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Potential impact of post Fukushima nuclear policy on the future role of CCS in climate mitigation scenarios in Switzerland

Nicolas Weidmann, Hal Turton, and Ramachandran Kannan

Energy Economics Group, Laboratory for Energy Systems Analysis, Paul Scherrer Institute, Switzerland

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   - Carbon capture and storage
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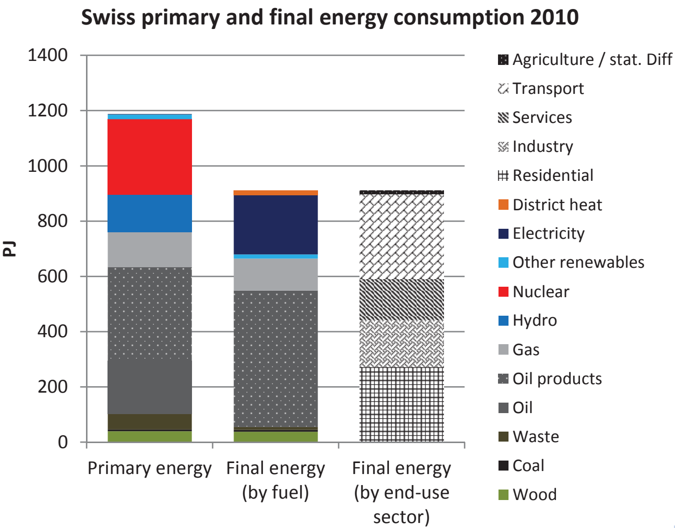
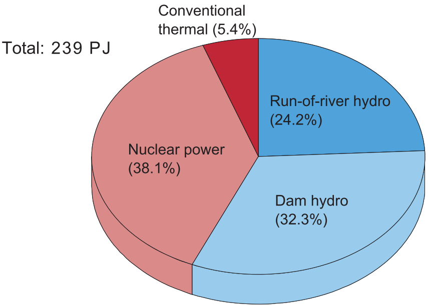
Overview Swiss energy system

Primary and final energy consumption



Overview Swiss energy system

Electricity generation mix (2010)



- Power sector nearly decarbonised
- Self sufficiency in annual electricity generation but still dependent on import for seasonal demands
- Electricity trading is important (power system balance, revenue)

Overview Swiss energy system

Challenges for the future Swiss energy system

- Development of future electricity demand (population/GDP growth increase, electrification)
- Nuclear phase-out
- Climate policy
- Energy security
- Future availability of technologies supporting low carbon energy system

Objective and Methodology

Objective

- Analyze how uncertainties may affect future Energy system and cost-effectiveness of technologies
- Identify robust combinations of technologies and fuels
- Potential role of low carbon electricity sources (new renewables, CCS) under nuclear and climate constraints

Scenario analysis

- Uncertainties → Definition of scenarios
- Scenarios analysed using Swiss MARKAL energy system model

Swiss MARKAL model

Description of modeling framework

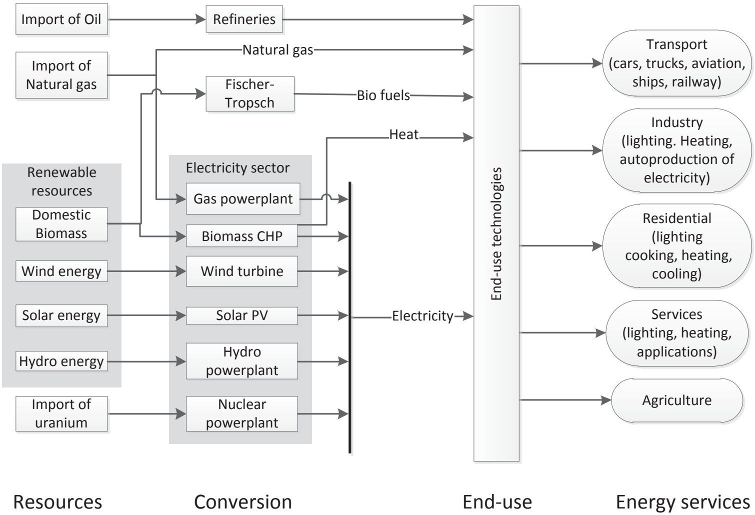
- Technology-rich bottom-up energy system model of entire Swiss energy system (single region model)
- Extensive representation of end-use efficiency technologies
- 40-years time horizon (2010-2050)
- Calibration to years 2000-2010

