17th Conference on Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction, 23-27 August 2014, Prague, Czech Republic

“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:

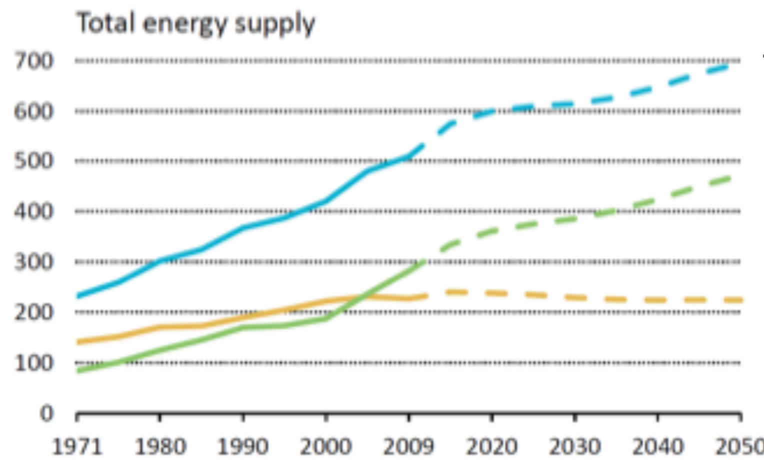
- Introduction
- Literature review
- The platform
- The model
- Use of the platform & Conclusions

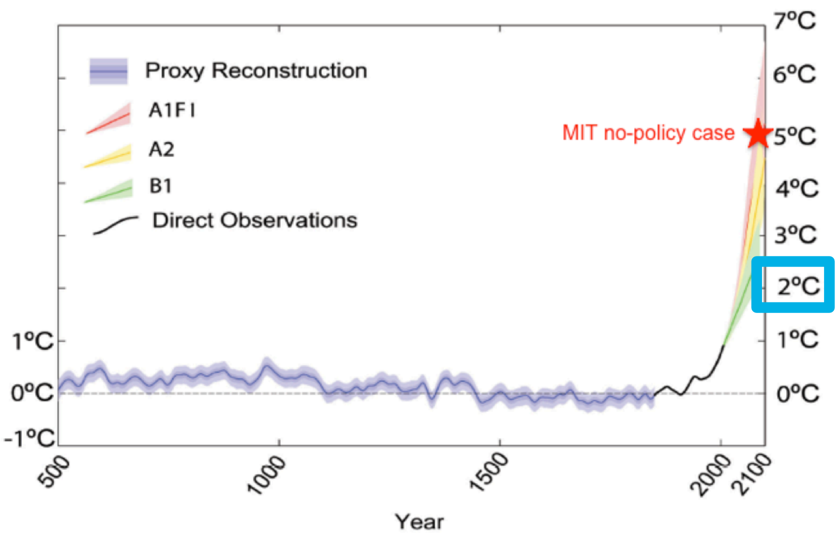
INTRODUCTION
The global context

Sources:
- Copenhagen Diagnosis 2009, with MIT data taken from Sokolov et al. 2009.
- Jonathan Koomey, "Energy and society" lecture notes, UC Berkeley 2011
- IPCC 2013 report, Climate change 2013 - The physical science basis
- IEA, ETP 2012

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°C ΔT limit CO_2 emissions need to be halved by 2050

Challenge: **4x** emissions reduction by 2050

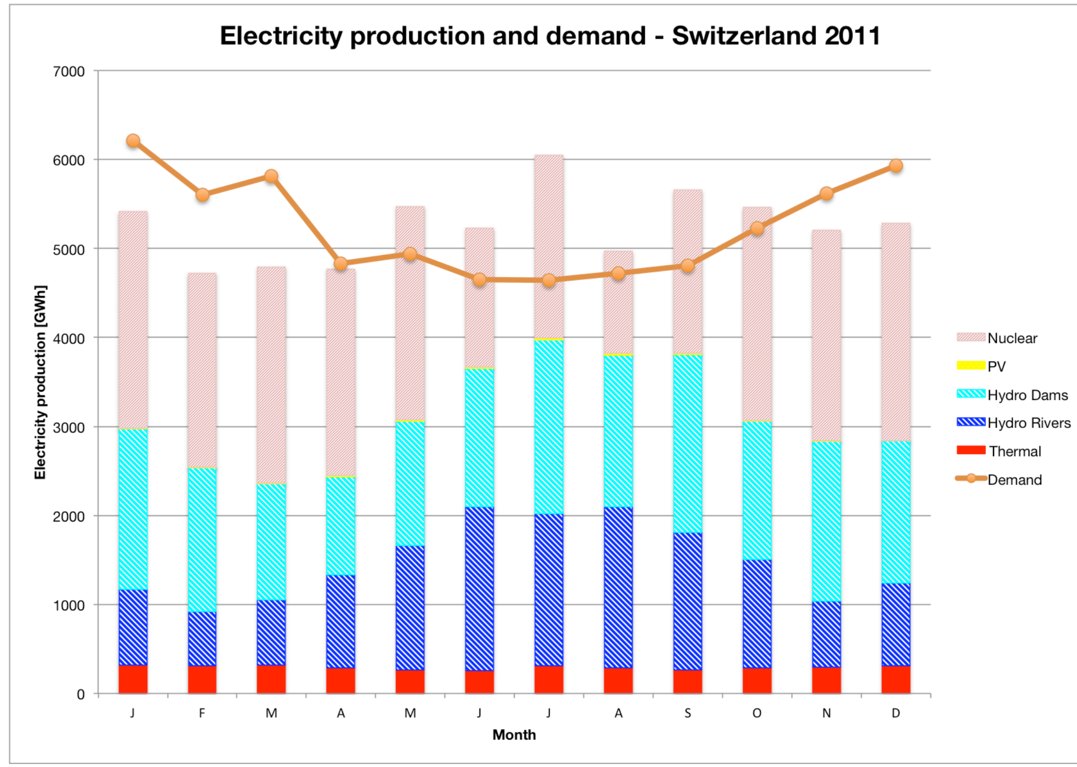
Introduction | Literature review | The platform | The model | Use & Conclusions

INTRODUCTION
The Swiss context

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

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 | Literature review | The platform | The model | Use & Conclusions

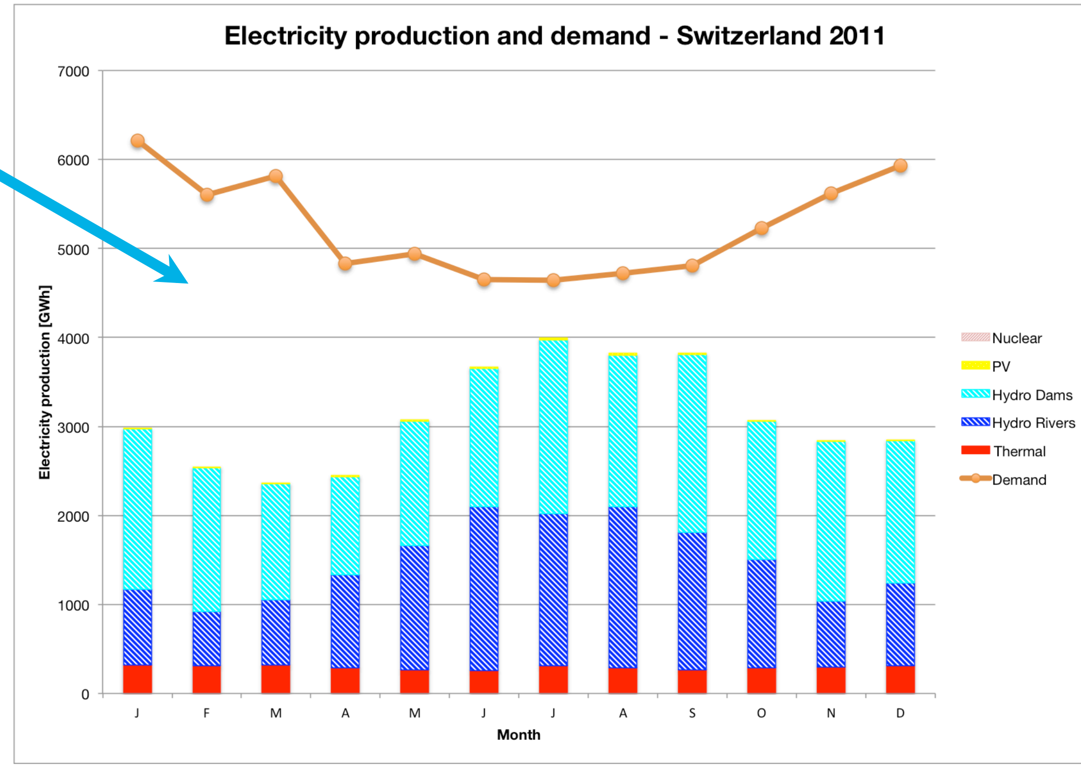
INTRODUCTION
The Swiss context

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

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!

