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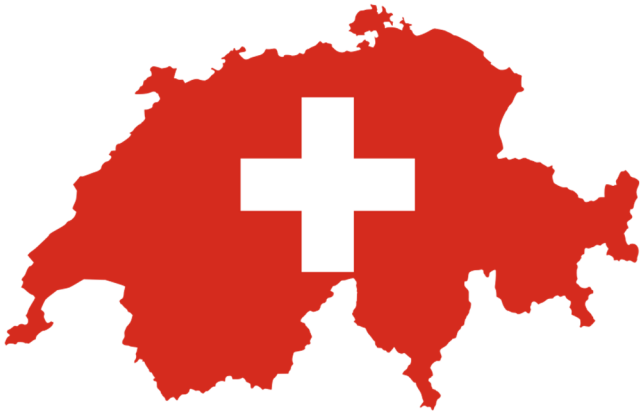
K. Volkart, N. Weidmann, Ch. Bauer (Paul Scherrer Institut, Switzerland)

Integrating LCA, Scenario Modelling and Multi-criteria Decision Analysis for Sustainable Policy-Making in the Energy Sector

Motivation / Case study

- Switzerland has recently defined its ***Energy Strategy 2050***. The strategy is framed by:
  - nuclear phase-out by ~2035*
  - stringent greenhouse gas reduction targets
  - potential availability of Carbon Capture and Storage (CCS)



- The **goals** of the *Energy Strategy 2050* are:
  - Increase in energy efficiency
  - Decrease in the use of non-renewable fuels
  - Decrease in dependency of foreign energy sources

→ How could the Swiss energy system develop in consideration of these (uncertain) boundary conditions?

→ For the assessment of the future development of the Swiss energy sector, different scenarios were developed

** Current policy; may be subject to a referendum.*

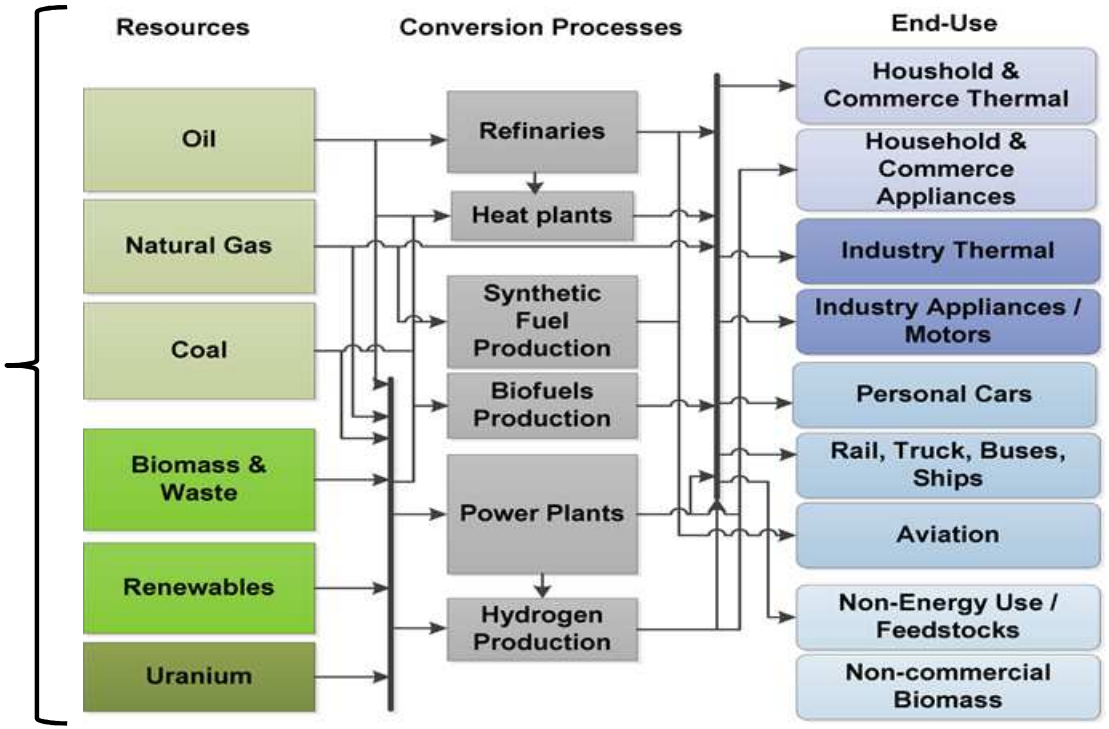
Scenarios (2035)

