Analyses provided to support preparation of CAP23

January 2023

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An Roinn Comhshaoil,
Aeráide agus Cumarsáide
Department of the Environment,
Climate and Communications

Introductory note to this document

The support to DECC for the preparation of CAP23 built on previous analyses done during the support of the Sector Emissions Ceilings preparation (included as an appendix in this document). Unlike previous efforts, the support for CAP23 was less focused on primary analytical outputs but focused more on specific support to the various CAP23 working groups (such as performing additional model runs to further explore the sector solution space, provide insights into global best practices, outlining common methodological approaches the different working groups could adapt, etc.), and as such the outputs summarized in this document necessarily do not reflect the full breadth and depth of support given during this engagement.

Sectoral modeling

Appendix: details of SEC analysis

Residential buildings

Residential dwellings: a sensitivity analysis on retrofitting impact and heat pump uptake rate has been conducted to assess the impact on achieving the SEC for residential buildings

Heat pump installation rate until 2025

Retrofitting impact on energy savings

	Higher	Lower	
Higher - ~61%	① **SEC aligned** • Heat pumps uptake based on National Heat Study • Retrofit energy saving from EU E2MLab Modelling study	② **Lower heat pumps uptake** • Heat pumps uptake in line with SEAI projections • Retrofit energy saving from EU E2MLab Modelling study	
Lower - ~40%	③ **Lower retrofit impact** • Heat pumps uptake adjusted to reach SEC • Lower bound of retrofit energy saving potential[1]	④ **Lower retrofit impact and lower heat pumps uptake** • Heat pumps uptake in line with SEAI projections • Lower bound of retrofit energy saving potential[1]	Assumption used in CAP 23

Note: Scenario 1 was modelled based on projected 2021 emissions (6.23 Mt). Scenarios 2, 3 and 4 use the provisional EPA figures for 2021 emissions (7.04 Mt), which also contributes to potential SEC overshoot.

Key considerations

- The SEC target for the existing residential dwelling segment is ~**5.45 Mt CO2eq** in 2025 and ~**4.16 Mt CO2eq** in 2030
- Sensitivity scenarios 2 & 4 will not meet the SEC
- Sensitivity scenario 3 can meet the SEC targets by adjusting the heat pumps uptake

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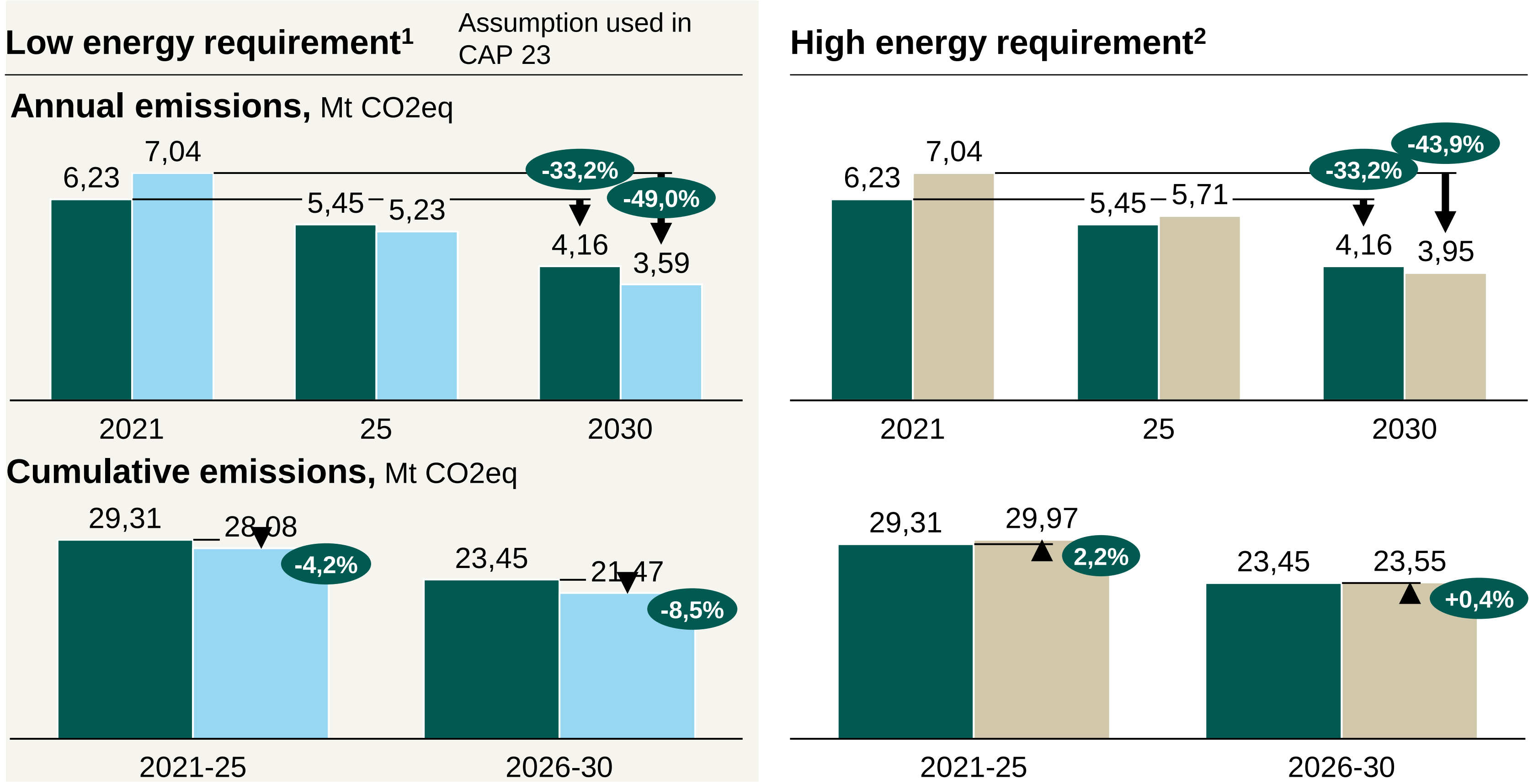
[1] Policy Modelling for Ambitious Energy Efficiency Investment in the EU Residential Buildings

Meeting the Residential Buildings SEC is sensitive to fuel use per dwelling

🟩 Sector Emission Ceiling Residential Buildings
▨ Residential emissions under high energy requirements
🟦 Residential emissions under low energy requirements

Comparison of main scenario (assuming high persistent price effect) under low and high energy requirement per dwelling outlook



1. Low energy requirement scenario assumes 2019 fuel consumption factors flat until 2030, as the 2018 fuel consumption was a high year in an overall downward trend | 2. High energy requirement scenario assumes 2018 fuel consumption factors flat until 2030 as a bearish counterfactual

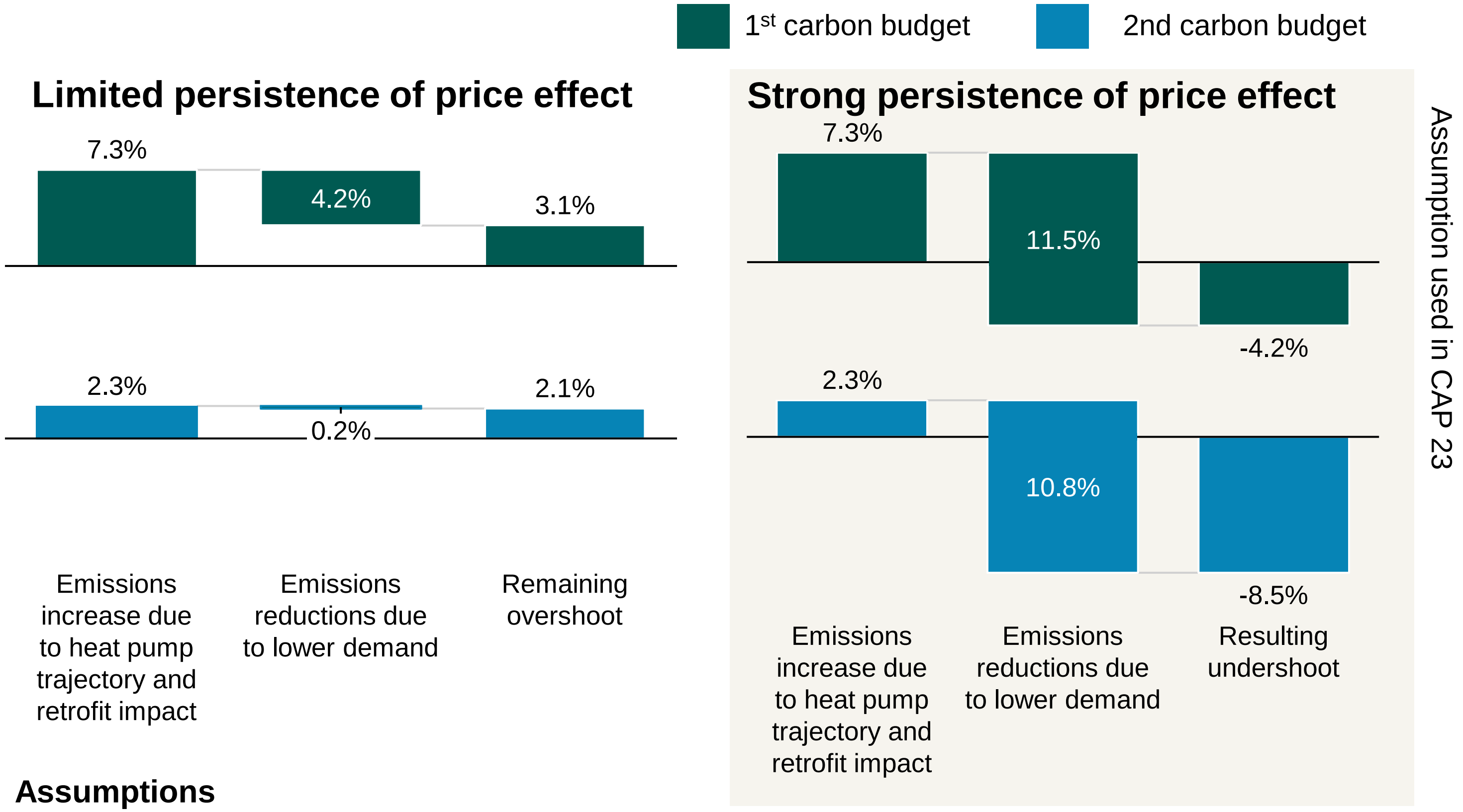
Observations

Cumulative emissions in the low energy requirement scenario **undershoot the SEC by 4.2% in 2025-2030 period and 8.5% in the 2026-2030 period**

Cumulative emissions in the low energy requirement scenario **overshoot the SEC by 2.2% in 2025-2030 period and 0.4% in the 2026-2030 period**

Close monitoring of fuel use trends and concrete measures (e.g., smart thermostats) will increase the certainty of meeting SEC commitments

Higher energy prices may result in short-term emissions reduction as a result of lower demand



Assumptions

- "Limited persistence" scenario implies a one-off effect, with consumers reverting to previous patterns of consumption relatively quickly. This scenario applies price elasticity to year-on-year price changes to estimate demand reduction.
- "Strong persistence" scenario implies long-term or permanent changes in behaviour. In this scenario, price elasticity is applied to price changes as compared to 2021 to estimate demand reduction.
- Price elasticity of approx. -0.22 as per Labandeira, Labeaga & López-Otero (2016)
- Energy price projections for oil, gas and electricity as per SEAI National Energy Modelling Framework. Price increase for coal taken as average of price increases of other fossil fuels.

Short term demand reduction

As illustrated here, price effects do not only have significant adverse social impacts, but are also not a reliable decarbonization lever – emissions impacts vary greatly depending on consumer reaction and persistence of high prices which are significantly uncertain. The ‘rebound effect’ where consumption goes up in the long run as consumers get used to higher prices is also well documented.

In this particular instance, the government has also provided subsidies to mitigate the impact of high energy prices on households. This could dampen (or even eliminate) price effects on consumers.

Demand reduction can be systematically achieved through concrete measures like the wide-scale provision of smart meters/thermostats, temperature guidelines for buildings etc.

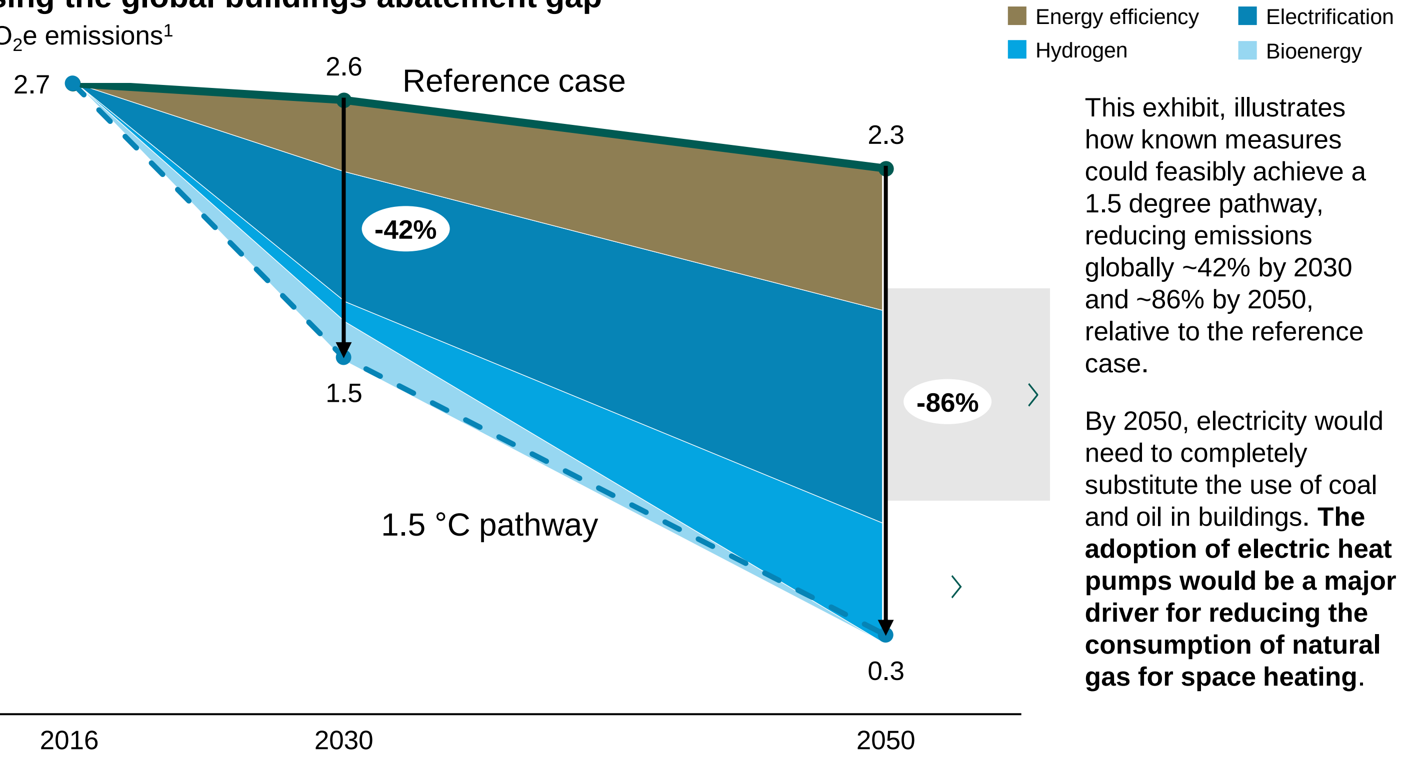
Heat pumps are the primary technology driving emissions reductions in the buildings sector

The residential sector in Ireland is the second largest source of CO_2, after transport and ahead of industry, with 42% of all energy used sourced from oil

There is significant potential to reduce these emissions through heat pumps. This has not only been possible in other comparable countries, but also cost-effective over the lifetime when compared to other technologies

Closing the global buildings abatement gap

Gt CO_2e emissions[1]



This exhibit, illustrates how known measures could feasibly achieve a 1.5 degree pathway, reducing emissions globally ~42% by 2030 and ~86% by 2050, relative to the reference case.

By 2050, electricity would need to completely substitute the use of coal and oil in buildings. **The adoption of electric heat pumps would be a major driver for reducing the consumption of natural gas for space heating**.

An ambitious target for heat pump installation in Ireland…

1. **Is required to meet Sectoral Ceilings Emissions and EU regulation** to reduce emissions in the buildings sector
2. **Has shown to be possible in other countries in northern Europe**, such as Sweden and Finland, where 100,000 heat pumps are being installed per year
3. **Has ready-to-go potential in Ireland:** Over 18% of Irish homes are heat pump ready and geographically concentrated so there is significant potential for quick deployment
4. **Can be a cost-efficient option:** evidence shows that heat pumps can offer the lowest cost for new and existing residential buildings with further potential for price reduction over the next decade

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1. For simplicity, a linear path is shown between the fixed points in 2018, 2030, and 2050. In reality, the trends of abatement measures may not be linear
2. IEA

Source: 1. McKinsey 1.5˚C Scenario Analysis | 2. SEAI: https://www.seai.ie/data-and-insights/seai-statistics/key-statistics/residential/ | 3. IEA https://www.iea.org/reports/installation-of-about-600-million-heat-pumps-covering-20-of-buildings-heating-needs-required-by-2030

1: Significant abatement in the buildings sector is required by the SEC and EU but Ireland’s progress underperforms compared to peers

Significant abatement is required at national and EU level…

A **The Sectoral Emission Ceiling (SEC) mandates an ambitious abatement target for the residential building sector**

- By 2025, an emissions reduction of ~20% compared to 2018 levels
- By 2030, an emissions reduction of ~40% compared to 2018 levels

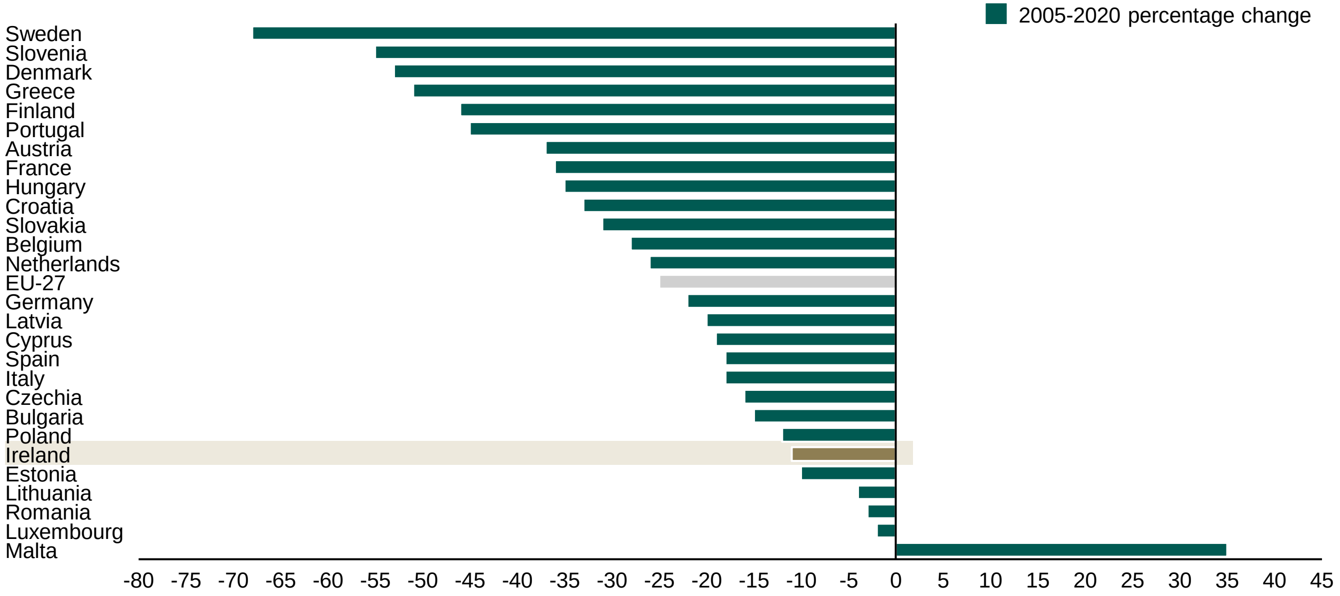
B **EU regulations set significant abatement targets for the building sector**

- According to the EU Commission, building renovation would be needed at an average rate of 3% annually to accomplish the Union’s energy efficiency ambitions in a cost-effective manner
- The EU has amended its Directive on the energy performance of buildings to mandate:
  - All new buildings to be zero-emission by 2030
  - All existing buildings to be zero-emission by 2050
  - Minimum energy performance standards for residential buildings

…but progress in Ireland falls short compared to peers

- **Ireland’s emissions abatement from energy use in buildings was below EU-27 average**. Between 2005-2020, Ireland reduced its greenhouse gas emissions from energy use in buildings by 11%, performing only above Estonia (-10%), Lithuania (-4%), Romania (-3%), Luxembourg (-2%) and Malta (+35%)
- **Ireland would still perform below EU-27 average (-35%) by 2030 with existing abatement measures** and can only outperform EU-27 average (-42%) by implementing additional measures included in the current national level planning

Greenhouse gas emissions from energy use in buildings, percentage change[1]



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1. Existing measures refers to policies already in place.

Source: EUR-Lex: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.156.01.0075.01.ENG | European Environment Agency: https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emissions-from-energy/assessment

2: Heat pump deployment in other EU countries is significantly above that of Ireland

Country	Heat pumps per 100,000 people	Main policies used to drive heat pump deployment
Norway	24,675	Government subsidies to encourage homeowners to dispense of oil and gas boilers. Oil heating is now banned
Sweden	19,510	Taxes on heating oil, tax credit to replace and install oil boilers and widespread information to consumers
Finland	18,314	Strong support for research & development, government subsidy covers up to 20% of the cost of switching to heat pumps and cost installation of installation is tax-deductible
Estonia	14,726	Financial grants for improving energy performance, subsidy programme and information campaigns
Denmark	7,549	Subsidies to purchase and install heat pumps to replace oil and gas boilers
France	4,586	Ended subsidies for gas heaters, subsidy scheme for heat pumps and biomass heaters
Switzerland	4,110	Offers financial incentives for environmentally friendly heating systems and has a high tax on fossil fuels
Austria	4,037	Delivered through a holistic package that included financial incentives, regulatory measures, and information and education
Ireland	881	Delivered through a holistic package that included financial incentives, regulatory measures, and information and education

Source: The ecoexperts https://www.theecoexperts.co.uk/heat-pumps/top-countries | SEAI. https://www.seai.ie/publications/Heat-Pump-Adoption.-Maximising-Savings..pdf

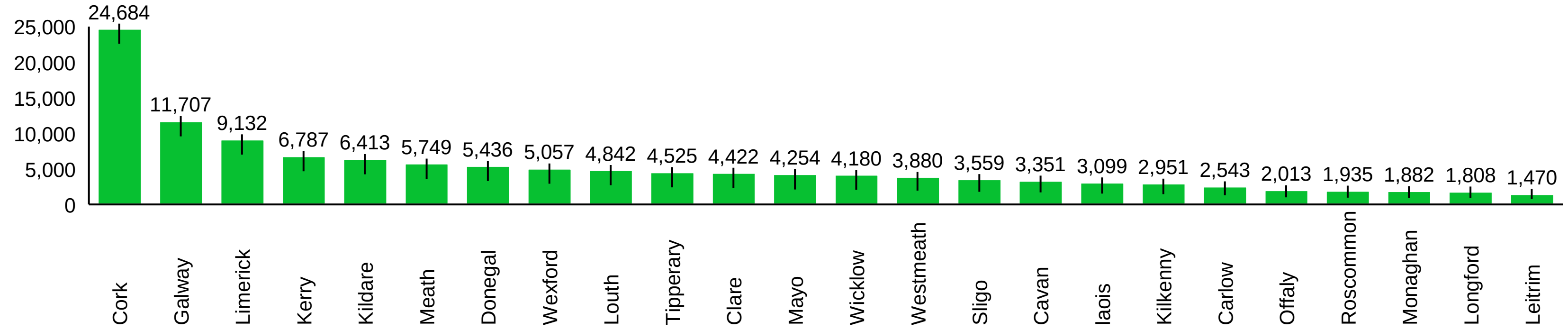
Key insights

- **Sweden and Finland are leading the heat pump installation rate** hitting a record installation of **100,000 heat pumps per year** in 2020. Switzerland installed 36,000, the United Kingdom around 35,000 and Ireland close to 10,000

- **There is high ambition across countries to further ramp up heat pump installation efforts.** The United Kingdom aims to install 600,000 heat pumps a year by 2028, while Germany aims to install 500,000 heat pumps a year by 2024

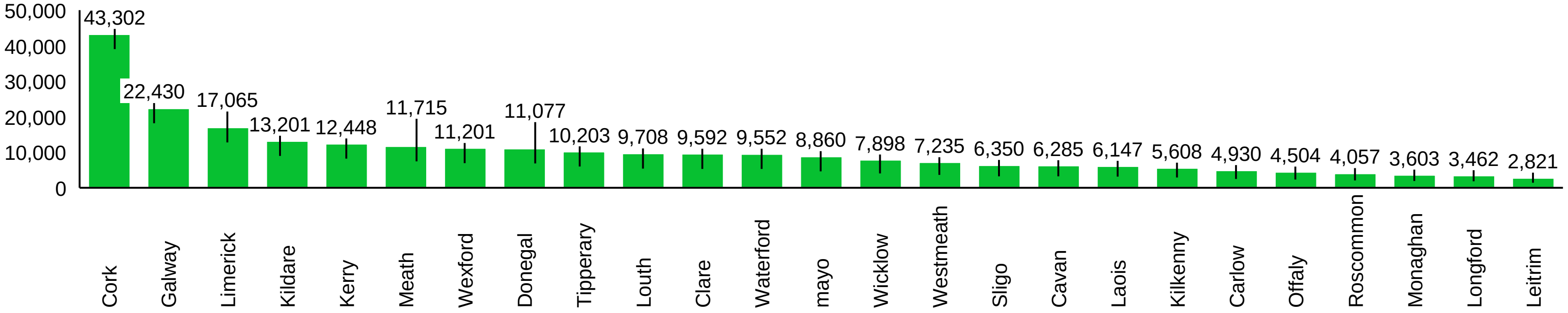
3: A significant number of Irish homes could be heat pump ready and are geographically concentrated - there is significant potential for quick deployment

Potential Heat Pump-Ready Homes, HLI ≤ 2 by County built up to 2010



Dublin 65,335

Potential Heat Pump-Ready Homes, HLI ≤ 2.3 by County built up to 2010



Dublin 98,041

Homes[1]	**Number of Homes**	**%**
In Ireland	2,003,645	100%
In BER database	860,000	86%
With HLI of 2 W/K/m^2 or less	196,244	9%
With HLI of 2.3 W/K/m^2 or less	351,295	18%

Key insights:

- Over 350,000 homes have a heat loss indicator of 2.3 or less and 196,000 have a HLI of 2.0 or less
- Heat pump-ready homes are concentrated in three key counties: Cork, Galway and Limerick

1. Heat pump installation requires homes to have a heat loss indicator (HLI) of less than 2 W/K/m^2 or 2.3 W/K/m^2 with some caveats

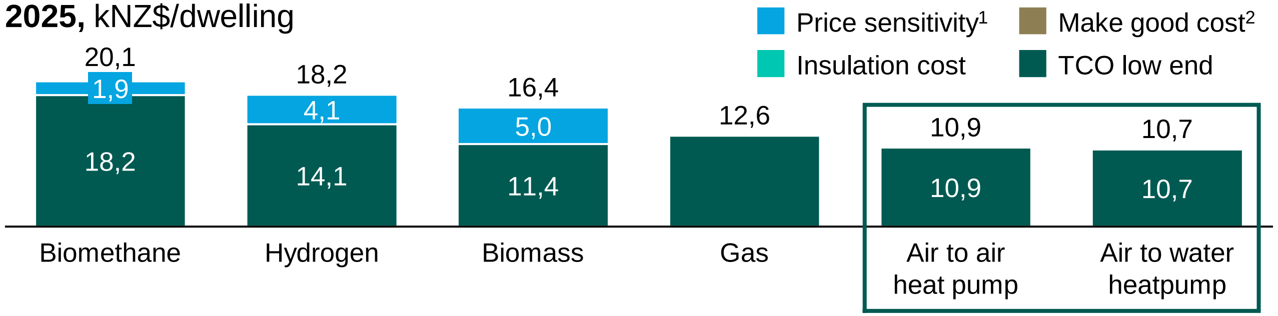
Source: SEAI https://www.seai.ie/blog/opportunities-for-heat-pu/

4: Case study New Zealand: Heat pumps are the lowest-cost option in new and existing residential buildings when considering the product's lifecycle

The Total Cost of Ownership (TCO) includes the overall cost throughout the product's lifecycle. This would include the cost of purchasing, deploying, using and retiring the heat pumps

TCO, new residential buildings

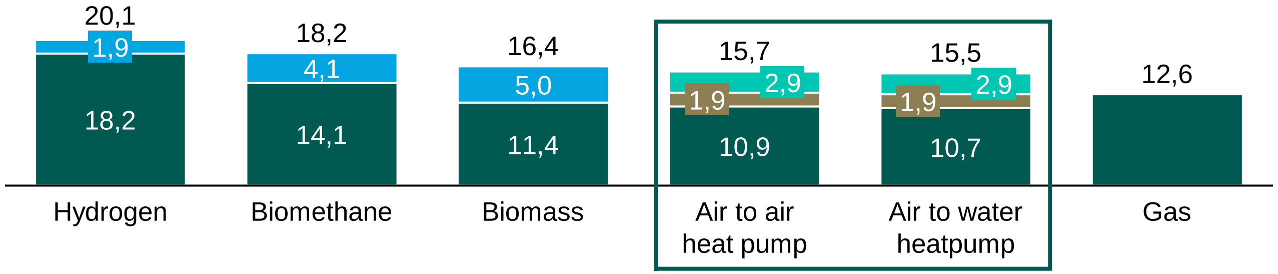
2025, kNZ$/dwelling



- **For new residential buildings, heat pumps are the lowest-cost option**. Historically, consumers have preferred gas given the higher upfront capital costs of heat pumps.

TCO, existing residential buildings

2025, kNZ$/dwelling



- **For existing residential buildings**, heat pumps offer the lowest TCO, but their TCO exceeds gas boilers' when **insulation and make good costs** are considered
- However, rising gas prices, shifting consumer preferences and further governments incentives to support heat pump deployment can further decrease the cost advantage of gas or even reverse it in favour of heat pumps

1. Price sensitivity considers an upper and lower bound for fuel costs prices. Biomethane price sensitivity based on production technology (i.e., anaerobic digestion and thermal gasification), hydrogen price sensitivity based on transport of hydrogen via refurbished pipelines and trucks, and biomass price sensitivity based on the type of biomass (i.e., forest residue and chipped pulp logs)
2. Make good cost: the cost to properties from removing fossil gas appliances and making repairs to the property

Source: Sustainability Insights

4: There is potential for heat pumps prices to drop by up to ~20% driven by non-equipment costs once it hits mass market

Expected cost reduction	Driver for Cost reduction
Non-equipment costs **40–50%**	**Installers & distributors reduce their margins:** More 'volume buys' across supply chain gives **~10% cost reduction** **Overheads and distribution – Could reduce by 20%:** A more developed supply chain, increased local demand, more heat pumps sold via wholesaler **Labour costs (~30% of which is installer margin) – Could reduce by 10–20%:** Increased installer confidence & experience, lower perceived "risk", increased work availability, & increased competition
Equipment costs **10%**	**Standard HVAC components** – Limited cost reduction: Components already at mass market products; reduction driven by economies of scale, better integration of various components to form 1 system and better raw material

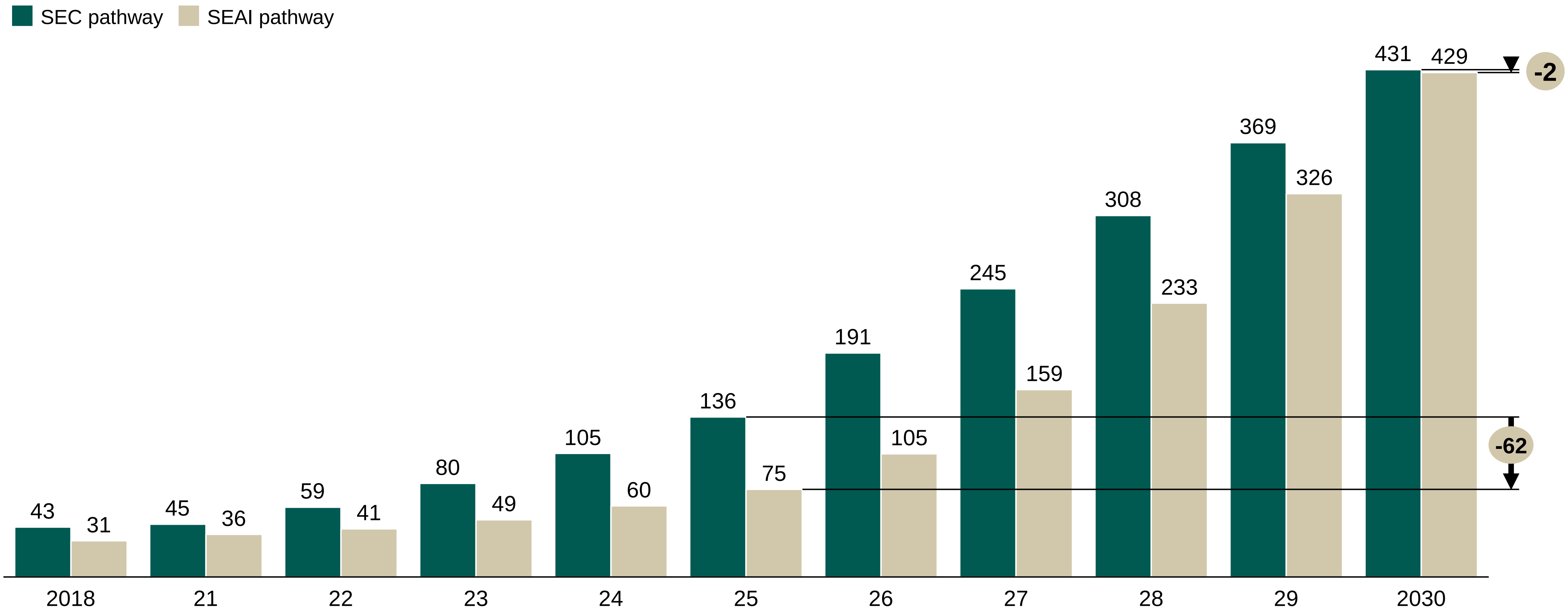
1. Capex levelized over lifetime at discount rate of 4%

Source: 1. Department of Energy and Climate Change (DECC), 2016 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/498962/150113_Delta-ee_Final_ASHP_report_DECC.pdf | 2. IEA https://www.iea.org/commentaries/is-cooling-the-future-of-heating

Comparison of SEC and SEAI pathway on heat pump uptake in existing residential buildings

 # heat pumps in existing homes

In thousands of heat pumps

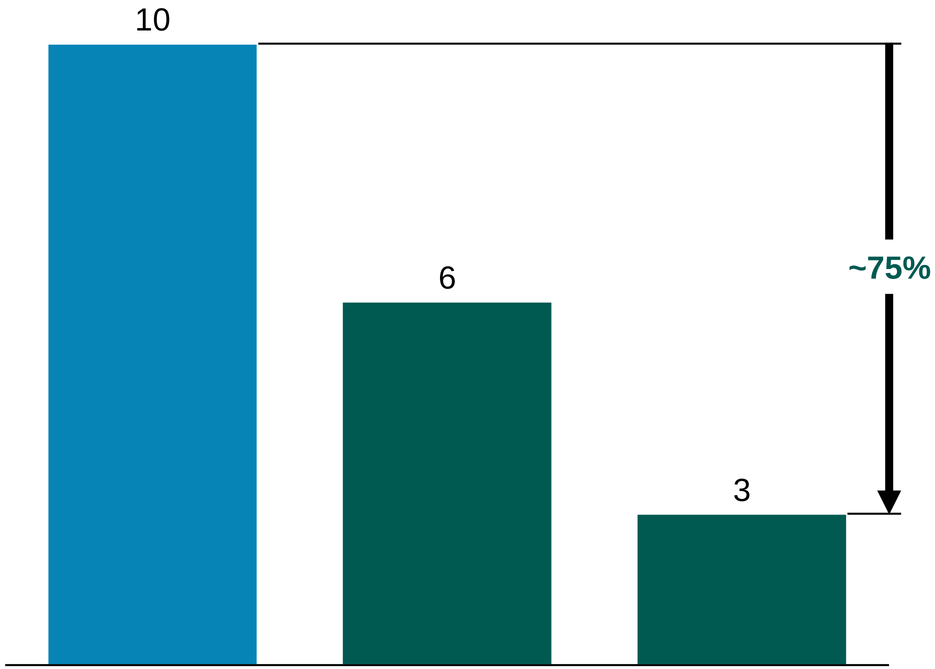


	SEC pathway	SEAI pathway
2018	43	31
21	45	36
22	59	41
23	80	49
24	105	60
25	136	75
26	191	105
27	245	159
28	308	233
29	369	326
2030	431	429

Contents

The proposed sectoral emissions ceilings deliver ~40% emissions reductions by 2025 and ~75% by 2030

	GHG emissions[1], MtCO2eq (AR5)			% change vs. 2018		% impact outlined in CAP 2021	Sectoral emissions ceilings, MtCO2eq	
	2018	2025	2030	To 2025	To 2030		2021-2025	2026-2030
Electricity	10	6	3	~40	~75	60-80	40	20



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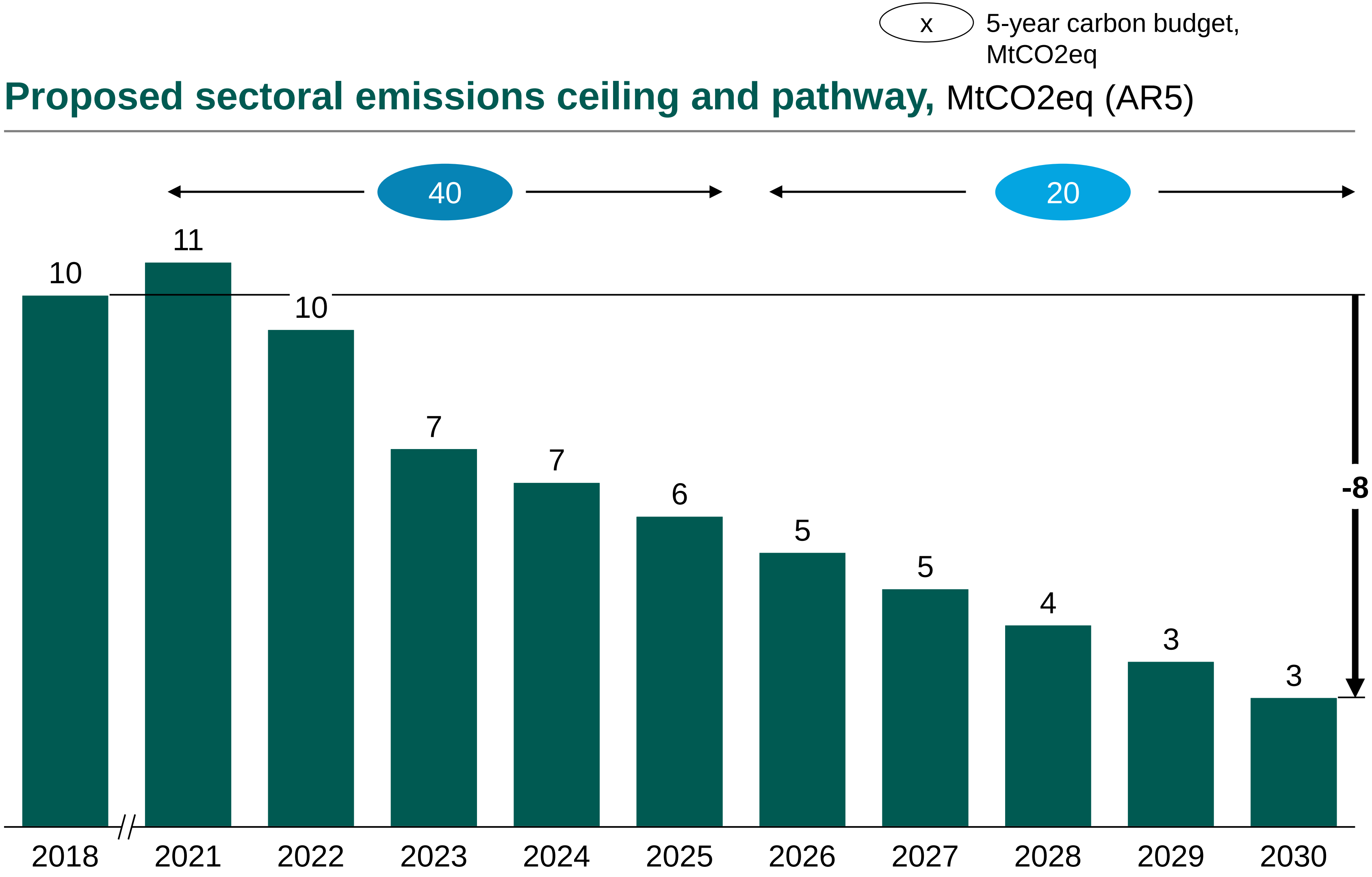
1. GHG emissions and abatement impact based on AR5 2021 EPA methodology

Source: Climate Action Plan 2021, Government of Ireland; Programme for Government 2020, Government of Ireland

Annual emissions from the electricity sector could decline by ~8Mt by 2030

Proposed sectoral emissions ceiling and pathway, MtCO2eq (AR5)



Source: Climate Action Plan 2021, Government of Ireland

Key takeaways

Scenario:

- Moneypoint operational from 2021-22 (utilization decreasing from 70% in 2021 to 30% in 2022)
- Later offshore wind ramp-up following DECC
- Biomethane use: ~1.1TWh 2030, ~2.5 TWh in 2025
- 100 EUR/t ETS
- Additional marginal carbon price:
  - 2025: EUR 20
  - 2030: EUR 50

Scenarios developed with different constraint assumptions reach similar emissions ceilings

