Project Windmaster

Participatory multi-modelling of the energy transition

Dr. ir. Igor Nikolic and Windmaster partners

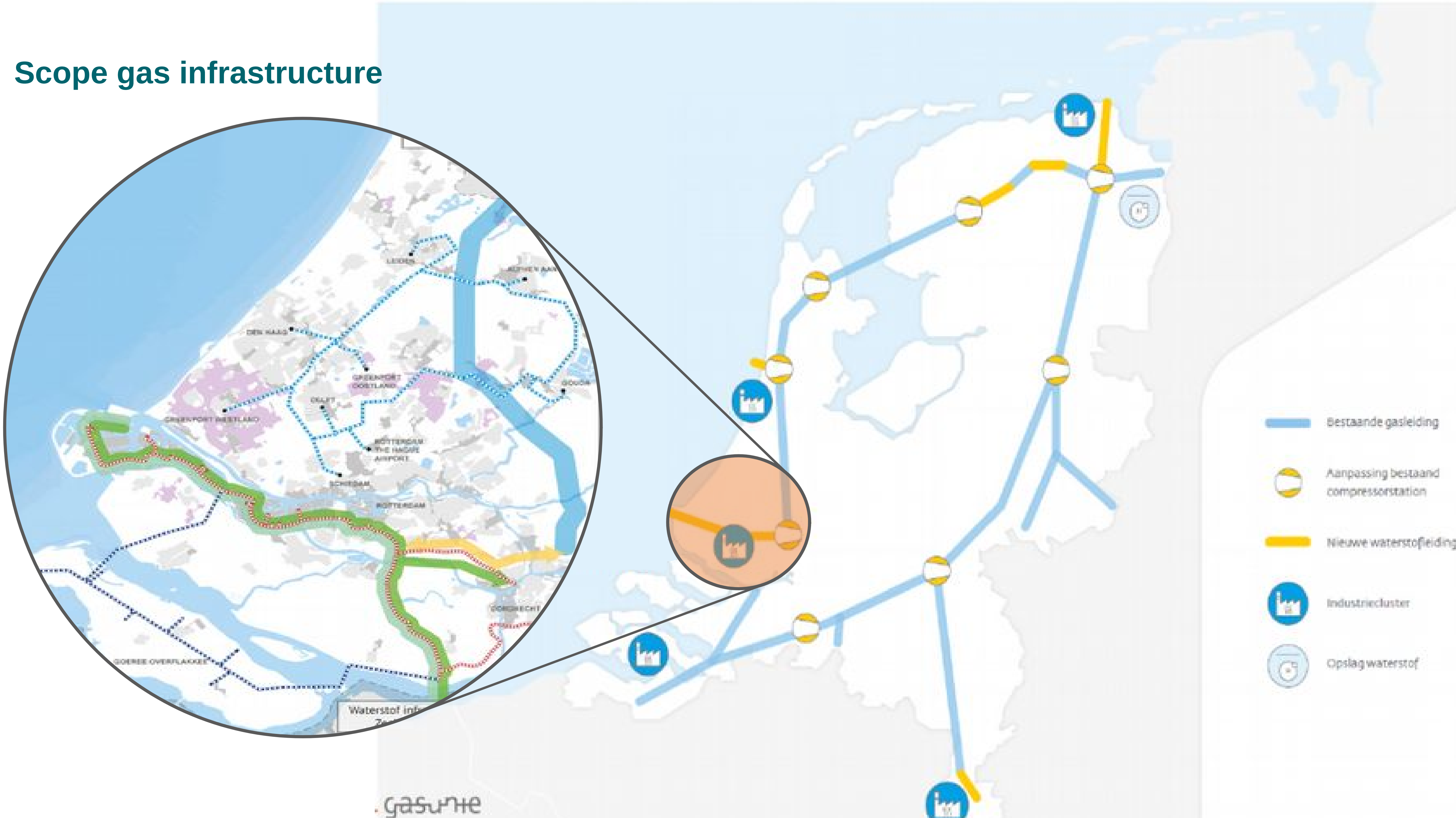
16-4-2019

Goal en scope of Windmaster project

- Goal
  - Proof of concept multi-modelling approach for the development of a robust adaptive energy infrastructure investment strategy
  - Insight into the effectiveness of investment decision policies of infrastructure providers
  - First insights into the investment options
- Scope
  - Electricity-, H_2- en natural gas infrastructure in the Port of Rotterdam
  - Landfall of 5 GW of wind generated electricity in Maasvlakte 2
  - 2020 - 2050
  - no spatial limitations considered
  - no company investment dynamics

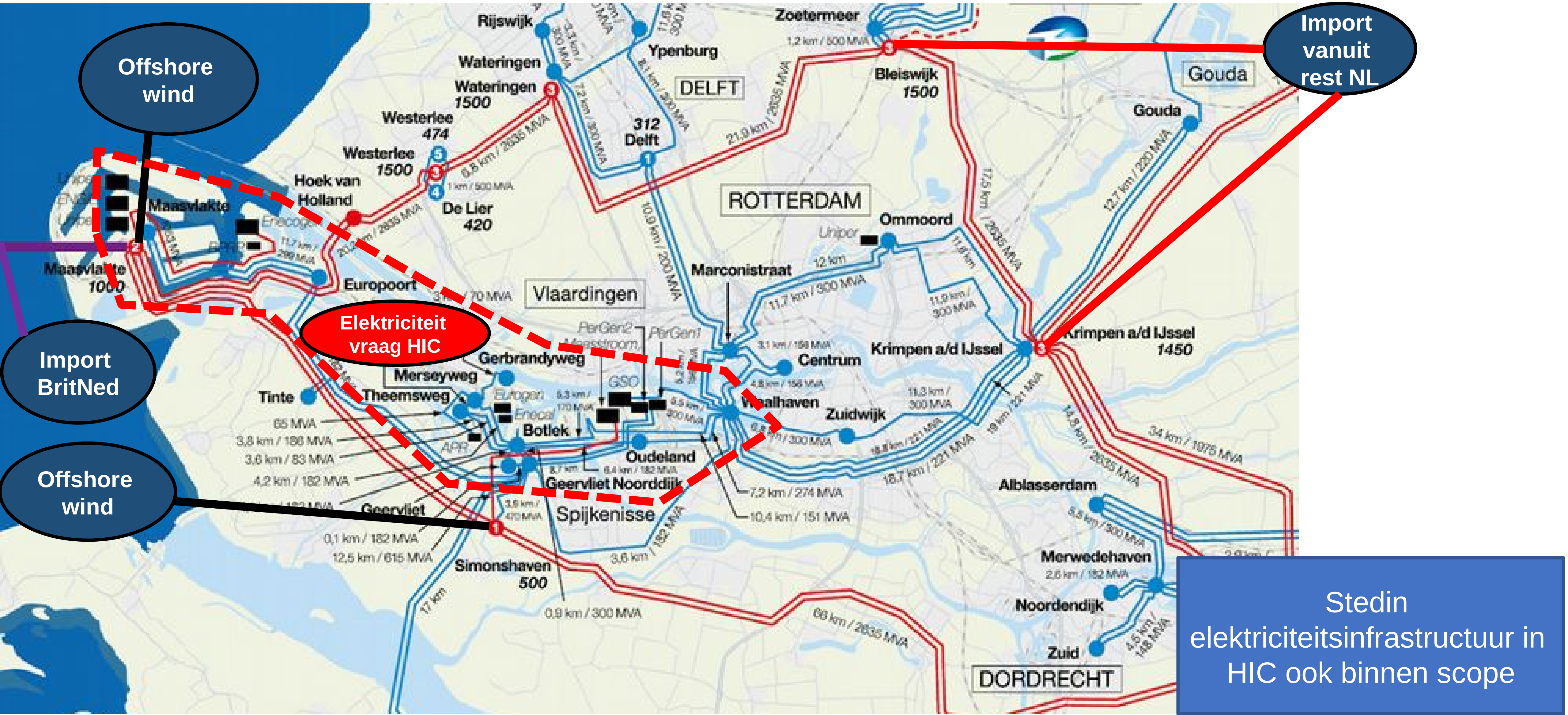
- Performed under very tight time schedule and very limited hours
- Very large potential impact - hot political issue
- Close industry - academia collaboration

Scope gas infrastructure



** Bron: Naar een groene waterstofeconomie in Zuid-Holland, een visie voor 2030, een advies aan de Provincie Zuid-Holland, Maart 2019*

Scope electricity infrastructure (380 - 11KV)



Scientific setup

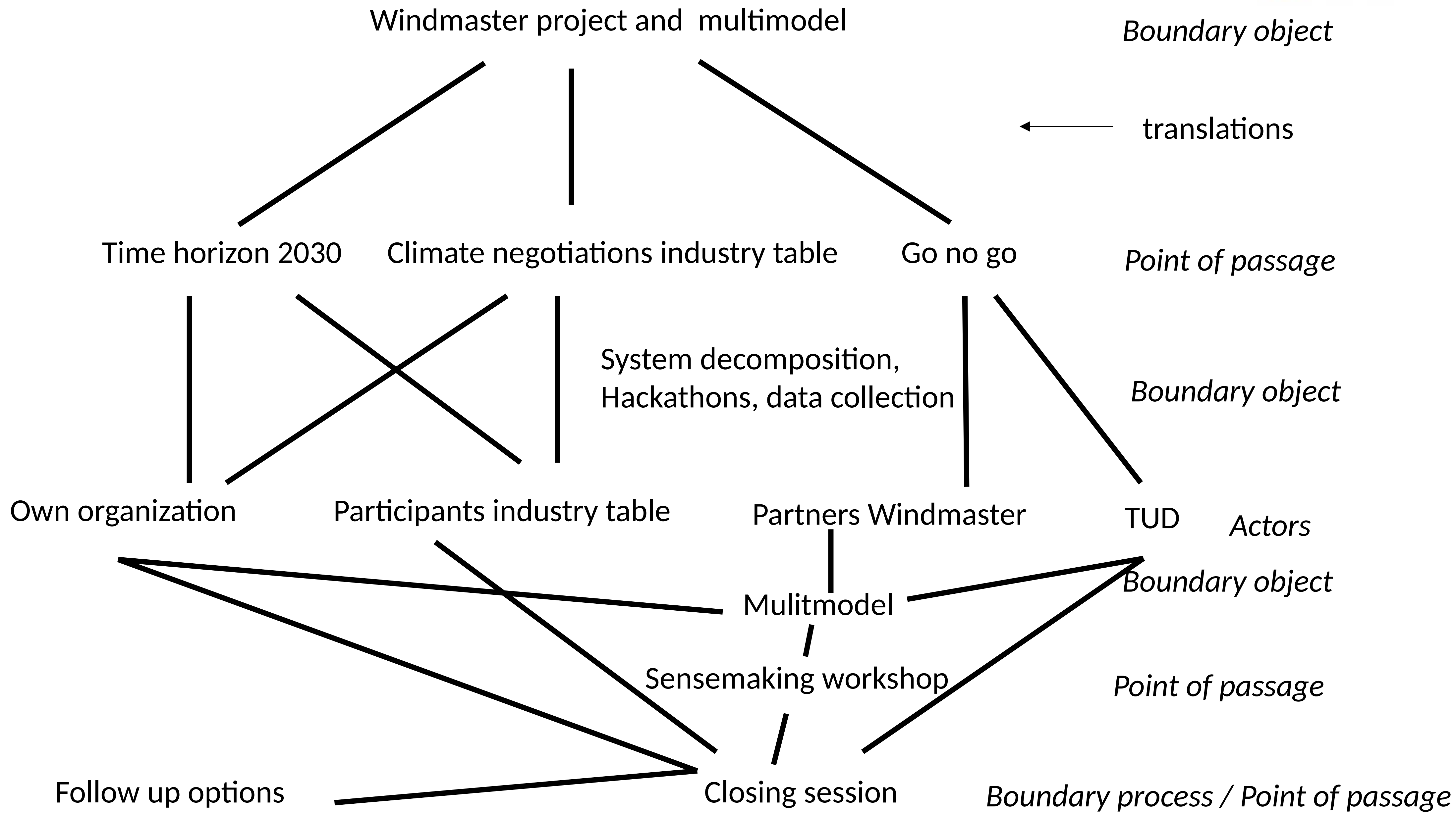
- Deep integration of social sciences and engineering
- Participatory
  - Design of the participatory social process
  - Boundary Object approach
    - Boundary object, process, institutions
    - Points of Passage and Translation between social worlds
  - Exposing the stakeholder and initialising the multi-model ecology
- Multi-modelling
  - Boundary object co-creation
  - Test of Netlogo py extension, as a possible route to Sim0MQ
  - EMA - NetLogo - Python
  - (Integration of Business Model Ecosystem approach by Siemens)

