Analyzing low emissions policy scenarios in an European context:

A contribution to the LinkS project

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CenSES

Annual Conference, November 29–30, 2012

Outline

1. Part I – Asgeir
   - Introduction to the LinkS project
   - The global climate assessment model (GCAM)
   - Motivation for regional study
   - Power system investment model

2. Part II – Christian
   - Analysis of the 650 ppm scenario
   - Analysis of the 450 ppm scenario
   - Conclusion and remarks about the policy study
   - Future work

What is LinkS?

The LinkS project

- Working (mainly) with long term sustainable energy system development
- Multi-disciplinary (and integrated) research group
  - Integrated assessment modeling
  - Power market modeling
  - Gas market modeling
  - Regional energy system modeling
  - Scenario analysis
  - Policy analysis
- Global and regional perspective

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Joint Global Change Research Institute (JGCRI)

Pacific Northwest NATIONAL LABORATORY

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SINTEF Group

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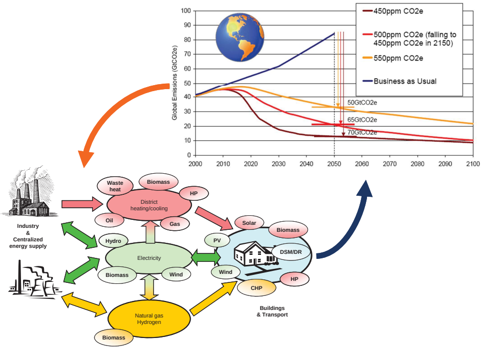
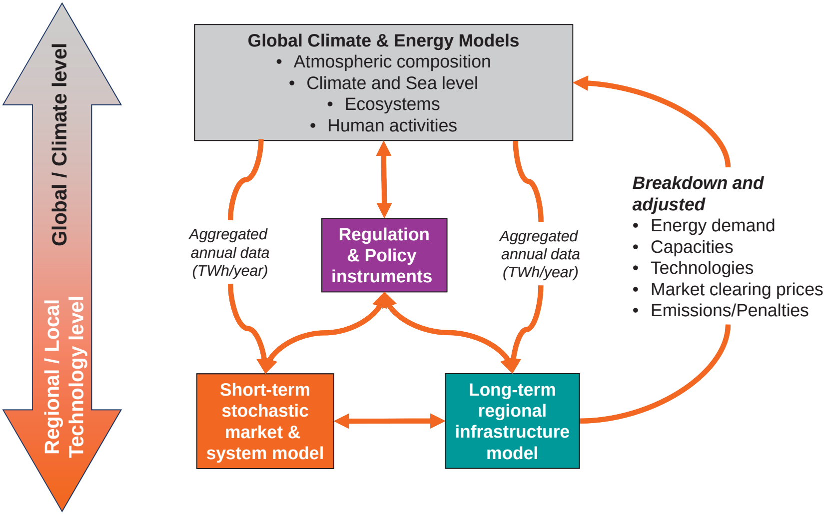
Understanding regional impacts of climate targets



- Analyze optimal development of the European power system given global GHG emission mitigating strategies.
- Linking of a global top-down energy/climate model and a regional power system model.
- Address the feasibility of long-term climate stabilization strategies.

Interaction between research tasks



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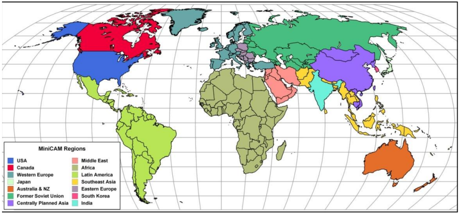
Global Climate Assessment Model (GCAM) – I

An integrated assessment model developed at The Joint Global Change Research Institute in Maryland.

- Dynamic recursive partial equilibrium model.
- Comprises an economic module, an energy system module, an agricultural and land use module and a climate effects module.
- Essentially models interlinked regional markets and finds an equilibrium solution by adjusting prices.
- World is modeled as 14 regions and annual demand and supply of energy available in 5 year time steps. Horizon is until 2100.



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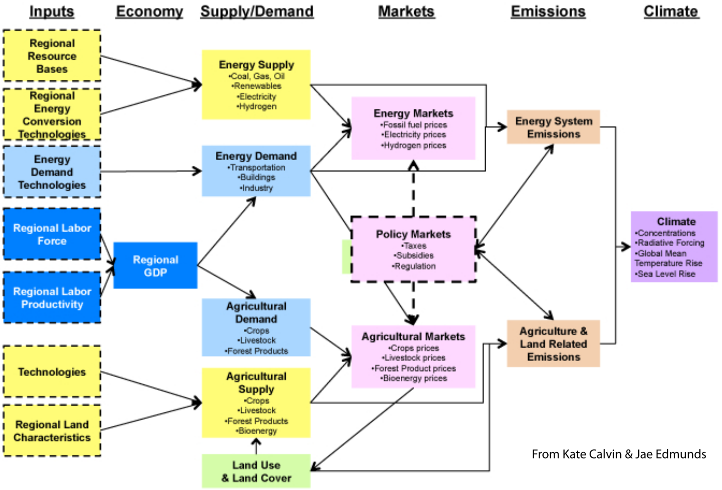
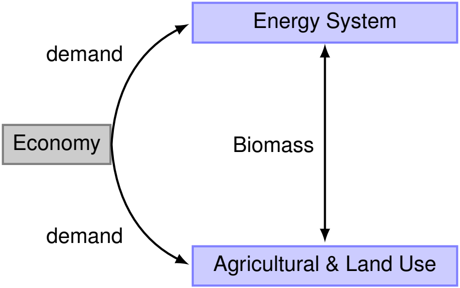
Global Climate Assessment Model (GCAM) – II



From Kate Calvin & Jae Edmunds

Global Climate Assessment Model (GCAM) – III



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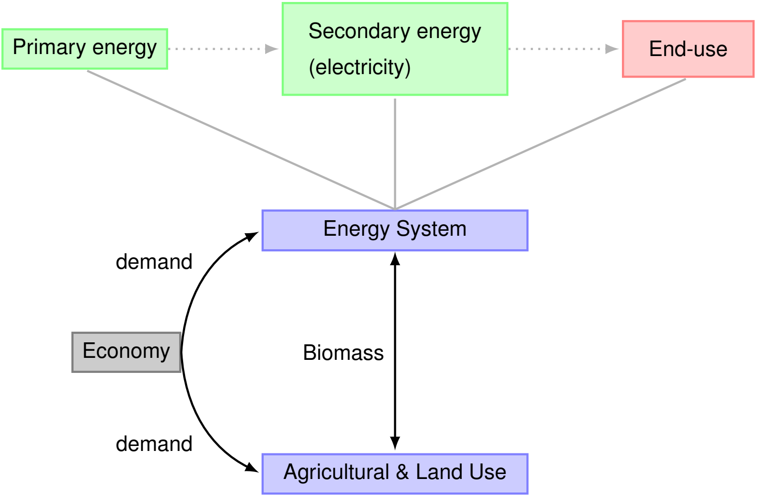
Global Climate Assessment Model (GCAM) – III



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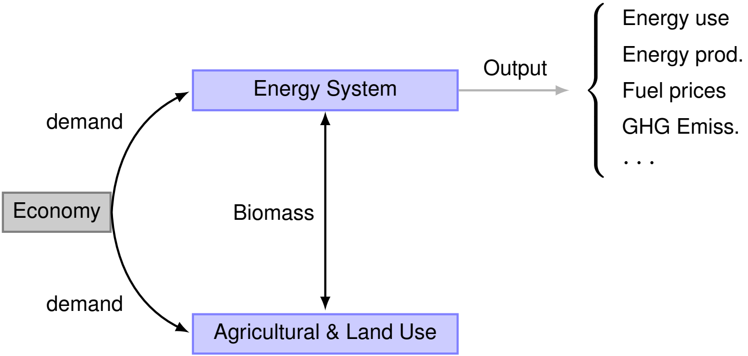

Why more detail? (I)

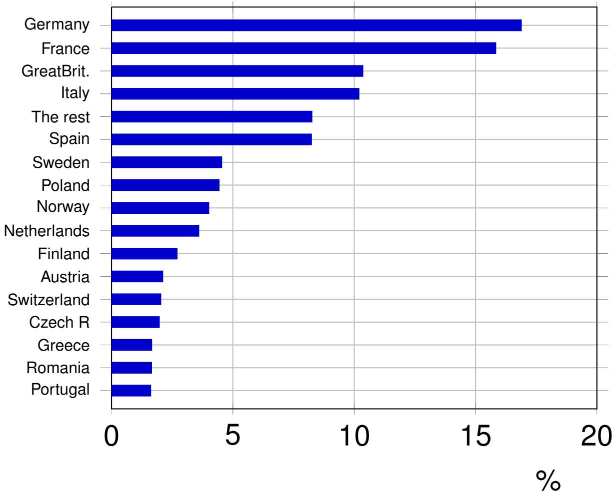

Figure : Share of total demand for electricity European countries (WE+EE) 2010 (Source: ENTSO-E)

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Why more detail? (II)

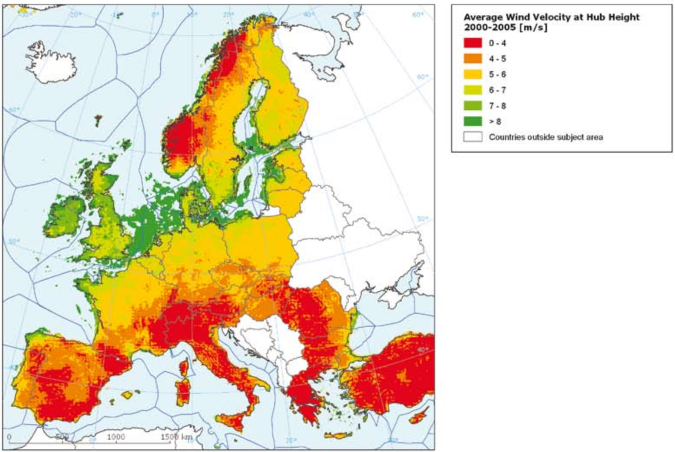

Figure : ECMFW wind field data for Europe (source: European Environment Agency)

