MANCHESTER 1824
The University of Manchester

A pragmatic approach to decarbonising transport in an era of social, financial & technology pressures

Professor Aoife M. Foley
Chair in Net Zero Infrastructure

Thursday 17th November 2023

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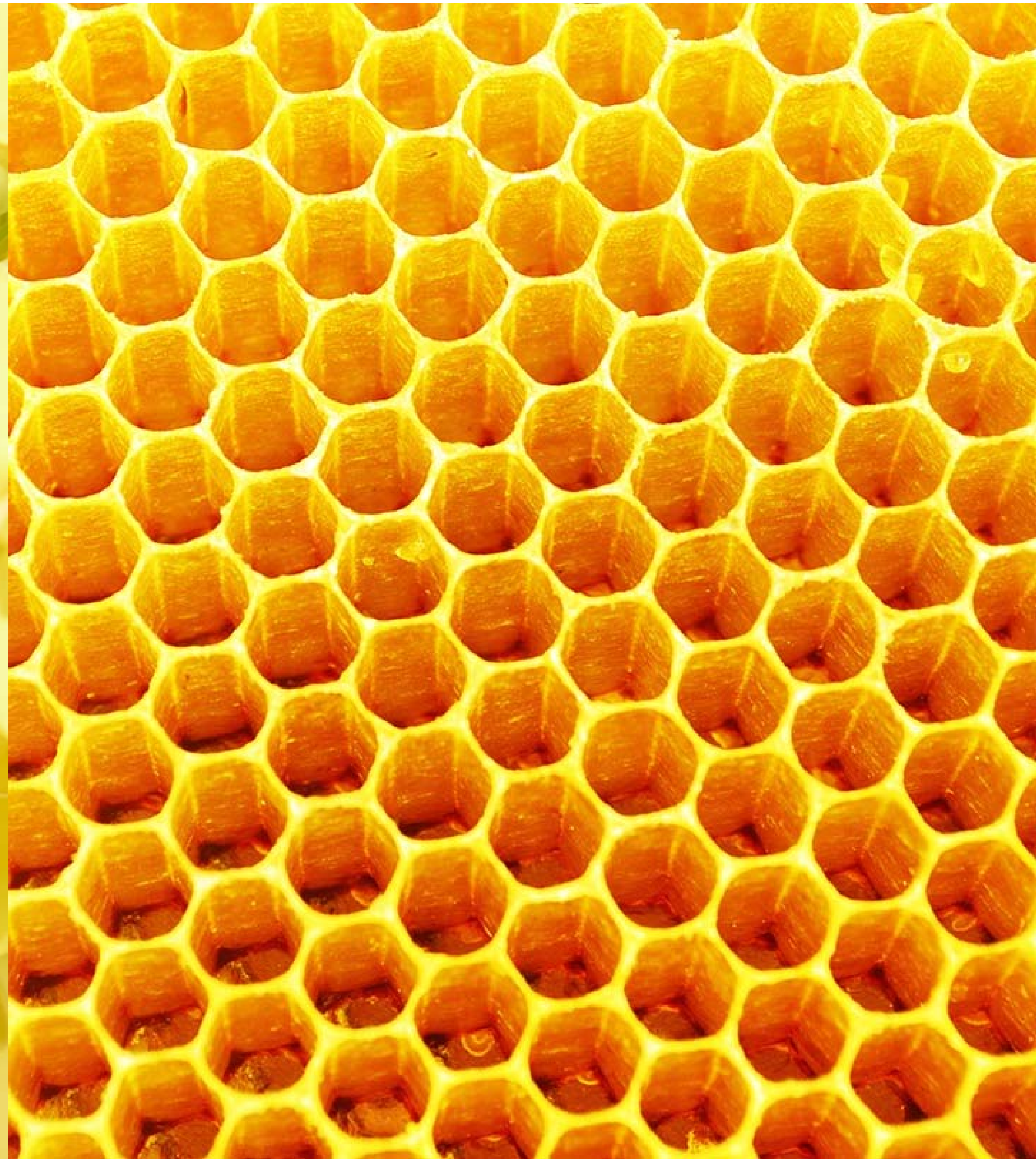

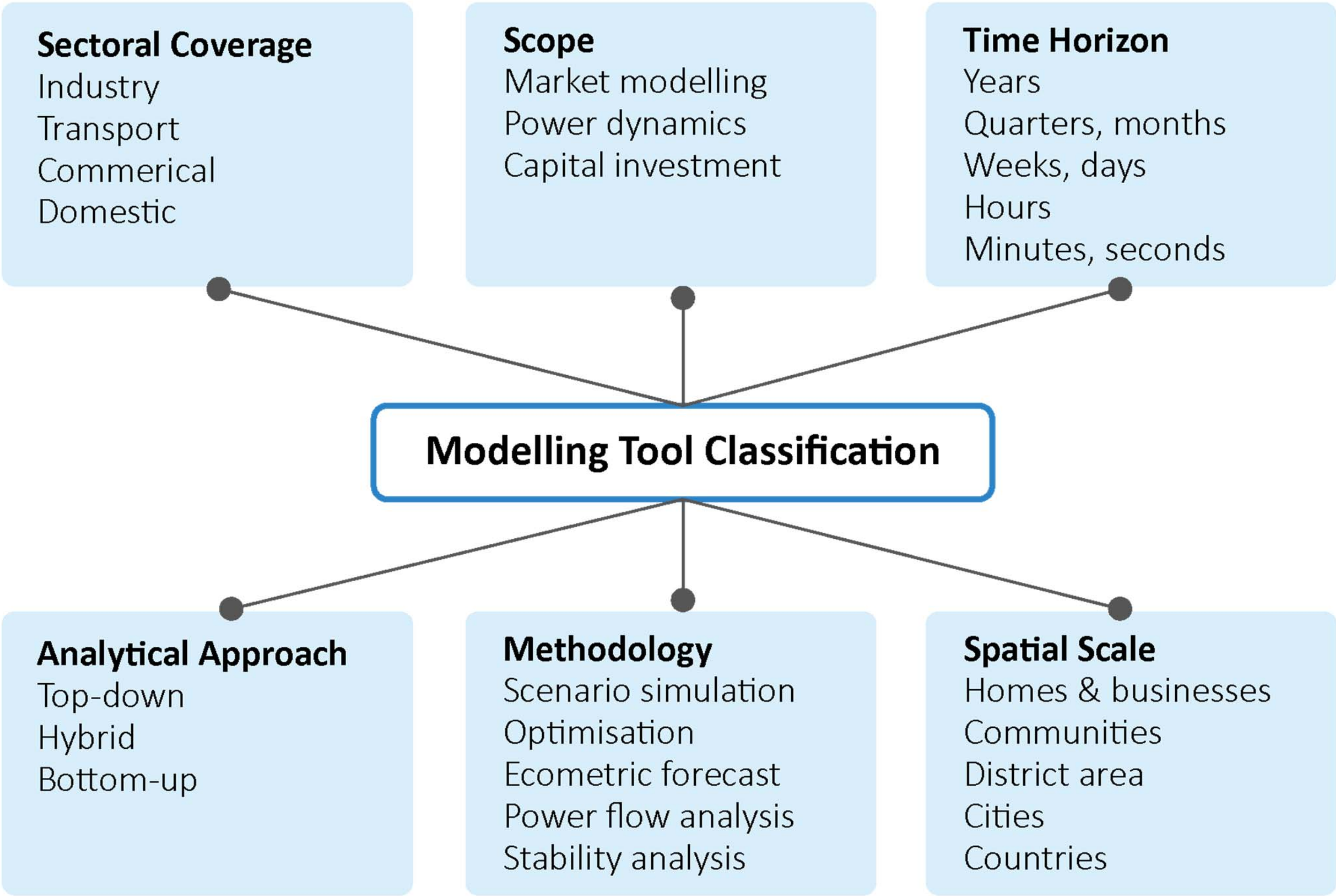
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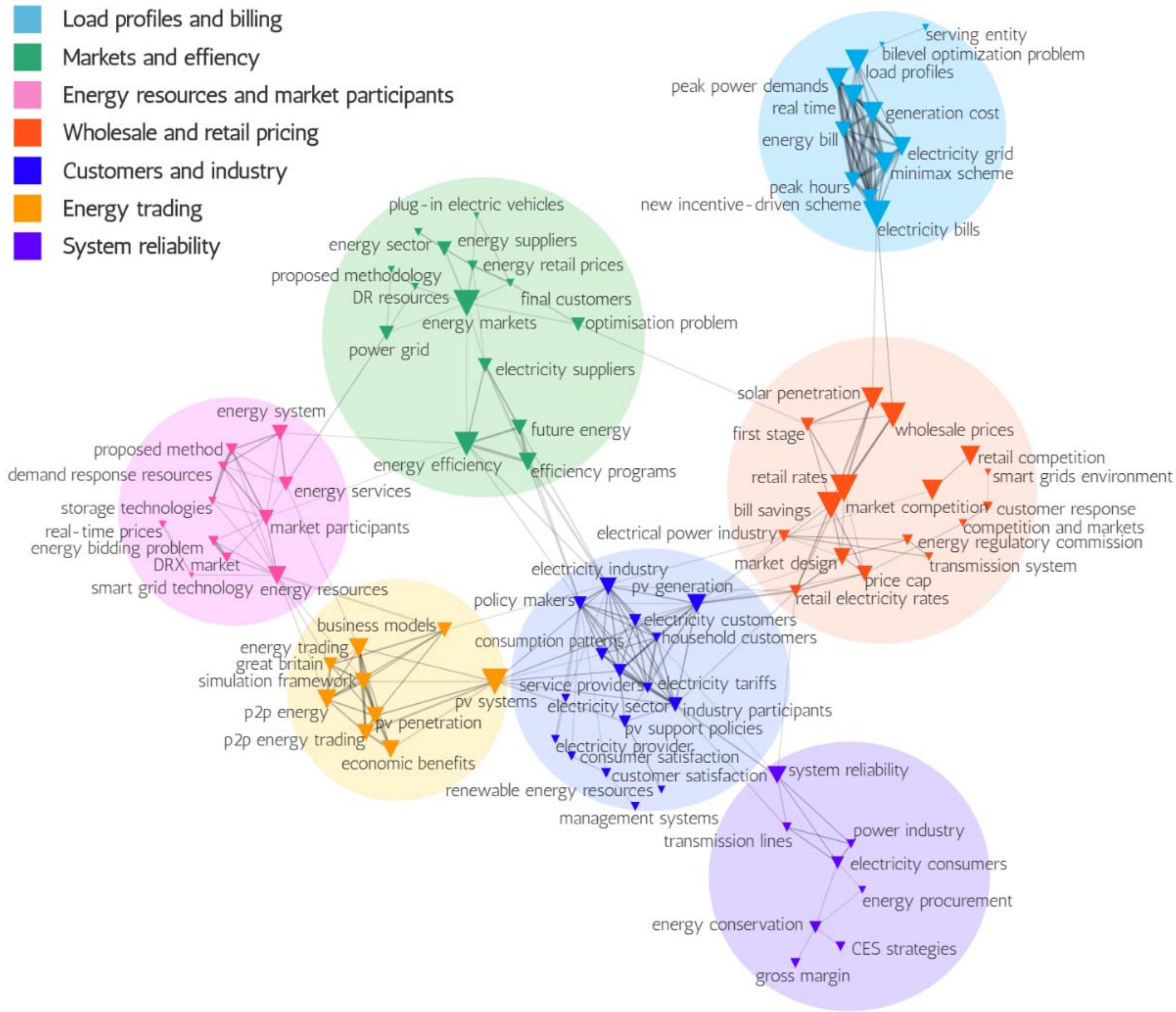

