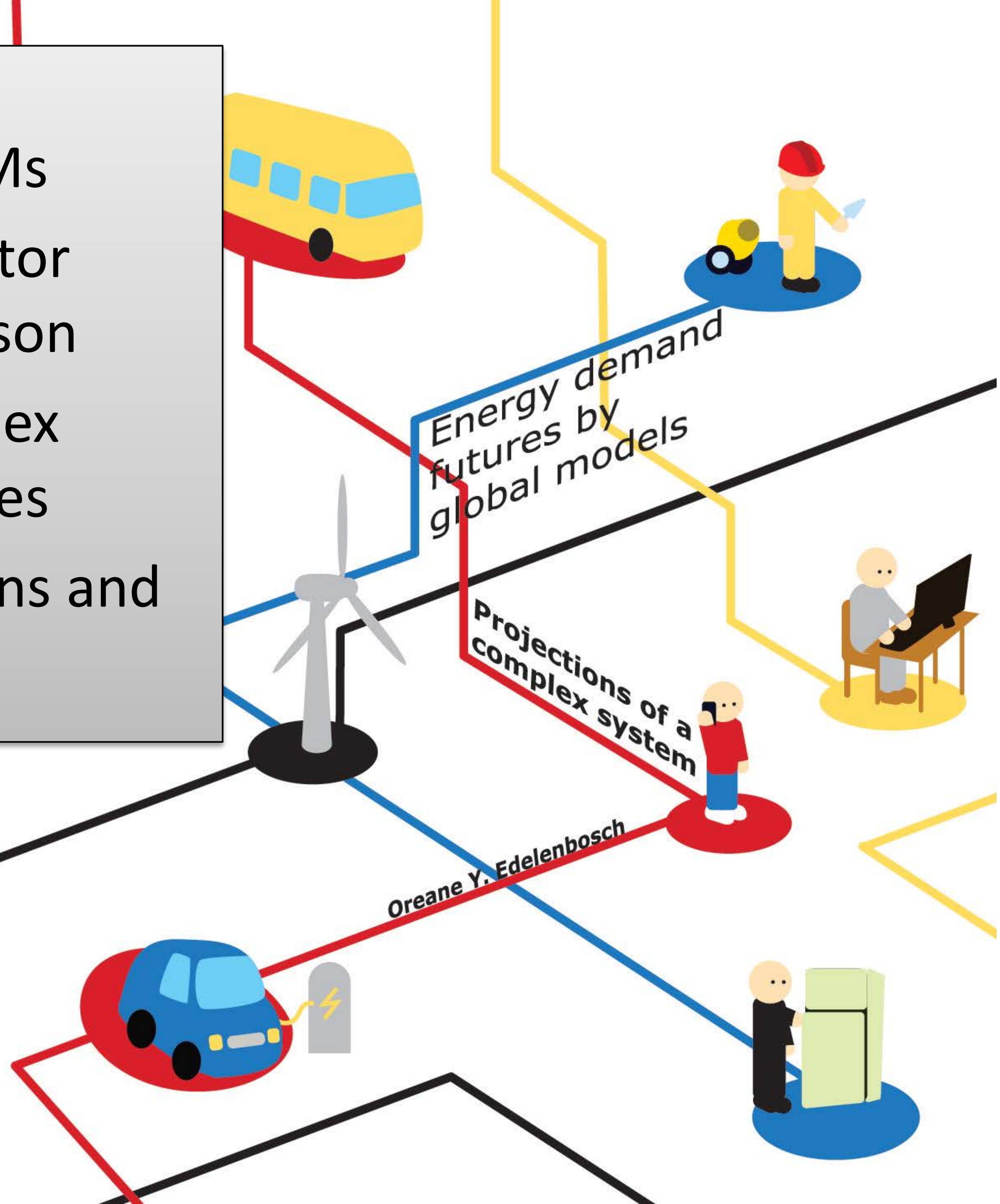
- Energy demand modelling by IAMs
- Cross sector/Sector specific comparison
- Modelling complex demand processes
- Recommendations and conclusions



