and also given the economic situation of many of the involved and surrounding countries. They are trying to develop an energy plan that focuses more on demand-side changes rather than supply-side; if they can convince the user to use less energy it will be a lot easier to implement these new energy plans, sources, and policies. This action plan coincides with the comprehensive European 2020, 2030, and 2050 plans for emissions cuts and increased efficiency (Jones, 2014).

On behalf of Switzerland, and the Canton of Zürich, ZHAW submitted a proposal to COST for the development of the canton into a Smart Energy Region. The university has been working to develop various scenarios with impact variables, or components, that help to define what a Smart Energy Region in Zürich means. We worked exclusively with the ideal scenario:

- Strong increase in population development
- High share of tertiary education
- Very high quality of life
- 80% of the population living in a 2000 Watt Society lifestyle
- Taxes and subsidies exist to support energy and emissions related initiatives
- Stable and safe geopolitics
- Economic growth
- High energy prices
- Stable security of energy supply
- On the European SuperSmart Grid
- Decentralized energy supply
- High energy efficiency
- Energy storage that can adjust for monthly and yearly equalization
- An 85% decrease in CO_2 Tax and other GHG emissions
- No extreme catastrophes between now and 2050
- High share of renewable energies in energy production

These variables are more specifically defined and analyzed in the Data and Analysis chapter. Our work focused mainly in Work Package 4, one of 5 subsections to ZHAW's Smart Energy Project. "Validation of steps towards a smart energy region comprising an integrated analysis and scenario development." We were validating and evaluating the scenarios developed in the workshops that ZHAW held this last summer with experts from the various fields associated with a Smart Energy Region.

Over the past 7 weeks we have conducted extensive research and interviews in an effort to analyze each impact variable for its plausibility and consistency with the other impact variables to develop our roadmap. We conducted background research to understand the baseline from which we were making recommendations: We researched energy in Switzerland and Zürich; identified key stakeholders in the energy industry, specifically clean energy; researched the politics behind green energy; and developed an understanding for the social aspects related to making cultural changes such as the development into a Smart Energy Region. We interviewed experts to gain a better understanding of all of the impact variables and the ideal goals associated with them. We conducted specific research on the impact variables as well. From this analysis we came up with a plausible, consistent, sustainable, and desirable roadmap from 2015 to 2050 for the development of the Canton of Zürich into a Smart Energy Region.

Chapter 2: Background and Literature Review

This chapter is broken up into four sections. We start by discussing the general energy infrastructure of Switzerland. This sets the scene for energy in Switzerland, so from there we move onto the topic of the private sector. The private sector will powerfully influence the development of Zürich into a Smart Energy Region. Without private initiatives and technological developments, Zürich will not be ready to make this transition. That being said, industry often needs support in the form of policy and public initiatives. The third section discusses currently enforced policies as well as policies in development in regards to sustainable development and energy reform as well as general public initiatives related to energy. The final section is about the social aspects related to change, specifically in the energy field. All of these topics are interconnected and they all will affect one another throughout the implementation of the roadmap that we develop; it's important to understand these relationships before getting into the specifics of the work we have completed.

2.1 Swiss Energy Supply and Consumption

Switzerland relies on fossil fuel imports to supplement domestic energy production. Imported fossil fuels, in the form of oil and natural gas, make up half of the total energy supply. Domestic energy production consists of electricity generation from nuclear power and renewable energy (Energy Policies of IEA Countries, 2012). More careful energy management with a Smart Energy Region could reduce dependence on foreign fuels and decrease emissions.

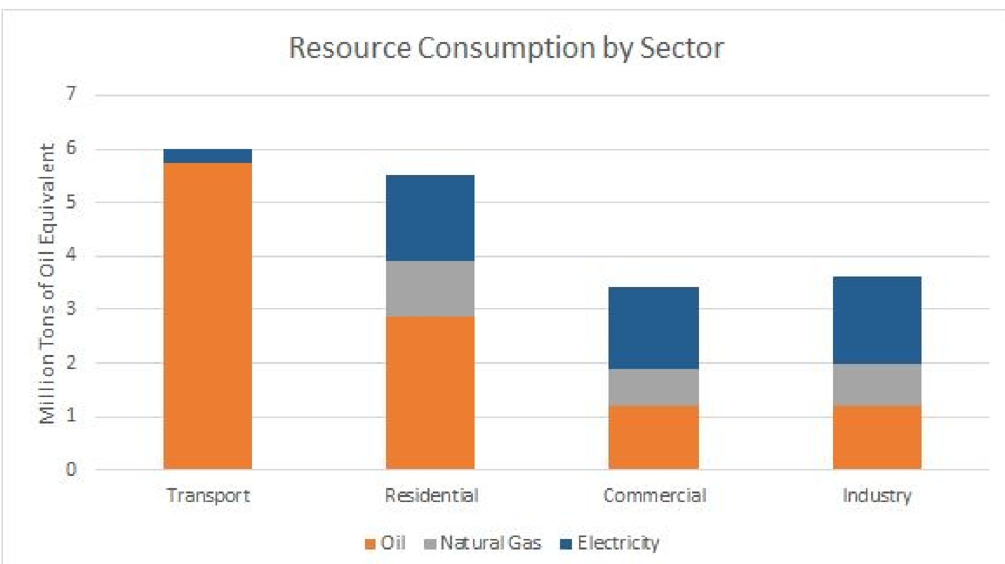


Figure 1: Breakdown of what different sources of energy are used for

Reducing dependence on oil remains a difficult problem, as the transportation sector relies on it heavily. While the residential, commercial, and industrial sectors all rely on oil, natural gas, and electricity in similar proportions, the transportation sector almost exclusively relies on oil. Much of Switzerland's train and tram networks are electric, but planes, cars, and other forms of transport mostly require oil-based fuels; electric vehicle penetration is low. Additionally, the transportation sector also consumes the most energy, resulting in a high dependence on fossil fuels for individual and commercial transport (Energy Policies of IEA Countries, 2012).

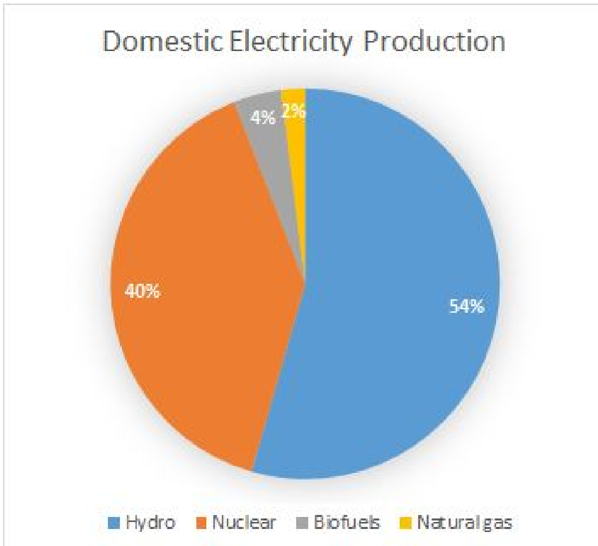


Figure 2: Breakdown of the electricity supply produced in Switzerland

Nuclear reactors, which currently provide 40% of all electricity generation, are set to be phased out entirely by 2050 (Energy Policies of IEA Countries, 2012). Following the Fukushima nuclear disaster, attitudes towards nuclear power have shifted towards a full shutdown of all reactors by the completion of the 2050 Plan (Nuclear Power in Switzerland, 2015). These 40% must be replaced with other forms of energy or demand must be reduced; better energy management in the Canton of Zürich could alleviate this problem.

Renewables are an important source of energy for Switzerland, and there is a large capacity for further development. More than half of Switzerland's domestic electricity production comes from renewables, of which 93% is produced by hydropower. Since hydropower is mostly unavailable during the winter, Switzerland exports surplus electricity in the summer and imports it in the winter, with a small net export of electricity each year. Estimates of available resources indicate that electricity from hydropower, biofuels, and wind energy could be increased by 2-4 TWh each, while solar power could have a theoretical maximum between 6 and 17 TWh (Energy Policies of IEA Countries, 2012). A Smart Energy Region would take advantage of all available sources of potential renewable energy.

With the changing energy landscape in Switzerland, it is more important than ever to find ways of minimizing demand, developing renewable energy sources, and improving energy infrastructure. By focusing on transforming the Canton of Zürich into a Smart Energy Region, these areas can be addressed in a way that benefits both the citizens and the environment. Numerous companies are already working on addressing many of these topics on various fronts, and the private sector is a major force in driving not only technological innovation in the energy field, but also energy efficiency standards and other initiatives.

2.2 Private Sector

2.2.1 Current Technology

Switzerland and the Canton of Zürich's current technology is enabling smooth progress towards the 2050 goals of the Smart Energy Region. Geothermal technology is being implemented on residential and commercial levels for heating and cooling in newly built and old renovated buildings (EGEC, 2015). Solar technology is being implemented on a residential and commercial basis for many of Zürich's buildings. Battery technology while currently limited is undergoing tests with a 15 MegaWatt Pilot Plant in the town Niederhasli (TFC, 2015). Biofuel technology is currently in its second generation of research. Biofuels are now becoming scalable to enter the marketplace and future large scale production through the company TA-Swiss (TW-Swiss, 2010). Wind technology, while limited in Zürich, is undergoing new turbine efficiency innovations through projects by AG Wind (AWP, 2015).

2.2.2 Technology Initiatives

Swiss Power's Digital Energy Meter Initiative is a key building block for the canton's energy efficiency. These meters serve to maximize customer knowledge about their personal energy use and supplier (SwissPower, 2013). Digital electricity meters can be read physically or from a mobile device, thereby allowing them to be read flexibly. The meters also make accessible to users their current and previous user data, which can educate them about their energy usage. The initiative's goal to further educate the canton's users on their current and past energy consumption should promote energy efficiency and reduce consumption.

Minergie is a quality label for building standards that ensures that new and modernized buildings maintain energy efficiency and reduce energy consumption. Minergie has several different modules encouraging a variety of options depending on commercial or residential building construction. Certification is met affordably and rechecked yearly to ensure "very high standards of low-, passive-, and net-positive-energy houses."(Minergie, 2015) In Zürich, the label has over 35,000 buildings that follow the Minergie standards (Minergie, 2015). Minergie certifications' expansion presents another method to reaching the 2000 Watt Society proposed in the goal of the Smart Energy Region.

EKZ's battery development project with the company ABB developed a 1-MegaWatt battery storage and pilot plant in 2012 and are currently testing it. This represents a possibility for widespread battery implementation in the future "for the operations of storing energy in the distribution network" allowing for long term greater energy efficiency (EKZ Battery, 2014). The plant testing in Dietlikon has an operating mode between 80-90 percent and can be integrated with hydroelectric power plants, photovoltaics, electric vehicles and other methods. The plants test results have been positive with the system working in stand-alone operation with office buildings and the photovoltaic systems for peak load management, reactive power control, and control reserve testing. The battery represents a possible energy storage alternative for Zürich's energy distribution network.

Alpiq and E-Vite Interest Group have invested in several electric vehicle plans, which is one major initiative that will help to expand Swiss mobility. E-Vite promotes the initiative E-Mobility that gives electric vehicles the ability to charge quickly at any time to undertake long journeys for free. The initiative has installed several charging stations including the Kölliken-Nord motorway (Alpiq, 2012). Alpiq's software, GridSense, is a 2015 pilot project for load management and forecasts ideal charging time for vehicles to avoid load peaks. The technology is currently being tested in all forms for electricity consumers to measure various parameters including electricity consumption and production and grid load for increased energy efficient usage (Alpiq GridSense, 2015). Alpiq's long term goal in promoting electric vehicle usage and energy use efficiency has the potential to heavily reduce carbon emissions and energy consumption.

2.2.3 Private and Public Interaction

Interactions between the private and public sectors have promoted technological, political, and research and development in energy infrastructure development. Their relations display the focus and need to develop renewable energy initiatives. Switzerland's Parliament voted in 2013 for a 25% increase in R&D funding and a substantial increase to funding of the private sector to continue to promote energy innovation. High investment allowed Swiss enterprises to lead the world in innovation, allowing the country to rank number one across innovation processes (GBI Index, 2014). Numerous private and public Swiss agencies involved in R&D policies promote private and public energy investments (The State Secretariat for Education and Research, Swiss National Science Foundation, Federal Development for Economic Affairs, the Swiss Science and Technology Council, SwissNex, etc.). SwissNex, a networking embassy initiative of the Swiss Government and Private Companies, connects, facilitates, and supports peoples and organizations in strengthening Swiss leadership. The embassy also hosts the Watt D'or competition to promote Swiss growth of energy efficient technologies.

Whether we mention the companies that form its base to the technologies they bring to market, the private sector holds obvious value to the consumers and the entire country. Businesses enable progress towards new energy innovations that bring the Canton of Zürich closer to its 2050 goals. While the private sector's breakthroughs represent what the general public sees, none of those breakthroughs would have come to fruition without the support of the public sector. Every policy put in place towards the movement towards clean energy and the Smart Energy Region have enabled countless new innovations and subsidies to support new businesses. Whether a company can even confidently invest in new future technology within the Canton of Zürich directly depends on the choices of politicians and their ability to acquire public support for many private projects. After seeing the current innovations and understanding the value the Public Sector has to the Private Sector it is crucial to learn about the Public Sector's policies.

