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Modelling low-carbon energy transition scenarios with the TIMES-Ireland Model (TIM) - Results

Hannah Daly, Andrew Smith & Olexandr Balyk

Climate Change Advisory Council Carbon Budget Committee
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HOST INSTITUTION

UCC University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

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TIM development team

- **Dr. Hannah Daly**
  - Lecturer in Energy Systems Modelling, UCC & Funded Investigator, MaREI
  - Co-PI CAPACITY project, PI/Supervisor of CCAC Carbon Budget Fellowship
- **Dr. Olexandr Balyk**
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- **Dr. Xiufeng Yue**
  - Former postdoc, CHIMERA project, lecturer Dalian University of Technology
- **Ankita Gaur**
  - MaREI PhD researcher – energy demand drivers

With support from wider Energy Policy & Modelling Group at UCC & E4sma

Introduction

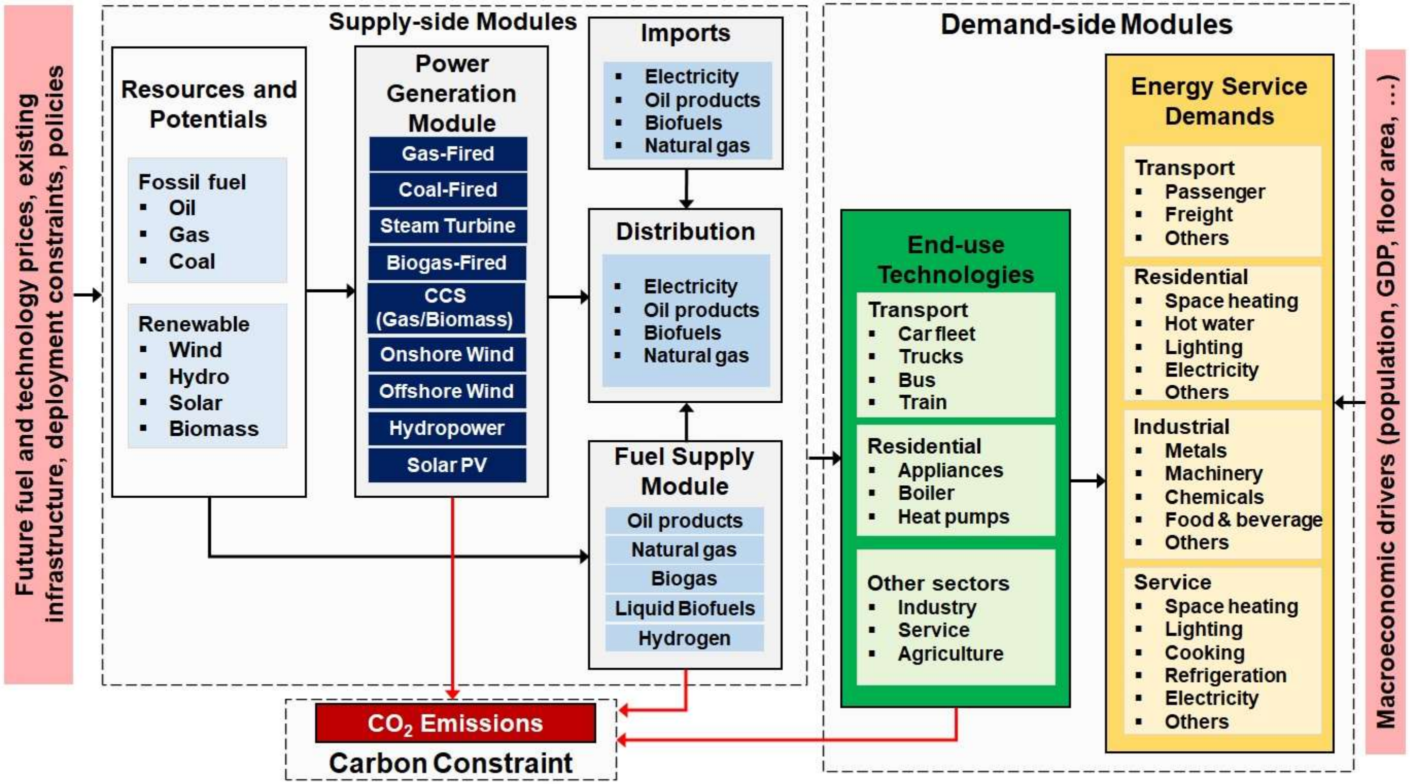
- First assessment of energy system pathways of very deep near-term decarbonisation target to meet the 2030 target with the TIMES-Ireland Model

- The short time horizon requires a faster energy system transition than the natural renewal of many technologies, so early retirement may be needed

- Very challenging modelling task, pushing the limits of modelling capabilities, requiring careful calibration of existing energy technology stock

TIMES-Ireland Model (TIM)

TIM is an Energy Systems Optimisation Model (ESOM) which calculates the "least-cost" configuration of the energy system which meets future energy demands, respecting technical, environmental, social & policy constraints defined by the user.



Given

- Final energy demands
  - e.g., passenger kms, home heating
- CO_2 constraints on energy
  - e.g., carbon budget, annual target
- Technology, fuel costs & efficiency
  - Existing & future cost and performance
- Resource availability
  - e.g., on/offshore wind, bioenergy
- User-defined constraints
  - e.g., speed of technology uptake, policies