History of Swiss MARKAL model

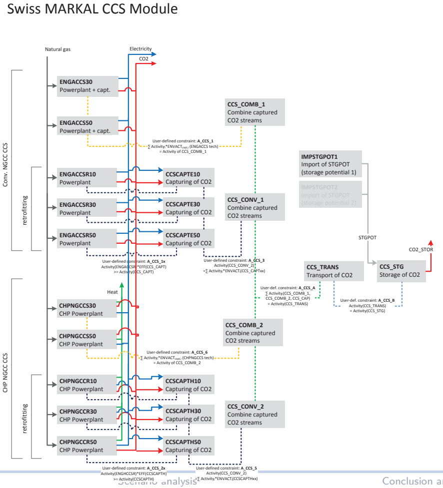
- Model development initiated by M. Labriet at the University of Geneva (Labriet, 2003)
  - Building up first version of the model including five end-use sectors, conversion and supply
- Further developments and analyses by T. Schulz (Schulz, 2007; Schulz et al., 2007, 2008)
  - Implementation of extensive end-use technology options in transport and residential sector (including energy saving options based on marginal cost curves)
- and N. Weidmann (Weidmann, Turton, and Wokaun, 2009; Weidmann, Kannan, and Turton, 2011; ETS, 2009)
  - Further development of the model in all end-use sectors
  - Calibration of the entire model to 2010 data and demand update
  - Development and implementation of CCS module

Swiss MARKAL model

Reference energy system



CCS module


Swiss MARKAL CCS Module
Natural gas
Electricity
CO2
Conv. NGCC CCS
retrofitting
ENGACCS30
Powerplant + capt.
ENGACCS50
Powerplant + capt.
CCS_COMB_1
Combine captured
CO2 streams
User-defined constraint: A_CCS_1
∑ Activity$_i$*ENVACT$_{capt,i}$ (ENGACCS tech)
= Activity of CCS_COMB_1
IMPSTGPOT1
Import of STGPOT
(storage potential 1)
IMPSTGPOT2
Import of STGPOT
(storage potential 2)
ENGACCSR10
Powerplant
CCSCAPTE10
Capturing of CO2
ENGACCSR30
Powerplant
CCSCAPTE30
Capturing of CO2
CCS_CONV_1
Combine captured
CO2 streams
ENGACCSR50
Powerplant
CCSCAPTE50
Capturing of CO2
STGPOT
CO2_STOR
User-defined constraint: A_CCS_1x
Activity(ENGACCSR)*EFF(CCS_CAPT)
>= Activity(CCS_CAPT)
User-defined constraint: A_CCS_3
Activity(CCS_CONV_2)
=∑ Activity$_i$*ENVACT$_i$(CCS_CAPTxx)
CCS_TRANS
Transport of CO2
CCS_STG
Storage of CO2
Heat
User-def. constraint: A_CCS_A
∑ Activity$_i$(CCS_COMB_1,
CCS_COMB_2, CCS_CAP)
= Activity(CCS_TRANS)
User-def. constraint: A_CCS_B
Activity(CCS_TRANS)
= Activity(CCS_STG)
CHP NGCC CCS
CHPNGCCS30
CHP Powerplant
CHPNGCCS50
CHP Powerplant
CCS_COMB_2
Combine captured
CO2 streams
User-defined constraint: A_CCS_6
∑ Activity$_i$*ENVACT$_{capt,i}$ (CHPNGCCS tech)
= Activity of CCS_COMB_2
CHPNGCCR10
CHP Powerplant
CCSCAPTH10
Capturing of CO2
CHPNGCCR30
CHP Powerplant
CCSCAPTH30
Capturing of CO2
CCS_CONV_2
Combine captured
CO2 streams
CHPNGCCR50
CHP Powerplant
CCSCAPTH50
Capturing of CO2
User-defined constraint: A_CCS_2x
Activity(ENGHCCSR)*EFF(CCSCAPTH)
>= Activity(CCSCAPTH)
User-defined constraint: A_CCS_5
Activity(CCS_CONV_2)
=∑ Activity$_i$*ENVACT$_i$(CCSCAPTHxx)

