“Swiss-EnergyScope.ch: a platform to widely spread energy literacy and aid decision-making”

S. Moret*, V. Codina Gironès, F. Maréchal, D. Favrat
OUTLINE

Outline:

• Introduction
• Literature review
• The platform
• The model
• Use of the platform & Conclusions
Growing trend in energy consumption, mainly from non OECD countries

$CO_2$ Emissions 2050 = 2x emissions today

IPCC 2013: climate has changed due to human activities

To target the $2^\circ C$ $\Delta T$ limit $CO_2$ emissions need to be halved by 2050

Sources:
- Copenhagen Diagnosis 2009, with MIT data taken from Sokolov et al. 2009.
- IPCC 2013 report, Climate change 2013 - The physical science basis
- IEA, ETP 2012
INTRODUCTION

The Swiss context

Various countries taking strategic decisions about their energy future

March 11th, 2011
Fukushima nuclear disaster

2034: Phase-out of nuclear power plants
Strategic decisions for the energy future!
INTRODUCTION
The Swiss context

Various countries taking strategic decisions about their energy future

How to fill this gap?

March 11th, 2011
Fukushima nuclear disaster

2034: Phase-out of nuclear power plants
Strategic decisions for the energy future!

Sources:
- SFOE, Swiss electricity statistics 2011
- SFOE, Energy strategy 2050 explanatory document

Introduction
Literature review
The platform
The model
Use & Conclusions
INTRODUCTION
The problem of energy literacy

An energy-literate person (US DOE definition):

• Can trace energy flows and think in terms of energy systems.
• Knows how much energy they use, for what purpose, and where the energy comes from.
• Can assess the credibility of information about energy.
• Can communicate about energy and energy use in meaningful ways.
• Is able to make informed energy use decisions based on an understanding of impacts and consequences.

But various studies highlight..

• “Serious deficiencies” in understanding of energy consumption and savings → missing order of magnitudes (survey on 505 individuals)
• In 2001, 12% of Americans could pass a very basic energy quiz
• In 2010, only 40% of Canadians could relate gas to electricity production

Sources:
- Energy.gov – education – energy literacy
- Attari et al. (2012)
- DeWaters, Powers (2009)
- Energy literacy survey, Canada (2010)
In the case of Switzerland:

- Active involvement of the population in political decision-making (referendums)
- Vibrant debate on the energy transition (mostly on electricity, though)
- Need of fact-checking

Swiss-EnergyScope.ch is the EPFL contribution to this debate. Key goals:

- Aid citizens and decision-makers understanding an energy system
- Associate numbers and facts to opinions and choices
- Provide a calculator as common basis to different scenario development
- Model a national energy system in a flexible, easily-adaptable way
Key features:

- **Goal:** “strengthen the level of debate on energy issues in the UK”
- **Output:** pathway to 2050 in terms of energy, electricity, GHG emissions, costs
- **Input:** 42x4 input variables
- Online available wiki
- Available pre-defined scenarios
Adapted to other countries:

- Belgium
- China
- South Korea
- Taiwan
- India
- …

2050 Global calculator
Key features:

- **Goal:** “strengthen the level of debate on energy issues in the UK”
- **Output:** pathway to 2050 in terms of energy, electricity, GHG emissions, costs
- **Input:** 42x4 input variables
- **Online available wiki**
- **Available pre-defined scenarios**

Why didn’t we just adapt it?

- **Seasonality → monthly distribution**
- **No automatic balance supply/demand**
- **Reduction of the number of input**
LITERATURE REVIEW
In Switzerland

ECO-2 calculator

- “Personal” and “regional” scale
- Input: personal behavior and socio-technical parameters
- Output: possibility of scaling-up to country level

Suisseénergie calculators:

- Online applications for estimating demand
- Comparison to average and recommendations
- No large-scale impact

Sources:
- Novatlantis – ECO2 calculator
- Suisseenergie.ch
THE PLATFORM
Overview

- Energy calculator
- Wikipages
- MOOC
- Pocket book / e-book

Introduction
Literature review
The platform
The model
Use & Conclusions
THE PLATFORM
Energy calculator

Introduction

The platform
Key novel features:

- 23 standard + 6 percentage selection input sliders → simplification
- Representation of final consumption as heating + electricity + transportation
- No need of sequential input
- Seasonal/monthly resolution with storage
- No automatic balancing → possibility of deficit/oversupply
- Highly uncertain variables in sliders (forecasting → sensitivity analysis)
- All values in the same units!
- LCA approach: not only CO₂ emissions
THE PLATFORM
Overview

Energy calculator

Wikipages

MOOC

Pocket book / e-book

Introduction  Literature review  The platform  The model  Use & Conclusions
THE PLATFORM

Wikipages

HYDRO DAM

Hydro Dam power refers to the utilisation of the gravitational potential energy contained in a water reservoir usually created by a dam, creating an artificial basin.

