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Net0Pathways through impRoved IAMs across Sectors, diMensions, and scAles

Digitalisation and low-carbon lifestyles: Projections for the Shared Socio-economic Pathways (SSPs)

Scenarios Forum, University of Leeds, UK, 16th-18th July 2025

Hazel Pettifor, Maureen Agnew, Charlie Wilson
Environmental Change Institute, University of Oxford

This project has received funding from the European Union's Horizon Europe programme under grant agreement No 101081604.

Modelling low-carbon lifestyle change in future scenarios including SSPs

	implicit (part of a more general phenomenon)	**explicit** (discrete, identifiable phenomena or processes)
exogenous (externally specified)	scenario narrative translated into general modelling approach *e.g., energy service demand is a function of GDP growth*	scenario narrative translated into behavioural assumptions or parameters *e.g., energy service demand in lifestyle change scenario*
endogenous (internally generated)	behavioural phenomenon codified without resolving lifestyle-specific causal mechanism *e.g., cost-minimising technology adoption*	specific lifestyle change dynamic codified in model relationships *e.g., social influence and learning* *e.g., lifestyle change (LIFE)*

2x2 based on: Mundaca, L., D. Ürge-Vorsatz and C. Wilson (2019). *Energy Efficiency*. https://doi.org/10.1007/s12053-018-9722-9

LIFE model example: Pettifor, H., Mastrucci, A., Wilson, C., van Ruijven, B., Agnew, M., & Gallic, T. L. (2023). *Environmental Research Letters*. https://doi.org/10.1088/1748-9326/acf6d6

The LIFE model of low-carbon lifestyle change: cognitions-behaviours-contexts

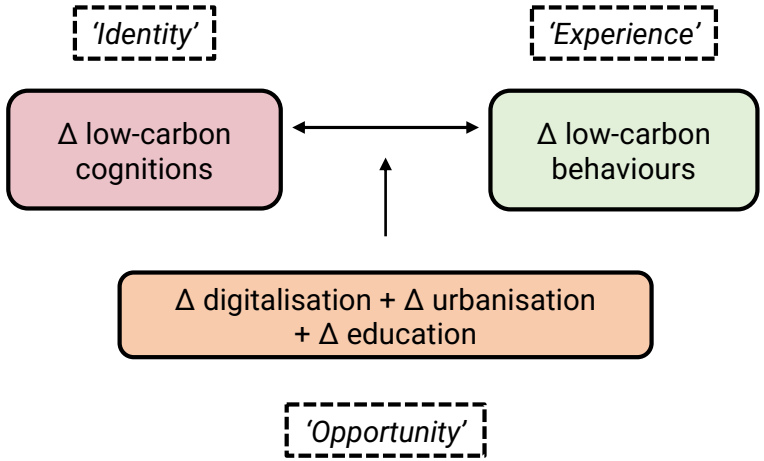
Lifestyles = interactions between cognitions, behaviours, and contexts

Three mechanisms of lifestyle change:

- '**opportunity effect**': acquiring new skills or accessing improved infrastructure

- '**identity effect**': new or strengthened beliefs & perceptions

- '**experience effect**': familiarity with new behaviours



the LIFE model: based on empirical relationships in *cross-sectional* data from 4 countries (Pettifor et al. 2023)

Pettifor, H., Agnew, M., & Wilson, C. (2023). A framework for measuring and modelling low-carbon lifestyles. *Global Environmental Change*. https://doi.org/10.1016/j.gloenvcha.2023.102739

