Anhydrous Ammonia

A Battery for Stranded and excess energy sources

by

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Sacramento , September 23rd , 2013

Why ammonia as storage medium

- Some characteristics of ammonia
- Logistics of today's fuels/chemicals
- Decentralised production for ammonia using NFUEL UNITS
- Case study Rotterdam
- Storage feature

Characteristics Ammonia

- Fertiliser
- Chemical -agricultural uses such as
  - Nylon, Acrylonitrils, PUR foams
- All chemical and physical characteristics known for long time

But:

- Fossil based ammonia creates 1,8 ton/ton ammonia as CO_2
- Dubious smell/toxicity issue???
- No Carbon containing product , so as fuel CO_2 footprint zero
- It is relatively safe to handle (years experiences in USA)
- USA acquainted to use anhydrous ammonia for fertilisation
- Ideal to start Ammonia for fuel in USA
- Physical conditions like LPG (Pressure Temp, no Cu)
- LPG tanks can be replaced by NFUEL tanks (NH_3-tanks)

- However:
  NFUEL shall be produced from sustainable sources

Logistics of today's fuels/ Chemicals

- Is exploration safe
- Are logistics safe
  - Perception public
  - Insurance issues
- Are large scale production processes safe
  - External safety risks
- Is the application safe
- May ammonia be used as energy carrier
- Advantages of ammonia versus fossil fuels

Is exploration safe and secured?

BP Deepwater Horizon 2010
Source : Norm Olson: Portland conference)

- Logistics
- Geopolitical problems
- Technical mistakes
- Peakoil
- Economic recession/dip
- Natural disasters
- Terrorism
- Supply/demand balance

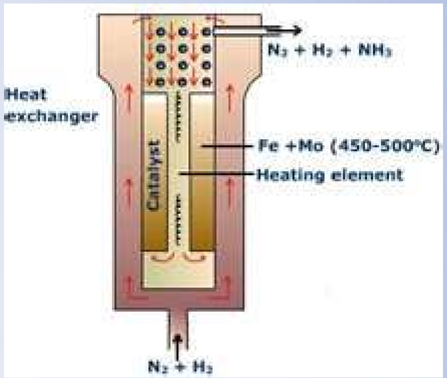
Train incident Belgium spring 2013

Incident in West , Texas, USA

Haber Bosch Processes

Typical look of Ammonia plants

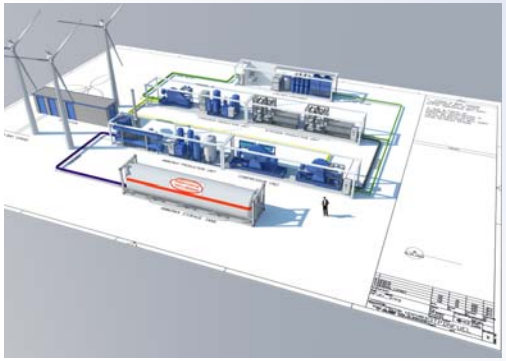
Ammonia reactor



NFUEL vs Industrial Ammonia plant

• 1000 ton per annum	versus 1000.000 ton
• No front-end	versus front-end
• High pressure	versus low pressure
• No refrigeration	versus refrigeration
• pressurised storage	versus refrigerated
• Lower purity ammonia	versus high purity
– (option for high purity for chemiclas versus fuel)	
• Power based	versus natural gas
• Sustainable	versus using natural gas/ CO2 emissions

NFUEL process

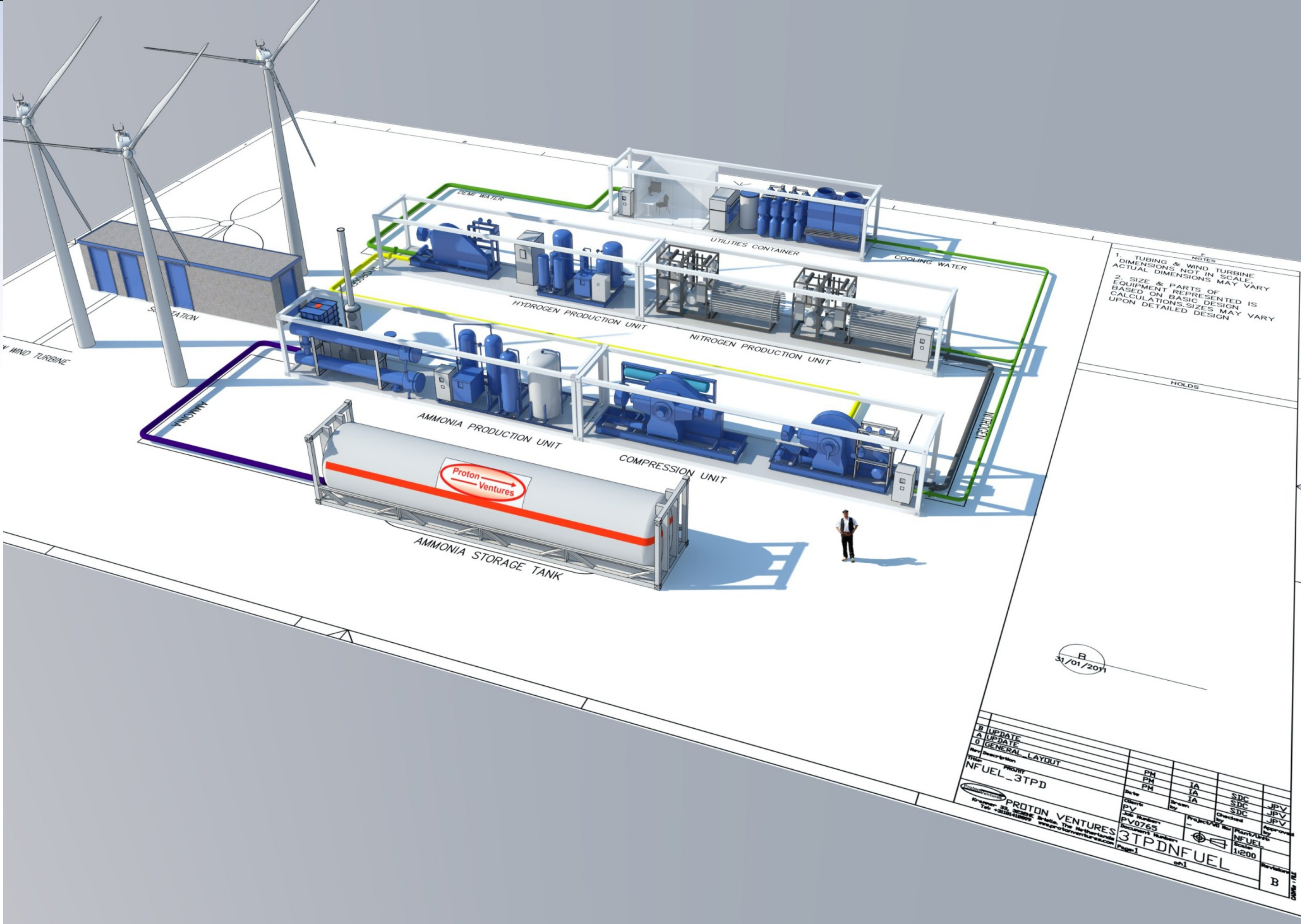


H2 via electrolysis
H2 via reforming flare gas/biogas, waste gas
All decentralised

Fertilisers
Urea replacer

Green Chemicals
Denox

NFUEL applications
Gasturbine
Direct injections engines


UTILITIES CONTAINER
DEMI WATER
COOLING WATER
HYDROGEN PRODUCTION UNIT
NITROGEN PRODUCTION UNIT
AMMONIA PRODUCTION UNIT
COMPRESSION UNIT
AMMONIA STORAGE TANK
AMMONIA
NITROGEN
Proton Ventures
NOTES
1. TUBING & WIND TURBINE DIMENSIONS NOT IN SCALE, ACTUAL DIMENSIONS MAY VARY
2. SIZE & PARTS OF EQUIPMENT REPRESENTED IS BASED ON BASIC DESIGN CALCULATIONS,SIZES MAY VARY UPON DETAILED DESIGN
HOLDS
B
31/01/2011
B UPDATE
A UPDATE
0 GENERAL LAYOUT
NFUEL_3TPD
PROTON VENTURES
PV0765
3TPDNFUEL
1:200

NFUEL vs Industrial Ammonia plant

Small storage 18 ton	versus larger 60000 ton
Fully automated	versus 5 shift 3-5 FTE
Low external safety risk	versus higher risk
Transport (fit for purpose)	versus huge logistics
Low Break-Down risk	versus higher BD risk
Easier permit	versus more difficult
No marketing (own)	versus marketing
Independancy feed stock	versus dependancy
Battery of stranded energy	versus "on purpose" production
Raw materials "free"	versus "gas costs"

QRA NFUEL unit

5 Resultaten

5.1 Plaatsgebonden risico

Op basis van de scenario's in hoofdstuk 4 zijn met behulp van het rekenprogramma SAFETI-NL de risicoberekeningen uitgevoerd. Het berekende plaatsgebonden risico is weergegeven in figuur 5.1.