Introduction | Literature review | The platform | The model | Use & Conclusions

INTRODUCTION
The problem of energy literacy

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

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

INTRODUCTION
Key goals

In the case of Switzerland:

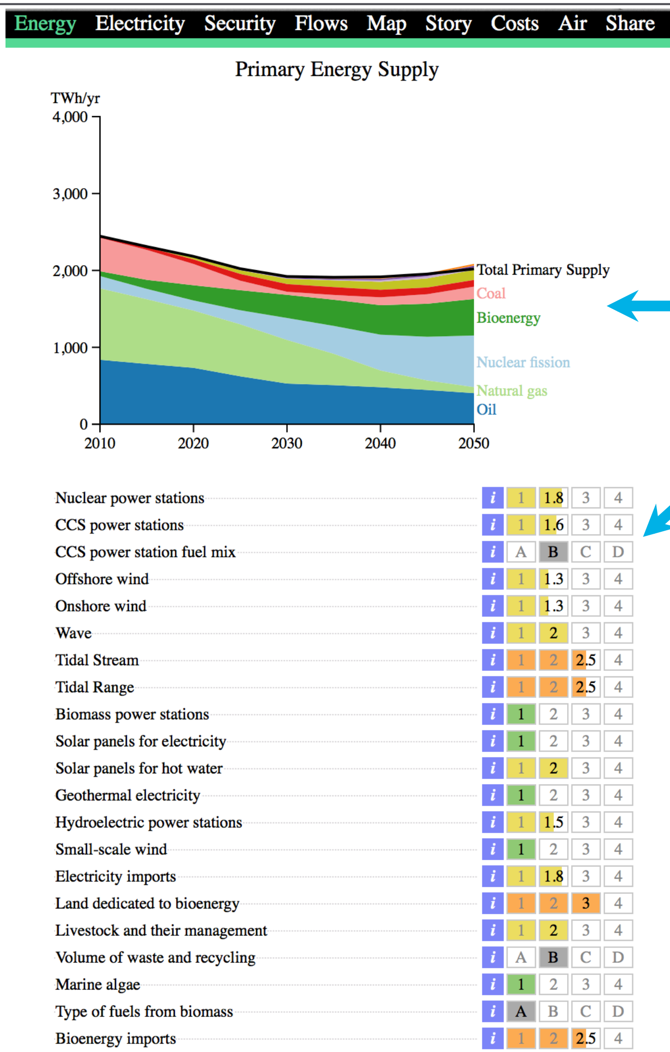
- Active involvement of the population in political decision-making (referendums)
- Vibrant debate on the energy transition (mostly on electricity, though)
- Need of fact-checking

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

LITERATURE REVIEW
2050 Pathways - UK

Sources:
- UK DECC (2014)

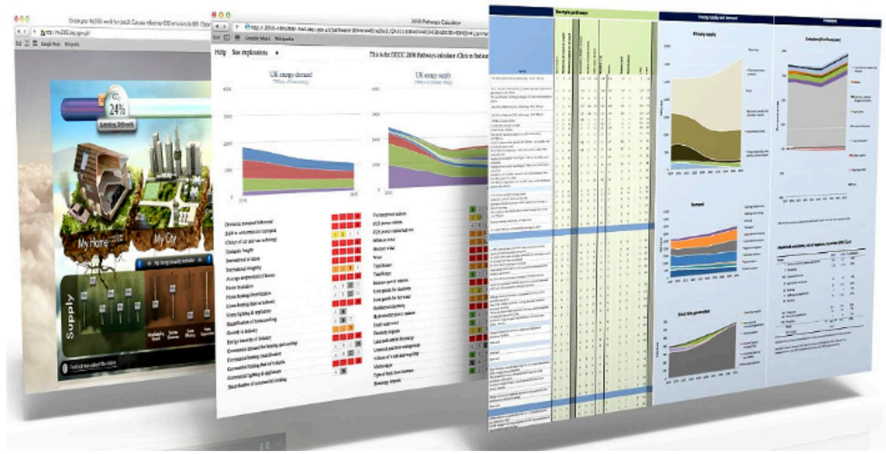


Key features:

- 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

LITERATURE REVIEW
2050 Pathways - UK

Sources:
- UK DECC (2014)



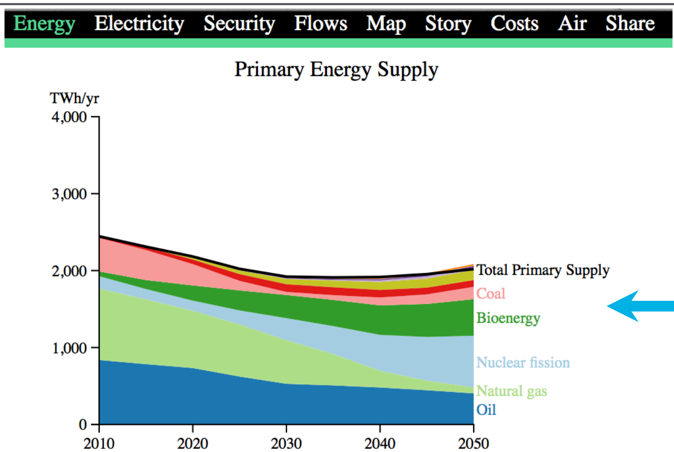
Adapted to other countries:

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

2050 Global calculator

LITERATURE REVIEW
2050 Pathways - UK

Sources:
- UK DECC (2014)



Nuclear power stations	i	1	1.8	3	4
CCS power stations	i	1	1.6	3	4
CCS power station fuel mix	i	A	B	C	D
Offshore wind	i	1	1.3	3	4
Onshore wind	i	1	1.3	3	4
Wave	i	1	2	3	4
Tidal Stream	i	1	2	2.5	4
Tidal Range	i	1	2	2.5	4
Biomass power stations	i	1	2	3	4
Solar panels for electricity	i	1	2	3	4
Solar panels for hot water	i	1	2	3	4
Geothermal electricity	i	1	2	3	4
Hydroelectric power stations	i	1	1.5	3	4
Small-scale wind	i	1	2	3	4
Electricity imports	i	1	1.8	3	4
Land dedicated to bioenergy	i	1	2	3	4
Livestock and their management	i	1	2	3	4
Volume of waste and recycling	i	A	B	C	D
Marine algae	i	1	2	3	4
Type of fuels from biomass	i	A	B	C	D
Bioenergy imports	i	1	2	2.5	4

Key features:

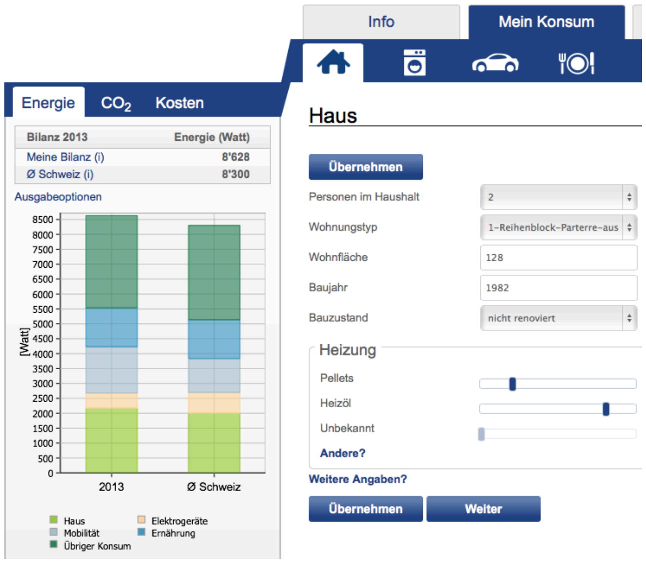
- Goal: *"strengthen the level of debate on energy issues in the UK"*
- Output: pathway to 2050 in terms of energy, electricity, GHG emissions, costs
- Input: 42x4 input variables
- Online available wiki
- Available pre-defined scenarios

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

Sources:
- Novatlantis – ECO2 calculator
- Suisseenergie.ch



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

suisse énergie
Notre engagement : notre futur.

