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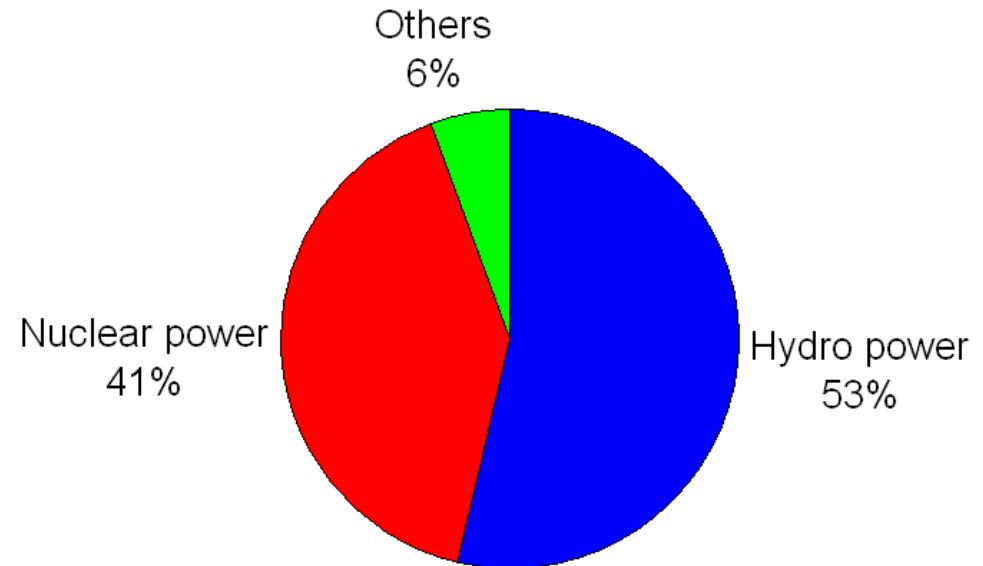
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Mitigation of CO₂ emissions in the future Swiss power sector:
Which options are most sustainable?

Power generation (2011)

- Swiss production mix:
~20 g CO₂/kWh_{el} (life-cycle)
- European production mix:
~500 g CO₂/kWh_{el} (life-cycle)

