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How higher spatial resolution impacts energy systems analysis: Evidence from multi-region TIMES-Ireland model

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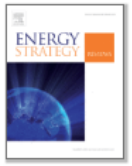

A review of spatial resolution and regionalisation in national-scale energy systems optimisation models

Vahid Aryanpur [a, b], Brian O'Gallachoir [a, b], Hancheng Dai [c], Wenying Chen [d], James Glynn [a, b, e]

https://doi.org/10.5194/gmd-2021-359
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Geoscientific Model Development Discussions
Open Access
EGU

TIM: Modelling pathways to meet Ireland's long-term energy system challenges with the TIMES-Ireland Model (v1.0)

Olexandr Balyk[1,2], James Glynn[1,2,3], Vahid Aryanpur[1,2], Ankita Gaur[1,2], Jason McGuire[1,2], Andrew Smith[1,2], Xiufeng Yue[1,2,4], and Hannah Daly[1,2]

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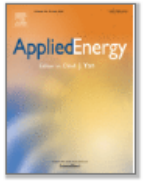
Volume 316, 15 June 2022, 119078



Decarbonisation of passenger light-duty vehicles using spatially resolved TIMES-Ireland Model

Vahid Aryanpur [a, b], Olexandr Balyk [a, b], Hannah Daly [a, b], Brian Ó Gallachóir [a, b], James Glynn [a, b, c]

CHIMERA
marei.ie/project/chimera/

EPMG
ENERGY POLICY & MODELLING GROUP

CAPACITY
CLIMATE ACTION PATHWAYS & ABSORPTIVE CAPACITY
marei.ie/project/capacity/

Further details:

GitHub https://github.com/MaREI-EPMG/times-ireland-model

zenodo https://zenodo.org/record/5517363

Results https://tim-carbon-budgets-2021.netlify.app/results

Background and scope

❑ Background:

- **Problem:** Energy systems models are usually criticised for the aggregate treatment of spatial dynamics.
- **Solution:** Sub-national details should be incorporated into the national energy system analysis.

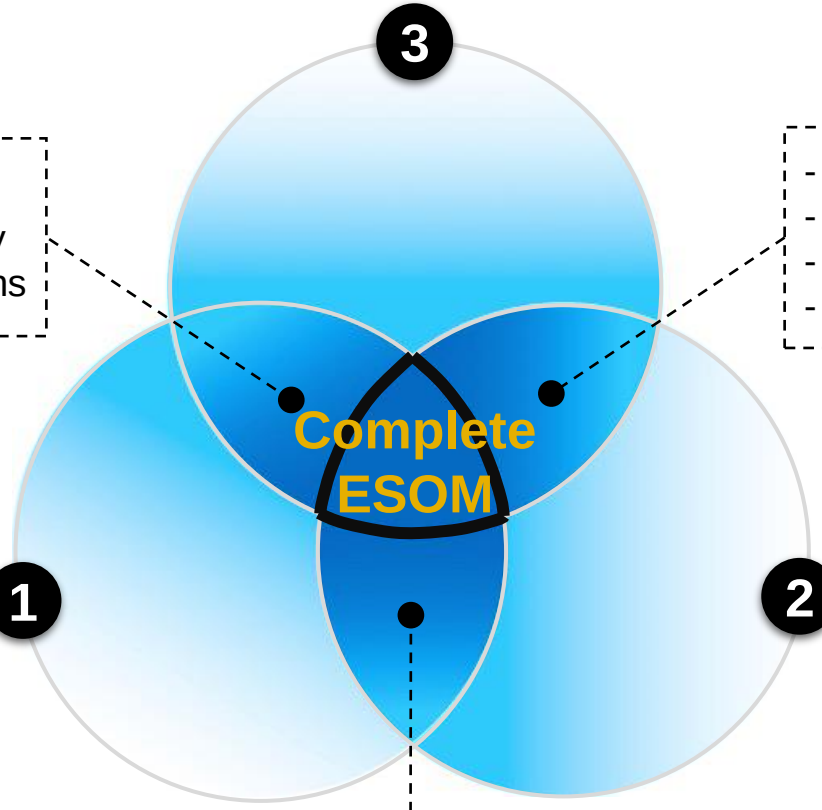
❑ Outlines:

I. Reviewing existing national-scale ESOMs
II. Evidence from multi-region TIMES-Ireland Model
III. Lessons learnt from review
IV. Lessons learnt from TIM

Motivations for higher spatial resolution

Socio-economic, environmental & political motivations

- Demographics, Regional responsibilities, Political acceptability
- Local actors, stakeholders, Income level



- Equitable generation
- Environmental impacts & energy security
- Social resistance against new installations

- Regional consumer affordability
- Regional willingness to pay
- Region-specific financial incentives
- Energy consumption habits

Supply-side motivations

- VRE generation potential
- Infrastructure development
- Regional resource endowment

Demand-side motivations

- Regional demand variability
- Regional consumer preferences
- Impact of climate condition on demand

- Load-following and storage technologies
- Centralized vs. decentralized energy supply
- VRE generation and demand fluctuation