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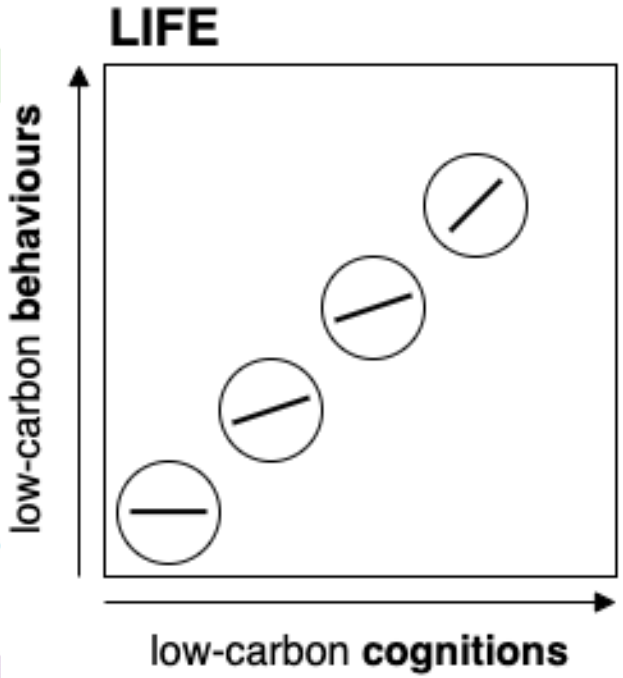

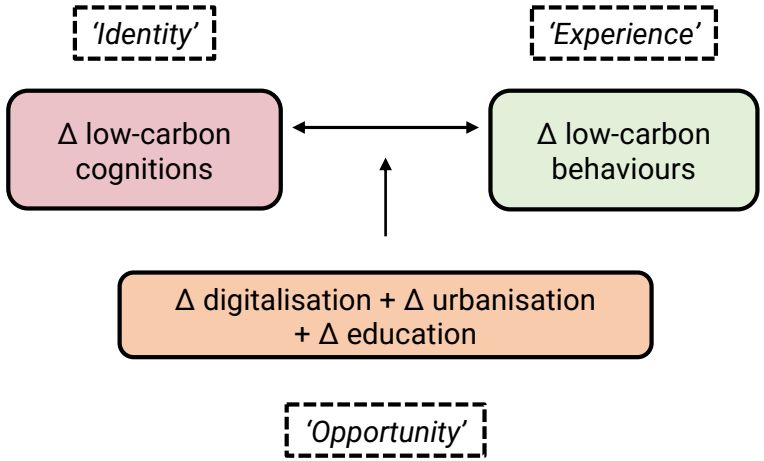

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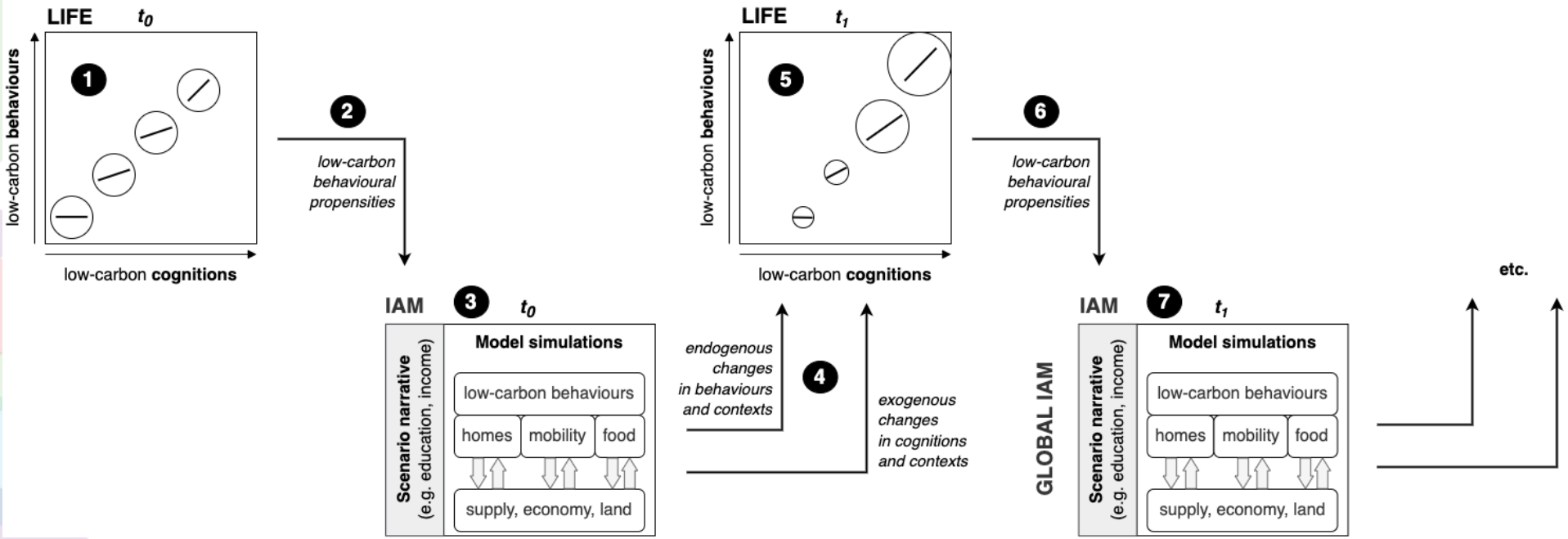
The LIFE model of low-carbon lifestyle change: IAM coupling for endogenous simulation



