DEPLOYMENT OF NUCLEAR ENERGY IN DEEP DECARBONIZATION OF THE ENERGY SYSTEM

, KIVI SYMPOSIUM: "NIEUWE KERNENERGY, WAT IS ER VOOR NODIG?" UTRECHT, 28TH OCTOBER 2022

ANDRÉ FAAIJ

DIRECTOR OF SCIENCE, TNO ENERGY TRANSITION

DISTINGUISHED PROFESSOR ENERGY SYSTEM ANALYSIS, UTRECHT UNIVERSITY & UNIVERSITY OF GRONINGEN

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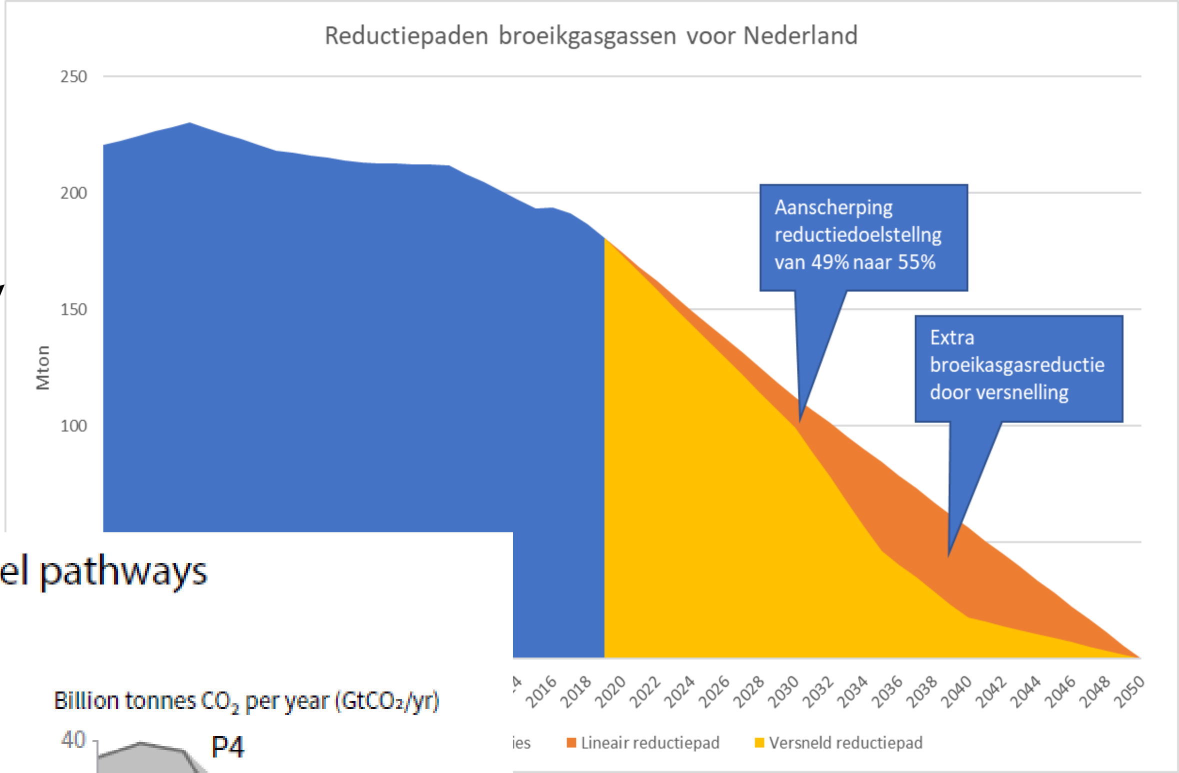
Universiteit Utrecht

rijksuniversiteit groningen

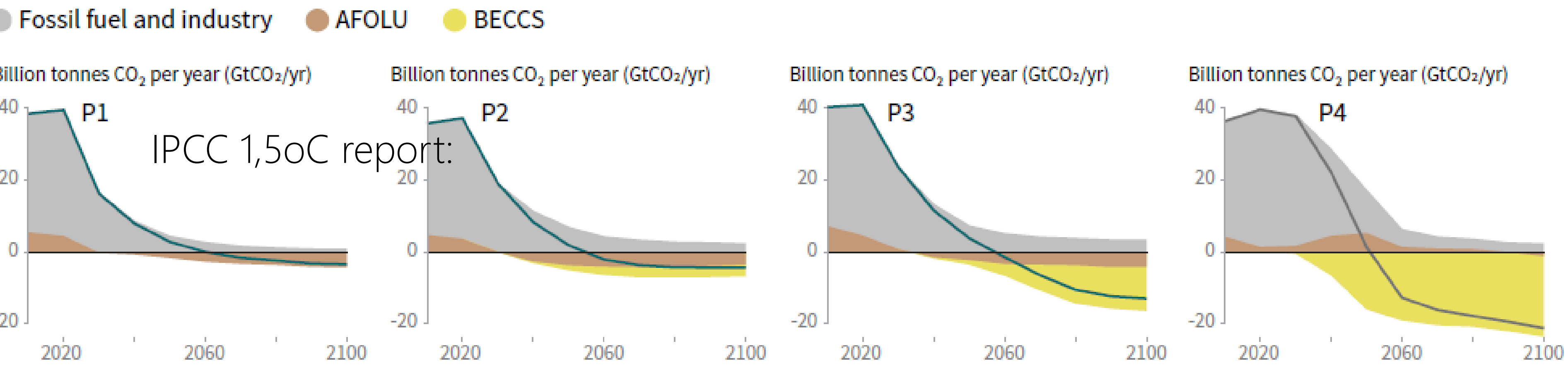
ACCELERATING THE ENERGY TRANSTION

Implications for the Netherlands:



Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways

IPCC 1,5oC report:



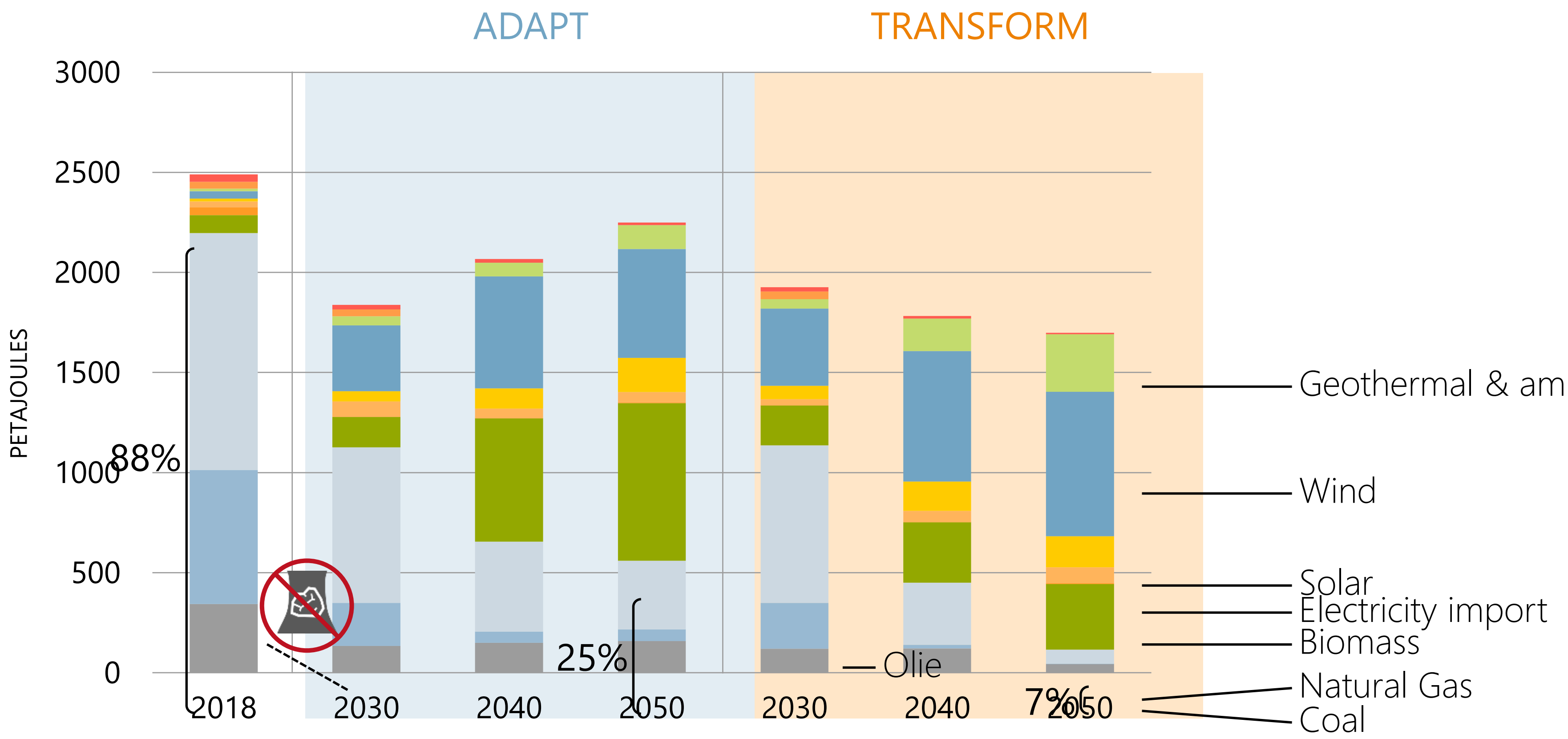
P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

2 FUTURE ENERGY SCENARIO'S FOR THE NETHERLANDS; PRIMARY ENERGY SUPPLY MIX

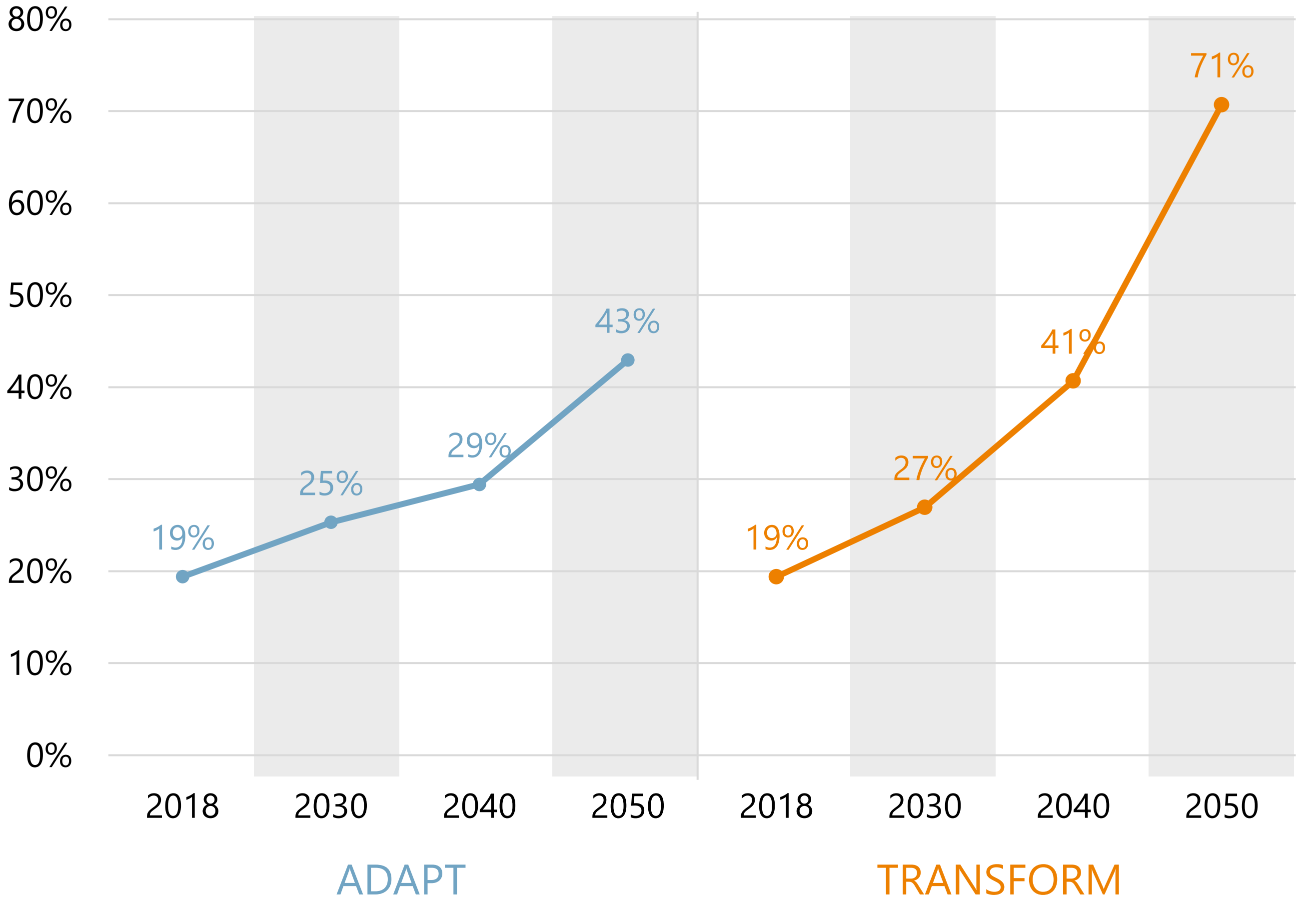


- Excludes:
- Non-energetic use
- International aviation & shipping

SHARE OF ELECTRICITY IN THE ENERGY SUPPLY

DOUBLING – TRIPLING COMPARED TO TODAY

Share electricity in total energy supply



Share low C electricity

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

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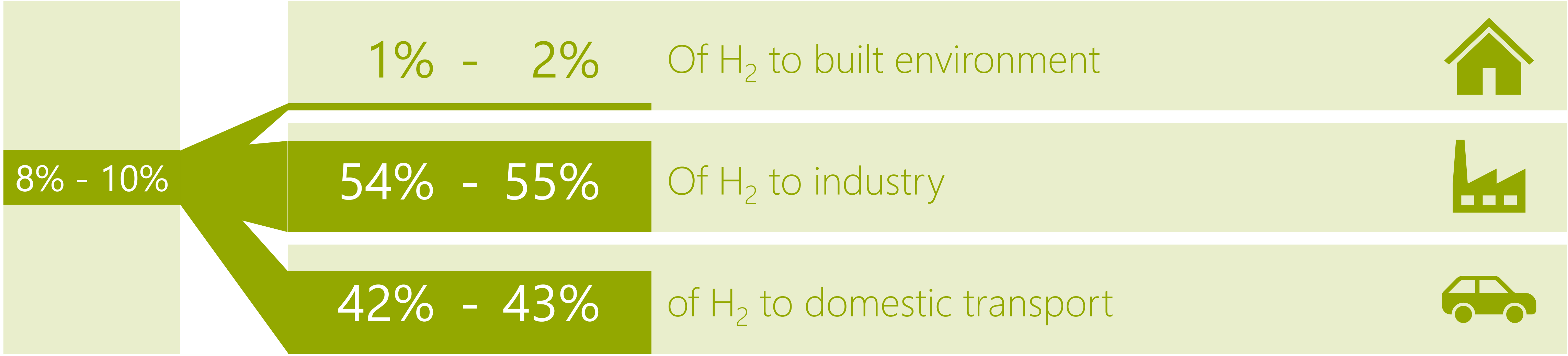
HYDROGEN RELATIVELY MODEST, BUT...