- **CARMA project**: Exploration of the potential and feasibility of CCS in Switzerland (www.carma.ethz.ch)

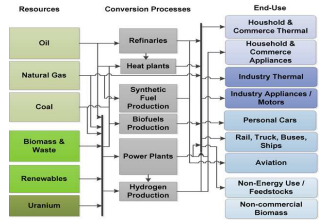
- **Scenarios**:

Ref	nuclear phase-out	no stringent climate policy	CCS not available
Clim	nuclear phase-out	60% CO_2 reduction by 2050	CCS not available
Clim+CCS	nuclear phase-out	60% CO_2 reduction by 2050	CCS available

- **Swiss MARKAL Model** (SMM):
  - energy-economic system model
  - whole energy system (not only electricity)
  - partial equilibrium (PE) model
  - least cost optimization model
  - direct CO_2 emissions

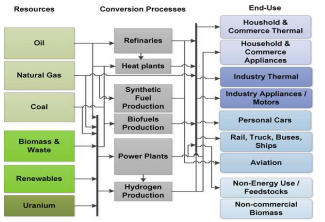


Scenario quantification with SMM (2035)



Source: Weidmann (2013)

Idea and goal



Limitations of the Swiss MARKAL model

- only direct CO_2 → no LCA perspective
- only costs → no other aspects

Idea

Is there a possibility to integrate

- system perspective of the Swiss MARKAL model
- detailed environmental assessment of LCA
- variety of indicators considered in Multi-criteria Decision Analysis (MCDA)…?

→ Comparison of complete scenarios of energy systems
→ Evaluation of the whole energy system using MCDA

} **MCDA of scenarios**

Laboratory for Energy Systems Analysis (LEA) at PSI

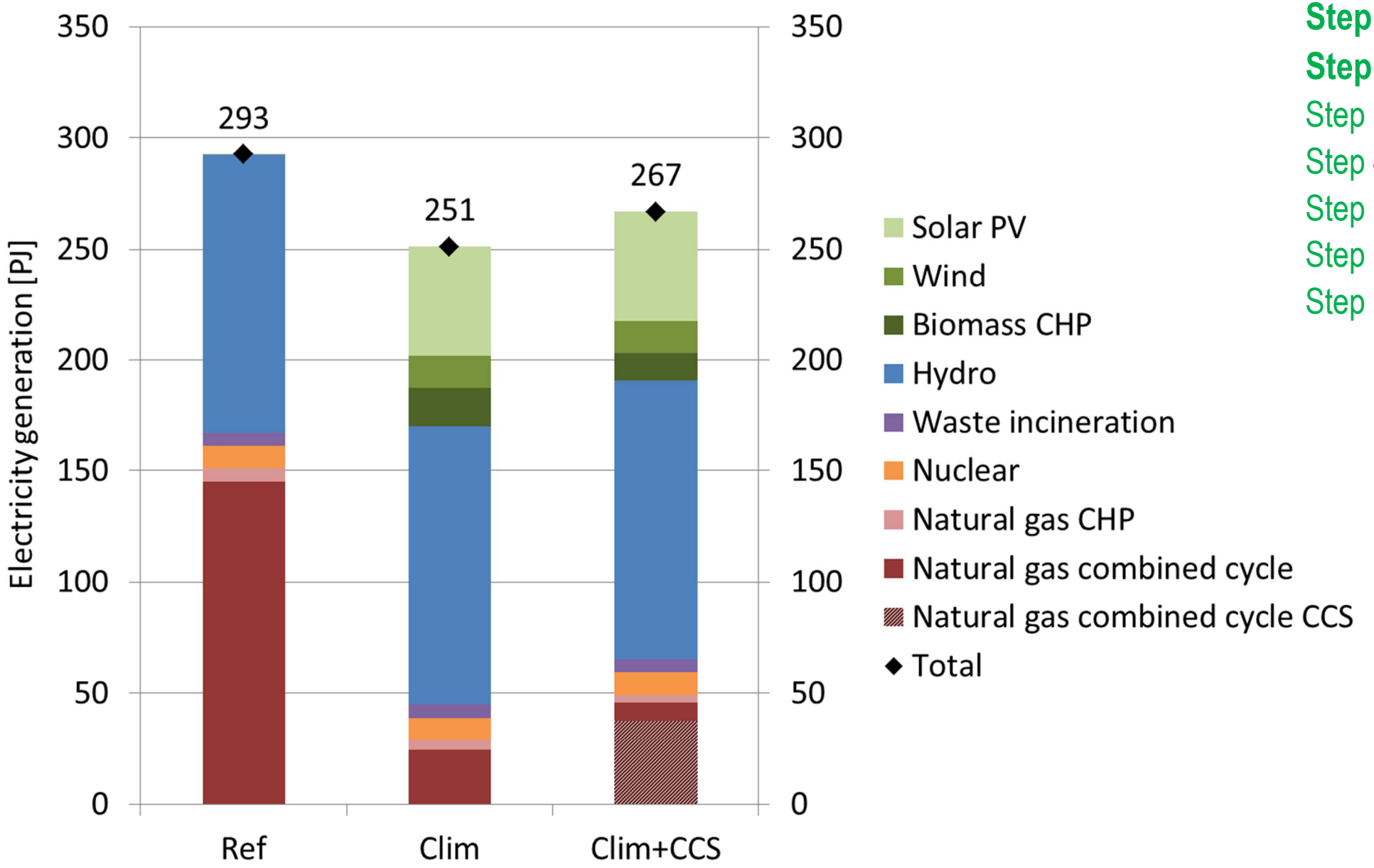
Experience in LCA, cost assessment, risk assessment, energy-economic modelling, multi-criteria decision analysis

