The Port of Rotterdam:
the largest “capacitor” of the Netherlands

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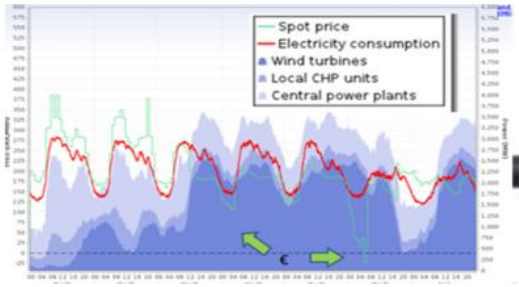
Rob Stikkelman
r.m.stikkelman@tudelft.nl

TU Delft
Technische Universiteit Delft

The “Flexible Energy in Rotterdam” project



E-Variability ⇔ **E-Flexibility**

(Demand, Supply) (Demand, Supply)

The Harbour Industrial Cluster (HIC) of Rotterdam:

- represents a huge power system,
- potentially offers significant E-flexibility

However,….

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The “Flexible Energy in Rotterdam” project

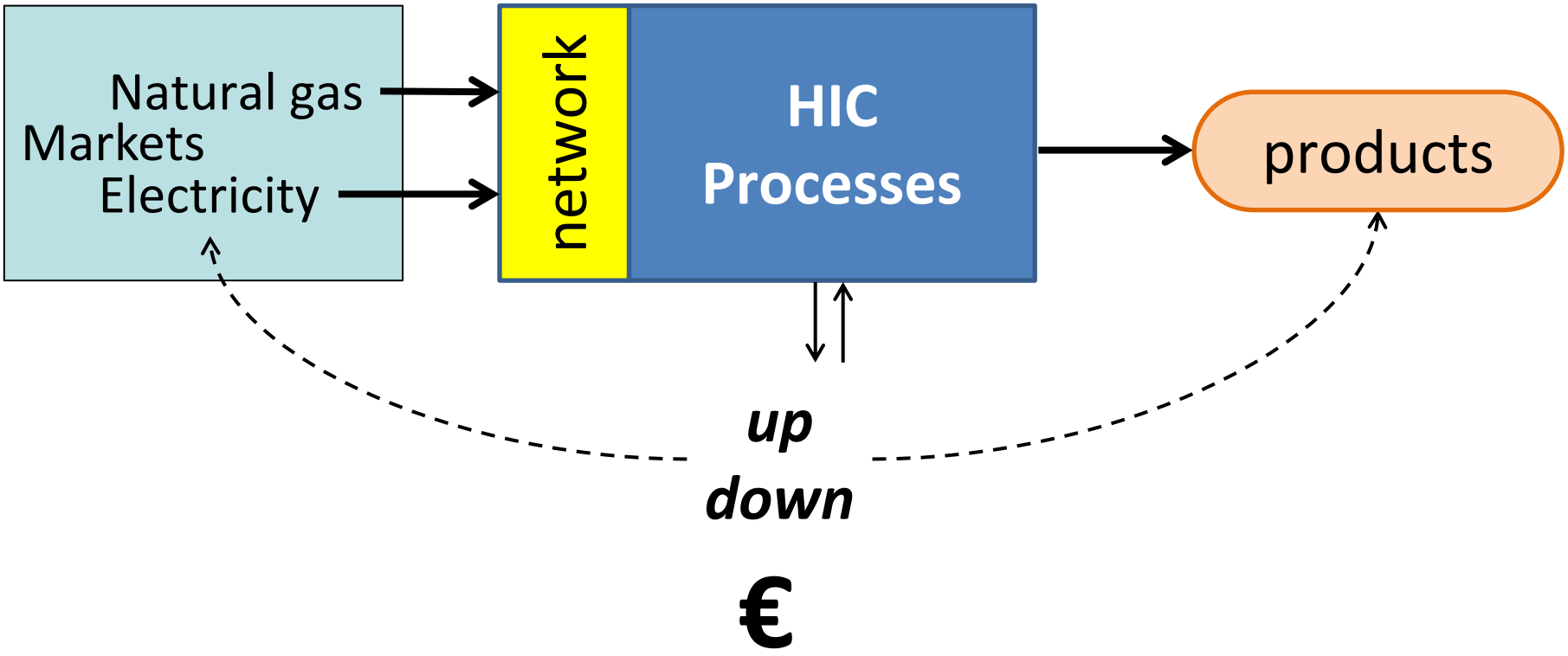
There was a lack of data and knowledge:

- Which flexibility options can we create within individual companies and clusters?
- What is the effect of integrated processes?
- How much variability do we observe in the electricity markets?
- How do we harvest this variability?
- To which extent is the electric power grid a limiting factor?
- Etc.

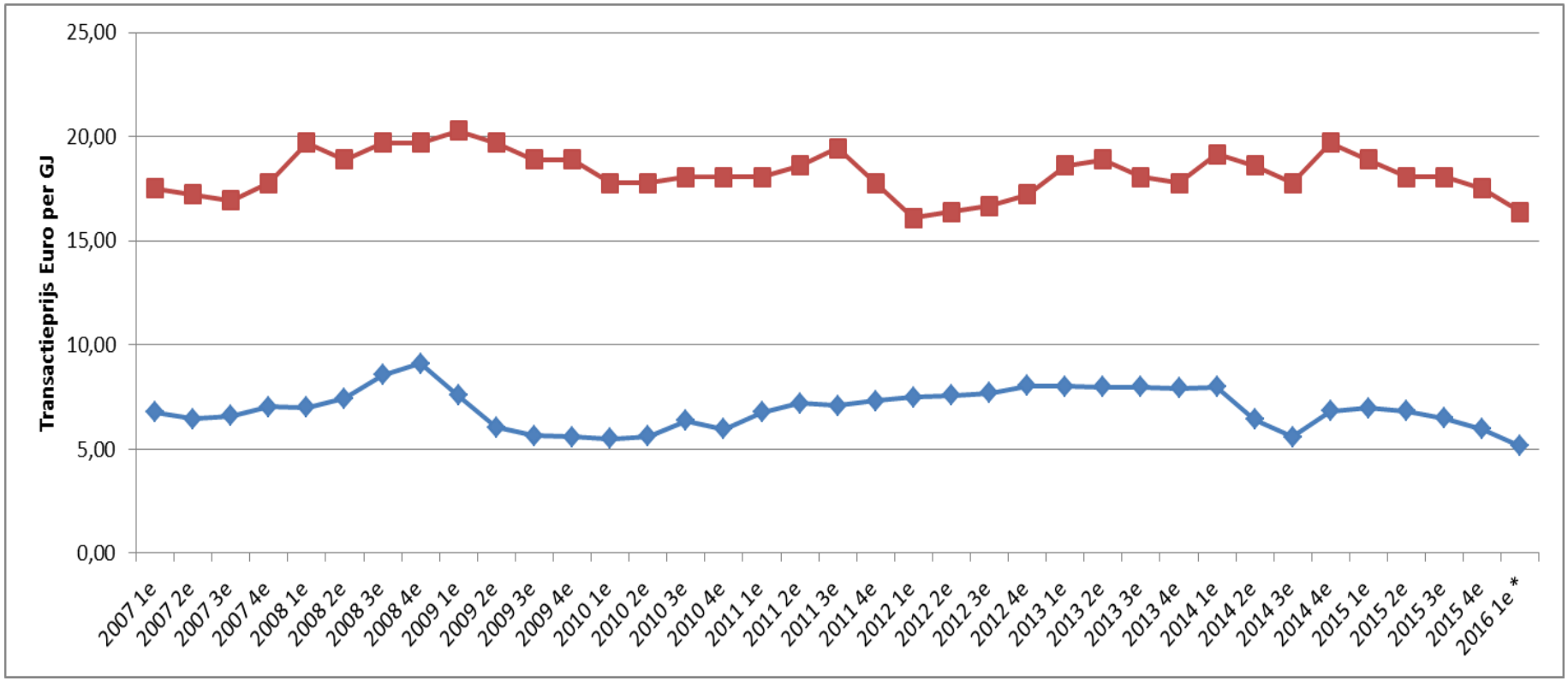
The “Flexible Energy in Rotterdam” project