IMPORTANT ROLE IN THE ENERGY SYSTEM

TOTAL H_2
257/260 PJ

PERCENTAGE H_2
per sector

Share hydrogen in the energy system
ADAPT 8% (257 PJ) en TRANSFORM 10% (260 PJ) in 2050



Production

ADAPT	Largely blue H_2, in 2050, also 25% green H_2
TRANSFORM	Only green H_2

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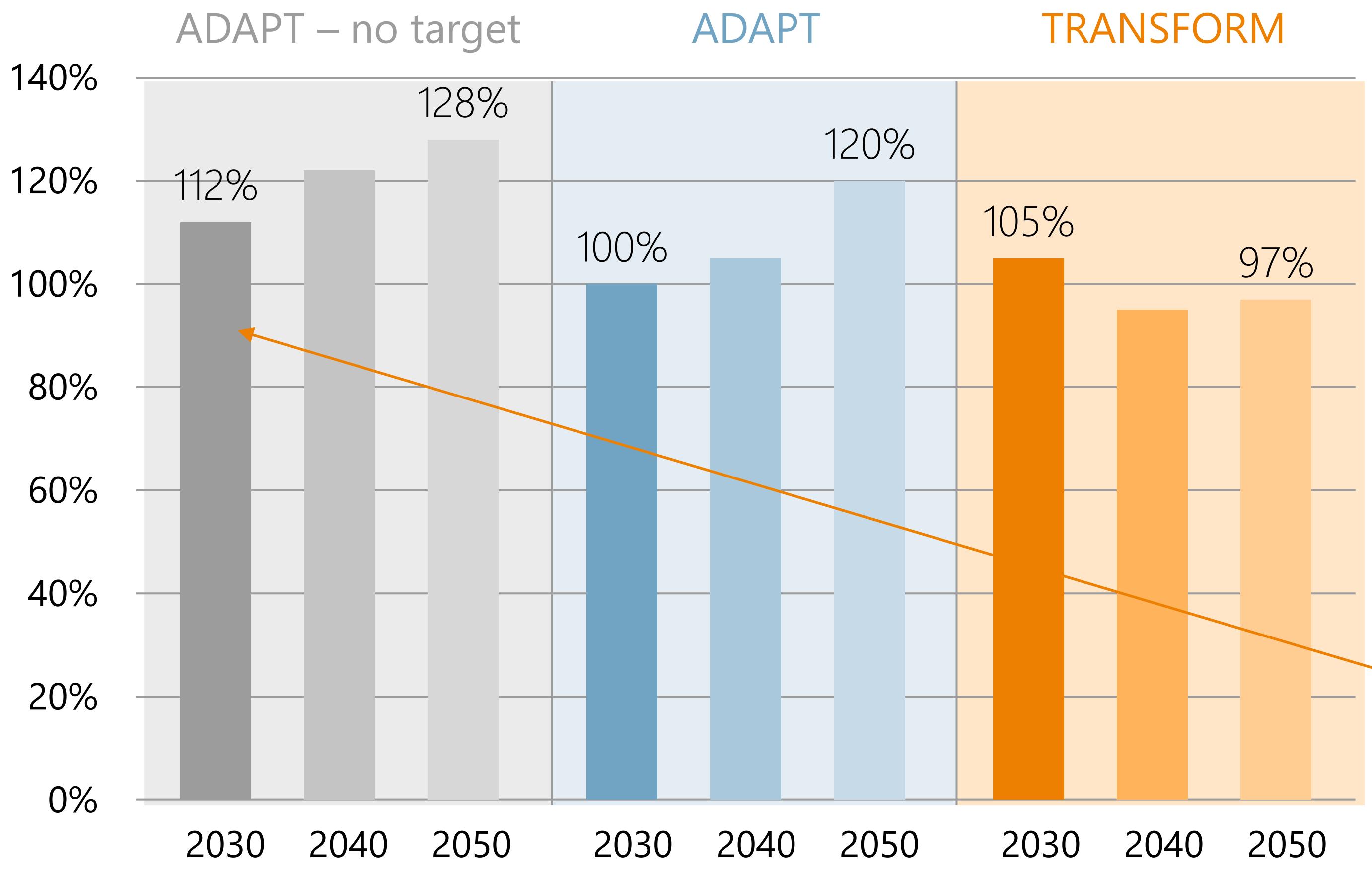
COSTS OF A SUSTAINABLE ENERGY SYSTEM

LOWER COMPARED TO A SCENARIO WITHOUT A GHG TARGET.