Introduction | Literature review | The platform | The model | Use & Conclusions

THE PLATFORM
Overview

Energy calculator	Wikipages
MOOC	Pocket book / e-book

THE PLATFORM
Overview

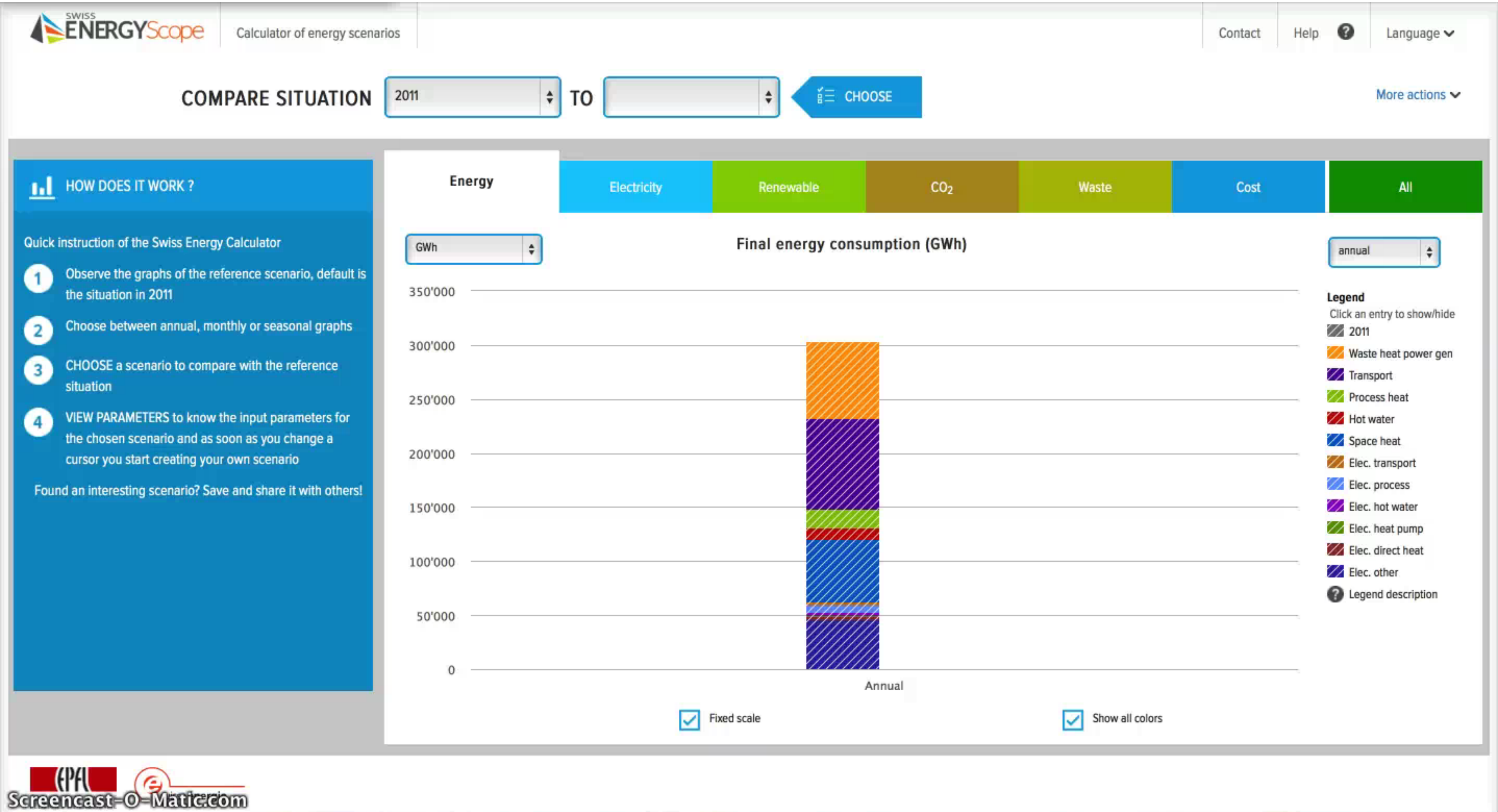
Energy calculator

Wikipages

MOOC

Pocket book / e-book

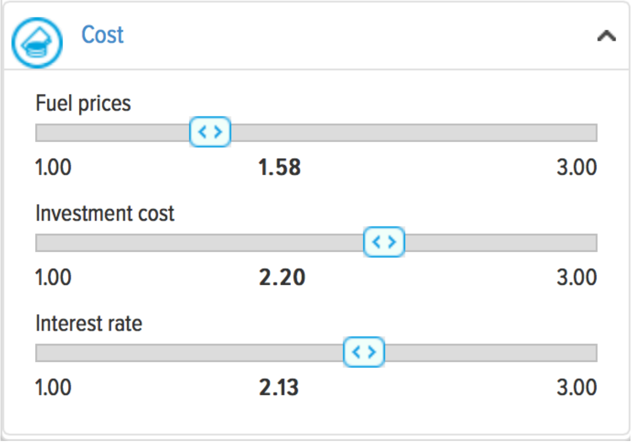
THE PLATFORM
Energy calculator



THE PLATFORM
Energy calculator

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 CO_2 emissions



THE PLATFORM
Overview

Energy calculator

Wikipages

MOOC

Pocket book / e-book

THE PLATFORM
Wikipages

HYDRO DAM

Table of contents

Hydro Dam power refers to the utilisation of the gravitational potential energy contained 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.

Edit

CALCULATOR

Edit

ASSUMPTIONS

Next tables contain the assumptions that have been introduced in the Hydro dam model of the calculator.

Capacity factor		
2011	**2035**	**2050**
0.244	0.244	0.244

Electricity production distribution	
Winter	**Summer**
48%	52%

Emissions	
	2011-2050
CO_2-eq. emissions [$kgCO_2$-eq./kWh_e]	0.00530
Deposited waste [UBP/kWh_e]	0.449

Cost

Click for detailed description

Edit

VALUE RANGES

MIN Value: 8.1 GW [1]. It corresponds to the installed capacity in 2011.

MAX Value:

2035	8.2GW	The potential for 2035 is estimated to be 17.40 TWh, produced by 8.13 GW (Capacity factor = 0.244).
2050	8.2GW	The potential for 2035 is estimated to be 17.48 TWh, produced by 8.18 GW (Capacity factor = 0.244).

Edit

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:

Development potential of the hydro power [GWh/year][1]		
	Actual conditions	**Optimized conditions**
New big plants	770	1'430
Small hydro	1'290	1'600
Transformation, extension	870	1'530
LEaux effects	-1'400	-1'400
Total potential	**1'530**	**3'160**

PROGNOS(2012) [2] has based its forecast for 2050 on the development potential under optimized conditions of OFEN(2012) [1] and has done the next distribution between hydro river and hydro dam.

Development potential of the hydro power [GWh/year][2]	
Small hydro	1600
Hydro river	2000
Hydro dam	900
LEaux effects	-1400
Total potential	**3100**

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 LEaux production penalty is shared between hydro river and hydro dam depending on their net electricity production [3] in 2011:49% for hydro river and 51% 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:

Net electricity production [TWh/year]*			
	2011	**2035**	**2050**
Hydro river	16.94	18.73	19.85
Hydro dam	17.29	17.40	17.48

*The 2035 values has 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

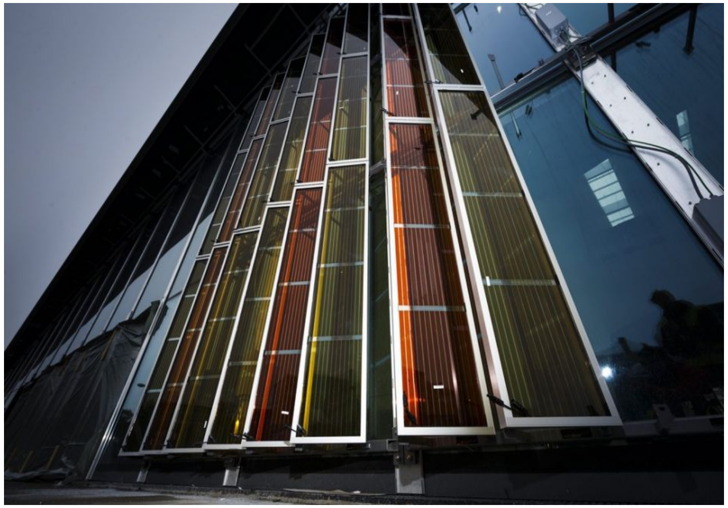
THE PLATFORM
Massive Open Online Course (MOOC)

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

La transition énergétique suisse

THE PLATFORM
Overview

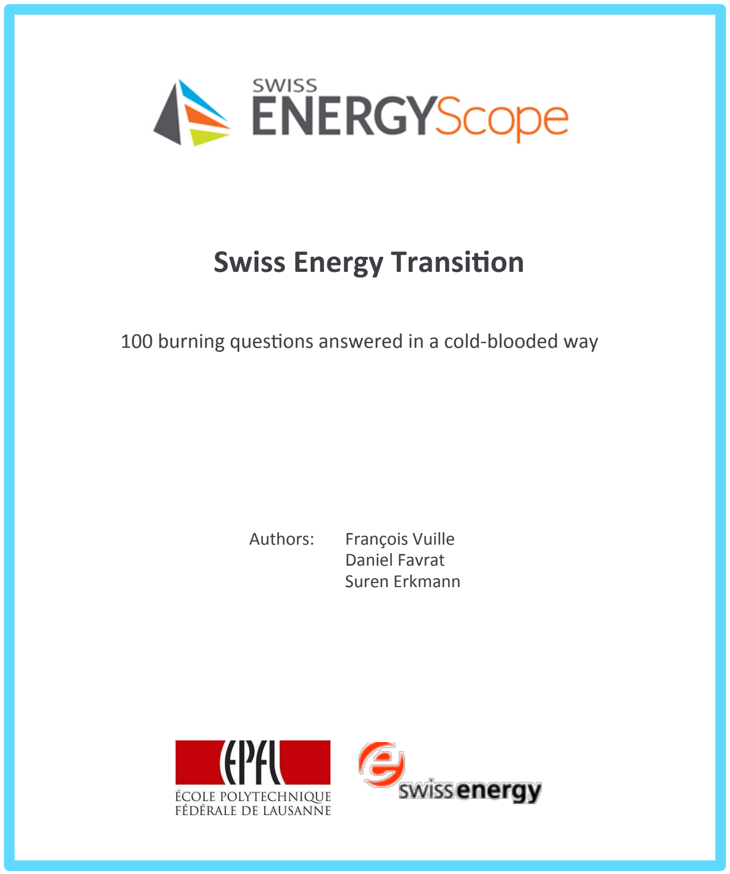
Energy calculator

Wikipages

MOOC

Pocket book / e-book

THE PLATFORM
Pocket book / e-book


SWISS ENERGYScope

Swiss Energy Transition

100 burning questions answered in a cold-blooded way

Authors: François Vuille
Daniel Favrat
Suren Erkmann

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

swissenergy

Groups of questions:

