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ENERGY RESEARCH

Decarbonising the Dutch power sector

18 May 2021

Based on Aurora Dutch Power Market Group Meeting (March 2021)

Key findings

- As governments throughout Europe are increasing their climate ambitions for 2050, Aurora Energy Research has analyzed what reaching a net zero power system would mean for the Netherlands. In this Strategic Insight Report we compare two scenarios: one based on enhancing current existing policies (Enhanced Policy) and a second one (Revised Policy) in which we optimized for system costs
- In any case, to reach net-zero by 2050, the power system will face radical changes: direct power consumptions doubles, and an additional 50-70 TWh is needed to produce domestic green hydrogen
- The demand for hydrogen will increase fourfold, which requires a mix of locally produced blue and green hydrogen as well as imported hydrogen
- To ensure consistent policy until 2050 the government must make a choice now:
  - Current policies (our Enhanced Policy scenario, in which subsidies for solar and wind are phased out by 2025) can be continued, but will have to be supported by a strong push for electrification and deployment of hydrogen
  - Alternatively, as shown in our Revised Policy scenario, the government chooses a more active policy on wind and solar and goes for a 'contract for difference' system, which reduces the risk for investors
- Our Revised Policy scenario shows a more substantial use of wind and solar capacities and a reduction of cumulative CO_2 emissions by up to 10% by 2050 compared to Enhanced Policy
- Importantly, Aurora shows that subsidizing (or continuing to subsidize) wind and solar could save about €3 billion per year in system costs for the Netherlands, which would bring down total costs by 18% compared to our Enhanced Policy scenario

Aurora's Dutch Power Market Group Meetings

Providing detailed answers to the most pressing questions in the Dutch Power Market, Aurora Energy Research organizes three Group Meetings per year. In a round table setting we discuss our analysis (such as this report) on the Dutch power markets with senior representatives from utilities, renewables developers, financiers, interest groups and the government.

Do you want to know more, or do you have comment or a question? Please reach out to Felipe.vandekerkhof@auroraer.com

Sources: Aurora Energy Research

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Aurora's roots

Founded by academics at the University of Oxford, Aurora Energy Research has grown to become the largest dedicated power market analytics company in Europe, providing data-driven intelligence for strategic decisions in the global energy transformation. We are a team of more than 170 experts covering power, hydrogen, carbon and fossil commodities markets in Europe, Australia and the US. We work with world-leading organisations to provide comprehensive market intelligence, bespoke analytic and advisory services, and cutting-edge software.

Agenda

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I. Reaching Net-Zero in Dutch Power sector in 2050

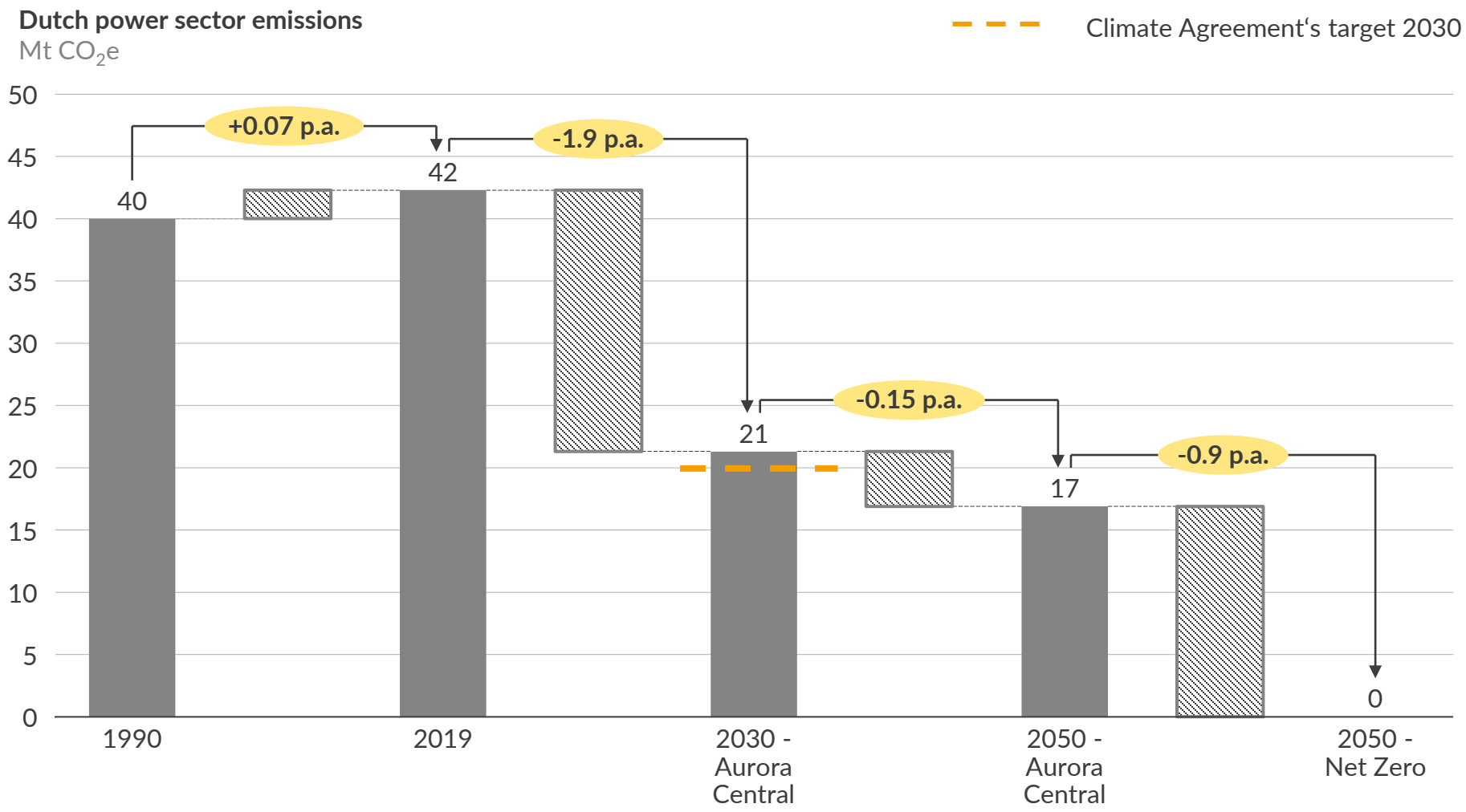
II. Key assumptions

III. Implications of Net-Zero

1. CO_2 emissions
2. Renewable capacities
3. Capture prices
4. Investment cases

IV. About Aurora

On its current trajectory, the Dutch power sector will not reach 'net zero' by 2050



1) Compared to 1990 levels. 2) See *Klimaatwet* Article 2, https://wetten.overheid.nl/BWBR0042394/2020-01-01.

Aurora Energy Research, Rijksoverheid

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Dutch climate commitments

- The Dutch Climate Law states a CO_2 emission reduction target of 95%[1] by 2050, implying a net zero target for the power sector[2]
- For 2030, the Dutch power sector is gearing up to meet the Climate Agreement's target of 20 Mt CO_2e
- Aurora's Central scenario represents our view of the most likely development, reflecting current policy and plausible future changes
- Under Aurora Central, the 2030 target will be missed only narrowly
- In contrast, the path beyond 2030 has not yet crystallised; significant policy amendments are required to reach net zero by 2050

Current policy aims to close coal and nuclear plants, phase out RES subsidies and support H_2; however the path to replace natural gas in power is undefined

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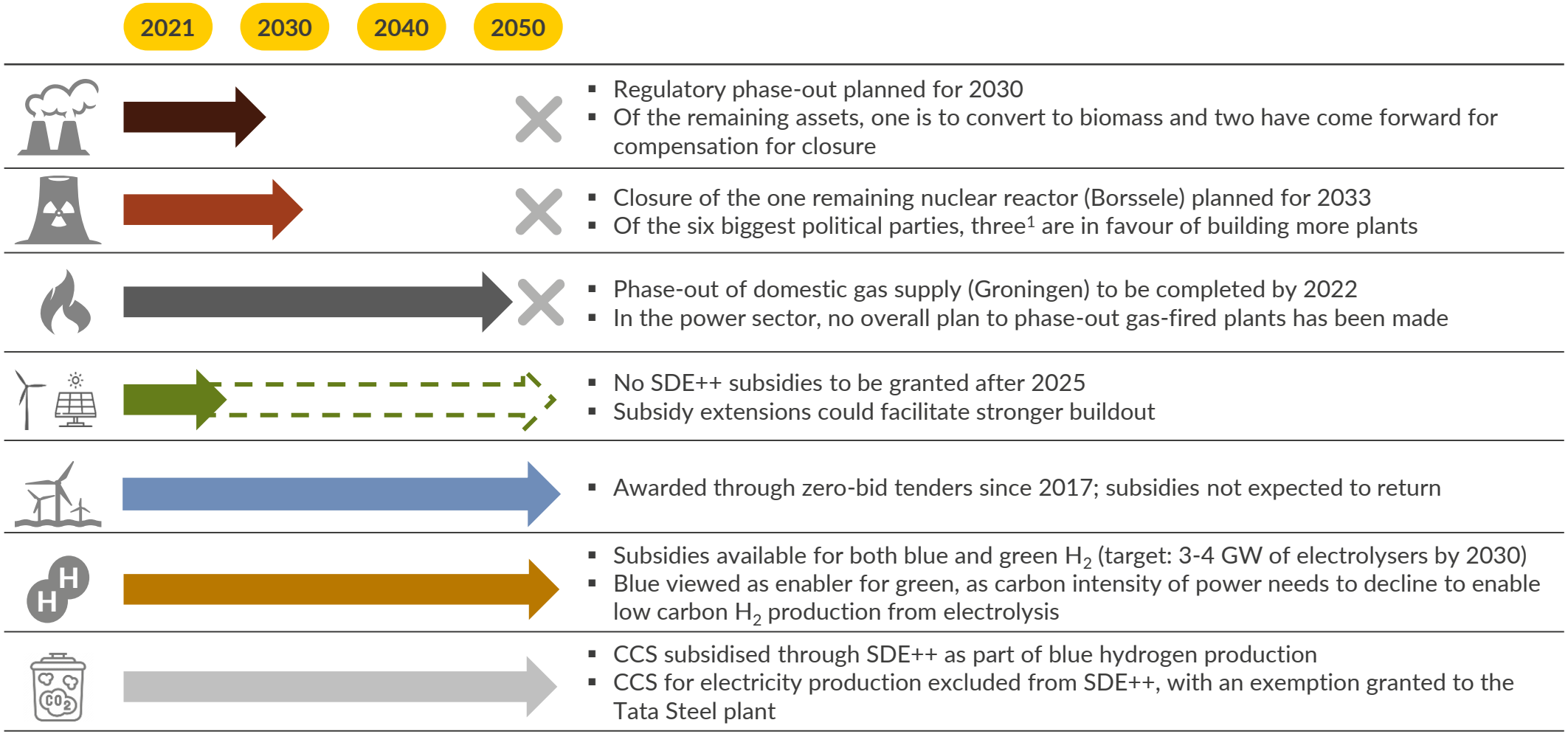
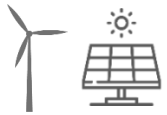


