Global-IQ work @ PIK

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Overview

- **Model development with MAgPIE**
- **The MAgPIE-Remind system (damages, coupling wrt bioenergy)**
- **Model development with Remind-R**

Model facts

- **MAgPIE – Model of Agricultural Production and its Impacts on the Environment**

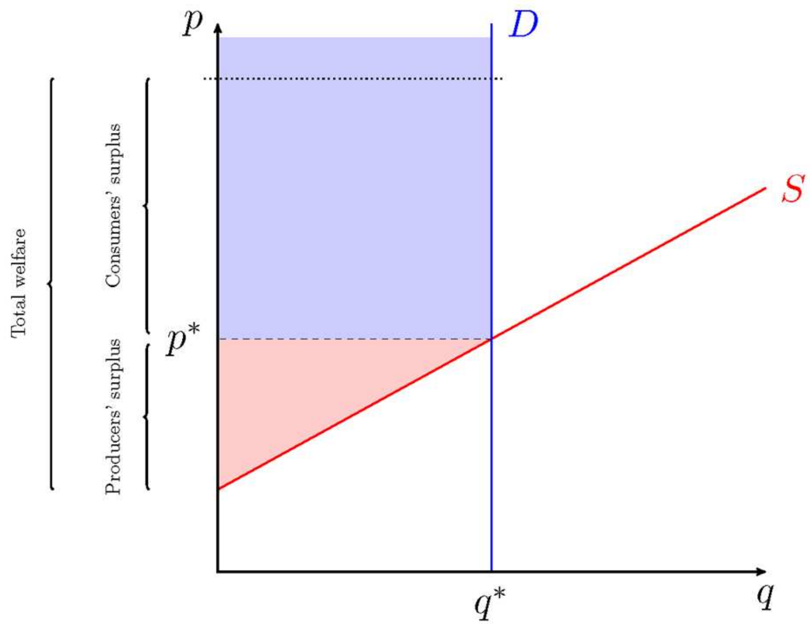
- **Recursive dynamic, non-linear mathematical programming landuse allocation model**
- **Objective function - minimize total cost of agricultural production**
- **Time horizon – from 1995 to 2095 in 10 years time period**
- **Spatial resolution:**
  - **geographic grid of 0.5° x0.5° → 100 – 2000 clusters → 10 economic world regions**

Features

- 16 cropping and 5 livestock activities.
- Bioenergy crops (1st and 2nd generation)
- Food & bioenergy demand
- Water- and landuse patterns
- Endogenous technological change.
- GHG emissions (CO_2, CH_4, N_2O)

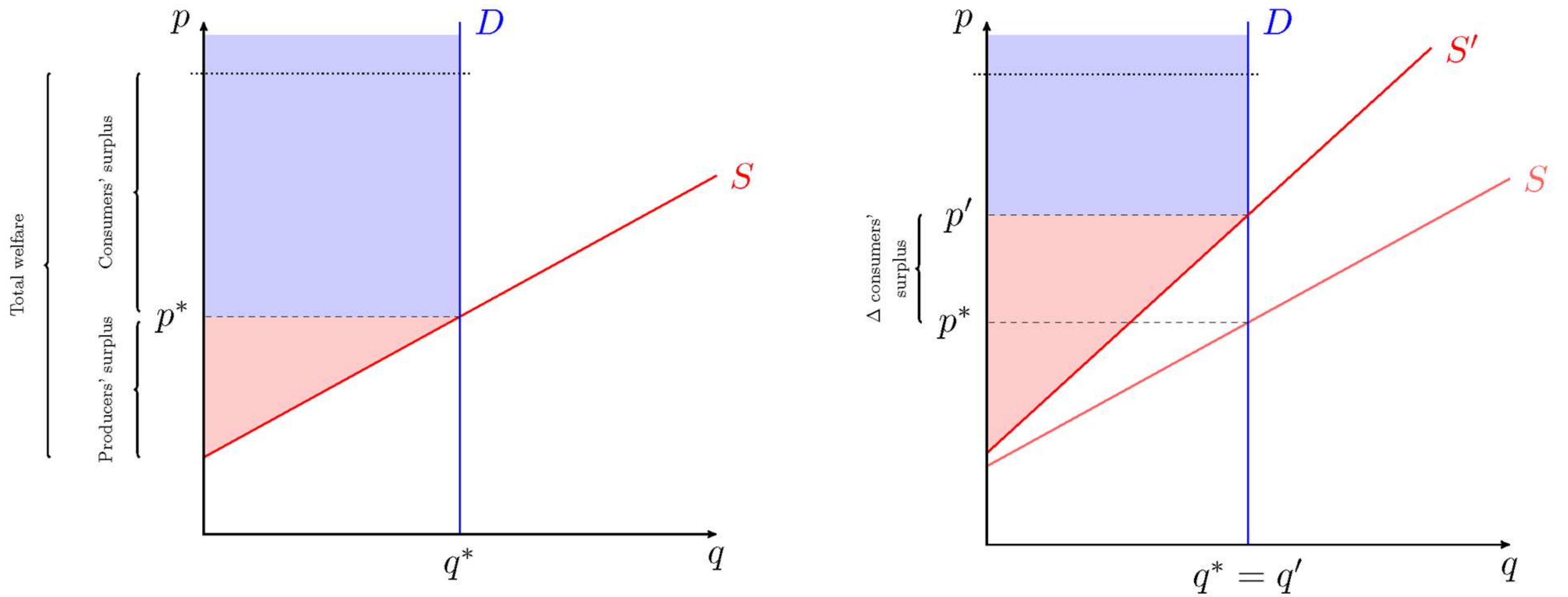
- Policy settings:
  - Emission pricing
  - Rain forest protection
  - International trade

