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Wir schaffen Wissen – heute für morgen

Experience from the development of a new Swiss TIMES Electricity Model

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Joint TERI-ETSAP Workshop
Energy Modelling Tools & Techniques to address Sustainable Development & Climate Change
New Delhi, 21-22 January 2010

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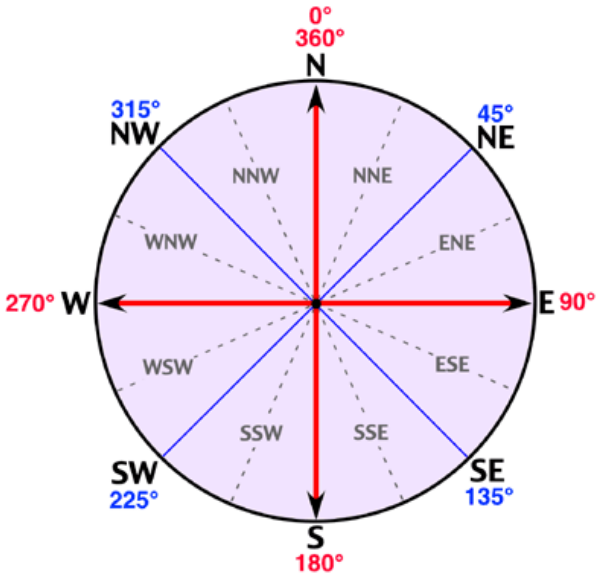
Presentation outline

- Overview of Swiss energy system
  - Energy and emissions
  - Policy objectives
- Swiss power sector
  - Challenges and opportunities
- Development of Swiss TIMES electricity model
  - Swiss MARKAL model
  - Motivations
  - Status of the current model (Sept-Nov 09)
- Preliminary results
- Future direction

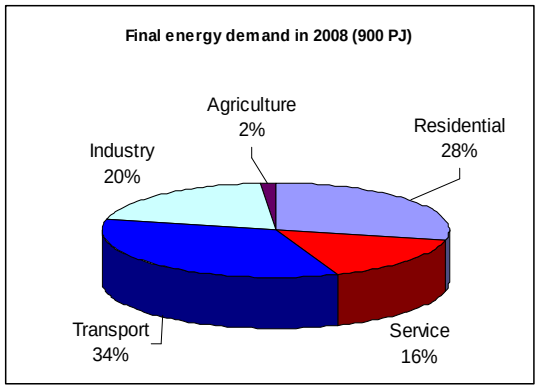


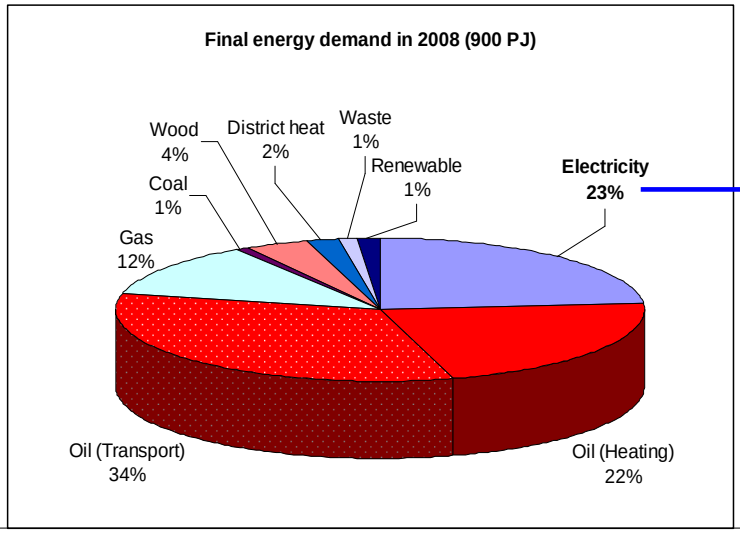
Swiss energy system overview

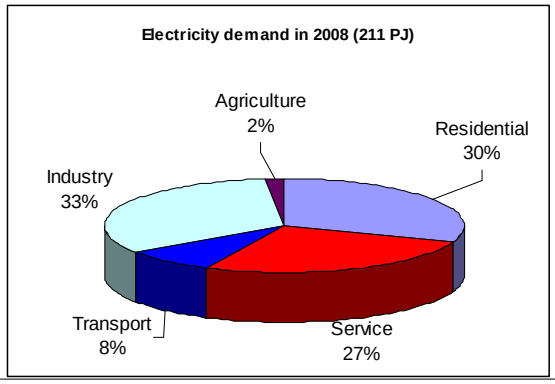
Energy Economy

- Energy expenditure: ~US$ 25 Billion* (5.4% of GDP)
- Energy import: 4.1% of total import expenditure
- Energy dependency: 80% (two-third of the final energy demand is fossil fuels)

* CHF 28. 29 Billion SOFE, 2008: Table 2





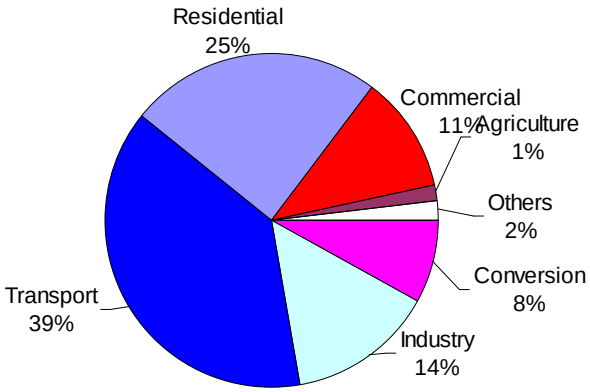


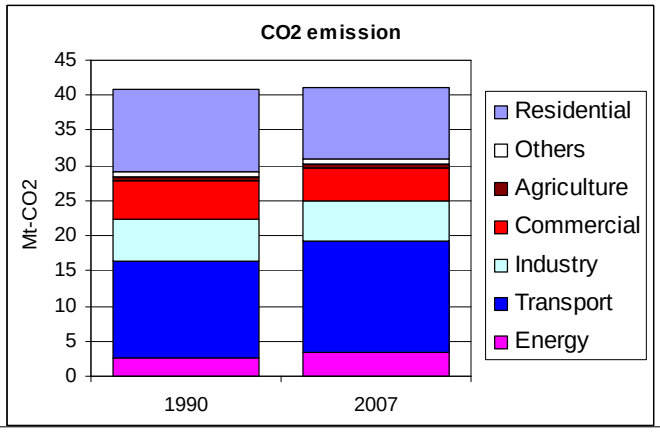
Swiss energy system overview

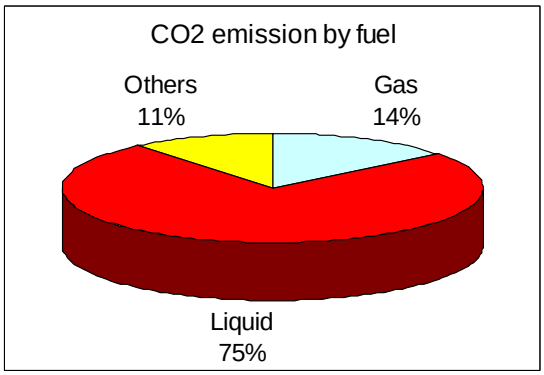
CO_2 emissions

- Energy use accounts for 82% of the total GHG emissions
- Residential and transport sectors account for two-third of the total CO_2 emissions
- Power sector is nearly decarbonised
- CO_2 emission declines in end-use sectors due to fuel switch from oil to gas while natural gas based emission increased by 65% from 1999 level

CO2 emission from fuel combusion (41 Mt-CO2 in 2007)