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Climate Change and Energy

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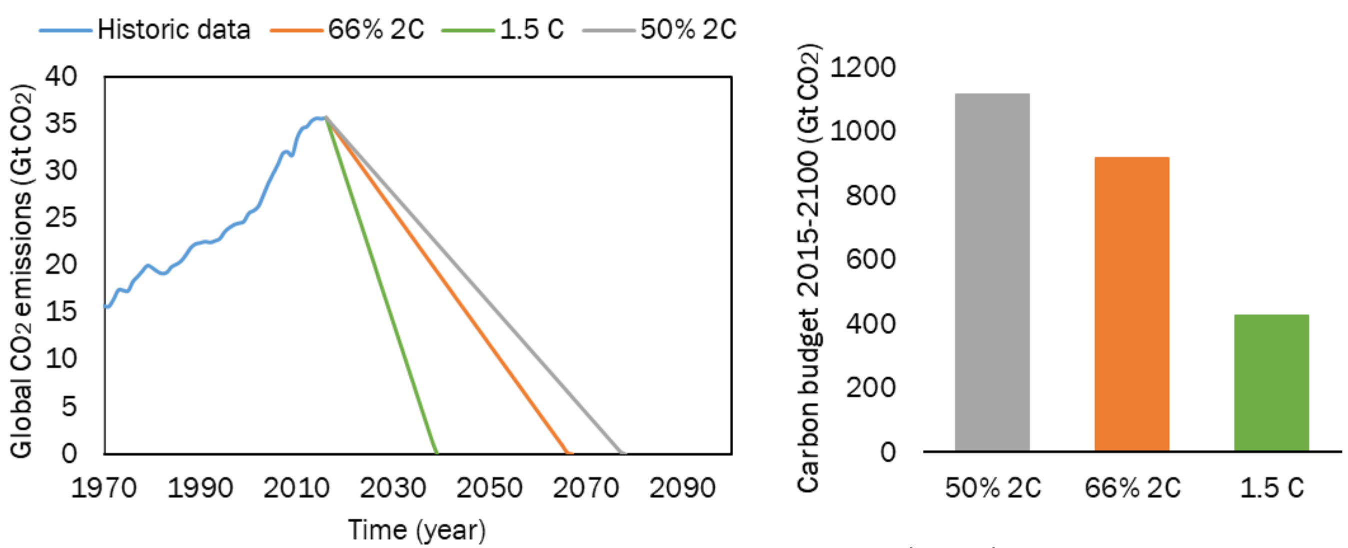
- 2/3 of GHG emissions from Fossil Fuel combustion and Industry

Carbon budgets

- Near linear relation between cumulative CO_2 and temperature rise
- Staying below specified temperature rise in probabilities



J.G.J. Olivier (2017); Janssens-Maenhout (2017); Rogelj et al. (2016)

Energy Supply and Energy demand

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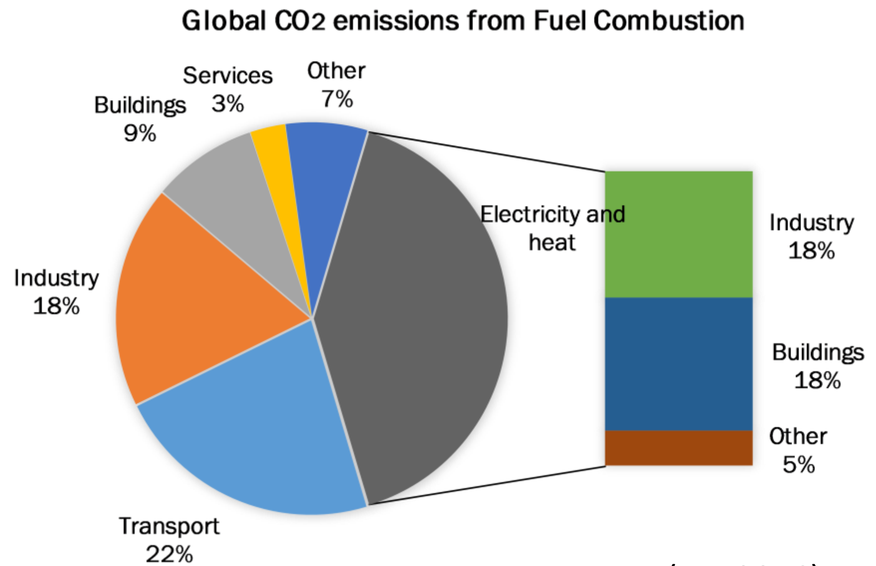
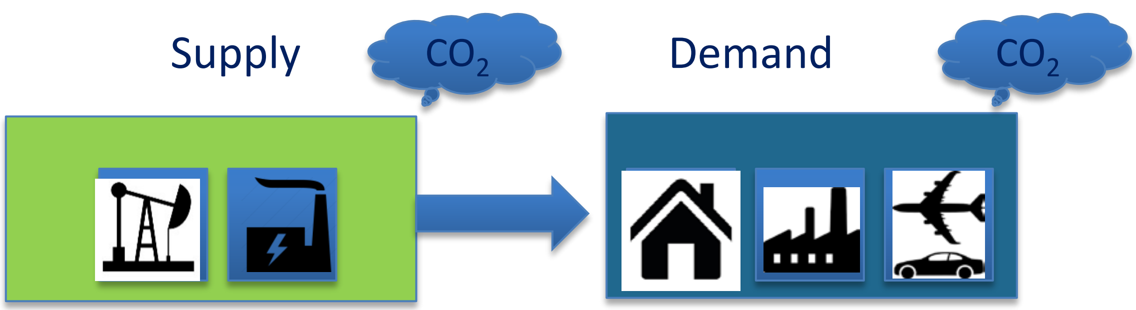
- Energy demand sectors: *Buildings, Industry and Transport*
- Energy demand sector directly and indirectly contribute to global CO_2 emissions
- Different trends across the demand sector



(IEA 2016)