Boundary object

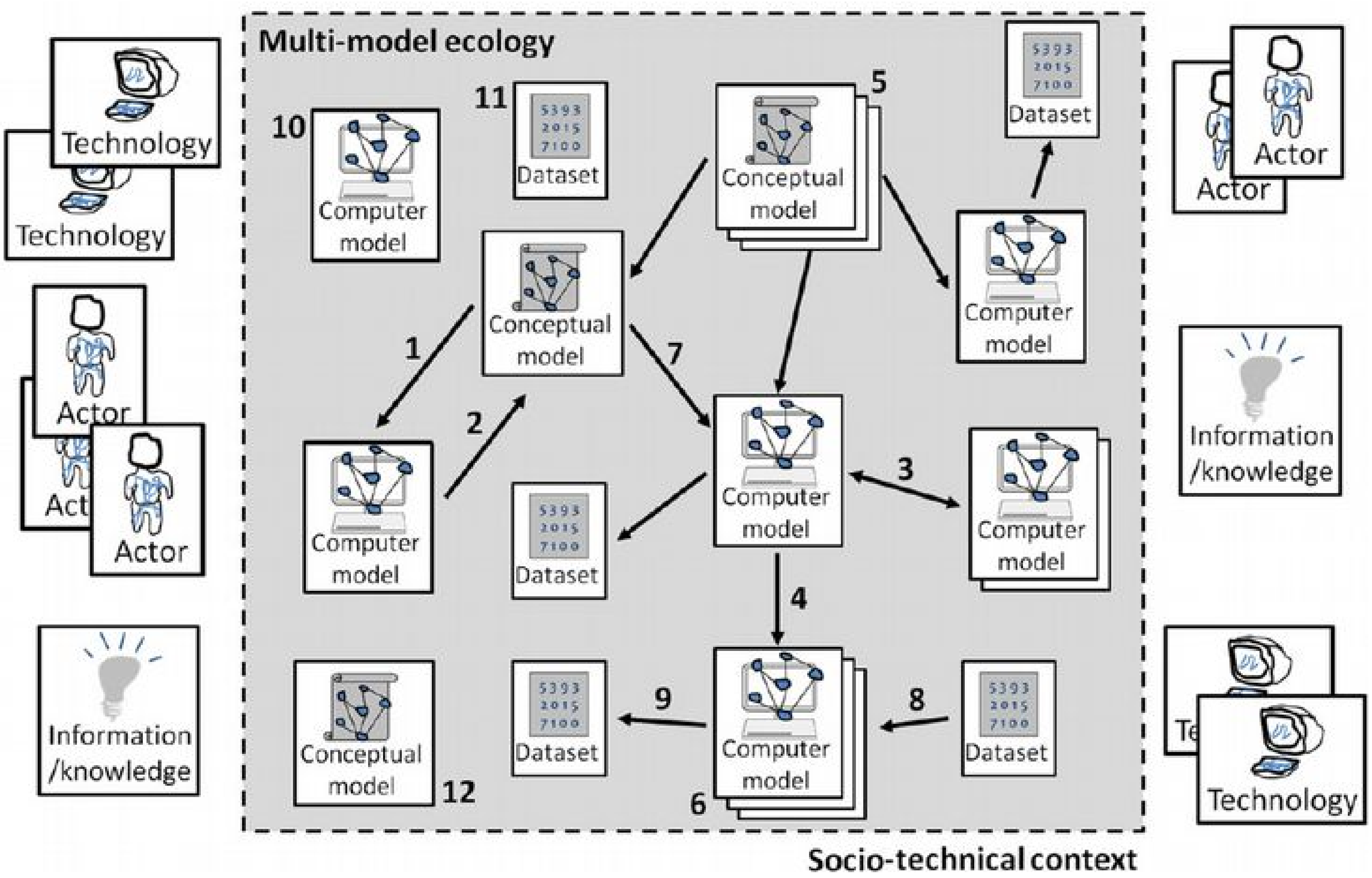
- Models as a boundary object (Star & Griesemer, 1989)
  - A good model is a model that is useful to stakeholders
- Boundary object:
  - “analytic concept of those scientific objects which both inhabit several intersecting social worlds […] and satisfy the informational requirements of each of them. Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties using them, yet robust enough to maintain a common identify across sites.“ (Star & Griesemer, 1989, p393)
- Translation between social worlds

TUDelft

SIEMENS Ingenuity for life



Multi-model ecology

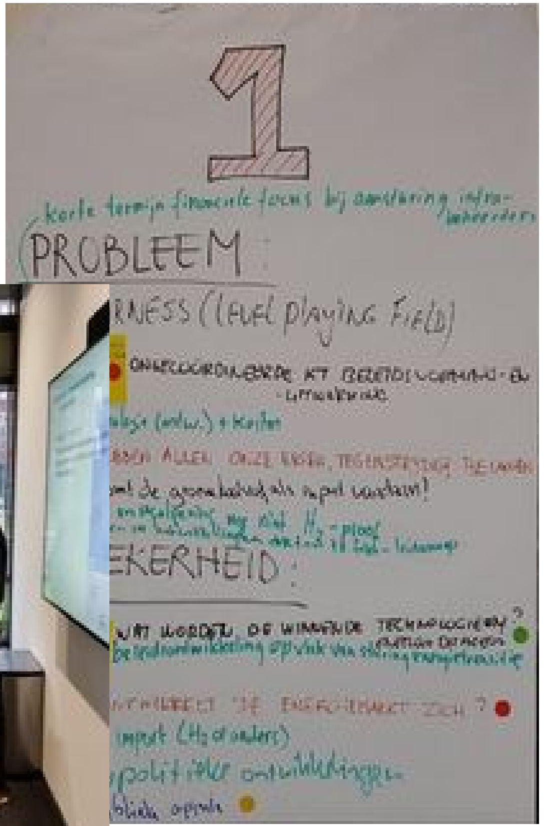


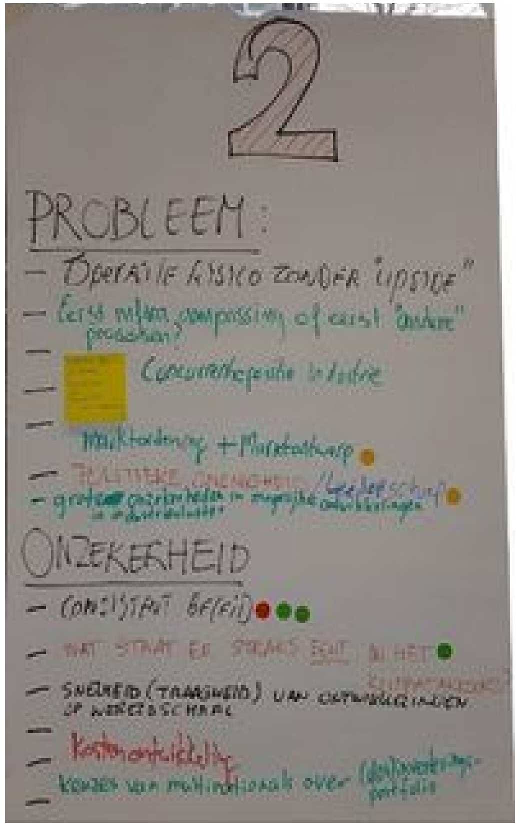
Project process flow

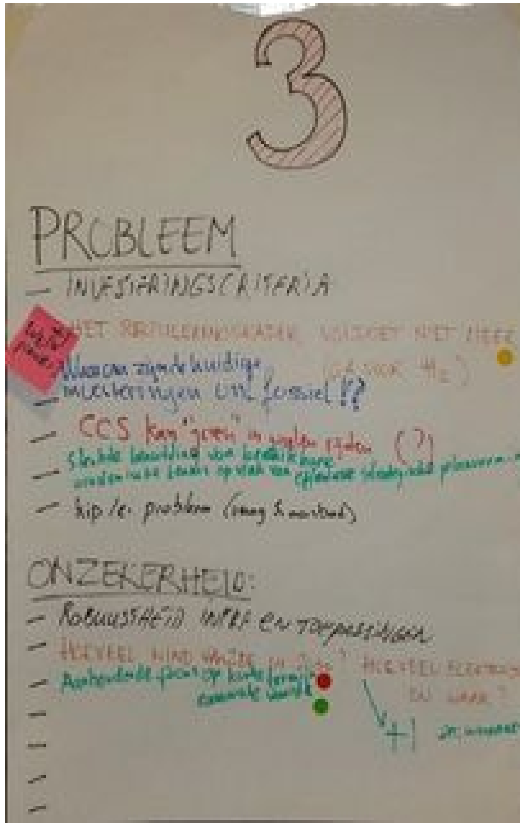
- Qualitative part
  - Kick-off / Generic visioning
  - Specific visioning
  - Back-casting
  - System decomposition
- Quantitative part
  - Hackathon
  - Multi-model implementation
  - Interpretation and sense-making
  - (Project closing session)