Why more detail? (III)

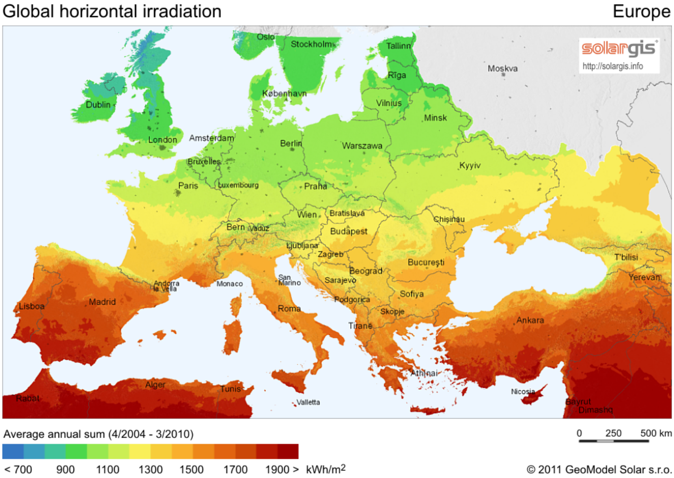

Figure : Average solar irradiation in Continental Europe (source: solargis)

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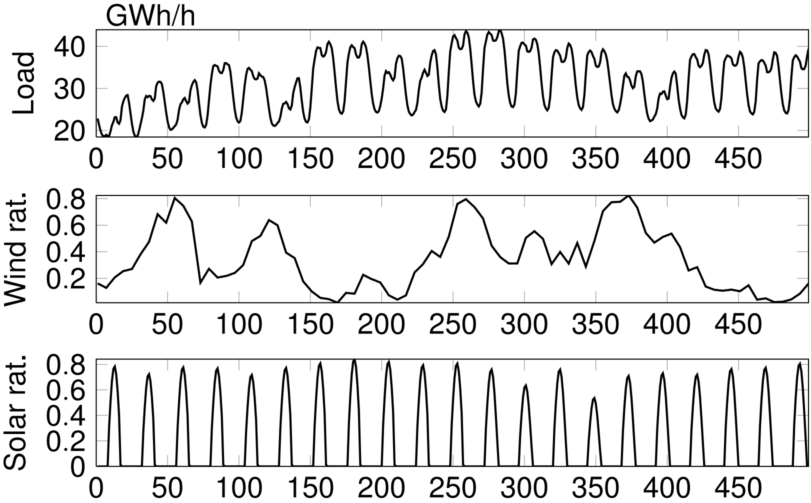
Load and intermittent resource availability in Spain



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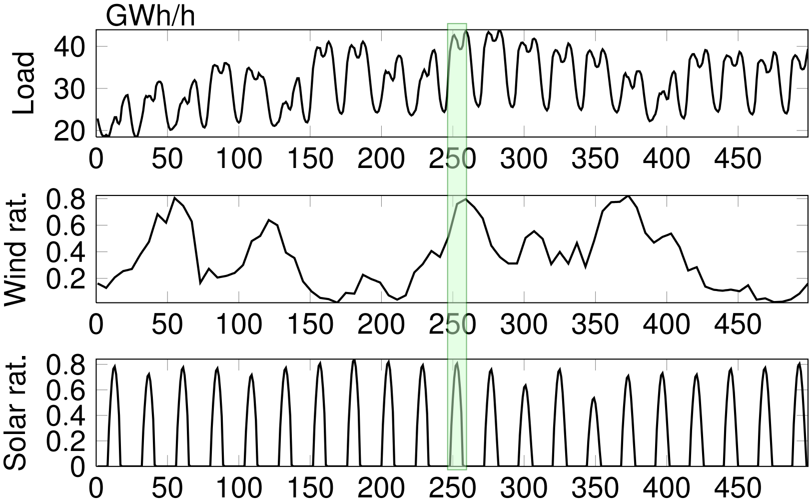

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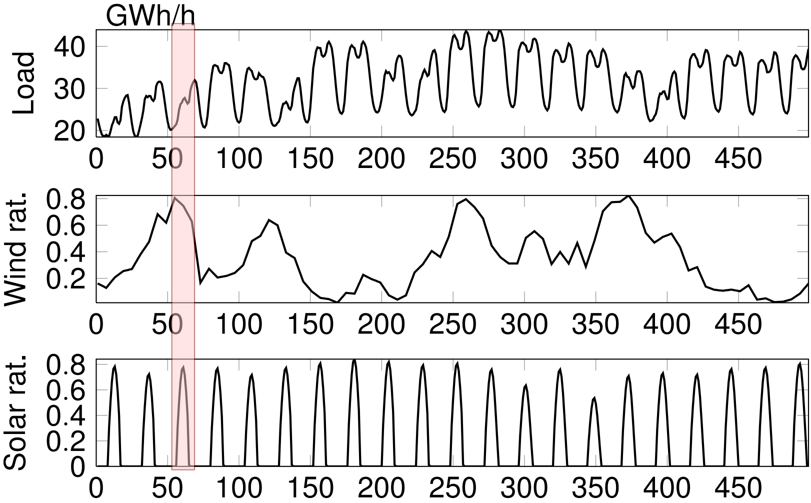

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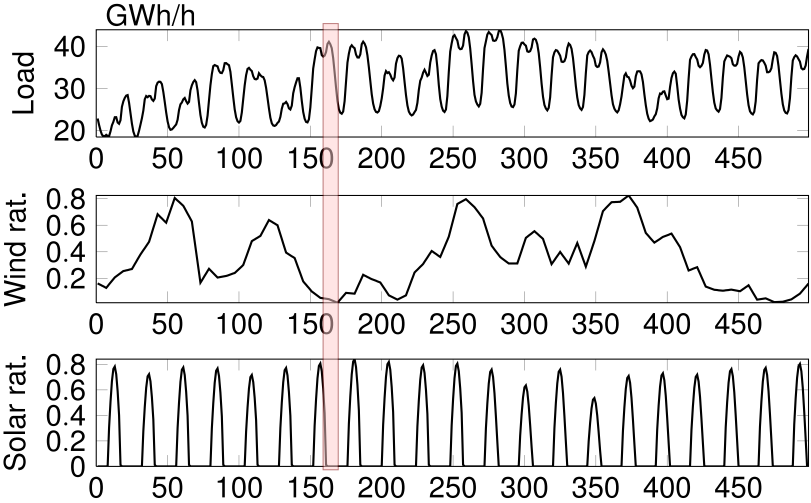

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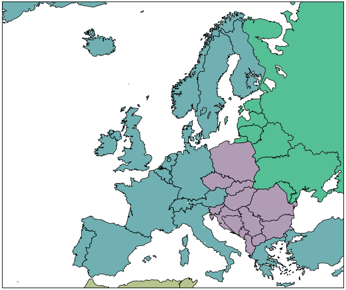
Interaction between models

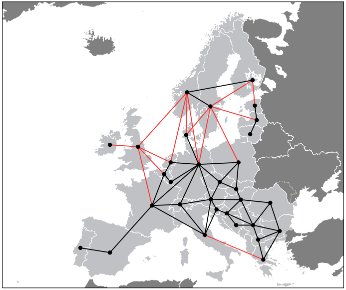
Global IAM



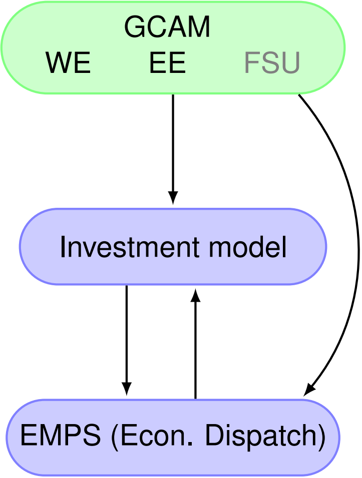
break down

Demand,
fuel prices,
CO_2 prices

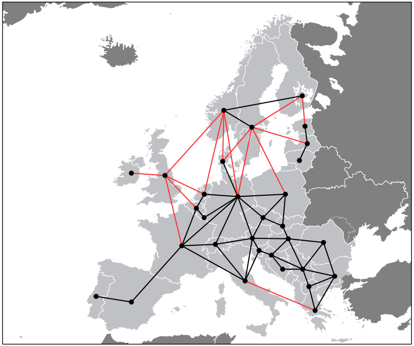
Power system model



We were picturing the following interaction between our models



Power system investment model – Modeling assumptions



- Investments are continuous
- Lines are independent (i.e. no Kirchoff's laws)
- Independent operational scenarios (e.g. no ramping, simplified storage)

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Structure of investment model

The investment model is a fairly standard two-stage stochastic model where

- Investments in generation capacity and transmission capacity are done in the first stage
- Uncertainty in availability of intermittent resources and in load are then revealed
- Second stage decisions, which are production levels, network flows and unserved energy, are then made *given* the investments.

