System dynamics for system innovation

JRC project and model development process: introduction & an update

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The project & model: an introduction

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Objectives and scope

Aim

Develop knowledge base for the *conceptualisation*, *measurement*, *modelling* and *evaluation* of **system innovation**

Objectives

- Develop a **working prototype quantitative system dynamics model** with policy applications that demonstrates feasibility and usefulness
- Contribute to the **definition of design specifications for a fuller and more rigorous model** of the system dynamics of transformative socio-economic change

How

A co-creation process that brings together:

- Pioneer **policy practitioners**, as the final users of policy evaluations
- JRC **researchers** and **other experts** on the measurement of policy inputs and outcomes, system dynamics models, new industrial policies and transformative innovation policy.

The model: POLYTRoPOS

POLY*valent model for the ex ante evaluation of* **TR***ansformative* **PO***licy* **S***cenarios*

ΠΟΛΥΤΡΟΠΟΣ = (adj.) literally "of many turns" or "of many ways" an epithet used to describe to Ulysses in the opening verse of the Odyssey, loosely interpreted as: "resourceful" or "versatile"

An empirically calibrated System Dynamics (SD) quantitative model adaptable to many policy questions

Key features:

(1) Challenge-oriented (demand-led)

(2) Production-focused (+ diversification)

(3) Policy portfolio (multi-ministry /-level) impacts on *deployment*, *production* and *wellbeing*

Current development status:

- Experimental prototype, continuous improvement
- Partial empirical calibration, in progress
- Missing societal wellbeing part

Advantages of the model

- ✓ Drawing on rigorous theory and empirical regularities
- ✓ Time dimension & dynamic feedback
- ✓ Transitions set-up & *large-scale* change
- ✓ Whole-of-government policy packages and mixes
- ✓ Integrating multiple evidence bases & other EC models
- ✓ Communication-friendly, allowing participatory modelling

https://publications.jrc.ec.europa.eu/repository/handle/JRC139240

Propositions underpinning current focus and boundaries of POLYTRoPOS

1. During a transition, enormous budgets are being mobilised for deployment, driving **historic expansions in demand** (Pomeranz, 2000; Arthur, 2009; Storper, 2018)

2. **Deployment is regular and straightforward to model** (Rogers, 1962; Perez 2002) – new solution emergence **is not** (**uncertainty** vs **risk**: see Mokyr, 1992; Scherer and Harhoff, 2002; Silveberg and Verspagen, 2007)

3. **During deployment,** in common with other demand-expansion episodes, there is a **window of opportunity** to develop domestic capabilities (Bell and Pavit, 1995; Bell, 2009;)

4. **Production capability** development is valuable, difficult and therefore should be a major policy objective (Andreoni and Scazzieri, 2013)

5. **Diversification** is necessary for domestic capabilities to accumulate (Hidalgo et al., 2007)

6. **A broad policy toolbox** can **couple** solution **deployment** and **capability accumulation** (Schot and Steinmueller, 2018)

7. New, more ambitious visions in keeping with local conditions and social values can be mapped onto **alternative demand** and **different paths of capability development** (potentially even more sustainable than purely technology-based solutions)