Theoretical background



- Exogenous demand (population & GDP based)
- Inelastic

Theoretical background

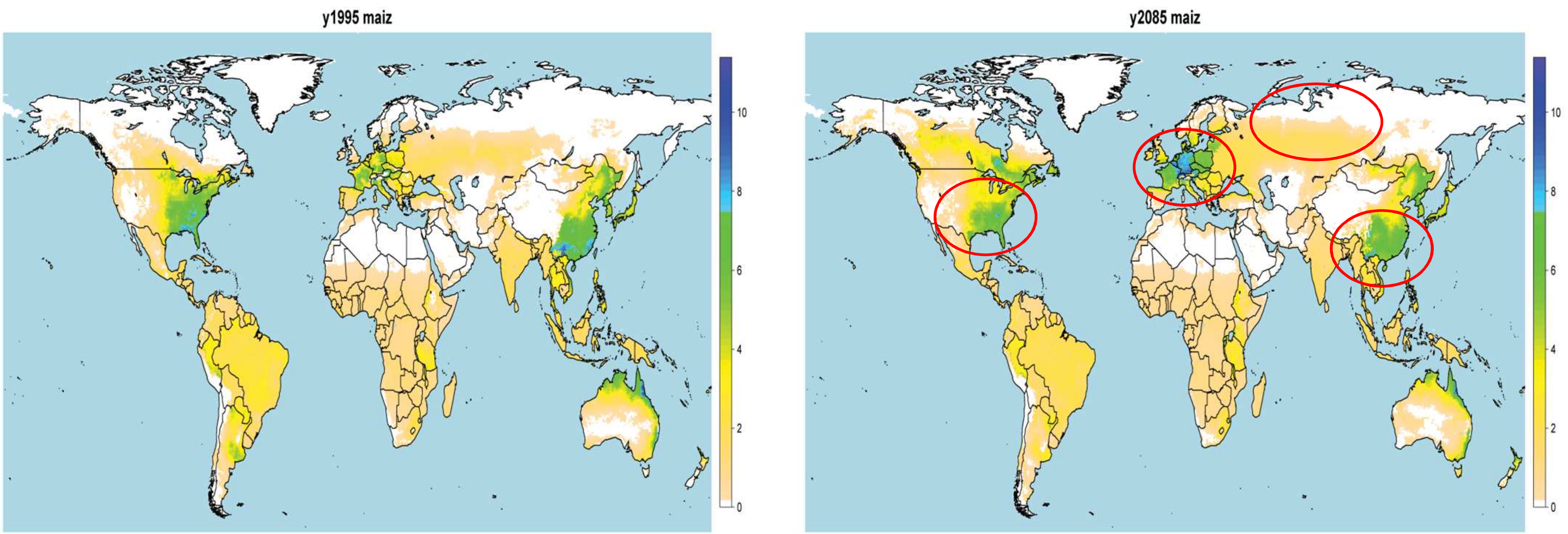


Indicators for impacts:

- Relative Change in Consumers' Surplus
- Relative Change in Producers' Surplus
- Relative Change in Total Welfare

Assessment of Climate Impacts (I)

- Spatial explicit changes in rainfed yields (LPJmL)
- SRES A2 scenario, “gdfl” climate model



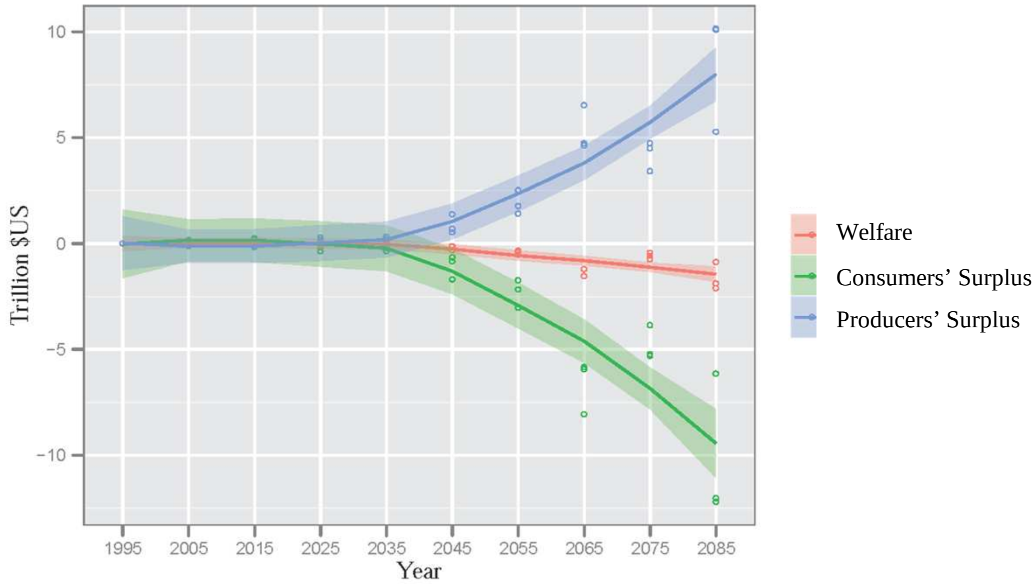
Adaptation options

- **Land expansion and (re)allocation**
- **Yield increase**
  - **Irrigation expansion and irrigation efficiency**
- **Diet shifts**
- **International trade**