Formulation of the investment model

The basic formulation of the two-stage stochastic model is:

- Minimize investment cost *and* expected operation costs
- Subject to:
  - Investment bounds (don't let the model go wild)
  - Max/min capacity requirements on generation within GCAM regions
  - Load constraints
  - Flow constraints (basically just upper/lower bounds on lines)
  - Production constraints

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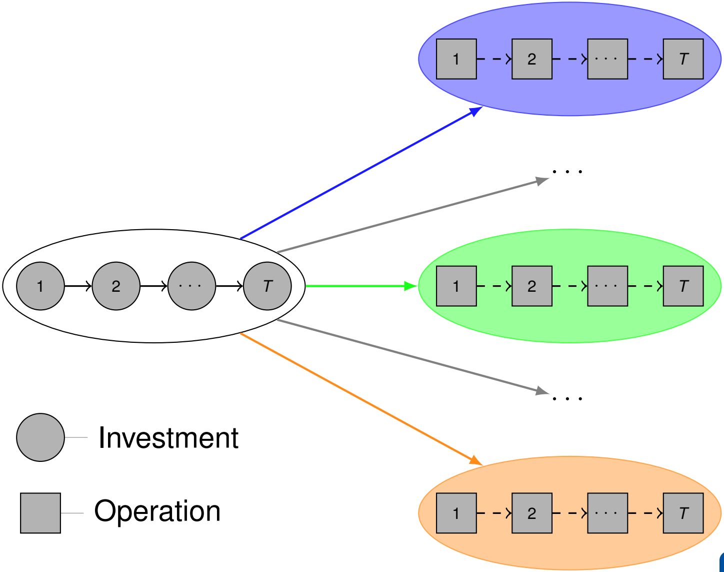
Scenario structure



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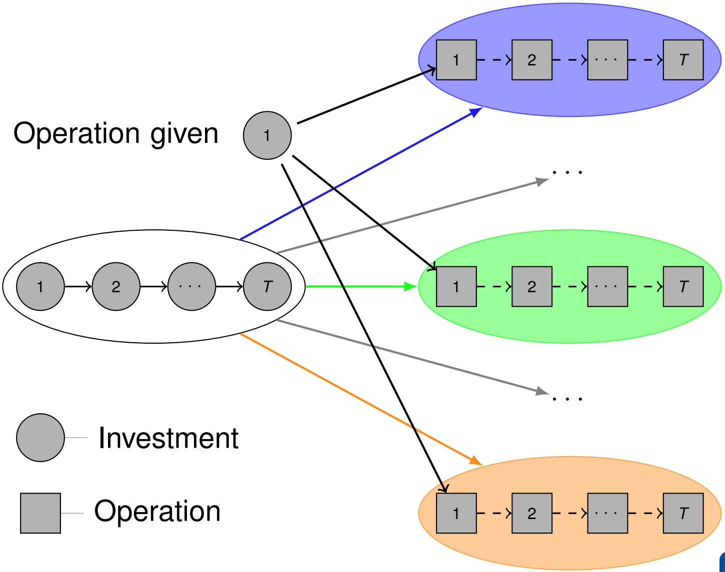

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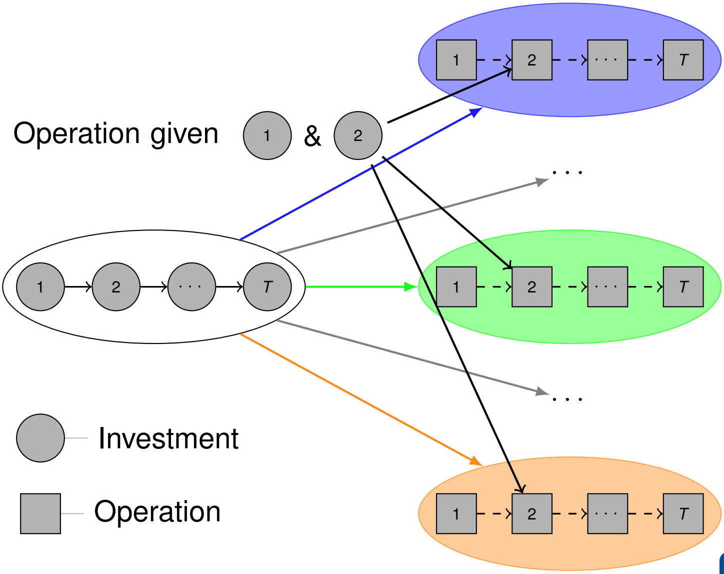

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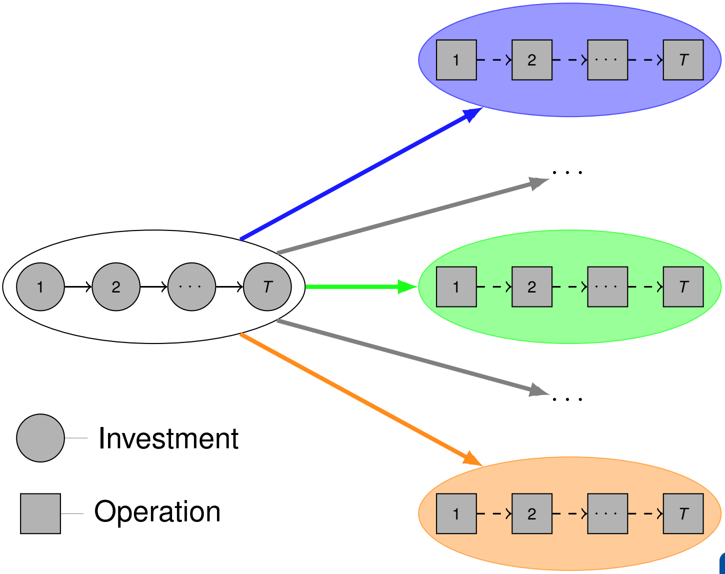
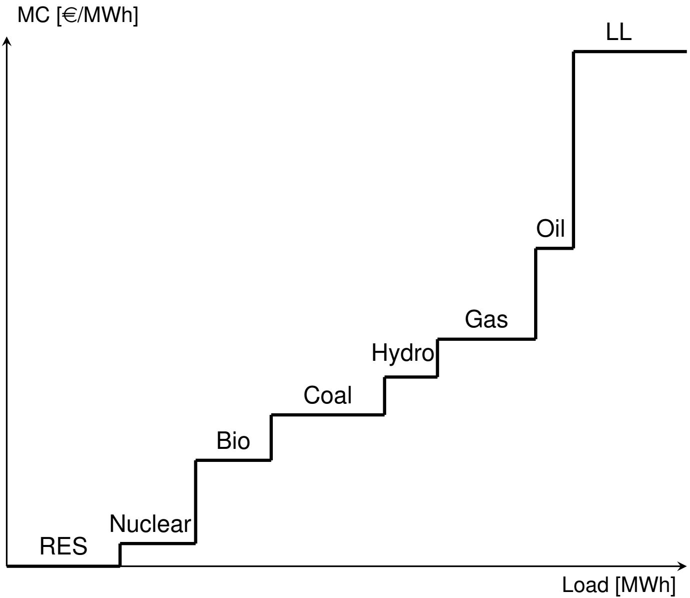


Second stage problem, node *n*, year *y*



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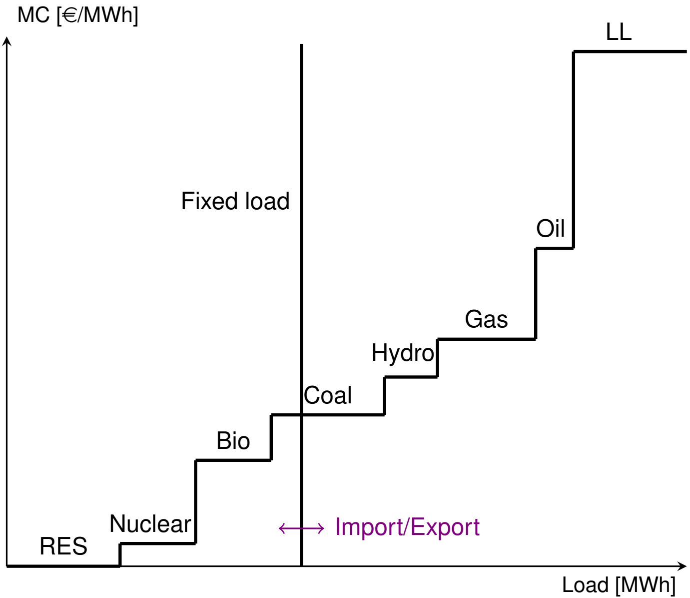

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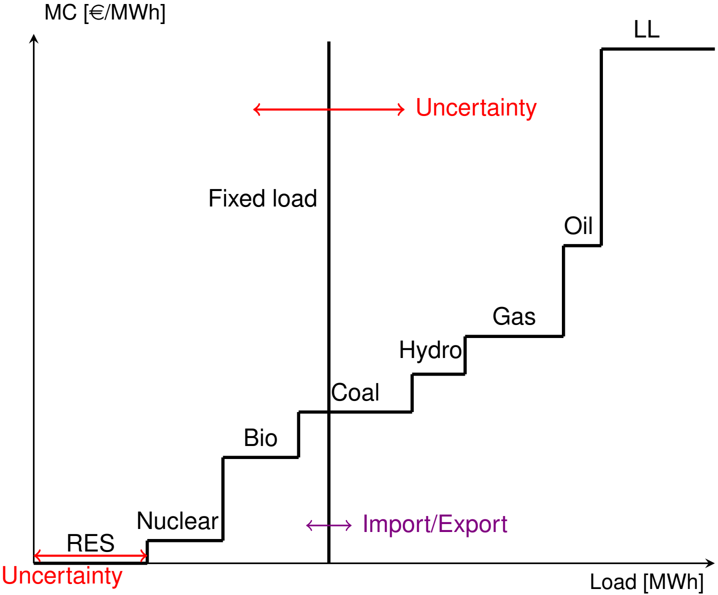

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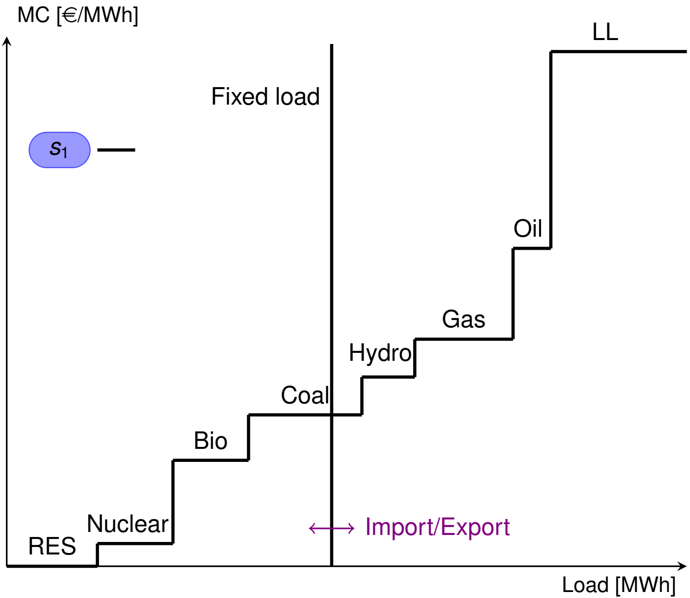