Integrated Assessment Models

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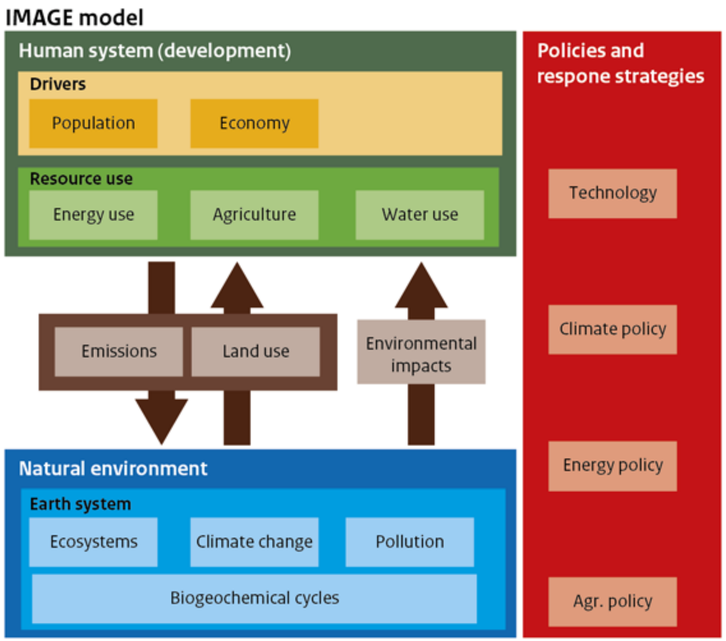

- Interaction of human development, earth system and environmental system
- Integration across different issues and disciplines
- Focused on decisions processes (*assessment*)

Integrated Assessment Models

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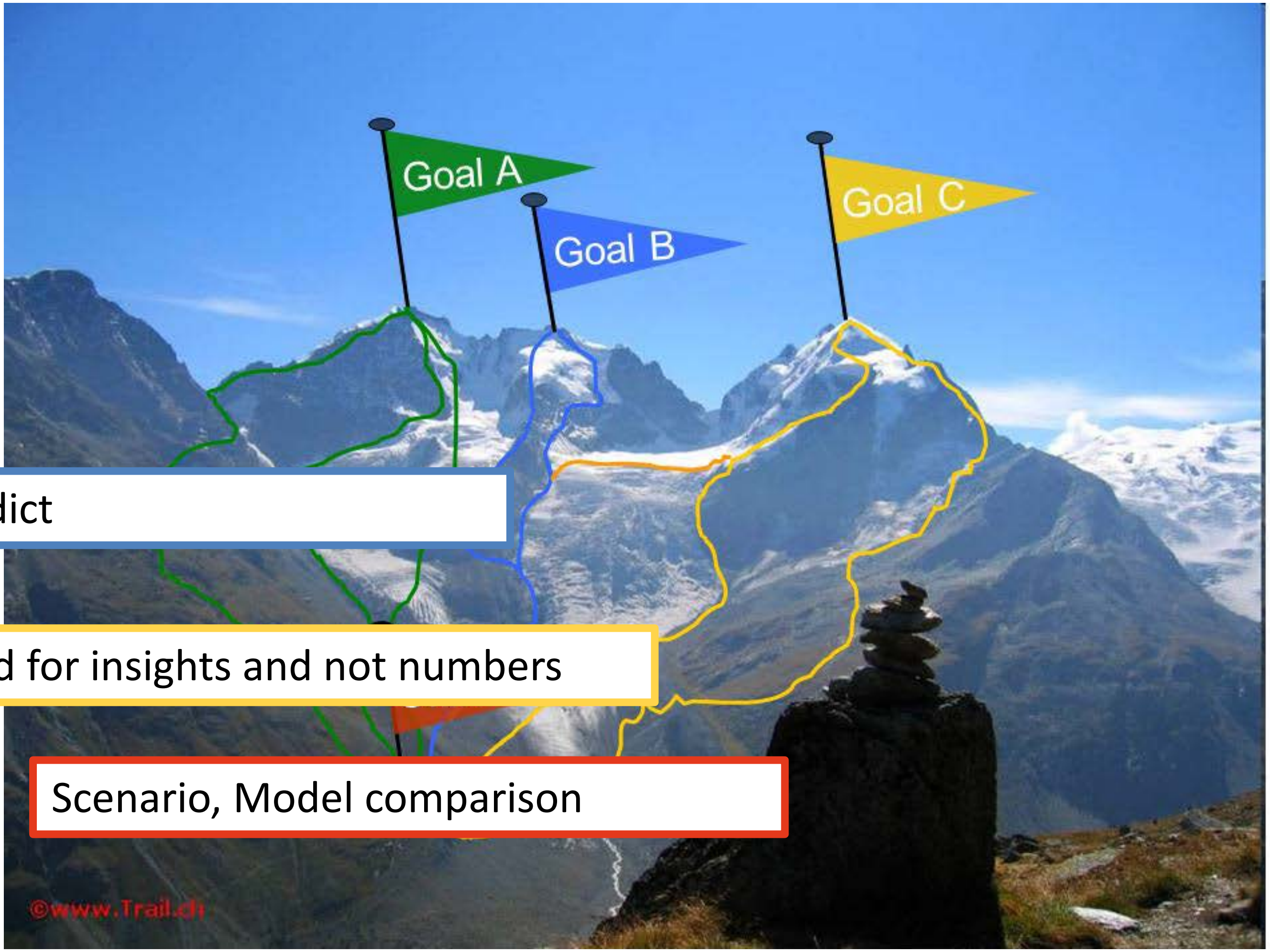