2.3 Public Sector

2.3.1 Swiss Federal Government

The Swiss Federal Government is committed to the development of an "adequate, diversified, safe, economical, and environmentally compatible energy supply," (Energy Act). In promotion of this commitment, the Federal Council and Parliament have developed a long-term energy policy, Swiss Energy Strategy 2050, which will reform the energy infrastructure in Switzerland. The initiative offers national support for the implementation of our roadmap through the year 2050. In addition, this national initiative shows that the federal goals of Switzerland align with some of the aspects of our ideal scenario. In addition, there are already several energy and environmental policies in place.

Energy	**Environmental**
Federal Energy Act	Water Protection Act
Electricity Supply Act	Nature and Cultural Heritage Act
CO_2 Act	Environmental Protection Act
Nuclear Energy Act	CO_2 Act
Mineral Oil Tax	Gene Technology Act

(Table 1: Federal. Environmental and Energy Legislation)

These policies have been continuously developing as the call for a sustainable society increases, and they will act as the building blocks for legislation in the roadmap. The team evaluated these policies in order to identify potential changes which will contribute to the roadmap. Furthermore, we used these policies to identify the fundamental principles the Swiss Federal Government considers in its development of environmental and energy policies. Moreover, financial contributions are made by the federal government in promotion of: careful/rational use of energy, renewable energy, use of waste heat, wastewater treatment, and service/industry plants. Examples of financial contributions can be found in varying policies, below are examples of different financial contributions.

- Federal Energy Act: Provides grants which will can cover anywhere from 0-60% of eligible costs (40-60% is only for exceptional projects). This act offers support from the government for energy projects which could be implemented throughout the roadmap (Energy Act).

- Electricity Supply Act: Cost-covering feed-in tariff which covers the difference between the production cost and market price for consumers producing their own renewable energy (Feed-In Remuneration). Assures the individuals that they are only paying for production cost. Also, the act includes one-off investment grants for Photovoltaic projects (up to 30% of eligible investment costs) (One-off Investment).

- Swiss Energy Strategy 2050: Expansion of financial support for refurbishment of buildings from 300 to 600 million CHF (Energy Strategy 2050).

These and other financial commitments made by the government will act as key drivers for the project to expand upon. This information was gathered so that the team could establish their initial resources stemming from national regulations, taxes, subsidies, etc. The team then turned its focus specifically on the political resources within the Canton of Zürich.

2.3.2 Canton of Zürich

The Canton of Zürich, specifically the Office of Waste, Water, Energy, and Air (AWEL), is working alongside the federal government to achieve the goals set by the Swiss Energy Strategy 2050. In fact, the Canton of Zürich has adopted its own energy goals (Vision Energie 2050) they hope to achieve for the year 2050. The Canton of Zürich’s energy goals show that they will be providing assistance throughout the duration of our roadmap. In particular, the Canton of Zürich has accepted the primary legislation responsibilities regarding energy reform in the building sector (SwissEnergy Programme). This identifies one of the main challenges which will need to be addressed by the roadmap in order to progress energy reform within the Canton of Zürich.

Fortunately, the acceptance of responsibility by the canton indicates some potential for the development of political drivers. Moreover, the Canton of Zürich has committed to identifying sectors for the development of renewable energy by 2018. In fact, the initiatives which will take place in the specified sectors are to be considered as a national interest (Energy Strategy 2050). The collaboration with the national initiatives supports the development of renewable energy throughout the roadmap. Additionally, it is consistent with the energy goals established by the canton.

It was necessary for the team to evaluate the public sector within the nation and canton. Political initiatives, regulations, taxes, subsidies, investments, etc. are important driving forces behind change in a society. To quote Moritz Leuenberger, former head of the Swiss Federal Department of environment, "The difficulty in enforcing these standards has nothing to do with technologies. The necessary political will has to exist in order to ensure that this vision can be turned into reality, i.e., implementation plans, energy-efficiency programmes, promotion of the concept of the zero-energy house, heat pumps, biogas, low-consumption cars, hybrid vehicles, and so on. It is our political responsibility to translate this concept into practice." (2,000 Watt Society)

With the proper technology and policies in place, you can only create so much change. By understanding the social aspects that enable or paralyze a change in society, the team aimed to provide suggestions on how the roadmap could create a change in society which would drive progression towards the ideal scenario without the influence of external (technical, political) drivers. For this reason, the next section will cover the social aspects addressed within the project.

2.4 Social Aspects

2.4.1 Public Support

It is important to be clear in explaining the expectations of society when making changes such as developing the Canton of Zürich into a Smart Energy Region. Equally as important is understanding where society won't change or sacrifice on the status quo. "Innovation always involves a tension between what designers had in mind and what people believe they want" (Honebein, Cammarano, and Boice; 2011). The development of Zürich into a Smart Energy Region will be a give and take; there are aspects that are necessary to ZHAW's vision of a Smart Energy Region and there are some with a little more room for change. Therefore, understanding where there is more flexibility will ensure smooth implementation of the roadmap.

Keeping the public informed and extensively educated about energy initiatives will increase support and eventual success of those initiatives. More specifically, it's important to involve the general public in their own energy consumption (Using Data to Drive Efficiency); keeping them involved and informed helps when energy initiatives call for reduced consumption. The more they know about their own situation, the easier it is for them to make the necessary changes, or to express their disinterest in those changes with solid data to back up their claim. This also makes it easier for the energy industry to inform the public further about ways to save energy, and therefore money, because both parties will be knowledgeable about the customer's energy usage. The general population also needs to be involved with developing these kinds of initiatives (Energy Roadmap 2050, 2012). When people feel more involved in proposing the change they need to go through, it's much more likely that the change will be more popular down the road when it is going into policy, for instance.

In general, the people of Zürich support energy initiatives similar to the Smart Energy Region project when they are informed about them and when the initiatives are backed by major governmental parties. In 2008 they voted in favor of working towards a 2000 Watt Society and there is extensive literature explaining clearly and simply what this kind of society looks like (2000-Watt Society). Swiss Parliament denied the passage, 80% against 20% in favor, of an ecological tax reform as proposed by Switzerland's Green Party, which was complicated and not properly explained (Geiser, 2015).

2.4.2 2000 Watt Society

The 2000 Watt Society is a concept that theorizes an average energy usage that is both sustainable and desirable to the general population. The lifestyle, as defined by the Federal Institute of Technology in Zürich, includes a reduction of the amount of energy consumed to 2000 watts, or 48 kWh/day, as well as a cut in CO_2 and other greenhouse gas emissions to 1 ton per person per year. Jose Goldemberg and eventually scientists at ETH in Zürich discovered that any amount of energy consumption above a certain threshold, in this case 2000 Watts, no longer improves quality of life, a concept commonly referred to as sufficiency (2000-Watt Society).

It would be a lot more difficult to convince the general population to convert to this kind of society if it involved any kind of appreciable decrease in quality of life. Experts claim that the technology necessary to live in this kind of society is already here, now it is just a matter of putting policies and programs into place that make it conducive for society to transition to this lifestyle change. This society has been discussed for years now and it's been voted into the constitution as a goal that Zürich should strive for, but substantial changes have yet to be made. It's clear that the government of Zürich needs to incentivize these changes and make the environment right before the general population feels comfortable moving towards this target.

Understanding all of these aspects of the energy environment and the public's thoughts about it was vital for us to develop our methods for creating the roadmap to develop the Canton of Zürich into a Smart Energy Region. The social aspects alone were essential to creating a roadmap that could be accepted and supported by the citizens of Zürich. This background research shaped how we developed the rest of the project, which is reflected in the following sections starting with the methodology.

Chapter 3: Methodology

At the completion of the project, we created a roadmap which could develop the Canton of Zürich into a Smart Energy Region by the year 2050. With this goal in mind, the team established intermediate goals which helped track the group's progression throughout the project period. To develop these goals, the team established a list of research questions vital to the creation of the roadmap. All of the intermediate research questions aimed to help answer our main research question: How do we create a consistent, plausible, sustainable, and desirable roadmap for the development of the Canton of Zürich into a Smart Energy Region? The intermediate research questions are as follows:

1. How do we define the impact variables and their relationships to one another?
2. What have other regions implemented which might prove useful?
3. What is the current status of the energy infrastructure in the Canton of Zürich?
4. What resources (technology, government authority, etc.) are available to implement throughout the roadmap? Are they reliable?

This provided the team with a starting ground from which they could implement different methods to address each question. The basic methods included interviews, surveys, and independent archival, social, and scientific research. This work provided the information needed to develop a consistent, sustainable, and desirable roadmap that addresses four key components: technology, industry, policy, and society.

Interviewing various experts helped us to analyze impact variables and their relationships with one another, a necessary step to fully understand the desired Smart Energy Region as defined by ZHAW. Without a concrete understanding for the components of the desired scenario the team would have no sense of direction. Before we arrived in Zürich, the experts had gathered at ZHAW for workshops dedicated to developing the impact variables and the various possible scenarios that ZHAW would like to attain at the end of the roadmap. Thankfully, our sponsors at ZHAW provided us with the contact information of each expert and their associated expertise/impact variable. The interview process provided valuable insight into the interconnectedness of all of the impact variables, helping us to understand what it will take to reach the desired scenario. For example, we needed to understand how bringing 80 percent of the population to a 2000 Watt society fits in with maintaining or improving the quality of life. In this case, the interviews allowed experts associated with sociology and psychology to share their opinions with us on what aspects of quality of life are crucial. While specific research on each impact variable could have given us comprehensive knowledge of all of the variables individually, speaking with experts who understand the context of the project helped us to avoid isolating them. This made it easier to treat all of the variables as one scenario, which is important as they all affect one another in many ways.

We evaluated various roadmaps to gain an insight into the effectiveness of different implementation strategies. Researching other roadmaps helped us to understand the drivers and barriers of similar initiatives. Examples of drivers and barriers include push back from the government or public on initiatives, technologies not being available when needed, or resistance from industry to adapt to new policies. Understanding these variables gave us some of the tools necessary to develop a plausible roadmap: if we could identify areas where there may be backlash or resistance before implementation, we could potentially account for that and avoid it as much as possible. Although other nations differ from Switzerland in many ways, our assessment of their roadmaps gave us insight into typical areas of resistance and support in regards to changes related to smart energy initiatives. For example, the Copenhagen roadmap that was reviewed provided different strategies for addressing energy reform in a city such as the use of district heating among new/renovated houses to promote greater energy efficiency.

Through archival research of the Zürich energy department, AWEL, and energy companies, such as Swissgrid and Swiss Power, we evaluated the Canton of Zürich's energy infrastructure to gain an understanding of the current state which we would be suggesting changes to throughout our roadmap. Addressing current technology, energy strategies, and lifestyle habits provided the information needed to understand the initial state of the roadmap. From there we made an assessment of what strategies for progress were sufficient in achieving the goals of our sponsors and what strategies needed to be improved. In addition, interviews with experts associated with the energy department and energy companies were used to gather more information. Not only did the experts help explain current initiatives, they also provided and translated documents of interest to the group. For example, the policies and budget of the energy department were located by the team, but the documents were not available in english and often referenced other documents. It was not until the team interviewed an expert from the energy department that they were truly able to understand the data within the documents.

Through our various interviews and research of the Canton of Zürich, we also developed an in-depth knowledge of the resources which would be most readily available throughout the implementation of the roadmap in order to assure the highest level of plausibility. The interviews provided information on who has control over the various impact variables we are trying to manipulate. Specifically, the team identified resources corresponding to policy, industry, technology, and society. The national and cantonal energy policies and initiatives were used to identify short-term and long-term projects, legislation, and goals. These governmental resources helped to identify methods of funding energy reform, current energy laws, suggestions for the progression of energy reform, and the energy goals driving political reform. By identifying trends in the industrial sector of the canton, we can understand existing plans for energy development in the area and assess the plausibility of potential milestones. Understanding the currently available technology in the energy sector, as well as initiatives and developments in energy technology, gave us the background needed to know where further developments are needed in order to achieve the goals for 2050. The general public drives a lot of what happens in policy, which means that in order to successfully develop the Canton of Zürich into a Smart Energy Region, the public needs to be educated and involved. We needed to understand how to best go about including the general public in the roadmap to achieve their approval and ongoing support.

Chapter 4: Data and Analysis

4.1 Impact Variables

In this section of the chapter, we broke up all of the impact variables into three or four subsections: Definition, Priority, Analysis, and Recommendations. Variables with a low priority do not have as much analysis because these variables did not contribute significantly to the project; variables with a medium priority are important to the development of a Smart Energy Region, but are not necessarily within the control of the cantonal government or ZHAW; variables with a high priority are critical to the development of a Smart Energy Region and have clear achievable goals that need to be met to ensure success.

It is also important to note that some of the information we gathered was from interviews that we conducted with various experts who have worked with ZHAW on this project in the past. These experts have requested that we do not quote them, so all information from the interviews will be from anonymous sources. To that end, all data presented in this section that are not noted or cited otherwise were collected in our interviews with experts relevant to the impact variable that the data pertains to.

Population Development

Definition:

Population development is defined as the resident population of the Canton of Zürich, or more specifically the growth of the population; this takes into account birth and death rates as well as intercommunal, intercantonal, and international migration. The ideal scenario for 2050 shows strong population growth from 1.45 million to 1.85 million citizens in the canton, a higher proportion of foreigners, and a higher proportion of people aged 65 and up.

