PAUL SCHERRER INSTITUT

Can a TIMES model be substituted for an Economic Dispatch model? – Insights from a Swiss TIMES electricity model

Ramachandran Kannan & Hal Turton

ETSAP Workshop, Stockholm, 24 June 2010

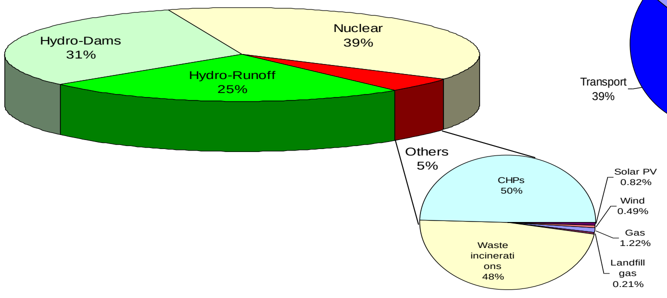
PAUL SCHERRER INSTITUT

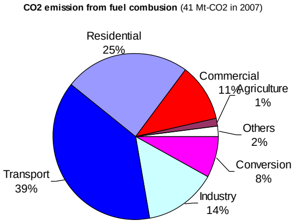
Presentation outline

- Swiss power sector overview
- Development of Swiss TIMES electricity model
- Key assumptions
- Preliminary results
- Modelling/calibration issues
- Conclusions
- Future direction

Swiss power sector

Electricity generation mix (2008)





- 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
- Limiting growth in electricity demand to < 5% from 2000 level - ***+12.1%*** ☹
- Renewable electricity production of 1% of 2000 level (0.5 TWh) - *+0.44 TWh* ☺

Swiss power sector

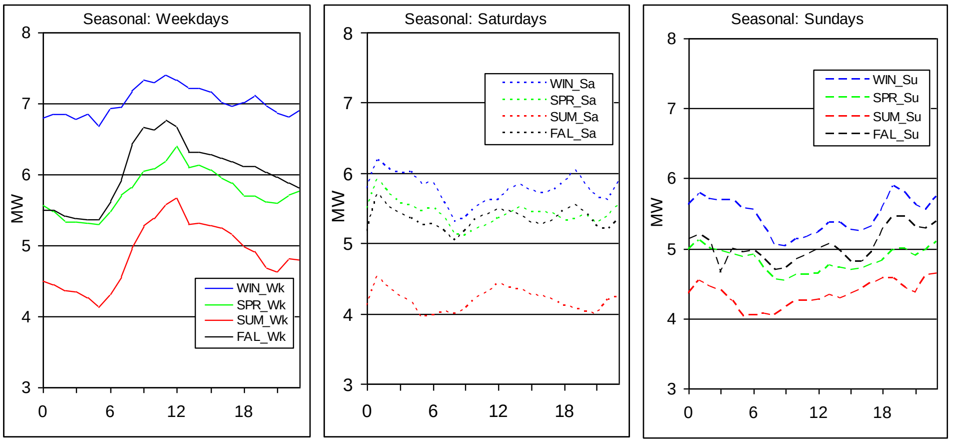
Challenges

- Carbon reduction targets of 10% by 2010 (& 80% by 2050) from 1990 level ***- 1.6%*** ☹
- 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
- Uncertainties in future growth of electricity demand - due to uncertainties in uptake of energy efficiency on the demand side
- Revenue from electricity trading - Uncertainty in electricity market development in neighbouring countries over low carbon

Swiss power sector

Electricity load curves (2008)

➢ Weekly demand pattern



Developments of Swiss TIMES electricity model

Model *(version 3.0)* overview

➢ Long time horizon (2000-2100) with a combination of 2, 5,10 and 20 years time steps

➢ 204 annual time slices with an hourly diurnal timeslice *[Began with 36 annual time slices (Sept – Jan 10)]*

➢ Five electricity demand sectors

➢ Calibrated to

- ➢ electricity generation and fuel data for years 2000-2008 within 3%
- ➢ near term forecast of electricity generation till 2015
- ➢ all existing technology stock with retirement schedule
- ➢ electric load curve for year 2008 (??)