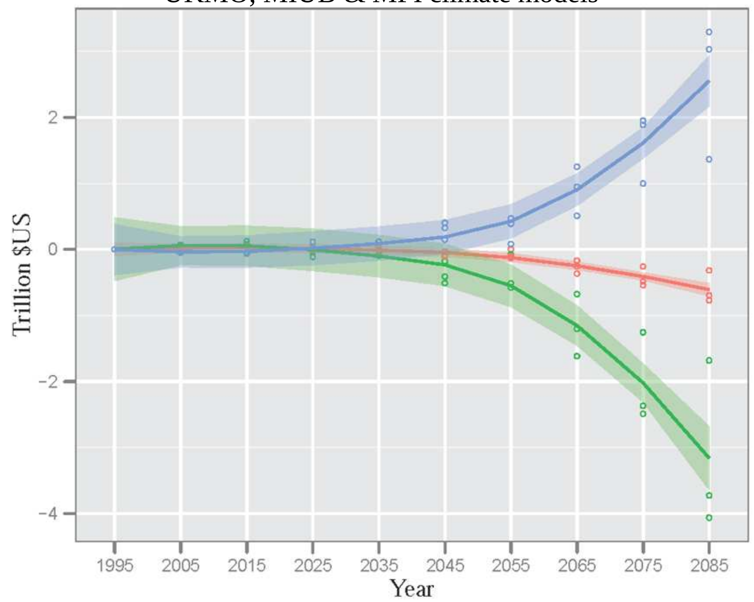
Assessment of Climate Impacts (II)

- Example (preliminary work) of **global impacts**:
  - SRES A2 scenario
  - Trade policies:
    - REF: trade at the 1995 level
    - POL: each decade there is 10% mode goods traded

REF trade scenario
UKMO, MIUB & MPI climate models

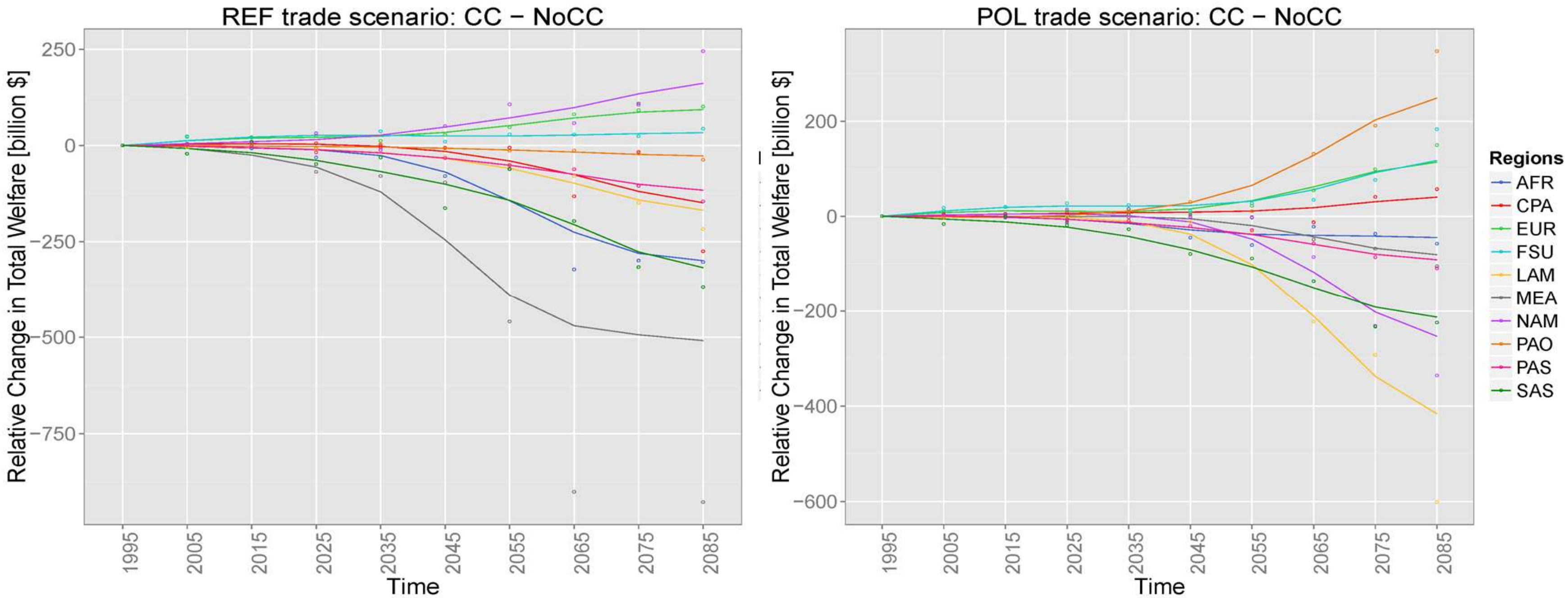


POL trade scenario
UKMO, MIUB & MPI climate models



Regional Assessment

- Climate change impacts on welfare at **regional** scale (preliminary):



Developments in Remind-R

- **Model overview**
- **Integration of damage functions**
- **Damages from MAgPIE**
- **Coupled Remind-MAgPIE system**
- **Integration of fluctuating renewables**
- **Super-grids**

The Remind-R model

- Global Ramsey-type optimal growth model
- 11 regions
- Time horizon 2005-2100, 5-10 year time steps
- Perfect foresight, welfare optimization
- Hybrid model with an economic growth module hard-linked to a detailed energy sector (stationary, transport) and a simple climate module
- Interregional trade in goods, energy carriers and emissions

The Remind-R model

Main focus:

- Regional GDP & consumption paths
- Investments into capital and different energy technologies
- Structure of the energy system
- Emission paths
- Analysis of climate change mitigation strategies and costs
- Trade patterns & equilibrium prices (energy, carbon)
- Taxes and subsidies in the energy sector