Source: ecoinvent

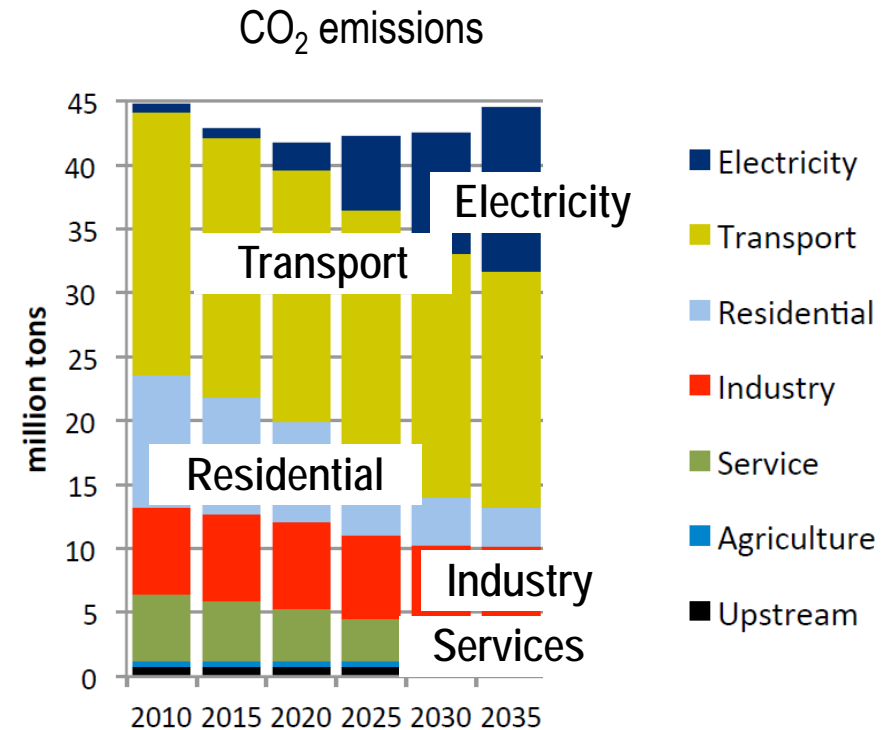
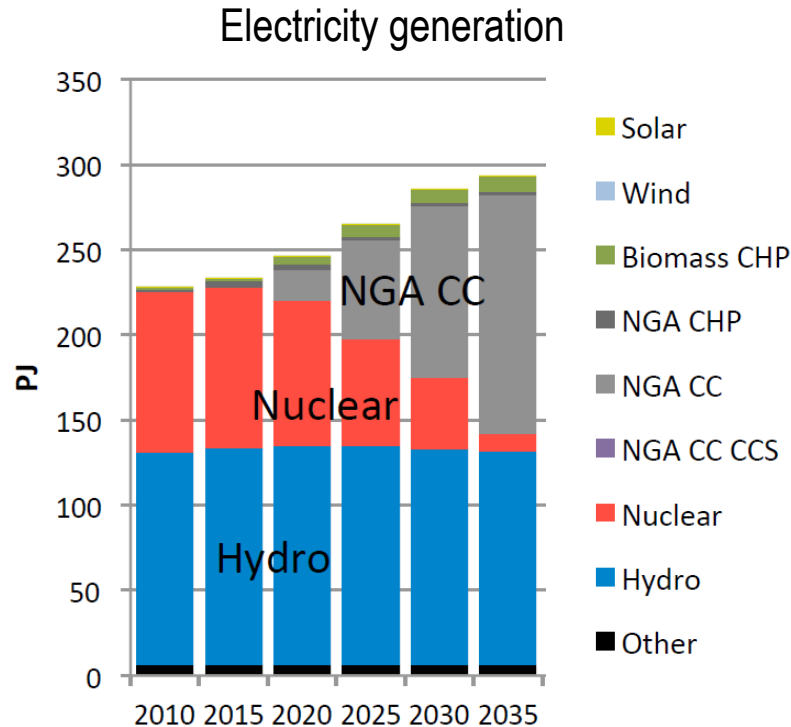


Source: Swiss Electricity Statistics 2011

Swiss political boundary conditions (2012)

- Nuclear phase-out: 2011 decision of the Swiss federal council on the decommissioning of the existing 5 nuclear reactors at the end of their safety-related life time and the abandonment of the construction of new reactors → phase-out ~2034
- CO₂ law: 2011 decision of the Swiss parliament on the reduction of the domestic greenhouse gas emissions by 20% until 2020 (compared to 1990)

Swiss energy system scenario (Reference)



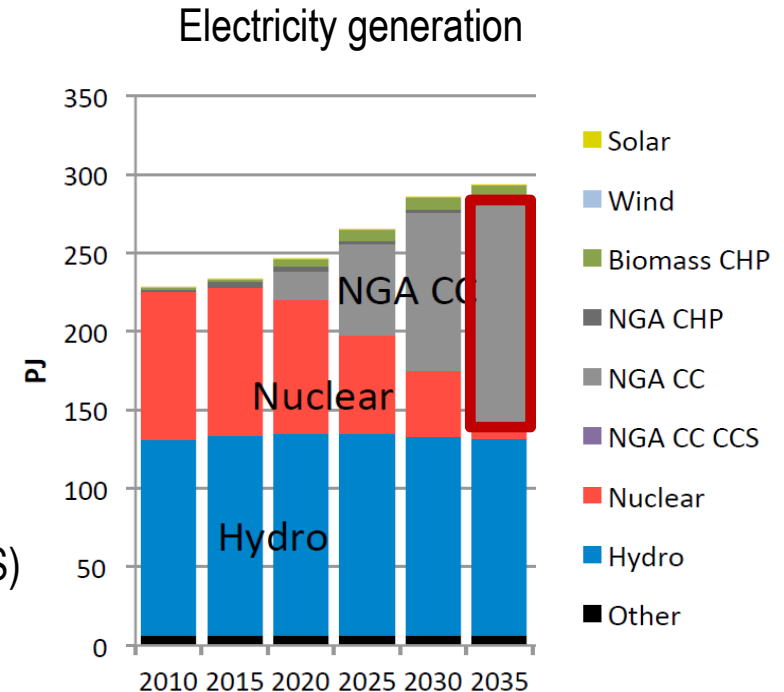
Source: courtesy of N. Weidmann (PSI, Swiss MARKAL model)

Research questions

- 1) What are the CO₂ mitigation options in the future Swiss power sector?
- 2) How sustainable are these options?