Project team

The Harbor Industrial Cluster as “Capacitor"

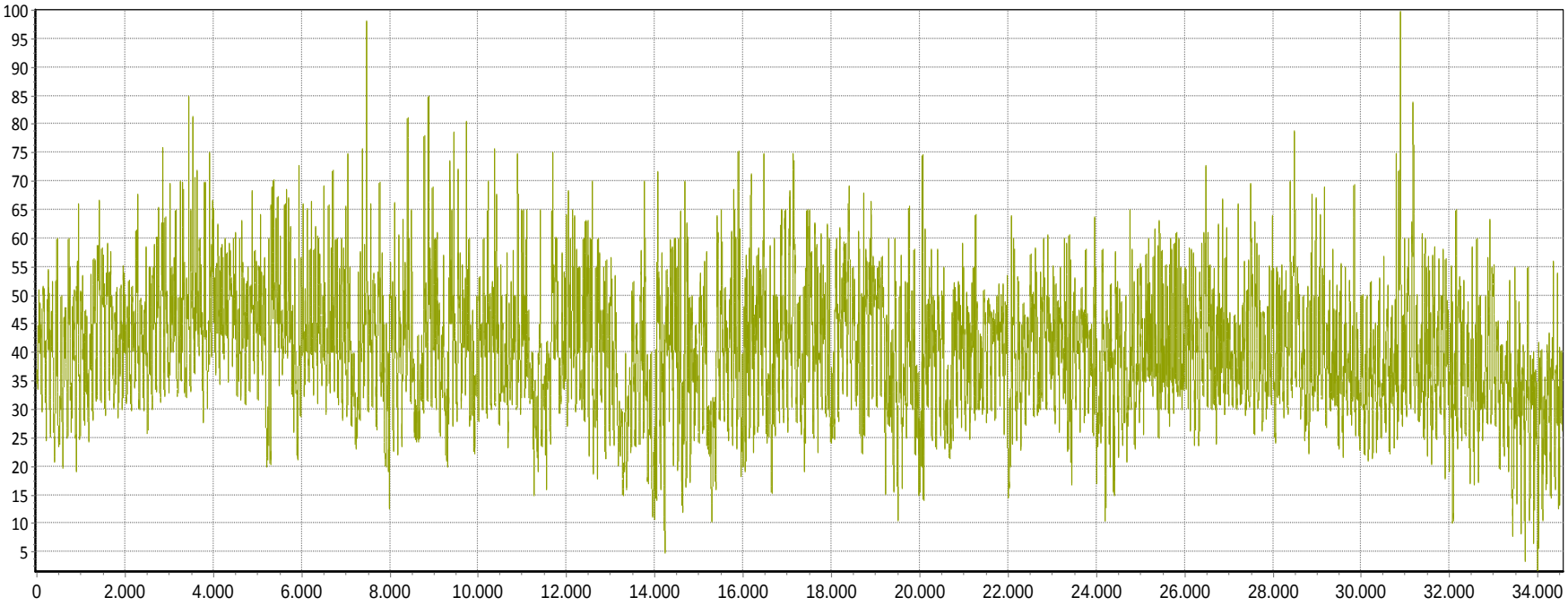


Markets: Average prices Gas and Power [Euro/GJ]



Gem. Transactieprijzen Aardgas (blauw) en Elektriciteit, grootverbruik ex BTW incl. Taks Bron CBS

Market: Day Ahead prices 2015 [pte, Euro/MWh]



Minimum: 1,7

Average: 40,1

Maximum: 99,8

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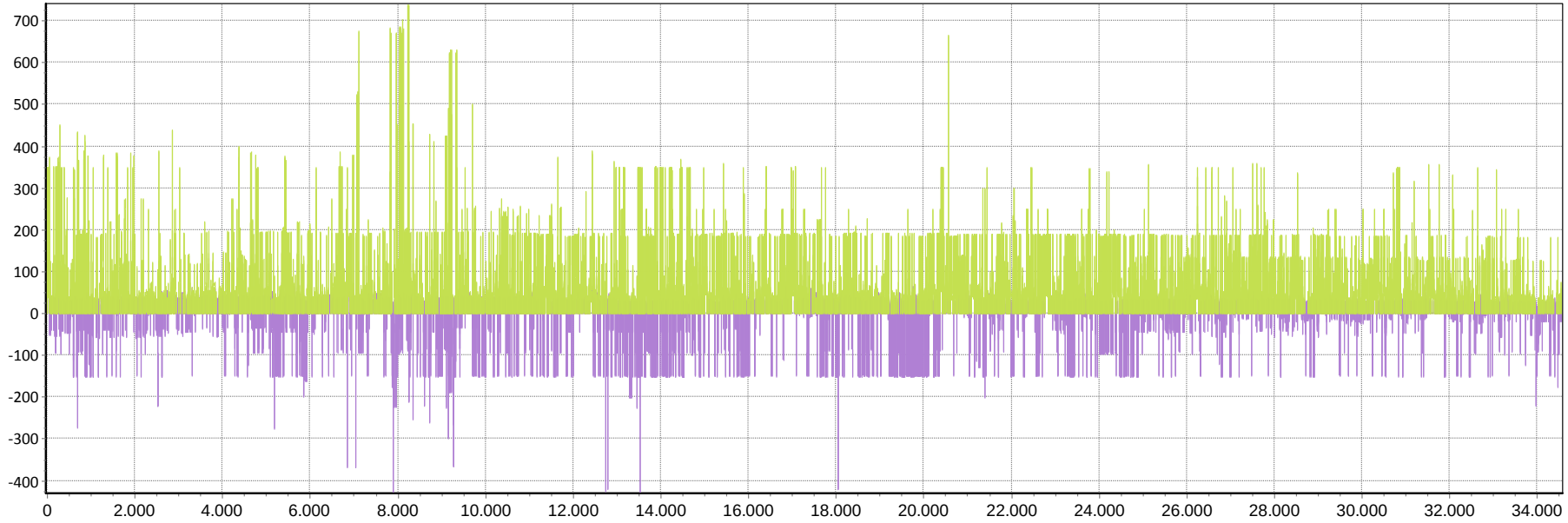
Market: Prices RRV trade 2015 [pte,Euro/MWh]