Scenario definitions

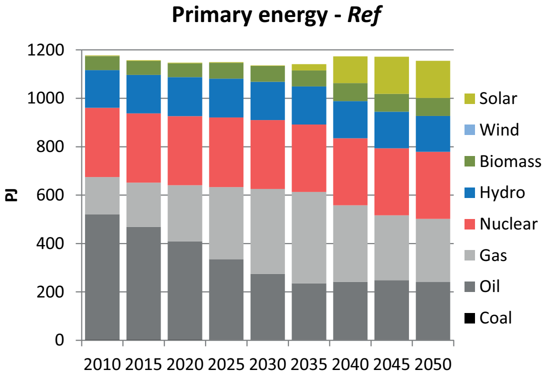
- ***Ref***: Reference scenario (nuclear replacement, no (climate) policies)
- ***NoNuc***: Nuclear phase-out
- ***Clim***: Climate target (domestic CO_2 reductions by 20% by 2020, 60% by 2050)
- ***Cumul A***: Cumulative CO_2 target
- ***Cumul B***: Cumulative CO_2 target with fixed end point)
- ***CCS***: Carbon Capture and Storage technologies available

General model assumptions

- Oil, coal, and geothermal based power generation are fully restricted
- Hydro assumed to follow a fixed production path (34.8 TWh_{el} in 2035, 33.0 TWh_{el} in 2050)
- Renewable potentials (Solar PV: 13.7 TWh_{el}, Wind: 4 TWh_{el}, Biomass: 28.1 TWh_{th})
- Discount rate: 3%

