Use of LCA-data in TIMES-Norway

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Motivation

- Optimize CO_2 footprint
- Extend the analyses beyond energy and CO_2
- Ensure the actual sustainability of new and conventional renewables
- Focus on research areas of IFE (battery, H2, wind, PV)

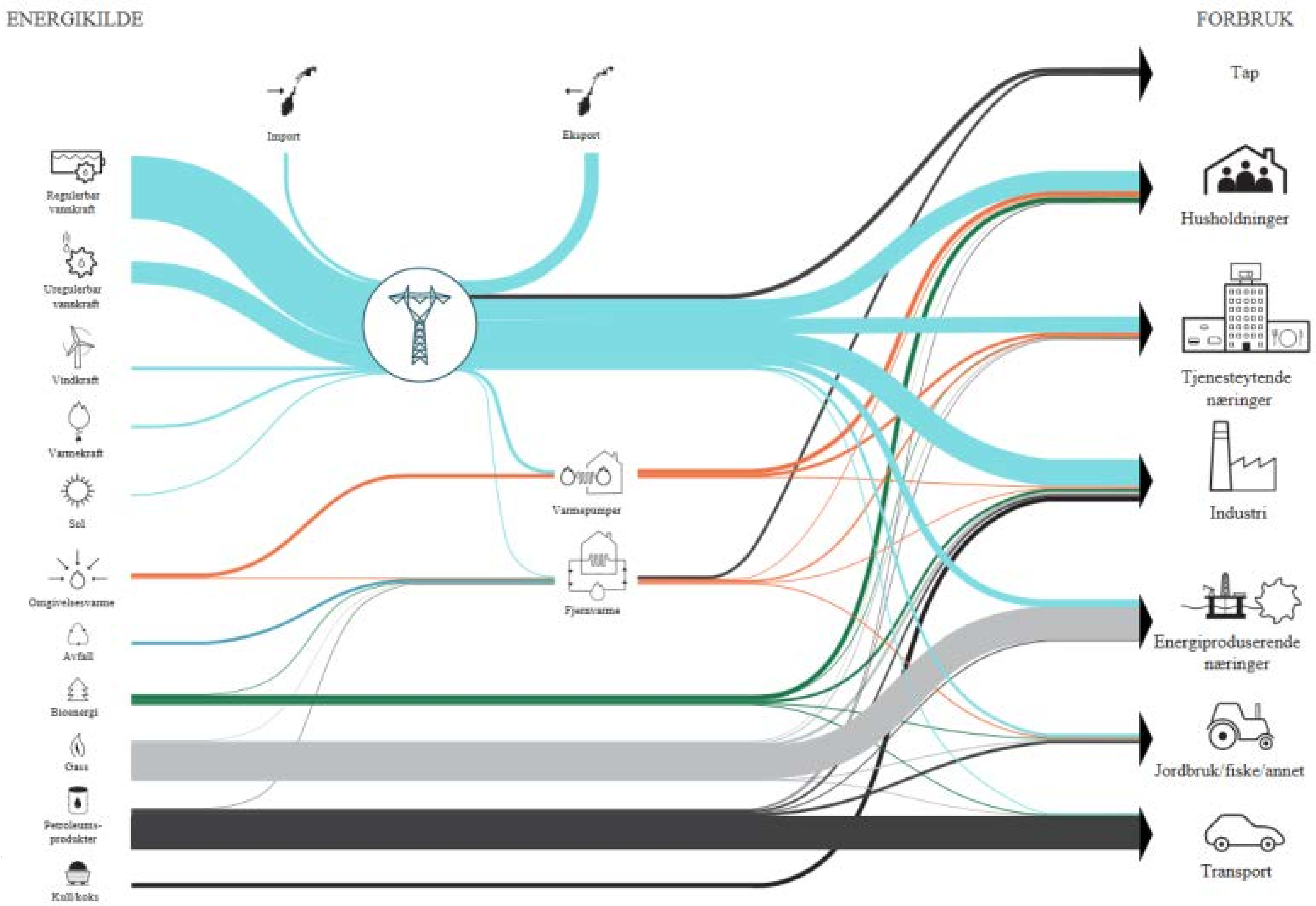
Objective:

- Develop a methodology coupling energy system modelling and LCA / LCC

Approaches:

- LCA of a future energy system
- Optimizing of an energy system, including LCA parameters

The Norwegian energy system 2015



Use of results from energy systems analysis in LCA is proved to be valuable

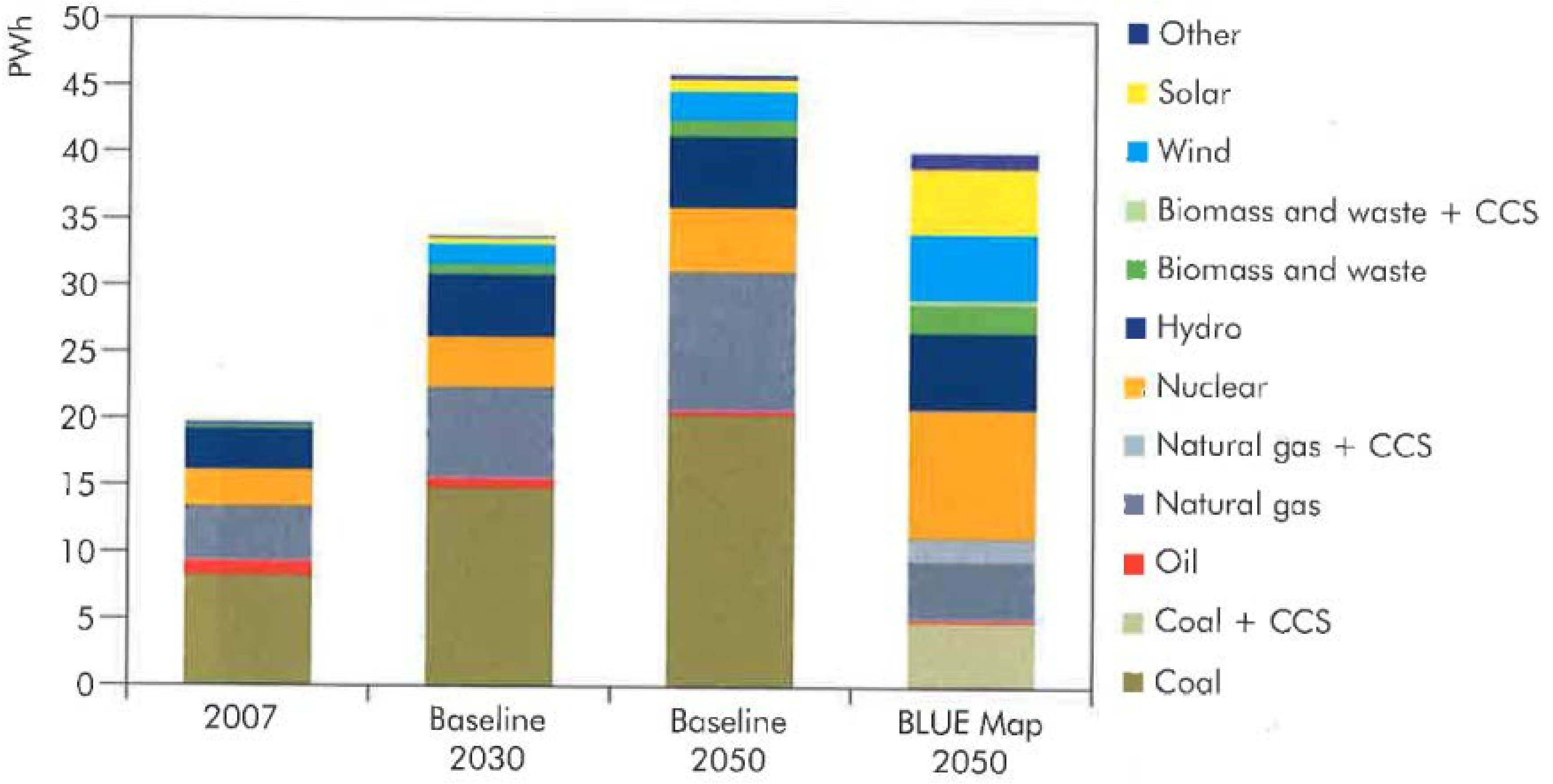
Examples, recent work:

1. National level: IMDEA/CIEMAT: "Prospective life cycle assessment of the Spanish electricity production" *in Renewable and Sustainable Energy Reviews 75 (2017)*

