Design of a Dutch carbon-free energy system NL2050

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Introduction

- NL2050 – a carbon-free energy system design for 2050
- Highlights
- Simulations
- Financials
- Work in Progress
- Discussion
    - Is this concept sufficiently future proof to guide strategic decisions for the next decades?

The future Dutch full carbon-free energy system

2018

Design of a Dutch carbon-free energy system

EnergyNL2050

A detailed follow-up study

with system simulations and

a financial analysis

May 2020

2020

Highlights of the 2050 NL energy system

Misconceptions, Commonalities and Variations

Misconceptions about renewable energy systems
Curtailment is wrong
Back-up gas turbines are essential for a reliable energy system
A low capacity factor for a power plant is bad for economics
Electric vehicle charging breaks the network
Solar energy implies network upgrades

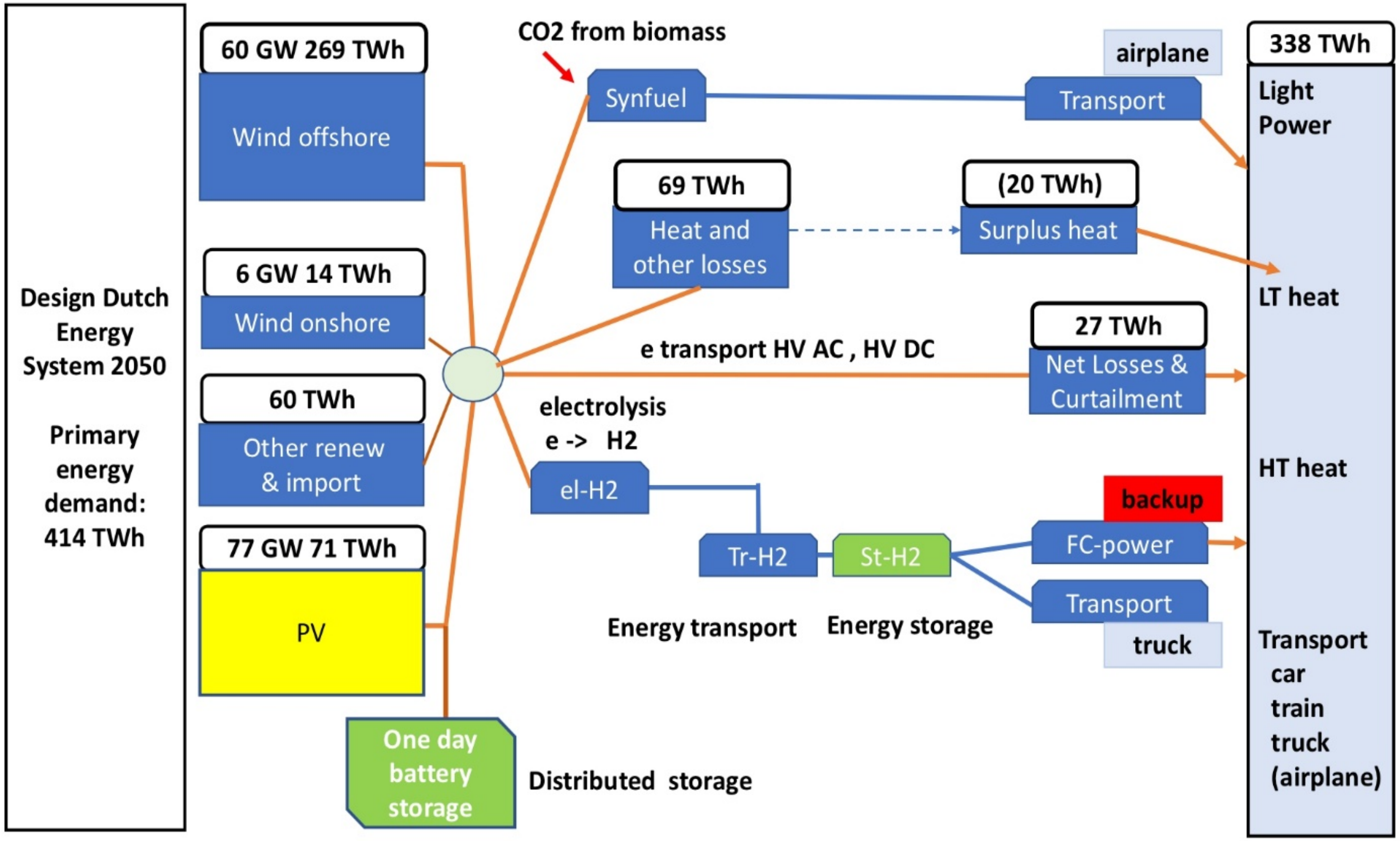
- Comprehensive analysis of the 2050 NL energy requirements
    - substantial energy savings, process innovation (steel) and electrification of transport and heating
- Full review of wind (offshore and onshore) and solar potential
- Cost evolution assessment of wind turbines, photovoltaic panels, battery systems, electrolysers, fuel cells etc.
- Focus on safeguarding energy supply with minimal seasonal (hydrogen) and short-term (battery) storage
    - production ratio wind to solar of 4:1
    - dynamic smart charging of battery electric vehicles
    - curtailment as design option
    - low-cost fuel cells (passenger cars) as (distributed) backup generators to minimize costly electrical network upgrades
    - Majority of buildings heated with all-electric heat pumps
- Simulation with hourly resolution based on scaled historical data (2016-2018) for consumption and generation as well as weather data to model heat pump consumption [1]
    - Light computational load allows for comprehensive exploration of the parameter space as well as evaluating forward looking (weather based) control strategies
- Financial optimization
    - Key assumption: in 2050 hydrogen will be an internationally traded commodity with high liquidity like oil today