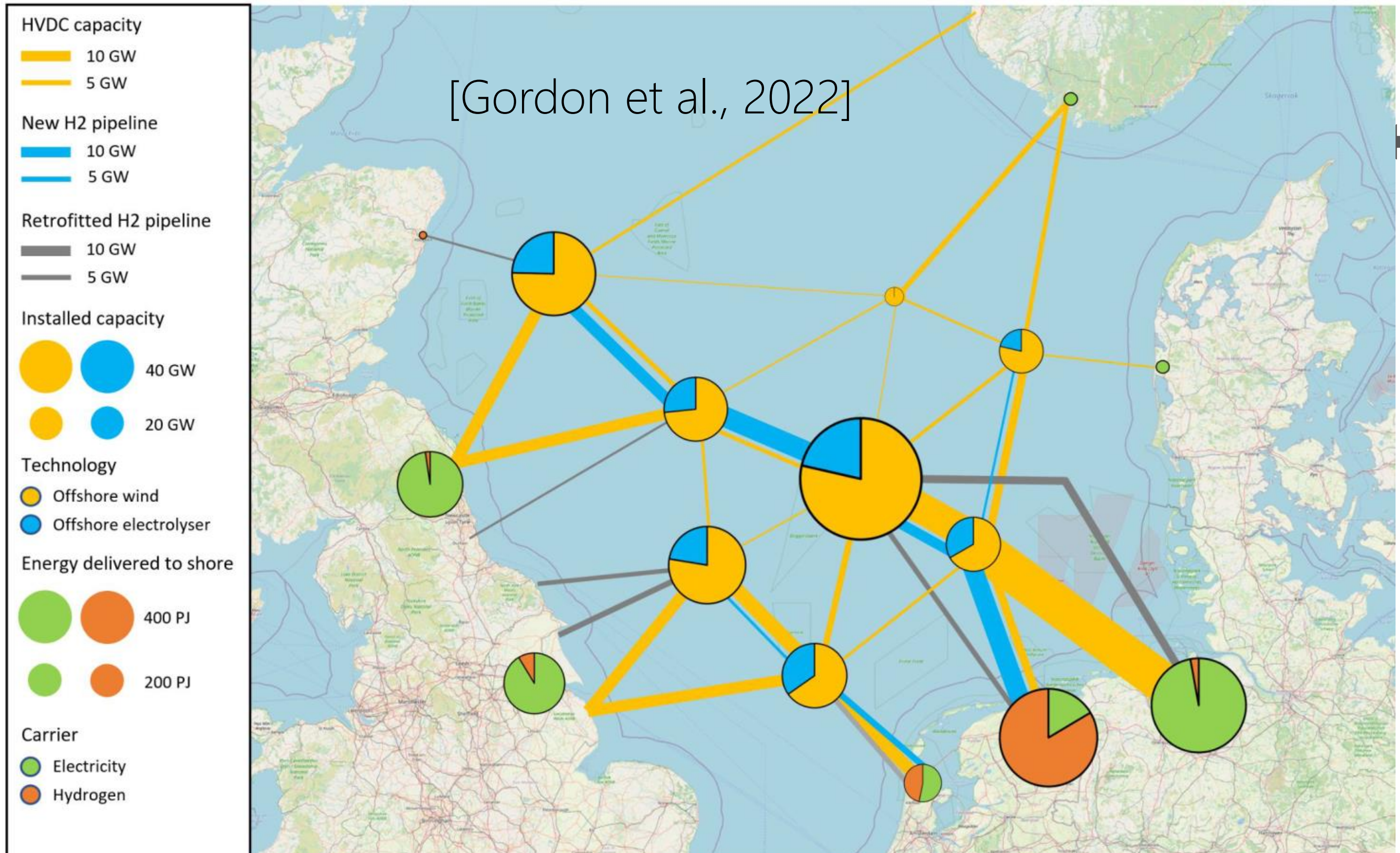
<u>Preconditions:</u>

- All options (need to) contribute!
- Innovation (cost reduction)
- Optimal planning / deployment.

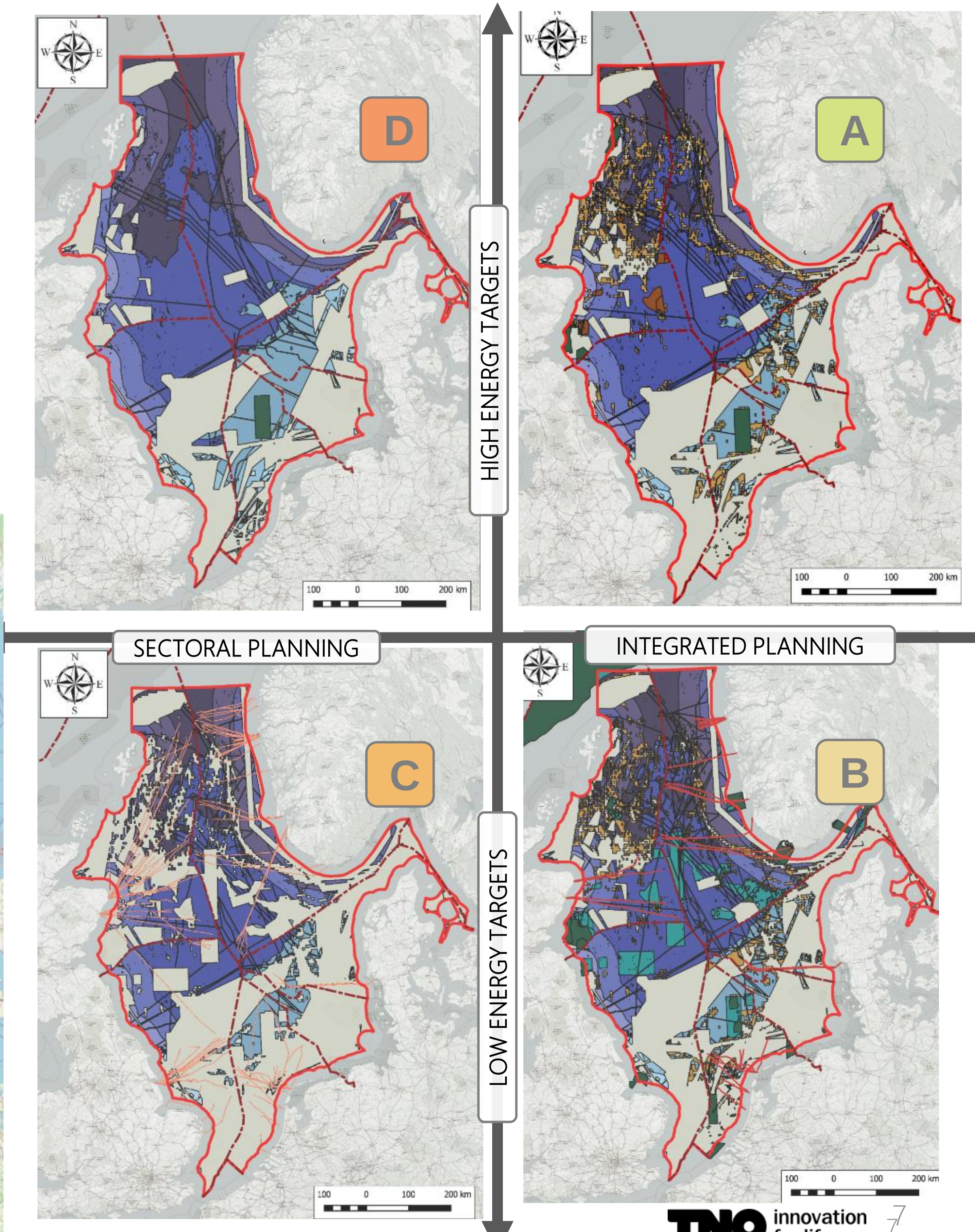
This has about doubled with the Ukraine war resulting price levels for gas and oil

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

source: Tennet



[Gordon et al., 2022]