	Up	Down
Minimum:	0	-429
Average:	79	7
Maximum:	738	78

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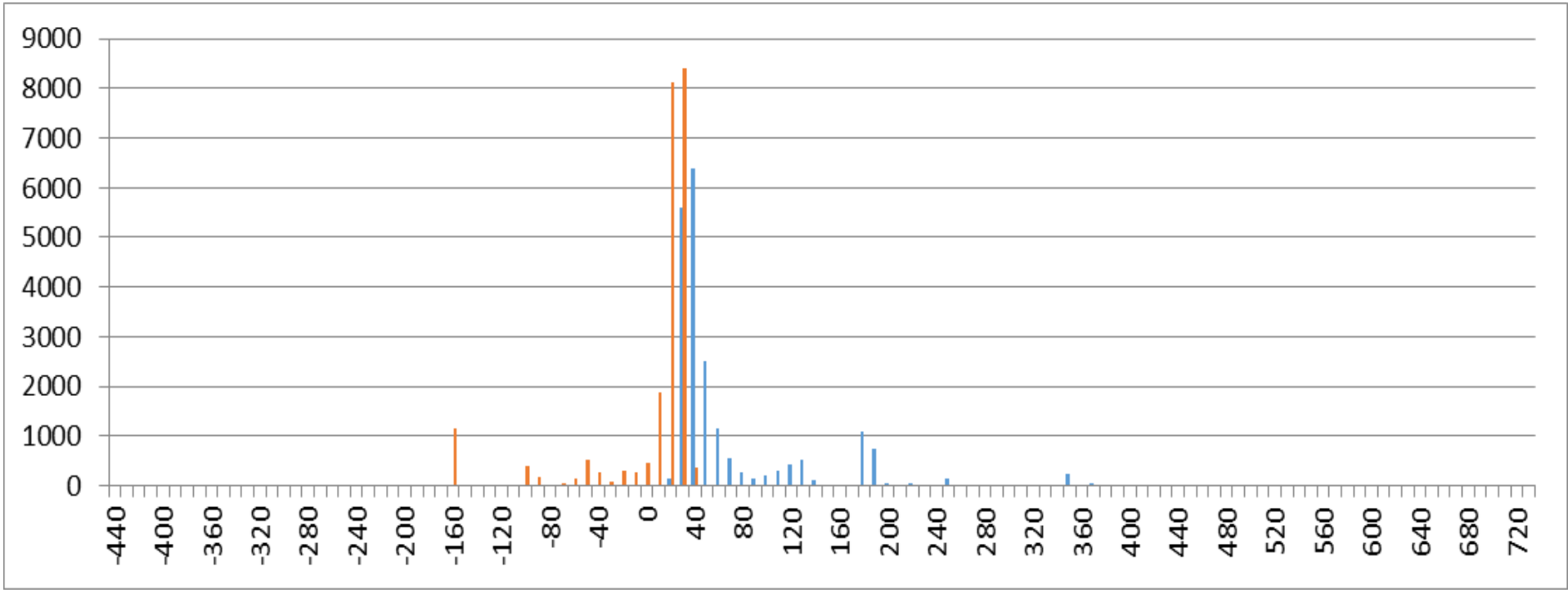
Market: Prices imbalance trade 2015 [Euro/MWh]



	<price> Euro/MWh	<Volume> MWh/pte
UP	79	15,1
DOWN	7	-13,9

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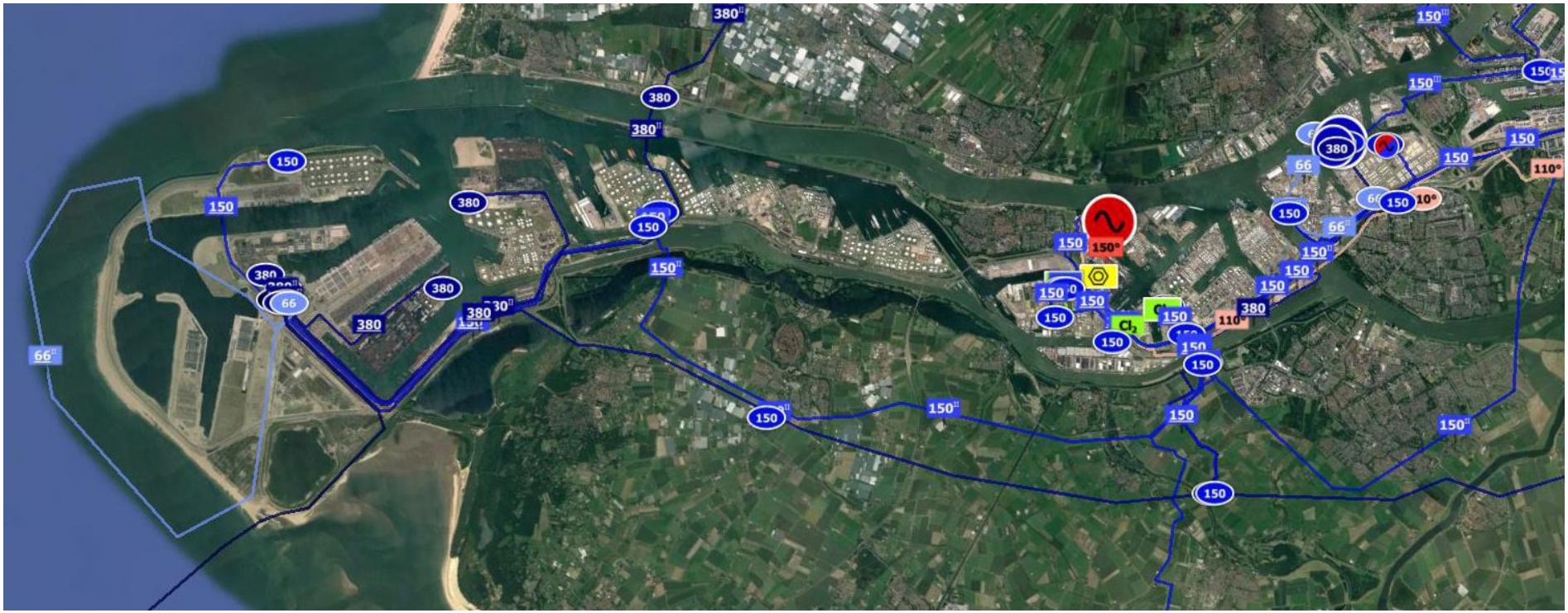
Networks: 150 and 380 kV net



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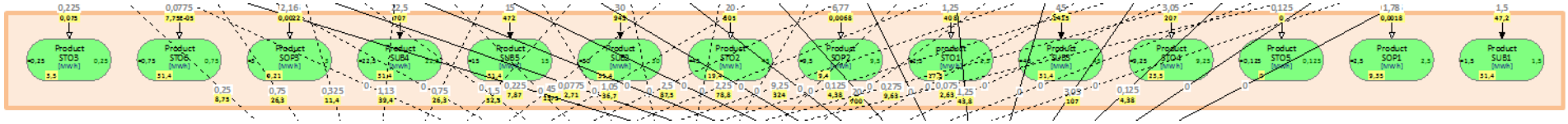
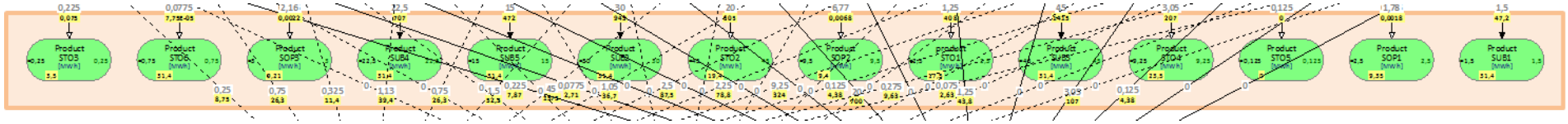
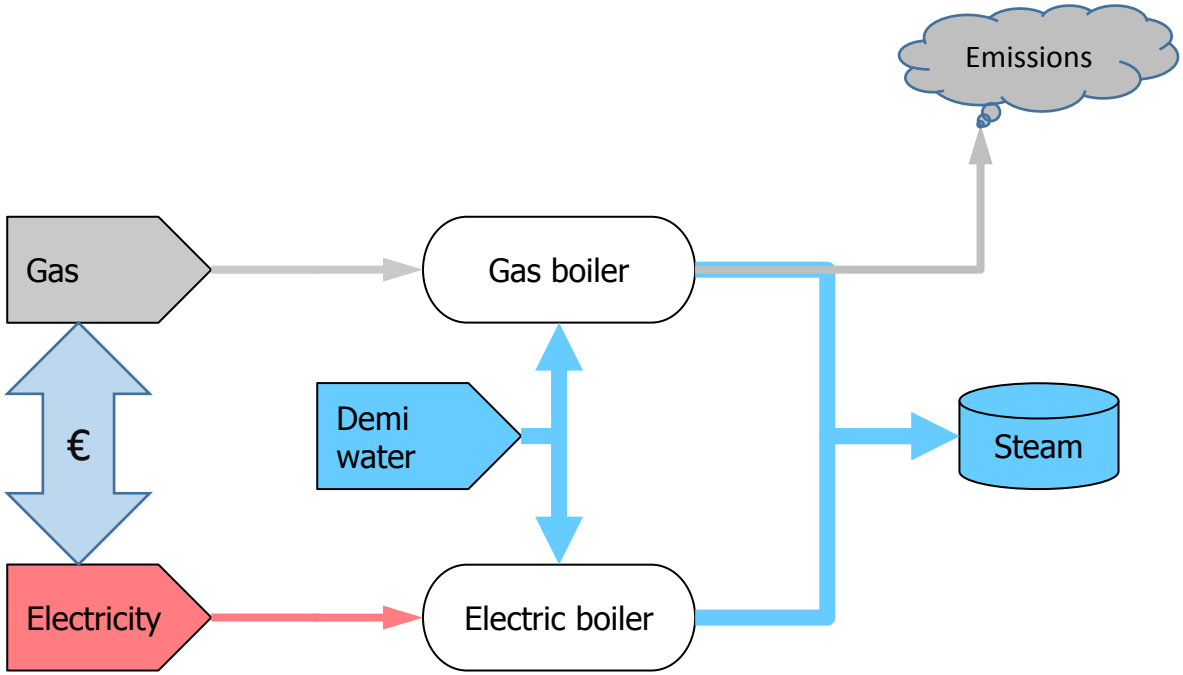
Selected processes and products



