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Swiss-EnergyScope.ch: a Platform to Widely Spread Energy Literacy and Aid Decision-Making

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We develop an energy calculator within an online teaching platform to aid citizens and decision-makers understanding an energy system. The model, designed in order to be easily adapted to any energy system at national or regional scale, is presented and applied to the case of Switzerland.
Although autonomous on a yearly balance, Switzerland today already relies on foreign imports to face higher electricity demand in winter months. The decision of the country of phasing out nuclear power by 2034 will have as a consequence to further increase this seasonal electricity deficit.
The Swiss-EnergyScope.ch project is a contribution to the public debate escalated concerning Switzerland's future energy strategy, helping citizens to take an active part in it by associating numbers and facts to opinions and choices. The online platform mainly consists of an energy calculator, enabling users to evaluate the effect of a list of possible choices on the energy future of the country. An online wiki and a MOOC will allow users to acquire basic knowledge on energy and to be guided through the learning process and the use of the calculator itself.
The robust conceptual design strategy adopted to model the Swiss energy system allows for the contextualization of the key issue of electricity supply within the framework of the overall energy system, conveying a holistic view in which technologies affecting both heat and electricity (such as heat pumping and cogeneration) can be easily integrated. The monthly approach used for the calculation and display of data allows highlighting the central role of seasonal fluctuations in supply and demand.
Overall, the designed tool and the associated learning experience allow popularizing energy issues, demystifying the complexity of a national energy system without oversimplifying it.

1. Introduction

The Swiss electricity production mix in 2011, reference year in the framework of this work, was mainly composed of hydroelectric (53.7 % of total electricity production) and nuclear (40.7 %) power plants, the remaining part being covered by thermal power plants (4.6 %) and other renewable energy sources (1.0 %) (Swiss Federal Office of Energy, 2012). Figure 1 shows the monthly electricity demand and supply curve by energy source: in winter electricity demand is higher, while production from hydroelectric power plants is lower due to the natural seasonality of run-of-river power plants. Thus, despite being autonomous on a yearly balance, the country has to rely on foreign imports of electricity to face this winter deficit.
The aftermaths of the Fukushima disaster have led the country to the decision of phasing-out its active nuclear power plants by 2034 (Swiss Federal Office of Energy, 2013), with the consequence of a gradual increase of this already-existing gap between supply and demand. Thus, a vibrant debate has recently escalated concerning the country's energy future, with multiple contributions though seldom supported by a structured contextualization and presentation format. In this context, the development of the online platform has the goal of informing and educating citizens and decision-makers, and of providing them with a calculation tool able to show the impact of their choices onto the evolution of the Swiss energy system in 2035 and 2050.