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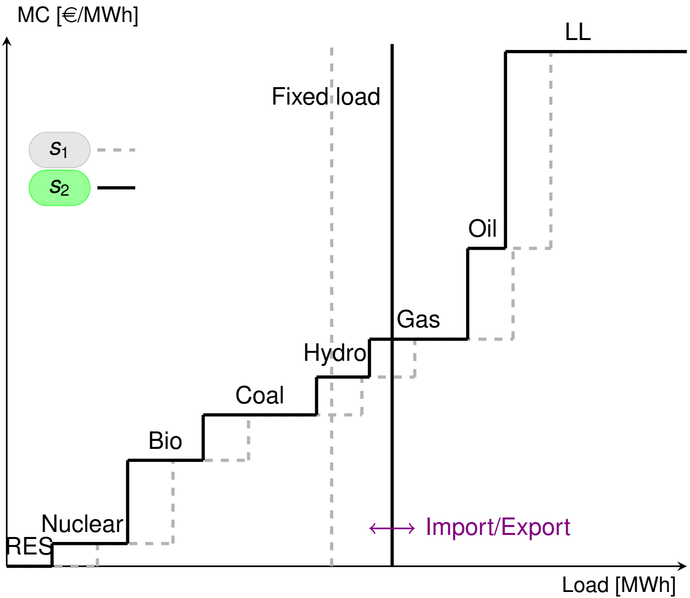

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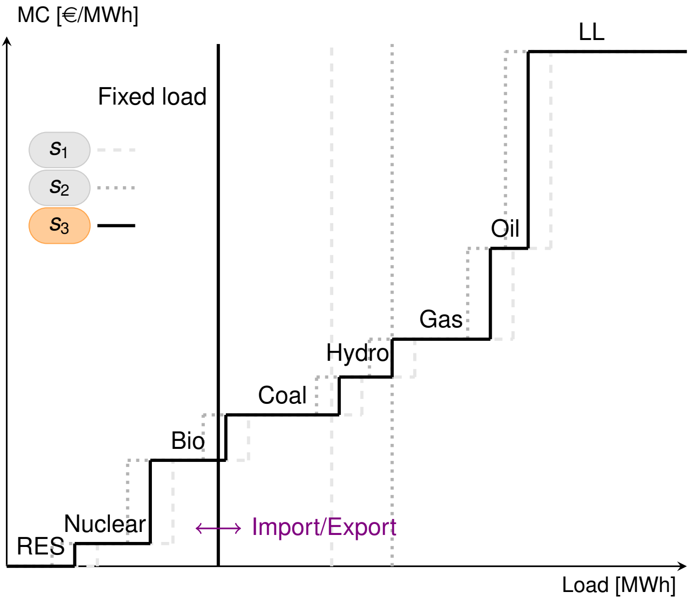

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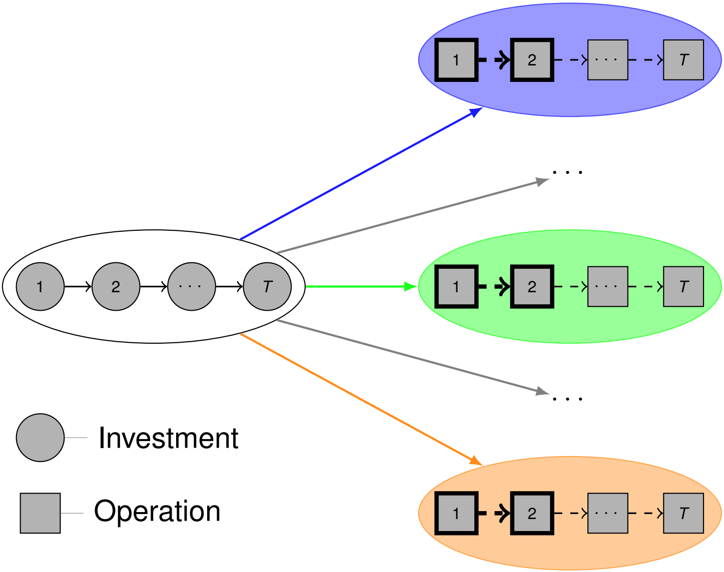

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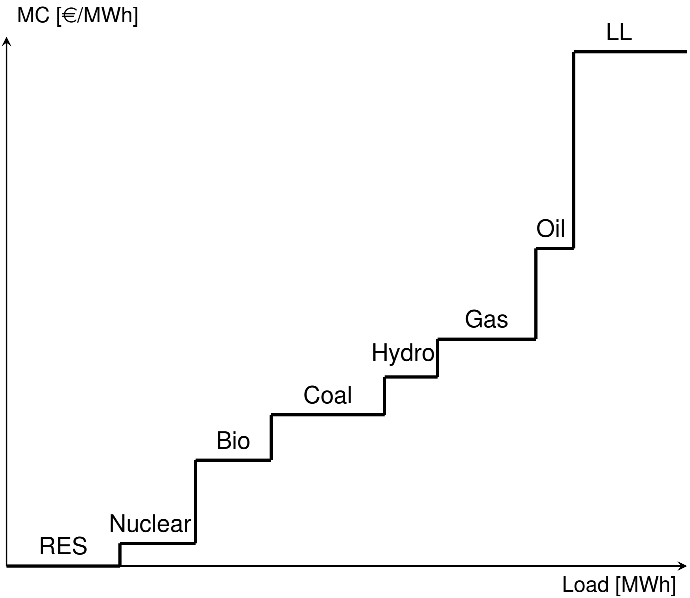
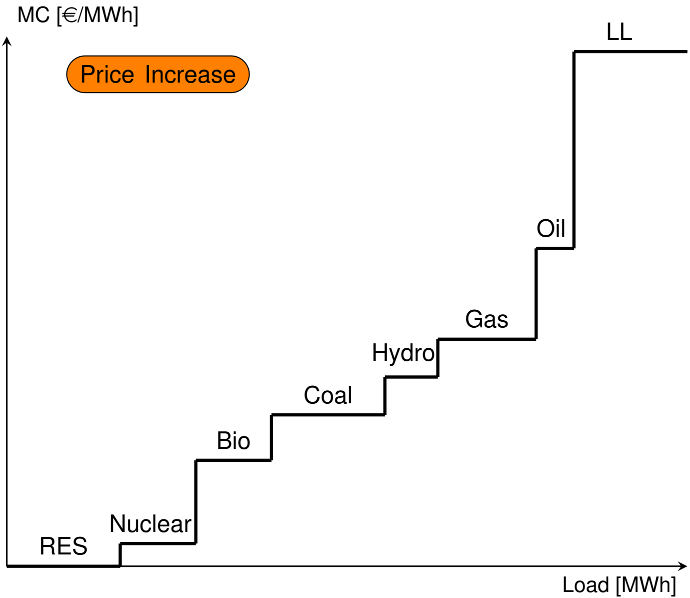
Second stage problem, node n, year $y + 1$



Second stage problem, node n, year $y + 1$



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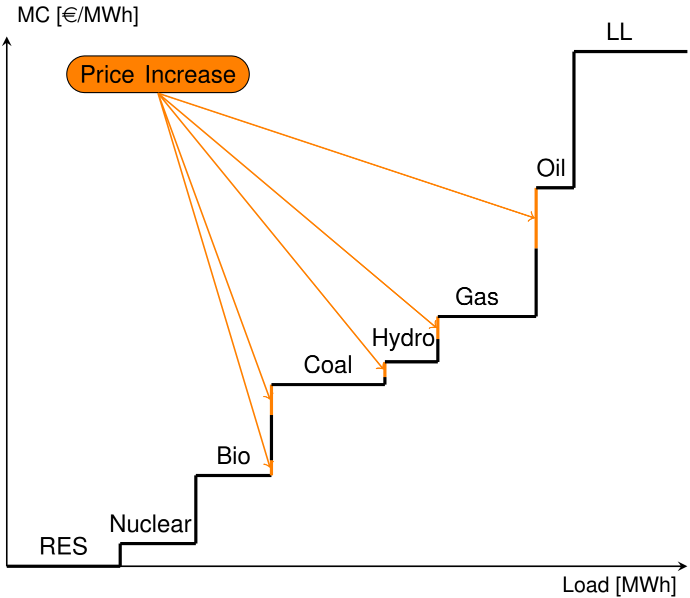

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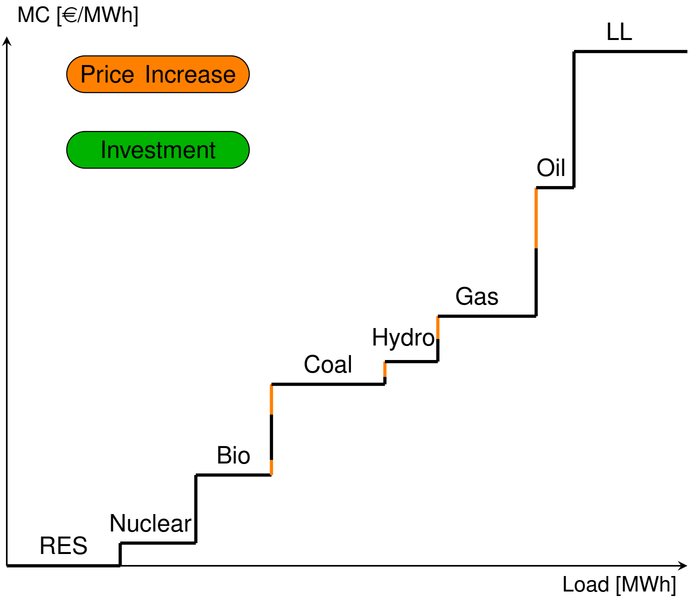