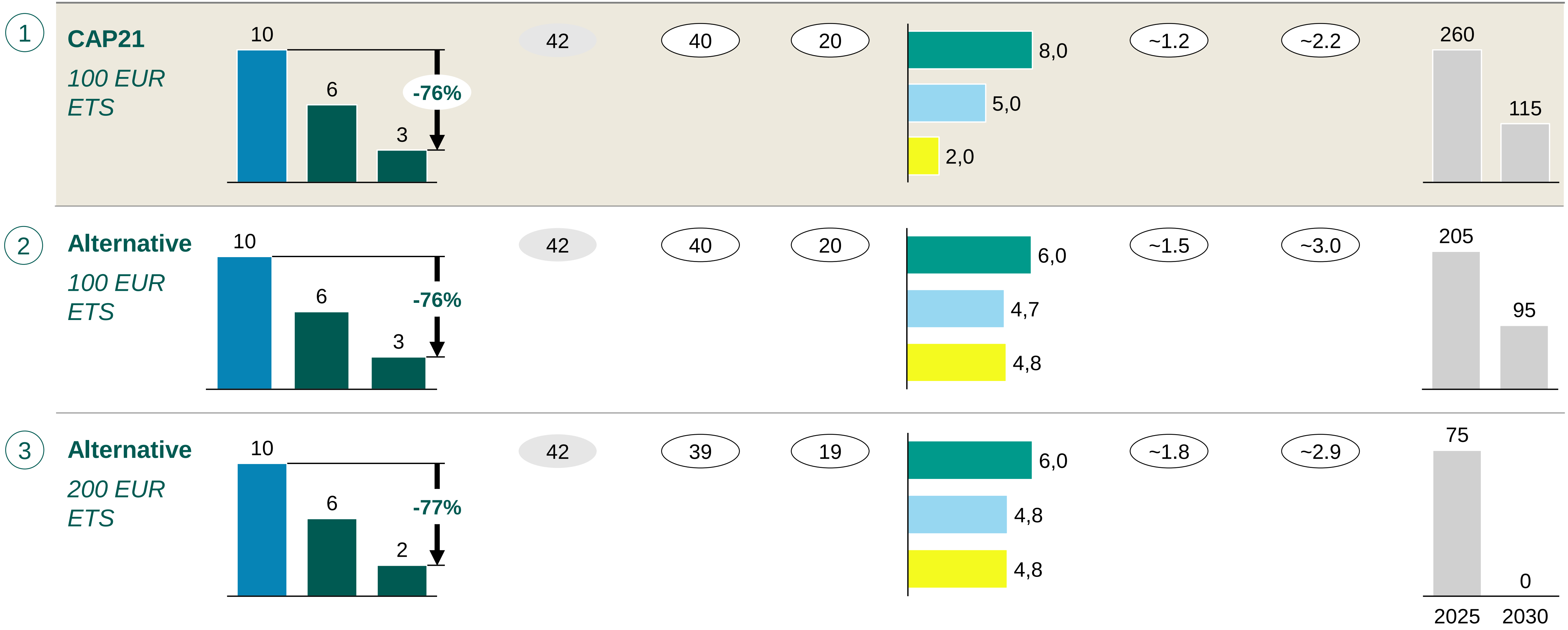
🟫 *Proposed scenario*

Capacity by 2030, GW

🟩 Onshore wind

🟦 Offshore wind

🟨 Solar



Scenario	UCC emissions Electricity pathway scenarios, Mt	% change vs. 2018-2025	Sectoral emissions ceilings, MtCO2eq 2021-2025	Sectoral emissions ceilings, MtCO2eq 2026-2030	2030 RES Capacity¹, GW	Net transmission inflows, TWh	Biomethane inputs 2030, TWh	Marginal additional carbon price, EUR
1 **CAP21** *100 EUR ETS*	10 6 3 -76%	42	40	20	8,0 5,0 2,0	~1.2	~2.2	2025: 260 2030: 115
2 **Alternative** *100 EUR ETS*	10 6 3 -76%	42	40	20	6,0 4,7 4,8	~1.5	~3.0	2025: 205 2030: 95
3 **Alternative** *200 EUR ETS*	10 6 2 -77%	42	39	19	6,0 4,8 4,8	~1.8	~2.9	2025: 75 2030: 0

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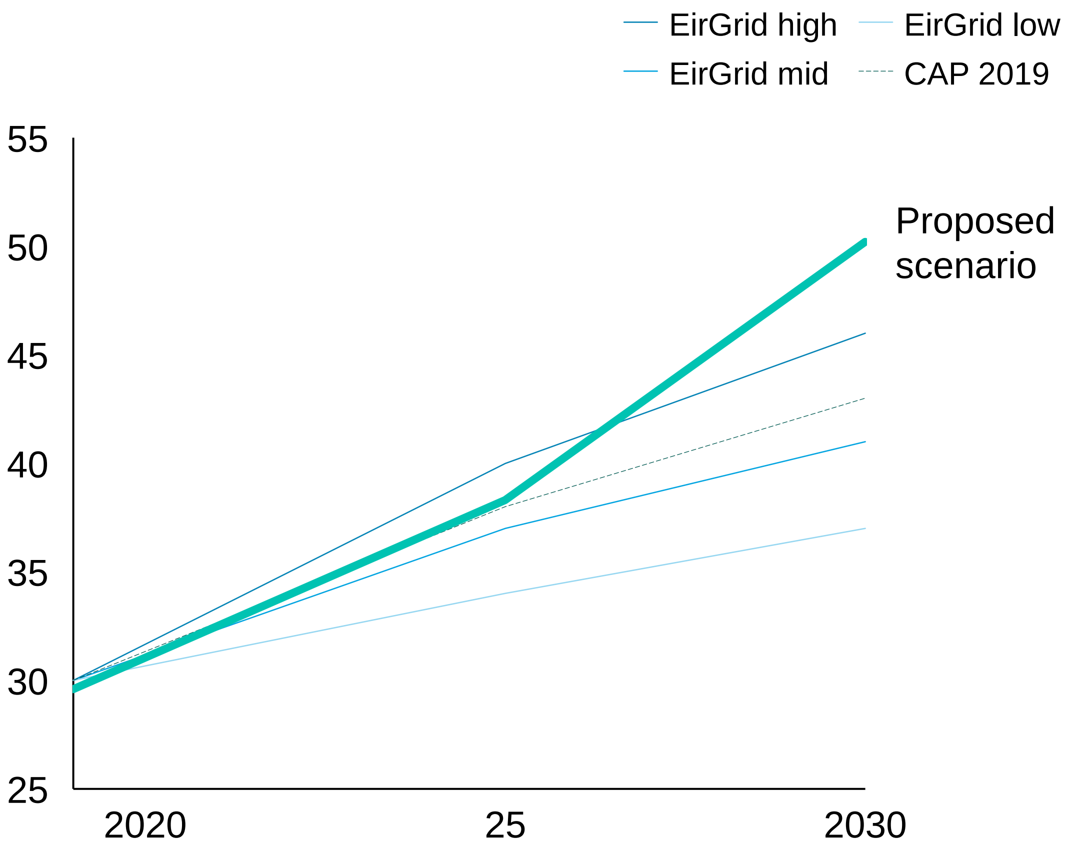
1. Does not show hydro, which remains at ~1GW in all scenarios

① Electricity demand is assumed to increase by ~65-70% by 2030

Electricity demand, TWh



Key sources of demand growth

	EirGrid mid, 2030	**CAP 2019,** 2030	**Proposed scenario,** 2030	**Low demand scenario,** 2030
Data centres	12 TWh	9 TWh	12 TWh[1]	6 TWh
BEV cars	500k	550k	~950k	600-800k
EV trucks & vans	N/A	95k	~90-100k	145k
Heat pumps	400k	600k	650-700k	650-680k
Industry electrification	N/A	~1 TWh	>5 TWh	>5 TWh

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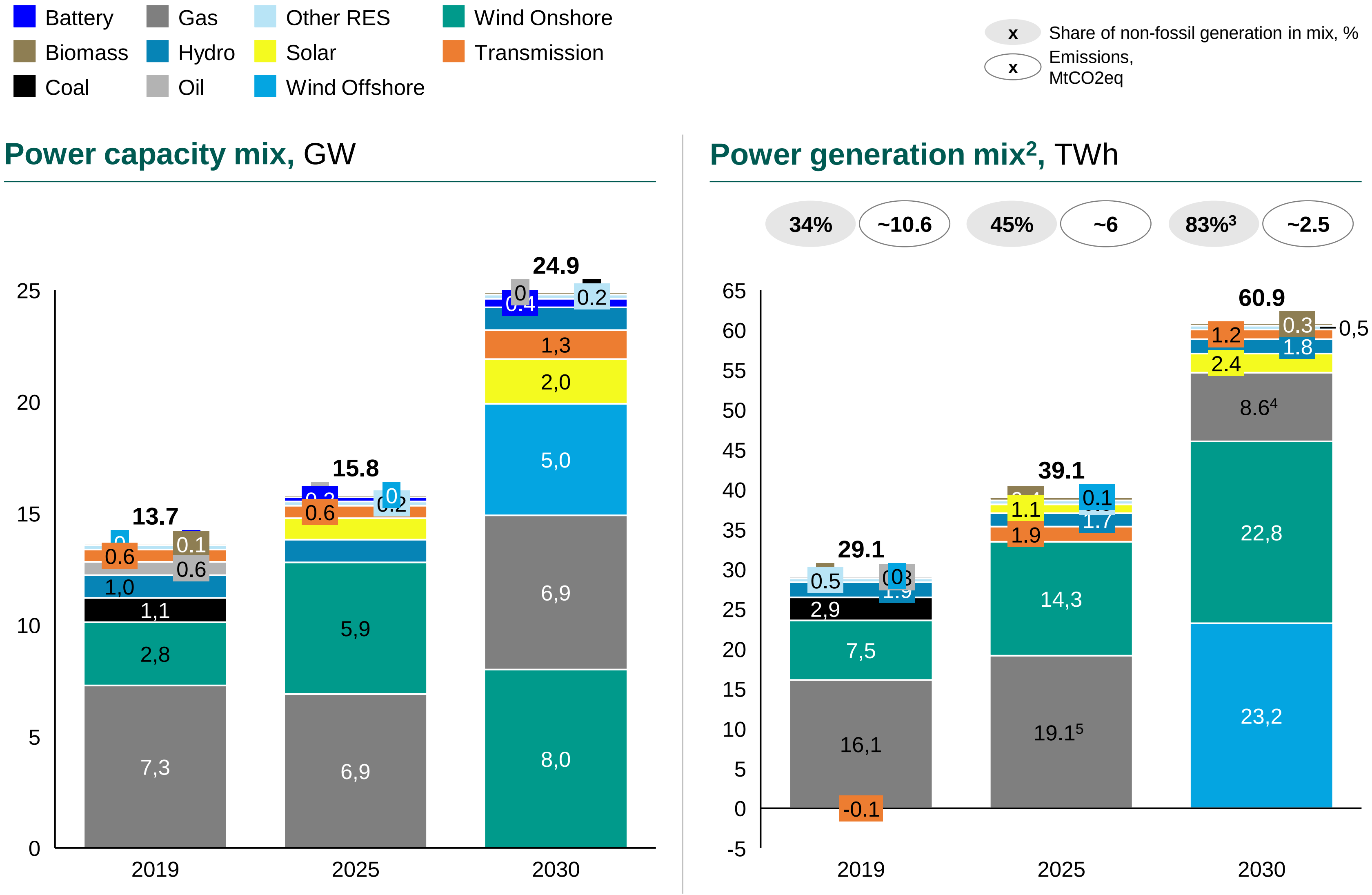
1. Data centre capacity is based on the EirGrid forecast of 790-1770 MW by 2030, assuming a load factor of 80%

Source: Climate Action Plan 201, Government of Ireland; EirGrid- All-Island Generation Capacity Statement 2020-2029

① CAP21 capacity and EUR100 ETS delivers ~80-85% of generation from renewable by 2030



Power capacity mix, GW

Power generation mix^2, TWh

1. Includes Biomass and/or battery storage
2. Power generated, not delivered (see curtailment next page)
3. With curtailment generation is ~70% of total by 2030
4. Note that this includes biomethane blended in (2.5 TWh input by 2030)
5. Note that this includes biomethane blended in, 1.1 TWh input by 2025

Source: Power Solutions Model, June 2022

Key takeaways

Scenario shown aligns with CAP targets to deliver:

- ~5 GW offshore wind
- ~8 GW onshore wind
- ~ 2 GW solar

Combined these deliver ~80-85% renewable power generation mix by 2030

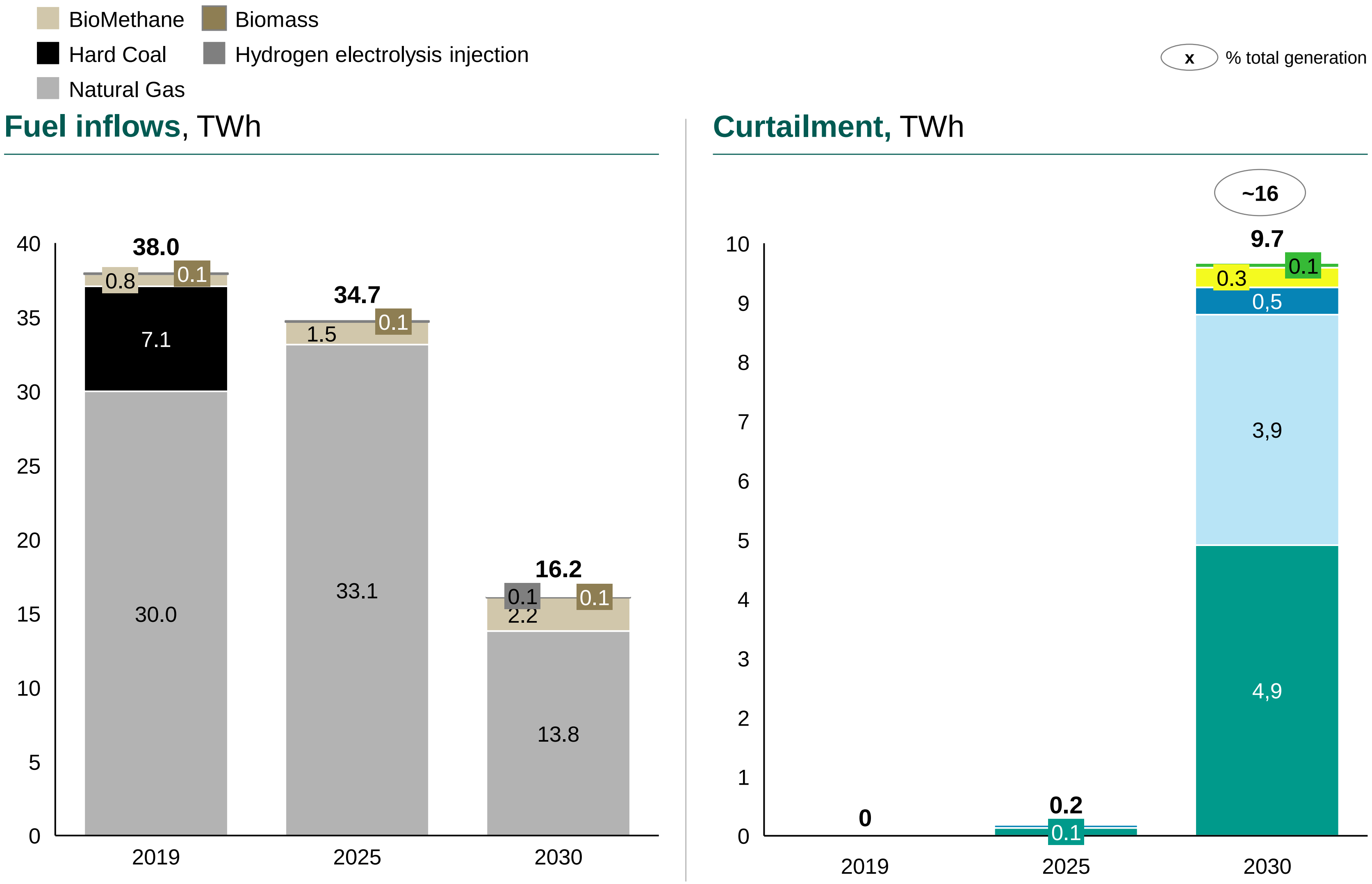
Actual capacity mix will vary due to competitive auctions. Assumed carbon price of ~EUR100/t

Marginal carbon price on top of ETS:

2025: ~EUR 260

2030: ~EUR 115

① CAP21 capacity and EUR100 ETS requires ~14 TWh of natural gas by 2030



Fuel inflows, TWh

Curtailment, TWh

1. Includes Biomass and/or battery storage

Source: Power Solutions Model, June 2022

Key takeaways

Scenario shown aligns with CAP targets to deliver:

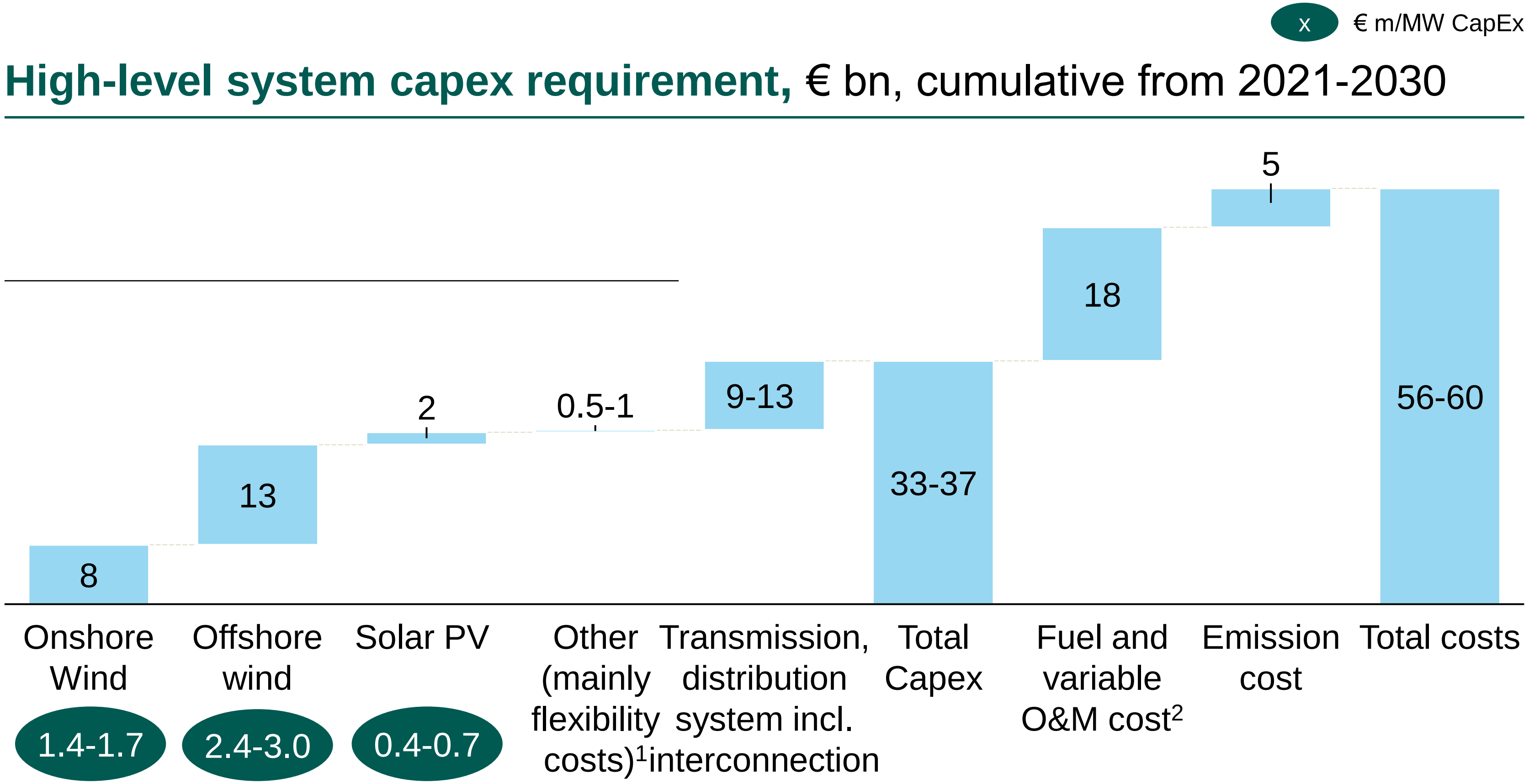
- ~5 GW offshore wind
- ~8 GW onshore wind
- ~ 2 GW solar

No coal generation from 2023 onwards. Significant fuel inflows from gas under EUR100 ETS

Curtailment at ~16% of total generation by 2030, driven by offshore and onshore wind

① This sector ceiling implies a total capex requirement of €56-60bn

High-level system capex requirement, € bn, cumulative from 2021-2030



1. Includes costs for short-time and long-time flexibility solutions such as battery storage, electrolysis for hydrogen production
2. Cost of natural gas based on forward curves at 18 EUR/mmbtu in 2025 and 16 EUR/mmbtu in 2030; subject to uncertainty and accounting for EUR 16Bn of total cost

Commentary

System cost estimates shown here based on scenario with the following renewables capacity mix:

- 8 GW of onshore wind
- 5 GW of offshore wind
- 2 GW of solar PV

Depending on the share of solar PV and wind capacity, these cost estimates will scale accordingly

① Implications and risks of delivering the proposed emissions pathway

◔ ◑ ◕ ●

Low → High

	Assumption in proposed pathway	Delivery risk	Impact on sectoral emissions ceiling
Ramp-down of Moneypoint	• 70% utilisation 2021 • 30% utilisation 2022, zero thereafter	• Potential for Moneypoint to be operational at higher utilisation rate and open after 2022, with significant implications for first emissions ceiling overshoot	●
Build-out of RES	• 2 GW solar; 8 GW onshore wind; 5 GW offshore wind	• Slower build out of RES capacity, likely from supply chain pinches and/or planning and investment delays • Potential replacement with natural gas	◔
Interconnection	• Relying on net imports (~0.6 TWh by 2025; ~1 TWh by 2030) to meet generation requirements	• Lower available net imports due to external circumstances • Potential replacement with natural gas domestic generation	◔
Biomethane	• Scaling up biomethane to power sector (~1.1 TWh by 2025; ~2.5 TWh by 2030)	• Ramp up of biomethane slower than estimated • Required efforts on land use change not realised	◑
Capacity factor growth	• Assumed capacity factors for RES technologies	• Lower capacity factors realised than assumed in real world • Potential resulting in further deployment of RES capacity and increased associated CapEx	◔
Grid constraints/synchronicity	• Grid assumed to be able to cope with synchronicity and constraints based on RES generation in scenario	• Grid not able to cope with required RES generation or loads in specific areas • Potential increase in CapEx to meet grid requirements	◑

Ramping down Moneypoint could incur an additional cost to move it down the merit order of generation

2023 ILLUSTRATIVE

~€116/tCO_2e

Carbon surcharge required to move coal down merit order[1]

Total cost switching from Moneypoint

~€39m × **2.1** = **~€113m**

Total surcharge to move from 1 TWh coal[2]

TWh coal generation *(2019 figure used)*

Total annual cost of removing coal generation in 2023

Potential cost per household

(~€113m × 0.3) ÷ **1.95m** = **~€17-20**

Proportion of energy demand from residential sector

Estimated total homes in 2023[3]

Potential annual cost per household

Subject to change based on policy decisions and other factors

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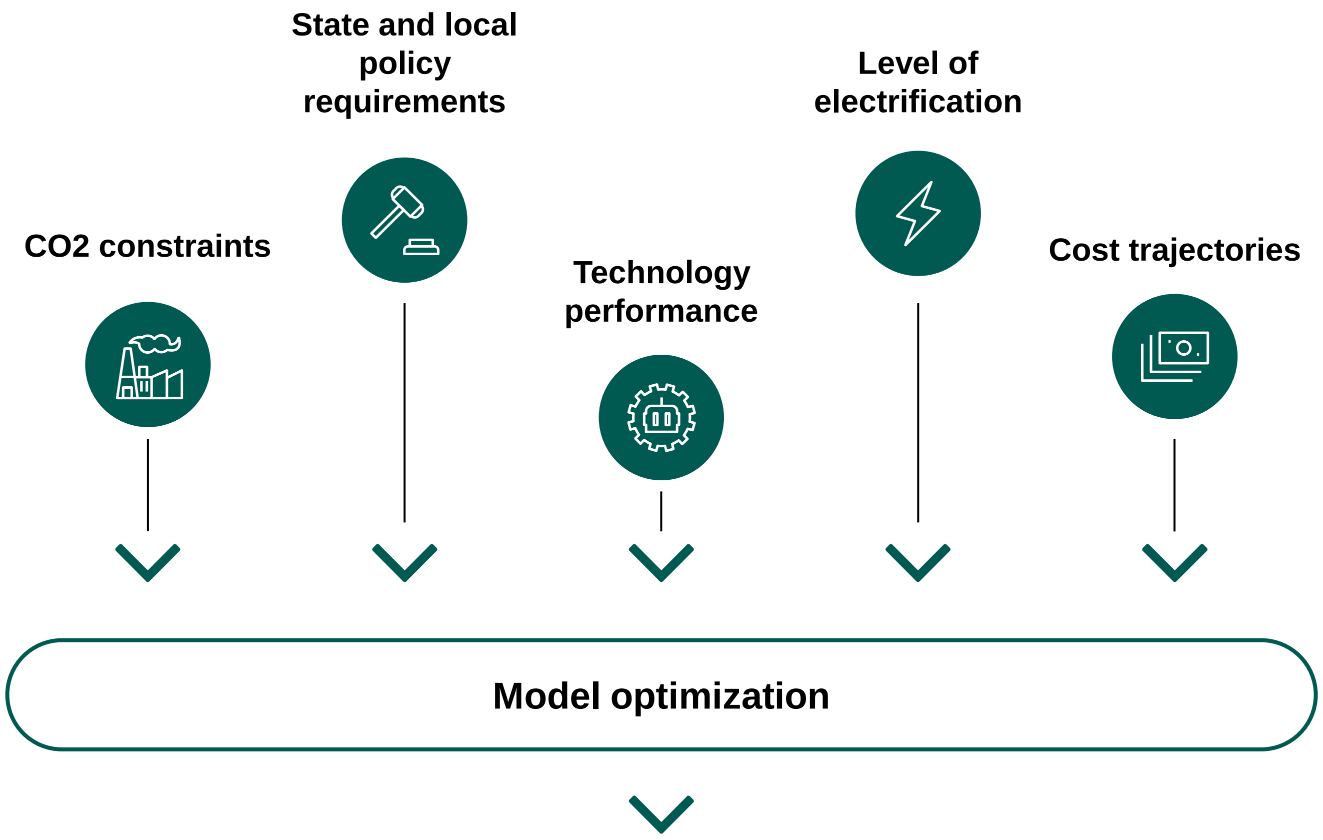
1. Carbon surcharge is calculated from DECC/SEAI modelling. Cost of coal and gas is taken from EU commodity projections. A cost from EU ETS is layered onto these prices based off EU ETS projections and emissions factors for coal/gas generation in Ireland (SEAI). The difference in total cost per t/CO2e emitted is taken to be surcharge required.
2. Coal emissions factor of 93t/TJ used (from DECC/SEAI modelling)
3. Taken from Sectoral Emissions Ceilings Appenix document, Residential Buildings sector projection

Source: SEAI, DECC

The Power Model identifies the potentially lowest cost pathway to meet national energy objectives

Inputs vary by scenario



CO2 constraints

State and local policy requirements

Technology performance

Level of electrification

Cost trajectories

Model optimization

Outputs

Least cost system decarbonisation for each scenario modelled, including capacity and generation mix, sources of flexibility, cost and investment required

The model determines which **power sector investments and operating decisions minimise costs** while meeting the targets

Markets are typically modelled under differing technology and policy scenarios to test key planning parameters

The model is based on an interconnected EU power system which spans 16 European countries/regions

Geographic resolution of the model with interconnections

1	Ireland
2	Poland
3	Germany
4	France
5	Italy
6	Czech Republic
7	Austria
8	Nordics
9	Benelux
10	Spain
11	Portugal
12	Other central Europe
13	Southeast Europe
14	UK
15	Norway
16	Switzerland

With the interconnection, the relative value of **excess offshore wind production from Ireland is significantly muted** vs some average EU market price given the installations present/ planned in GB

Granularity

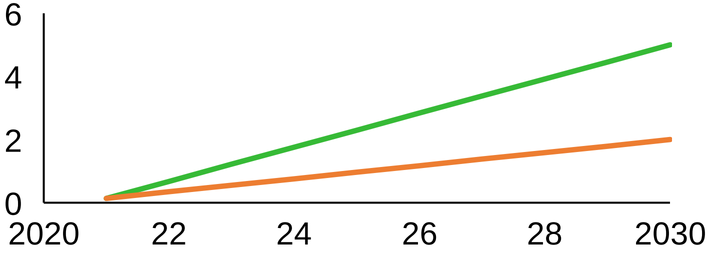
- Build up power capacity and net inter-regional transmission capacity within every 5 year resolution
- Dispatch of technology grouped generators on hourly basis within a year

Modelling scenarios took into account higher and lower bounds for feasible rollout of renewables, taxes and tariffs

Constraints arise from renewables capacity and inputs…

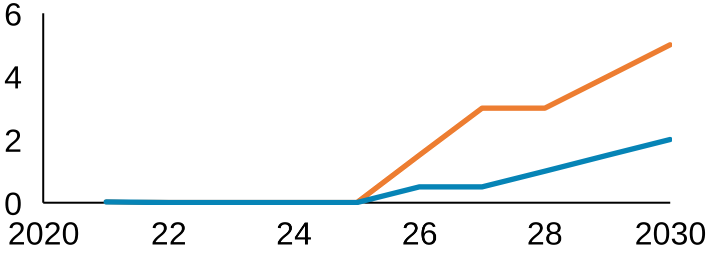
🟩 High bound 🟦 Low bound

Solar capacity, GW



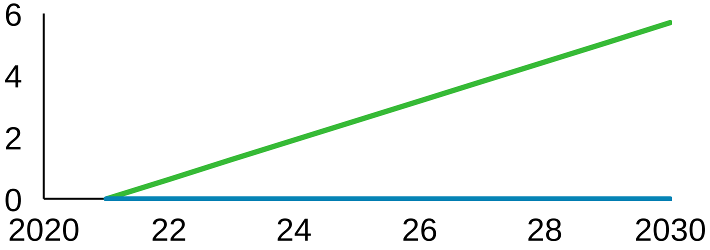
- 5GW max feasible in previous analyses (e.g. PfG) and uplift in solar seen in RESS-2
- CAP21 commits to ~1.5-2.5 GW

Offshore wind capacity, GW



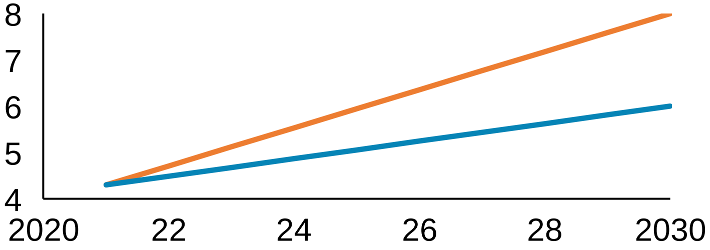
- CAP21 commits to ~5 GW capacity by 2030. Feedback from DECC finds max. ramp-up rate to achieve CAP21
- Low bound reflects assumed lower ambition rollout

Biomethane, TWh



- National Heat Study finds ~5.7 max domestic biomethane potential by 2030

Onshore wind capacity, GW



- CAP21 commits to ~8GW onshore wind. Likely max. potential given public perception
- Low bound 6GW represents assumed lower ambition

…and a range of other levers

Emissions targets

ETS pricing of fossil power generation (EUR100-200)

Tariffs on interconnector transmission to Ireland (~EUR35/MWh)[1]

---

1. Tariff can also be seen as the cost of not importing energy

Source: SEAI; Climate Action Plan 2021, Government of Ireland

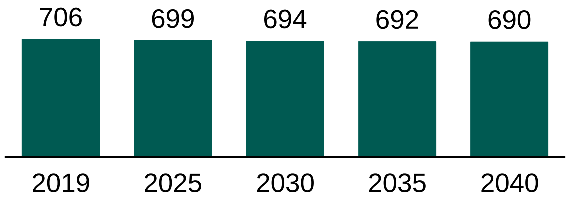
Key assumptions for new build power technologies (1/2)

CAPEX, Million 2020 EUR/MW

Gas CCGT

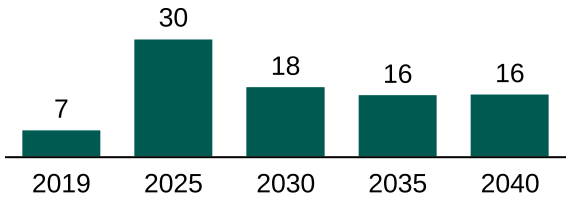
1.24 Fixed perspective 2017-2030

Gas OCGT



Fuel prices

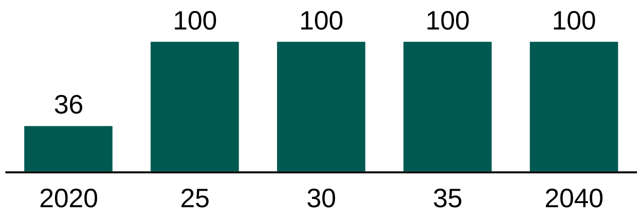
2020 EUR/MWh fuel



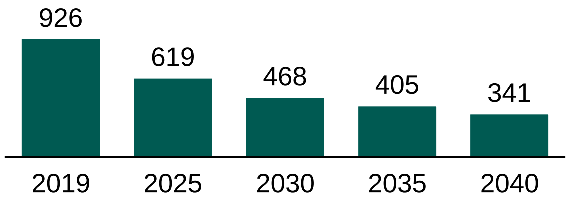
Other

Carbon price

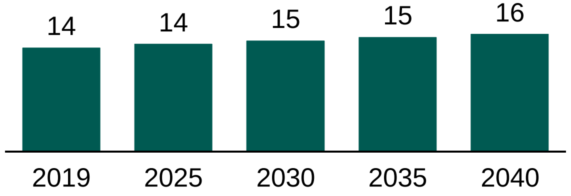
2020 EUR/tCO2e



Solar PV tracking



Capacity factor (AC), %

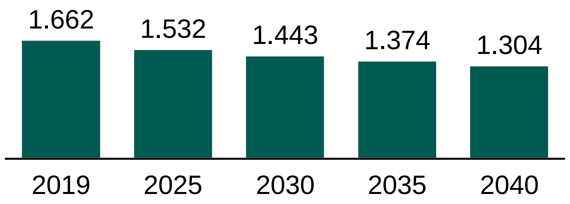


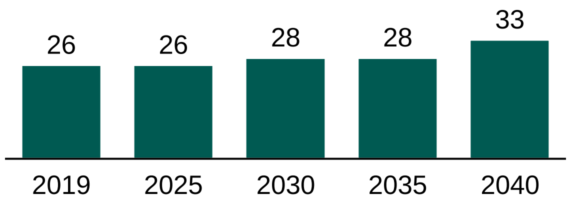
WACC

%

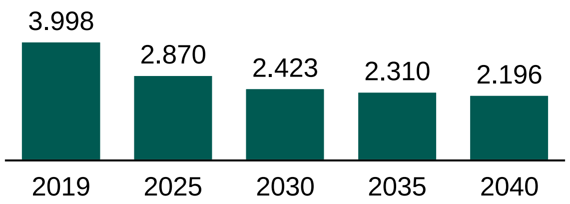
5

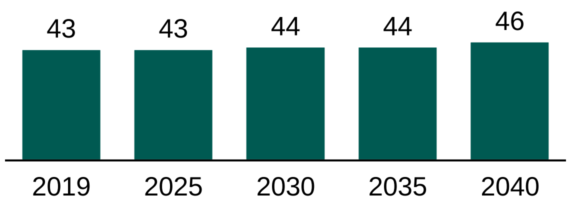
Wind onshore





Wind offshore





Source: Power Solutions Model, June 2022

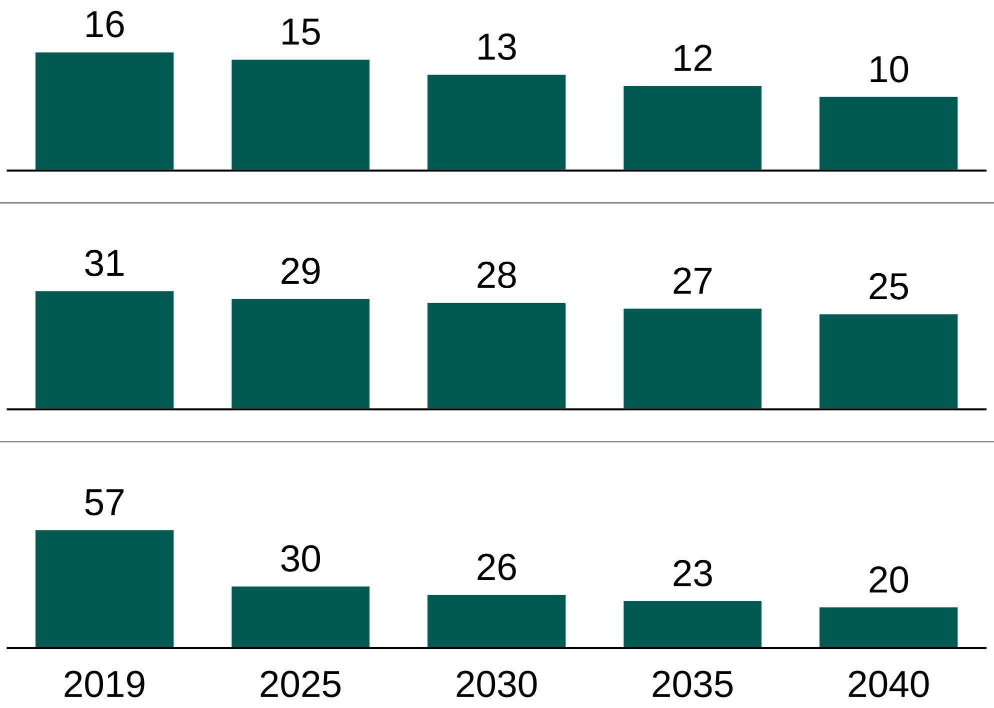
Key assumptions for new build power technologies (2/2)

	OPEX, Thousand 2020 EUR/MW/y		**Efficiency,** %	**Emissions factor,** tCO2e/MWh
Gas CCGT	**30**	Fixed perspective 2017-2030	**60**	**0.33**
Gas OCGT	**17**	Fixed perspective 2017-2030	**41**	**0.48**

Solar PV tracking

Wind onshore

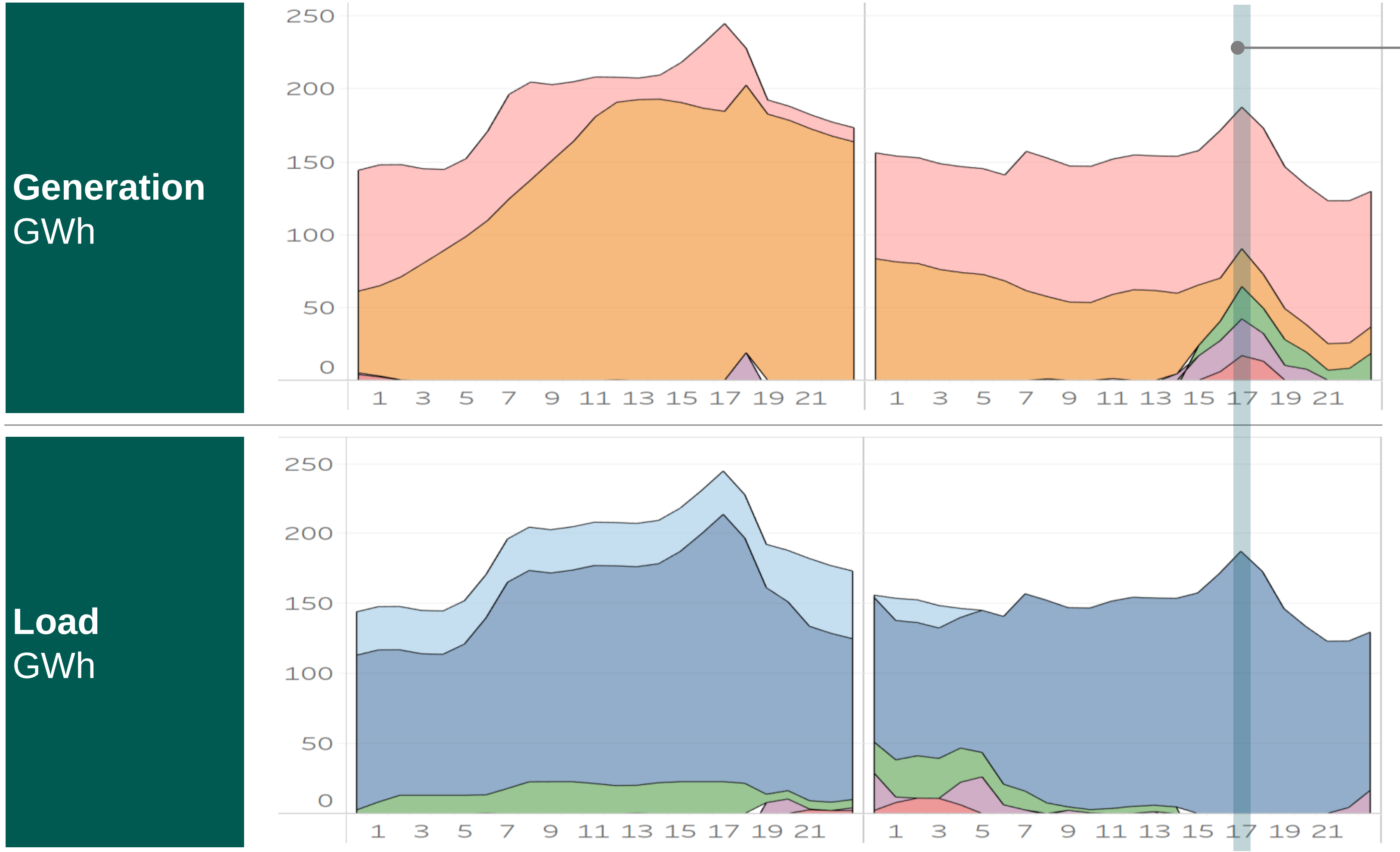
Wind offshore



Source: Power Solutions Model, June 2022

The Power Model dispatches flexibility resources for high renewables systems

Unconstrained day: 14th Dec, 2045 **Constrained day:** 18th Dec, 2045



- **Most constrained hour** for reliability is **defined by very low renewable output** during Dec 18th peak
- **Role** of (remaining) **thermal capacity** is to **maintain system reliability when renewables are low**
- **Dispatchable resources all contribute in the most constrained hour**, while dispatchable loads are zero
- **Dec 14th load higher than Dec 18th, but existence of higher renewables result in very residual need for thermal dispatch.** Extra energy used for P2G and exports to other regions

---

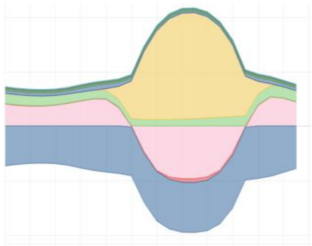
1. Imports/exports; 2. Flexible load is a conservative estimate that includes only flexible charging of electric vehicles; 3. P2G and hydrogen electrolysis