Cannot predict

Used for insights and not numbers

Scenario, Model comparison

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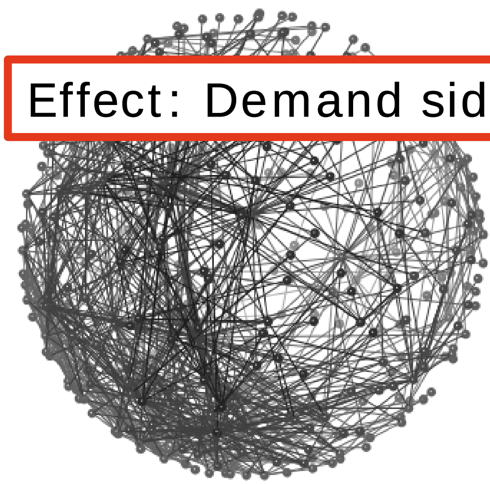
Demand sector complexity

Demand Sectors

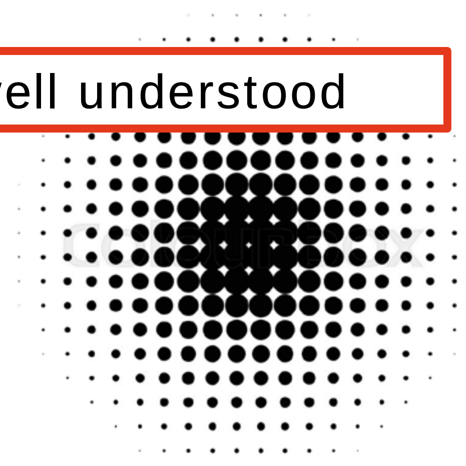
- Many subsectors
- Many technologies
- Different users
- High capital stock turnover
- Less defined decision-making criteria

In IAMs

- Adding more detail comes at a costs
- Data intensive
- Uncertain assumptions
- Transparent
- Aggregated trends



Effect: Demand side changes not so well understood



Aim of the thesis

How can the representation of energy demand side dynamics be improved in global models assessing long-term climate change?

- How do IAMs project energy demand and what do they project?
- How do energy demand sectors in IAMs respond to climate policy?
- How do IAMs perform in their energy demand representation?
  - (Cross) comparison of demand sector projections
- How can complicated processes be represented in global models?
  - IAM representation of technology transition

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Thesis Outline

- Comparing projections of industrial energy demand and greenhouse gas emissions in long-term energy models *Energy*
- Decomposing passenger transport futures: Comparing results of global integrated assessment models *Transp. & Env. Research Part D*
- Transport fuel demand responses to fuel price and income projections: Comparison of integrated assessment models *Transp. & Env. Research Part D*
- Transport electrification: the effect of recent battery costs reduction on a future transition *Climatic Change (in review)*
- Transitioning to electric cars: Interactions between social learning and technological learning *Environmental Research Letters (subm.)*
- Mitigating energy demand emissions: The integrated modelling perspective *Global Environmental Change (subm.)*

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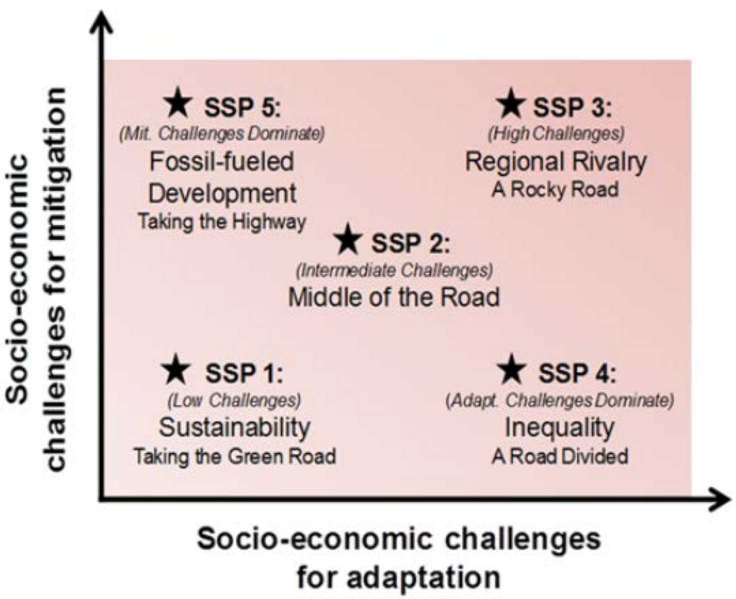
Mitigating energy demand emissions: *The integrated modelling perspective*

