› WATERSTOF IN DE ENERGIETRANSITIE

,JAARVERGADERING VERENINGING ZONNEKRACHTCENTRALES (20 MAART 2021

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Utrecht University

rijksuniversiteit groningen

TNO ENERGY TRANSITION: FOCUS ON ENERGY TRANSITION ALL ELEMENTS OF THE ENERGY SYSTEM

TNO some 3500 co-workers;
Energy Unit some 750 co-workers, approx.100 Meuro/yr turnover

ANALYZING THE WHOLE ENERGY SYSTEM: MODELLING APPROACH: JRC-TIMES

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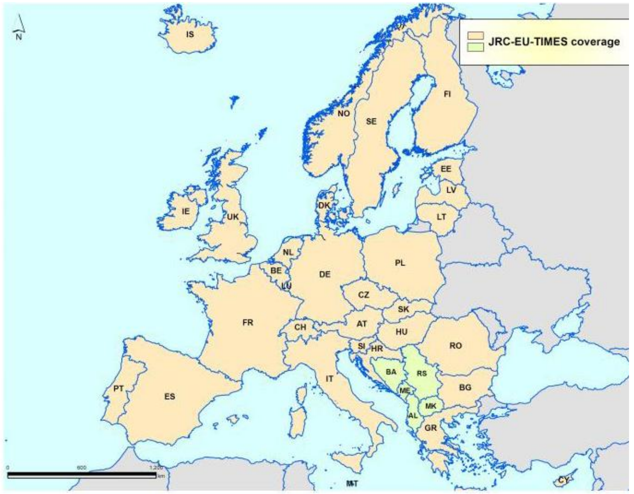


Aligned to latest EU Energy Reference Scenarios

- Energy services demands (pkm, tkm, PJ, Mt)
- Resources and costs

ETRI

- Technologies
- Policies (GHG and energy target, subs.)

Objective

- Minimise total energy system costs

$$NPV = \sum_{r=1}^{R} \sum_{y \in YEARS} (1 + d_{r,y})^{REFYR-y} \bullet ANNCOST(r, y)$$

Constraints

- Demand and supply balances: Transport, industry, buildings, agriculture - primary energy (RES, fossils), refineries and electricity
- Impacts of high variable RES-e
  - Flexible use possible excess RES-e: curtailment, Power2gas and storage
  - Reduced operation dispatch. power

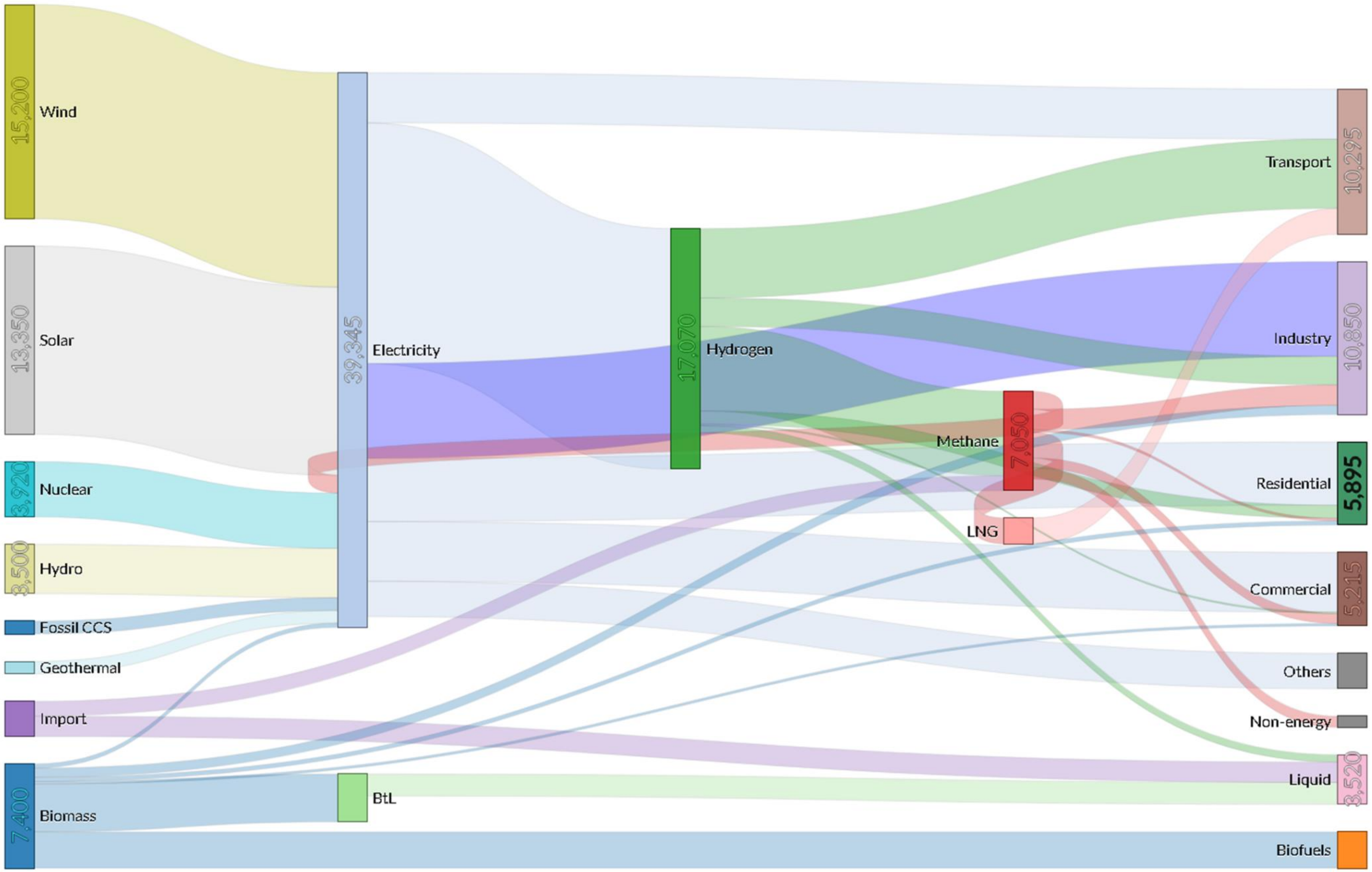
Outputs:

- Supply and demand technologies
- Material and energy flows
- Technology costs (O&M, investments)
- Emissions (t CO2) and prices

- Not forecasts or predictions
- Meant to develop understanding of trade-offs and robustness of decisions

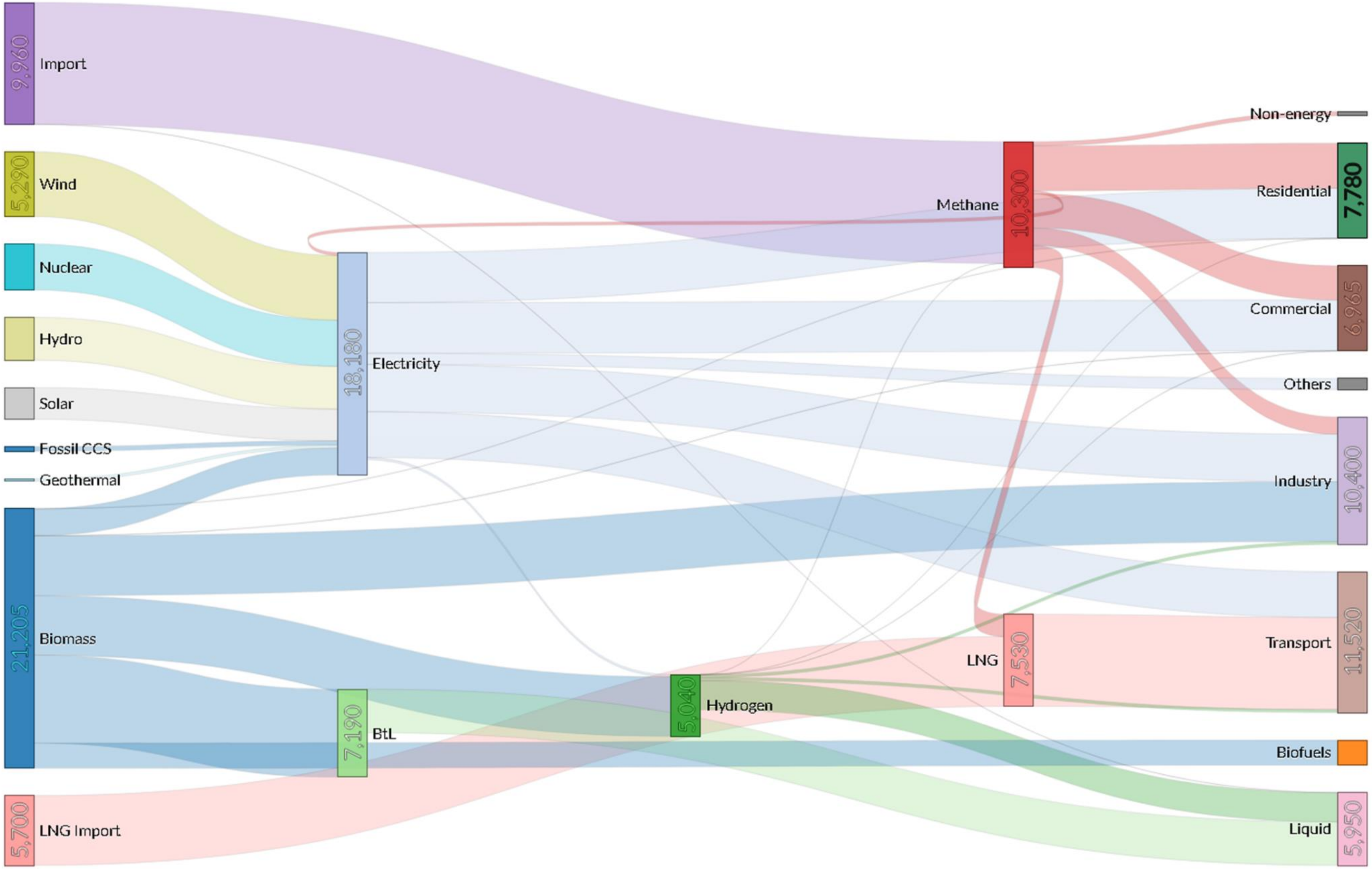
[Blanco et al., 2018]