- **Coal**
  - Regulatory phase-out planned for 2030
  - Of the remaining assets, one is to convert to biomass and two have come forward for compensation for closure
- **Nuclear**
  - Closure of the one remaining nuclear reactor (Borssele) planned for 2033
  - Of the six biggest political parties, three[1] are in favour of building more plants
- **Gas**
  - Phase-out of domestic gas supply (Groningen) to be completed by 2022
  - In the power sector, no overall plan to phase-out gas-fired plants has been made
- **Onshore wind & solar**
  - No SDE++ subsidies to be granted after 2025
  - Subsidy extensions could facilitate stronger buildout
- **Offshore wind**
  - Awarded through zero-bid tenders since 2017; subsidies not expected to return
- **Hydrogen production**
  - Subsidies available for both blue and green H_2 (target: 3-4 GW of electrolysers by 2030)
  - Blue viewed as enabler for green, as carbon intensity of power needs to decline to enable low carbon H_2 production from electrolysis
- **Carbon capture & storage**
  - CCS subsidised through SDE++ as part of blue hydrogen production
  - CCS for electricity production excluded from SDE++, with an exemption granted to the Tata Steel plant

1) These are: VVD (People's Party for Freedom and Democracy, heading caretaker government on 9 March 2021), PVV (Party for Freedom, in opposition on 9 March 2021) and CDA (Christian Democratic Appeal, in opposition on 9 March 2021).

Source: Aurora Energy Research

Neighbouring countries' approaches to 'net zero' differ significantly and will directly affect the development of the Dutch power market

	▪ Commitment to net zero power sector by 2050	▪ Supports increased CO_2 reduction goals from EC	▪ Advisory council recommends net zero power sector by 2035	▪ Commitment to net zero power sector by 2050
	▪ Target of 65% RES by 2030, however slow progress in particular for onshore	▪ Regional renewables schemes	▪ Government target of 40 GW of offshore wind by 2030	▪ Targets: 6 GW wof, 35 GW won and 44 GW sol by 2028
	▪ Strategy is focused on green hydrogen and industry offtake	▪ Regional hydrogen strategies paint important role for H_2	▪ National target of 5 GW of low carbon H_2 production by 2030	▪ H_2 strategy targets 6.5 GW of electrolyser capacity by 2030
	▪ CCS is currently banned	▪ CCS projects with Port of Antwerp consortium discussed	▪ Govt. plans to support at least one power CCUS project by 2030	▪ CCS is not a priority
	▪ Nuclear generation will be phased out by 2022	▪ Nuclear generation will be phased out by 2025	▪ Builds new nuclear plant and plans a commercially viable fusion reactor by 2040	▪ Decommissioning, extending and building of reactors planned ▪ Overall target is to ramp down
Uncertainties for the Dutch market	▪ **Slower than expected RES buildout could further increase power price after coal and nuclear phaseout**	▪ **Nuclear phase-out would create a tight market, hence extra demand from NLD**	▪ **Achievement of ambitious offshore targets would make for cheap exports to NLD (BritNed), potential risk for merchant RES**	▪ **Limited availability of nuclear reactors would have a destabilising effect on Dutch prices**

Source: Aurora Energy Research

We have analysed two possible pathways towards net zero in 2050: 'Enhanced Policy' and 'Revised Policy'

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	Aurora Central	Enhanced Policy (EP)	Revised Policy (RP)
Scenario description	Aurora view on the most likely development, corresponds with a 3°C trajectory	Net zero emission targets are met by building on and enhancing current policies	Net zero targets are met by revising current policies, to optimise on system costs
Onshore wind & solar	Subsidy phase-out by 2025 with capacity of 18 GW expected by then		Continued subsidies beyond 2025 (21 GW by 2025, 31 GW by 2030; 73 GW by 2050)
Offshore wind	Planned pipeline for offshore wind through zero-bid tenders	Enhanced pipeline for offshore wind compared to Central beyond 2030 (zero-bid tenders)	Reintroduced SDE++ style subsidies for offshore wind (33 GW by 2050)
Thermal plants	Buildout of gas plants permitted without regard for CO_2 emissions	Phase-out of existing gas-based assets via emission budgets (starting 2037), no new post-combustion CCS buildout	
Hydrogen production	Subsidies for H_2 as announced for the SDE++ (3 GW blue, 3 GW green by 2050)	Subsidies for H_2 with blue to replace the grey fleet and green buildout thereafter (5 GW blue, 10 GW green by 2050)	Subsidies for H_2 with the cheapest form to prevail (8 GW blue, 20 GW green by 2050)
Carbon capture & storage	CCS support for blue hydrogen limited to 10.2 Mt/year	Continued support for CCS as part of blue hydrogen	
Electricity & H_2 demand	Limited growth of electricity and H_2 demand	Strong government push for conversion to electricity and hydrogen, away from fossil fuels	

Source: Aurora Energy Research

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Direct power demand is expected to increase due to electrification in a net zero transition and by an additional 60% including electrolysis

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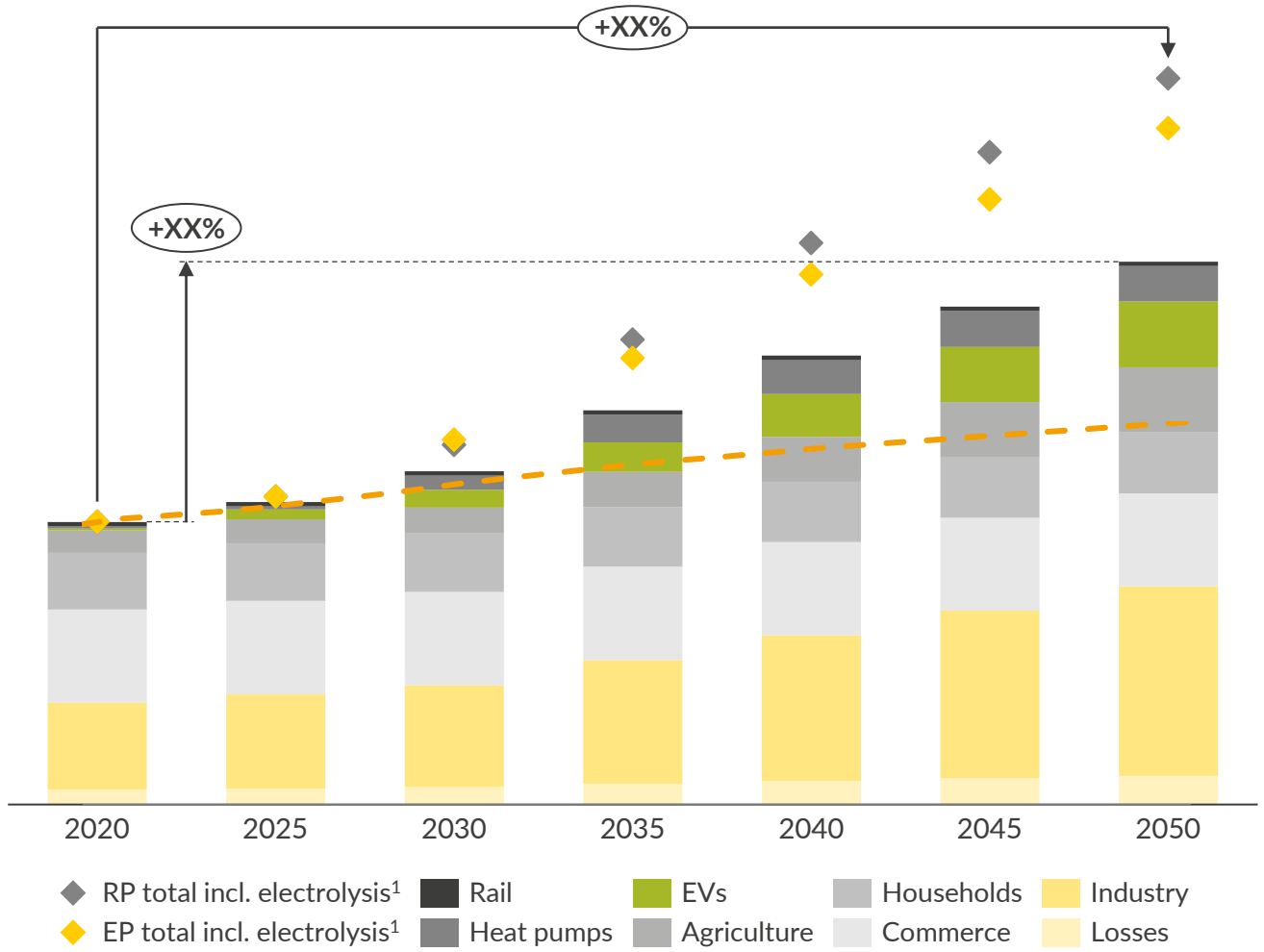
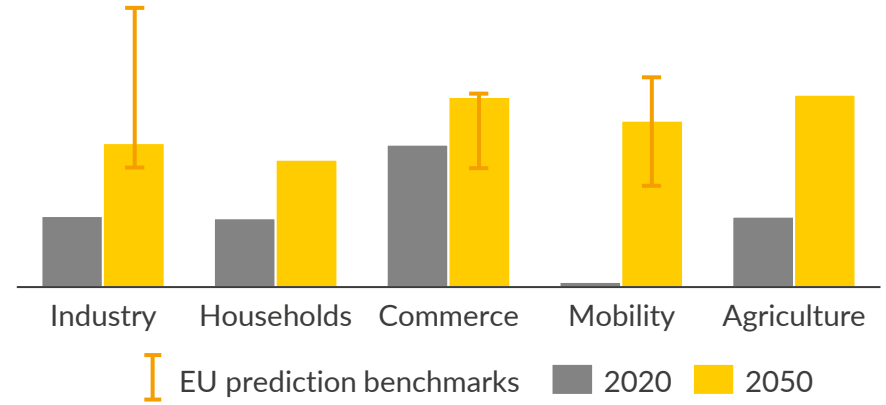
Power demand in the Netherlands