- Cross model
- Cross demand sector
- Cross scenario
- Decomposition

- Efficiency
- Electrification
- Fuel content



$$Direct\ emissions = Pop * \frac{FE}{Pop} * \frac{1-Elec}{FE} * \frac{Direct\ emissions}{1-Elec}$$

with $$\frac{FE}{Pop} = \frac{Energy\ service\ demand}{pop} * \frac{FE}{Energy\ service\ demand}$$

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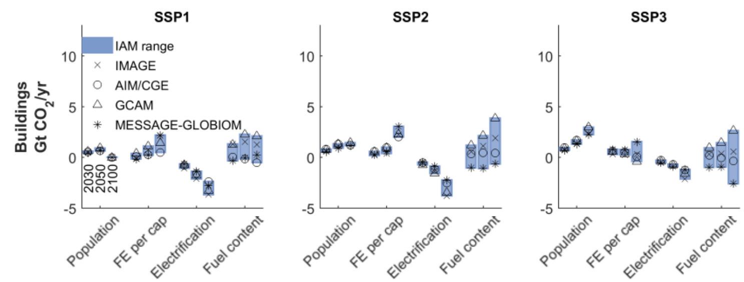
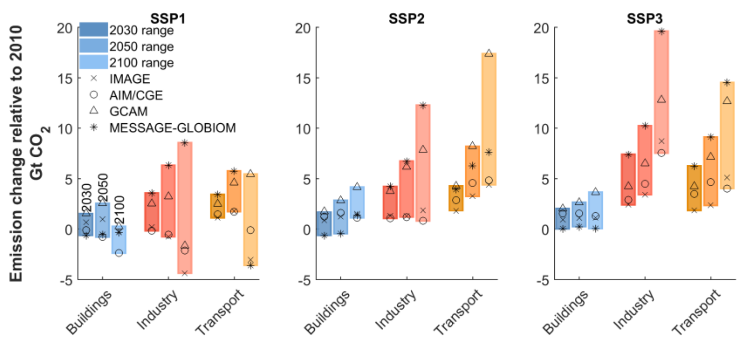
Mitigating energy demand emissions:
The integrated modelling perspective



Baseline emissions



Mitigating energy demand emissions:
The integrated modelling perspective

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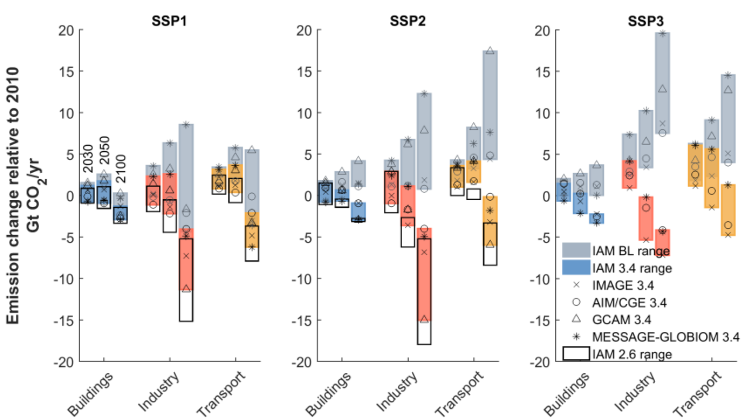
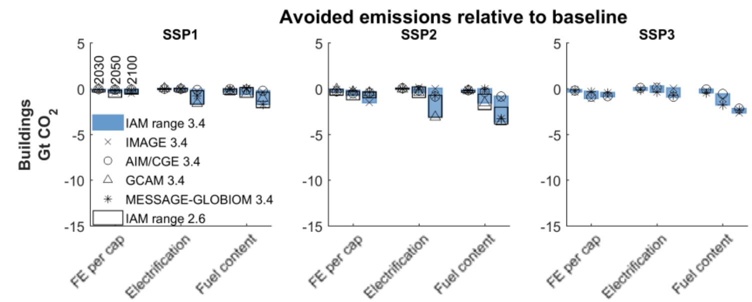
Stringent mitigation





Mitigating energy demand emissions:
The integrated modelling perspective

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- Comparison with bottom up technology assessment:
  - More potential for efficiency!

(UNEP GAP, 2017)

	Buildings	Industry	Transport
IAM total sector	*0.7 (0.3 to 1.0)*	*2.6 (0.9 to 3.2)*	*1.7 (0.9 to 2.7)*
IAM eff	*0.4 (0.0 to 0.7)*	*1.1 (0.2 to 2.0)*	*1.3 (0.0 to 2.5)*
IAM electrification	*0.0 (-0.1 to 0.0)*	*0.0 (0.0 to 0.2)*	*0.0 (0.0 to 0.3)*
IAM fuel switch	*0.3 (0.2 to 0.4)*	*1.4 (0.6 to 1.9)*	*0.3 (0.0 to 0.8)*
Technology-oriented assessment	*1.6-2.1*	*2.1-3.3 (incl. CCS 3.3 – 4.6)*	*4.1 – 5.3*
BU eff	*1.2 - 1.8*	*1.6 – 2.8*	*3.0 – 4.5*
BU electrification			
BU fuel switch	*0.4 – 0.8*	*0.4 – 0.6 + 0.9 – 1.5 (CCS)*	*0.6 – 0.8*