General Visioning

- Regulatory uncertainty key!
- Fairness during transitions
- Institutions regulating infra operators are broken



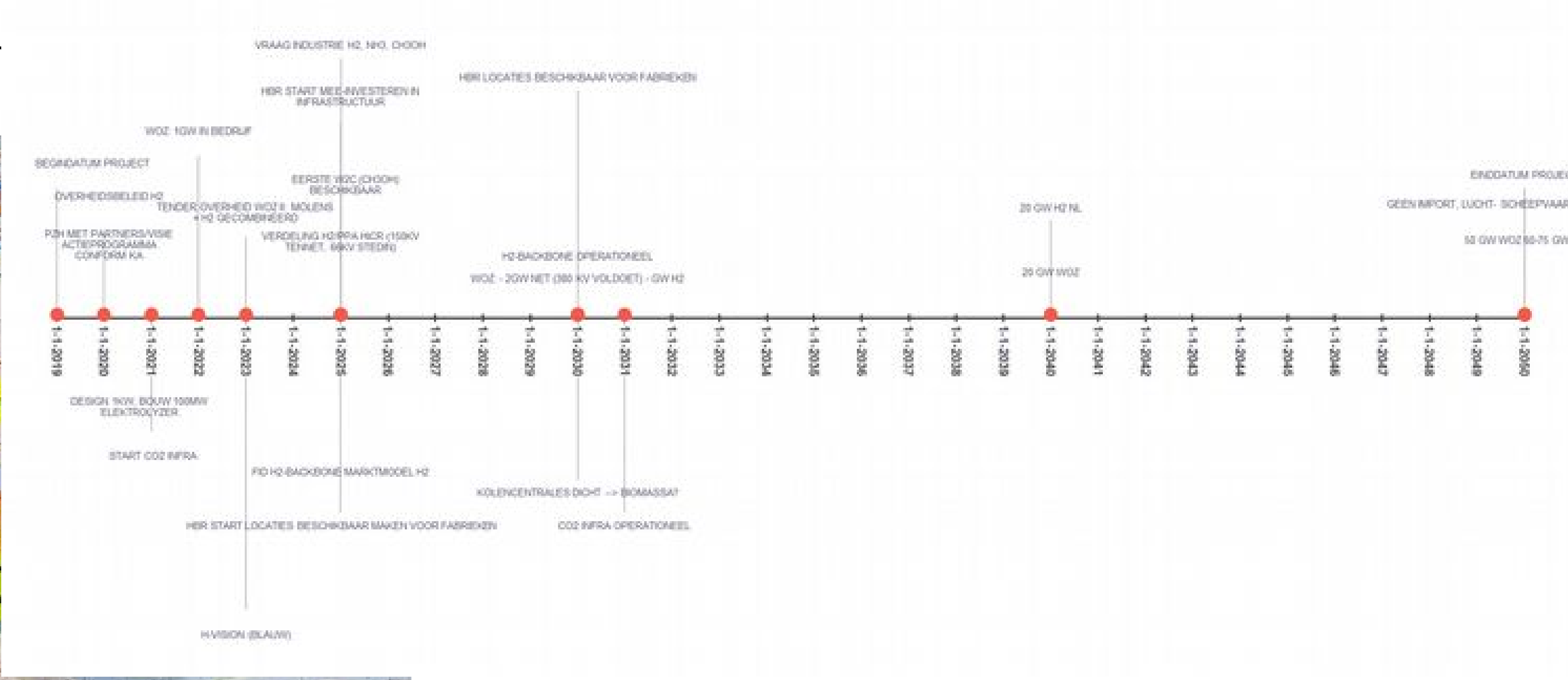




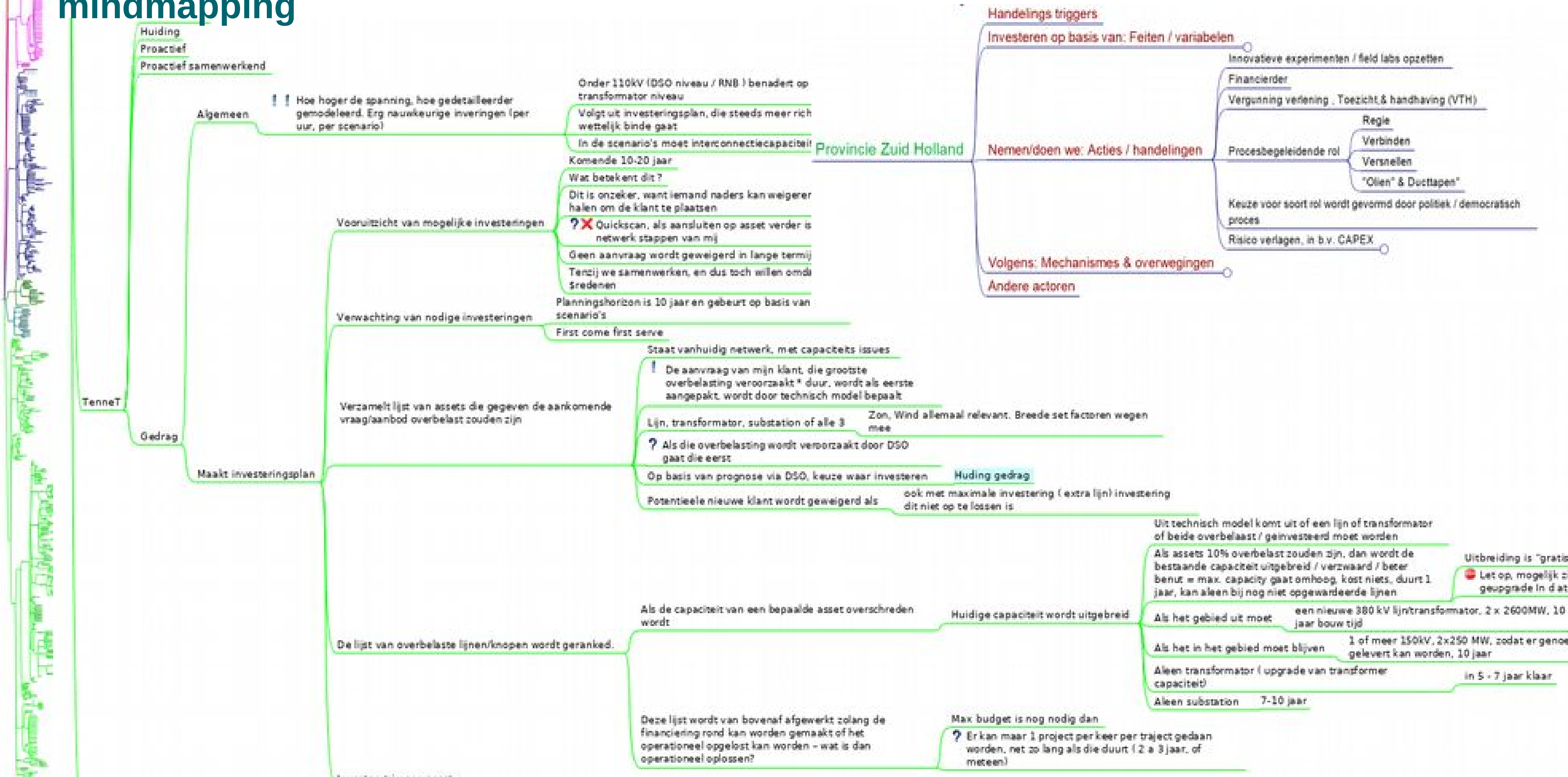
.1: Samengevatte problemen en onzekerheden.

Specific visioning and Backcasting

- Visions
  - High carbon, high growth
  - Low carbon, high growth
- 2 paths towards ther



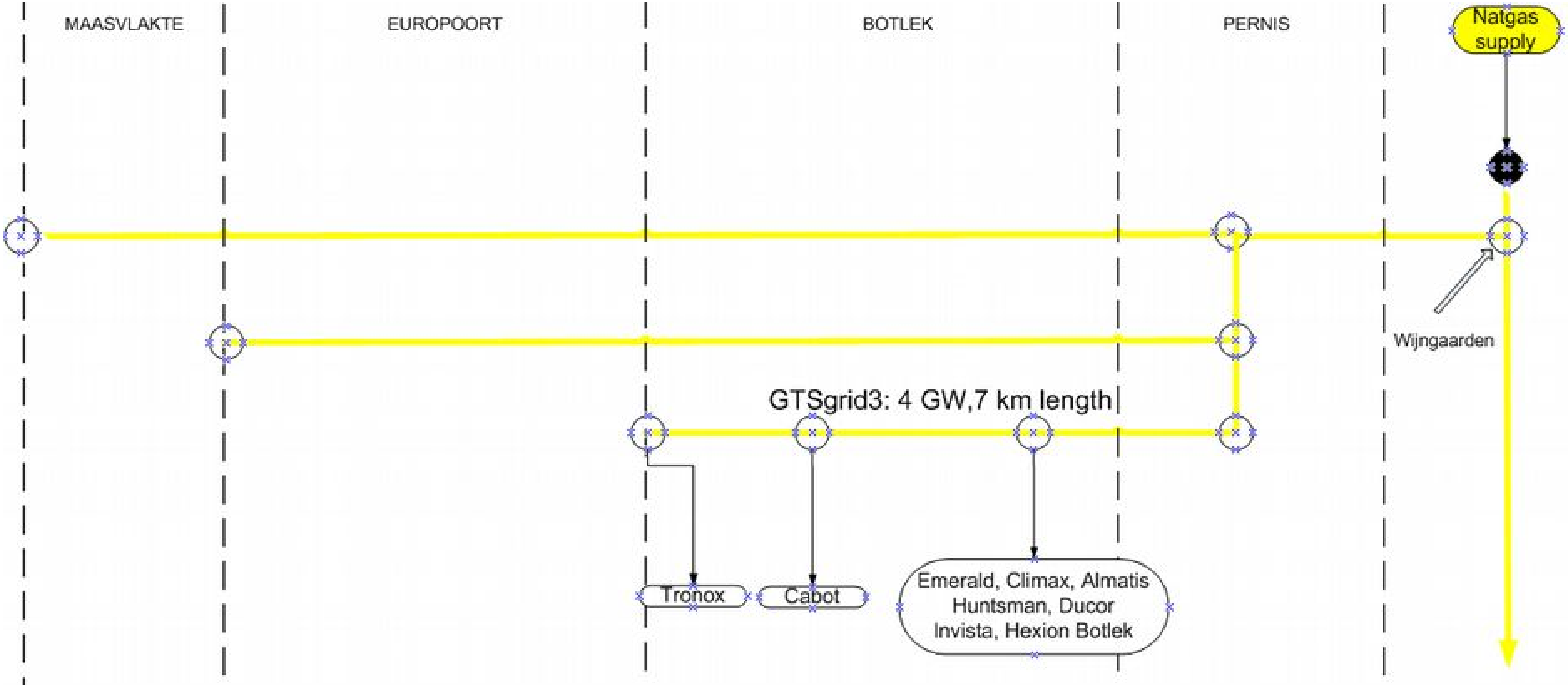
System decomposition - Guided brainstorms and interactive mindmapping