- Electrolysis of brine, Chlorine, Cl_2
- Production of liquid Carbon dioxide, CO_2
- Air separation, Liquid Oxygen O_2
- Charging Batteries of Automated Guided Vehicle (AGV)
- Milling Cement
- Cooling warehouses
- Production of steam
- Heating of stored bunker oil

Example of a flexible process: steam production





Modelling the system: Linny-R by Pieter Bots

- easy-to-use software tool for industrial process optimization (LP)
- allows to model a production system as (clusters of) processes that have products as inputs and outputs.
- calculates at what level processes should be scheduled to produce the desired quantities of end products while maximizing profit (or minimizing cost).
- Allows time series

- Uses the lp_solve library version 5.5.2.0 developed by Michel Berkelaar, Kjell Eikland, and Peter Notebaert,
- Uses the API for Delphi developed by Henri Gourvest

Modelling the system: Linny-R

Linny-R - [New model 2]

File Model Edit View About

Product 1 → Process A

Product properties

Name: Product 1

Unit: MWh

Comment:

Bounds (MWh)

Lower: Upper: ... (N = 0)

Source Sink

Storage Junction

Owner:

Initial level: 0 (MWh)

Fee for storage: (per time step) 0 (EUR/MWh)

Attributes

Price: (EUR/MWh) ... (N = 0)

Grade tolerance:

between d ... (N = 0)

Process properties

Name: Process A

Actor (no actor)

Comment:

Bounds

Lower: 0 Upper: ... (N = 0)

± 0 % relative to level at T=1

Average level over 0 ps: 0 % 0

Bounds depend on level at T-1

Bounds depend on other processes

Bounds depend on product stocks

Shut-down if lower bound (> 0) constrains

Start-up cost: 0 EUR

Variable cost: (at level = 1) 0 EUR

Reversible process

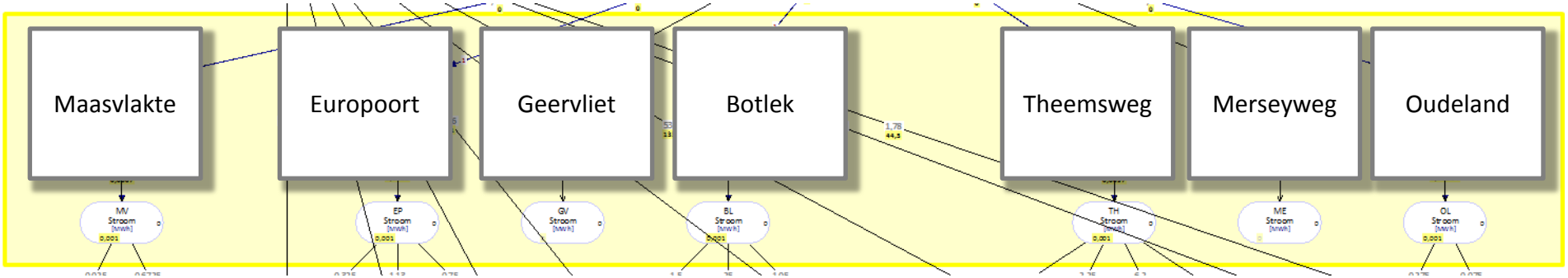
Draw process as small square only

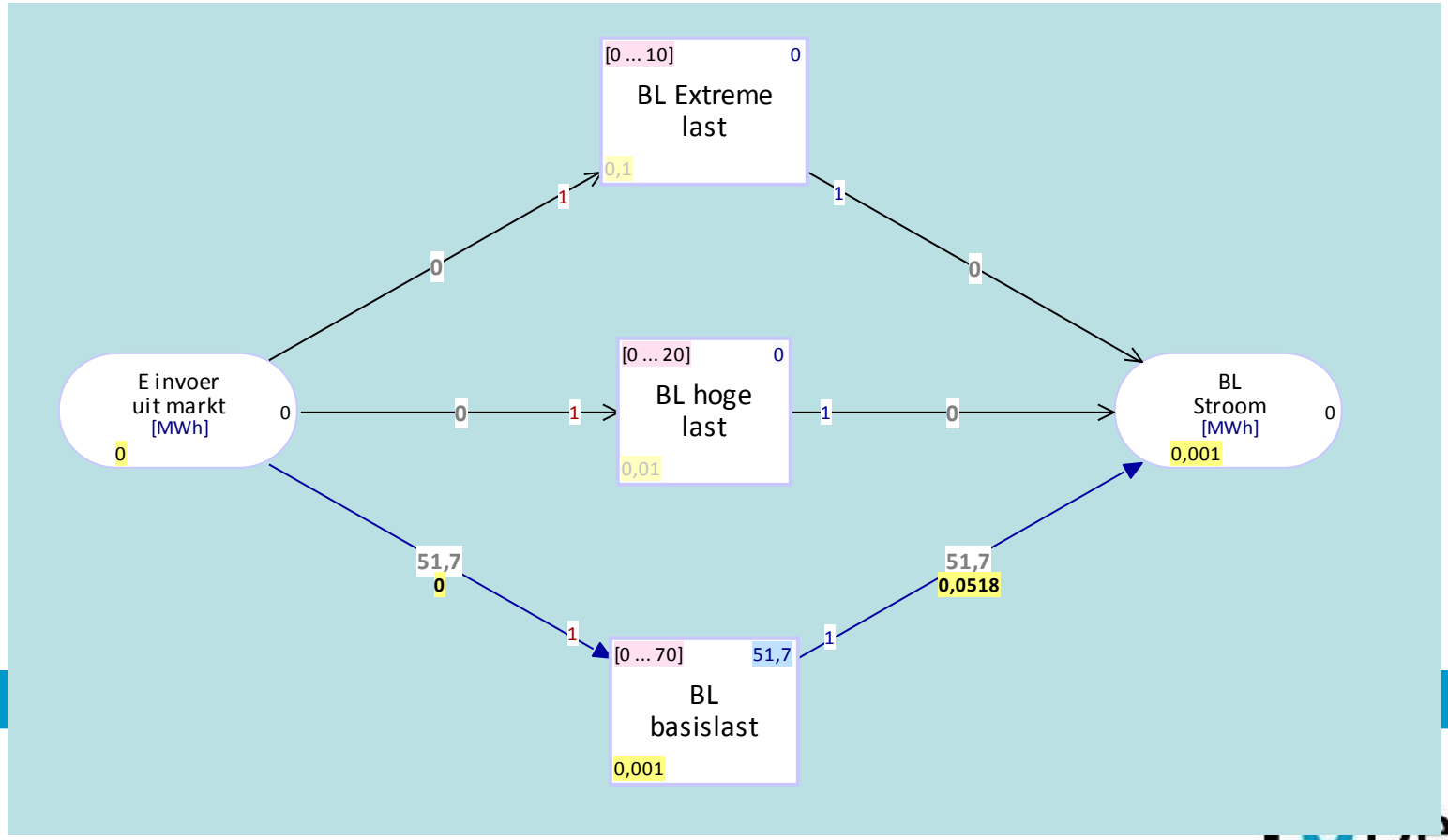
Products consumed (at level=1)	Quantity	Unit	EUR
Product 1	1	MWh	0