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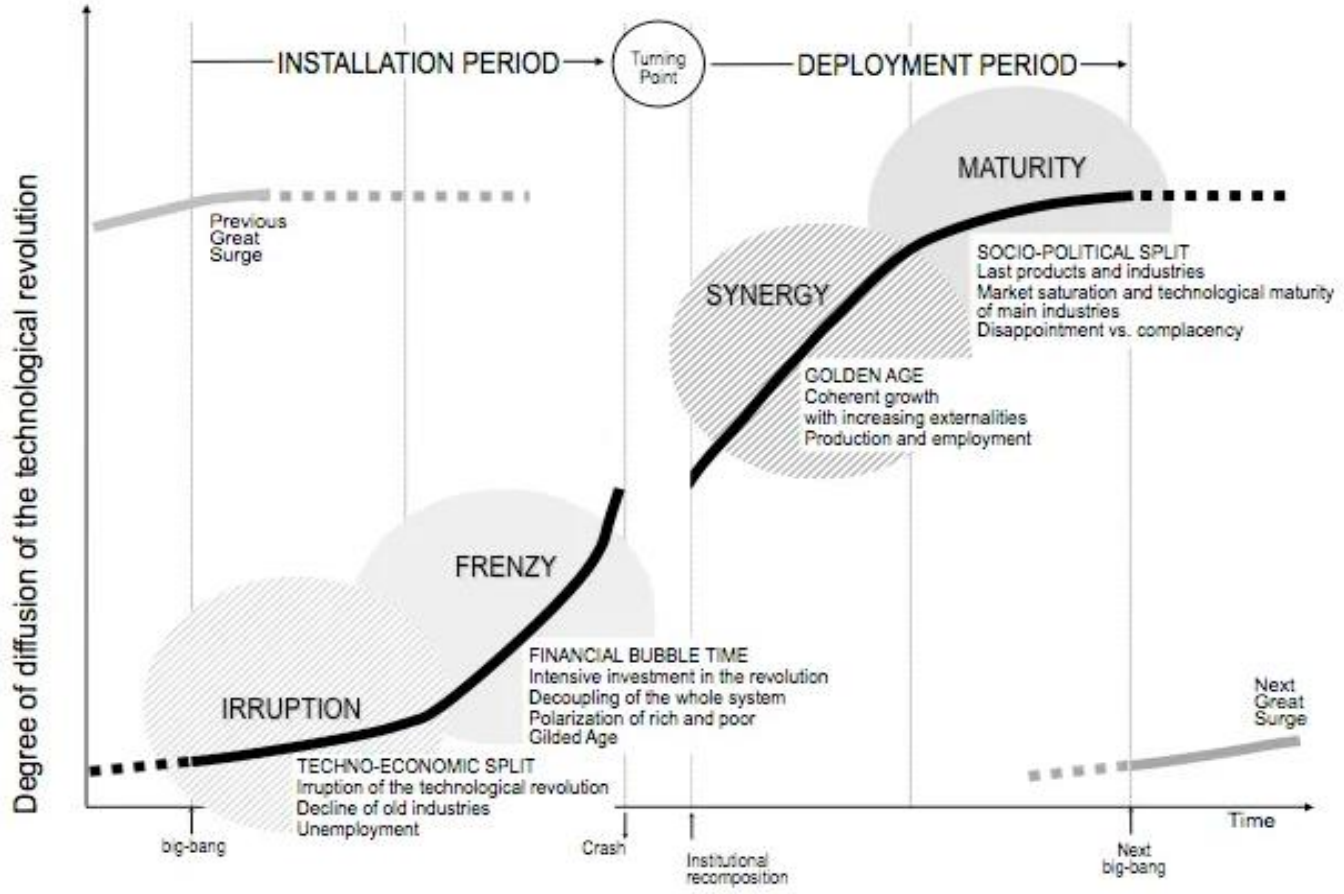
Past an inflection-point, deployment follows a regular pattern

Recurring stages of technological revolutions



Source: Perez, C. (2002), *Technological Revolutions and Financial Capital, The Dynamics of Bubbles and Golden Ages*, Edward Elgar, Cheltenham