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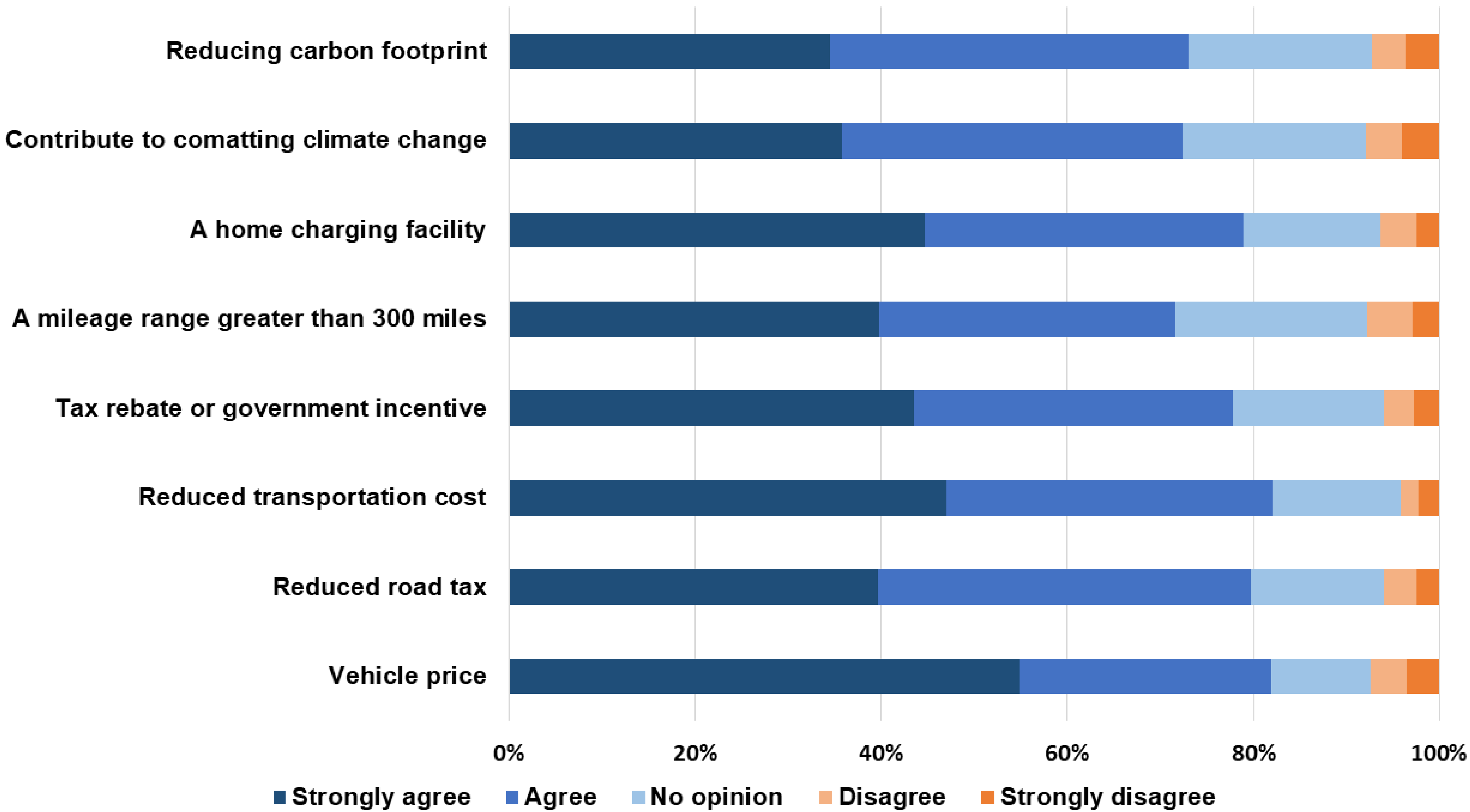
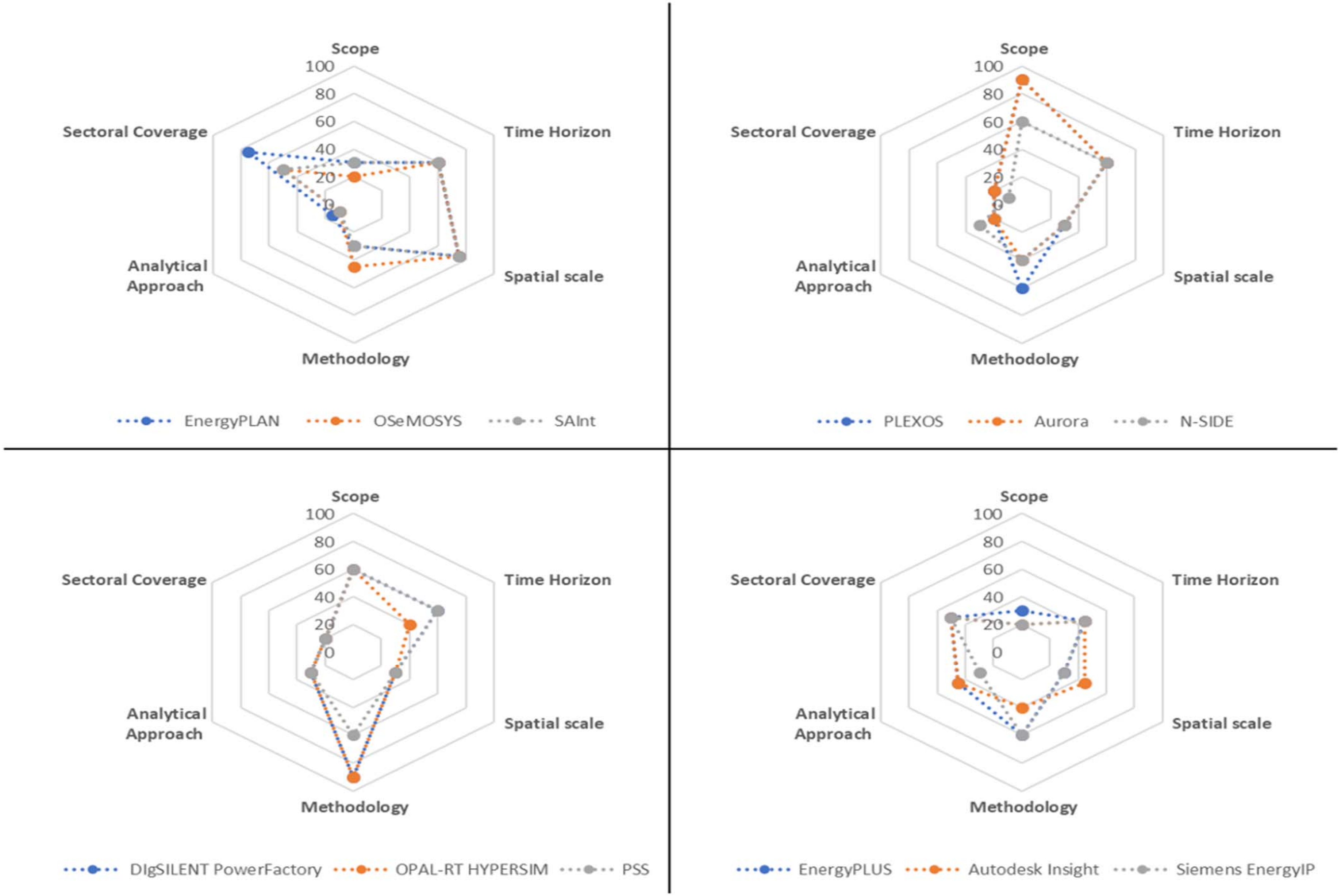

Reducing carbon footprint
Contribute to comatting climate change
A home charging facility
A mileage range greater than 300 miles
Tax rebate or government incentive
Reduced transportation cost
Reduced road tax
Vehicle price
0%
20%
40%
60%
80%
100%
Strongly agree
Agree
No opinion
Disagree
Strongly disagree



Scope
100
80
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20
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Time Horizon
Spatial scale
Methodology
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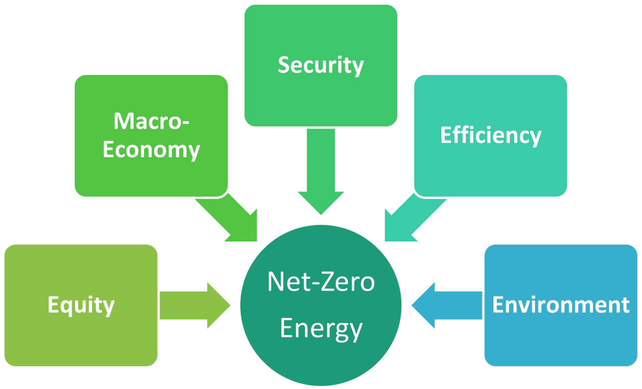
EnergyPLAN
OSeMOSYS
SAInt
PLEXOS
Aurora
N-SIDE
DIgSILENT PowerFactory
OPAL-RT HYPERSIM
PSS
EnergyPLUS
Autodesk Insight
Siemens EnergyIP

Cost-Benefit Analysis for Net-Zero Energy in Heat, Power, and Transport

Context

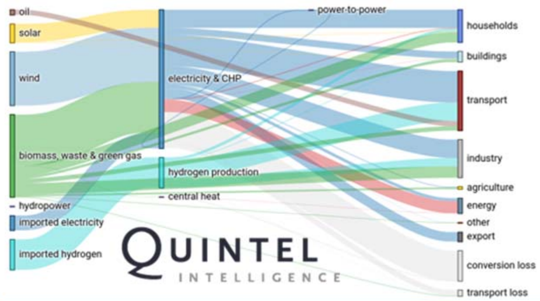
- **Net-Zero must be achieved by 2050** [1]
- **Decarbonisation** of the **energy system** is key to meeting this challenge
- **Rich renewable resources** exist in Northern Ireland, and the **technology to harness them** is available



Which **technological ensemble** and **vision of energy** is best for **people**, **society**, and the **environment**?

Methods

Explore Future Energy Scenarios [1,2]



ENERGY TRANSITION MODEL
Independent, Comprehensive and Fact-based

Quantify Scenario Impacts [3,4]

PLEXOS Energy Exemplar

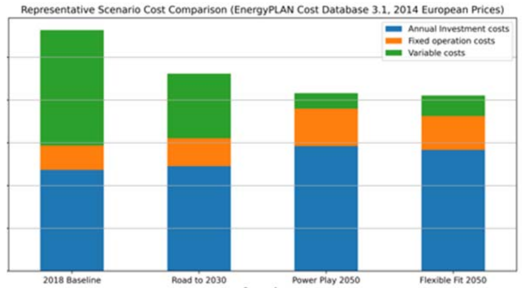
EnergyPLAN

Outputs

Scenarios Compared by Net Value [5,6,7]

Social CBA

Impact Pathway Assessment



Policy-Making Metrics

References: **[1]** Northern Ireland Department for the Economy, *'Energy Strategy - Path to Net Zero Energy'*, Dec. 21, 2021; **[2]** Quintel Intelligence, *Energy Transition Model*, https://pro.energytransitionmodel.com; **[3]** Energy Exemplar, PLEXOS, https://www.energyexemplar.com/plexos; **[4]** H. Lund, J. Z. Thellufsen, P. A. Østergaard, P. Sorknæs, I. R. Skov, and B. V. Mathiesen, *'EnergyPLAN: Advanced analysis of smart energy systems'*, Smart Energy, Feb. 2021 https://www.energyplan.eu/. **[5]** A. E. Boardman, D. H. Greenberg, A. R. Vining, and D. L. Weimer, *Cost-Benefit Analysis: Concepts and Practice*, 5th ed. Cambridge University Press, 2018; **[6]** HM Treasury, *The Green Book: Appraisal and Evaluation in Central Government*. 2020; **[7]** European Commission, Guide to cost-benefit analysis of investment projects: economic appraisal tool for cohesion policy 2014-2020;