Damages in Remind

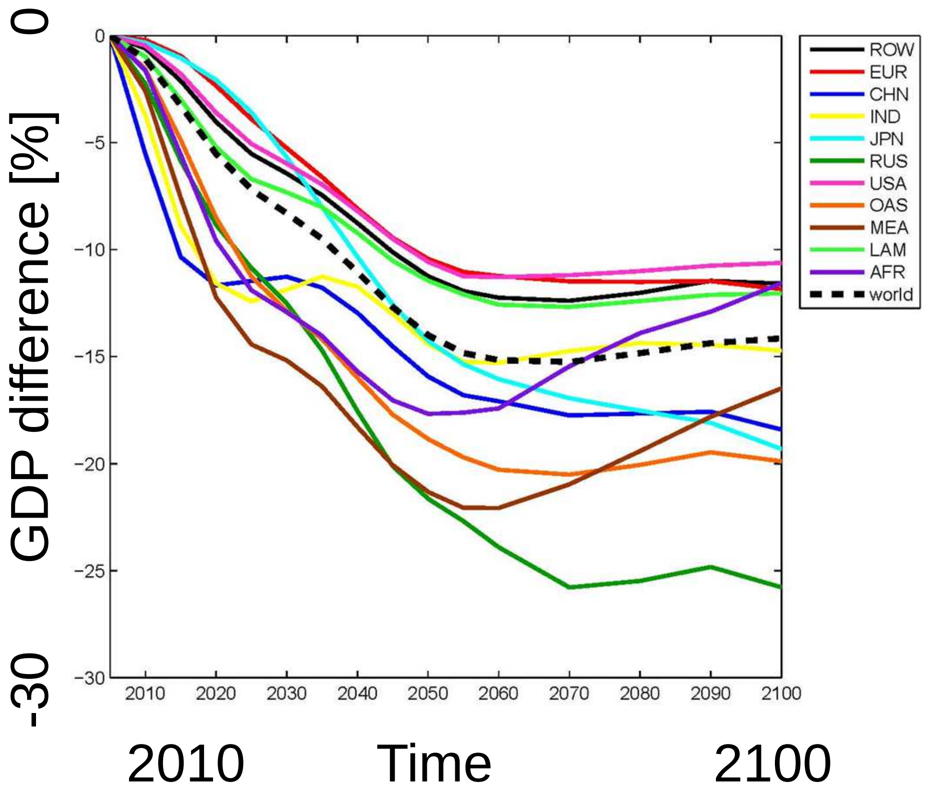
- **Goal: assess costs of global challenges via damage functions possibly derived with ICES**

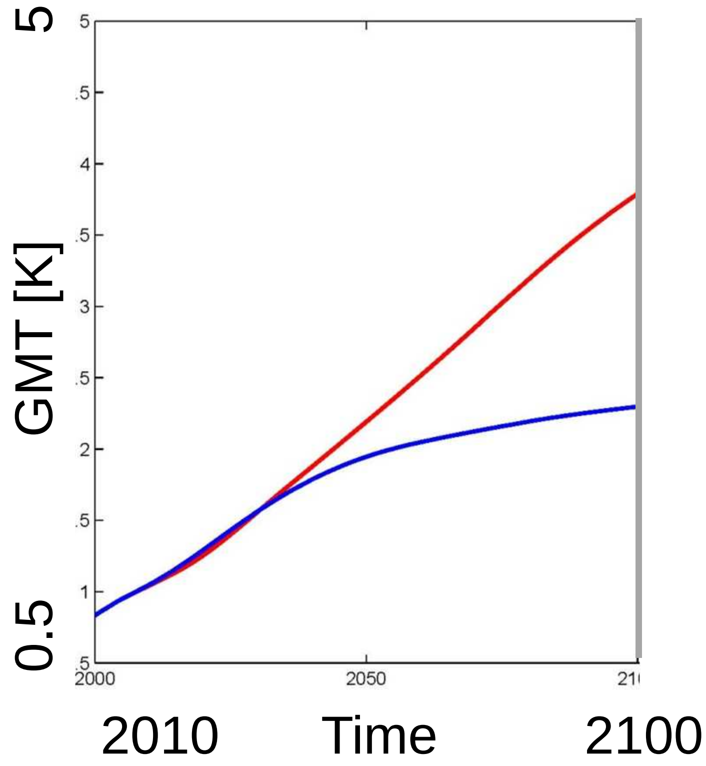
- **1st step: include climate change damages to test the system**
  - **Damage = 1+alpha*T^2**
  - **Inclusion in budget equation**

  - **Standard Remind favors „geoengineering“ by increasing SO_2 emissions (coal use) → avoid that via new SO_2 update mechanisms**

