Participatory Multi-Modelling for Decision Making Under Deep Uncertainty

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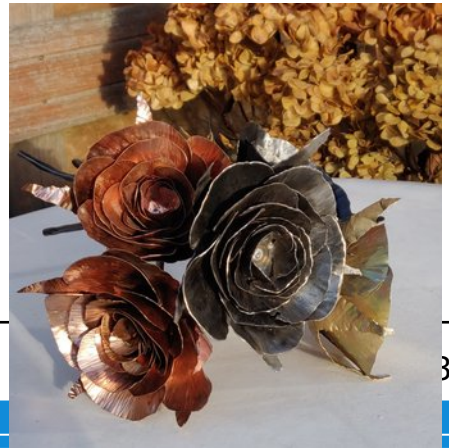
Structure of the presentation

- Some context
  - TU Delft, TPM, me
  - Worldview
  - Energy and Industrial Infrastructures
- Deep Uncertainty and (investment) decisions
- Participatory processes
- (multi) Modelling
- How it works in practice

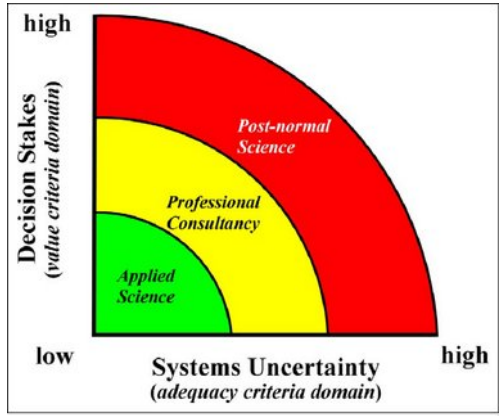
TU Delft, TPM and me

- Dr. ir. Igor Nikolic,
  - Associate professor participatory multi-modelling
  - Chemical / bioprocess engineer, environmental sciences, modeling and decision making, highly multi- and transdisciplinary
  - PhD thesis on evolutionary modeling approach to ABMs of industrial systems
  - Dad, neurodiverse nerd, hobby blacksmith, wannabe artist (https://complexevo.org/ and https://twitter.com/ComplexEvo)
- Delft University of Technology (www.tudelft.nl)
  - Faculty (department) of Technology, Policy and Management (https://www.tudelft.nl/en/tpm/)
  - department of Multi-Actor Systems (https://www.tudelft.nl/en/tpm/about-the-faculty/departments/multi-actor-systems)
  - Systems Engineering and Simulation group



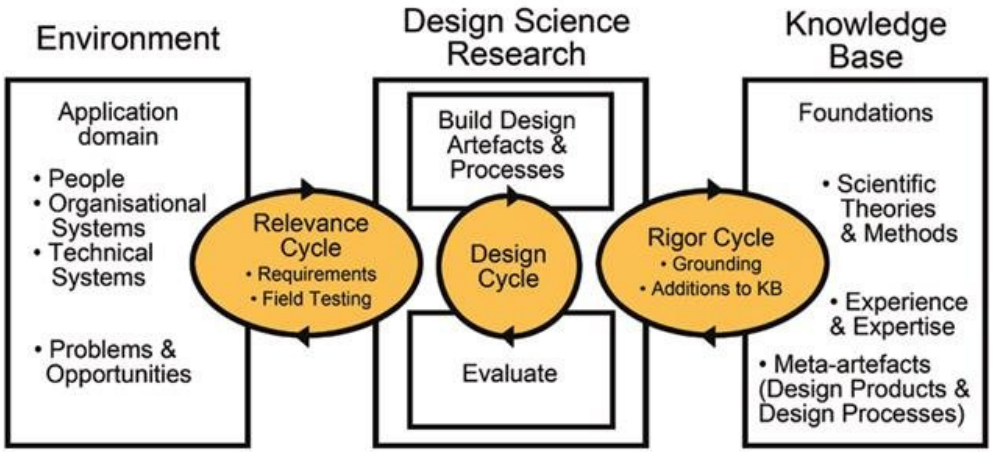
Complex Adaptive Bio-Geo-Chemical-Socio-Technical System

- Systems view
  - It is all connected and always changing
- Sustainable development
  - Retaining the ability to adapt
- Post normal science
  - Facts, values and quality matter
- Transdisciplinary
  - “Stuff I know about” vs “My field”



(Funtowicz, S. and Ravetz, J., 1993. "Science for the post-normal age", Futures, 31(7): 735-755.)

More engineering than science
Design science approach



- Engineering :
  - Explicit normative goals
  - Action and impact oriented
  - Acting with incomplete, imperfect and biased knowledge
  - “If it works, it ain’t stupid”
- Design
  - Application in real situations
  - Platform and tooling development
  - Methodological research

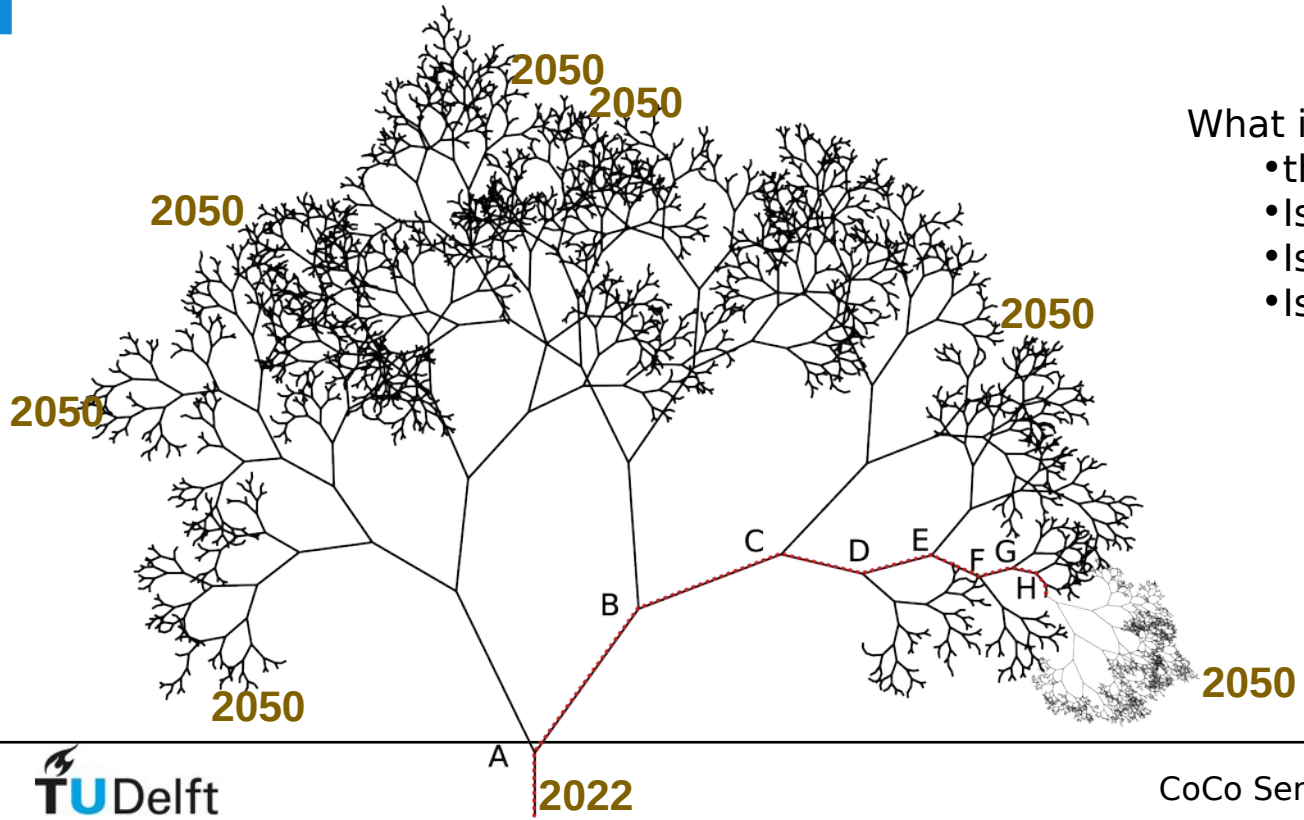
Hevner, Alan R. "A three cycle view of design science research."
Scandinavian journal of information systems 19.2 (2007)