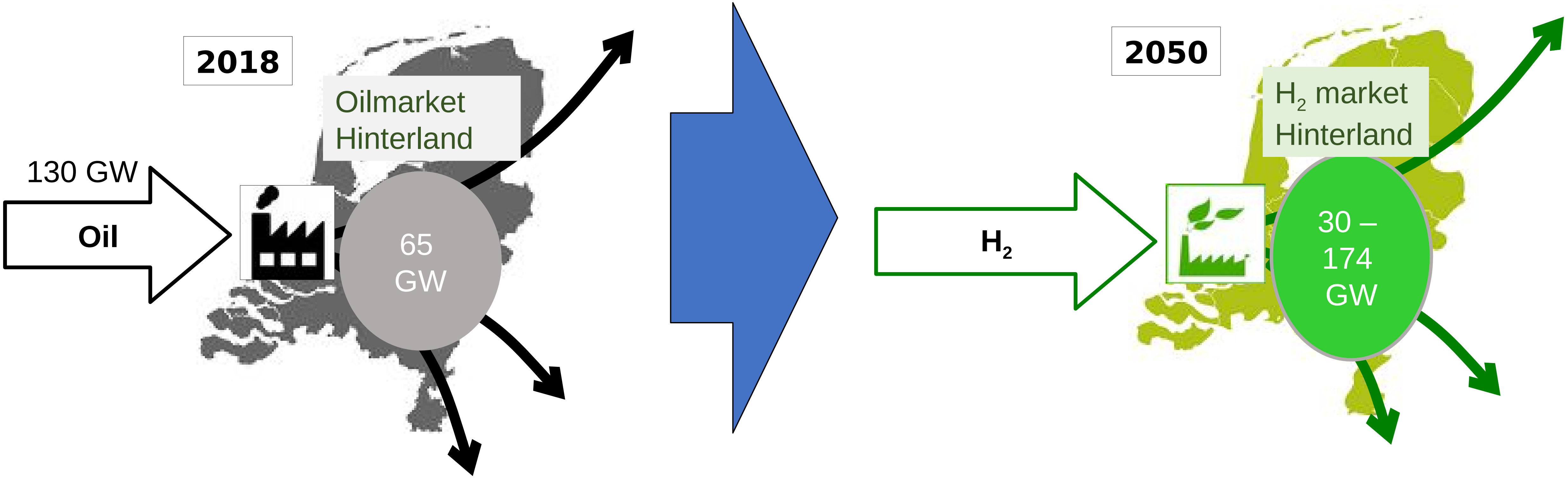
Insights through the modeling process

- Liberating segments of GTS backbone for H_2
- H_2 export to the hinterland and value creation for the the region
- “Low” invesment costs for creation of large H_2 transport capacity.

Liberating segments of GTS backbone for H2



H2 export to the hinterland and value creation for the the region



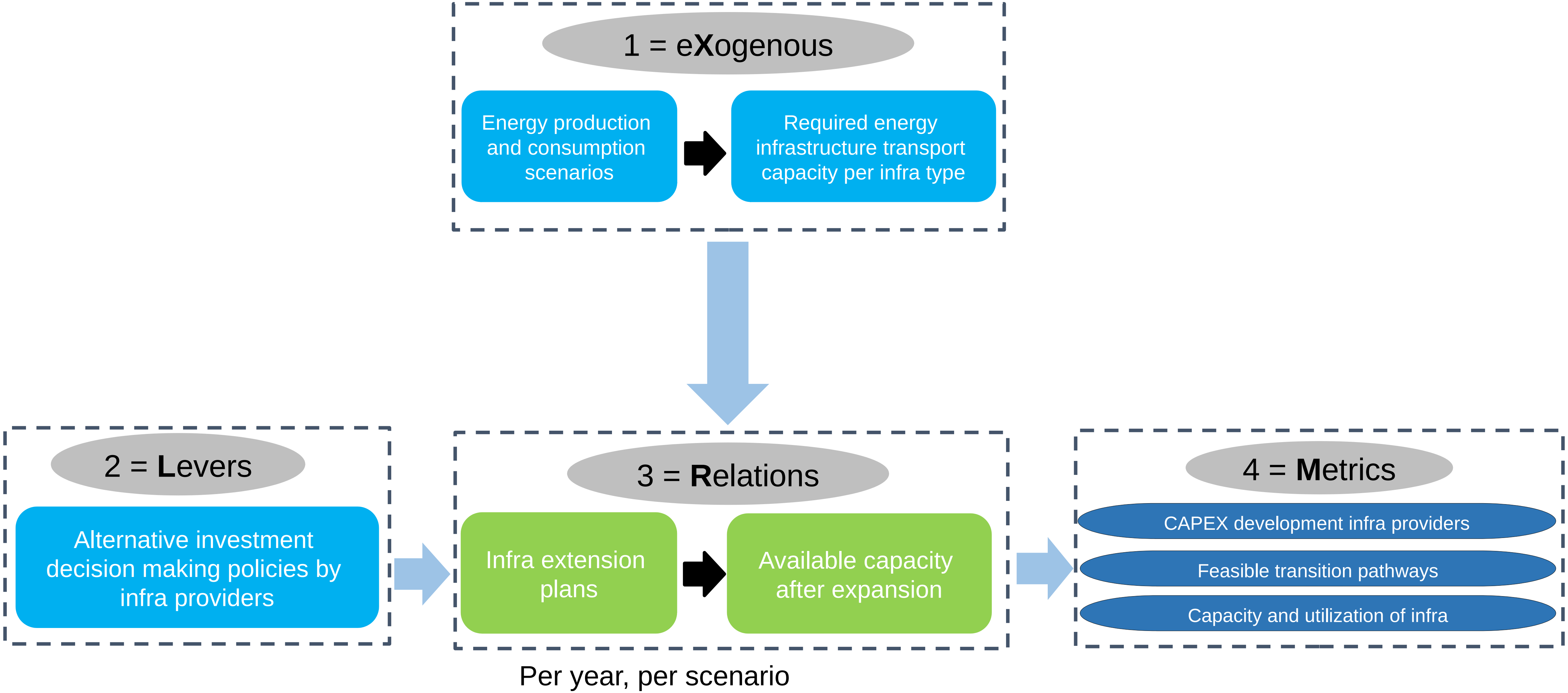
"Low" investment costs for creation of a large H2 transport capacity, and radically smaller spatial footprint