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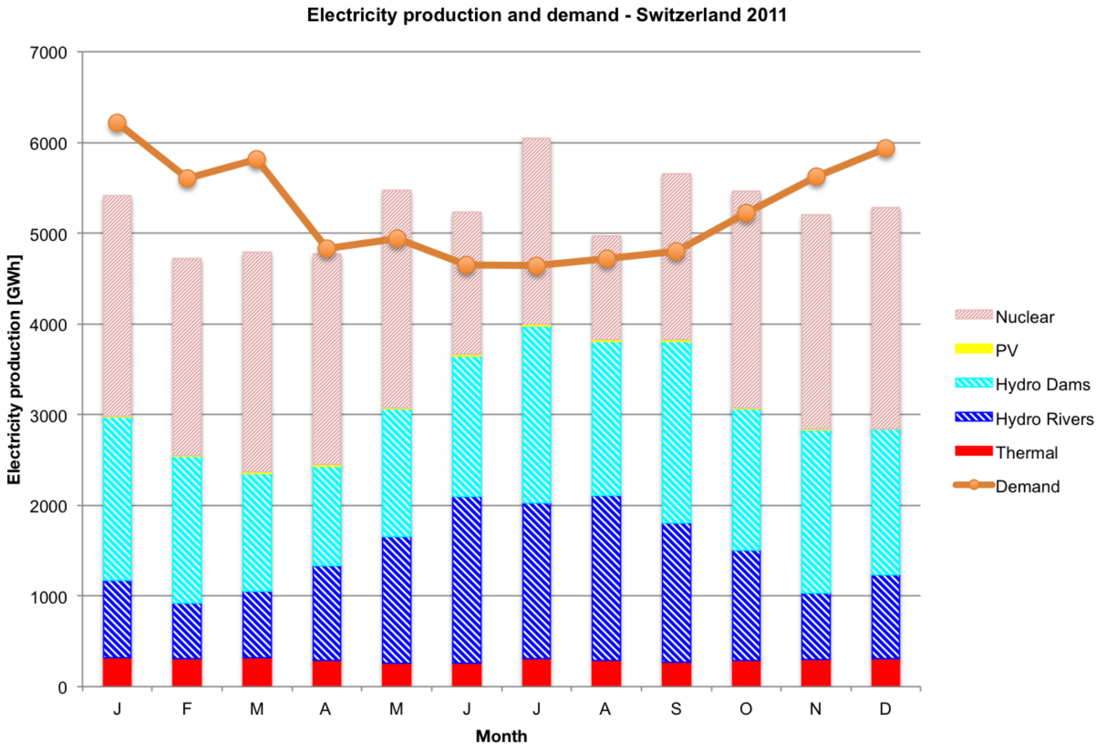

Figure 1: Monthly distribution of electricity demand and production (per energy source) in Switzerland for the year 2011 (Swiss Federal Office of Energy, 2012)

Furthermore, in the recent years online teaching tools have shown good potential in the framework of engineering education (Perry and Bulatov, 2012).
In this paper the Swiss-EnergyScope.ch platform is presented after a literature review covering previous similar contributions to energy teaching and energy scenarios definition. First, an overview describes the various tools available, then the focus is on the description of the energy calculator, the core of the platform, and on a brief introduction to the adopted modelling strategy.

2. Literature review

Several efforts have been made towards the development of information tools for energy scenario analysis. These tools generally allow policy makers and citizens to develop their own scenarios based on scientific data, considering both physical and technical restrictions. This way, the user gets insights into the future decisions and trade-offs in the energy puzzle.
The UK Department of Energy & Climate Change (DECC) heads the “2050 Pathways” project (UK Department of Energy & Climate Change, 2014). The core of this project is “The 2050 Calculator”, a tool giving the possibility of creating personalized UK energy pathways. The calculator is available at three levels of complexity, with the possibility of accessing the full Microsoft Excel™-based model version. The calculator is complemented with a wiki including the description of the model, sources and assumptions. The DECC also assists other countries and regions aiming at developing their own energy calculators based on “The 2050 Calculator” methodology. Up to date several countries/regions have published their 2050 Calculator (Wallonia, China, South Korea and Taiwan). One goal is to develop a “2050 Global Calculator” at world level.
“The 2050 Webtool”, the second level of complexity, is available online. On the input side, the model offers to the user 42 discrete variables to shape the pathway, these variables related to either demand or supply technologies. Despite some exceptions, it is possible to choose among four options for each variable, each of these four options representing a different evolution assumption. On the output side, the calculator displays the evolution (2010-2050) of the final energy demand, primary energy supply, electricity demand, electricity supply and CO_2-equivalent emissions. Other results are an energy flow diagram, information about energy security, required surface for renewable energies, economic cost and air quality.

At the level of Switzerland, the "ECO2-Calculator" software tool was developed (Goldblatt et al., 2005). This tool follows the idea that design of energy pathways requires both top-down (socio-technical) and bottom-up (individual change) approaches. Laypeople need to compare the effects of behavioural (personal efforts) and structural changes. As an input, users select values for variables/parameters that are related either to their behaviour or to external socio-technical conditions. In addition, they have the possibility to scale-up their behaviour to a Swiss level in order to see which would be the Swiss energy consumption if everyone's energy consumption matched their own one.