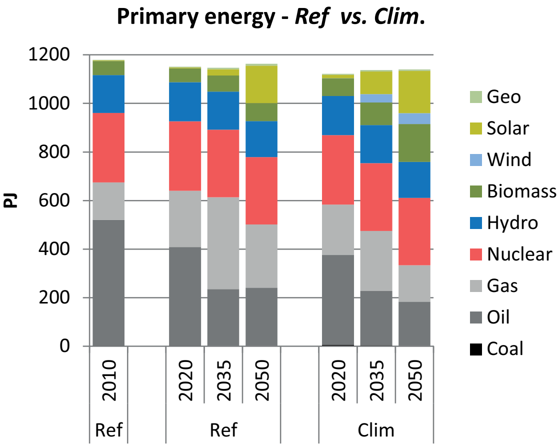
Reference scenario

Primary energy supply



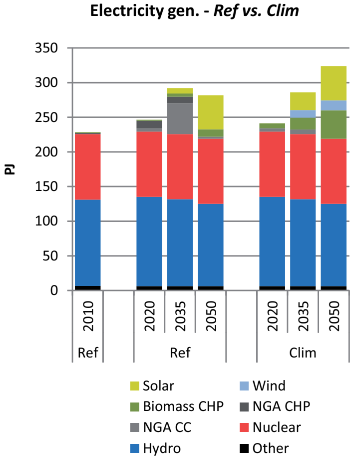
Climate scenario

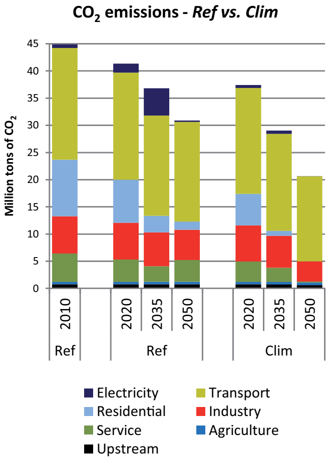
Primary energy supply



Climate scenario

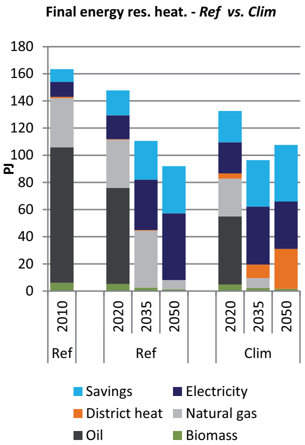
Electricity and CO_2 emissions

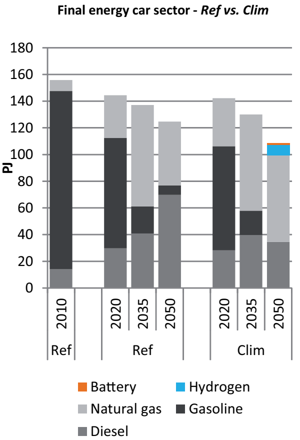




Climate scenario

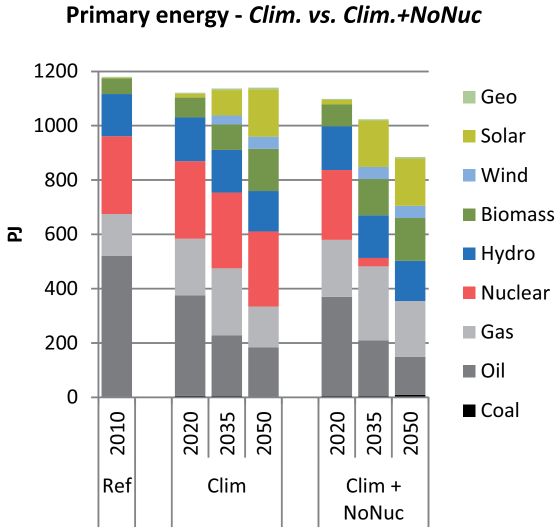
Final energy in residential heating and car sector





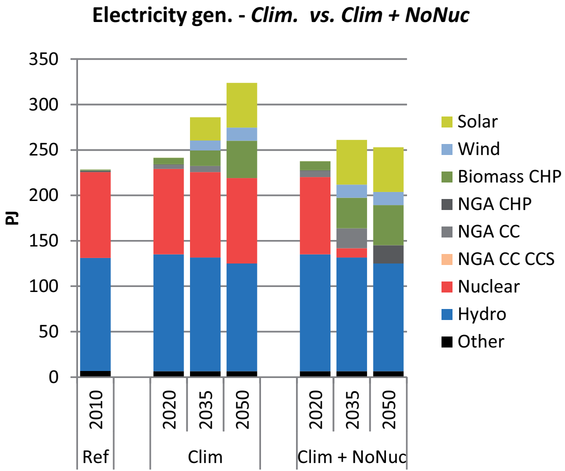
Nuclear phase-out under climate constraint

Primary energy supply



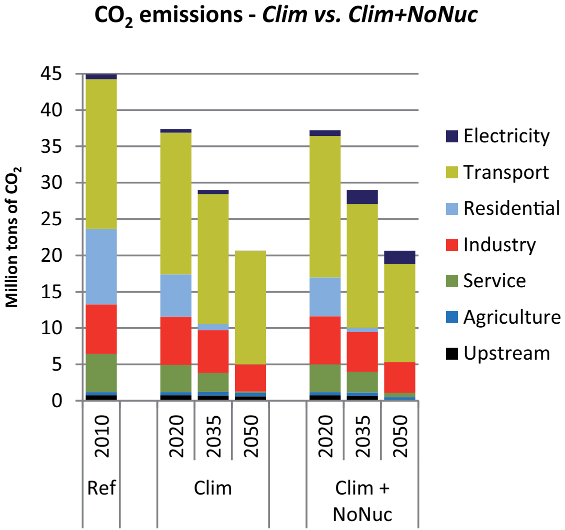
Nuclear phase-out under climate constraint

Electricity supply



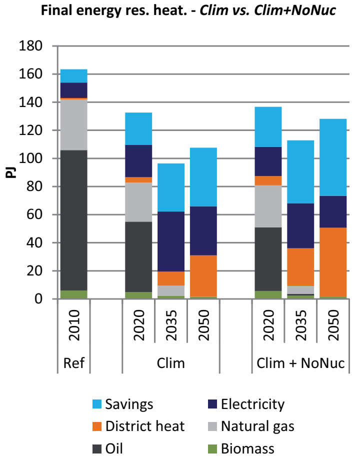
Nuclear phase-out under climate constraint