Activity has no outputs

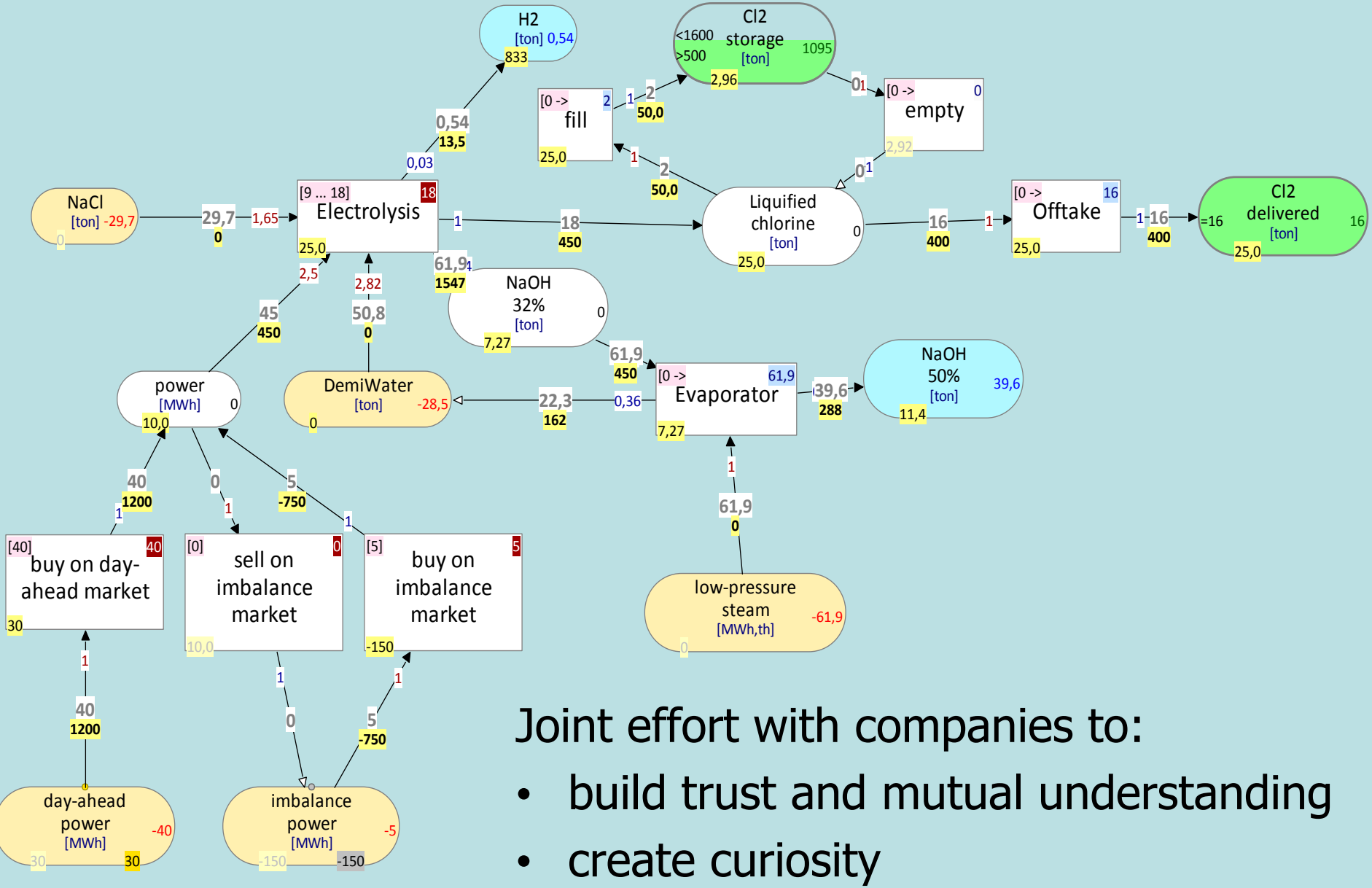
Cash out: 0 Cash in: 0 Value added: 0 EUR (at level = 1)

Network: A (too) Simple model





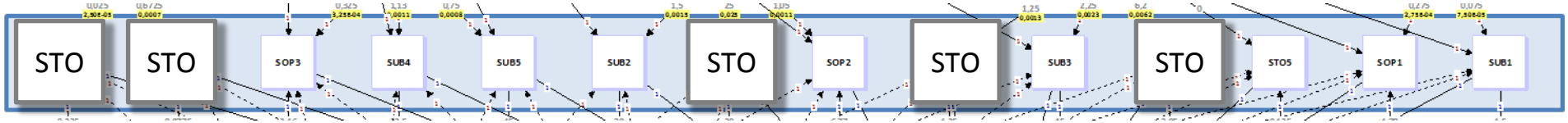
Modelling the system: The production of chlorine