The Power Model optimizes hourly dispatch across a full year, and tracks optimal capacity expansion for multi-decadal periods

Example: California net zero carbon by 2045 modeling example

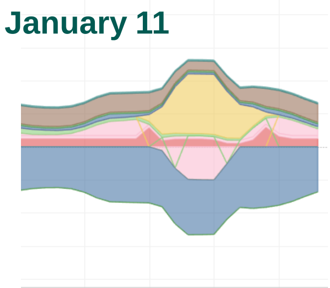
Hourly profiles for sample days, 2045

'Average' day



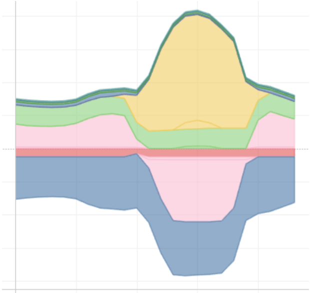
- Average day; does not exist in practice
- Indicative of solar/storage activity

January 11



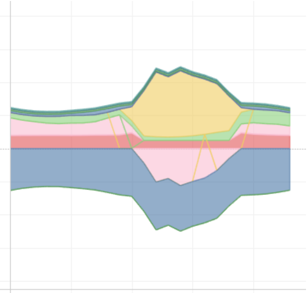
- Very low RE production
- Served by zero carbon gas

March 16



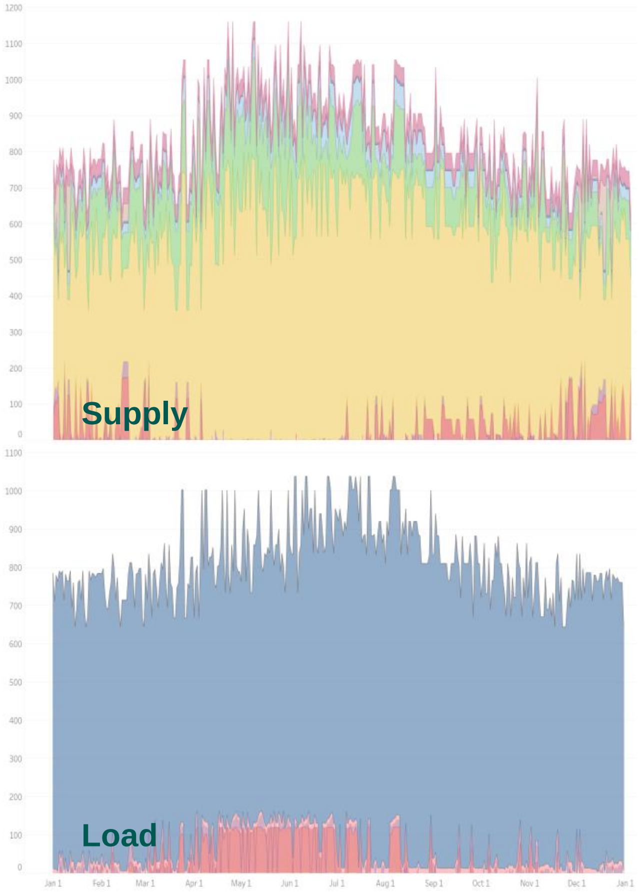
- High RE production day
- Full exports and even some curtailment

November 24

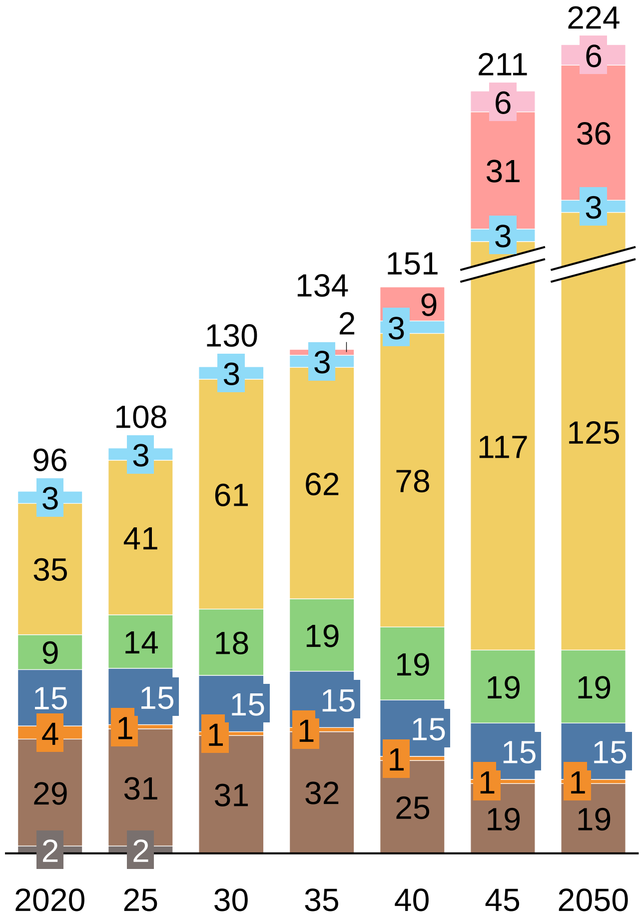


- Low production winter day
- Transmission imports able to bridge gap

CAISO 2045 daily supply/load, GWh



Capacity, GW



Source: Power Solutions Model, June 2022

The Power Model provides a granular and technology inclusive perspective on operational flexibility needs in high renewable systems

Description

Capacity expansion model with least cost investments and operations over the entire time horizon *(not a market model, no subsidies considered)*

Detailed hourly operations of **different generator types** and vintages *(not unit-by-unit level)*

Optimized investment in long-term storage of all types – imperative at high levels of renewables

View of generator fuel supply and **optimizes transition to cleaner blends**

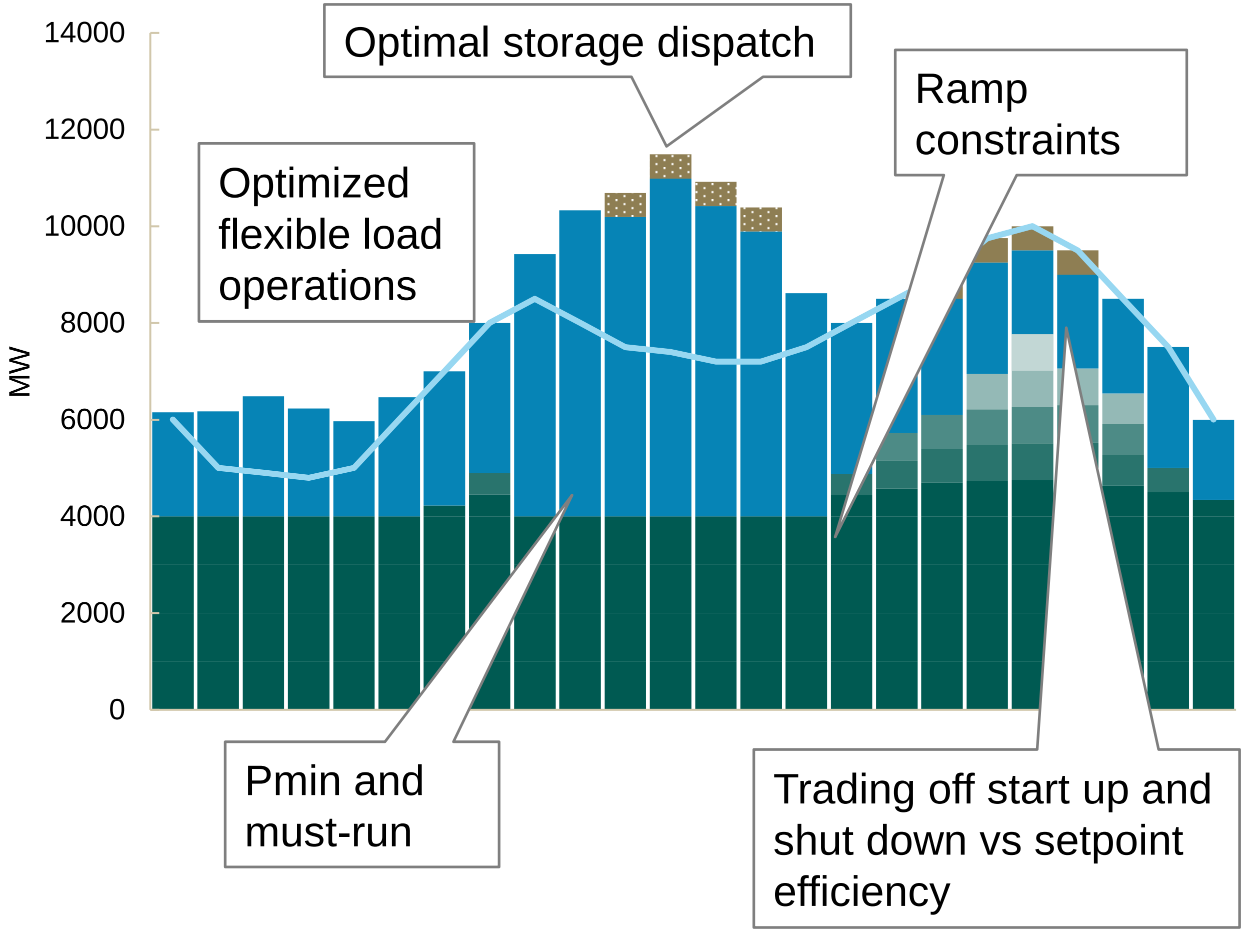
Transmission between zones – available down to desired level of granularity depending on the problem

Wide variety of **supply side energy technologies**, including electric fuels

Flexible loads – critical to balancing a highly intermittent grid – are **included in optimization**

Optimizes economic generator retirement, repowering, and extensions
not economic and policy decision

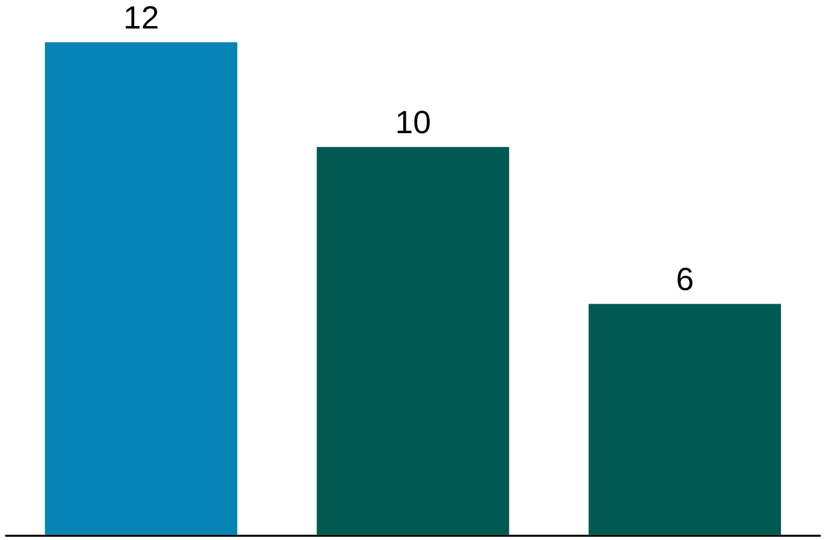
Hourly modelling illustration (by day)



Source: Power Solutions Model, June 2022

Contents

The proposed sectoral emissions ceiling delivers ~20% and 50% emissions reductions in 2025 and 2030

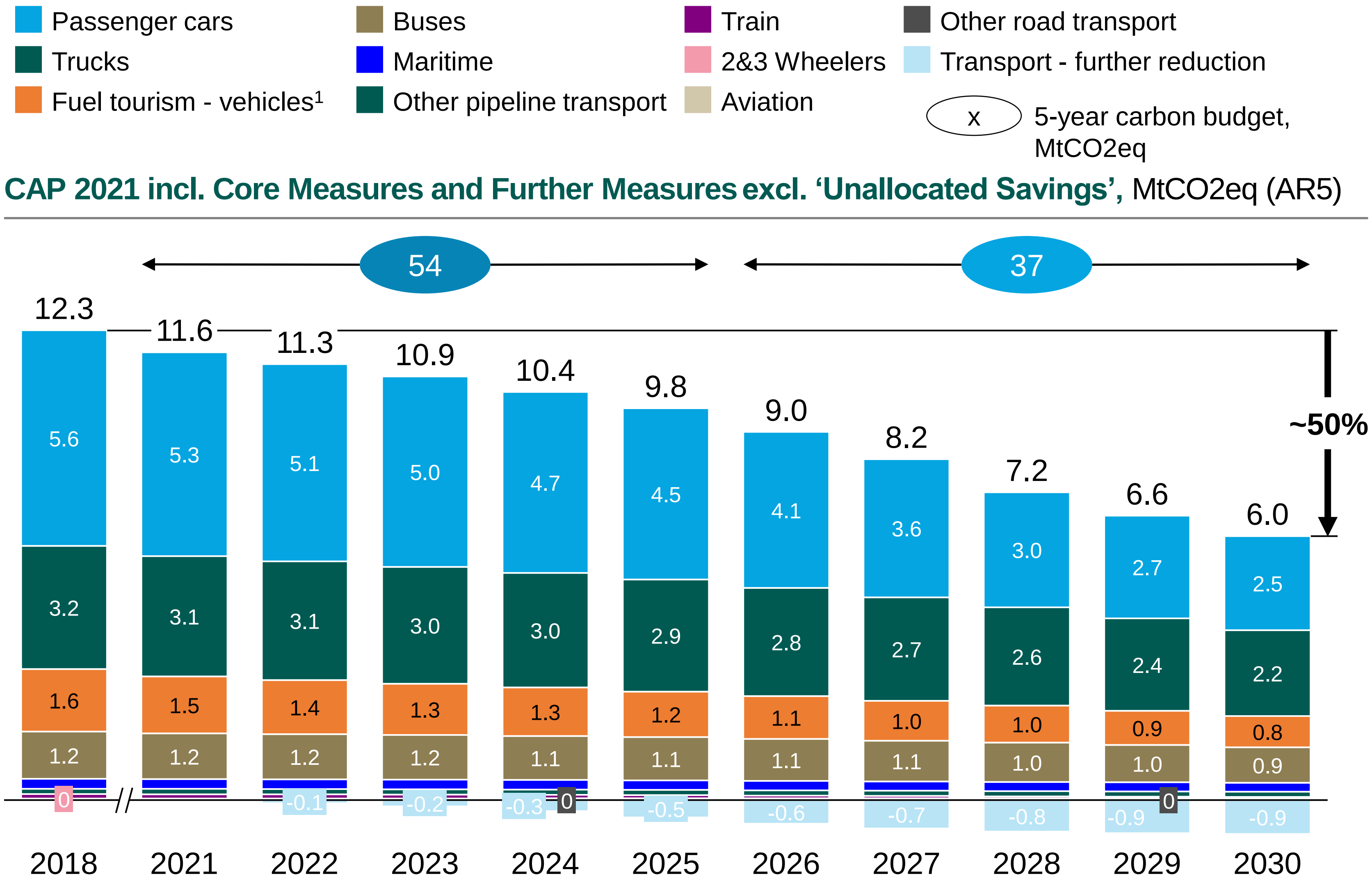


	GHG emissions[1], MtCO2eq (AR5)			% change vs. 2018		% impact outlined in CAP 2021	Sectoral emissions ceilings, MtCO2eq	
	2018	2025	2030	To 2025	To 2030		2021-2025	2026-2030
Transport	12	10	6	~20	~50	40-50	54	37

1. GHG emissions and abatement impact based on AR5 2021 EPA methodology

Source: Climate Action Plan 2021, Government of Ireland; Programme for Government 2020

Dept. of Transport will be responsible for overseeing a ~50% reduction in emissions to 2030



CAP 2021 incl. Core Measures and Further Measures excl. ‘Unallocated Savings’, MtCO2eq (AR5)

1. Fuel tourism accounted for ~2% of Ireland's national GHG emissions in 2015. Irish Journal of Social, Economic and Environmental Sustainability; January 2018

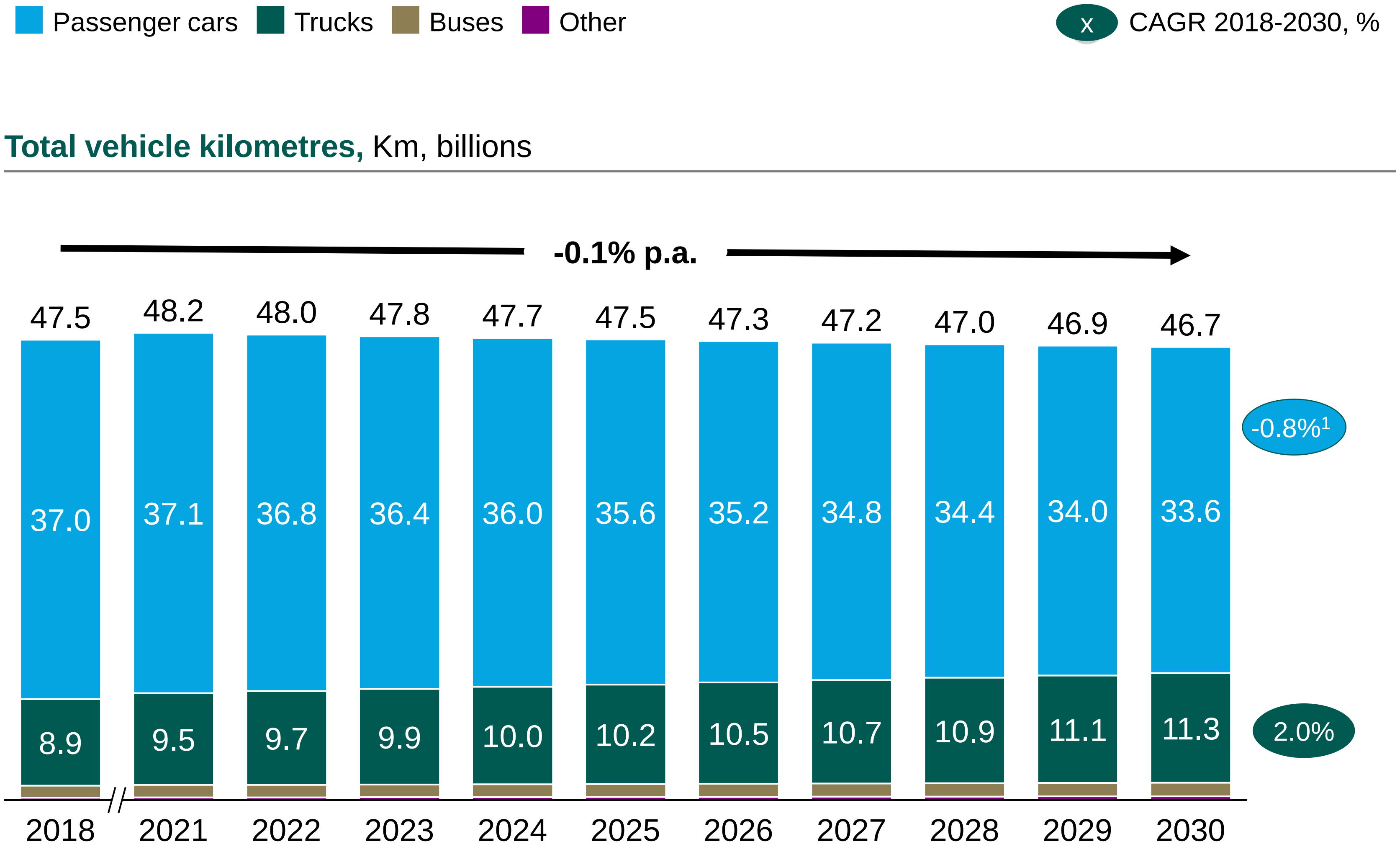
Reduction pathway in Climate Action Plan 2021 results in ~ 50% reduction by 2030 in emissions that could be covered by Department of Transport

Meeting the target emissions includes:

- Fully implementing the core measures outlined in CAP21
- Undertaking further modal shift (tier 2) through behavioral changes to reduce kilometers travelled to a greater extent

The sectoral emission ceiling assumes -0.1% annual growth in total vehicle kilometres through 2030

Total vehicle kilometres, Km, billions



1. Assumed a 0.6% increase in passenger kms through 2030, though this is reduced to -1.3% once a decrease in passenger kms travelled of 15.45% compared to a no action scenario is taken into consideration

Source: DSE Modelling assumptions

Key takeaways

Total vehicle kilometers are assumed to decrease by -0.1% per annum from the 2018 baseline to 2030

With further measures, passenger kilometers are forecast to decrease to ~31.7 billion in 2030 (-0.8% p.a.)

Achieving the proposed sectoral emissions could require an increase in the ambition for total stock of passenger EVs in 2030 from 845k in CAP21 to ~950k

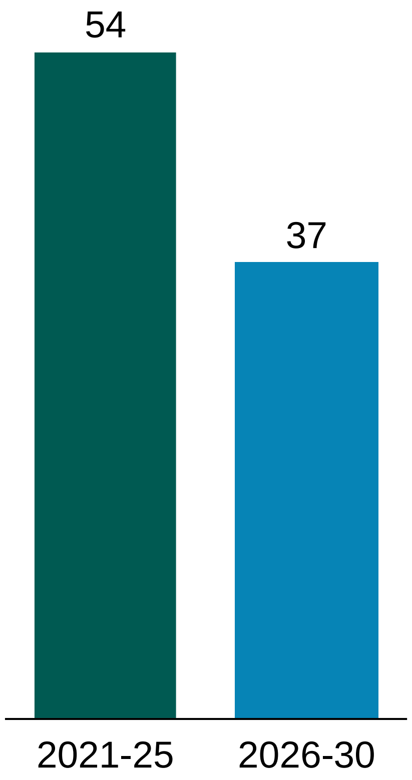
There are 5 measures that drive emissions reductions of ~5.6-6Mt by 2030

Abatement impact, MtCO2eq

○ <0.5 ◑ 1-1.5 ● >2

◔ 0.5-1 ◕ 1.5-2

Transport carbon budgets, MtCO2eq



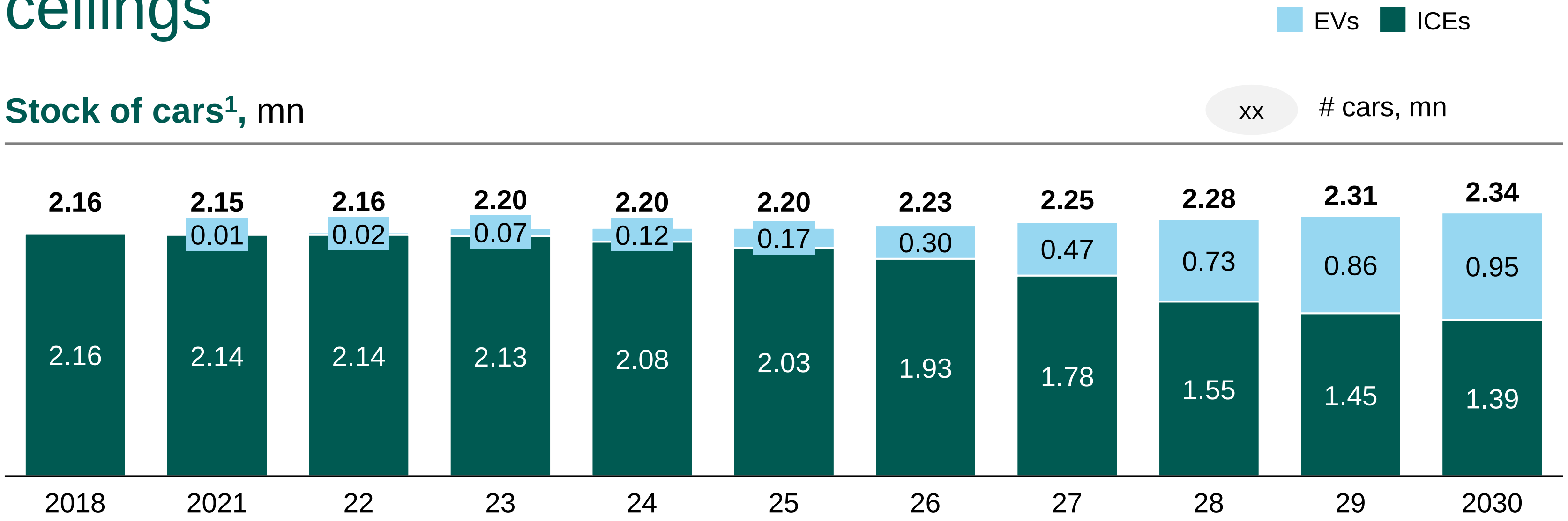
Potential Measures

		Measure	KPI 2025	KPI 2030	Abatement impact 2030 , MtCO2eq
Core measures **CAP21**	T1	**Electrify road transport: accelerated adoption of zero-emission passenger cars and commercial vehicles**	175k passenger EVs with focus on BEVs; ~20k vans and 700 HGVs	950k passenger EVs with focus on BEVs; ~95k vans and ~3.5k HGVs	●
	T2	**Increase bio-fuel blend-rate**	E10 bioethanol blend; B12 biodiesel blend	E10 bioethanol blend; B20 biodiesel blend	◕
	T3	**Electrify mass transportation**	300 EV buses and expanding electrified rail services	1.5k EV buses and expanding electrified rail services	○
	T4	**Sustainable transport journeys and demand management measures**	125k additional public transport and active travel journeys per day	15.5% reduction in car passenger kilometres vs do nothing	◑
Further Measures **CAP21**	T5	**Further modal shift** (tier 2) through behavioural changes to reduce kilometres travelled to a greater extent	To be defined	To be defined	◑ SUM ~5.6-6.0

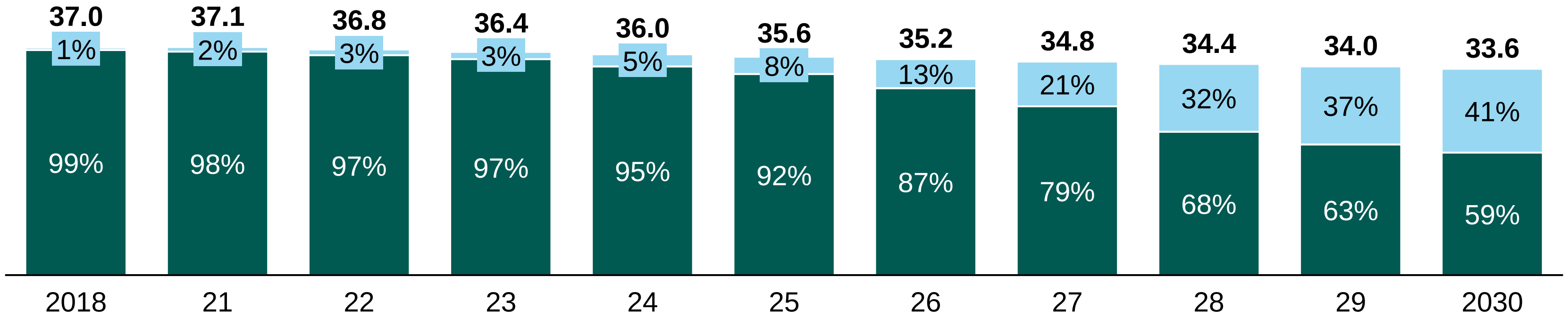
Source: Climate Action Plan 2021, Government of Ireland

T1: Stock of EV cars should increase from 845k to 950k in 2030 to achieve the proposed sectoral emission ceilings

Stock of cars[1], mn



Breakdown of total distance travelled by km and power train, (bn km,%)



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1. Growth in total number of cars is converted from total km driven, assuming 17,000 km average lifetime distance

Source: Climate Action Plan 2021, Government of Ireland

Proposed targets:

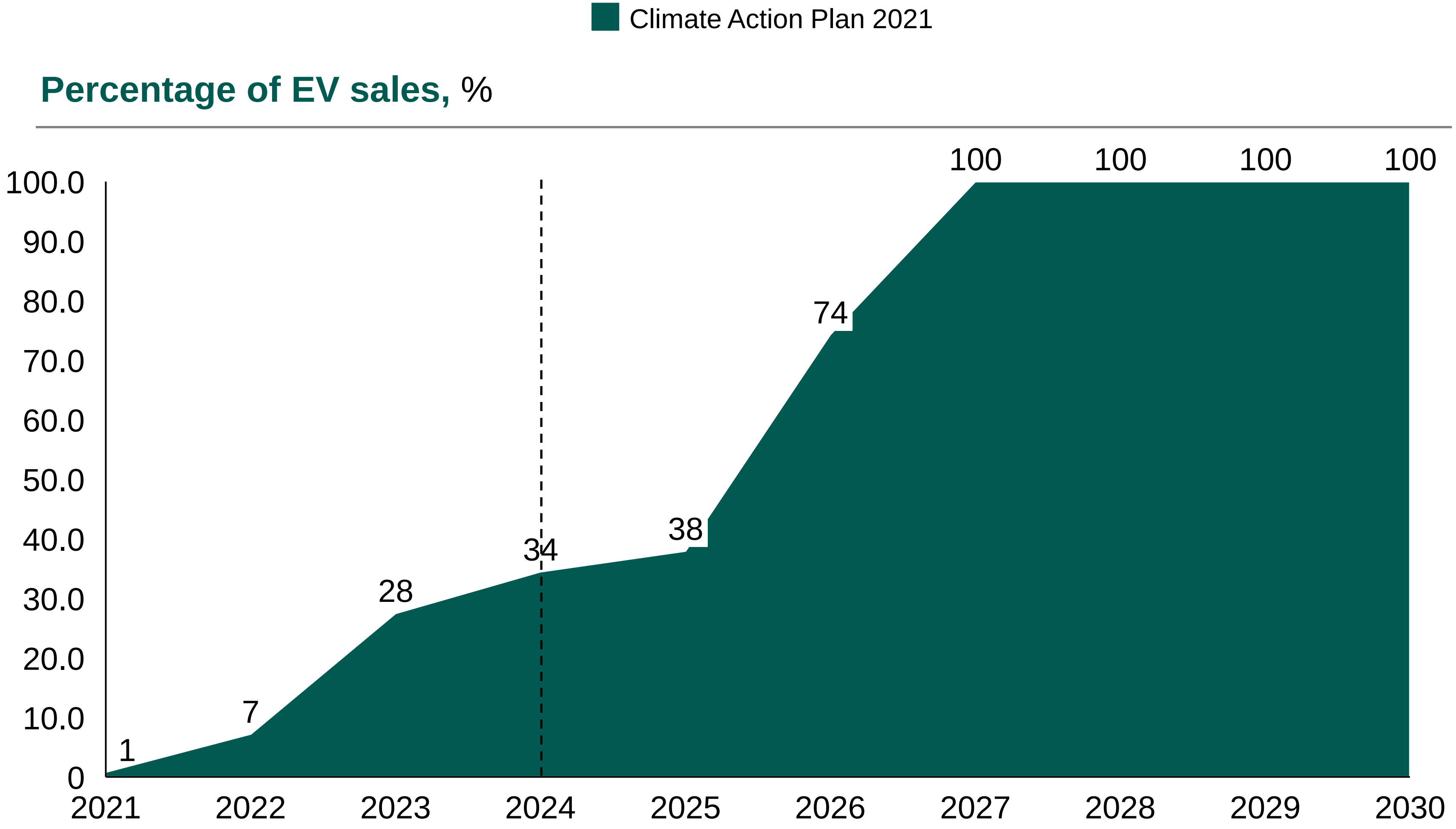
~175k passenger EVs by 2025

~950k passenger EVs by 2030

Key takeaways:

- Targets focused on BEV rollout over HEV or PHEV
- Ramp up based on assessment of when different car classes reach cost parity with petrol:
  - 2022: A/B class (e.g. Nissan Leaf)
  - 2026: C/D class (e.g. Hyundai Ioniq)
  - 2025: E/F class (e.g. Tesla)
  - 2023: J class (e.g. Volvo XC40)

T1: ~100% of passenger vehicle sales are assumed to be EV by 2030



1. Estimate; based on total vkm travelled and assuming 1/15th fleet retirement of ICE cars p.a.

Source: Irish EV owners association, SIMI; CAP21; HM Government, The Ten Point Plan for a Green Industrial Revolution, 2020.

Key takeaways

- ~950k ICE vehicles could be replaced by EVs on Irish roads by 2030
- Sale of EVs are ramped up to being 35-45% of new registrations (incl. imports) in 2025 after cost parity is achieved (2024) and ~100% from 2027[1]
- Ramp up in line with UK Government target to ban sales of new petrol and diesel cars in 2030
- Abatement cost for EV passenger cars is estimated to be in the range of -30 and -350 EUR/tCO_2

T1: Ambition is growing in support of EV rollout from regulators, manufacturers and consumers

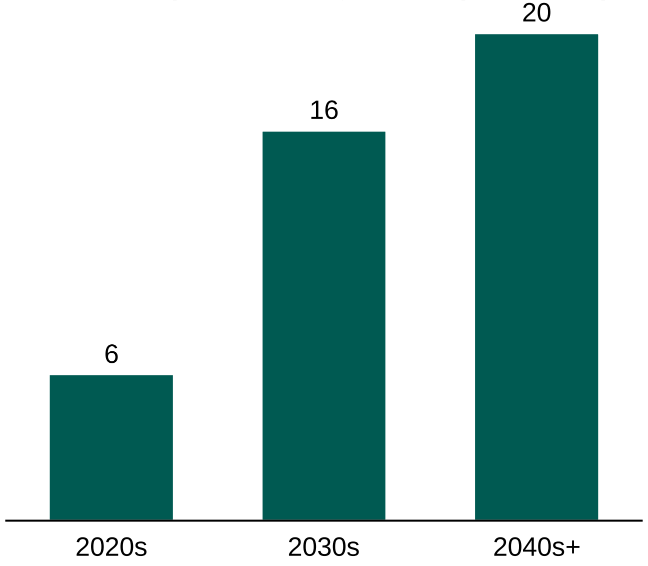
▨ Deep dive next page

Major regulatory packages signal an acceleration of EV uptake

Bans on ICE car sales	Share of global PC sales 2021
From 2025 Norway	**<1%**
From 2030 Israel[1], Iceland, Ireland, Netherlands, Denmark, UK, Sweden, China[2], Slovenia	**5%** incl. previous
From 2035 EU, Japan, USA[3], Chile, Canada, Thailand	**26%** incl. previous
From 2040 Taiwan, COP26[4]	**29%** incl. previous

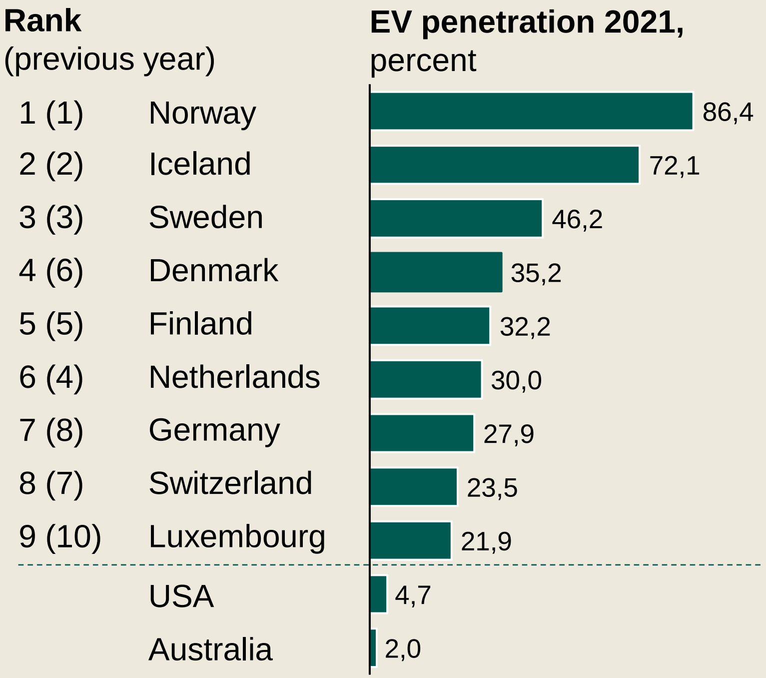
Manufacturers are phasing out ICEs in favour of EV models

Number of OEMs that have announced phase-outs of ICEs (cumulative by decade phased out)



Growing proportion of consumers are purchasing EVs

Electric[1] passenger vehicle sales by region, % of total



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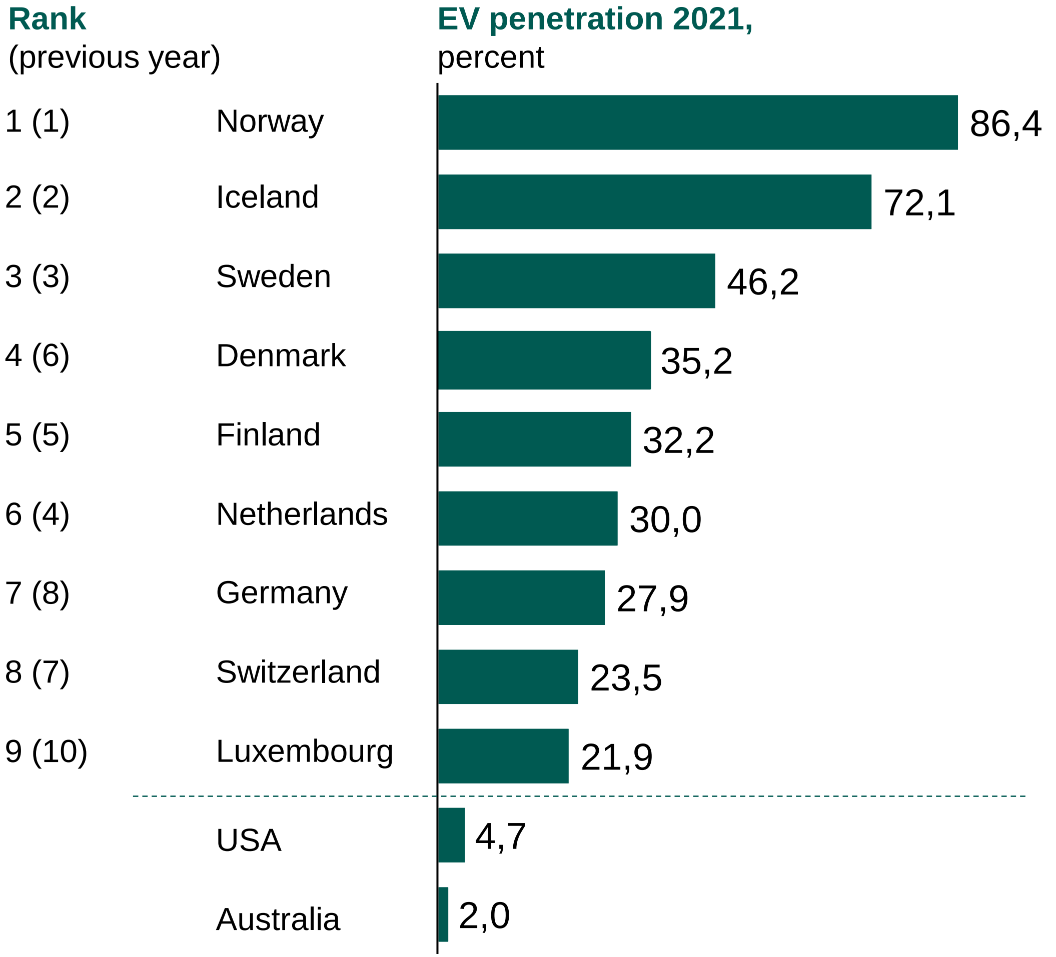
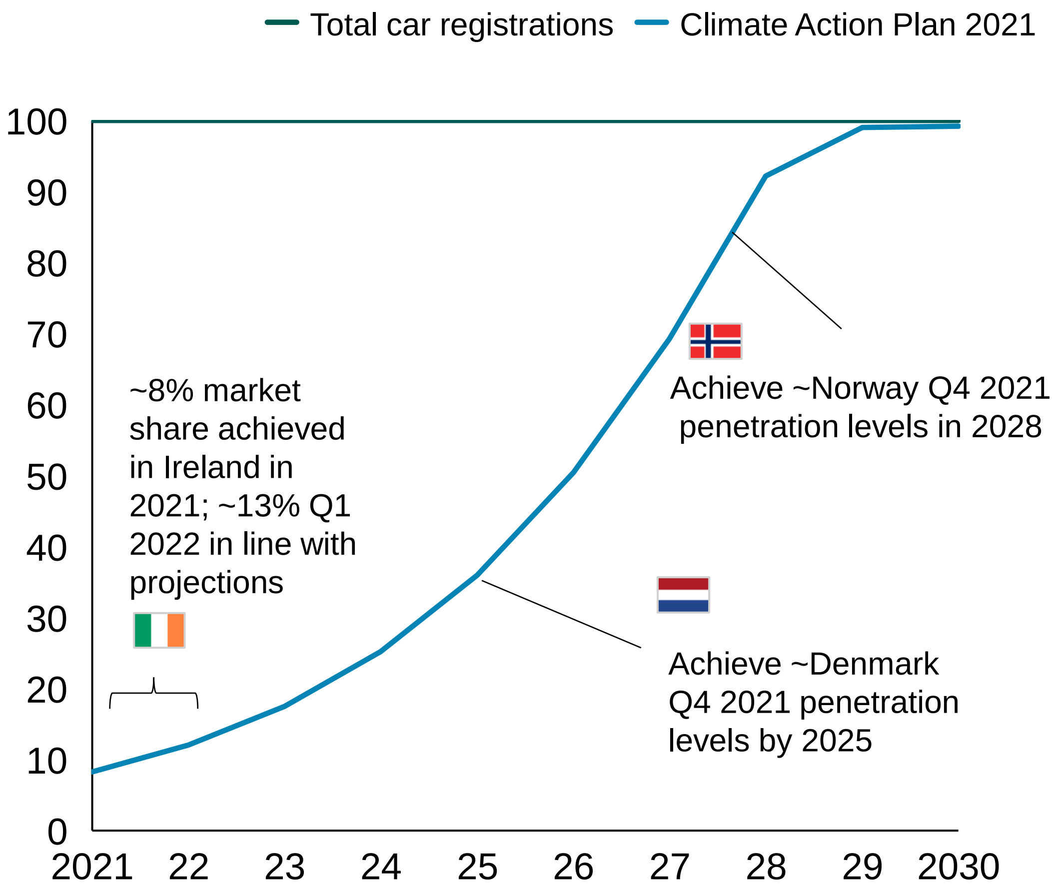
1. Only ZEV allowed, thus hybrid EVs will also be banned; 2. The Chinese province of Hainan will ban sales of new gas and diesel cars in 2030; 3. US states of CA, NY, NJ, MA, and OR will ban ICE sales by 2035, 4. Includes all national COP26 signatories with pre-existing commitments

T1: Peer countries have achieved similar EV ramp-up rates in recent years – Ireland on track in Q2 2022

Electric[1] passenger vehicle sales by region, % of total



Percentage of new EVs in Ireland under T1 measure
2021-30, %



~8% market share achieved in Ireland in 2021; ~13% Q1 2022 in line with projections