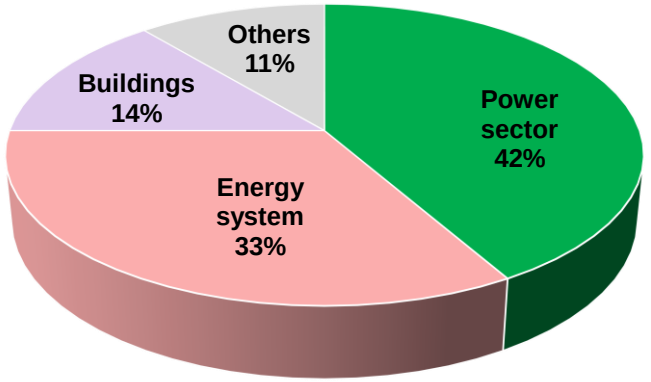
Legend

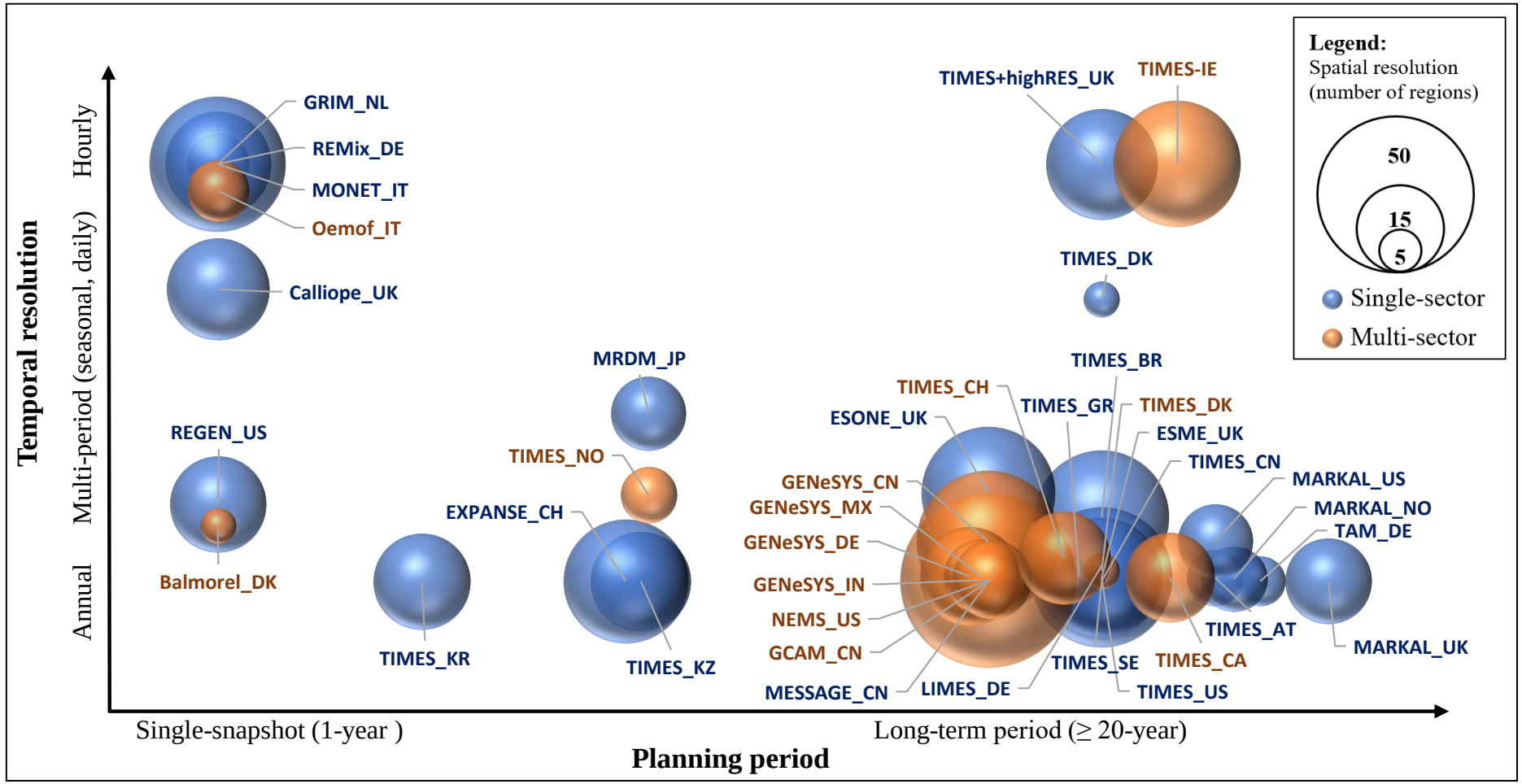
Stylised — Complete

❑ Filtration process: National-scale multi-region ESOM

- 1024 publications
- 76 national-scale
- 36 models
- 22 countries

Sectoral focus

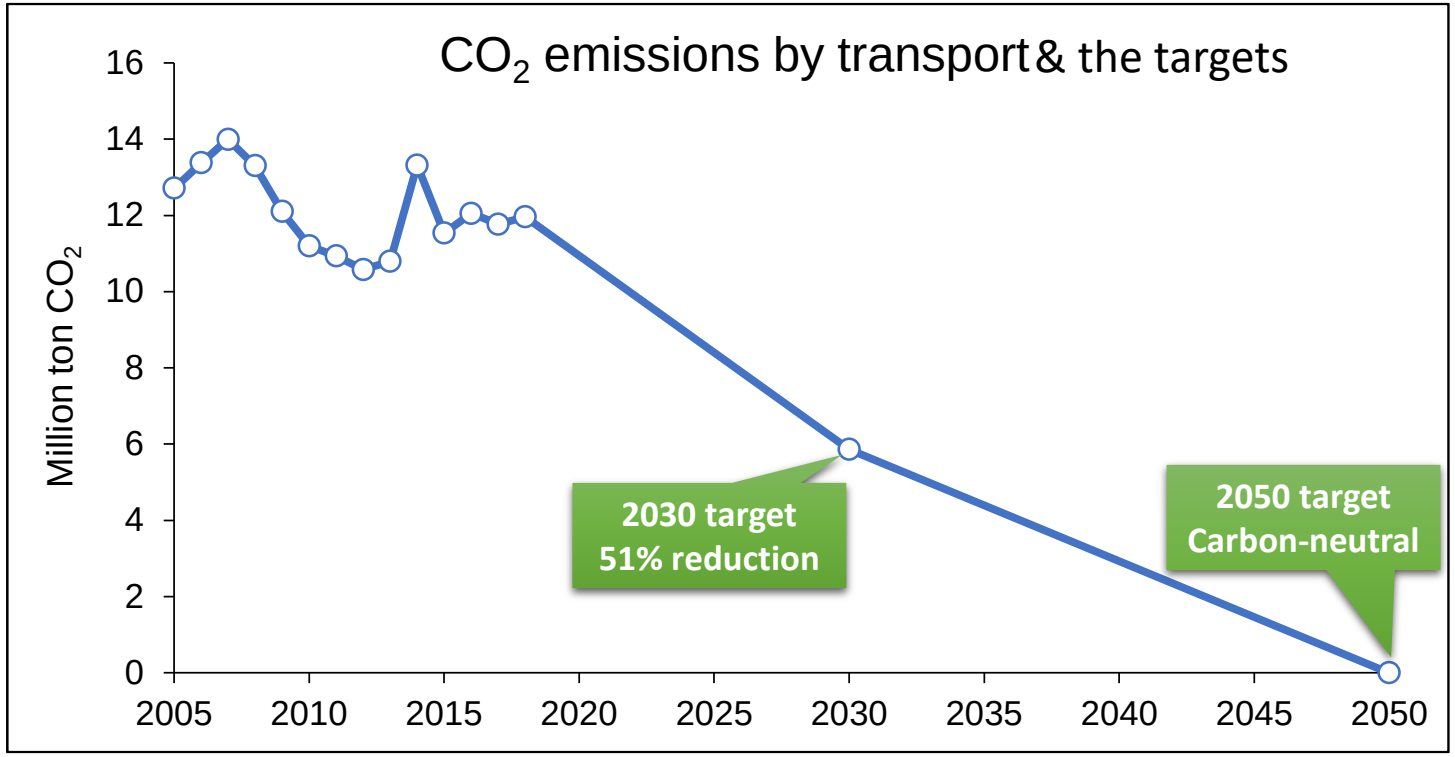


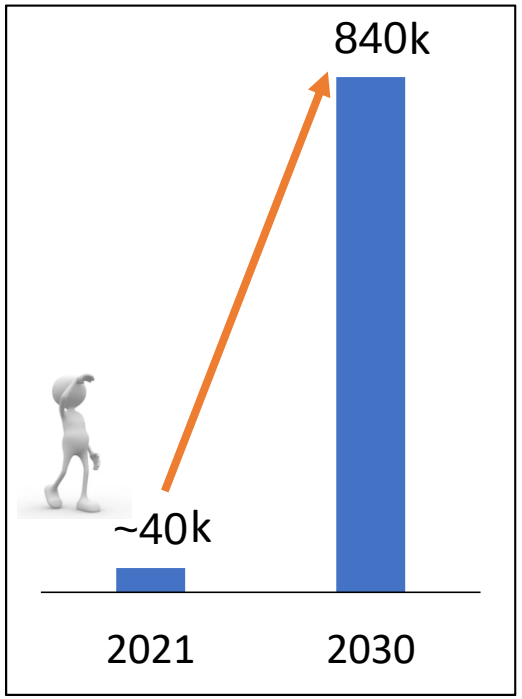


Source: Aryanpur V, O'Gallachoir B, Dai H, Chen W, Glynn J. A review of spatial resolution and regionalisation in national-scale energy systems optimisation models. Energy Strategy Reviews. 2021;37:100702.21 (link)