Swiss energy system overview

Energy policy objectives

- To improve energy efficiency
- To extend the use of renewable forms of energy
- To ensure the security of supplies
- To relieve the burden on the climate and thus promote a sustainable economy

Policy goals for the year 2010

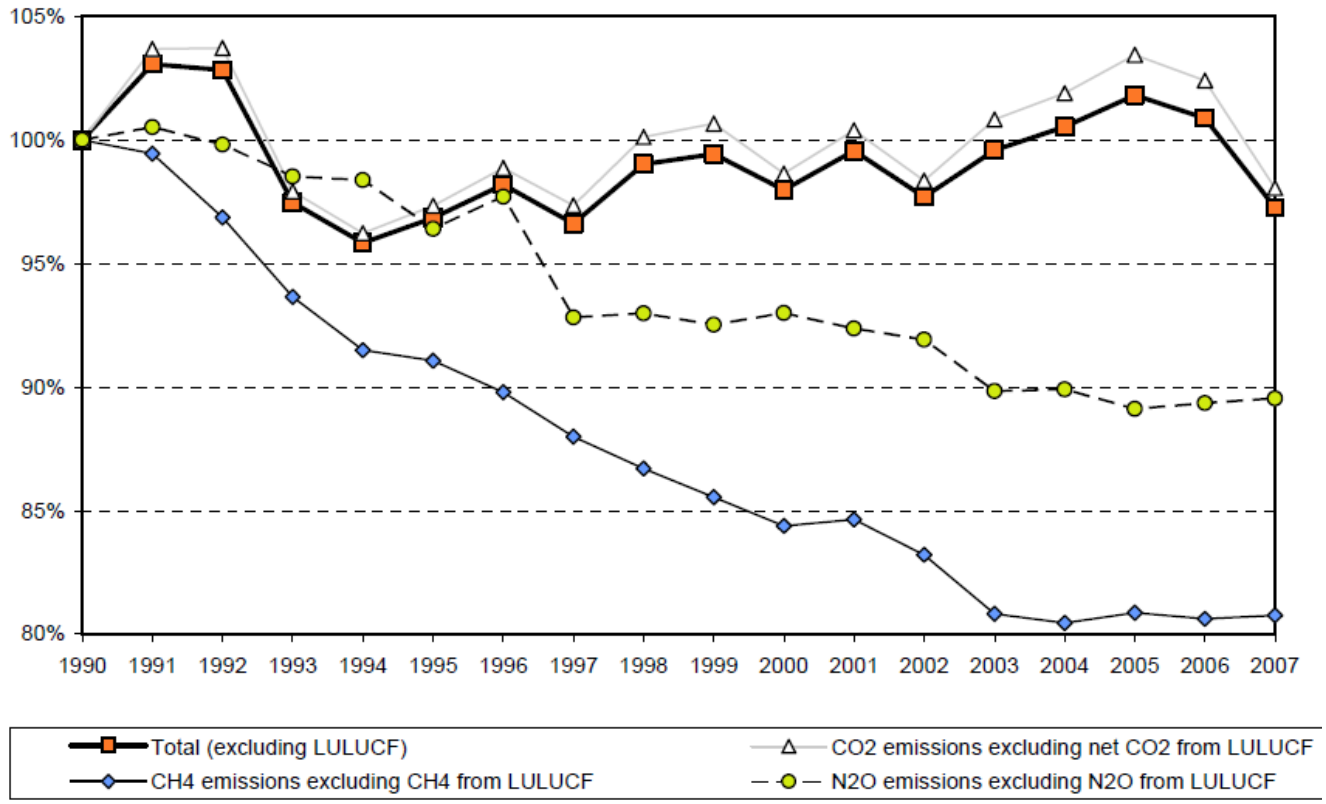
- Fossil fuel reduction target of 10% from 2000 level
- Carbon reduction targets of 10%* (& 80% by 2050) from 1990 level
- Limit the growth in electricity demand to < 5% from 2000 level
- Renewable electricity production of 1% from 2000 level (0.5 TWh)
- Renewable heat production of 3% from 2000 level (3 TWh)

*15% from combustible fuel and 8% from vehicle fuel

Source: SwissEnergy, 2009

Swiss energy system overview

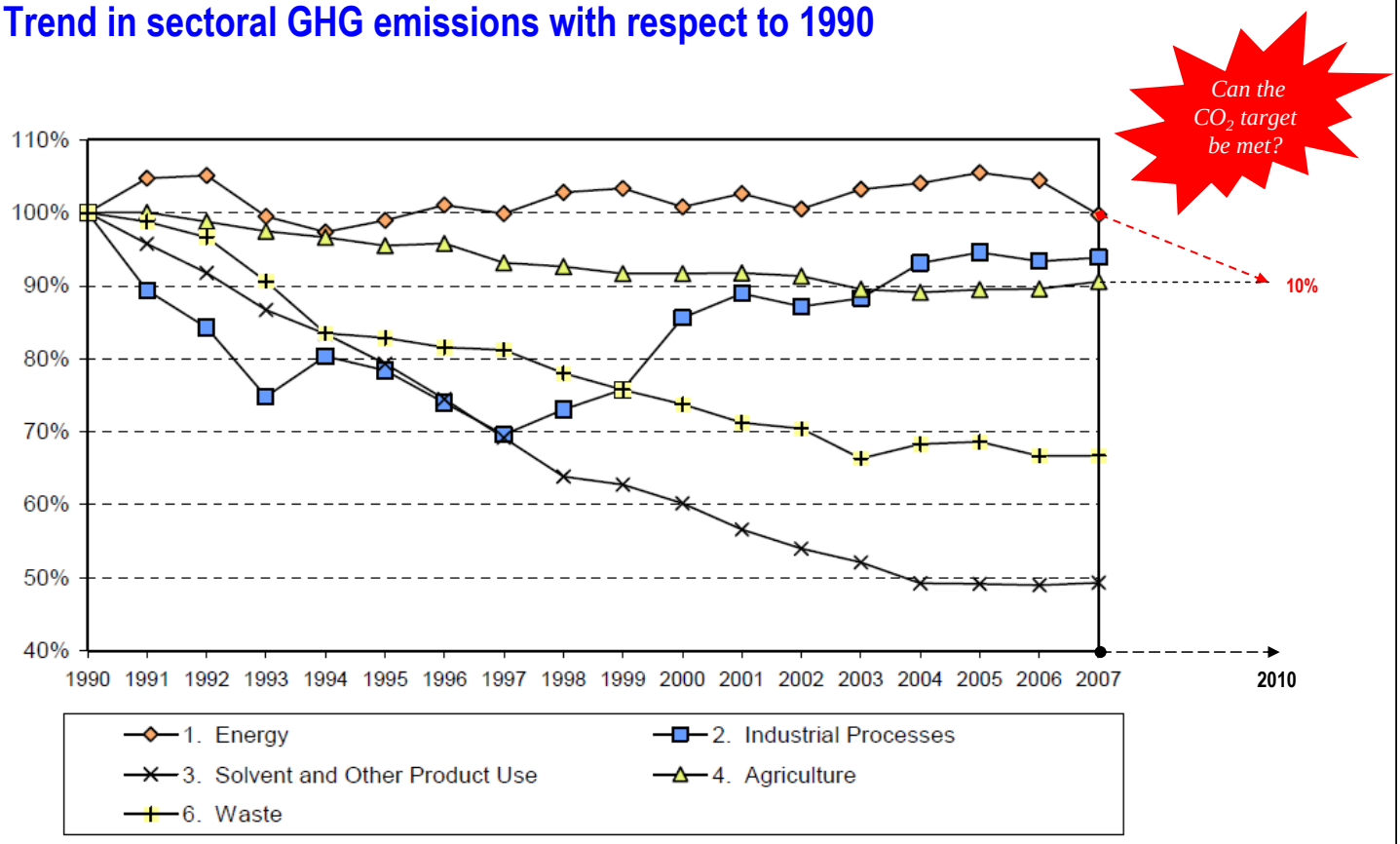
Trend in greenhouse gases with respect to 1990 level