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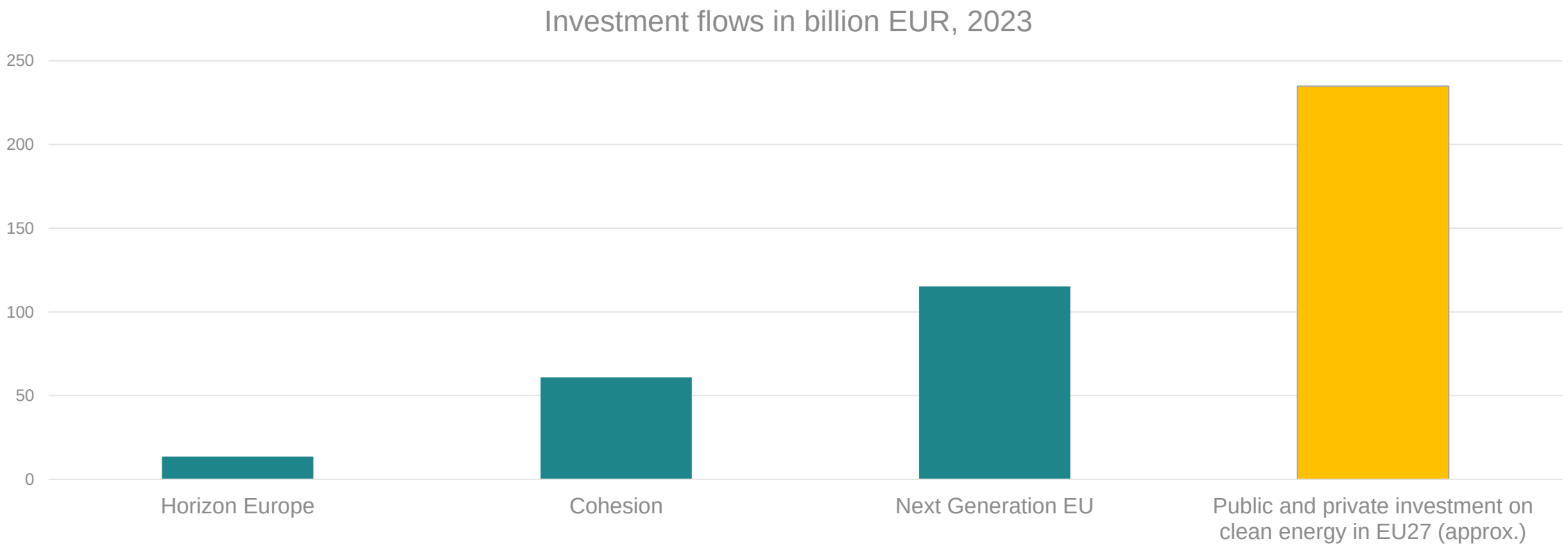
The resources mobilised for the transition are enormous – and growing predictably



Sources: Clean energy investment estimated from IEA (2023) by assuming the share of EU27 investment in the world total is equal to its share of world GDP. EU budget figures from European Commission (2024), annualised by dividing grand total by the duration of the multiannual funding framework.

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Stepwise accumulation of capabilities

Table 2 - Public support for production and innovation capabilities: the shifting focus of policy attention and indicative instruments at different stages of development

...business sector is predominantly characterised by	**A. Basic or no production capabilities**	**B. Nationally relevant production capabilities**	**C. Internationally relevant production capabilities**	**D. World class production capabilities**
	(Stars denote focus of policy attention/resources in each stage)			
I. New-to-the-firm or new-to-the-territory innovation capabilities (local problem solving)	(* * *) - Favourable capital depreciation allowances - Vocational and tertiary education - Training and certification	(*) - Favourable capital depreciation allowances - National skills strategy	*N/A* *(no additionality)*	*N/A* *(no additionality)*
II. New-to-the-market innovation capabilities (edge vs current competitors)	(*) - Innovation training - Microfinance - Knowledge-intensive employment subsidies - R&D Subsidies/tax incentives	(* * *) - Public procurement - Tertiary education (e.g. industrial PhDs) - Infrastructures - R&D Subsidies/tax incentives - National technology platforms	(* *) - R&D Subsidies - R&D tax incentives - International collaboration	*N/A* *(no additionality)*
III. New-to-the-world innovation capabilities (shifting global frontier)	*N/A* *("High tech fantasies")*	(**) - Public R&D - Technology transfer - R&D Subsidies/tax incentives	(* * *) - Cross-border innovation networks - Public R&D - Incentives to relocate multinational R&D	(* * *) - Global talent attraction - Tailored support to frontier sectors - Cross-border innovation networks

Source: Adapted from Pontikakis et al. (2020, p. 65). Inspired by Bell and Pavitt (1995) and Bell (2009).