Climate change damages in Remind-R

- **Example result with an extreme damage function**

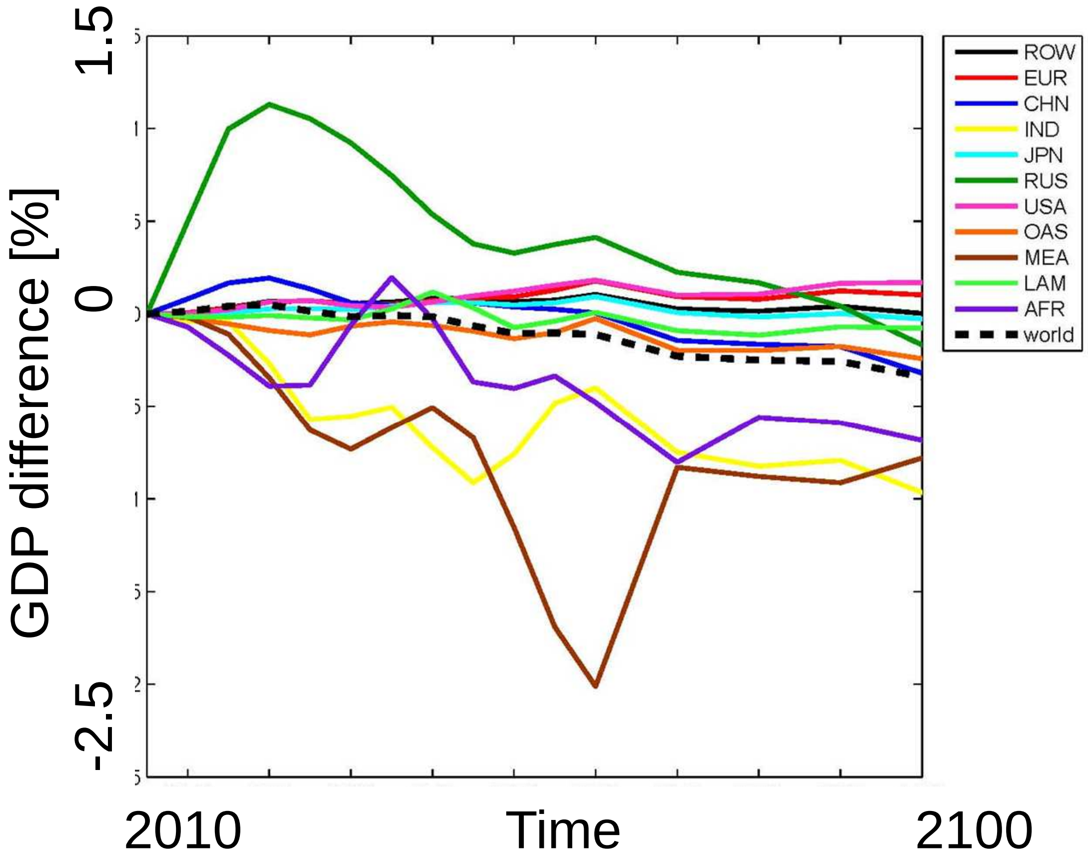




Integrating damages from MAgPIE in Remind-R

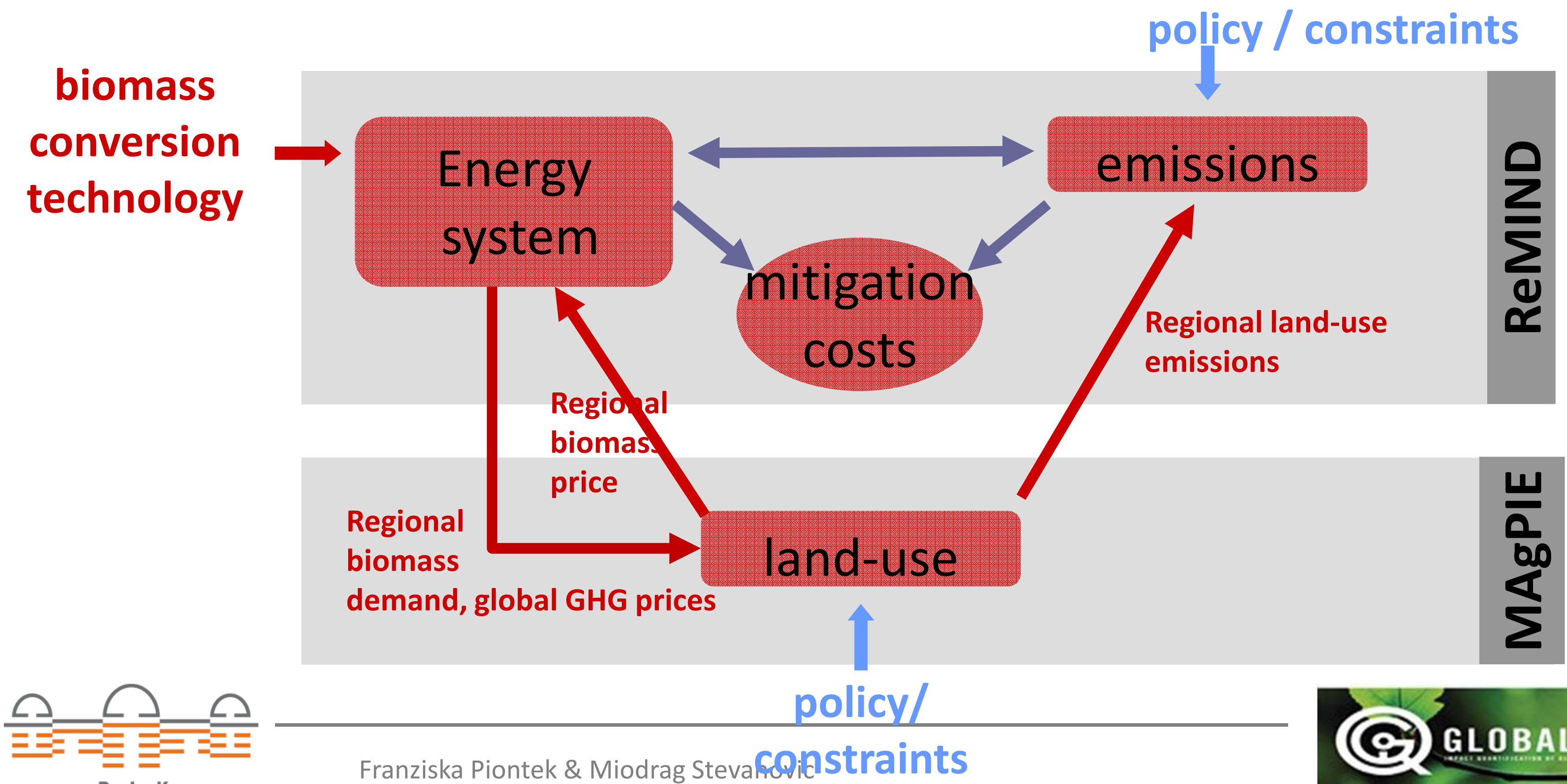
Problems:

- **Different regional aggregation**
- **No specific agricultural sector in Remind**
- **Very small effects**
- **Feedback to MAgPIE**



Coupled MAgPIE-Remind-R system: bioenergy trade

- **Where to use which kind of biomass most optimal? How to achieve sufficient emission reductions at minimum costs?**
- **Dynamic interaction of demand-side and supply-side**