Achieve ~Norway Q4 2021 penetration levels in 2028

Achieve ~Denmark Q4 2021 penetration levels by 2025

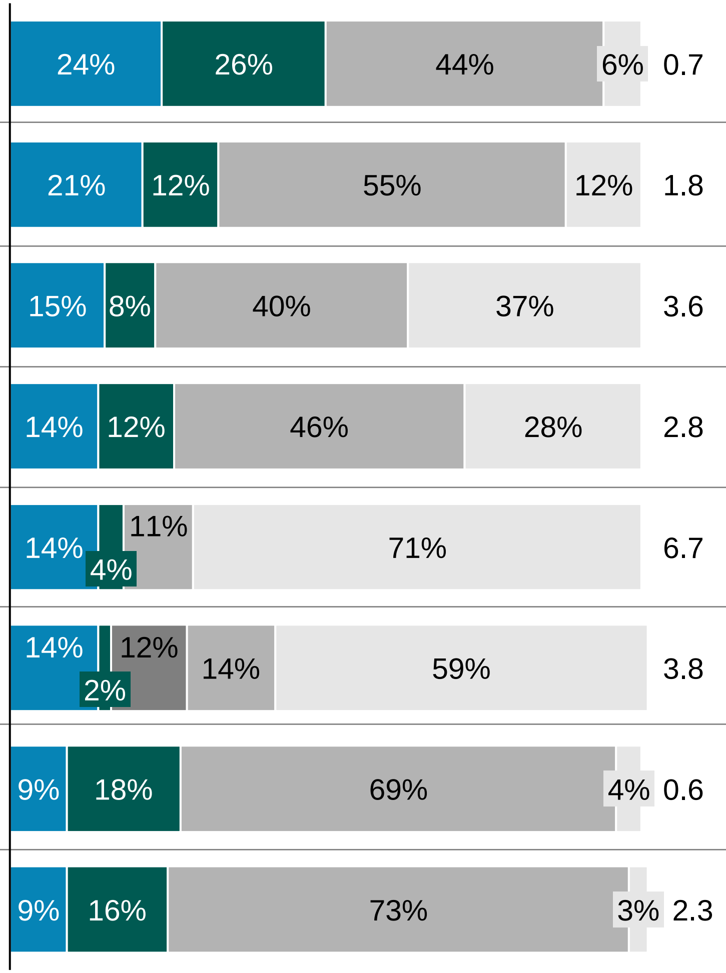
---

1. Share of BEV, PHEV in percent of total LV sales

Source: EV-volumes.com, IHS Markit, Irish EV owners association; Society of the Irish Motor Industry; Climate Action Plan 2021, Government of Ireland

T1: Volvo and Audi have greatest estimated production units for BEVs among European brands

Powertrain split in 2025
production units in %



Brand	EV strategy / targets
Volvo	• From 2019, all new Volvos will have an e-motor • By 2025, BEVs will account for 50% of global sales, hybrids for the other half • By 2030 will only sell fully electric cars
Audi	• By 2025, BEVs and PHEVs will make up 40% of the production volume • 30 electrified models will be launched on the market by 2025 incl. 20 BEVs • All new launches from 2026 will be electric, all sales to be fully electric by 2033
PSA	• As of 2019, all new petrol and diesel models will systematically come in a hybrid or all-electric version • An electrified variant will be available for every model range by 2025 • By 2025, the company will offer a fully electric portfolio
Mercedes-Benz	• Six new EVs using a new dedicated architecture to be launched from 2021 • By 2030, the number of ICE variants will fall by 70% • By 2025, all new launches will be electric only. It will be ready for all-electric market in the 2030s
VW	• Expects to produce 1.5 mn EVs by 2025 • Emission target will force VW to increase electrified vehicle share in the EU to 60% by 2030 • After 2026 only electric vehicles will be launched; 2040 100% of new sales will be electric
Renault	• Out of 24 new Renault Group vehicles by 2025, 10 will be BEVs • In Europe, 65% of model launches will be BEV and EV models by 2025, and 90% by 2030 • To become all electric by 2030
JLR	• Jaguar brand will become all electric by 2025 as part of the JLR strategy ‘Reimagine’ • Land Rover will launch 6 BEVs in the next 5 years with an all-electric variant being available for all Jaguar Land Rover will stop producing ICE vehicle for sale in the UK by 2030 in line with UK government plans
BMW	• By end-2021, five BEVs to be available on the market • 20% electrified vehicles sales share in 2023 • Developing a BEV platform by 2025 • Fully electric vehicles to represent at least 50% of sales by 2030

Source: Company websites and presentations; New Climate Economy. The ambition loop in motion for electric vehicles in the automotive industry, October 2021

T1: Purchase subsidies, reduced taxes, fuel cost savings and privileges for electric vehicles are among the most important consumer incentives

ILLUSTRATIVE, NON-EXHAUSTIVE

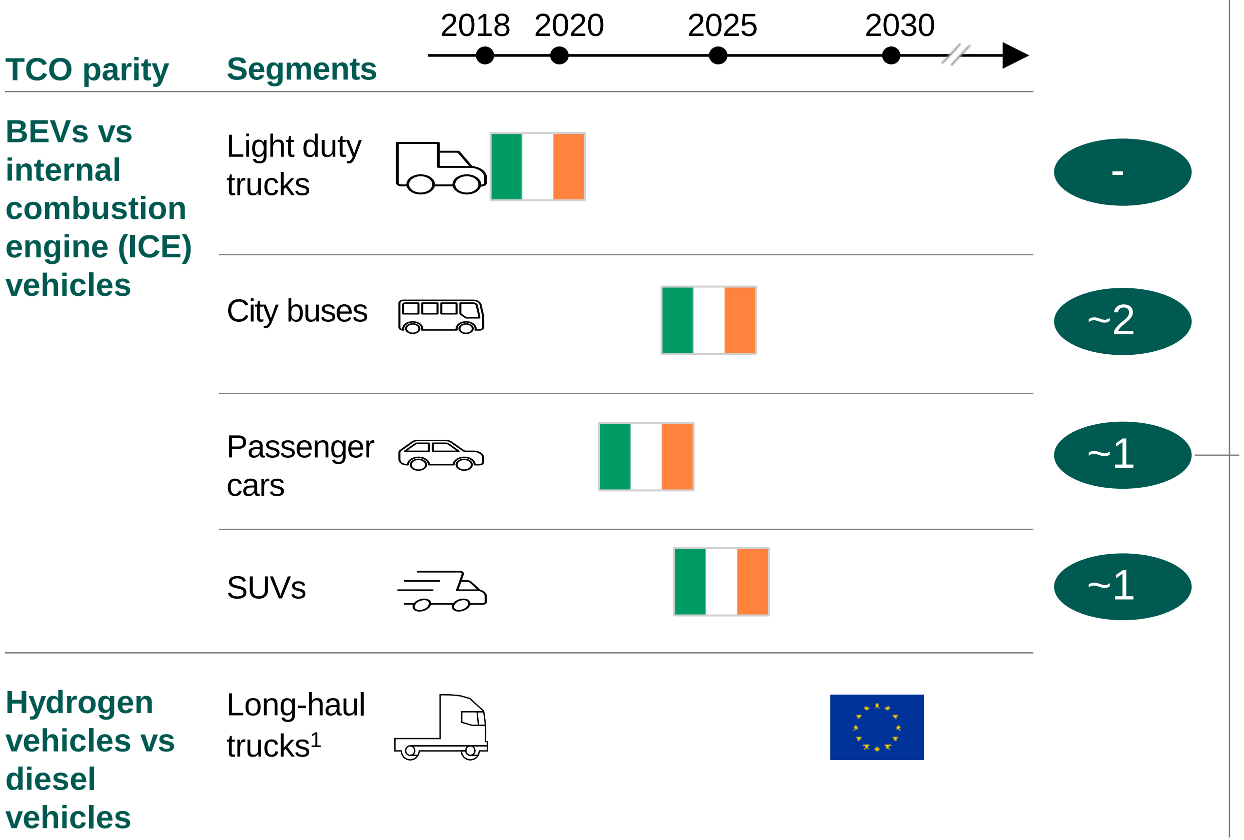
Type	Details	Example
Purchase subsidies	One-time purchase subsidy granted by the government and/or OEMs Different amounts often apply depending on, e.g., gCO_2/km, battery capacity, e-range, GVW, price difference EV vs. ICE Sometimes limited to specific xEV types and/or models Often limited to the maximum available subsidy budget	The German government grants an environmental bonus of EUR 9,000 for BEVs and EUR 6,750 for PHEVs
Tax incentives	Reduced purchase and/or annual tax Various forms already exist such as VAT, purchase tax, registration tax, annual circulation tax, company car tax, fuel consumption tax, luxury tax Size of discount often depends on CO_2 emissions, displacement, fuel type, or other factors	Colorado offers a USD 5,000 tax credit for purchase of a new EV South Korea exempts EVs from the excise tax
Fuel cost savings	Incentive because electricity prices are lower than fuel prices as a result of lower taxation and/or lower energy costs	Norway taxes are high on gasoline and low on electricity
Privileges and infrastructure investment	Often applied by both national and local governments Examples: incentives for home and workplace charging equipment, public installation of charging equipment, free charging, free parking, use of bus/taxi lanes, registration benefits	Low emission vehicles are allowed to park for free everywhere in Paris for 2 hours

Source: ICCT; ACEA;

T1: EV TCO is estimated to break-even with ICEs by 2024-5 in main segments in Ireland

● No. years earlier for TCO parity considering carbon tax

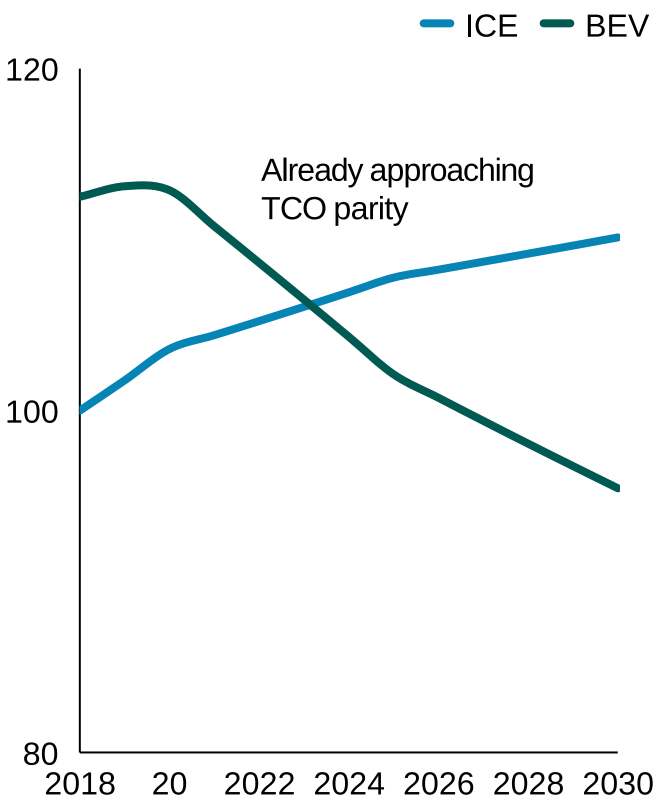
Timing of TCO parity



TCO parity	Segments	
BEVs vs internal combustion engine (ICE) vehicles	Light duty trucks	-
	City buses	~2
	Passenger cars	~1
	SUVs	~1
Hydrogen vehicles vs diesel vehicles	Long-haul trucks[1]	

TCO for passenger cars,

cost per km normalized to 2018 ICE, %



Commentary

Light duty trucks and passenger cars reach TCO parity earlier due to lower capacity of battery required

Progressive increase of carbon tax to 100EUR/t will accelerate TCO parity by 1-2 years

---

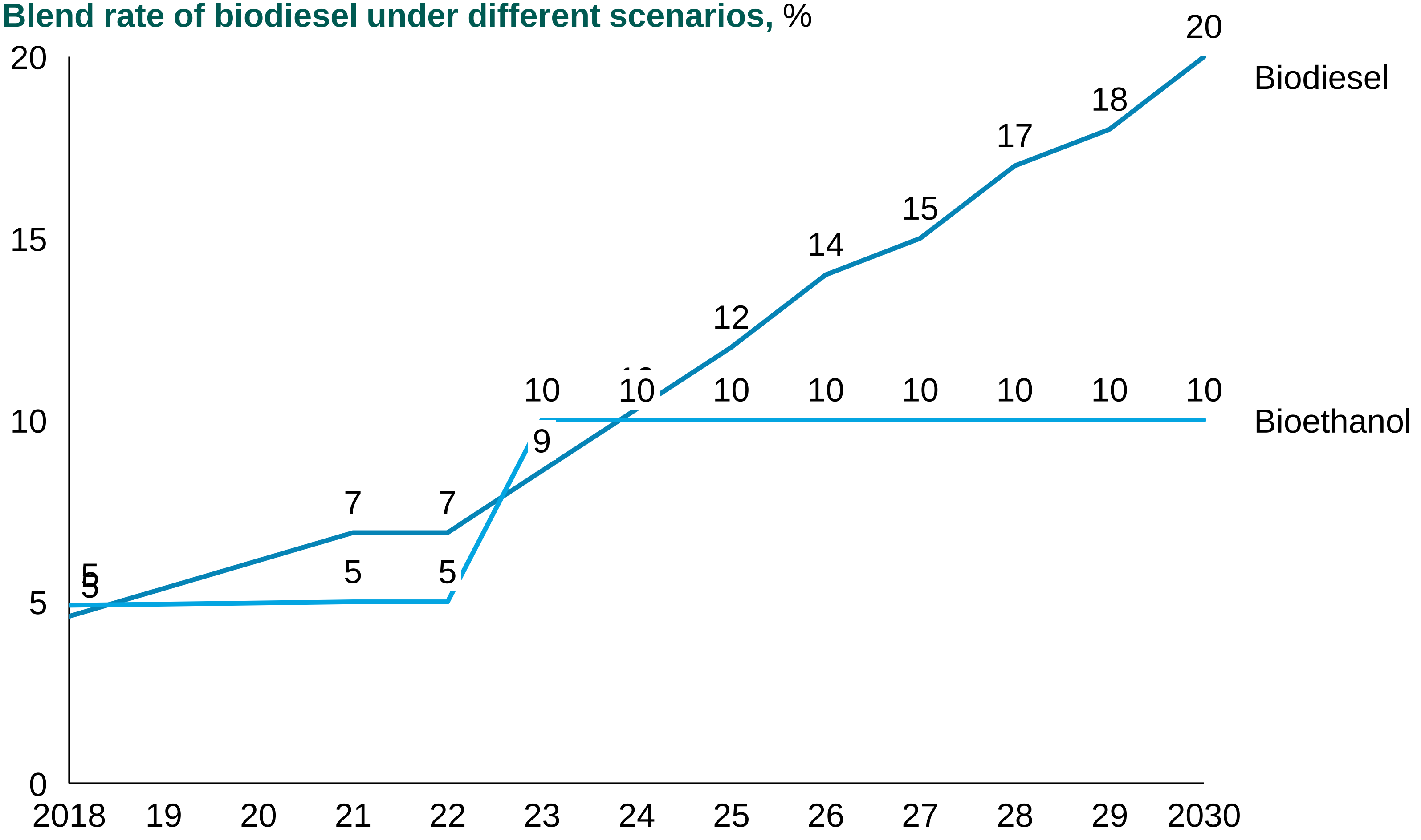
1. TCO expected for the EU

Note: Assumed carbon tax to increase up to 100 EUR/t in 2030

T2: The biofuel blend-rate is forecast to increase to B20 and E10 by 2030, in line with existing policy

Biofuel Blend Rate Impact

Blend rate of biodiesel under different scenarios, %



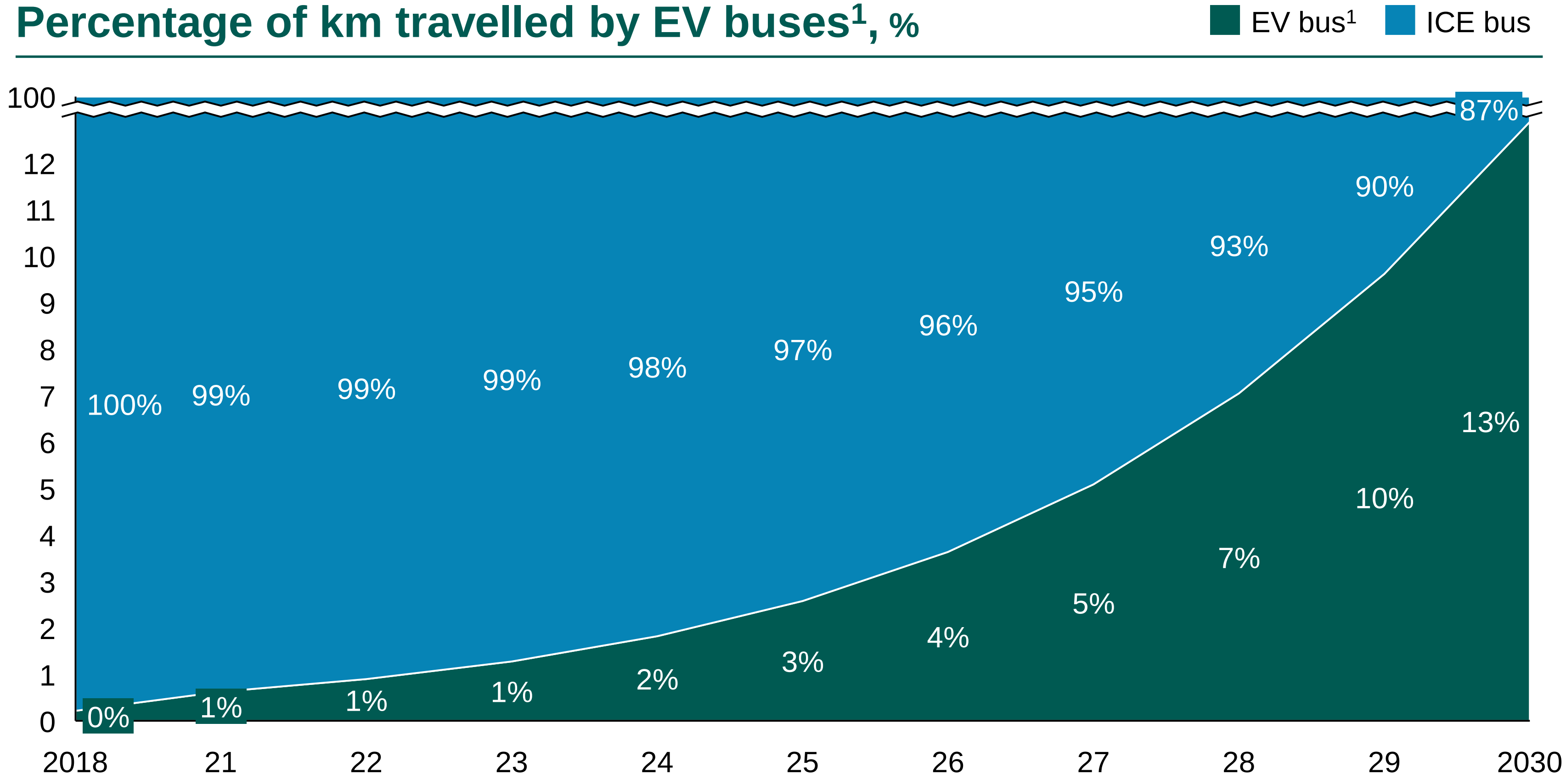
Source: Renewable Fuels for Transport Policy, Climate Action Plan 2021, Government of Ireland

Key takeaways

- Increasing the ambition on biofuel rate to B20 and E10 in diesel and petrol blends by 2030
- Increasing the biodiesel blend rate to 20% is within the technical limit of diesel engines. Increasing ethanol blend rate above 10% is not possible without replacing petrol cars with flex fuel cars. This has therefore been omitted from the analysis
- Average abatement cost for increasing biodiesel blend is estimated to be ~280 EUR/tCO_2

T3: Rollout of an EV bus fleet to ~13% of km travelled by EV buses by 2030 is core to electrifying mass transportation

Percentage of km travelled by EV buses[1], %



EV km[1], *mn*

~3	~8	~12	~17	~24	~34	~49	~69	~96	~133	~180

1. FCEV and EV buses

Source: DSE modelling assumptions, June 2022

Key takeaways

CAP21 targets:

- 300 EV buses by 2025
- 1,500 EV buses by 2030

EV km travelled increases to ~34mn km by 2025 and ~180mn km by 2030 as share of EV buses increases. Mix of FCEV and EV assumed

T4: Mode shift and demand reduction could drive significant abatement, with potential to stretch measures

Passenger car use reduction

- **Remove the need to move**
  - Incentivise working from home
  - Incentivise living close to workplace
- **Switch to transport modes with lower carbon intensity**
  - Improve pedestrian and cycling network
  - Shift vehicle mix away from SUVs
- **Increase # of passengers per vehicle trip**
  - Incentivise carpooling
  - Expand bus and tram networks
  - Implement publicly shared taxis and buses

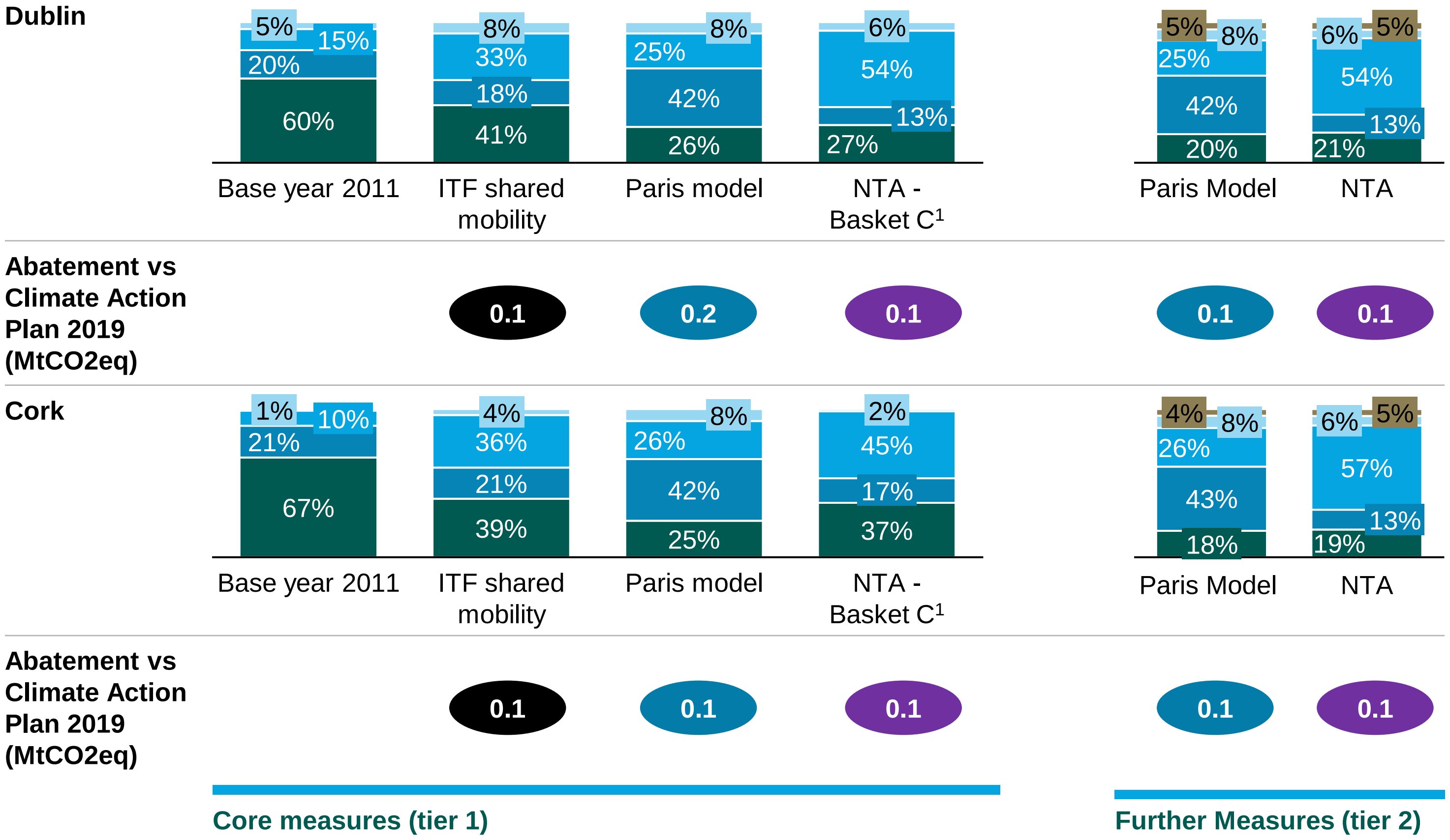
Key takeaways

Potential modal shift measures include:

- Shift in vehicle mix away from SUVs
- Mode shift in Dublin and Cork at peak times.
- Potential further measures includes countrywide demand shift

T4: Increasing active and public transport in Dublin and Cork could abate ~0.2-0.3 MtCO2eq

Current and planned share of transport modes in Dublin and Cork during peak travel time, %



Key takeaways

By focusing on shifting journeys from private cars to more sustainable transport modes in both Dublin and Cork during am and pm peak **0.3 MtCO2eq abatement could be achieved.**

Demand reduction can increase abatement further. **Reducing residual private car journeys by 20% in Cork and Dublin during peak times abates a further ~0.1 MtCO2eq.**

Extending demand reduction countrywide could result in 0.5 MtCO2eq abatement

These abatements assume fleet improvements for private cars have been successfully implemented (i.e. levers T1, T2 and T4 (shift away from SUVs))

Comparing to NTA model similar car use is projected in 2030 (~26-27%) however the make up of active and public transport is different. Note: NTA total abatement = 1.2MtCO2eq, this analysis just looks at peak travel times in two cities using the same modal breakdown

---

1. Analysis incl. impact of x1.5 increase in cost/km of car travel

Source: NTA, Transport Strategy for the Greater Dublin Area 2016-2035, Cork Metropolitan Area Draft Transport Strategy 2040, National Household Travel Survey 2017; Shared Mobility Simulations for Dublin, La nouvelle enquête globale transport 2018; CAP21

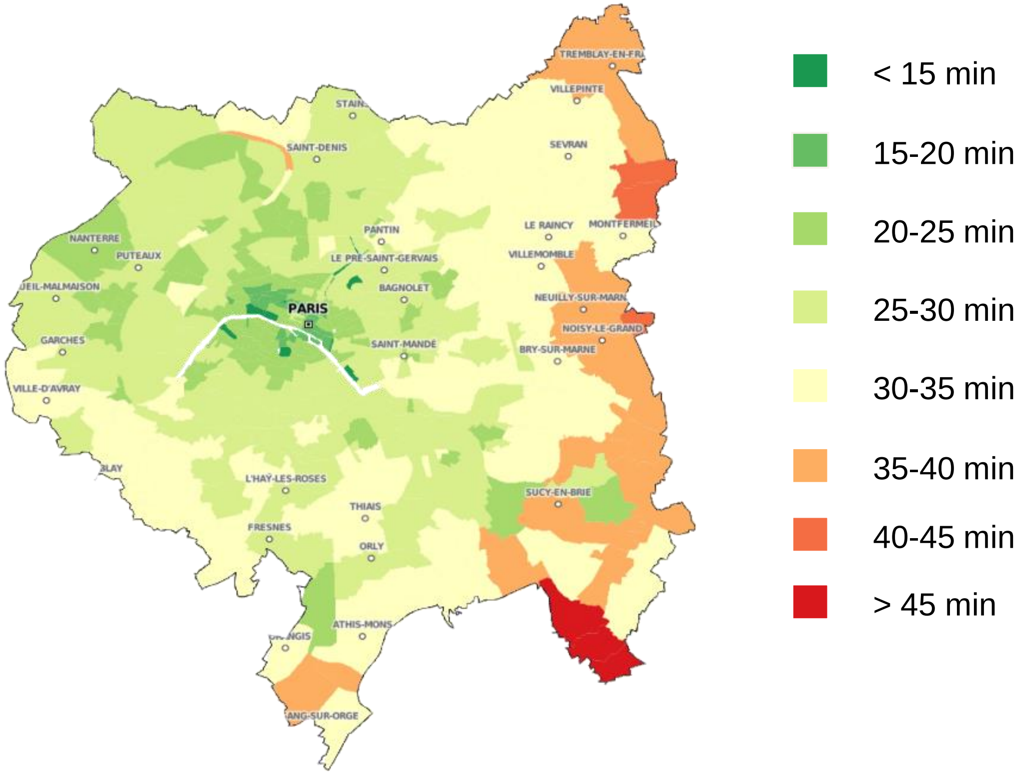
T4: Objective - These 5 performance dimensions help assess a city's transport system, enabling objective measurement of the system

	Availability	**Affordability**	**Efficiency**	**Sustainability**	**Convenience**
	How available are transit modes?	How much does transit cost to users and system?	How quick and reliable is transit?	How safe is transit? What are particle and CO_2 emissions?	What is the quality of the transit?
Underlying elements (illustrative)	Availability of public transit infrastructure near jobs, population and tourist destinations Availability of road infrastructure for passenger and commercial vehicles Availability of bicycle and shared infrastructure	Public transport affordability (e.g., cost of ticket, subsidized categories) Private transport affordability (e.g., cost of parking, congestion pricing, tolls)	Public transport efficiency (e.g., speed, waiting time) Private transport efficiency (e.g., congestion, commuting time predictability) Modal mix for residential and commercial traffic	Safety of public and private transport Environmental impacts of transport (Carbon emissions and air quality)	Travel comfort in public transit Convenience of ticketing system Number and convenience of transfers

Source: Elements of Success: Urban Transportation Systems of 24 Global Cities

T4: Approach to modal shift - build a digital twin of the system using data from millions of commuters

Average commute (min), by origin



Note: The illustration shown is based on an representative sample from the original data set encompassing > 3 mn origin-destination flows on an average day between 6 am and 11:59 am. This will be developed with legal guidance on regulatory compliance in terms of privacy laws, etc., and will draw on publicly available data wherever possible.
Note: Multi-modal trips (e.g., travel via public transit plus walking to and from public transit stations) are categorized by the main mode of transport (in this case public transit)

Details on approach

Data from millions of actual commuters with information on individual origin-destination routes

Geospatial model to create a digital twin of roads, transit lines, bike lanes, and commuters' mode choices

Tens of GBs from more than a dozen different sources, e.g.,

- **Demographic data** on population details and job density
- **Integrate data from thousands of traffic cameras** to derive in-depth insights on congestion and traffic speed

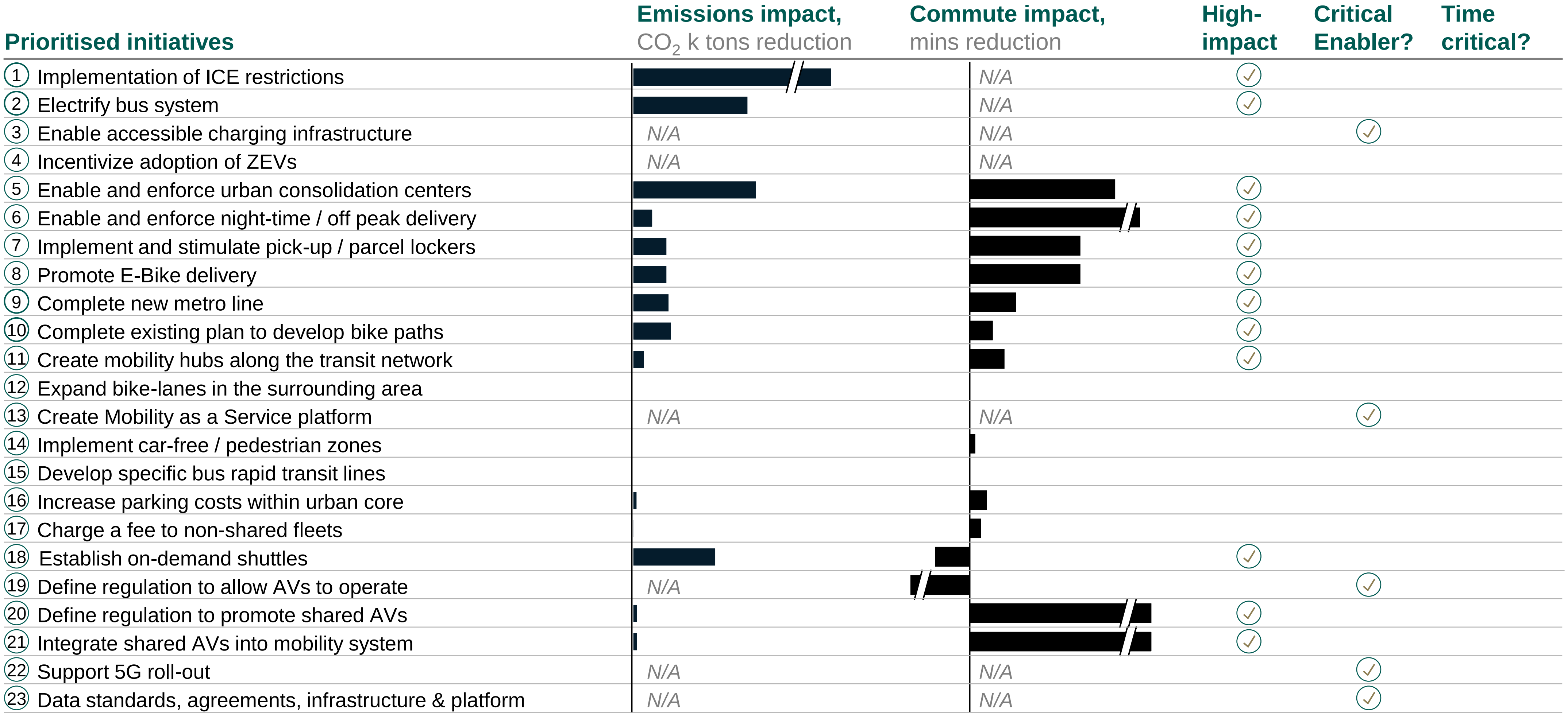
Data privacy and responsible usage of date will need to be ensured when creating and using the model

Required data (publicly) available for majority of C40 cities

NOT FOR FURTHER DISTRIBUTION

T4: Outcome - Impact of identified measures in a European city are shown for both environmental and commuter metrics

Disguised client example



Prioritised initiatives	**Emissions impact,** CO_2 k tons reduction	**Commute impact,** mins reduction	High-impact	Critical Enabler?	Time critical?
① Implementation of ICE restrictions		*N/A*	✓		
② Electrify bus system		*N/A*	✓		
③ Enable accessible charging infrastructure	*N/A*	*N/A*		✓	
④ Incentivize adoption of ZEVs	*N/A*	*N/A*			
⑤ Enable and enforce urban consolidation centers			✓		
⑥ Enable and enforce night-time / off peak delivery			✓		
⑦ Implement and stimulate pick-up / parcel lockers			✓		
⑧ Promote E-Bike delivery			✓		
⑨ Complete new metro line			✓		
⑩ Complete existing plan to develop bike paths			✓		
⑪ Create mobility hubs along the transit network			✓		
⑫ Expand bike-lanes in the surrounding area					
⑬ Create Mobility as a Service platform	*N/A*	*N/A*		✓	
⑭ Implement car-free / pedestrian zones					
⑮ Develop specific bus rapid transit lines					
⑯ Increase parking costs within urban core					
⑰ Charge a fee to non-shared fleets					
⑱ Establish on-demand shuttles			✓		
⑲ Define regulation to allow AVs to operate	*N/A*			✓	
⑳ Define regulation to promote shared AVs			✓		
㉑ Integrate shared AVs into mobility system			✓		
㉒ Support 5G roll-out	*N/A*	*N/A*		✓	
㉓ Data standards, agreements, infrastructure & platform	*N/A*	*N/A*		✓	

T4: Roll out - Paris aims to reduce air emissions from transportation through mix of bans on highly-emitting vehicles and subsidies on EVs (Crit'Air system)[1]

Pre-2015

WHO publications on effects of road pollution trigger discussions about low-emissions zones

2015

National Minister of Ecology established the Crit'Air system:

- Local Authorities can settle a ZPA (Crit'Air only during pollution peaks) or a ZPA+ZCR (continuous Crit'Air)
- Establishing Crit'Air is by decree

2016

Paris announces Crit'Air 2016, as well as other French cities[1]

National government introduces public subsidies to change a personal car from diesel to EV (based on household income)

2017

City of Paris introduces Crit'Air level 5:

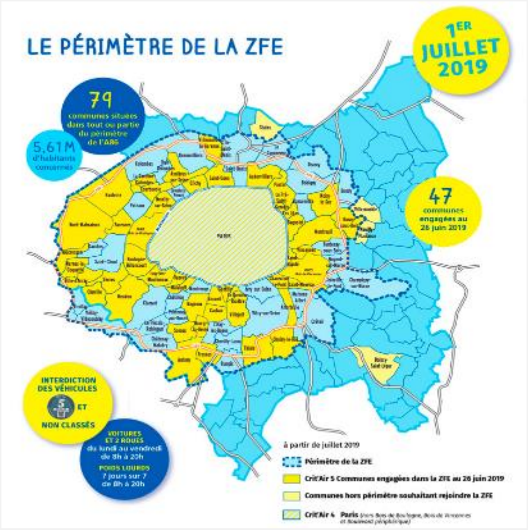
- No access for unclassified cars
- All drivers need to request a vignette before Summer 2017
- Category 5 cars prohibited

National government introduces another lump-sump subsidy for EV purchase

2019

Catg. 4 prohibited within the area, affecting 8% of current vehicle parc

Crit'Air area per July 1 2019



2022

Catg. 3 prohibited within the area,

2024

Catg. 4 prohibited within the area

2030

Fossil-fueled catg. 1 prohibited

Category[2]	Powertrain	EURO norm	Estimated share of current car parc
CRIT'Air	Electric / Hydrogen	n.a	1%
1	Gas, Hybrid or Gasoline	If gasoline, EURO 5/6	26%
2	Gasoline or Diesel	If Gasoline, EURO 4 If Diesel, EURO 5/6	43%
3	Gasoline or Diesel	If Gasoline, EURO 2/3 If Diesel, EURO 4	22%
4	Diesel	EURO 3	7%
5	Diesel	EURO 2	1%

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1. Most of French urban areas settled Crit'Air system, all between S2 2017 and S1 2019: ZCR + ZPA system for Paris, Grenoble, Lille, Lyon, Strasbourg and Toulouse ; ZPA only for Angers, Annecy, Auch, Bordeaux, Chambery, Chartres, Clermont-Ferrand, Dijon, Guéret, La Roche sur Yon, Marseille, Montpellier, Niort, Orléans, Pau, Poitiers, Rennes, Valence & Vallée de l'Arve
2. All other cars (oldest and/or not complying to EURO 2 norm) are not classified and forbidden by default

Source: Paris Climate Action Plan

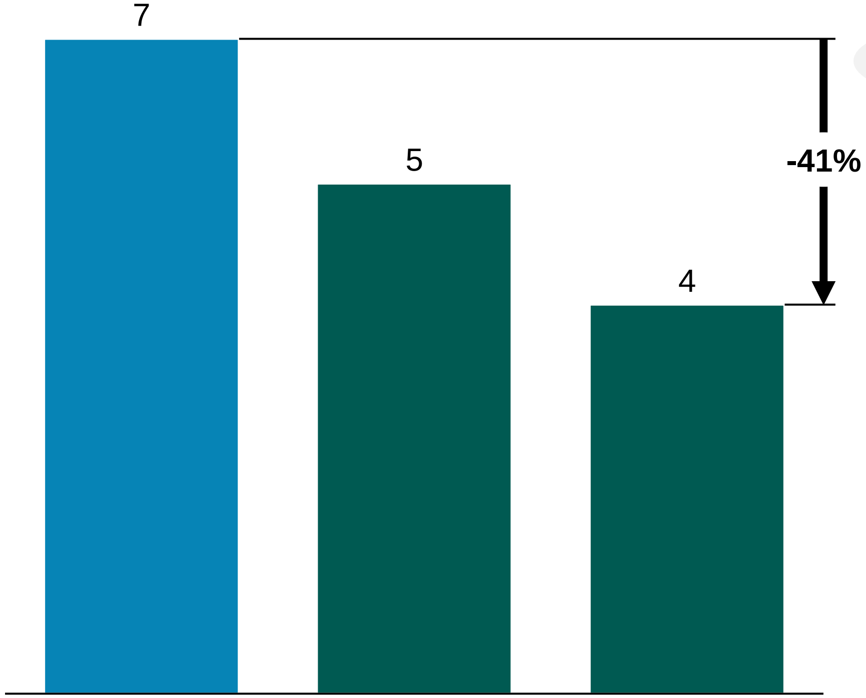
Contents

The sector emission ceilings for residential buildings could imply ~20% emissions reductions by 2025 and ~41% by 2030

Climate Action Plan 2021 incl. Core Measures and Further Measures

Buildings (residential)

GHG emissions[1], MtCO$_2$e (AR5)



	% change vs. 2018		Sectoral emissions ceilings[2], MtCO$_2$e	
	To 2025	To 2030	2021-2025	2026-2030
Buildings (residential)	~20	~40	29	23