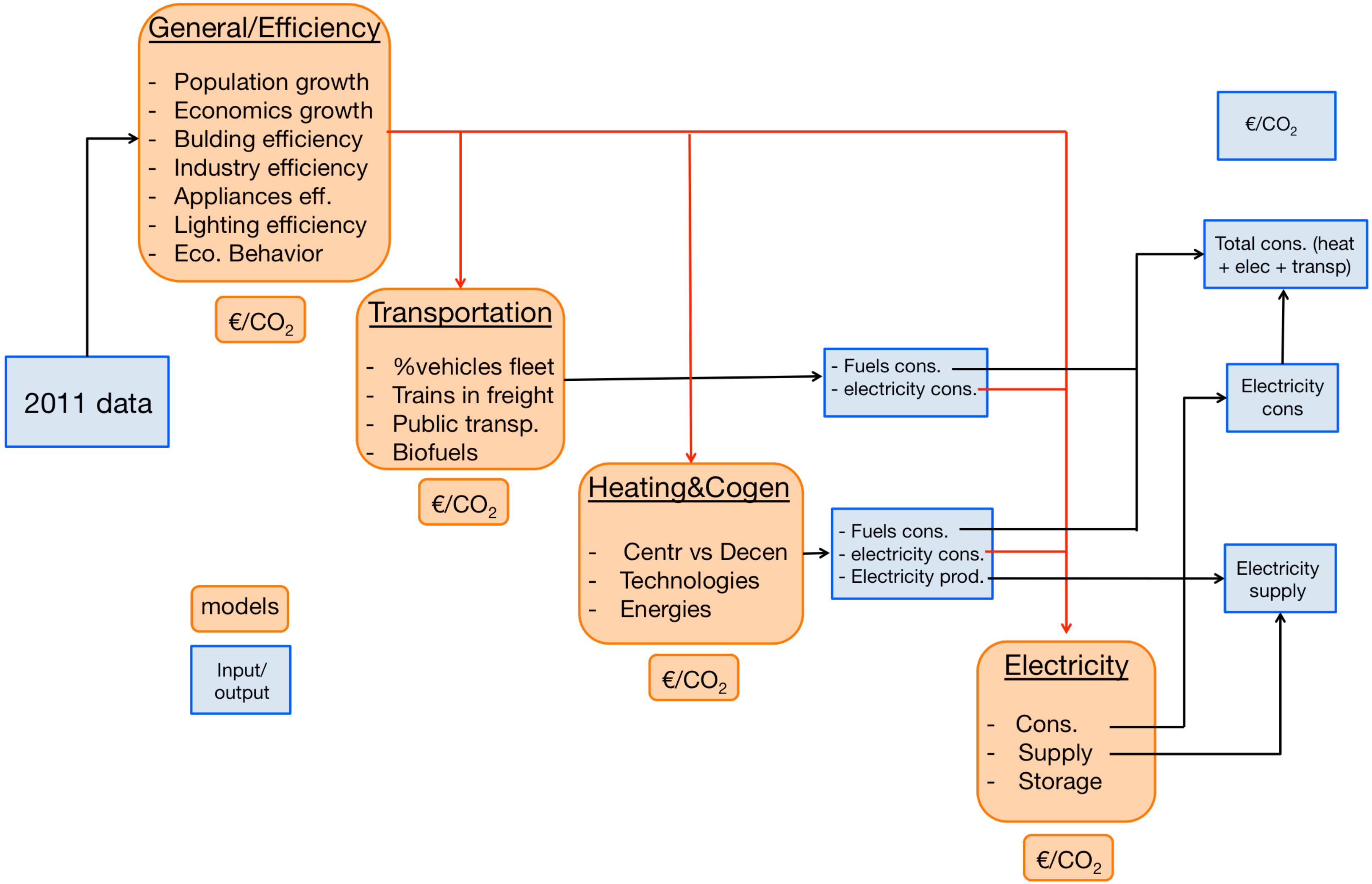
1. Problems of the energy transition
2. Actual state
3. Energy security
4. Potential of the energy efficiency
5. Advantages and disadvantages of the renewable energies
6. Energy storage
7. Effects on the electricity grid
8. Energy policies (taxes and subsidies)
9. Energy scenarios analysis

THE MODEL
Modeling approach

Modeling a national energy system is a demanding task. Key challenges:

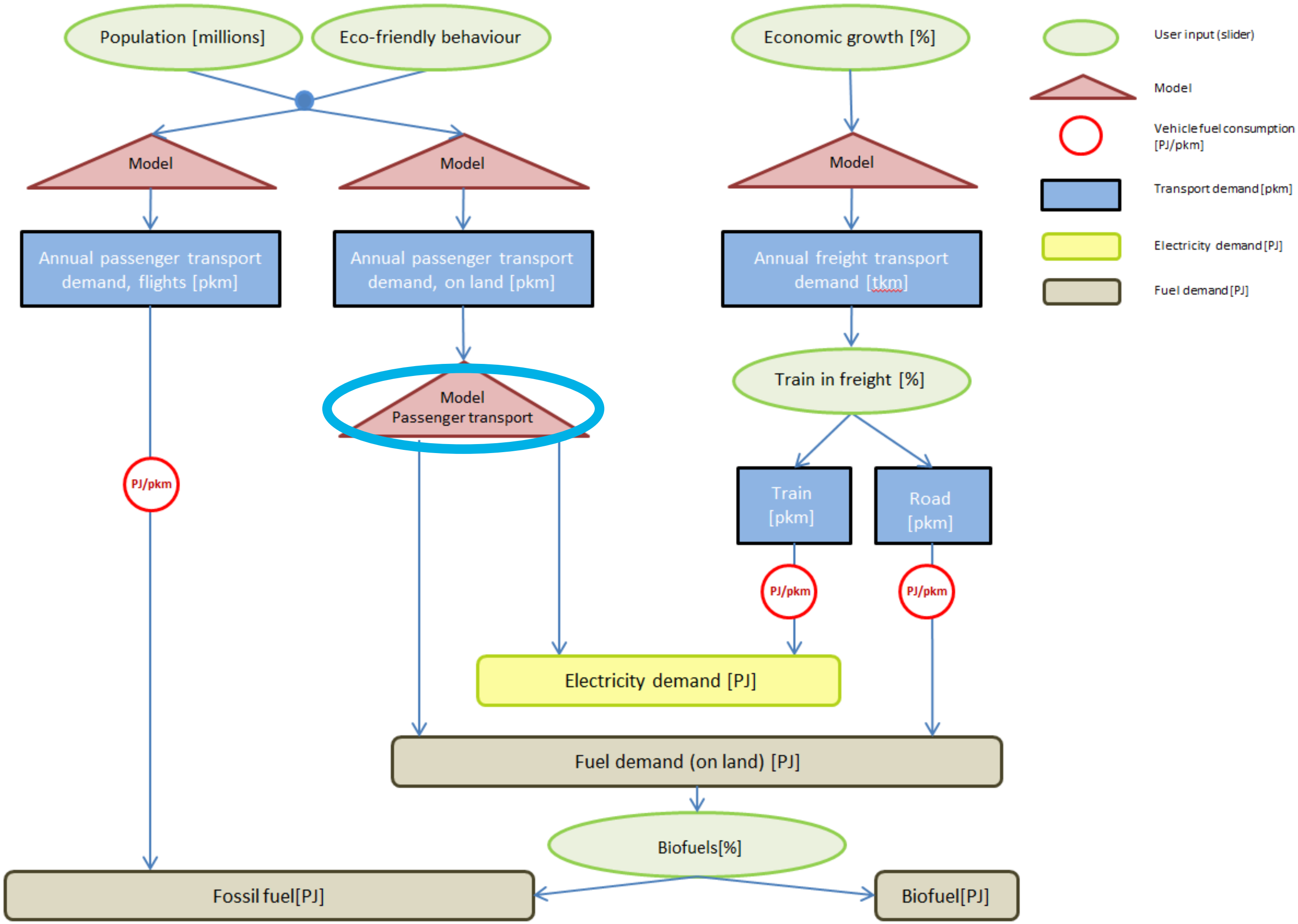
- Level of detail: Trade-off between simplification and resolution
- Identification and choice of key variables impacting the system
- Clear distinction between supply and demand side
- Sequential VS simultaneous input
- Integration of heat pumps and cogeneration without creating loops