VS

0.1 5.7

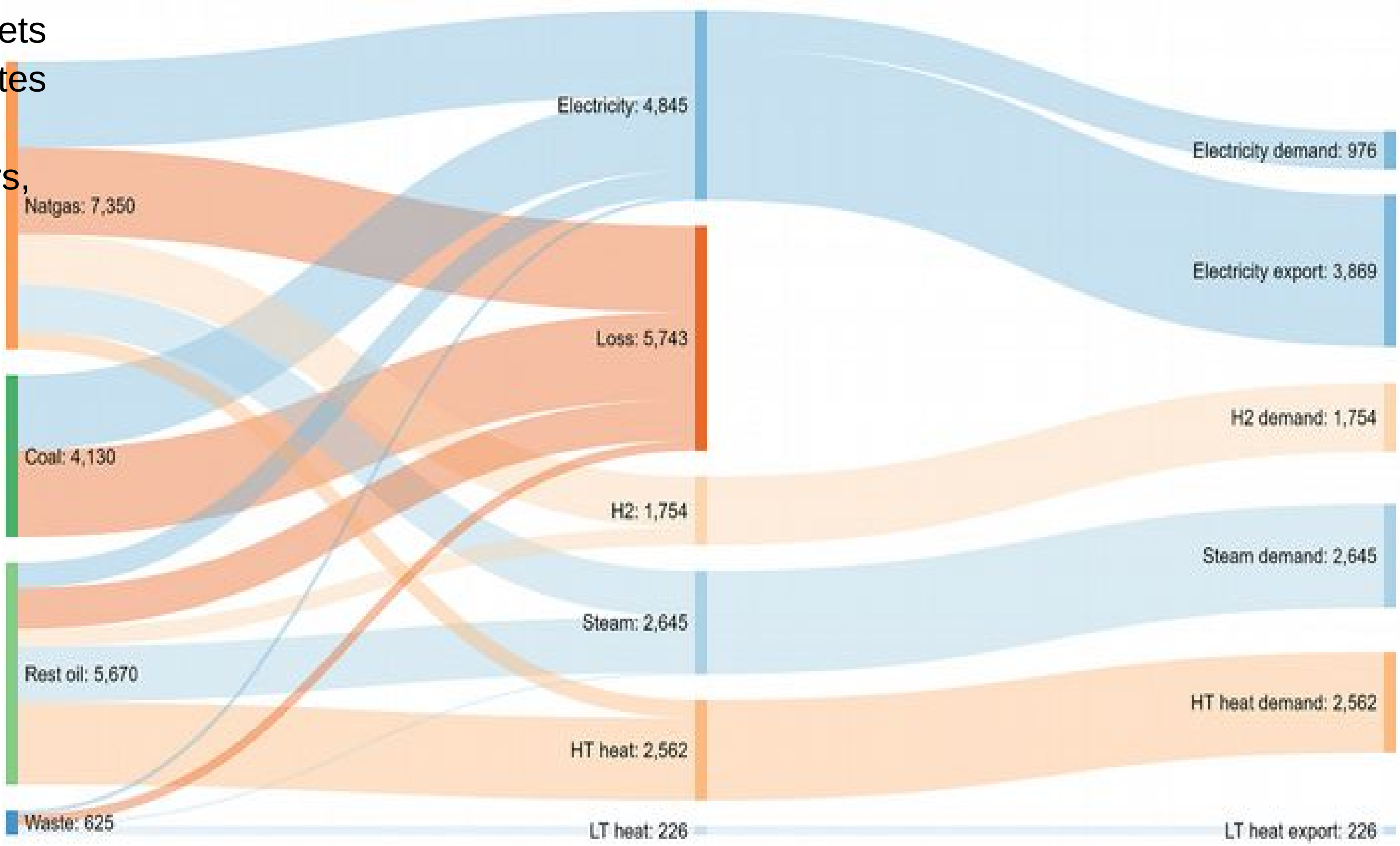
Meuro/meter/GW

Quantitative modelling

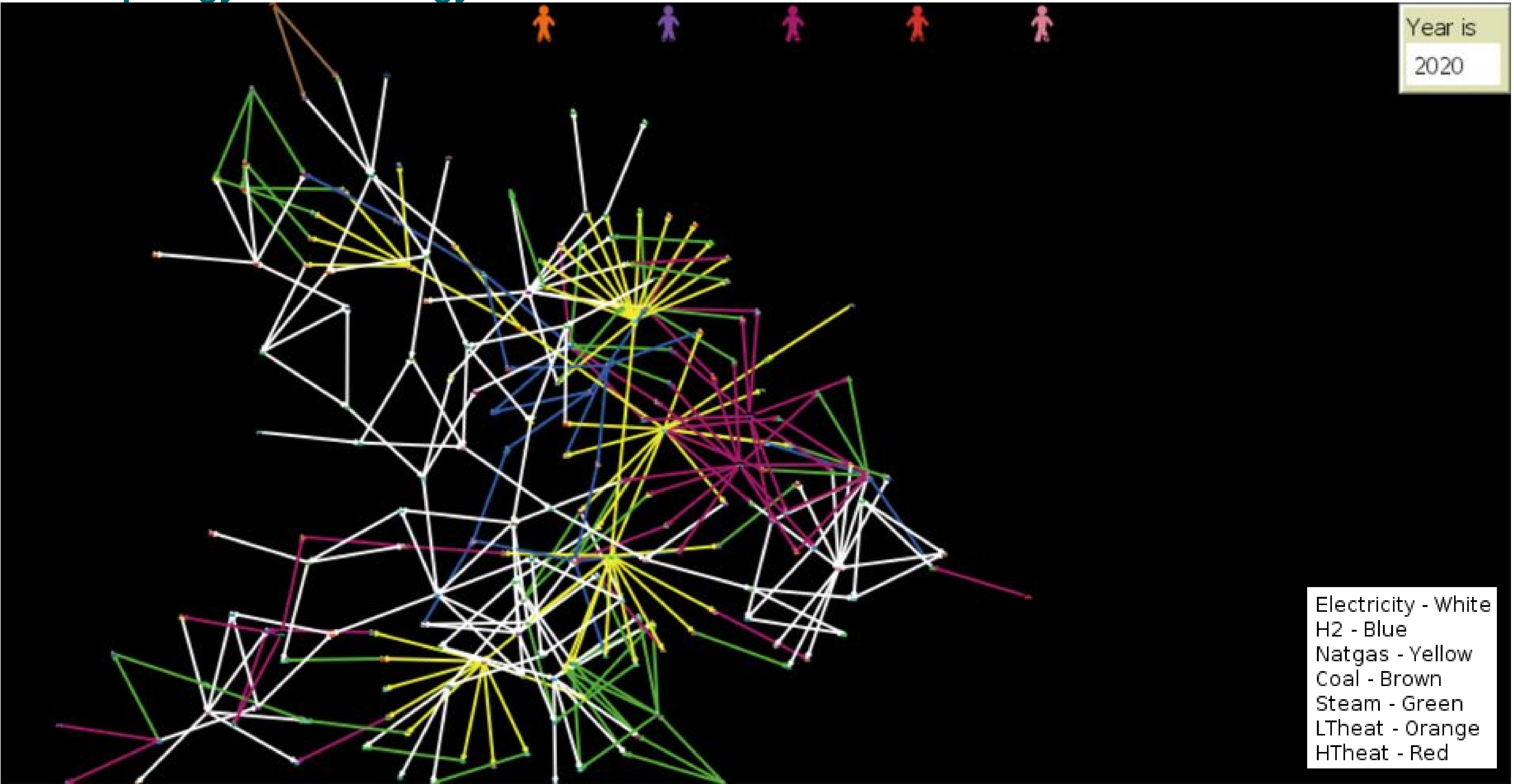


Public, open data and process models

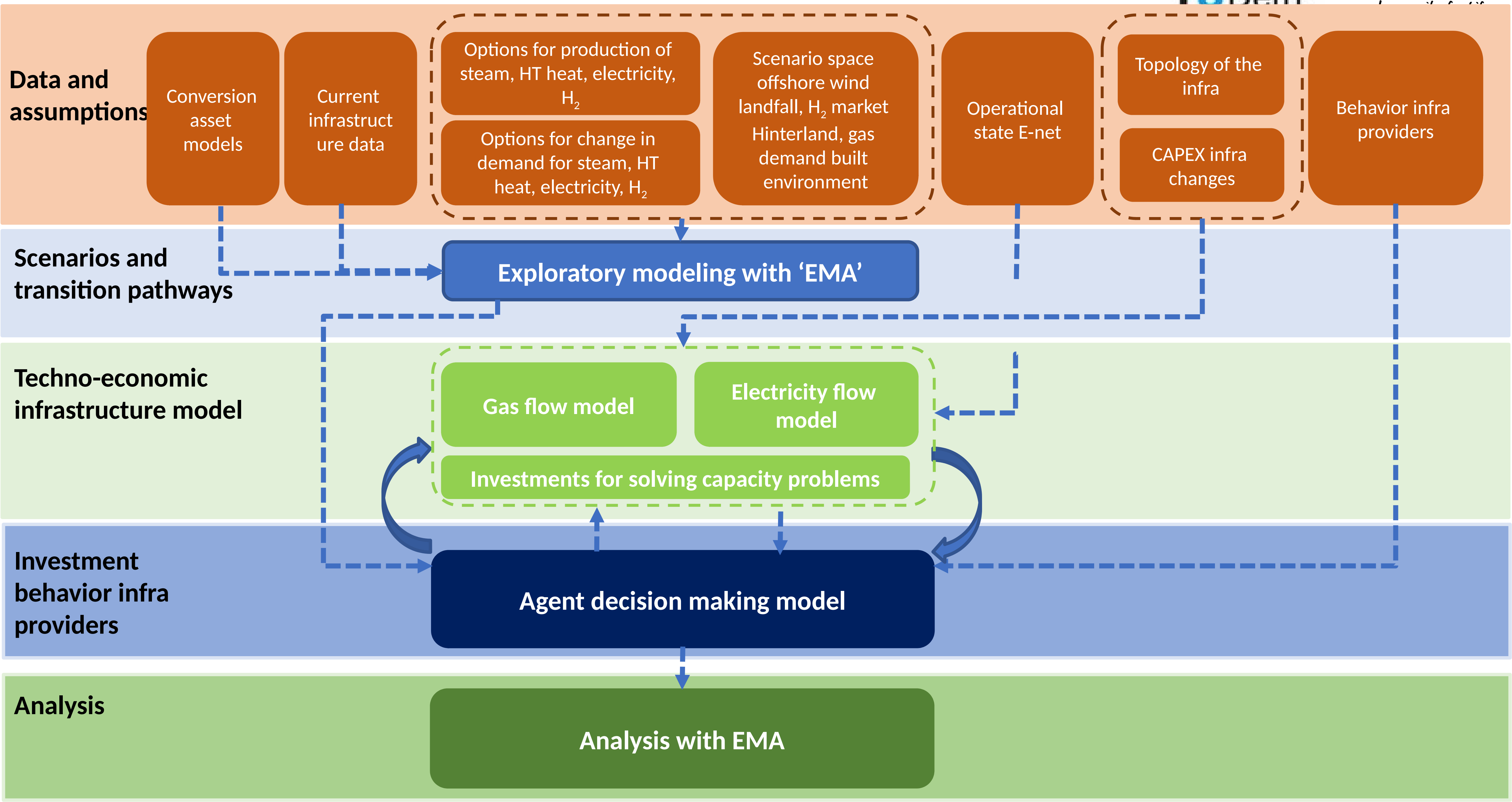
- Strictly based on public information
- 73 energy conversion assets
- 33 energy consumption sites
- Boilers, Ovens,
  Steam Methane Reformers,
  CHPs, Powerplants...