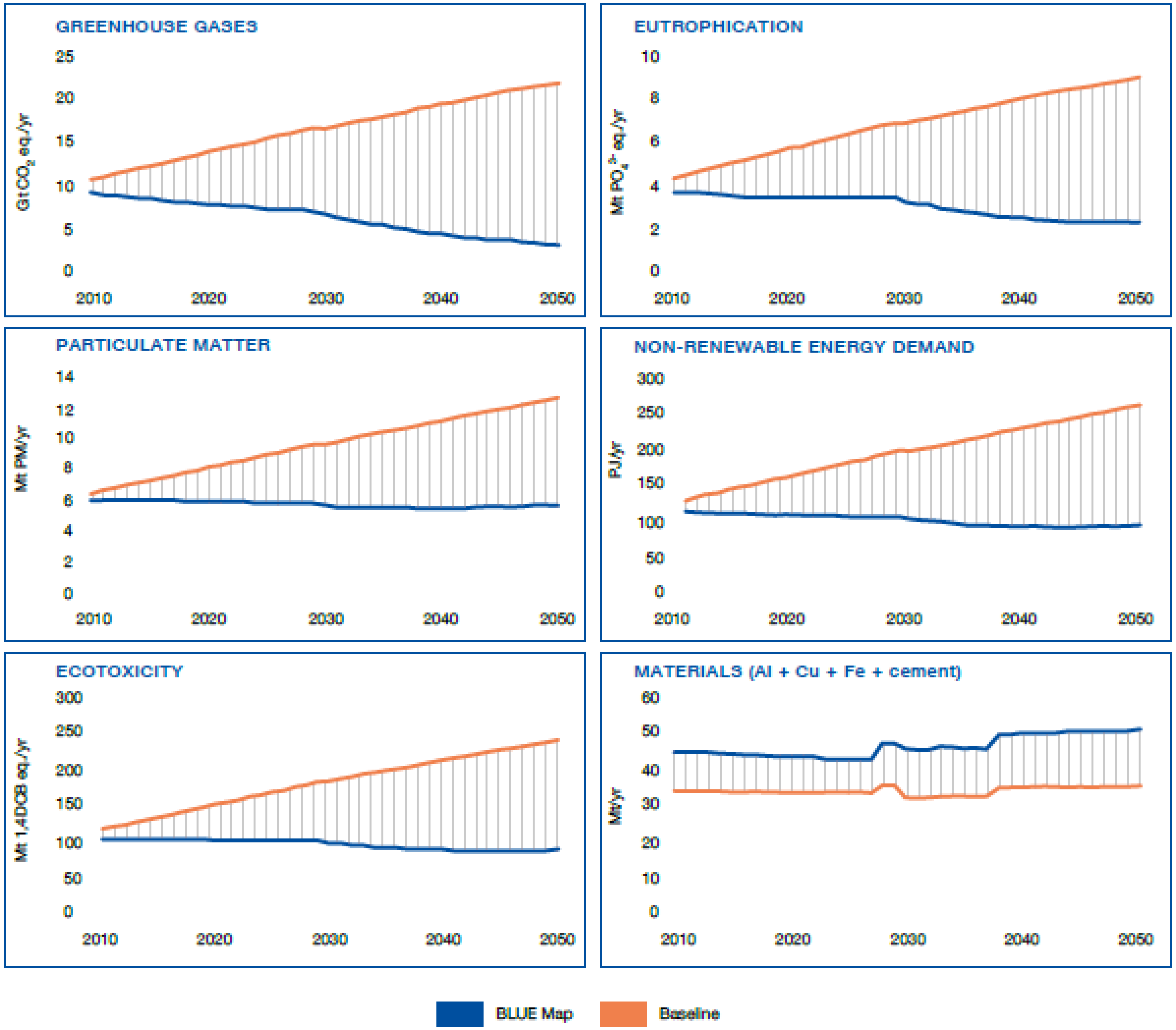
2. European level: NTNU/DLR: " Environmental impacts of high penetration renewable energy scenarios for Europe" *in Environmental Research Letters 11 (2016)*

3. Global level: UNEP: "Green Energy Choices: the benefits, risks and trade-offs of low-carbon technologies for electricity production" (2016)
   - PNAS (2014): Integrated life-cycle assessment of electricity-supply scenarios confirms global environmental benefit of low-carbon technologies