EU 2050 MAX SOLAR & WIND SCENARIO (+ NO CCS, MINIMAL BIO)



[Blanco et al., applied Energy 2018]

EU 2050, HIGH BIOMASS AND CCS SCENARIO



[Blanco et al., applied Energy 2018]

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TOEKOMSTBEELD NEDERLANDS ENERGIESYSTEEM
& SCENARIO'S 2050

ADAPT

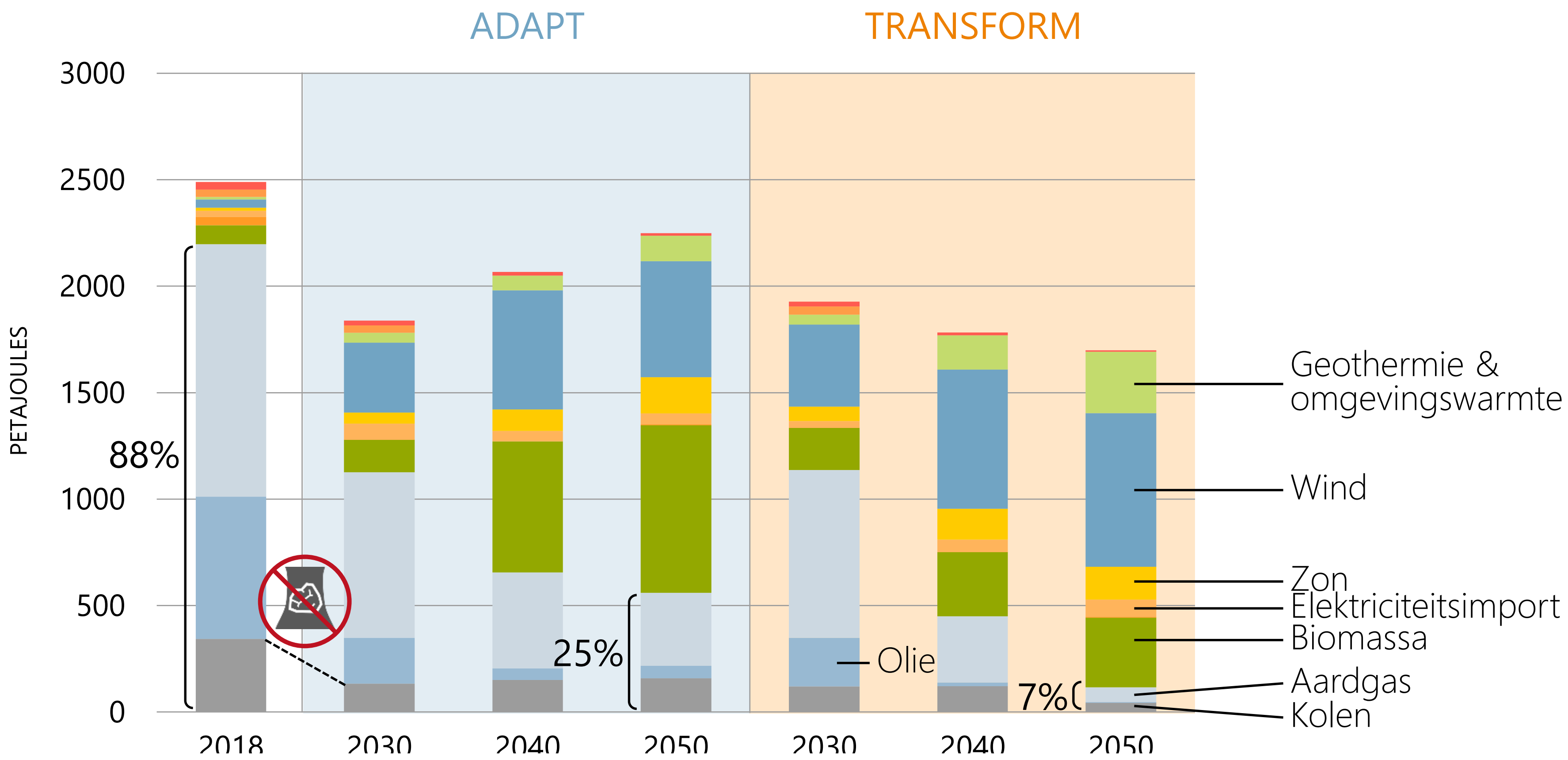
- Handhaven levensstandaard
- Industriële structuur blijft bestaan
- Overheid neemt voortouw
- Aanpassing energiesysteem om doel te halen
- Fossiele brandstoffen gebruikt met CO_2-opslag
- Ruime import van biomassa

TRANSFORM

- Sterk milieubewustzijn: reductie van vraag
- Innovatief EU en Nederland
- Initiatieven van burgers en bedrijven
- Transformatie energiesysteem en industrie
- Geen CO_2-opslag
- Beperkt gebruik biomassa

Demografie | Economische groei | Commodity-prijzen | Klimaatdoelen

PRIMAIRE ENERGIE AANBOD MIX
TOONT DECARBONISATIE ENERGIESYSTEEM

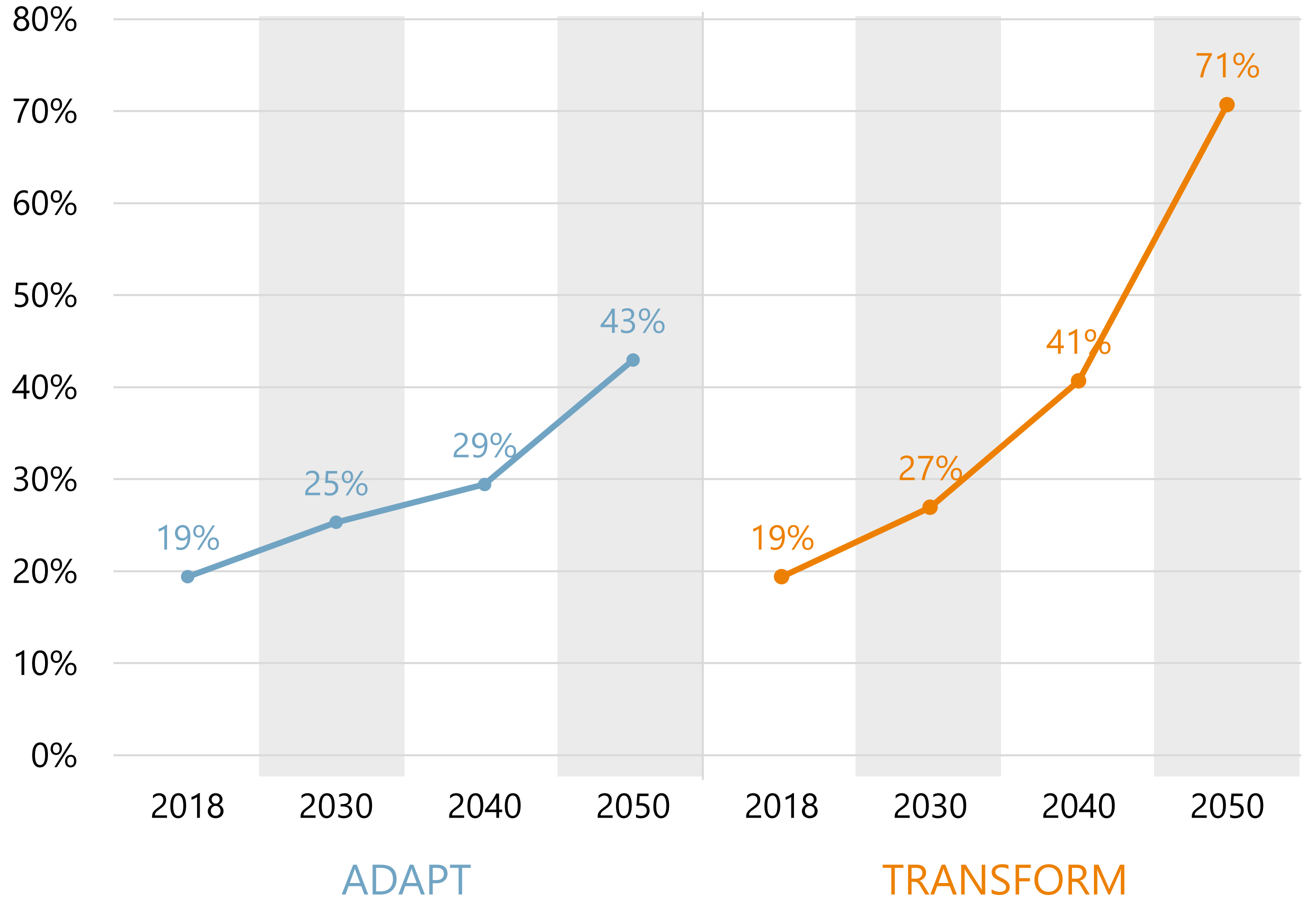


EXCLUSIEF:

- Non-energetisch gebruik
- Internationale lucht- en scheepvaart

AANDEEL ELEKTRICITEIT ENERGIESYSTEEM
GAAT MEER DAN VERDUBBELEN

Aandeel elektriciteit energieaanbod



Aandeel koolstofvrije elektriciteitsproductie

	ADAPT	TRANSFORM
2018	19%	19%
2030	81%	76%
2040	97%	97%
2050	99%	99%

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WATERSTOF BESCHEIDEN, MAAR...
CRUCIALE ROL IN DUURZAAM ENERGIESYSTEEM

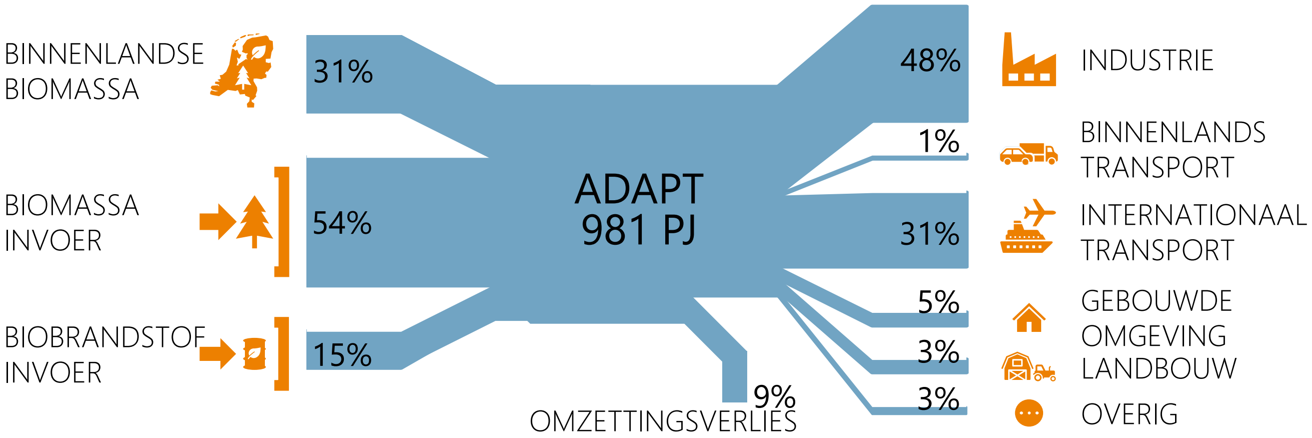
TOTAL H_2 257/260 PJ	PERCENTAGE H_2 naar sector	AANDEEL WATERSTOF ENERGIESYSTEEM ADAPT 8% (257 PJ) en TRANSFORM 10% (260 PJ) in 2050
8% - 10%	1% - 2%	van de H_2 naar gebouwde omgeving
	54% - 55%	van de H_2 naar industrie
	42% - 43%	van de H_2 naar binnenlands transport

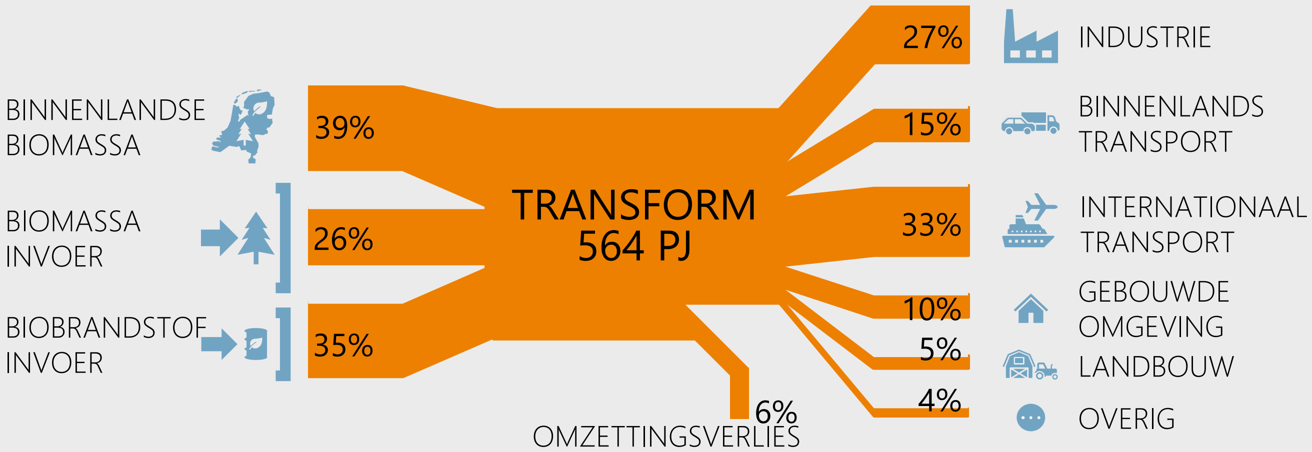
Productie

ADAPT — Voornamelijk blauwe H_2, in 2050 ook 25% groene H_2

TRANSFORM — Alleen groene H_2

BIOMASSA VOORAL GEBRUIKT IN
INDUSTRIE EN TRANSPORTSECTOR





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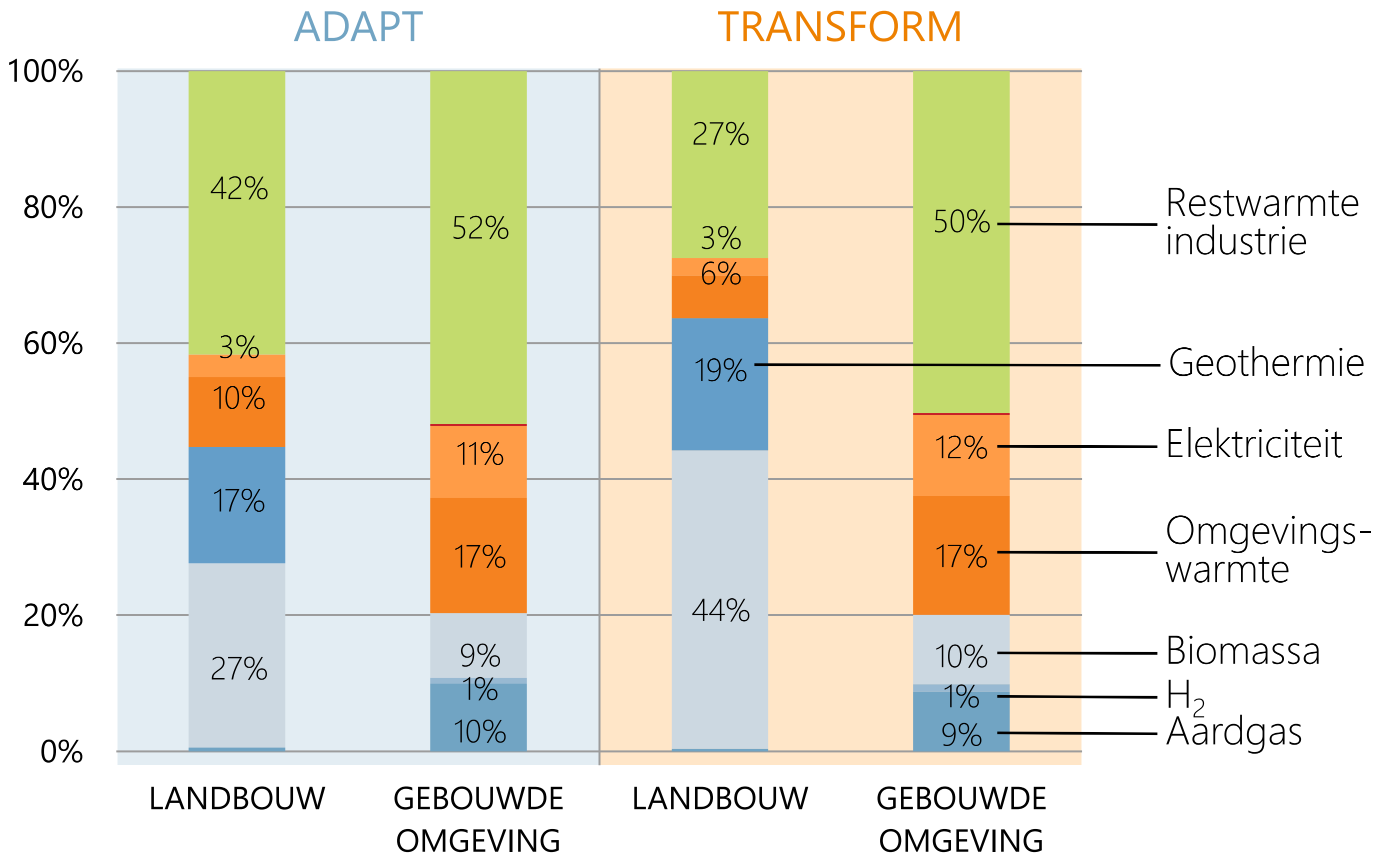
ANDERE WARMTEBRONNEN EN ENERGIEOPTIES
NEMEN ROL AARDGAS OVER