TIM calculates

- "Least-cost" energy system meeting all constraints
- Investment and operation of energy technologies
- Emissions trajectories
- Total system cost
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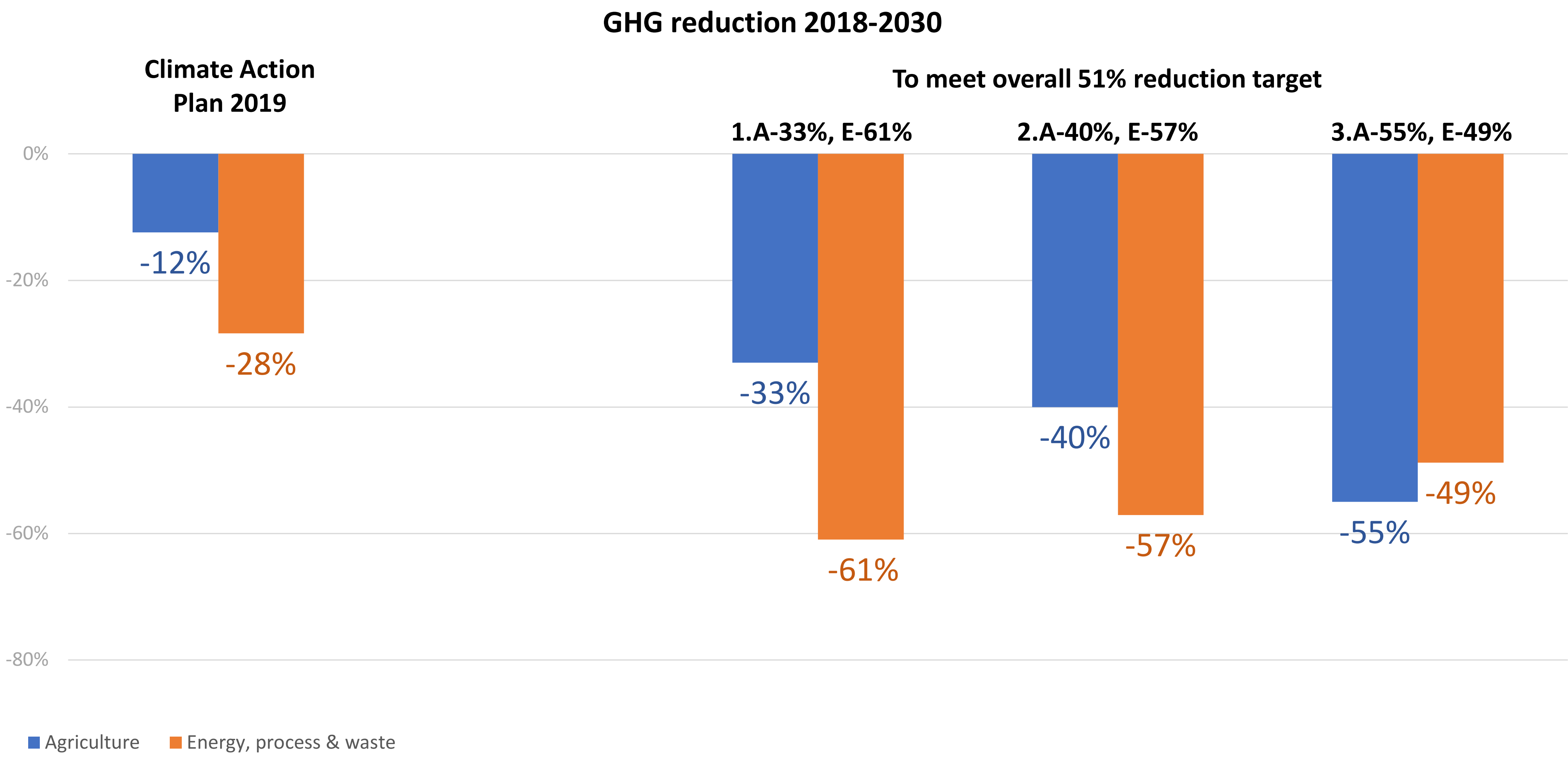
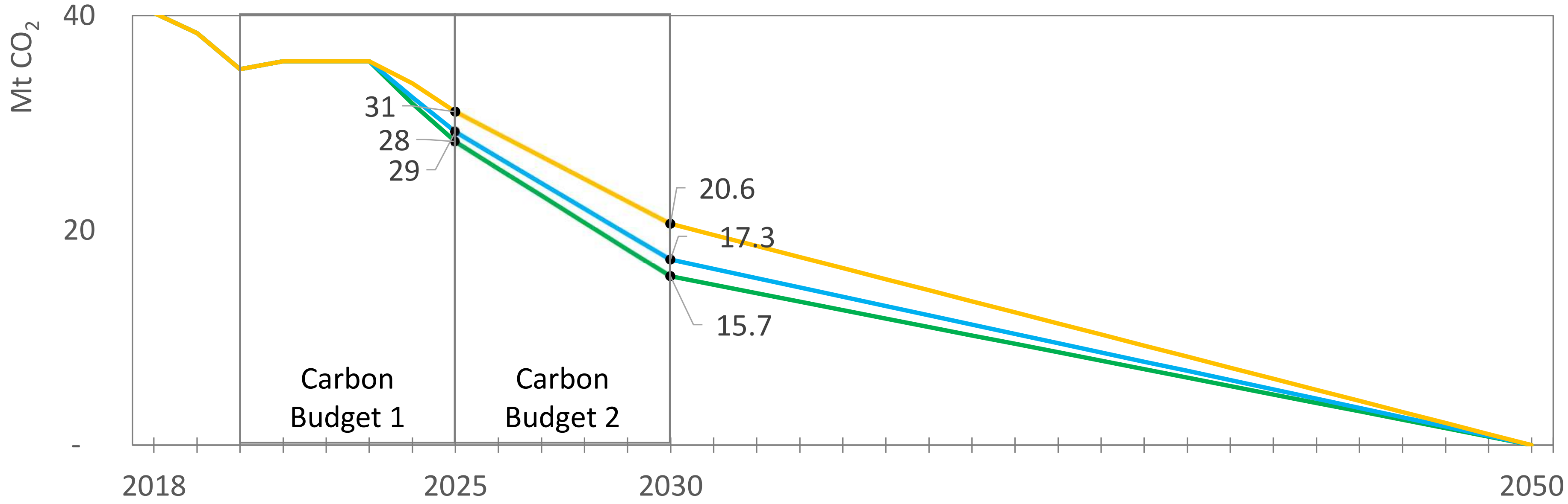
- Marginal energy prices

Decarbonisation trajectories modelled in TIM



Decarbonisation trajectories modelled in TIM & carbon budget outcomes



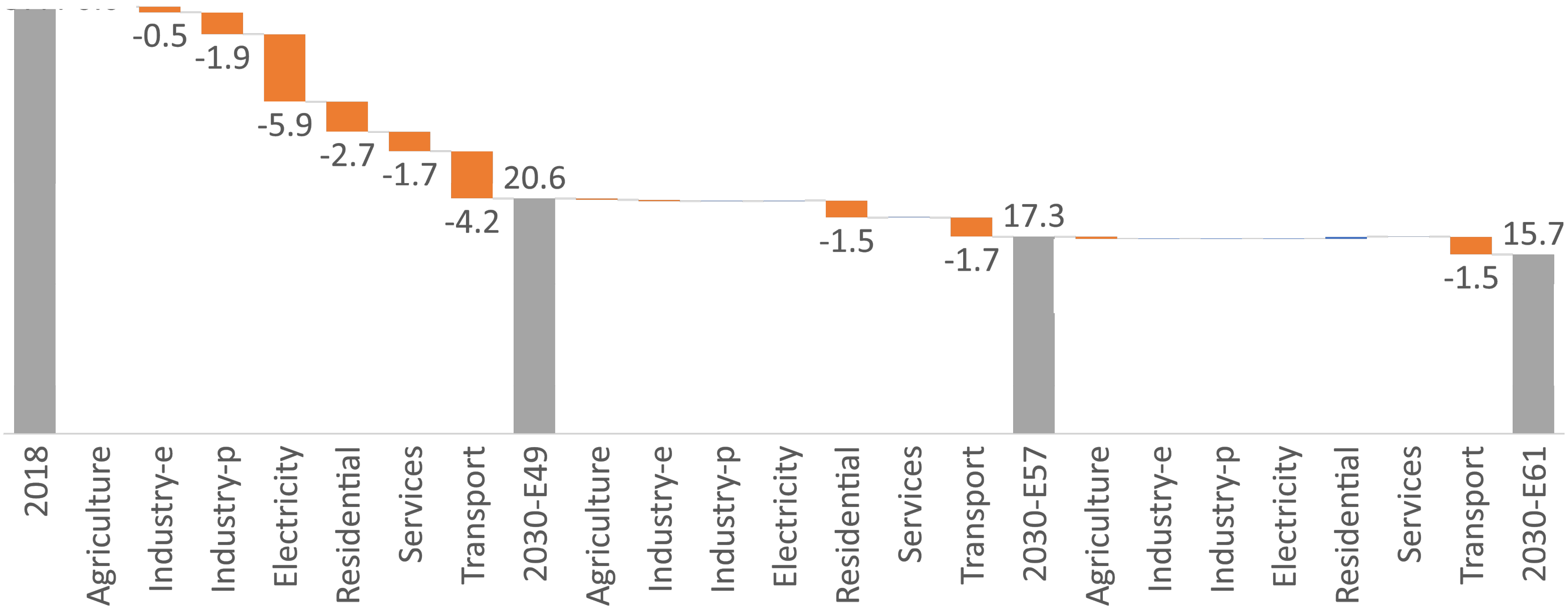
1. Agri-33%, Energy-61%	167	101	14.9
2. Agri-40%, Energy-57%	170	108	13.4
3. Agri-55%, Energy-49%	174	122	10.0