Energy infra and investments for transition

- Energy transition deeply uncertain
  - Use / technology change in households, transport, industry?
  - Which carrier & where?
  - Climate & extreme weather?
- Slow, expensive and “forever”
  - 380KV: ~ 10 year to build, ~6M€/GW/km, ~50-100 years
- Deep interconnection with other systems
  - Nat gas, H2, electricity, LT/HT heat, transport & mobility
- Culture of infra providers
  - Must Work, maintenance first, deterministic planning
- Disjointed, neo-liberal regulatory mess
  - Markets on natural monopolies, financial benchmarking

Challenge of the Decision maker

Reducing the uncertainty about the consequences of your actions



What is uncertain

- the value of the parameter?
- Is this even a relevant parameter ?
- Is this a relevant / correct model?
- Is it even the right question?

Challenge of the Decision maker

Reducing the uncertainty about the consequences of your actions

Two ways

1: Reduce your uncertainty about the future

- Identify the single correct scenario

2: Make your decisions more robust to uncertainty

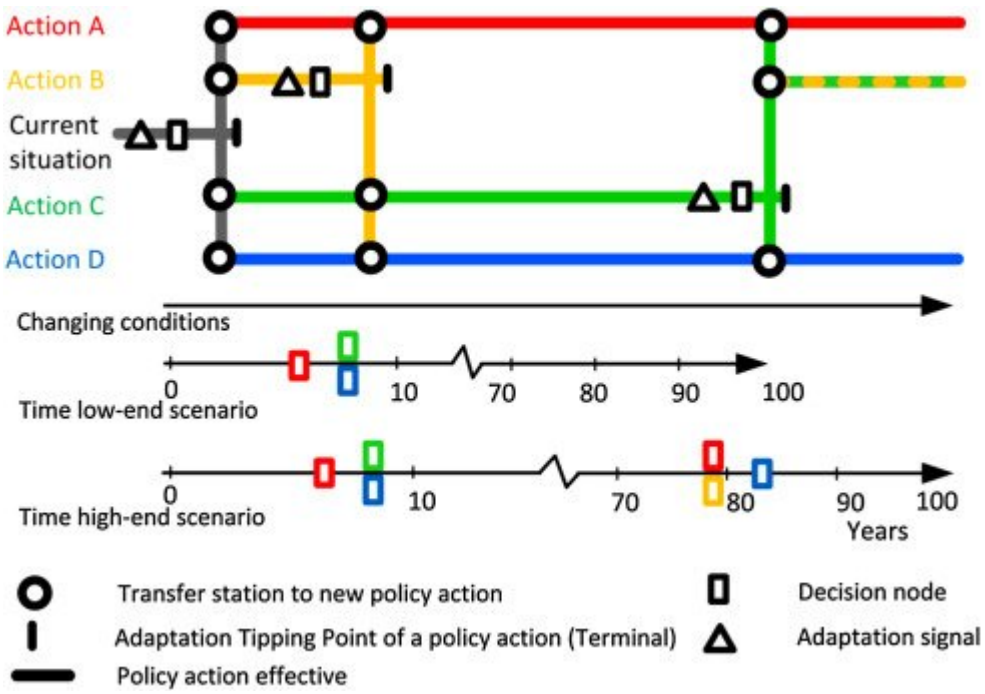
- Deal with the the scenario space

from **Predict** and **Act** to **Explore** and **Adapt**

- from **predict** to **explore**
  - Scenario discovery (Bryant & Lempert 2010)
  - Robust multi-objective optimization (Kwakkel et al. 2015)
  - Info-Gap decision theory (Ben Haim, 2001; Hall et al. 2012)
  - Adaptation tipping points (Kwadijk et al 2010)
  - Decision scaling (Brown et al. 2012; LeRoy Poff et al. 2015)
- from **act** to **adapt**
  - Assumption-Based Planning (Dewar et al.1993)
  - Adaptive Policymaking (Kwakkel et al 2010)
  - Dynamic Adaptive Policy Pathways (Haasnoot et al. 2013)
  - Robust Decision Making (Lempert & Collins 2007)

So how to Explore and Adapt ?

- Explore : jointly develop networks of models together and test them across vast scenario spaces
- Adapt : robust, regret minimizing plans that with explicit adaptation choices



https://emaworkbench.readthedocs.io/en/latest/

Hermans, L. M., Haasnoot, M., ter Maat, J., & Kwakkel, J. H. (2017). Designing monitoring arrangements for collaborative learning about adaptation pathways. Environmental Science & Policy, 69, 29-38.

Participatory - why and how?

- Analysis, Design and Testing of participatory processes for
  - (multi)-modelling
  - analysis and sense-makling

- Use of (physical) games
  - on understanding decision making
  - communicating / sense-making of models
  - calibrating /developing models

Participatory : Theoretical foundations

- Social Learning Systems

Wenger, E. (2000). Communities of Practice and Social Learning Systems. Organization, 7(2), 225–246. https://doi.org/10.1177/135050840072002

- Organisational learning / Levers of control

Simons, R. (1994). Levers of control: How managers use innovative control systems to drive strategic renewal. Harvard Business Press.

- Participatory Modelling

Voinov, A., & Bousquet, F. (2010). Modelling with stakeholders. Environmental modelling & software, 25(11), 1268-1281.

- Multi-level group selection / Collaboration cascades

Boyd, R., & Richerson, P. J. (2010). Transmission coupling mechanisms: cultural group selection. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1559), 3787-3795.

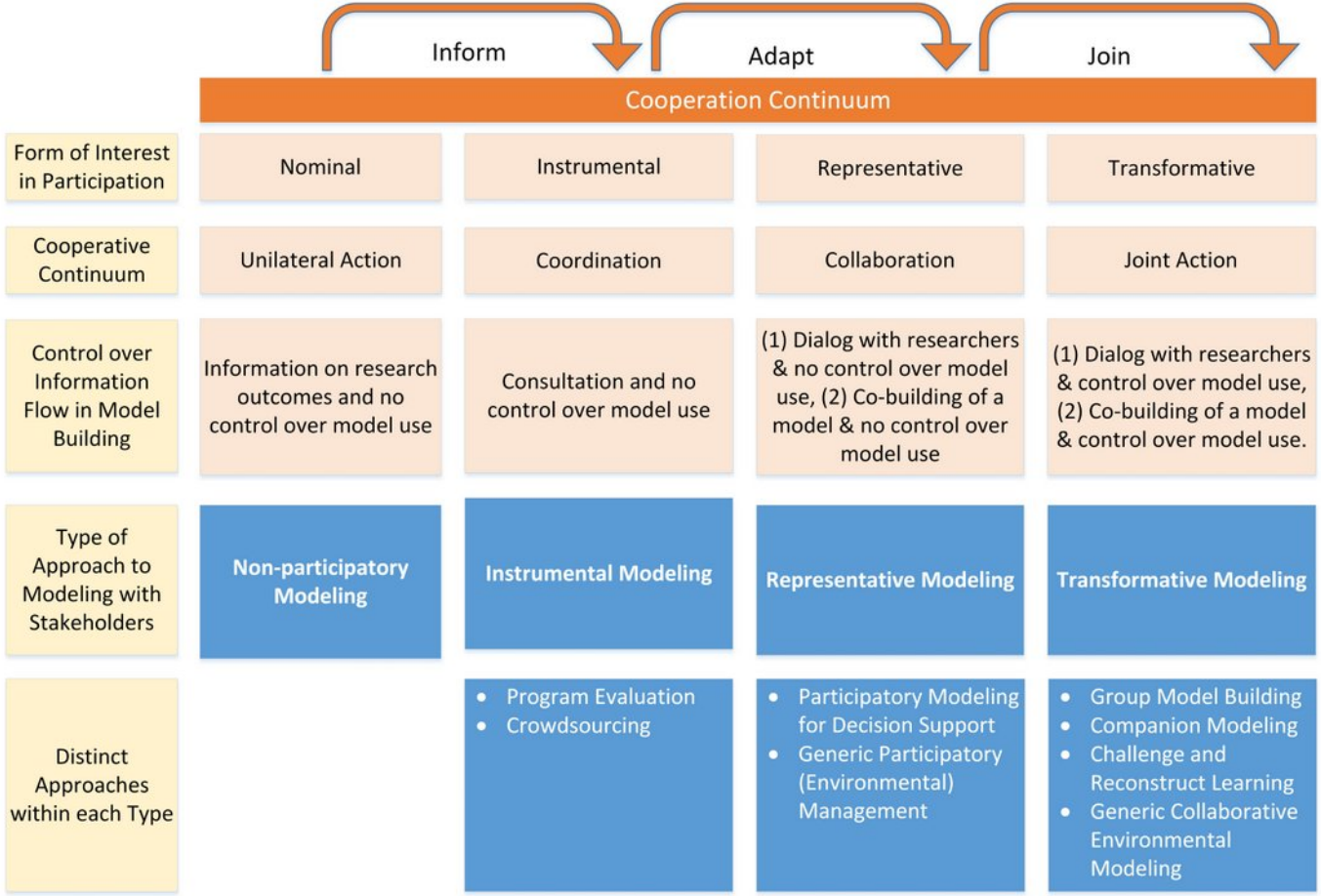
- Boundary object (ecology)