Figuur 5.1 Plaatsgebonden risicocontouren Proton (10^{-6} rood, 10^{-7} geel en 10^{-8} groen)

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Avoiding large scale issues: make it decentralised produced

- A battery for energy which could absorb energy for almost all sources such as:
  - Waste energy sources (general)
  - Stranded energy (power/ gas)
  - Excess energy from production processes (hydrogen/ syngas/ steam / hot water/ off- gasses
  - Byproduct energy (hydrogen / CO / steam)
  - Bio-energy (CH4/CO/CO2/ power)
  - OTEC (power)
  - Geothermal (power)

Ammonia characteristics for storage?

K.I.S.S

NH**3**: = "the other Hydrogen (H2),
containing 50% more hydrogen

Abundantly available raw materials

N –	**Nitrogen from air**	**78% of earths atmosphere**
H –	**Hydrogen from water**	**most abundant element in the universe**
Power:	**from any sustainable source**	

NH3 – potential for "the best choice for a practical, sustainable alternative BATTERY"

Alternative Energy storage in Rotterdam

A case study

- Initiative Proton Ventures BV plus partners
- Large industrial partners involved :
  - Power production company EON
  - Port of Rotterdam
  - Grid operator (national level) Tennet
  - Local power distribution company ENECO
  - Technical university Delft

Next Generation Port Infra, powered by Maasvlakte 2

Projectpresentatie en Workshop

Flexibel afvangen van windenergiepieken in de Rotterdamse haven

"Electricity meets Chemistry"

Contactpersonen

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Maasvlakte 2

Next Generation Port Infra, powered by Maasvlakte 2

Next Generation Port Infra,

Powered by Maasvlakte 2

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Projects

1. Simulation of Cluster Development of Maasvlakte 2
2. Flexibility in Port Development and Management
3. Development and Greening of a Syngas Infrastructure
4. 3D Spatial Data
5. DUBROVNIK
6. Asset Life Cycle Management
7. Masterplan +
8. Apps Development in Port of Rotterdam
9. Industrial Capture of Surplus Wind Energy
10. BENEGRIDS
11. Flexibility Counterproject

Verbinding met havenindustrieelcluster

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Sustainability

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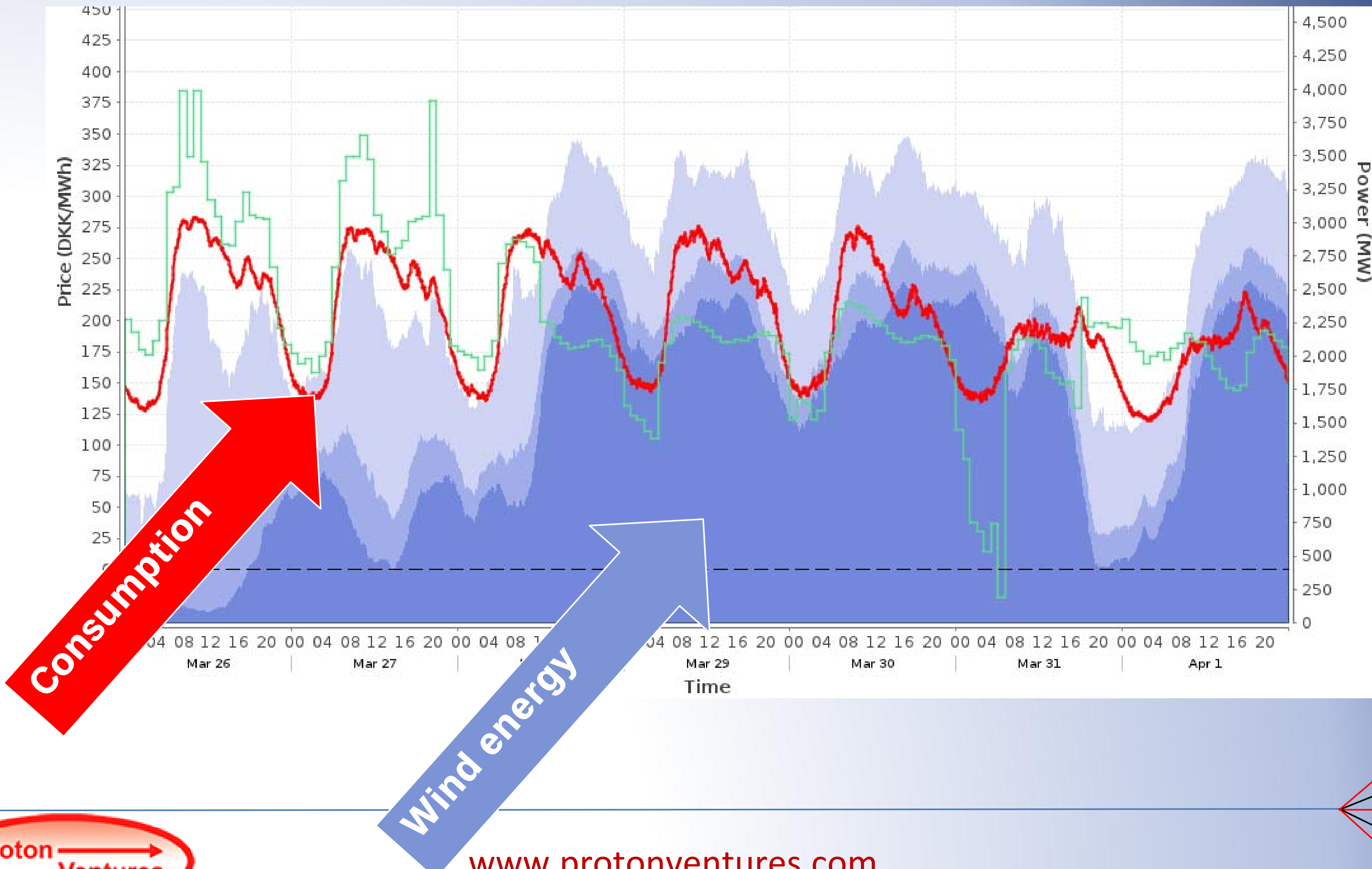
Flexible Catching of Wind Peaks in a port-industrial cluster