Steps of the proposed methodology

	PE model	LCA	MCDA
Step 1	Develop scenario storylines for a case study		
Step 2	Quantify the scenarios using an energy-economic system model		
Step 3			Define indicators for the scenario comparison
Step 4		Quantify the indicators*	
Step 5			Weight the indicators according to preferences
Step 6			Calculate the ranking of the scenarios
Step 7	Policy recommendation		

* *additional methods: cost assessment, risk assessment, expert judgement, …*

Scenario quantification (2035)



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Step 7

Source: Weidmann (2013)

Indicators for the scenario comparison

Definition of indicators based on stakeholder interaction

Environment

- Metal depletion
- Fossil energy depletion
- Ecosystem damages
- Greenhouse gas emissions

Society

- Conflict potential
- Human health damages
- Expected mortality in an accident
- Maximal fatalities in an accident
- Chemical waste

Economy

- Investment cost
- O&M cost

Security of supply

- Resource autonomy of the supply chain
- Resource variability

Step 1
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Step 6
Step 7

Quantification of indicators based on LCA, cost and risk assessment, expert judgement

Weighting of the indicators

Indicator / Focus on…	Fossil energy depletion GHG emissions Resource autonomy	GHG emissions Investment cost O&M cost
Metal depletion	5.3%	5.3%
Fossil energy depletion	**15.8%**	5.3%
Ecosystem damages	5.3%	5.3%
Greenhouse gas emissions	**15.8%**	**15.8%**
Investment cost	5.3%	**15.8%**
Operation & Maintenance cost	5.3%	**15.8%**
Conflict potential	5.3%	5.3%
Human health damages	5.3%	5.3%
Expected mortality in an accident	5.3%	5.3%
Maximal fatalities in an accident	5.3%	5.3%
Chemical waste	5.3%	5.3%
Resource autonomy of the supply chain	**15.8%**	5.3%
Resource variability	5.3%	5.3%