Carbon budgets implied for energy & process-related ($MtCO_2$)

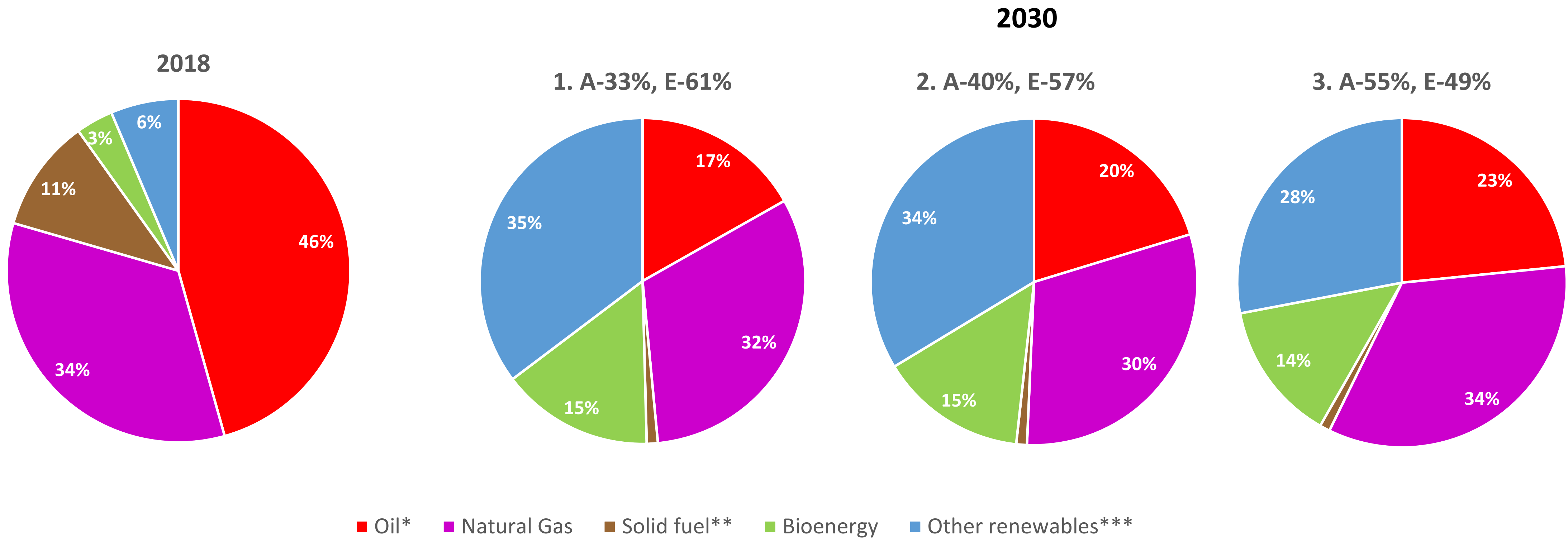
Agri emissions in 2030 ($MtCO_2e$)

Emissions savings by scenario and sector

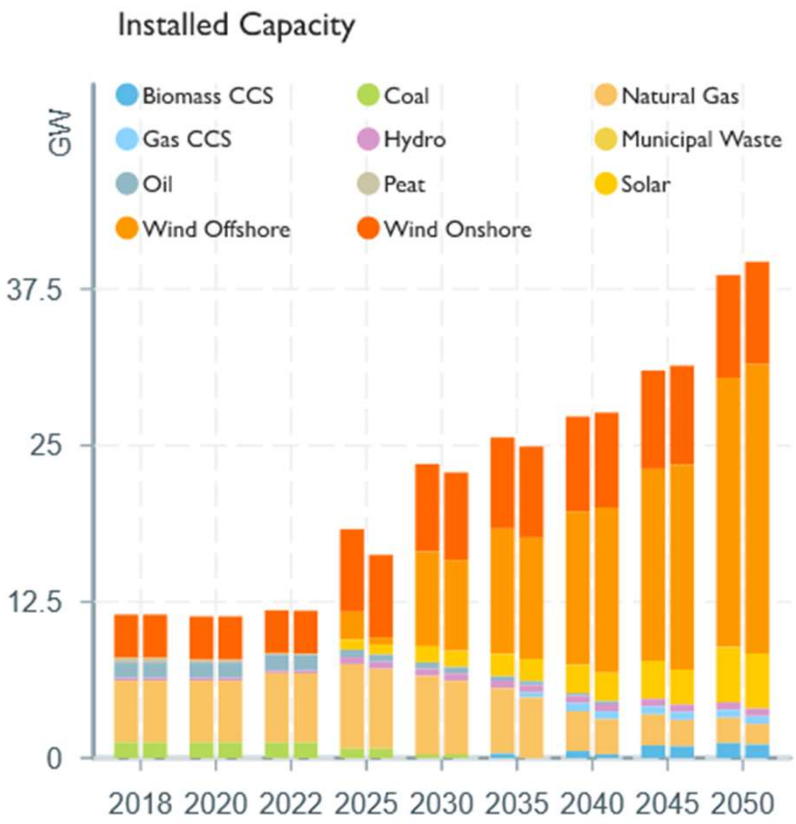
CO_2 emissions savings by sector – 2018-2030 and by scenario