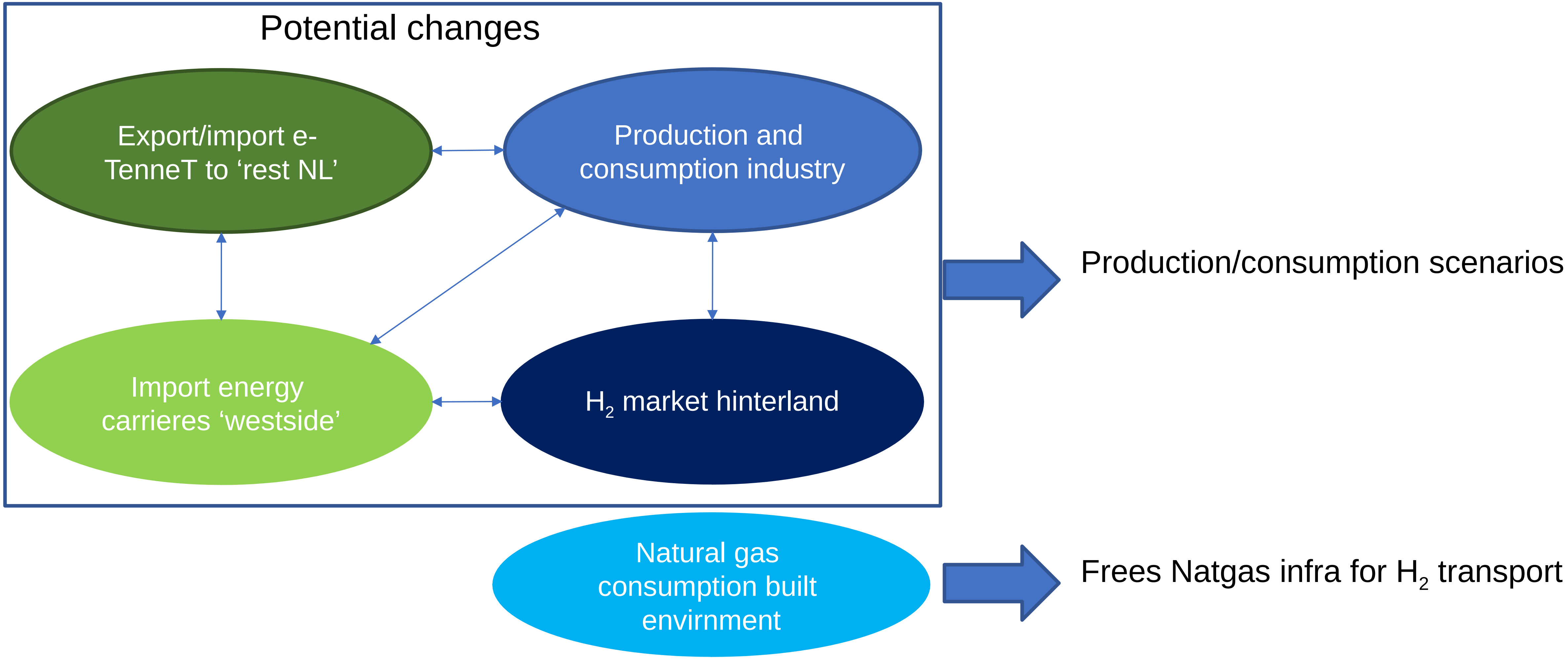
Topology of the energy-infrastructure



Multi-model approach

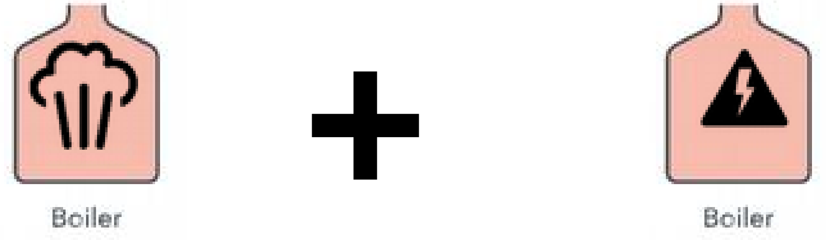


Scenario space via EMA

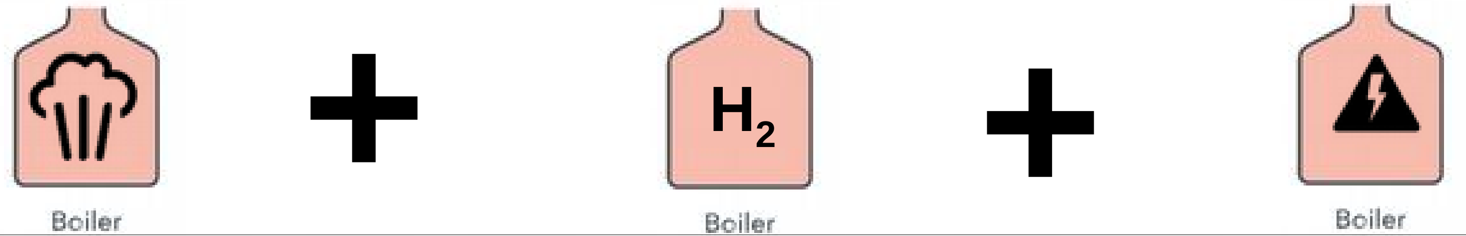


Possible pathways for steam

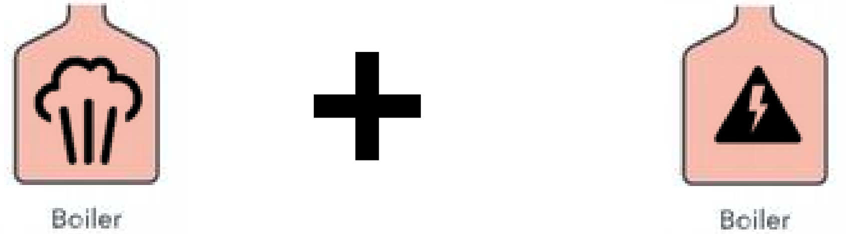
Optie 1:
Hybride huidig



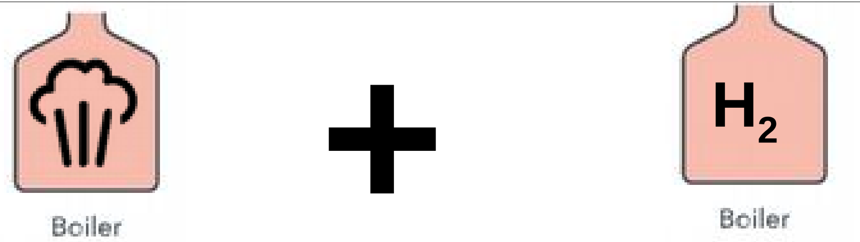
Optie 2:
Hybride $\mathbf{H_2}$



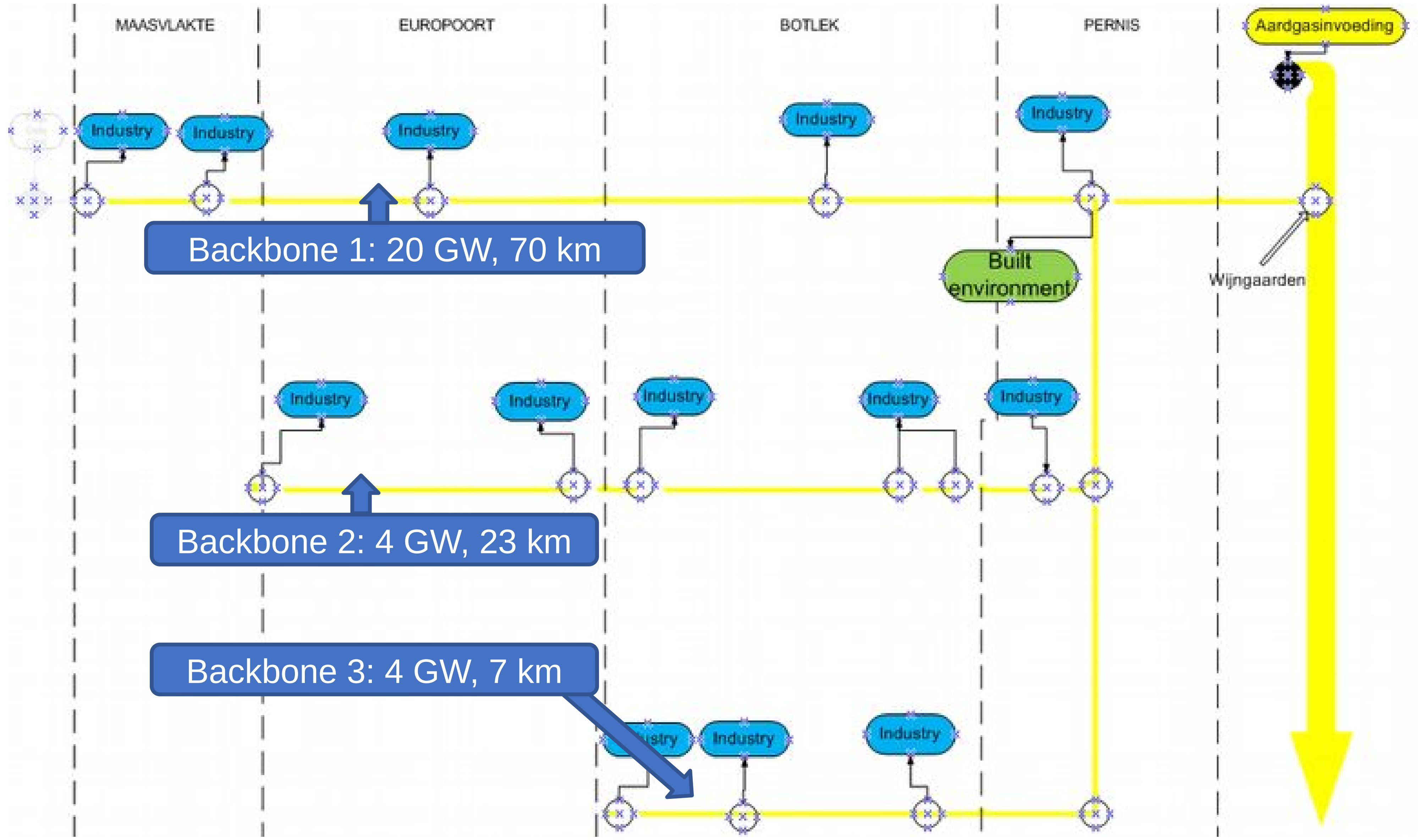
Optie 3:
E-Boiler



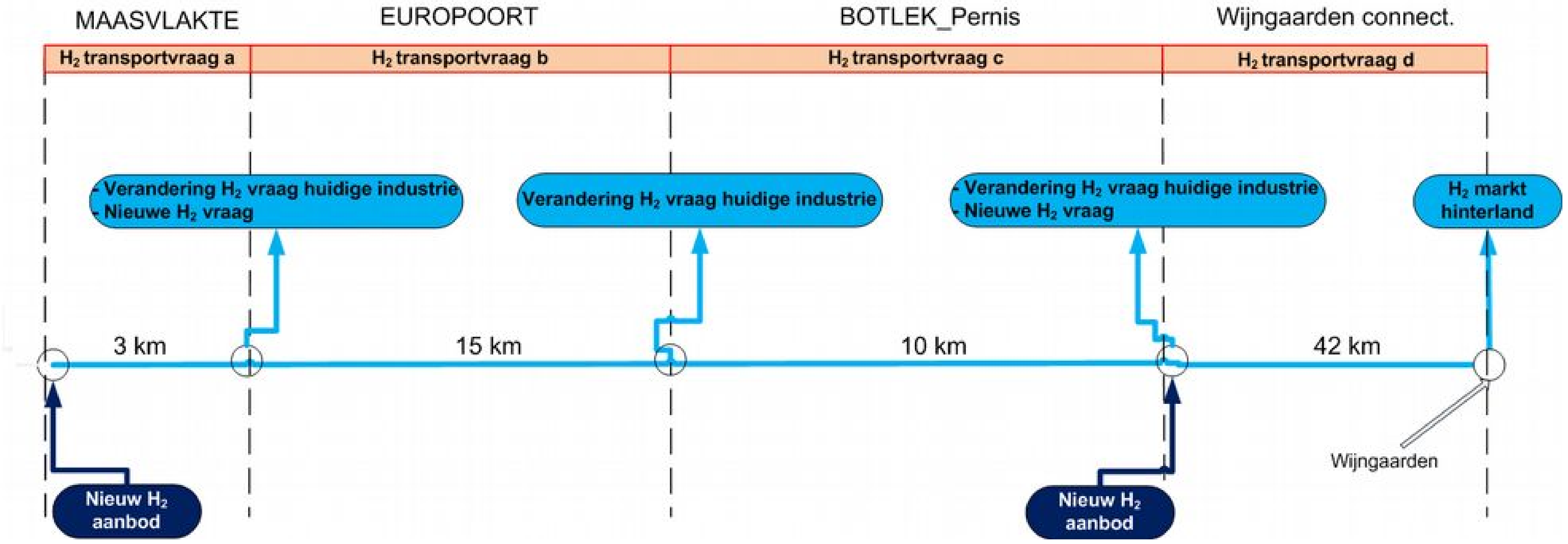
Optie 4:
H_2-boiler



Capacity of curent natural gas infrastrucutre is sufficient for all future scenarios