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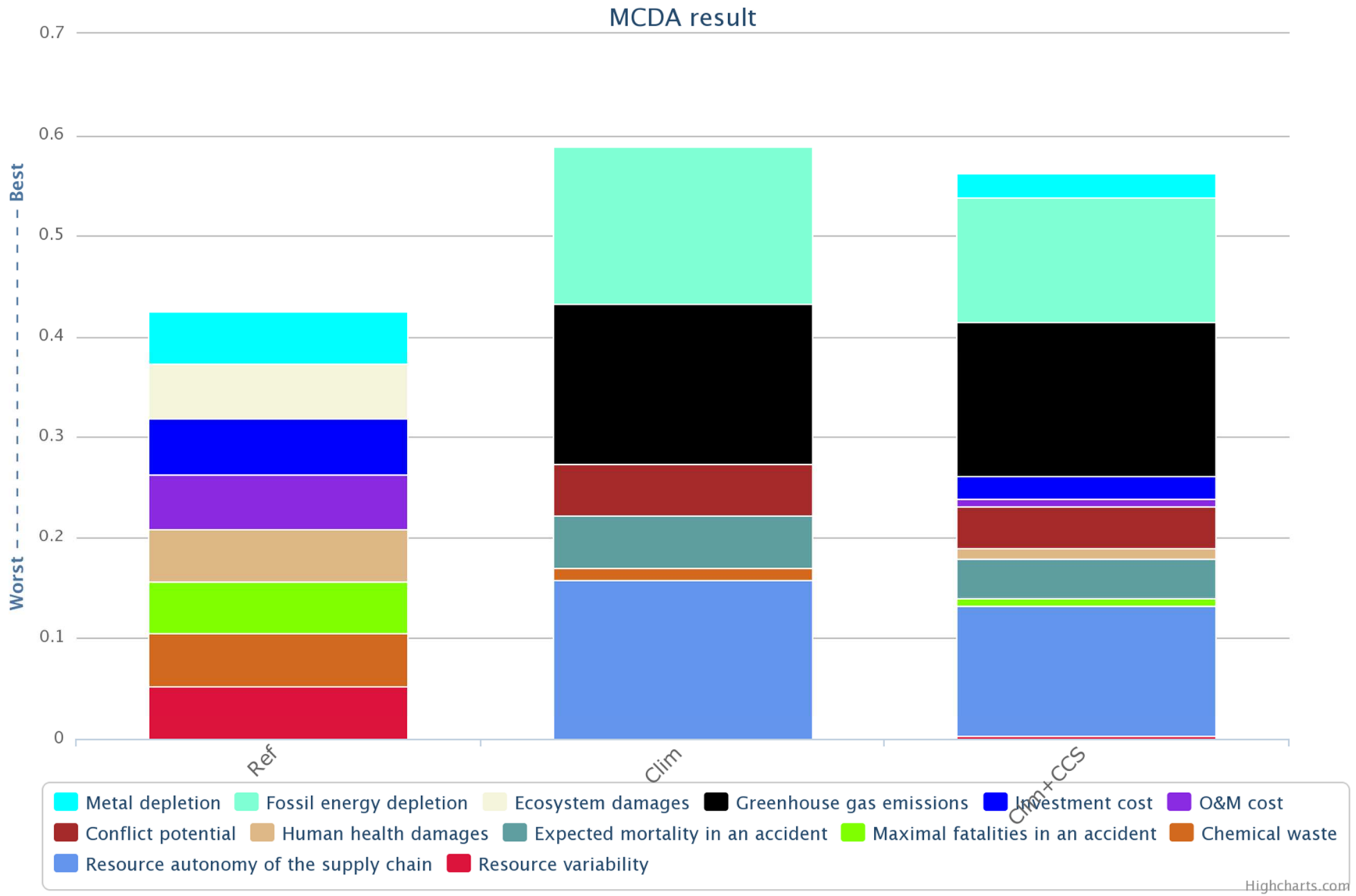
Result: selected weighting profile

High weights on **fossil energy depletion, GHG emissions** and **resource autonomy**



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Result: selected weighting profile