Landscape Review: Renewable Energy Generation and Application

		Item	Group	2018	Power / Energy						Heat					Transport				Enabling					
					Win	Solar PV	Tidal Wave	AnaerobiC	Solar Heat	Geothermal	Heat Pumps	Low-Carbon	District	Insulation	Electric	Electric	Hydrogen	Alt. Fuels	Demand	Hydrogen	CCUS	CHP	Storage	Biomass	eFuels
	Emissions	1		0	1	1	1	0	1	1	1	-1	0	0	1	1	1	0	1	1	0	0	1	0	0
	Net-Zero	1		0	1	1	1	0	0	1	0	-1	0	0	-1	0	0	0	1	1	0	0	1	0	0
Decarb.	Sustainability	1	1	0	1	0	0	1	1	1	1	-1	1	1	0	-1	-1	-1	1	1	-1	1	0	1	1
	Scalability	1		0	1	0	-1	1	-1	-1	0	0	1	1	0	0	0	-1	0	1	-1	1	-1	0	0
	Pollution	1		0	1	1	0	0	1	1	1	-1	1	1	1	0	0	-1	1	1	1	0	1	-1	-1
	Accessibility	1		0	-1	1	-1	1	1	-1	0	1	-1	1	-1	0	-1	0	0	-1	-1	0	0	0	-1
	Affordability	1		0	0	-1	-1	0	-1	-1	-1	1	-1	1	-1	-1	-1	0	1	-1	-1	1	-1	0	0
Equity	Acceptability (SRL)	1	1	0	-1	1	0	0	1	0	0	1	-1	1	0	1	-1	1	0	0	1	0	1	1	1
	Disruption	1		0	0	1	-1	0	1	-1	-1	1	-1	1	-1	0	-1	1	-1	-1	1	0	0	0	1
	Value	1		0	1	0	-1	0	0	0	0	0	1	1	0	0	0	0	1	0	-1	0	0	0	0
	Flexibility	1		0	-1	-1	0	0	-1	1	0	1	1	1	0	0	0	0	1	0	-1	1	1	0	0
	Reliability	1		0	1	1	-1	0	1	1	1	1	1	1	0	1	0	0	0	0	-1	1	1	1	1
Security	Availability	1	1	0	1	1	-1	1	1	-1	0	1	0	1	0	1	-1	-1	0	-1	-1	1	0	-1	-1
	Exposure	1		0	1	1	1	1	1	1	0	-1	-1	1	0	-1	-1	0	1	1	-1	0	-1	1	0
	Readiness (TRL)	1		0	1	1	-1	1	1	0	1	0	1	1	-1	1	-1	-1	0	-1	-1	1	0	-1	-1
	Green Growth	1		0	1	1	1	1	1	0	1	-1	0	0	0	0	0	1	0	1	-1	0	1	1	1
	Export Potential	1		0	0	-1	1	0	-1	-1	-1	-1	-1	-1	0	-1	-1	1	-1	1	-1	-1	0	1	1
Macro.	Skills Ready	1	1	0	1	1	0	0	0	-1	0	0	-1	1	-1	0	-1	-1	0	-1	-1	0	0	-1	-1
	Subsidy	1		0	1	-1	-1	0	-1	-1	-1	0	-1	1	0	0	-1	-1	-1	-1	-1	0	0	0	0
	Long Term Value	1		0	0	0	1	0	0	1	0	-1	1	1	0	0	0	0	1	1	0	0	1	1	1
	Energy Usage	1		0	0	0	1	1	0	1	1	0	1	1	1	-1	0	0	1	1	-1	1	1	0	0
	Application Eff.	1		0	0	0	0	0	0	1	1	-1	1	1	0	0	0	0	1	1	-1	1	1	0	0
Efficiency	Curtailment / Waste	1	1	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1	1	1	0	1	1	1	1
	Time and Effort	1		0	0	1	-1	0	1	-1	1	1	-1	1	-1	0	-1	-1	0	-1	0	0	1	1	1
	Implementation	1		0	0	1	-1	0	1	-1	0	1	-1	1	-1	0	-1	-1	-1	-1	-1	-1	0	-1	-1
	TOTAL	-		0	10	10	-4	9	8	1	5	0	1	19	-5	0	-12	-4	8	3	-14	8	9	4	3
					10	10	-4	9	8	1	5	0	1	19	-5	0	-12	-4	8	3	-14	8	9	4	3

Four energy sectors

- Power
- Heat
- Transport
- Enabling Technology

Five policy pillars [1]

- Decarbonisation
- Equity
- Security
- Macroeconomy
- Efficiency

Findings distilled to PUGH chart [2]

- Adjust per policy pillar and goal [3]
- **Insulation has highest net benefit**
- **CCUS has worst net score**

References: **[1]** Northern Ireland Department for the Economy, *'Energy Strategy - Path to Net Zero Energy'*, Dec. 21, 2021; **[2]** N. McIlwaine et al., 'A state-of-the-art techno-economic review of distributed and embedded energy storage for energy systems', Energy, vol. 229, p. 120461, Aug. 2021, doi: 10.1016/j.energy.2021.120461; **[3]** J. A. Annema, N. Mouter, and J. Razaei, 'Cost-benefit Analysis (CBA), or Multi-criteria Decision-making (MCDM) or Both: Politicians' Perspective in Transport Policy Appraisal', Transportation Research Procedia, vol. 10, pp. 788–797, 2015, doi: 10.1016/j.trpro.2015.09.032

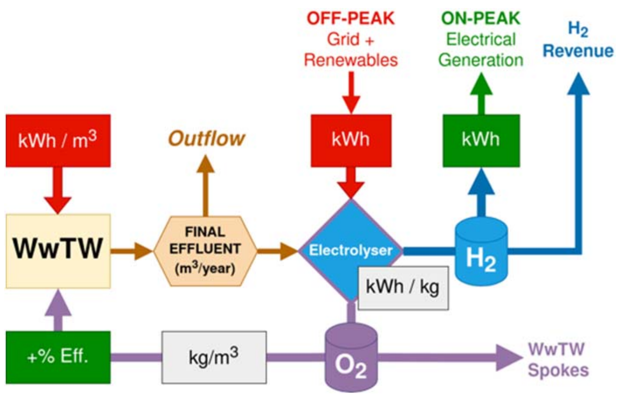
Techno-Economic Study: NI Water and Hydrogen Production Co-Location

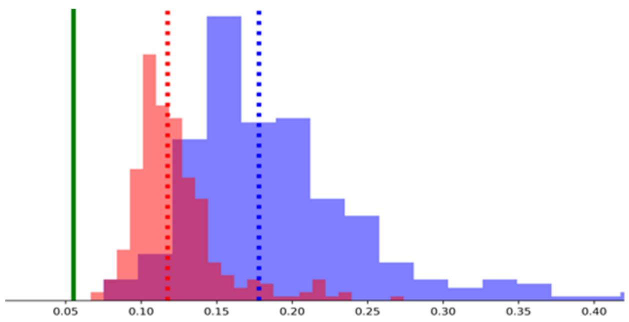
Northern Ireland Water

northern ireland water

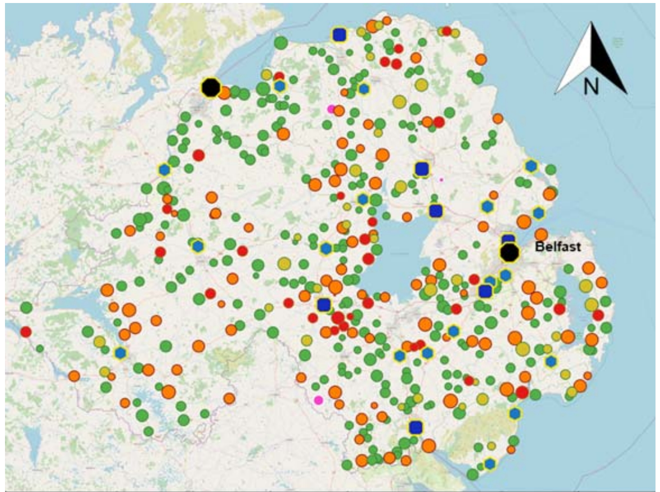
- **Largest electricity user** in Northern Ireland (**2.76% of demand** [1])
- **Aeration uses most of the electricity** in water treatment [2]
- **Concentrated O_2 increases aeration efficiency** [3]
- Electrolytic **hydrogen production** creates **by-product O_2**
- **Recover up to 2.56% energy** used for H_2 production by using O_2

Hydrogen Production





Synergistic Co-Location



Cluster	0	1	2	3	4	5	6
Oxygen Potential	LOW	MED	LOW	HIGH	HIGH	HIGH	LOW
Hydrogen Site					YES	YES	

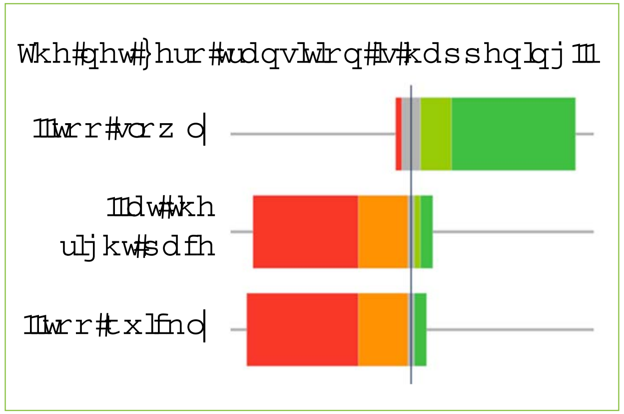
- Water treatment **scales naturally with population and industry** [4]
- Potential **hydrogen demand scales in synergy** with water treatment

References: **[1]** R. Kernan, Xueqin Liu, S. McLoone, and B. Fox, ‘Demand Side Management of public clean water supply’, in 2015 50th International Universities Power Engineering Conference (UPEC), Stoke On Trent, United Kingdom: IEEE, Sep. 2015, pp. 1–7. doi: 10.1109/UPEC.2015.7339923; **[2]** D. Rosso, L. E. Larson, and M. K. Stenstrom, ‘Aeration of large-scale municipal wastewater treatment plants: state of the art’, Water Science and Technology, vol. 57, no. 7, pp. 973–978, Apr. 2008, doi: 10.2166/wst.2008.218; **[3]** J. A. Mueller, W. C. Boyle, and H. J. Pöpel, Aeration: principles and practice. in Water quality management library, no. v. 11. Boca Raton: CRC Press, 2002; **[4]** Jacobs, ‘How can the water sector engage with a future hydrogen economy?’ http://www.jacobs.com/newsroom/news/how-can-water-sector-engage-future-hydrogen-economy

Stakeholder Engagement: DELPHI-Sandpit with Regional Experts

DELPHI

Expert survey [1] **engaging stakeholders across industry, policy, academia, and charities**



The net zero transition is happening ***too slowly****, and actions producing* ***tangible impact must be prioritised***

Sandpit

In-person round-table debate of DELPHI results [2]**, to explore consensus and contentious issues**

"It is very important to ***distribute costs fairly - but what does fair mean?*** *It is likely to be a complicated answer, depending on fluid circumstances and* ***not just a fixed split*** *of costs."*

"Some [technologies] are ***ready, but just too expensive.****"*

Panel discussions highlighted the **contentious** and **complex** issues of **cost allocation** and **subsidy targets**