THE MODEL
Modeling approach



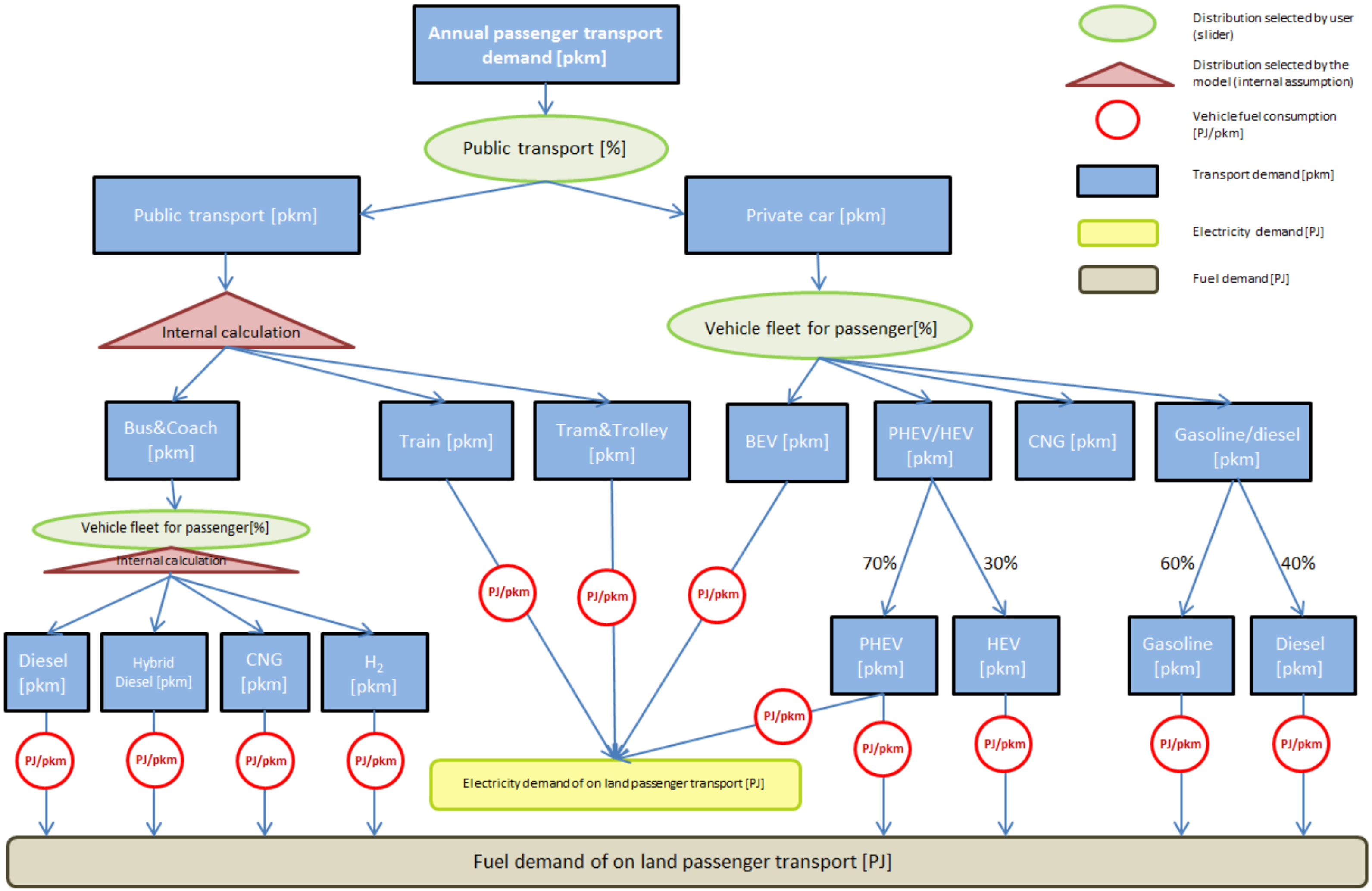
Introduction | Literature review | The platform | The model | Use & Conclusions

THE MODEL
Transport

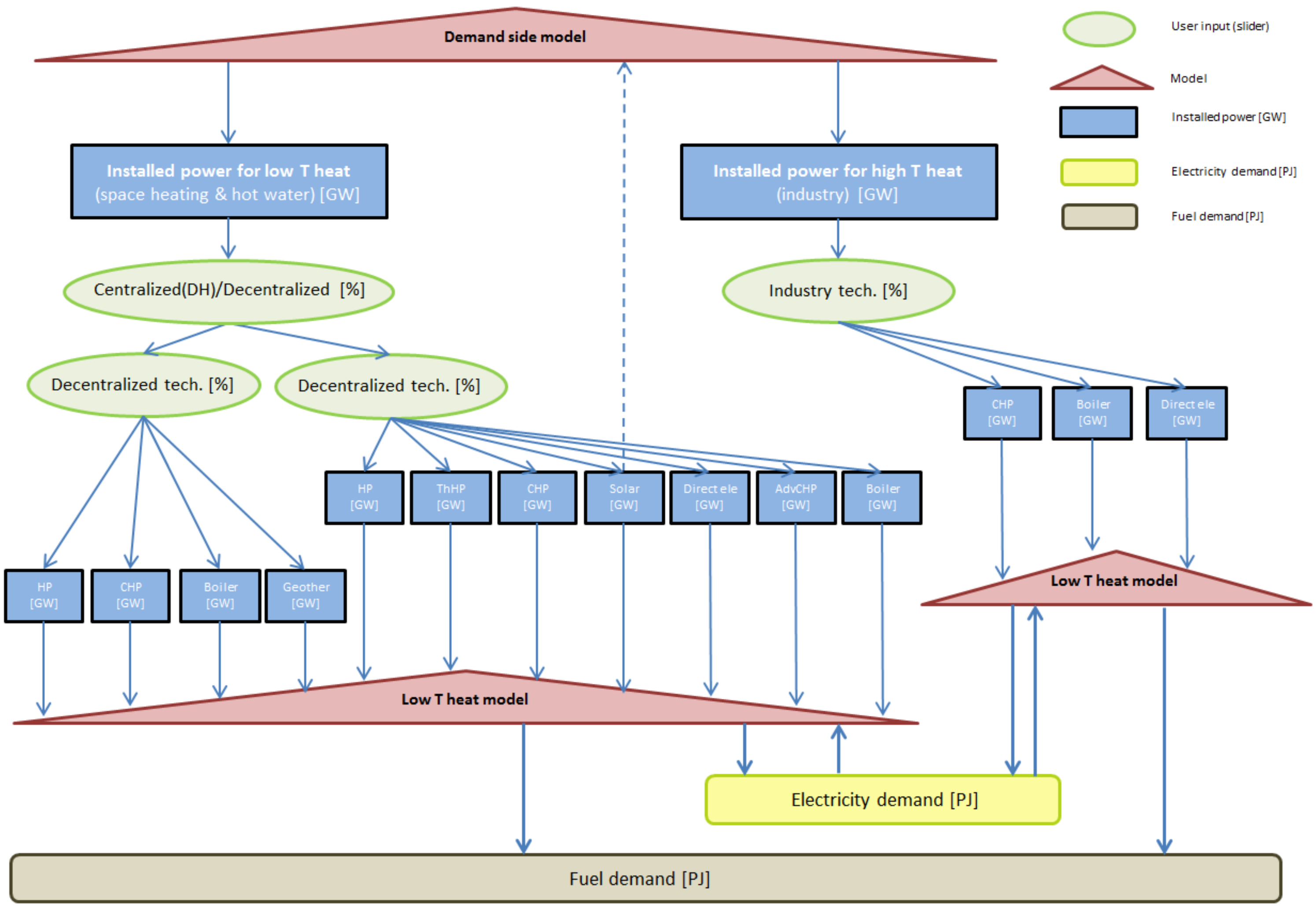


Introduction | Literature review | The platform | The model | Use & Conclusions

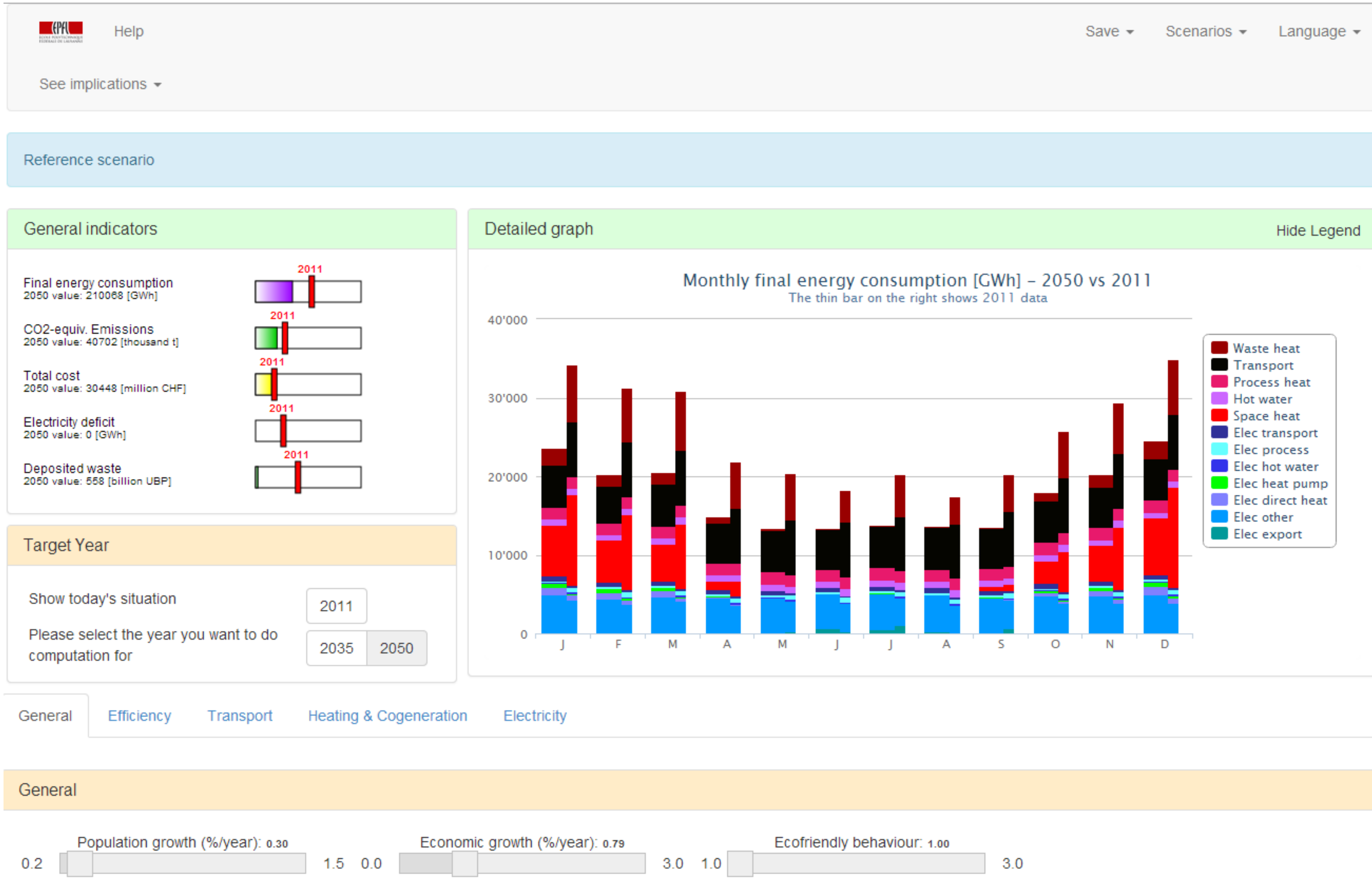
THE MODEL
Transport – Passenger transport