TWh



Electricity share of total final energetic demand[2]

%



- Growth in direct power demand is driven primarily by strong electrification of most sectors
- This is partially offset in some sectors by decreasing total energy demand (households) or decreasing real output (some industry subsectors – see next slide)
- Aurora's prediction for electrification shares in the Netherlands is in line with net zero predictions for the EU
- Hydrogen electrolysis adds significantly to total demand by 2050, although this amount is highly uncertain, depending on both market development and policy choices

Aurora Central November 2020

1) Across the two net zero scenarios, power demand assumptions differ only with respect to demand for electrolysis. 2) Includes demand for (ambient) heat, e.g. from heat pumps.

Source: Aurora Energy Research

Hydrogen demand grows with more than 250%, which stems primarily from industry, in Aurora's net zero view

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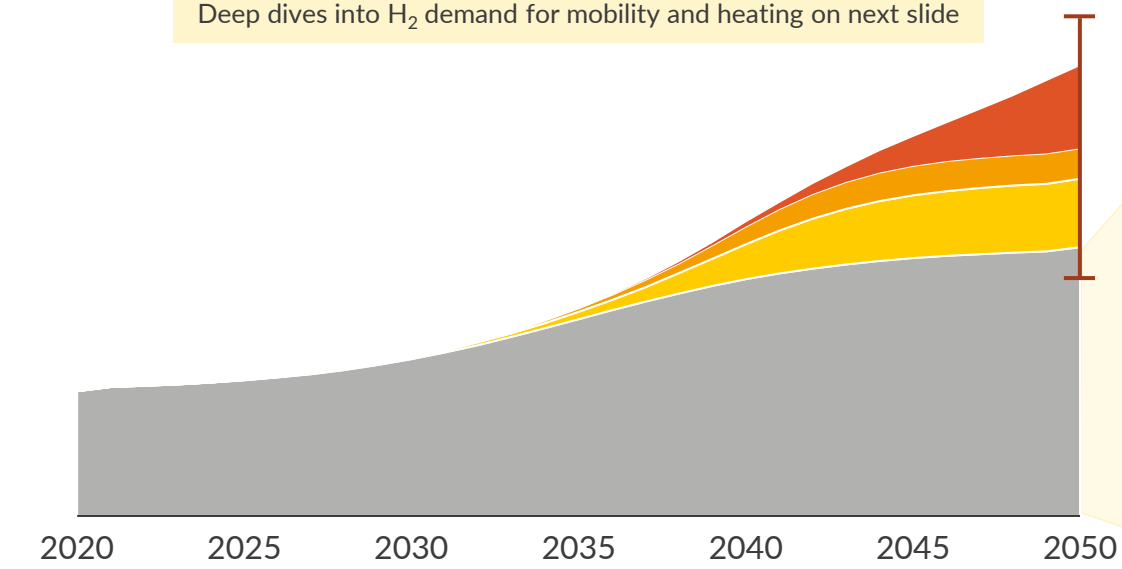
Total annual hydrogen demand by sector for both scenarios

TWh H_2

Deep dives into H_2 demand for mobility and heating on next slide

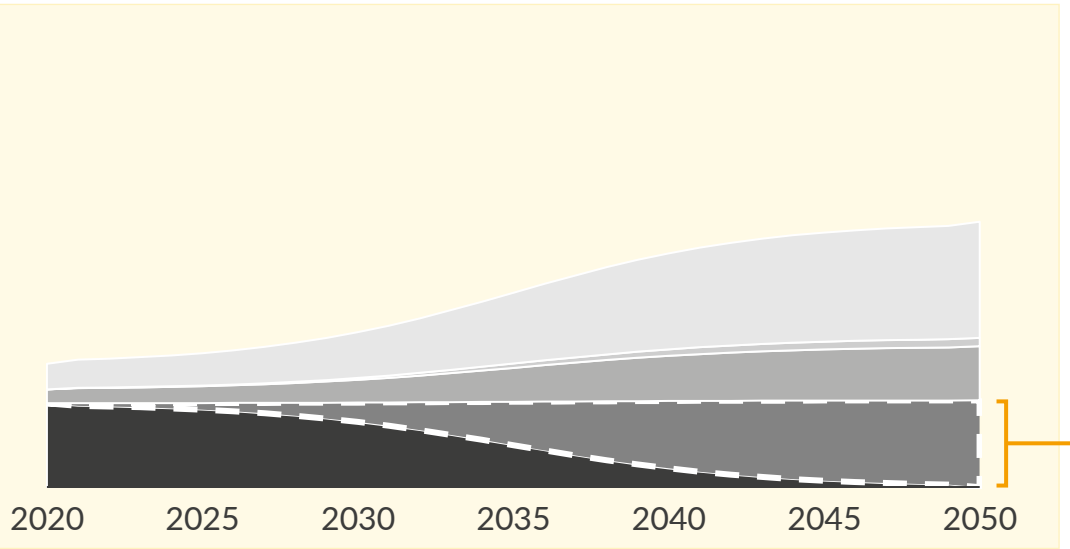


Power (Enhanced Policy)[2] | Mobility | External benchmarks
Heat | Industry

- The bulk of Dutch hydrogen demand will continue to stem from industry
- The conversion of process heat to hydrogen is an important driver of this growth
- Whilst this demand could be met domestically, this is not necessarily the cheapest option

Hydrogen demand for industry by process

TWh H_2



Other chem. and process heat | Cement | Refineries | Steel | Fertiliser

- The chemical industry is expected to convert a large portion of its process heat supply to H_2
- During the 2030s, ammonia production will be replaced by imports, due to cheaper production options abroad and its relative ease of transportation
- We assume that the Netherlands' one steel plant is converted to use H_2 instead of CO_2-intensive coke. This alone is responsible for 20-25 TWh of demand.

1) In their study *Klimaatneutrale Energiescenario's* Berenschot & Kalavasta explore four scenarios: *Regionale Sturing, Nationale Sturing, Europese CO_2-sturing and Internationale Sturing*. The indicated bandwidth of hydrogen demand reflects the variation between the scenarios 2) Demand from power in the Revised Policy scenario deviates too little from the Enhanced Policy to merit showing.