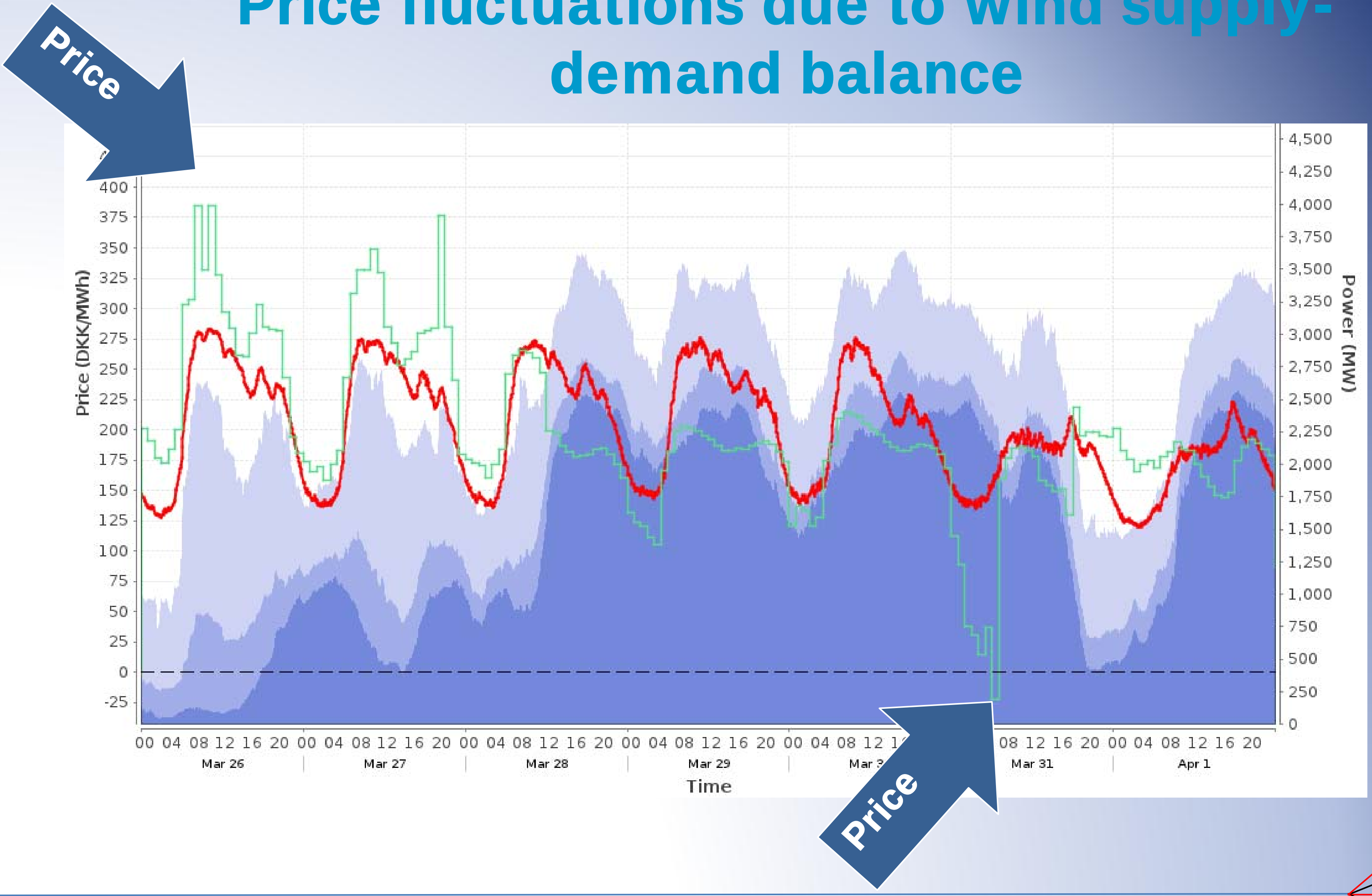
Projectteam

E-on Benelux N.V. :	Sander Fijn van Draat, Daniel Lauwen, Menno Ros
TenneT TSO B.V.:	Hans van Hooijdonk
Proton Ventures B.V:	Hans Vrijenhoef, Anish Patil
Stedin:	Guy Konings
Port of Rotterdam N.V.:	Nicole van Klaveren-Pleumeekers, Wilco Van der Lans
Technical University Delft:	Kas Hemmes, Rob Stikkelman

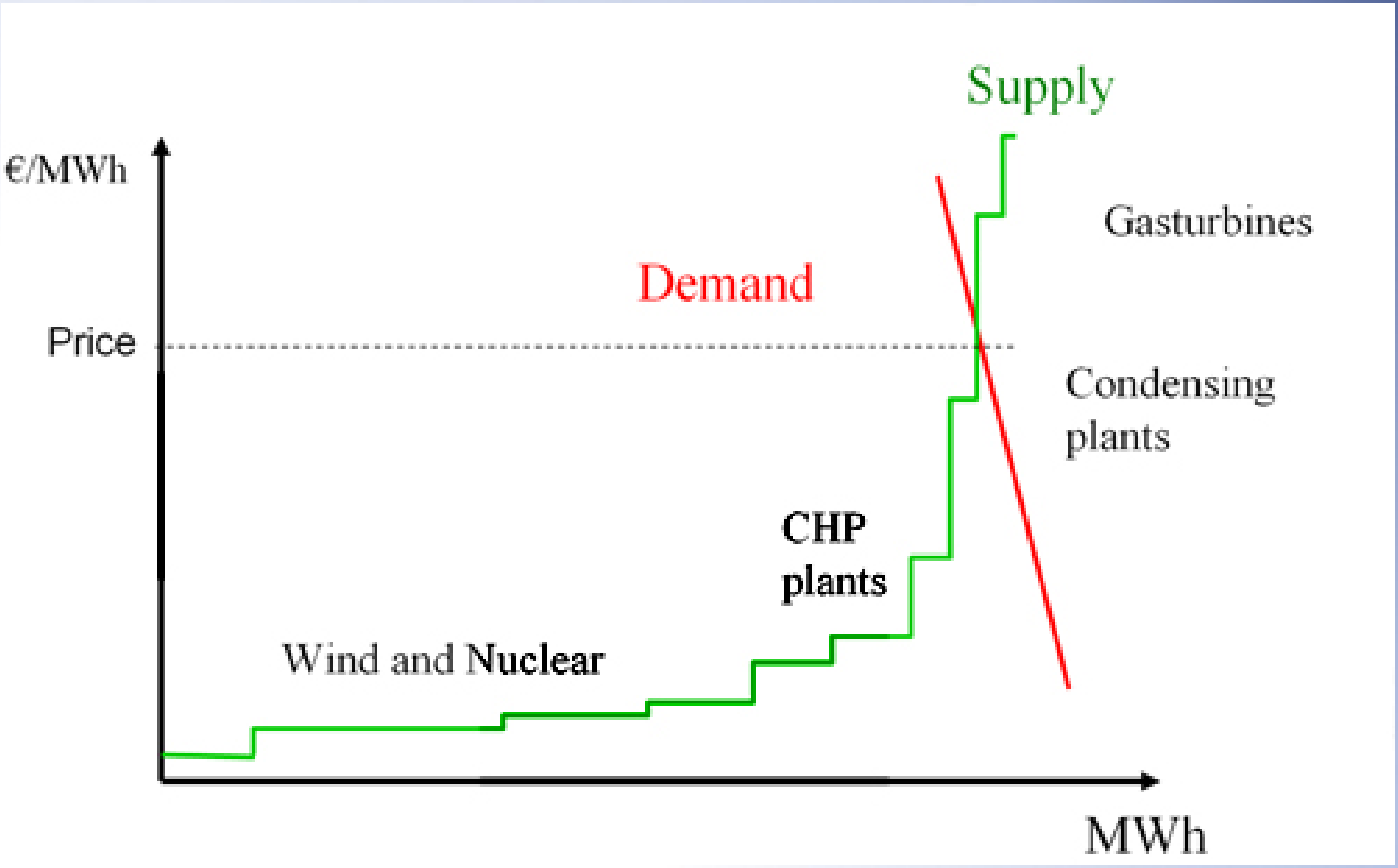
West Denmark, 2012
Monday March 26th till Sunday April 4th