➢ Large scale hydro/nuclear plants are characterised at plant level based on historical data

➢ Four country specific interconnectors with their seasonal AF

➢ A range of new technologies with technical and cost characteristics, including lead time for construction

➢ Preliminary results for core scenarios and a number of sensitivity analyses focusing on uncertainties of new technologies of strategically importance

Developments of Swiss TIMES electricity model

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/nuclear fuel prices
    - PSI Technology Assessment group (to be updated to new Dataset)
  - Renewable energy potential
    - Renewable energy map of SATW (Swiss Academy of Engineering Sciences)
- Technology data
  - PSI Technology Assessment group (Axpo)
- Electricity demand projection
  - Indirectly linked to drivers in the Energy perspective 2035

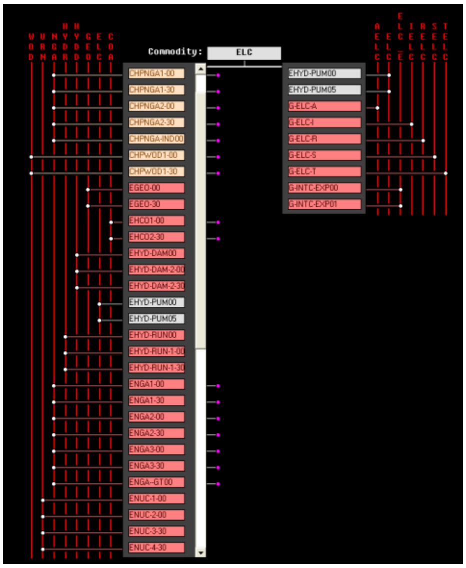
Key assumptions

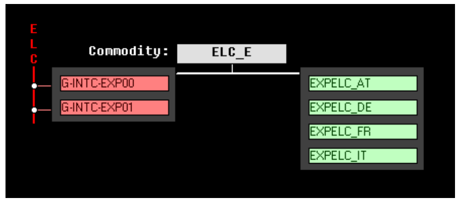
Key assumptions

- Electricity demand of 250 PJ in 2050 and 280 PJ in 2100 (Vs. 210 PJ in 2010)
- Reserve margin of 30% and T&D loss of 7%
- Discount rate of 10%
- Costs in 2005 Swiss Francs (CHF_{2005}) [1$ ~1.1 CHF_{2010}/1.25 CHF_{2005})
- Hydro power is maintained at today's level independent of their cost
- Nuclear is limited to 5 GW by 2050 and 8 GW by 2100 (vs. today's level of 3 GW)
- Electricity imports/exports are constrained to the last ten years' average
- Imported electricity is assumed as 'zero' carbon
- Time depended import/export costs for electricity during weekdays (linked to gradient of demand curve)
- Renewable potentials are based on technical potential
- Seasonal AF for solar PV based on sunshine hours. No seasonal AF included for other renewable energy sources
- Distributed generation is not modelled
- No credit for heat from CHP

Key assumptions

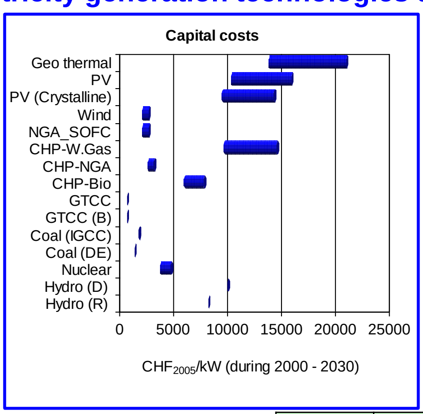
Reference energy system

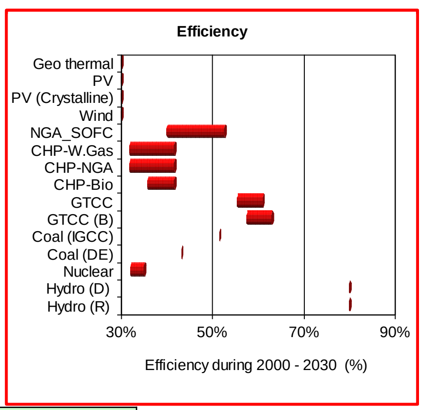




Key assumptions

Electricity generation technologies data





Resources	Cost (CHF$_{2005}$/GJ)
Gas	6.2 - 10.5
Oil	8 - 13.5
Coal	2.5 - 2.8
ELC Import	15.78 - 26.72
ELC Export	11 - 18.7
Wood	9.7 - 8..5