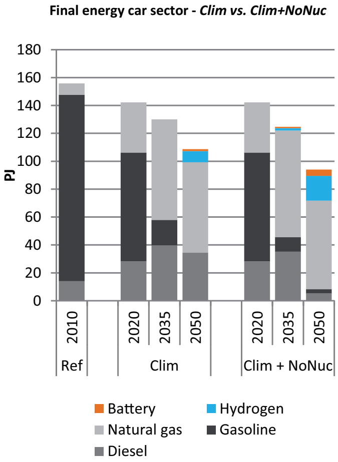
CO_2-emissions



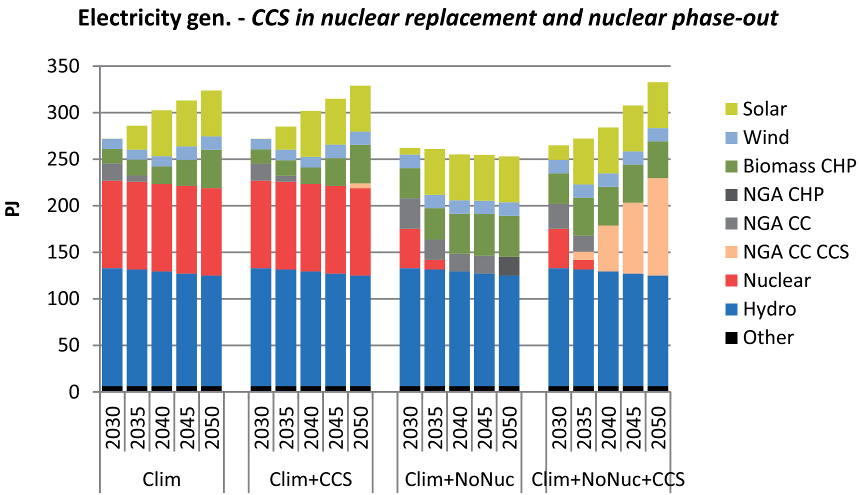
Nuclear phase-out under climate constraint

Final energy in residential heating and car sector

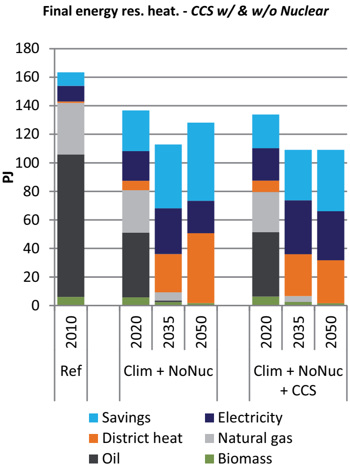


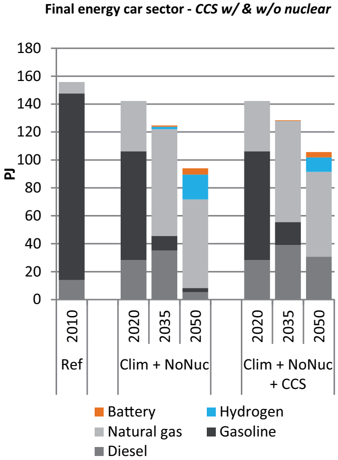


Electricity supply



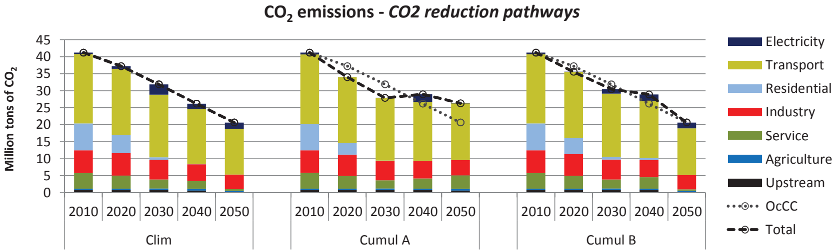
Final energy in residential heating and car sector