Sources: Aurora Energy Research, Berenschot & Kalavasta, TNO

In mobility and heating, Aurora foresees hydrogen uptake for heavy goods vehicles and older houses

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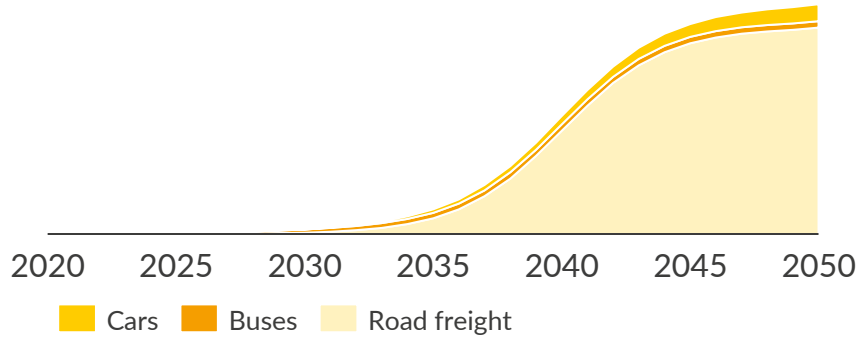
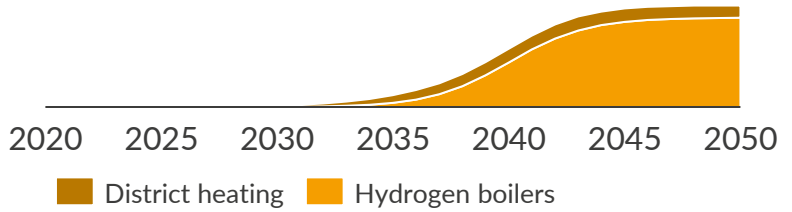
Hydrogen demand for mobility by sector
TWh H_2



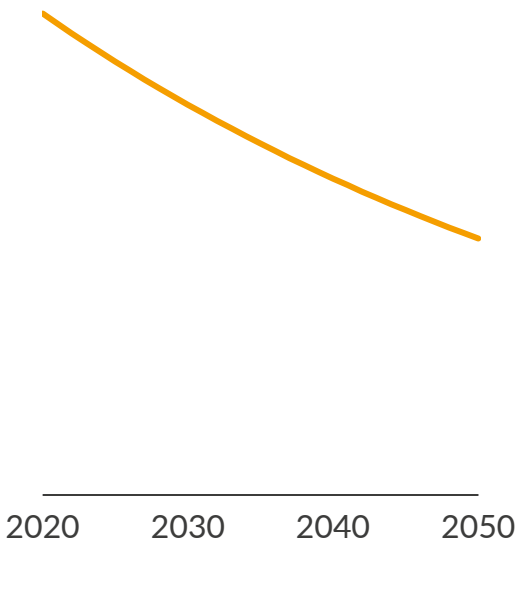
- By 2050, half of road freight will be powered by H_2, with the rest equally split between batteries and biofuel
- Buses will see the quickest uptake of H_2 fuel cell technology, but with limited total potential
- Only 5% of passenger cars will run on hydrogen by 2050, with the remaining 95% battery electric vehicles

Hydrogen demand for building heat
TWh H_2



- Better-insulated, more efficient buildings drive a strong decrease in heat demand
- A small portion of domestic heat demand will be covered by hydrogen boilers, concentrating on older, less insulated homes
- In district heating, hydrogen is forecasted to be primarily used for peak and potentially for CHPs at moments of high electricity prices

Heat demand for the built environment
TWh heat



The transition to 'net zero' is expected to be accompanied by lower gas prices and higher carbon prices

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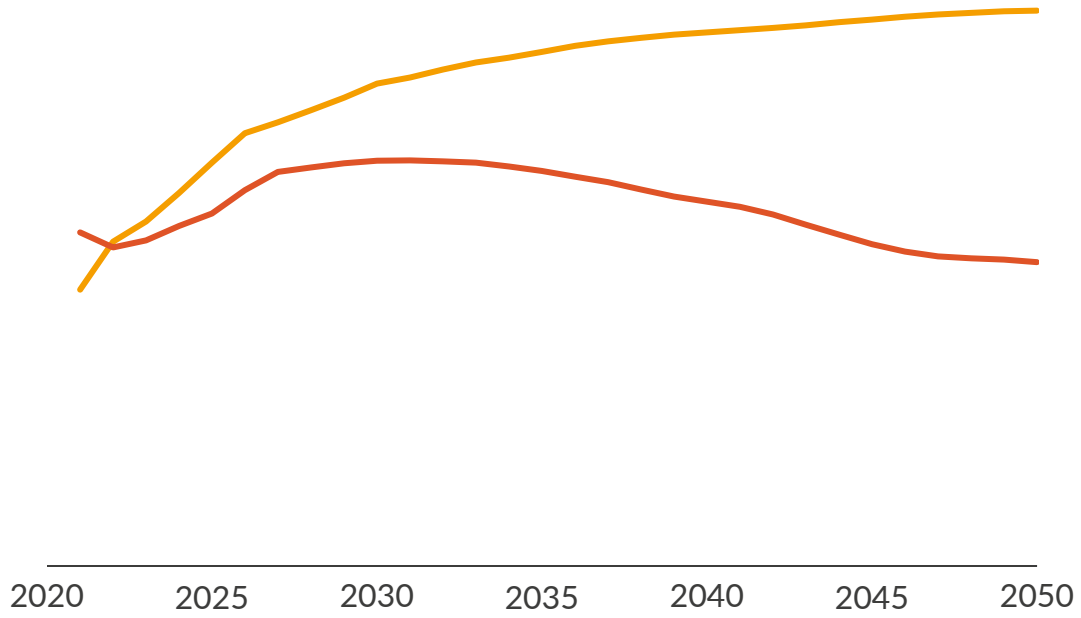
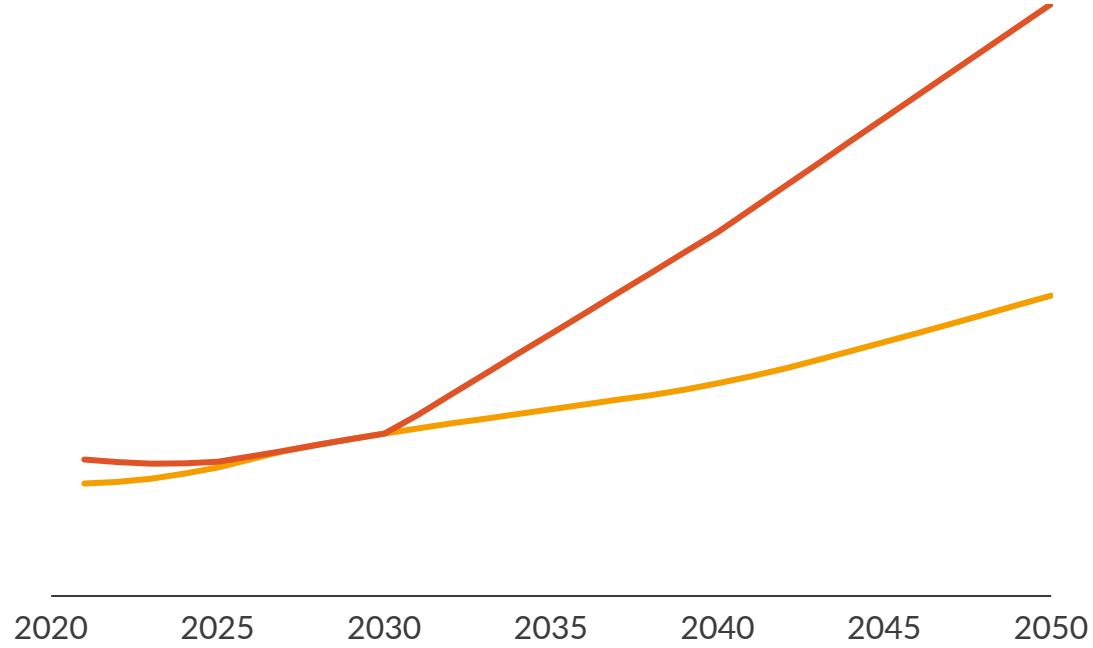
Gas prices
€/MWh (real 2019)



- In our 'net zero' analysis, the gas price is expected to increase to 2030, driven by coal-to-gas switching and rising global LNG demand
- From 2030 onwards prices start to decline, falling up to 2050
- This trend is due to Asian gas demand falling with growing renewable penetration, which drives down the marginal cost of LNG shipments to Europe

Carbon prices
€/tCO_2 (real 2019)



- Higher carbon prices are expected with stringent Net Zero targets
- We assume a rise in carbon prices by 2050, reflecting the required marginal abatement across most sectors to decarbonise

Historical — Nov 2020 Central — Net Zero

Source: Aurora Energy Research

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IV. **About Aurora**

Due to lower thermal generation, 'Revised Policy' saves >70 Mt in cumulative power sector emissions by 2050, twice today's annual output