[1] Suggested by ex-colleague Fons Bruls

Commonalities
Solar and wind replacing fossil fuels
Electrification
Hydrogen

Variations
Go slow with onshore wind
Solar on the roof - in the built environment
No back-up gas turbines in 2050
Large-scale network upgrades avoidable
Biomass reserved for plastics
Curtailment as design tool

Simplified block diagram

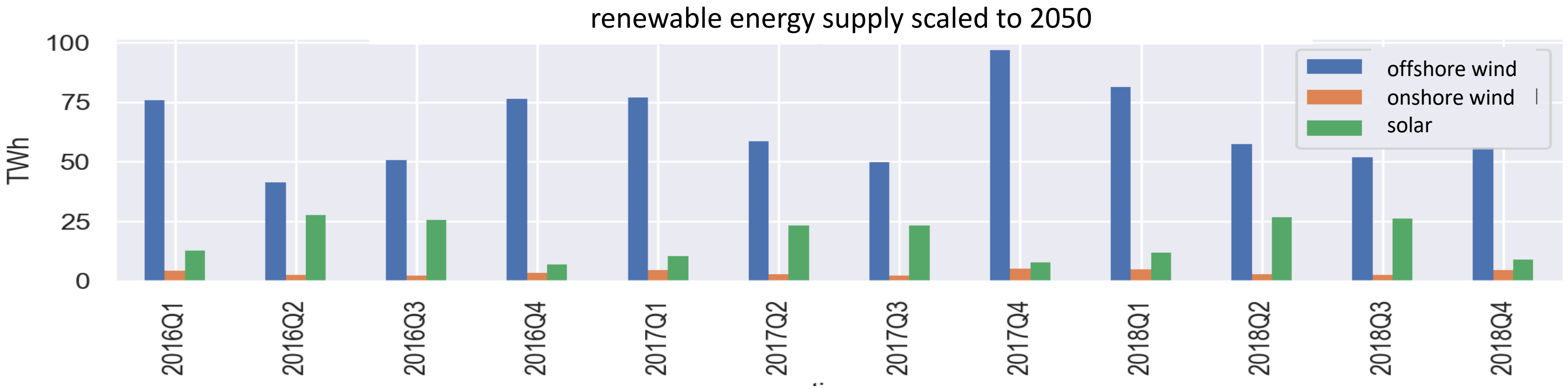


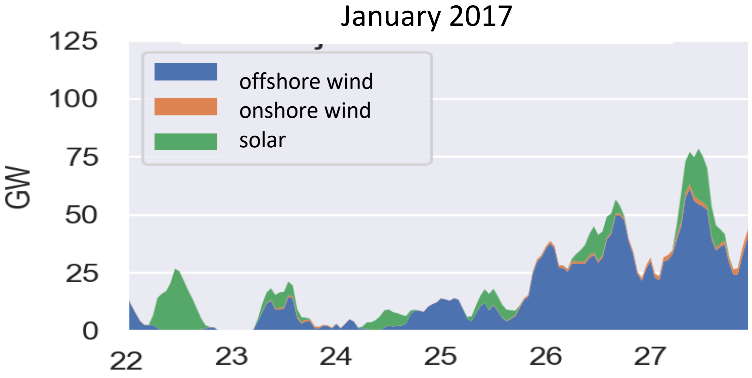
Energy supply 2050

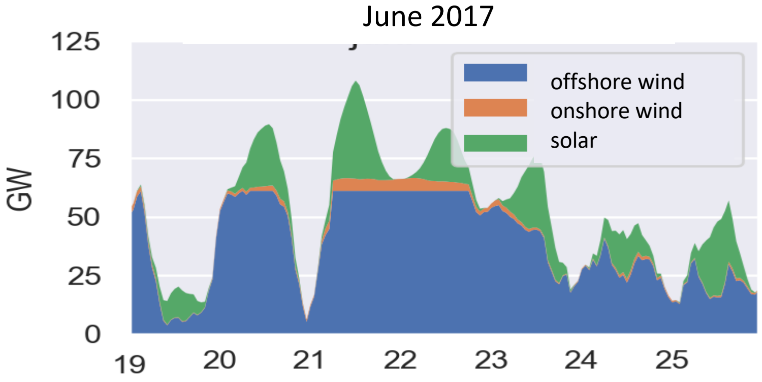
Scaling hourly historical data 2016-2018 (TenneT)