[Gusatu et al., 2020}

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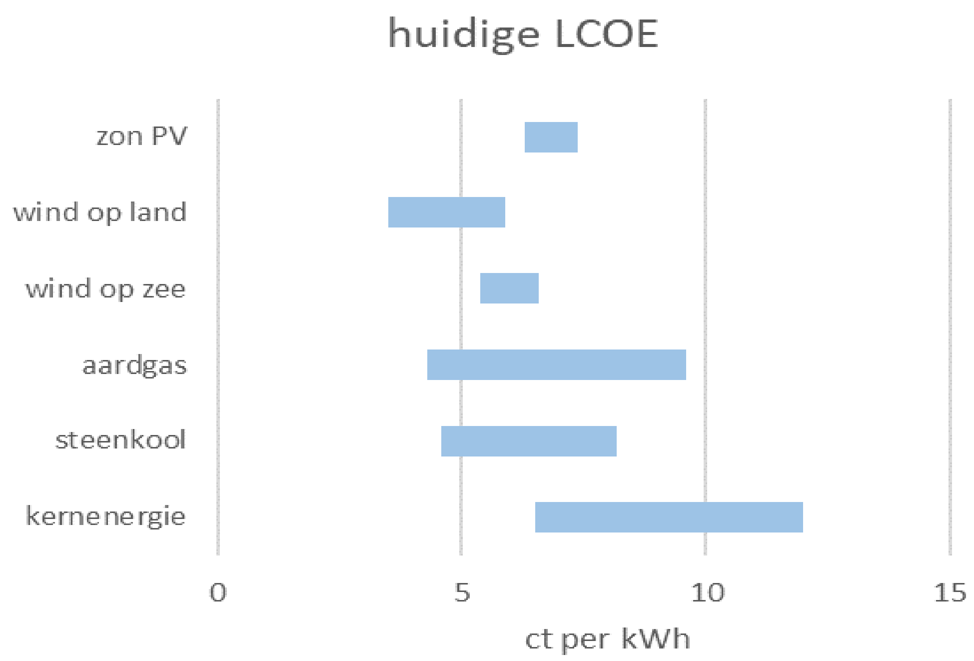
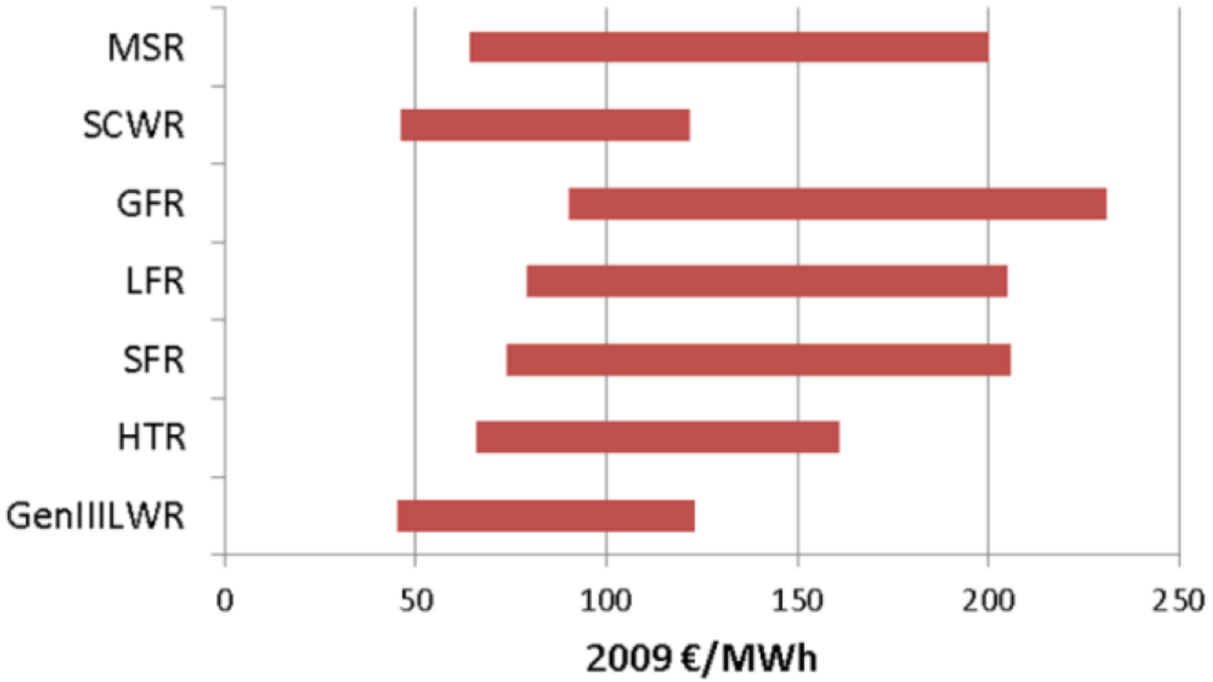
COST OF NUCLEAR ENERGY



[LCOE electricity production options 2020, source: TNO]



LCOE new reactor types [Heek Aliki, 2012]; long term estimates: 5 – 8ct/kWh [ETI, 2020]

Major issues economic performance nuclear energy

- Construction time and licencing.
- Coverage of societal risks and costs of dismantling.
- Deployment in future electricity market in combination with large shares of intermittant renewables

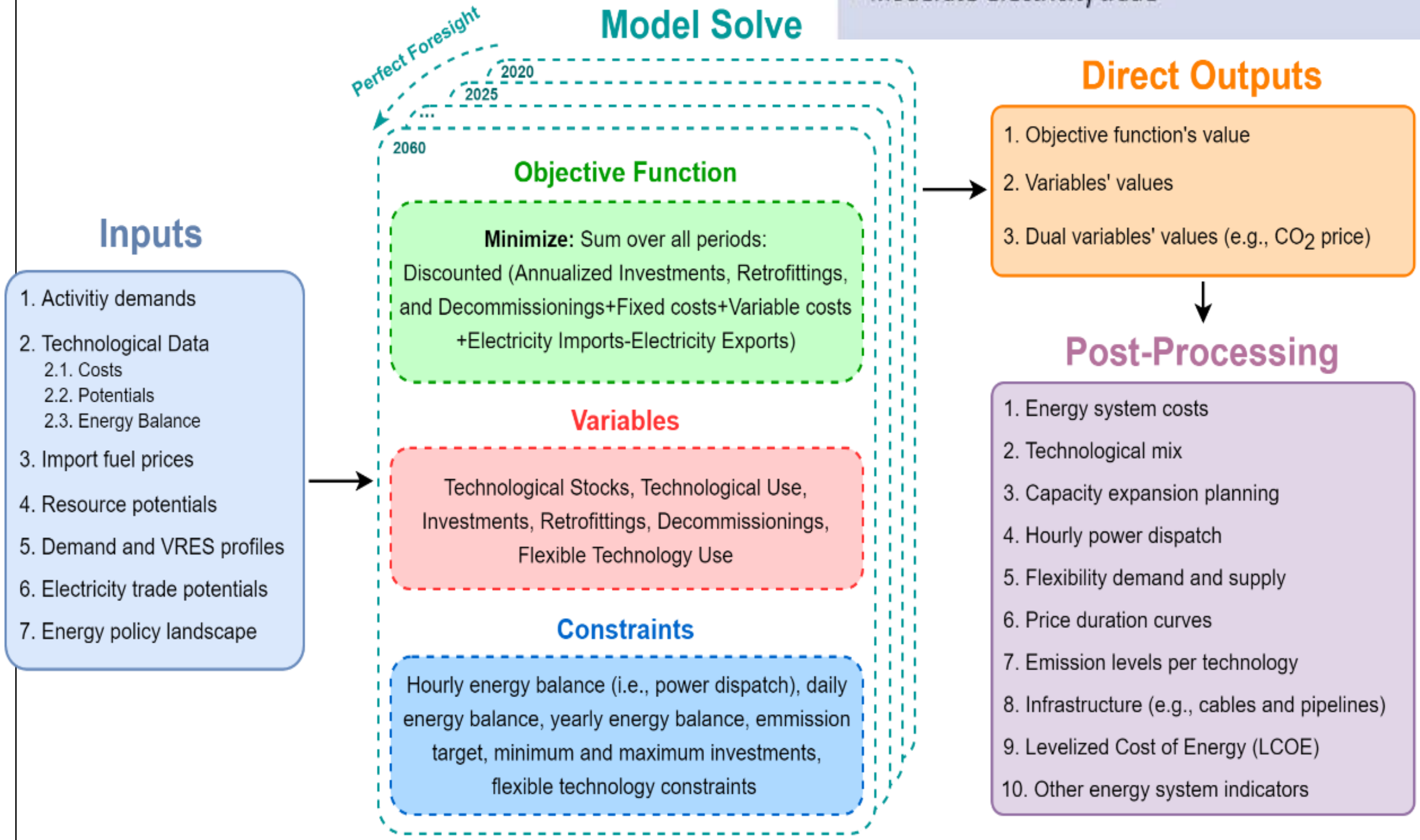
DETAILED INTEGRATED ENERGY SYSTEM ANALYSES; IESA-OPT MODEL

Reference scenario (IESA-Opt)