first order effect: **techno-economic processes in the IAM**

second order effect: additional lifestyle changes (differentiated by type)

Pettifor, H., A. Mastrucci, C. Wilson, B. van Ruijven, M. Agnew and T. L. Gallic (2024). "Endogenous simulation of low-carbon lifestyle change in global climate mitigation pathways." *Environmental Research Letters* 19(1): 014016. https://doi.org/10.1088/1748-9326/acf6d6

The *digi*LIFE model of low-carbon lifestyle change: statistical model fitted to historical dynamics

H1. **Identity effect**.

Classic 'value' shift rationale for strengthened low-carbon behaviours (e.g. SSP1)

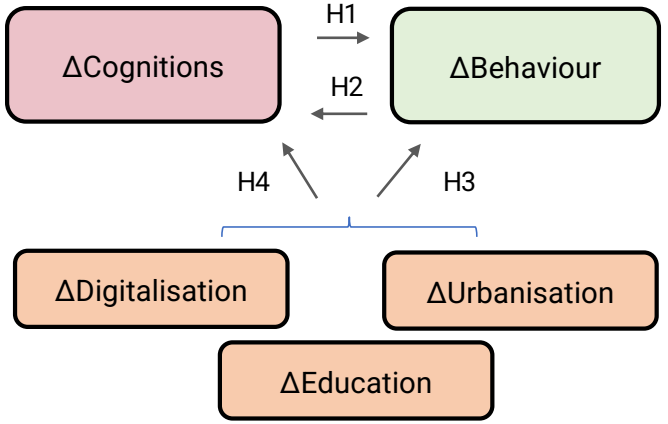
H2. **Experience effect**.

Reverse rationale to identity.

H3+H4. **Opportunity effect.**

Digitalisation (& urbanisation, education) widens access to low-carbon behaviours & cognitions.

H5. **All effects combined**.



$$Beh_{i,t} = \alpha + \beta Cogs_{i,t} + \beta Digi_{i,t} + \beta Urban_{i,t} + u_{i,t} + v_{i,t}$$

Random effects panel model

Variables & data used in the historical models (EU23, 2002-2022)

Construct		Variables	Source
ΔLow-carbon cognitions	=	***Agency*** (freedom to make own decisions) ***Values*** (caring for others, equality between people who are different) ***Beliefs*** (caring for nature is important)	European Social Survey (ESS) 2002-2022, household level
ΔLow-carbon behaviours	=	***Avoid*** energy-intensive travel (telework) ***Shift*** to low-carbon diet ***Improve*** ways of managing resources (waste)	Eurostat, Euromonitor 2002-2022, country level
ΔDigitalisation ΔEducation	=	Scope and quality of ***online services***, development status of telecommunications ***infrastructure***, human capital (accumulated ***knowledge, and skills***)	UN e-Government Development Index (EGDI) 2002-2022, country level
ΔUrbanisation	=	Share of the total population living in ***urban*** environments	United Nations Population Division, 2002-2022, country level

All lifestyle change hypotheses are confirmed: digitalisation as an enabler has the strongest effect