As an output the calculator displays the short-, mid- and long-term impacts. For the output, users can choose between energy (primary energy requirements or end energy consumption) and CO_2 emissions per year indicators.

Both calculators ("The 2050 Webtool" and "ECO2-Calculator") show only annual data. Users do not have access to monthly distributions, thus the concept of seasonal variation for supply and demand is not evident to them. In fact, in scenarios with high percentage of strongly seasonal renewable sources for electricity production the key role played by the monthly distribution of supply and demand would need to be highlighted, as it is a critical aspect in the choice of the electricity production mix. As an example, a combination of wind and photovoltaics (PV) generated electricity could dampen the seasonal variability due to the opposite monthly production pattern characterizing these two resources. The implementation of seasonal storage facilities or backup power plants is another possible solution to this issue. Also, in the view of future widespread deployment of PV, conversion to synthetic fuels could be a way to exploit the excess power available in summer in Central-Northern Europe.

Although the monthly distribution is not shown to the user, "the 2050 Webtool" outputs the number of back-up power plants needed in order to be able to guarantee electricity supply during periods of low renewable-based electricity production and high electricity demand.

At institutional level, SuisseEnergie (2014) offers online applications for estimating individual energy consumption for space heating, hot water, electricity and transport. These tools allow users to compare their situation with respect to the Swiss average and give some recommendations for reducing the energy consumption, but without providing any information on large-scale energy scenarios.

3. Presentation of the platform

3.1 Overview

The Swiss-EnergyScope.ch online platform offers a variety of tools to enhance the user's learning experience:

1. The energy calculator: the heart of the platform, allows users to visualize various scenarios proposed by the government. Furthermore it shows the effect of decision variables on Key Performance Indicators (KPIs) of the energy system, allowing users to create their own pathways. A wiki at three levels of detail, available in four languages, allows for self-learning, and an online MOOC (Massive Open Online Course) guides the user through the educational process. The calculator will be available in two versions: a detailed one targeting more experienced users, and a more simplified one for the general public. A thorough description of the tool follows in the next sub-section.
2. Online e-book (under development): an e-book will be available online to guide users through the basic concepts of energy under technical, environmental and economic points of view.
3. Q&A (under development): a list of 100 questions and answers concerning key concepts of energy.
4. Pocket book: printed pocket book summarizing key data about the Swiss energy situation.

Energy data are often presented with a variety of measuring units, either derived from the practice or due to historical reasons, this making the comparison between different energy sources for the same final use unintuitive and difficult for non-experts. Thus, for the four teaching tools presented above, a choice has been made to present all energy units in [GWh]. However, to facilitate the generalization to other countries, a shift is planned to [kWh/capita] or [kWy/y/capita], the latter referring to the concept of a 2,000 W society, meaning a society with an average power consumption of 2,000 Wy/y/capita (Marechal et al., 2005), which happens to be the world average consumption at the turn of the century. (Haldi and Favrat, 2006) have treated methodological aspects to implement this vision, while (Fink and Stulz, 2012) have recently analysed the application of this concept in the Swiss context.

3.2 The energy calculator

Figure 2 summarises the features of the Swiss-energyscope.ch online calculator. The layout of the complete calculator is very similar to the one presented in the screenshots, apart from showing just one "Detailed graph" at a time.

Figure 2: Screenshots of the Swiss-EnergyScope.ch calculator: (a) “General Indicators” showing calculations output KPIs, (c) “Target Year” for calculation year choice, (b) “Detailed graph” showing the 2011 final energy consumption and (d) a possible projection for 2050 electricity production (the black line on top of the bars representing the demand), (e) “Transport” input tab allowing for technologies selection

“General indicators” (a) and “Detailed graph” (b)(d) are the output of the calculator. When drawing the output, 2011 data are always kept as the reference, thus reducing the risk of showing figures which cannot be interpreted by users due to lack of contextualisation.