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology,translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. Social studies of science, 19(3), 387-420.

- Serious Gaming

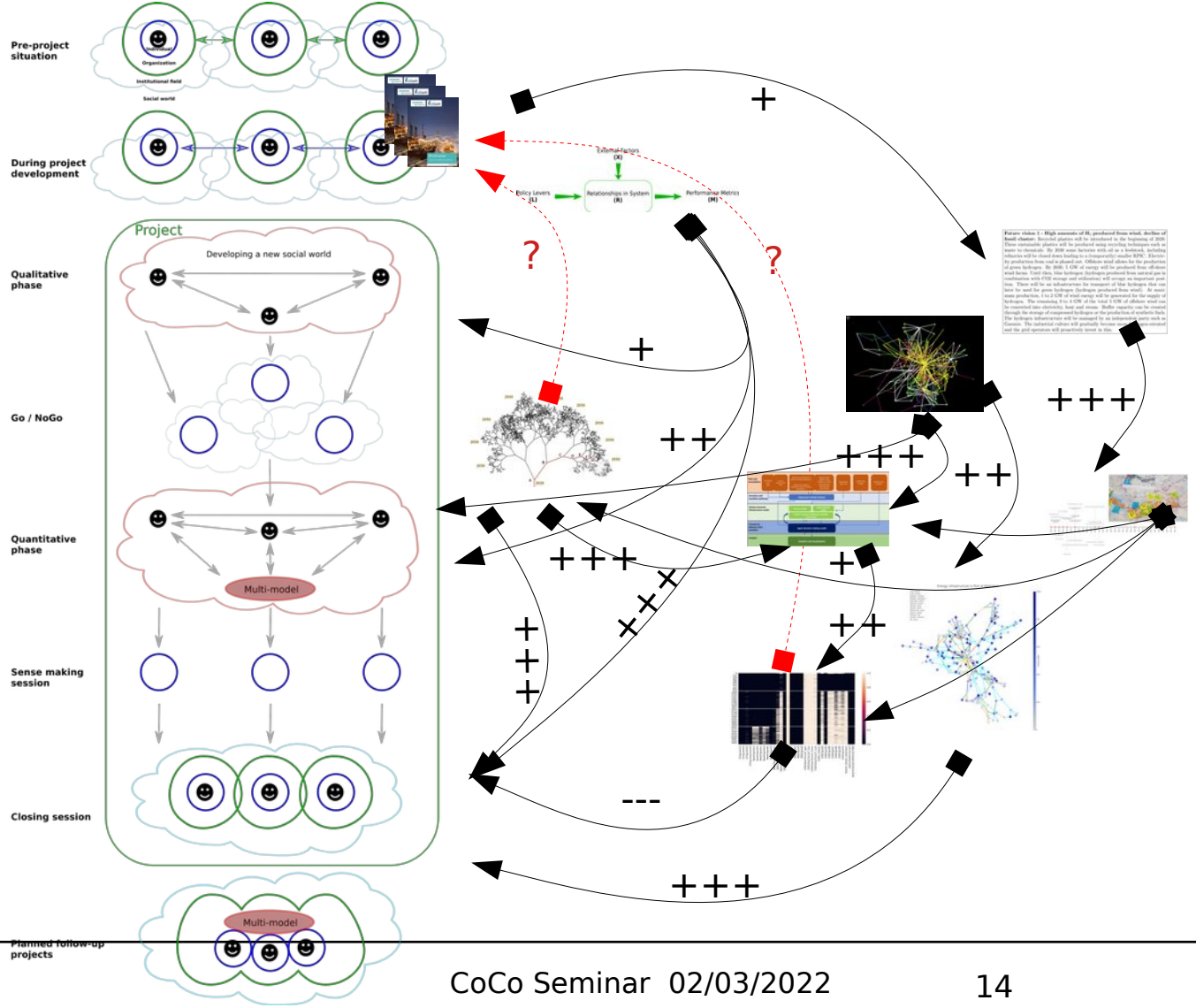
Lukosch, H. K., Bekebrede, G., Kurapati, S., & Lukosch, S. G. (2018). A scientific foundation of simulation games for the analysis and design of complex systems. Simulation & gaming, 49(3), 279-314.

Levels of participatory engagement



Modeling with stakeholders for transformative change, A van Bruggen, I Nikolic, J Kwakkel, Sustainability 11 (3), 825

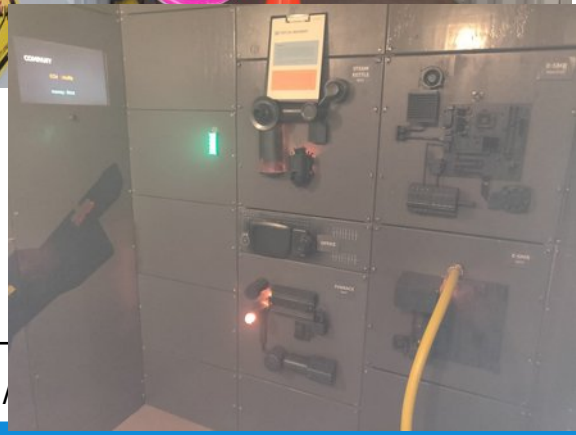
Participatory modelling process and boundary object ecology design



Participatory multi-modelling as the creation of a boundary object ecology: the case of future energy infrastructures in the Rotterdam Port Industrial Cluster
E Cuppen, I Nikolic, J Kwakkel, J Quist
Sustainability Science 16 (3), 901-918