Fossil fuels fall from 90% of primary energy demand to 49-57% in 2030



Power generation

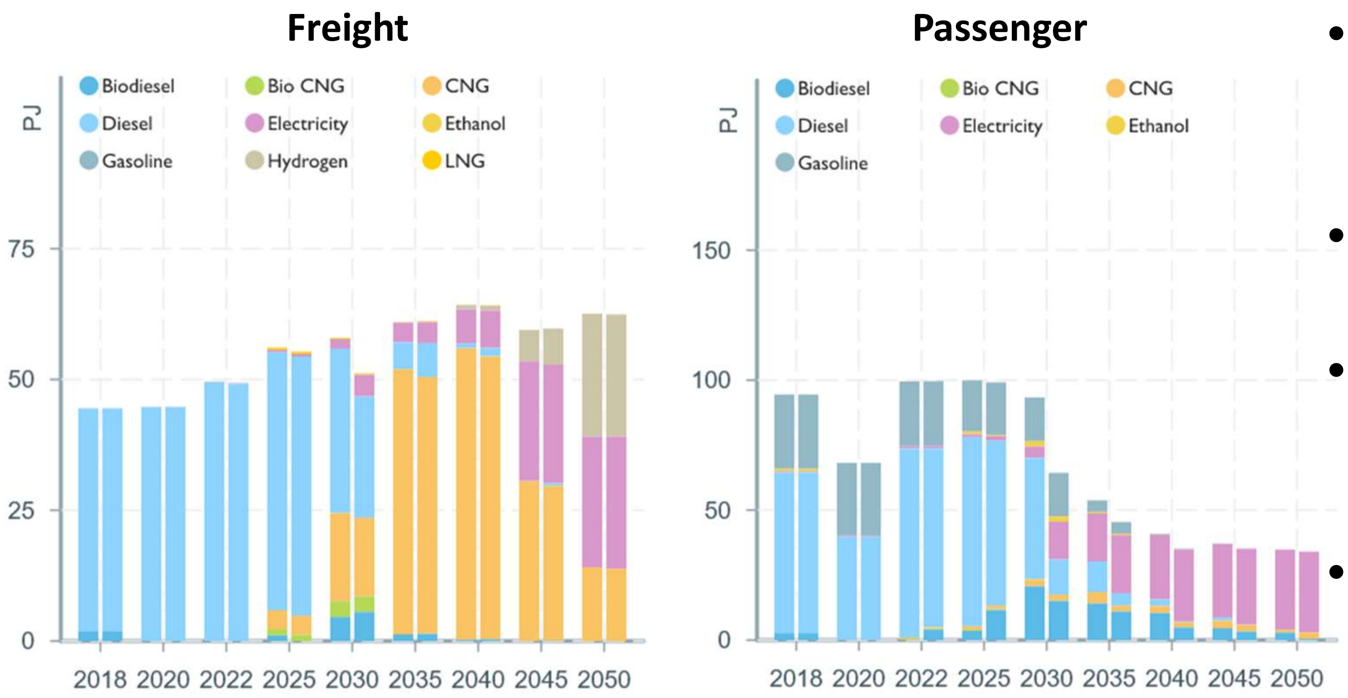


E-49% (left), E-69% (right)

- All scenarios grow renewables potentials to our maximum feasible level in 2030
    - 75% renewable electricity generation (RES-E)
    - 7.5 GW offshore wind capacity in 2030; ~2 GW already in 2025
    - 7 GW onshore wind in 2030; already 6.6 GW in 2025 (3.5 GW in 2017)
    - 1.3 GW solar in 2030

Transport sector

Transport final energy consumption

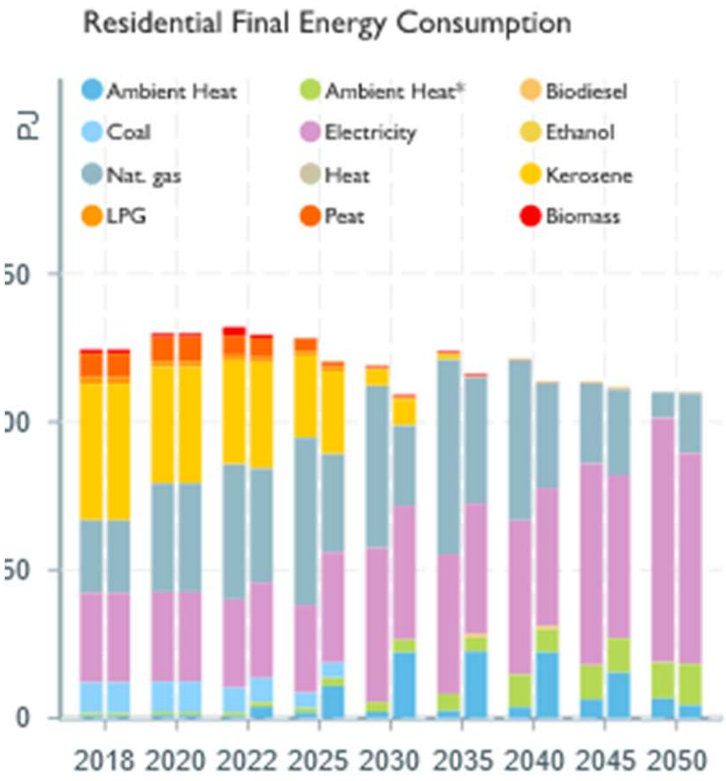


E-49% (left), E-69% (right)

Achieving the 2030 target

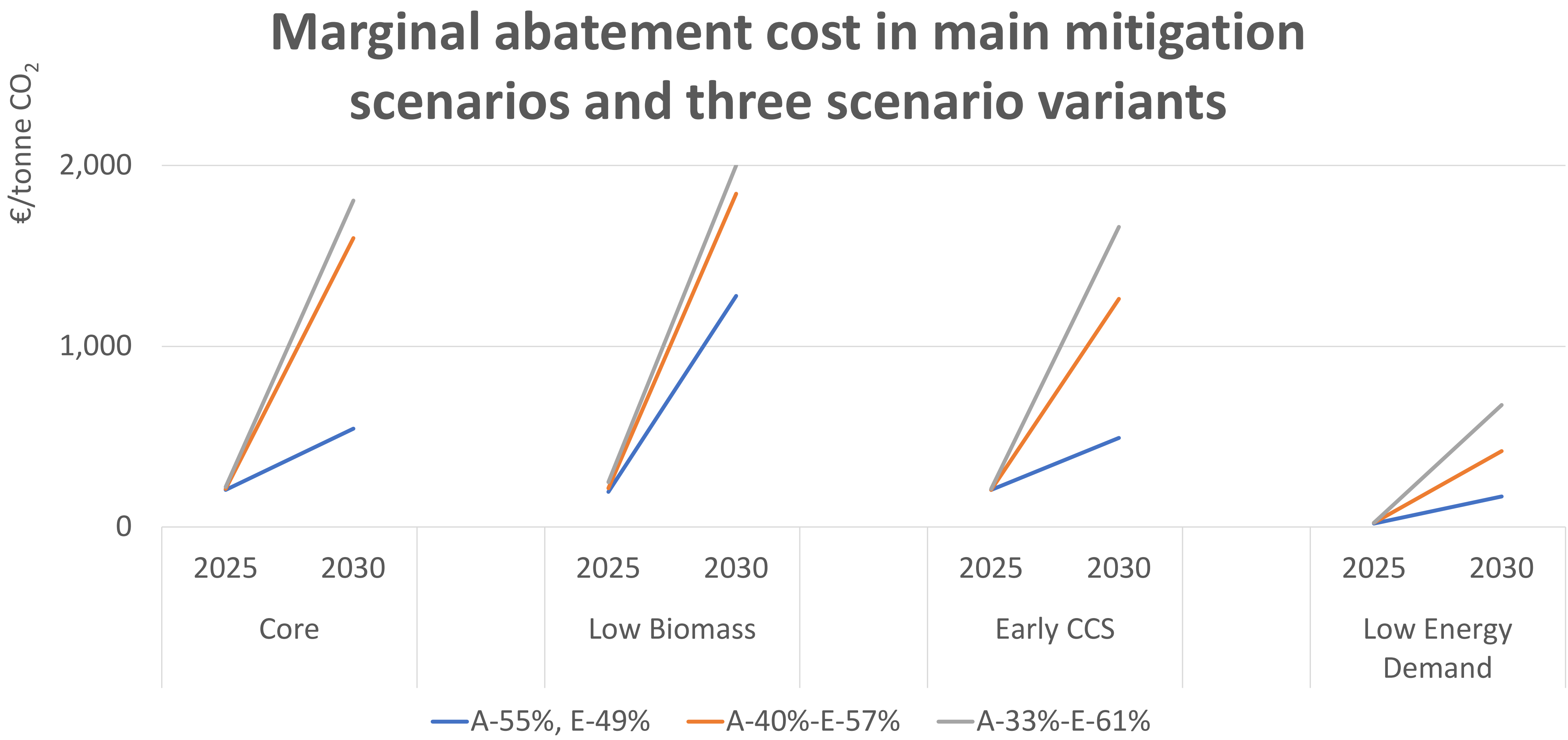
- Maximising electrification of transport (cars & vans)
- Additional biofuel blending
- Lower carbon freight fuels, like CNG and biogas
- 1.4 million EV passenger cars by 2030 in E-69% requires almost all sales from now or early retirement of fossil fuels cars