Priority: Medium

The canton should watch population development, but it is not within their control. Increasing the population at an unnatural rate could be detrimental to some of the other goals that have been set. For example, quality of life is bound to be adversely affected if the canton starts heavily promoting to other cantons and countries that they should move to Zürich and the population density rapidly skyrockets. Based on the ideal scenario's nature that was proposed, this impact variable seems more like a prediction than a goal that the canton should work towards.

Analysis:
The current population development statistics are conducive to the changes proposed in the goal. As of 2013, the population increase between 2010 and 2013 was 3.8%, which is an average of 0.95% per year. The proposed population increase would be 27.59% over 35 years, which is an average of 0.70% per year. In 2013 the proportion of the population that is foreign was 25.4%, the crude birth rate was 11.3%, and the crude death rate was 7.6% (Key Figures, 2015). That data all suggests that supplementary resources or efforts would be unnecessary to achieve their goals for population. In fact, if population growth continues at the rate that it has been they will surpass their goal by 2050.

According to our interviews with experts, reasonable population density is an important aspect to quality of life, especially in the cities. While the expert did say that the citizens of Zürich would prefer increased population density in the city as opposed to the rural areas, that is still generally unpopular; there is a certain level of population density that is no longer acceptable in the eyes of the Swiss. Increased density affects a lot of aspects of everyday life such as public transit, car and foot traffic, availability of goods and services, etc. This was important for us to consider when we were working with this impact variable because in order for any of the plans related to this project to be carried out, the general public has to be in support of the project as a whole.

Recommendation:
We do not recommend resources from the development to a Smart Energy Region be heavily focused on population development, as the current standards appear to be sufficient in reaching the ideal scenario. There is little that can be done to control this impact variable, but it does have value in that it could affect other impact variables associated with the project. We recommend the use policy/guidelines within the government to regulate population density within the city, but to isolate density increases to these areas, and to avoid development in the rural areas of the canton. It seems like the "least of all evils" is to focus population growth in the cities, but it could cause problems with services like public transportation if they are not maintained and updated to keep up with the growth.

Level of Education

Definition:
Level of education is defined as the percentage of the residential population aged 25-65 years with an educational attainment on the tertiary level, which includes universities and higher vocational training. The ideal scenario for the level of education of Zürich in 2050 is that more than 60% of the population is educated on the tertiary level. For reference, it was at 36.4% in 2012 (Key Figures, 2015). This is expected to happen as a result of an increased number of high

school graduates as well as migration from within Switzerland and abroad of highly educated individuals.

Priority: Low

Resources should be more aimed towards making sure that the level of education needed to achieve the goals is maintained. Basically, the level of education should match the necessities of the available jobs. If this project creates jobs that require higher levels of education, the statistics for the canton should reflect that. Increasing education with no purpose or no demand from the economy will not create solutions. In our research and interviews we have not found any correlation between energy usage and level of education. In fact, in our interviews experts claimed that there was in fact no correlation, and suggested that what is more important is that the level of education matches the needs of the available jobs.

Recommendation:

We recommend that less focus be put into raising the percentage of citizens with a tertiary level of education, and perhaps to put more focus into educating citizens about the initiatives that will be implemented over the next few decades. Our research indicates that Swiss citizens typically are in favor of clean energy and environmental initiatives, but only when they are sufficiently explained and supported by major governmental bodies. It is important that people understand the changes that are being made, as well as the changes that they may have to make, so that the implementation goes smoothly. We also recommend that instead of arbitrarily trying to improve the level of tertiary education, the canton focuses more on ensuring that the level of education matches the needs, as suggested by our interviews.

Quality of Life

Definition:

Quality of life is defined as level of happiness or satisfaction. It is dependent on personal attitude and the social and cultural environment a person is living in and can be influenced by the individual as well as various external factors. The 2050 goal for the quality of life of the Canton of Zürich is that there is a high quality of life in all age groups, with an emphasis on people between the ages of 26-65.

Priority: Medium

Without at least the preservation of the current quality of life, this project will not receive support from the general population. The canton currently has a very good quality of life that needs to be maintained throughout the process of its development into a Smart Energy Region. According to a Mercer Quality of Life survey, the city of Zürich has had the highest quality of life until it was surpassed by Vienna in 2012. Additionally, in a European survey called the

Urban Audit, it was revealed that 98% of the participants were either satisfied or very satisfied with their living situation in the city (Canton of Zurich). These are strong indications that the people who live at least in the city like the current status quo of life in Zürich, and anything that disrupts that negatively could result in a loss of support in the Smart Energy project. In designing our roadmaps and recommendations for each impact variable, quality of life was of the utmost importance to maintain if not improve.

Analysis:

In our interviews, we found that the experts agree that people enjoy not only living in the city of Zürich, but the canton as a whole. They also agreed with our initial notion of the necessity to maintain that satisfaction to ensure support from the general population for the development of the canton into a Smart Energy Region. One concern the experts brought up was the question of what people would prioritize as aspects of quality of life in 2050; it is hard to say or predict exactly what will constitute comfort and satisfaction in 2050, just as it was impossible to consider the same for today in 1980.

Recommendation:

Our recommendation for achieving the 2050 goal for quality of life is that it is continuously monitored with the various surveys given out locally and internationally, and adjustments to the plan be made accordingly. The general public should be involved in this entire process because it not only helps to educate them about the changes that are being made and what is expected of them, but it also makes it more likely that they will support the initiative in the long run. It is impossible to predict what factors will play the major roles in quality of life over the next 35 years: if energy becomes a more prevalent issue because of shortages or significant effects on the climate, these issues could be pushed to the forefront of quality of life; if technology progresses in the entertainment industry, that could be more important to people than saving energy and being energy efficient. The most important thing is that the quality of life be maintained in such a way that the other goals of the Smart Energy Region are unaffected.

Way of Life

Definition:

Way of life is defined as a combination of behavior, attitude, and morals or values. It can be influenced by age, level of education, job (title), gender, and social status, just as a few examples. In the context of the development of the Canton of Zürich into a Smart Energy Region, way of life specifically pertains to the 2000 Watt Society. In a 2000 Watt society, the individual only consumes 2000 Watts of energy and emits a maximum of 1 ton of CO_2 per year. The ideal scenario for the way of life for the population of Zürich in 2050, as laid out in the beginning of the project, is that 80 percent of the population will be living in this 2000 Watt society.

Priority: High
It is necessary to implement these types of changes into society in order to take advantage of the other changes that will be implemented. However, our data and analysis will show that aiming for 80% of the population to be living in a 2000 Watt society may be too far-reaching.

Analysis:
The City of Zürich has already begun work on transitioning to a 2000 Watt Society. The city has set building and renovation standards, proven the effectiveness of those standards in practice, begun providing energy coaching for all real estate/land owners in the city, been working with small to medium-sized companies to help them make optimize their energy consumption, and started energy consulting, just as a few examples of the work that has already begun (2000-Watt Society). The government's investment in the transition is evident in these actions and services. The city has laid out a roadmap for itself to be developed into a 2000 Watt Society by 2050. However, while it is easy to provide economic incentives to companies and other high energy users, doing so for the individual who pays a small household electricity bill every month is not as effective (2000-Watt Society). That being said, the bulk of the work necessary to realize this goal of a 2000 Watt Society is in figuring out how to incentivize people to consume less and use the energy they are consuming efficiently.

In the interviews we conducted with experts related to the 2000 Watt Society, it was clear that the general outlook for the ideal goal was negative. Most experts feel that the current energy infrastructure is not conducive to such a significant shift in the way of life of the citizens of Zürich. They also agree that in order for the public to feel inclined to move towards this kind of society, the government needs to support and drive initiatives that make it convenient for anyone to convert. A common theme we discovered when we asked how to make changes that favor a transition to the 2000 Watt society is that the government needs to take small steps; if it's decided now that the Canton of Zürich will reach 80% participation in a 2000 Watt society, we are looking more at an energy revolution rather than evolution, so to speak. People will feel the effects of the change more significantly if it is forced on them through policy and mandates and restrictions. However, if smaller changes are made and the citizens of Zürich are involved in the development and implementation of these changes, they are more likely to receive general support. There are important changes that need to be made before the general population is expected to be able to participate; for example, buildings in the canton are general very old and many have strict restrictions on if and/or how they are renovated. This leads to significant inefficiencies that make it much more difficult to live on an average of 2000 Watts.

Depending on who is asked, the outlook on the development of Zürich into a 2000 Watt society can be positive or negative. Stadt Zürich takes the optimistic view whereas the experts we interviewed took a more pessimistic view. In looking at the facts beyond the biases of the various sources of information, it seems that there is a significant amount of work that needs to get done before the Canton of Zürich is fully ready for this kind of culture change. It is more than just changing energy policies and being more efficient. It involves people actively choosing to consume less, use public transportation over private cars, purchase products made with materials that do not require as much energy to manufacture, and have an active role in their energy consumption; it involves companies choosing to take advantage of the incentives provided, use the most energy efficient material rather than the cheapest one, become more knowledgeable about their overall energy usage and to optimize it. As a society, people are not used to having such an active role in energy. Up until now, the thought behind energy was that the more that was available and used, the higher the quality of life of a given region. This concept challenges that deep seeded belief.

Recommendation:
We recommend that ZHAW re-evaluate the goal for having 80% of the population be living in a 2000 Watt Society by 2050. There are currently zero people living within the criteria. Based on our research, there are a variety of actions that need to be taken before it is viable for the general public to participate in this society. Government should increase funding for renovating old buildings and should reevaluate the number of buildings protected by historical preservation. There should also be incentives and/or punishments put in place for renovating privately owned buildings. This is especially necessary for the residential buildings.

Gross National Income

Definition:
Gross National Income is defined as the sum of all a country or a canton's income including Gross Domestic Product (GDP), Gross National Product (GNP), Gross National Income (GNI) and income from abroad. The ideal scenario for 2050 is to achieve 3.8% growth per annum of the GNI.

Priority: High
The Gross National Incomes stability and growth ensures the positive outcomes across numerous other variables who would lack any financial backing to meet 2050 goals if the GNI collapsed. However, heavy increases to 3.8% are hard to predict or manage due to the numerous variables that make up the Gross National Income instead focus should simply be that the GNI maintains a positive trajectory.

Analysis:
Gross National Incomes desired growth of 3.8% per annum currently is implausible due to the lack of control over all the variables that make up the GNI. The GNI, while just a single impact variable, is built over several expansive variables that are very hard to heavily control and manage from the income from abroad to the gross domestic product. The difficulty in managing all the pieces collectively makes it improper to claim anything concrete towards growth beyond speculation (Economic Data, 2015). Switzerland itself maintains a GNI growth hovering at 1% a year since last openly displayed in 2013 with a 1.06% increase (WorldBank, 2013). Switzerland's citizens and by extension Zürich have experienced a per capita growth hovering at 1% per annum, and specifically 1.07% in 2013 (WorldBank, 2013). Beyond the observation of growth currently being 2% lower than the desired scenario GDP was also analyzed. GDP, one internal influence on GNI has maintained a growth hovering at 1% to 1.5% over the last five years making it seemingly impractical for the 3.8% per annum growth (GDP per Canton, 2012), (WorldBank, 2013).

Recommendation:
The Gross National Income requires no immediate recommendations towards increasing its per Annum average growth of 1%. However, further studies into the variables of GNI are necessary to understand how a growth rate above 1% can be achieved for the Gross National Income.

Energy costs

Definition:
This impact variable addresses the changing cost of energy for renewable and nonrenewable sources. The original target set by the project was "strongly increased costs," with an increase of 20% for all energy and 100% for fossil fuels by 2050 compared to 2015 levels.

Priority: High
This is a high-priority variable due to the significant effect that energy costs will have on the balance between renewable and other energy sources. Adoption of renewable energies is tightly connected to this difference in cost.

Analysis:
While the target scenario specified precise cost increases of 20% on energy overall and 100% on fossil fuels by 2050, it is very difficult to predict the future of energy costs with any significant degree of accuracy.This has been showcased by recent geopolitical events that have significantly dropped the price of oil, making renewables less attractive in the short-term. The consensus of

experts we interviewed has been that price changes are exceedingly difficult to predict, and attempting to plan around them is futile.

However, long term trends must be kept in mind when developing the roadmap. As fossil fuels are limited by their nature as a nonrenewable resource, their price must rise in the long-term. However, how significantly this will be felt within the next 35 years is uncertain. On the other hand, as technology improves, renewables are predicted to become cheaper, leading to greater adoption of them. Specifically, technology improvements in power storage, photovoltaic cells, and electric vehicles would all incentivise a move towards renewable energy sources.

Recommendation:
Our recommendation is to accelerate the pace of this price differential by artificially raising costs of non-renewables and lowering costs of renewables. This is already set to occur by 2050 with new taxes that will be placed on consumption of nonrenewable forms of energy beginning in 2025. We recommend steadily increasing these taxes as necessary to drive the shift towards renewables; additional subsidies for renewable energy would also be effective.

Security of Supply

Definition:
The security of supply can be defined as a continuous, constant, cheap, and reliable supply of energy to a region. The ideal scenario aims to maintain the current high level of security of supply for the canton through 2050 and the future.

Priority: High
Currently there is no threat to the security of supply. However, security issues may begin to arise due to slow infrastructure development in critical locations within the canton. The variable maintains a high priority due to the fact that a disturbance to the security of supply can jeopardise the ability for the canton to function.