IEA ETP2010: Global electricity production by energy source in the Baseline and BLUE Map scenarios



Impact indicators, resource demand and deployment characteristics of the investigated power generation technologies under the IEA BLUE Map scenario



- IEA BLUE Map compared to the IEA Baseline scenario
- a doubling of electricity generation from 2007 to 2050
- reduction of pollution-related environmental impacts
- a substantial increase of material consumption, specially copper

Source: UNEP: Green Energy Choices: the benefits, risks and trade-offs of low-carbon technologies for electricity production (2016)

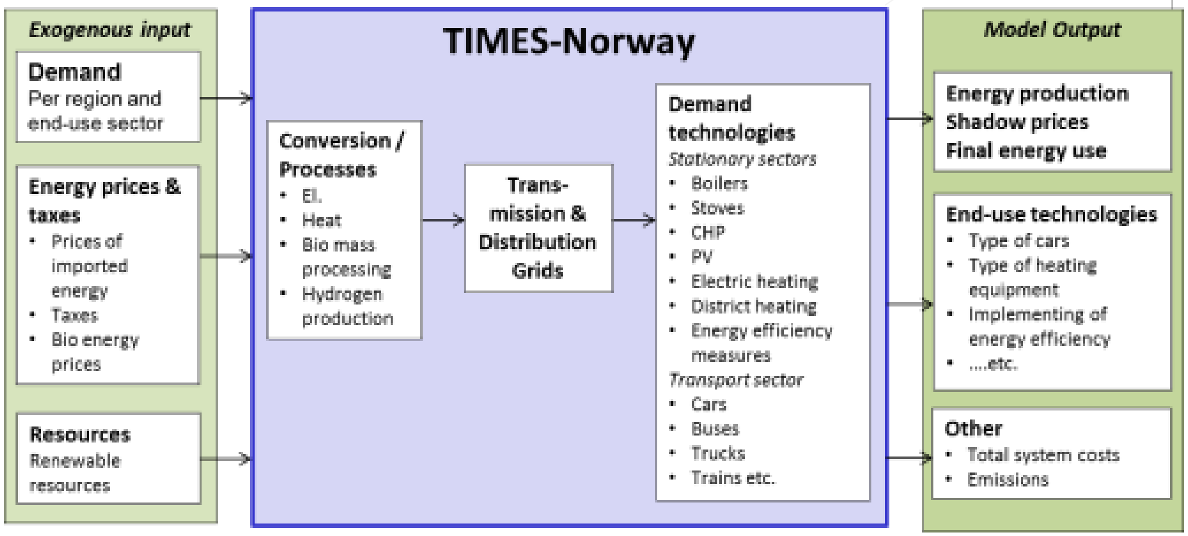
Use of LCA data in energy system models

What are the benefits of including LCA-data in a TIMES-model?

- Including the life-cycle perspective on energy system modelling
    - Energy used outside the model region can be included
    - Emissions from production of technologies used in the model can be included
- Adding new functionality
    - Including LCA impact categories
    - Including other emissions than CO_2
- Optimization with limits of added parameters
    - GHG limit including a cradle-to-gate or cradle-to-grave perspective (GWP)
    - Other parameters as NOx, resources, human health…..
- …