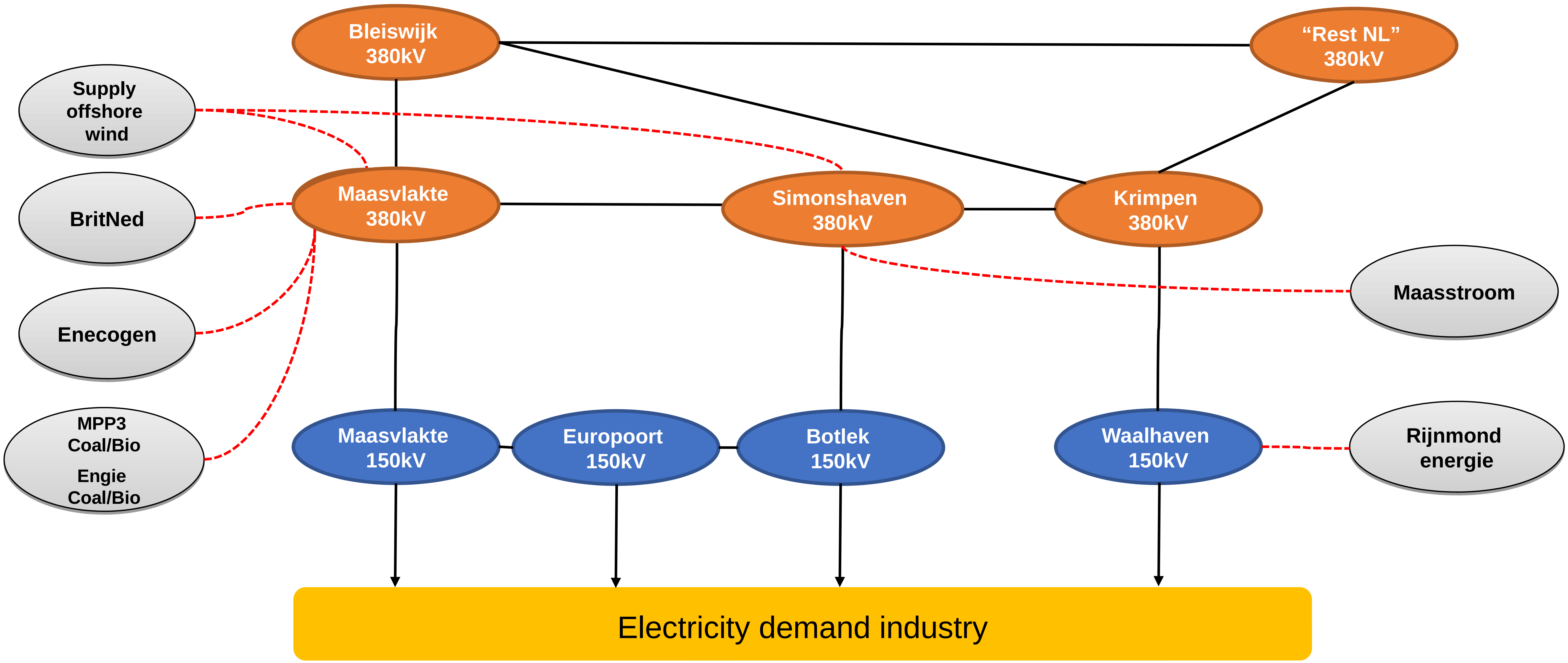


H_2 transport capacity requirements



- Energy balance over 4 pipe segments leads to transport capacity requirements

Topology of TenneTs e-transport net



Modelling of transport capacity of TenneT

Extreme operational state

- Hourly power ballance needed for determining possible transport capacity
- Capacity calculations done for 1 ‘extreme’state per year:
  - Max. offshore wind, min. flexibible gas generation , max. coal generation, BritNed exchange

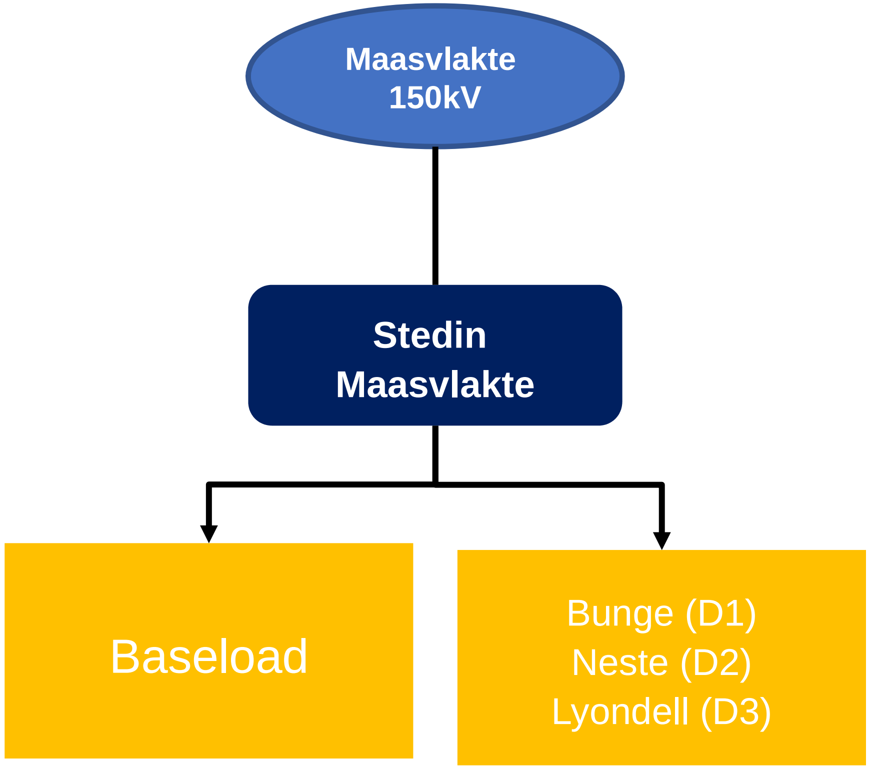
Ballance

- Closed electricity balance with the “rest NL” node

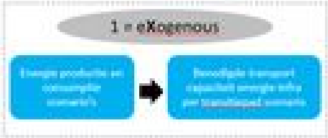
Rules of thumb

- Connection station Stedin > 50MW -> TenneT 150 kV
- Connection station TenneT 150 kV > 300MW -> TenneT 380kV

Modeling distribution grid of Stedin
- 7 “separate” distribution grids



$$Capaciteitsvraag_{Stedin} = gelijktijdigheidsfactor \cdot \left(\sum piek\ capaciteitsvraag - \sum piek\ productiecapaciteit\right)$$