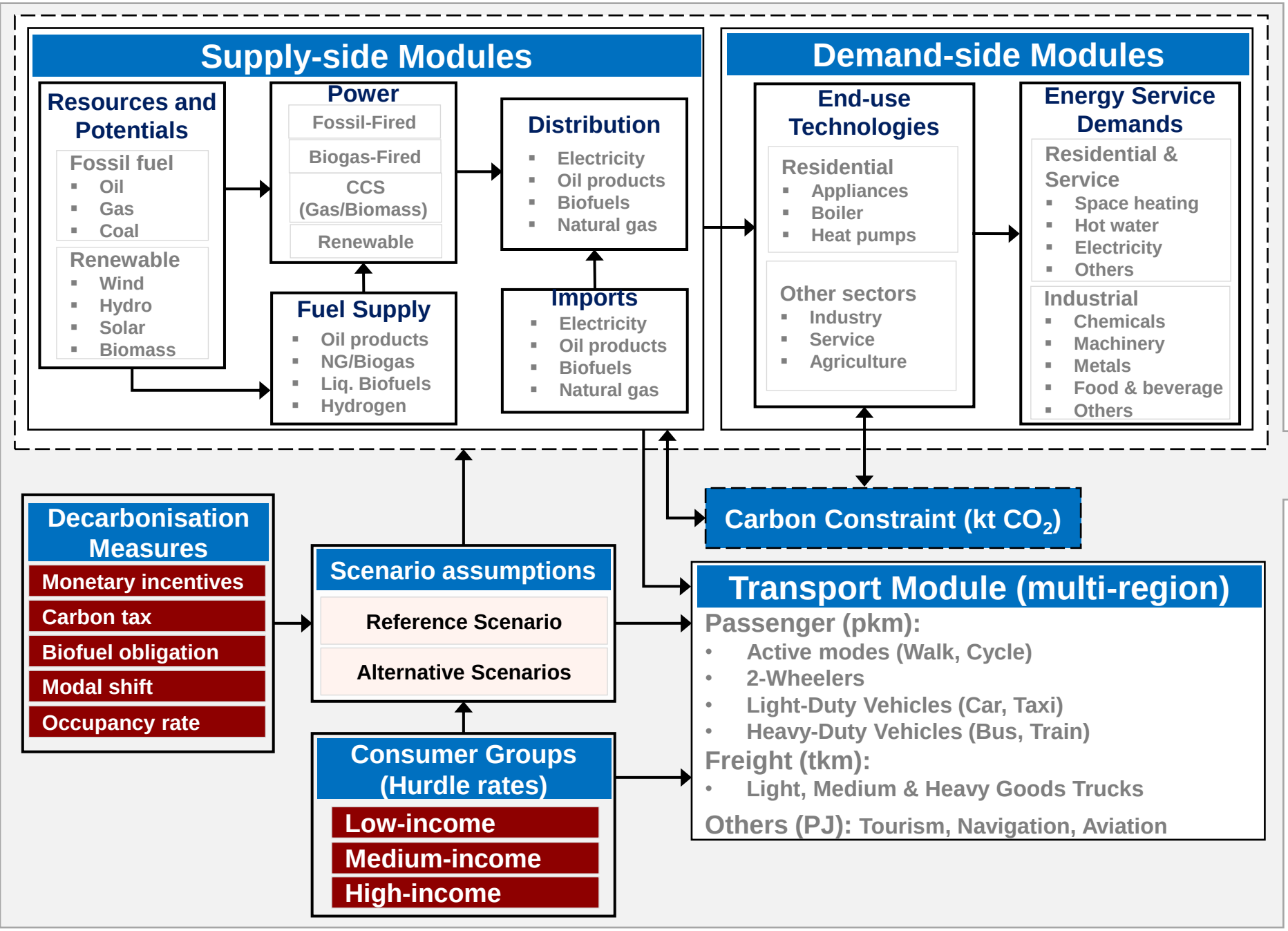
Ireland's Climate Action Plan (CAP)

- Transport is the **largest energy-consuming sector** in Ireland (>40%)
- This sector significantly relies on fossil fuels (**~40%** of energy-related CO_2 emissions)
- **Private cars** are responsible for the largest share of transport **emissions at 40%**
- CAP: a **51% reduction** in GHG emissions by 2030 and **carbon-neutral** society by 2050





Supporting EV adoption by monetary incentives



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TIMES-Ireland Model (TIM)

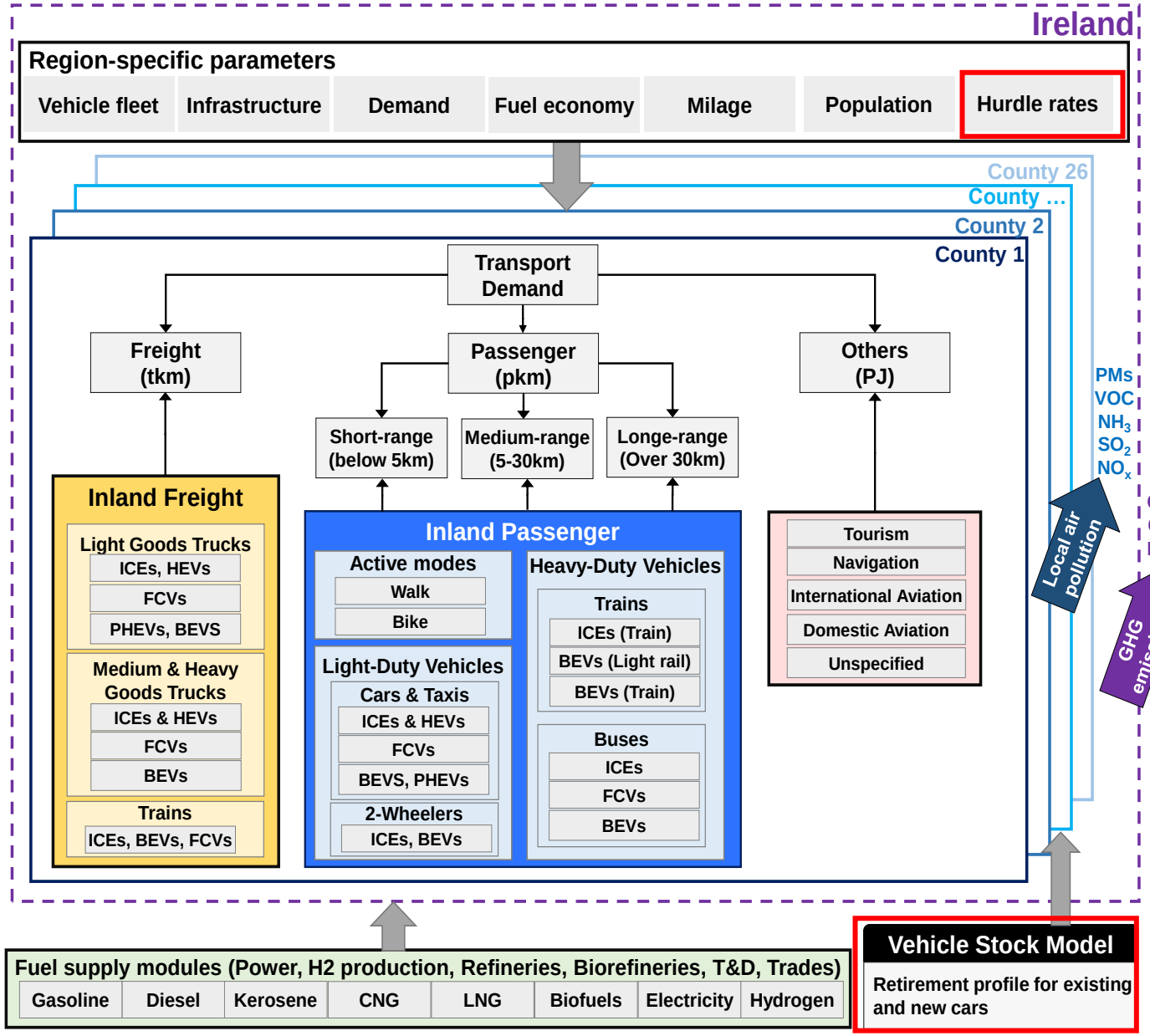
- Impacts of policy measures on emissions reductions