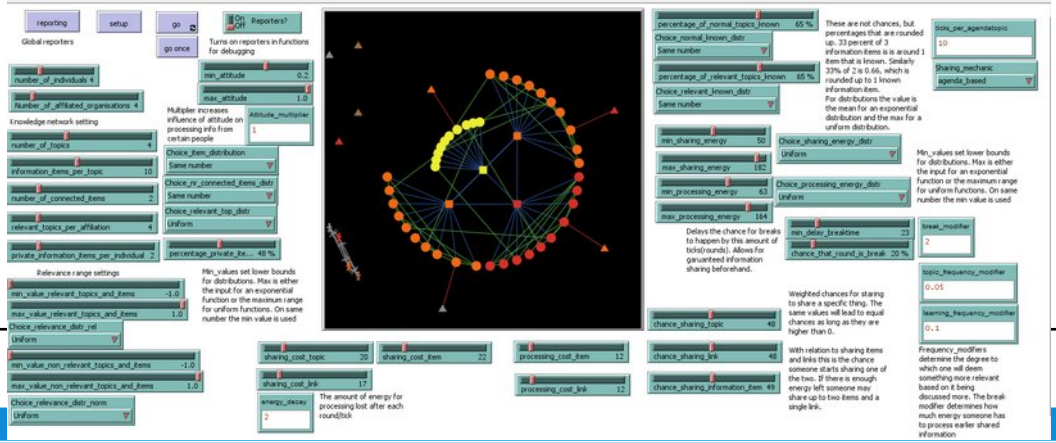
Participatory - Infrarium

- LAB
  - Controlled environment for behavioral observations
  - Hi-def cameras and Biometric tracking for overview and emotional recognition AI
- SERIOUS GAMING RESEARCH
  - Design principle development for physical and emotional immersion
  - Impact of emotional engagement in game effectivity
  - Repeatable game in a highly controlled environment
- MULTI MODELLING
  - Backend simulation based on multi-model ecosystem concepts
  - Scaleable resolution and fidelity
- DECISION MAKING UNDER UNCERTAINTY
  - How does emotional stress and cognitive overload affect small groups of individuals making high-impact decisions?
  - Does a physical and emotional experience impact the decision making compared to purely rational intellectual processes?
- AFFECTIVE COMPUTING
  - Development of affective computing under low-quality environmental conditions (smoke, noise, low light)
  - Calibration of AI for relatively low stress situations
- DESIGN LOGIC
  - Modular platform design : easy reconfiguration and reuse of components for different types of games
  - Maximal reuse of second hand materials and equipment
  - Low cost approach to construction and hardware control
  - Open source design



Modelling learning in participatory processes

Theory	Origin	Main source - Selection based on modelability, perceived usefulness and (inter)compatibility
Group diversity and conflict theories	Social psychology	*Jehn, K. A., Northcraft, G. B., & Neale, M. A. (1999). Why differences make a difference: A field study of diversity, conflict and performance in workgroups. Administrative science quarterly, 44(4), 741-763. *Greer, L. L., Jehn, K. A., & Mannix, E. A. (2008). Conflict transformation: A longitudinal investigation of the relationships between different types of intragroup conflict and the moderating role of conflict resolution. Small group research, 39(3), 278-302.
Social categorisation theory	Social psychology	*Hogg, M. A., & Reid, S. A. (2006). Social identity, self-categorization, and the *communication of group norms. Communication theory, 16(1), 7-30. *Hogg, M. A., & Tindale, S. (2008). Blackwell handbook of social psychology: Group processes. John Wiley & Sons.
Faceworks	Communication science	Littlejohn, S. W., & Foss, K. A. (2010). Theories of human communication. Waveland press.
Input-process-Output model	Communication science	Littlejohn, S. W., & Foss, K. A. (2010). Theories of human communication. Waveland press.
Common Knowledge effects	Social psychology	Stasser, G., & Titus, W. (1985). Pooling of unshared information in group decision making: Biased information sampling during discussion. Journal of personality and social psychology, 48(6), 1467.
Cognition and information processing theories	Communication science & Social psychology	Littlejohn, S. W., & Foss, K. A. (2010). Theories of human communication. Waveland press.
Information integration theory	Communication science	Littlejohn, S. W., & Foss, K. A. (2010). Theories of human communication. Waveland press.



- Formalise our understanding of these processes
- Link with empirical observations
  - infrarium data on emotional states and cognitive overload
  - sociological/psychological observations
- Long term goal : design tool for social processes

Modelling social learning during participatory modeling processes,
N Peters, I Nikolic, G de Vries
10th International Environmental Modelling and Software Society

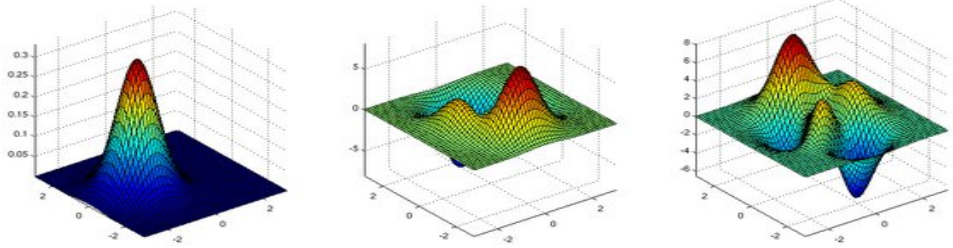
Multi-modelling : boundary object for social learning

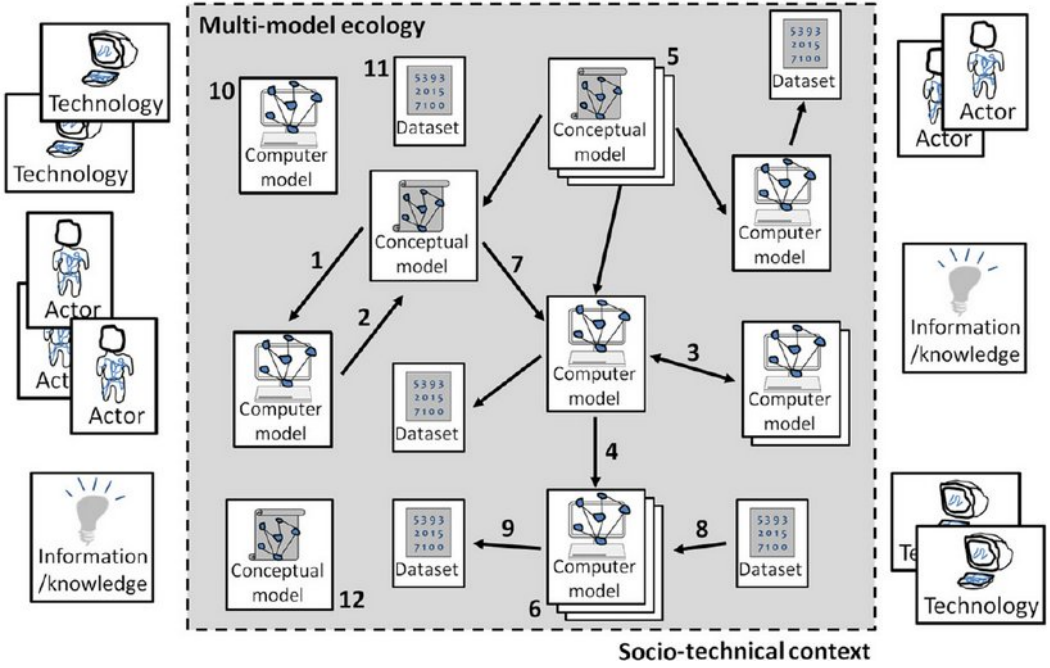
- Why:
  - More comprehensive understanding of impact of decisions
  - Comparison of different model of the same system
  - Reuse of existing models
- How:
  - Ad-hoc model coupling
  - Multi-model infrastructure?
- Really hard!
  - methods and tools sorely lacking
    - uncertainty (propagation)
    - scaling
    - interoperability of different operational principles

Multi-modelling

- Traditionally :
  - Hard systems engineering
  - Command and control paradigm
  - High Level Architectures (HLA)
  - Task oriented
- Now :
  - Socio-technical process
  - No control over model parts
  - Massive technical debt
  - Policy oriented

Core concepts :
Coupled fitness landscapes and Multi-model ecologies





Kauffman, Stuart A., and Sonke Johnsen. "Coevolution to the edge of chaos: coupled fitness landscapes, poised states, and coevolutionary avalanches."
Journal of theoretical biology 149.4 (1991): 467-505.