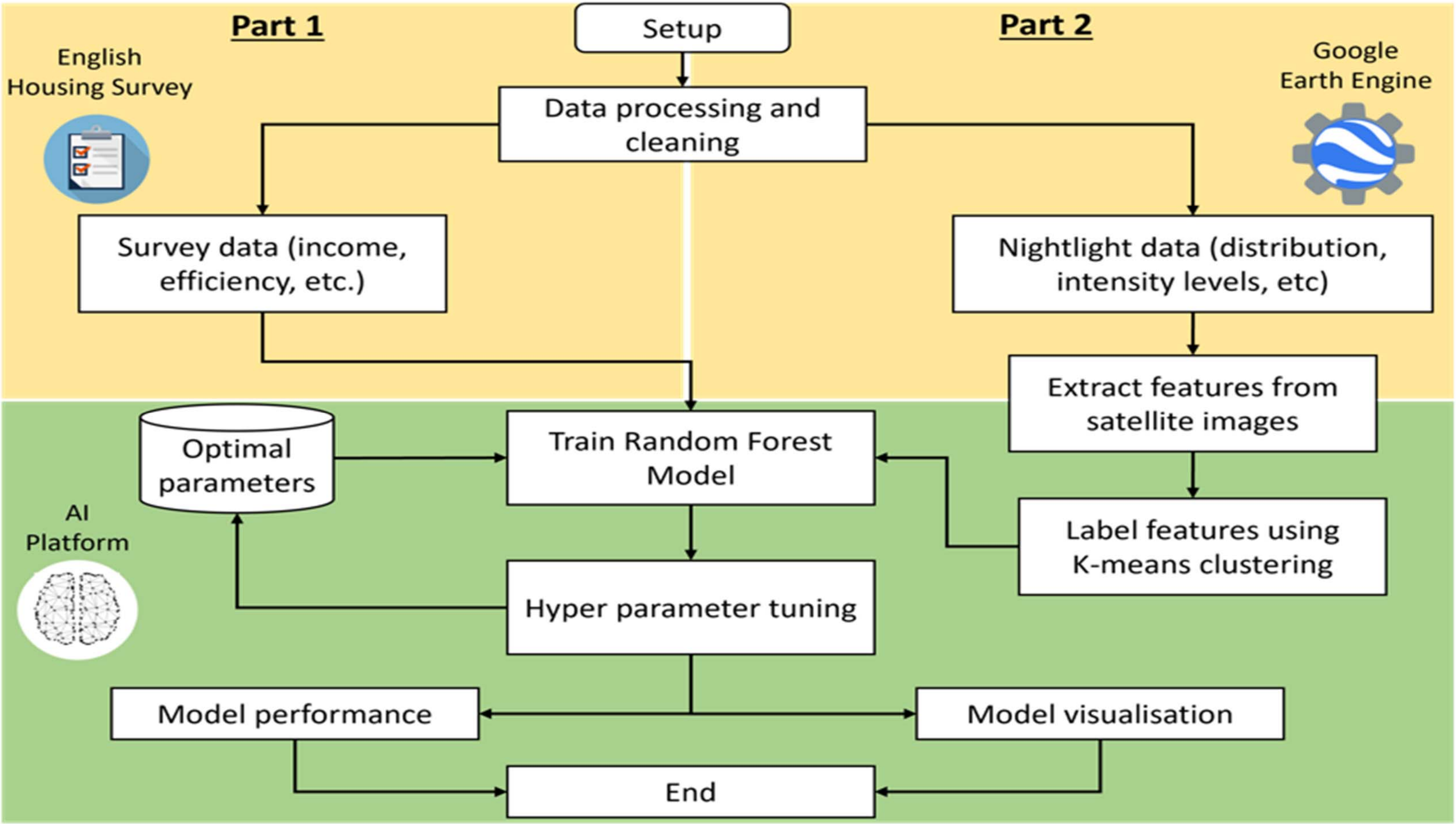
Findings

Synthesis of results in the context of state-of-the-art policy-making [3] **and technology frameworks** [4]

	TRL	Delphi	*Delta*	SRL	Delphi	*Delta*
Generation						
Wind Generation	9	**8.3**	-0.7	9	**8.9**	-0.1
Photovoltaics	9	**8.1**	-0.9	9	**8.7**	-0.3
Geothermal	6 (9)	**6.0**	0.0	4 (9)	**8.2**	4.2
Solar Thermal	9	**8.1**	-0.9	8	**8.4**	0.4
Anaerobic Digestion	9	**7.7**	-1.3	9	**7.8**	-1.2
Marine Energy	7	**6.3**	-0.7	6	**7.8**	1.8
CHP	9	**7.4**	-1.6	9	**8.2**	-0.8
Carriers						
Biofuels/Biomass	9	**7.2**	-1.8	9	**7.9**	-1.1
Electro-fuels	6	**5.6**	-0.4	4	**8.3**	4.3
Energy Storage	8	**6.5**	-1.5	9	**9.0**	0.0
Smart Grid	7	**6.6**	-0.4	6	**9.0**	3.0
CCUS	7	**5.7**	-1.3	7	**8.3**	1.3
Hydrogen	7	**6.2**	-0.8	7	**8.8**	1.8
Applications						
EV and H2	9	**6.6**	-2.4	9	**8.8**	-0.2
Micro-Mobility	9	**7.4**	-1.6	6 (9)	**7.5**	1.5
Electric Heat Pumps	9	**7.1**	-1.9	9	**8.8**	-0.2
Hydrogen Boilers	6.5 (9)	**5.7**	-0.8	4 (9)	**8.5**	4.5
District Heat Networks	6.5 (9)	**6.1**	-0.4	3 (9)	**8.4**	5.4

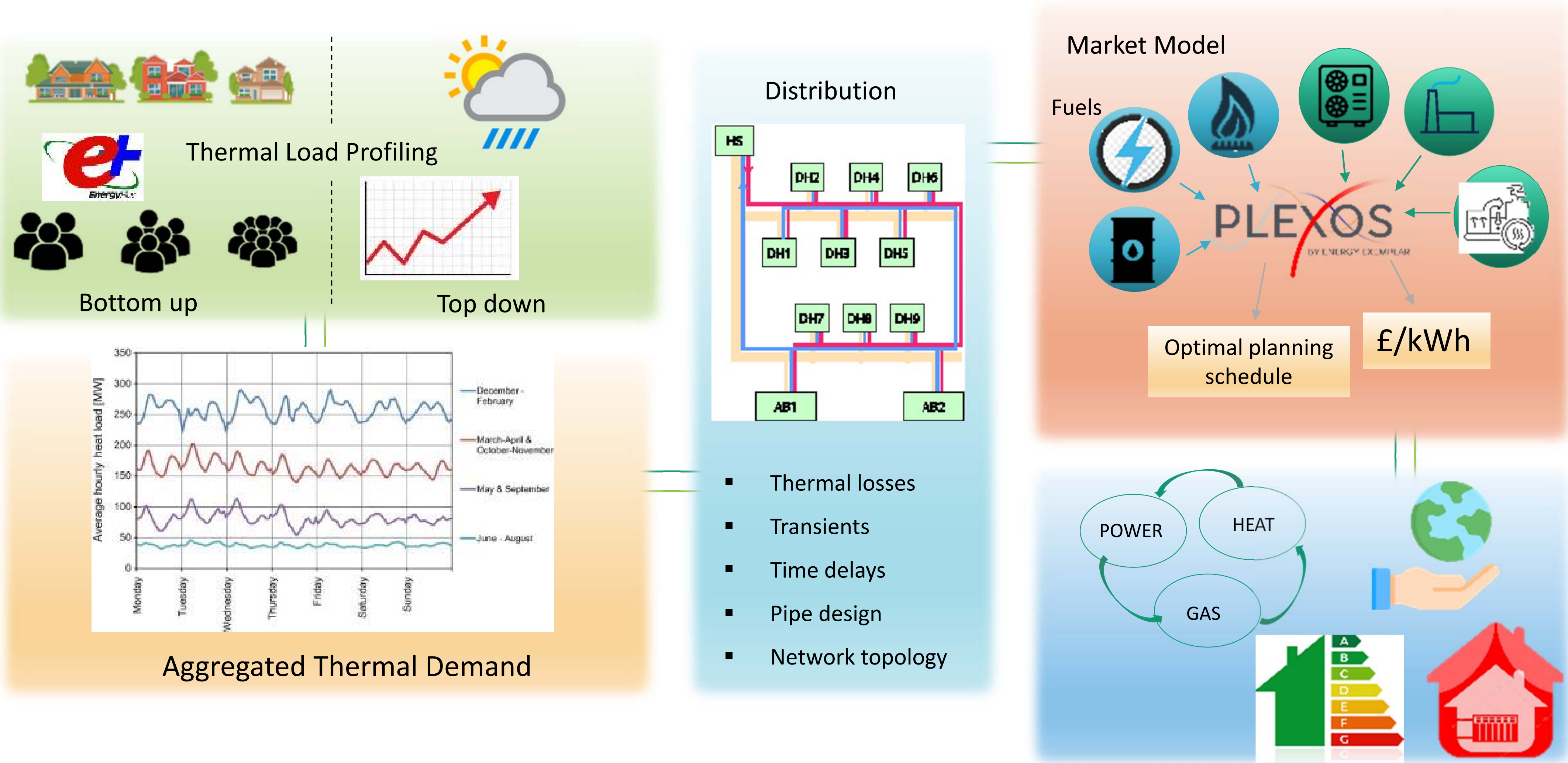
A ***diverse range*** *of technology is welcomed, but* ***Geothermal [5]*** *and* ***District Heating [6] are neglected***

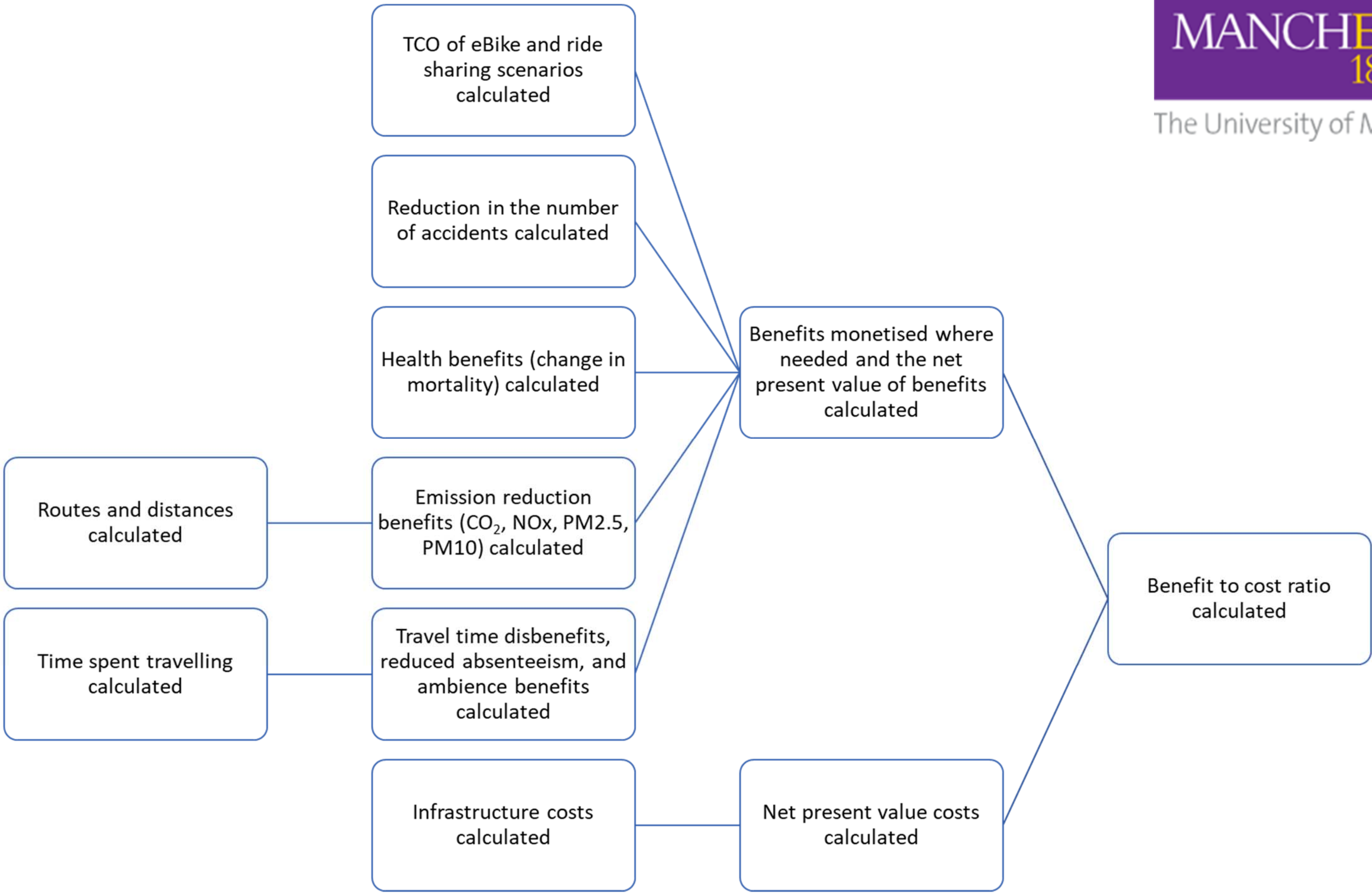
References: **[1]** F. Hasson and S. Keeney, 'Enhancing rigour in the Delphi technique research', Technological Forecasting and Social Change, vol. 78, no. 9, pp. 1695–1704, Nov. 2011, doi: 10.1016/j.techfore.2011.04.005; **[2]** 'Social Sciences and Humanities for Advancing Policy in European Energy | SHAPE-ENERGY Project', CORDIS, European Commission. https://cordis.europa.eu/project/id/731264; **[3]** T. Mai, J. Logan, N. Blair, P. Sullivan, and M. Bazilian, 'RE-ASSUME: A Decision Maker's Guide to Evaluating Energy Scenarios, Modeling, and Assumptions', NREL/TP-6A20-58493, 1090954, Jun. 2013. doi: 10.2172/1090954; **[4]** A. Foley, H. Hampton, A. Brown, N. McIlwaine, D. Al Kez, and D. Furszyfer, 'Support scheme options to incentivise renewables investment in Northern Ireland: Report for the Department for the Economy as evidence for the Northern Ireland Energy Strategy 2021', Northern Ireland Department for Economy, Queen's University Belfast, Dec. 2021