Mitigating energy demand emissions:
The integrated modelling perspective

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Conclusions:

- Baseline emissions can grow rapidly in **industrial and transport** sectors
- Key uncertainty is **saturation of final energy**
- Demand side mitigation is dependent on energy efficiency and fuel switching in the short term but **fuel switching becomes dominant**
- **More potential for energy efficiency** improvement

Confirmed by sector comparison

Transport

- Service demand

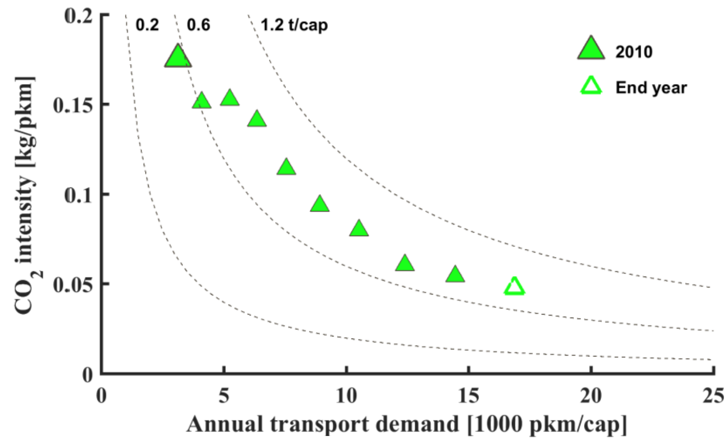
- Mode shift

- Energy efficiency

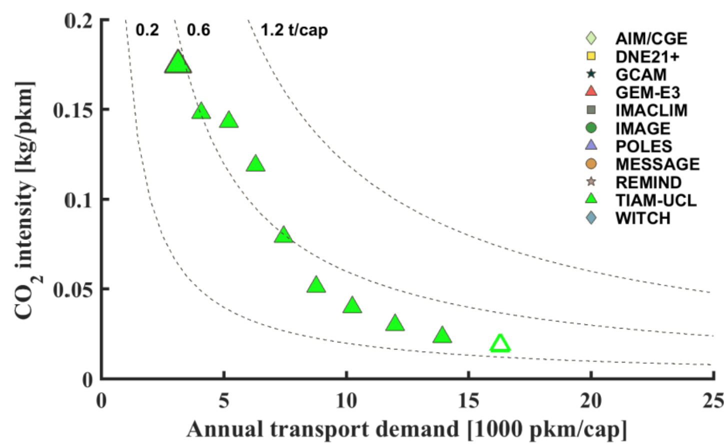
- Electrification

- Fuel content

Baseline



2 °C



Confirmed by sector comparison

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Transport

- Service demand

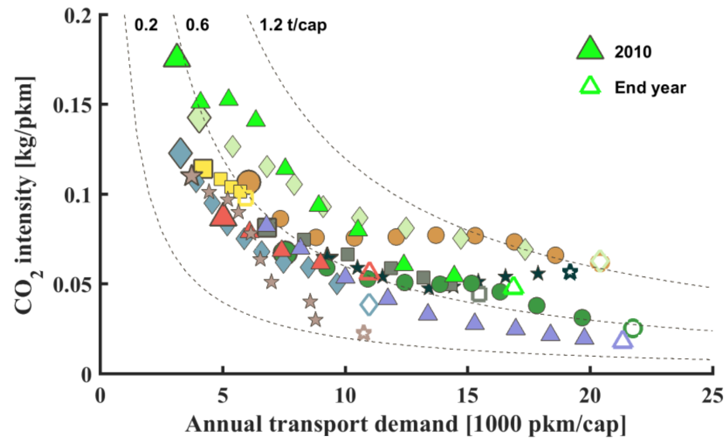
- Mode shift

- **Energy efficiency**

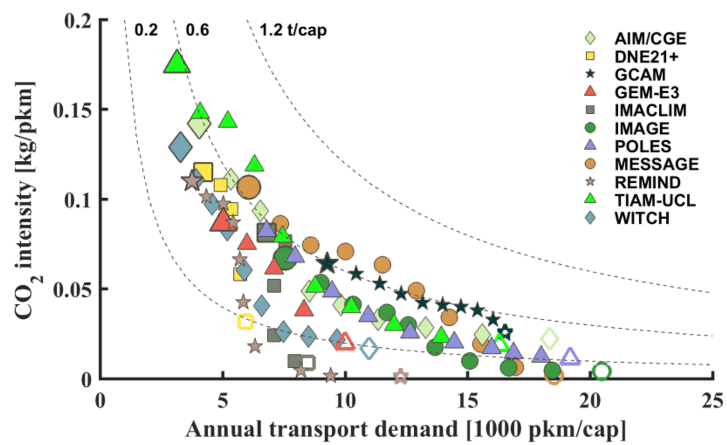