Source: FOEN, 2009

Swiss energy system overview

Trend in sectoral GHG emissions with respect to 1990

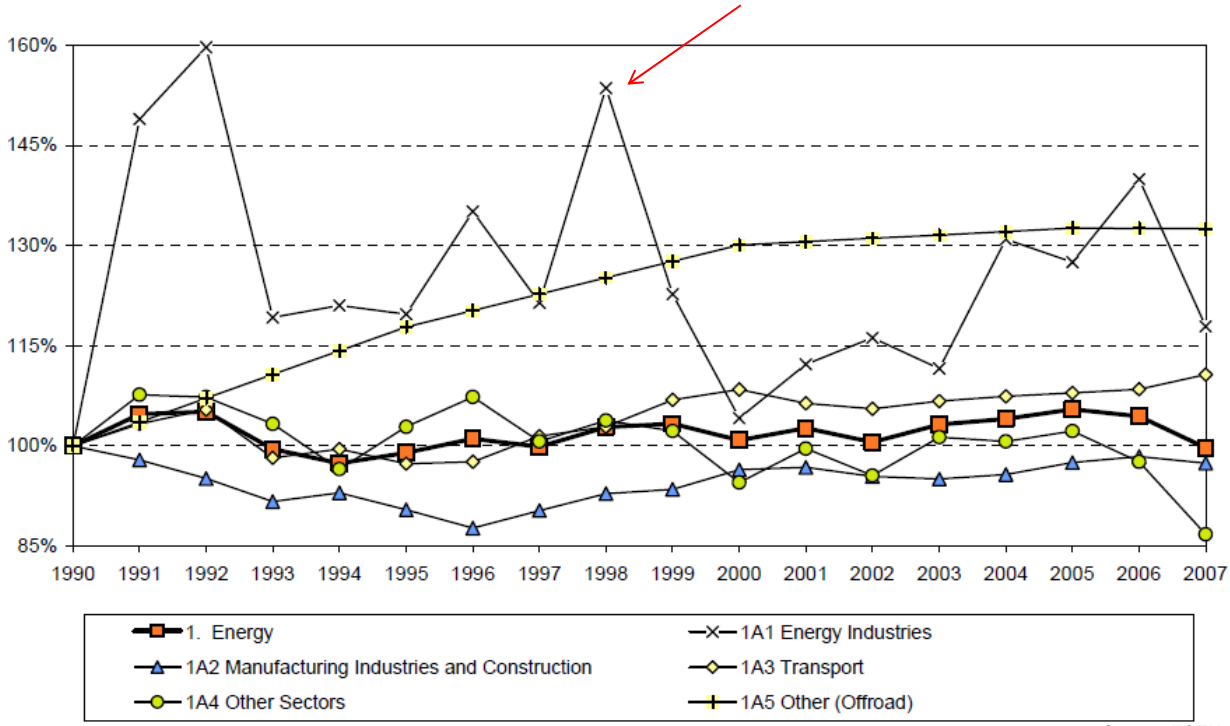


Source: FOEN, 2009

Swiss energy system overview

GHG emissions within energy sector

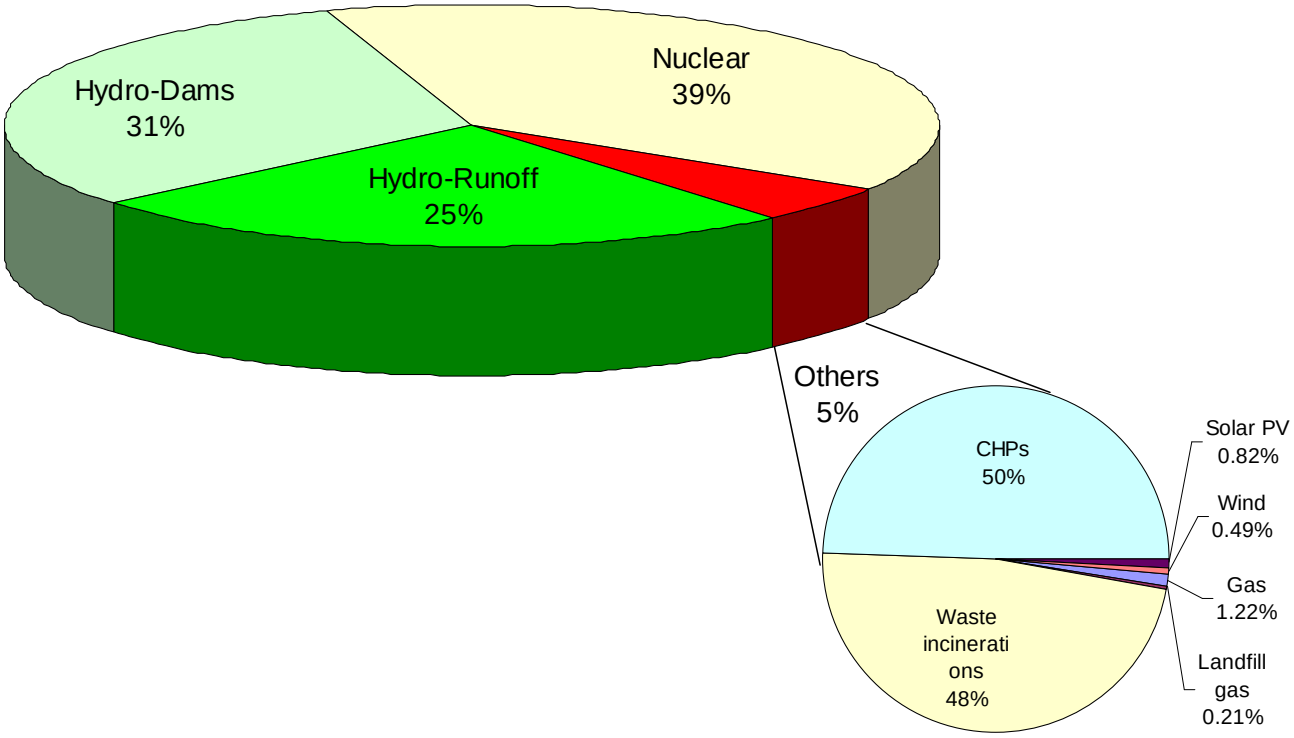
➢ The fluctuation from ***energy industry*** is caused by annual fluctuation in waste incineration and combustion activities in the petroleum refinery industry



Source: FOEN, 2009

Swiss power sector

Electricity generation mix (2008)