Processing

- Linear scaling onshore wind/ offshore wind /solar to 269/14/71 TWh annually
- Compensate for growth installed base during 2016-2018
- Compensate for expected capacity factor increase of offshore wind to 50% in 2050
- Compensate for solar capacity factor increase thanks to East-West orientation of PV panels


renewable energy supply scaled to 2050


January 2017


June 2017

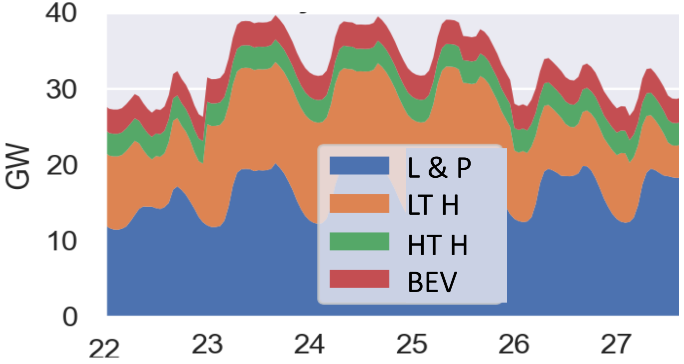
Energy consumption 2050

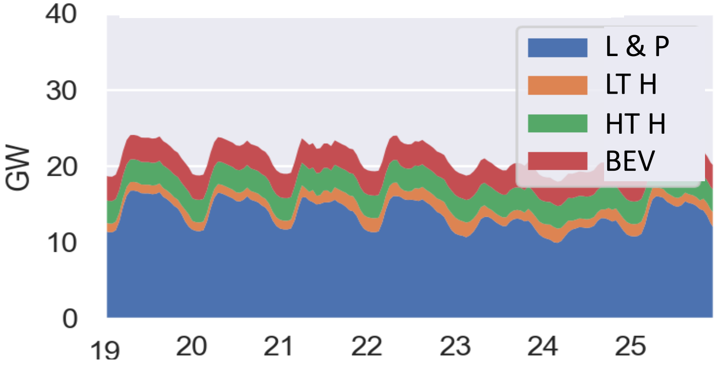
Scaling hourly historical data 2016-2018 (TenneT & KNMI)

Processing

- Linear scaling Lighting & Power to 127 TWh annually onshore wind/ offshore wind /solar to 269/14/71 TWh
- Add electrical consumption for Low-temperature Heating derived from historical ambient temperature
- Stress condition: artificially lower ambient temperature to -10C constant for 72 hours
- Add electrical consumption for High-temperature Heating (industrial)
- Add electrical consumption for BEV charging

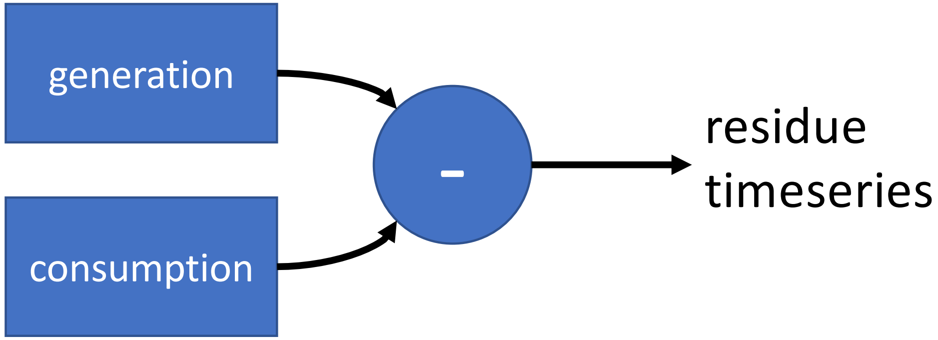

energy consumption scaled to 2050


January 2017


June 2017

Power Duration Curve residue generation minus consumption

necessity of energy storage

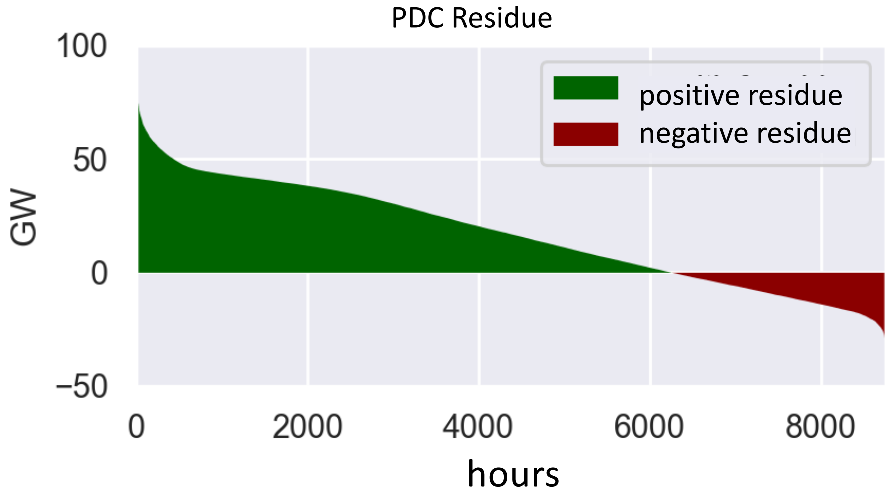


generation

consumption

-

residue timeseries



Annual positive residue 193 TWh:

- 6100 hours
- peak residual power 90 GW
- converted to hydrogen

Annual negative residue 21 TWh

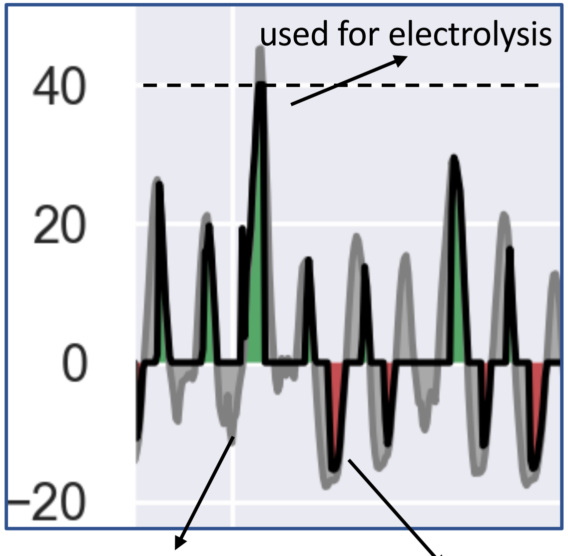
- 2600 hours
- peak residual load 33 GW

Addressing the unbalance:

- smart charging BEV’s etc. time-shift consumption
- batteries time-shift generation
- fuel-cells generate back-up electricity

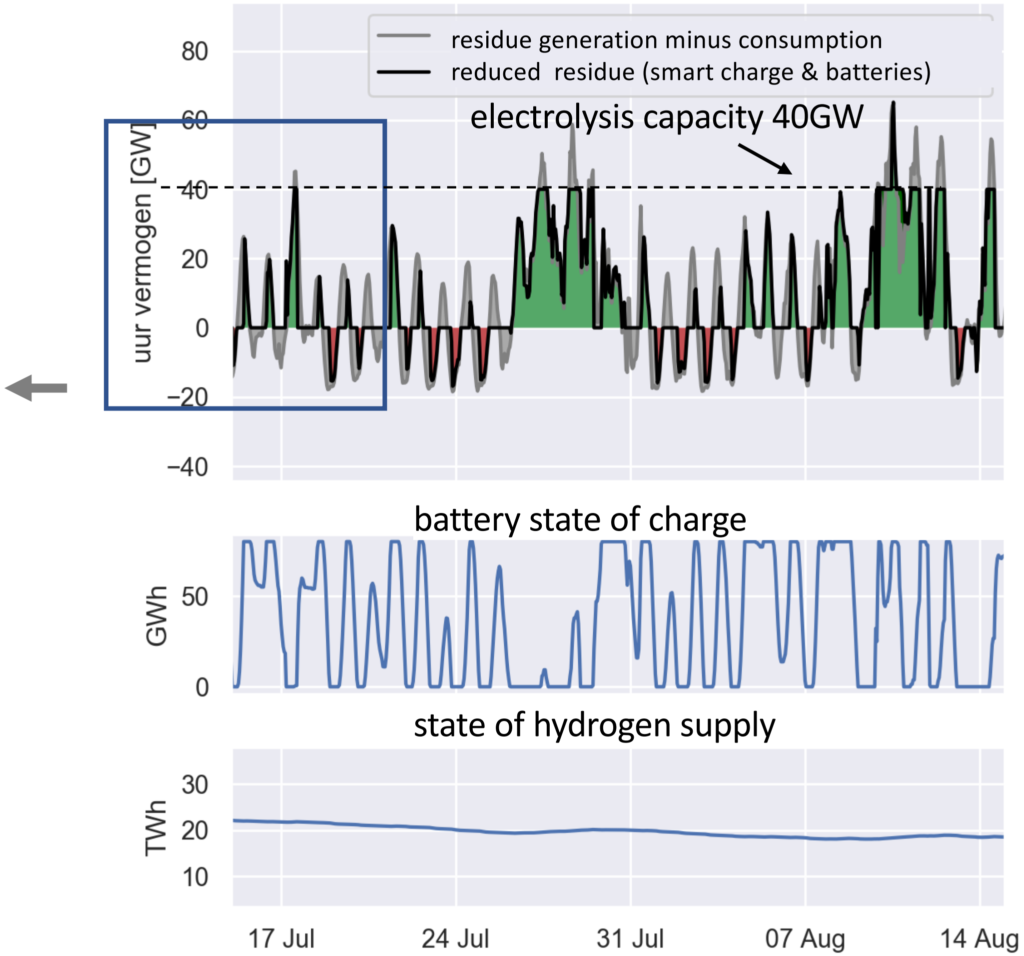
Control strategy & simulation results

Tool	**round-trip efficiency**
Smart charging	100%
Battery charge / discharge	95%
Electrolysis – hydrogen storage – fuel cell	37%