High weights on **GHG emissions, investment cost** and **O&M cost**

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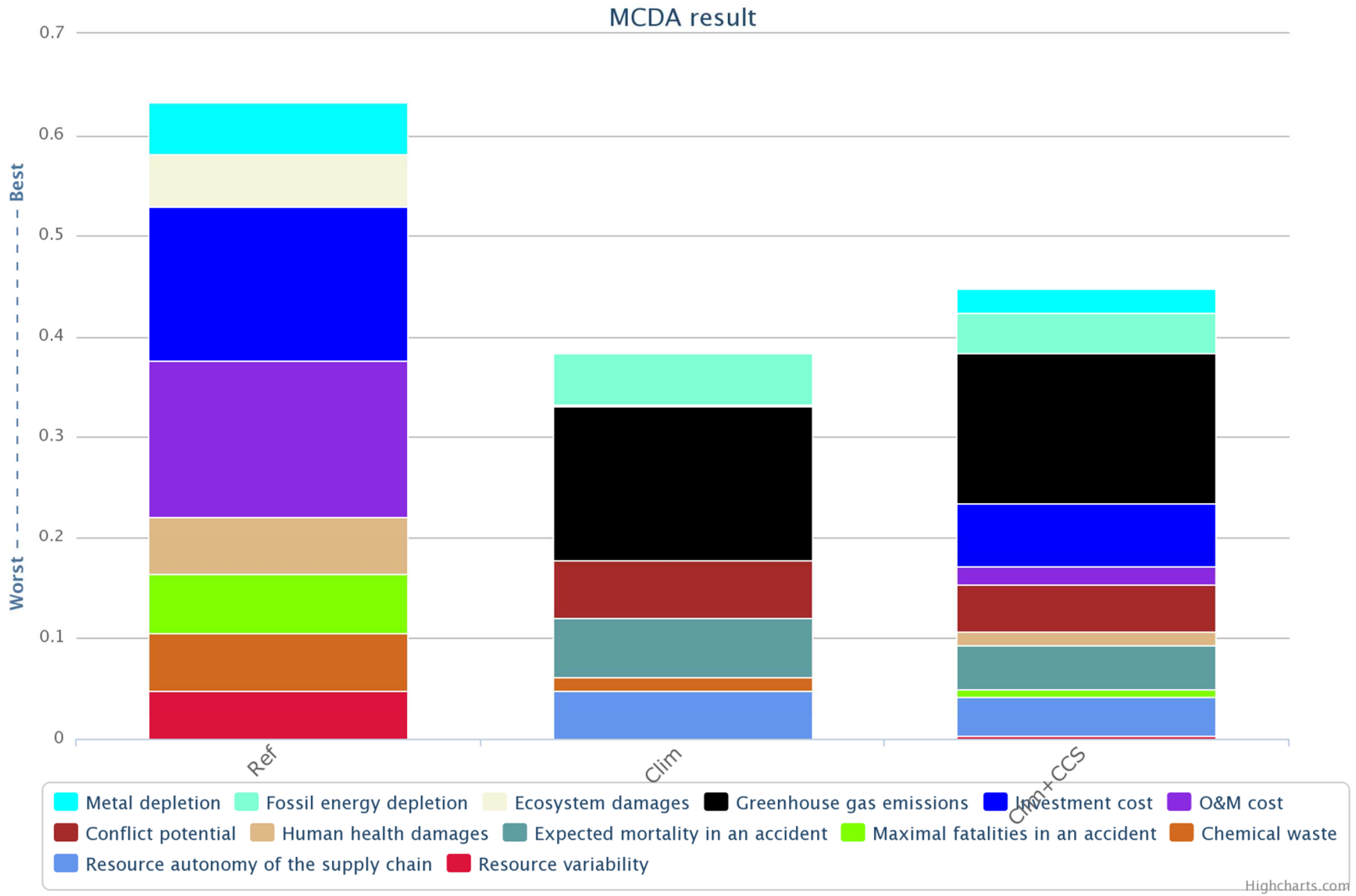

Policy recommendations

- Focussing on **fossil fuel depletion, GHG emissions and resource autonomy** favours the two climate action scenarios compared to the reference case.
- Focussing on **GHG emissions, investment and O&M costs** favours the Clim+CCS case compared to the Clim case.

- Following the goals of the ***Energy Strategy 2050*** of Switzerland (less non-renewable energy, more resource autonomy), one of the two climate action scenarios is preferable over the reference scenario.
- Depending on the preferences elicited from the upcoming **political process**, one or the other scenario should be aspired for as future framework.