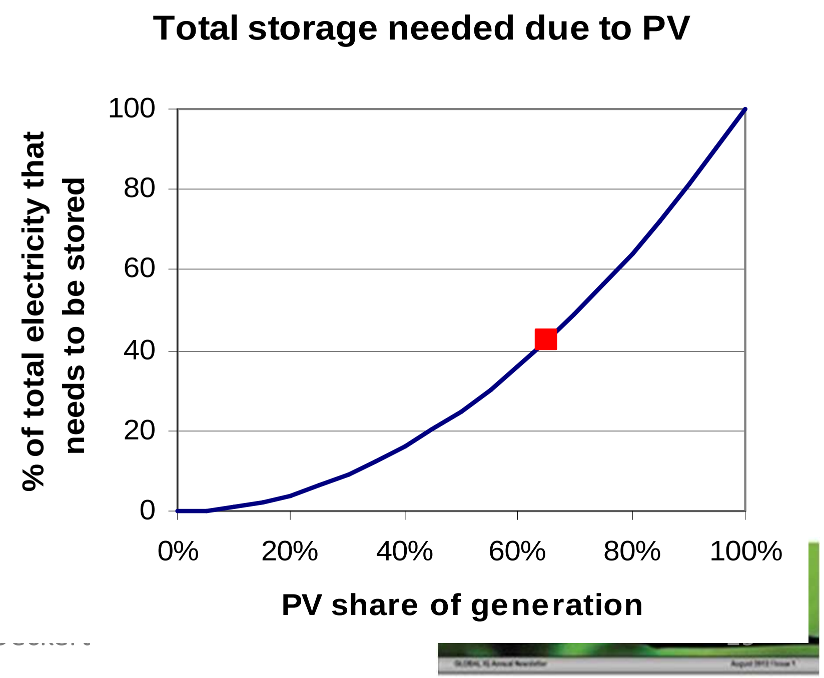
Fluctuating renewables and electricity trade

- **Goal: improve realism with respect to challenge of energy, energy security, fuels availability**

- **Adaptation to challenges of depletion of non-renewable energy resources, environmental threats (e.g. air pollution from coal use) and climate change**

Integration of fluctuating renewables (Robert Pietzker, Falko Ueckert)

- **Wind, PV and CSP are:**
  - **Fluctuating → need storage**
  - **Not homogeneously distributed → extra long-distance grids (intra-regional focus)**
- **Implementation: requirement to install storage and grid with degree of installation of fluctuating te**
- **Requirements rise more than linearly (exponent 1.5-2)**
- **Parameterization of storage along costs of flow batteries and electrolysis**



Reference for techno-economic parameters of storage: Chen, H., et al. (2009) Progress in Natural Science 19, 291-312

Fluctuating renewables – regional differentiation

Some regions are clustered into several groups with different exponents and multiplicative factors for the storage and grid equations:

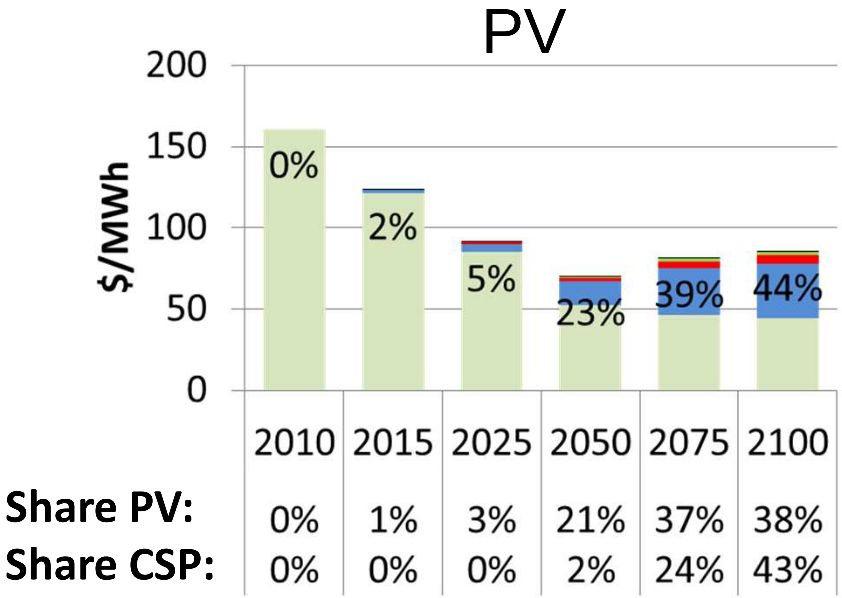
a. **RE potential is evenly distributed**
   ➔ fewer grid requiremets:
   EUR, USA, IND, JPN

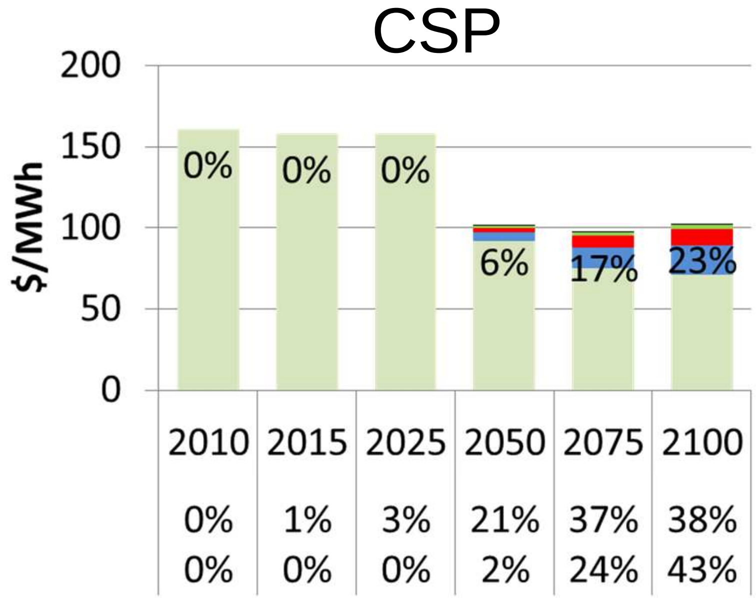
b. **Strong seasonal winds coincide with seasons of high demand**
   ➔ less storage needs for wind:
   EUR

c. **High solar irradiance coincides with seasons of high demand**
   ➔ less storage needs for solar technologies :
   USA, ROW, AFR, IND, MEA