Preliminary results

Core scenarios

1. **BASE**: Business as usual (without coal)
2. **CO2_S**: Stabilizing CO_2 at 2000 level by 2050 and beyond* (excluded)
3. **CO2_Z**: Zero carbon electricity by 2050 and beyond

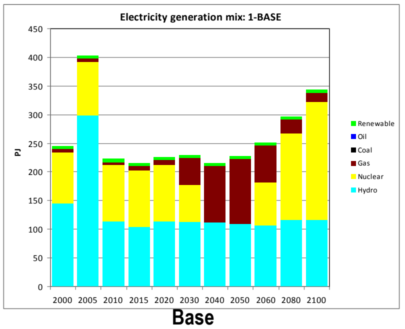
Sensitivities

1a. B_NoNuc: BASE without new nuclear plants
1b. B_RNW: BASE Renewable only (without new nuclear, coal, gas plants and 'limited' import of electricity*)
1c. B_Coal: BASE with coal plants (excluded)
3a. Z_NoNuc: CO2_Z scenario without any new nuclear
3b. Z_RNW: CO2_Z scenario with renewable only (without any new nuclear and limited import of electricity)

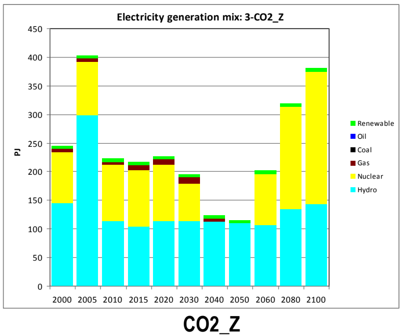
* CO_2 emissions from waste incineration and biomass are not accounted!
** Electricity import limited to 30% of total demand by 2050 and 35% in 2100