- **Electrification**

- **Fuel content**

Baseline



2 °C



Confirmed by sector comparison

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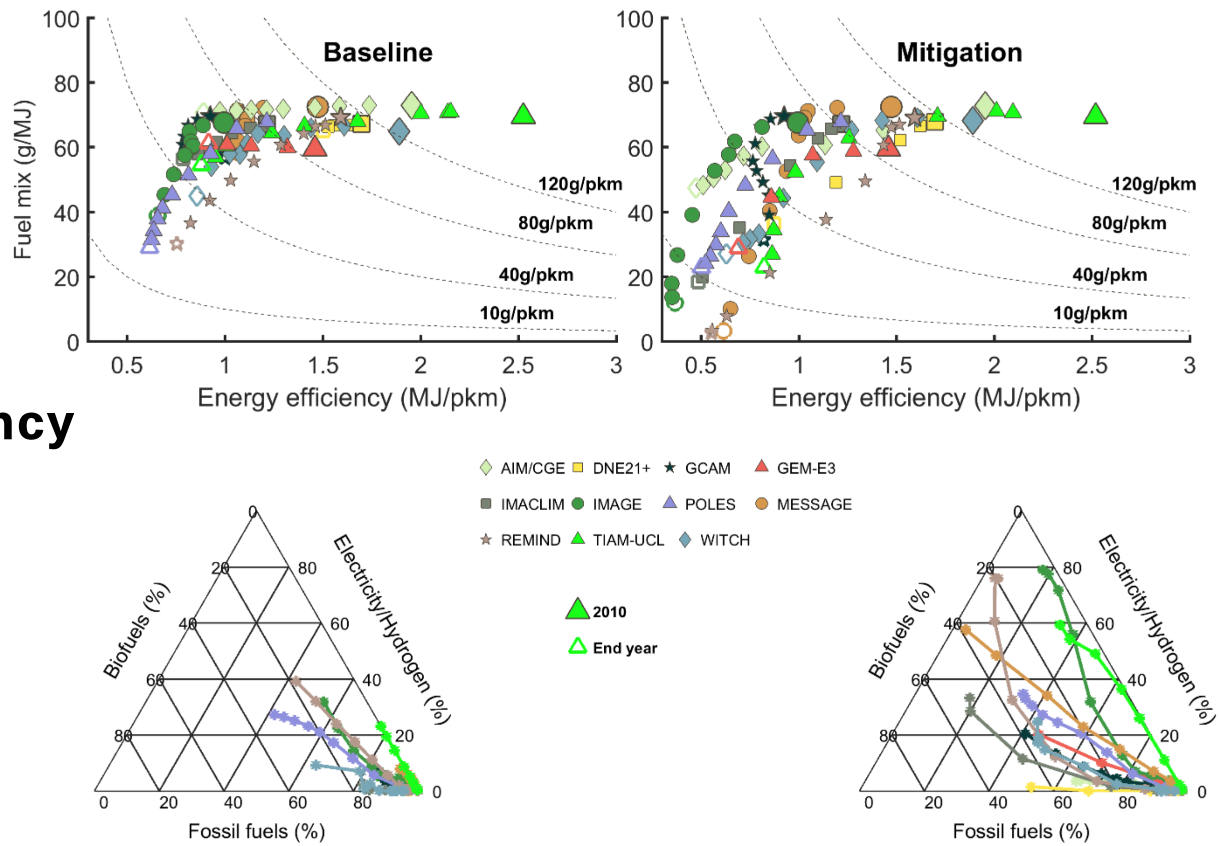
Transport

- Service demand
- Mode shift
- **Energy efficiency**
- **Electrification**
- **Fuel content**



Historic sector comparison

Transport

- *Through decomposition analysis*
- *Through price and income elasticity*

2030

2060

Historic sector comparison

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Conclusions:

- Generally, projections are well within historic range
- In fact historic range is even larger
- While in the short term trends are comparable, in the long term global energy demand very uncertain
- Fuel switching goes beyond historic measurements

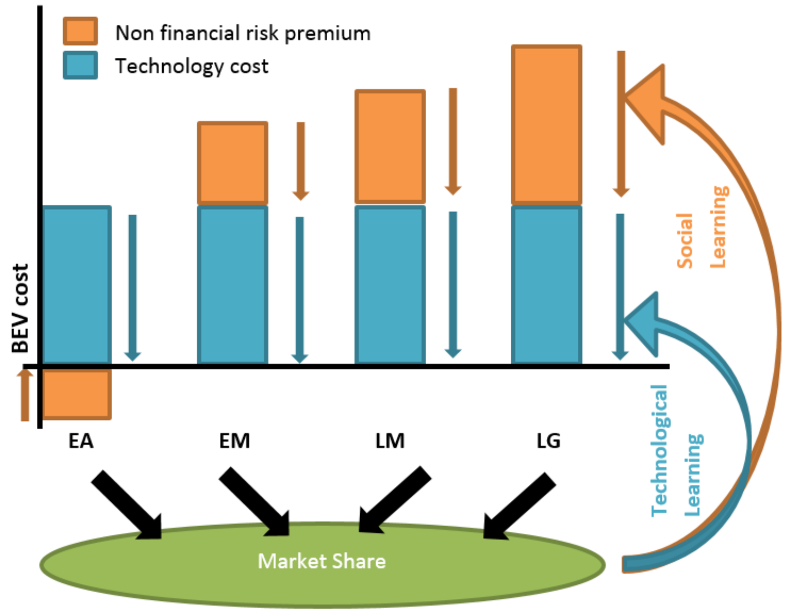
Transitioning to electric cars: *Interactions between social learning and technological learning*