- In 2050 aardgas nog gebruikt voor:
  - flexibele elektriciteitsproductie
  - in industrie (alleen in ADAPT scenario)
  - gebouwde omgeving
- Aardgas gebouwde omgeving vervangen door:
  - Individuele systemen (warmtepompen, elektriciteit, waterstof)
  - Collectieve systemen (restwarmte industrie, afvalverbranding, biomassa)

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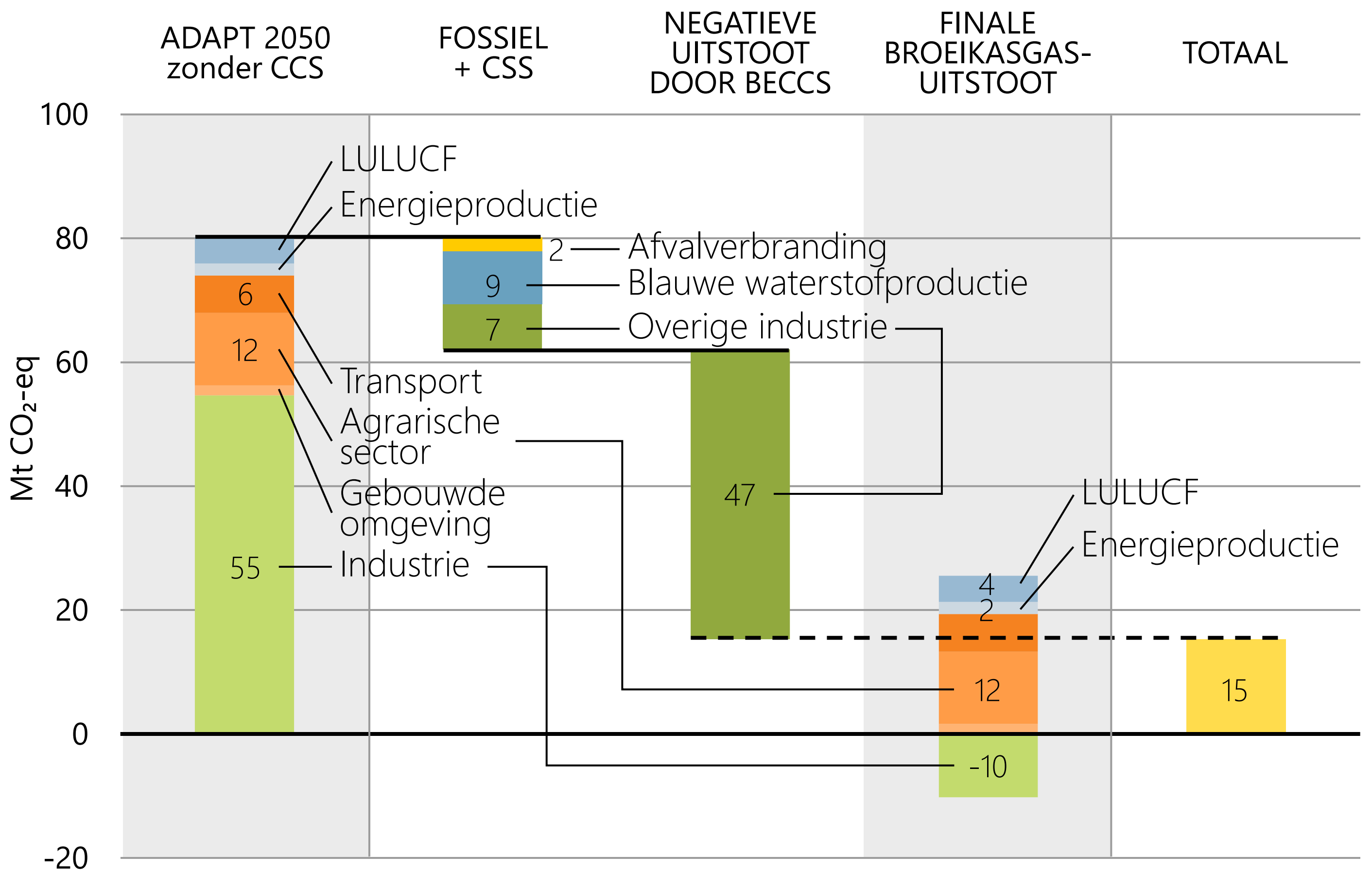
CO_2 AFVANG EN OPSLAG
IN HET ADAPT-SCENARIO IN 2050



RESTERENDE BROEIKAS-GASEMISSIES

In 2050 met name agrarische sector (veeteelt) transport en LULUCF

CO_2 AFVANG- EN OPSLAG (CCS) IN ADAPT

- 2030: 6,2 Mton
- 2040: 19 Mton
- 2050: 50 Mton

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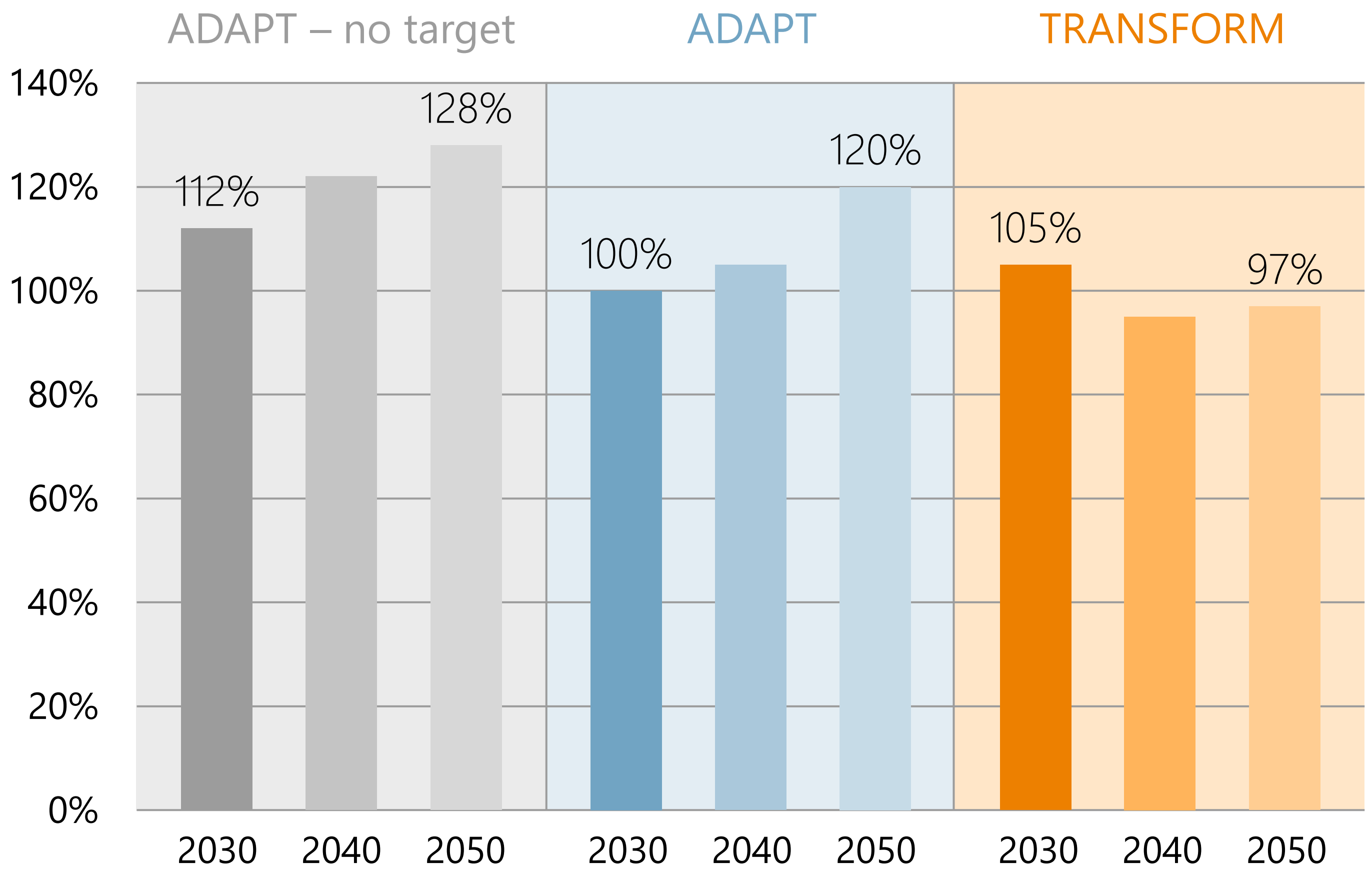
KOSTEN DUURZAAM ENERGIESYSTEEM
LAGER T.O.V. SCENARIO ZONDER DOELSTELLING



ADAPT NO-TARGET

- 60% BKG reductie duurzame energie en hogere fossiele energieprijzen
- Nederland blijft sterk afhankelijk van import fossiele brandstoffen