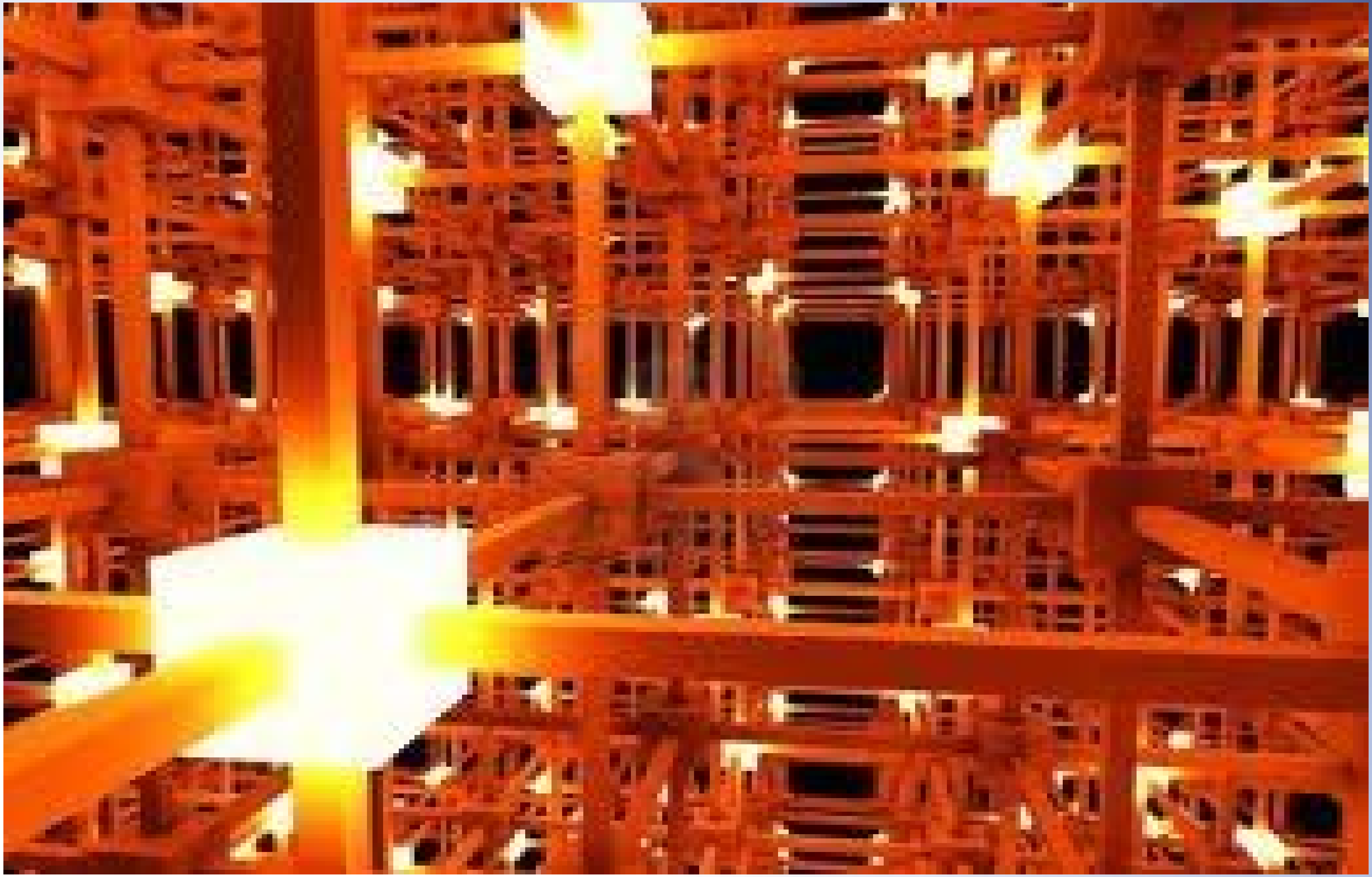
Cause of the R&D (1)
Price fluctuations due to wind supply-demand balance



Cause (2): Costs for imbalances (penalties)