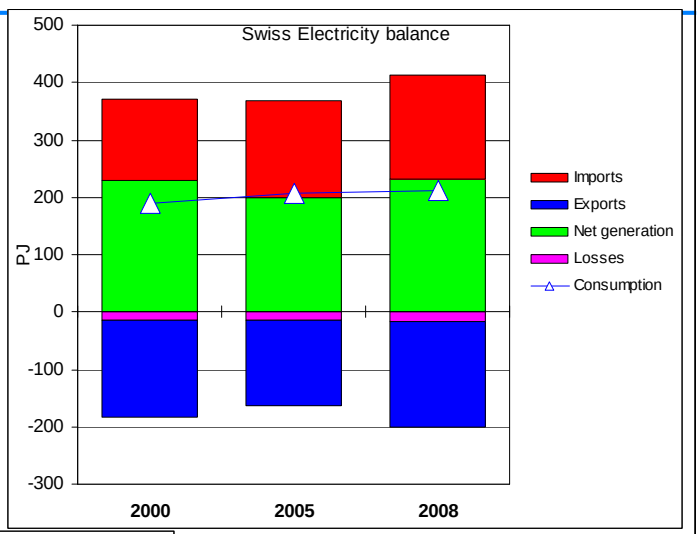


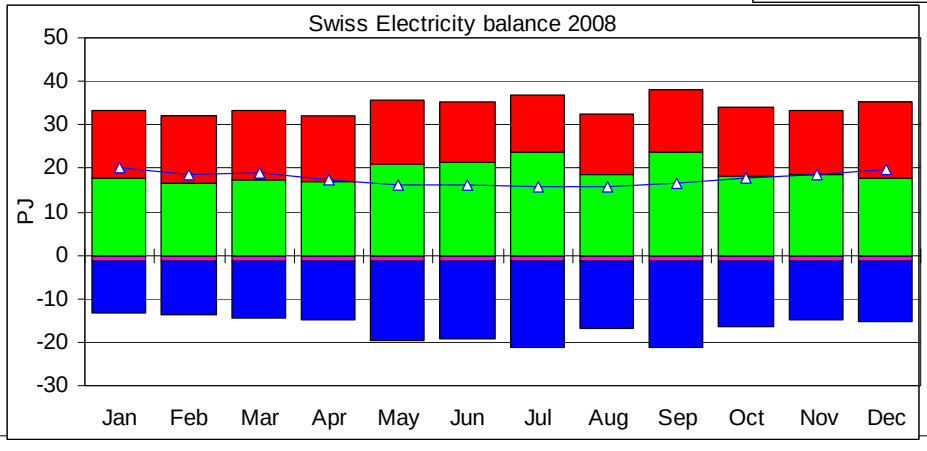
Swiss power sector

Swiss Electricity balance (2008)

- Electricity demand: An annual average growth of 1.7% over the past ten years
- Self sufficiency in annual electricity generation, but still dependent on imported electricity for seasonal demand
- Electricity trading (US$ 7 Billion in 2008*) is important in terms of power system balance and trade revenue

* CHF 7.96 B, Source: SOFE, 2008: Table 42

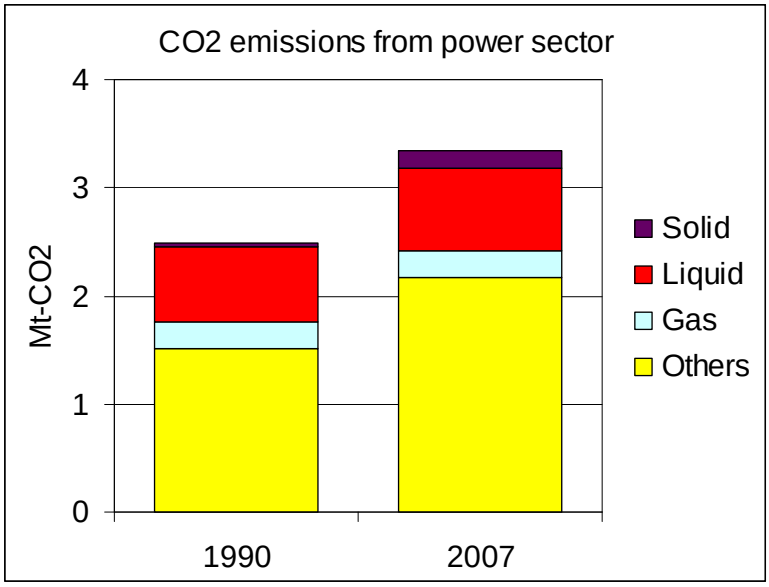




Swiss power sector

CO_2 emissions trend since 1990

- Power sector CO_2 emission is increased by 35%, but mainly from incineration plants!

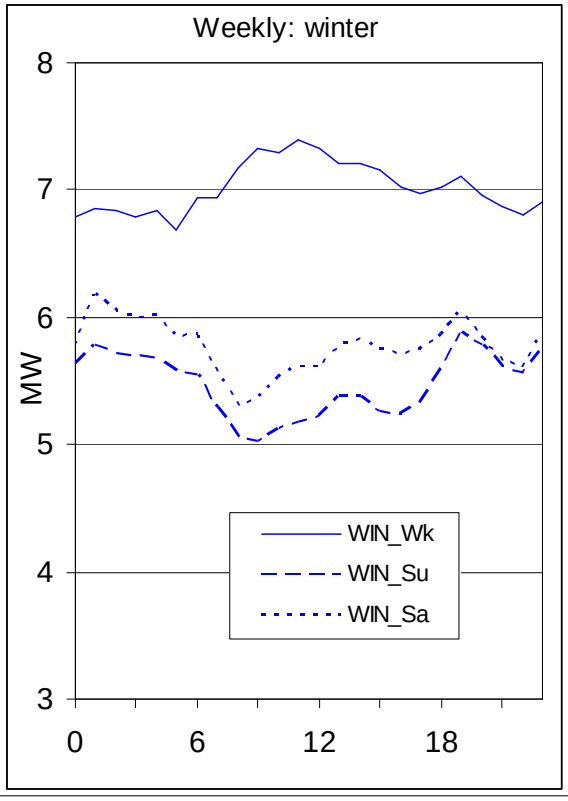


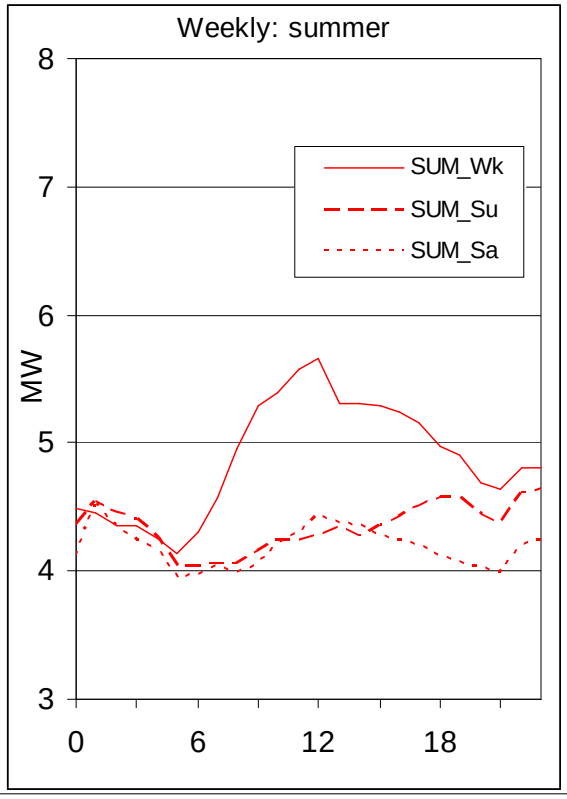
Source: FOEN, 2009

Swiss power sector

Electricity load curves (2008)