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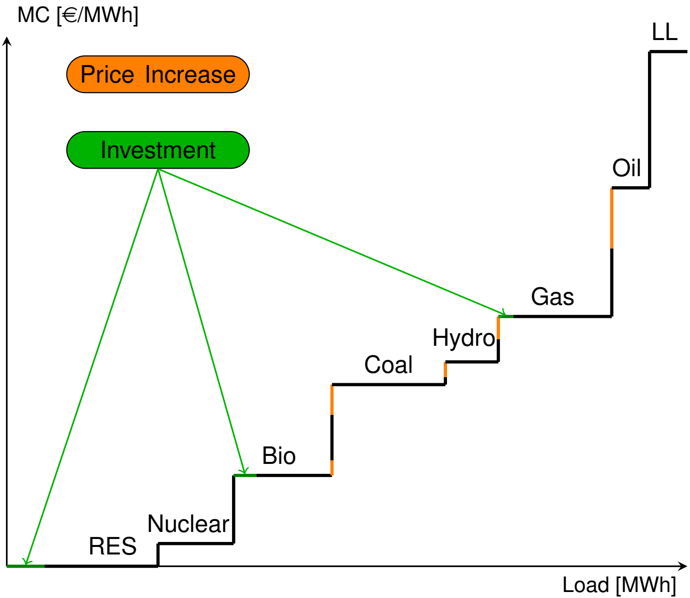

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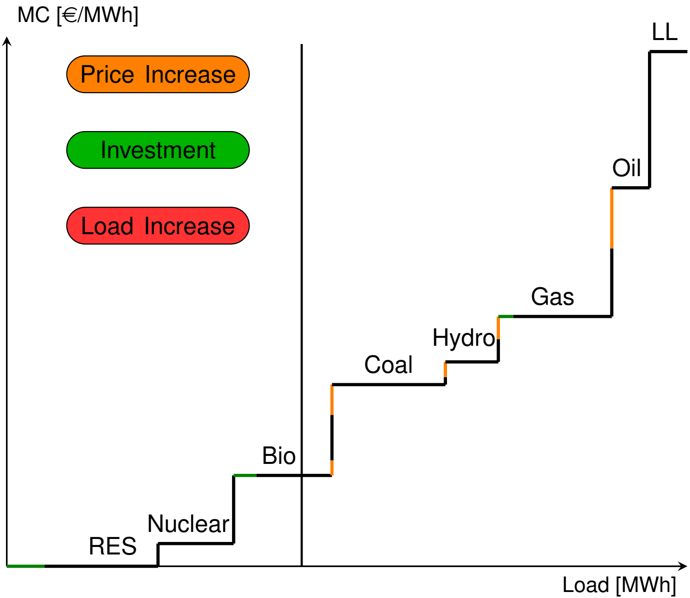

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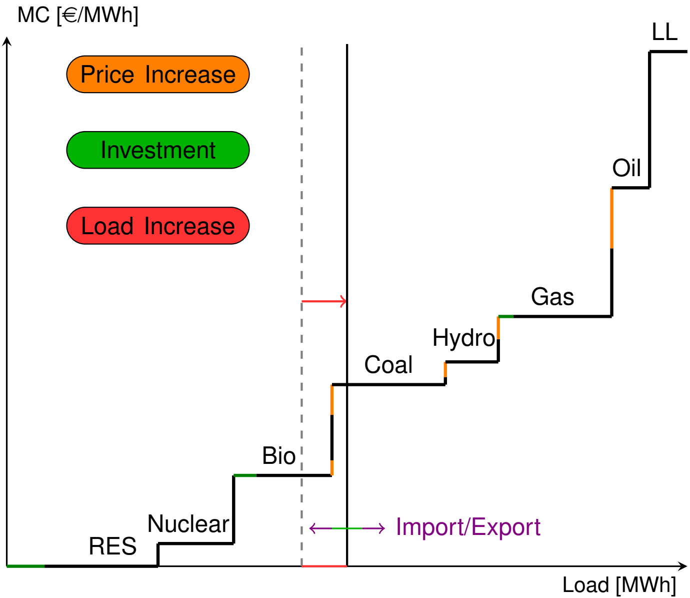

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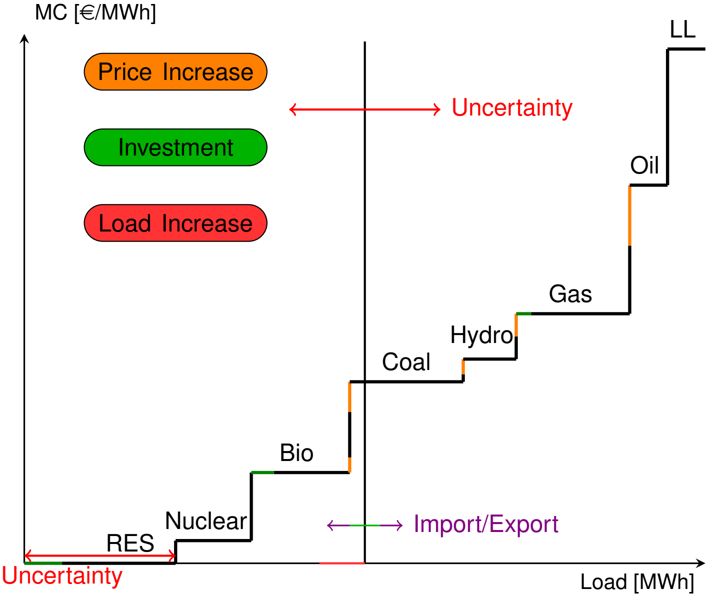

Outline

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650ppm stabilization scenario

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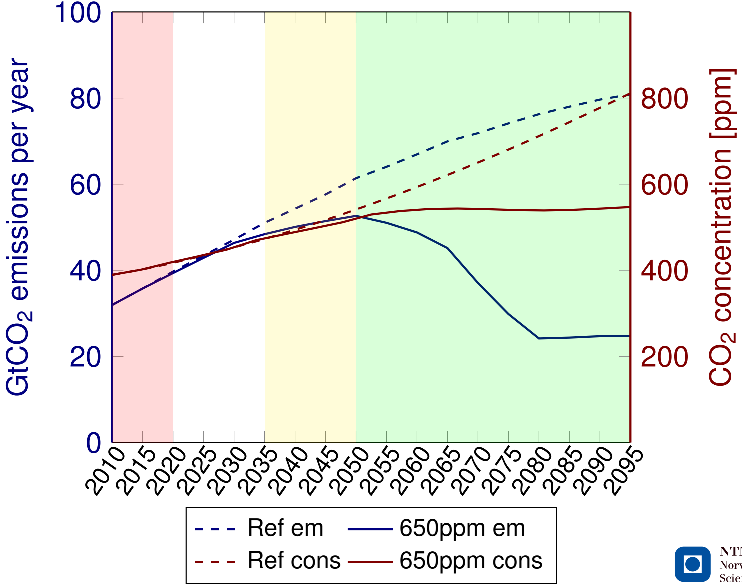
Global emissions and CO_2 concentration 650 ppm



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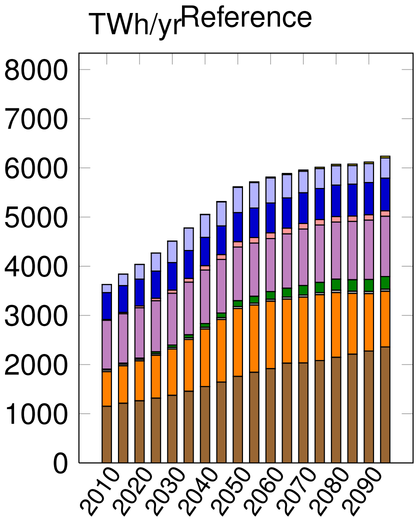
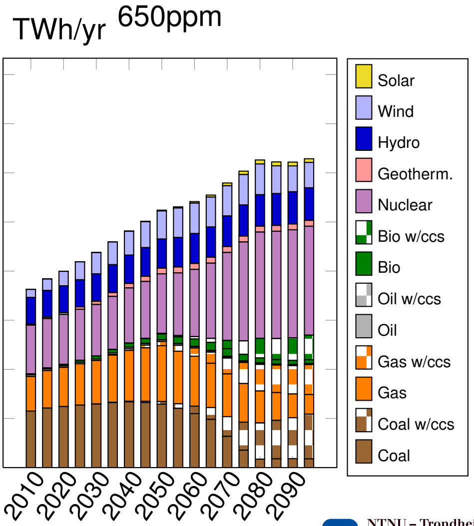
European electricity mix reference vs 650ppm





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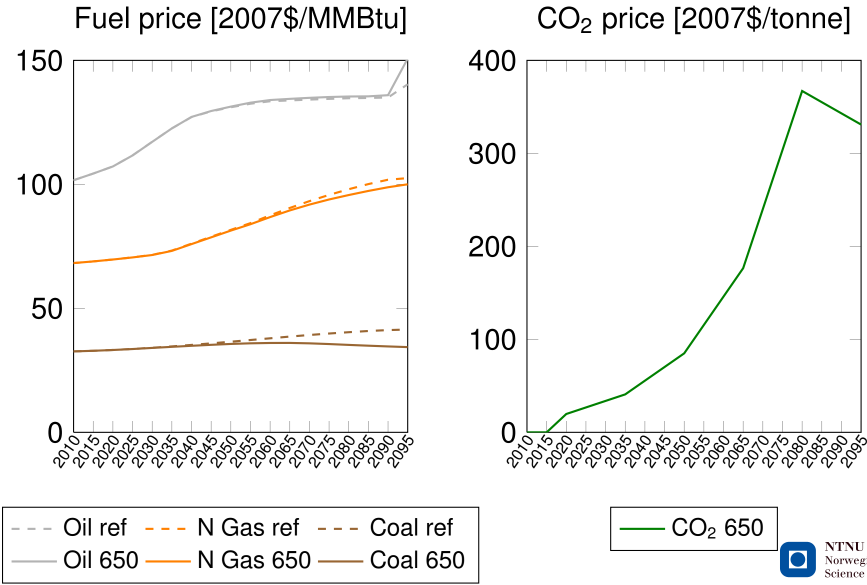
Fuel prices 650 ppm