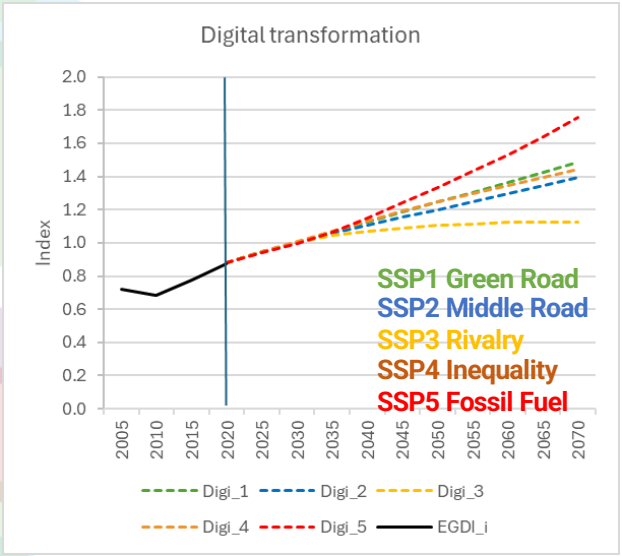
	Primary outcome (impact on lifestyle change): effect size [SE]				
Intervention effect	Identity (test H1)	Experience (test H2)	Opportunity 1 (test H3)	Opportunity 2 (test H4)	**All - Combined model (test H5)**
Model	$Cogs_{t-1}$->Beh_t	Beh_{t-1}->$Cogs_t$	$Context_{t-1}$->Beh_t	$Context_{t-1}$->$Cogs_t$	**Cogs, Context->Beh_t**
ΔCognitions	3.20 [0.523] **	-	-	-	**1.41 [0.385] ****
ΔDigitalisation	-	-	1.62 [0.095] **	0.03 [0.011] **	**1.53 [0.090] ****
ΔUrbanisation	-	-	0.95 [0.315] **	0.14 [0.041] **	**1.06 [0.319] ****
ΔBehaviours	-	0.02 [0.004]**	-	-	**-**
R^2 (total)	2.7%	3.2%	36.7%	1.0%	**35.4%**

Effect size = %Δ in the outcome variable for a 1% Δ in the predictor variable.
** = 0.05 significance level. Square brackets denote robust std errors.

Historical lifestyle change model can used for projections as predictors are SSP elements or extension variables

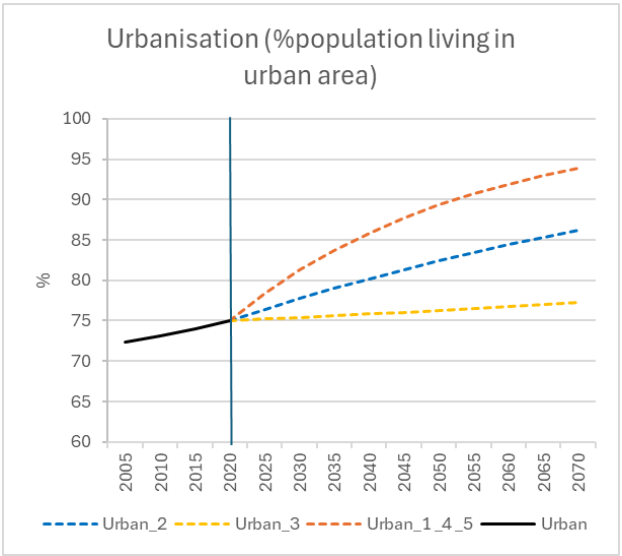
Construct		Data for SSP-consistent projections (2020-2070)
ΔLow-carbon cognitions	?	New analysis based on longitudinal survey data (World Values Survey, European Social Survey) & relationship with HDI. ** Pettifor et al. Scenarios Forum! **
ΔDigitalisation	=	Digital transformation projections as a function of GDP, population, R&D expenditure based on historical relationships [Fan, Wilson et al. 2025]
ΔEducation		Education (human capital) projections as main SSP element https://data.ece.iiasa.ac.at/ssp/
ΔUrbanisation	=	CDM Urbanization 2024 model, core SSP driver (https://data.ece.iiasa.ac.at/ssp/#/workspaces

Historical lifestyle change model can used for projections as predictors are SSP elements or extension variables