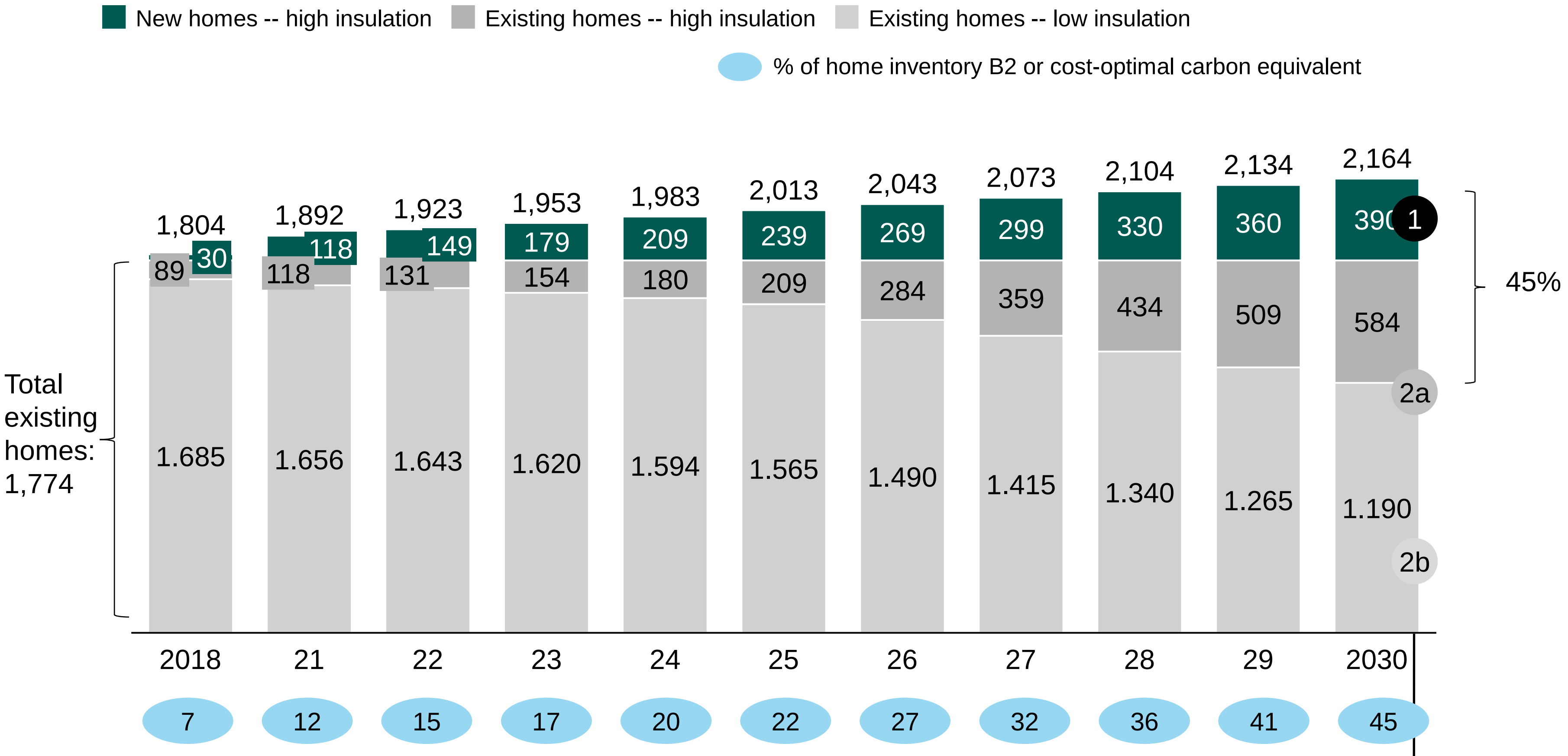
---

1. GHG emissions and abatement impact based on AR5 2021 EPA methodology;
2. Buildings range in CAP 21 was 45-55%, however there were no splits for commercial buildings

Source: Climate Action Plan 2021, Government of Ireland; Programme for Government 2020, Government of Ireland

Homes with high insulation are forecast to represent 45% of total homes by 2030

Number of homes by segment and BER rating, thousand dwellings



Deep dives on existing homes and new homes in following pages

Note: Unlocking full abatement potential from retrofitting requires a representative mix of insulation standards of houses to be retrofitted to B2 standard

Source: DSE modelling assumptions, June 2022

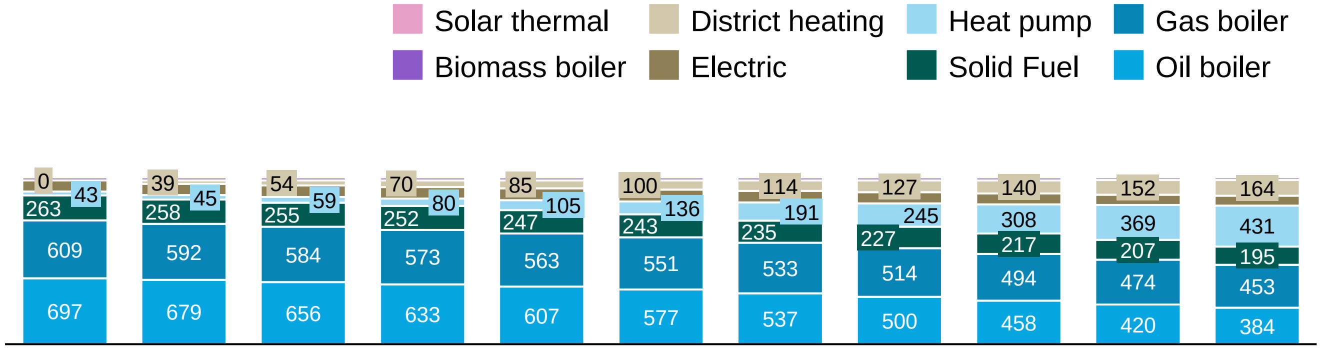
Relevant potential measure

B1 Retrofit residential dwellings and deploy zero-emission heating in existing homes

Technology mix and energy consumption for existing dwellings would change to 2030

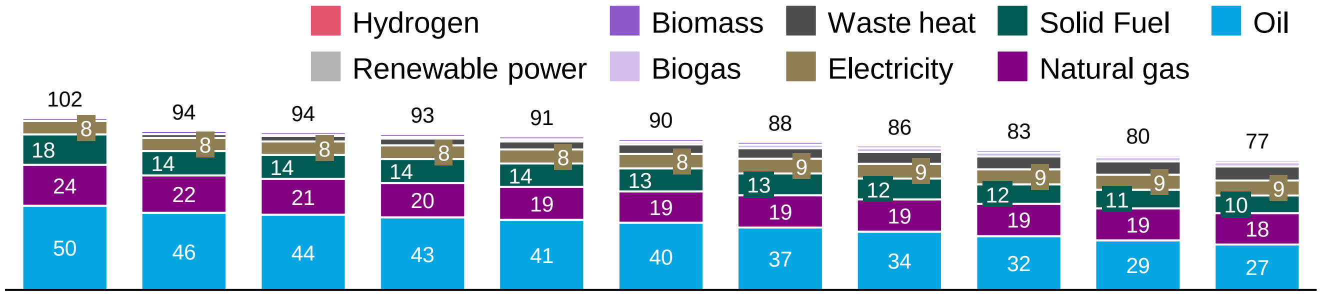
Technology mix

Thousand dwellings



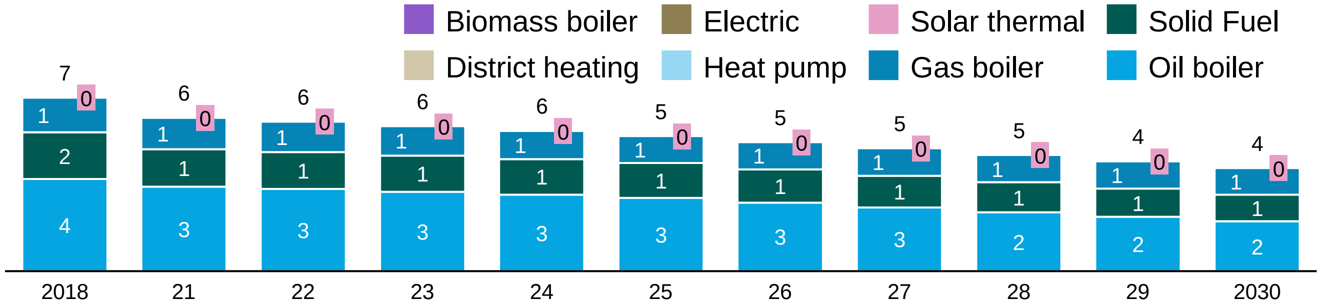
Energy consumption

PJ



Annual Emissions

Bn kg CO2e/year



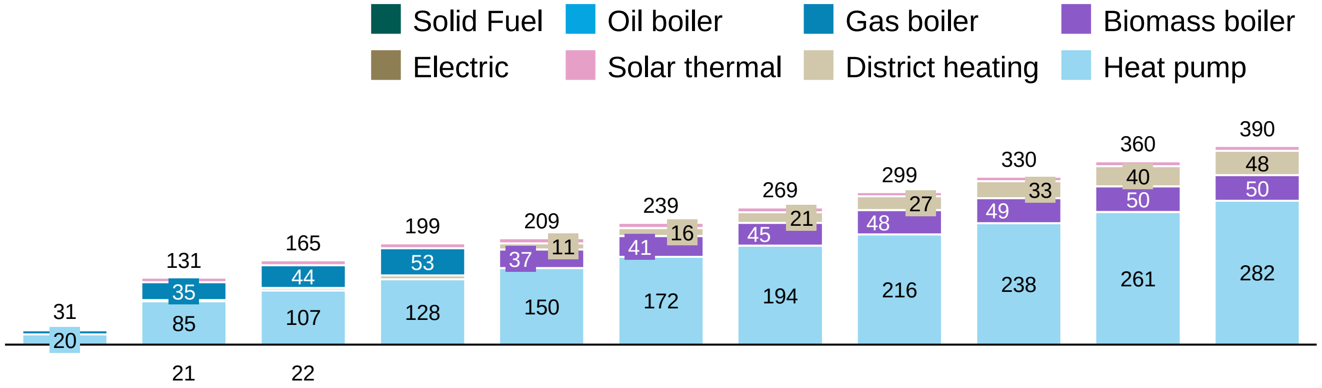
Relevant measure

- **B1** Retrofit residential dwellings and deploy zero-emission heating in existing homes
- **B2** Increase targets for roll-out of district heating
- **B4** Blend in zero-emission gas for fuel use in buildings

Technology mix and energy consumption will also change for new dwellings to 2030

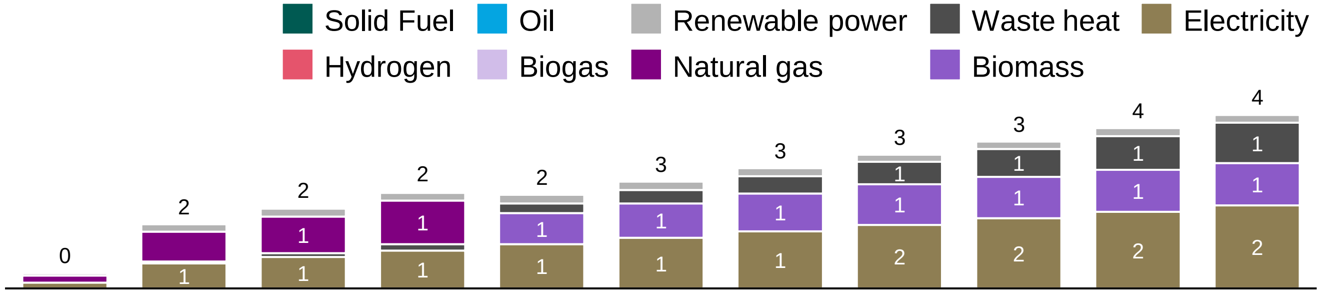
Technology mix

Thousand dwellings



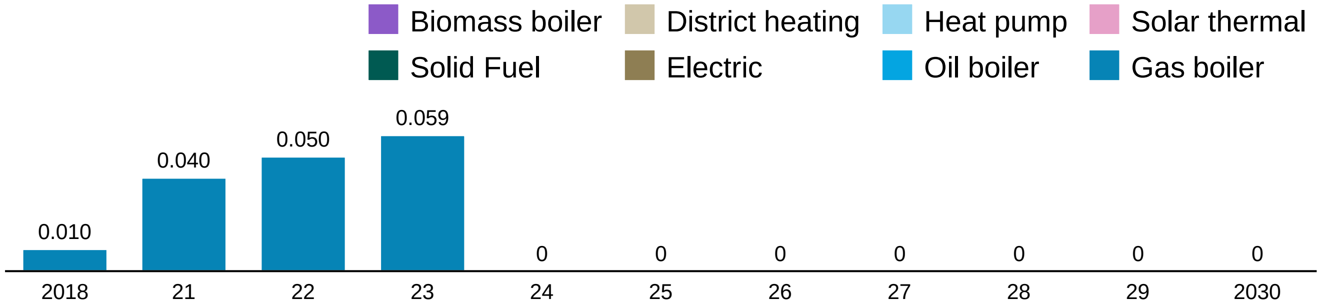
Energy consumption

PJ



Annual Emissions

Bn kg CO2e/year



Relevant measure

- **B1** Retrofit residential dwellings and deploy zero-emission heating in existing homes
- **B2** Continue to phase out fossil fuels in new homes
- **B2** Increase targets for roll-out of district heating
- **B4** Blend in zero-emission gas for fuel use in buildings

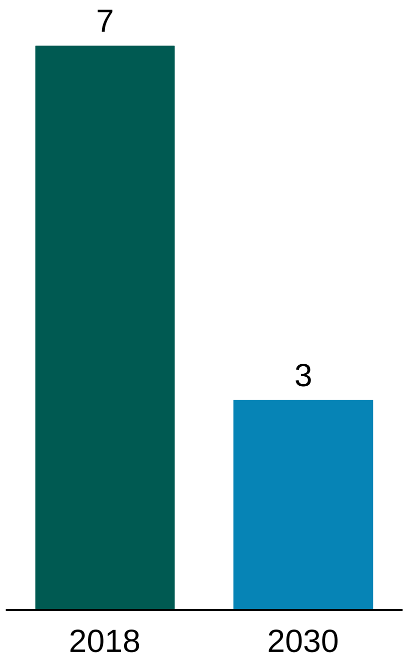
There are four measures that would reduce emissions by 3.7-4.1Mt by 2030

PRELIMINARY

Abatement impact, MtCO2eq

○ <0.5 ◐ 1-1.5 ◔ 0.5-1 ◕ 1.5-2 ● >2

Residential carbon budgets, MtCO2eq



Potential Measures

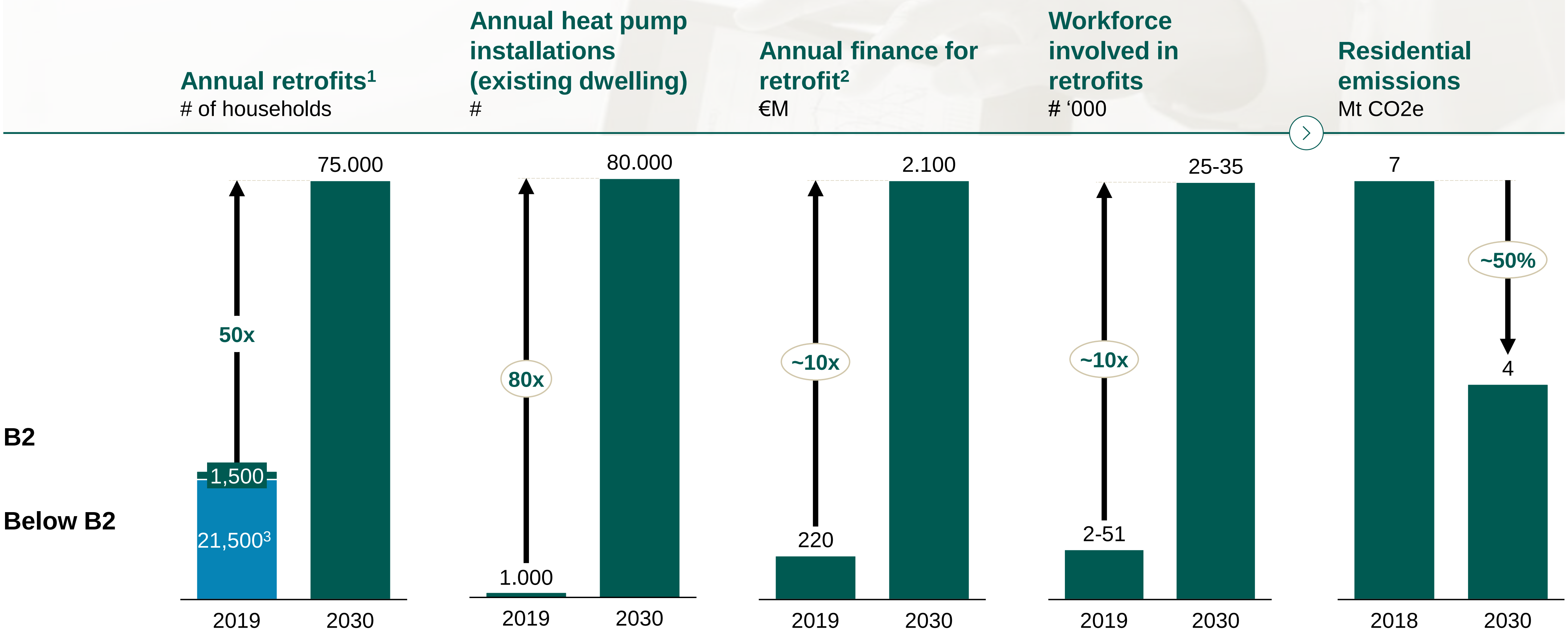
		Measure	KPI 2025	KPI 2030	**Abatement impact by 2030,** MtCO2eq
Core measures from CAP 2021	B1	Retrofit residential dwellings and deploy zero-emission heating in existing homes *Retrofitting skewed to solid-fuel homes to increase abatement*	**120k** retrofitted homes (to BER B2) **~275k** zero-emission heating in residential dwellings (heat pumps), 170k in new buildings, ~105k existing buildings	**495k** retrofitted homes (to BER B2) **680k** zero-emission heating in residential dwellings (heat pumps), 280k in new buildings, ~400k existing buildings	●
	B2	Continue to phase out fossil fuels in new homes	**+170k** new homes without fossil heat (heat pumps)	**+280k** new homes without fossil heat (heat pumps)	○
			Zero new gas connections established in new homes beyond 2023		
	B3	Increase targets for roll-out of district heating *Further emissions reduction possible with increased district heating potential of 5.1TWh in line with National Heat Study – see B5*	**~1.6 TWh** of district heat supplied **e.g., ~95-115k homes** connected to district heating network	**2.5 TWh** of district heat supplied **e.g., ~200-220k homes** connected to district heating network	○
Further measure	B4	Blend in zero-emission gas for fuel use in buildings *Further emissions reduction possible with increased biomethane production potential of 5.7TWh in line with National Heat Study*	**0.4 TWh** consumption of zero-emission gas[1]	**0.7 TWh** consumption of zero-emission gas[1]	◔
	B5	Accelerate phase out of fossil fuels in homes	No fossil fuel boilers in new dwellings from Q4 2023 onwards Stable number of gas boilers in existing dwellings		◐
Total					**3.7-4.1Mt**
Potential stretch measures identified – *not included in scenario*	B6	Increase ambition for district heating	**~1.4 TWh**[2] of district heating additionally supplied	**2.16 TWh**[2] of district heating additionally supplied	○
	B7	Complete phase out of fossils fuels use	**~35% reduction** in consumption of solid fuels in existing homes	**90% reduction** in consumption of solid fuels in existing homes	◐

Additional levers beyond sectoral emission ceiling

1.Representative share of 5.7TWh of biomethane production. Revised downwards from 1-3TWh identified in CAP21 to avoid double counting across sectors.
2.Additional potential of 2.4TWh beyond measure 3 to reach 5.1TWh as outlined in SEAI National Heat Study, also split 90/10 residential/commercial;

Source: Climate Action Plan 2019; 2021, Government of Ireland

B1: A true ‘step-change’ in activity across multiple dimensions will be needed to meet the proposed retrofit ambitions



Annual retrofits[1] # of households

Annual heat pump installations (existing dwelling) #

Annual finance for retrofit[2] €M

Workforce involved in retrofits # ‘000

Residential emissions Mt CO2e

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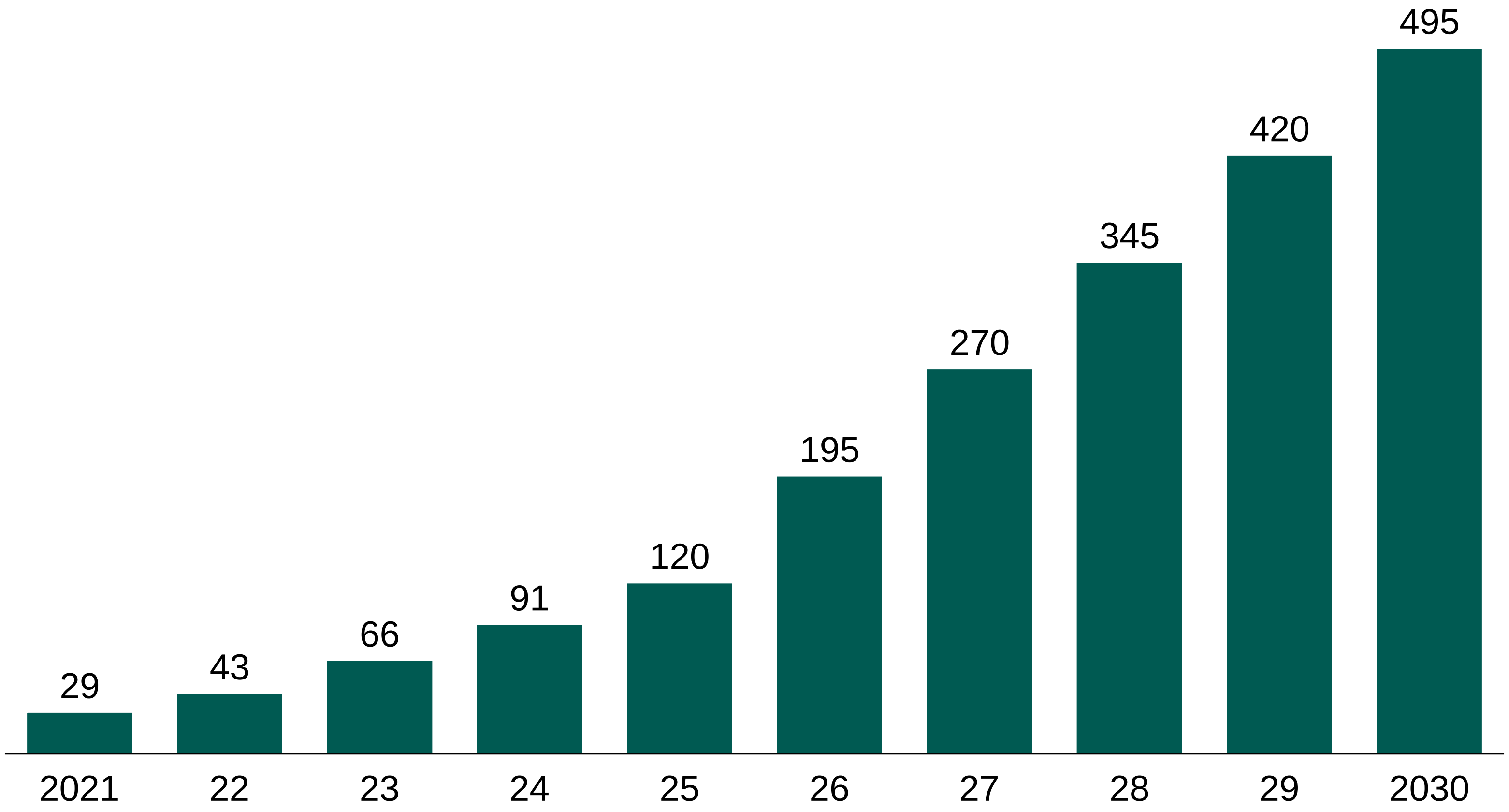
1. Based on assumption that the 1,500 houses in 2019 to B2 level were ‘deep’ retrofits, and the outstanding 21,500 were ‘shallow’ retrofits
2. Excludes financing for works outside of the SEAI schemes (including via supplier obligation, local authorities
3. Excludes ~2800 homes retrofitted by local authorities

Source: SEAI; DSE modelling assumptions, June 2022

B1: The retrofit ramp up rates assumed by this work have been aligned with the national retrofit plan

Cumulative Number of Retrofits Carried Out in line with National Retrofit Plan[1] **,**
000 Existing Dwellings



2021	29
22	43
23	66
24	91
25	120
26	195
27	270
28	345
29	420
2030	495

The retrofit ramp up rate used in our analysis is aligned with the **ramp up rate set out in the National Retrofit Plan**

In order to achieve **CAP 21 ambition of ~500k dwellings retrofitted to B2 or cost optimal carbon equivalent by 2030** a upturn in retrofitting rates in the second half of the decade will be required

---

1. National Retrofit Plan considers LA B2 homes, SEAI B2 homes and includes carbon savings from non-B2 upgrades equivalent to 120,000 B2 upgrades over the 2019-2025 period

Source: National Retrofit Plan 2021

B1: The existing National Retrofit Plan outlines a set of policies and approaches

1 Driving Demand and Activity

- Implement a national awareness campaign for residential retrofit
- Provide a personalised roadmap for homeowners on how to upgrade their home to a BER B2 in the new BER advisory report
- Develop a network of retrofit One-Stop-Shops to simplify the customer journey and enhance consumer confidence
- Launch new SEAI National Retrofit Scheme (One Stop Shop Service) to drive the delivery of B2 retrofits with heat pumps
- Utilise Sustainable Energy Communities to drive community activation
- Support those least able to afford to retrofit
- Rollout of Social Housing National Retrofitting Programme in 2021 with retrofitted properties required to reach BER B2 or equivalent
- Launch a new Energy Efficiency Obligation Scheme

2 Financing and Funding Models

- Allocate funding to residential/community retrofit from Departmental capital envelope in line with NDP funding trajectory
- Carry out research to further understand the needs of homeowners in relation to financing retrofit
- Introduce a residential retrofit loan guarantee scheme
- Pursue funding through European Union initiatives as appropriate
- Explore the potential for new tax measures to support retrofit

3 Supply Chain, Skills and Standards

- Publish a forecast of the skills required to deliver on our retrofit target
- Deliver the necessary increase in upskilling, reskilling and apprenticeship supports for residential retrofitting
- Introduce initiatives to ensure the required number of BER assessors
- Launch a study into the Heat Loss Indicator criteria for the installation of heat pumps
- Publish new Standards and Guidance Documents for retrofit
- Help to address the split incentive issue for rental properties

4 Structure and Governance

- Establish a cross-Departmental group to oversee implementation of the National Retrofit Plan
- Further develop and resource the SEAI as the National Retrofit Delivery Body
- Enhance the collection and monitoring of retrofit activity data delivered with Government support
- Enhance the capacity of local authorities to deliver their retrofit programme according to budgets allocated

Source: National Retrofit Plan 2021

B1: Ireland has already funded over 370,000 energy efficiency upgrades since 2010

①	**Better Energy Homes**	**Better Energy Warmer Homes**	**Better Energy Communities**	**Deep Retrofit Pilot**
Program design, delivery, and governance	• Since 2009 funded energy upgrades for nearly 220,000 homes • Market led scheme. Householders receive grants for energy efficiency works i.e. insulation • Householders pay up front costs, grants are paid after works are completed and approved	• Since 2000, over 135,000 homes undergone upgrades • Householders in receipt of certain benefits can apply for an upgrade • Accepted homes undergo an assessment for recommendation of upgrades. SEAI organises contractors and coordinates works • BER may not change after works complete	• Since 2012, 18,200 homes and 2,570 commercial buildings upgraded • Focuses on retrofit works for residential and non-residential buildings • Community groups or other organisations apply on behalf of the property owners • SEAI provides funding, partnerships and technical support	• A pilot scheme(now closed) that aimed to deliver deep retrofits and improve BER to at least A3 in residential buildings • An aggregator recruits interested parties to participate and applies on the groups behalf • Aggregator acts as project manager through the process
Driving demand and activity	• Reduced cost of energy works	• Free upgrade to a home • **All aspects of the retrofit handled by SEAI, removing 'hassle factor'**	• Partly funded retrofit • **Works coordinated centrally in the community rather than the householder organising themselves**	• **Deep retrofit that is coordinated by a third party- which removes the hassle for householders**
Financing and funding models	• Householders get grants towards certain energy works	• SEAI funds all the works	• SEAI provides 35-80% funding for cost of works for residential housing and up to 50% for commercial buildings • Remaining funding raised privately from householders	• The SEAI provides 50% of funding for upgrades and 95% for fuel poor homes • The remainder was funded by householders
Supply chain, skills and standards	• Supplier register with SEAI to provide works	• Contactor receives contract for a number of buildings	• SEAI tenders for a panel. Panel allocated work as it comes up	• **Opportunity to generate demand/projects and apply for funding**

B1: Ireland can learn from international peers embarking on similar retrofit programs

	② **PACE - USA**	③ **KfW1-Programm Energieeffizient Sanieren – Germany**	④ **Energiesprong - Netherlands**
Program design, delivery, and governance	• Since 2010, 235,000 homes have undergone upgrades • Program focused on financing energy efficiency improvements • Local governments issue PACE financing • Householders apply for funding, organise all aspects of the retrofit and then repay the funding through property taxes	• 4.6m energy measures funded since inception • Owners engage technical experts themselves • 50% of professional support subsidised	• Demonstrated how an innovative approach to installation and financing can create a strong customer proposition • Since inception 800 homes completed, 15,000 planned • **Initial focus on social housing** to increase scale and provide learnings • Focus on getting building to net zero emissions • Interventions include wall enveloping, PV built into roof and convert heating source to electricity only
Driving demand and activity	• Easy access funding that can be repaid through property taxes	• Support throughout the process • Can use loans for other home improvements alongside energy efficiency improvements • Low cost finance	• **Whole life financing** • 30 year performance warranty • Works completed in under a month
Financing and funding models	• Local governments fund PACE by issuing a bond interest rates vary from 5-8% • Householders apply for PACE financing and make repayments through property taxes. Reduces risk for local governments	• KfW raises capital through markets • Funding provided via subsidies and low cost loans through a German national bank • Amount of grants received depends on what level of efficiency is reached	• Program operator covers upfront costs, funding from various sources e.g. EU programs • **Householders pay housing authority or building supplier equivalent of energy bills**
Supply chain, skills and standards	• Registered suppliers connect with customers through the program	• Opportunity to access customers through KfW site	• **Suppliers offered a number of houses per tender** making the proposition more attractive and financially viable • Suppliers can leverage initial pilots to implement learnings and achieve cost savings over time

B2 / B6: Sweden and Finland have eliminated fossil fuel use for heating

✓ Phase Out Complete → Phase Out In Progress

	Sweden	Finland	Netherlands	Austria	Denmark
Status and announced timelines	✓ **Already completed phase out** of fossil fuels in heating	✓ **Already completed phase out** of fossil fuels in heating	→ 2021 – gas phase out in new buildings 2050 – gas phase out in all buildings 2050 – all buildings using low-carbon alternative to fossil fuels	→ 2021 – oil phase out in new installations 2025 – gas phase out in new buildings 2035 – oil phase out in all buildings	→ 2013 – oil phase out in new buildings 2016 – oil phase out in existing buildings 2030 - Oil for heating purposes and coal are to be phased out
Key updates and actions	Cities now fueled from renewable energy sources, relying on district heating combining heat and power production	District heating now provides 90% of heat demand with remainder provided either by oil or electricity	Over 90% of newly built dwellings were not connected to the gas grid by 2019	Introduced funding priority to phase out fossil-fuel powered heating systems in residential housing	Achieved the highest reduction[1] in CO2 emissions intensity from residential heating by replacing oil and coal with biomass

- Sweden and Finland's **successful elimination of fossil fuel in heating** help illustrate feasibility of Ireland's ambition for the **full phase out of fossil fuels in buildings by 2050** with the right conditions in place
- **Ireland's stated ambitions are aligned with those of the Netherlands,** where leaders have announced a plan to phase out gas in all buildings by 2050

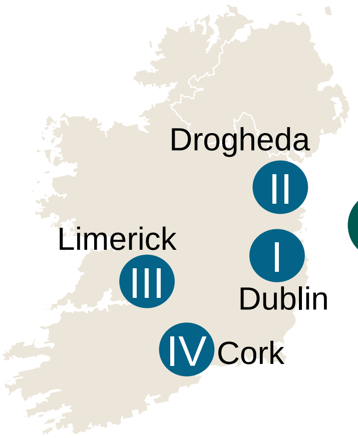
---

1. Reduction of 244 gCO2/kWh in 1990 to 118 gCO2/kWh in 2015

Source: Member States' ambition to phase out fossil-fuel heating – an analysis

B3: District heating could supply ~2.7 TWh of heat in four cities by 2030 for residential & commercial buildings

Potential district heating projects



High potential cities identified by IrDEA based on availability of excess heat as well as density of heat demand

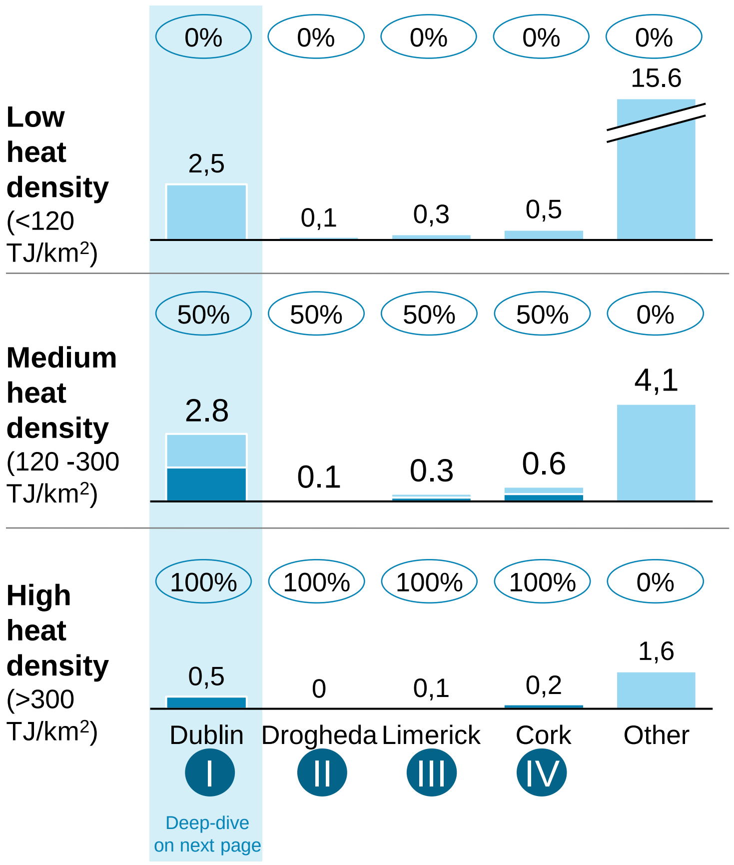
2030 district heat ambition

XX Percentage targeted

Not targeted

Targeted[1]

Heat demand by location and heat density, TWh



Total district heat demand 2030, TWh

26.6

2.7

i.e. ~9% of heat demand

Sweden, Denmark and Finland have historically achieved +10%-pts of district heating per decade

Commentary

District Heating should be deployed in the most **cost-effective areas throughout Ireland with a heat density >1,000MWh/km²**

Targeting dense heating demand areas that are close to waste heat sources, almost 10% of Irish heat demand can be filled in with district heating. Dublin alone could see the uptake of almost 2 TWh of district heating

2.7 TWh of District Heating could support heat demand of ~150-200k residential dwellings and ~15-20k commercial buildings

As district heating aims to roll out in older cities and apartment buildings, where heat pumps are less likely to pick up, the two roll-out efforts are aimed at different assets

Abatement cost of switching oil boilers to district heating in commercial buildings is expected to be -20 EUR/t CO2

Abatement impact by 2030

Depending on if district heat replaces gas, heating oil or other fuels, it can abate a total of 0.6-0.9 MtCO2eq. Conservatively, at least 0.7 MtCO2eq can be abated

Abatement impact by 2030, MtCO2eq **~0.7**

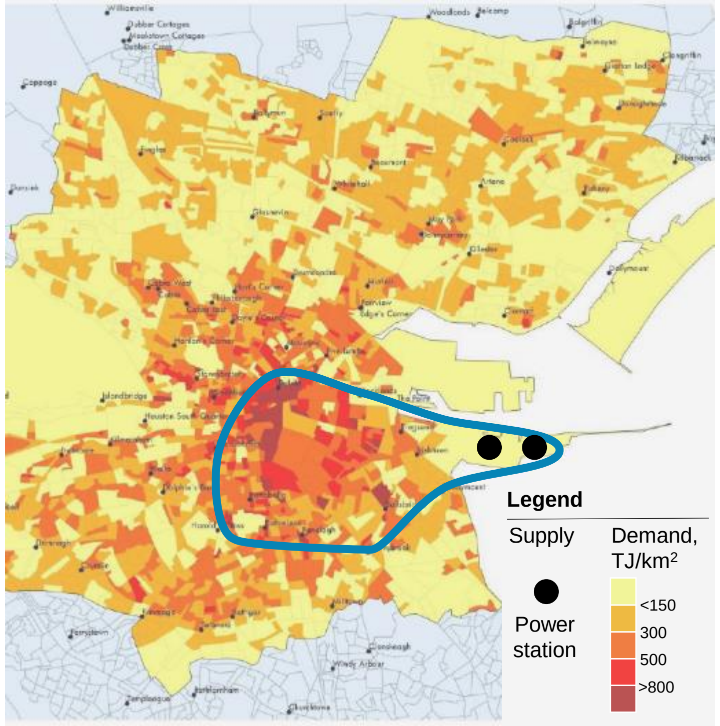
1. Based on heat demand density and availability of local waste heat demand
2. In the National Heat Study 2022 scenarios, district heating is deployed in the most cost-effective areas based on the linear heat density analysis coupled with the modelled cost comparison with each building's counterfactual heating system technology. The National Heat Study 2022 revised the cut-off point of economic viability for district heating downwards to >1,000MWh/km

Source: Irish Heat Atlas, Codema, IrDEA, SEAI National heat Study 2022

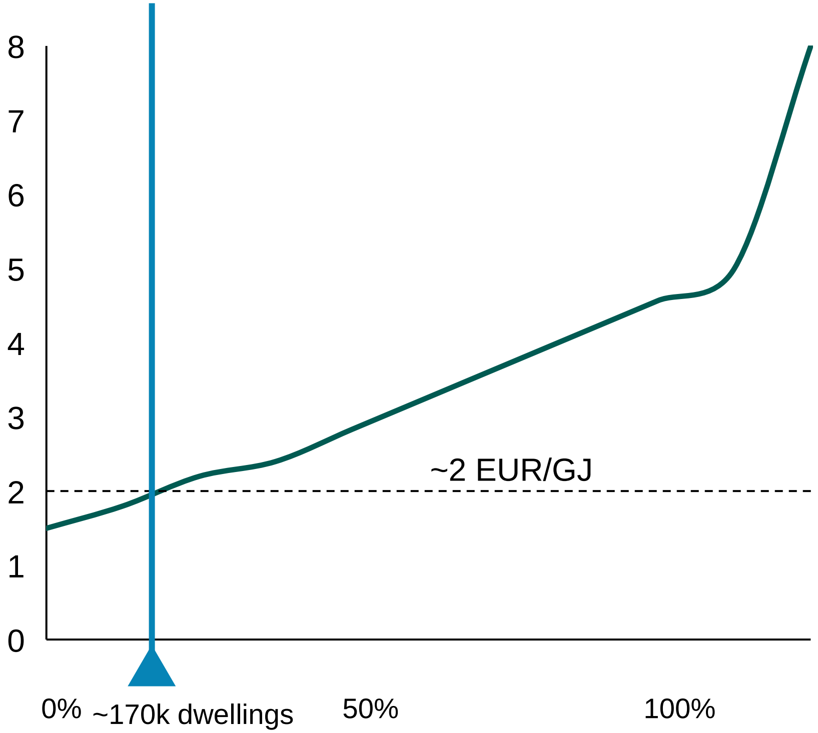
B3: Rolling out district heating in Dublin alone could abate ~0.5MtCO2eq

High concentration of heat demand in Dublin provides a cost-effective opportunity to scale up district heating to some 170k dwellings

Heat demand and waste heat supply map



District heating infrastructure cost versus share of Dublin heat demand, EUR/GJ demand



Source: Irish Heat Atlas

Commentary

Some 170k dwellings could be provided with heat from the Poolbeg and/or Covanta power stations.

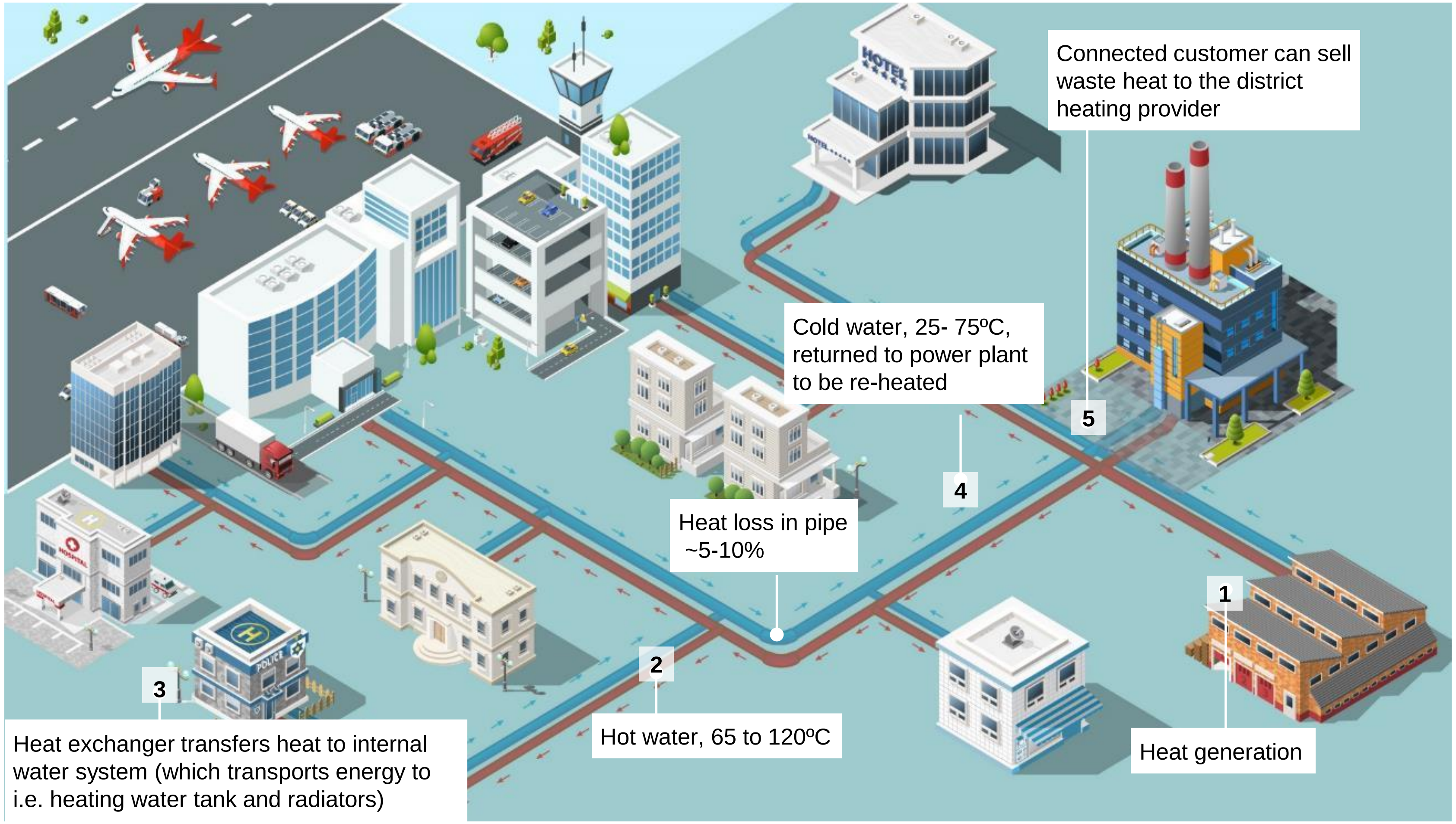
Further scaling up of district heating could be considered post 2030 as infrastructure costs even beyond 170k dwellings remain low. Up to 50% of Dublin heat demand could be covered at a cost of just over 3 EUR/GJ.