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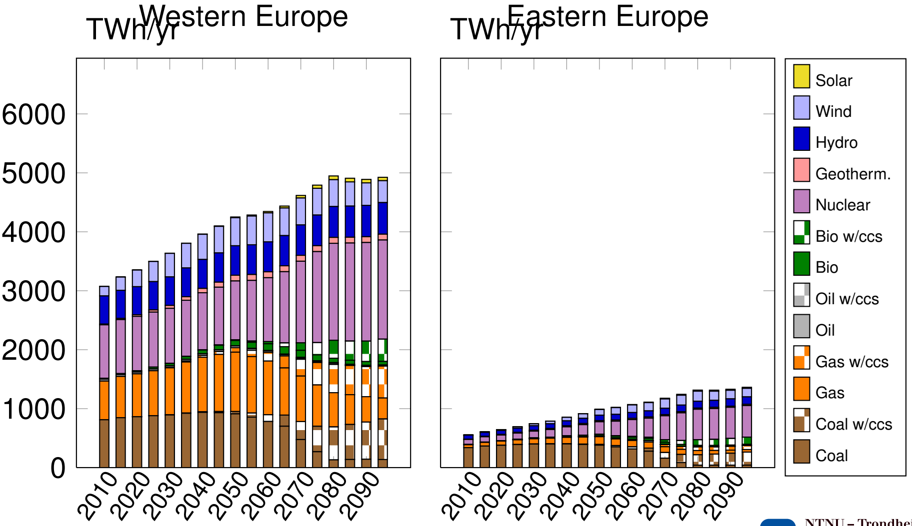
Regional European electricity mix 650ppm



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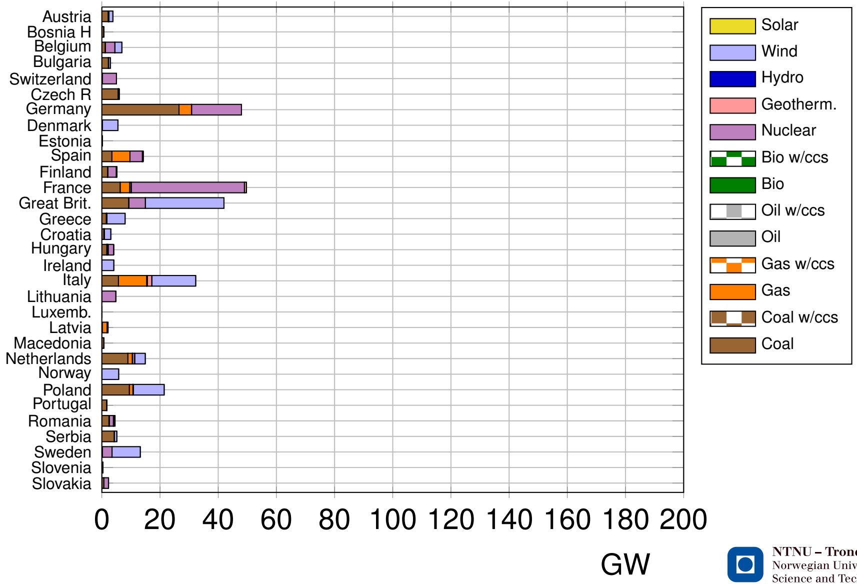
Cum. investments generation 2030, 650 ppm



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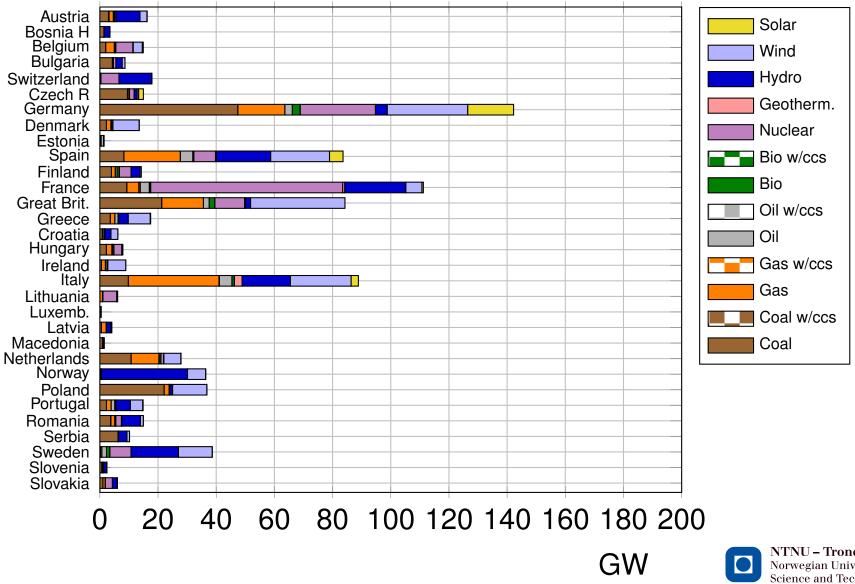
Total capacity 2030, 650 ppm



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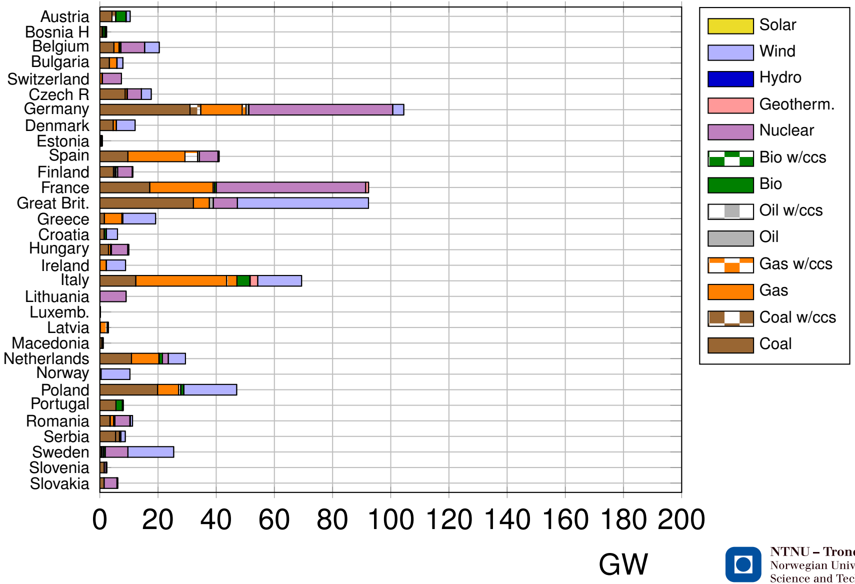
Cum. investments generation 2050, 650 ppm



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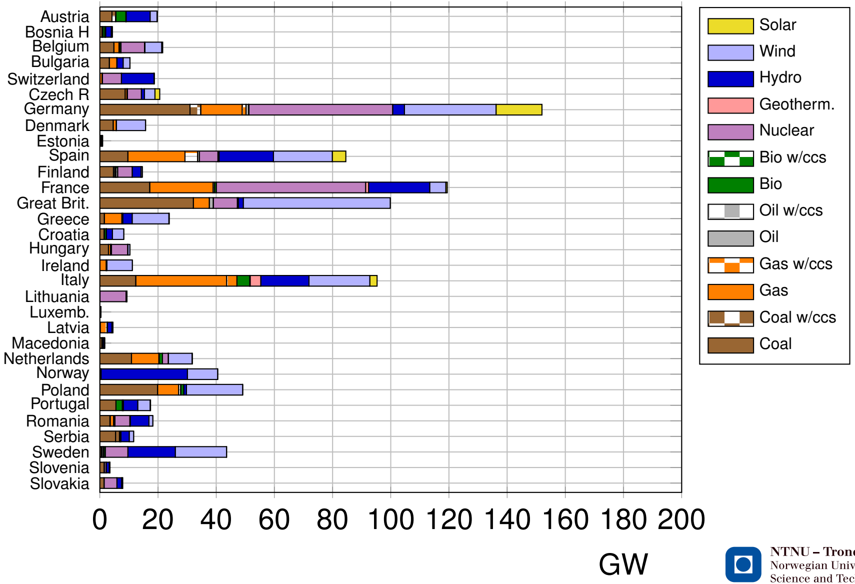
Total capacity 2050, 650 ppm



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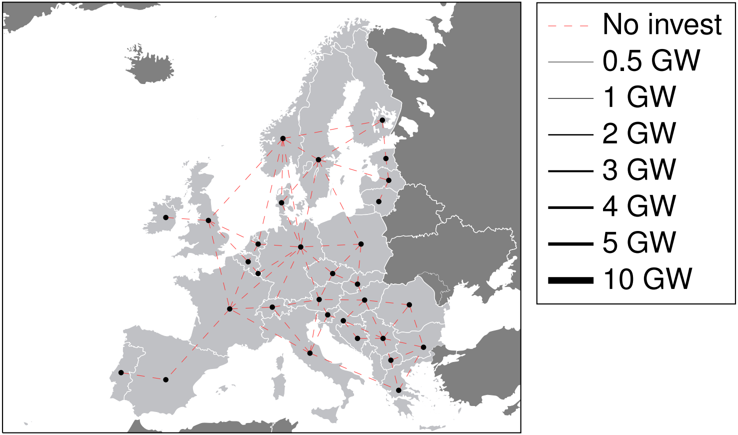
Investment options