The authors deliberately chose to limit the number of KPIs to five general indicators: Final energy consumption (GWh), CO_2-equivalent emissions, Total cost, Electricity deficit and Deposited waste. The “General indicators” bars offer a graphical comparison between the scenario that has been designed and the situation of 2011. The red vertical bars represent the 2011 situation as reference.

On the right of the “General indicators” users will find the “Detailed graph”. The “Detailed graph” represents the monthly distribution for one “General indicator”. It is possible to change the “General indicator” displayed on the “Detailed graph” by clicking on a different “General indicator”.

When users access the calculator, 2011 data are displayed by default (b). Then they are requested to choose the target year (c) for their scenario (2035 or 2050). Once they have made their choices, the target year values are displayed on the left column while the right thinner bar shows 2011 figures. At that point the detailed graph has the appearance of the one in (d).

The legend of the “Detailed graph” offers the possibility of removing some elements of the monthly distribution by clicking on their name. For example, it is possible to see which would be the electricity gap (demand-supply) in 2011 if nuclear power plants contribution was eliminated.
The input part of the calculator is shown on the bottom of the Figure 2(e). It has five sections which users can access through the respective tabs. In this example the “Transport” inputs are shown also as an example of the two types of sliders that users can find in the calculator. The first one (“Transport: Vehicle fleet for passengers”) sets the percentage of different types of vehicles in the car fleet. The positions (value) of the sliders are dependent on one-another in order to impose that the sum is equal to 100 %. The choice of using sliders is due to the goal of having a more user-friendly system compared to the ones found in the past literature.
On the left of every name there is a locker. The locker gives the possibility of fixing the value of a certain slider. Sliders with a closed locker will not change their value when another one is moved. This feature allows users to choose any fleet composition while having the sum of the options always equal to 100 %.
The multi-color row above the group of sliders is a visual representation of the car fleet. Its total length is constant while the lengths for the different type of vehicles change depending on their percentage, as a linear adaptation of a pie chart.
The second group of inputs for the transport contains sliders which are independent on each other. In this case they let the user choose the percentages of passenger transport demand covered by public transport, freight transport done by train and the transport energy demand supplied with biofuels.
Due to space constraints some expressions have been replaced by abbreviations or initials (e.g. BEV = Battery Electric Vehicle). For this reason when the user positions the cursor on a word (name of a slider or name on the graph legend) a bubble with complementary information appears. The same principle is applied to the graph. For example, it is possible to obtain the value of the electricity produced by wind turbines in January by placing the cursor on the corresponding chart area.

3.3 Modelling approach

Developing a holistic but simplified model of a national energy system is a demanding task. Therefore the quality of the conceptual modelling approach is directly proportional to the degree of simplification possible to achieve, both under the calculation and the ease-of-use point of view. Key issues to face in this regard are the choice of the level of detail, the identification of the key variables impacting the system, the distinction between the demand and supply side, the presence of technologies producing or requiring both heat and electricity (e.g. heat pumps and cogeneration).
The classical way of presenting the final energy consumption of a country as the resulting contribution of the four main sectors (residential, services, transportation, industry) is overcome by a distribution into electricity, heating and transportation, this allowing to easily highlighting the competition between electricity and fuels in the supply of some end-uses.
Figure 3 shows an overview of the conceptual modelling approach, which will be described in detail in a follow-up paper. A complete set of data referred to 2011 serves as starting point for the analysis of the country’s final energy consumption, and its conversion into end-uses. A handful of “General/Efficiency” choices influences the evolution of the demand projected for the years 2035 and 2050. The “Transportation” and “Heating & Cogeneration” sub-models define which set of technologies is chosen to fulfill this demand, giving the necessary input to the “Electricity” sub-model where the choice concerning the amount of electric power generation is left as a free variable. The graph clearly shows how the sequential approach chosen to model the energy system allows for the integration of cogeneration and heat pumping technologies without the need of excessively complicating the model itself.
Models for the key LCA (Life Cycle Analysis) indicators are available for each technology, while cost models are currently under development. It is assumed that daily and weekly fluctuations are solved independently.
The modelling strategy is designed to easily allow adaptation to any national or regional energy system.