A heating network that covers 170k households could replace mostly gas and oil boilers.

A typical fossil household heating system emits ~2-3 tCO_2 per year, hence switching 170k homes away from fossil heating could save ~0.5 $MtCO_2$

B3: District heat networks distribute heat from a centralized location through a network of insulated pipes

Illustration



Connected customer can sell waste heat to the district heating provider

Cold water, 25- 75ºC, returned to power plant to be re-heated

Heat loss in pipe ~5-10%

Hot water, 65 to 120ºC

Heat generation

Heat exchanger transfers heat to internal water system (which transports energy to i.e. heating water tank and radiators)

Description

1 **Heat generation:** water is heated at a central facility (waste heat from electricity power plant)

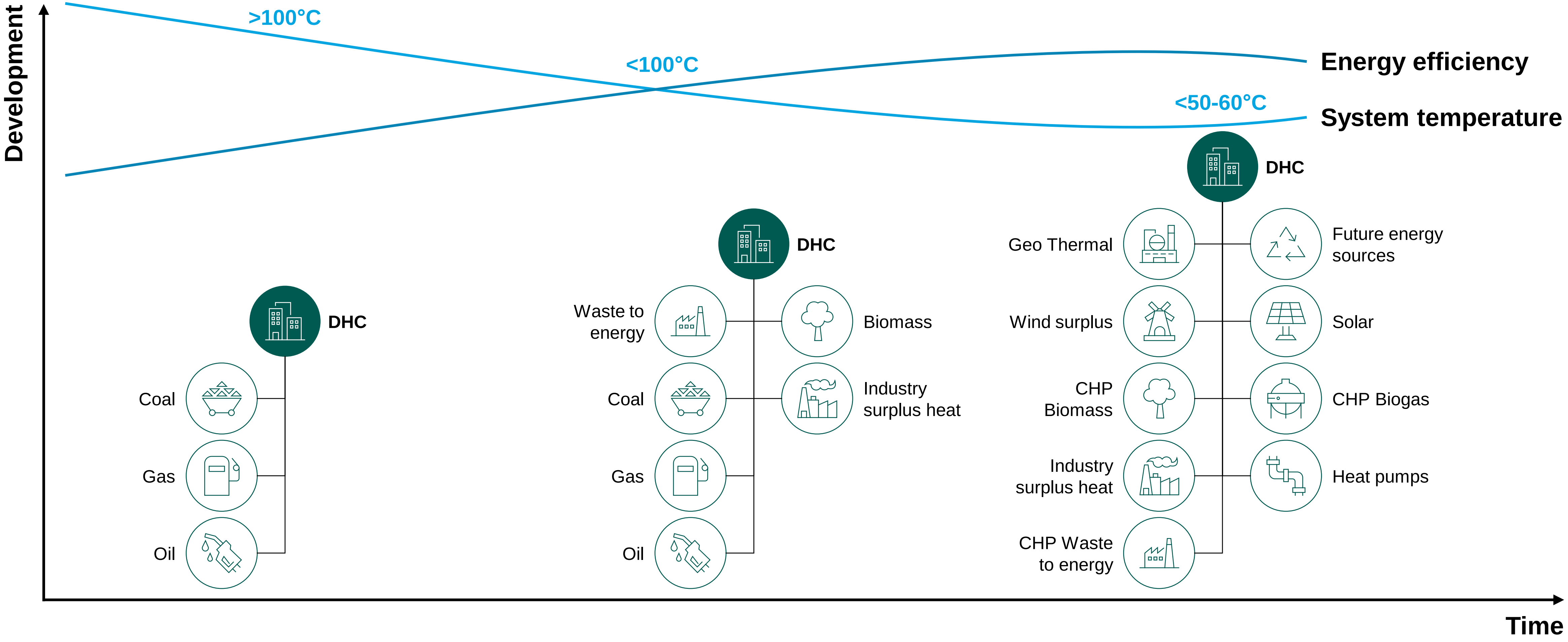
2 **Transport & distribution:** A network of insulated pipes buried underneath the ground transports the hot water to the customer

3 **Delivery:** Each customer is connected by a heat exchanger that transfers energy from the district heating water to the customer's internal network

4 **Transport & distribution:** A parallel pipe system takes cooled water back to the heating center

5 **Transport & distribution:** Waste heat can be sold from excess sources s.a. industrial plant or data center

B3: District heating solutions have become more sustainable over time, leveraging renewable energy sources and lower temperatures

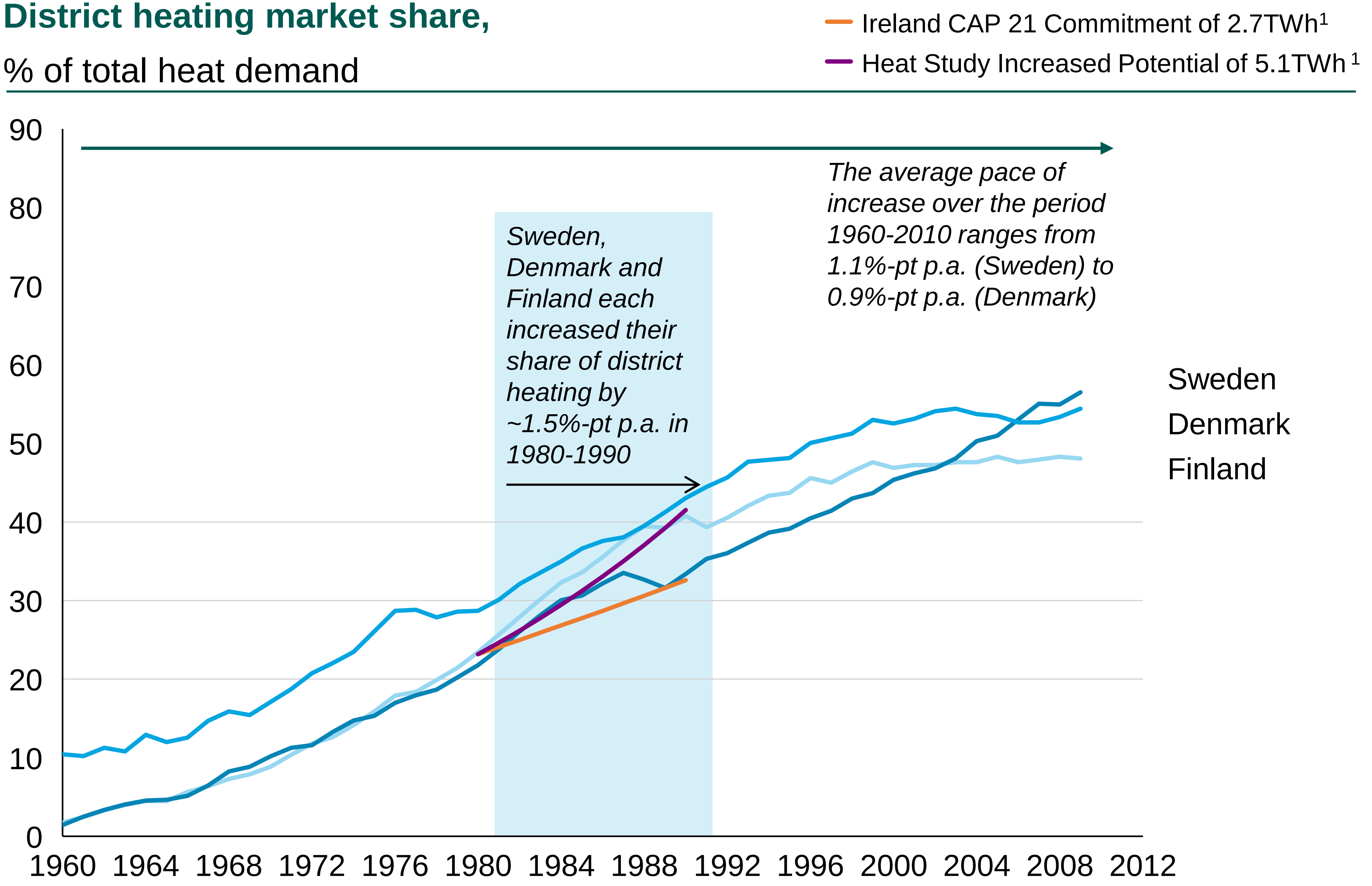


Source: https://www.euroheat.org/knowledge-hub/district-energy-explained/

B3: Other countries have historically been able to increase district heating by >1%-pts per year

District heating market share,

% of total heat demand



Sweden, Denmark and Finland each increased their share of district heating by ~1.5%-pt p.a. in 1980-1990

The average pace of increase over the period 1960-2010 ranges from 1.1%-pt p.a. (Sweden) to 0.9%-pt p.a. (Denmark)

1. 2020-2030 ramp up rates normalised to Sweden's 1980 baseline for comparison purposes

Source: IEA, DSE modelling assumptions, June 2022

Commentary

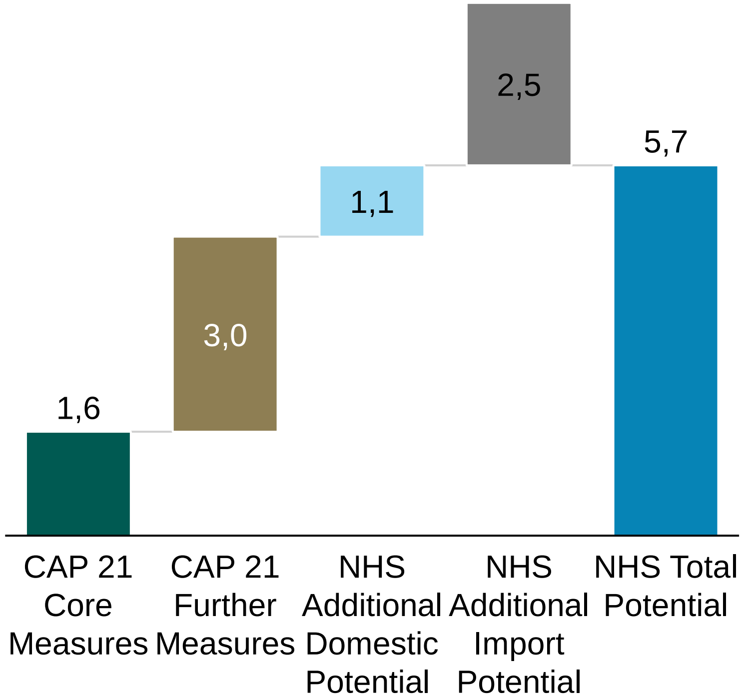
CAP 21 requires Ireland to increase the share of district heating by ~1% p.a. which is lower target than Sweden, Denmark and Finland, who increased district heating share by ~1.5% p.a. in 1980-1990

To achieve the increased ambition set out in the National Heat Study of 5.1TWh, the share of district heating would have to increase by ~1.8% p.a.

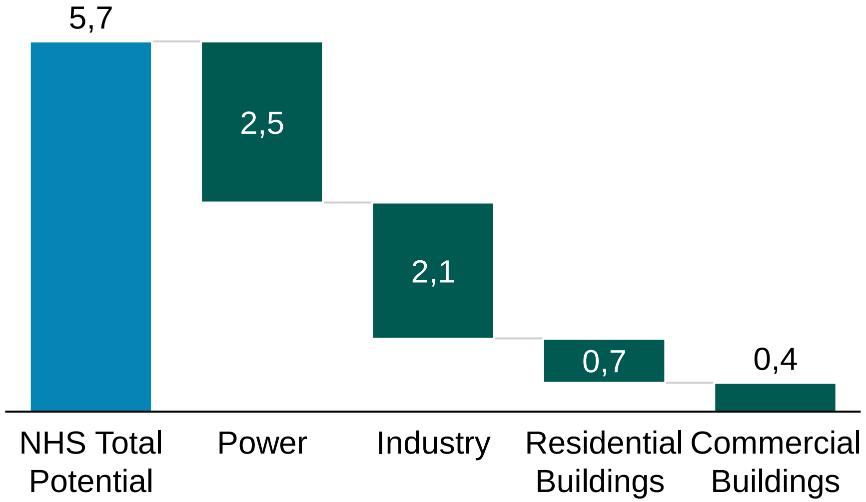
Nordic countries could experience a greater decrease in costs than Ireland as the annual household heat demand is higher, increasing network utilization

B4: The National Heat Study identified a maximum potential of 5.7TWh of biomethane production by 2030

Biomethane production potential[1,3,4]**,**
2030, TWh



Biomethane consumption[2]**,**
2030, TWh



Commentary

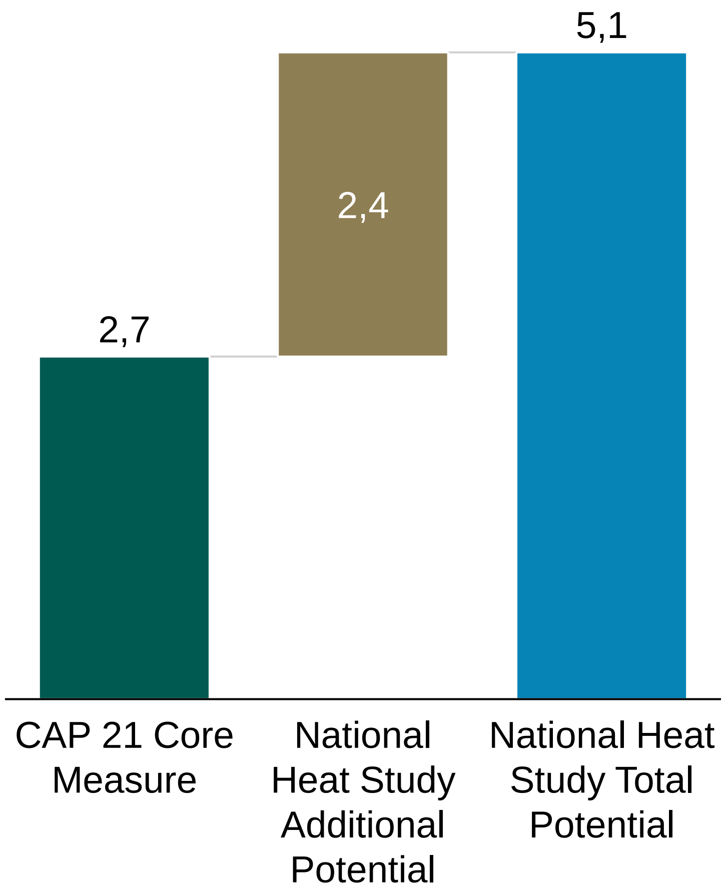
- **CAP21 identifies 1.6TWh of biomethane production potential without land use change**
- **Maximum domestic biomethane production** is estimated at ~5.7TWh under the ‘rapid progress’ scenario laid out in the National Heat Study (2022)
- Residential buildings are assumed to **consume 0.7TWh by 2030**, in line with their share of natural gas consumption in 2021

1. Considers the Rapid Scenario proposed in the SEAI National Heat Study
2. Consumption in proportion to 2021 natural gas consumption
3. As per recommendation of SEAI National Heat Study, increasing the growing of energy crops must be done in line with nationally appropriate sustainability governance to minimise upstream emissions, align with circular and bioeconomy goals, and avoid increasing emissions in non-energy sectors
4. Total Domestic Potential of 5.7TWh includes 4.7TWh from grass silage/slurry AD supplemented by 0.98TWh from food waste and pig slurry.

Source: SEAI National Heat Study 2022, CAP 21

B6: The National Heat Study suggested the ambition for district heating could be increased by ~2.4TWh

District Heating Potential 2030[1,2], TWh



SEAI National Heat Study Findings

Key findings	Beyond the ~2.7TWh potential outlined in the CAP 21, the National Heat Study identified an **additional ~2.4TWh to increase the total potential ambition to ~5.1TWh for district heating**
Approach	This estimate of **~5.1TWh** was based on **high-resolution spatial analysis of heat demand in Ireland**, investigating both the supply options and demand for district heating networks
Sources of Supply	Supply options identified include waste heat recovery from power stations and industrial sites, biomass boilers, biomass combined heat and power (CHP), air source heat pumps (ASHP), geothermal via ground source heat pumps (GSHP) and low-carbon gas CHP Significant potential for heat recovery from ~20 data centres across Ireland but further site-specific analysis required to accurately size this potential
Increase in Demand	Previous understanding[3] of DH potential suggested Small Areas with a heat density <10,000MWh/km are not viable for district heating The National Heat Study revised this **cut-off point for economic viability to 1,000MWh/km[4]** As a result**, up to ~54% of heat demand for buildings** could potentially be served by district heating (>1,000MWh/km) Further local analysis and feasibility studies are required to identify feasible uptake in specific areas

---

1. National Heat Study Rapid Scenario outlines total potential of 5.1TWh in 2030 and 8.1TWh in 2050 which corresponds to 30% of base year heat demand based on limits imposed by the model, in this scenario growth in heating demand met by district heating occurs linearly between 2023-2034 with max roll out of district heating achieved by 2040
2. Consumption will be split residential (80%) and residential(20%)
3. SEAI District Heating Study, 2015 carried out by AECOM
4. Construction costs plateau at 1,000MWh/km hence the critical cut off point for economic viability lies at 1,000 MWh/km;

Source: SEAI National Heat Study 2022, CAP 21

Sectoral emission ceilings were updated during engagement with departmental colleagues

Progress to date

Upgraded ambition for existing measures

Measure	Revised assumptions
B1 Retrofit residential dwellings and deploy zero-emission heating in existing homes	Eliminate new gas connections from 2025 onwards
B2 Continue to phase out fossil fuels in new homes	Skew retrofitting efforts towards dwellings currently using oil or solid fuels to maximise emissions reduction benefit
B3 Increase targets for roll-out of district heating	Ensure heat pumps are not installed in areas viable for district heating

Dismissed Potential Stretch Measures Identified

Measure	Considerations
B6 Increase ambition for district heating	Current ambition already considered to be a stretch in terms of feasibility
B7 Complete phase out of fossils fuels use	Further ambitions to phase out fossil fuels deemed unrealistic given resistance to current ambitions

Next Steps

- Continue geospatial analysis to determine specific areas suitable for district heating
  - Areas identified with limited potential for district heating to be targeted with retrofitting implementation[1]
- Establish delivery system to coordinate implementation of agreed levers

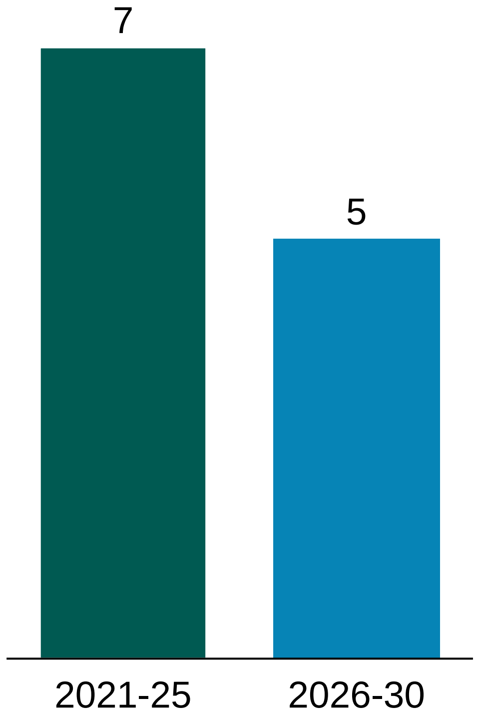
1. Areas with limited potential for district heating should be targeted for oil boiler replacements as part of retrofitting ambitions

Contents

There are two measures that could reduce emissions by ~0.6Mt in 2030

▨ Deep dive next page

Commercial buildings carbon budgets, MtCO2eq



Potential Measures

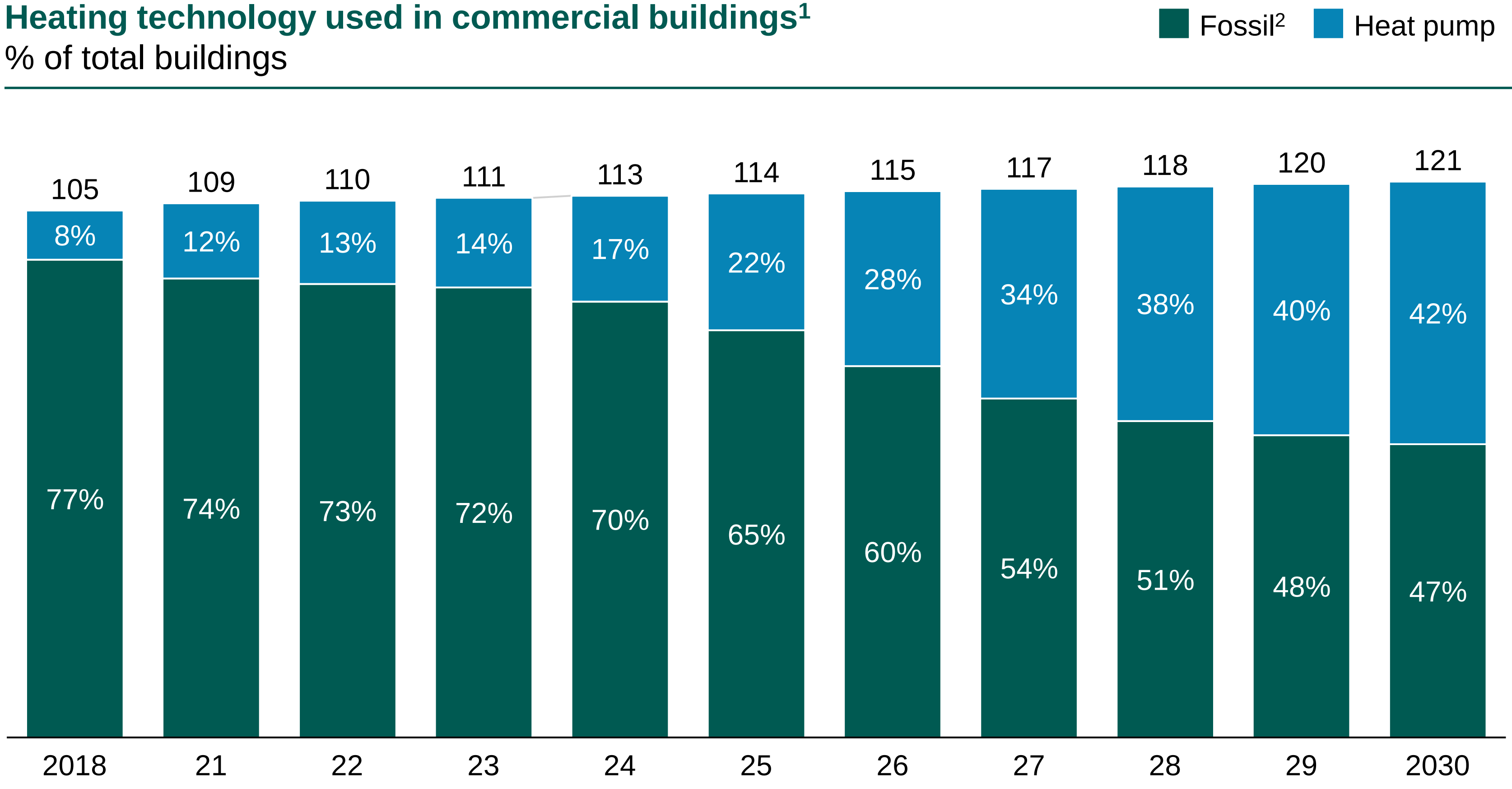
	Option	KPI 2025	KPI 2030	Abatement impact, MtCO2eq 2025	Abatement impact, MtCO2eq 2030
Core measures	▨ Zero-emission heat in commercial buildings	Number of buildings with zero-emission heating: ~28k	Number of buildings with zero-emission heating: ~55k	~0.3	~0.6
	District heating in commercial buildings	Energy demand in TWh: ~0.1	Energy demand in TWh: ~0.2	~0.03	~0.04
			Sum	~0.3	~0.6

Source: Climate Action Plan 2019, Government of Ireland

NOT FOR FURTHER DISTRIBUTION

A fast ramp-up zero-emission heat in commercial buildings could reach ~46% penetration by 2030

Heating technology used in commercial buildings[1]
% of total buildings



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1. Including public buildings
2. Fossil classified as gas and oil boilers

Source: Climate Action Plan 2021, Government of Ireland, SEAI

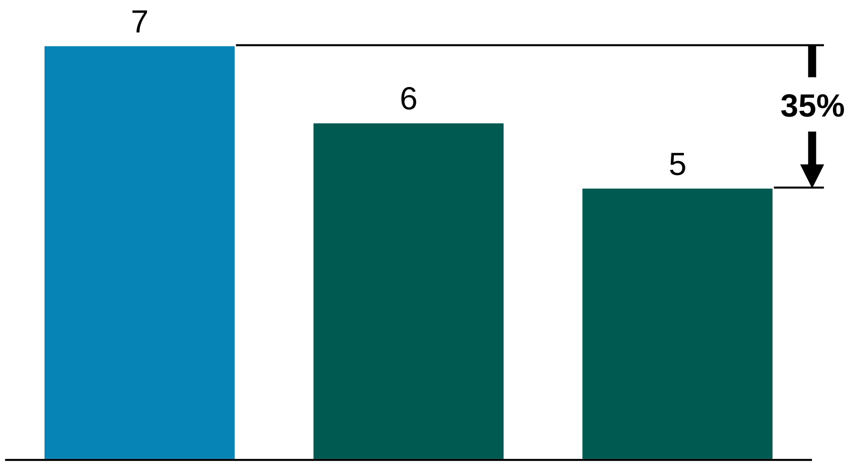
Commentary

- Rapid phase out of oil boilers and natural end-of-life replacement of gas with low carbon alternatives (e.g. heat pumps)
- Potential to reduce emissions by ~42% from commercial heating. There are currently ~120k commercial and public buildings in Ireland
- Abatement cost from switching oil and gas boilers to a heat pumps could range from ~5 to ~350 EUR/tCO2

Contents

The sectoral emissions ceilings proposes ~20% emissions reductions by 2025 and ~35% by 2030

	GHG emissions[1], MtCO2eq (AR5)			% change vs. 2018		Sectoral emissions ceilings, MtCO2eq	
	2018	2025	2030	To 2025	To 2030	2021-2025	2026-2030
1 **Industry[2]**	7	6	5	~20	~35	31	25



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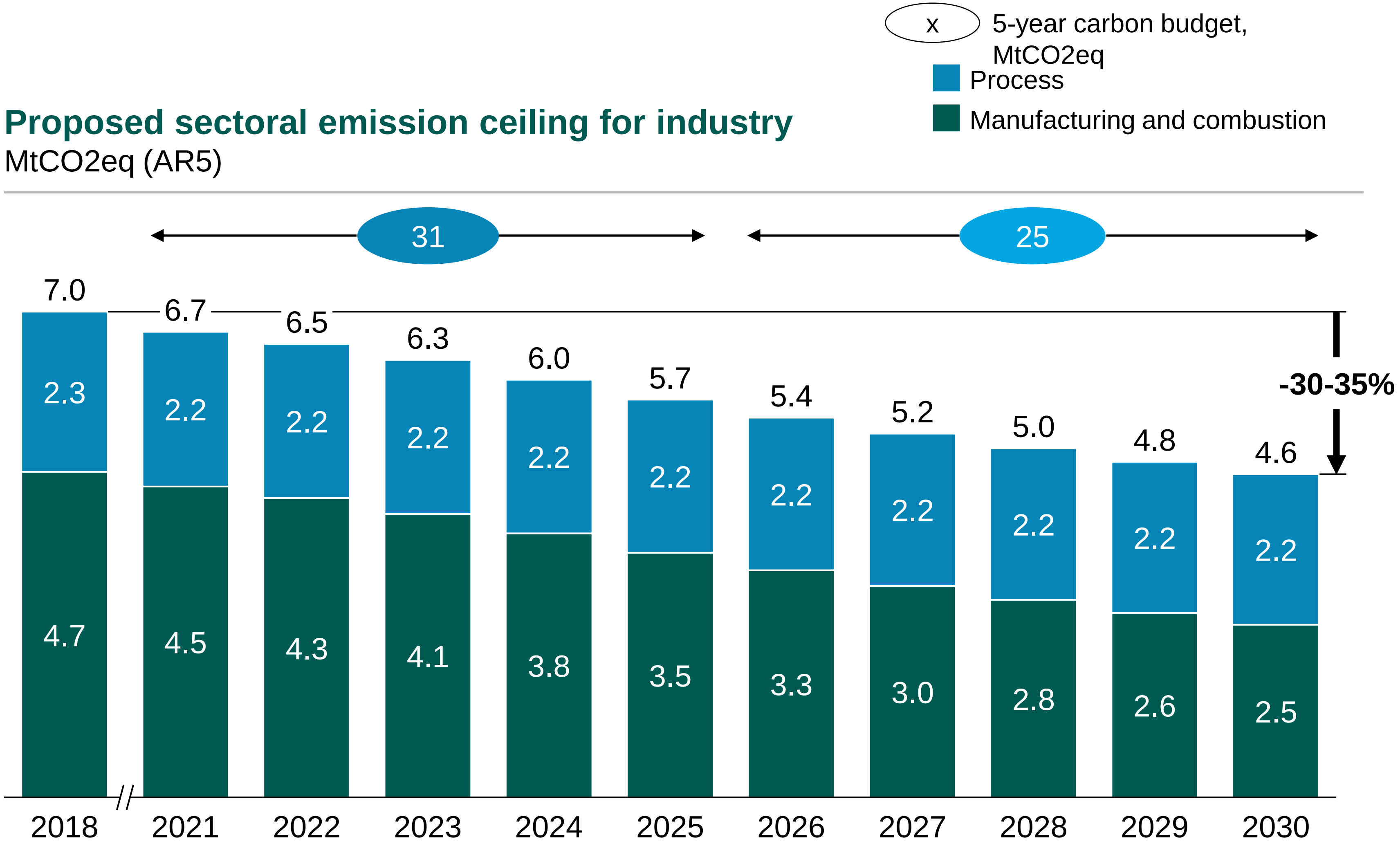
1. GHG emissions and abatement impact based on AR5 2021 EPA methodology

Source: Climate Action Plan 2021, Government of Ireland

DETE could be responsible for overseeing a ~30-35% reduction in emissions to 2030

Proposed sectoral emission ceiling for industry

MtCO2eq (AR5)



	2018	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Process	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Manufacturing and combustion	4.7	4.5	4.3	4.1	3.8	3.5	3.3	3.0	2.8	2.6	2.5

1. Includes high and low temperature heat, mining and other categories

Source: Climate Action Plan 2021, Government of Ireland

Reduction pathway in Climate Action Plan 2021 results in ~30-35% (~2-2.5Mt) reduction in emissions by 2030

Meeting the target emissions includes:

- Ramp-up of zero emissions heat and district heating in commercial buildings
- In industry: uptake of alternative fuels; phase decrease in embodied carbon; blend in zero emissions gas

There are 5 measures that could reduce emissions in industry by ~2-2.5 MtCO2eq

Abatement impact, $MtCO_2eq$ ○ <0.5 ◔ 0.5-1 ◑ 1-1.5 ◕ 1.5-2 ● >2

Industry carbon budgets, MtCO2eq

Potential Measures

		Measure	**KPI 2025**	**KPI 2030**	**2030 abatement impact,** MtCO2eq
Core measures **CAP21**	I1	Accelerate uptake of carbon-neutral heating in industry	**~40-50%** share of carbon neutral heating in total fuel demand (excluding measures I3, I4 and I5)	**~50-60%** share of carbon neutral heating in total fuel demand (excluding measures I3, I4 and I5)	◔
	I2	Decrease embodied carbon in construction materials	**E.g. 5%** decrease in embodied carbon in construction materials	**10%** decrease in embodied carbon in construction materials	○
	I3	Enable electrification of high-temperature heat generation	**70%** of steam production from gas-electric hybrid heating	**100%** of steam production from gas-electric hybrid heating	◔
Further Measures **CAP21**	I4	Decrease embodied carbon in construction materials	Demand remains flat to 2030, 20% decrease vs ‘do nothing’ scenario	Demand remains flat to 2030, **30% decrease** vs ‘do nothing’ scenario	○
	I5	Blend in zero-emission gas	**~1.2 TWh** consumption of zero-emission gas	**~2.1 TWh** consumption of zero-emission gas	○
				Sum (exc. CCS)	**~-2-2.5**
Not included in Climate Action Plan 2021 pathway		Deploy Carbon Capture and Storage (CCS)	**1** out of 4 cement/lime plants retrofit CCS	**2** out of 4 cement/lime plants retrofit CCS	◑

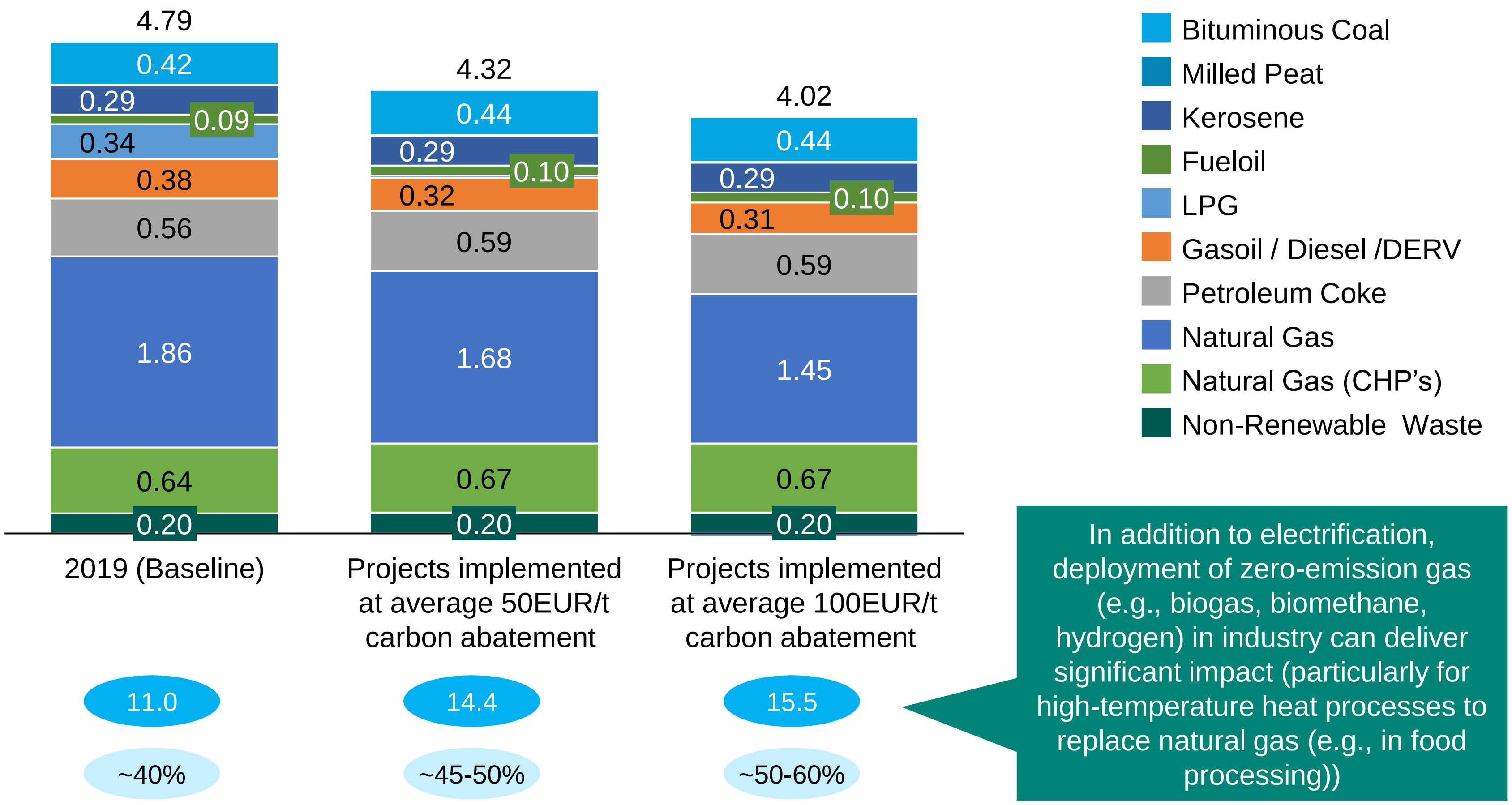
1. Including waste management | 2. Impact of further measure included in CAP21 within the indicated range

Source: Climate Action Plan 2019, Government of Ireland

I1. A rapid roll-out of low carbon industrial heating, e.g. electric boilers, is required to meet proposed ambitions

xx Electricity demand, TWh   xx Share of carbon neutral heating in total fuel demand[1], %

Projected Fuel Mix Emissions (CAP Enterprise),MtCO2eq



In addition to electrification, deployment of zero-emission gas (e.g., biogas, biomethane, hydrogen) in industry can deliver significant impact (particularly for high-temperature heat processes to replace natural gas (e.g., in food processing))

Source: Dept of Enterprise Trade and Employment – Total Zero Carbon model

Key takeaways

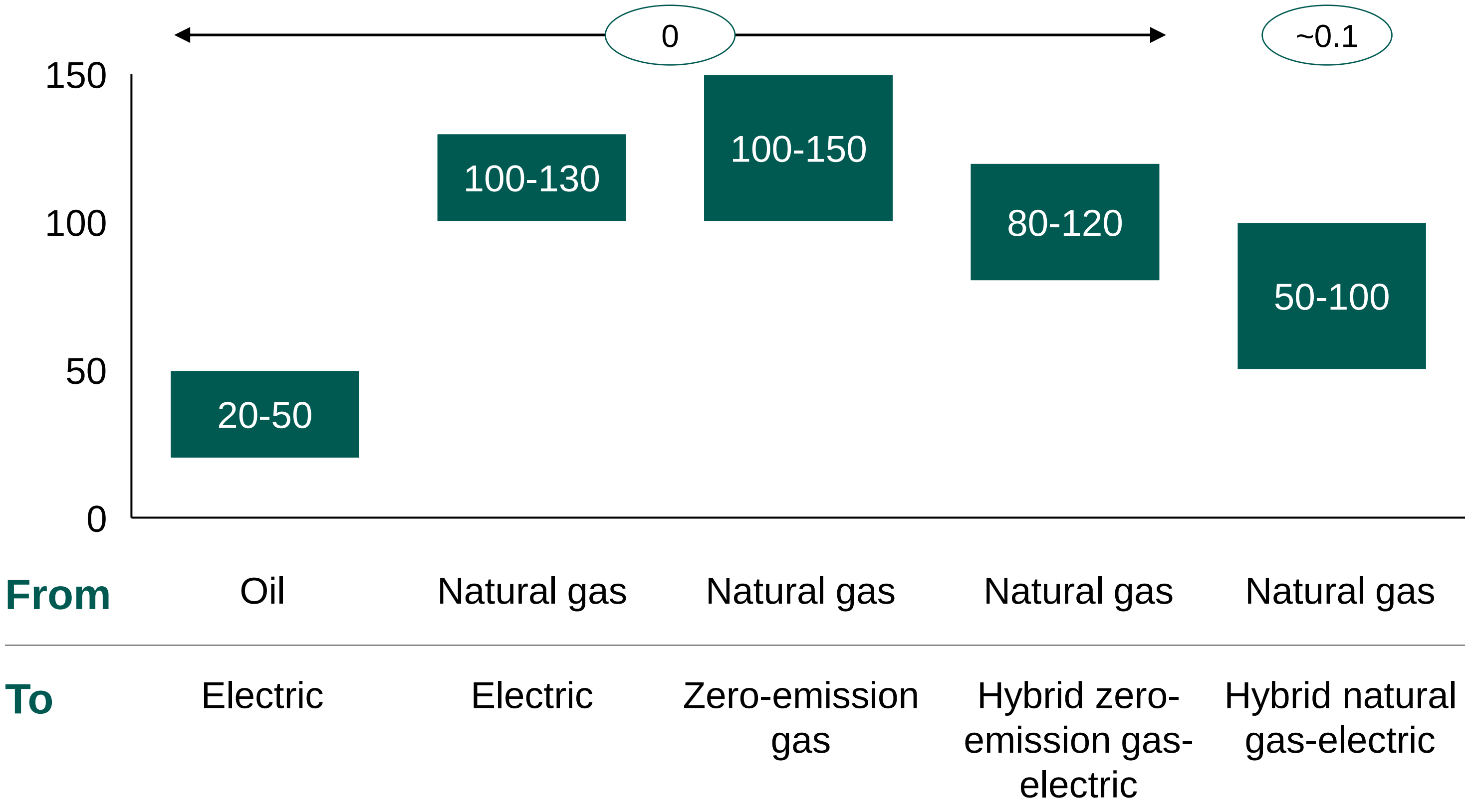
Results show the impact of:

- 100EUR/tCO_2 in 2030; and
- Impact of average 50EUR/t and 100EUR/t cost from implementing sustainable measures (measures typically have a cost of 50-150 EUR/t CO_2)

I1. Differences in abatement cost for low/medium industrial heating options mainly driven by fuel price cost differential

xx Residual emissions after switching, tCO2eq/MWh

Abatement cost of low-carbon low/medium temperature industrial heat options (excl. EU ETS price), EUR/tCO2eq



Key takeaways

Switching to low-carbon industrial heating based on electrified and zero-emission gas heat sources has significant abatement potential

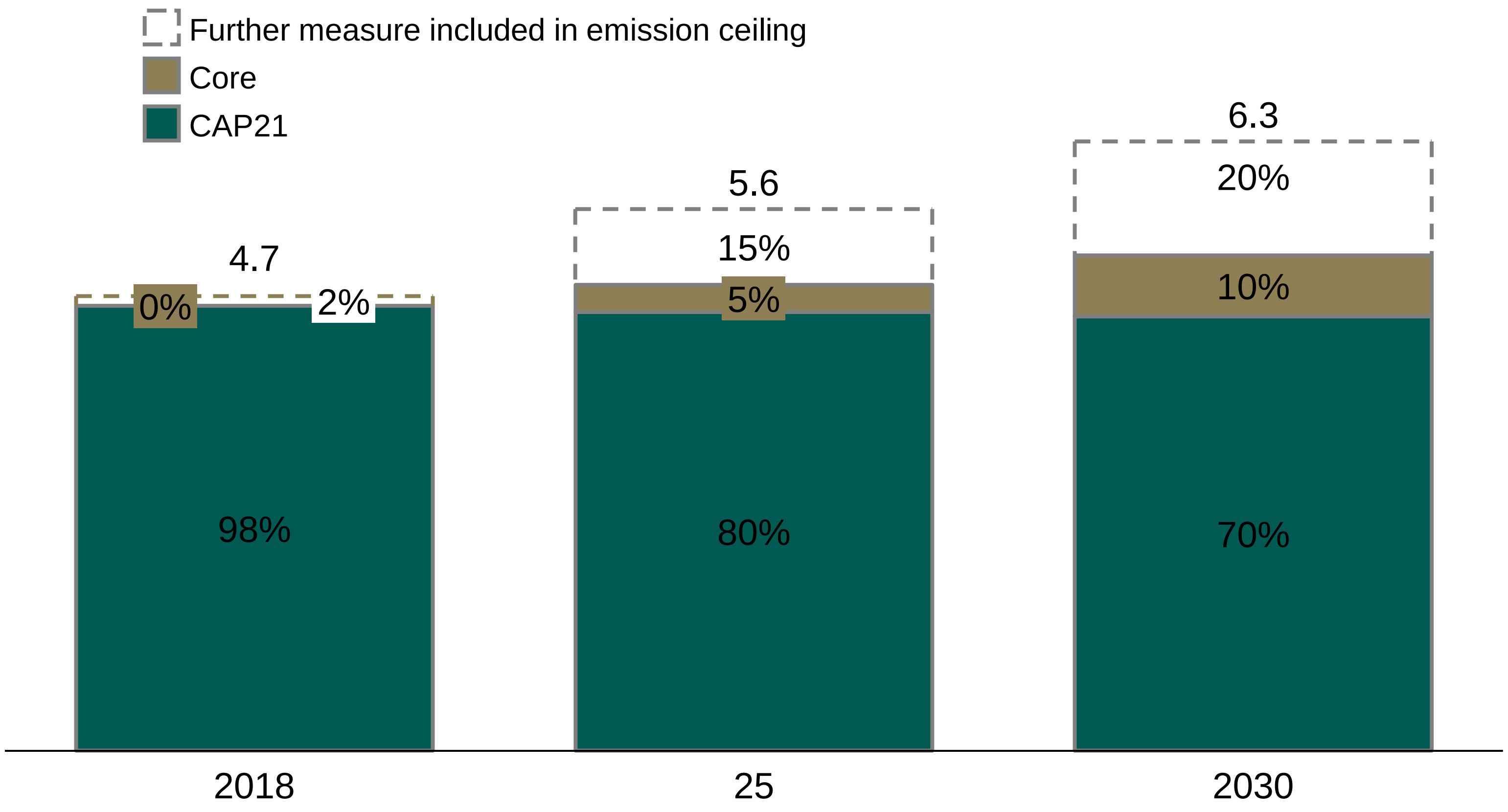
Converting oil-fired heat sources to electric may be the lowest cost option at 20-50 EUR/tCO$_2$eq compared to switching from to zero-emission gas at 100-150 EUR/tCO$_2$eq.