- Seasonal demand pattern

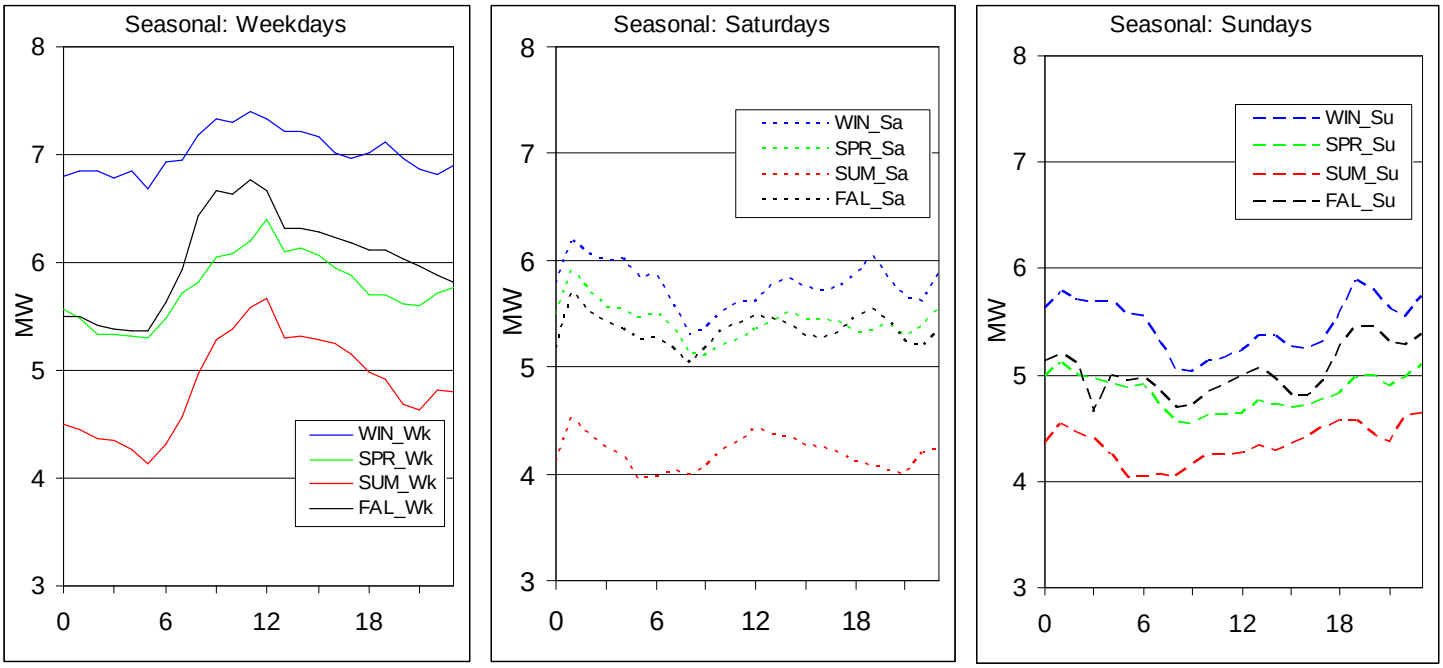




Swiss power sector

Electricity load curves (2008)

- Weekly demand pattern



Swiss energy system overview

Where are we in meeting the policy targets for 2010? - *Status in 2007*

- Fossil fuel reduction target of 10%: ***+1.5%*** ☹
- Carbon reduction targets of 10%: ***-1.6%*** ☹
- Limit the growth in electricity demand to < 5%: ***+12.1%*** ☹
- Renewable electricity production of 1% (0.5 TWh): ***+0.44 TWh*** ☺

1. Solar power (2.7%)
2. Biomass (12.8%)
3. Wind energy (1.4%)
4. Proportion of renewable energy from waste (73.8%)
5. Proportion of renewable energy from drainage (9.3%)

- Renewable heat production of 3% (3 TWh): ***+2.63 TWh*** ☺

1. Solar power (3%)
2. Ambient heat (20.5%)
3. Biomass (55%)
4. Proportion of renewable energy from waste (19%)
5. Proportion of renewable energy from drainage (2.5%)

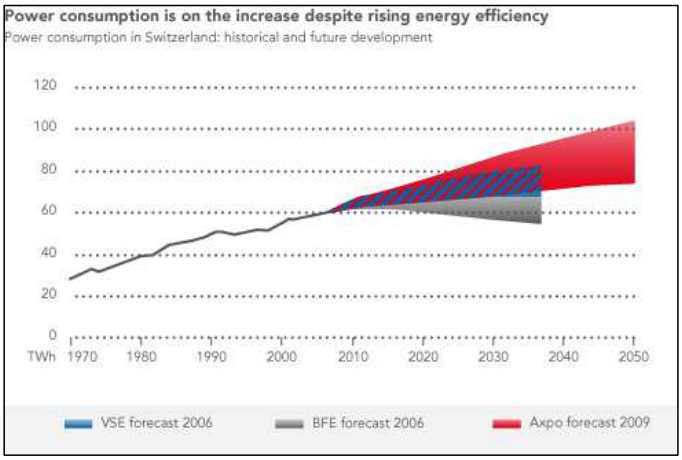
Source: SwissEnergy, 2009

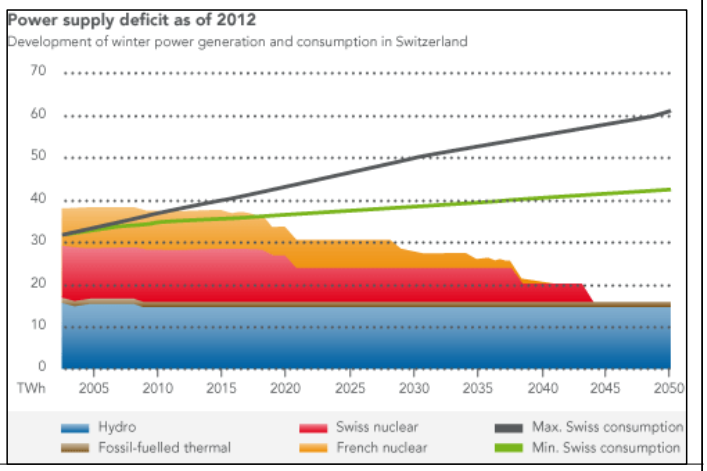
Swiss power sector

Challenges

- Far away from the policy target of limiting the electricity demand growth by <5%
- Uncertainties in future growth of electricity demand
  - due to uncertainties in uptake of energy efficiency on the demand side
- Retirement of the exiting nuclear reactors and filling the supply gap
  - political uncertainty over new investment / possible life extension of nuclear reactors
- Discussions on new natural gas plant or distributed CHP
  - ongoing consultation of carbon offset policy