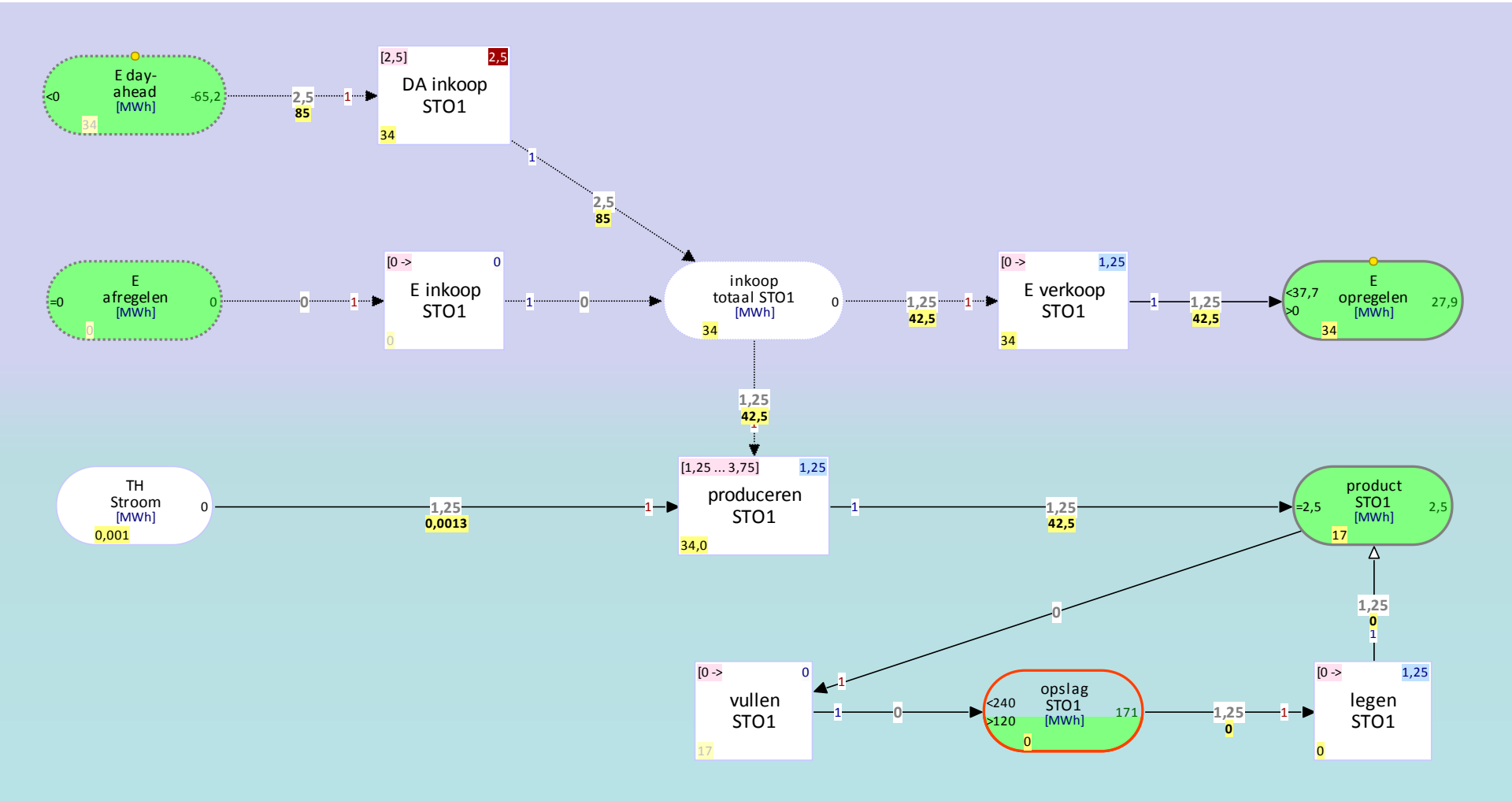


Joint effort with companies to:

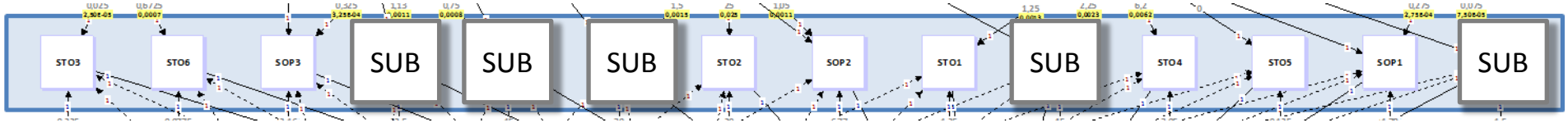
- build trust and mutual understanding
- create curiosity

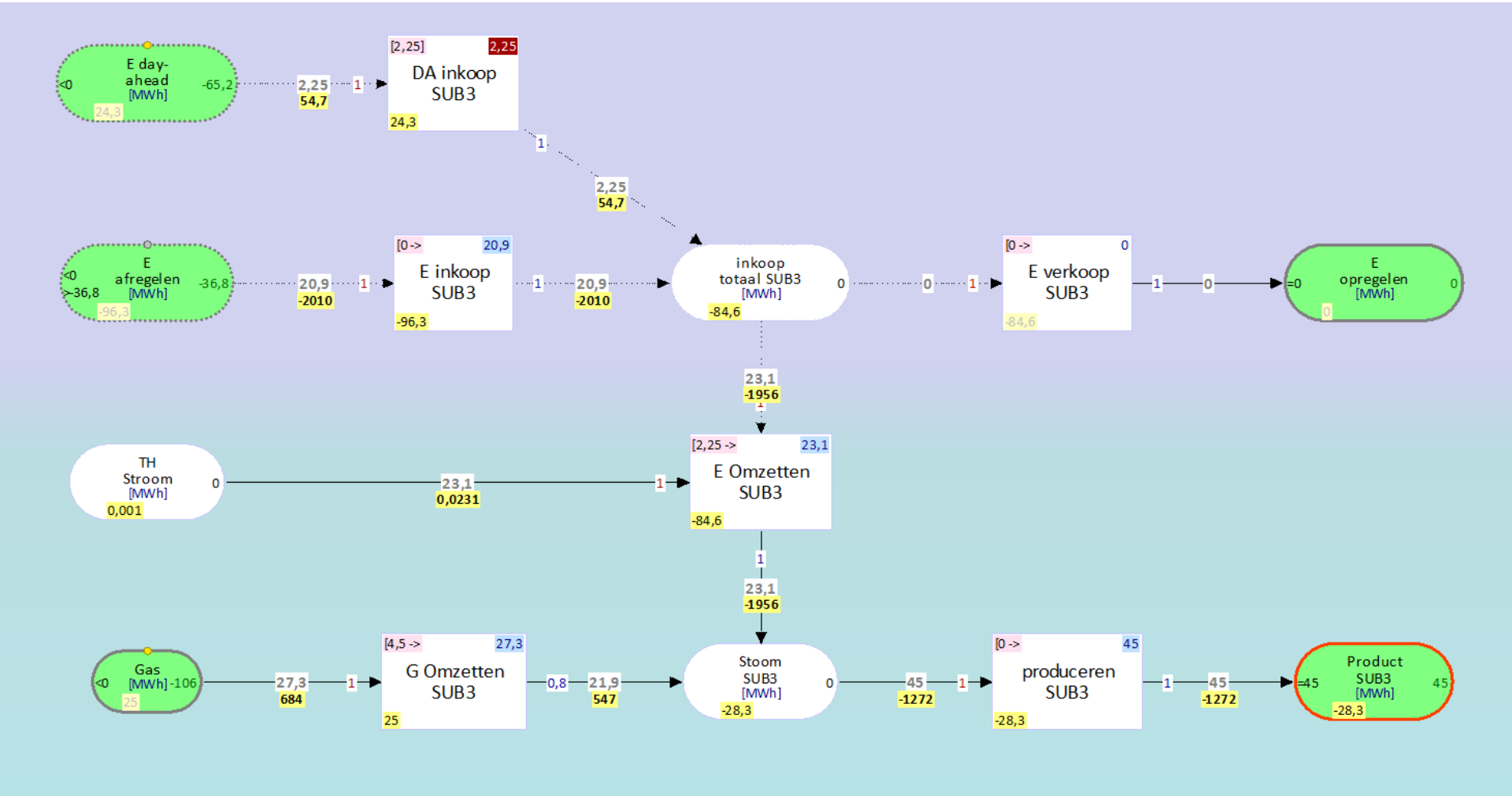
Modelling the system: standard storage process