TOENAME SYSTEEMKOSTEN IN ADAPT SCENARIO

Door stijgende energievraag

KOSTEN IN TRANSFORM SCENARIO 2050

Lager dan ADAPT scenario door lagere energievraag industrie en transportsector

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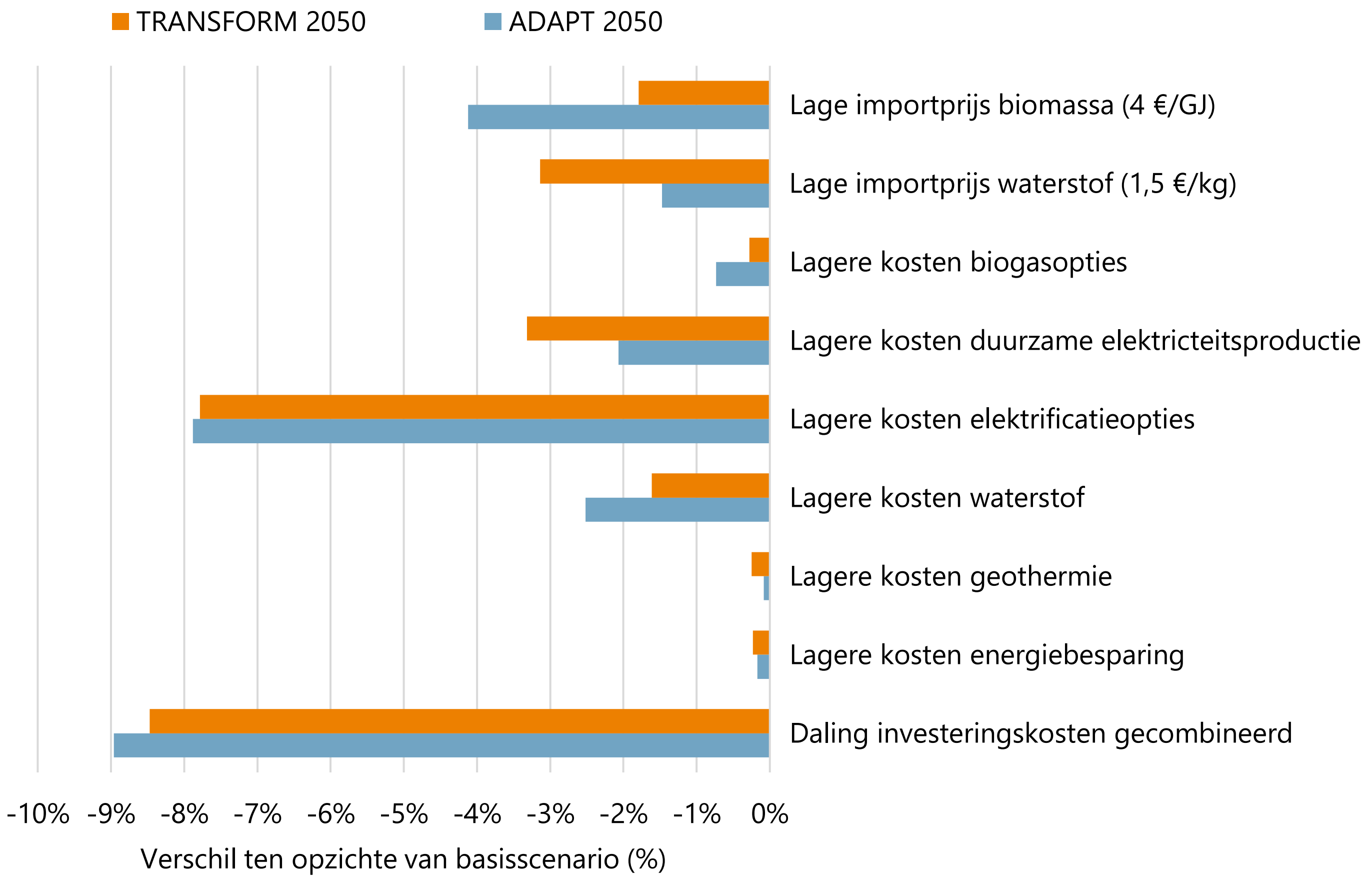
KOSTEN TOEKOMSTIG ENERGIESYSTEEM
KUNNEN DOOR INNOVATIE LAGER WORDEN



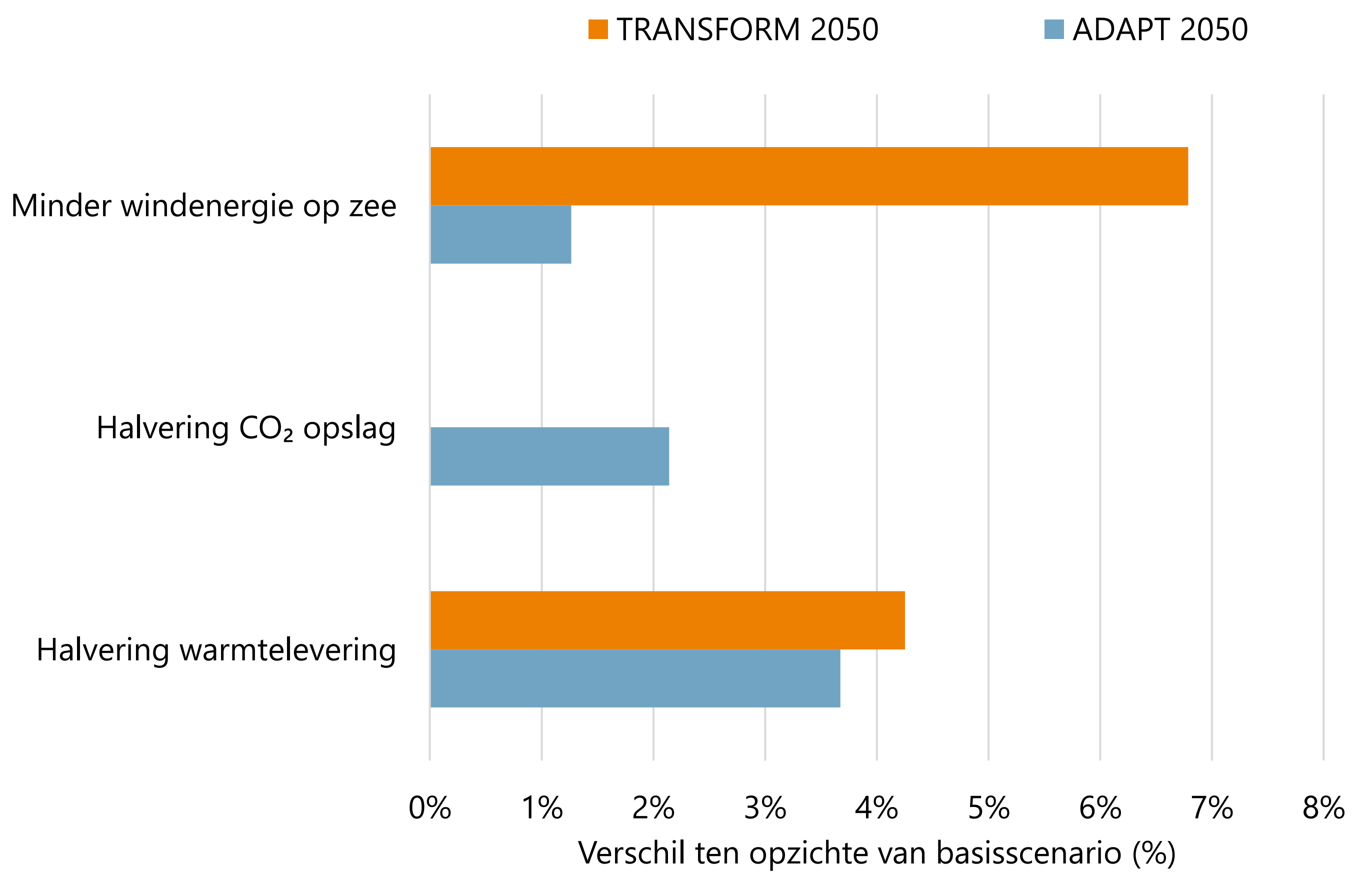
IMPACT OP TOTALE SYSTEEM-KOSTEN AFHANKELIJK VAN

- Omvang technologie in energiesysteem
- Resterende potentieel voor toepassing technologie

TECHNOLOGIE-OPTIES CONCURREREN MET ELKAAR

Dit beperkt impact van som kostenreducties op systeemkosten.