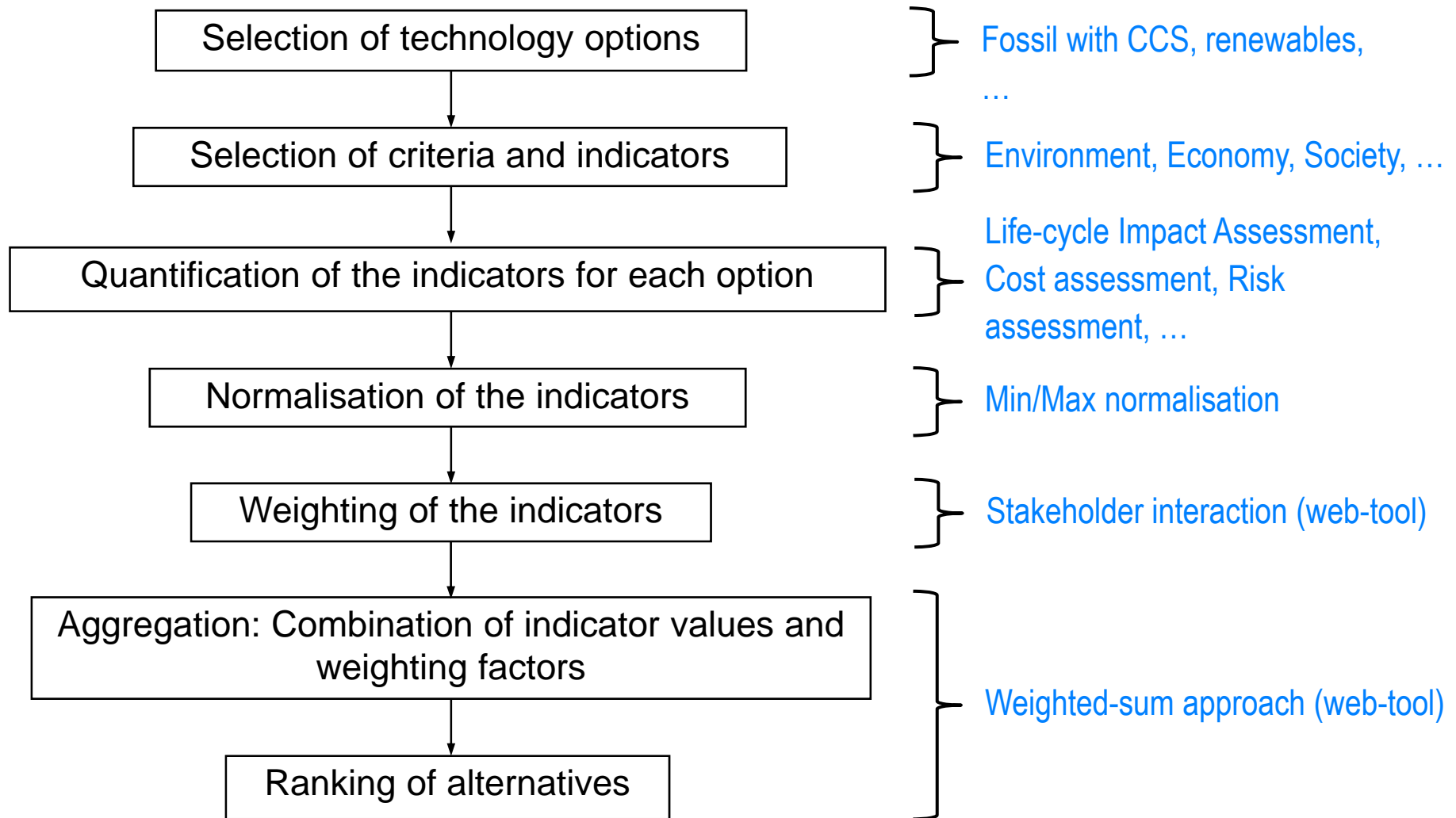
1) What are the CO₂ mitigation options in the future Swiss power sector?