Source: Axpo, 2009

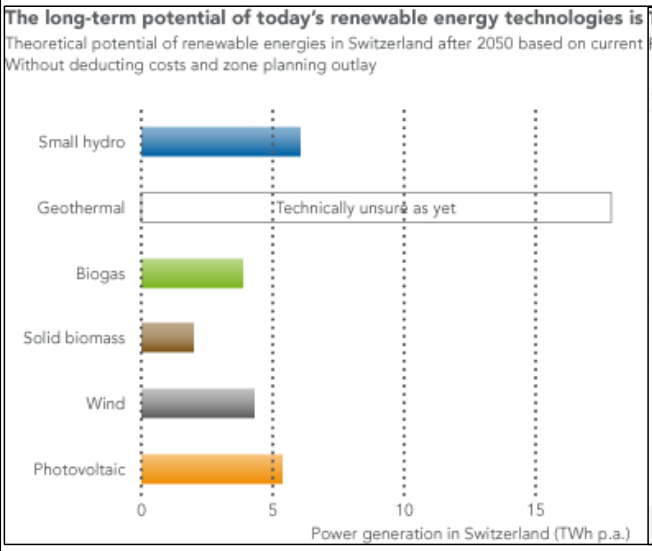


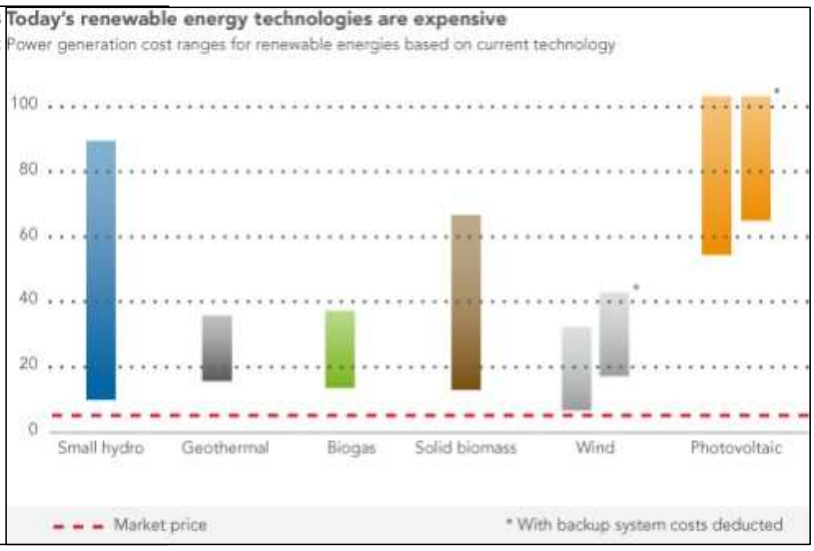


Swiss power sector

Opportunities

- Large pumped storage potential - unique position to store off-peak electricity (from base load plants or intermittence renewable) and supply (and export) for peak load demand
- Large potential for geothermal power (and heat) generation without any intermittence issues – unproven technology, but relatively cheap
- Electricity feed-in tariff to promote small scale (<10MW) renewable sources
- Can contributes to the decarbonisation of transport sector via electric (plug-in or battery) or hydrogen (ICE or fuel cell), whichever will be the winner





Source: Axpo, 2009

Developments of Swiss TIMES electricity model

Swiss MARKAL model

- 2000-2050 in 5 years time step
- Five end-use sector with detailed energy pathways, including advanced vehicle technologies and biorefineries
- Key analytical tool used for the analyses of 2 kW society and Energie Trialog project

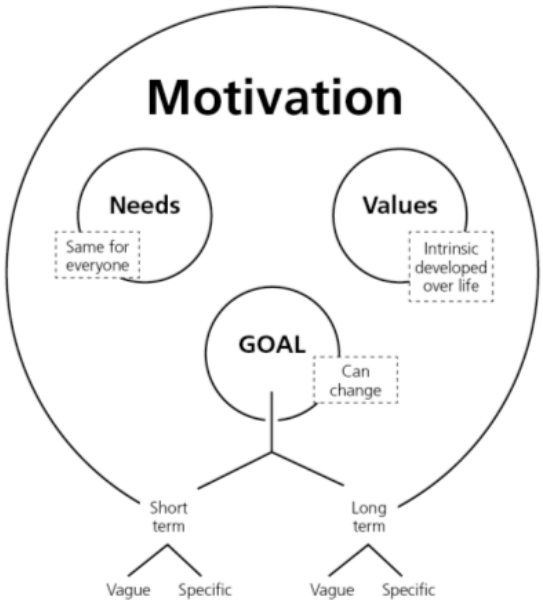
Limitations of Swiss MARKAL

- Load curve is not fully implemented within the MARKAL approximation of six timeslices
- Electricity trading is fully exogenous (not cost optimized)
- Issues of end-of-horizon effects to analyse long-term policy goals
- Reinvestment or refurbishment for hydropower plant (i.e. retrofit / repower / reengineering) has not been fully accounted
- Inadequate model documentation to understand the model input data
- **Other general limitation within MARKAL paradigm**

Developments of Swiss TIMES electricity model

Motivations

- An advanced analytical tool similar to MARKAL
  - To generate better insights for the short and medium time horizon with smaller time steps while retaining long model time horizon
  - Better treatment of technical and economical life time to reflect market risks or behaviours
- Possibilities of implementing high number of seasonal, weekly and diurnal timeslice, thereby enhancing the depiction of load curve
  - Exploring the possibilities of electricity trading under a cost optimal framework
  - Peak demand for non-electric commodity (e.g. to see the tradeoffs between gas and electricity distribution networks at peak hours)
- Easy data management with Veda interface
  - Option for scheduling retirement or refurbishment of the existing power plants (over 3000 small hydropower plants)
- Limited improvement in MARKAL through ETSAP supports



Model *(version 1.0)* overview

- Long time horizon (2000-2100) with a combination of 2, 5,10 and 20 years time steps
- 36 annual timeslices - the finest timeslice has an hour resolution
- Actual electric load curve for year 2008 is implemented
- Calibrated to actual electricity and fuel data for years 2000-2008, and near term calibration till 2015
- Large scale hydro and nuclear plants are characterised at plant level based on historical data
- Explicit electricity demand for the five end use sectors
  - Demand drivers can be implemented e.g. residential demand linked to population growth or household income; industrial demand linked to GDP, …
  - Enable to analyse tax and subsidies at sectoral level, e.g. carbon tax for service sector or subsidies for residential renewable micro electricity generation
- Preliminary results for four scenarios focusing on low carbon objectives and uncertainties of new investment in nuclear plant

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Developments of Swiss TIMES electricity model

Model input data sources

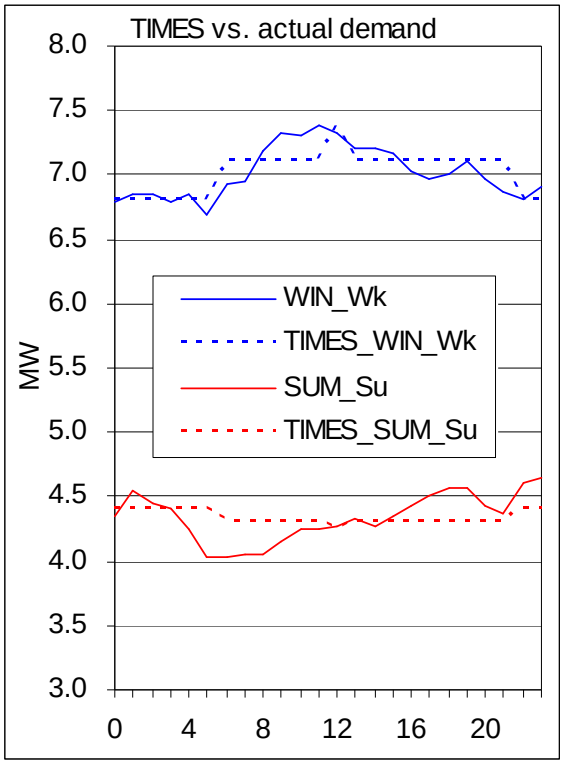
(Caveat: So far the focus has been on model methodology and structure. Input dada to be updated!)

- Calibration
  - Various publications of SOFE
    - Schweizerische Gesamtenergiestatistik, Elektrizitatsstatistik, Statistik der Wasserkraftanlagen, Thermische Stromproduktion inklusive Wärmekraftkoppelung,
  - FOEN
    - Swiss communication to UNFCCC
  - European Network of Transmission System Operators for Electricity
    - Load curves, electricity trading, ….
- Energy resources
  - Fossil fuel prices
    - UK Climate Change project
  - Renewable potential
    - Renewable energy map of SATW (Swiss Academy of Engineering Sciences)
- Technology data
  - Swiss MARKAL, IEA
- Electricity demand projection
  - Energy perspective 2035

Developments of Swiss TIMES electricity model

Modelling issues

- Input data quality – extensive sensitivities, working with the Technology Assessment Group and external stakeholder, ….
- The three diurnal timeslices did not give a perfect fit for weekend electricity demand pattern - could be improved by choosing 8-10 diurnal timeslices but computational and data availability issues need to be addressed
- Difficulties in capturing electricity trading mechanism (price vs. cost) – Enhancing the time slice for peak load
- What currency to adopt CHF vs. $ (vs. €)?