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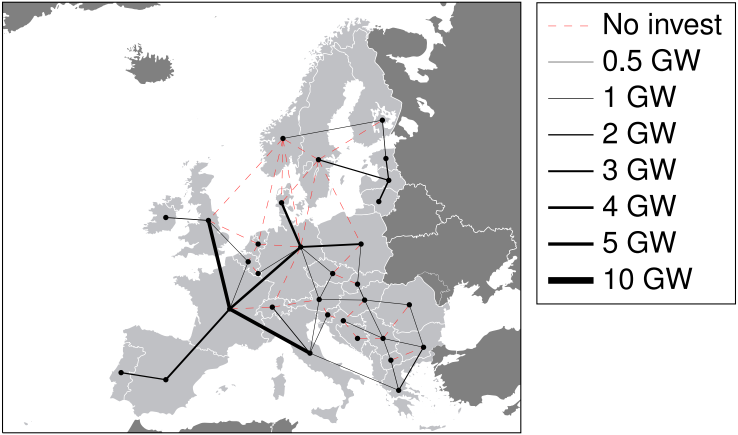
Cum. investments transmission 2030, 650 ppm



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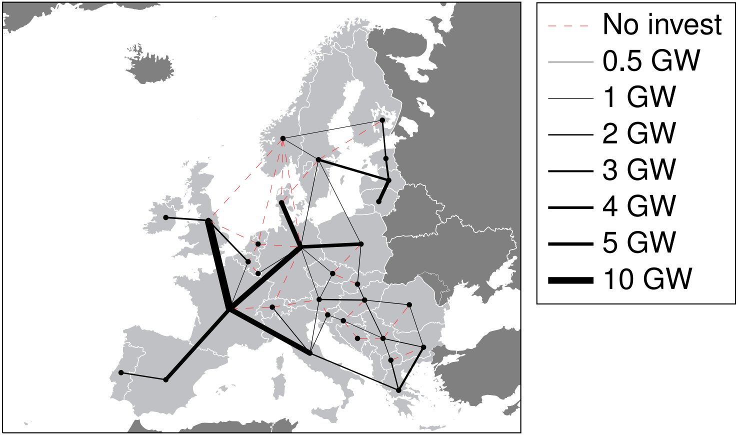
Cum. investments transmission 2050, 650 ppm



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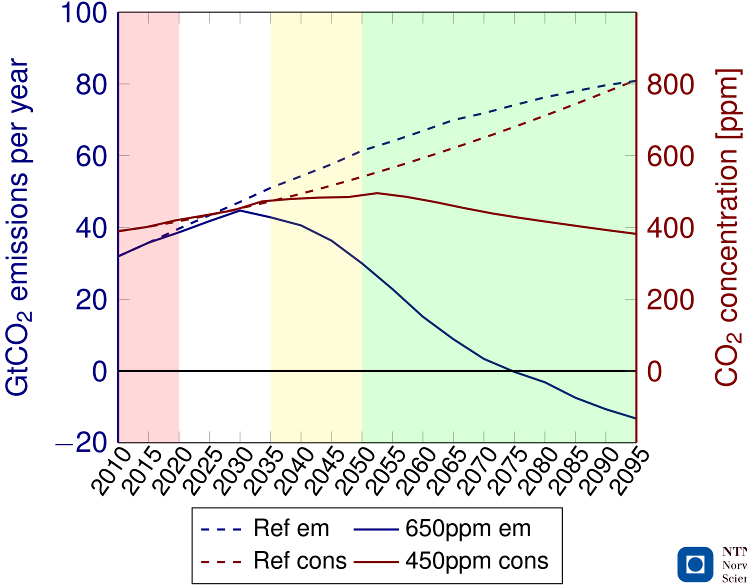
450ppm stabilization scenario

Global emissions and CO_2 concentration 450 ppm



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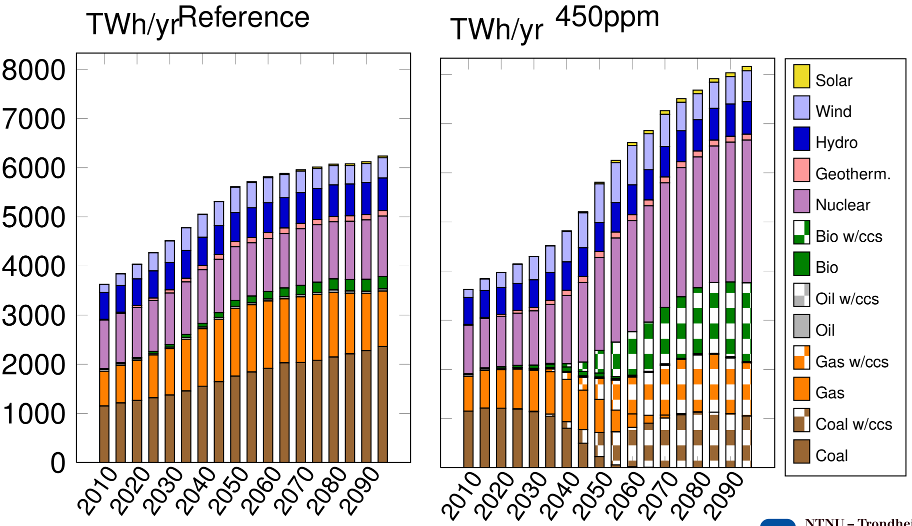
European electricity mix reference vs 450ppm



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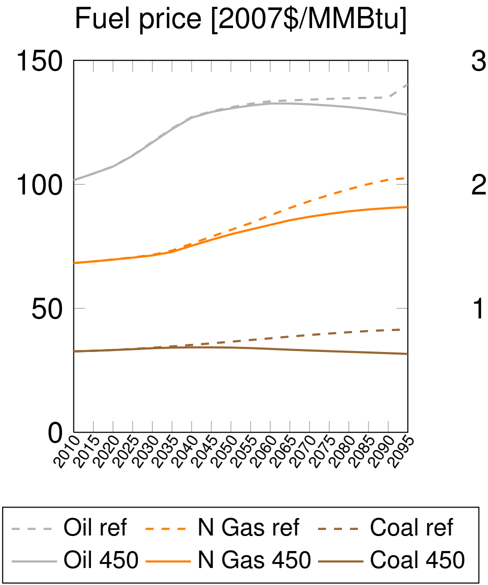
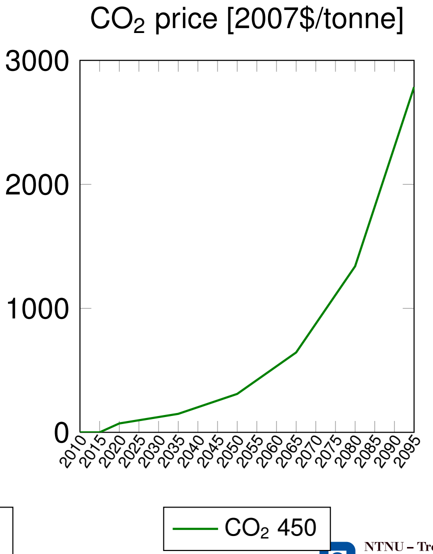
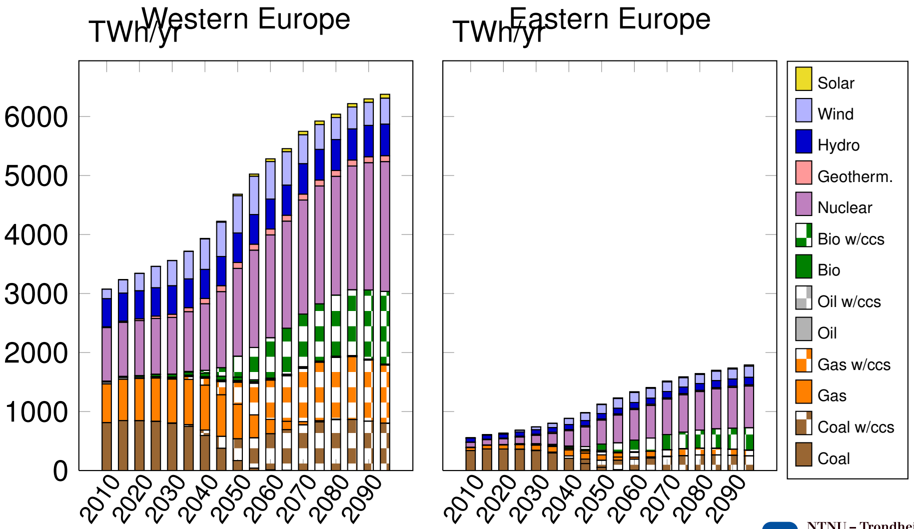
Fuel prices 450 ppm





Regional European electricity mix 450ppm



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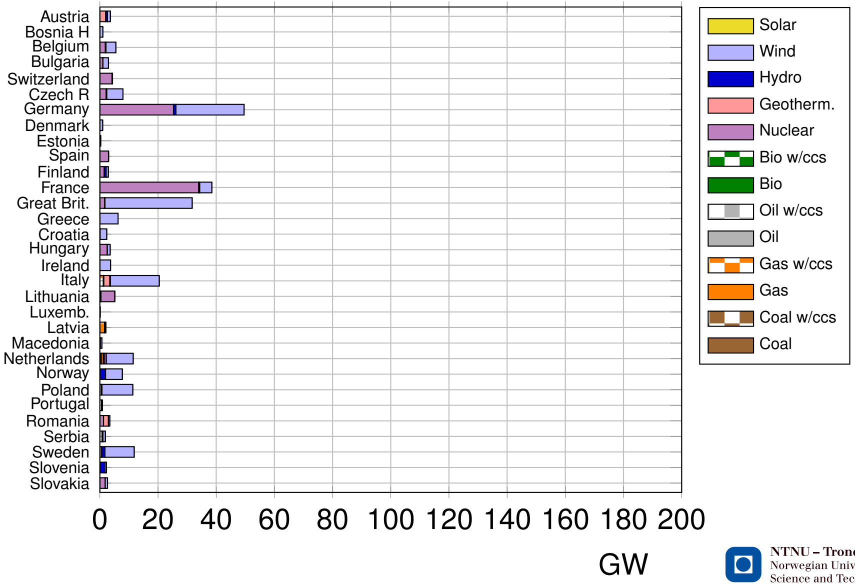
Cum. investments generation 2030, 450 ppm