Residential sector



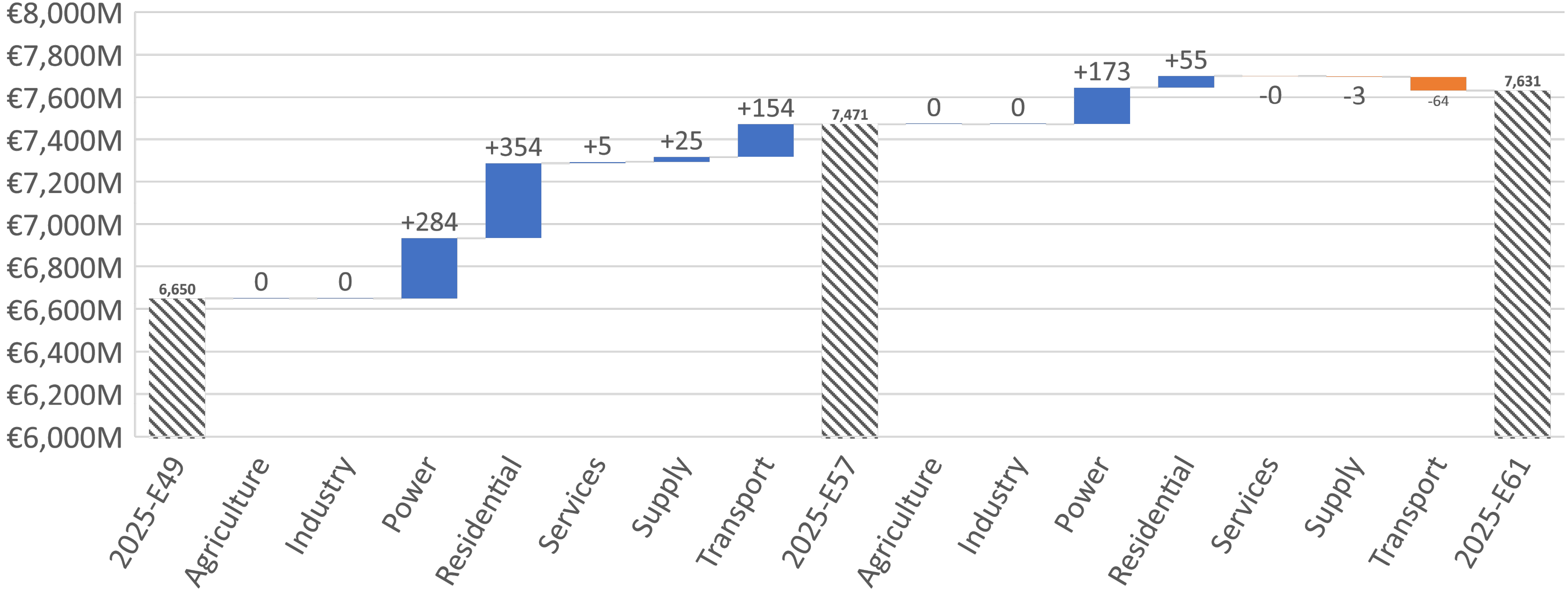
E-49% (left), E-69% (right)

- Complete removal of coal and peat heating
- Up to 613,000 retrofits between 2020 & 2030
- 80% reduction in kerosene heating between 2018 and 2030
- Large-scale electrification of heating
- District heating in apartments



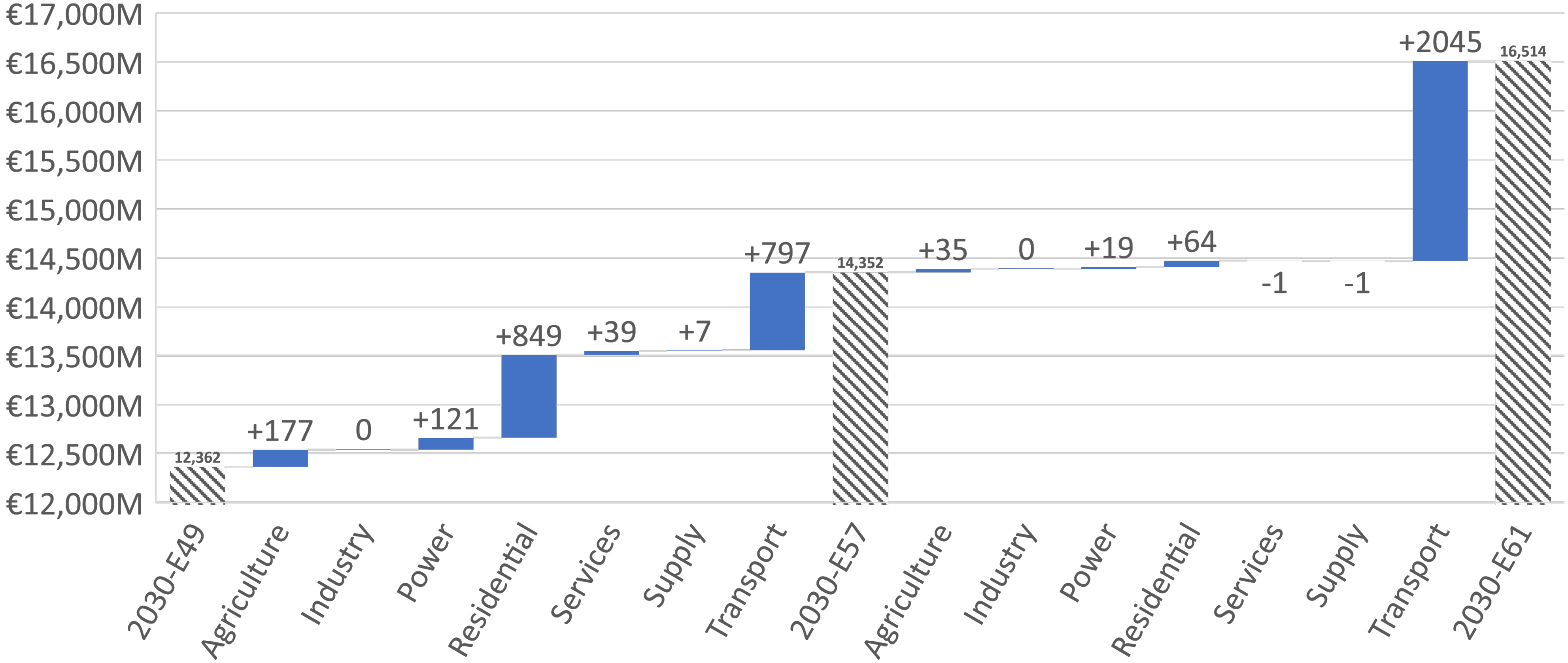
The Marginal Abatement Cost represents the cost of mitigating the most expensive tonne of CO_2 in each scenario for the energy sector