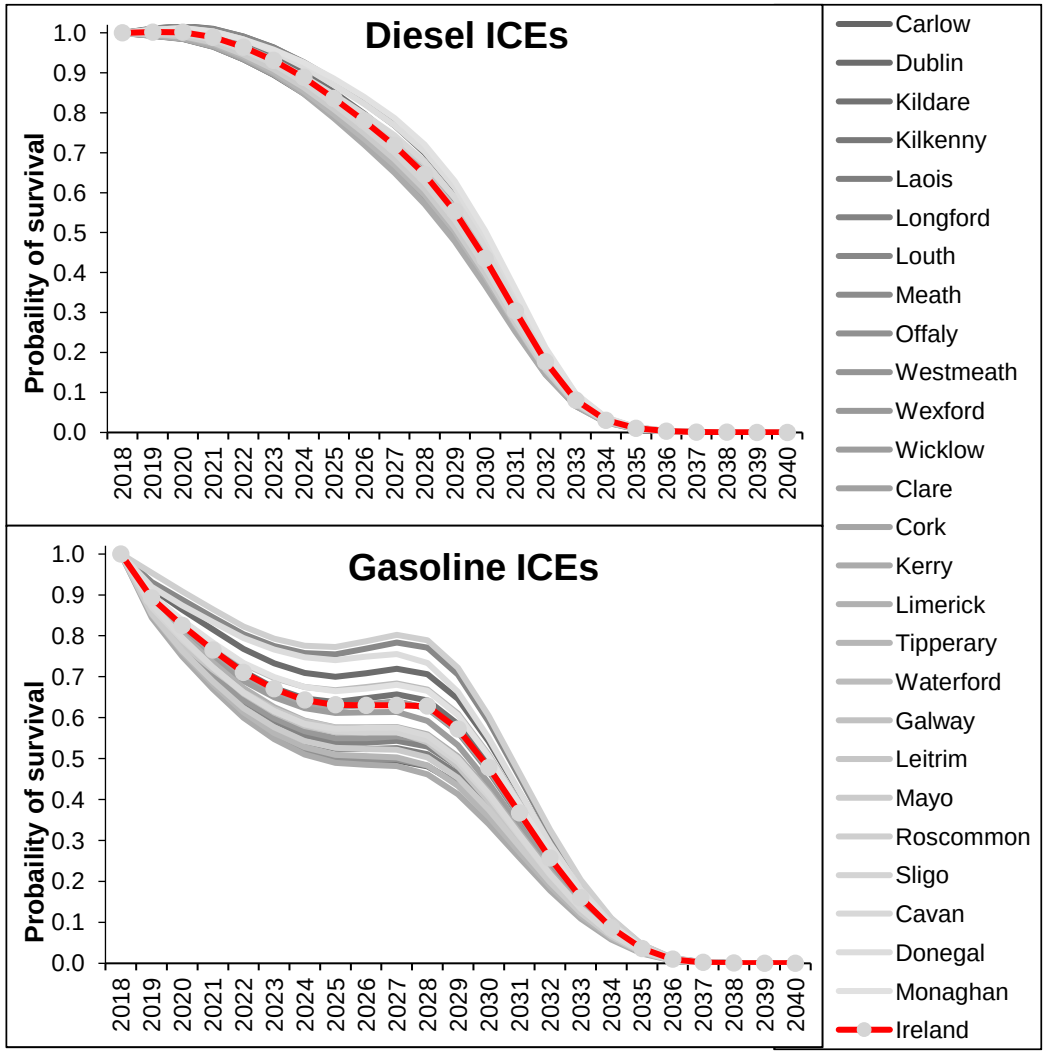
- Impact of region-specific characteristics (consumer heterogeneity) on EV adoption

- Higher spatial-resolution impact results

Description of TIM: Balyk O, Glynn J, Aryanpur V, Gaur A, McGuire J, Smith A, Yue X, Daly H. TIM: Modelling pathways to meet Ireland's long-term energy system challenges with the TIMES-Ireland Model (v1. 0). Geoscientific Model Development Discussions. 2021 Nov 22:1-45 (link).