Step 1
Step 2
Step 3
Step 4
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Conclusions on the approach

(Session) Goals achieved

- Consideration of *interactions between different sustainability aspects* using LCA and MCDA
- Incorporation of *political and regulatory context* using a PE model
- Taking into account *economic and social aspects* using MCDA and a PE model

→ Assessment that combines LCA, MCDA and a PE model to support energy policy-making

→ Application to a case study

Outlook

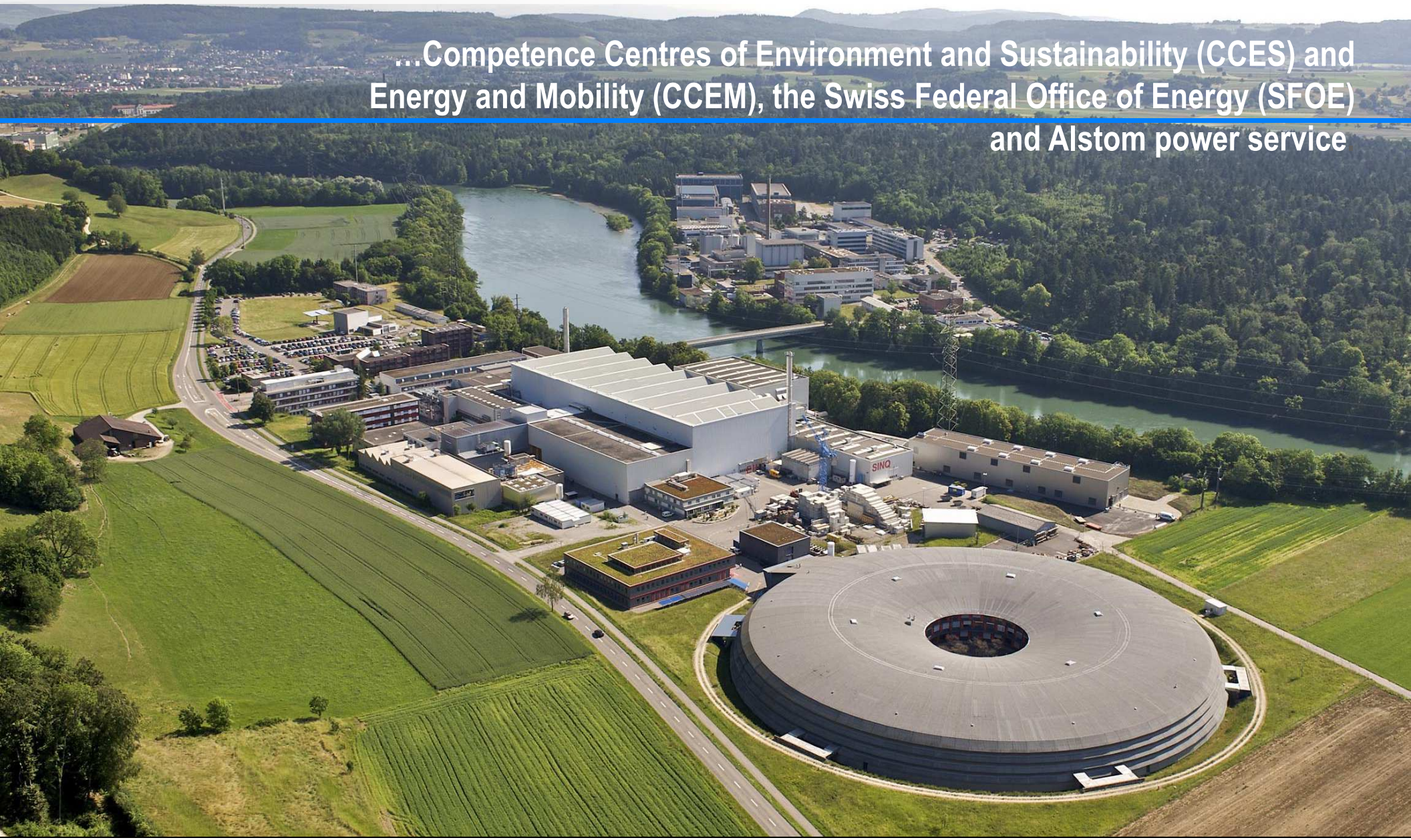
- Full integration of an energy-economic system model and LCA

- Special session at LCA XIV in San Francisco in October 2014
  "*Integration of LCA and Energy-Economic System Modelling for Policy-Making in the Energy Sector*"
  (http://www.lcacenter.org/lca-xiv.aspx)

I would like to thank…

…Nicolas Weidmann, Christian Bauer, and the PSI team

…Competence Centres of Environment and Sustainability (CCES) and Energy and Mobility (CCEM), the Swiss Federal Office of Energy (SFOE) and Alstom power service



Thank you for the attention

Are there any questions?