Impact of investment behavior

Assesing the impact of different investmnet behavior of infra providers

Reactive

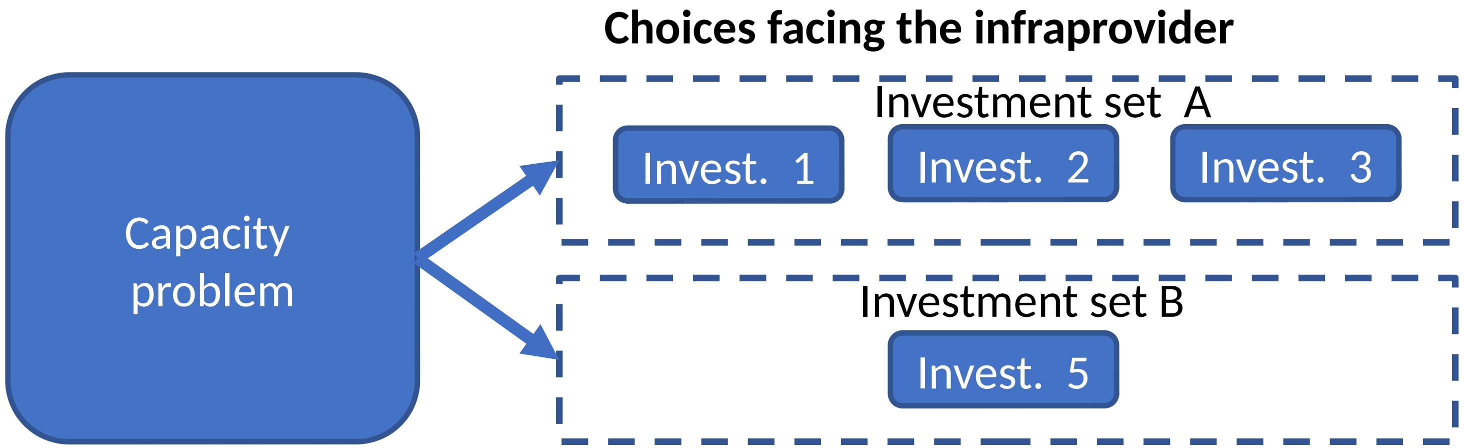
Current

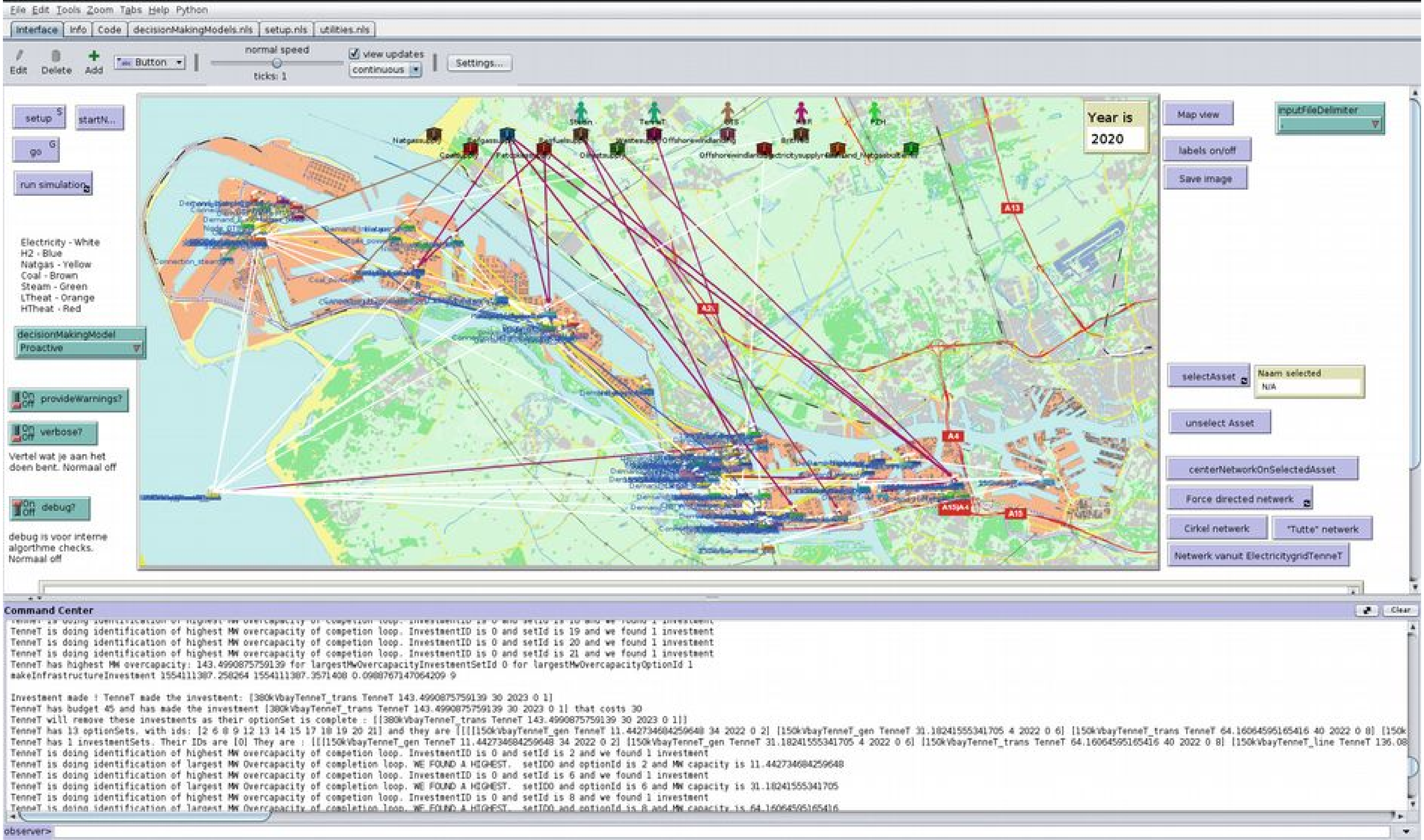
Collaborative

Agent	Reactive	Current	Proactive	Collaborative
TenneT	✓	✓	✓	✗
GTS	✓	✓	✓	✗
Stedin	✓	✓	✓	✗
Haven infrabeheerder	✗	✗	✗	✓

Agent can choose from different sets of investments

- Reactive
  - events within 1 year time horizon
  - investment with smallest overcapacity and only if we stay within the existing budget, if a part of the investment outside budget ->skip that part
  - No saving
- Current
  - Short time horizon
  - build the thing that will be done soonest
  - if you can't afford it, wait ill text year, save up
- Proactive
  - Much longer time horizon
  - Build the thing with biggest overcapacity
- Collaborative
  - One large infraprovider, very long time horizon
  - Combined budget
  - Build the biggest overcapacity

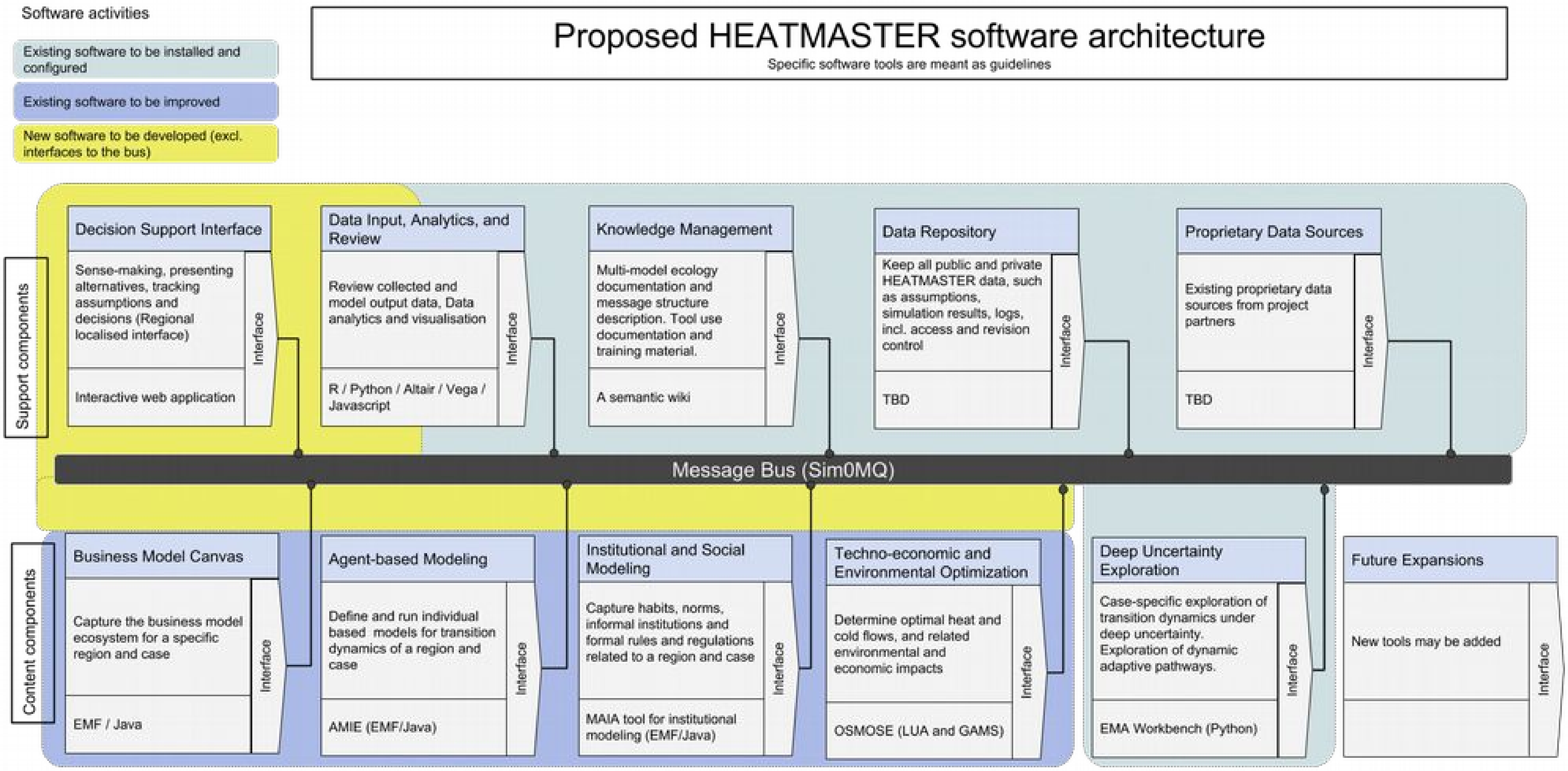




File Edit Tools Zoom Tabs Help Python
Interface Info Code decisionMakingModels.nls setup.nls utilities.nls
Edit Delete Add
Button
normal speed
ticks: 1
view updates
continuous
Settings...
setup
startN...
go
run simulation
Electricity - White
H2 - Blue
Natgas - Yellow
Coal - Brown
Steam - Green
LTheat - Orange
HTheat - Red
decisionMakingModel
Proactive
provideWarnings?
verbose?
Vertel wat je aan het doen bent. Normaal off
debug?
debug is voor interne algorthme checks. Normaal off
Year is
2020
A13
A4
A15
Map view
labels on/off
Save image
inputFileDelimiter
selectAsset
Naam selected
N/A
unselect Asset
centerNetworkOnSelectedAsset
Force directed netwerk
Cirkel netwerk
"Tutte" netwerk
Netwerk vanuit ElectricitygridTenneT
Command Center
Clear
TenneT is doing identification of highest MW overcapacity of competion loop. InvestmentID is 0 and setId is 19 and we found 1 investment
TenneT is doing identification of highest MW overcapacity of competion loop. InvestmentID is 0 and setId is 20 and we found 1 investment
TenneT is doing identification of highest MW overcapacity of competion loop. InvestmentID is 0 and setId is 21 and we found 1 investment
TenneT has highest MW overcapacity: 143.4990875759139 for largestMwOvercapacityInvestementSetId 0 for largestMwOvercapacityOptionId 1
makeInfrastructureInvestment 1554111387.258264 1554111387.3571408 0.09887671470642O9 9
Investment made ! TenneT made the investment: [380kVbayTenneT_trans TenneT 143.4990875759139 30 2023 0 1]
TenneT has budget 45 and has made the investment [380kVbayTenneT_trans TenneT 143.4990875759139 30 2023 0 1] that costs 30
TenneT will remove these investments as their optionSet is complete : [[380kVbayTenneT_trans TenneT 143.4990875759139 30 2023 0 1]]
TenneT has 13 optionSets, with ids: [2 6 8 9 12 13 14 15 17 18 19 20 21] and they are [[[[150kVbayTenneT_gen TenneT 11.442734684259648 34 2022 0 2] [150kVbayTenneT_gen TenneT 31.182415555341705 4 2022 0 6] [150kVbayTenneT_trans TenneT 64.16064595165416 40 2022 0 8] [150k
TenneT has 1 investmentSets. Their IDs are [0] They are : [[[150kVbayTenneT_gen TenneT 11.442734684259648 34 2022 0 2] [150kVbayTenneT_gen TenneT 31.182415555341705 4 2022 0 6] [150kVbayTenneT_trans TenneT 64.16064595165416 40 2022 0 8] [150kVbayTenneT_line TenneT 136.08
TenneT is doing identification of highest MW overcapacity of competion loop. InvestmentID is 0 and setId is 2 and we found 1 investment
TenneT is doing identification of largest MW Overcapacity of completion loop. WE FOUND A HIGHEST. setID0 and optionId is 2 and MW capacity is 11.442734684259648
TenneT is doing identification of highest MW overcapacity of competion loop. InvestmentID is 0 and setId is 6 and we found 1 investment
TenneT is doing identification of largest MW Overcapacity of completion loop. WE FOUND A HIGHEST. setID0 and optionId is 6 and MW capacity is 31.182415555341705
TenneT is doing identification of highest MW overcapacity of competion loop. InvestmentID is 0 and setId is 8 and we found 1 investment
observer>

Results!

Architecture as we would like to have it



(some of the) methodological issues with multi-modelling

- Software implementations
- Scales (nesting, contguity) time, space, organisation, institutions, social
- Model fidelity / resolution / accuracy / precision
- Uncertainty (propagation)
- Multi-formalism alignment and incompatible ontologies
- Conflicting rationalities / abstractions /
- Participatory modeling process , “bundary institutions”, sense-making and authoritativeness

Thank you !

Windmaster team

and
Dr. Ir. Igor Nikolic
I.nikolic@tudelft.nl
@ComplexEvo