Part 1
Setup
Part 2
English
Housing Survey
Google
Earth Engine
Data processing and
cleaning
Survey data (income,
efficiency, etc.)
Nightlight data (distribution,
intensity levels, etc)
Extract features from
satellite images
Optimal
parameters
Train Random Forest
Model
Label features using
K-means clustering
AI
Platform
Hyper parameter tuning
Model performance
Model visualisation
End

Creating a Retail Business Model for District Heating to aid the Decarbonisation of Domestic Heating





MANCHESTER 1824
The University of Manchester

State-of-the-Art in Electric Vehicle Charging Infrastructure

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Abstract **— The international introduction of electric vehicles (EVs) will see a change in private passenger car usage, operation and management. There are many stakeholders, but currently it appears that the automotive industry is focused on EV manufacture, governments and policy makers have highlighted the potential environmental and job creation opportunities while the electricity sector is preparing for an additional electrical load on the grid system. If the deployment of EVs is to be successful the introduction of international EV standards, universal charging hardware infrastructure, associated universal peripherals and user-friendly software on public and private property is necessary. The focus of this paper is to establish the state-of-the-art in EV charging infrastructure, which includes a review of existing and proposed international standards, best practice and guidelines under consideration or recommendation.**

Keywords – electric vehicles, charging infrastructure, charging stations, guidelines, standards, transport

I. Introduction

The successful deployment of electric vehicles (EVs) over the next decade is connected to the introduction of internationally agreed EV standards, universal charging hardware infrastructure, associated universal peripherals and

established EV targets, policies and plans in order to su in deploying EVs. Table 1 lists some internal gover policies and targets.

Country	Targets
Austria	2020: 100,000 EVs deployed[1]
Australia	2012: first cars on road, 2018: mass deployment, 2 up to 65% of car stock[2]
Canada	2018: 500,000 EVs deployed[3]
China	2011: 500000 annual production of EVs[4]
Denmark	2020:200,000 EVs [5]
France	2020: 2,000,000 EVs[6]
Germany	2020: 1,000,000 EVs deployed[7]
Ireland	2020: 10% EV market share[8]
Israel	2011: 40,000 EVs, 2012: 40,000 to 100,000 EVs annually[9]
Japan	2020: 50% market share of next generation vehicle
New Zealand	2020: 5% market share, 2040: 60% market share[11]
Spain	2014: 1,000,000 EVs deployed[12]
Sweden	2020: 600,000 EVs deployed[13]
United Kingdom	No target figures, but policy to support EVs[14]
USA	2015: 1,000,000 PHEV stock[15]

1 http://www.iea-retd.org/files/RETRANS100128%20Schauer.pdf
2 http://australia.betterplace.com/assets/pdf/Better_Place_Australia_energy_white_paper-doc.pdf
3 http://www.evtrm.gc.ca/pdfs/E-design_09_0581_electric_vehicle_e.pdf
4 http://www.nytimes.com/2009/04/02/business/global/02electric.html
5 http://www.ens.dk/en-US/Sider/forside.aspx
6 http://www.physorg.com/news173639548.html
7 http://www.evworld.com/news.cfm?newsid=23301
8 http://www.dcenr.gov.ie/Press+Releases/2008/Government+announces+plans+for+the+electrification+of+Irish+motoring.htm
9 http://www.betterplace.com/

Aspects which need to be examined and standardized include the following:

- Signage,
- Layouts, access and lighting in areas where public charging is proposed,
- Disabled persons requirements,
- Installations on properties subject to flooding,
- Certification of charging equipment,
- Trip hazards, liability issues and public insurance,
- Ventilation,
- LEED and BRE building certification requirements,
- Installation certification,
- Engineering design, construction and permitting on public and private property,
- Charging post ownership, maintenance and operation, metering and subscription services,
- Smart metering for home charging to control the time of charging, which can be related to costs, time of day and so forth,
- Battery swopping option,
- Vandal proofing,

Energy Conversion and Management
Volume 291, 1 September 2023, 117337

Towards more equitable energy transitions in low-income households: An integrated analysis of energy and transport poverty in Northern Ireland

Christopher Lowans [a b], Aoife Foley [a b c], Dylan Furszyfer Del Rio [a d e], Benjamin K. Sovacool [d f g]

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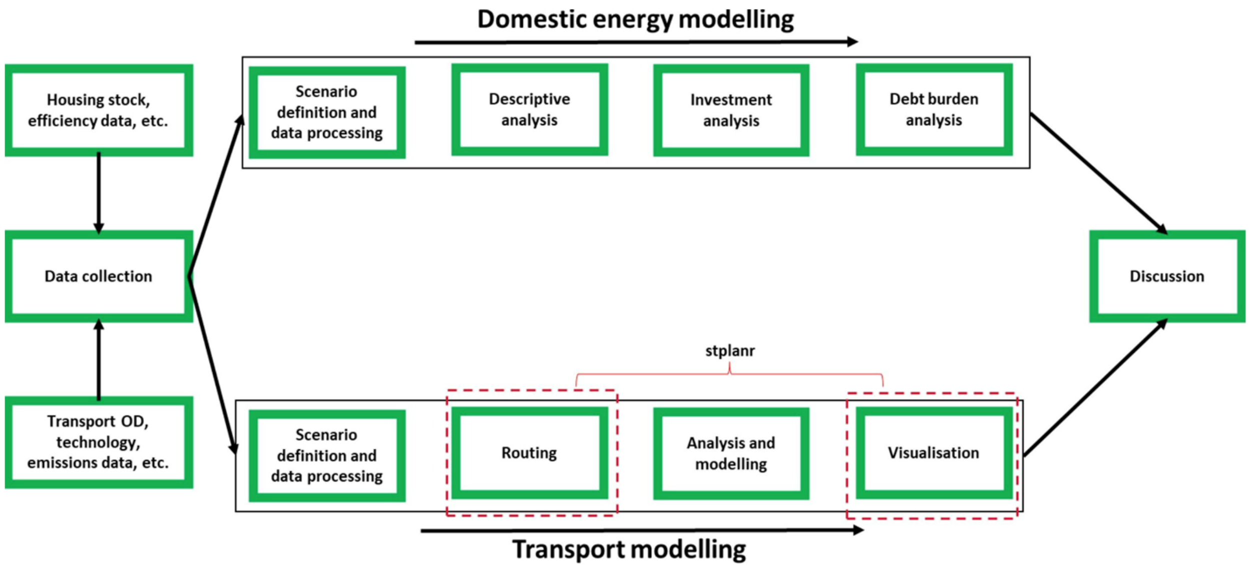
Highlights

- Explores equitable domestic and transport energy futures in Northern Ireland.
- Transport modal shift incurs economic benefits but also time penalties.
- EVs cost competitive across all case study scenarios from 2025.
- Post retrofit assessment shows lingering nature of financial burden.
- Expansion of supports is a crucial component of the Just Transition.



ELSEVIER

Sustainable Cities and Society
Volume 94, July 2023, 104573

Identifying optimal locations for community electric vehicle charging

Anna Charly [a], Nikita Jayan Thomas [a], Aoife Foley [b c], Brian Caulfield [a]

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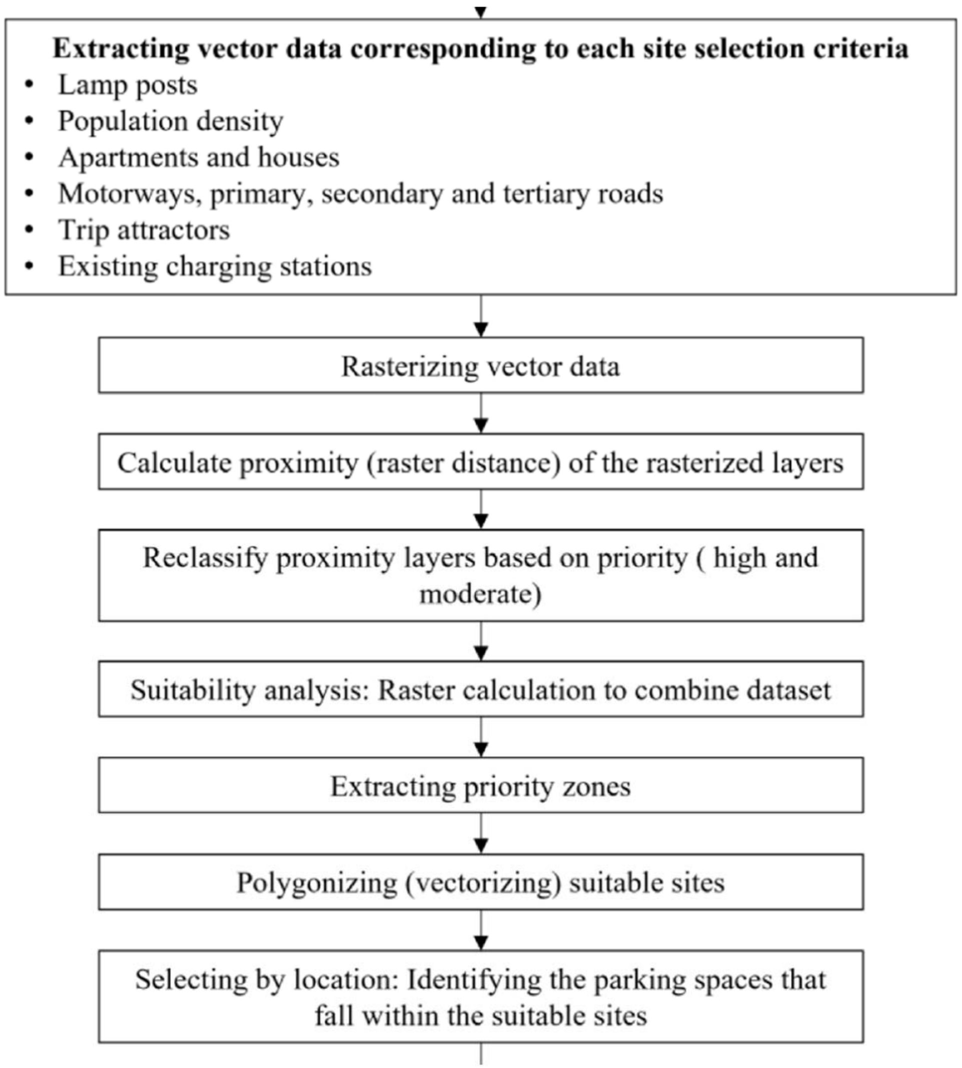
https://doi.org/10.1016/j.scs.2023.104573 Get rights and content

Highlights

- Optimal charging locations are identified using GIS-based multi-criteria analysis.
- Novel transferable methodology utilising QGIS and open street maps.
- The study identified 770 ideal locations for 2025 and 3080 locations for 2030.
- Population served by a five-minute walk or five-minute cycling is estimated.