- High VRES potential
- Moderate hydrogen and biomass import potential
- Business as usual demand growth
- No investments in coal and nuclear
- Climate neutrality by 2050
- Moderate electricity trade

Nuclear scenario (IESA-Opt)

- Based on the reference scenario
- Allowed investment in nucelar power Gen III in the Netherlands with maximum 9 and 12 GWe of nuclear capacity in 2040 and 2050, respectively.
- Maintain the current nuclear power capacity (0.48 GWe) untill 2050

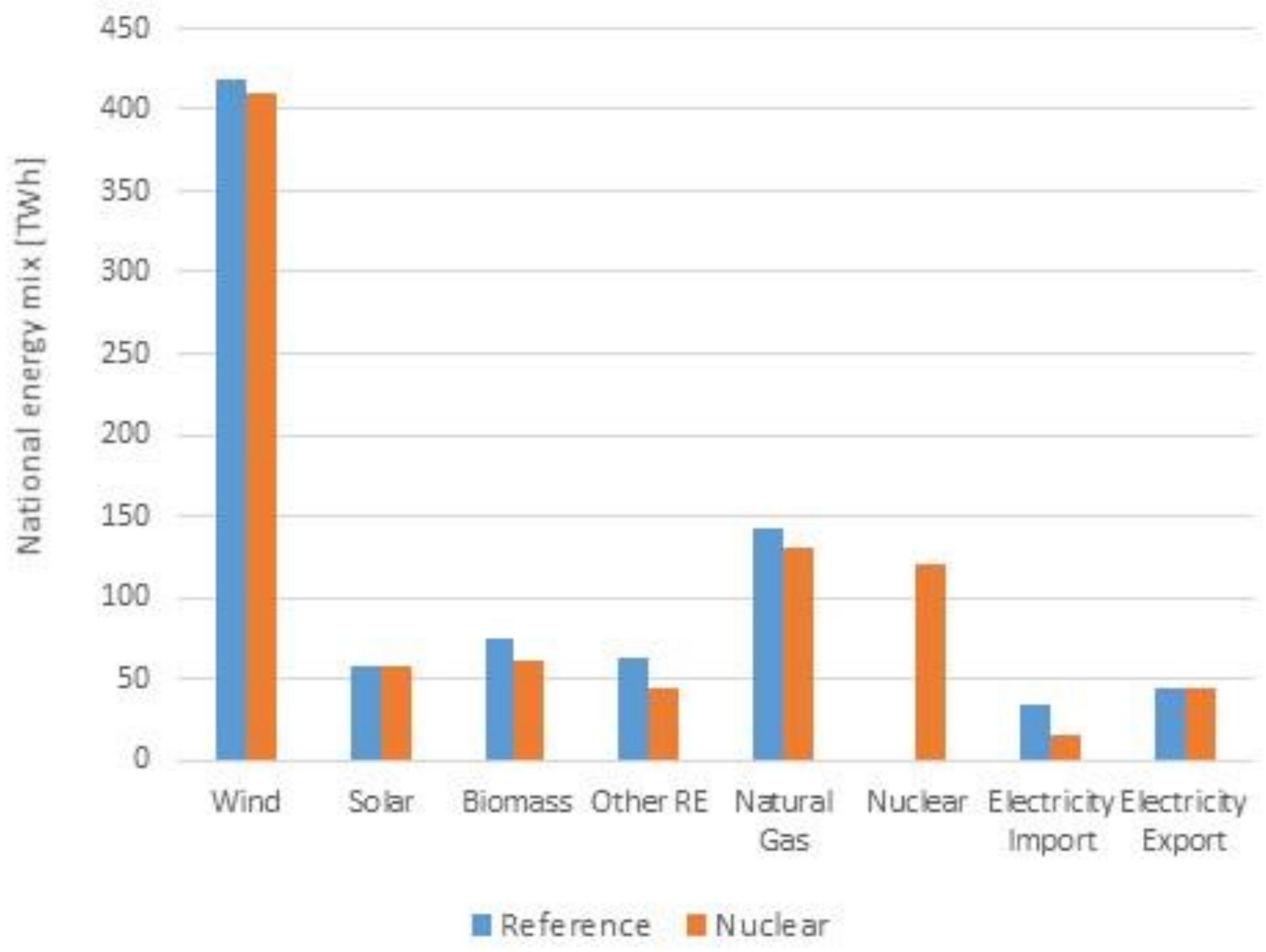


<u>Four key factors</u>:

- System costs (integral!)
- Uncertainty in costs of technologies
- SMR and flexibility
- Cross border trade

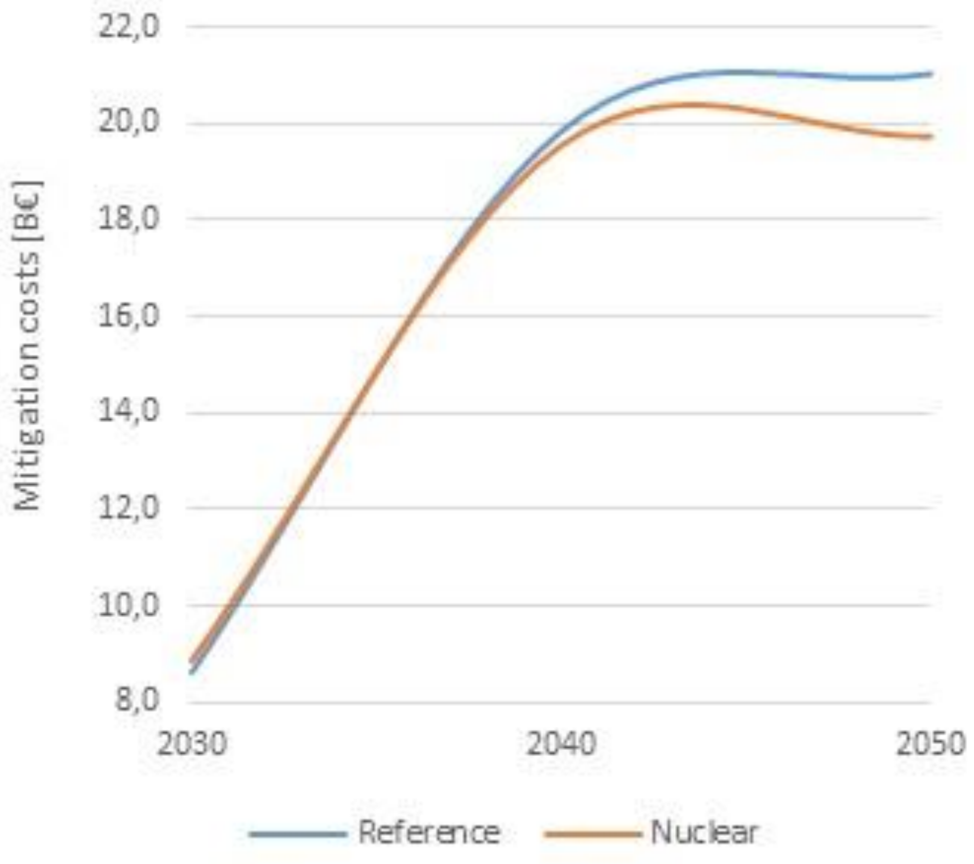
[Fattahi et al., pre-print, 2022 (via Google Scholar)]