Analysis:
Switzerland's diverse energy suppliers and the canton's renewable energy initiatives have made the country and canton's security of supply only threatened by slow critical infrastructure maintenance. The country itself, which produces no crude oil, receives imports from numerous countries, thereby increasing security in case one pipeline is jeopardized. Several of Switzerland's largest supplier include Belgium, Italy, France, the Netherlands, and Germany (IE, Supply Security, 2014). Switzerland follows the same security mechanisms towards gas with multiple importers including Germany, Netherlands, France and Italy. The canton itself has several power companies, including Swiss Power, which distribute 100% of their power through

renewable sources, thus making numerous municipalities nearly immune to supply security threats.

Switzerland, and the Canton of Zürich by extension, have multiple emergency security measures in place. Crude Oil security is ensured through emergency oil stocks as an emergency response policy, which can be complemented by demand restraint measures. Switzerland and Zürich's gas security are in compulsory stocks in heating oil for fuel switching. A major gas supply disruption can be then mitigated through a switch from gas to fuel oils using dual-fuel gas installations (IE, Supply Security, 2014). These two security measures allow the canton and country to be fully secure should any immediate crisis occur due to loss of power.

The canton's supply policies enable consistent security, however, the ability to maintain the infrastructure on a level that will not threaten security over time is necessary. Currently, municipalities' abilities to veto new infrastructure or work can deter projects for upwards of twenty years. No current policies or authorities allow power companies to bypass a veto to maintain critical infrastructure. The deterrence has the ability over time to make maintenance not be handled at a fast enough rate to ensure constant supply security through the canton.

Recommendation:
We have concluded on the basis of our interviews with experts several recommendations to the security of supply to continue to ensure a fully secure system. Current mechanisms for supply security are efficient , but we advise to observe future geo-political stability in case new emergency security methods are necessary. A Fast-Track Authority is also necessary to be implemented to allow power companies to overrule Municipalities to ensure the repairs and maintenance of infrastructure that is critical to the supply security.

Development of the Power Grid

Definition:
The Development of the Power Grid can be defined as the grid's continuous development based upon renewables and future technological breakthroughs. Within the scope of the 2050 Smart Energy Region, the development of the power grid would lead to regional micr
grids and European Super Smart Grid.

Priority: Medium
While the development of the power grid is important, it is implausible for the canton to exert influence on grid implementation on a European level or to install micro grids without new technological innovations. Focus should be passively changed to observing power transmission

technology innovations and what is seen in other variables' improved grid maintenance strategies.

Analysis:
The Canton of Zürich's desired target for the European Super Smart Grid (ESSG) is impractical due its massive scale where the canton has no control over its development. The ESSG itself alone is a multi-country initiative that requires substantial investments on an international scale. The Canton of Zürich may be marginally affected if at all when the grid is eventually created. The canton itself will also be unable to have any major influence on its creation. Furthermore, local power companies will see little to no change to how they currently work and process power distribution. The ESSG secondarily requires advancement of power transmission technology and its implementation on massive scale, all of which is handled by the countries and not by their individual regions.

The Development of the Grid itself is also not a necessary focus, but focus is necessary towards continuous grid maintenance and the Renewable Grid Initiative to increase the proportion transmission systems for renewable sources (RGI, 2013, European Collective Goals).The grid itself currently suffers lack of efficient repair mechanisms due to observable veto powers discussed in grid decentralization (See Decentralization of the Grid and Security of Supply for more information). The development of microgrids as self sufficient grid networks for current implementation are inefficient and technology currently doesn't exist for its competitiveness against the centralized grid structure. Energy Storage technology innovations are necessary for this development to take place (See Power Storage for more information). However, transmission systems are necessary to be expanded within the Canton of Zürich that are capable of incorporating electricity from renewable energy sources for decentralized power generation growth.

Recommendation:
We recommend that policies for increased funding be instituted to support expansion of transmission systems to accommodate future growth of renewable energy sources. Observation of technological breakthroughs is also advised in the case microgrids become a viable and efficient technology.

Decentralization of the Energy Supply

Definition:
Decentralization of Energy Supply is understood as the expansion of renewable power, causing increased decentralization through a change from consumer to prosumer, bidirectional power

flow, and the constructed of self sufficient micro-grids. The definition itself fully exemplifies the desires of the Smart Energy Region project by 2050.

Priority: High

Decentralization is a crucial requirement for meeting 2050 Smart Energy Region goals because it allows for long term higher grid efficiency through higher personal renewables usage. While microgrids still lack efficient technology, the adoption of photovoltaics will reduce energy consumption over time and increase the feasibility of future power storage implementation.

Analysis:

Decentralization is a gradual change where recommendations should be directed to small scale improvements and policy change rather than impractical, self-sufficient grids. The first major step towards feasible decentralization is the Non-Renewable Tax Implementation projected for introduction in 2025, which will steer consumers towards renewable energy sources. Following the Tax, increased subsidies policies are necessary towards small-scale renewable energy implementations. Currently, photovoltaics are the primary source of financially viable sources consumers can own and use to produce their own power.

Centralized infrastructure is currently far more efficient than microgrids and is continuously updated. Furthermore, technology is not in place in power storage to support any current self-sufficient micro-grid. More information is available in the power storage section. Should technological breakthroughs occur, focus should be directed towards diversified power storage for increased efficiency on the grid through self-sufficient microgrid production.

Recommendation:

After analysis and discussion with experts, we have concluded there is no recommendation beyond the recommendations currently being advised through other impact variables there is little else currently necessary. We advise observation towards technology breakthroughs that can allow for self-sufficient microgrid creation and expansion.

Energy Efficiency

Definition:

This variable addresses the efficiency of various parts of the energy production, transmission, and consumption network, with a focus on efficiency of power plants. Within the scope of the Smart Energy Region project is an increased understanding of areas of energy loss and the improvement of these systems to improve efficiency.

Priority: High.

Improving efficiency of existing systems is an often straightforward way of reducing waste through reduced consumption or increased production. In many cases, this can be easily accomplished through upgrading of existing infrastructure with new technology without the need for the development of new technology.

Analysis:

While many energy companies are describing the various energy efficiency measures they are implementing, there are few third-party assessments of the state of power plant efficiency. For instance, Alpiq describes the various new technologies they are implementing in their hydropower plants to improve efficiency and decrease waste through large projects to replace turbines with newer designs (Alpiq, 2015). Many companies naturally strive to improve efficiency as a matter of decreasing costs, but in many cases the cost of upgrading exceeds the amount that would be saved and so the inefficient plants remain in place. Unfortunately, assessing plant efficiencies currently relies on self-reported information by the plant operators, typically presented in a way to show the company in the best possible light. No third-party studies exist to analyze areas of inefficiency.

Recommendation:

Our recommendation is to perform a survey of all power plants and transmission systems in the canton to gather data on areas of inefficiency. Such a third-party audit would provide the canton with a clear picture of where energy efficiency can be improved, and what measures could be put into place to increase it. Such a survey would ideally also show how much it would cost to improve each aspect that is described, allowing the canton to encourage companies to upgrade technology through subsidies or other incentives.

Power Storage

Definition:

The power storage impact variable addresses the feasibility of storing energy for the purpose of load equalization. Load equalization allows surplus power to be stored, and then retrieved when there is a deficit of power production. This capability is especially important for intermittent power sources that cannot always provide power, including renewables such as wind and solar energy. The Smart Energy Region project presented a goal of achieving both daily and yearly power equalization within the scope of self-sufficient communities.

Priority: Medium
Improved power storage technology would have a significant impact on the feasibility and efficiency of decentralized power production. However, this technology improves slowly and current technology is insufficient.

Analysis:
The goal of daily and yearly load equalization for small communities presented in the desired scenario is infeasible using current technologies or ones that can be expected to develop in the near future. Neither hydropower nor electrical batteries provide a solution that could be used on a small scale for self-sufficiency.

The current primary method of load equalization in Switzerland is hydro storage and pumped-storage power plants. Storage hydro plants work by storing water in reservoirs and increasing water flow and energy production as necessary to meet demand, such as during peak hours. On the other hand, pumped-storage hydro plants use excess energy production from other areas to pump water into a higher reservoir to store potential energy; this energy can then be converted back into electricity during energy deficit. Currently, storage and pumped-storage hydro plants produce the most power during daytime and evening peak demand, while nighttime electricity is stored. However, as solar power takes a larger share of the market, hydro plants will begin to produce more during the nighttime and store energy during the day when solar power is plentiful.

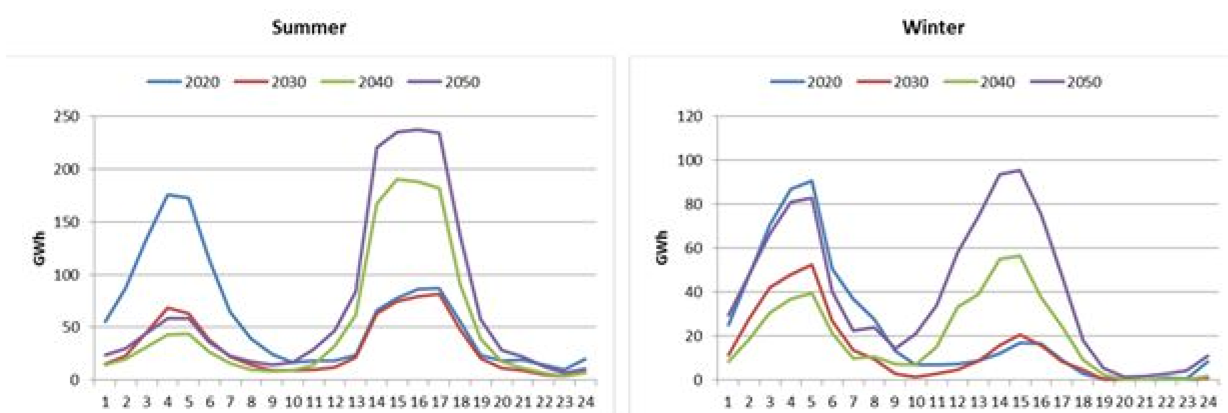


Figure 3: Daily energy production projection for 2050 (Schlect and Weigt, 2014)

Daily load balancing using hydropower is already in place on a national level, but it is infeasible on smaller scales due to the large facilities required. However, seasonal load balancing using hydro is impractical and inefficient for several reasons. Hydro storage and pumped-storage plants do not have the capacity for storing energy between seasons; even though summer production will increase in the future and winter production will remain scarce, there is no opportunity to increase storage limits to balance summer surplus with winter deficit. Optimizing energy production on the scale hours through frequent storage and release, as is currently done, is also more efficient than performing one transfer a year, as it can be used to respond to daily price fluctuations.

An alternative method of storing energy is in the form of batteries, which can be installed in a home or community. However, electrical batteries are currently expensive and don't have enough capacity to be efficient for daily equalization of power storage; they cannot store a full day's worth of electricity consumption, which would be necessary when intermittent power is unavailable. Since such self-sufficiency is attainable currently or in the near future, households and communities must still depend on the electrical grid. With such a dependency, it is simply more efficient and cost-effective to send generated power back to the grid immediately on production rather than attempting to balance load locally. New developments in battery technology, such as Tesla's Powerwall household battery, are increasing the capacity and efficiency of batteries, but daily equalization is still not possible and experts do not believe it will be possible soon. Yearly equalization, to balance seasonal fluctuations, is likely to remain impossible on a household or community level well past 2050, barring a potential breakthrough in this technology.

Recommendation:
While we believe the goals as stated are unlikely to be met, we believe that further funding should be provided in the form of grants towards research laboratories developing power storage technologies. Additional funding would lead to a more rapid development of this technology, increasing the feasibility of localized self-sufficiency and increasing the effectiveness of local energy production.

Catastrophes

Definition:
Catastrophes are defined as an occurrence of a technical, natural, or health related disaster. Any kind of major catastrophe would severely hinder the Canton of Zürich's ability to be developed into a Smart Energy Region because necessary resources, such as money and governmental support/attention, would be diverted from that development to handling the incident. ZHAW has estimated that no extreme catastrophes, or at most one every 10 years with a maximum of 5000 deaths, is the ideal scenario in which the Smart Energy Region can be developed.

Priority: Low

There seems to be little that anyone can do to prevent the occurrence of a major catastrophe, and if one were to occur it makes sense that available resources would be directed towards relief from that catastrophe.

Recommendation:
We recommend that there not be much time and effort put into accounting for catastrophes in the context of developing the Canton of Zürich into a Smart Energy Region. At any time, any number of natural disasters could occur; any disease, new or old, could surface; any powerplant or energy technology could malfunction in a way that causes the public to lose trust in its safety. There is a higher risk of natural catastrophe near mountains because of the risk of avalanches and flooding in the valleys (From interview). Based on the information gathered in our interviews and research, it did not make sense to go through and categorize all possible catastrophes and come up with plans for each one. There is no way to avoid a catastrophe or to predict how much time is going to be needed to bounce back from the damage caused. The only action that should be taken is the normal practice the canton employs to prevent as much damage as they can.

Renewable Energies

Description:
Renewable energies refer to the renewable energy sources which contribute to the overall energy consumption within the Canton of Zürich; that is, the energy sources which are not depleted of their energy potential as they are used. The ideal scenario presented to our team by ZHAW aimed to have renewable sources contribute 25% of the energy demand for the Canton of Zürich, excluding hydropower. With the addition of hydropower, 90% of the overall energy demand would be met by renewables. Moreover, the less ideal scenario called for the same percentage of hydropower, 65%, with only 15% from other renewables.