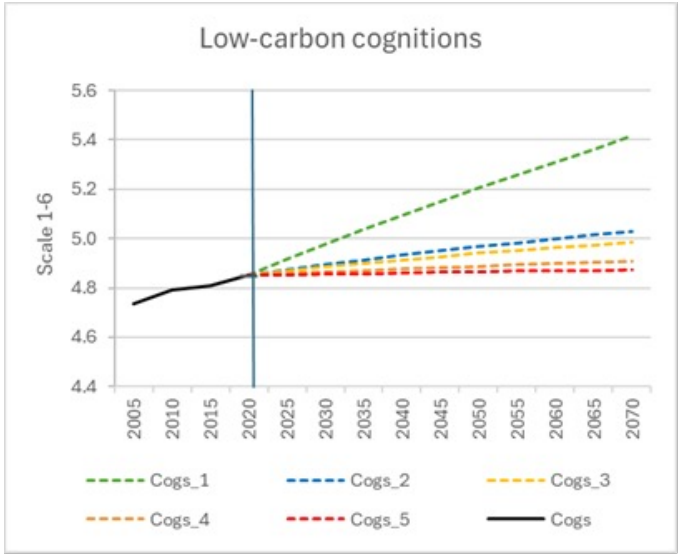
Source: Fan, Wilson et al. forthcoming

Fastest under SSP5 assumptions. Digitalisation enables accelerated globalisation and rapid development in knowledge economies.



Source: SSP Scenario Explorer (IIASA).

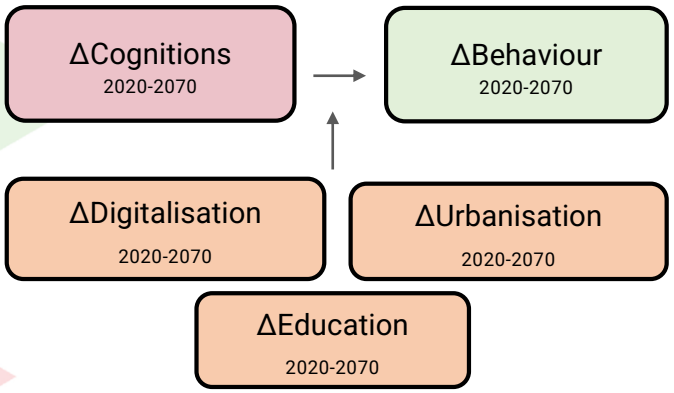
In EU, similarly rapid urbanisation in SSP1 (green), 4 (inequality) and 5 (fossil fuel).



Source: Pettifor et al. forthcoming.

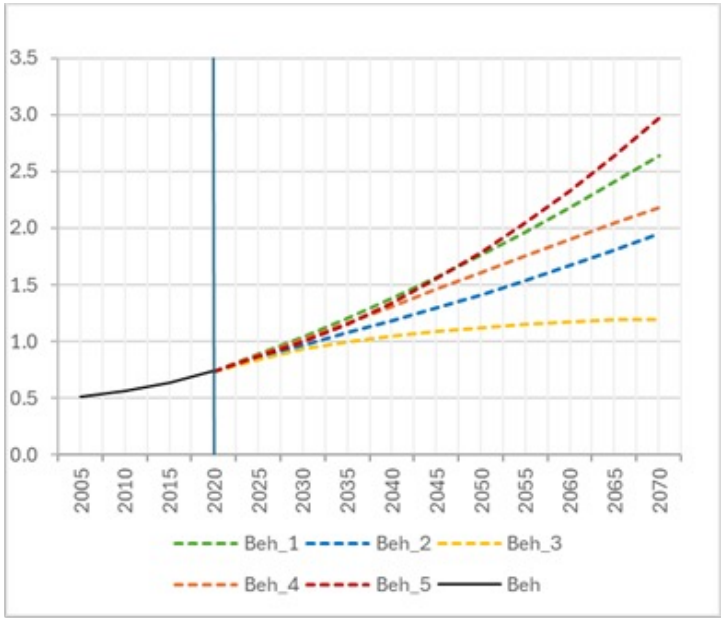
(Much) fastest under SSP1 assumptions; weakest under SSP4 & 5.