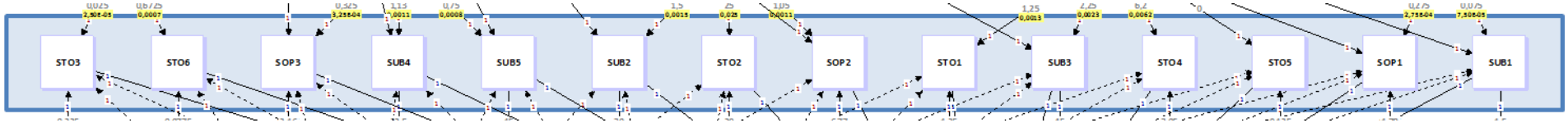


Modelling the system: standard substitution process

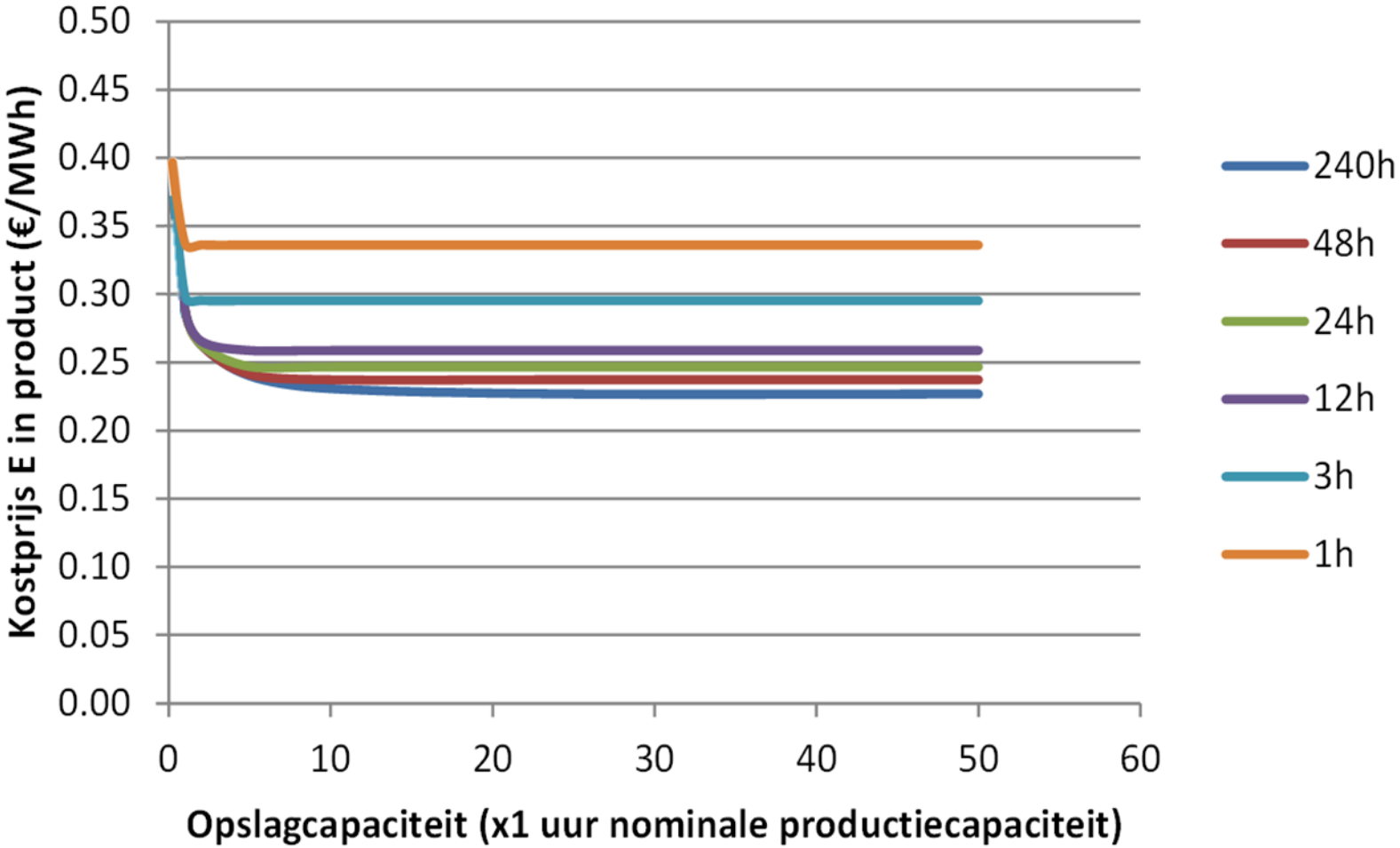




Results: Single storage process and imbalance prices



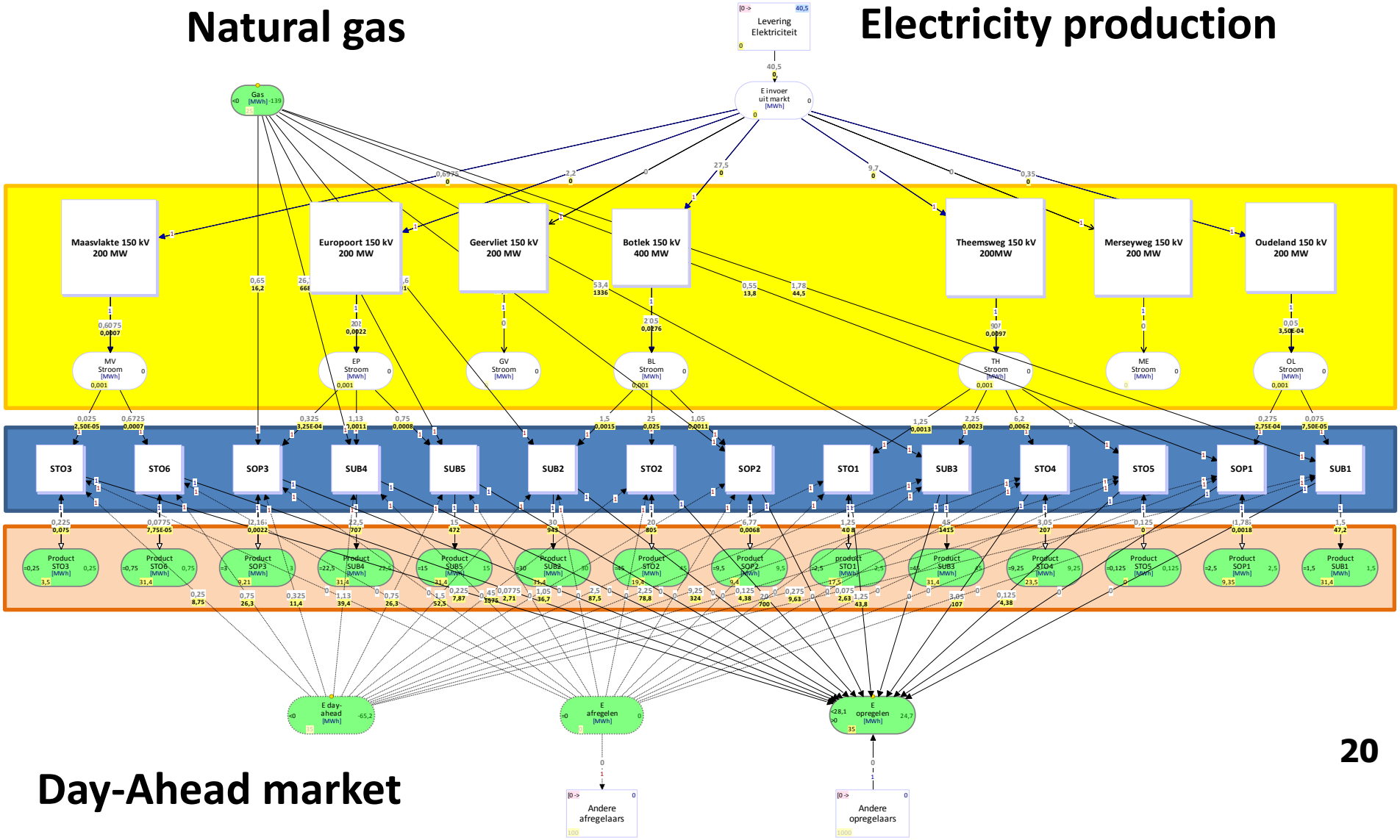
Effect of storage size and future knowledge of prices