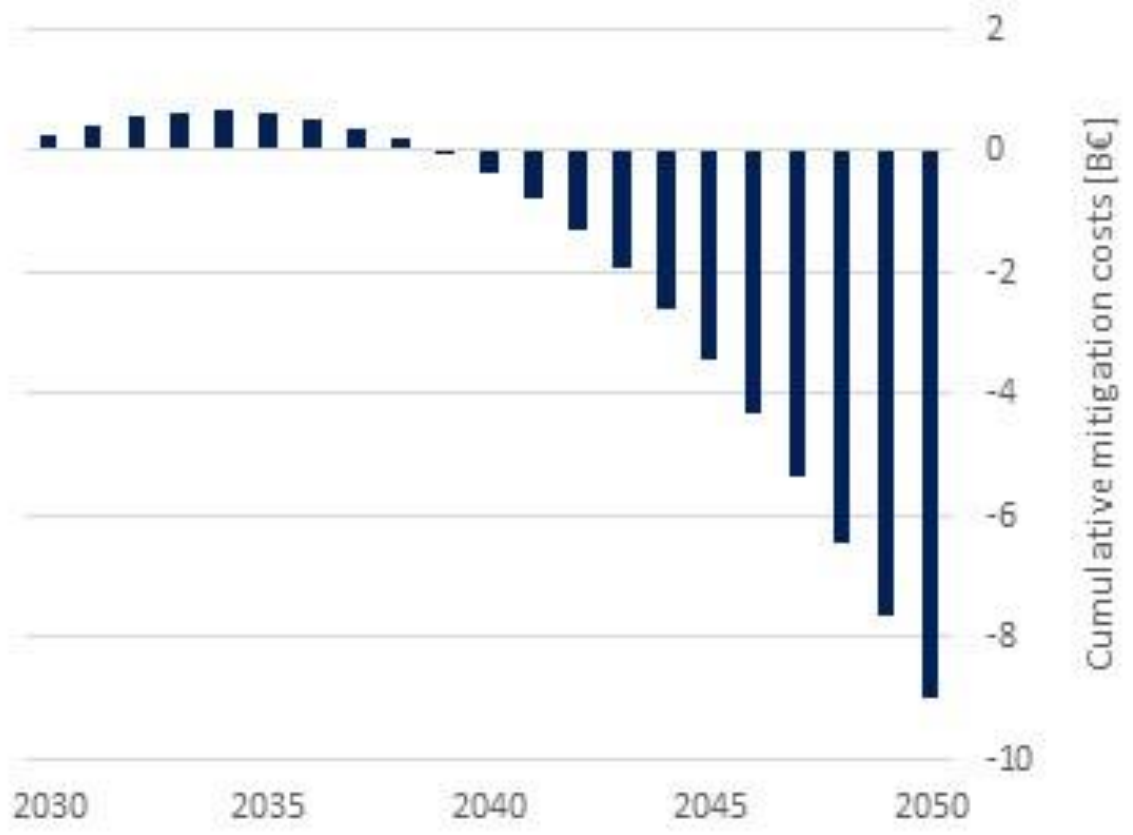
POWER GENERATION MIX



Significant contribution of nuclear
Tot total power generation, but
Limited impact on the overall mix and
Role of wind and solar..

MITIGATION COSTS FOR THE TWO SCENARIO'S





Left: Mitigation costs (B€$_{2019}$) evolution in the reference and nuclear scenarios. Nuclear scenario mitigation costs increase slightly in 2030 but reduce in the long term.
Right: The interpolated cumulative mitigation costs in the nuclear scenario minus the reference scenario. Investments in nuclear power reduce cumulative mitigation costs by 9 B€ in the long term.