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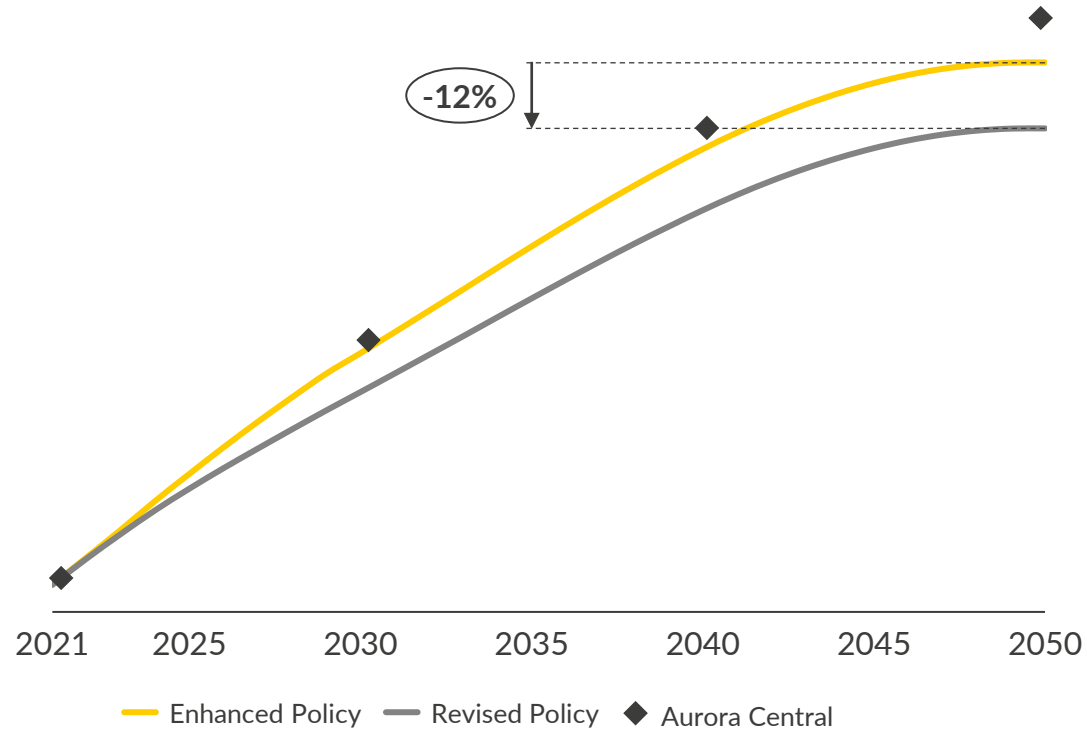
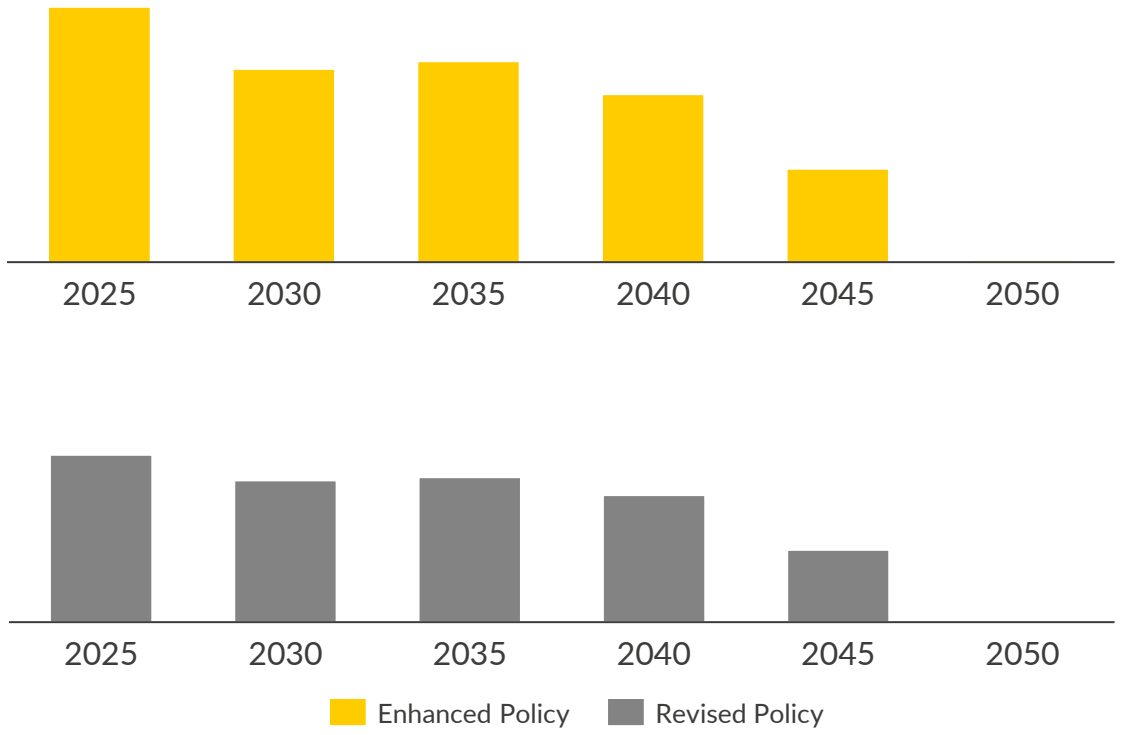
Cumulative emissions from the Dutch power sector (starting 2021)
Mt CO_2e



Annual emissions from the Dutch power sector
Mt CO_2e



- As thermal production ramps down earlier, cumulative emissions by 2050 are >70 Mt CO_2e lower in the Revised Policy than in the Enhanced Policy scenario
- On top of this reduction in national emissions, the Netherlands imports less power from Germany, leading to further emission reductions across borders

- In the Revised Policy scenario, the Dutch power market sees a faster phase-out of gas generation assets as lower prices lead to worsening of economics
- This acceleration is facilitated mainly by significantly more renewables generation

Reaching ‘net zero’ by 2050 requires renewables capacities a factor 7–8 higher than today, or additions of about 3 GW per year

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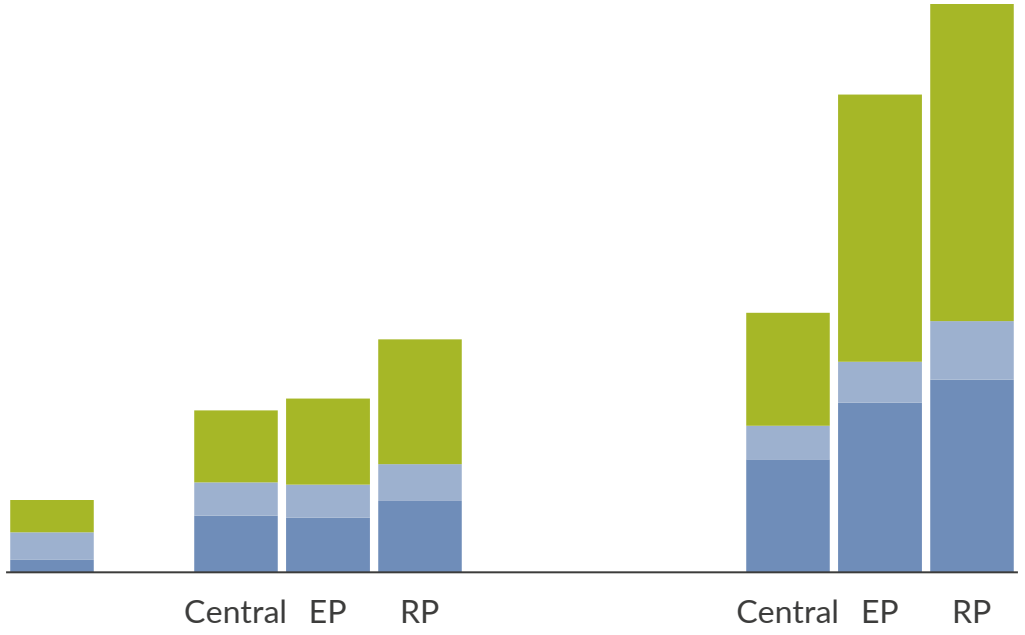
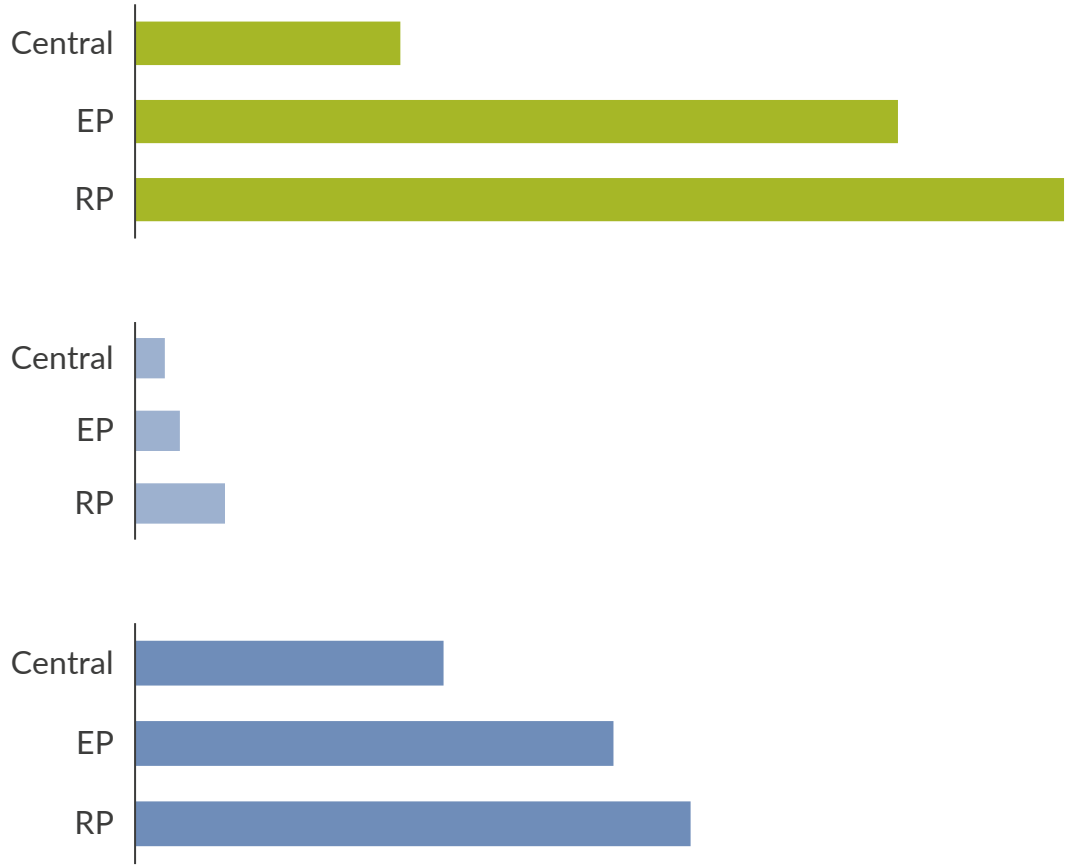
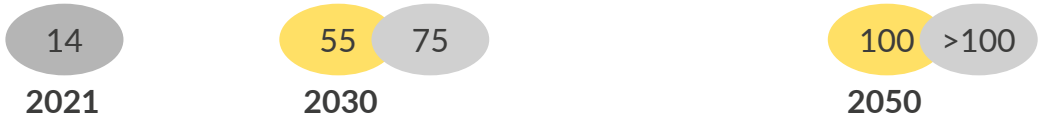
Installed intermittent renewables capacity
GW



Required annual net buildout
GW



Appx. share of renewable production in direct consumption[1]
%



1) Excludes demand from electrolysers and supply from green hydrogen.