Principles, challenges and guidelines for a multi-model ecology.
Nikolic, I., Warnier, M., Kwakkel, J. H., Chappin, E. J. L., Lukszo, Z., Brazier, F. M., ... & Palensky, P. (2019).
Whitepaper

Multimodel ecologies: cultivating model ecosystems in industrial ecology
LA Bollinger, I Nikolić, CB Davis, GPJ Dijkema - Journal of Industrial Ecology, 2015

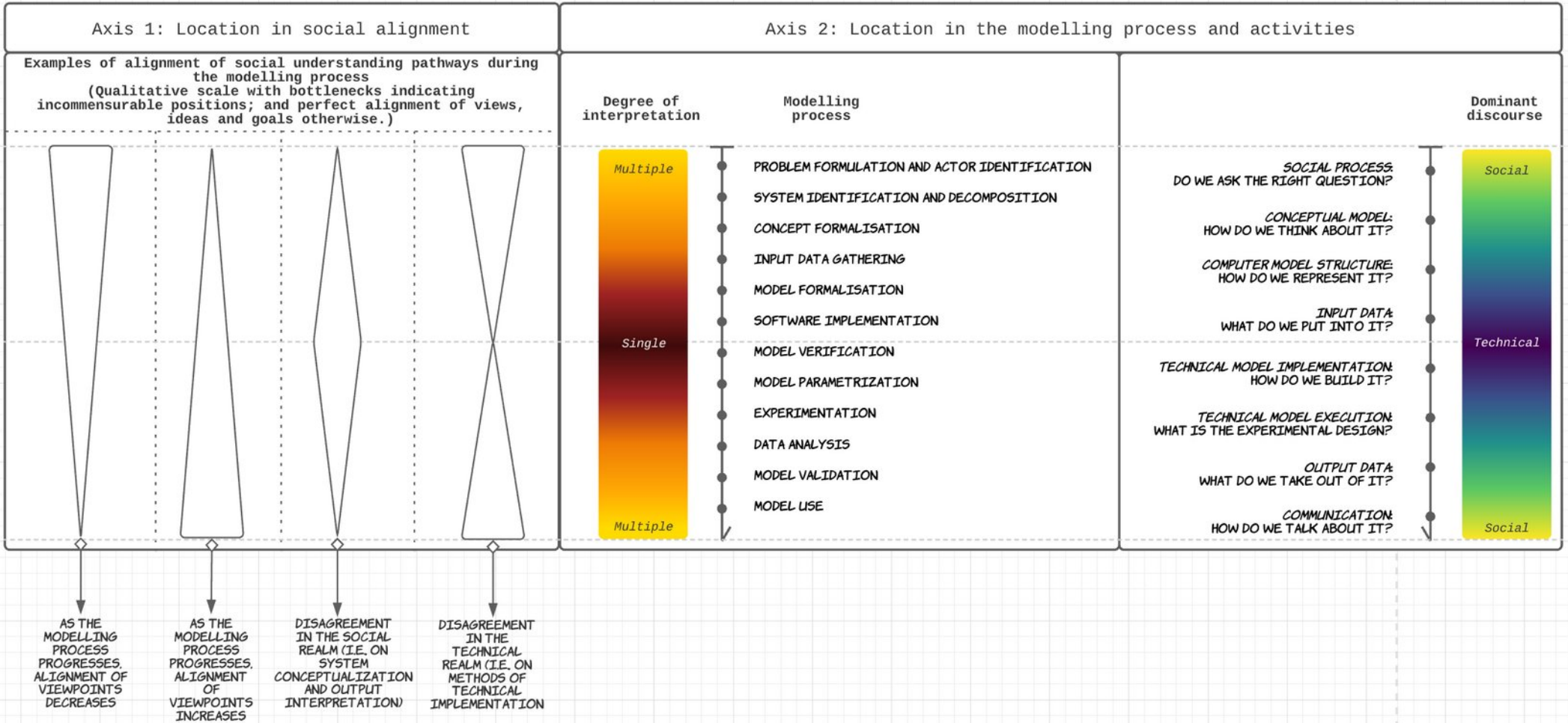
multi-model.nl : project in a nutshell

- 2 years, start 1 sept 2021
  - Spring 2022 : hello world
  - Summer 2022 : first operational version
  - Autumn 2023 : 3rd iteration MVP
- Practice, R&D and academia in close collaboration
- Case driven, agile, learning by doing
- Focus on methods, tooling and community
- Main goal :
  making (modelers/ energy consultants) life easier and the models more powerful

Goals of multi-model.nl

- Researches, designs and implements a "minimum viable product" multi-model infrastructure for integral decision making in the energy transition
- Coupling of models within a technical platform and methodological framework
- Allows for model interactions that are
  - Transparent
  - Traceable
  - Testable
- Design, support and understanding supported by a Community Of Practice
  - Modelers
  - Decision makers
  - Researchers