Technological learning

- Advanced propulsion vehicles can reduce emissions but currently costs are still high
- Cost decreasing with experience

Social influence/learning

- Heterogeneity
- Diffusion
- Learning about benefits/risks of new technologies
- Recent work on social influence by Pettifor et. al (2017)



Transitioning to electric cars: *Interactions between social learning and technological learning*

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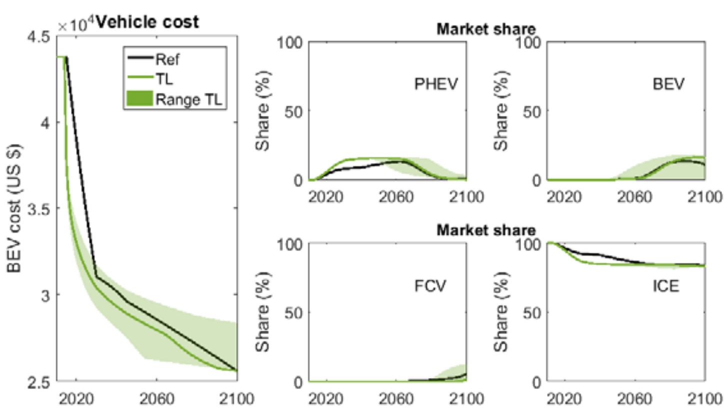
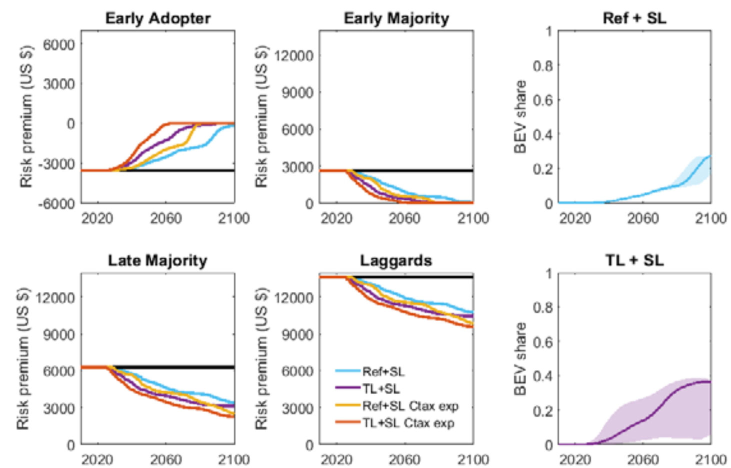
Technology learning



Social learning



Transitioning to electric cars: *Interactions between social learning and technological learning*

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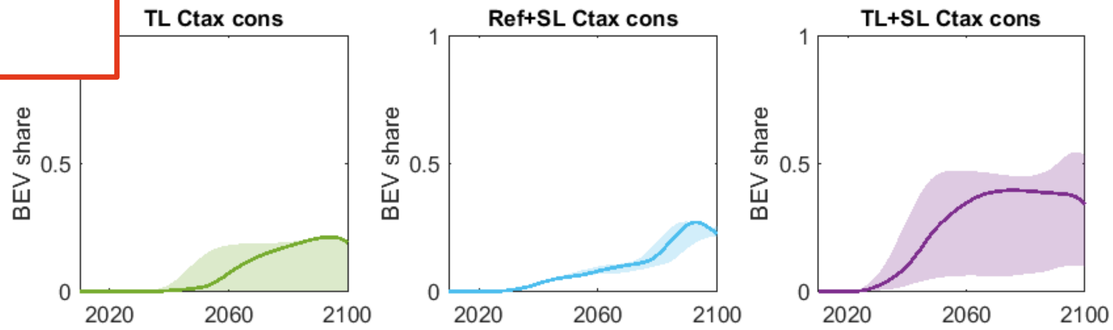
Carbon tax



Conclusions:

- Including social and technological learning effects the transition dynamics
- The two processes can mutually reinforce each other
- Finding robust patterns that explain the sector dynamics is the key challenge, while keeping the model simple

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Conclusions and discussions

- Global energy demand is projected to grow, energy efficiency partly offsetting service demand
- While in the short term model results are comparable in the long term large uncertainties
- Differences between models can be traced back to projected service demand (travel volume) and energy efficiency
- Energy efficiency and fuel switching both important to reduce emissions but service reduction/change plays minor role
- Activity and energy intensity projections well within historic range
- Income and price elasticities in the short term as well, long term diverge
- Finding the right level of detail and explain the sector dynamics

Conclusions and discussions

- Behaviour factors
  - difficult to quantify but cannot be ignored
- Physical demand
  - understanding drivers and dynamic
- Representation of climate policy
  - Demand sector specific policies
- Barriers
  - Infrastructure, building stock
- Short term and long term dynamics
  - Finding ways to communicate between different approaches, level of detail

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