Priority: High
The expansion of renewable energy sources in some way directly or indirectly affects most aspects of this project. For this reason, we have assigned this impact variable a high level of priority throughout the continuation of ZHAW's work. For example, CO_2 emissions cannot be reduced unless the dependency on fossil fuels decreases, either through improved efficiency or alternative energy sources.

Analysis
To start, we evaluated the canton's plans for developing renewable energy to determine how plausible it was and what sources they planned to focus on. Similar to the federal government, the Canton of Zürich has adopted an energy vision for the year 2050. The vision includes a drop in CO_2 emissions to only 2.2 tonnes per person per year, an increase in renewable energies, a

phase-out from nuclear energy, and declining consumption trends among citizens (Vision Energie 2050).

More specifically, the Canton of Zürich’s energy department, AWEL, worked with an energy consulting company to develop projections for the growth of renewable energy in the canton. By 2050, they expect to produce 85% of heat and 35% of electricity demands from renewable energy sources (Energy Planning 2013). To gain a better understanding for the projected growth rate of these renewable energies, please examine the pie charts and a helpful translation below.

Table 2: Translation of Figure 4

Phrase	**Translation**	**Phrase**	**Translation**
Aktueller Anteil am gesamten Bedarf im Kanton Zürich	Current share of the total demand in the Canton of Zürich	Umweltwärme	environmental heat
Möglicher Anteil Erzeugung am gesamten Bedarf im Kanton Zürich	Possible production share of total demand in the Canton of Zürich	Sonne	Solar
Warme	Heat	Tiefe geothermie	Deep Geothermal Energy
Elektrizitat	Electricity	Wasser	Hydropower
Abwärme (inkl. KVA)	Waste Heat (Waste Incineration Plants)	Restbedarf	Remaining Need

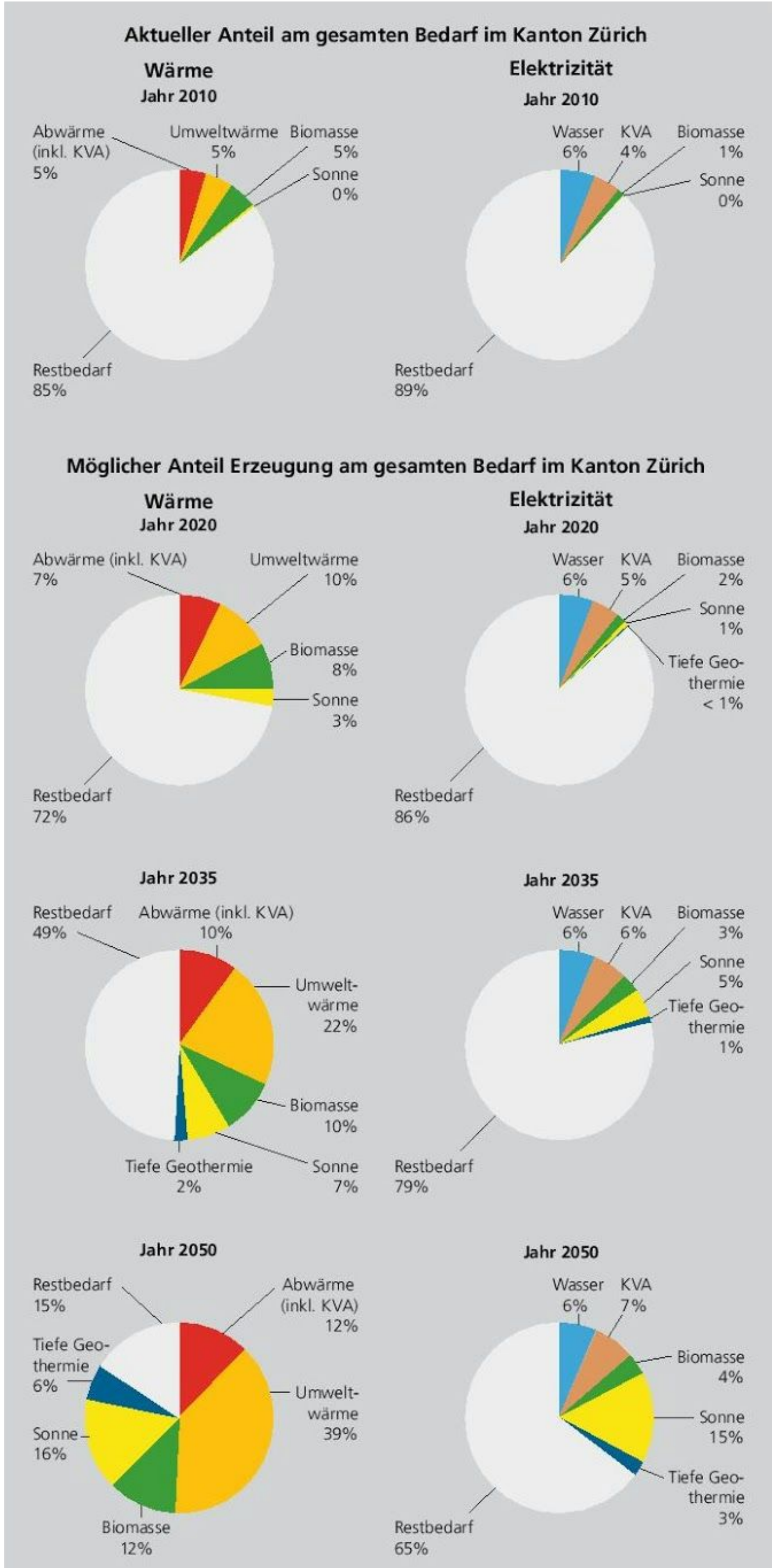


Figure 4: Projected Development of Renewable Sources - Energy Planning 2013

As the graphs indicate, the dependency on hydropower, 65%, called for by the ideal scenario does not appear to be plausible. After further research and interviews with experts, we believe that this number will have to be significantly lowered for the continuation of ZHAW's work. Switzerland as a whole already has a tremendous amount of energy production from hydropower, about 93% of its total renewable energy (see lit review section 1). That being said, there is little potential for further development of hydropower within the country. More specifically, the Canton of Zürich is using nearly all of its hydropower potential. Unless it is being imported from other cantons or countries, the canton should not expect a large rise in energy production from hydropower.

On the other hand, the Canton of Zürich has the capabilities to significantly increase their renewable energy production from other sources, especially for heating purposes. The heat demand is almost completely met by the predicted output of renewable energy sources in 2050. In addition, the expected development of technological efficiencies and renovation of buildings throughout the next 35 years will only lessen the energy demand for heat. If all goes well, these advances and the expansion of renewable energy sources will almost eliminate the need for fossil fuel heating within the Canton of Zürich.

Unfortunately, the canton does not expect to develop its electrical production from renewable energy as much as heating production. However, there is promising potential for the development of solar electricity production. From an interview, we were informed that the canton has already almost met its goal for solar electricity production for the year 2020. With funding from the government for the continued development of solar energy in industry and households, the future looks bright for the canton's solar industry. Overall, the electricity demand will be harder to fill with renewable sources than the heat demand, but the continued expansion of solar energy is a promising path.

In order to further analyze the information gathered from cantonal documents, we compared the expected rise in renewable energy production to our own scenario. For the construction of our scenario, we first had to use the percentages of energy production from the pie charts for each of the varying sources. The ratios for each year would be maintained within our scenario, but we constructed our own expectations for the overall energy demand in the canton. To do this, we referenced the canton's vision for the year 2050 and their expected consumption per person per year as shown below.

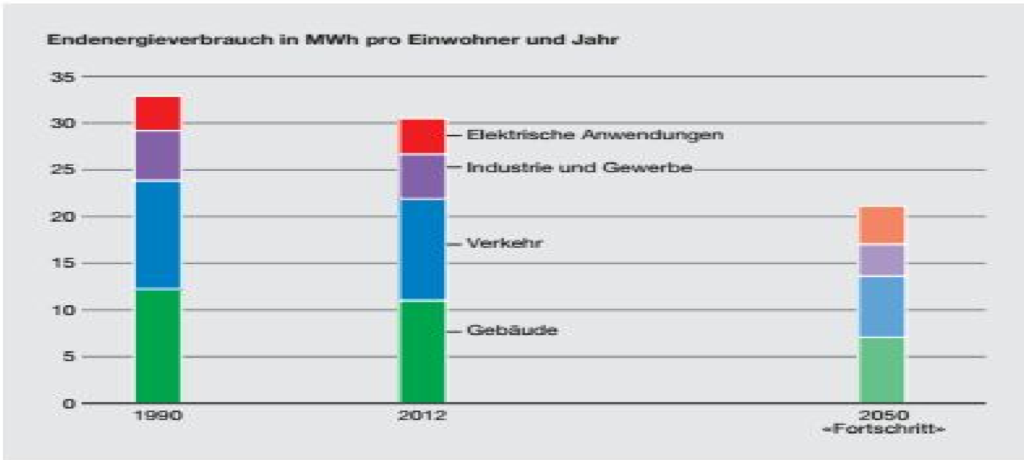
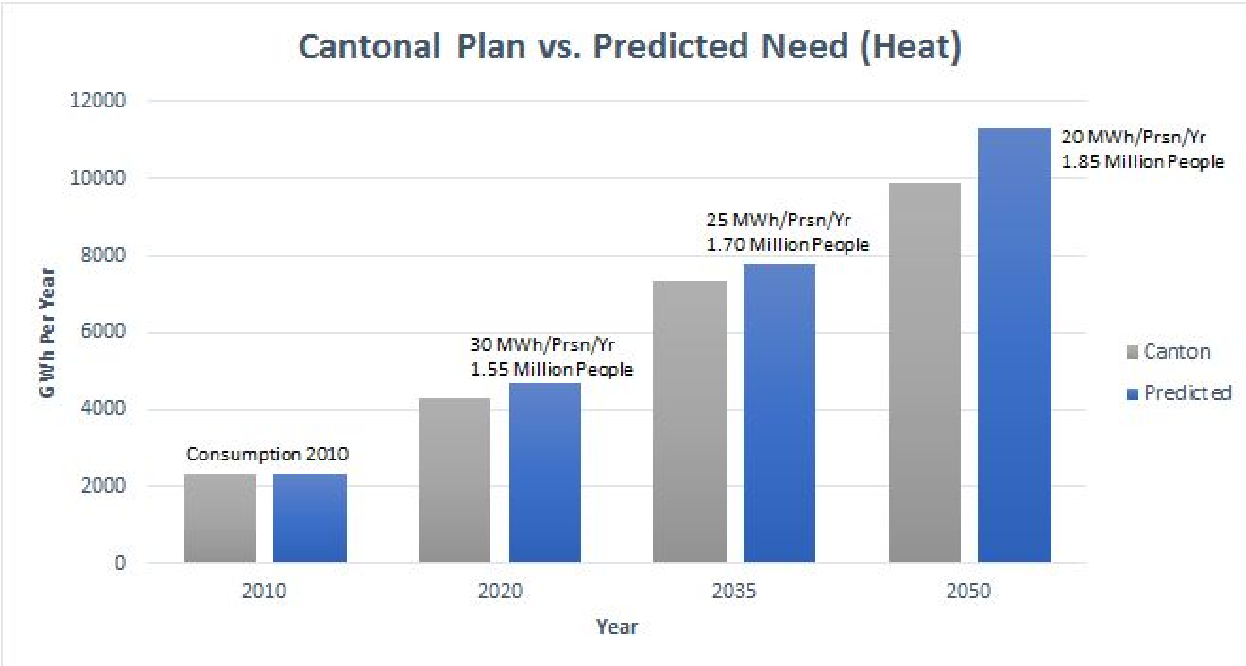
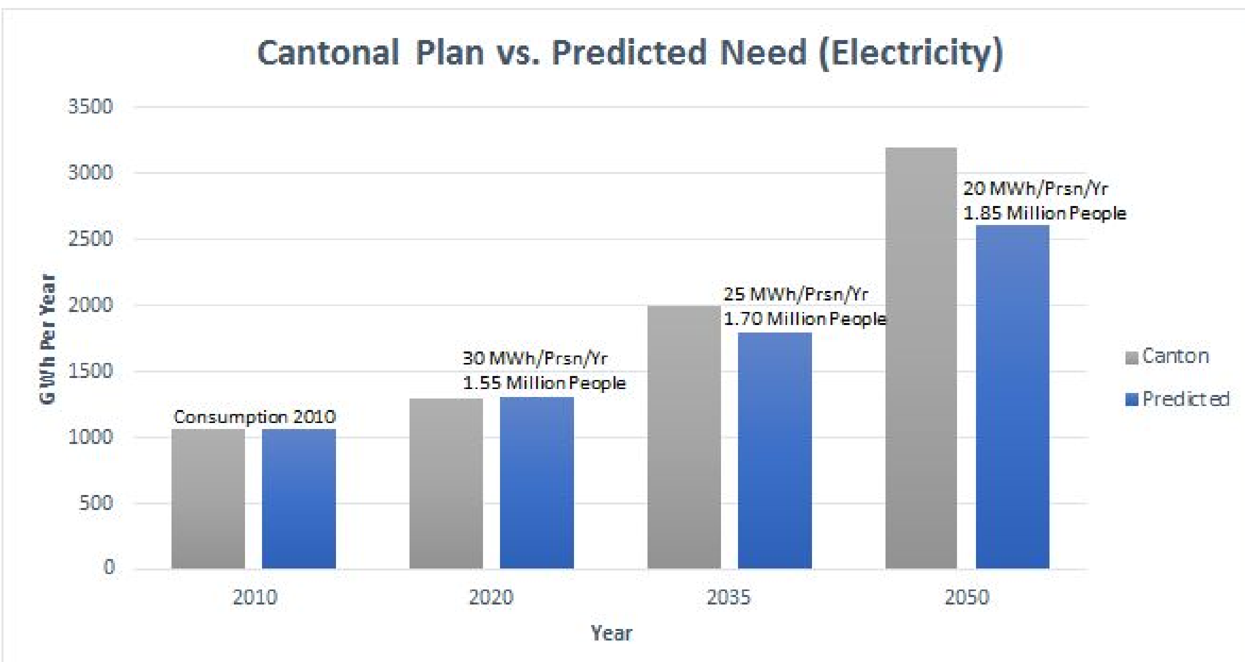


Figure 5: Energy consumption per person per year - Energy Planning 2013

In this graph, the total value of the bars is a representation of the total energy consumption by one citizen per year, in MWh. The mean consumption is expected to drop by the year 2050. Our research indicates that this drop in consumption is an expected result of the development of technology, education programs, financial incentives and burdens, projects, and regulations (Vision Energie 2050). Therefore, we then combined this expected trend in consumption with the ideal population development scenario presented to us by ZHAW to estimate the overall heat and electricity demands for 2020, 2035, and 2050. Although If you look at the graphs below, you'll see how the energy production planned for by the canton compares to the energy production needed to maintain the ratios in the pie charts for our development scenario. In other words, we created our own predictions for the heat and electricity demands of the canton so that we could compare it to the canton's plan; both resulting in 85% of heat and 35% of electricity produced by renewable sources (Energy Planning 2013).