While strong buildout cannibalises renewables capture prices, the additional demand from electrolysers has a stabilising effect

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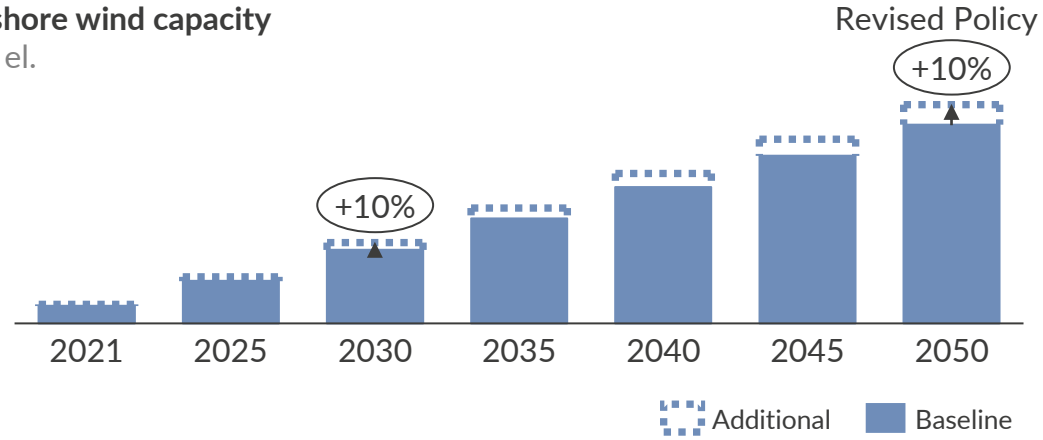
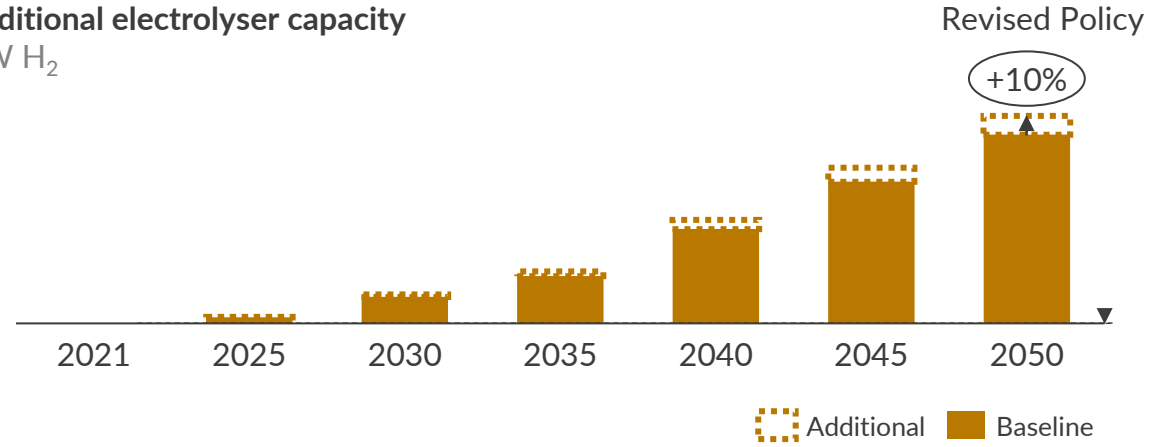
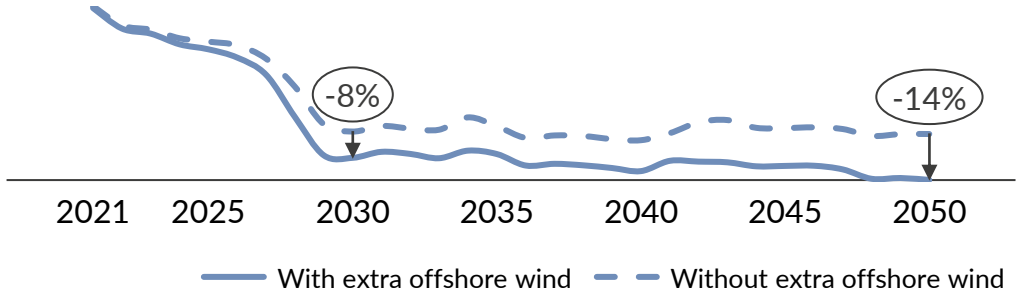
Offshore wind capacity
GW el.



Additional electrolyser capacity
GW H_2



Offshore wind capture price
EUR/MWh (real 2019)



Offshore wind capture price
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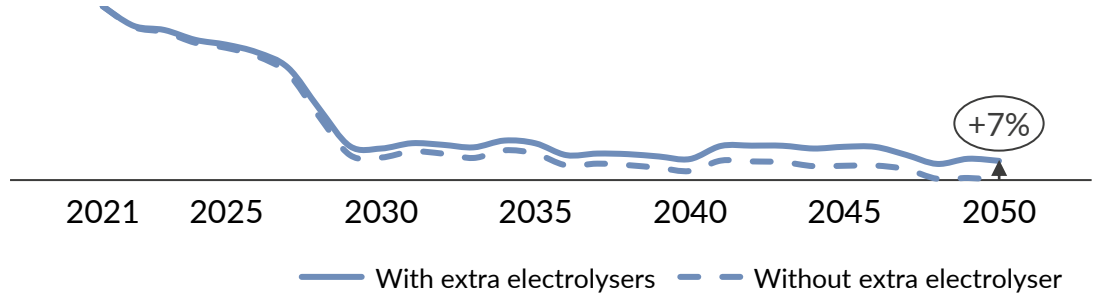

- Additional offshore wind buildout depresses the offshore wind capture price
- In Aurora's Revised Policy scenario, 10% of additional offshore wind buildout in 2050 decreases the capture price by 14%

- On the other hand, electrolyser buildout boosts capture prices
- The positive effect is due to increased power demand from electrolysers during periods of excessive RES production

1) Including demand from electrolysers.

In ‘Enhanced Policy’, required renewables buildout is met on a merchant basis; higher level in ‘Revised Policy’ necessitates further subsidy support

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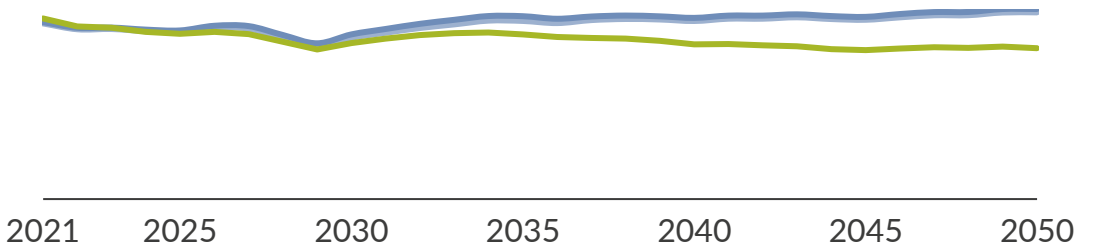
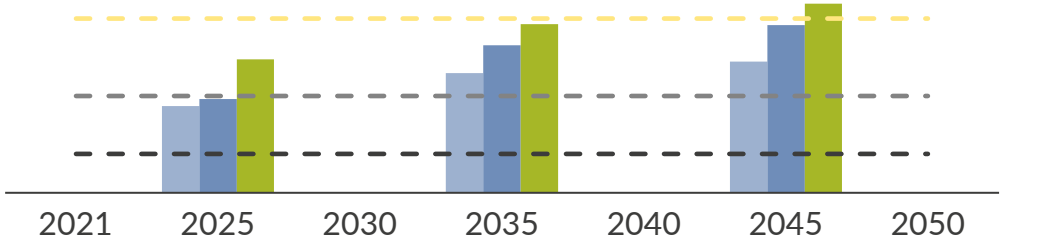
Capture prices
EUR/MWh (real 2019)

Enhanced Policy



Internal rate of return
%

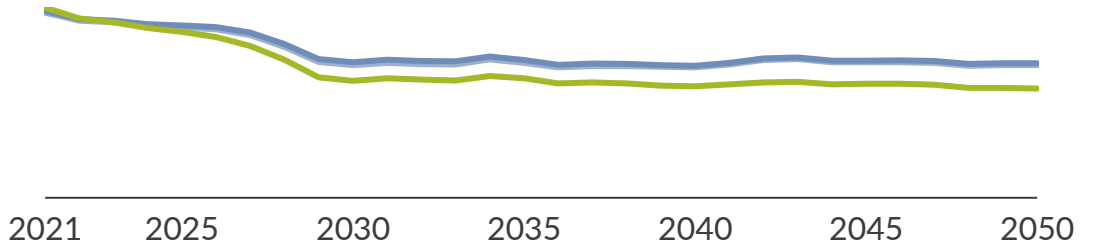
Hurdle rates
%



- In EP, solar and onshore wind will not be subsidised after 2025 and subsidies for offshore wind will not return
- Rather, renewable buildout is supported indirectly through incentives for electrification and hydrogen demand