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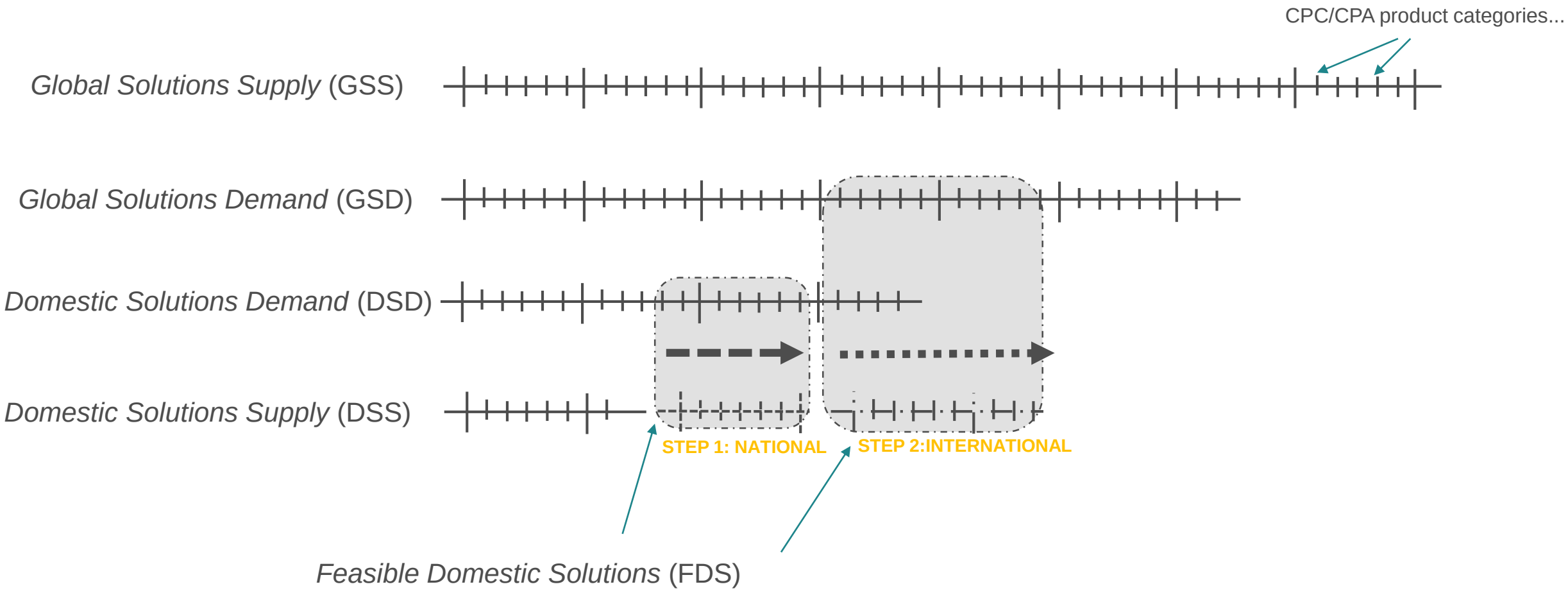