Preliminary results

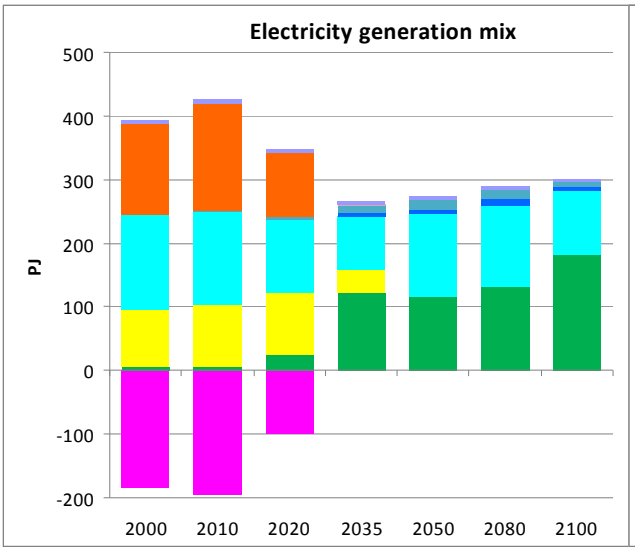
Scenarios

1. **BASE**: Business as usual
2. **CO2_S**: Stabilizing CO_2 at 2000 level (power sector only)
3. **NoNuc_S**: The above scenario without any newly built nuclear
4. **CO2_Z**: Zero carbon electricity by 2050
5. **NoNuc_Z**: The above scenario without any newly built nuclear

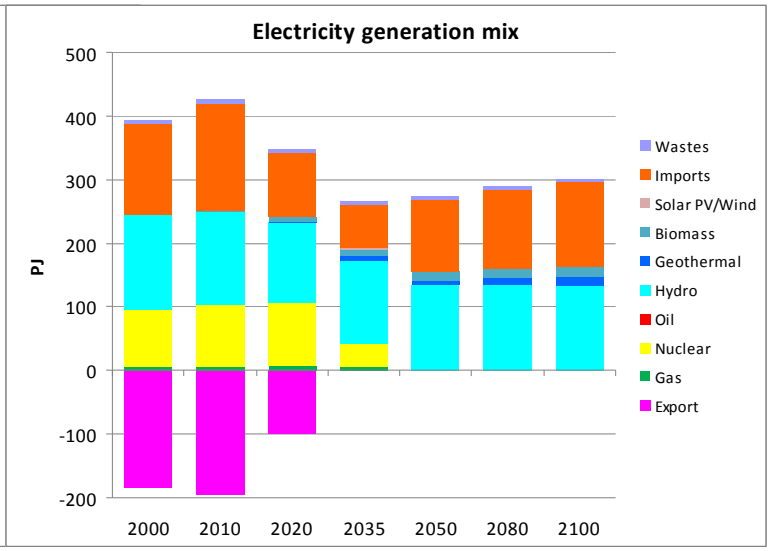
CO_2 emissions from waste incineration and biomass are not accounted!