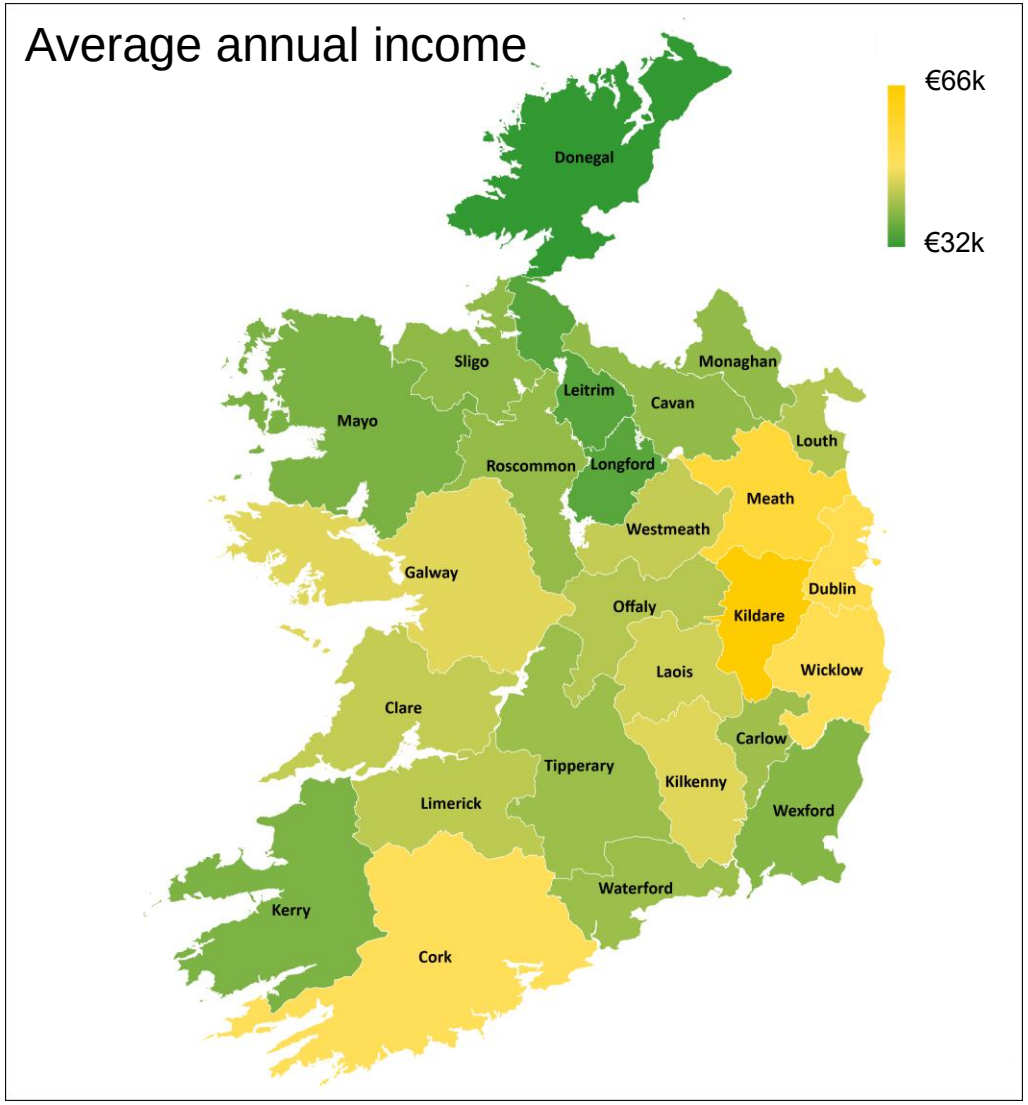
Transport sector structure within TIM

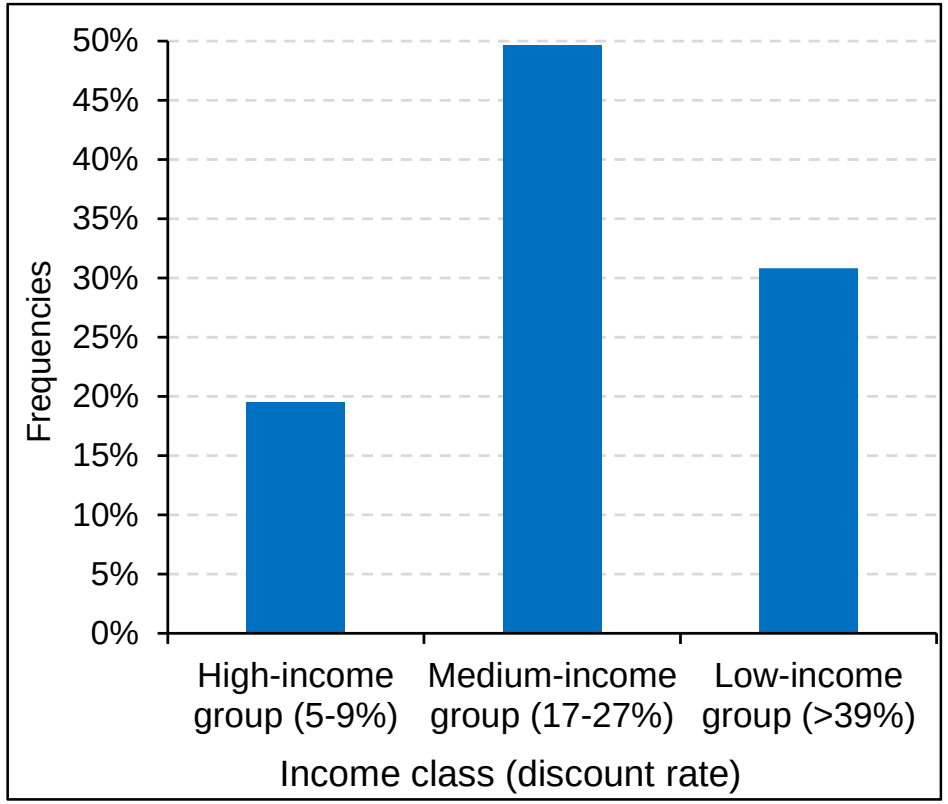




Vehicle Purchase Decision

- **Hurdle rates** are used to capture the consumer behaviour when purchasing a transport technology