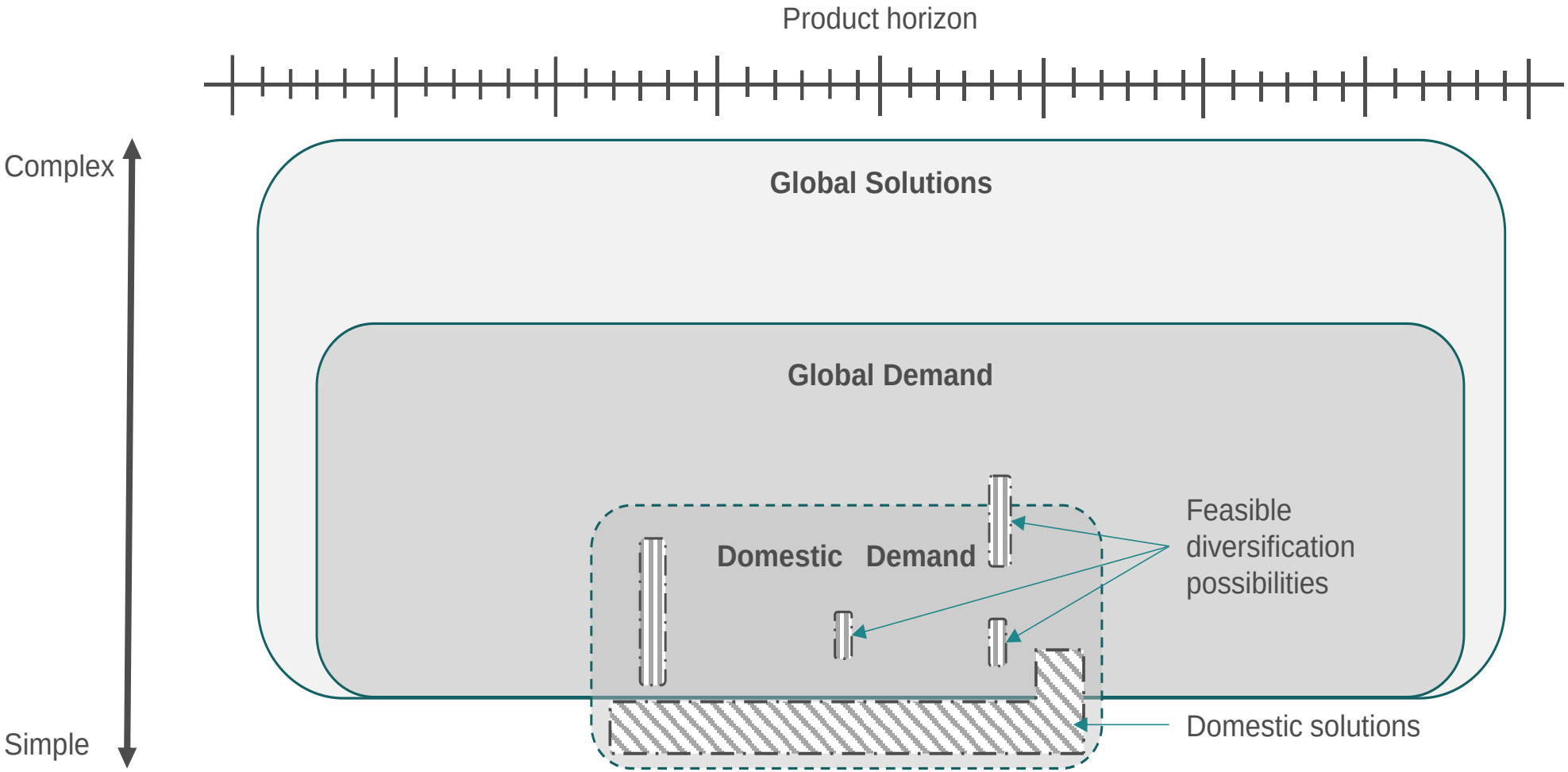
Diversification is necessary for domestic capabilities to accumulate