ELSEVIER

Volume 174, March 2023, 113160

Pathways to decarbonising the transport sector: The impacts of electrifying taxi fleets

L. Kinsella [a], A. Stefaniec [a b], A. Foley [a c d], B. Caulfield [a]

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https://doi.org/10.1016/j.rser.2023.113160 Get rights and content

Highlights

- Fully electrifying taxi fleet leads to a 77% reduction in total CO_2 emissions produced.
- Upgrade to all plug-in hybrid EVs in the fleet is the second lowest emissions option.
- Rapid growth in the share of EVs in the fleet is required to reach a net-zero target.

Scenario	Description
Business as usual (BAU)	The current composition of the fleet (see Table A-5).
S-1 Removal of all ICEVs lower than Euro 5	In S-1 scenario any ICEV that falls under this category is divided between the Euro 5 and Euro 6 vehicle types. The HEVs and EVs remain the same as in the BAU scenario (see Table B-1).
S-2 Removal of all ICEVs lower than Euro 6	All Euro 5 ICEVs are removed from the fleet and replaced with Euro 6 vehicles (see Table B-2).
S-3 Complete removal of all ICEVs	All ICEVs are removed and replaced with a combination of the different types of HEVs. Petrol ICEVs are upgraded to petrol HEVs of Euro 4, 5 or 6 standard, and diesel ICEVs to petrol PHEVs of Euro 6. COPERT does not provide an option for a light commercial vehicle in the hybrid category. For this reason, the Large-SUV-Executive option is selected for these vehicles (see Table B-3).
S-4 Removal of all non-PHEVs	The petrol HEVs are removed and replaced with PHEVs Euro standard 6. The older PHEV vehicles are also removed and only the Euro 6 remains (see Table B-4).
S-5 Full electrification of the fleet	The entire fleet represented in the BAU scenario is converted to EVs. The original composition of each make and model in the current stock configuration is used to calculate a percentage

ELSEVIER

Energy
Volume 248, 1 June 2022, 123588

Measuring the equity impacts of government subsidies for electric vehicles

Brian Caulfield [a], Dylan Furszyfer [b c], Agnieszka Stefaniec [a], Aoife Foley [a c d]

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https://doi.org/10.1016/j.energy.2022.123588   Get rights and content

Highlights

- Demonstrates the correlations between equity and EV ownership.
- Explores how regional income levels impact upon EV density.
- Commuting characteristics are examined to ascertain their impacts on EV ownership.

Fig. 6. a: Household EV charging locations - Dublin. b: Average Household Income - Dublin.

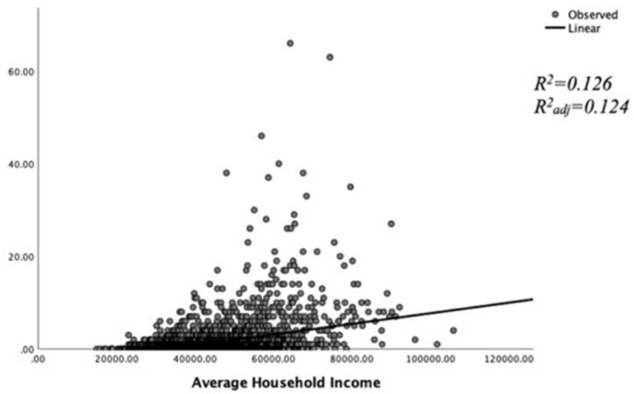

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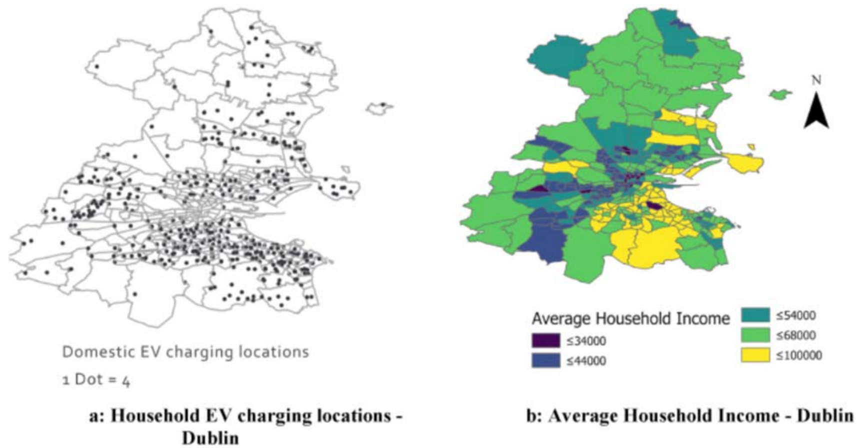
Fig. 7. Linear regression of average household income and domestic charging

Fig. 5. a: Household EV charging locations. b: Average Household Income.



ELSEVIER

Energy Policy
Volume 172, January 2023, 113313

What causes energy and transport poverty in Ireland? Analysing demographic, economic, and social dynamics, and policy implications

Christopher Lowans [a], Aoife Foley [a b], Dylan Furszyfer Del Rio [a c], Brian Caulfield [b], Benjamin K. Sovacool [c g i], Steven Griffiths [e], David Rooney [h]

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https://doi.org/10.1016/j.enpol.2022.113313 Get rights and content

Highlights

- Energy and transport poverty rates are similar across the island of Ireland.
- Survey respondent knowledge of causal factors and potential solutions alike is low.
- Self-reported energy and transport poverty do not correspond to modelled data.
- Ever refined targeting for support measures is not optimal.

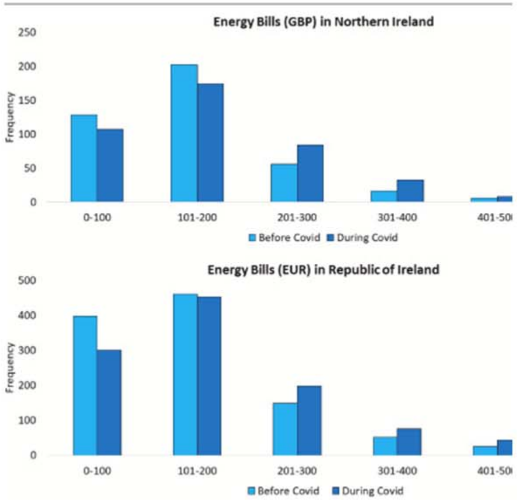

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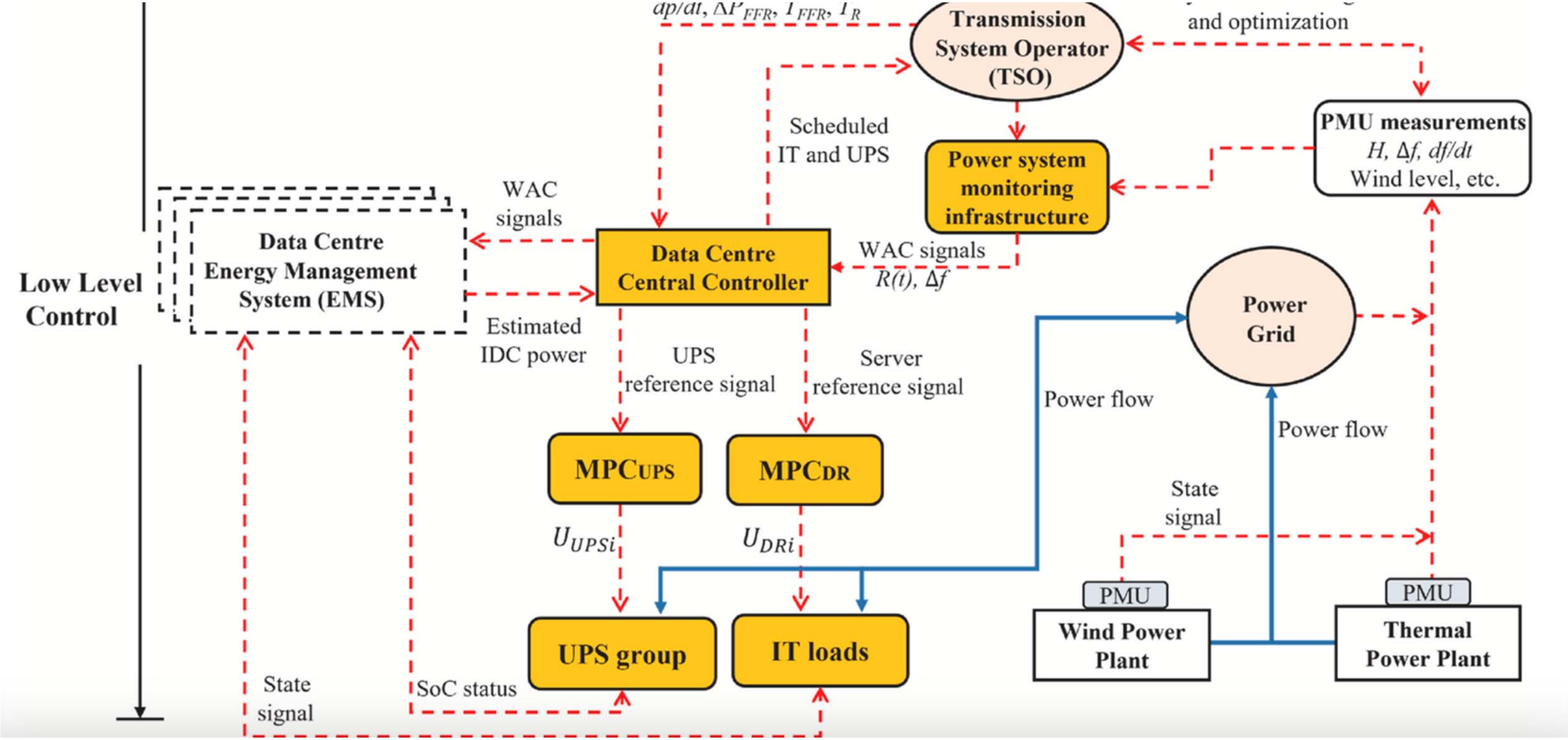
Fig. 1. Respondent's energy bills in each jurisdiction, prior to and during the Covid-19 pandemic. Panel A) Northern Ireland, Panel B) Republic of Ireland.

Table 2. Median energy expenditures in each jurisdiction.

Jurisdiction	Median Monthly energy Bill before pandemic	Median monthly energy bill during the pandemic	Mean Monthly energy Bill before pandemic	Mean monthly energy bill during the pandemic
Northern Ireland [GBP]	150	171	181	212
Republic of Ireland [EUR]	138	151	177	206

Table 11. Respondents' perception of item which would make greatest difference to meeting household energy needs.