The water is directed through turbines that are connected to a generator to produce electricity.

A distinction should be made between conventional, one-way hydro power systems and systems with two reservoirs connected by pipes. In the latter configuration electricity can be stored (at 80% efficiency) by pumping water from the lower to the higher reservoir.

CALCULATOR

ASSUMPTIONS

Next tables contain the assumptions that have been introduced in the Hydro Dam model of the calculator:

<table>
<thead>
<tr>
<th>Capacity factor</th>
<th>2011</th>
<th>2035</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.244</td>
<td>0.244</td>
<td>0.244</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electricity production distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Winter</strong></td>
</tr>
<tr>
<td>46%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emissions</th>
<th>2011-2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ eq. emissions (kgCO₂-eq/Wh)</td>
<td>0.000309</td>
</tr>
<tr>
<td>Deposited waste (UBP/KWh)</td>
<td>0.449</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost</th>
<th></th>
</tr>
</thead>
</table>

Click for detailed description

VALUE RANGES

MIN Value: 8.1 GW\(^1\) It corresponds to the installed capacity in 2011.

MAX Value:

**2035** 20.0 GW The potential for 2035 is estimated to be 17.40 TWh, produced by 8.19 GW (Capacity factor = 0.244).

**2050** 25.0 GW The potential for 2050 is estimated to be 17.48 TWh, produced by 8.16 GW (Capacity factor = 0.244).

### HYDRO VALUE RANGES

The OFEN has evaluated the development potential of the hydro power\(^1\). The results of the study are presented on the next table:

<table>
<thead>
<tr>
<th>Development potential of the hydro power [GW/year](^1)</th>
<th>Actual conditions</th>
<th>Optimized conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>New big plants</td>
<td>770</td>
<td>1'430</td>
</tr>
<tr>
<td>Small hydro</td>
<td>1'200</td>
<td>1'600</td>
</tr>
<tr>
<td>Transformation, extension</td>
<td>870</td>
<td>1'300</td>
</tr>
<tr>
<td>Leaks effects</td>
<td>-1'400</td>
<td>-1'400</td>
</tr>
<tr>
<td>Total potential</td>
<td>1'530</td>
<td>3'160</td>
</tr>
</tbody>
</table>

PROGNOS(2012)\(^2\) has biased its forecast for 2050 on the development potential under optimized conditions of OFEN(2012)\(^1\) and has done the net distribution between hydro river and hydro dam.

<table>
<thead>
<tr>
<th>Development potential of the hydro power [GW/year](^2)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Small hydro</td>
<td>1'600</td>
</tr>
<tr>
<td>Hydro river</td>
<td>2'000</td>
</tr>
<tr>
<td>Hydro dam</td>
<td>900</td>
</tr>
<tr>
<td>Leaks effects</td>
<td>-1'400</td>
</tr>
<tr>
<td>Total potential</td>
<td>3'100</td>
</tr>
</tbody>
</table>

The next assumptions have been considered to calculate the net potential development for hydro river and hydro dam by 2050:

- Small hydro development is attributed to run-of-river.
- The Leaks production penalty is shared between hydro river and hydro dam depending on their net electricity production\(^3\) in 2011 and 2050 for hydro river and 0% for hydro dam.

The net development potentials for each technology are added to the 2011 net electricity production\(^3\) to obtain the electricity production potential of Swiss hydro power plants in 2050:

<table>
<thead>
<tr>
<th>Net electricity production [TWh/year](^4)</th>
<th>2011</th>
<th>2035</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro river</td>
<td>16.94</td>
<td>18.73</td>
<td>19.85</td>
</tr>
<tr>
<td>Hydro dam</td>
<td>17.29</td>
<td>17.40</td>
<td>17.45</td>
</tr>
</tbody>
</table>

*The 2035 values have been calculated with a linear interpolation between 2011 and 2050 due to the lack of data for 2035.

For the cost model it is necessary to know how the new electricity production is obtained (new dams, new run of river plants, existing plants improvement and renovation). The next table has been created with the information from PROGNOS(2012)\(^2\) and OFEN(2012)\(^1\).
THE PLATFORM
Overview

- Energy calculator
- Wikipages
- MOOC
- Pocket book / e-book

Introduction
Literature review
The platform
The model
Use & Conclusions
The Energy in Switzerland

Introduction to the Swiss energy transition

Prof. D. Favrat

with contributions of P.-A. Haldi, F. Maréchal, F. Vuille
Que vaut 1 kWh?