Additional costs in 2025



Annualised undiscounted investment, OM, Fixed and fuel costs

Additional costs in 2030



Annualised undiscounted investment, OM, Fixed and fuel costs

Conclusions

- Very high marginal abatement cost due to near-term ambition
- Small additional decarbonization efforts leads to much higher marginal cost
- Results very sensitive to assumptions on new technology speed & availability
- Careful sensitivity analysis & multi-model analysis needed
- 2030 is on the path to net-zero in 2050 -
- Key questions to be refined:
  - What level of mitigation for energy vs agriculture?
  - What target for 2025 – front- or backloading?
  - What level of bioenergy availability (domestic and imports)? H2?
  - Timing of availability of CCS & bio-CCS?
  - What speed of deployment of EVs, heat pumps etc?
  - What (if any) level of demand reduction?

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Thank you

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Additional considerations

- The speed and scale of change needed across the energy system required to meet even a 51% reduction target stretches the model to the limits
  - "Here be dragons"
- Feasibility is very highly dependent on the assumed cost, availability and speed of deployment of **<u>new</u>** low-carbon technologies and fuels
  - CCS for cement & power, hydrogen and bioenergy (production or import), electric freight
  - Domestic bioenergy & Bio-CCS interact with agriculture, compete for land-use & negative emission credits
- Lower energy service demands can't be modelled "endogenously"
  - Lowering transport demand, mode shift, lowering household temperatures, economic structure
  - But lowering energy demands in the "Low Energy Demand" scenario makes decarbonisation more feasible
- TIM considers costs to the system, but not all costs related to infrastructure, but does not consider who pays or what policies can achieve the target

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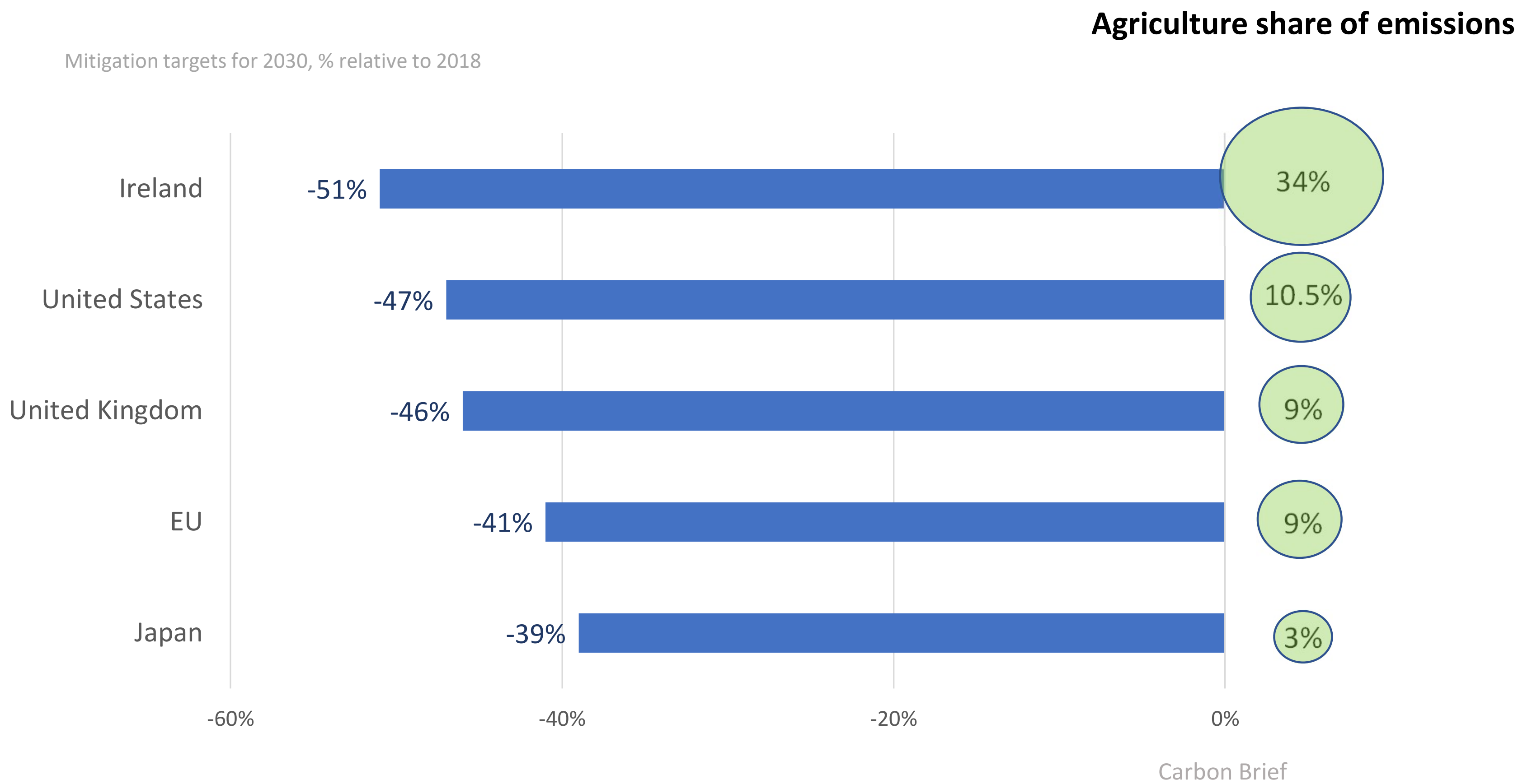
Ireland has the highest 2030 decarbonisation target



Ireland's high share of emissions from agriculture make this target even more challenging