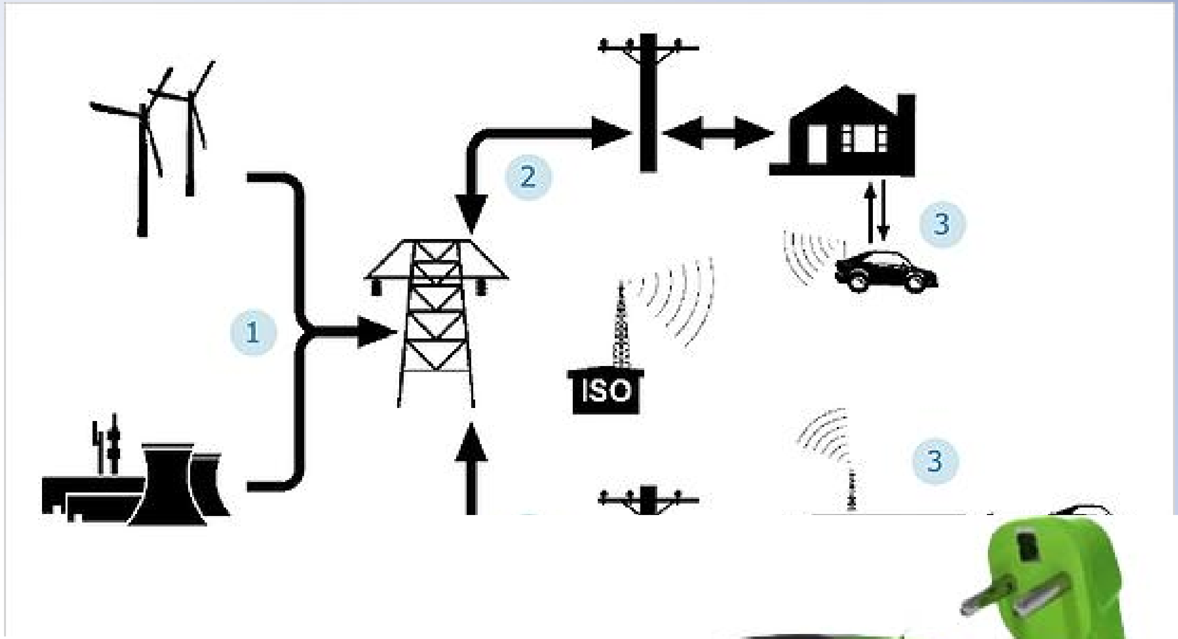


Cause (3): congestion on the net
Curtailment versus investment costs



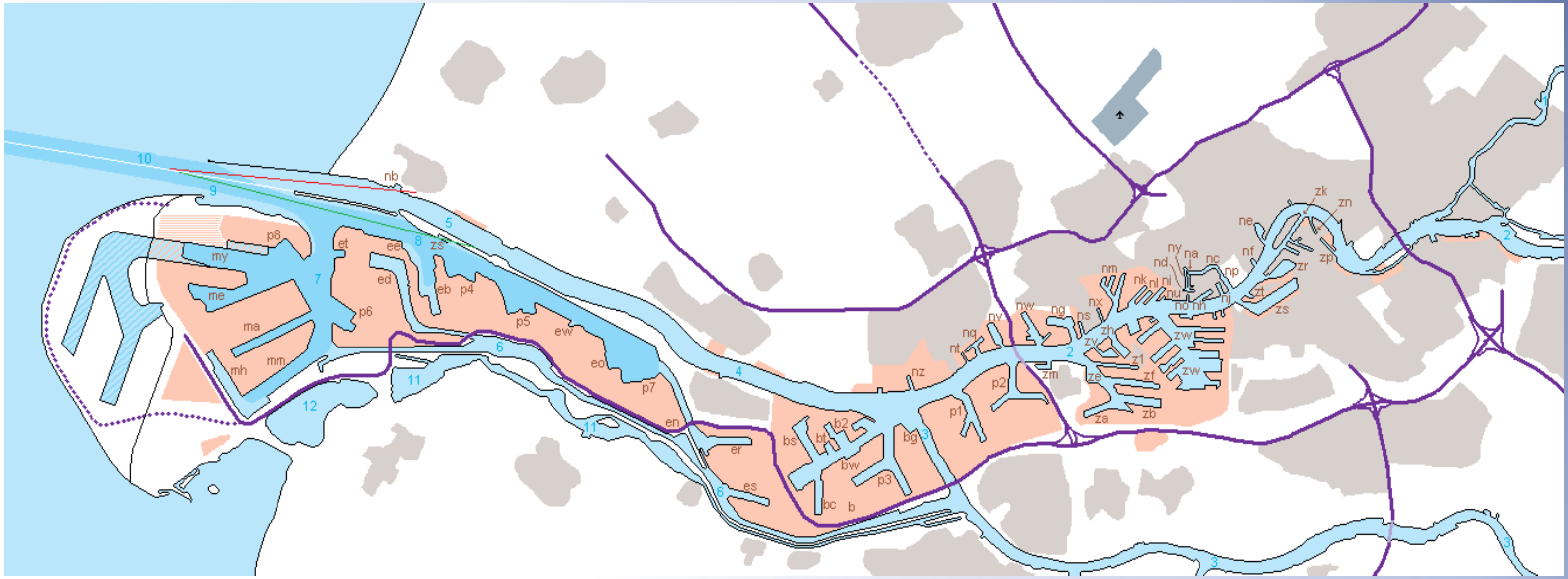
Variation in sustainable power supply

Today's concept:
Smart grids and electrical cars



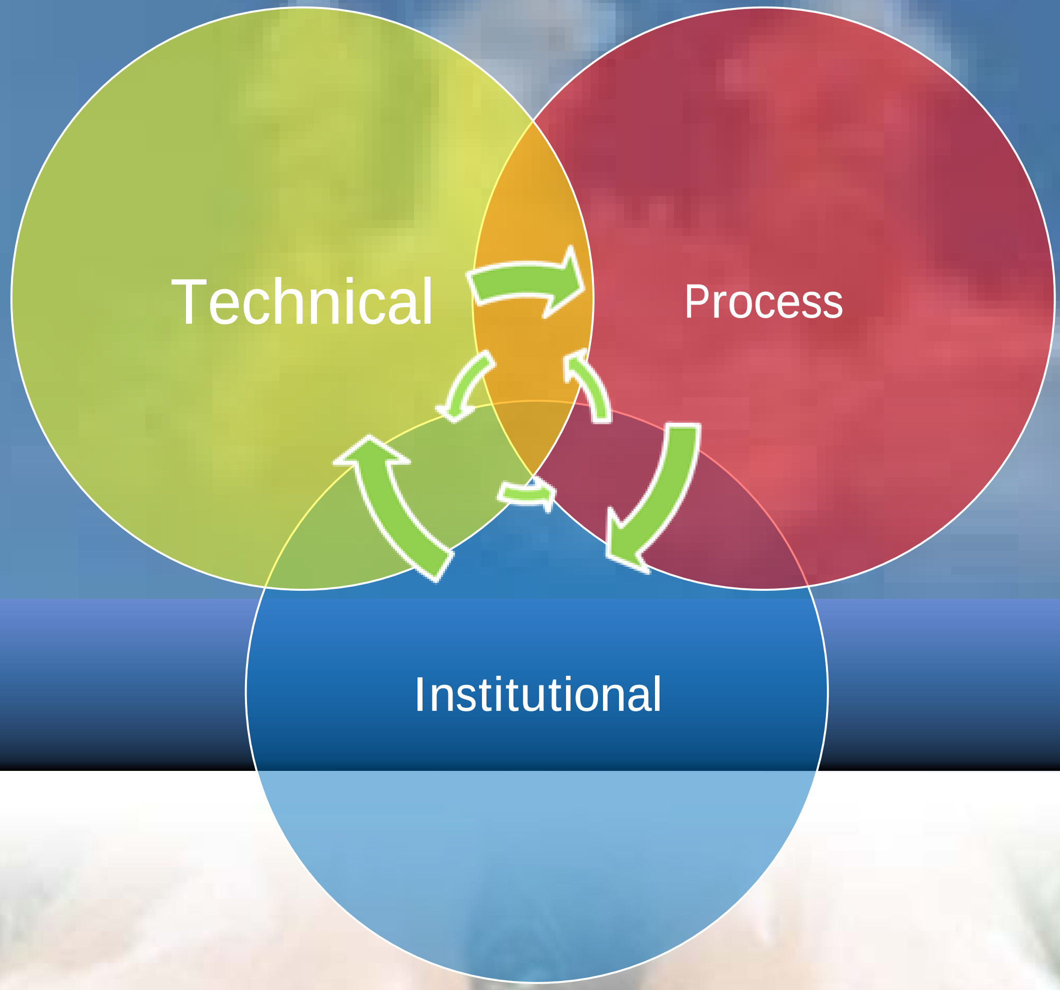
Our concept:

Is the Rotterdamse Industrie cluster able to catch power on MW scale as electrical cars may do on kW levels?



R&D question:

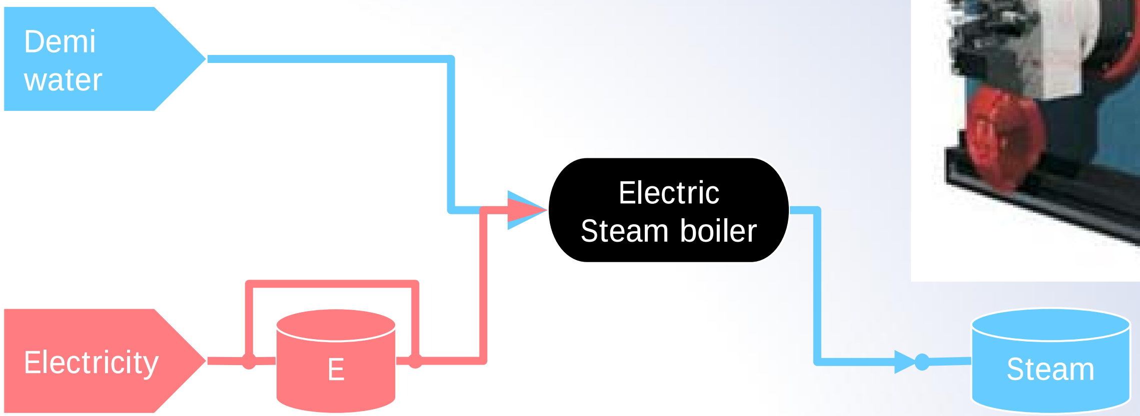
"In which way could we define a qualified technical and institutional design which will convert variable excess energy (based on windor solar) into relevant chemical raw materials or products in an integrated Port-Industrial Cluster?"