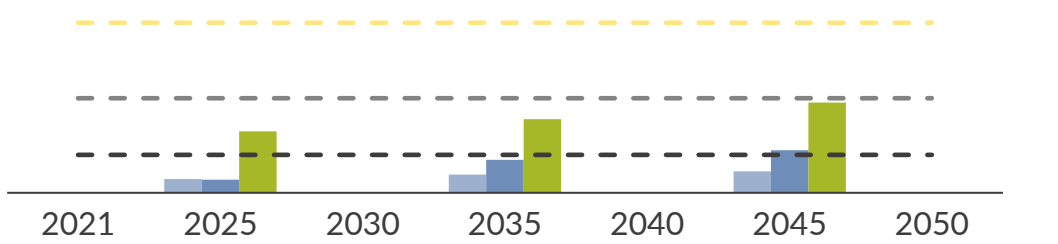
Capture prices
EUR/MWh (real 2019)

Revised Policy



Internal rate of return
%

Hurdle rates
%



- In RP, RES subsidies are extended for onshore wind and solar and return for offshore wind (e.g. through a CfD scheme)
- The high buildout depresses capture prices and consequently bring IRRs of merchant assets down to a range that is close returns for subsidised assets

Onshore wind | Offshore wind | Solar | Supported renewables: 2% | Corporate PPA assets: 5% | Merchant-risk assets: 9%

Source: Aurora Energy Research

Market: 'Net zero' can support today's merchant investments if buildout follows a market-based approach; more subsidised RES are the key risk

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- Reaching 'net zero' with strong demand incentives but market-based supply buildout as in 'Enhanced Policy' leads to baseload prices stabilising between 55-65 €/MWh and is compatible with merchant renewable investment.
- Capture prices for wind approach and solar stay high enough, enabling merchant renewable investments over the coming decade to reach high single-digit returns.
- Electrolysers will become investible without support in the 2030s as competition from blue hydrogen is limited.
- Thermal investments require a clear transition strategy from 2030 onwards. Aiming for CCS retrofits is risky; the requirements for new gas-fired generation to be 'hydrogen ready' will become more important.

- The main risk to merchant investment is a return to subsidised buildout on a more ambitious trajectory. In 'Revised Policy' this leads to a decrease in baseload prices
- Capture prices for wind and solar fall. In such an environment, merchant investments would face low one-digit returns over the coming years.
- Blue hydrogen playing a larger role in the supply mix presents a risk to electrolyser merchant revenues.
- In 'Revised Policy', thermal investments face lower overall revenues and higher volatility.

- Even in a net zero system with a high amount of subsidised renewables extra (flexible) demand, high marginal cost of clean thermal capacity and European market integration limit downside risks for current merchant renewables significantly.

Source: Aurora Energy Research

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IV. **About Aurora**

Aurora provides data-driven intelligence for the global energy transformation

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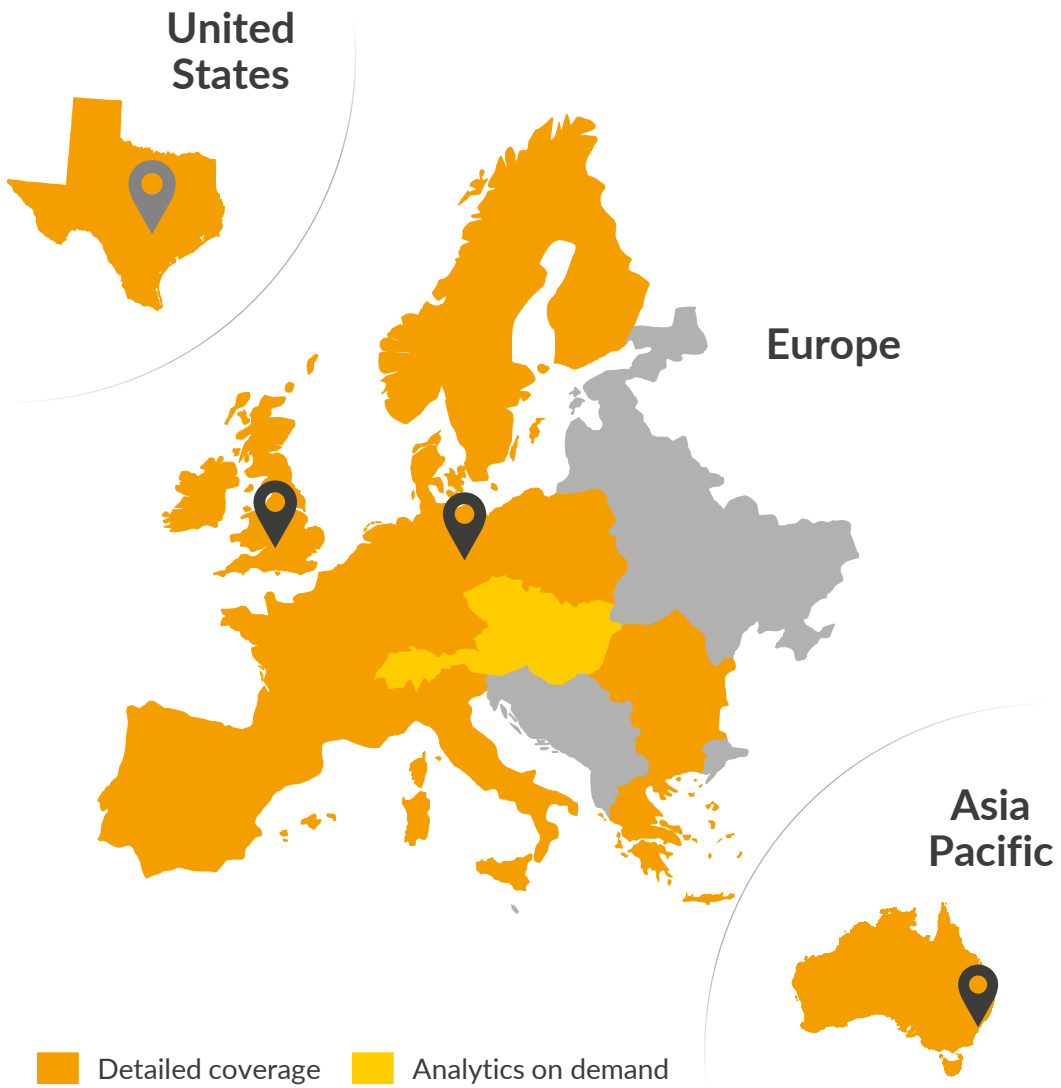
- Power markets
- Renewables
- Storage
- Electric vehicles
- Hydrogen H_2
- Carbon CO_2
- Natural gas



3 Offices
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175+
market experts

350+
subscribing companies

90+
transactions in 2020

Source: Aurora Energy Research

Aurora brings a sophisticated approach to the provision of analysis and insight to the energy industry

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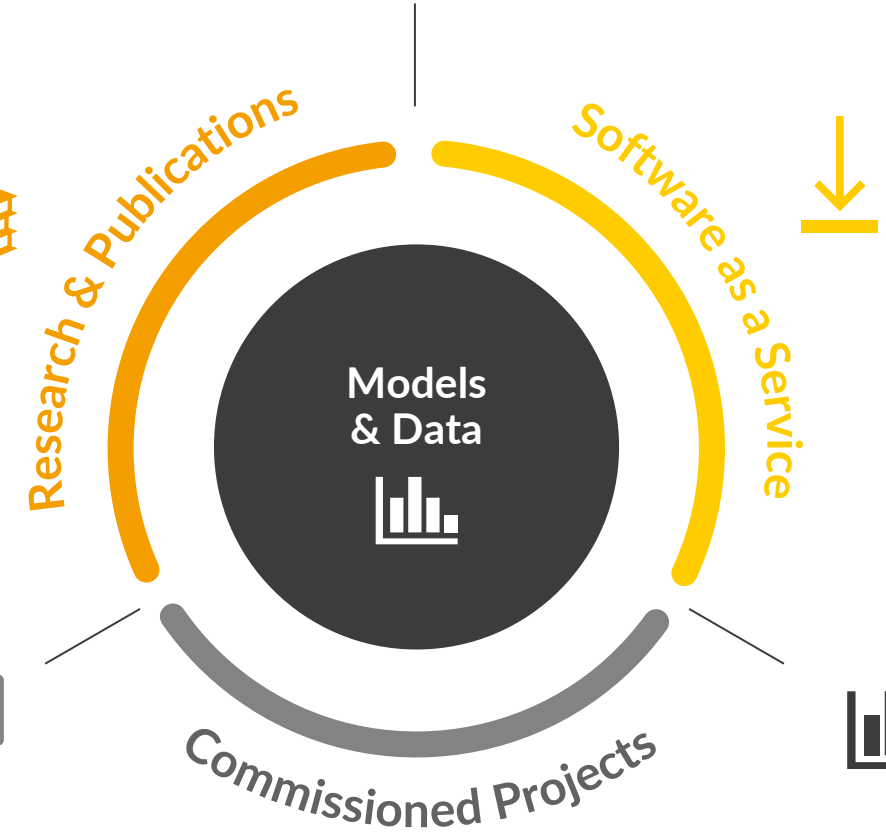
Research & Publications

- Industry-standard market outlook reports and price forecasts for power and gas markets
- Read and constantly challenged by over 350+ subscribers from all industry sectors