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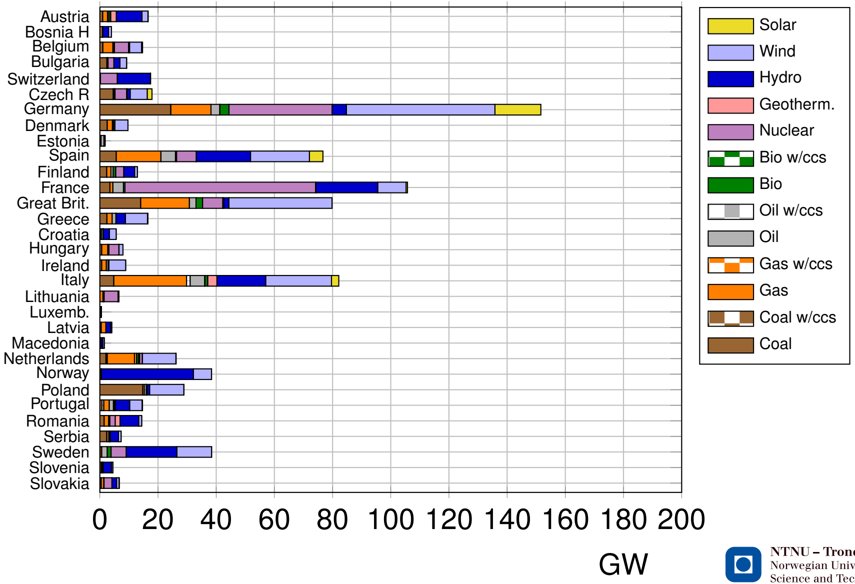
Total capacity 2030, 450 ppm



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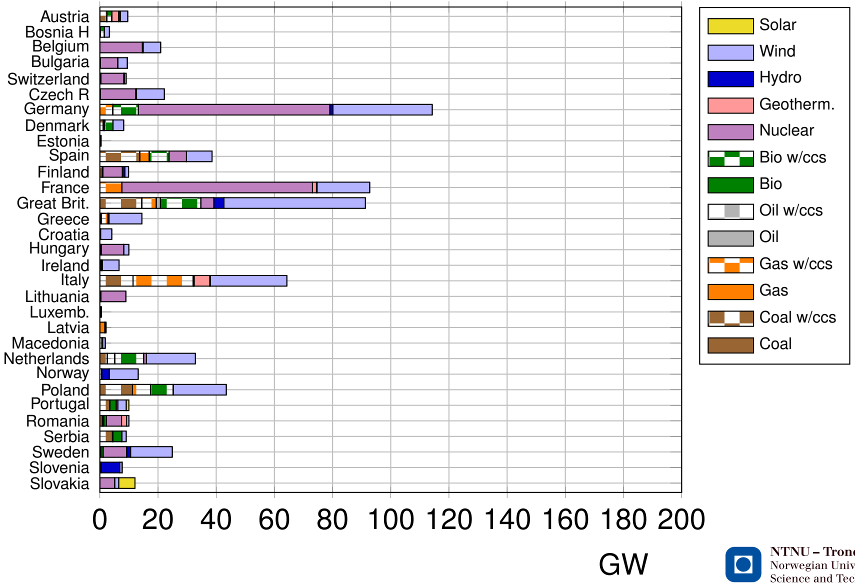
Cum. investments generation 2050, 450 ppm



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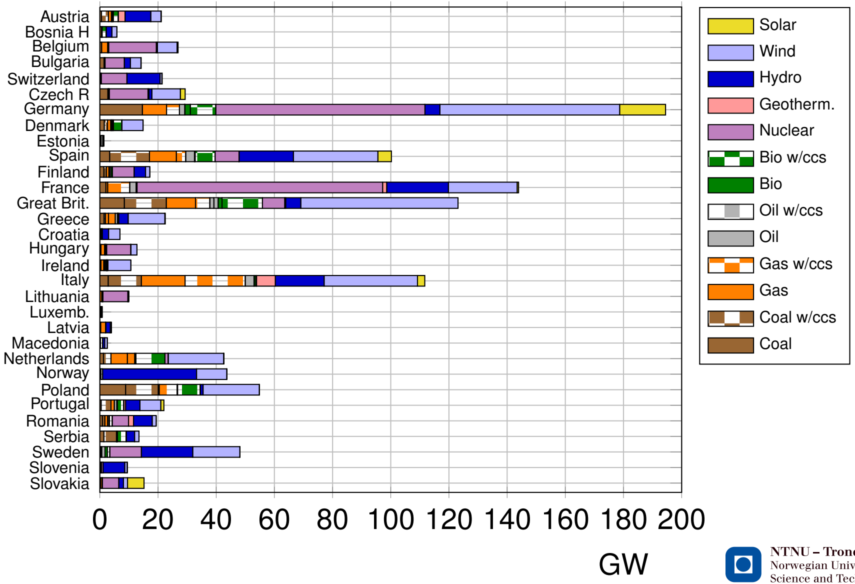
Total capacity 2050, 450 ppm



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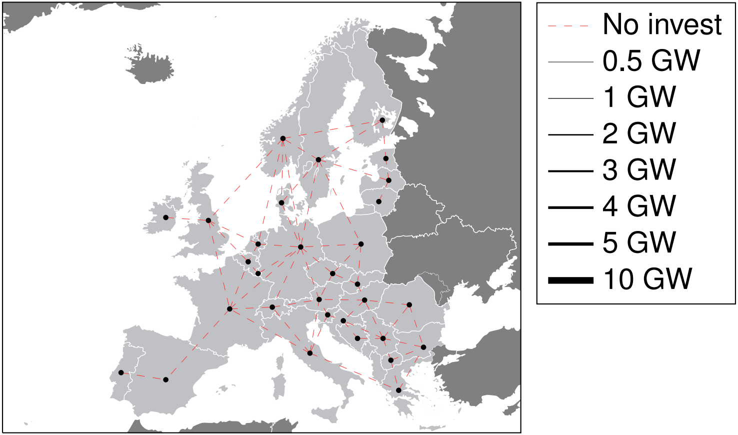
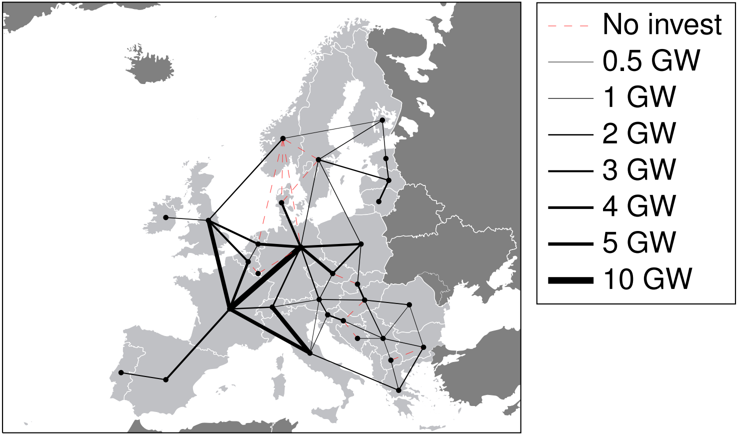
Investment options



Cum. investments transmission 2030, 450 ppm



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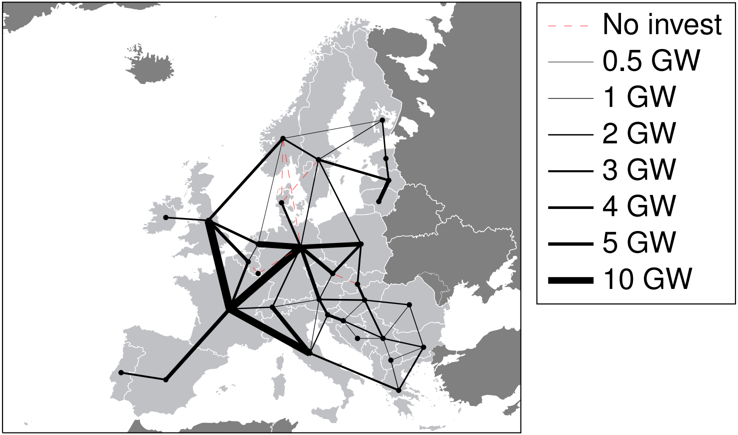
Cum. investments transmission 2050, 450 ppm



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Conclusion

- This approach provides additional information about effects of a climate policy on a regional power system
- The results can now be used to adjust GCAM scenarios
- Can be useful for policymakers on a national level
- The results indicate that an optimal expansion involves high investments in transmission to support balancing of supply and demand.

Further comments on operational modeling – Hydro power

- Including enough time steps to cover a full planning cycle for a big reservoir quickly makes the operational problem prohibitively large.
- One possible way to circumvent this is to construct scenarios for water values, that is, the alternative cost of the water in a reservoir.
- Water values can be used to represent different seasons in a year, but also different hydrological situations (dry year, wet year, normal year, etc)
- The plan is to use a specialized hydro power production model for making the water value scenarios.

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Possible future extensions of the model

- A network flow model
- Integer values in the investment stage
- Relaxing the constraint that the energy mix computed by capacity expansion model should match GCAM. The GCAM results can be used to generate scenarios for climate policy uncertainty.
- Develop a multi-stage model with strategic uncertainty.

Thank you for your attention

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