Tools

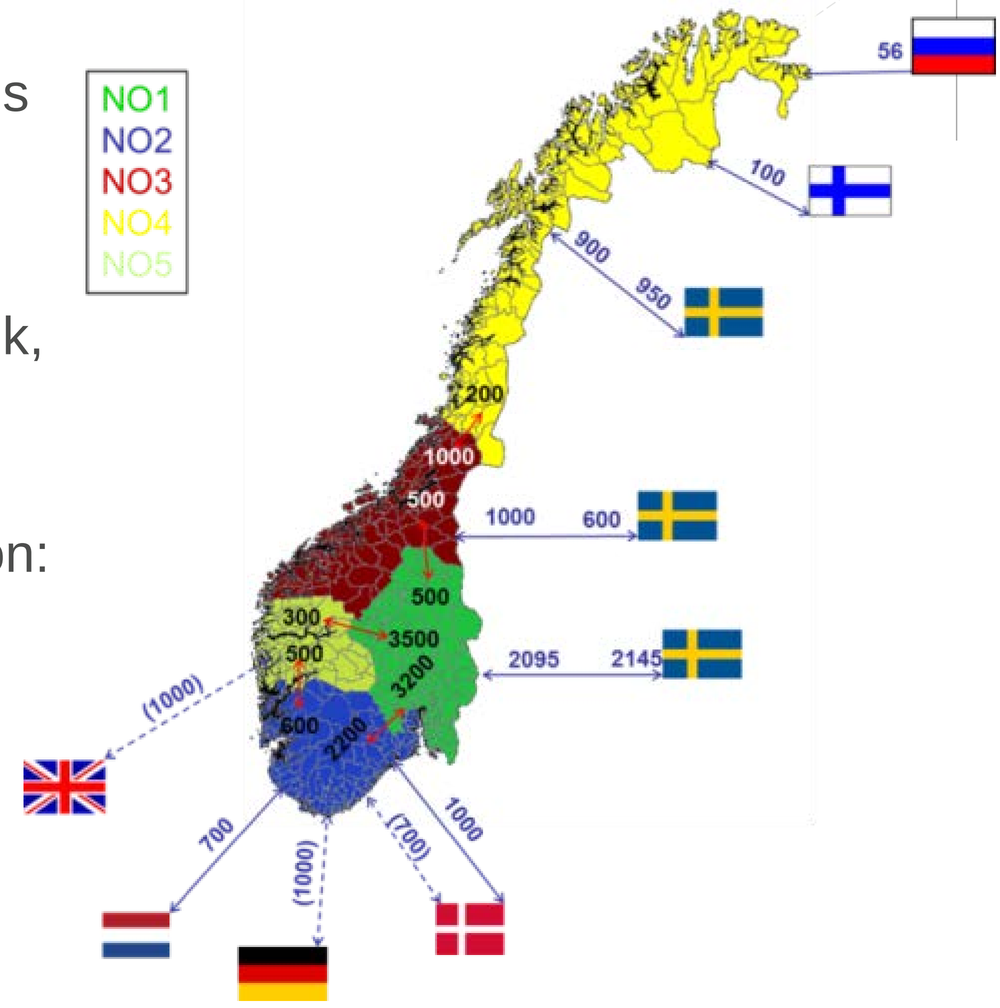
- **TIMES models**
  - TIMES-Norway
  - TIMES-North-Europe
  - TIMES-Oslo
  - ETSAP-TIAM



- **LCA**
  - Software: openLCA
  - Databases:
    - Ecoinvent
    - NEEDS
    - ELCD