Fluctuating renewables – storage impacts on levelized costs of electricity (LCOE)

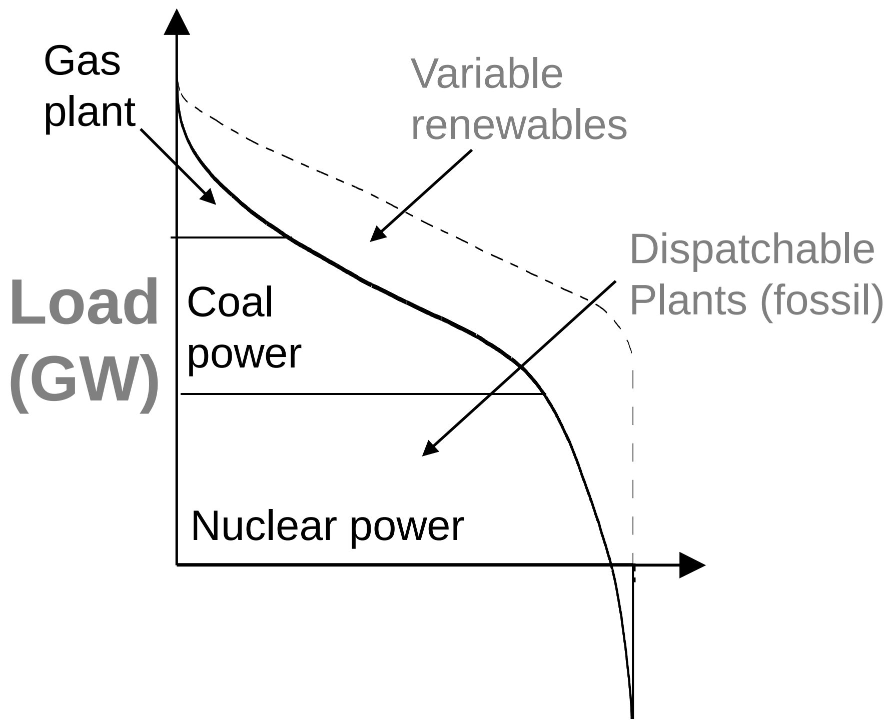
Example: LCOE for solar technologies in China in a strong climate protection scenario





Light green – pure LCOE
Blue – LCOE increase from curtailement
Red – grid
Green - storage

Fluctuating renewables – electricity as heterogenous good



- Due to numerical limits ReMIND-R treats electricity as if it was a homogenous good (baseload)
- Mid- and peakload technologies are discriminated

→ This is compensated by a flexibility constraint

The flexibility constraint accounts for:

- Technical flexibility of plants (minimum load, ramp rate, minimum downtime)

→ Sufficient flexible generation even with high shares of wind and solar PV

- Heterogeneity of electricity due to heterogenous demand

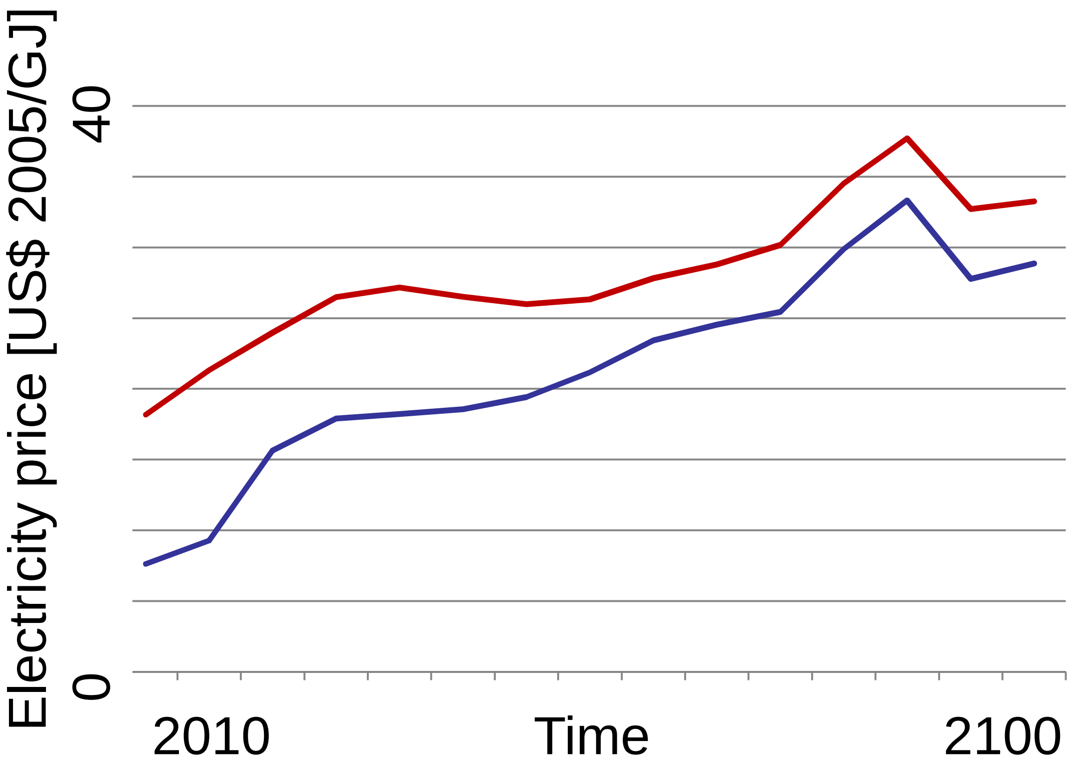
→ Sufficient peak and mid load technologies