Projected low-carbon behaviours are strongest under SSP5 assumptions: opportunity effect > identity effect



DigiLIFE Combined historical model with projected data

$$Beh_{i,t} = \alpha + \beta Cogs_{i,t} + \beta Digi_{i,t} + \beta Urban_{i,t} + u_{i,t} + v_{i,t} \quad [Eq\ 1]$$



SSP5 Fossil Fuel

SSP1 Green Road

SSP4 Inequality

SSP2 Middle Road

SSP3 Reg. Rivalry

Figure – Projected **low-carbon behaviours (low-cost composite)**

Although low-carbon cognitions are an important driver of low-carbon behaviour,
digitalisation (and to a lesser extent urbanisation) create the contextual conditions that enable low-carbon lifestyles.
This is strongest in SSP5 not SSP1.

Use cases for SSP-consistent quantitative projections using digiLIFE

Applications	Quantitative measures needed
Calibration tool to validate IAM assumptions using quantitative measures	Relative historic ASI behavioural shifts (digiLIFE)
	Comparative input model assumptions
Calibration tool to validate IAM output via using ex-post comparison with quantitative measures	Relative ASI behavioural shifts within SSPs (digiLIFE)
	Model output, such as activity or service levels.

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	Model output, such as activity or service levels.
Impact assessment of digitalisation (+cogs) on high-upfront-cost low-carbon behaviours **	Relative historic/future changes in lifestyle elements (digiLIFE)
	Demand for high-upfront-cost consumer tech (historic)
Direct energy impact assessment of 'low-carbon' lifestyle (low-upfront-cost behaviours) **	Relative ASI behavioural shifts within SSPs (digiLIFE)
	Energy intensity for relevant sectors
Simulation tool - values as important drivers of social development (e.g., equality, wellbeing)	Relative cognitive change within SSPs (digiLIFE)
	SSP extensions (IIASA) such as Gini, or other external sources
Low-carbon lifestyle index – track progress across regions / time	Relative changes in digitalisation, urbanisation, & low-carbon cognitions / behaviours (digiLIFE)

** expanding the empirical foundations and applications of digiLIFE

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Useful slides

Using the digital lifestyle model (DigiLIFE) to justify exogenous low-carbon behaviour change assumptions in the lifestyle MIP (SSP2)

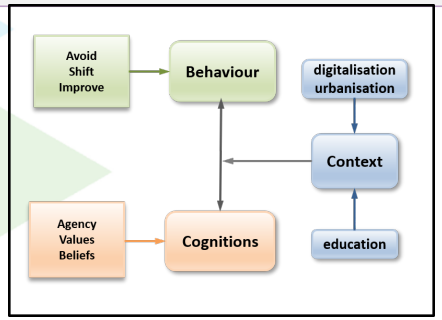

Figure 1 Digital lifestyle model (DigiLIFE)

DigiLIFE – a statistical model of low-carbon lifestyles. Theoretically substantiated and empirically derived (2002-2022) and used to project under SSP assumptions (to 2070).

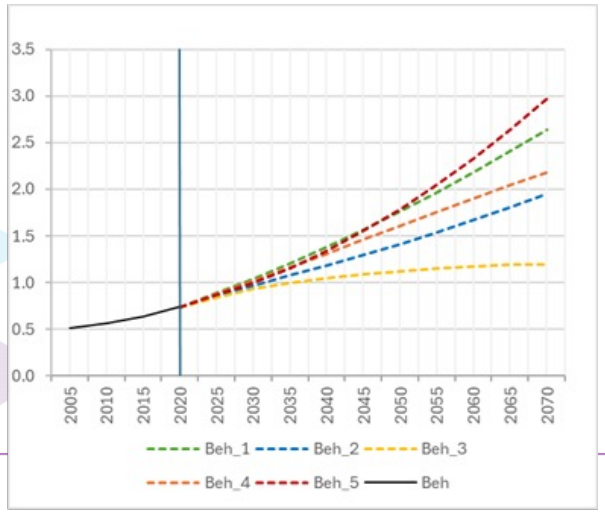

Figure 2 Projected 'index' of low-carbon behaviours (2020-2070) SSP1 (green line), SSP2 (blue line), SSP5 (red line)

