Integrating Global Energy-economic System Modelling and Life-cycle Assessment

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Motivation

Today's energy system

The world faces various challenges related to the (global) energy system, e.g.

- climate change
- resource depletion
- energy access
- human health damages

Addressing one of the challenges mentioned above may influence (the solution of) other challenges.

→ This leads to complex decisions for energy policy-makers.

→ Therefore, integrated and consistent assessment methodologies are required for decision support and for the transition to sustainable energy systems.

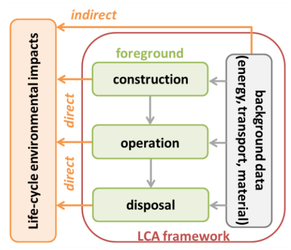
Concept and Methodology

Life-cycle assessment (LCA)

LCA is used for environmental assessment of energy technologies. The *ecoinvent* database provides detailed background data.

Characteristics:

- detailed environmental indicators
- detailed human health indicators



Energy system modelling

The 15-region Global Multi-regional MARKAL (GMM) energy system model is used to develop, quantify and analyze scenarios of the global energy system.

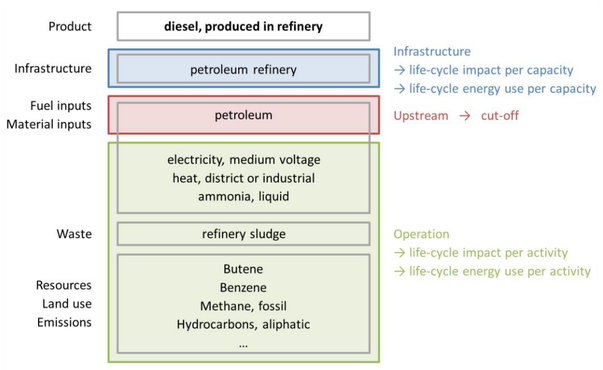
Characteristics:

- system perspective
- temporal development
- techno-economic indicators

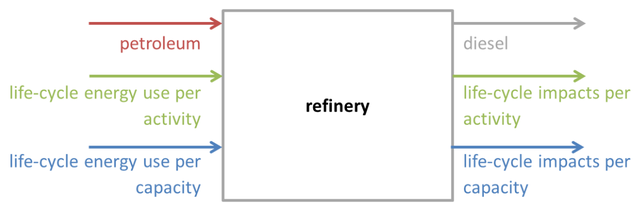
Integration

Methodological approach

(1) Disaggregation of the relevant *ecoinvent* datasets into upstream, infrastructure and operation phase

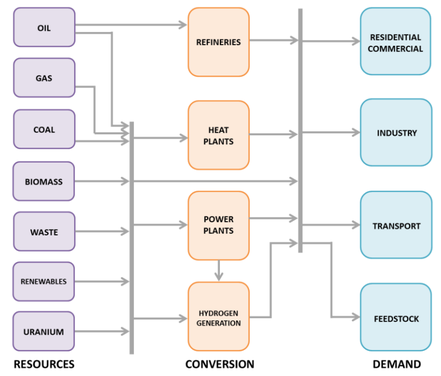


(2) Calculation of the LCA results per activity and capacity for each process of the GMM model



LCA software: Brightway2

(3) Integration of the LCA results in the GMM model



Results for World Energy Council (WEC/PSI) scenarios

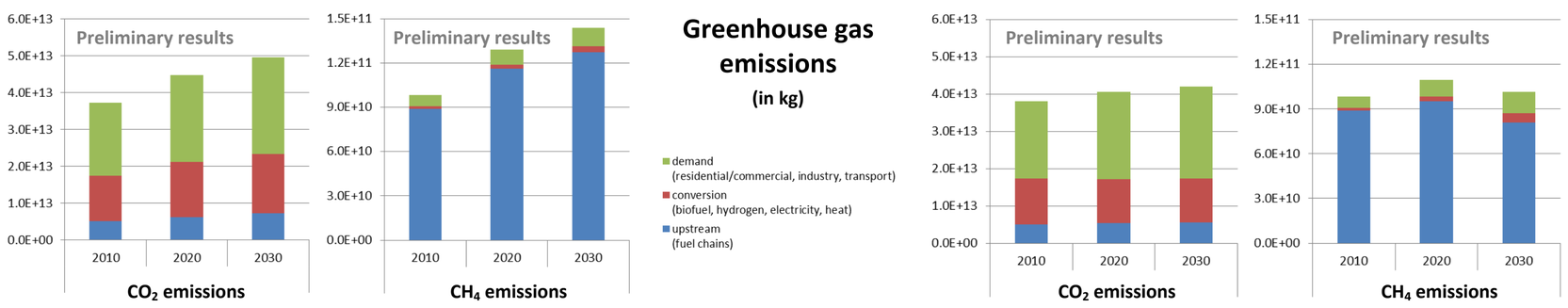
Assessment of global environmental impacts 2010 to 2030