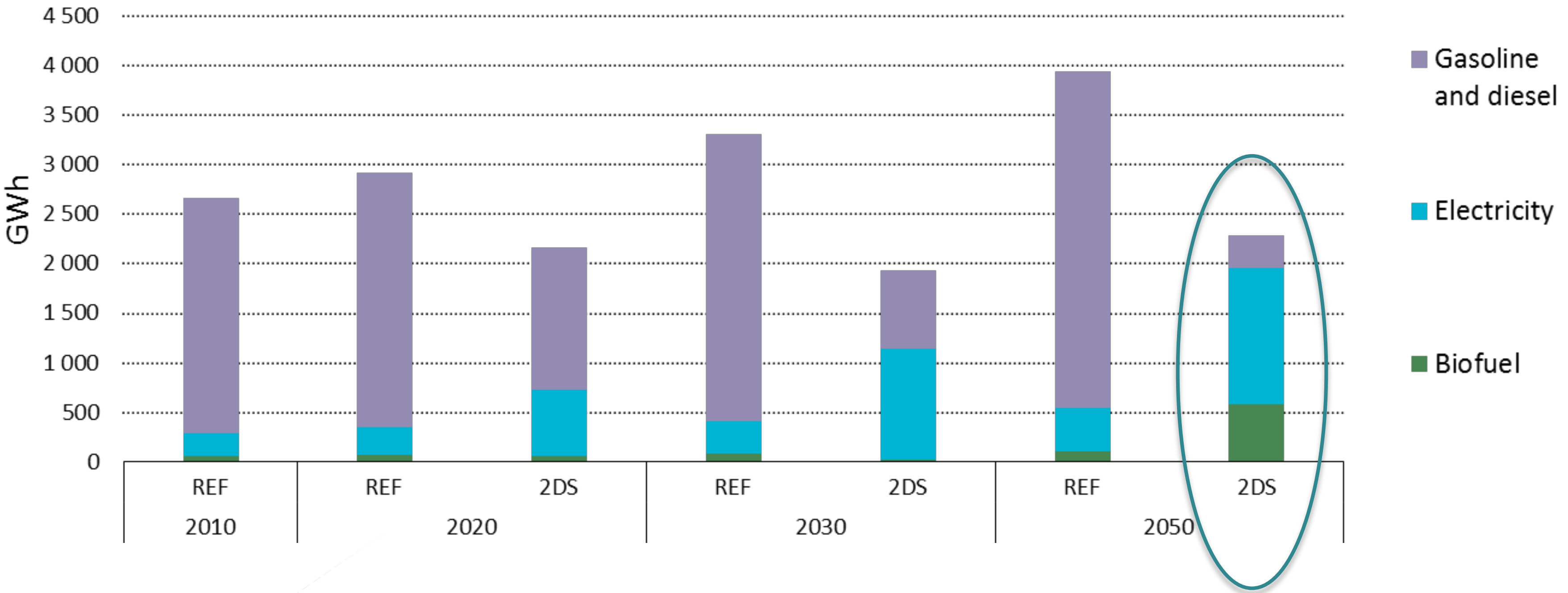
TIMES-Norway

- Norway is divided into five regions and Sweden in 4 regions (electricity spot markets)
- 52 weeks/year, 5 time slices/week, a total of 260 time slices/year
- Time horizon 2015-2050
- Demand categories in each region:
  - Agriculture (3)
  - Commercial (21)
  - Industry (33 -36)
  - Residential (10)
  - Transport (8)
- Exchange of electricity between regions and neighbour countries
- Can be linked with a power market model (EMPS)



Use of transport fuels in REF and 2DS

One region of Norway



- Same demand for transport in both scenarios
- Electrification and bio fuels

Approaches

Use of LCA data in energy system models

1. Adding LCA-indicators to TIMES-Norway
   - The SuReTool project (EEA/NILS Science and Sustainability programme)
   - IMDEA & IFE (2014-2015)
   - *Integration of life-cycle indicators into energy optimisation models: the case study of power generation in Norway,* Journal of Cleaner Production, 2016