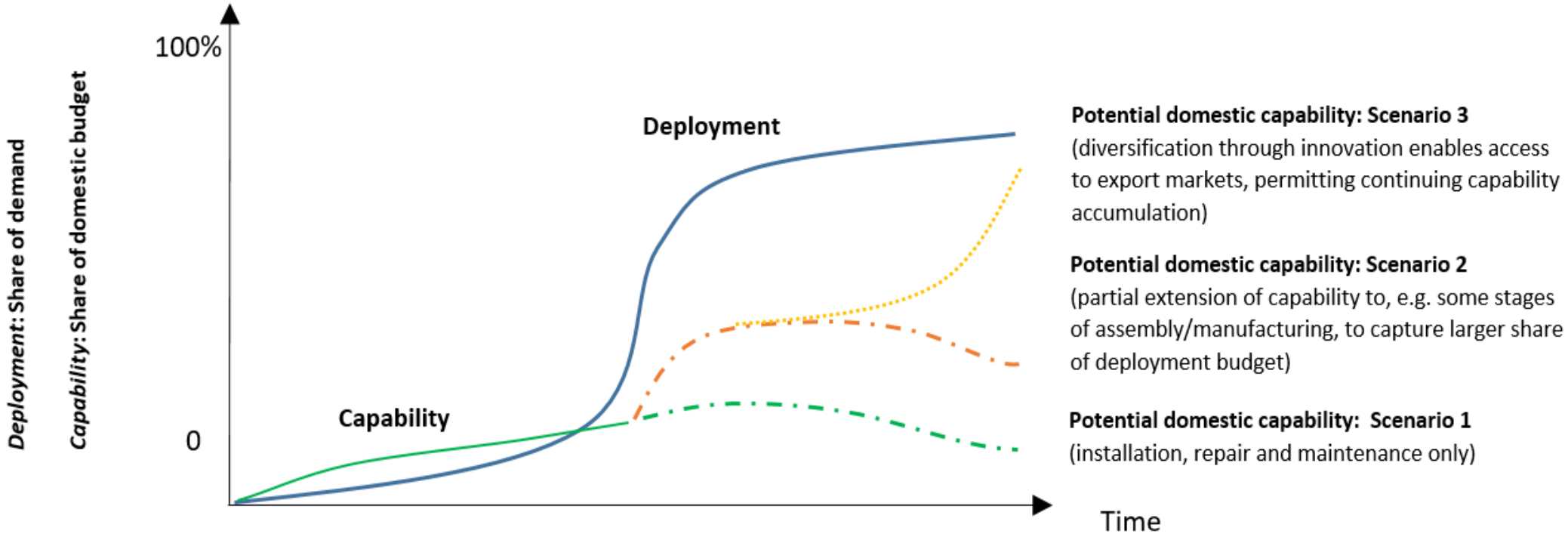


Capturing global demand requires capability to produce progressively more complex products



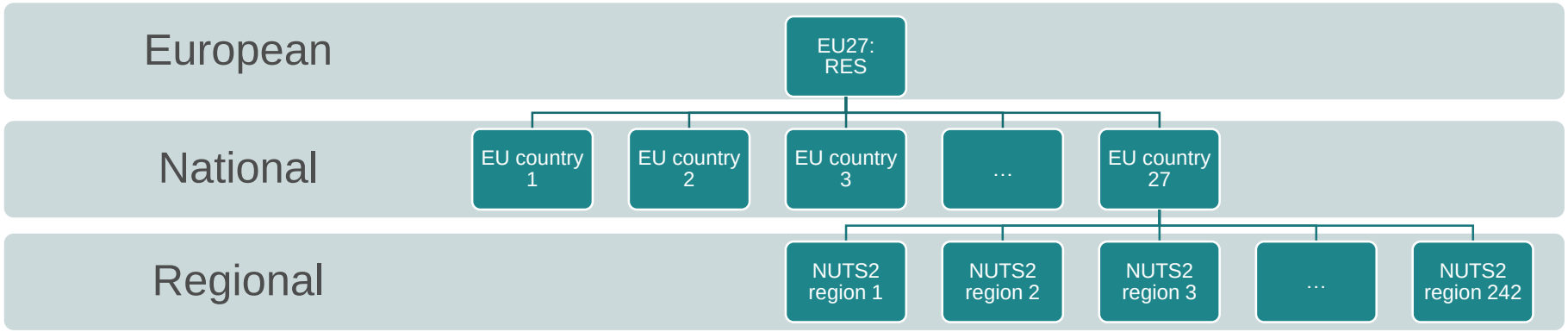
Policy uses of the model

- Challenge-oriented mapping of policy mixes;
- Ex-post and ongoing evaluation of policy instruments and instrument mixes.
- Ex-ante comparative impact assessment of policy options.