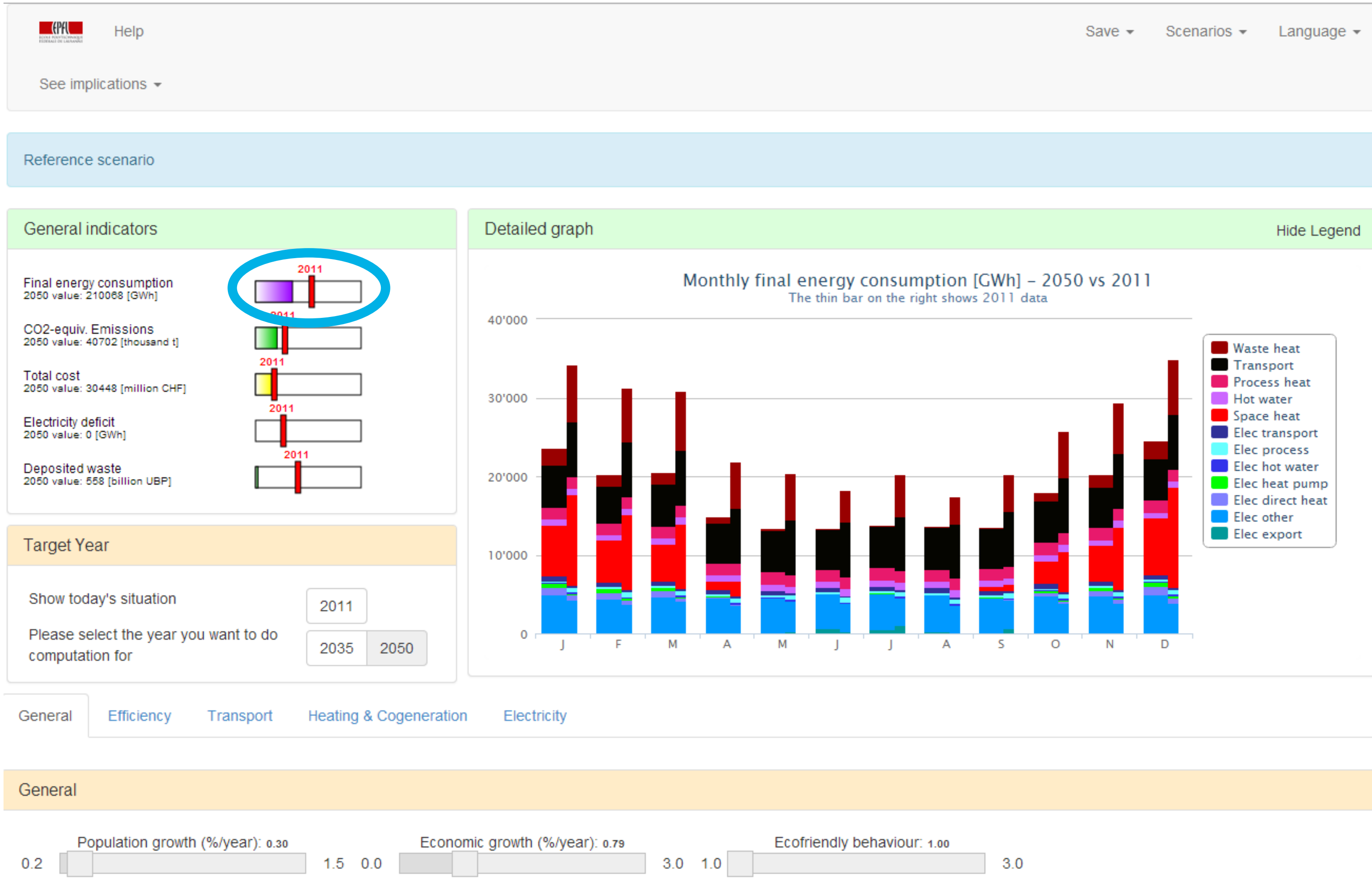
THE MODEL
Heating & Cogeneration



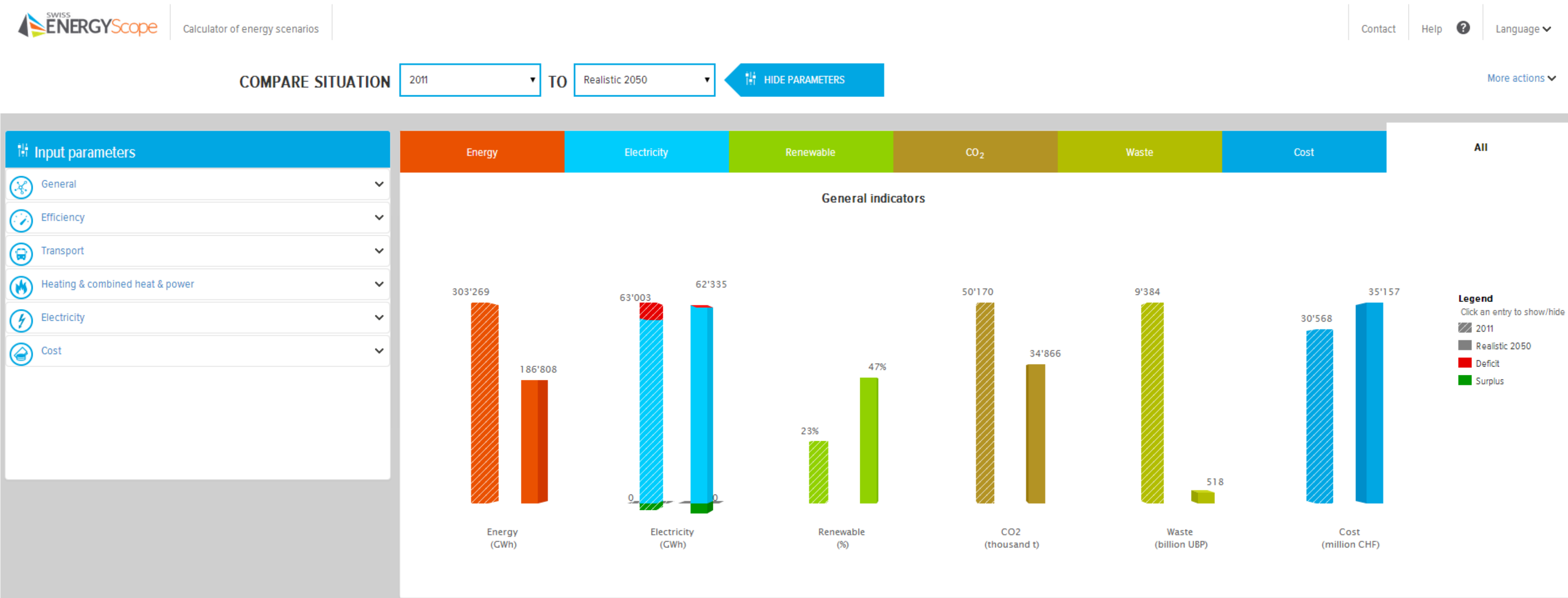
USE & CONCLUSIONS
The first version



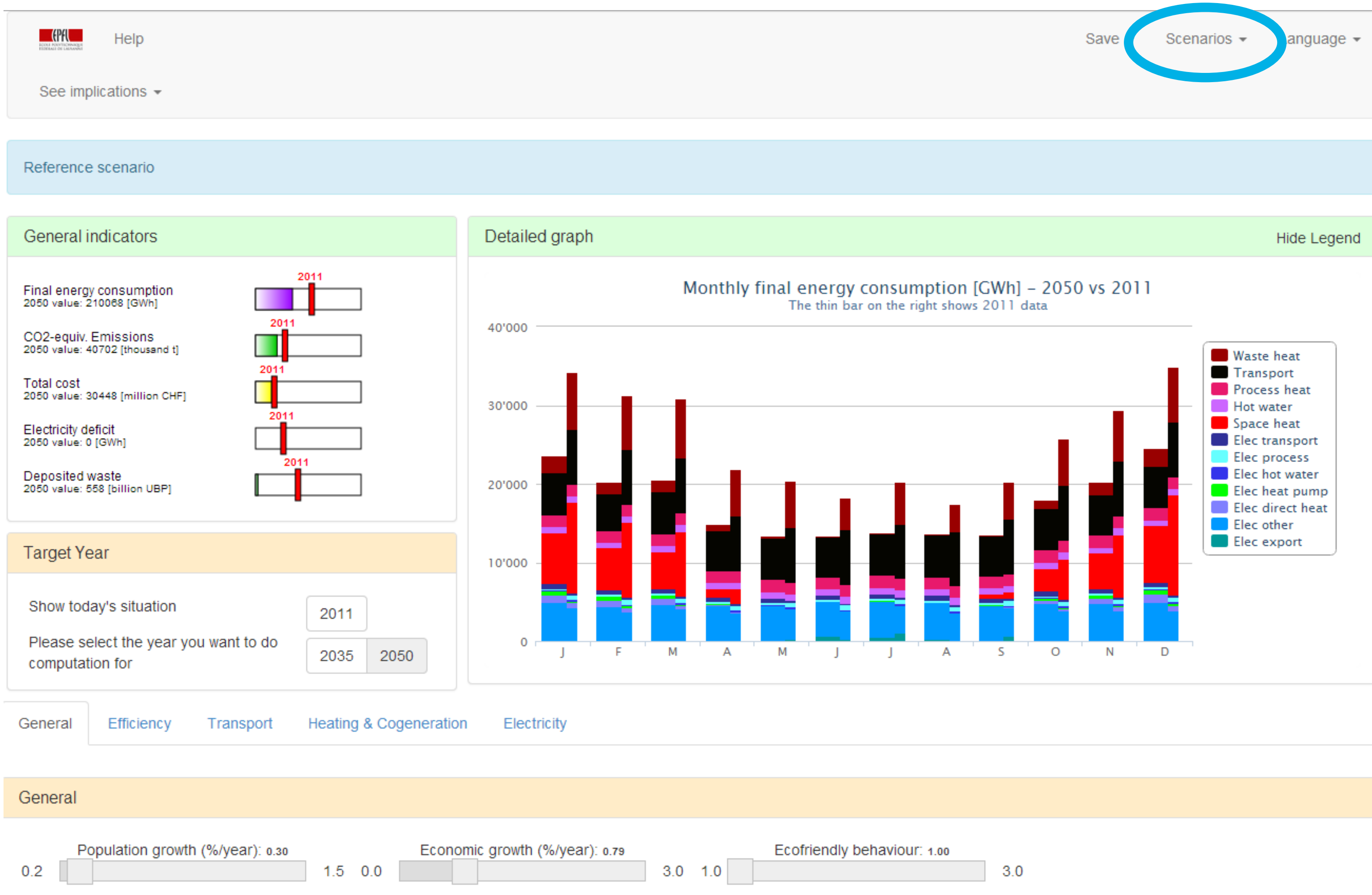
USE & CONCLUSIONS
β-testers feedback



USE & CONCLUSIONS
β-testers feedback

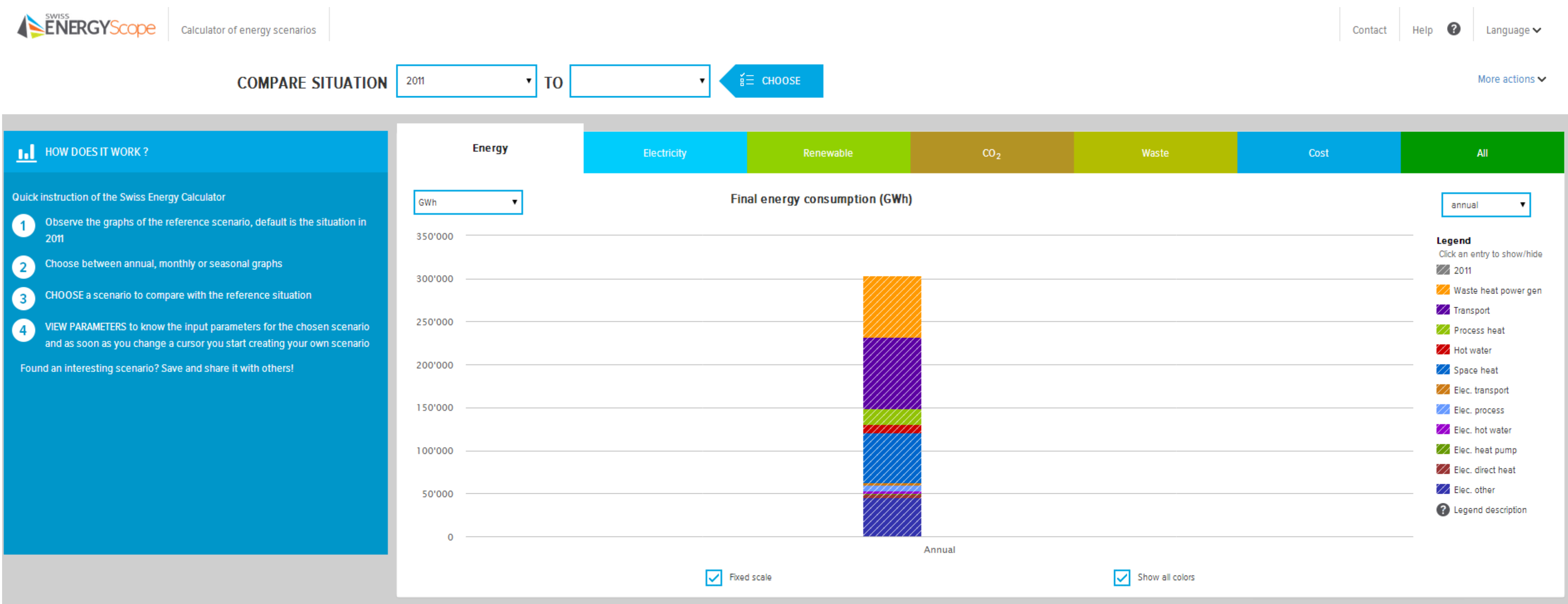


USE & CONCLUSIONS
β-testers feedback

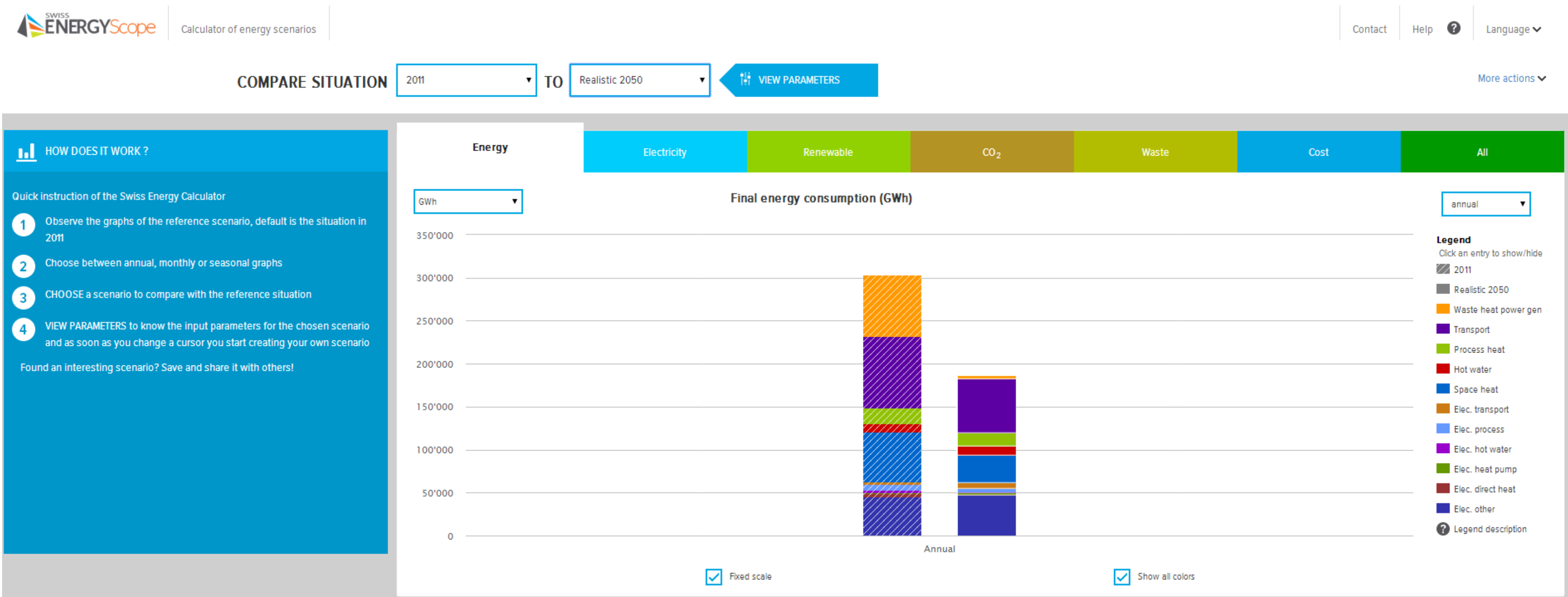


Introduction | Literature review | The platform | The model | Use & Conclusions

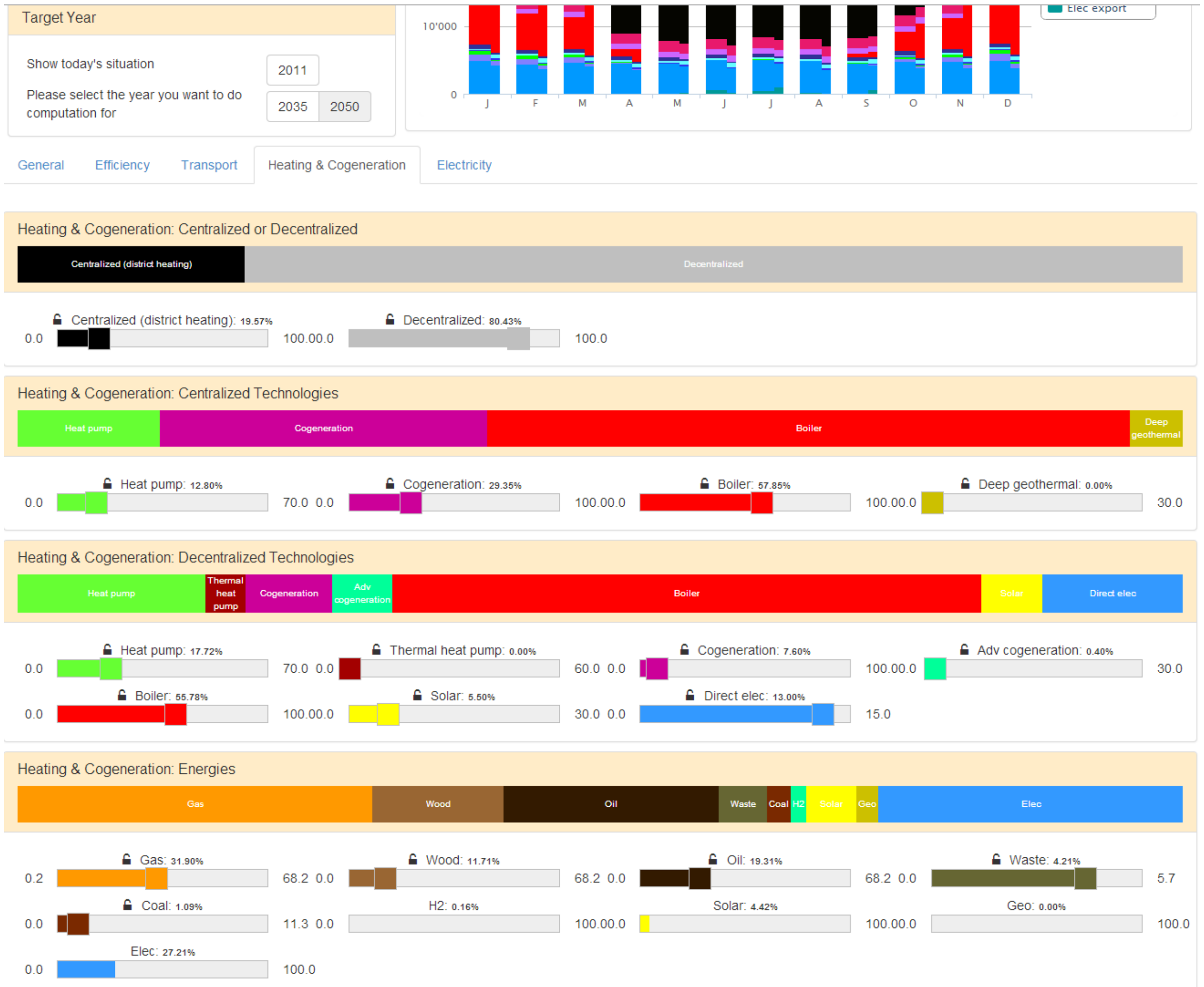
USE & CONCLUSIONS
β-testers feedback



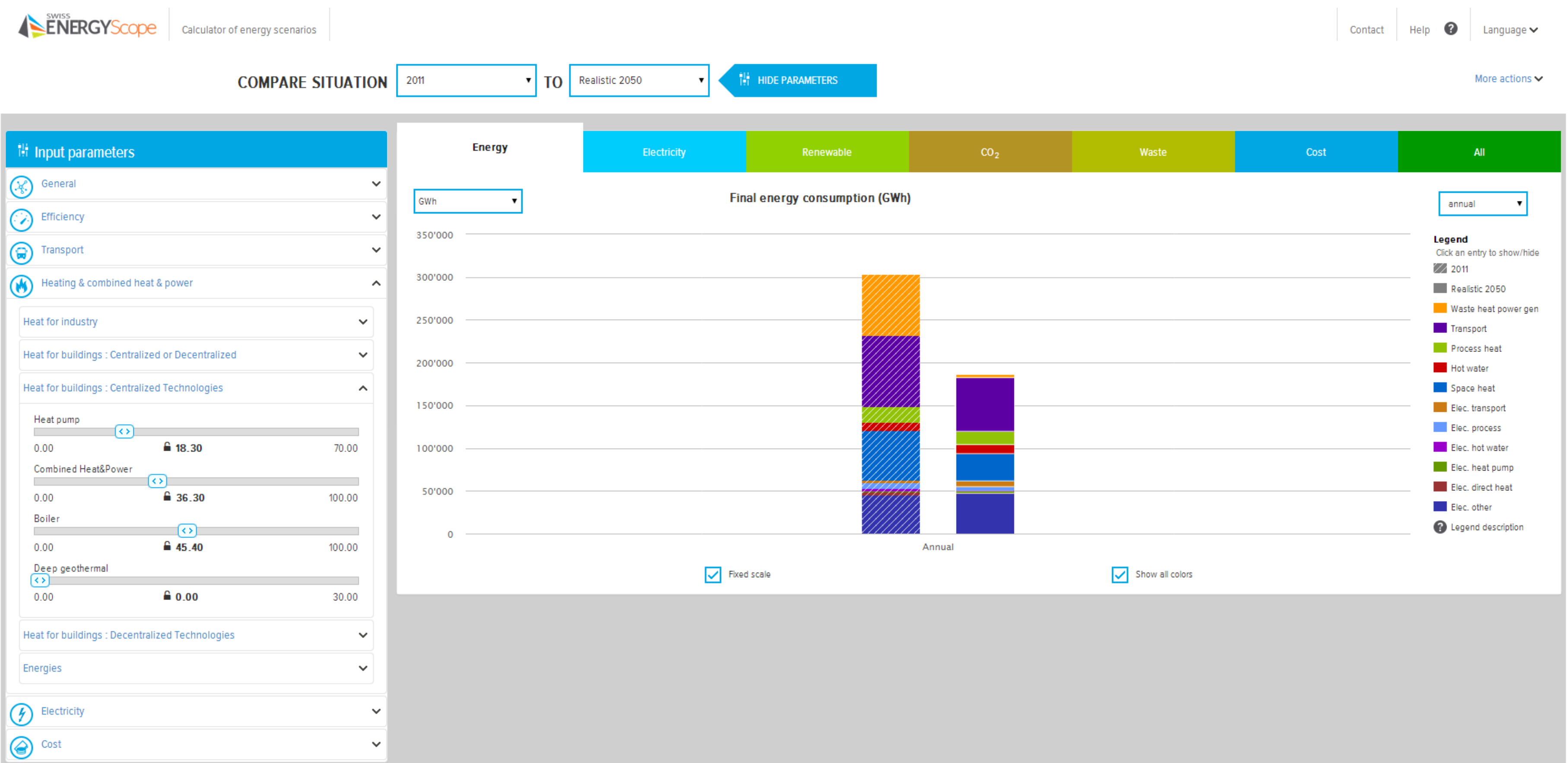
USE & CONCLUSIONS
β-testers feedback



USE & CONCLUSIONS
β-testers feedback



USE & CONCLUSIONS
β-testers feedback



Introduction | Literature review | The platform | The model | Use & Conclusions

USE & CONCLUSIONS
Field test at the EPFL

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

A scenario for the Swiss energy system in 2035