1 kWh = consommation de 10 lampes de 100 W pendant une heure

1 kWh = quantité de chaleur dégagée par 10 personnes pendant une heure
THE PLATFORM
Overview

Energy calculator

Wikipages

MOOC

Pocket book / e-book

Introduction

Literature review

The platform

The model

Use & Conclusions
Groups of questions:
1. Problems of the energy transition
2. Actual state
3. Energy security
4. Potential of the energy efficiency
5. Advantages and disadvantages of the renewable energies
6. Energy storage
7. Effects on the electricity grid
8. Energy policies (taxes and subsidies)
9. Energy scenarios analysis
Modeling a national energy system is a demanding task. Key challenges:

- Level of **detail**: Trade-off between simplification and resolution
- Identification and choice of key variables impacting the system
- Clear distinction between supply and demand side
- Sequential VS simultaneous input
- Integration of **heat pumps** and **cogeneration** without creating loops
THE MODEL
Modeling approach

Introduction
Literature review
The platform
The model
Use & Conclusions

General/Efficiency
- Population growth
- Economics growth
- Building efficiency
- Industry efficiency
- Appliances eff.
- Lighting efficiency
- Eco. Behavior

Transportation
- % vehicles fleet
- Trains in freight
- Public transp.
- Biofuels

Heating&Cogen
- Centr vs Decen
- Technologies
- Energies

Electricity
- Cons.
- Supply
- Storage

2011 data

Total cons. (heat + elec + transp)

€/CO₂

€/CO₂

Models
Input/output

Electricity cons.
- Fuels cons.
- Electricity cons.

Electricity supply

€/CO₂

€/CO₂

€/CO₂
THE MODEL

Transport

Introduction

Literature review

The platform

The model

Use & Conclusions
Introduction

Literature review

The platform

The model

Use & Conclusions

USE & CONCLUSIONS

The first version

Reference scenario

General indicators

- Final energy consumption: 2050 value 2,150,000 GWh, 2011 value 2,150,000 GWh
- CO2-equiv. Emissions: 2050 value 40,000 thousand t, 2011 value 40,000 thousand t
- Total cost: 2050 value 30,419 million CHF, 2011 value 30,419 million CHF
- Electricity deficit: 2050 value 0 (MWh), 2011 value 0 (MWh)
- Deposited waste: 2050 value 5,560 (millions of CHF), 2011 value 5,560 (millions of CHF)

Target Year

- Show today's situation: 2011
- Please select the year you want to do computation for: 2035, 2050

Detailed graph

Monthly final energy consumption [GWh] – 2050 vs 2011

The thin bar on the right shows 2011 data

Legend:
- Waste heat
- Transport
- Process heat
- Hot water
- Space heat
- Elec transport
- Elec process
- Elec hot water
- Elec heat pump
- Elec direct heat
- Elec other
- Elec export

General:

Population growth (%/year): 0.50
Economic growth (%/year): 0.75
Ecofriendly behaviour: 1.00
USE & CONCLUSIONS
β-testers feedback

Introduction

Literature review

The platform

The model

Use & Conclusions
USE & CONCLUSIONS

β-testers feedback

Introduction
Literature review
The platform
The model
Use & Conclusions

COMPARE SITUATION

Energy
Electricity
Renewable
CO₂
Waste
Cost

General indicators

Energy (GWh)
Electricity (GWh)
Renewable (%)
CO₂ (thousand t)
Waste (billion CHF)
Cost (million CHF)

LEGEND
Click on entry to show/ hide

2011
Realistic 2050
Operet
Eurasia

Input parameters

General
Efficiency
Transport
Heating & combined heat & power
Electricity
Cost
USE & CONCLUSIONS

β-testers feedback
USE & CONCLUSIONS
β-testers feedback
**USE & CONCLUSIONS**

β-testers feedback

---

**Introduction**

**Literature review**

**The platform**

**The model**

**Use & Conclusions**
USE & CONCLUSIONS

β-testers feedback
A scenario for the Swiss energy system in 2035

Bousquet C., Cihuga B., Gallant K., Piccinini L., Popa C., Wang Q. 1

Abstract
The Swiss government has decided to shut down nuclear power plants by 2035. As a consequence, new actions will have to be found in order to satisfy the increasing energy demand while aiming at reducing environmental impacts related to energy production. This report presents a possible scenario for the Swiss energy system in 2035. The Swiss Energy Scope Online Calculator was used to assess the influence of a more eco-friendly behaviour. In view of consumption, the results show a reduction of almost 39% of the demand, from 304.787 GWh in 2011 to 188.905 GWh in 2035. An estimate of the costs for the implementation of the new system gives an amount of more than 50 billion CHF per year. Transport and heating account for more than 70% of the total costs, mainly due to fuel consumption. Finally, in the context of climate change, specific CO2 emissions would slightly increase from 50.08 to 67.18 ktcO2e/kWh, but the overall emissions would decrease by 44%, which seems very optimistic and reflects the chosen perspective for the scenario.