Preliminary results

Electricity generation mix

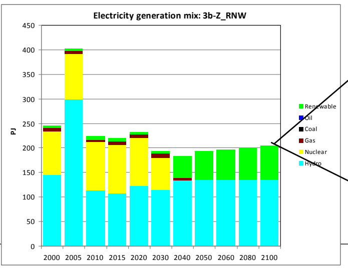


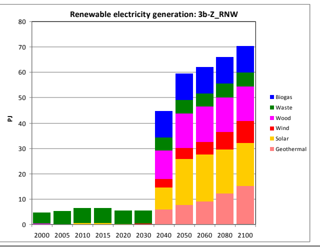
Base



CO2_Z

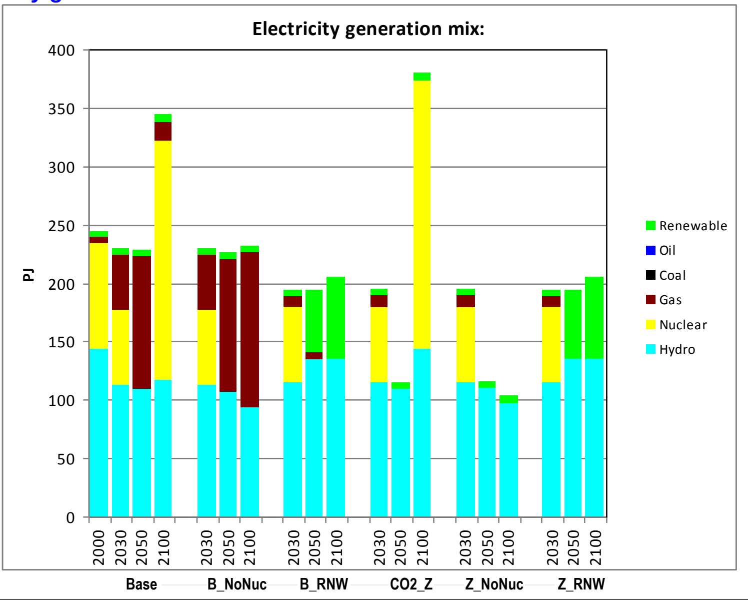
Z_RNW





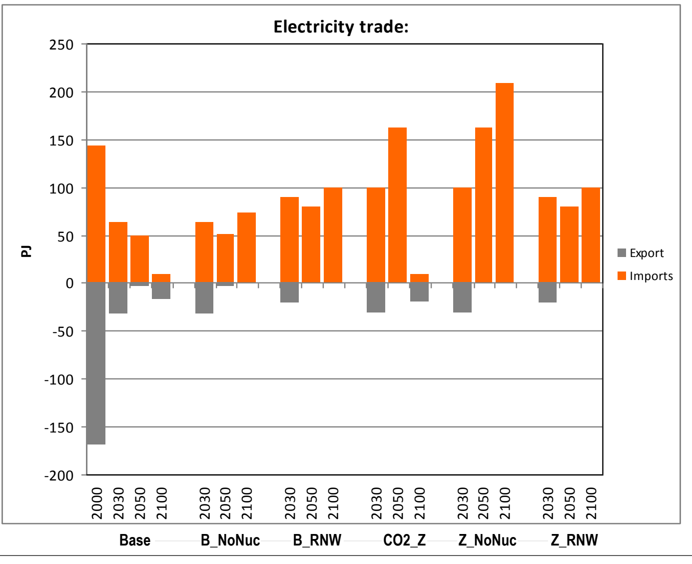
Preliminary results

Electricity generation mix

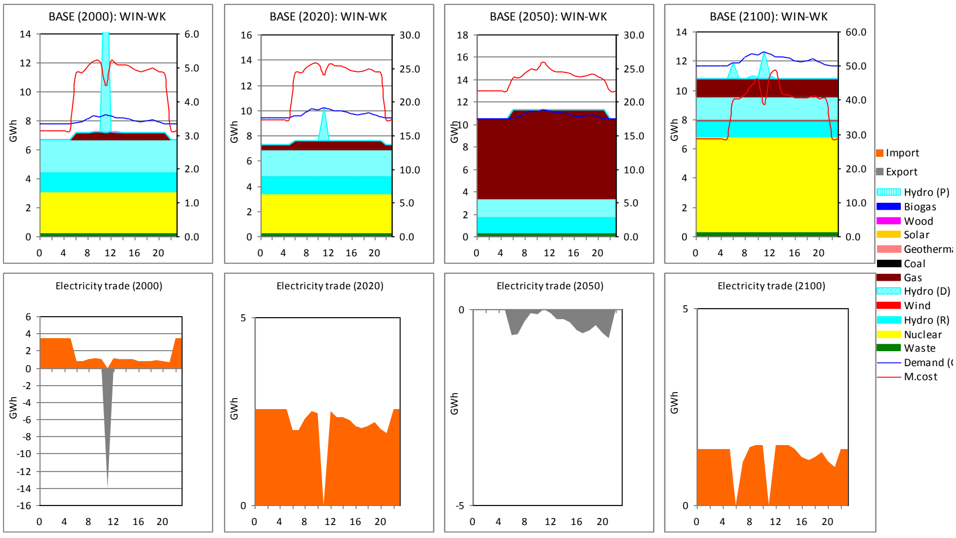