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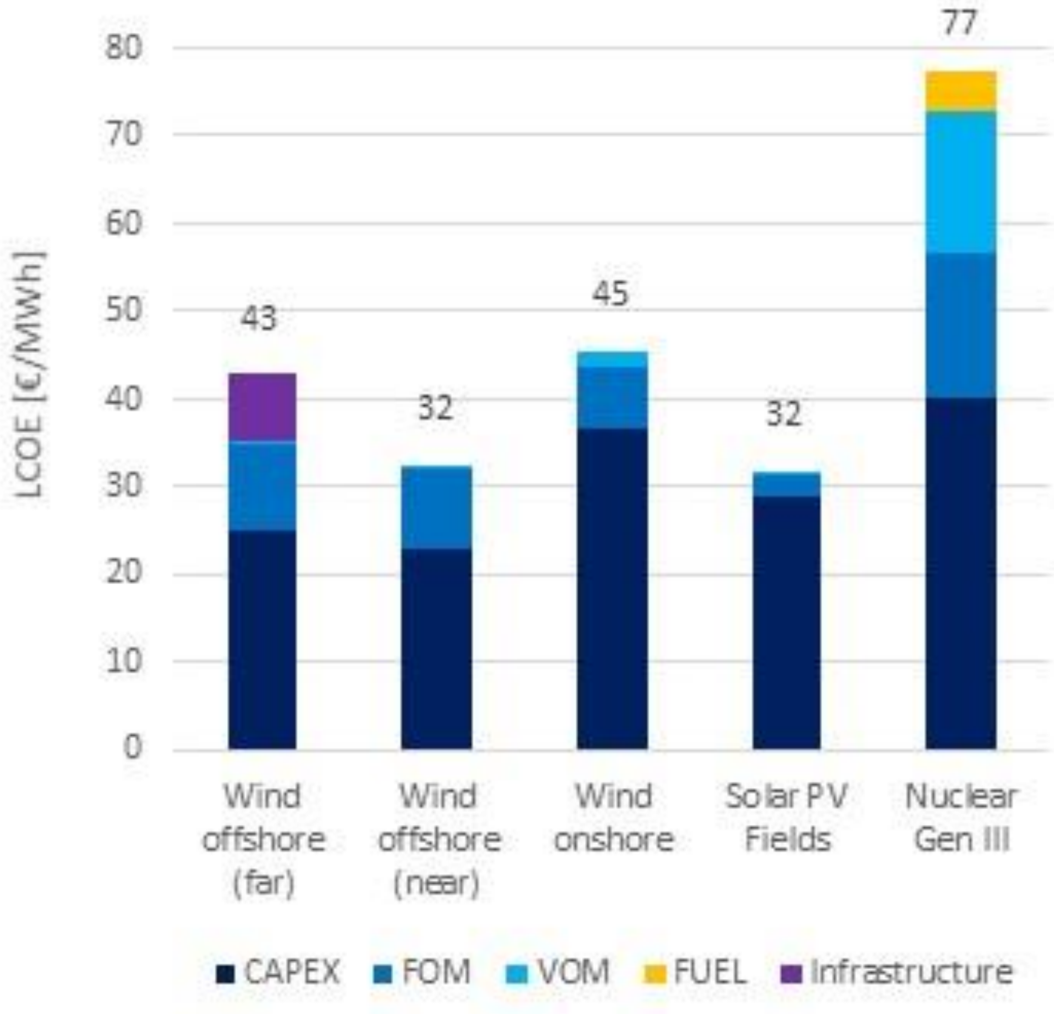
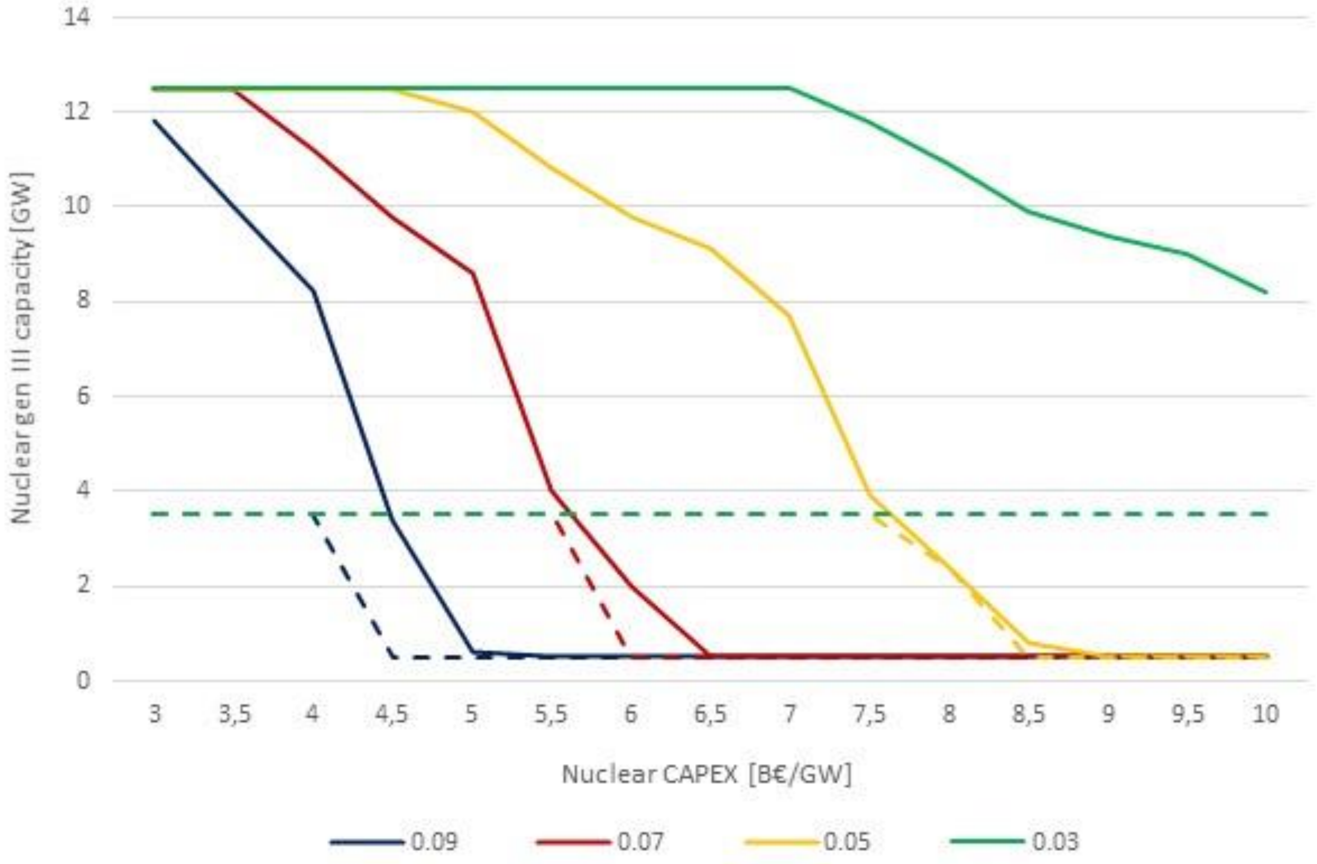
IMPACT OF VARIATION IN CAPITAL EXPENDITURES



The realized LCOEs under the nuclear scenario in 2050 for intermittent renewables and nuclear technologies.



The installed nuclear gen III capacity variations with different nuclear interest rates and capital costs.
Straight lines refer to 2050 investments, while dashed lines indicate the investments in 2030.

INSTALLED NUCLEAR GENERATION CAPACITY (GW) RELATED TO VARIATION IN VRES CAPEX AND NUCLEAR CAPEX

VRES CAPEX	Nuclear gen III capacity [GWe] in 2050											
Highest	12.5	12.5	12.5	12.5	12.5	9.5	7.6	3.7	3.5	3.5	1.2	0.5
High	12.5	12.5	12.5	9.5	9.4	8.2	4.5	3.5	3.5	1.3	0.5	0.5
Mid	12.5	12	10.9	9.6	8.9	7.7	3.9	3.5	1.2	0.5	0.5	0.5
Low	12.5	12	10.9	9.8	8.8	7.7	4	2.1	0.5	0.5	0.5	0.5
Lowest	12.5	12	10.9	9.8	8.7	8	4	1.9	0.5	0.5	0.5	0.5
	4.5	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**8**	**8.5**	**9**	**9.5**	**10**

Nuclear CAPEX [B€/GW]

Installed nuclear generation capacity with variations in the VRES capital costs against nuclear capital costs.

SOME KEY FINDINGS

- Investing in nuclear power can reduce the mitigation costs of the Dutch energy system by 1.6% and 6.2% in 2040 and 2050, and 25% lower national CO_2 prices by 2050.
- However, given all the uncertainties around the cost and technological assumptions, this cost reduction is not significant.
- In addition, this study has shown that lower financing costs (e.g., EU taxonomy support) considerably reduce the relevance of nuclear cost uncertainties on its investments.
- The economic feasibility of national nuclear power investments can vary considerably depending on the cross-border electricity trade assumptions.
- Under the specific assumptions of this study, nuclear power can play a complementary role in supporting the Dutch energy transition from the sole techno-economic point of view.

THE DEBATE ON NUCLEAR ENERGY IN THE NETHERLANDS; ADVICE OF THE COUNCIL ON LIVING ENVIRONMENT AND INFRASTRUCTURE (RLI) PLEADS FOR THOROUGH ANALYSES AND SOCIETAL DEBATE

On the following dimensions:

- Energy security and reliability of the energy system
- Affordability
- Safety
- Sustainability
- Intergenerational justice

And the following key questions

- Is nuclear energy:
- -accelerating the energy transition or not? (realisation time and capacity, lesser energy infrastructure issues)
- - going to be realized/implemented in such a way that the lower part of the cost range is achieved?
- - going to avoid conflicts (e.g. spatial) or increase them (issues on safety and storage of nuclear waste)