Respondents' perception of item which would make greatest difference to meeting household energy needs			
	Island wide	**Northern Ireland**	**Republic of Ireland**
More income	26%	25%	27%
A more efficient home and appliances	25%	23%	26%
Lower heating and electricity costs	46%	48%	45%
Other	3%	4%	3%



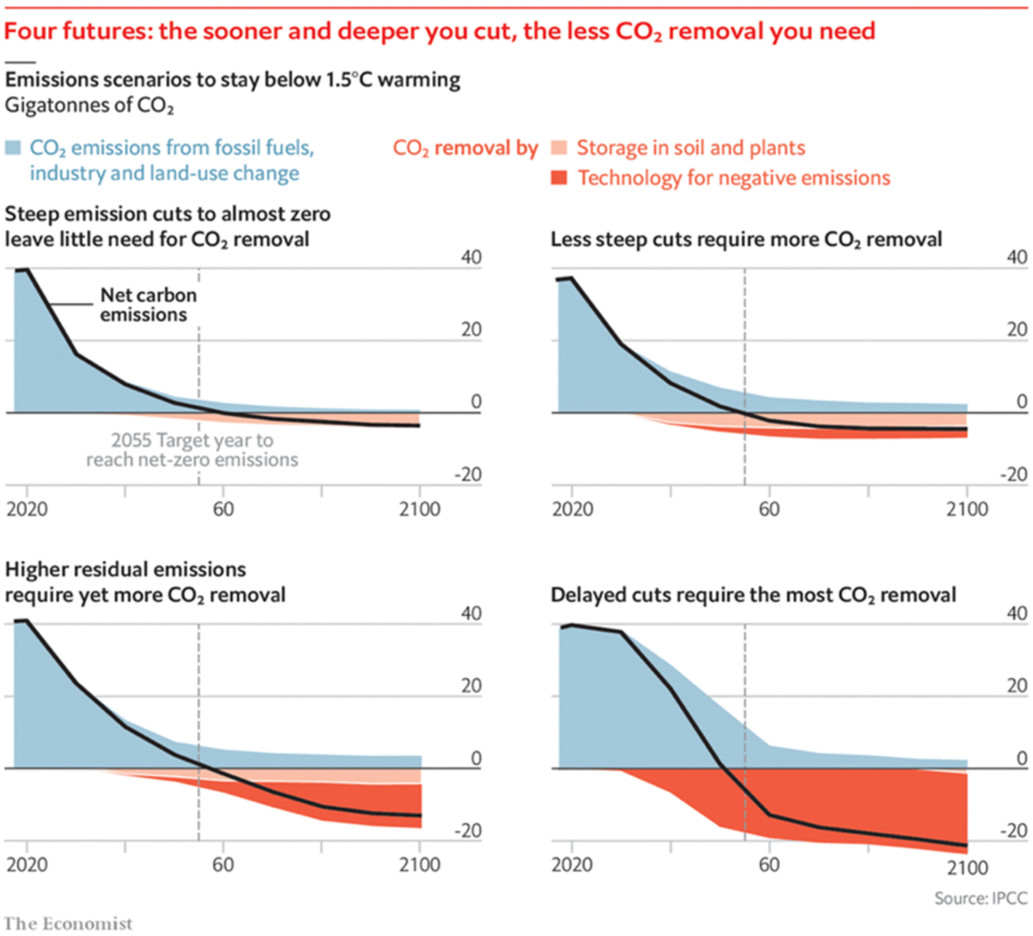
dp/dt, ΔP_FFR, T_FFR, T_R
Transmission System Operator (TSO)
and optimization
Scheduled IT and UPS
Power system monitoring infrastructure
PMU measurements
H, Δf, df/dt
Wind level, etc.
WAC signals
Data Centre Energy Management System (EMS)
Low Level Control
Data Centre Central Controller
WAC signals
R(t), Δf
Estimated IDC power
Power Grid
UPS reference signal
Server reference signal
Power flow
Power flow
MPCUPS
MPCDR
State signal
U_UPSi
U_DRi
PMU
PMU
Wind Power Plant
Thermal Power Plant
UPS group
IT loads
State signal
SoC status



Where next??


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

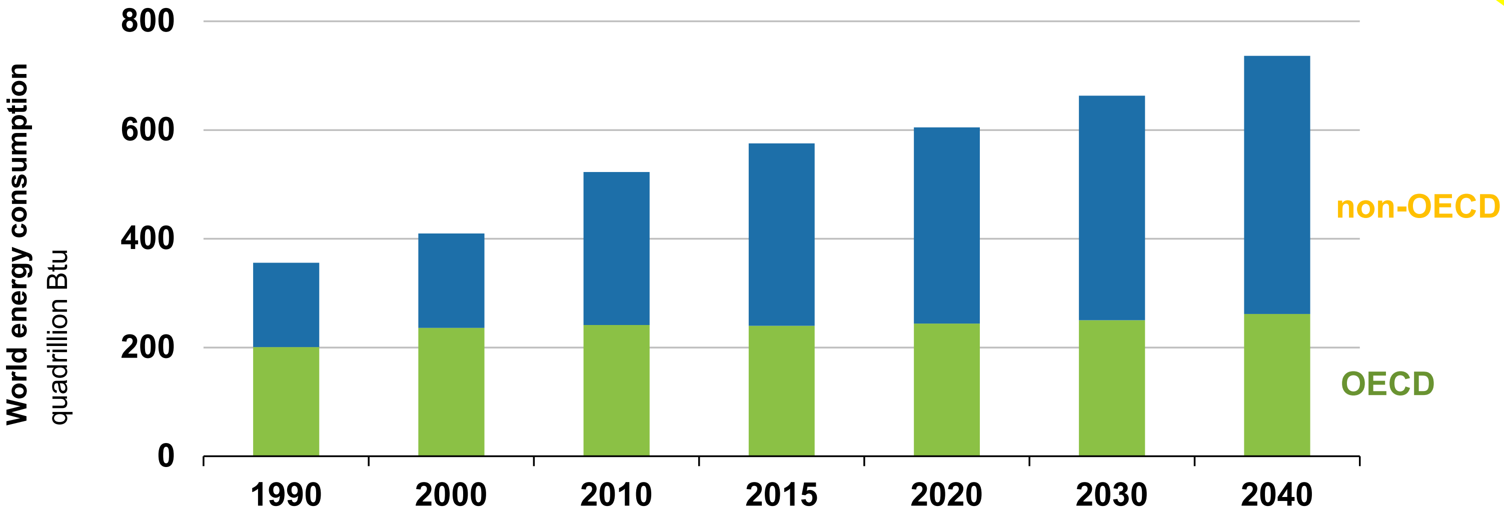
Emissions Scenarios to Stay below 1.5°C: Net Zero Emissions by 2050 – Four Ways



- 60 countries and 100 cities have promised to get to net zero emissions by 2050
- This means that they will take as much carbon out of the atmosphere as they put in
- At the moment the carbon going into the atmosphere (in blue) is mostly coming from fossil fuels and industry
- The chart shows 4 possible pathways to net zero emissions

Global policy drivers

VIRTUAL FOOTPRINTS



US Energy Information Administration

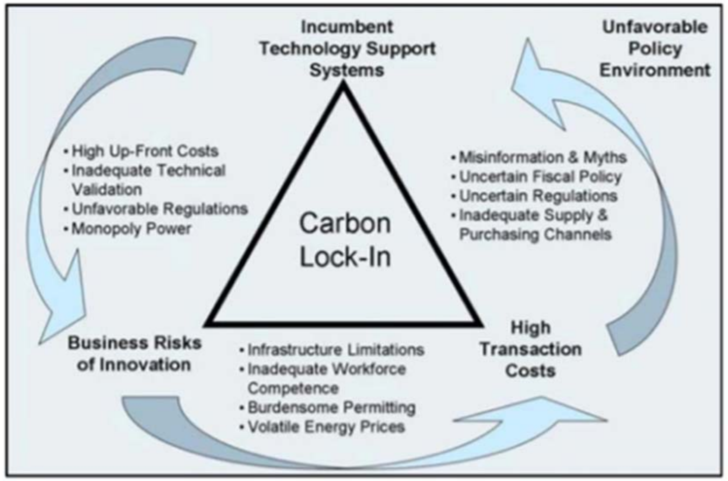
World energy consumption expected to rise 28% between 2015 and 2040

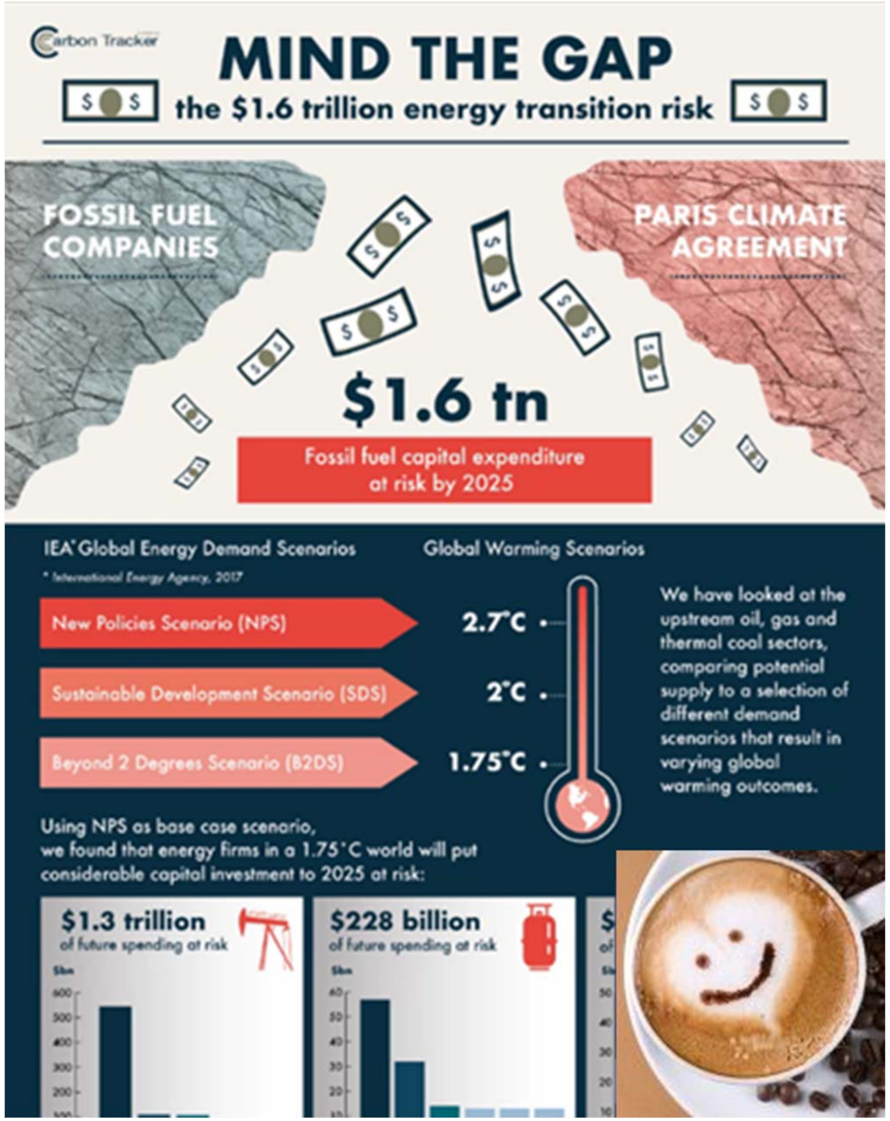
CO_2 emissions increasing globally as non-OECD countries ‘develop’