Preliminary results

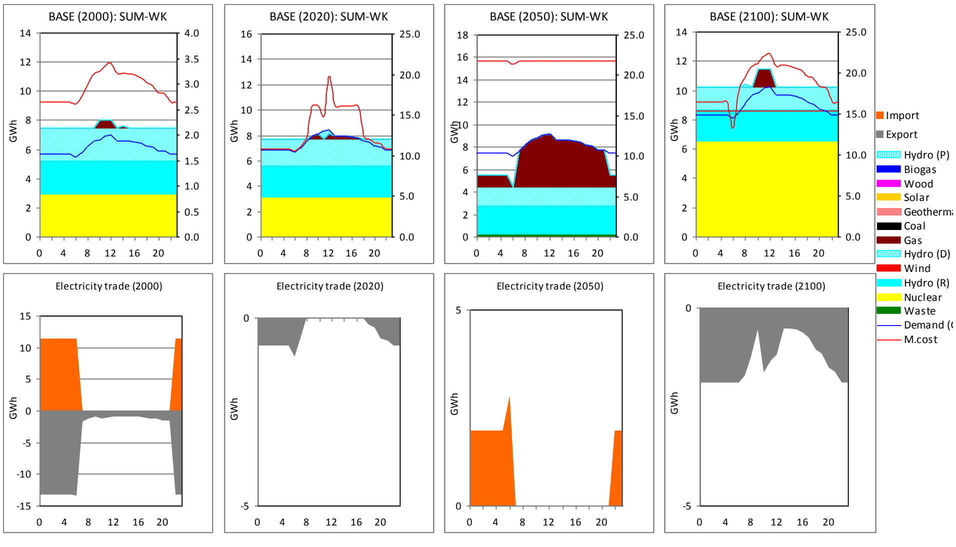
Electricity trade balance



Electricity dispatch: Base Winter Weekdays

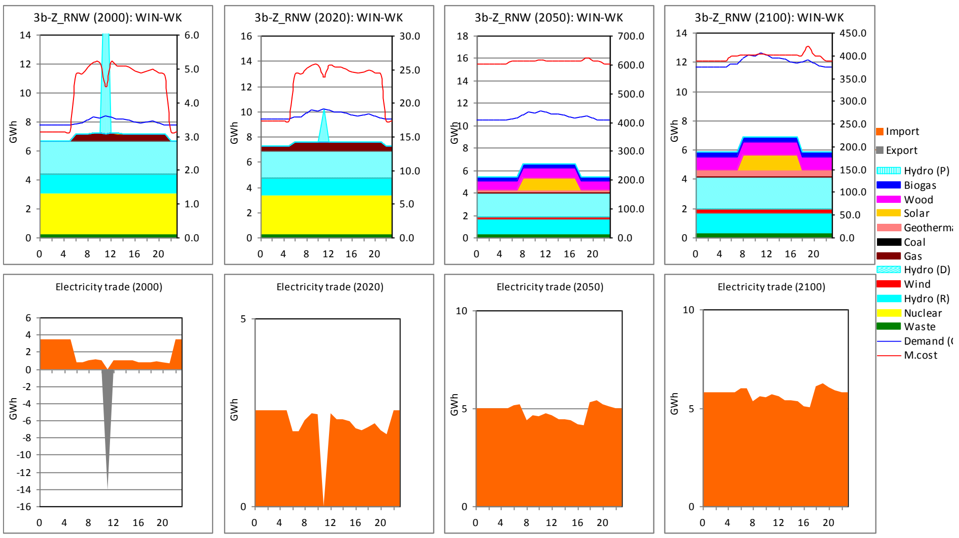


Electricity dispatch: Base Summer Weekdays



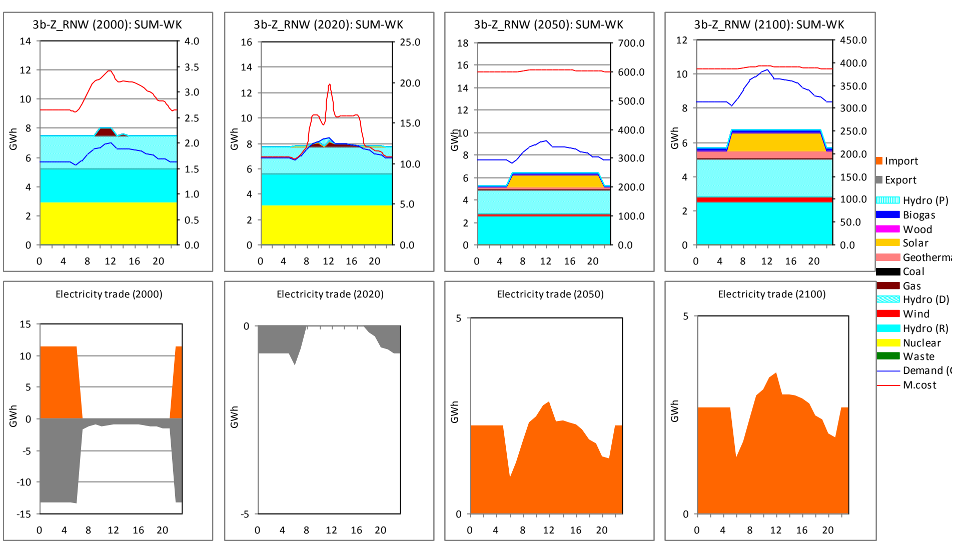
Preliminary results