Terms of reference for developing carbon budgets

Top-down: Estimate an appropriate carbon budget for Ireland for the period 2021 – 2050 based on consideration of the global carbon budget [addressing criteria: national climate objective, UN, Paris Agreement, **science**, climate justice]

a. The **potential for negative emissions**
b. The **role of different gases**
c. The global carbon budget

Bottom-up: Consider what legislative requirements at national and EU level mean for emissions up to 2030, covering the first two carbon budgets. [addressing criteria: national climate objective, 51%, **EU, inventories and projections, science**, reporting, **economy**, and **climate justice**]

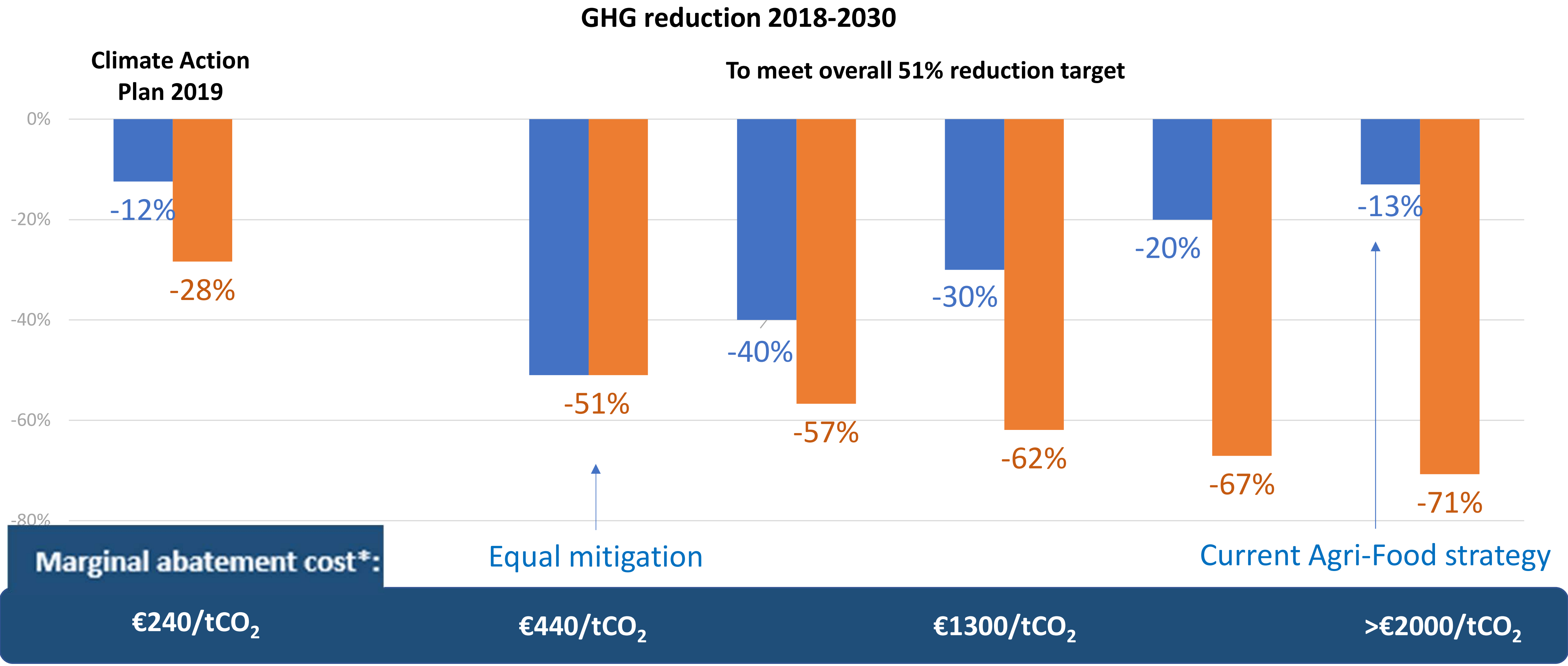
a. The implication of required compliance with **EU and National Targets** (e.g. 51%) incl. treatment/inclusion of LULUCF
b. **Feasibility, competitiveness impacts, implications for investment**
c. **Distributional impacts, jobs**

Factors in green require a consideration of not just what size is the carbon budget, but how it is allocated over time and over sectors and how policies and measures deliver mitigation

Near-term development timeline

❖ March 12-26th	Expert review stage
❖ March 29th-April 16th	Model developments in response to review comments
❖ By April 16th	Finalised scenario results
❖ By April 30th	Draft report to DECC
❖ Early May	Publication of final report with interactive website
❖ May onwards	Further model enhancements, developments, collaborations and publications.

Low agriculture abatement requires other sectors to do more



■ Agriculture ■ Energy, process & waste

*Preliminary analysis on energy & process emissions marginal abatement cost with TIMES-Ireland Model

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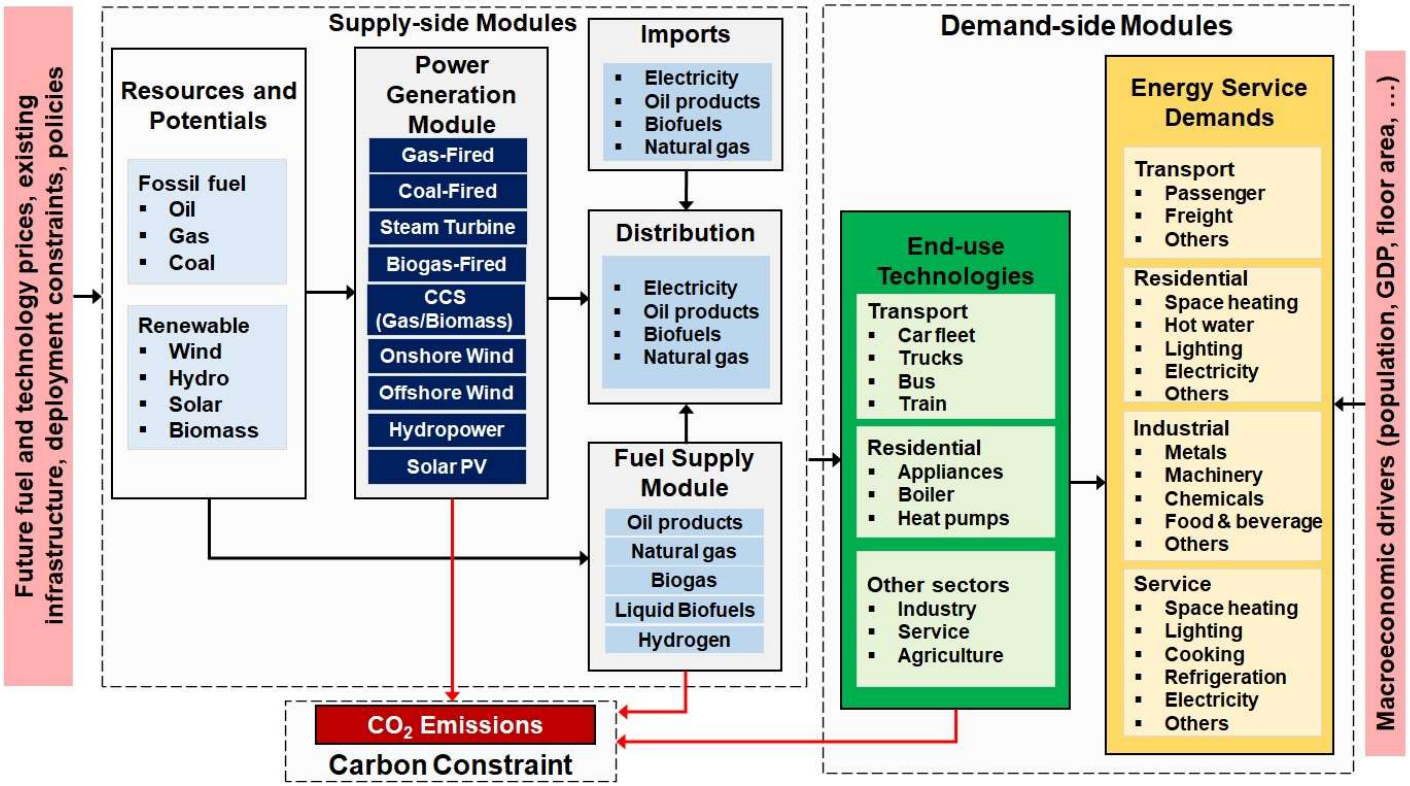