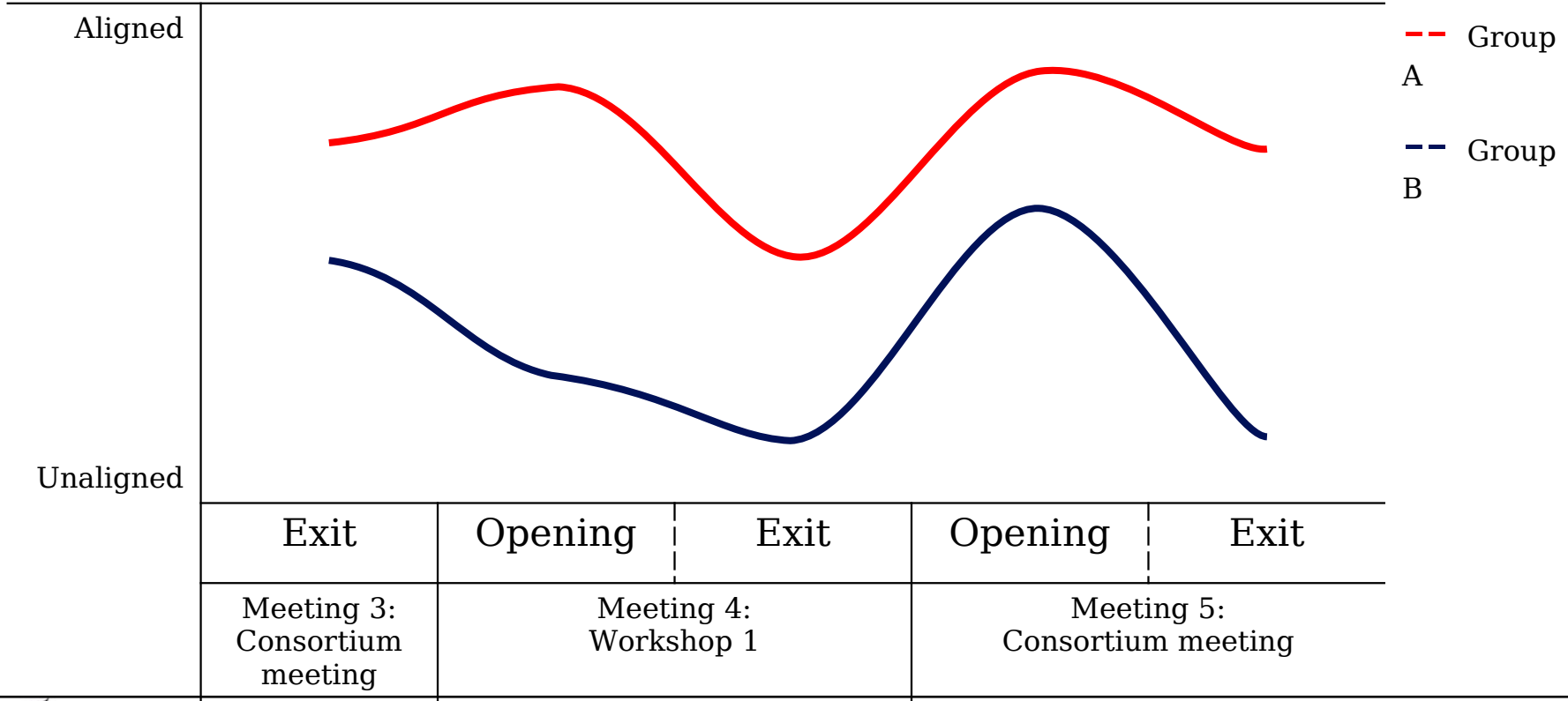
Multi-modelling chalanges



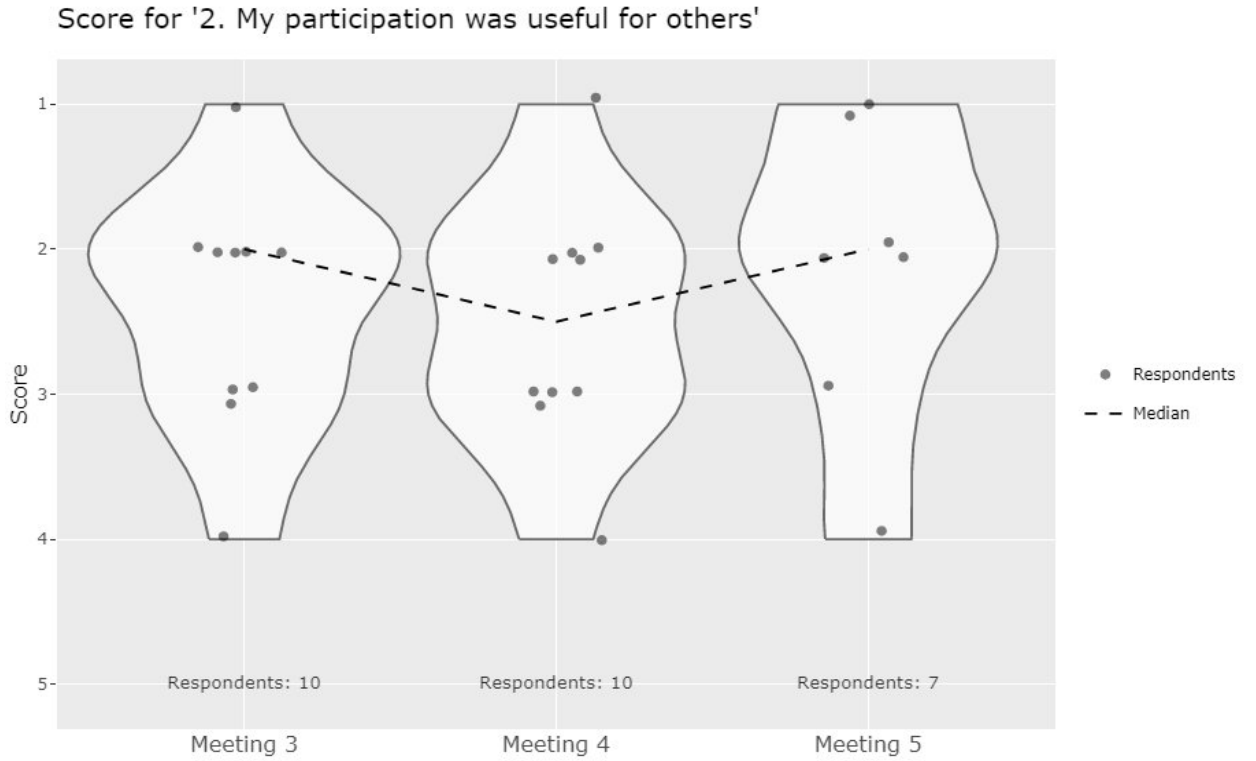
Participatory : Quantifying social process

Qualitative survey overview:

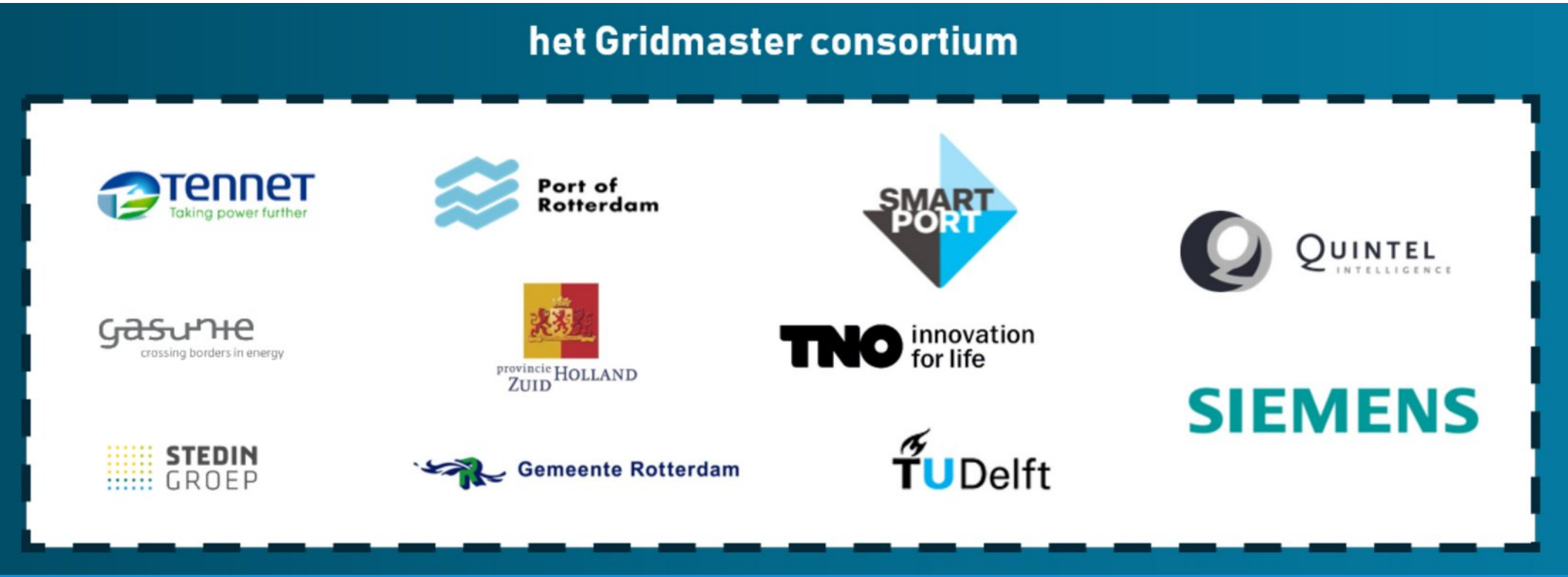
To what extent do respondents think all participants are aligned in their goals and expectations?