Cost differentials are driven by OPEX, i.e. fuel prices: electricity prices are assumed to be ~50-60 EUR/MWh, natural gas prices ~20-30 EUR/MWh, oil prices 45-55 EUR/MWh, biomethane ~40-60 EUR/MWh and green hydrogen ~75 EUR/MWh

Switching to hybrid heating (e.g. alumina) costs 50-120EUR/MWh, depending on hybrid option. Lower costs achieved by running electric for ~50% of time when electricity prices are ~25-45% lower than annual average

I2/I4: Implementing potential measures could enable demand to remain stable through 2030

Cement production, mn t cement/y



Source: UNFCCC, EPA

Key takeaways

Cement demand forecasted to grow to ~6.3 Mt in a BAU scenario to 2030

The emission ceiling scenarios assume that through implementation of demand reduction measures of 30% by 2030, demand will remain flat

Some 60% of Irish cement demand is used for building construction. Alternative construction materials could displace part of cement demand.

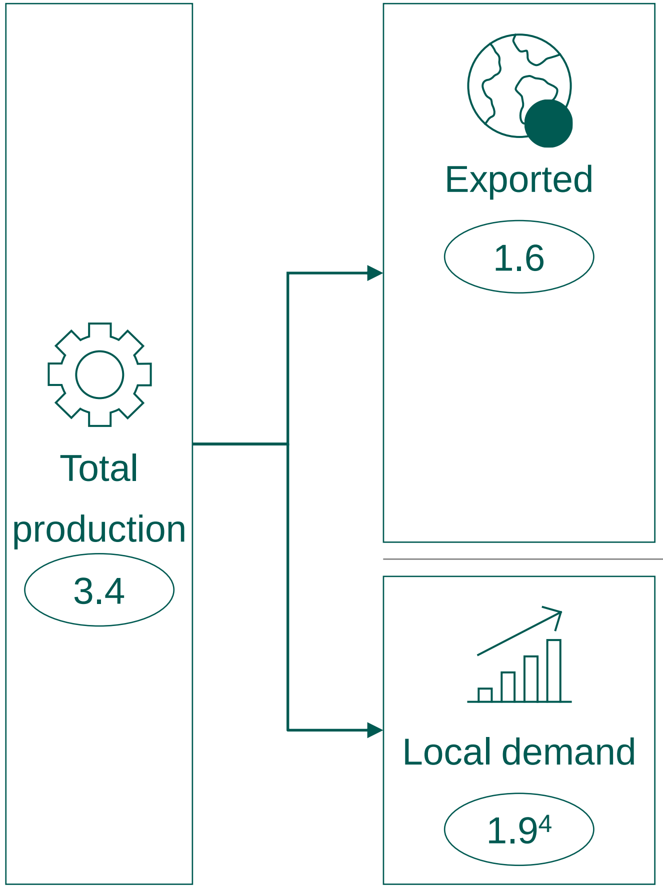
I2 /I4 : Cement demand anticipated to be driven by local consumption

Cement demand could increase in a BAU scenario, driven by building/infrastructure projects in Ireland

Cement breakdown 2020[1], Mt

BAU demand in change in 2030

Rationale



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New CBAM measures remove allowances for cement:

- Carbon border adjustment mechanism (CBAM) measures will remove European allowances for cement manufacturers, meaning they must pay for all rights to emit
- Turkey and Algeria main exporters to EU – both have lower prices at present due to low labour costs and affordable energy (e.g. Algeria large supply of natural gas and energy subsidies)

Leading exporters of cement to the UK have decarbonization targets

- Majority of exports to the UK are intra-company, involving companies that have ambitions to decarbonise (e.g. CRH SBTi target) and explore alternative technologies
- UK is not capacity constrained: 15.5 Mt capacity, vs. production 9-9.5Mt and local demand 11-11.5 Mt

↑

Local demand increases are the main driver in the BAU scenario:

- Housing for All Scheme targets ~33k new houses per year through 2030. ~10k additional to new builds historically[2] build rates. Potential ~4-6% increase in local demand[3] (90kt)
- Further infrastructure projects could also increase demand

---

1. Note total 2019 production was 3.4Mt. Total imports ~0.2Mt; 2. ~20k new dwellings completed; 2020 ~21k; 3. avg. house requires ~30m3 concrete, 0.3t cement per m3 concrete; 4. Note additional imports of ~0.2Mt

Source: European Commission, establishing a carbon border adjustment mechanism, 2021/0214 (COD), July 2021

I2 /I4 : Global cement players are already focusing on measures to redesign cement use and alternative materials

▨ Demand management

Not exhaustive

⊖ Below median ⊜ Around median ⊕ Above median

		Heidelberg Cement	CRH	Cemex
Vision		**CO2-neutral concrete** by 2050 at the latest	**Carbon neutrality** along the **cement** and **concrete value chain** by 2050	**Net-zero concrete** by 2050
Ongoing initiatives (examples)	**Reduce**	Sustainable concretes (e.g., EcoPlus®) Alternative fuels	Special cement based on slag with a clinker factor of 32% New binders Alternative fuels	Sustainable concrete (Vertua) Solar-powered heat source (instead of fuel) Hydrogen used in the fuel mix
	Repurpose	Launched kiln electrification pilot in 2017 Initiated full-scale CCS project – 400k t CO2/a, 50% of emissions captured	Joined LEILAC1 project with Tarmac (CRH) Executed a demo project for carbon capturing in 2018	Initiated study on innovative carbon capture technologies based on membranes
	Redesign	Delivers more efficient 3D printed concrete for Europe's largest 3D printed residential building	2.6m tonnes of total alternative materials were internally recycled back into processes where possible	Investigates production of light-weight aggregates from plastic waste (low CO2 footprint and greater durability for non-structural use)

---

1. SAM ESG ranking by S&P Global, 2021 ranking, based on 2019 company data 2. Calculated value

Source: Sustainability and annual reports; Company websites and presentation;

I2 /I4 : Example: CLT has various applications; even for higher constructions

Key information cross-laminated timber (CLT)

- **Cross-laminated timber (CLT) is an engineered wood product** that is rapidly gaining popularity as a sustainable alternative to concrete and steel construction
- **System consists of multilayer panels made from solid wood boards** stacked crosswise and glued together
- **Configuration improves rigidity, dimensional stability, and mechanical properties** and as well stands out on appearance, versatility, sustainability
- **CLT offers performance comparable to concrete or steel**, with panels suitable for use as walls, floors, and roofs and other applications

Case example: T3 Bayside, Toronto, Canada

Office complex currently under construction; to be finished in 2023

Two 10-story buildings made in CLT and glulam are part of the 45,000-square-meter complex

Tallest CLT building in North America once finished with max. 42 meters

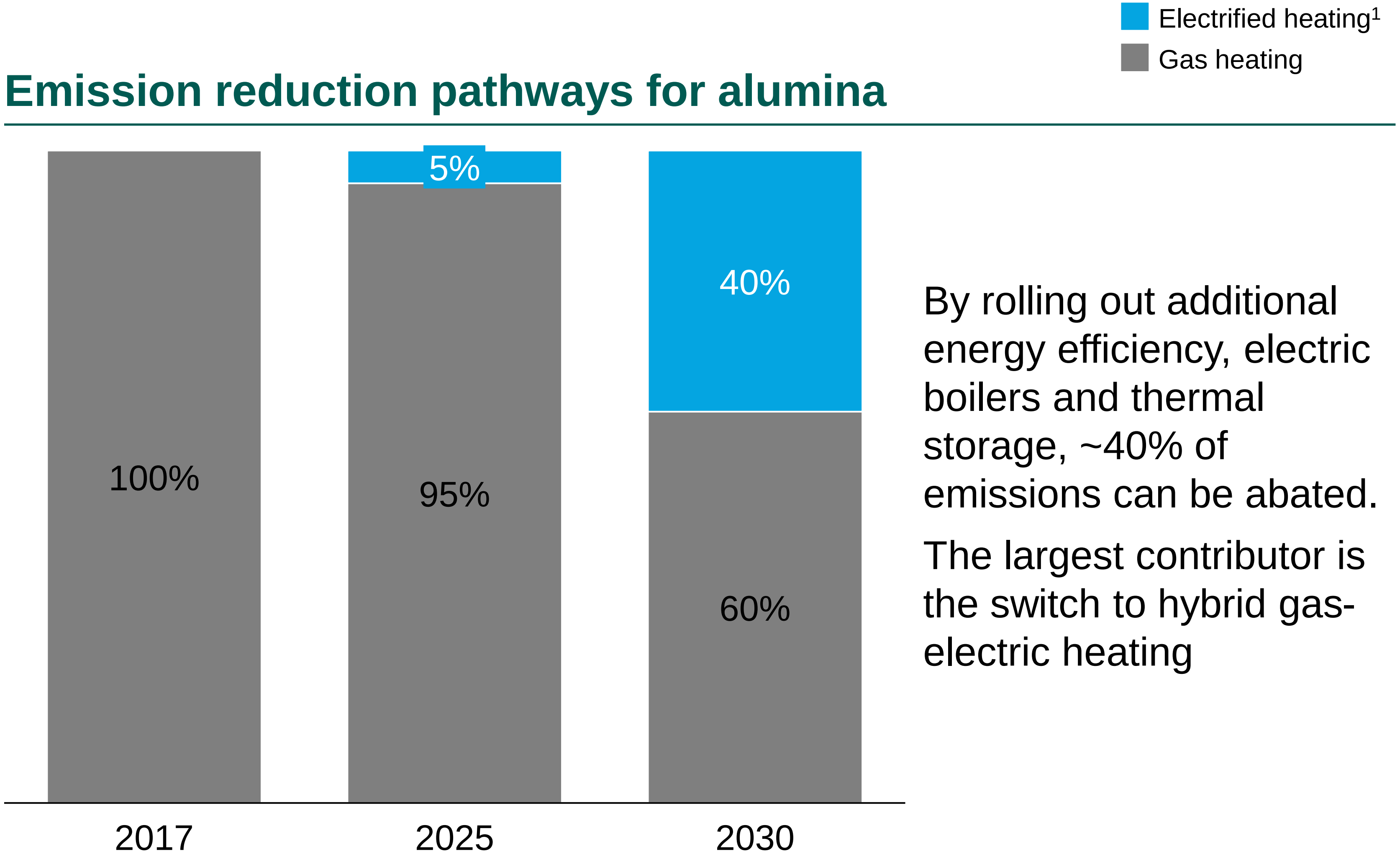
Environmental sustainability is at the core of using CLT at T3 Bayside; but improved health of residents and overall better well-being are further positive side effects according to 3XN

High flexibility in design phase through using CLT

Source: European journal of Wood and Wood Products; 3XN & Hines

I3: Full rollout of hybrid-gas electric heating in alumina production could reduce 40% of emissions by 2030

Emission reduction pathways for alumina



By rolling out additional energy efficiency, electric boilers and thermal storage, ~40% of emissions can be abated.

The largest contributor is the switch to hybrid gas-electric heating

Key takeaways

Hybrid gas-electric heating can generate cheap and low-carbon heat

Additionally, it supports the ambition of the national electricity system of increasing renewables by helping balance the volatility in the grid.

There is potential to pursue further abatement in alumina by running the hybrid gas-electric heating more hours per year on electricity.

1. Combination of electric boiler and thermal storage

Source: UNFCCC, EPA, team analysis

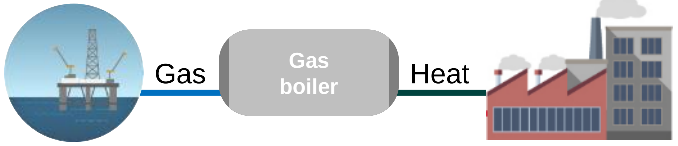
I3: Hybrid gas-electric heating can generate affordable and low-carbon heat whilst balancing the grid

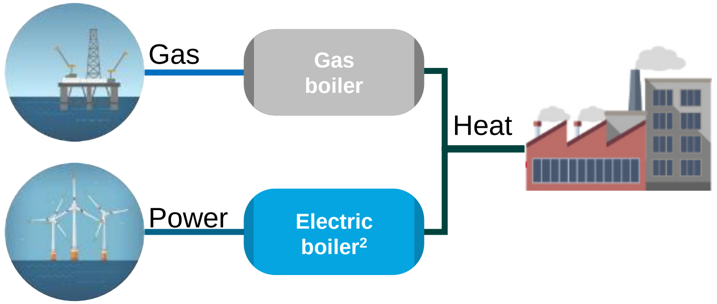
Xx Emissions of example 5 MW system[1], ktCO2

Current typical heating setup

Hybrid gas-electric heating setup

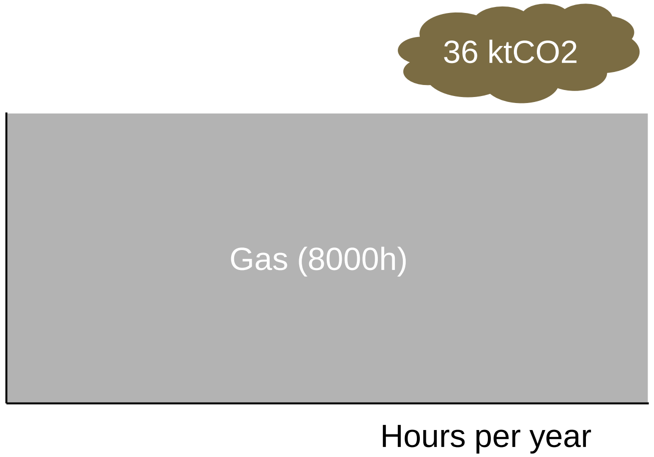
Heating system setup

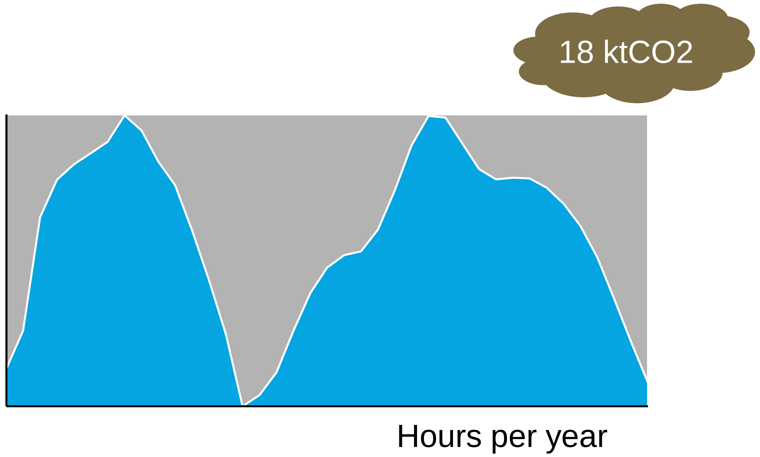




- By adding an electric boiler or heat pump to a heating system, the heating source can instantly be switched from gas to electric power when power prices fall below gas prices

Energy consump-tion for heat





- By switching to electric heating in low price hours – typically induced by high renewable generation – the hybrid gas-electric setup can balance the grid (or e.g. balance a portfolio)
- The more hours that run on electricity, the larger the decarbonization impact

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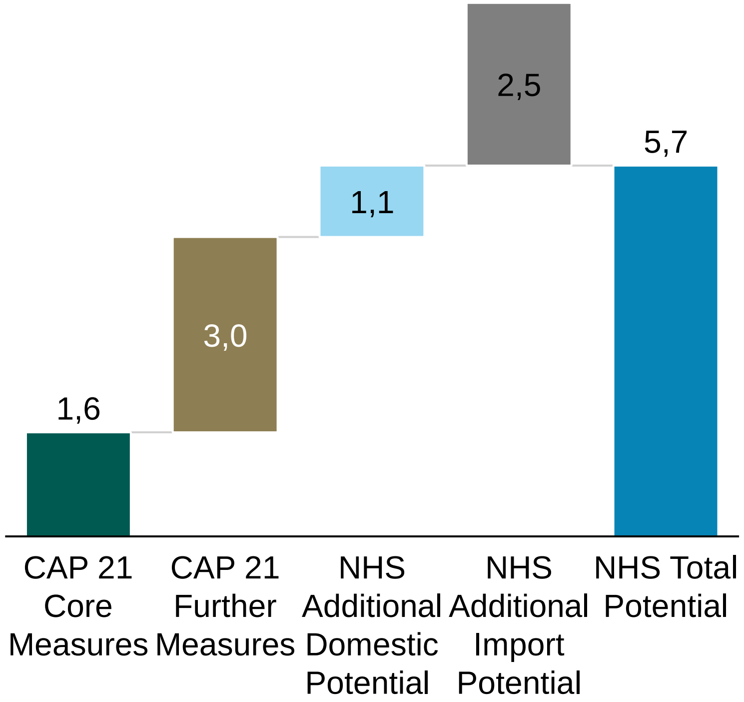
1. Typical size of heating system of single industrial player

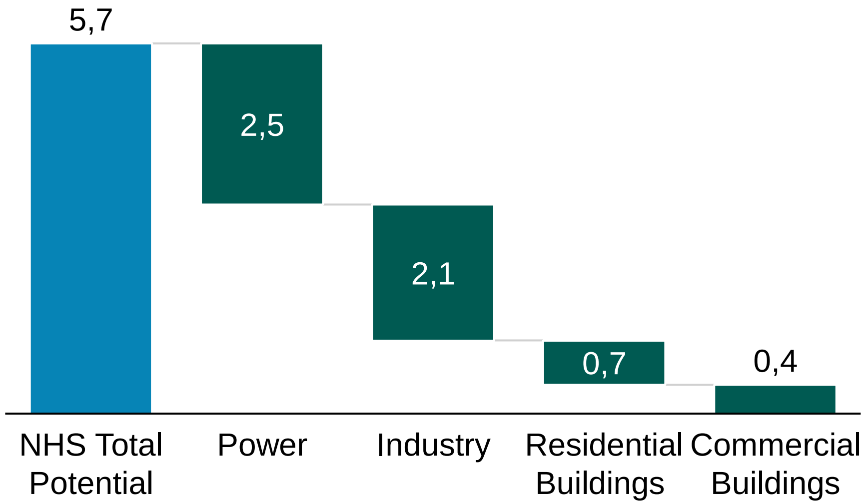
Note: It is also possible to install a hybrid boiler instead of separate independent electric boiler, which could be cheaper and better for location space optimization

I5: The National Heat Study has identified a maximum potential of 5.7TWh of biomethane production by 2030

Biomethane production potential[1,3,4],
2030, TWh



Biomethane consumption[2],
2030, TWh



Commentary

- **CAP21 identifies 1.6TWh of biomethane production potential without land use change**
- **Maximum domestic biomethane production** is estimated at ~5.7TWh under the ‘rapid progress’ scenario laid out in the National Heat Study (2022)
- **Industry is assumed to consumed ~2.1TWh** of biomethane by 2030
- **Potential for industry to use more than ~2.1 TWh**, given high willingness to pay for decarbonized gas. Outcomes dependent on availability and use by other sectors

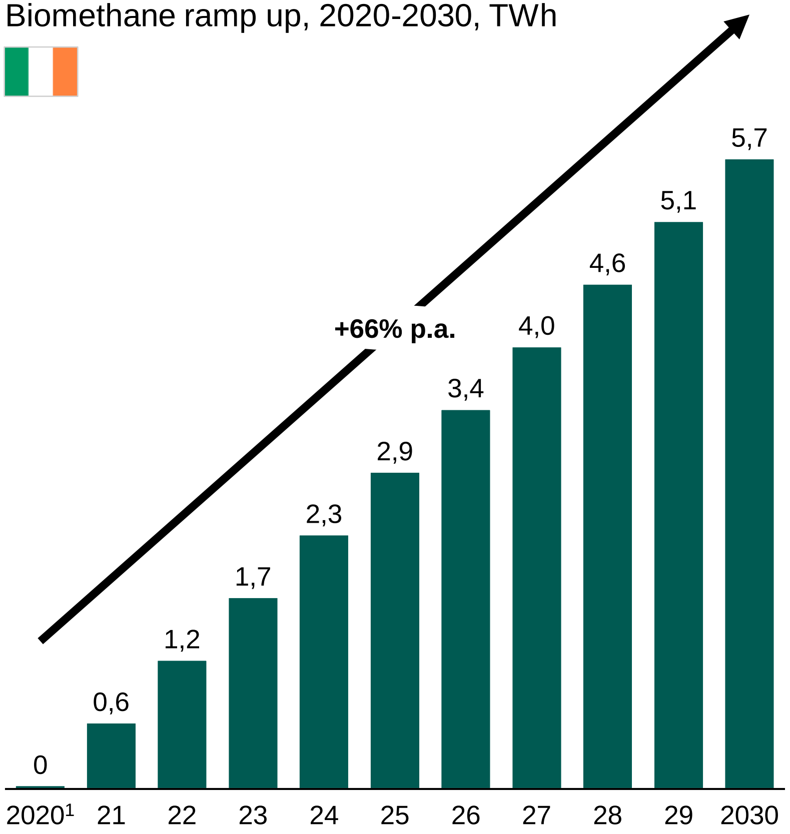
1. Considers the Rapid Scenario proposed in the SEAI National Heat Study; 2. Consumption in proportion to 2021 natural gas consumption; 3. As per recommendation of SEAI National Heat Study, increasing the growing of energy crops must be done in line with nationally appropriate sustainability governance to minimise upstream emissions, align with circular and bioeconomy goals, and avoid increasing emissions in non-energy sectors; 4. Total Domestic Potential of 5.7TWh includes 4.7TWh from grass silage/slurry AD supplemented by 0.98TWh from food waste and pig slurry.

Source: SEAI National Heat Study 2022, Climate Action Plan 2021, Government of Ireland

I5. To meet maximum biomethane potential, ramp up will be similar to highest production European countries

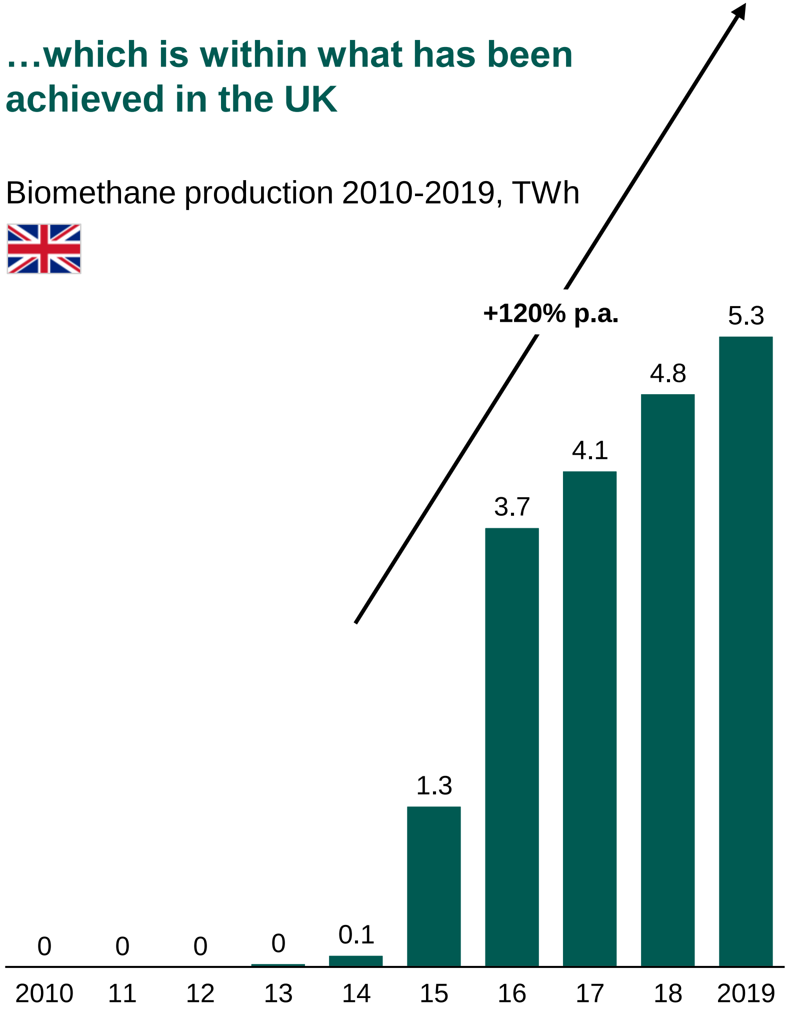
Ireland could be required to grow production by ~65% p.a. to reach highest potential by 2030…

Biomethane ramp up, 2020-2030, TWh



…which is within what has been achieved in the UK

Biomethane production 2010-2019, TWh



[1] First biomethane injection plant in Cush, Co. Kildare came online in 2020

Source: EBA 2020, expert interviews

Key takeaways

To reach highest potential biomethane production in 2030 as outlined by SEAI, ~66% p.a. increase required

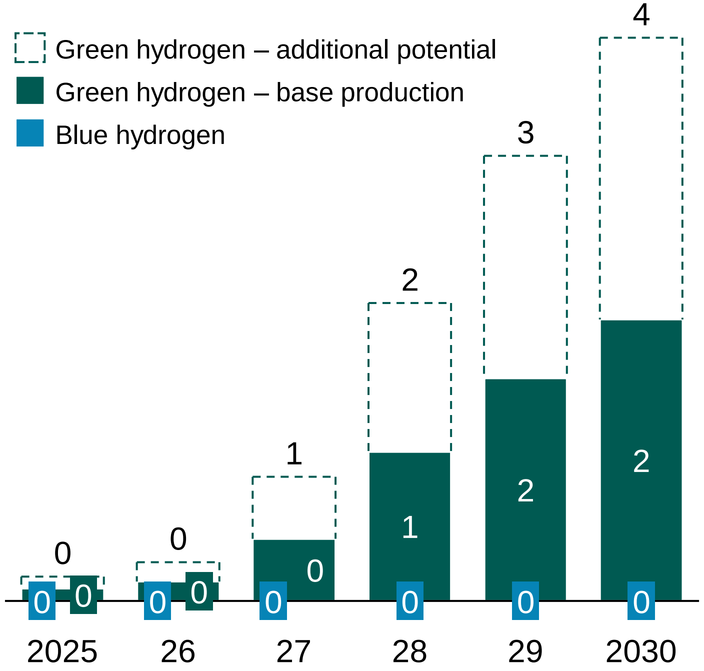
This is similar to ramp up in production across the highest producing biomethane countries in Europe. UK achieved ~120% p.a. growth between 2014-19

I5. Zero-emissions gas: potential for 2-4 TWh of green hydrogen production in Ireland

CAP21 further measure commits to 1-3 TWh of zero emissions gas[1] but there is potential to stretch green hydrogen to ~4 TWh

2-4 TWh of green hydrogen could come into production by 2030…

Potential Irish hydrogen production, TwH



… there are already movements in Ireland to develop capacity…

Production facilities in-build or planned:

- **Green Atlantic at Moneypoint:** EUR50m green energy hub being built by ESB, including investment in green hydrogen production
- **E1-H2 electrolysis plant**: EUR120m investment in a 50MW plant – Ireland's first facility – planned to be operational by 2023.

Storage facilities:

- **ESB and DCarbonX**: planning to develop a 3TWh storage project at the decommissioned Kinsale Head gas field – enough storage to power ~10% of Ireland's current annual electivity demand

…and action within Europe is ramping up rapidly

EU hydrogen targets:

- ~17TWh[2] of renewable hydrogen production capacity between 2020-24
- 112[2] TWh of renewable hydrogen electrolyser capacity by 2030

UK government hydrogen strategy:

- Plan to attract £4bn hydrogen investment by 2030
- 14[2] TWh production by 2030, powering heavy industry, transport and homes
- Hydrogen to power 20-35% of UK energy consumption by 2050

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1. CAP21 commits to identifying a route to deliver 1-3 TWh of zero emissions gas (including green hydrogen) by 2030, potentially equivalent to 0.2-0.4 MtCO2eq abatement
2. Conversion based on German National Hydrogen Strategy conversion (5 GW capacity producing 14TWh of H2. Note, requires 20 TWh electricity). EU 6GW and 40GW capacity by 2030 and 2050 respectively; UK 5GW capacity

Source: International Renewable Energy Agency Report 2022

I5. More than a dozen governments have announced national hydrogen strategies and related initiatives to support green & clean hydrogen uptake

Governments are launching increasingly ambitious hydrogen strategies and targets

NOT EXHAUSTIVE

2019

Europe

- 🇳🇱 Climate act targeting **3-4 GW electrolysis by 2030**
- 🇬🇧 Net-zero 2050 & plans for **4 GW wind for green H_2** production

APAC

- 🇯🇵 H_2 is a core part of energy strategy, with a target of 800k FCEV by 2030 (first country to fully commit)
- 🇰🇷 FCEV road map targeting 80k FCEV by 2022 & **1.8m FCEV by 2030**
- 🇨🇳 Listed H_2 as energy source in national law, and targets **1 mn FCEV by 2030**
- 🇦🇺 **National H_2 strategy** aiming to be a major player by 2030

2020

Europe

- 🇪🇺 H_2 strategy targeting 6 GW electrolysis in 2024 & **40 GW electrolysis in 2030**
- 🇳🇴 H_2 strategy pledging $380 mn for 'green transition'
- 🇩🇪 H2 strategy pledging **€9 bn & 5.0 GW electrolysis by 2030**
- 🇫🇷 H2 strategy pledging **€7bn & 6.5 GW electrolysis by 2030**
- 🇪🇸 H_2 strategy aiming to install **4 GW electrolyzers by 2030**
- 🇩🇰 Target to install **5 GW wind to (partially) produce green H_2**
- 🇵🇹 H_2 strategy pledging investments of **€7bn by 2030**
- 🇬🇧 **Acceleration of ICE-ban to 2030;** Target to produce **5GW of low-carbon hydrogen capacity by 2030**

APAC

- 🇳🇿 Released **H_2 vision** and working on developing a national strategy
- 🇨🇳 Net-zero 2060; **New regional subsidies for FCEV and FC-component production**

LatAm

- 🇨🇱 H_2 strategy targeting 5 GW electrolysis in 2025 & **30 GW electrolysis in 2030**

North America

- CALIFORNIA REPUBLIC Hydrogen industry roadmap with **CA + 15 states mandating 30% of trucks to be ZEV by 2030**

⊕ **National hydrogen strategies under development in**

🇮🇹 🇸🇪 🇫🇮 🇦🇹 …

75+ GW

🇪🇺 🇬🇧 🇨🇱

National targets for low-carbon hydrogen production until 2030

3.5mn+

🇨🇳 🇰🇷 🇯🇵

FCEVs targeted to be on the road in China, Japan, and Korea by 2030

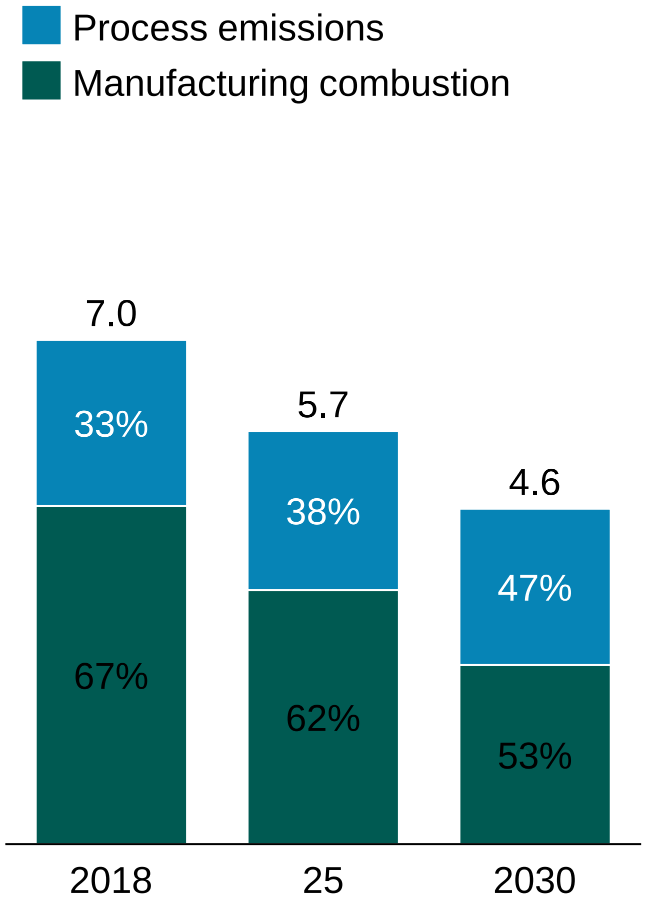
10,000+

Refueling stations deployed by 2030 globally

Source: Country Hydrogen strategy, press search

The allocation of emissions according to the EPA can be aligned to the DSE

Emissions in MtCO2eq



Classification (MtCO2eq in 2018)

EPA	DSE
Process emissions (~2.3)	**Cement** (~1.9) **Mining** (~0.04) **Other process emissions** (~0.3)
Manufacturing combustion (~4.7)	**Alumina** (~1.2) **Cement** (~1.2) **FBT** (~0.8) **Other Energy emissions** (~0.9) **Other industry HT/LT heat** (~0.6)

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1. Without Public electricity and heat production

Key takeaways

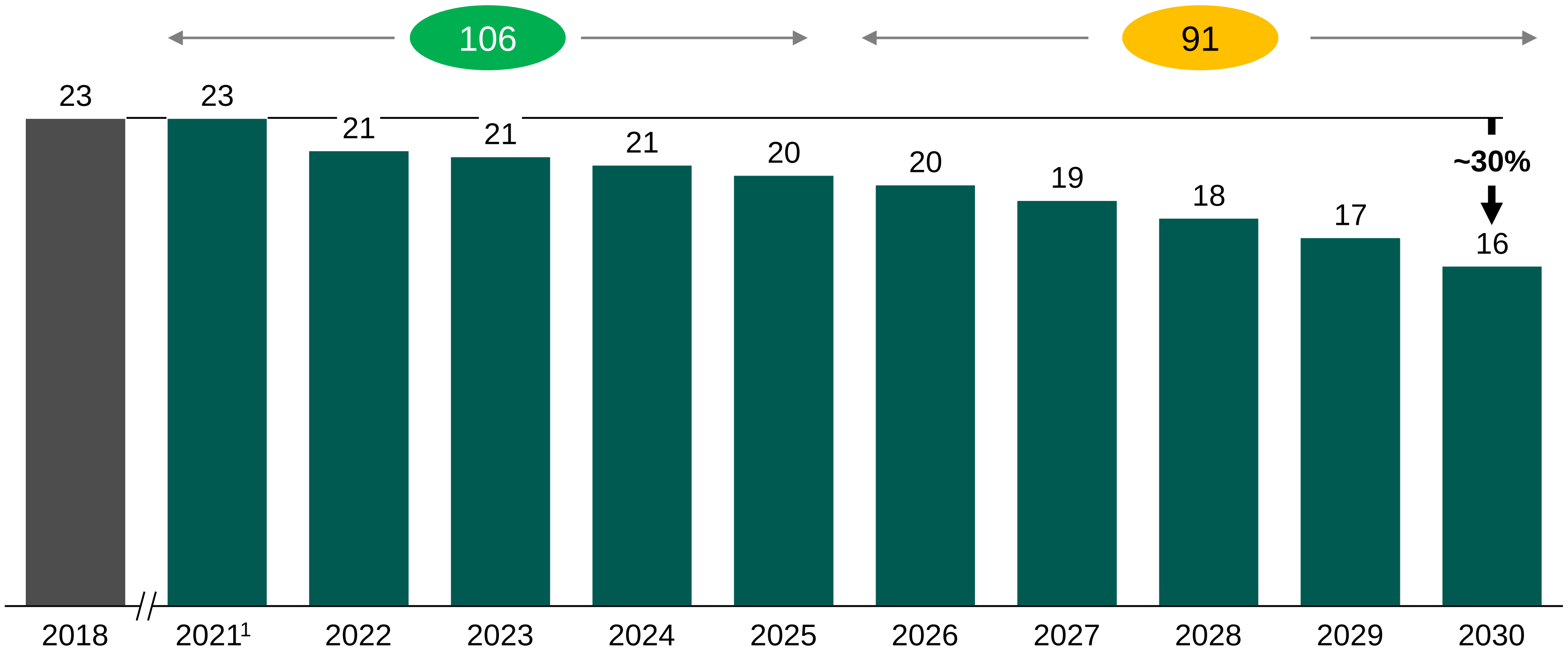
- ➢ **EPA** and **DSE classification** methodologies **vary**, however, they can be **mapped** to each other.
- ➢ The DSE baseline was aligned based on the **UNFCCC**

Contents

The agriculture reduction pathway could result in a ~30% reduction by 2030

CAP 2021 incl. Core Measures and Further Measures excl. 'Unallocated Savings', MtCO2eq (AR5)

x 5-year carbon budget, MtCO2eq



Agriculture

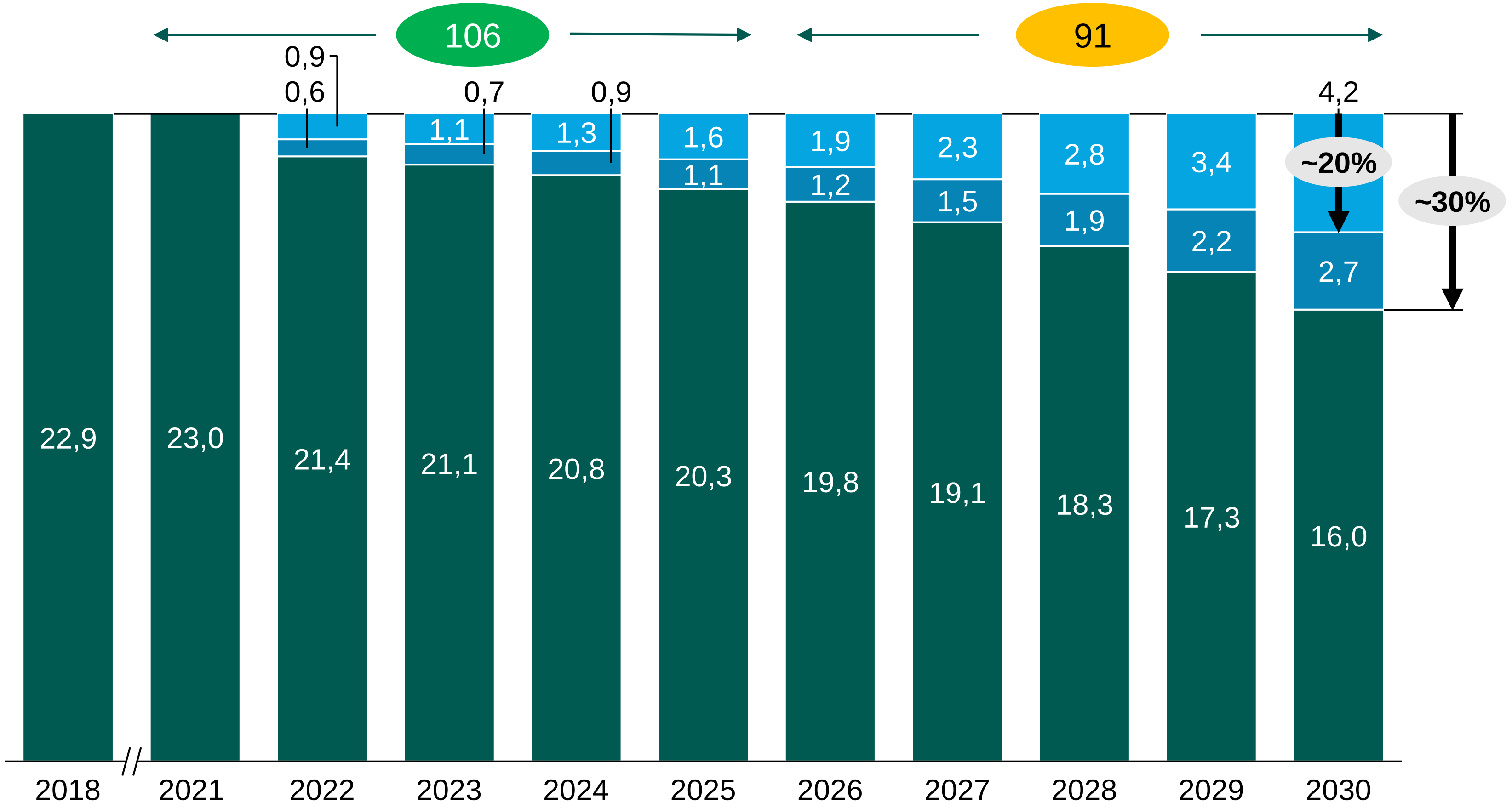
The proposed sectoral emissions reduction pathway as laid out in Climate Action Plan 2021 for **agriculture results in a ~30% reduction by 2030**