Technical
Process
Institutional

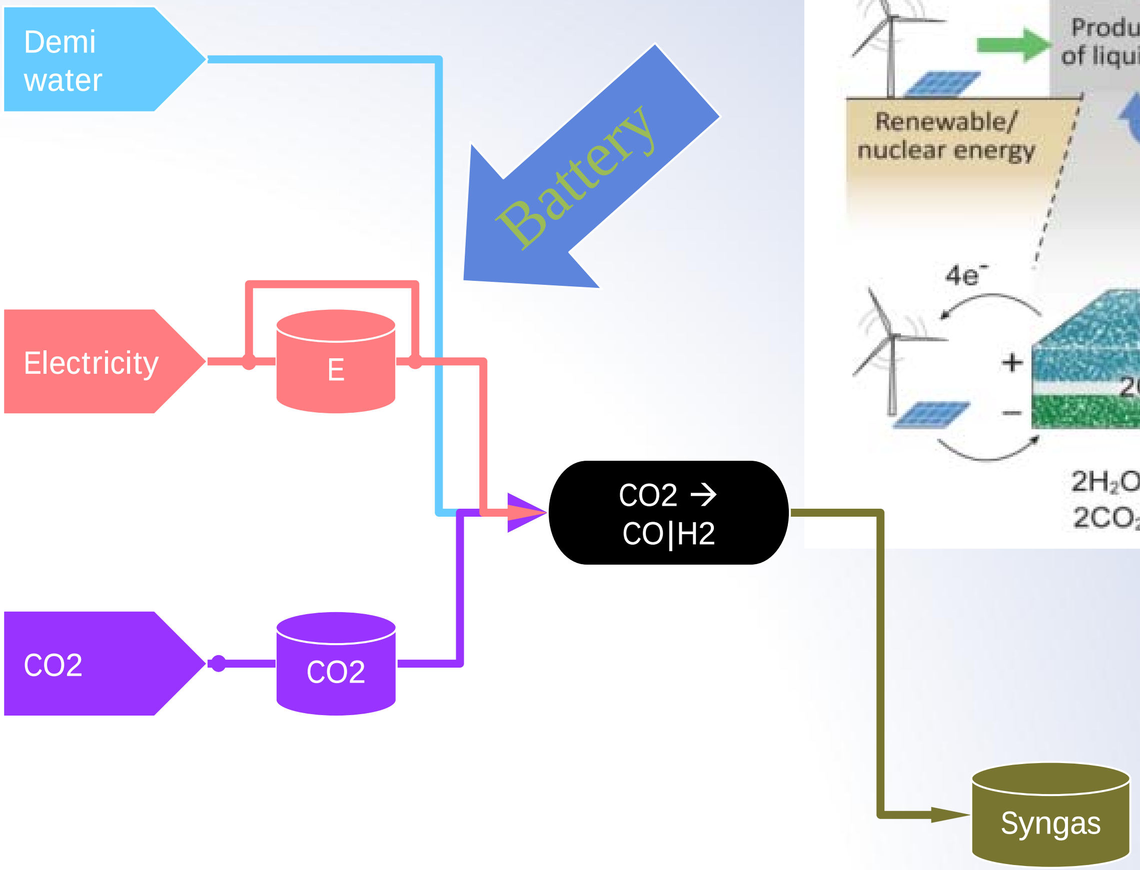
Technologies

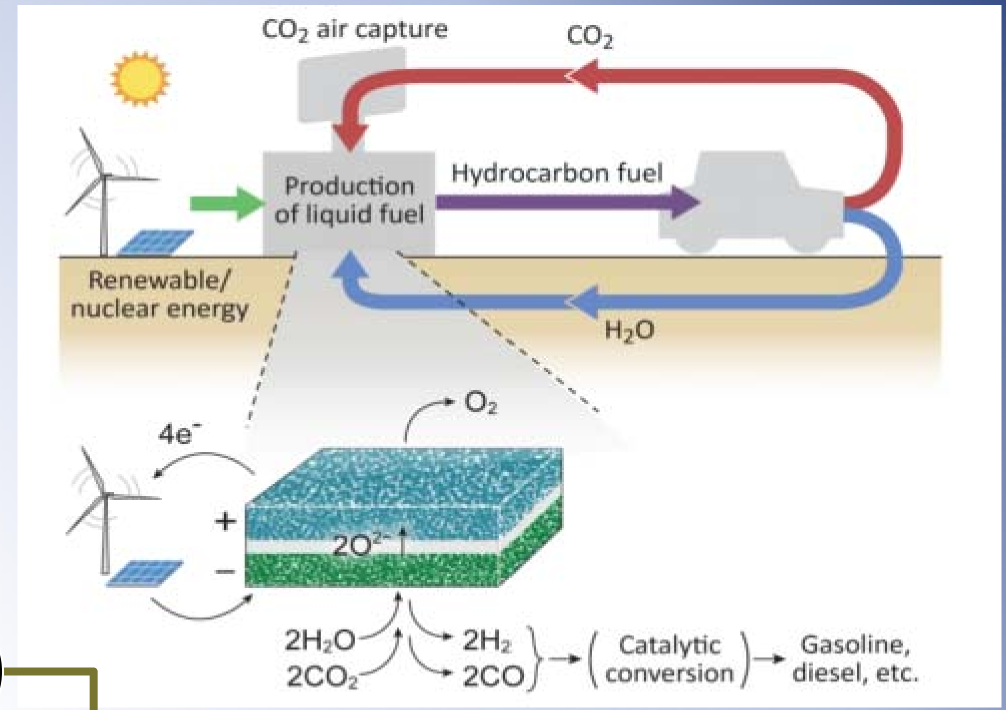
- Inventarisation & Fact sheets
- Design space
- Concept's of combinations of existing and new technoligies
- Integration in a concept case