Bousquet C., Cîrlugea B., Gallandat 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 solutions 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 ecofriendly behaviour. In terms of consumption, the results show a reduction of almost 39% of the demand, from 304'787 GWh in 2011 to 186'905 GWh in 2035. An estimate of the costs for the implementation of the new system give an amount of more than 50 billion CHF/yr. 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 CO_2 emissions would slightly increase - from 50.08 to 67.18 kt $CO_{2,eq}/kWh_{el}$ - but the overall emissions would decrease by 44%, which seems very optimistic and reflects the chosen perspective for the scenario.

[1] *Ecole polytechnique fédérale 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 CO_2 emissions related to the chosen scenario, which mainly focuses on the promotion of ecofriendly 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 SESOC provides data for 2011 which are used in what follows to describe the present situation.

The total electricity demand in Switzerland in 2011 was 63'002 GWh whereas the total production was only 60'4038 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 2034 [2]. 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 2035 is considered to be 5% only [3]. 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 SESOC. 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

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

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

USE & CONCLUSIONS
Conclusions

- Platform still to be refined, but positive feedbacks
- Both learning and decision-making support tool
- Sequential modeling strategy:
  - Simplification → 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

USE & CONCLUSIONS
Thank you!

Public release:
November 2014

Thank you for your attention! Questions?