Option 1 – Include an introductory/framing narrative for LIFMIP study (main text intro section or as appendix)

(Key points)

- Lifestyle consists of interacting elements: cognitions, behaviour and context [Agnew et al 2023]. See Figure 1.
- Lifestyle is observable through behaviour but the cognitive processes that direct and shape behaviour are complex to endogenize in IAMs [Pettifor et al 2023]. Exogenous approaches bridge this gap.
- Lifestyles shift as context changes e.g., people have more wealth, more education, and improved access to infrastructure e.g., digitalisation, urbanisation [Prede et al. 2020].
- But lifestyles also shift when societal values change [Saujot et al 2020].
- In our statistical models, where concern for others, and care for the environment are dominant values we see an increase in low-carbon behaviour (under the assumptions of SSP1) (Figure 2, green line).
- But where self-interest, status and success are dominant values (under the assumptions of SSP5) we see a larger increase in low-carbon behaviour. This is because contextual enablers (including the provision of enabling infrastructure such as digitalisation) are stronger.
- SSP2 (reference for LIFMIP) is continuation of historical value trends.

Using the digital lifestyle model (DigiLIFE) to justify exogenous low-carbon behaviour change assumptions in the lifestyle MIP

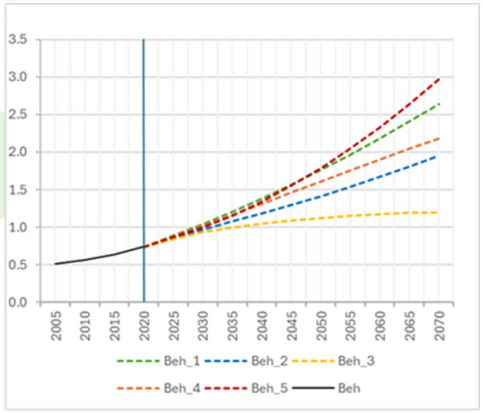

Figure 3 Projected low-carbon behaviours (2020-2070)

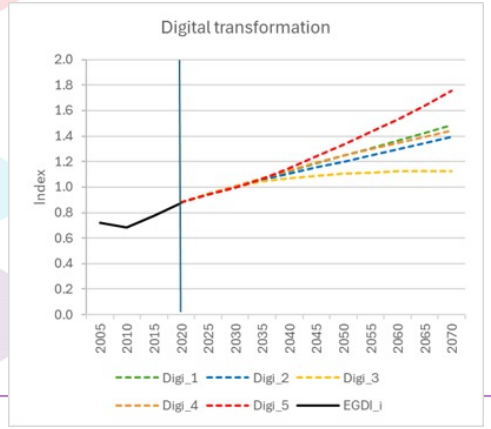

Figure 4 – Projected digital transformation (2020-70)

Option 2 (or in addition to Option 1) – Ex-post comparison of MIP results to DigLIFE results by comparing relative behaviour change over time

- DigiLIFE statistical/empirical projections (SSP2) capture % change across 3 representative behaviours (Avoid = teleworking, Shift = vegetarian diet, Improve = reduced waste/recycling).
- These are all low upfront cost pro-environmental behaviours (A+S+I).
- By comparing our projected behaviour outcomes for SSP2 (2020-2070) with equivalent LIFMIP behaviour outcomes (e.g., teleworking, uptake meat-free diet, reduction in food waste) we can validate the exogenous approach taken in the LIFMIP protocol.
  - For comparison purposes the LIFMIP outcome variables (e.g., activity, service demands) can be combined into a single behaviour change index
  - This will be directly comparable with the composite index of A+S+I behaviours in the DigiLIFE projections.
- Subject to findings we can also expand LIFMIP insights on SSP2 behavioural outcomes to different scenarios (see Figure 3).
- E.g., faster change expected under SSP1 due to values, but particularly SSP5 due to urbanisation and digitalisation, key enablers (see Figure 4).