4. Conclusions

In this paper the energy teaching platform Swiss-EnergyScope.ch has been presented with attention to the four main tools of which it is composed. Its role in the educational process is described. The energy calculator at its core has been presented in a detailed way, both from the user interface and the modelling point of view, which will be subject of an upcoming paper.
A key innovation represented by the approach is the calculation and presentation of the monthly distribution of the energy demand and consumption, highlighting the key aspect of seasonality in this context. Furthermore, the modelling approach allows for a holistic representation of the energy system, contextualizing electricity into a system view together with heating/cogeneration and transportation.

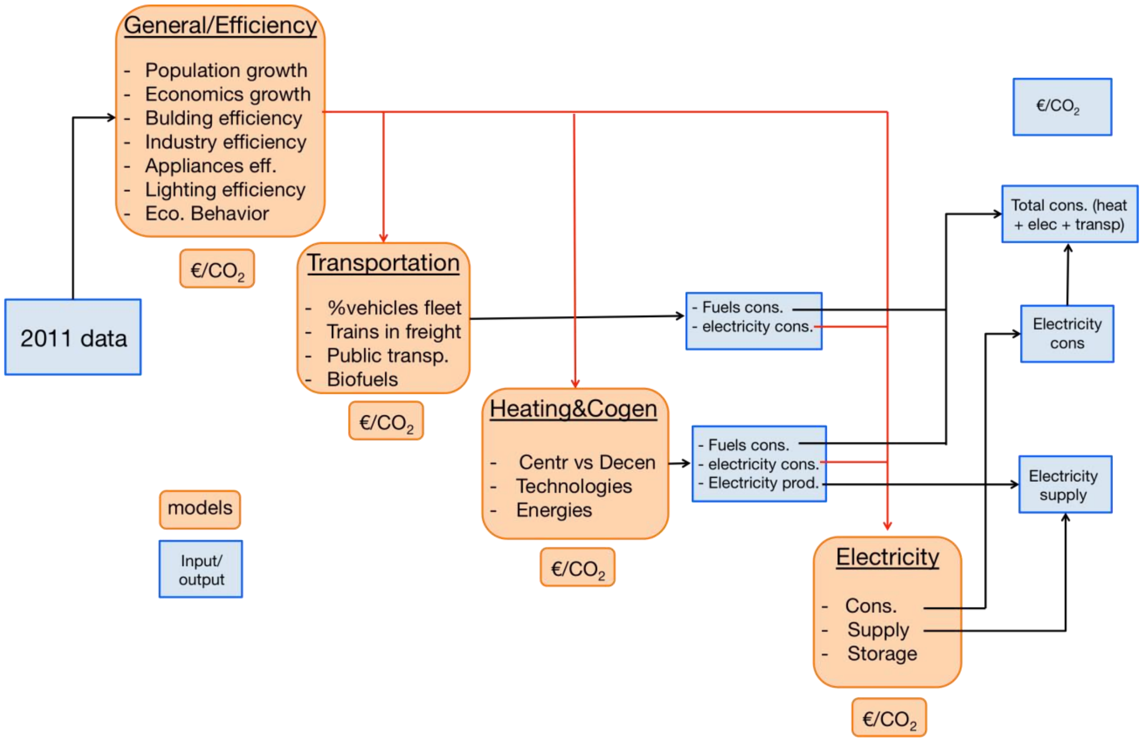

Figure 3: The conceptual structure of the sequential model developed in the framework of the Swiss-EnergyScope.ch online platform

The online platform is currently under testing and development of some parts is still in progress. A first public release will be available in the year 2014. Future work, already under development, involves the finalization of the teaching support tools guiding users through the use of the calculator. Adaptation of the platform to other energy systems both at national and regional scale has also been requested and implementation is planned in the future.

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