Preliminary results

Electricity generation mix



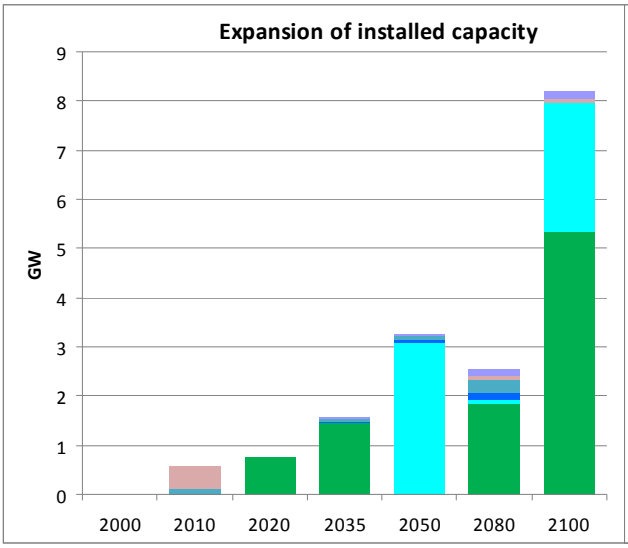
Base



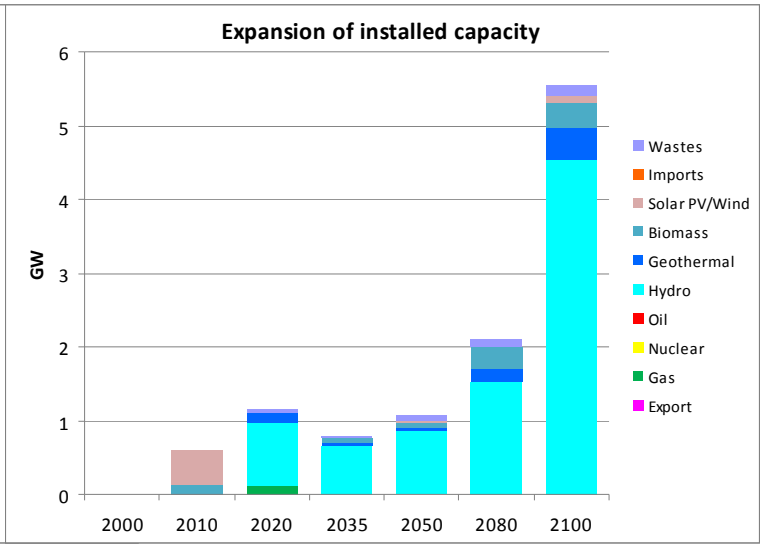
NoNuc_Z

Preliminary results

Electricity expansion plan



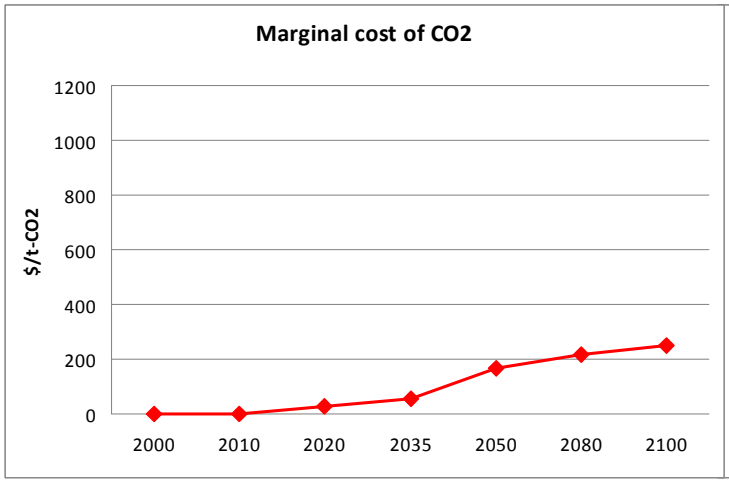
Base



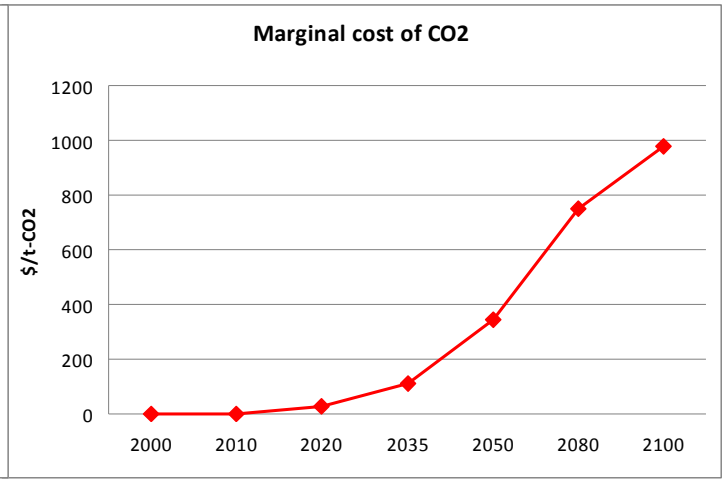
NoNuc_Z

Preliminary results

Marginal cost



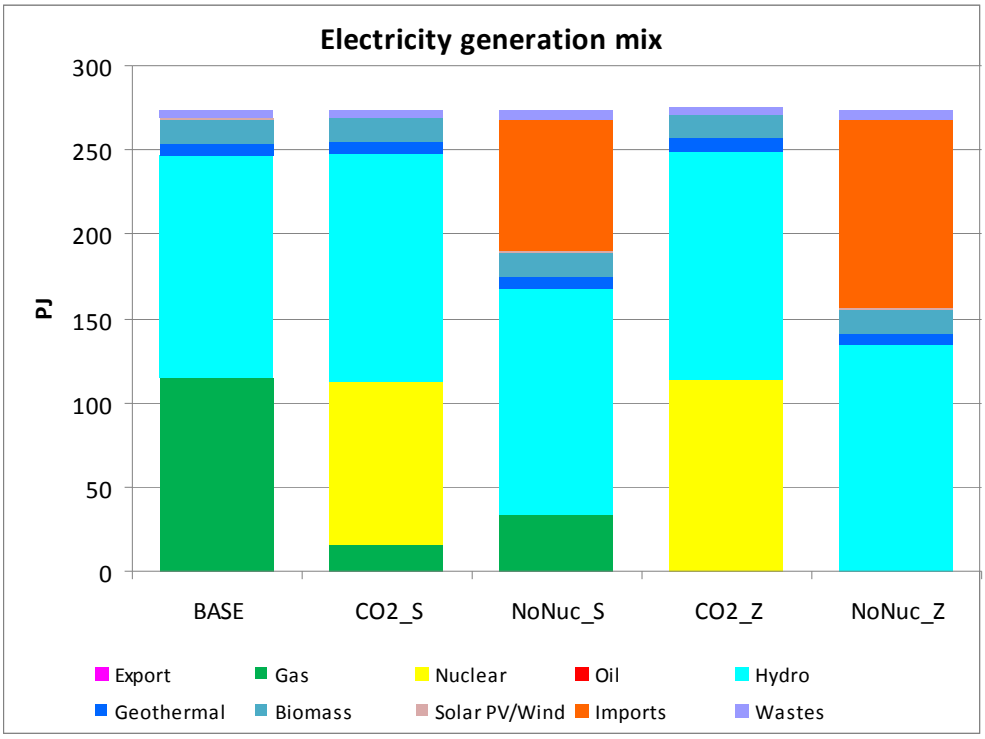
CO2_Z



NoNuc_Z

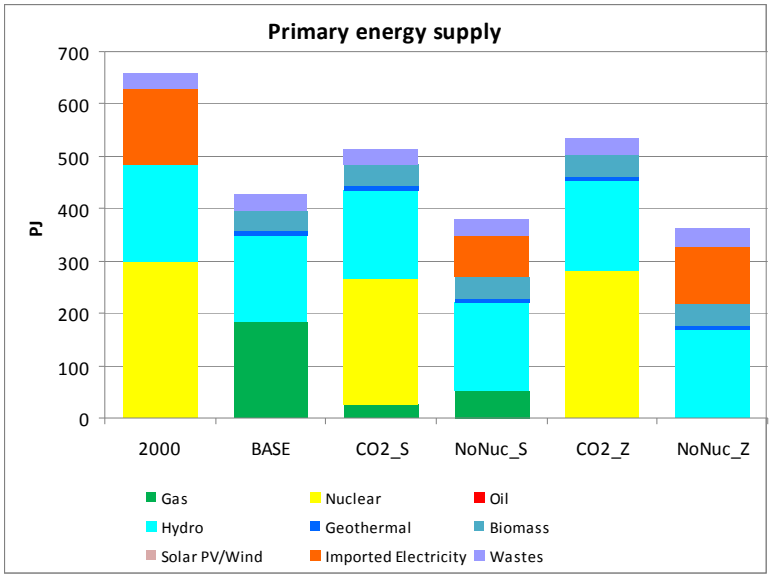
Preliminary results

Comparison of electricity generation mix in 2050



Preliminary results

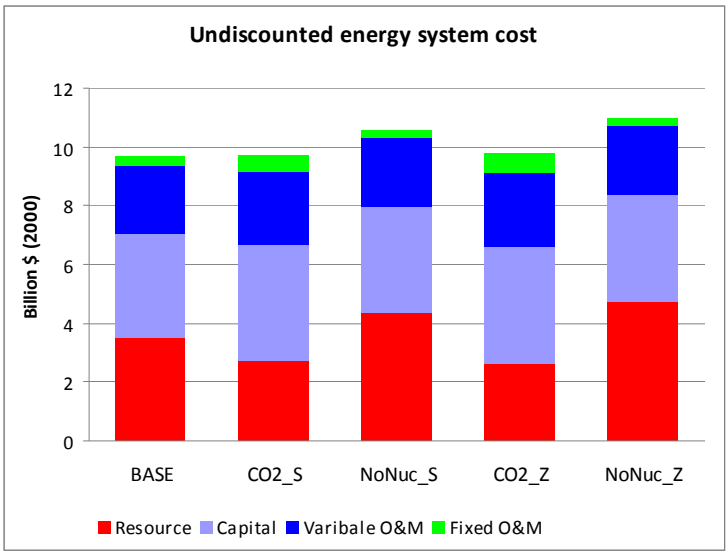
Comparison of primary energy supply in 2050



*In 2000, an equal amount of imported electricity was exported

Preliminary results

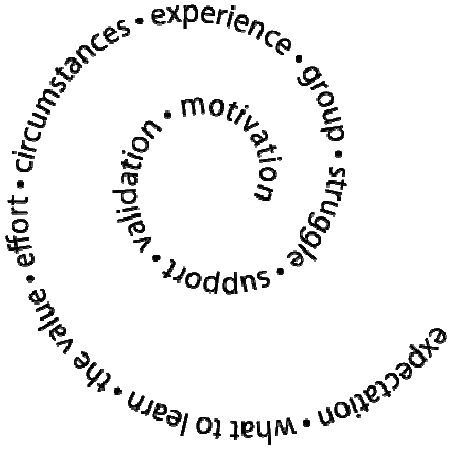
Comparison of energy system cost



- Resource cost includes imported electricity

Future direction

- Updating the input data parameters:
  - Technology data (NEEDs, Axpo, ??)
  - Electricity demand
  - Fossil fuel price
- Disaggregation of hydropower plants at individual plant level to enhance reinvestment and/or refurbishment under a cost optimization framework
- Implementing electricity feed-in tariff policy
- Enhancing the characteristics of electricity trading – country specific interconnectors, and price
- Extending the timeslice to 72 or 144 to enhance load curve fit
- Extension to other energy service demands (migration from electricity model to energy system model)
- Stakeholder engagement for data validation
  - Internal (PSI and other 'like' minds)
  - External



Energy Economics Group

Laboratory for Energy Systems Analysis

General Energy Research Department & Nuclear Energy and Safety Research Department