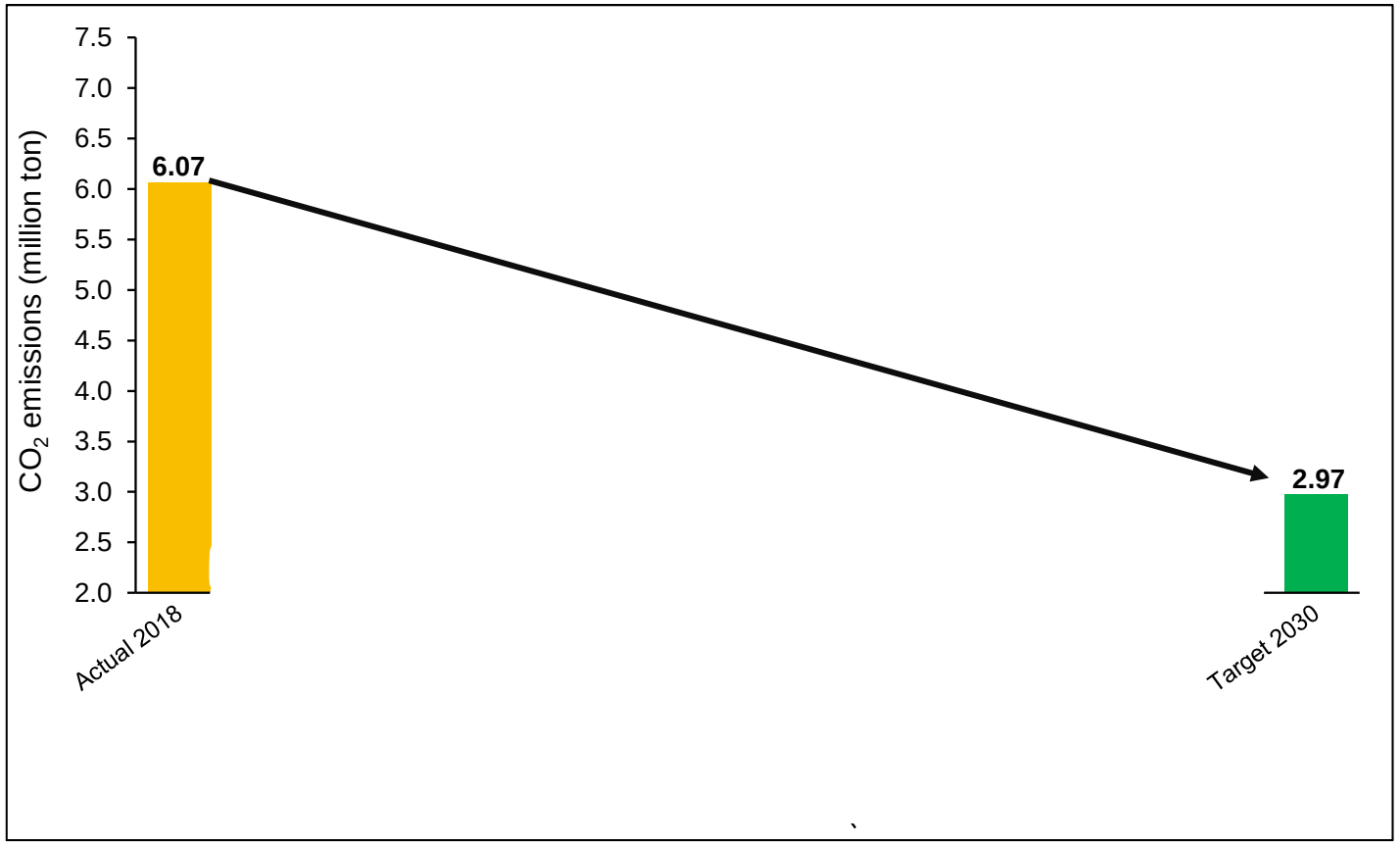


Scenarios

Measures / Scenarios	LDV improvements	Carbon tax	BOS	Radical BOS	Active modes	OR 10% to 70%	MIR2021 to MIR2029
REF	✓						
REF+TAX	✓	✓					
REF+BOS	✓		✓				
REF+RBOS	✓			✓			
REF+Modal	✓				✓		
REF+Tax+Modal	✓	✓			✓		
REF+Tax+BOS	✓	✓	✓				
REF+Modal+BOS	✓		✓		✓		
REF+Tax+Modal+RBOS	✓	✓		✓	✓		
REF+OR	✓					✓	
REF+MIR	✓						✓

REF: reference case without any measures
BOS: Biofuel Obligation Scheme
OR: Occupancy Rate
MIR: Monetary Incentive Removal

Results: CO_2 emissions



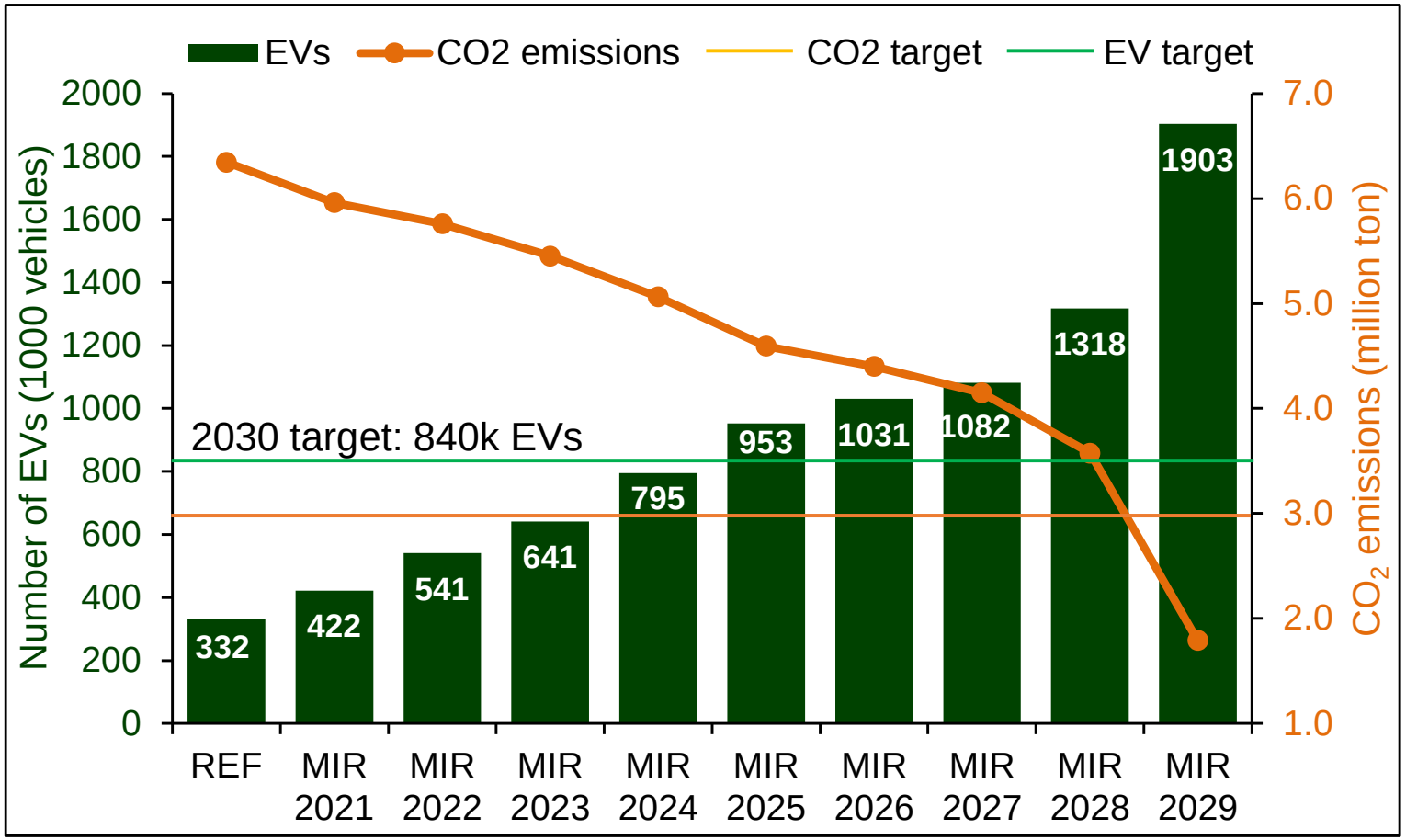
Key point:

- Running scenarios without monetary incentives
- EV adoption is ~330k

Key Results:

- ✓ Individual measures cannot significantly reduce the emissions
- ✓ Shift strategy including fuel switching to biofuels and modal shift can cut CO_2 emissions up to 14%
- ✓ Improve, shift and carbon tax can together contribute to 31% of total reduction

Results: EV adoption



- The early removal may result in significant gap between the target and the probable penetration of EVs

- Monetary incentives, applied individually, are unlikely to achieve the national decarbonisation targets