Electricity dispatch: Z_RNW Winter Weekdays



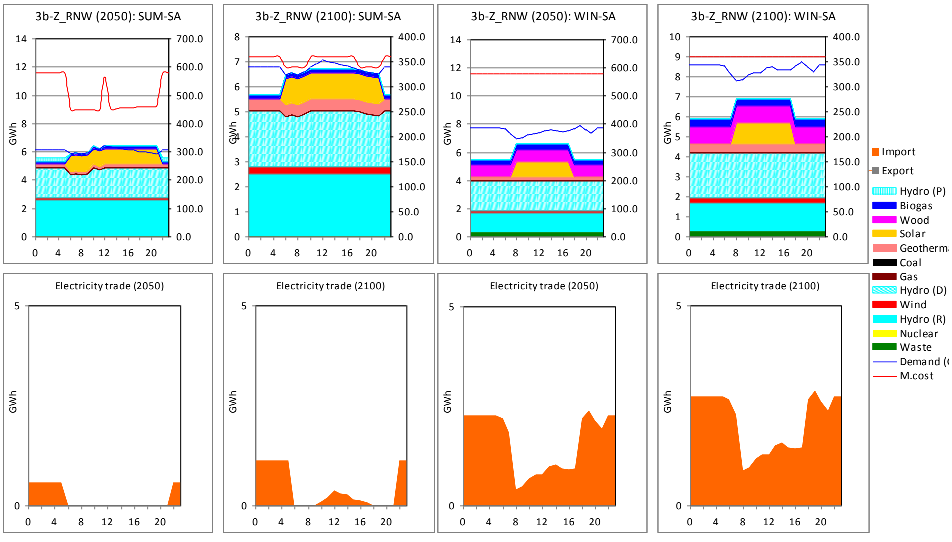
Preliminary results

Electricity dispatch: Z_RNW Summer Weekdays



Preliminary results

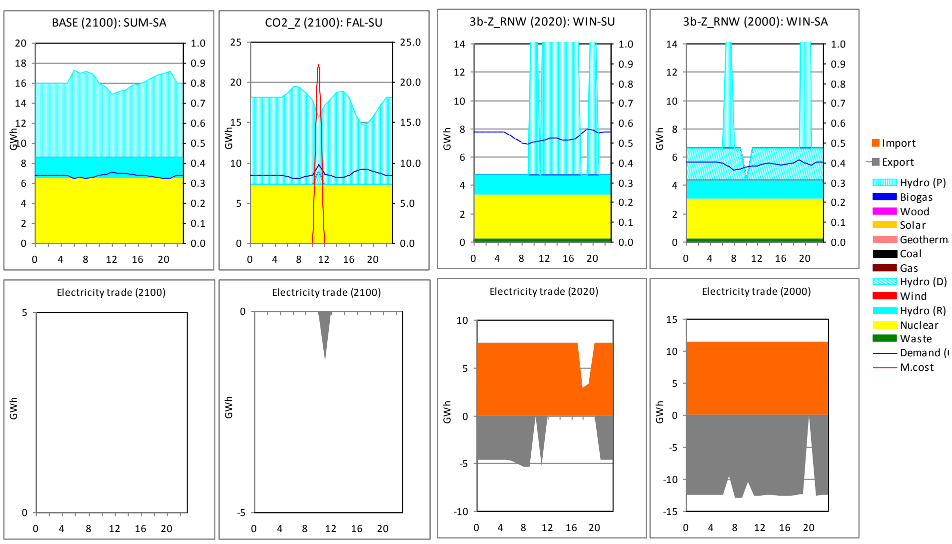
Electricity dispatch: Z_RNW Saturdays



SUM-SA (2050) SUM-SA (2100) WIN-SA (2050) WIN-SA (2100)