2. Adding CED (Cumulative Energy Demand) of electricity production technologies to TIMES-Norway

3. Adding GWP of technologies to TIMES-Norway

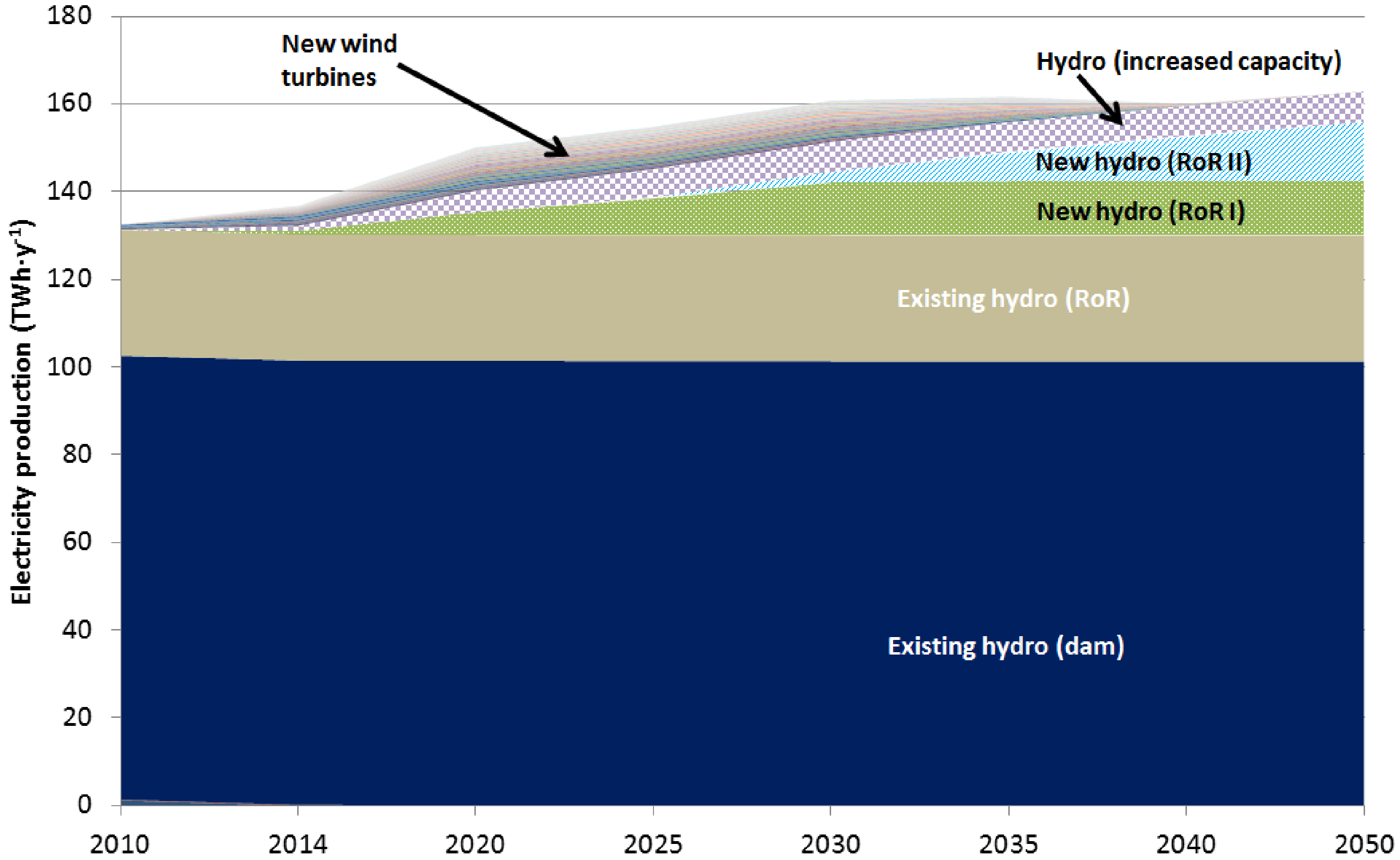
SuReTool: LCA-indicators in TIMES-Norway

LCA indicators added to TIMES-Norway as emission factors (FLO_EMIS)

I. Created new commodities to name these 4 indicators
   1. CLICH Climate Change, CC
   2. ECOSYS Ecosystems Quality, EQ
   3. HUHEA Human Health, HH
   4. RESOU Resources

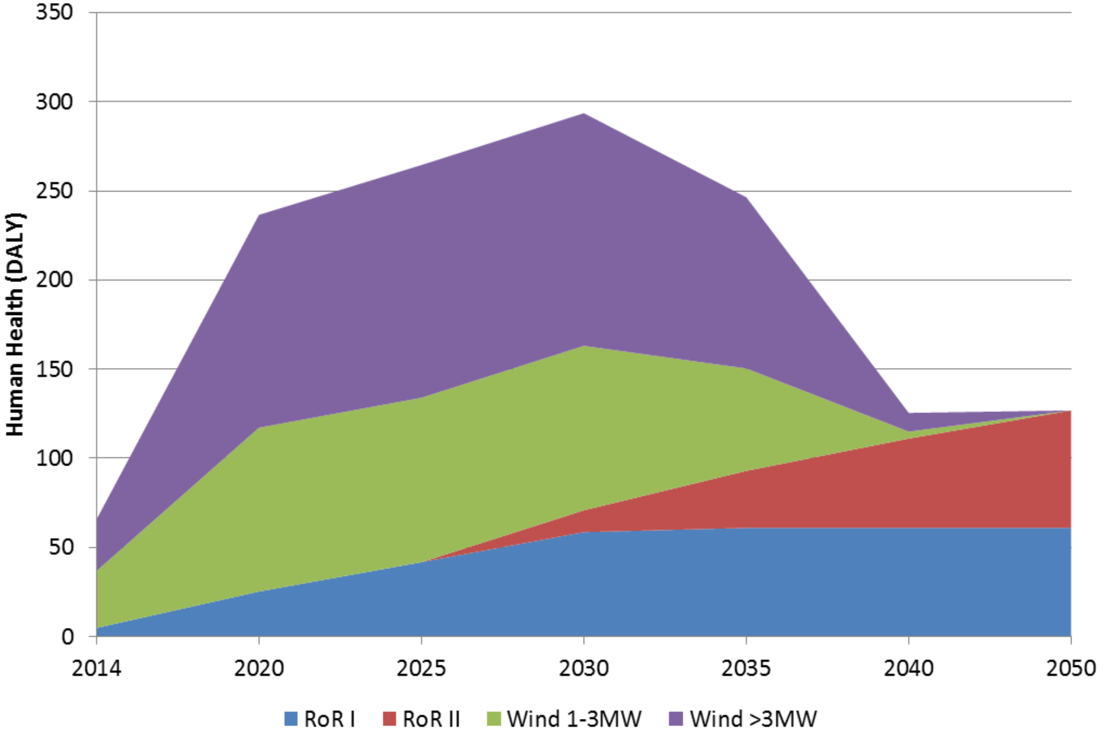
II. Allocated FLO_EMIS for those commodities in each of the new power technologies in TIMES-Norway
   - 6 hydro power technologies
   - 140 wind onshore technologies
   - 3 wind offshore technologies
   - 2 gas power technologies (NGCC)
   - 1 CHP technologies
   - Trade processes