- Collection of potential power generation options in Switzerland and abroad
- Identification of the CO₂ mitigation options by comparing the life-cycle CO₂ emissions to the ones of the prospective **natural gas-fired power plants**
- Functional unit: 1 t CO₂ mitigated (life-cycle)
- Special focus on the Carbon Capture and Storage (CCS) options as an emerging CO₂ mitigation technology



2) How sustainable are these options?

- Applying Multi-Criteria Decision Analysis (MCDA) for the assessment of the sustainability of the power generation options





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Fossil

Lignite PC with post-combustion capture

Lignite PC with oxy-fuel combustion

Lignite IGCC with pre-combustion capture

Hard coal PC with post-combustion capture

Hard coal PC with oxy-fuel combustion

Hard coal IGCC with pre-combustion capture

Natural gas CC with post-combustion capture

Auto-thermal reforming with pre-combustion capture

SOFC-GT with CCS

Nuclear

European Pressurised Reactor (EPR)

Renewables

Wood combustion

Wood combustion with post-combustion capture

Synthetic natural gas (SNG) CC

SNG CC with post-combustion capture

Biogas CHP

Reservoir

Run-of-river

PV monocrystalline

PV Cadmium-Telluride

Wind onshore

Wind offshore

Solar thermal

Geothermal

Environmental indicators

Resources

Fossil energy depletion	[MJ/kWh _{el}]
Nuclear energy depletion	[MJ/kWh _{el}]
Metal depletion	[kg Fe-eq/kWh _{el}]

Ecosystems

Ecosystem damages	[species*a/kWh _{el}]
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Climate

GHG emissions	[kg CO ₂ -eq/kWh _{el}]
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Economic indicators

External operating figures

Production cost	[CHF/MWh _{el}]
Fuel sensitivity	[share]

Internal operating figures

Capital cost	[CHF NPV/kW _{el}]
Marginal cost	[CHF cents/kWh _{el}]

Societal indicators

Social conflicts

Conflict potential	[ordinal scale]
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Normal operation

Human health damages	[DALY/kWh _{el}]
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Accidents

Expected fatalities	[fatalities/kWh _{el}]
Max. number of fatalities	[max. fatalities/accident]

Waste

chemical waste	[m ³ /kWh _{el}]
radioactive waste	[m ³ /kWh _{el}]

Security of supply indicators

Resource origin

share of domestic supply	[ordinal scale]
diversity of resources	[ordinal scale]

Reliability

plant availability	[ordinal scale]
fuel availability	[ordinal scale]



MULTI-CRITERIA DECISION ANALYSIS FOR CO₂ MITIGATION IN THE FUTURE SWISS POWER SECTOR

INFORMATION MCDA PROFILE LOGOUT

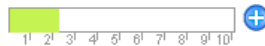
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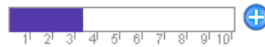
ENVIRONMENT 