Participatory: Group divide on level of participation

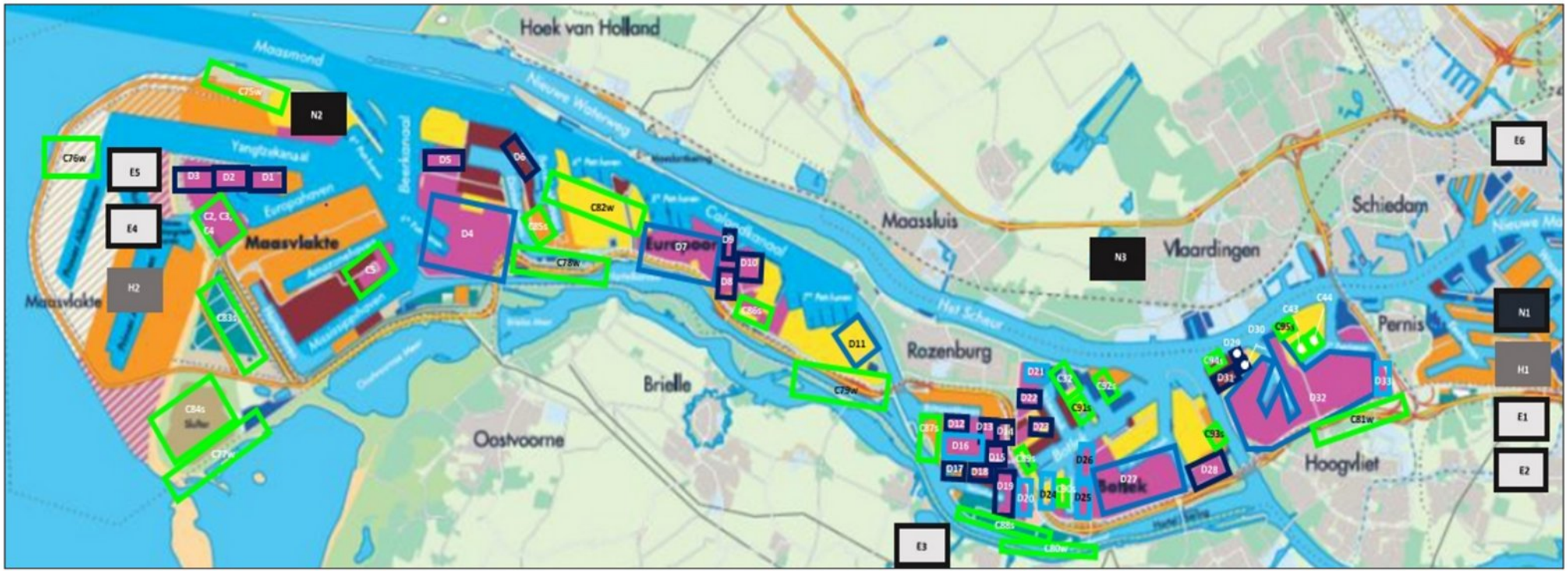


In practice : Gridmaster.nl project



Gridmaster scope

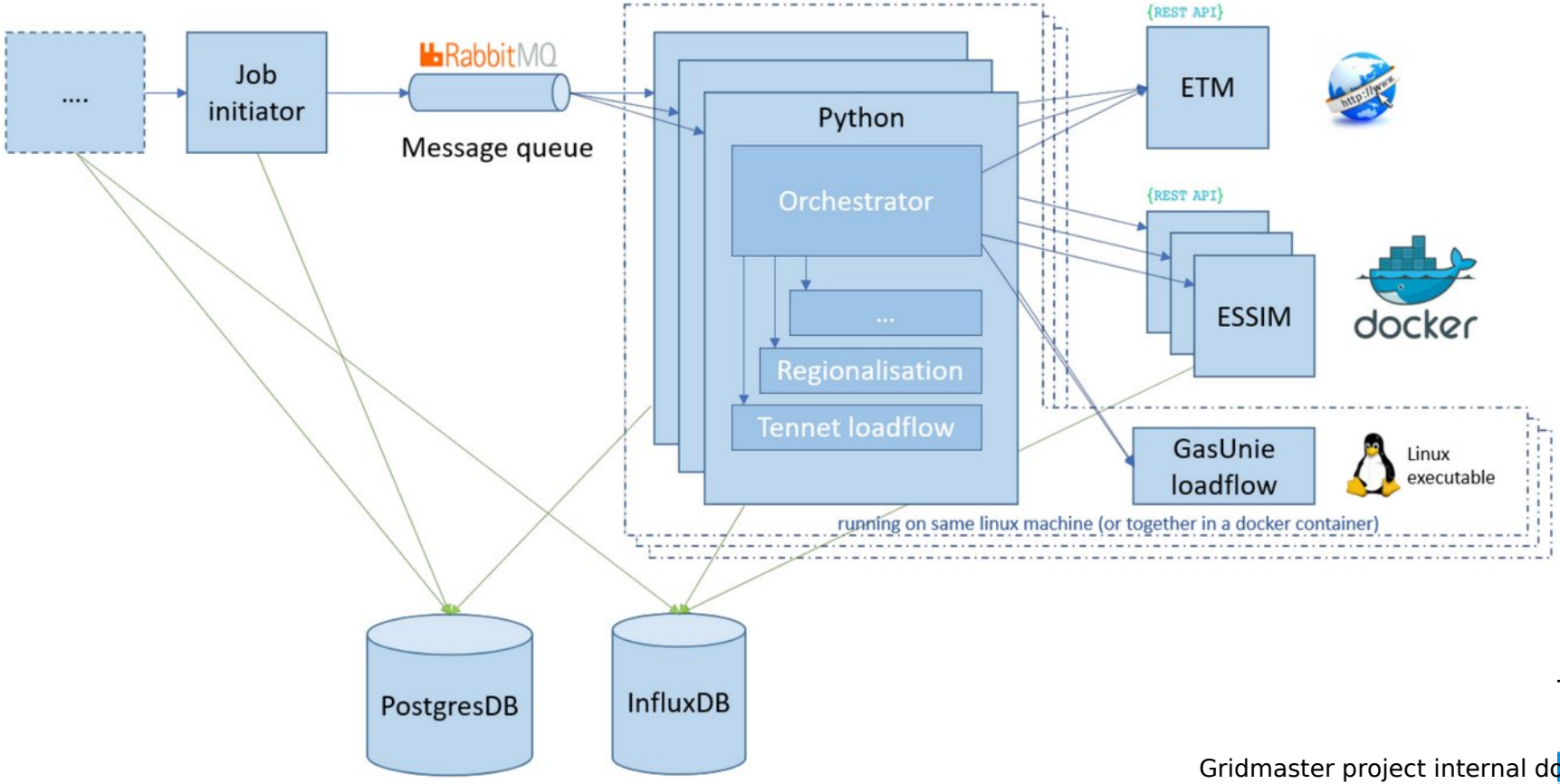
GRIDMASTER HIC ROTTERDAM – GEOGRAFISCHE SCOPE



Industrial site: Oil refinery
Industrial site: Chlorine based value chain
Industrial site: Other
Central utility and H_2 production site
Nature gas import/export site
H_2 import/export site
Electricity import/export site

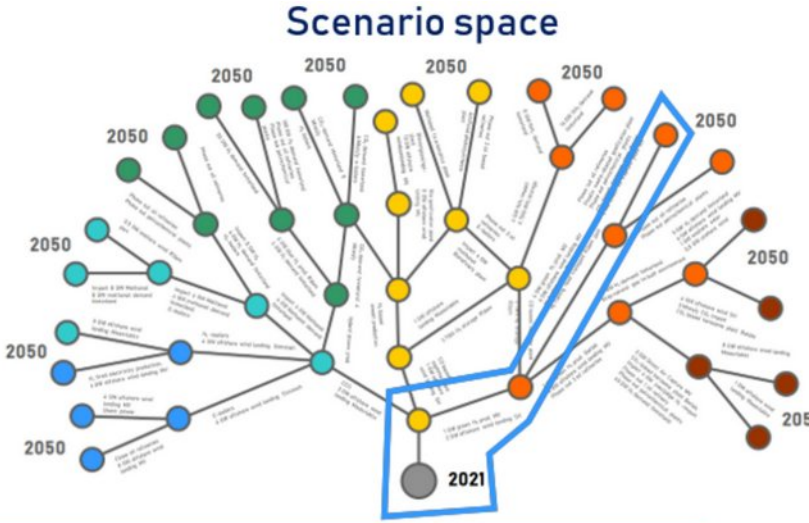
Gridmaster project internal documentation