Spatially resolved distribution of EVs

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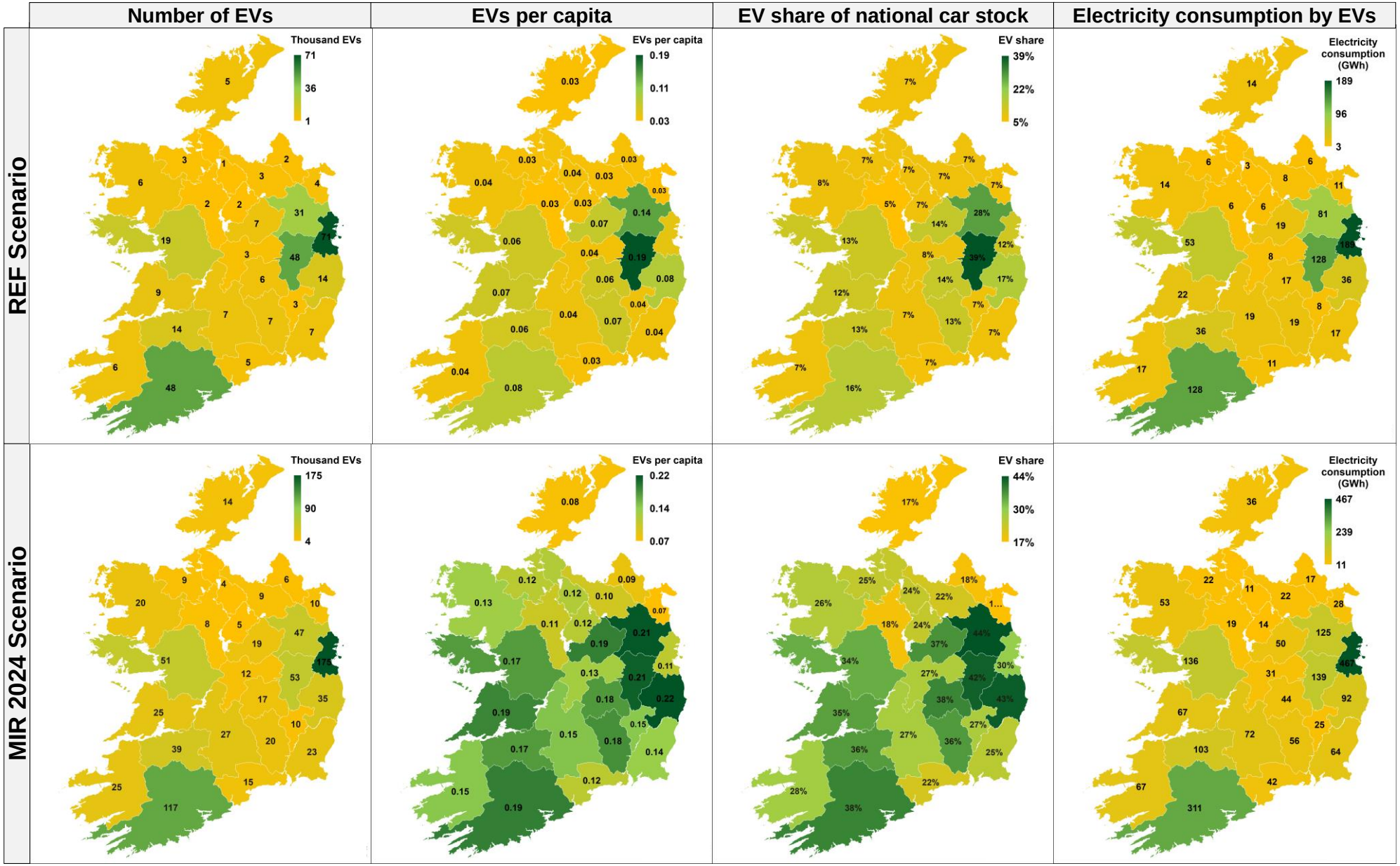
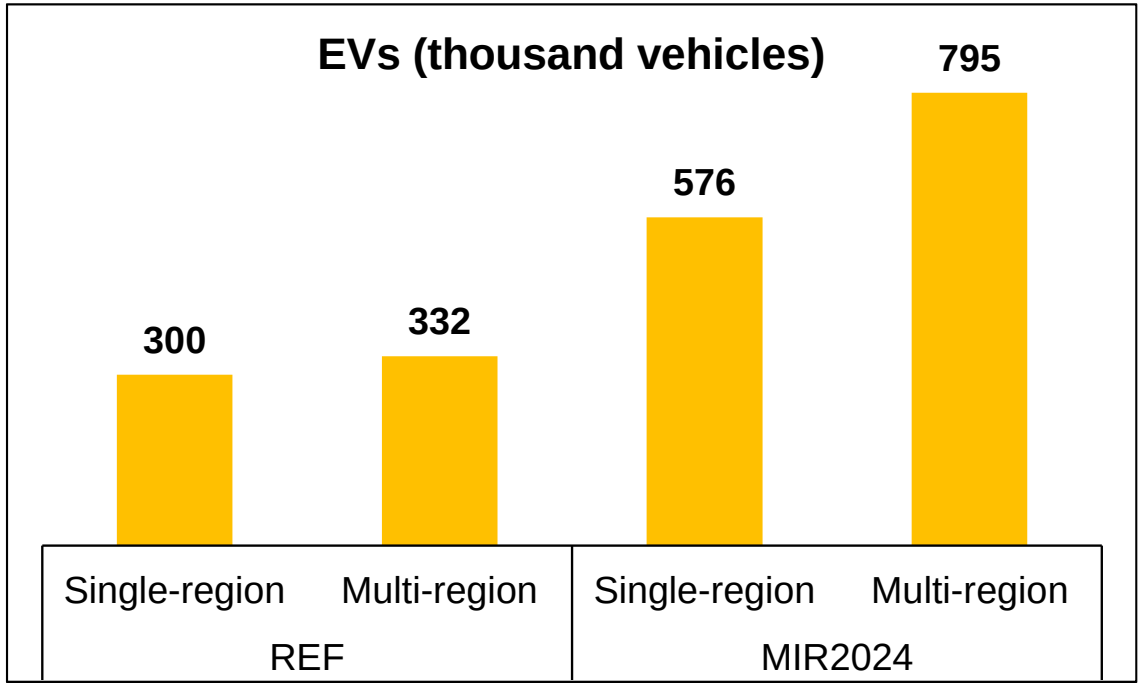
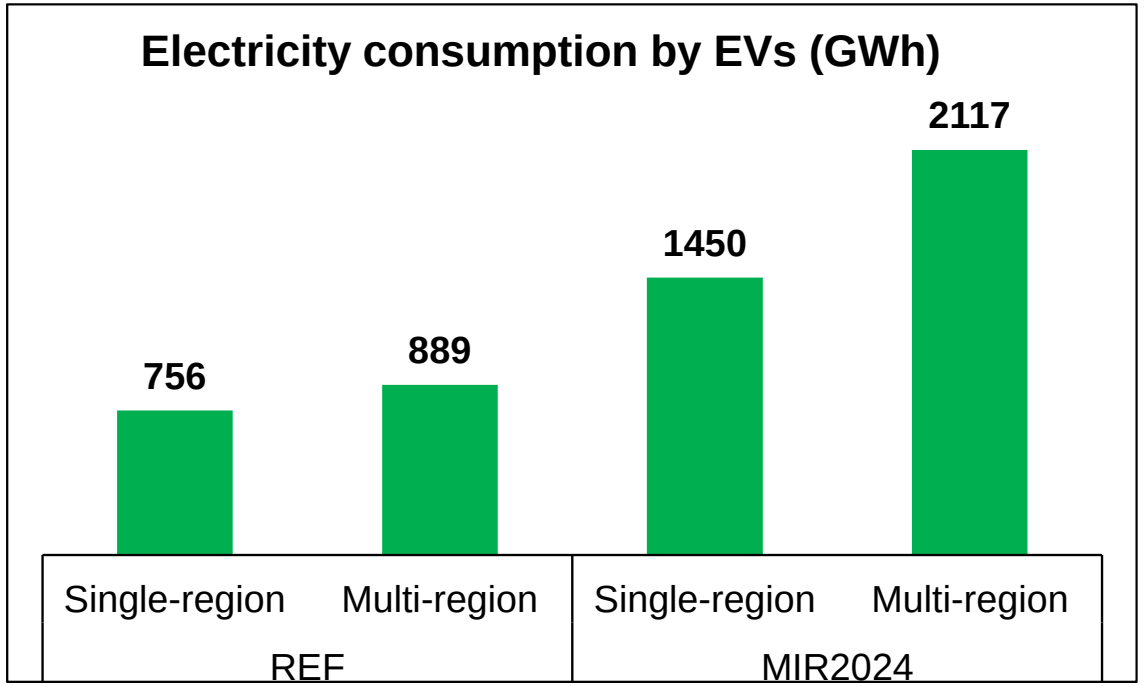