Preliminary results

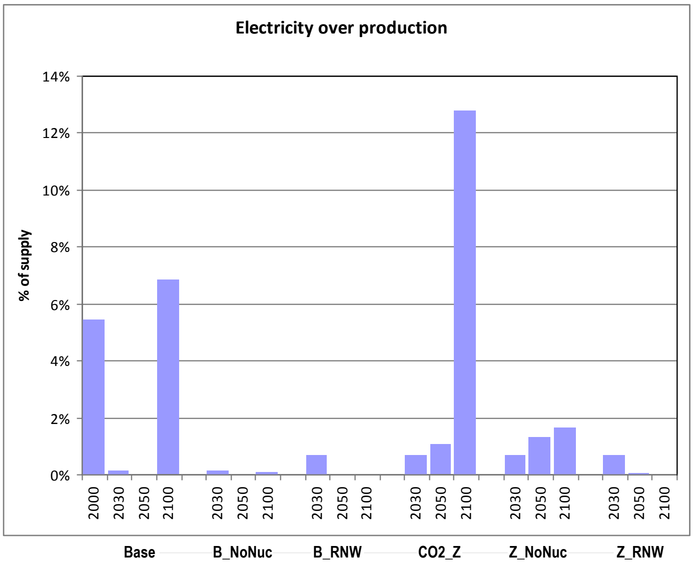
Issues with calibration and electricity balance



SUM-SA FAL-SU WIN-SU WIN-SA

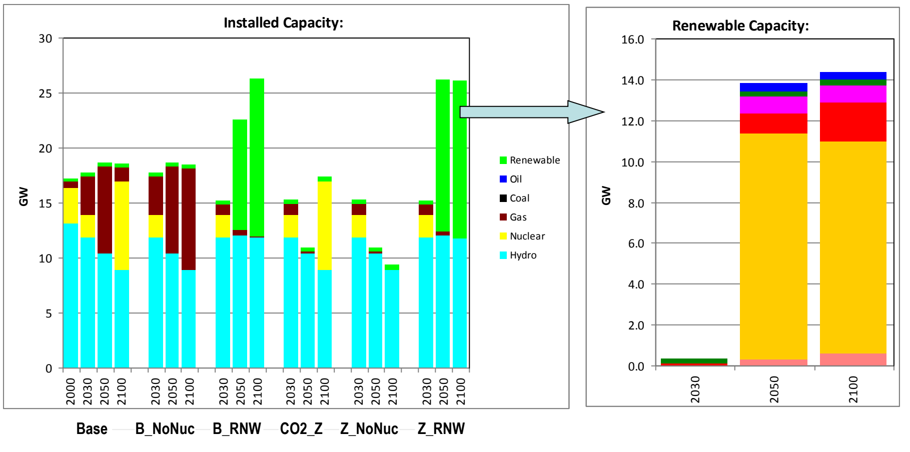
Preliminary results

Electricity supply and demand balance (over production)