BEPERKEN HERNIEUWBARE ENERGIE-OPTIES
LEIDT TOT HOGERE SYSTEEMKOSTEN



BEPERKEN GEBRUIK OPTIES LEIDT TOT HOGERE SYSTEEMKOSTEN

- Door uitbreiding andere, duurdere energie-opties
- Door nog niet gebruikte technologie

BIJ NIET TOESTAAN OF BEPERKEN MEERDERE OPTIES TEGELIJK

Energievraag niet meer gedekt met realisatie BKG doelstellingen

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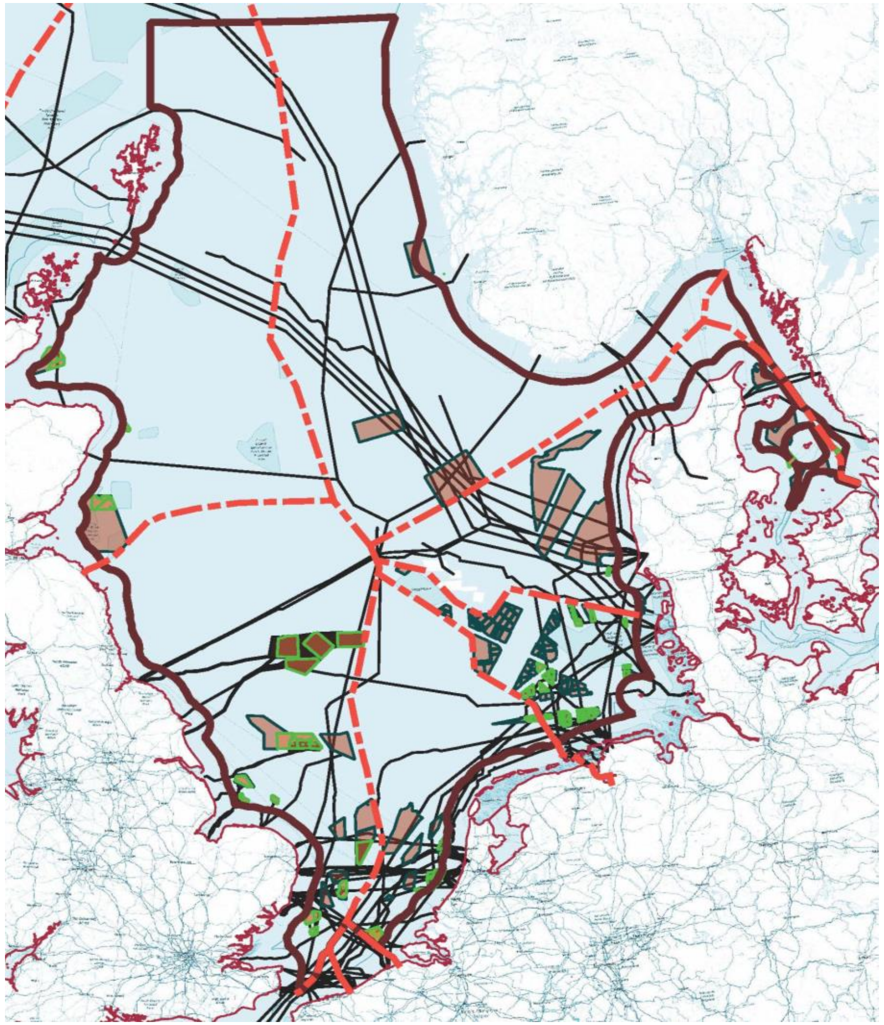
NORTH SEA REGION: BIGGEST LIVING ENERGY TRANSITION LABORATORY IN THE WORLD

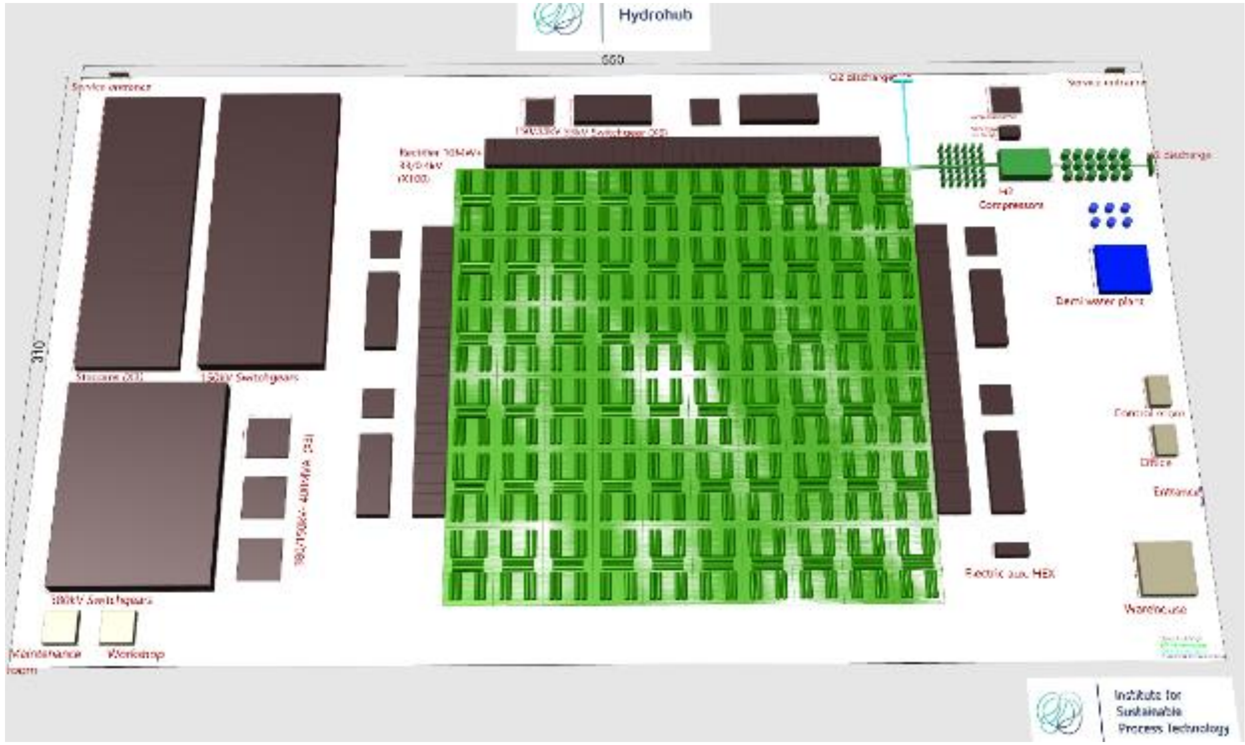
source: Tennet



[Gusatu et al., 2020

Part of the Marie Curie programme ENSYSTRA
with 15 Ph.D. project at 5 universities (&TNO)]

SCALE UP OF ELECTROLYSIS FROM OFFSHORE WIND

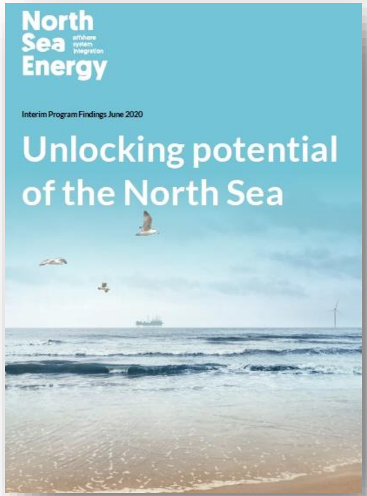


Connecting offshore wind with onshore hydrogen backbone with GW electrolysis plants in industrial clusters

HYDROGEN PRODUCTION

HYDROGEN PRODUCTION OFFSHORE

North Sea Energy offshore system integration



In collaboration with:

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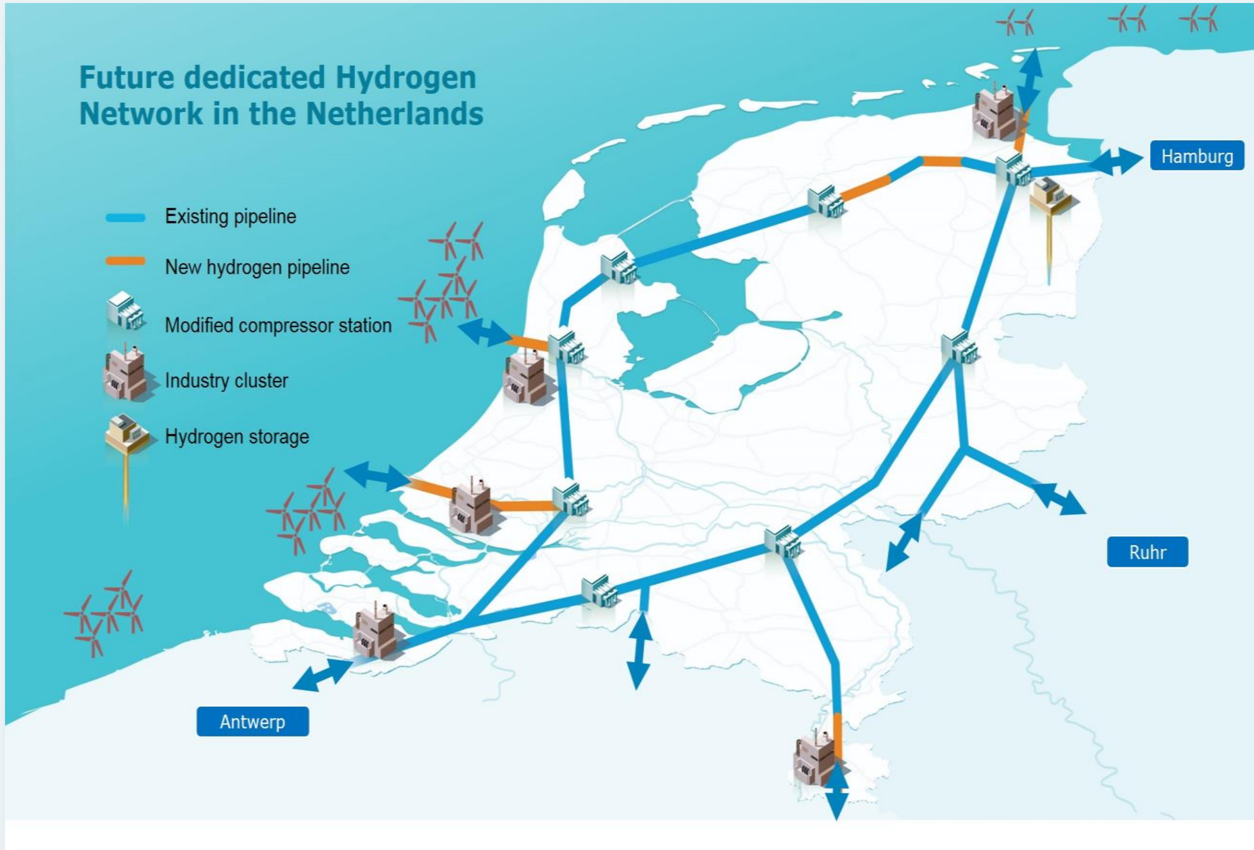
FUTURE: DEDICATED HYDROGEN BACKBONE IN NL