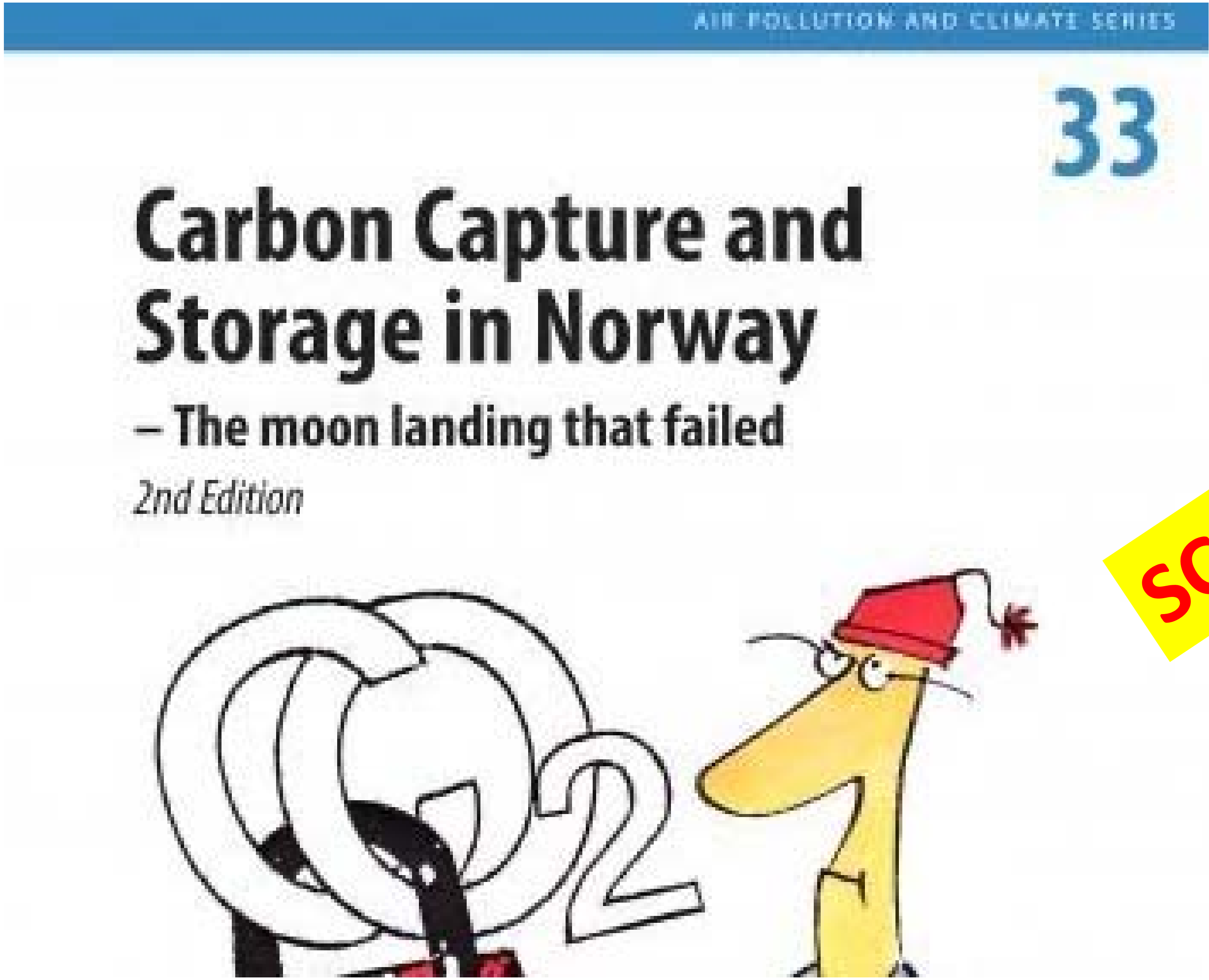
What is 'Lock-in'

"The difficulty lies, not with the new ideas, but in escaping the old ones"

John Maynard Keynes





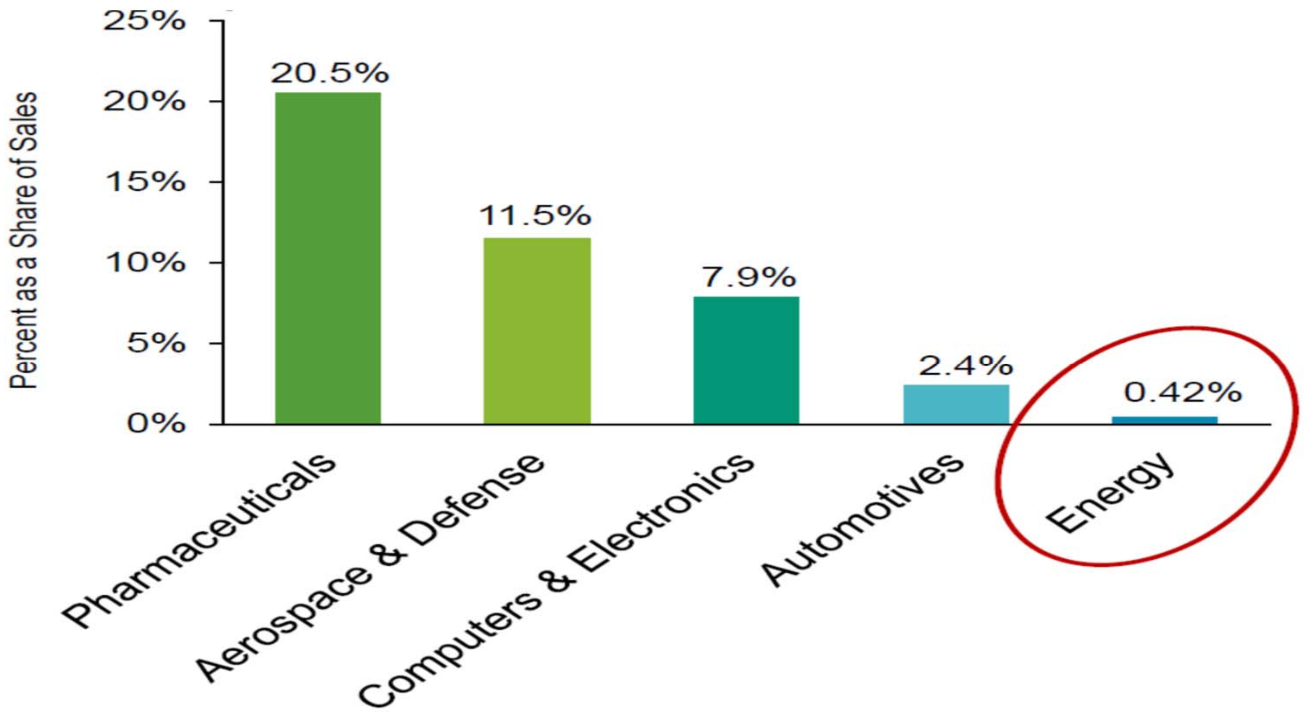


SCOPE 3 EMISSIONS!


UN CLIMATE
CHANGE
CONFERENCE
UK 2021


THIS WAY
THAT WAY
ANOTHER WAY

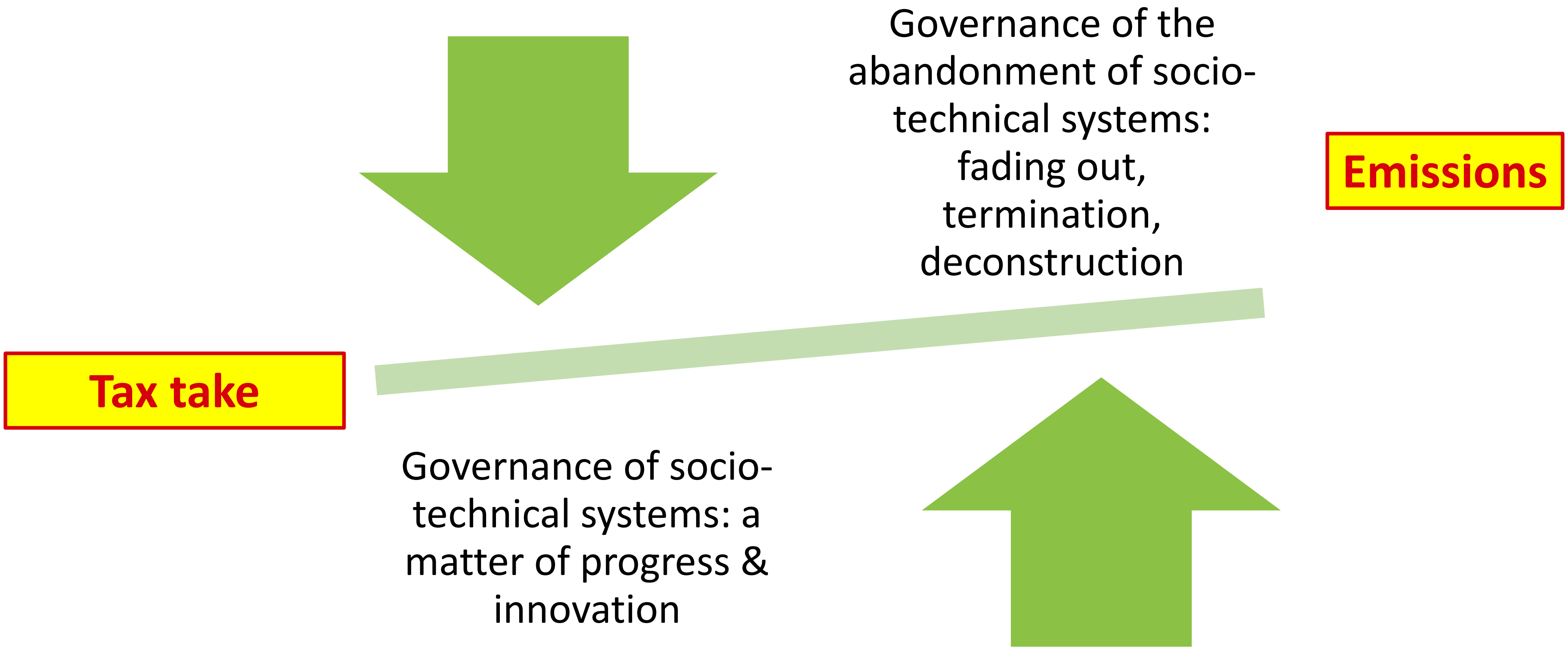
Total Private Sector R&D Spending % as a Share of Sales



Source: Bill Gates, "Energy Innovation: Why We Need It and How to Get It," https://www.gatesnotes.com/Energy/Energy-Innovation

Source: American Energy Innovation Council

Sectoral energy system transition - Innovation & abandonment



Role of the Finance Industry, Activist Investors, Decarbonisation & Investor Returns

PRI | Principles for Responsible Investment

Larry Fink urged to make BlackRock tougher on climate change

Jennifer Thompson JANUARY 14 2019

Larry Fink has been challenged by responsible investment campaigners to force BlackRock to take a tougher line on climate change when dealing with the companies in which it invests.

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Newsroom

PRESS RELEASE
April 9, 2018

Apple now globally powered by 100 percent renewable energy

Nine More Apple suppliers commit to 100 percent clean energy production

Low carbon technologies, TRL & resilience

- Industry - Advanced industry energy use technologies
- **Transport – Hybrid, electric & hydrogen, light weighting, ICE efficiency**
- Buildings – HVAC, materials, solar water heating, heat pumps
- Smart appliances
- Solar PV
- CCS and CCUS
- Onshore & offshore wind
- Advanced CHP etc
- 4th Generation nuclear
- Solar thermal
- Wave energy & TEC
- Storage…….
- Hydrogen, ammonia, methanol…….

THE GLOBAL COMPACT

Who Cares Wins

Connecting Financial Markets to a Changing World

Recommendations by the financial industry to better integrate environmental, social and governance issues in analysis, asset management and securities brokerage

Discussion & Questions…?

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