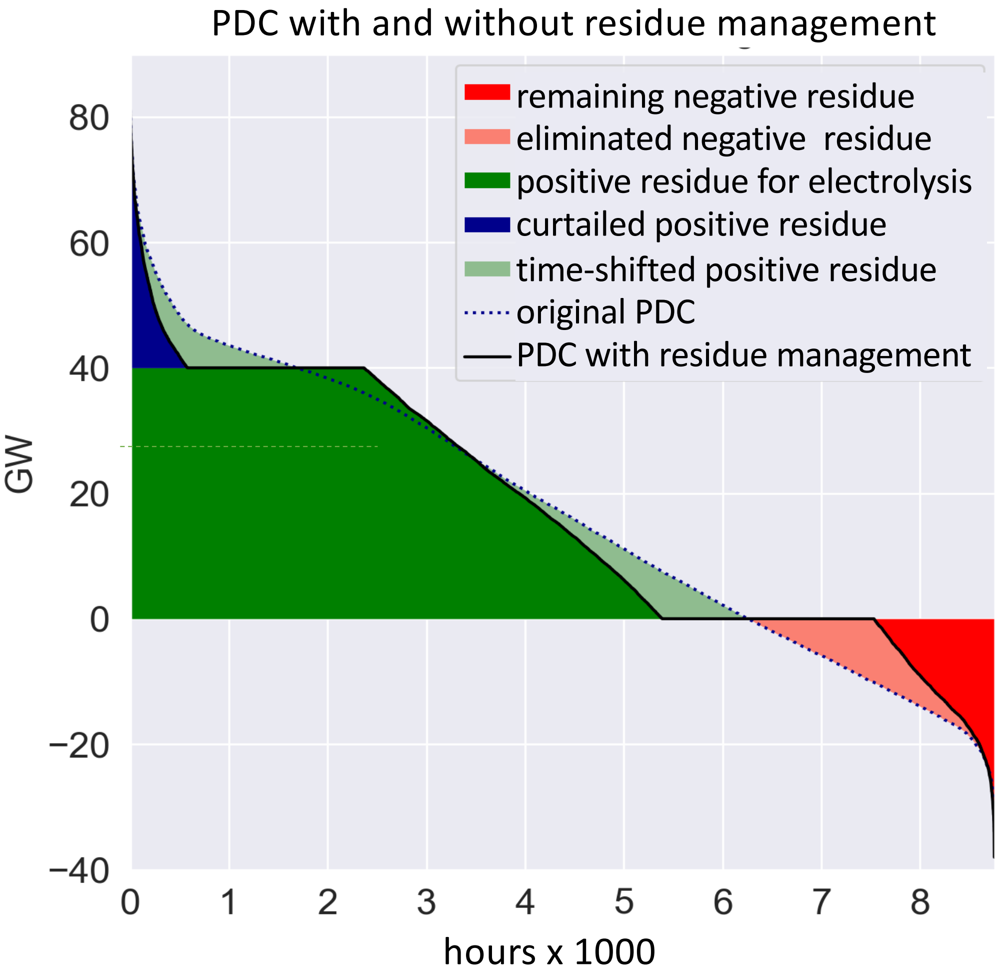
time-shifted away

fuel-cell generation



state of hydrogen supply over three-year period

Effectiveness residue management



- Capacity: electrolysis 40 GW, batteries 80 GWh, fuel cells 40GW
- Energy supply secured under all conditions
- Remaining curtailment 6.3 TWh, less than 2%
- Negative residue significantly reduced
- Fuel-cell capacity factor low (ca. 1000 hours)
  - benefits overall system efficiency
  - allows re-use of low-cost automotive technology.

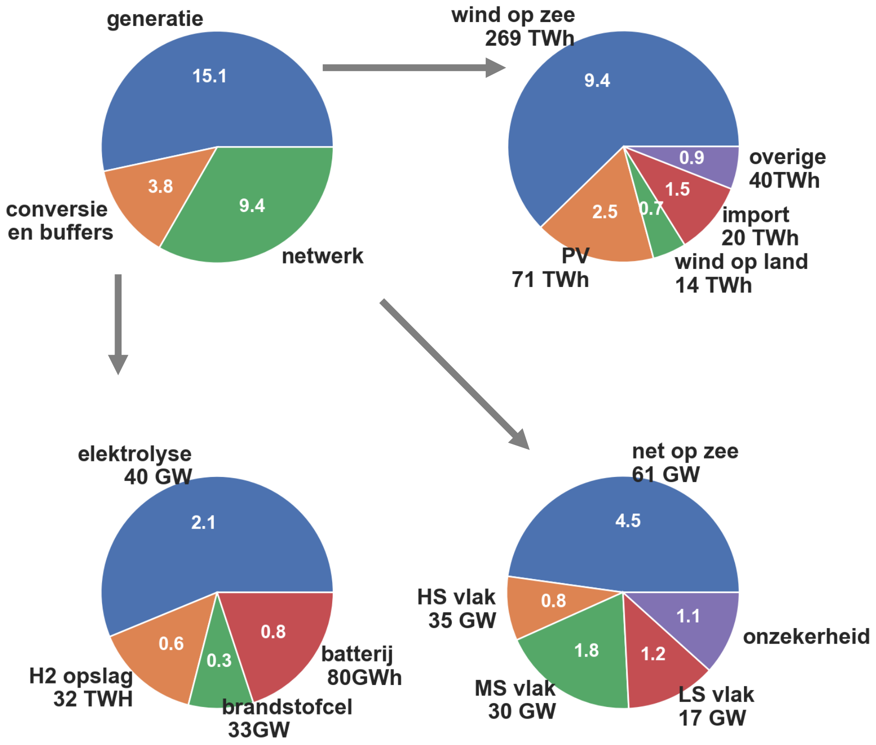
Note: US DOE target $30/kW (stack only)