Examples of existing technologies



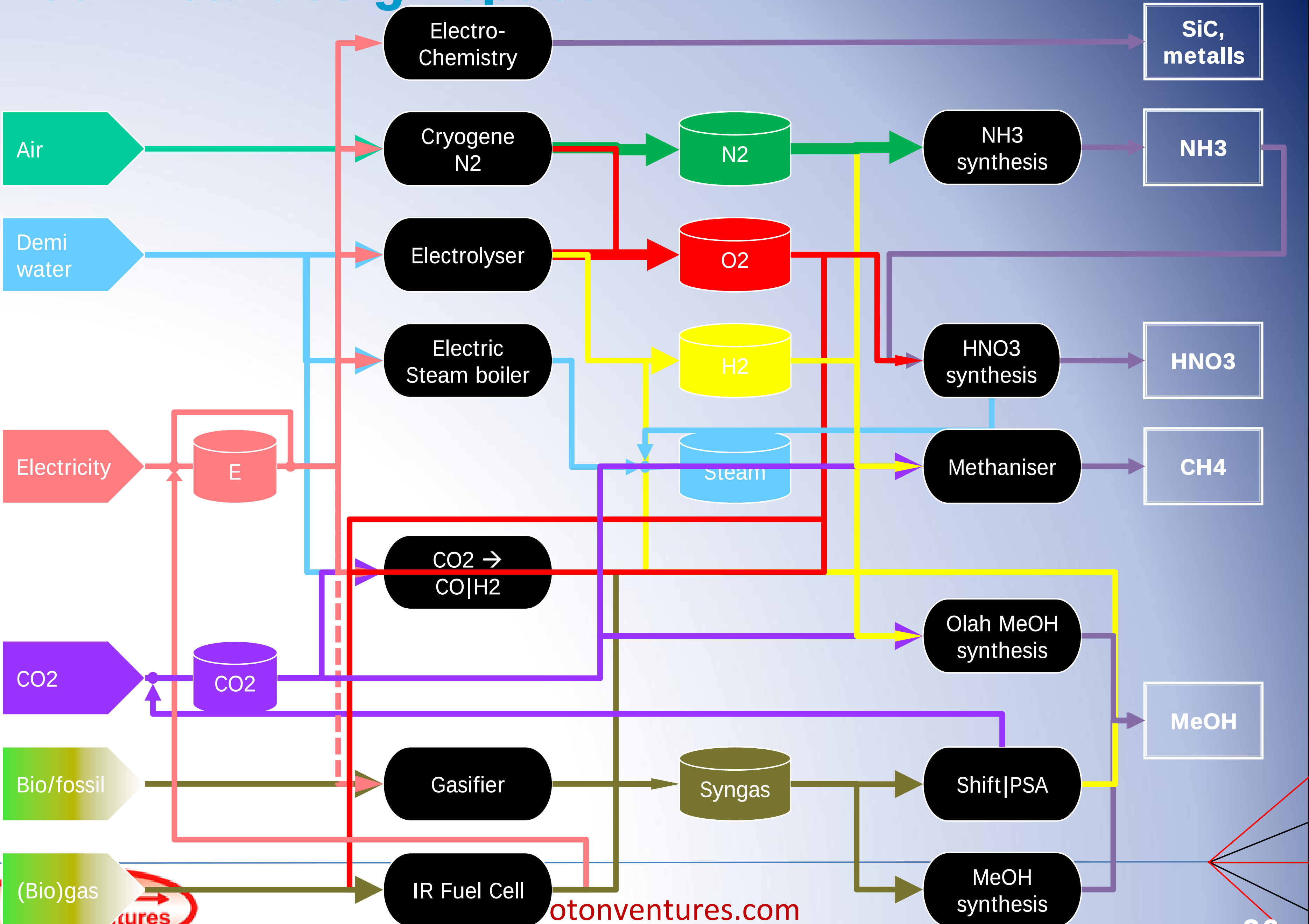
Example of a technology in development





Defining the design space

Technical design space



There is more than technology

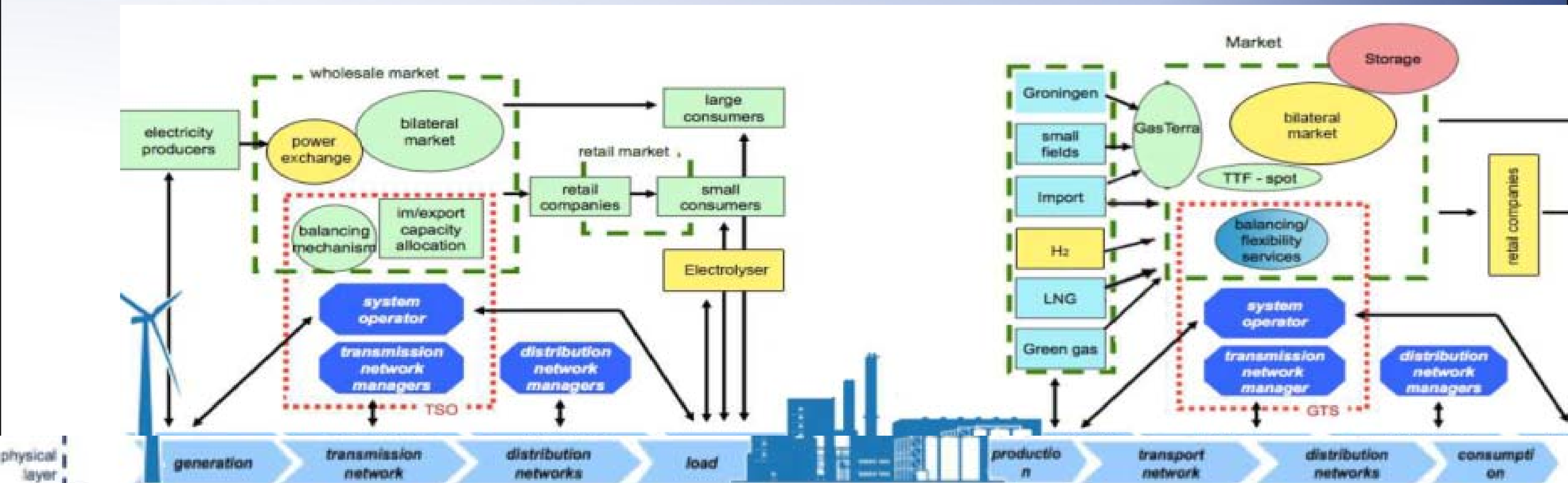
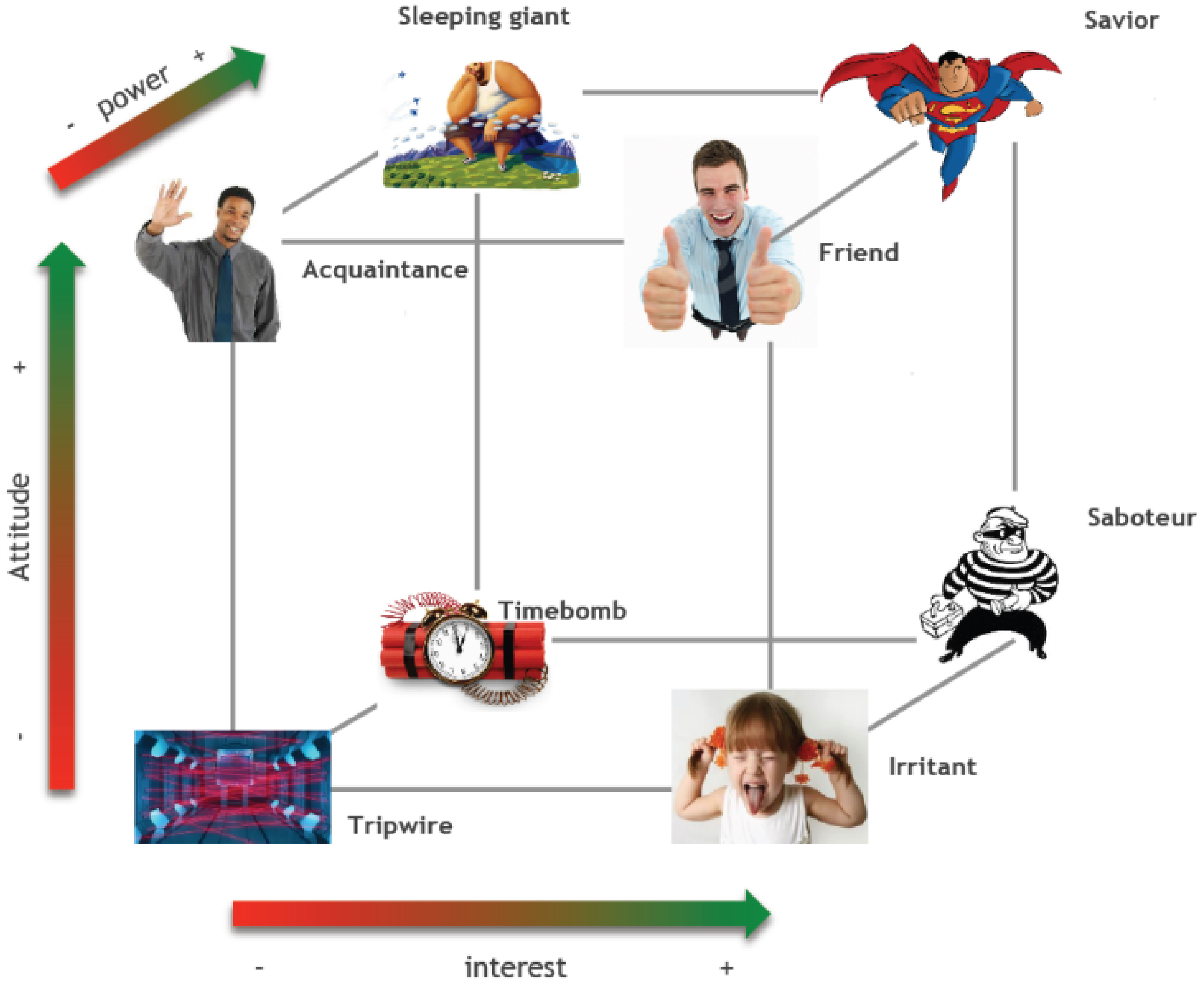


Figure 11: Institutional fit of potential hydrogen production and injecti

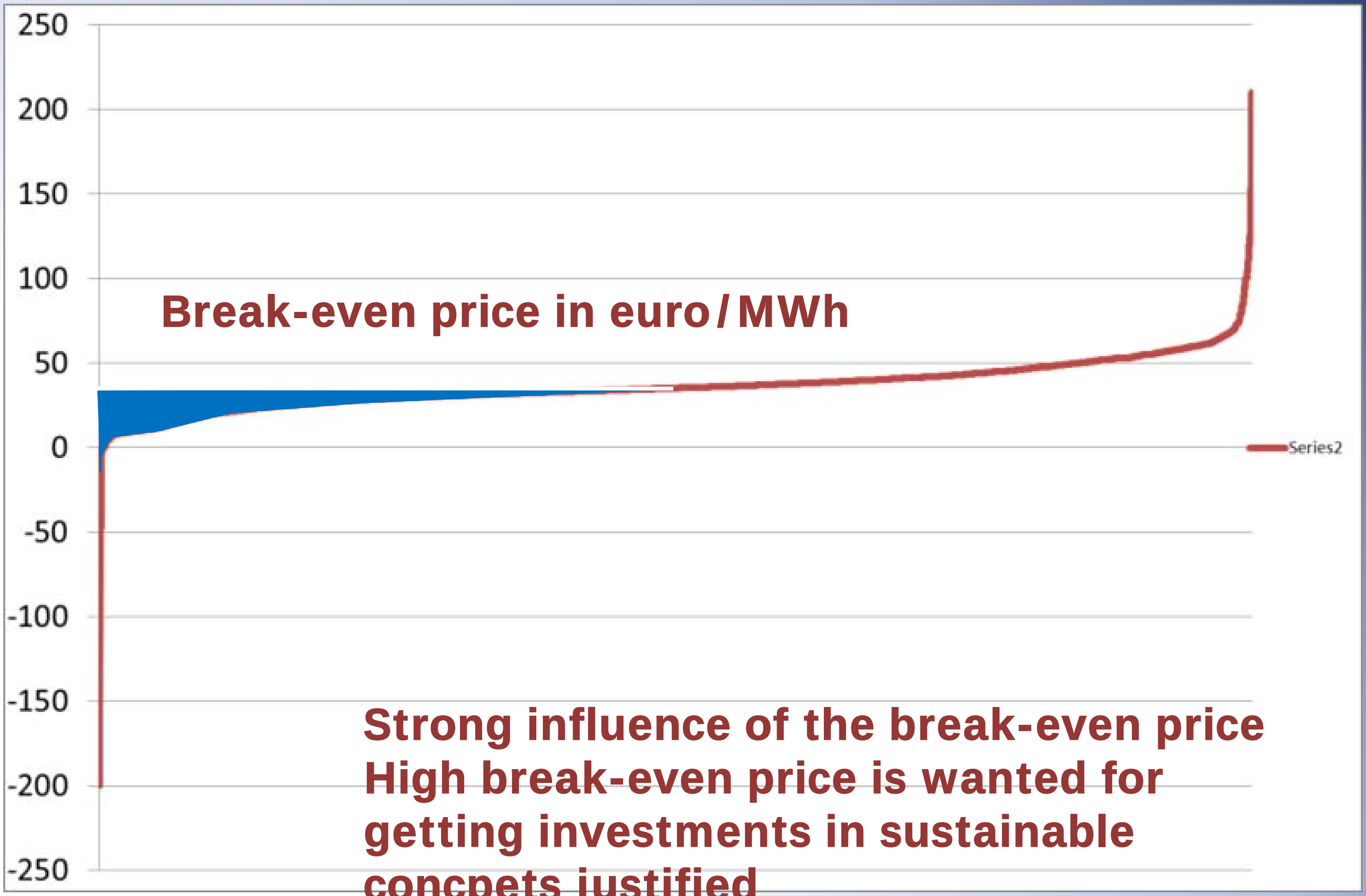
Institutional

- Inventarisation actors, Fact sheets
- Concepts of existing and future combinations of actors/institutions
- Integration in concept design