1 Ecole polytechnique fedérale de Lausanne (EPFL), Environmental Sciences and Engineering Section

1. Introduction
The Swiss government has decided to shut down nuclear power plants by 2035. As a consequence, solutions to replace the nuclear electricity production and to supply the increasing energy demand have to be found. Involved stakeholders will need to consider a trade-off between ecology and costs to meet this challenge.

In this report, a description of the current situation and main factors influencing the energy demand is followed by the presentation of a possible solution for the Swiss energy system in 2035. An estimate of the costs and CO2 emissions related to the chosen scenario, which mainly focuses on the promotion of eco-friendly behaviours among the population, is then provided. Calculations were made possible by the Swiss Energy Scope Online Calculator (SESOC), a tool that is under development at the Industrial Energy Systems Laboratory at EPFL, and aims at facilitating the assessment of the influence of decisions on the future energy system of Switzerland.

2. Analysis of the current energy demand
The analysis of the current energetic situation in Switzerland is a necessary step to identify critical constraints and to assess the feasibility of the scenario for 2035 that is presented below. The SESCOC provides data for 2011 which are used in what follows to describe the present situation.

The total electricity demand in Switzerland in 2011 was 63’802 GWh, whereas the total production was only 60’403 GWh. The deficit between demand and production is therefore 2564 GWh, which has to be covered by imports. Nevertheless, the production largely covers the demand during summer months 2343 GWh were exported between May and October 2011 and lags behind demand only during winter. The electricity demand gets higher during winter months mainly because of the heating requirements. These seasonal variations are of concern when defining an energetic scenario for the future, since the chosen technologies should cover the higher demand in winter. For instance, renewable energy technologies such as PV panels, which are attractive from an ecological point of view, produce less electricity in winter than in summer, whereas gas turbines have a higher production rate during winter. The efficiency of gas turbines is in fact directly related to the ambient temperature - i.e. the higher the temperature, the lower the efficiency [1].

Focusing on the currently in-use technologies, one can observe (see Figure 1) that the overall electricity production is essentially based on three technologies only: nuclear power plants, dams and run-of-the-river installations.Cogeneration accounts for 6% and a negligible 0.2% of the total production is due to PV panels. Nowadays, nuclear power accounts for the major share of the electricity production, with four operational plants: Beznau (AG), Mühleberg (BE), Gösgen (SO) and Leibstadt (AG). The decommissioning of these plants is planned to start in 2019 and has to be finished by 2041 [1]. Replacing the nuclear electricity production with other technologies is therefore a critical challenge for Switzerland.

The hydroelectric potential of the country is already highly exploited. In fact the growth potential till 2015 is considered to be only 5% [2]. Moreover, in the case of run-of-the-river installations, 65% of the yearly production occurs during spring and summer, based on data from the SESCOC. It is therefore not realistic to rely on an increase in hydroelectric production to cover the gap left by the shut-down of nuclear power plants.

Regarding the share of electricity consumption among the different sectors, it can be noticed in Table 1 that households and industry are the main consumers. Since the Swiss population

Use & Conclusions
Field test at the EPFL

Energy Conversion
Prof. François Maréchal, Spring 2014

• 50 master students
• Background: environment, management of technology, engineering, architecture
• Group project

Key tasks:
• Use the calculator to define a scenario for 2035
• Challenge: develop the cost model!
• 6-8 pages scientific paper style report

Introduction
Literature review
The platform
The model
Use & Conclusions

26/08/2014

36
**USE & CONCLUSIONS**

Field test at the EPFL

Do you think the calculator, once finalised in all its parts, could help citizens and politicians to understand energy and make decisions?*
Take into account you tested a beta version for both model, interface and wiki. This question concerns the future use of the tool after some improvements.

1 2 3 4 5

Totally disagree ☐ ☐ ☐ ☐ ☐ Totally agree

Did the use of the calculator allow you to gather a better understanding of the Swiss energy system?*

1 2 3 4 5

Totally disagree ☐ ☐ ☐ ☐ ☐ Totally agree

Did you find the use of the calculator intuitive/easy?*

1 2 3 4 5

Totally disagree ☐ ☐ ☐ ☐ ☐ Totally agree

Did the use of the wiki help you in the use of the calculator?*

1 2 3 4 5

Totally disagree ☐ ☐ ☐ ☐ ☐ Totally agree

Average
Respondents: 11/47
Conclusions

- Platform still to be refined, but positive feedbacks
- Both learning and decision-making support tool
- Sequential modeling strategy:
  - Simplification $\rightarrow$ fewer inputs
  - Integration of heat pumps and cogeneration
  - Monthly/seasonal approach
- Adaptation to other energy systems under-way
- Demystifying the complexity of an energy system without oversimplifying it
Thank you for your attention! Questions?

Public release: November 2014