Multi-model setup



Scenario space > 10^30 plausible pathways

- Scenario space:
  - Total set of scenarios



- Scenario:
  - Current situation + structural change

Structural change

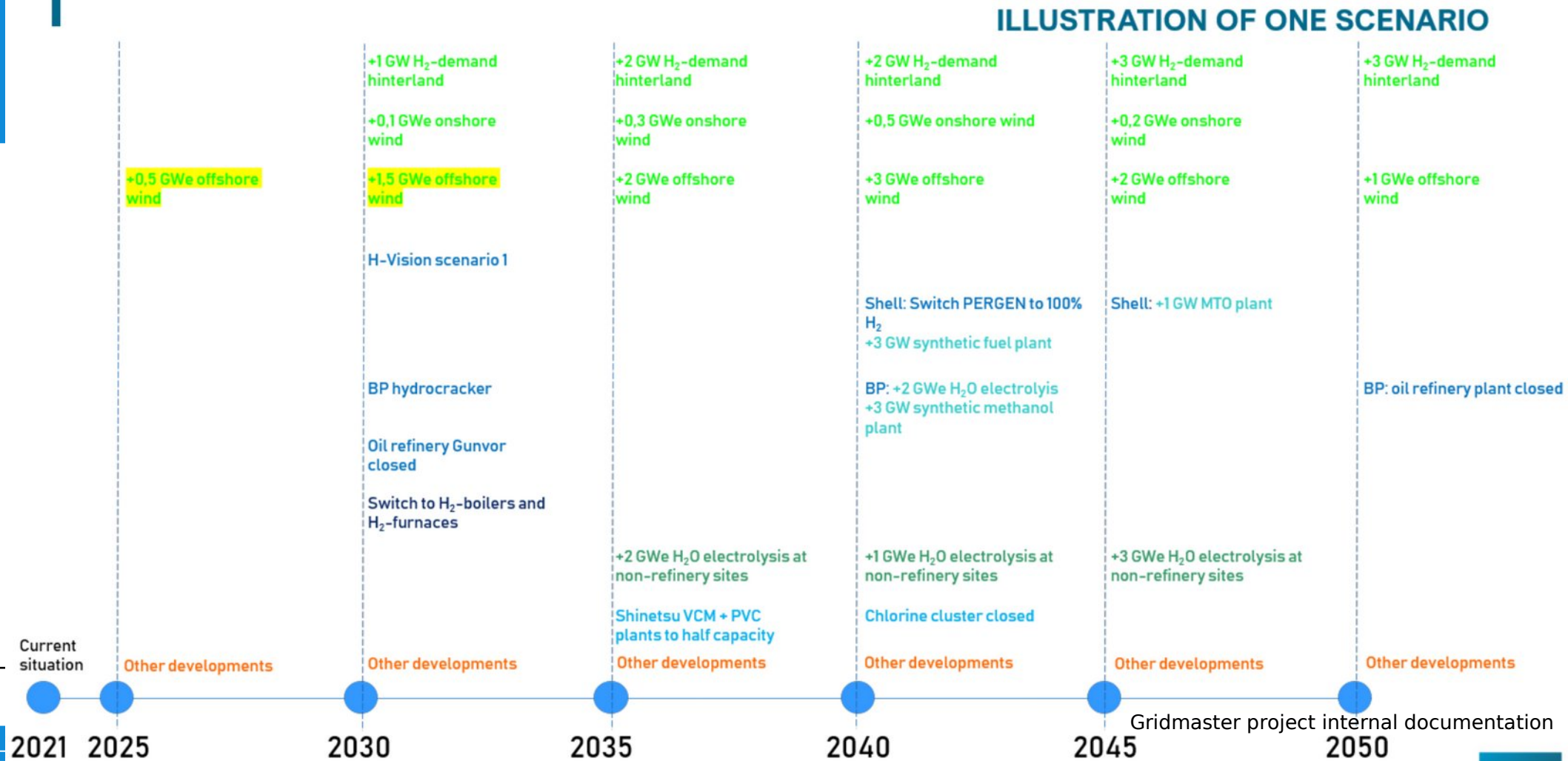
I. Structural change HIC

- Ia. Technology change conversion assets
- Ib. Capacity change conversion assets
- Ic. Capacity change exchange energy carriers HIC – environment

II. Energy commodity price development (excl. electricity)

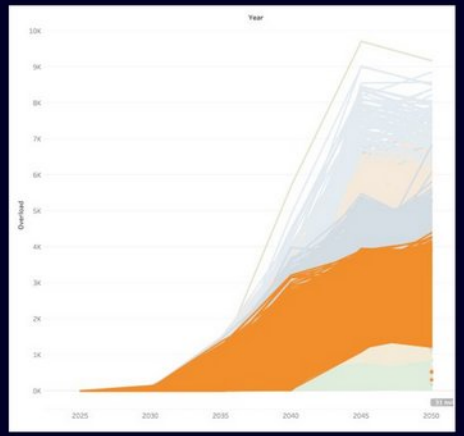
III. Structural change 'rest NL'

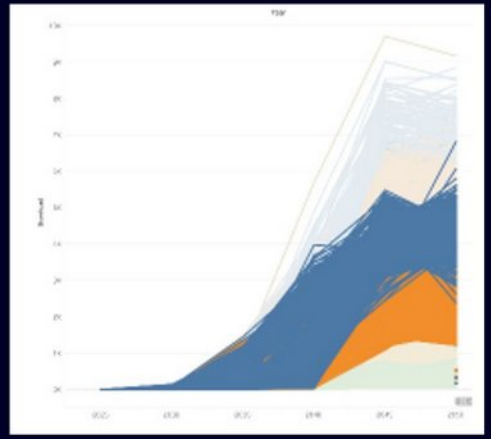
Specific scenario -> “future history”

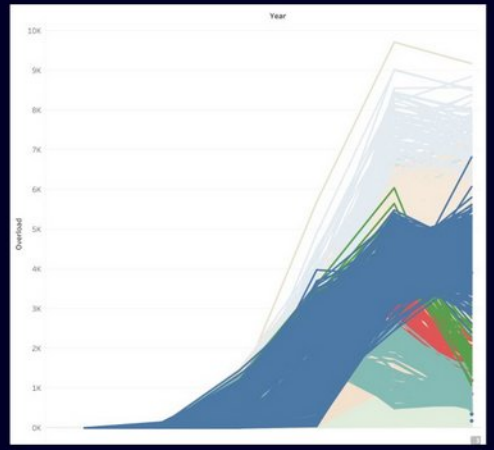


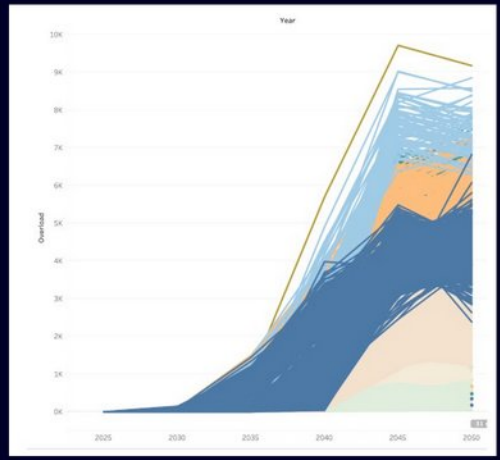
Gridmaster project internal documentation

Voorbeeld analyse: tijdserie clusteren – TenneT groep 3









Cluster groep	Cluster ID's	# scenario's in groep
1	5	4908
2	7	2545
3	2	1369
4	0, 2	1848
5	0, 4, 9, 10	745
6	0, 1, 3, 6, 8	923

Robuustheidsscore van 4908/10011 = 48,6 %

Recap - Takeaway

- Participatory
  - transformative collective sense-making of the world
  - modelling, quantification and design of the process
- Multi-modelling
  - processes for creating (multi-)models
  - methods for using them (uncertainty, scale, operating principles)
  - creation of social and technical infrastructure for multi-models
- Decision making under deep uncertainty
  - Scenario spaces and structural uncertainty exploration
  - Goal oriented impact on investment decision process

- In close industry - government - academia collaboration


Thank you very much!
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