Results: Single-region vs. multi-region

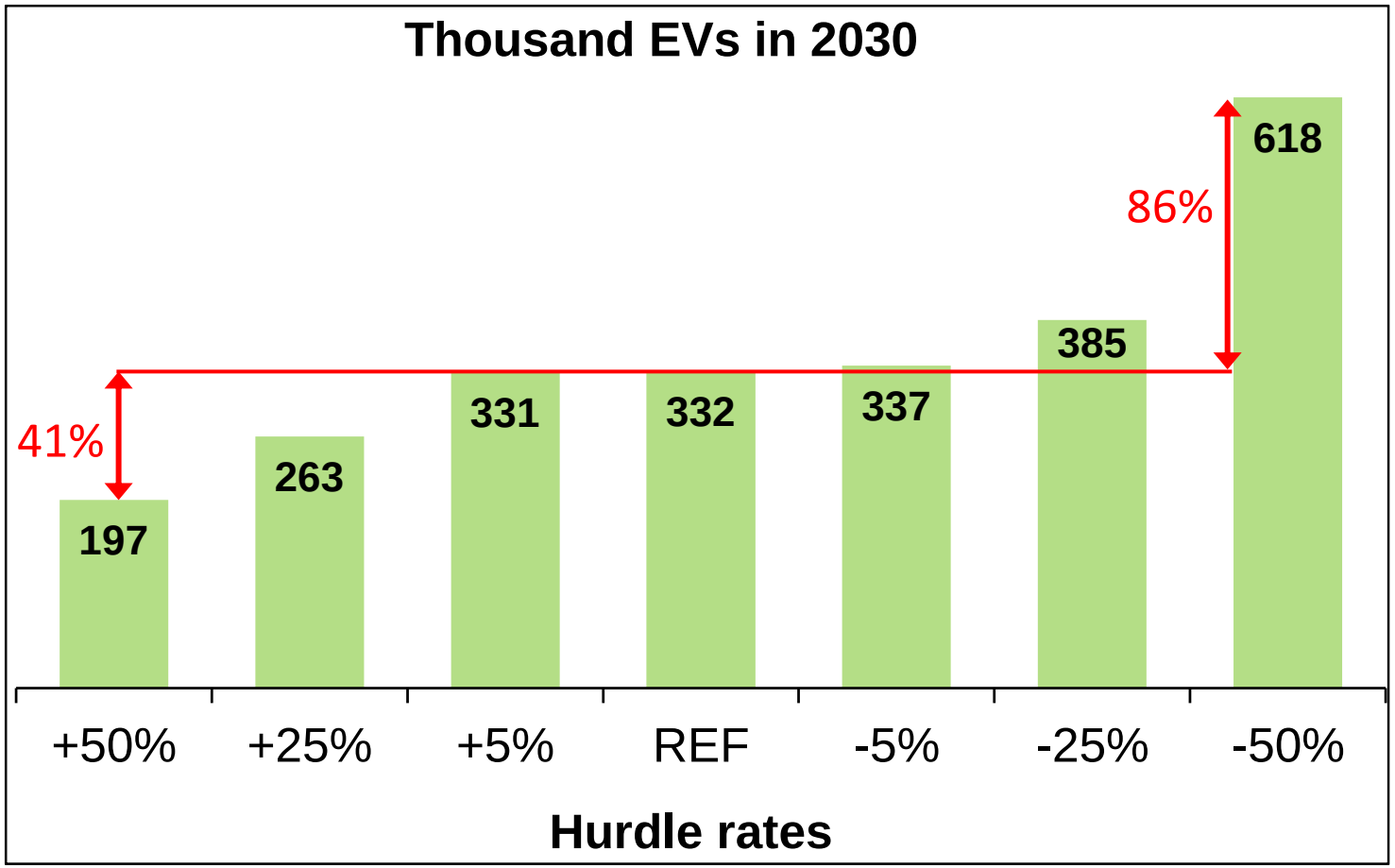




- The averaging process hides the tendency of high-income consumers to purchase EVs
- Average retirement profile is another potential source of divergence

- Higher spatial resolution offers more reliable results for infrastructure development
- Higher spatial resolution can better inform policy makers

Sensitivity analysis



Variations in hurdle rate

±5%: Insensitive

±25%: Almost symmetric

±50%: Unequally change

Lessons from +50% case

Different consumer preferences (non-monetary attributes) could significantly decelerate the EV growth

Lessons from -50% case

Encourage high & medium-income regions to buy EVs. This may increase regional disparities and equity issues.

Source: Aryanpur V, Balyk O, Daly H, Gallachóir BÓ, Glynn J. Decarbonisation of passenger light-duty vehicles using spatially resolved TIMES-Ireland Model. Applied Energy. 2022;316:119078. (link)

Model dimension and solution time

- **Model detail:** >60 Attributes; >150 User Constraints; >300 Commodities; >2000 Technologies
- **Time slices:** 40
- **Planning Horizon:** 2018-2050
- **Number of periods:** 19
- **Computer Spec.:** 16 GB of RAM, Intel® Core™ i7-8705G at 3.1 GHz, 4 Cores

Statistics	Unit	Single-region (national level)	Multi-region* (26 counties)
Number of equations	million	1.2	2.4
Number of variables	million	1.1	2.1
Non-zero elements	million	5.9	11.3
Solution time	min	4.5	9.1
Iterations	number	94	169

* Just transport sector, others are nationally analysed.

Impacts of higher spatial resolution on modelling results

Q1: When?

- Heterogeneous regions (weather-driven variability/energy demands) require more disaggregation
- Homogeneous areas, aggregated modelling is more efficient (reduce data/computational complexity)

Q2: How impact on development of VRES?

- Multi-region: Locations with higher availability → ✚ VRES
- Single-region: Blind to grid bottlenecks and ignore congestion → ✚ VRES
- Single-region: Average resource supply curve reduce the competitiveness → ▬ VRES
- The trade-off should be analysed case-by-case

Q3: How impact on overall system costs?

- Disaggregation of renewable resources leads to lower costs
- Disaggregation of transmission grids leads to higher costs

Lessons from TIM

❑ Insights for modellers

- **Tractability:** Computational time and burden are manageable with a normal PC
- **Flexibility:** Easily switch between single and multi-region option
- **Transparency:** Code and data are publicly available, stakeholder engagement
- **Sensitivity:** Conduct ample scenarios & stress test to understand parametric and structural uncertainties

❑ Policy implications from spatial disaggregation

- More reliable results help to better estimates the requirement for electric vehicle supply equipment
- It addresses equity issues hidden behind subsidy schemes

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