The model development process

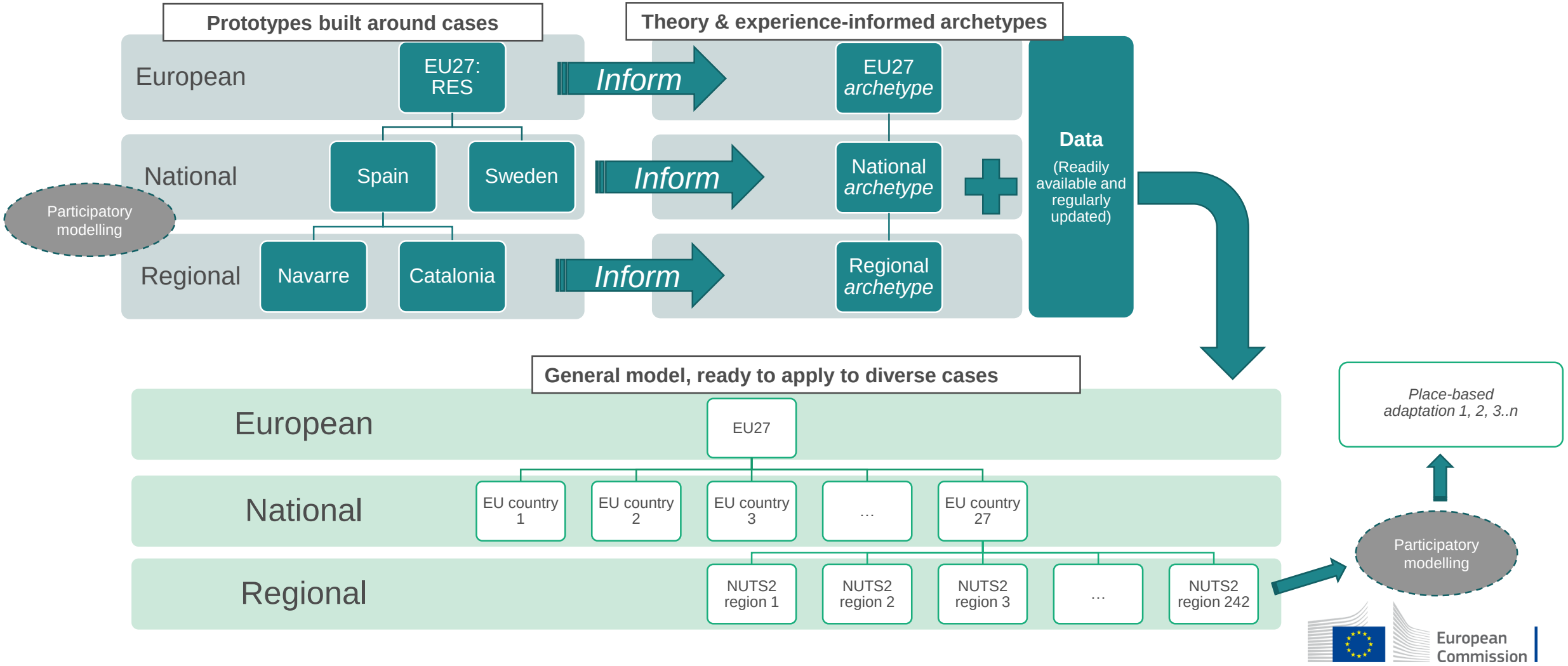
End product



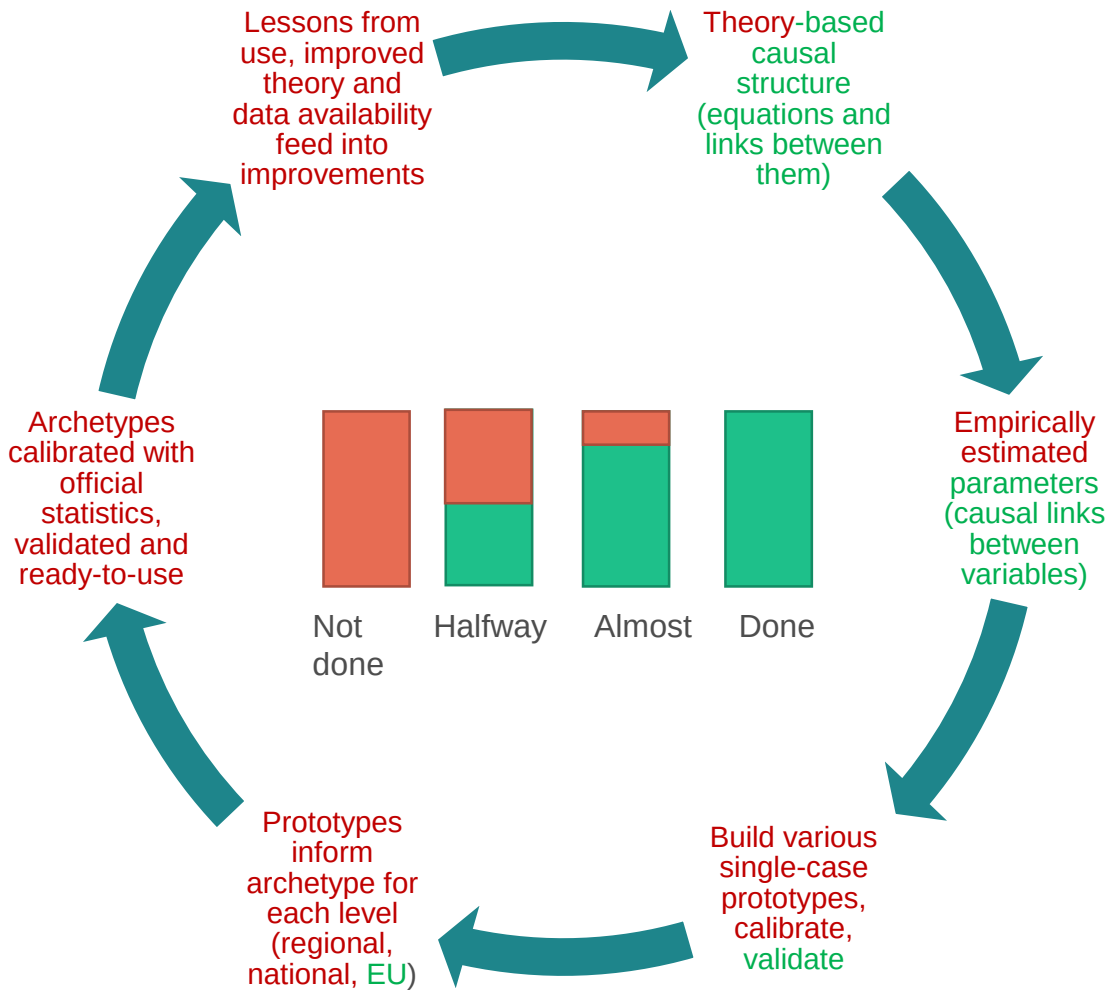
Long-term objective

- A **general model** that can be readily applied to cases, or '**episodes**', of industrial transition (e.g. energy, mobility, defence)
- Model should be **multi-level** (regional/national/EU), and **macro-aggregated** to draw on readily available and regularly updated statistics
- Focus on **assessing approximate policy impacts** along the duration of a transition episode.
- Common feature across different episodes (general model): triggered by an *expansion in demand* THEN accompanied by a process of *structural change in production* and ensuing feedback

The model development process: prototypes, archetypes and the general model



Development process



Experimental prototype

Territory: EU27 (single-country model)

Episode: Renewable energy and related value chains (grids, storage etc.)

Timescale: 2010-2050

Progress so far

- ✓ Theory review (April)
- ✓ Causal loop diagram (May)
- ✓ Stock and flow structure in Stella Architect (August)
- ✓ Data work (November)

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Future plans, next phase 2025-26

- National, regional cases yield lessons
- Co-created scenarios guide development
- Endogenous technology emergence
- Societal wellbeing (incl. environmental / social dimensions)
- General economy model
- Data infrastructure permitting easy calibrations of different episodes
- Visual interfaces for policy makers

Guiding questions

- Is the general idea clear?
- Any suggestions for improvements in the model development process?
- Directions for future development?

Thank you

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