The port model

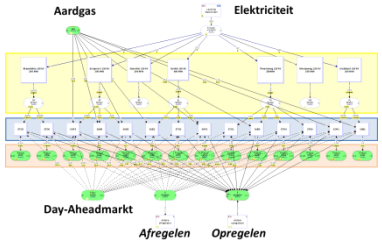
Natural gas

Electricity production



Day-Ahead market

Down ***Up***



Experiments for 2015

1. **Reference case**
   - Day- Ahead and RRV prices
   - Volumes Up and Down RRV per pte
   - Gas price is 25 €/MWh
2. **No balancing**
   - As reference case, but volumes Up and Down are zero
3. **Zero flexibility**
   - As No balancing, but no gas tipping point
4. **No limits**
   - As reference cases, but infinite volumes for Up and Down

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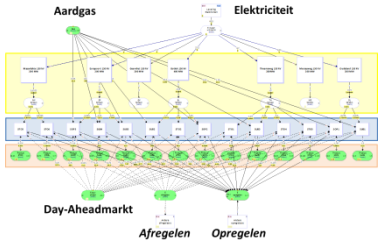

Results: Reference case

	Mean	St.dev.	Min.	Max.	Sum
	[MWh/pte]				[GWh/year]
Down BM	-6,1	12,5	-122	0	-210
Up BM	1,0	3,4	0	66	35
Day-ahead	-68,8	22,5	-210	-65	-2377
E-load	73,8	24,1	37,3	203,9	2550
G-Load	141,3	24,8	14,7	152,1	4883

Flex load HIC 2015

4*(1,0 – -6,1)= 28,4 MW

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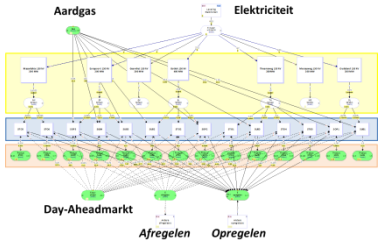

Results: No Limits

	Mean	St.dev.	Min.	Max.	Sum
	[MWh/pte]				[GWh/year]
Down BM	-41,3	56,3	-139	0	-1428
Up BM	3,4	13,9	0	173	116
Day-ahead	-68,8	22,5	-210	-65	-2377
E-load	107	59,3	37,3	204	2550

Upper limit average Flex load HIC

4*(3,4 – -41,3) = 179 MW

Max transport capacity

4*173= 692 MW

Network OK?

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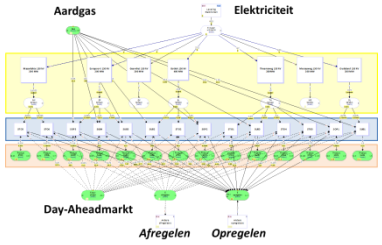

Results: Value of Flexibility

	Sum
Energy costs	[M€/year]
Zero flexibility	221,7
No balancing	219,9
Referentie casus	205,8
No limits	157,6

Value flex HIC in 2015

221,7 – 205,8= **15,9 M€**

Market volume limits

Maximum value flex

221,7 – 157,6= **64,1 M€**

Technique limits

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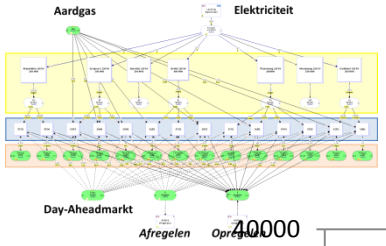
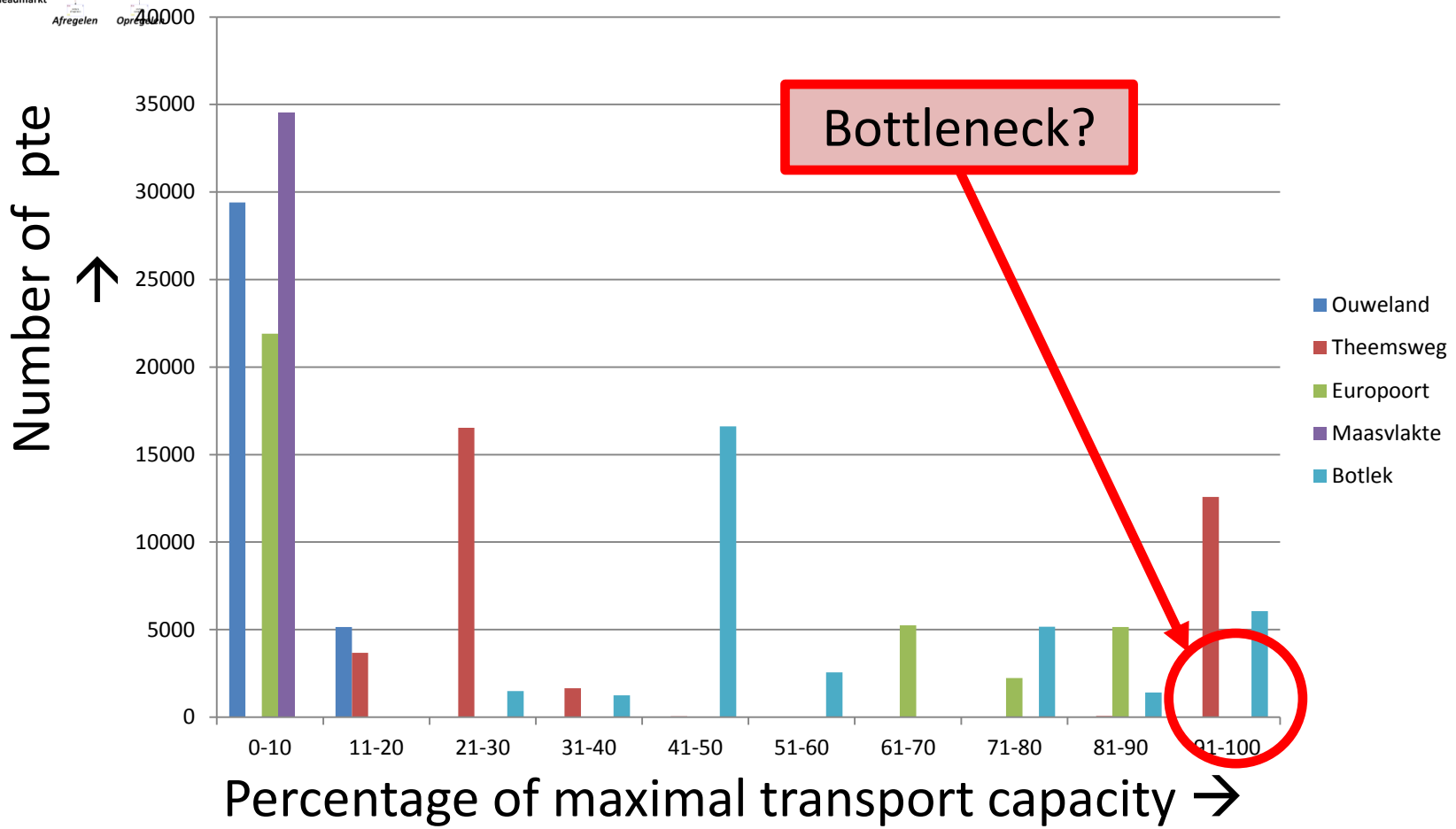


Results: Network performance at No Limits



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Closure

Model results for 2015 case:

- The port of Rotterdam is able to offer on average 179 MW of flexibility
- The RRV market offered on average 53,2 MW of variability
- Due to market limitations only 28 MW on average was used with a total value of 15,9 million Euro

- Value of the RRV market in 2015 was 32,4 million Euro

Closure

The project was a success:

- Project members were always on board
- We learned a lot
- Follow-up projects are developed

Simple LP model has been made:

- New insights were generated
- The model can easily be adjusted for other industrial area
- Too simple?