16 September 2020 - Hyundai Motor Company today began shipping its proprietary fuel cell system to Europe for use by non-automotive companies including a Swiss hydrogen solution firm, GRZ Technologies Ltd.

source Hyundai

Financial optimization

Annual cost in billion (miljard) €



National annual cost (no taxes & subsidies)

- full system cost 28.2 billion €
- +36% increase
- € 41 increase per saved ton CO_2
- WACC 4.5 %
- centralized fuel cells and batteries leads to high increase in network cost
- electrification cost (LT/HT heat) not included

reference (hypothetical) annual cost:

- no NL wind and solar, import all energy as hydrogen and generate electricity as needed
- full system cost 34,2 billion €
- hydrogen landed cost € 2,25/ kg

Work in Progress

Issues still needing (more & better) answers

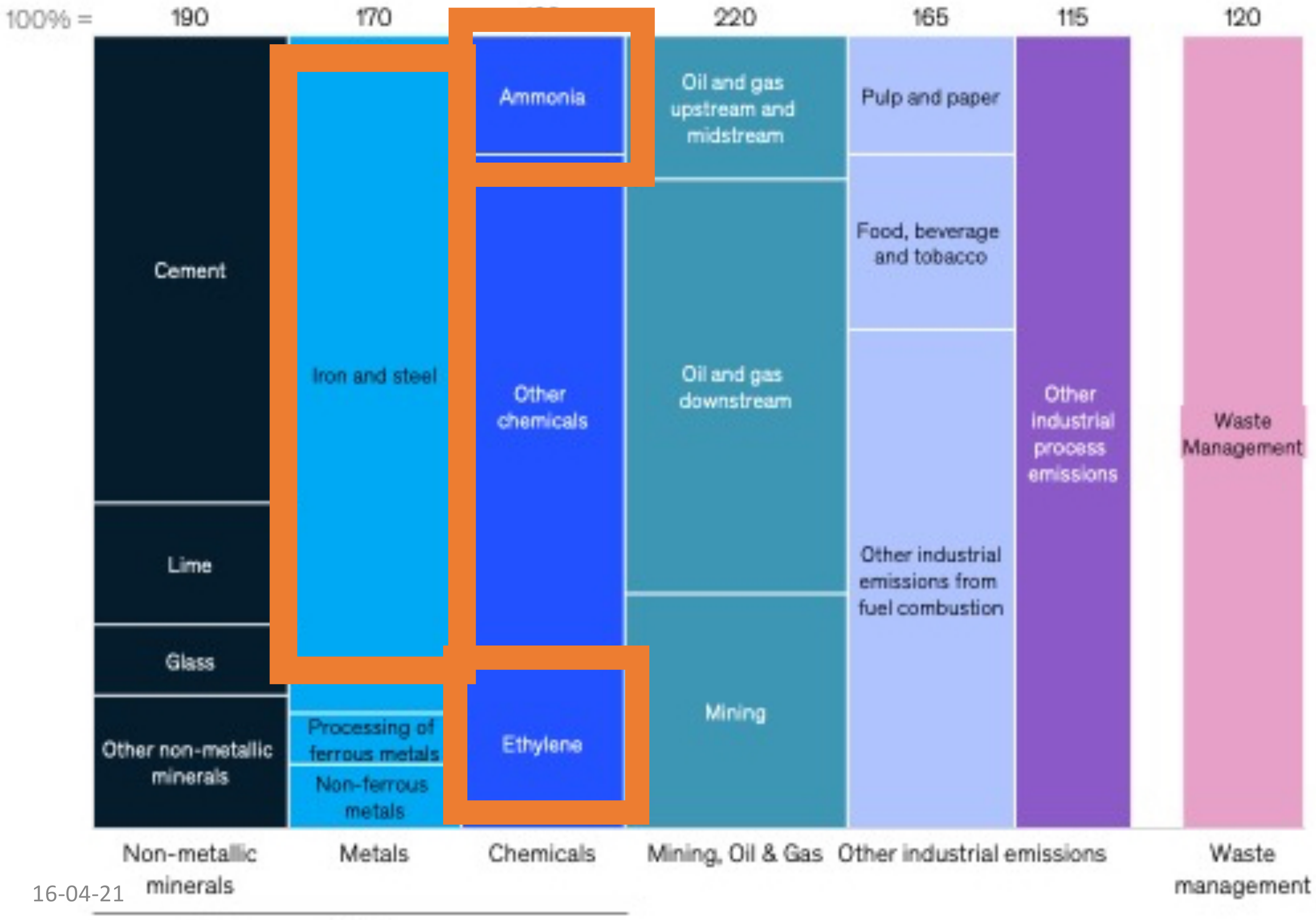
Recent report from McKinsey

McKinsey
& Company

Net-Zero
Europe

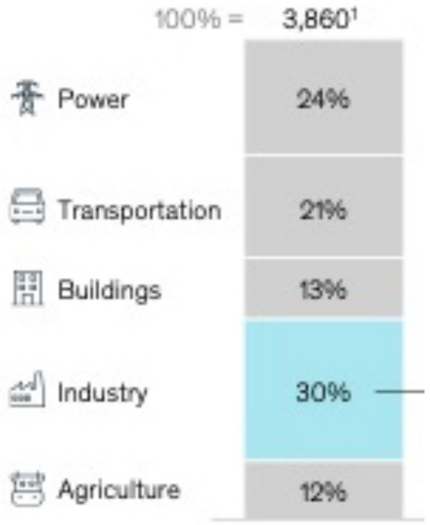
Decarbonization pathways and
socioeconomic implications