(*Figure 6: Cantonal Plan vs. Predicted Need 'Heat'*)



(*Figure 7: Cantonal Plan vs. Predicted Need 'Electricity'*)

In conclusion, we expect the Canton of Zürich to meet or exceed the expectations set forth in its energy plan from 2013. Furthermore, the canton revises its energy plan every four years. We believe that the energy plan for 2017 will illustrate an even stronger development of renewable energy sources due to the expected increase in government funding and steering set forth by the Swiss Energy Strategy of 2050.

Recommendations:
In order to increase the share of electricity produced from renewable energies, we would encourage an increase in foreign, renewable imports. Right now, the Swiss Federal Energy Act limits the consumption of electricity from foreign, renewables to 10% of the total consumption (Energy Act). However, by 2035 the country is expected to completely phase-out from nuclear energy. In order to fill the loss of nuclear power and decrease dependency on fossil fuels, changes must occur. With hydropower nearly exhausted and the potential for solar energy limited by space, we recommend that the country increase its importation of renewable energy. Without an increase in imports, the country will have to exceed its expectations for renewable energy production or decrease its consumption in order to avoid a rise in fossil fuel dependency. Alternatively, the country is exploring the option of developing combined heat and power (CHP) plants. Although these are more efficient than the plants in place now, they are still dependent on fossil fuels and should be considered only after other renewable sources. That being said, surrounding European countries are expanding their renewable energy production at this very moment and should be considered as a viable option.

In addition, the canton should place an emphasis on the development of solar power. Solar power has already showed strong potential for development as it has almost reached its goal for 2020 already. Not to mention, the government already provides varying financial support systems for the development of solar power (see subsidies and taxes). The team was concerned by the restrictions on solar panels within some parts of the canton. From an interview, we learned that some communities within the Canton of Zürich restrict the construction of solar panels on buildings. For example, a community may not allow the installation of solar panels which can be seen from the street. In the interest of this project, we recommend that any restrictions in place be reevaluated throughout the next 35 years in hopes that compromises can be made. In addition, we recommend that the canton allocate land for the development of concentrated solar farms. By 2018, the canton has to allocate land for the use of renewable energy sources (Energy Strategy 2050). With the promising future of solar power in the canton, this land allocation could drive significant progress in the development of solar energy production.

CO_2 Emissions

Description:
CO_2 emissions are described specifically as the measure of the total greenhouse gas emissions within the Canton of Zürich measured in a total CO_2 equivalent. For instance, methane is a

greenhouse gas which has detrimental effects on the environment in large doses. Scientists have created $CO_{,2}$ equivalents to determine the amount of CO_2 which would have the same environmental impact as an arbitrary amount of another greenhouse gas, such as methane. The ideal scenario presented to us by ZHAW envisioned an 85% decrease in the amount of CO_2 emissions by 2050. Alternatively, the less ideal scenario still aimed to decrease the amount of CO_2 emissions by 50%. Our following work will show that the ideal scenario is unlikely to be achieved.

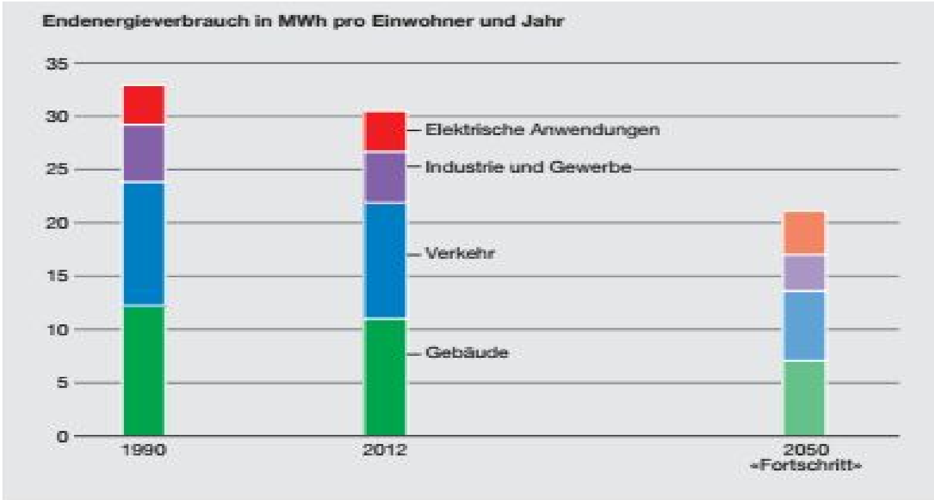
Priority: High

The emission of carbon dioxide and other greenhouse gases is contributing to climate change around the world. For this reason, we have assigned this impact variable a high level of priority for ZHAW. The efforts put forth by this project, ZHAW, Switzerland, and numerous other organizations and governments are all aimed at a common goal: to lessen the burden our lives place on the environment. As the science behind global warming becomes more and more accepted, the call for decreasing our greenhouse gas emissions increases. It is our belief that addressing these emissions will be a priority beyond the year 2050.

Analysis

To start, we wanted to first understand the effect that greenhouse gas emissions have on the environment. Research showed that when greenhouse gases are emitted into our ozone they contribute to radiative forcing (Radiative Forcing). To clarify, radiative forcing is the capacity of the gases in our ozone to insulate the earth. Essentially, radiative forcing determines how much energy from the sun reaches the earth and how much is radiated back into space. Greenhouse gases increase the amount of energy reaching the earth as they build up in our ozone due to their absorption of the infrared radiation from the sun. This would be denoted as positive radiative forcing, increased energy to the earth.

With a better understanding of the effect that emissions had on the ozone, we wanted to see how the government planned to decrease its emissions. By 2050, the canton wants to reduce its CO_2 emissions to 2.2 tonnes per person per year (Vision Energie 2050). As a result, the canton and the nation have begun to address their emissions. Let’s first take a look at how their carbon dioxide emissions currently stand.



CO_2 Emissions per person per year in tonnes CO_2	
Elektrische Anwendugen	Electrical Applications
Industrie und Gewerbe	Industry and Trade
Verkehr	Transport
Gebaude	Buildings
Fortschritt	Progress

Figure 8: CO_2 Emissions per person per year- Energy Planning 2013

To start, the nation is doubling its investment in the "building program," from 300 to 600 million CHF (Energy Strategy 2050). Regarding the canton, this would call for their building program budget to at least double as well, currently at 22 million CHF (Energy Planning 2013). There is potential for an even bigger increase though as the Canton of Zürich is one of the larger and more economically prosperous cantons in the country. The graph above indicates that buildings within the canton contributed about 40% of the total carbon emissions in 2012. By continuing and expanding the building program, the canton should be able to significantly cut emissions from buildings. In short, the building program helps introduce renewable energies to buildings, replace inefficient equipment, and improve the overall efficiency of buildings through changes in the structure, such as insulation or windows. For more information on the building program, please reference the subsidies and taxes section.

In addition, the nation has continuously reduced emission standards for personal vehicles. As shown in the graph, transportation accounts for the largest share of CO_2 emissions. The largest share of these transportation emissions is attributed to road transport, about 90%. More specifically, cars contribute about 75% of the emissions from road transport, so about 68% of the total emissions within the canton (Vision Energie 2050). As time progresses, a rise in the use of personal vehicles is expected based on current trends. In order to reach the emission goals of the canton and the ideal scenario, addressing the emissions and use of personal vehicles will be necessary. By 2050, the emissions of cars is expected to drop to 35 g CO_2/km (Swiss Emissions Perspective). This is just over 25% of the emissions standards for 2015, 130 g CO_2/km. Therefore, despite the expected increase in use of personal vehicles, the average emissions from cars are expected to significantly decrease.

Moreover, the federal government plans to undergo an ecological tax reform which will help steer the amount of emissions in the country and increase the use of renewable energy sources. For more information on the ecological tax reform, please reference the subsidies and taxes section.

Recommendations:
The ideal goal for ZHAW is too low to realistically expect. An 85% decrease in CO_2 emissions would drop the emissions per person to under 1 ton of CO_2 per year. From our research on the 2000 Watt society, we have yet to identify a Swiss citizen who emits less than 1 ton of CO_2 per year. Based on this information, we recommend that ZHAW adjust their goal to be more plausible. The cantonal goal of 2.2 tonnes of CO_2 per person per year appears to be much more realistic. By striving to achieve too much, the goals can create doubt and uncertainty. By adjusting the goal to a reduction of about 60-65% they are still surpassing their less desirable goal while also aligning with the expectations of the canton.

In order to reduce emissions in various areas, we recommend ZHAW develop emission life cycle assessments (LCAs) for renewable energy sources, nuclear energy, and industry practices which will be used in the canton. The construction, operation, maintenance, and distribution of renewable energy sources has an impact on the environment that can be calculated in the form of a carbon dioxide equivalent value. Our research led us to varying LCAs for different sources of energy. The inconsistency in LCAs for energy sources hindered our ability to further evaluate the emissions expected from the development of renewable energy sources. By developing LCAs for the renewable energy sources within the canton, ZHAW would be able to evaluate how much they are reducing their CO_2 emissions by replacing fossil fuel dependency with renewables. In addition, an LCA of nuclear power could provide valuable insight into whether or not a continuation of the nuclear energy program should be continued. Lastly, developing LCAs for various industry practices can help to identify ways to further reduce emissions in everyday operations. With the LCAs, ZHAW will be able to better predict the reduction of emissions that will occur as renewable energy sources are developed and industries/buildings are renovated.

In addition, there are policy changes which will contribute to the reduction of emissions within the canton. First, the building program within the canton should continue until 2050 and increase its funding along the way.The building program helps reduce the dependency on fossil fuels in buildings through the promotion/funding of more efficient heating solutions and adoption of renewable energy sources. Furthermore, the program supports renovations of buildings that decrease the heat/electricity demand by funding the installation of more efficient insulation, wiring, heating, etc. The federal government plans to double its budget for the building program in 2015, possibly later. Once this occurs, the canton should take the initiative to at least double their funding for the program as well.

Furthermore, the government should mandate the reduction of emission standards for vehicles as outlined in the national emission perspectives for 2050. Cars in Switzerland only have about a 10 year ownership span. By making the industry standards stricter earlier rather than later, more of a reduction can be expected in the mobility sector despite the expected increase in transportation that comes with population development.

Similarly, the introduction of subsidies for the development of charging stations for electric vehicles will contribute to reducing CO_2 emissions. The technology needed to integrate electric vehicles into everyday life within the canton already exists. However, the adoption of electric vehicles into society will not occur unless the necessary political action is taken. By promoting/steering the development of charging stations within the canton, the use of electric vehicles can transition into society. Then, electric vehicles can become a more dependable mode of transportation thanks to the accessibility of charging stations. This is a perfect example of how technology, policy, and society need to interact with each other in order to drive change.

Lastly, we recommend that the canton continue to improve and expand the public transportation system. The public transportation system operates well within the canton and can be relied on to be on time and get you to your destination as scheduled. Although not everyone will be willing to sacrifice their personal vehicle, by expanding the use of public transportation in the canton you can begin to attract more users, especially in the more rural areas of the canton. The city of Zürich already has a well developed public transportation which is integrated into everyday life. In the more rural areas, the decreased density results in a higher dependency on personal vehicles. If the public transportation systems within these rural areas can effectively replace the need for personal vehicles in daily activities, individual consumers will have a better reason to avoid their personal vehicles.

Subsidies & Taxes

Description:
Subsidies are defined in this project as financial benefits from the public domain for private companies to promote sustainable energy sources. Taxes are defined as the taxation of fossil fuels and power from non-renewable sources. The ideal scenario created for these impact variables is a combination of the two which establishes an ecological tax reform. In a less ideal case, the subsidies follow a retrogressive path.