Super-grids: focus electricity trade MENA-Europe – with Nico Bauer (Sylvie Ludig, Michael Lüken)

- Electricity trade technology between MEA & EUR
- Currently investments only by EUR (in principle any region possible)
- Electricity from any primary energy
- Parameterized based on Trieb et al. 2006 assuming a 3000 km HVDC line
- Driver: difference in electricity prices in MEA and EUR

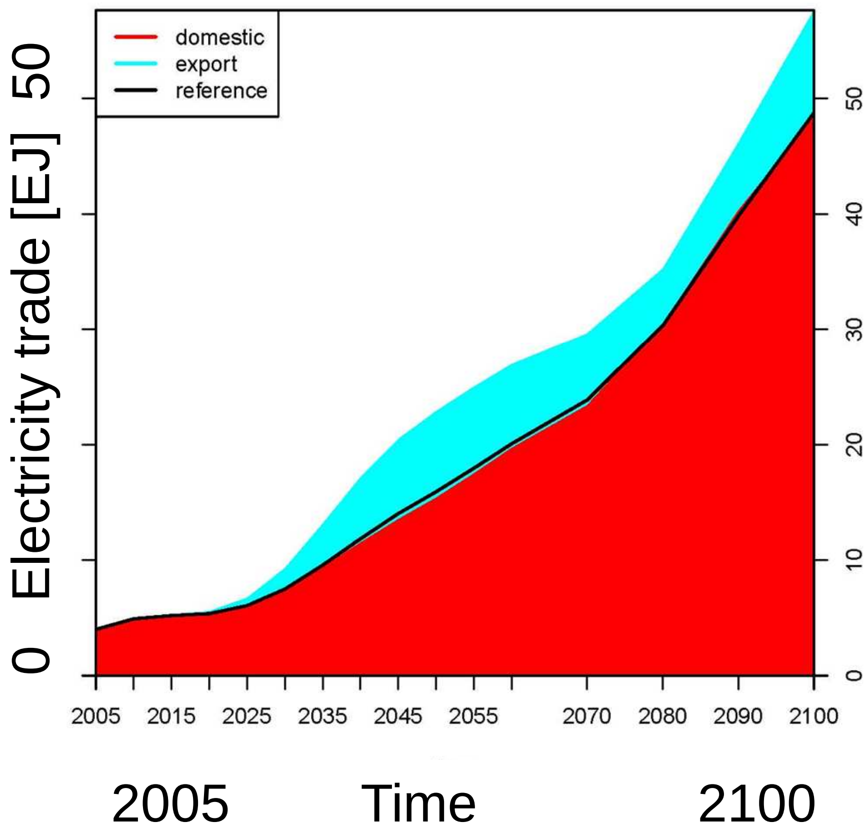
Investment costs	450 $/kW
efficiency	90%
Lifetime	45 years

Electricity trade – sample results (strong climate policy case)

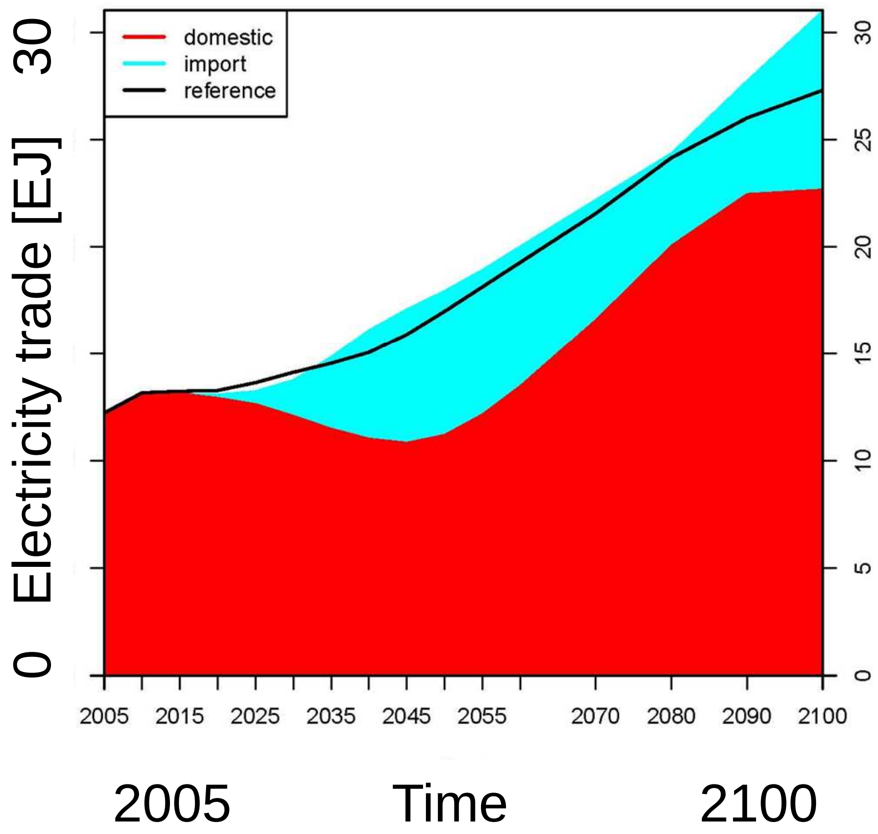


Electricity trade – sample results (strong climate policy case)

MEA



EUR



Next steps

- **Further explore electricity trade & finalize implementation**
- **Test damage function from ClimateCost to prepare for GIQ damage function for climate change impacts from ICES**
- **Study input of damages from MAgPIE**
- **Explore specific options to study chosen global challenges with Remind**
- **Specify options for restricting adaptation to these global challenges in Remind**

THANK YOU!