ECONOMY 




SOCIETY 



SECURITY OF SUPPLY 

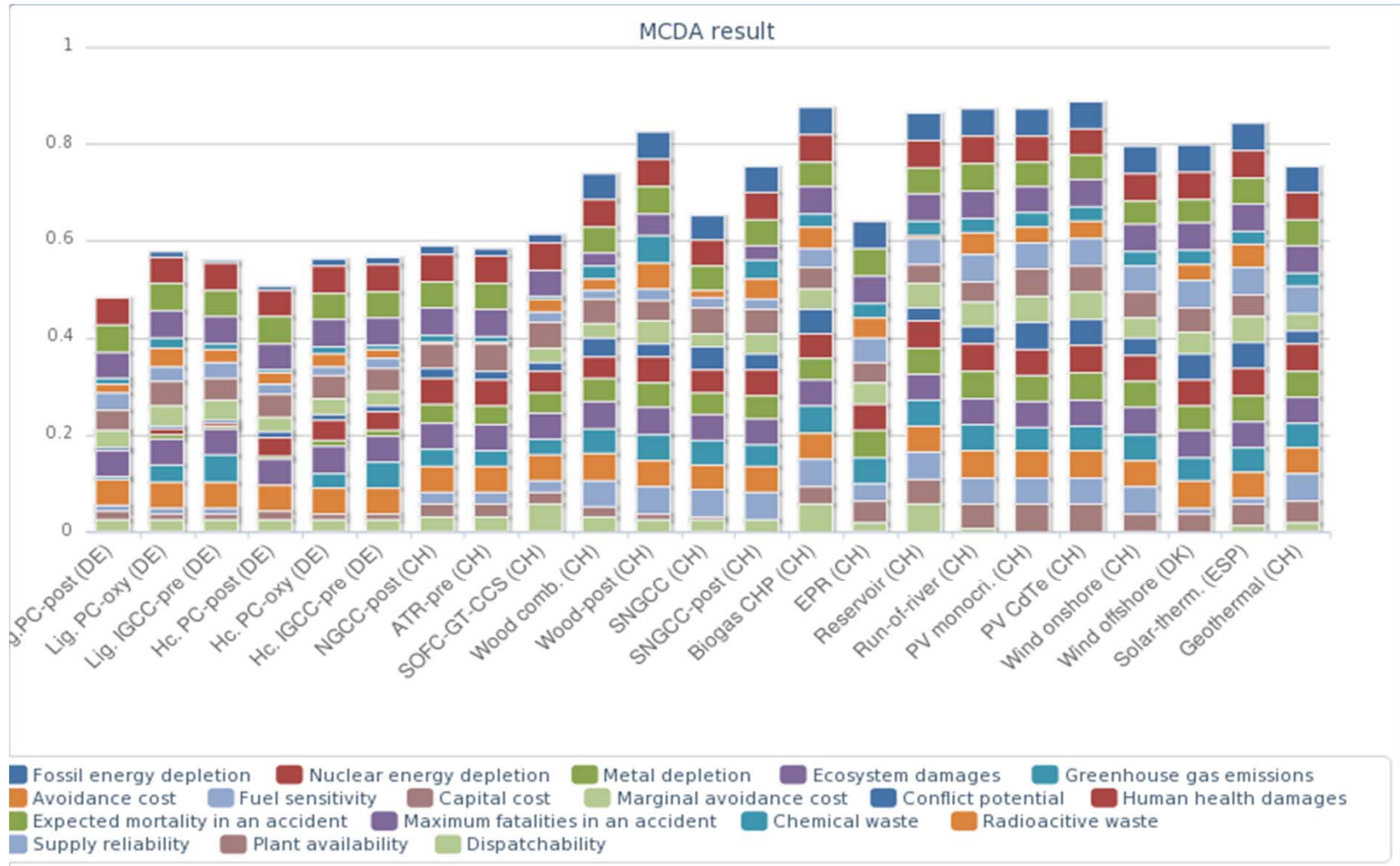


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General

- Renewable power generation generally performs better than fossil and nuclear power generation.
- Depending on the weighting of the indicators, different rankings are possible.

Carbon Capture and Storage (CCS)

- CCS is generally more interesting for lignite and hard coal than for natural gas power plants.
- Oxy-fuel combustion and pre-combustion capture generally perform better than post-combustion capture.
- Depending on the weighting of the indicators, CCS can be an interesting option.

Swiss power supply

- There is a variety of domestic and foreign options to mitigate CO₂ in the future Swiss power sector.
- Imports of electricity are a viable option from a sustainability point of view.
- Despite the good sustainability performance of the renewable energies, their development potential has to be considered which may be limited.

This assessment was carried out as a part of the research project **CARMA**, a joint research activity involving various partners from the ETH domain and private institutions.

CARMA aims at the exploration of the potential and feasibility of CCS systems deployment in Switzerland within the framework of future energy scenarios.

CARMA is funded by CCES and CCEM and financial support is gratefully provided by ALSTOM, the Swiss Federal Office of Energy and *swisselectric research*.

<http://www.carma.ethz.ch/>



Thank you for your attention!

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