Results from TIMES-Norway
Norwegian electricity production 2010-2050



Result from TIMES-Norway
Impact of LCA-indicators

- Similar impact of all LCA-indicators (human health, climate change, ecosystems quality and resources)



SuReTool: Experiences

- Impacts of total operating phase in TIMES-Norway – is this correct?
  - Often impacts are related to construction, not operation

- What new goal/optimization parameter should be used?
  - It is difficult to establish a goal in the long-term

- What technologies should include LCA burdens; the new ones only?

- Importance of system boundaries
  - Electricity import/export

Adding Cumulative Energy Demand from LCA into TIMES-Norway

- Brief literature survey of some interesting technologies in the Norwegian energy system:
  - PV multi-Si systems
    - 1.1 - 7 years energy payback time (EPBT)
    - 30 years lifetime
    - CED 4-23% of energy production
  - Offshore wind power
    - 1.6 - 2.7 years EPBT
    - 20 years lifetime
    - CED 8-13% of energy production

- H2 fueling station, electrolyser, wind power (one source, stand-alone)
    - CED 34.4 MJ / kg H2
    - CED 24% fueling station /kWh fuel

CED reflections

- High CED variation/uncertainty – what data should be used?
  - Technology origin often varying and unknown
  - Use local parameters for irradiance, wind full load hours etc.

- The impact of CED is expected to be reduced in future

- The uncertainty of the production technologies are large – sometimes overshadowing the CED value

- Energy used outside Norway interferes with the Norwegian energy balance – difficult to handle in a regional model

Adding Climate Change impacts (GWP)

Literature review:

- PV, multi-Si panels, roof or ground mounted
  - GWP 10-136 g CO_2-eqv./kWh (reviews)
  - Avoided CO_2-emissions 4-800 g CO_2-eqv./kWh (reviews)
  - Example: 100 g CO_2/kWh = 1 mill. ton CO_2/TWh
  - 1TWh PV = 2 % of total Norwegian CO_2 emissions
- Battery for BEV (one source)
  - «Leaf»-size car without battery 4-4.5 ton CO_2/car
  - 26.6 kWh battery («Leaf»-size) 4.6 ton CO_2 (170 g/kWh)
  - 2.6 million batteries = 0.8 mill ton CO_2/year
- H2 fueling station, electrolyzer, wind power
  - 1.92 kg CO_2/ kg H_2 (one source)
  - If all road freight transport use H_2, GWP of construction add 0.4 mill ton CO_2

GWP reflections

- High variation/uncertainty – what data should be used?
  - Technology origin often varying and unknown
  - Use local parameters for irradiation, wind full load hours etc.
- The impact expected to be reduced in future
- Which electricity mix should be used?
- May give additional information on national climate studies by taking into consideration emission from the construction phase
  - But national climate agreements do not include emissions from construction or decommissioning

Conclusions

- It is difficult to find an optimization parameter for the LCA-parameters
- Problem with national energy balances in a life cycle perspective
- TIMES-Norway
  - It is not so interesting to include LCA-indicators of renewable energy technologies due to the high share of hydro power in the present system
  - Transport technologies will be further analyzed
- We will continue to learn and test how we can use LCA to enrich our energy system analysis
- NEEDS?