Software as a Service

- Cloud-based tools for quick, accurate, asset- and site-specific valuations using Aurora's trusted forecasts
  - First-of-a-kind wind tool launched in 2019 and already widely adopted in GB, Germany, France, Iberia, Poland and Australia



Commissioned Projects

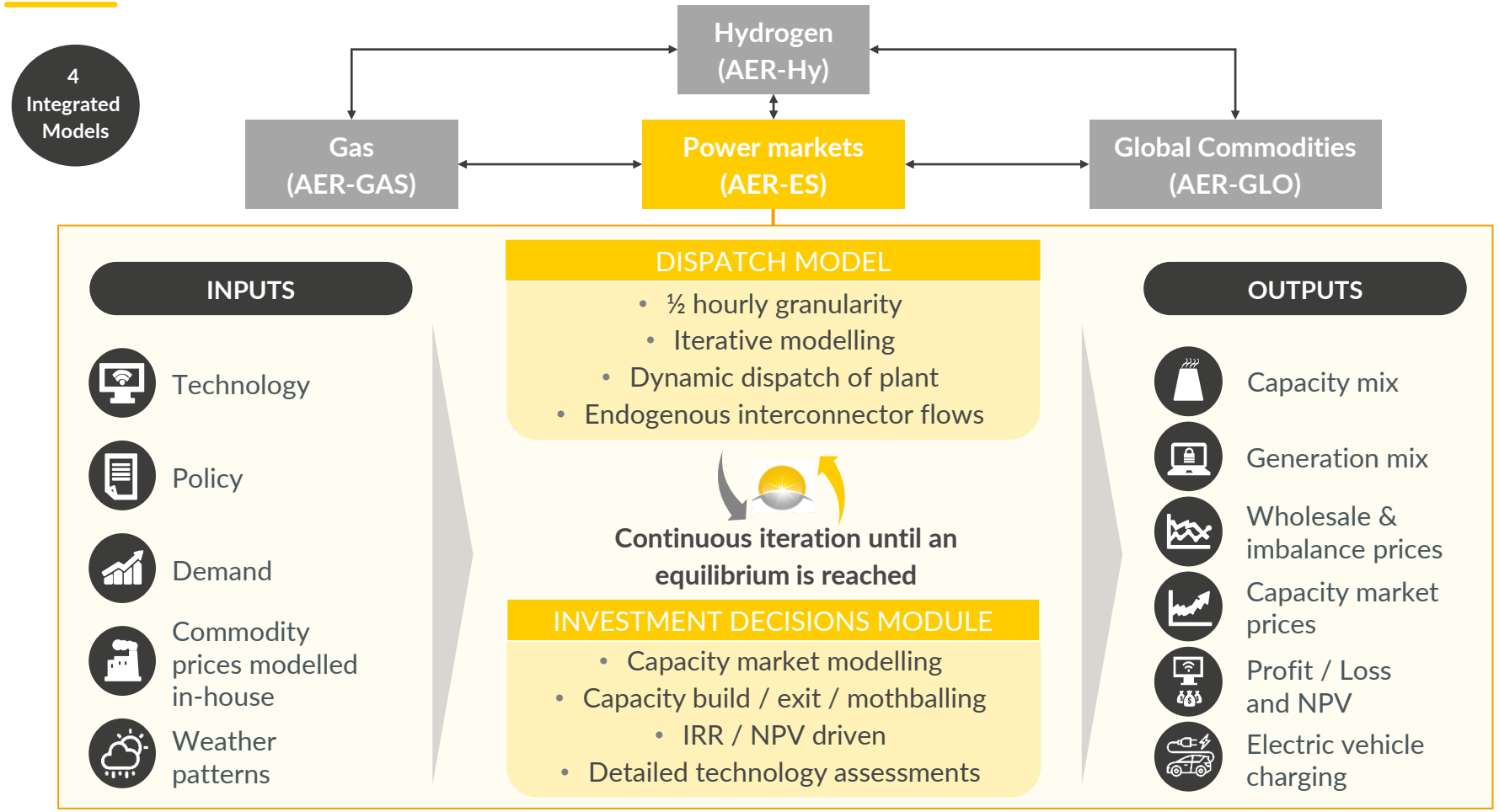
- Bespoke analysis, drawing upon our models and data
- Trusted advice for all major market participants proven in 400+ projects: transaction support, valuations, strategy & policy engagement

Models & Data

- Market-leading long-term models for power, gas, carbon, oil and coal markets
- Continuous model improvements through client feedback

Source: Aurora Energy Research

Our analysis of power markets uses our unique, proprietary, in-house modelling capabilities



Up to 70
specifications modelled for each plant

c. 55k
investment hours on modelling capabilities

3k - 4k
model runs per week

30+
strength of modelling team globally

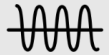
AURORA

Advantages of our approach:

- Aurora have invested heavily in developing our dispatch models since 2013 and believe they are the most sophisticated available
- Our models have been rigorously tested and refined in a wide range of client contexts
- Flexible and nimble because we own the code
- Transparent results
- State-of-the-art infrastructure
- Zero dependence on black-box third-party software (e.g. Plexos)
- Constantly up to date through subscription research
- Ability to model complex policy changes quickly

Through substantial & ongoing investment, our models have important capabilities that other models do not

AURORA

Endogenous entry and dispatch 	▪ Proprietary iterative modelling approach enables different discount rates for different revenue streams ▪ Endogenous build-out and dispatch of conventional fleet on wholesale and capacity market as well as renewables, flexible and decentralized capacities such as batteries, DSR, micro CHP
Detailed regional capture prices 	▪ Hourly/half-hourly prices and market value factors for renewable (onshore, offshore, PV) and conventional technologies ▪ In regional resolution and for sub technologies (i.e. 9MW turbine) if required
Impact of EVs and behind-the-meter applications 	▪ Full forecast of EVs and behind-the-meter applications ▪ Charging behaviour of behind-the-meter batteries and electric vehicles and their impact on the wholesale power market, including "smart" EV charging
Integrated balancing & auxiliary markets 	▪ Balancing and auxiliary markets are fully integrated in the dispatch model ▪ Existing plants participate in markets and we allow technologies to build out e.g. batteries for frequency response
Global commodity prices 	▪ Our Global Energy Market Model provides a long-term view on production and consumption of oil, gas and coal by country/region
High flexibility 	▪ We own the code so amendments are easy and flexibility is maximized ▪ Our modelling methodology reflects all essential policy and regulatory features (e.g. Capacity Market) that other off-the-shelf models are unable to capture

Data inputs are thoroughly scrutinized within the commodity, gas and power market subscription of all major utilities and regulators in UK, Germany, Ireland, France and many utilities in the Benelux, Poland, Czechia, Switzerland and Spain

Source: Aurora Energy Research

We offer Power & Renewable Market Intelligence Services across key markets and add-ons for flexibility

AURORA

	Power market	Renewable power	Flexible and distributed power	Gas market	H_2 market
	GB Power Market Service	GB Renewables Service	GB Distributed & Flexible Energy Service	European Gas Market Service	Hydrogen Market Service
	Ireland Power & Renewables Market Service		Ireland Flexibility Service		
	German Power Market Service	German Renewables Service	North-West European FCR Forecast		
	French Power & Renewables Market Service				
	Dutch Power & Renewables Market Service				
	Belgian Power & Renewables Market Forecasts				
	Iberian Power & Renewables Market Service				
	Italian Power & Renewables Market Service				
	Nordics Power & Renewables Market Service				
	Polish Power & Renewables Market Service				
	Romanian Power & Renewables Market Forecasts				
	Bulgarian Power & Renewables Market Forecasts				
	Greek Power & Renewables Market Forecasts				
	ERCOT Power & Renewables Market Service				
	Australian Power & Renewables Market Service		Australian Flexibility Service		

Source: Aurora Energy Research

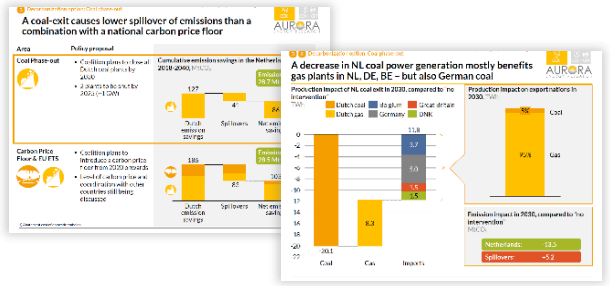
Dutch Power Market Service: Key market analyses and forecasts for all participants in the Dutch power market

Biannual data and market reports to assess business models

- **Yearly forecasts of wholesale market prices** till 2050
- **Price distributions**, dark and spark spreads
- **Capacity development**, generation mix, interconnector capacity, capacity buildout, exports
- **Capture prices** of key technologies (onshore, offshore, solar)
- **Utilisation rates** of key thermal technologies along different efficiencies
- EU-ETS carbon price forecasts
- ***Global Energy Market Forecasts*** *on oil, gas and coal*

Group Meetings and Strategic Insight Reports

- **In-depth thematic reports** on topical issues
- **Three multi-client roundtable discussions** per year in Amsterdam to discuss reports with actors across the Dutch power market (utilities, developer, investors, project finance, government, regulation)



Interaction through workshops and ongoing support

- **Bilateral workshops** at your office discuss specific issues on the Dutch market
- **Ongoing availability** (calls, access to market experts, modellers) to address any questions across European power markets
- Discounted invitations to Aurora's annual **Spring Forum**

All intelligence for a successful business, based on bankable price forecasts

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Details and disclaimer

Report based on Aurora's March 2021 Dutch Group Meeting:

'Decarbonising the Dutch power sector'

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