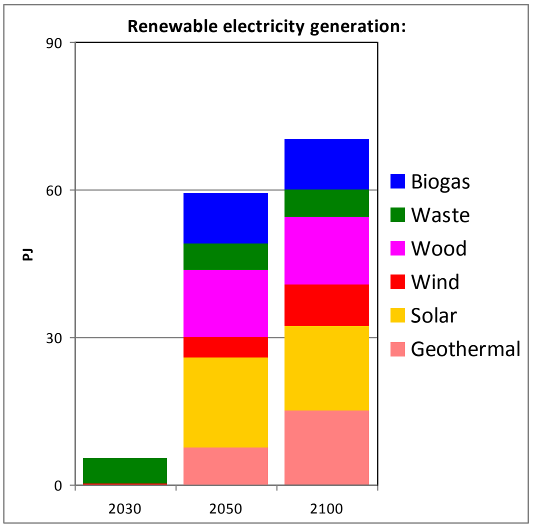
Preliminary results

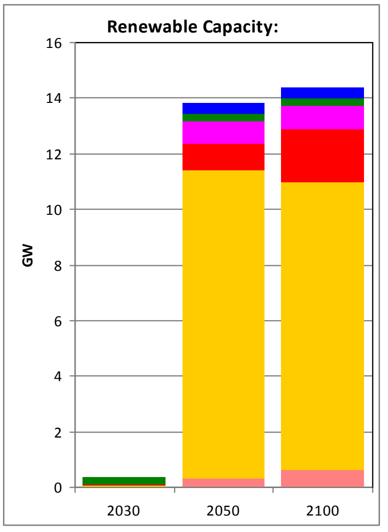
Electricity expansion plan



Preliminary results

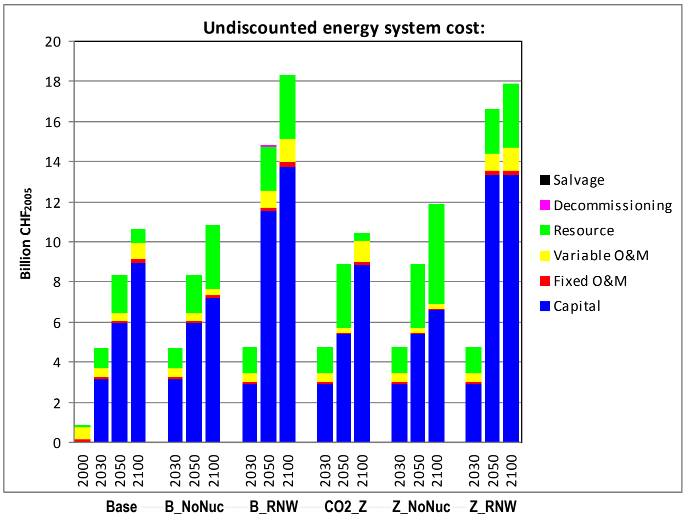
Renewable electricity generation vs. capacity in Z_RNW





Preliminary results

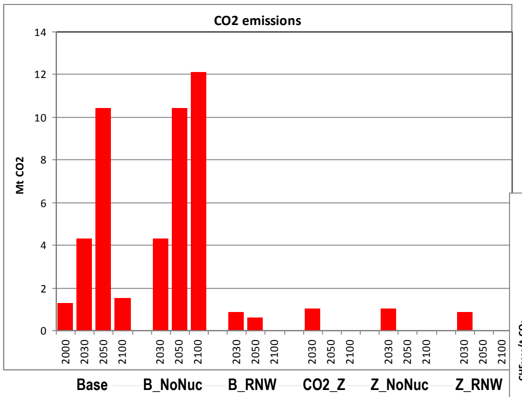
Electricity system cost

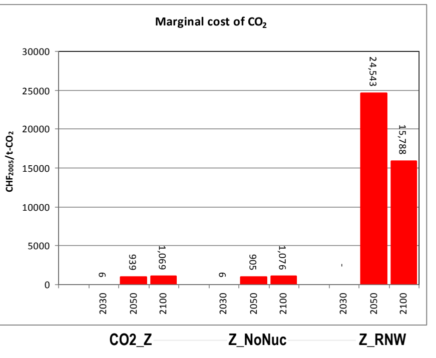


*Resource costs includes electricity trade balance

Preliminary results

CO_2 emission and marginal cost





Modelling and calibration issues

- Inadequate data on power plant operational schedule for calibration to an hourly level
- Absence of seasonal AF for other renewable technologies (e.g. wind has been chosen as a base load plant within its AF)
- Difficulties in calibrating to electricity trading (price vs. cost) and discrepancies in data sources
- Storage (STG) process in TIMES vs. reality *(energy flow without any activity)*
- Processing of model results and understanding at an hourly level (>100'000 data points), e.g. unknown drivers in certain timeslices
- Electricity supply/demand balance (excess production in some period)
- Input data handling (e.g. large rows of data for solar AF)

Conclusions

- Nuclear seems cost-effective in BASE scenario, but construction time delays the deployment in medium terms
  - In absence of nuclear, gas becomes cost effective
  - Coal is the most cost-effective option
- Renewable scenario almost meets the low carbon objectives
- Without imported electricity, meeting zero carbon objective is technically not feasible
- While comparing marginal cost, caution with other constraint (e.g. marginal cost of carbon vs. renewable constraints)
- Hourly timeslice provides additional insights on operation of power plants, though the role of storage to be addressed
- There is no parameters for system reliability if TIMES were to be compared to an electricity despatch model
- Extension to other energy supply and end use sectors would enhance modelling framework and enable better understanding of power plant operation

Future direction

- To update input data:
  - Technology data, electricity demand projection, fossil fuel price (July 10)
- Implementation of AF for all renewable resources
- Introduction of electricity import/ export regions with their electricity demand profile
- Make necessary changes to storage technologies
- Implementation of all electricity policy, e.g. feed-in tariff
- Implementation of CCS (CARMA - Carbon Management in power generation project)
- Moving from electricity model to energy system model: *Developing a Swiss TIMES Energy System Model (STEM) for transition scenario analysis* - SOFE funded project (2010-2013)

Energy Economics Group

Laboratory for Energy Systems Analysis

General Energy Research Department & Nuclear Energy and Safety Research Department