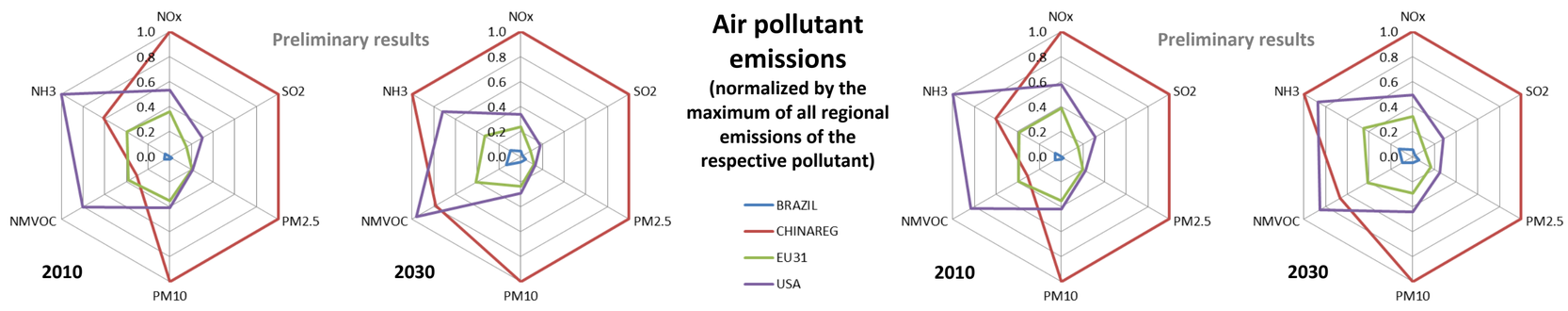
JAZZ scenario

- Affordable access to energy through free markets
- GDP growth has priority
- Population increase to 8.7 billion in 2050
- CO_2 price in 2050: 23–45 \$/tCO_2
- Mainly adaptation to environmental damages
- CCS is market driven; pilot plants by 2030
- Nuclear plants under construction partially not in operation

SYMPHONY scenario

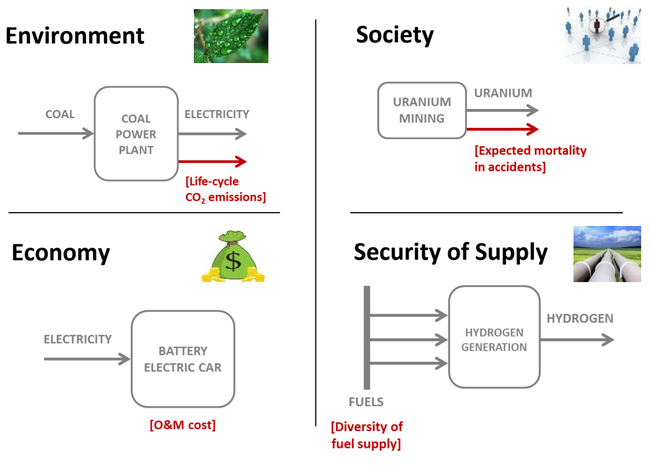
- Secure access to energy through regulation
- Less GDP growth compared to JAZZ
- Strong population increase to 9.3 billion in 2050
- CO_2 price in 2050: 70–80 \$/tCO_2
- Mainly mitigation of environmental damages
- CCS available from 2020
- State support for nuclear energy





Goals of the PhD thesis

Integrating the GMM model and Multi-criteria Decision Analysis (MCDA)



The further assessments based on the existing framework include:

- External cost calculations
- Optimization of other indicators than costs / Near cost-optimal solutions

Extensions to existing framework encompass:

- Integration of further sustainability indicators
- Multi-criteria assessment
  min (cost) → min (w_1 * INDICATOR$_1$ + w_2 * INDICATOR$_2$ + …)

Expected overall insights are:

- Trade-offs between different sustainability aspects of energy systems
- Policy recommendations based on multi-criteria assessment of energy systems

Challenges

Methodological difficulties

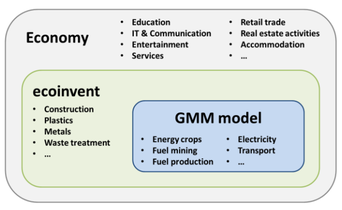
- Finding equivalent processes in the two models, i.e. allocation of one *ecoinvent* to each GMM process
- Harmonizing of *ecoinvent* and GMM modelling data by adjusting information on:
  - energy carrier flows
  - units
  - efficiencies
- Regionalization, i.e. choice of the *ecoinvent* region(s) used to model the corresponding region in the GMM model
- Modelling of future technologies that are not represented in the *ecoinvent* database
- Modelling of the energy own-use of the energy sector

Conclusions

Preliminary findings

Methodology

- The methodological approach was successfully implemented, i.e. the GMM energy system model was extended by environmental data on LCA basis.



- The modelling challenges were overcome within the limits of the two models.

Results

- Regionally and temporally differentiated LCA results were generated for a variety of key air pollutants and greenhouse gases.
- The global emissions calculated based on the modelling framework were validated with real global emission data from 2010.

Acknowledgements

I would like to thank

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