Emission Industry in 2017 – EU 27 Mt CO_{2e}



EU CO_2 3860 Mt CO_{2e}
NL CO_2 193 Mt CO_{2e}

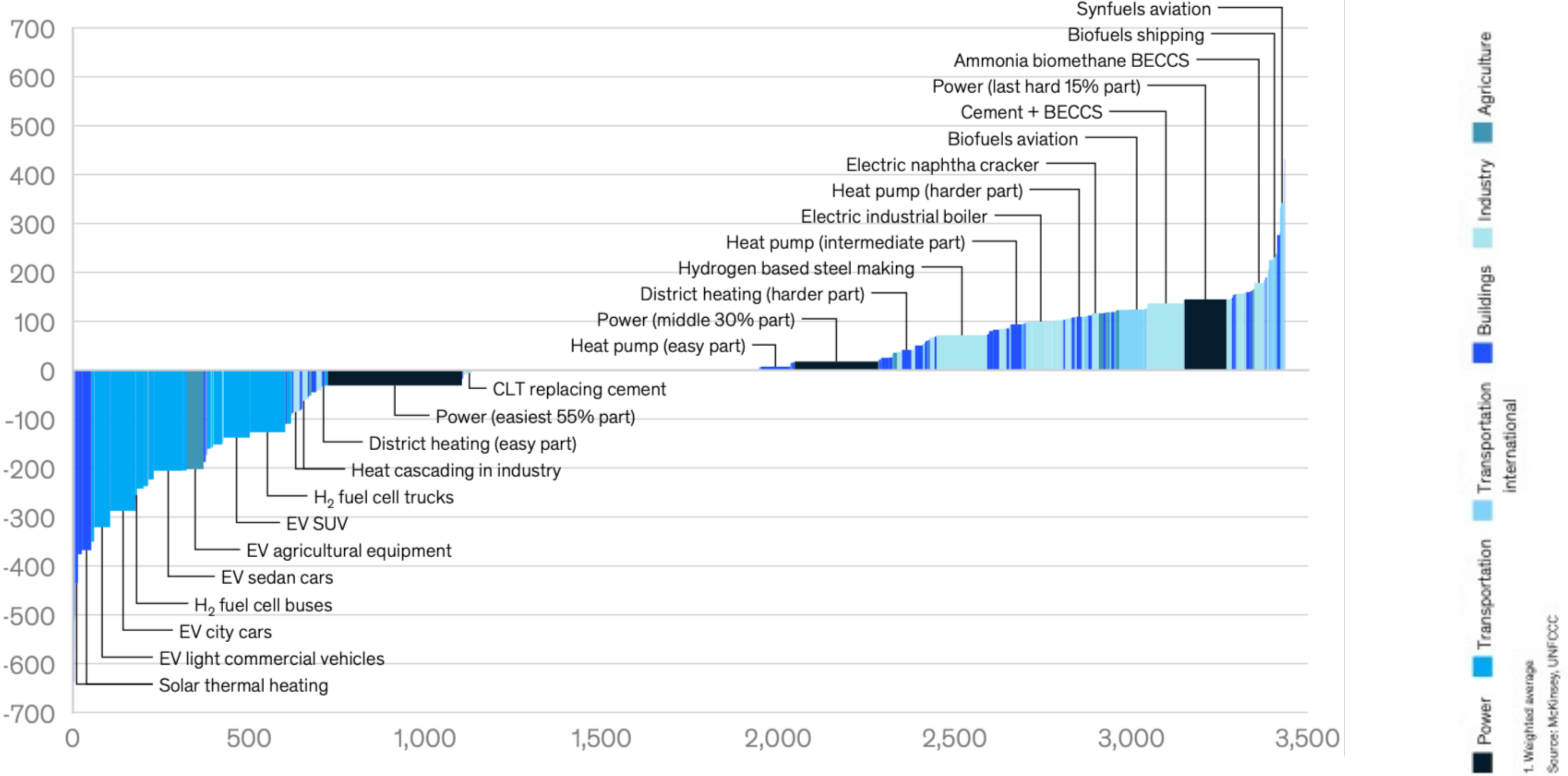
EU CO_2 industry 1140 Mt CO_{2e}
NL CO_2 industry 68.3 Mt CO_{2e}