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Reflections on the use of TIM for informing the National Climate Objective

What questions can TIM inform in the short term?

- What energy system changes would be needed to meet given decarbonisation targets (budget or given year)
- For an "all-time carbon budget", what is the "optimal" energy decarbonisation pathway over time and across sectors?
- What is the "effort gap" between current measures and what is needed, sector-by-sector?
- What is the impact of excluding mitigation options (or adding new options)? <u>"Feasibility"</u>

What can TIM not (yet) inform?

- What should the carbon budget for energy vs. agriculture emissions be?
- Who pays?
- What policies should be used to achieve the target?
- What are the interactions and trade-offs between energy, land-use and food systems for mitigation?
- Services and industry sectors in TIM are currently low-resolution

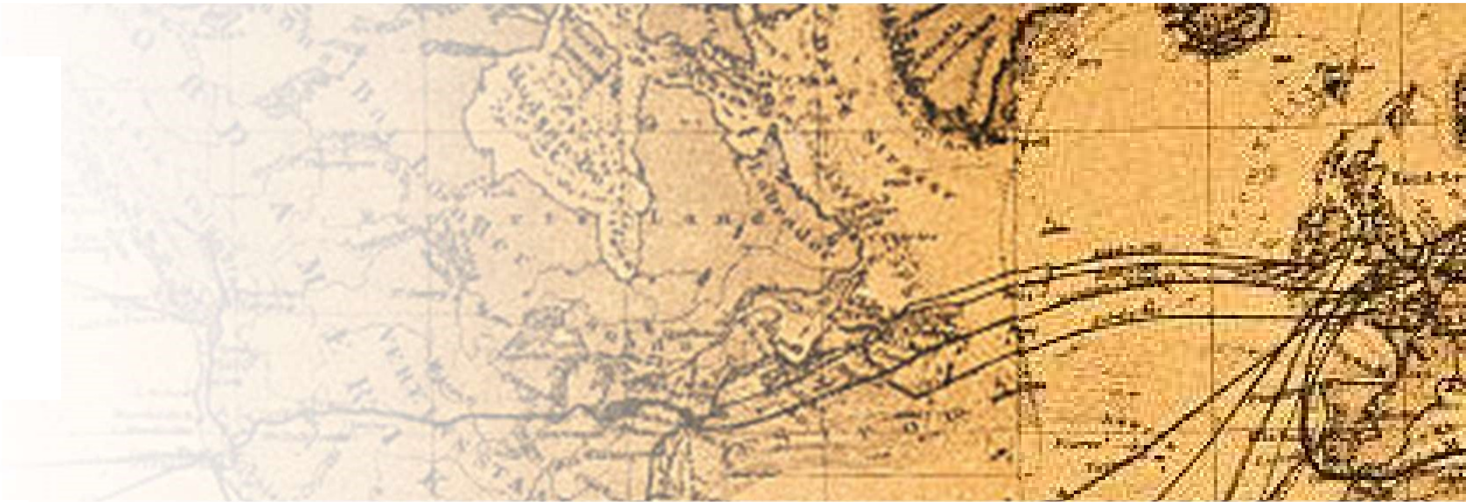
Additional considerations

- We can provide and run the tool – but the "recipe" (constraints, assumptions, etc.) need wider discussion – non-trivial
- Expertise needed for deep dives on different sectors and topics
- Long-term model maintenance, updating and development requires stable funding base, long planning horizon, and the ability to attract and retain top modellers.

Strengths of TIM & development process

- Model to be fully **open-source** – documentation can be downloaded here: https://tim-review1.netlify.app/documentation
- "Best-practice" **development approach** – Git used for version control and integration, open web app for results analysis & diagnostics
- Developers with **international expertise** and links with global TIMES community, allowing knowledge-sharing
- Using **TIMES framework** – well-proven, high quality, continuously developed/maintained, open source code
- **Flexible integration** – Simultaneously maintaining "stable, policy-ready" model and development of research variants, allowing innovations in ESOMs, pushing state-of-the-art – leveraging across projects
- Strength of **systems approach** – automatic "sector coupling" by design – where is the best use of resources? What are sectoral trade-offs?
- Extensive **stakeholder review** (https://tim-review1.netlify.app/)
- Training PhDs, interns etc. & wider engagement integral for national **capacity-building**
- A focus on **alternate scenarios**, sensitivities, "what if" analyses
- **Dynamic integration** with national data sources and other national models (where possible)
  - Will allow for "low-effort" updates going forward
  - I3E/COSMO (macro-economy), PLEXOS (power system), LEAP/Car Stock Model (transport & residential sectors)

Why model?



- One model doesn't give a prescriptive answer, in the same way a map doesn't tell us which route to take along a journey, or what the destination is. However, models (like maps) are indispensable for considering options & routes, as tools to collect best evidence, facilitating discussion and decision-making.

Models help us to make meaningful, consistent narratives of energy system transformation

- Achieving net-zero GHG energy systems require each sector to go as low as possible. Energy systems optimisation models provide a "big-picture approach":
  - Help prevent blind-spots
  - Ensure that the best of all options are considered, respecting national constraints
  - Important to consider system-wide dynamics and trade-offs

Scenarios for upcoming study

Scenario	Description
A. Core	Mitigation trajectory – can assume linear trajectories to 2030 and 2050 targets, based on different effort-sharing targets for agri & energy, or apply carbon budgets. Key resource and technology availability assumptions for bioenergy, wind, end-use technologies and CCS availability
B. Low Energy Demand	What if we focus on lowering energy demands?
C. High wind	What will it take for the power sector to deliver, and can it go further?
D. How far can we go in energy?	Can the energy system decarbonise deeper, faster, if agriculture does not scale up target?
E. “Green Precedent”	What if key low-carbon technologies fail to diffuse as quickly as hoped?

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