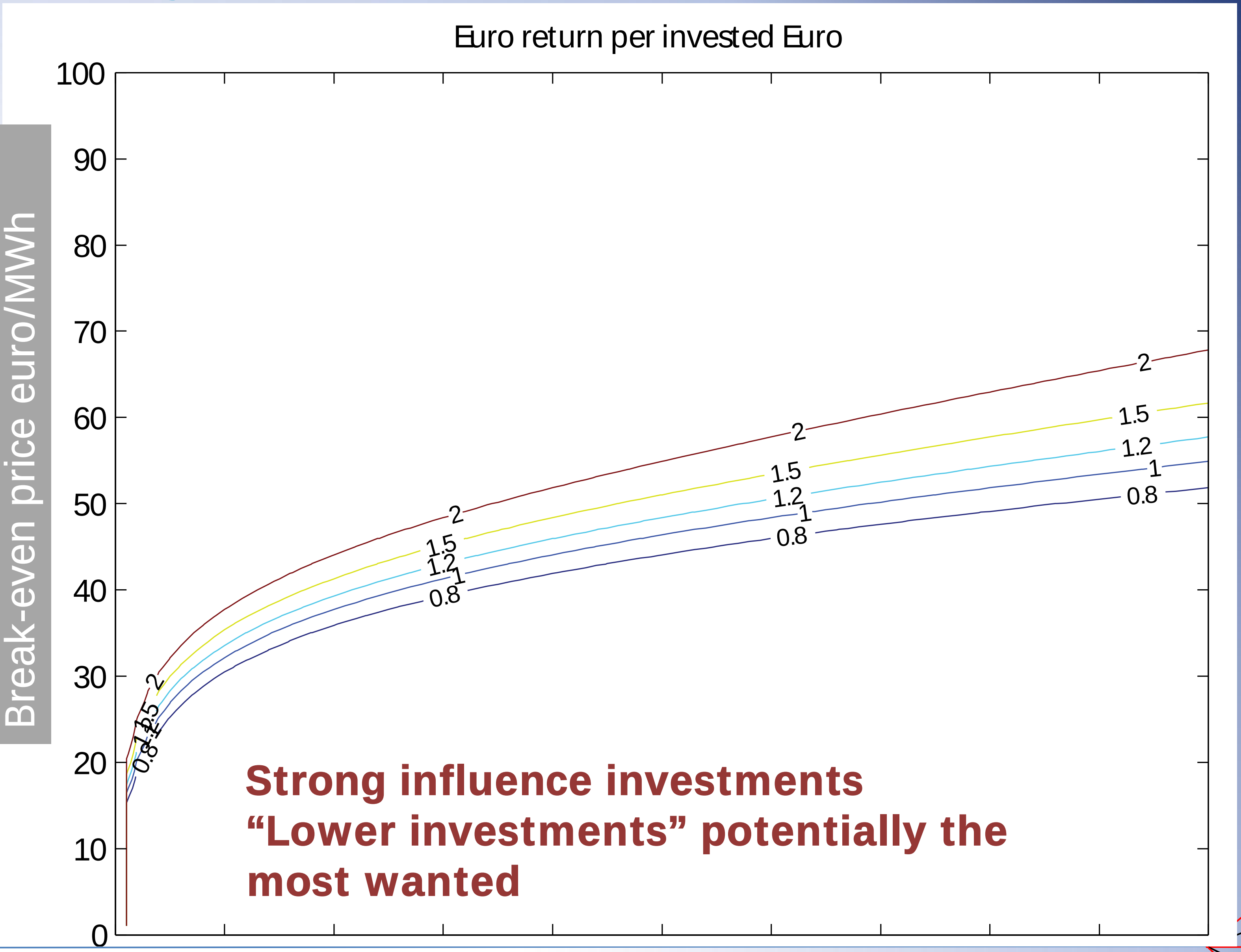
Institutional: Actors



Money: Price-Duration Curve Break-even Price



Money:



Break-even price euro/MWh

Investments per MW

Conclusions

- **An increase in variations for power price is expected due to more wind , solar and other stranded energy sources added to the grid in NL and Germany**

- **Almost impossible to predict the price fluctuations in future**

- **Technically, there are multiple ways to make use of the wind peaks. Parties, like grid owner, conventional producer, sustainable producer and consumer of power / chemicals have to find each other.**

- **The return depends on a higher break-even price than usually accepted and at low investments of accepted technologies.**

- **The economic forecasts look favorable for the Rotterdam Cluster since many technologies can be add-on to the existing infrastructure , resulting in lower than expected and a lower break-even price for power peaks.**

- **Ammonia as storage is considered one of these add-ons, since ammonia is used in multiple sites in Rotterdam**

And now….

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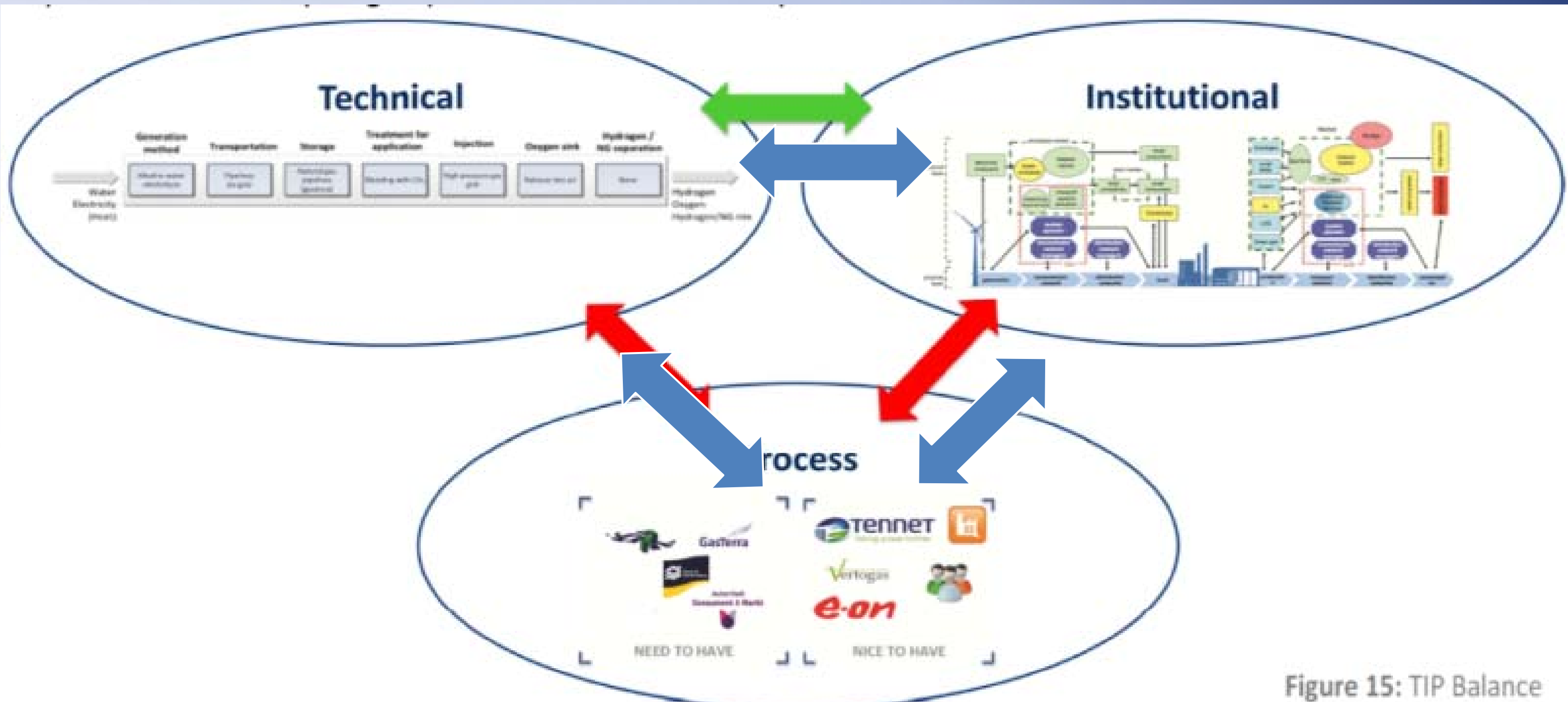

Figure 15: TIP Balance

First Price Erasmus University Rotterdam

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My conclusions

- In Netherlands first signs of considering ammonia storage for specific BATTERY applications
- Long way to go for general purpose
- Exploration, logistics and production of decentralised ammonia production is more safe or at least equal to other fuels.
- Set-up of electrolysers/ammonia /HNO3 infrastructure in development in Rotterdam
- Storage of waste energy to ammonia progressing:
  - 1000 t/a units (stranded small scale/ no transport)
  - 8000 t/a units (byproduct2ammonia) for chemical clusters
- Initiatives with "profitable" business cases
  - ROCE more like 8-10% than typical 15%
  - Long term investments (10-15 years) depreciation

Proton Ventures

Proton Ventures innovation centre in Schiedam/Rotterdam (Netherlands)

www.protonventures.com

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Any Questions left?

See also www.protonventures.com

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