Priority: High
The implementation of subsidies and taxes is a direct result of political action. The government's ability to drive change in society relies on these impact variables. How these subsidies and taxes

evolve over time will be a key factor in achieving any of the other goals necessary to create a Smart Energy Region. For example, the CO_2 Tax funds the federal building program. Our data and analysis shows that the implementation of an ecological tax reform is plausible. Therefore, these impact variables were assigned a high level of priority for the continuation of ZHAW's work.

Analysis

Policy reforms are more likely to build upon existing legislation (Key Messages). With this in mind, we focussed on the subsidies and taxes already established in order to identify what the ecological tax reform could change.

The Swiss Federal government already has taxes placed on mineral oils and CO_2 emissions. The CO_2 Tax is levied on fossil fuels used to generate heat, produce electricity in thermal plants, or operate combined heat and power (CHP) plants (CO_2 Tax). There are different charges introduced by the tax:

- 60 CHF per ton of CO_2
  - Expected Increase: (Swiss Emissions Perspectives)
  - 76 CHF/t in 2016
  - 96 CHf/t in 2018
- Extra-light heating oil: 159.00 CHF per 1,000 liters at 15 degrees celsius.
- Natural gas: 153.60 per 1,000 kg

On the other hand, the mineral oil tax is a tax on crude oil, other mineral oils, natural gas, their processed products, and engine fuels. Additionally, there is a surtax on engine fuels. The burden of the tax differs for each taxable product (Petroleum Tax):

- 73.12 cents for unleaded petrol per litre
- 75.87 cents for diesel oil per litre
- 0.3 cents for extra light heating oil per litre

Both of these taxes provide valuable funding for the government. The CO_2 Tax uses one third of its revenue, 300 million CHF, to fund the national building program (Redistribution of CO_2 Tax). This program directly affects the canton's ability to become a Smart Energy Region. Furthermore, the other two thirds of the tax revenues are distributed between the population and the economy while another 25 million CHF supports a technology fund. With an annual tax revenue of over 800 million CHF, the CO_2 tax is a very important piece of legislation to expand. The following table illustrates the revenue produced by the mineral oil tax.

The Mineral Oil Tax generated 7.8% of federal receipts in 2014 (Petroleum Tax). The Mineral Oil Tax can be used as a steering mechanism within the ecological tax reform. More information on steering mechanisms will be provided later in this analysis. The mineral oil tax has the potential to provide funding for government initiatives. Therefore, the reform of the Mineral Oil Tax can be used as key piece of legislation in the development of the Smart Energy Region. However, it is a national tax; changes would have to occur within federal legislation. The table below illustrates the revenue from the Mineral Oil Tax.

Mineral oil tax	**2013 receipts (in CHF 1,000)**	**Appropriation**
Mineral oil tax on fuel	2'971'315	50% to the Federal Treasury and 50% earmarked for tasks associated with road transport and aviation
Mineral oil surtax on fuel	1'982'948	100% earmarked for tasks associated with road transport and aviation
Mineral oil tax on combustibles	17'336	100% to the Federal Treasury

Table 3: Mineral Oil Tax

We identified the different subsidies in place by the federal government to understand how tax revenues contribute to energy reform. The federal government already has subsidies in place for the promotion of renewable energy sources. The Federal Energy Act allows for contributions in the promotion of careful/rational use of energy, renewable energy, use of waste heat, wastewater treatment and service/industrial plants (Energy Act). Grants are provided that will provide funding for 40% of the eligible investment costs, 60% for exceptional cases. In addition, there is funding for 30% of investment costs for the installation of photovoltaics (PVs) for new and expanding power plants when the production of the PVs does not exceed 30 kW.

The Electricity Supply Act provides subsidies as well. Particularly, a feed-in tariff was enabled within the act which covers the difference between the production cost and market price of renewable energy (Feed-In Remuneration). This guarantees the producers of the renewable electricity a price that corresponds to the production costs rather than the market costs. The funding of the feed-in tariff is generated through a consumer fee per kWh consumed. The feed-in tariffs apply to different technologies:

- Hydropower up to 10 MW
- Photovoltaics from 10 kW to 30 kW
- Wind
- Geothermal
- Biomass
- Biological Waste

Furthermore, the Electricity Supply Act provides one-off investment grants for Pv projects (One-off Investments). The act will cover up to 30% of eligible investment costs. If a PV project produces less than 10 kW, it can only use the one-off investment grants. However, PV projects between 10 kW and 30 kW can choose either the one-off investment grants or the feed-in tariff. Unfortunately, our research and interviews showed that the application process for these projects is rather slow. There are currently 20,000 applications waiting to be processed in 2015.

The federal government also provides financial support for energy reform within the cantons. The SwissEnergy program supports both the feed-in remunerations and the building program. The building program has a current budget of 300 million CHF. 22 Million CHf/yr goes to the Canton of Zürich's building program (Energy Planning 2013). However, the building program's budget is planned to double to 600 million CHF in 2015 (Energy Strategy 2050). This could prove to be very beneficial for the Canton of Zürich.

The Canton of Zürich's building program provides funding for various projects (Get Funding):

- Thermal Engineering Building Renovations
- Minergie Building Projects
- Use of Renewable Energy and Waste Heat
- Power Efficiency Program

The federal government is likely to implement an ecological tax reform within the next 10 years. The second phase of the Swiss Energy Strategy 2050 adopted by the Federal Council plans to shift from the promotion program to a steering mechanism in 2020 (Energy Strategy 2050). When we refer to a steering mechanism, we define it as a tax that drive change in the actions of the taxpayer (Environmental Taxation). In reference to an ecological tax reform, taxes would adjust to promote environmentally friendly behaviors while maintaining the overall tax revenue by reducing other taxes, so as to not increase the overall tax burden of citizens.

Recommendations:
We recommend that ZHAW increases the focus on the ecological tax reform for Switzerland. Speculations about the financial contributions needed to achieve the creation of a Smart Energy Region should be developed to identify how taxes and subsidies should be structured.

The ecological tax reform should address changes in technology and society which drive energy reform in the country. To start, the building sector will need to be benefit from the tax reform. The building program should receive increased funding throughout the implementation of the roadmap as it addresses one of the greatest sources for energy consumption and carbon dioxide emissions. Moreover, taking action in the households of citizens and their workplaces illustrates the government's dedication to energy reform in a transparent way. In addition, the transportation of the canton needs to be addressed. The ecological tax reform should promote energy efficient vehicles and public transportation. Specifically, funding should be provided for the installation of charging stations within the canton. Moreover, taxes on higher emission vehicles and promotion of a ride-sharing program could be viable options. Public transportation should be promoted, reducing ticket prices and funding of rural public transportation could increase the use of the system. Next, the tax reform should influence the energy production from renewable energy sources. Increasing the subsidization of renewable energy sources will financially drive both industry and individual consumers to adjust their sources of heat and electricity. The Federal Energy Act, Electricity Supply Act, and Building Program should all expand in order to drive the development plan for renewable energy sources in the canton. Additionally, increased taxes on fossil fuels and environmentally detrimental industry practices can act as steering mechanisms for renewable energy and increased efficiency.

We recommend the ecological tax reform fund a public interaction program as part of the Swiss Energy Strategy for 2050. Throughout our interviews, experts stressed that the public should feel involved in the national/cantonal energy initiatives. By creating a positive association with the effects of the tax reform, public support and the potential for further development of energy initiatives increases.

Similarly, we recommend that the ecological tax reform not have a detrimental effect on the financial contributions of citizens. Our interviews and research showed us that putting the financial burden of energy reform on the citizens could be detrimental to its transition into society. The government should reallocate funding or increase burdens on industry in order to provide for the funding needed to drive change.

Furthermore, the tax reform should be presented in the simplest, most transparent way possible. A good first impression is everything; the public needs to feel secure in the integration of the tax reform. The introduction of the reform needs to cover certain topics: the financial burden on the individual, where the money is going, and where the money is coming from.

In conclusion, ZHAW should dedicate more research to the development of the ecological tax reform. Different steering tax strategies, effects on the economy, areas to draw funding from, and transition management techniques are examples of areas of interest.

Geopolitics

Description
Geopolitics are defined by ZHAW as the balance of power within international relations, specifically the global impacts or risks associated with international politics. The ideal scenario for this impact variable was that the country is safe and there is an extremely low risk of war.

Priority: Low
Switzerland has maintained a neutral stance within their international politics for many years. During World War II, when the threat of war was at its peak, they managed to avoid invasion. Therefore, we assigned geopolitics a low level of priority for ZHAW's work.

Analysis
From our interviews and research, we learned that Germany is and will increasingly be a partner with Switzerland in the development of renewable energy as they often trade energy. As the roadmap progresses, Germany can provide renewable energy drawn from their wind and solar sources to Switzerland, helping Switzerland decrease its dependence on fossil fuels. In addition, during the summer when hydropower is producing excess amounts of energy, Germany is a favorable trade partner.

There are numerous international, cooperative programs for energy reform around the world. An example includes the International Energy Agency which is made up of 29 different countries. These other countries share the same goal as Switzerland: protection of the environment. Cooperation with other countries provides a system of accountability amongst the member countries to create progress.

Recommendations
We recommend that ZHAW re-define the definition of this impact variable. Geopolitics should focus more on how Switzerland and neighboring countries support energy reform. Identifying different international initiatives will provide different support systems which can help drive change.

In addition, we recommend that more research is contributed to analyzing energy initiatives of other countries. For example, Denmark and Germany have energy strategies which they are developing for the year 2050 (Energy Roadmap 2050). By researching the strategies which other countries implement, Switzerland may identify a new solution to energy reform.

Lastly, the Federal Energy Act may need to be revised to allow more electricity production from foreign renewable sources. Right now, only 10% of the total electricity consumption can come from foreign renewables. The limit may need to increase in order to account for the nuclear phase-out. The effects on Swiss electricity production plants should be considered first.

4.2 Roadmaps

As a part of our preliminary research into creating a roadmap, we researched various roadmaps from across the world to gain a better understanding of the methodology of creating a successful roadmap. In our research, we have identified three roadmaps that have been especially helpful in the development of our Smart energy Roadmap for Zürich (Europe Welfare Wealth Work, Birmingham Smart City Roadmap, UK Renewable Energy Roadmap). These three roadmaps utilized universally successful methods for introducing different kinds of changes to countries, whether it be related to policy, industry, technology, etc.

The Europe Welfare Wealth Work shows how renewable energies can be deployed and expanded across Europe and their effects on multi-national levels. The map highlights the desirable perspectives of numerous variables including environmental, geopolitical, and economic while highlighting barriers for a given sector's implementation. Furthermore, it analyzes policies and their driving forces or barriers towards renewable energy expansion with case study analysis. Finally, it highlights the economic feasibility of expanding solar and wind energy. The EWWW creates a clear example of recommendations towards large scale implementation giving guidance towards the canton's possible decisions in the future for policy, economic, or technological changes towards renewables expansion.

The Birmingham City is an exemplary framework towards organizing implementation plans within a roadmap and how to portray effective visuals. The BC roadmap well summarized and visually outlined the sections of Technology, People and the Economy. Each section includes current issues, desired goals, case examples, and the stakeholders necessary for success. Second, every section highlight the connections and interactions necessary between each other for greater successful implementation. The roadmap displays a strong example of well defined visuals and interlocking information to effectively educate a citizen on the roadmap and its impact.

The UK Renewable Energy Roadmap serves as an excellent model for roadmaps aimed at planning technological development, and as a roadmap building framework. The document addresses the challenges of developing sources of renewable energy in the United Kingdom and exploiting the plentiful energy sources available in the country. Based on existing research, it argues that certain established goals (e.g. 15% of UK energy from renewable sources by 2020) are feasible using current technology, and presents eight technologies that could be used to reach these goals. For each technology outlined, the feasibility and cost of each technology are described, and a set of actions proposed for developing that technology in the UK to provide a source of energy. Each section devoted to a technology additionally details the potential 2020 energy production and the upcoming planned projects. The roadmap also provides an in-depth visual timeline of the steps necessary to deploy technologies and the drivers and barriers between all parties involved. Overall, the roadmap represents an excellent display of how any roadmap should be initially made while maintaining both in depth knowledge and inviting visuals.

Chapter 5: Conclusions and Recommendations

When we first began this project, our sponsor told us that they wanted a "consistent, plausible, sustainable, and efficient" roadmap. In order to accomplish this, we constructed our roadmap with four main sections: technology, industry, policy, and society. These sections were chosen due to their affiliation with the impact variables. Furthermore, we discussed the way each section would interact with one another in order to create the most plausible roadmap. The roadmap would not be dependable if changes which were introduced in policy countered the developing technology or goals in society. The following recommendations, which were introduced to the roadmap, emerge from the impact variables and the goals of the Smart Energy Region.

5.1 Roadmap Recommendations

In the following sections we will evaluate the different colored boxes in the timeline. The roadmap shows several boxes with varying colors. The boxes that share the same color indicate that they have a relationship with one another. The bold text of a box indicates that it is the main goal or recommendation for those colored boxes. The following subsections will review the relationships between the similarly colored boxes and their importance to the development of a Smart Energy Region.