- Production of green hydrogen from offshore wind
- Blue hydrogen from natural gas and CCS
- Connection to key industrial demand centres
- Interconnection with Germany and Belgium
- Large scale H2 storage in salt caverns or gas fields
- Exisiting gas infra will become available beyond 2025

NortH2



SPECIFIC ROLE NNL & GRONINGEN; HIGH INTERMITTANT RET SCENARIO 2050

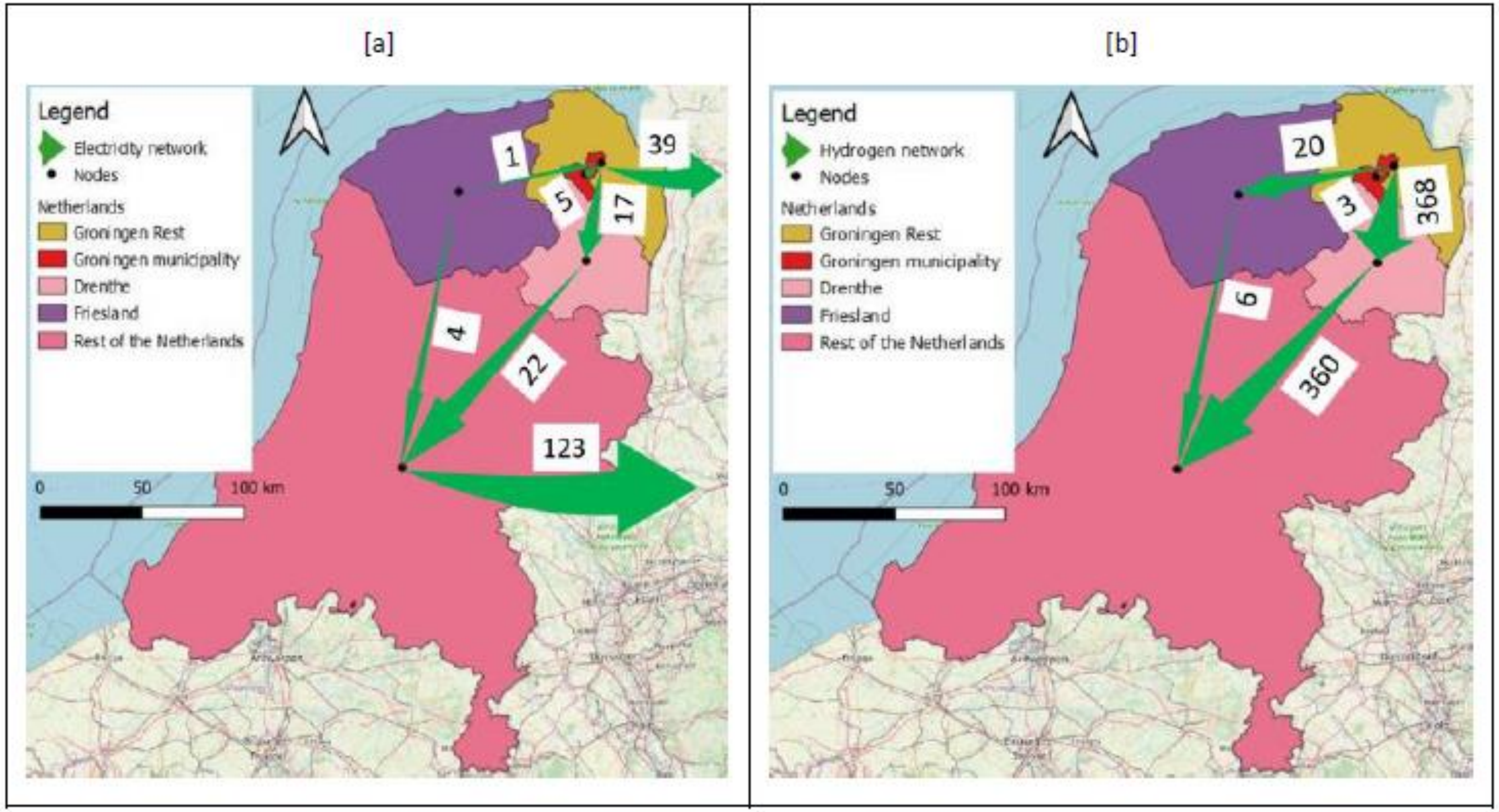


Figure 23 Internodal flows of electricity, and hydrogen (data in PJ). [a] represents electricity network flow and [b] represents hydrogen network flow.

[Sahoo et al, under review at Applied Energy, 2021; Regional and spatially explicit energy model].