Source McKinsey

Abatement cost €/tCO$_2$ 2050

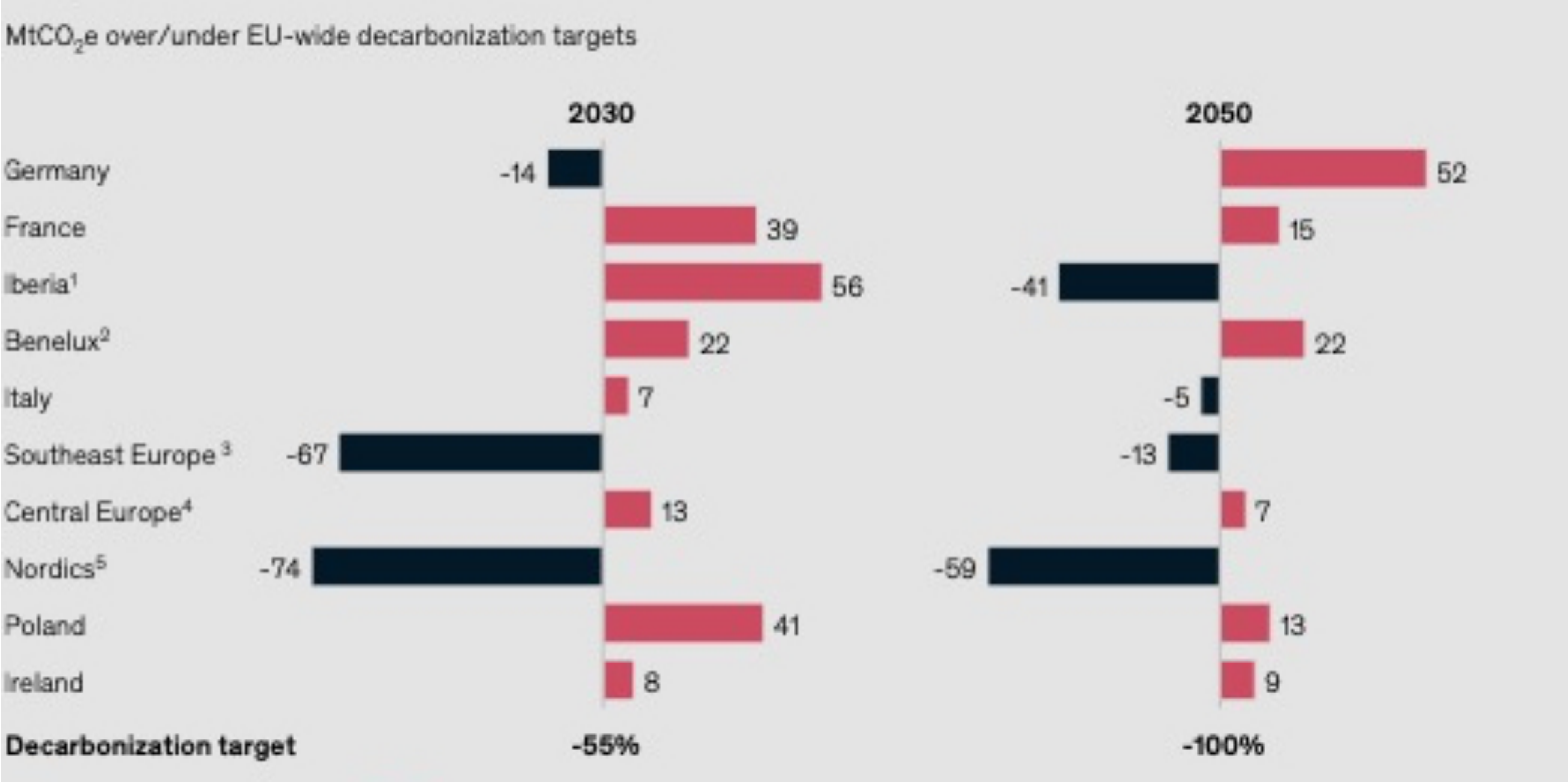
Huge differences



Source McKinsey

Optimal decarbonization pathway for EU-27

Nordics and Iberia compensate for Germany



Source McKinsey

Work in Progress

Issues still needing answers

- Voice of the “Customer”
- Electricity markets with near-zero marginal cost for wind and solar
- Implementation of smart grids including rewards
- Cost-effective alternatives for non-energetic use of fossil fuels (plastics)
- Cost-effective alternatives for concrete (cement)
- Cost-effective green fuels, especially kerosene
- Industrialisation of low-cost/low-operating hours fuel cells (e.g. from FCEV passenger car)
- Strategy for the built environment: all-electric heating turns out quite costly
- Cost/benefits hugely different per sector – from stakeholder perspective investment case often lacking

Discussion

“Is this concept sufficiently future proof to guide strategic decisions for the next decades?”

References:

More info about the 2050 Nederland study of the KIVI Elektrotechniek working group energyNL2050

- www.kivi.nl/energieplan

Chemistry for Climate: Acting on the need for speed
Roadmap for the Dutch Chemical Industry towards 2050

https://vnci.nl/Content/Files/file/Downloads/VNCI_Routekaart-2050.pdf

McKinsey: How the European Union could achieve net-zero emissions at net-zero cost

https://www.mckinsey.com/business-functions/sustainability/our-insights/how-the-european-union-could-achieve-net-zero-emissions-at-net-zero-cost