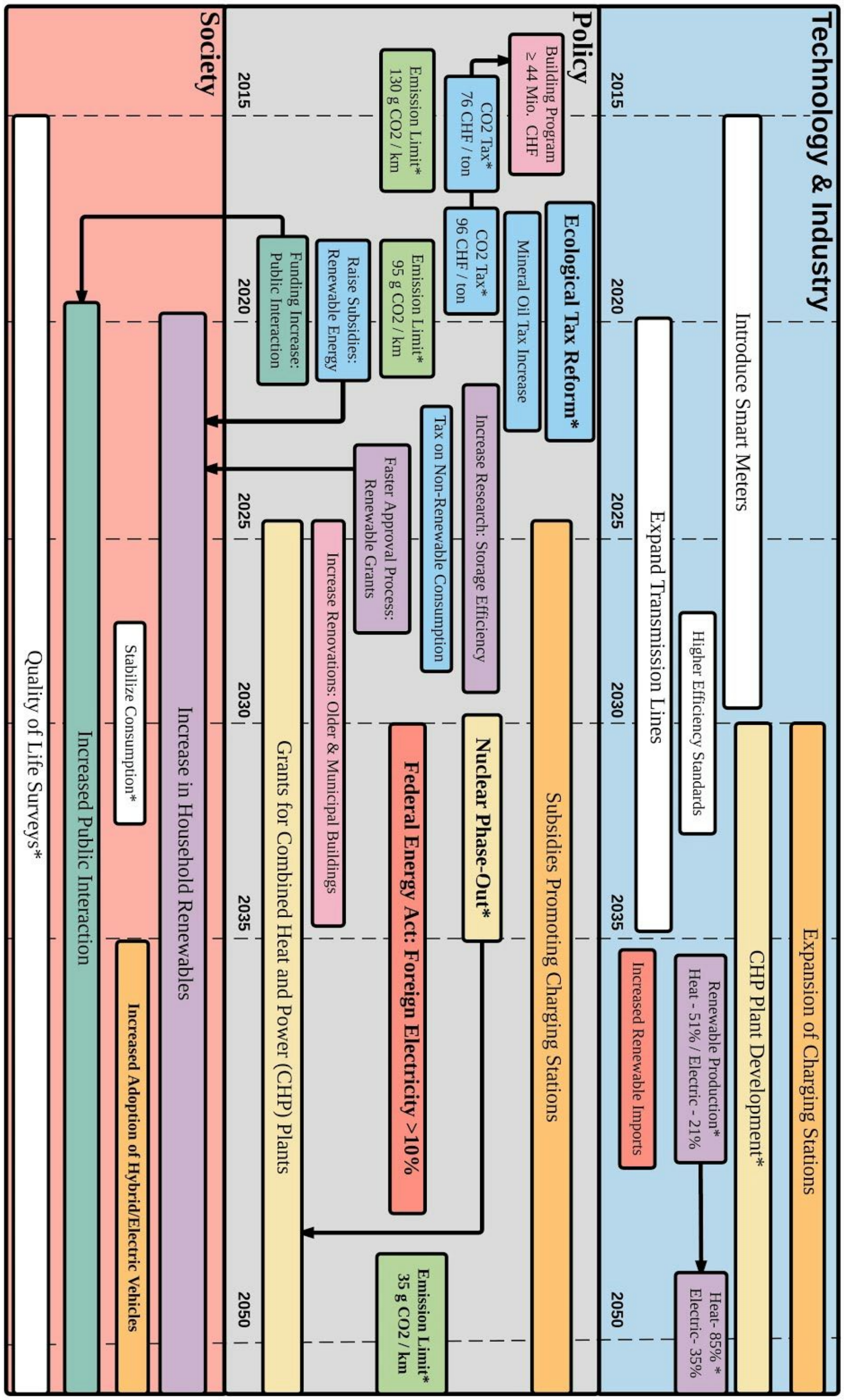


Figure 9: Final Roadmap

5.1.1 Ecological Tax Reform: Light Blue Boxes

The ecological tax reform was introduced to the roadmap due to its direct effect on the subsidies and taxes within the country. As the roadmap indicates, the light blue boxes reference the changes to the timeline associated with the ecological tax reform. The changes in taxes and subsidies are suggestions on how the government can renovate the current legislation to begin steering the energy reform in the country. The federal government plans to implement this ecological tax reform in 2020, and we see this as a milestone for energy reform in Switzerland. The ecological tax reform will have plenty of positive effects on the development of the Smart Energy Region; by undergoing an ecological tax reform, Switzerland can accomplish the following: increase funding for energy initiatives, steer consumption/production practices through financial methods, and show the government's commitment to the goals for 2050. Overall, the importance of an ecological tax reform should not be underestimated. Our research showed that the technology needed to achieve the goals for 2050 is already there. With an ecological tax reform, the government can exert its political will on society and transition the necessary technology into everyday life.

5.1.2 Increase Foreign Renewable Electricity: Red Boxes

The nuclear phase-out that is scheduled to occur by 2035 will call for the development of other energy sources. If the country is going to cut its dependency on fossil fuels, these energy sources will need to be renewable. If the potential for renewable energy is exhausted in Switzerland, it will be necessary to increase the importation of renewable electricity. The red boxes in the roadmap indicate the changes that would be associated with an increase in imports. Specifically, the Federal Energy Act would need to be revised as it currently limits the total importation of foreign, renewable electricity to only 10% of the country's total electricity consumption. In 2050, the Canton of Zürich only expects to produce 35% of its electricity from renewable sources in the canton. To account for the other 65% of electricity demand, the canton will need to import renewable energy either from other cantons or from foreign sources. Alternatively, they could use fossil fuels to produce the needed electricity; but, this contradicts the overall goals of the canton and country to lower the dependency on fossil fuels. However, by increasing the importation of renewable electricity the country can also positively influence its geopolitical cooperation. Furthermore, the recommendation should not go into action if there is further research which indicates a negative effect on the energy industry.

5.1.3 Increased Adoption of Hybrid/Electric Vehicles: Orange Boxes

The majority of CO_2 emissions in the canton are created by the transportation sector. Unfortunately, the trends in personal transportation are only expected to rise as the population develops throughout the timeline. In order to lower this level of emissions, society should evolve to use a higher proportion of electric/hybrid vehicles. The orange boxes in the roadmap are associated with this societal goal. As the roadmap indicates, the change in society should stem from the governmental promotion of introducing more vehicle charging stations to the canton. Thankfully, the technology needed to create this change already exists and will only improve in efficiency as time progresses. In order to transition into a society with more electric/hybrid vehicles, the government will need to implement their technology into everyday life. If a citizen is able to charge their vehicle conveniently without having to go out of their way to find a station, they can integrate the new vehicle into their lifestyle. Gas stations are already well established and people can rely on the fact that a gas station will be nearby; this must occur for charging stations. Otherwise, individuals will not be swayed to change their mode of transportation.

5.1.4 Increase in Renewables: Purple Boxes

The energy goals set by the canton and the country will rely on the development of renewable energy sources. The purple boxes in the roadmap correlate to changes needed to achieve the renewable energy production in the canton. First, there should be continued development of the power storage capabilities. With greater power storage capabilities, consumers can expect renewable energy sources to be more reliable. The problem right now is that the energy produced from renewable energy sources during peak times, such as summer days for solar panels, cannot be stored efficiently for use later. In other words, if a consumer uses only solar panels to provide his/her household with electricity, the consumer will not have access to electricity for most of the night. As it stands right now, the solar panels this person is using would contribute to the overall energy consumption of his/her grid and they would be rewarded through the feed-in tariff. If power storage capabilities are increased, the individual could use a microgrid in which the energy production is stored efficiently. The development of storage efficiency will provide helpful technological advancements for both the individual and the canton. In addition, the approval process for renewable grants needs to be faster. There are currently 20,000 projects on the waitlist for 2015. By improving the rate at which these projects are accepted, processed, and funded, the development of renewable energy sources and introduction of higher efficiency technology should increase. Moreover, if the ecological tax reform and increase in building program funding occur as planned, there will be greater capability for funding projects. The goals for the canton's renewable energy production in the purple boxes will be more plausible as these changes occurred as planned. However, this slow approval process will only hinder the energy reform in the canton.

5.1.5 Building Program Changes: Pink Boxes

The building sector accounts for a significant proportion of energy consumption and CO_2 emissions. The pink boxes in the roadmap illustrate the changes we would make to the building program to address the energy consumption and emissions. First, the increase in the building program budget from 22 million to CHF to at least 44 million CHF should occur early in the roadmap. The building program in the canton stems from the national program, SwissEnergy. The initial legislative package of the Swiss Energy Strategy 2050 called for an increase in the funding for national the building program from 300 million to 600 million CHF. That being said, the canton should expect to at least double its budget. The Canton of Zürich is one of the larger cantons and is expected to be a leader in energy reform for the country. Furthermore, the national CO_2 tax which funds the building program is expected to increase in 2016 and 2018, shown in the roadmap. This calls for the expansion of the building program. Moreover, the building program should address the renovations of municipal and older buildings. The canton has the authority to directly influence the municipal buildings in the canton. Given that most of these municipal buildings are older structures, there energy efficiency does not meet the minergie standards. Similarly, the Canton of Zürich has other older buildings that do not meet the minergie standards. Unfortunately, some of these older buildings are protected by their historical significance. The expansion of the building program should focus on these municipal and older buildings. Addressing the municipal buildings will be within the total control of the canton's government, so there is no reason to procrastinate when they have the power to act now. Additionally, the renovation of older buildings will be a good illustration of the government's commitment to energy reform. The public will be able to witness the transition of older buildings into the modern era, showing that it is never too late to create change.

5.1.6 Emission Limits: Green Boxes

As stated before, the emissions from transportation make up the greatest proportion of CO_2 emissions in the canton. Similar to the development of charging stations, making stricter emission standards for vehicles can assist in the reduction of greenhouse gases. The green boxes in the roadmap indicate the lowering of emission standards planned for by the federal government. By improving the emission standards, the government can hold the automobile industry responsible for their contribution to emissions and drive increased efficiency. Overall, the implementation of stricter energy standards can be expected to have an impact on the emission levels in the canton.

5.1.7 Combined Heat and Power (CHP) Plants: Yellow Boxes

To reiterate, if the nuclear phase-out occurs in Switzerland as scheduled for 2035, there will be an share of energy production that needs to be replaced. Earlier, we proposed that the country increase its imports of renewable electricity as a possible solution to the loss of energy production. Alternatively, the country could invest in the development of CHP plants, represented by the yellow boxes on the roadmap. CHP plants increase the efficiency of electricity and heat production when compared to separate plants by recovering thermal energy that would be wasted in separate plants. However, CHP plants are still dependent on the use of fossil fuels. Assuming the nuclear phase-out occurs, CHP plants are a viable replacement. Ideally, CHP plants could be introduced periodically while separate plants are decommissioned or the existing plants can be modified into CHP plants. Overall, the expansion of CHP plants can improve the efficiency of fossil fuel use in Switzerland.

5.1.8 Public Interaction, Quality of Life Surveys: Cyan Box

The roadmap shows two boxes in a cyan color. These boxes correspond to the societal goal of increasing the public interaction with energy reform. Additionally, there is a white box which represents the annual quality of life surveys that occur in the canton. These aspects of the roadmap are being explained together as they relate to public support from the canton. In order to have the canton involved in the energy reform, they need to experience the changes that are occurring hands on and share a vision for the future. By funding a public interaction program within the canton, the government can drive a societal evolution rather than introducing policies that create an energy revolution. Furthermore, the quality of life surveys can be continuously used as a tool for measuring how the energy reform is impacting people. The Canton of Zürich already has a high level of quality of life, assuring that this remains constant will help avoid resistance from the public. Overall, both of these roadmap recommendations will be needed to assure a smooth transition of the energy reform into society.

5.1.9 Smart Meters, Efficiency Standards, Transmission Lines: White Boxes

The technology needed to achieve the goals of a Smart Energy Region already exist. However, the technology has yet to be fully integrated into society. The white boxes in the technology section of the roadmap illustrate technologies which should continue to integrate into society. To start, smart meters allow for energy companies to better understand the use of energy in individual consumers rather than the consumption of larger grids. Additionally, smart meters allow the individual consumers to monitor their energy consumption instead of simply paying the bill when it arrives. Next, improving efficiency standards within industry will help to improve the overall emission life cycle assessments for various processes, such as building construction. By making accepted standards stricter, the government is also able to implement financial burdens for failing to meet the standards, which can contribute funding to different programs. Lastly, developing transmission lines will help supply the centralized energy source with energy produced from individual producers rather than just large-scale operations. In other words, the transmission lines allow household renewables to feed back into the grid. By expanding the connections of the transmission lines, the grid has a greater potential for renewable production from individual sources. All of these recommendations to the timeline will provide the canton with the technological advancements which drive the development of a Smart Energy Region.

Overall, the roadmap provides an illustration of the recommendations we believe will lead the Canton of Zürich to the most ideal scenario. Technology and industry have a promising future in Zürich as most of the current technology can provide for the needs of the smart energy region. Moreover, technological breakthroughs could drive rapid change in the roadmap. For example, an extraordinary development in power storage would have an impact on the development of the power grid. In addition, society's interaction with the roadmap will be an indication of the success of the roadmap. As long as the quality of life is not drastically influenced, society should not restrict the development of the smart energy region. Additionally, strong and positive interactions between society and the rest of the roadmap will help drive progress. On the other hand, negatively impacting the lives of the people will introduce barriers to the roadmap. Lastly, policy needs to create the sense of urgency which calls for the changes in society and technology. When the technology is available and climate change is acknowledged within society, it is up to the government to act. Until the government accepts the responsibility to take action and drive change, progress will be challenged. For the continuation of this project, the interactions and development of impact variables as change is introduced to the roadmap will determine how successfully the canton transforms into a smart energy region.

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