IMPROVING EXISTING AND DEVELOPING NEW TECHNOLOGIES

High

Level of maturity

Low

Alkaline

100 MW

PEM

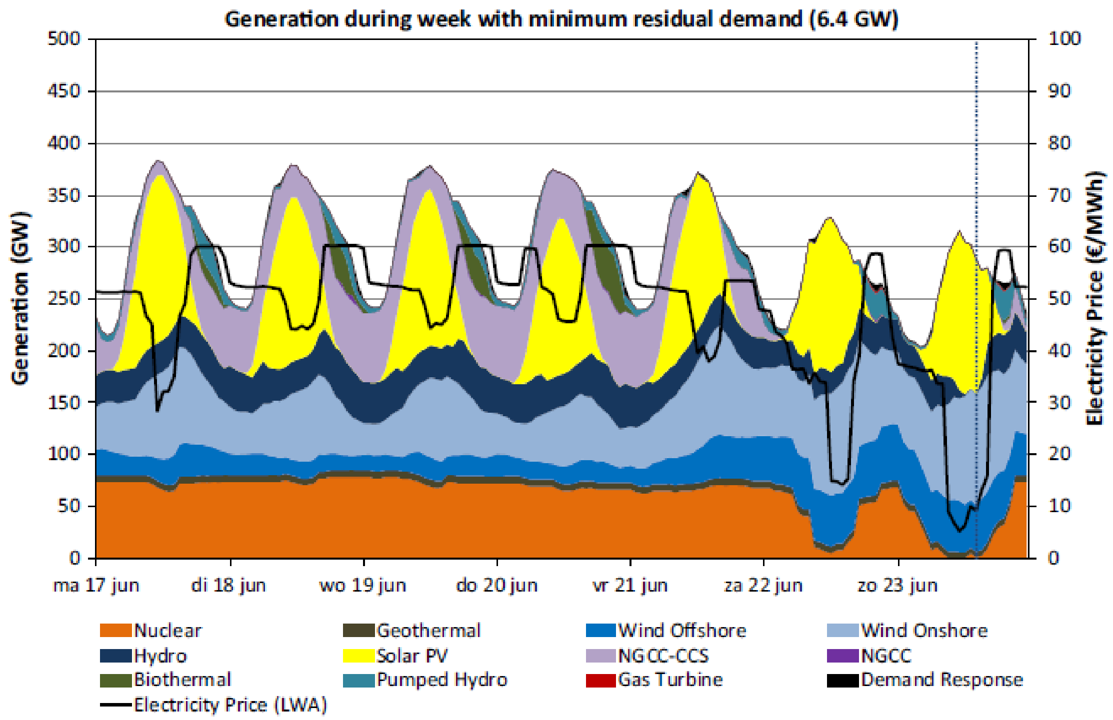
10 MW

SOE

1 MW

AEM

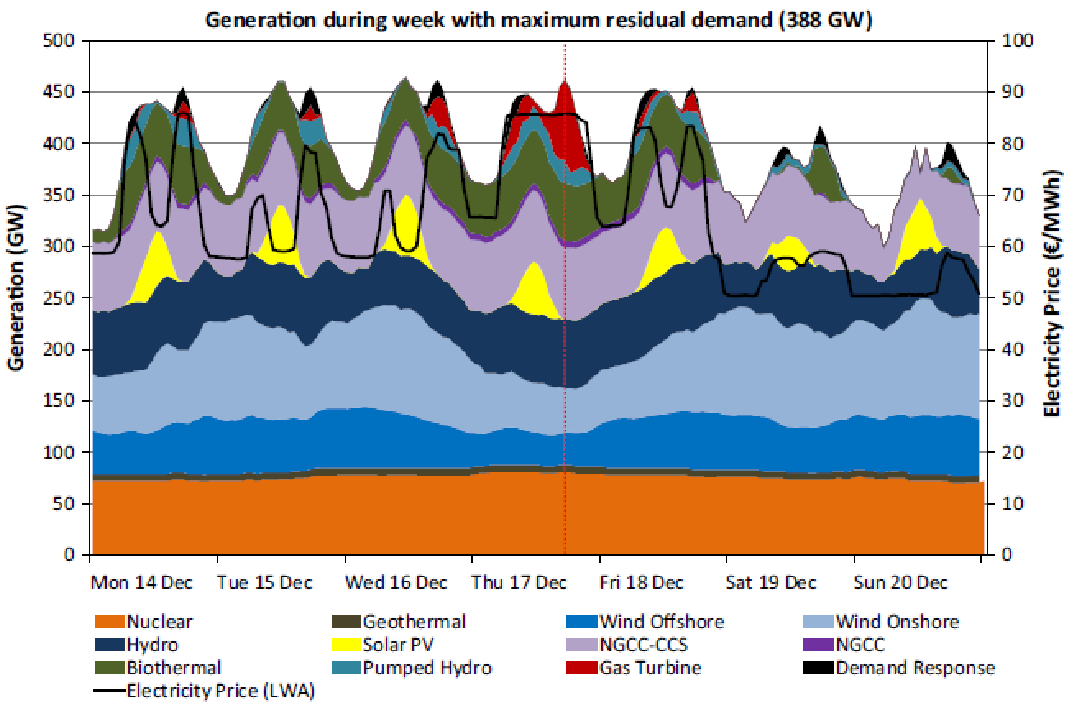
10 KW



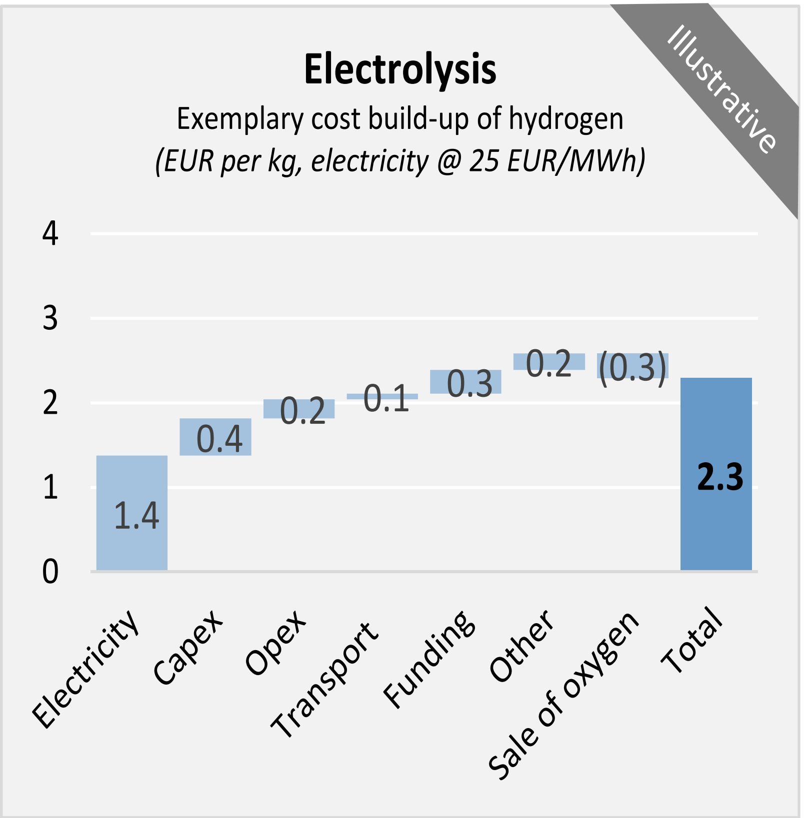
System implications!

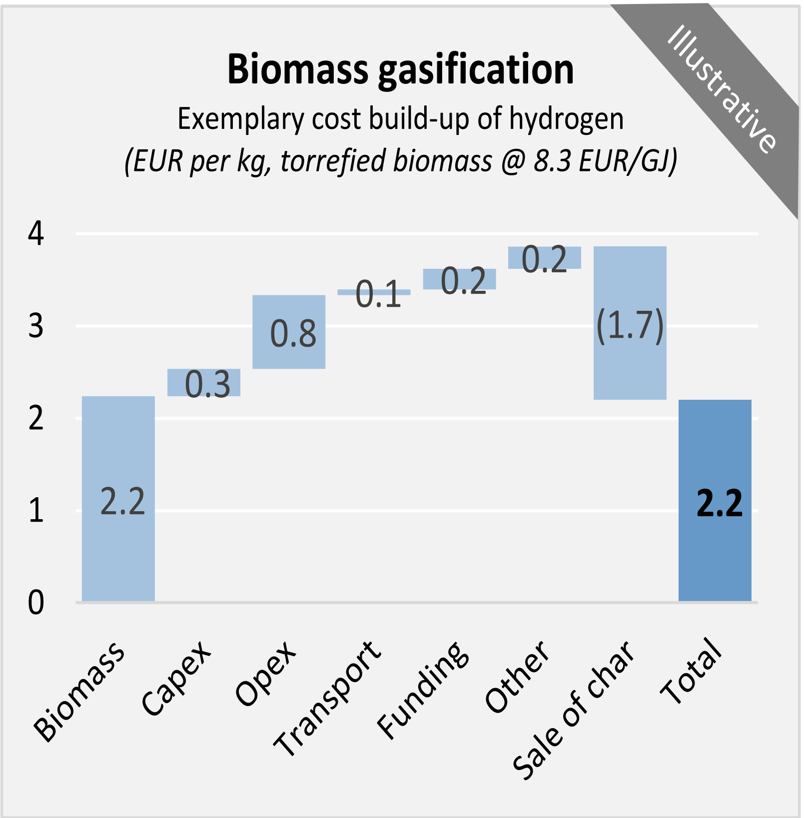
Electricity system simulations
NW Europe 2050 with 60% iRES
Weeks with maximum and minimum residual loads during the year.

[Brouwer et al., Applied Energy, 2016]



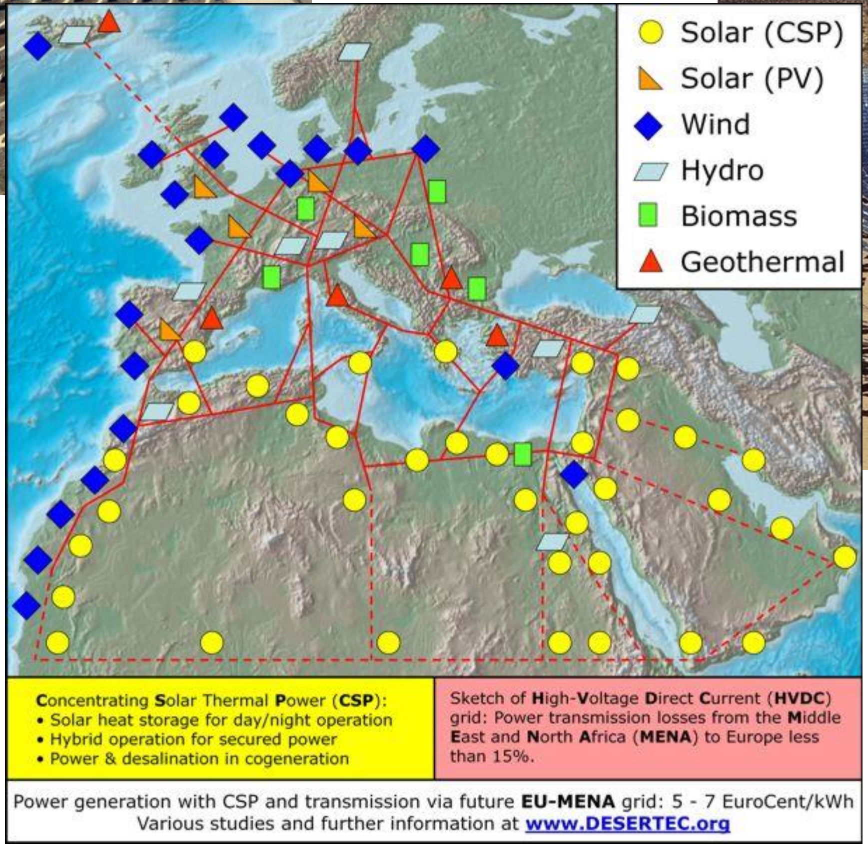
HOPED ECONOMICS HYDROGEN PRODUCTION (NATURAL GAS BASED PRODUCTION: 2-3 EURO/GJ)





Source: Rabobank/NIB H2 roadmap, van Wijk, 2017
However, electricity now some 50 Euro/MWh, surpluses of power minimal during short periods, and infrastructure costs not yet included.

FURTHER ENERGY SYSTEM INTEGRATION…



KEY (POSITIVE) DRIVERS FOR THE ENERGY TRANSITION

- Innovation – technological learning of multitude of energy technologies.
- Optimize implementation pathways and technology portfolio's (…).
- Macro-economic benefits (growth sectors, trade balance, lower costs than BAU…), stability energy prices.
- Full Cost Benefit balance (lower environmental impacts, more resource efficient); better services…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