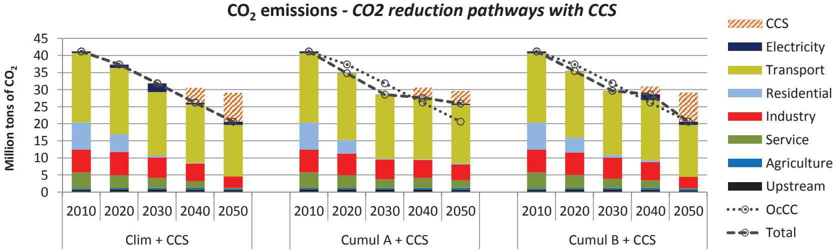




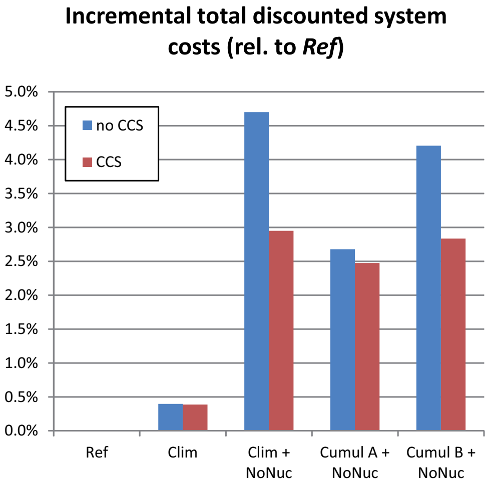
Alternative CO_2-reduction pathways

CO_2-emissions





System costs



Summary and conclusion

- Changes over time across entire energy system (supply and end-use). Climate-, nuclear policy constraints have system-wide effects (e.g. interplay between end-use and power sectors)
- Car sector: Trends towards higher efficiency (across all scenarios) and low carbon intensity (climate scenarios). However, fossil fuels will play major role during the next 40 years.
- Residential heating: Implementation of energy saving options and low carbon heatings systems attractive across wide range of scenarios (with and without climate targets)

Summary and conclusion (cont.)

- New renewables become attractive towards the end of time horizon. Climate targets and nuclear phase-out promote earlier deployments.
- CCS only attractive under nuclear phase-out and stringent climate targets. First, new renewables are deployed.
- CCS has effects on end-use sectors:
  - Residential heating: Electrification of energy system → more heat pumps, less saving measures
  - Car sector: Decarbonisation of electricity sector → lower efficiency and more fossil fuels in car sector
- Costs: Nuclear phase-out → increase in system costs. CCS could reduce costs for climate mitigation under nuclear constraint (dependent on stringency of climate target).

Outlook

- Improvements and extension of technology detail in services and industrial sectors (including energy efficiency options)
- Sensitivity analysis on crucial model input parameters (technology costs, discount rate)
- Extension of CCS module in Swiss MARKAL model and analysis of additional CCS scenarios
- Energy service demand update (to be implemented in Swiss MARKAL and Swiss TIMES models)

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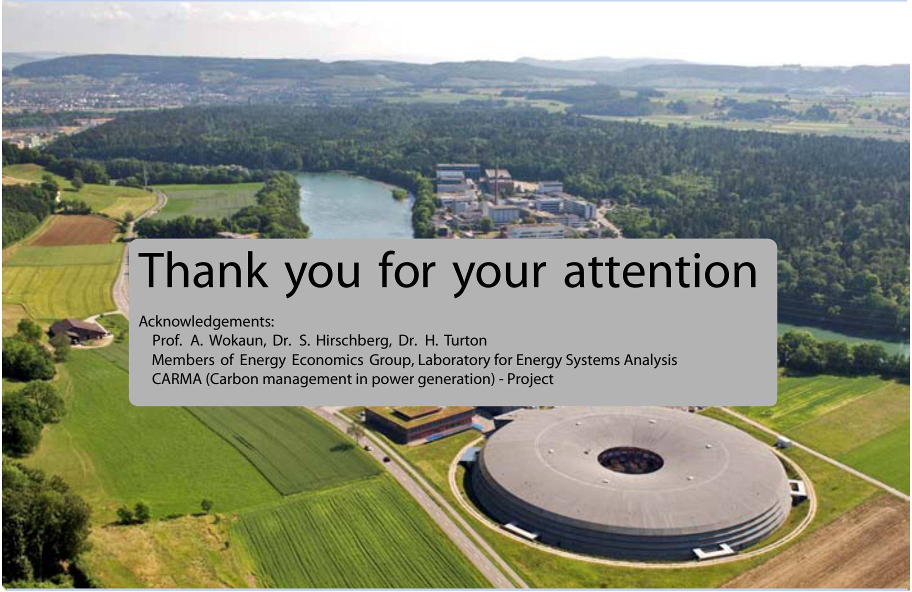

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