Both Core and Further Measures could be required to deliver the ~30% reduction to Agriculture's emissions ceiling of ~16MtCO$_2$eq

🟦 Core Measures
🟦 Further Measures

CAP 2021 incl. Core Measures and Further Measures excl. 'Unallocated Savings'[1], MtCO2eq (AR5)

○ 5-year carbon budget, MtCO2eq



1. To achieve -30% reduction, diversification in line with Teagasc Scenario D, such diversification can be reduced if technological measures are accelerated

Source: Climate Action Plan 2021, Government of Ireland

Core Measures alone will deliver ~20% reduction by 2030

Further Measures could be required to deliver the ~30% reduction needed to reach Agriculture's 2030 emissions ceiling of ~16MtCO2eq

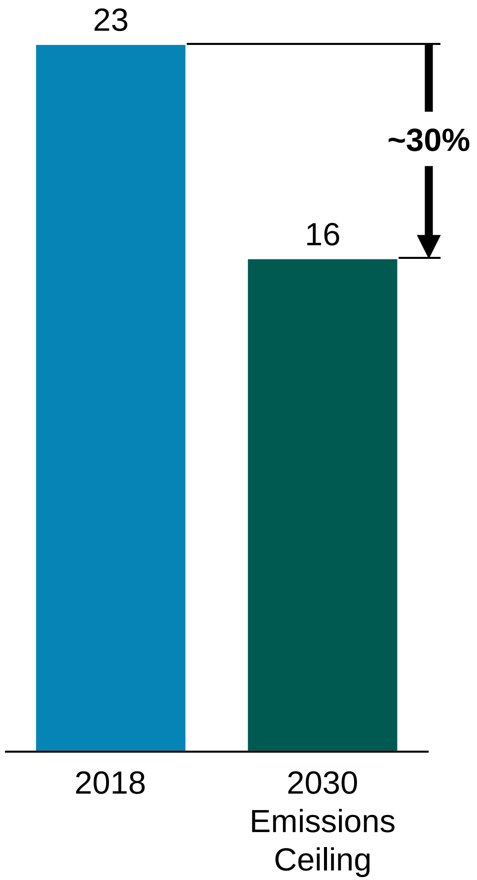
NOT FOR FURTHER DISTRIBUTION

The Climate Action Plan 2021 identified two core measures that could support 3.6-4.2 Mt emissions reduction in agriculture

○ <0.5MtCO2 ◔ 0.5-1MtCO2 ◑ 1-1.5MtCO2
◕ 1.5-2MtCO2 ● >2MtCO2

PRELIMINARY – SUBJECT TO DATA VALIDATION

GHG emissions agriculture, MtCO2eq (AR5)



		Option	KPI 2025[2]	KPI 2030	Abatement impact by 2030[1], MtCO2eq
Core measures	A1	**Increase adoption of GHG-efficient farming practices**	**~0.6x** Climate Action Plan 2019 ramp up	**~1.5x** Climate Action Plan 2019 ramp up	●
Example sub-measures		Reduction in nitrous oxide emissions	< 350kt nitrogen use, replacement of ~30% of ammonium nitrate through urea, aim for ~90% uptake of low emission slurry spreading	< 325kt nitrogen use, replacement of ~65% of ammonium nitrate through urea, reach ~90% uptake of low emission slurry spreading	●
		Improved animal breeding	Aim for suckler beef weight/dairy herd recording of 70/90%	Increase suckler beef weight/dairy herd recording to 70/90%	◑
		Improved animal feeding	Reduce crude protein content of livestock food	Reduce crude protein content of livestock food	◕
		Early finishing age of cattle	Reduce average age of slaughter to 24 months	Reduce average age of slaughter to 24 months	◕
		Increasing organic farming	Increasing organically farmed area to ~145kha	Increasing organically farmed area to ~350kha	◑
	A2	**Create new biomethane business opportunities**	**~0.7 TWh** of bio-methane production achieved without land use change	**~1.6 TWh** of bio-methane achieved without land use change *Note: the sectoral emissions ceilings assumes 5.7TWh of biomethane production by 2030*	◑
		Total			Σ **~3.6-4.2**

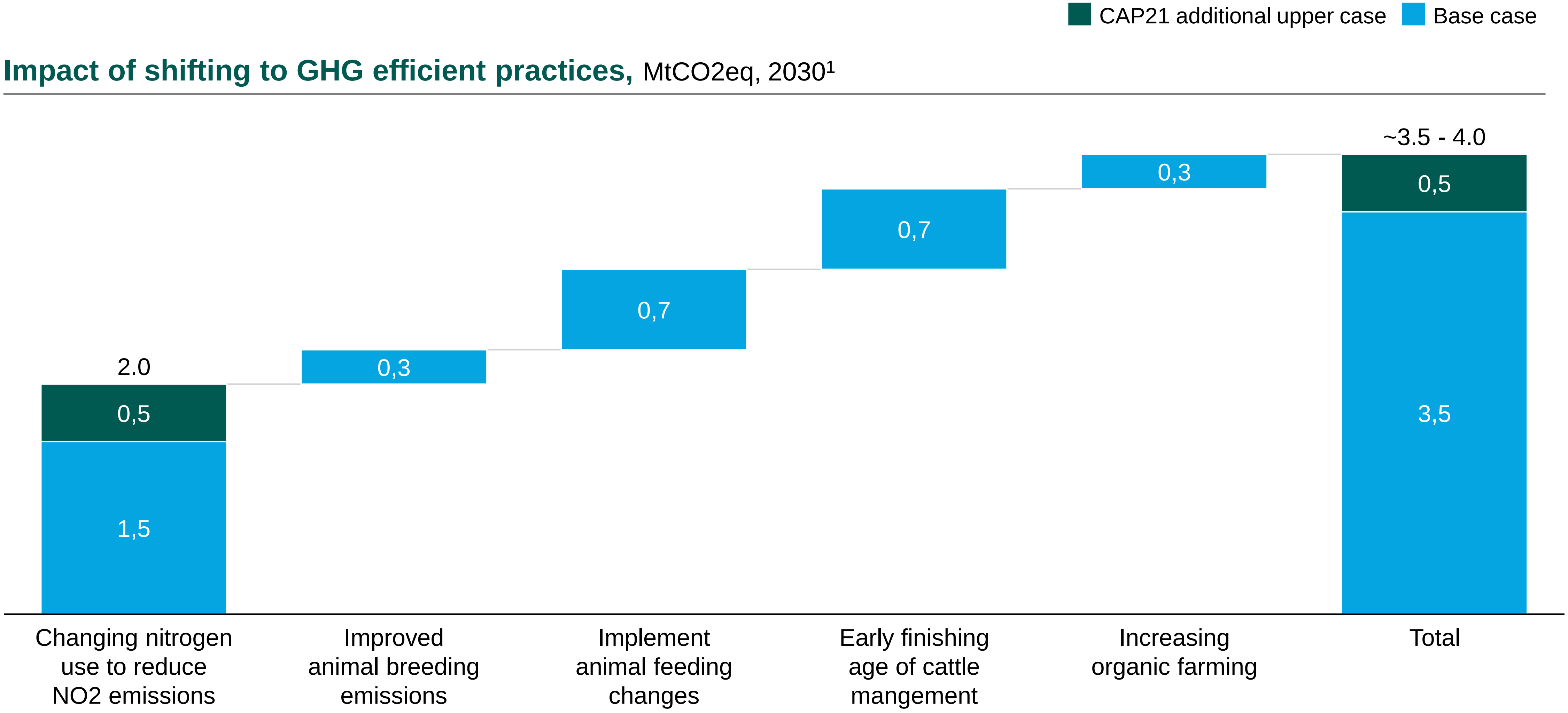
Core measures proposed in CAP21 provide 3.6-4.2 MtCO2eq of abatement by 2030, but are **insufficient to meet the proposed ~7MtCO2eq of abatement** implied by the sectoral emissions ceiling

---

1. Abatement impact combines 2019 and 2021 core and further measures; 2. KPIs weighted based on respective share of 2030 emissions

A1: Increased adoption of GHG-efficient farming practices could abate an additional ~3.5-4.0 MtCO2eq

Impact of shifting to GHG efficient practices, MtCO2eq, 2030[1]



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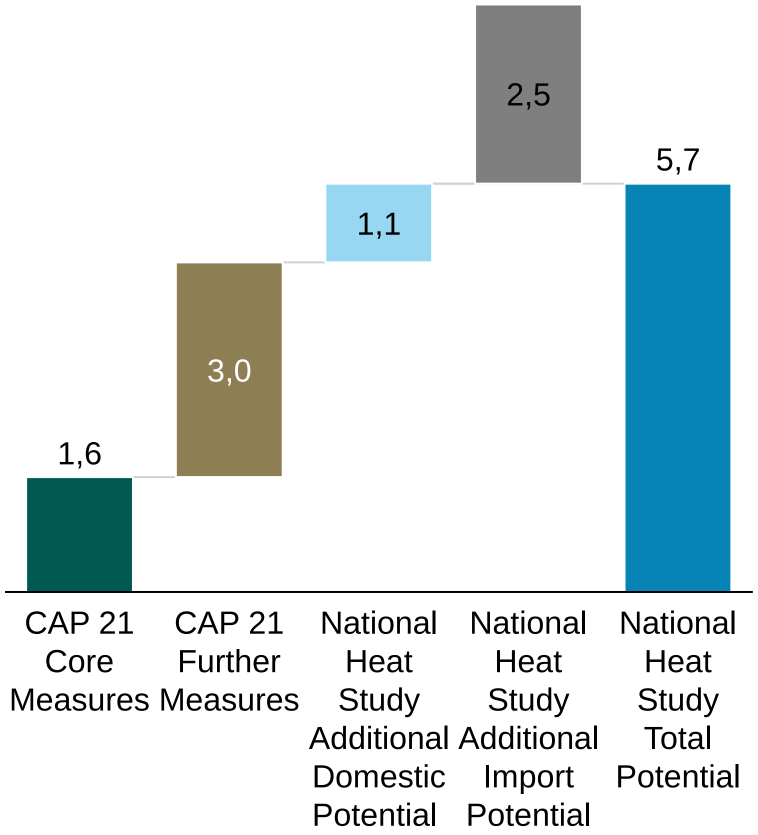
1. Abatement values updated to reflect AR5 2020 methodology; impact of measures following AR4 methodology not changed

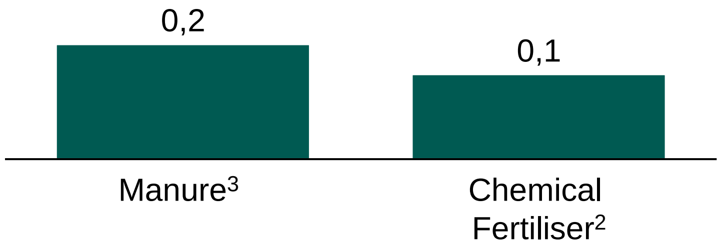
Source: Climate Action Plan 2021, Government of Ireland

A2/A4: 1.6TWh of biomethane production was identified in CAP21 with a further 4.1TWh identified included in the sectoral emission ceilings

Biomethane production potential[1,2,3], 2030, TWh



Abatement in agriculture from CAP21 core measure, 2030, MtCO2eq



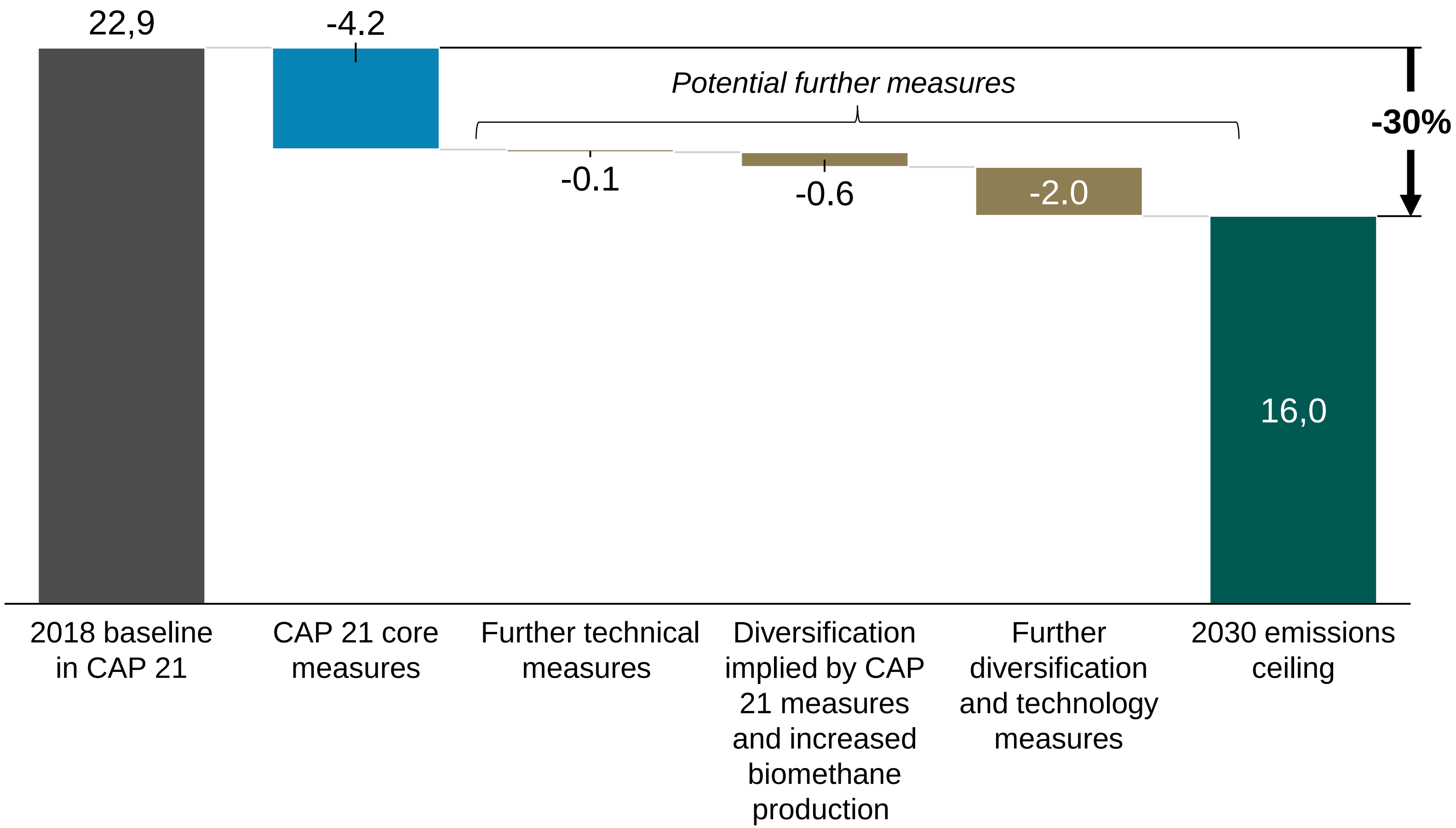
- **CAP21 identifies 1.6TWh of biomethane production** potential without land use change
- The proposed sectoral emission ceilings assume 5.7TWh of biomethane production by 2030, in line with **maximum domestic biomethane production** estimated in the 'rapid progress' scenario of the National Heat Study (2022)

1. Considers the Rapid Scenario proposed in the SEAI National Heat Study which does not account for market conditions such as market price of silage, fertiliser costs, as well as behavioural changes required at farm level; 2. As per recommendation of SEAI National Heat Study, increasing the growing of energy crops must be done in line with nationally appropriate sustainability governance to minimise upstream emissions, align with circular and bioeconomy goals, and avoid increasing emissions in non-energy sectors; 3. Total Domestic Potential of 5.7TWh includes 4.7TWh from grass silage/slurry AD supplemented by 0.98TWh from food waste and pig slurry.

Source: SEAI National Heat Study, CAP21

Core measures outlined in CAP21 are insufficient to reach the sectoral emissions ceiling for agriculture by 2030

Agriculture sectoral emissions ceiling 2030, MtCO2eq (AR5)

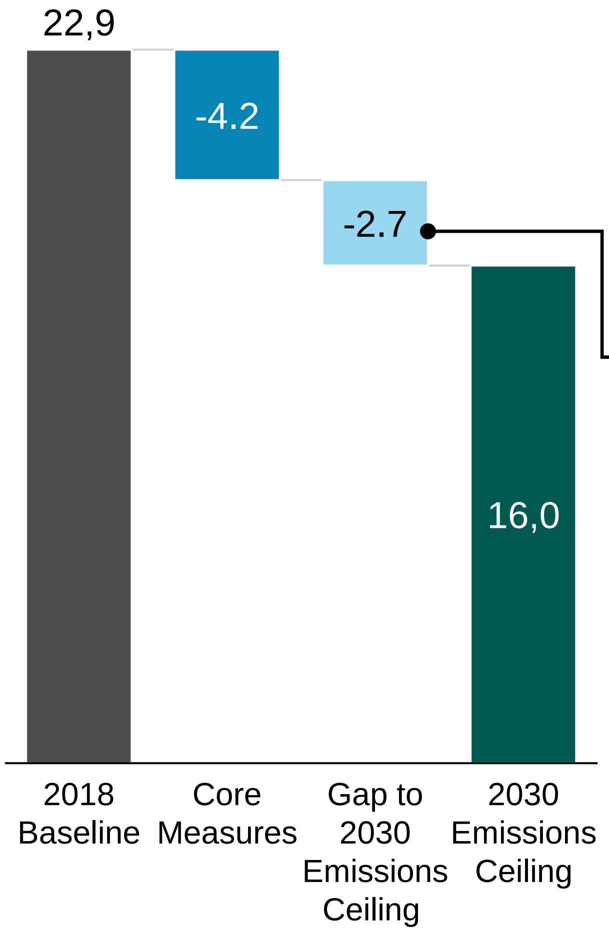


- Agriculture's proposed emission ceiling requires **abatement of ~ -7MtCO2eq by 2030**
- **Core measures alone are insufficient** to reach the sectoral emissions ceiling, reducing emissions by ~4.2MtCO2eq
- **Four categories of additional further measures have been identified** to help bridge this gap:
  - Further technical measures to reduce GHG emissions from existing production
  - Further biomethane production potential identified by the SEAI National Heat Study
  - Further agricultural diversification implied by CAP21 land use change assumptions
  - Further measures for additional diversification and potential for technological innovation

NOT FOR FURTHER DISTRIBUTION

Additional further measures have been identified which could help reach the proposed sectoral emissions ceiling

GHG emissions agriculture, MtCO2eq, AR5 2020 methodology



Measure	Description	KPIs	Abatement impact by 2030[2], MtCO2eq
A3 **Further technical measures**	**Advance manure management**	30% uptake of extended grazing techniques	~0.07
	Electrification of tractors	3% of tractor vehicle stock are battery electric vehicles	~0.05
A4 **Diversification implied by CAP21 and increased biomethane production**	**Diversification from afforestation and biomethane production**	Diversification aligned with **Teagasc scenario D**, which sees -19% reduction in total herd size	~2.6
A5 **Additional diversification to achieve the Climate Delivery Act**	**Additional diversification**	*Diversification requirement can be reduced if **technological measures are accelerated (e.g., 3NOP)***	
		Σ	~2.7

Note: Emissions factor revised downwards from 1.88tCO2/head/year to 1.792tCO2/head/year following expert syndication, reflected in change in diversification figure from 1.4m to 1.47m suckler head

Source: K. Hanrahan, T. Donnellan & G.J. Lanigan. “Scenarios For Agricultural GHGs” 2019

A3: Earlier estimates suggested abatement potential from adoption of the GHG-efficient farming practices beyond what is identified in CAP21

🟦 CAP19 and CAP21 commitments 🟦 Additional potential beyond CAP19 and CAP21 commitments

Mitigation strategy		**Uptake rates 2030,** %	**Abatement 2030,** MtCO2eq[1]	**Source of uptake increase**
Advance manure management	Extended grazing	30	0.13 // 0.07 0.20	Teagasc 2019 report: An Analysis of Abatement Potential of Greenhouse Gas Emissions in Irish Agriculture 2021-2030 (maximum technical potential)
Energy/ Electricif-ication	BEV tractors	3	0,05 0.05	Based on an average lifespan of ~30 years and introduction starting in 2030

Total abatement potential: ~0.13 ~0.12

---

1. Abatement values updated to reflect AR5 2020 methodology; impact of measures following AR4 methodology not changed

Source: TEAGASC “An Analysis of Abatement Potential of Greenhouse Gas Emissions in Irish Agriculture 2021-2030” 2018

A4: CAP21 implies potential land use change that could unlock emission reductions from diversification

▢ Beyond CAP21 commitments

Measure	Description	Implied Land Use Change, ha[3]	Implied diversification, head	Abatement in 2030[1,2], MtCO2
Afforestation	CAP21 presupposes a total of ~72kha of afforestation through 2030	~72,000	~90,000[3]	~0.16
Bio-methane Production from Grass Silage/Slurry[4]	The SEAI Heat Study proposes potential biomethane production of 4.72TWh from domestic resources requiring ~199kha of land	~199,000[5]	~248,500[3]	~0.45
Total		**~257,000**	**~321,000**	**~0.61**

Note: herd displacement from land use change uncertain and variable

- CAP21 core measures imply land use change of ~72kHa
- Further biomethane production beyond CAP21 implies additional ~199,000Ha of land use change

1. Abatement resulting from diversification only; 2. Assumes Emissions Rate of 1.792tCO2/head; 3. Assumes Beef Stocking Rate of 1.25LU/ha based on National Farm Survey 2019; 4. SEAI National Heat Study proposes total potential for biomethane production of 5.7TWh comprised of 4.72TWh from grass silage/slurry supplemented with 0.98TWh from food waste and pig slurry; 5. Heat Study; Rapid Scenario assuming that of 617k released, 199kha is suitable for silage production, 103k actually used for silage once behavioural consideration taking into account. 103kha is assumed to be required to produce 13Mt DM needed to produce 4.7TWh of biomethane

Note: Emissions factor revised downwards from 1.88tCO2/head/year to 1.792tCO2/head/year following expert syndication, reflected in change in total abatement figure from 0.64 to 0.61

Source: Teagasc “National Farm Survey” 2019; Teagasc “Profitable Organic beef Production” 2017; IPCC “Emissions from Livestock and Manure Management” Guidelines for National Greenhouse gas Inventories, 2006; K. Hanrahan, T. Donnellan & G.J. Lanigan. “Scenarios For Agricultural GHGs” 2019

A5: Further diversification or technological measures will be required to meet proposed 2030 emissions ceiling of ~16 MtCO2

1 Opportunities to diversify farm activities

Bioenergy	• Farmers **collect grass for use in energy production** via Anaerobic Digestion • Farmers **grow energy crops** for **energy and fuel production** (e.g., heating, bioethanol)
Extensification	• Farmers could be **financially incentivized** to **decrease their use of inputs** (e.g., livestock, fertilisers) on a given area of land
Forestry	• Farmers **plant and maintain trees for multiple purposes incl. building materials**, heating and electricity generation, carbon sequestration, and production of other wood products
Agroforestry	• Farmers **implement agroforestry practices,** which aids biodiversity, **soil fertility, and carbon sequestration**
Other environmental activities	• Farmers implement **additional environmental practices e.g., creation of "no fertilizer zones"**, or protection of natural land and water
Other business diversification	• Farmers **generate additional income through alternative revenue streams** e.g., food processing, leisure and hospitality

2 Emerging technological measures

Low-emitting feed additives. Lowest proposed commercial dose of 3-NOP (60 mg/kg DM of the total daily ration) when applied to TMR can reduce methane emissions from dairy cows by 22–35%

Improved manure management through lower cost anaerobic digesters for the capture and combustion of biogas to produce energy or flaring

Anti-methanogen vaccine targets a reduction in methane emission in sheep and cattle of at least 20% by suppressing the growth of methane-producing microbes.

Low-methane-emitting breeding of dairy cattle and sheep – Precision Breeding techniques can be used to deliver GHG efficient traits

1

A5: Teagasc have outlined a range of potential diversification scenarios and abatement implications

Scenarios develop by Teagasc indicating abatement resulting from changes in land use

	Cattle (m head)		**Cow (m head)**		**GHG (Mega t)**		**Land Made Available[2](Ha)**
	2030	**2030/2018**	**2030**	**2030/2018**	**2030**	**2030/2018**	**2030**
BAU[1]	7.10	-2%	2.43		20.61		~116,000
Scenario A	7.10	-2%	2.43	0%	17.29	-14%	~116,000
Scenario A+	7.63	+5%	2.67	+10%	18.73	-8%	-
Scenario B	6.87	-5%	2.32	-5%	16.72	-17%	~290,000
Scenario C	6.43	-11%	2.11	-13%	16.10	-20%	~637,000
Scenario D	5.88	-19%	1.84	-24%	14.97	-25%	~1,105,000
Scenario E	4.66	-36%	1.23	-50%	12.18	-40%	~2,100,000

In addition to Teagasc analysis, land use change implied by proposed diversification calculated using a stocking rate of 1.25LU/Ha[2]

1. BAU scenario with measures delivers GHG reductions consistent with CAP 2019; 2. Assumes beef stocking rate of 1.25LU/Ha based on Teagasc National Farm Survey 2019 data

Source: K. Hanrahan, T. Donnellan & G.J. Lanigan. “Scenarios For Agricultural GHGs” 2019; Teagasc “National Farm Survey” 2019

2 A5. 3-NOP may contribute to a significant and immediate reduction in emissions as it is rolled out in the EU market in the coming years

2022

February - Royal DSM secured EU approval for the marketing of *Bovaer*,(3-NOP), for dairy cows in the EU

First use of 3-NOP in Europe expected in second half of 2022

2023

Ongoing research to extend 3-NOP's application under grazing conditions

DSM intend to launch slow-release pellet suited to grazing livestock in the EU market

2024

DSM plans to turn its research and development focus to 3-NOP's application to the beef herd

2025

To meet growing EU demand, DSM's new 3-NOP manufacturing facility in Scotland will begin operation

- 3-NOP has the potential to deliver on average **~26% emissions reduction** when a rate of 60mg/kg of feed DM is applied[1]
- Potential adaptations to **extend 3-NOP application under grazing conditions** include adding 3-NOP to pasture supplements, use of lick blocks, encapsulation, slow-release ruminal devices, and so forth
- A slow-release pellet would pay out over the course of 8-12 hours making it highly suitable for **Ireland's predominately grazing dairy herd**

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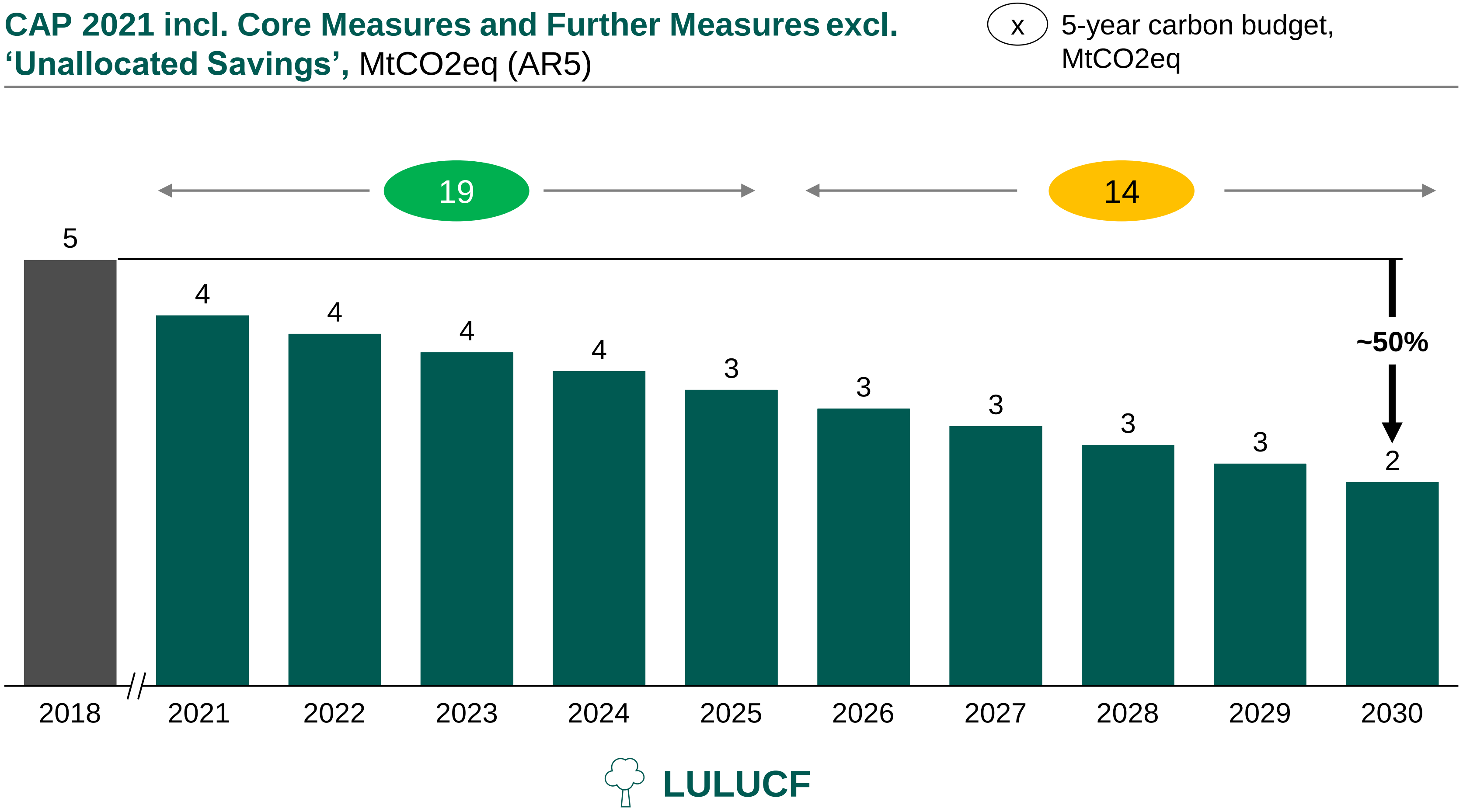
1. Assumes controlled feeding over a 15-week housing period

Source: DSM, "Reducing emissions to reduce climate change" 2022; A. Melger et al., "Enteric methane Emission, Milk Production, and Composition of Dairy cows fed 3-nitrooxypropanol" Journal of Diary Science, Vol 104, 2021.

Contents

The LULUCF reduction pathway from CAP 2021 could result in a ~50% reduction by 2030

CAP 2021 incl. Core Measures and Further Measures excl. 'Unallocated Savings', MtCO2eq (AR5)



LULUCF emission estimates under review. Emission ceilings will likely be updated once work is published.

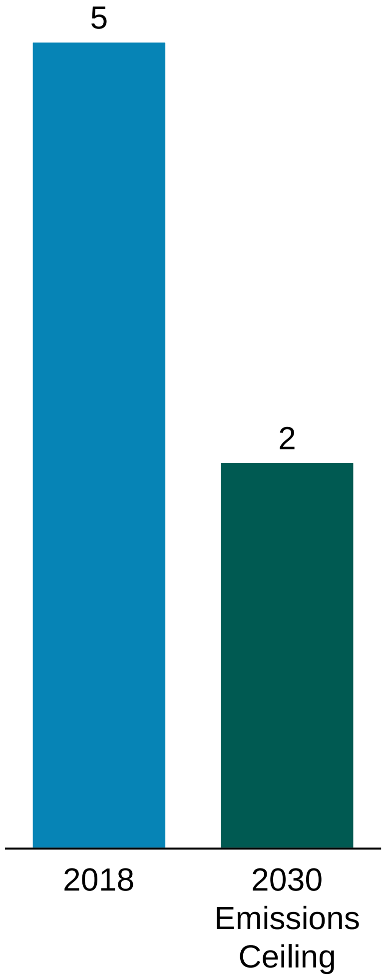
The proposed sectoral emissions reduction pathway for **LULUCF could result in a ~50% reduction by 2030**

NOT FOR FURTHER DISTRIBUTION

CAP21 identified 8 measures to further reduce emissions through LULUCF

○ <0.5MtCO2 ◔ 0.5-1MtCO2 ◑ 1-1.5MtCO2 ◕ 1.5-2MtCO2 ● >2MtCO2

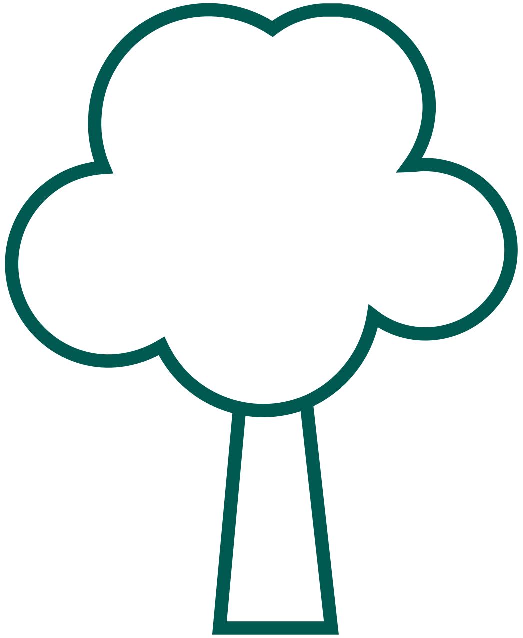
GHG emissions LULUCF, MtCO2eq, AR5 2020 methodology



Land Use (total area)[1]	**Option**	**KPI 2025**	**KPI 2030**	**Abatement impact by 2030,** MtCO2eq
Forestry	**L1 New afforestation to 2030**	**~4,700 ha/yr** planting rate	**~8,000 ha/yr** planting rate	◔
Cropland (0.78m ha)	**L2 Increase use of cover crops**	**~29 kha** of cover crop planted	**~50 kha** of cover crop planted	○
	L3 Incorporate excess straw into tillage	**5%** of cereal area to incorporate straw directly into soil	**15%** of cereal area to incorporate straw directly into soil	○
Grassland (4.15m ha)	**L4 Increase mineral grassland carbon sequestration**	**~263 kha** grassland managed better to improve sequestration	**~450 kha** grassland managed better to improve sequestration	○
	L5 Manage organic grasslands better (farmed peatlands)	**~23 kha** organic grassland soils rewetted	**~80 kha** organic grassland soils rewetted	○
Peatlands/ Wetlands (1.22m ha)	**L6 Bord na Mona and LIFE Peatlands rehabilitation**	**…**	**~ 35,900kha** peatland rewetted	○
	L7 Additional wetlands rehabilitation	**...**	**~ 41,700kha** wetland rewetted	○
Total			Σ	**~2.5**
Not included in emission ceiling	**L8 Accounting for afforestation of removals realised post 2030**			●

1. Areas based on 2018 land use. Total area = 7.11m ha (settlement/other = 0.18m ha, abatement from these land uses do not get

Our understanding of LULUCF will continue to evolve



Our understanding of LULUCF will continue to evolve, based on:

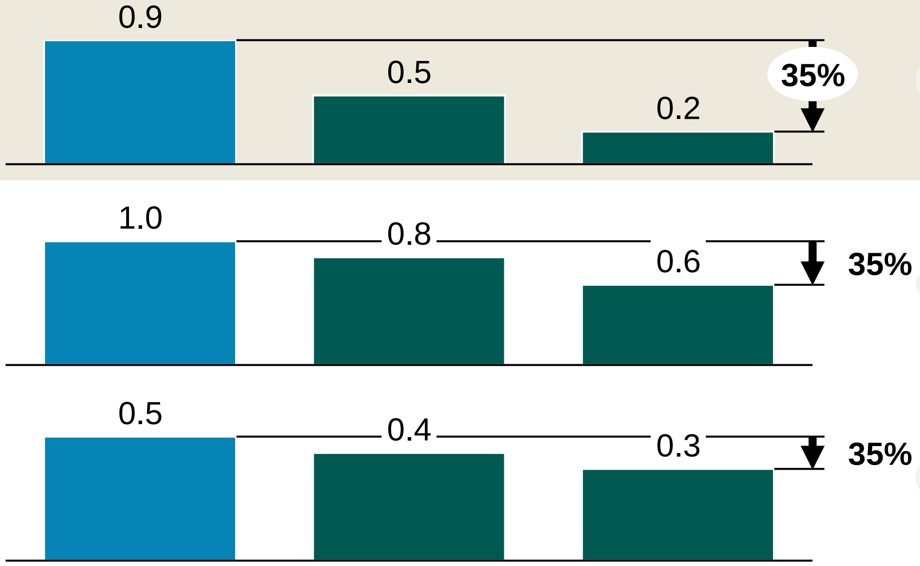
- **Updated National Inventory Report and projections** which may revise the LULUCF baseline and outlook
- **Publication of Phase 1 Evidence Gathering of the Land Use Review** being led by the EPA. Phase 2 Land-use Strategy will build on the evidence from Phase 1, and will consider policies, measures and actions in the context of the Government’s wider economic, social and climate objectives
- Insights from CAMG on **land use change requirements to reach net zero by 2050**

The implications of these on LULUCF emissions ceilings will be considered when available. The Climate Action and Low Carbon Development Amendment Act 2021 allows for the recalculation of carbon budgets in the event of a material change in scientific understanding.

Contents

The sectoral emissions ceilings have been set for F-gases, waste management and petroleum refining

▨ Detail to follow

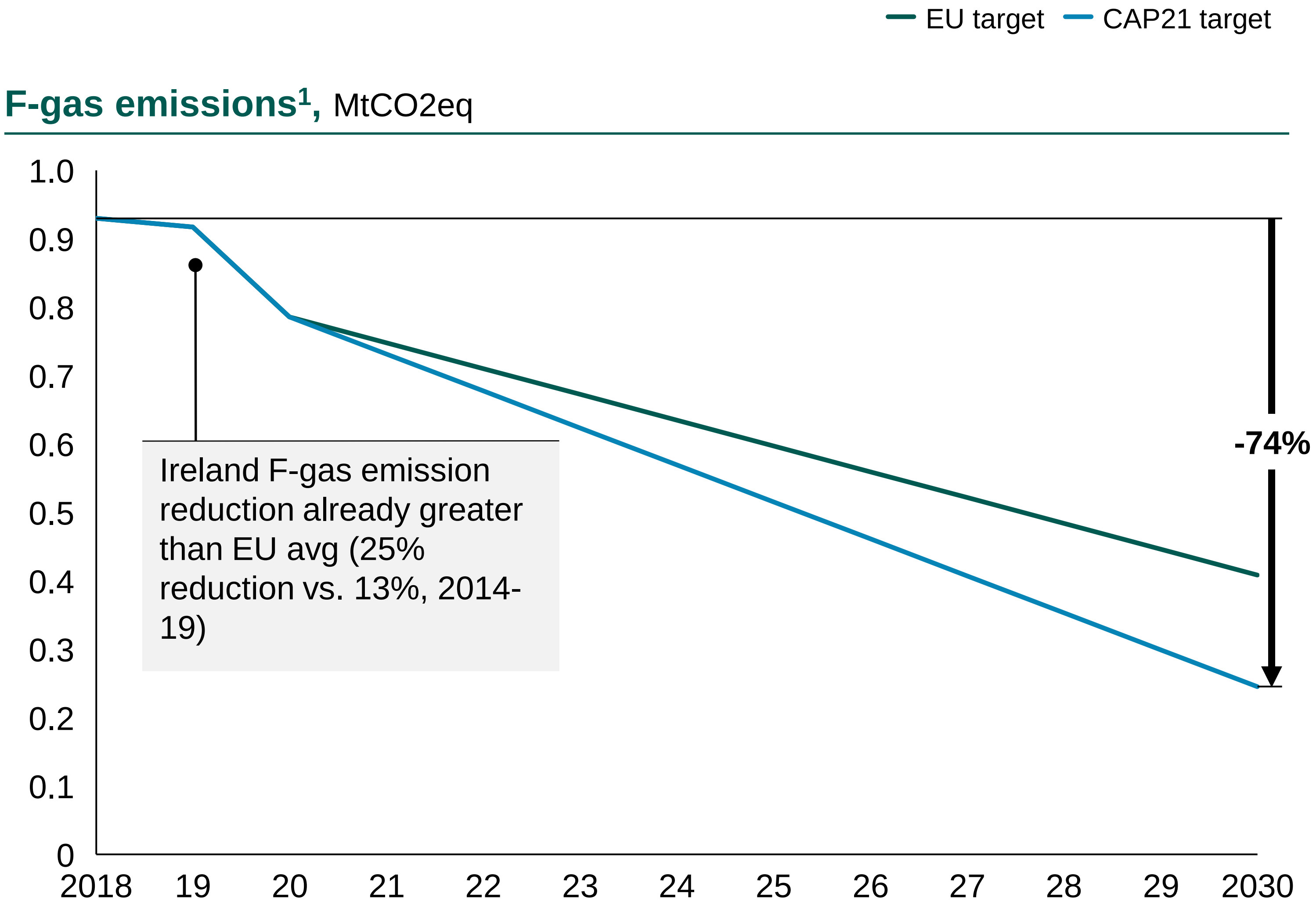


	GHG emissions[1], MtCO2eq (AR5)				% change vs. 2018		Sectoral emissions ceilings, MtCO2eq	
	2018	2025	2030		To 2025	To 2030	2021-2025	2026-2030
① **F-gases**	0.9	0.5	0.2	35%	~45	~75	3	2
② **Waste**	1.0	0.8	0.6	35%	~15	~35	4	4
③ **Petroleum refining**	0.5	0.4	0.3	35%	~15	~25	2	2

Source: Climate Action Plan 2021, Government of Ireland

1. Increasing ambition on phasing out F-gases beyond EU targets could deliver further abatement

F-gas emissions[1], MtCO2eq



Ireland F-gas emission reduction already greater than EU avg (25% reduction vs. 13%, 2014-19)

Key takeaways

EU regulation has a reduction target of 67% of F-gas emissions by 2030 vs 2014

CAP21 sets a higher ambition to commit to 80% reduction of F-gas emissions. A linear phasing down of emissions is assumed

F-gases accounted for ~1.4% of Ireland’s emissions in 2020. A ~15% decrease in 2019-20 was driven by reduction in refrigeration and air conditioning emissions, due to phasing out of F-gases with high global warming potentials (GWPs) and replacement with blend of HFCs and hydrofluoroolefins with low GWPs

1. GHG emissions based on AR5 2021 EPA methodology

Source: EPA, European Commission

1. A number of countries have already increased their ambition vs. EU targets

EU regulation increased in ambition…

F-gas emissions reduction by ~67% in 2030 vs. 2014.

Achieved by:

- 80% phasedown of HFC sales and imports in 2030 vs. 2014
- Banning use of F-gases in new types of equipment (e.g. stationary refrigeration)
- Preventing F-gas emissions through mandating better maintenance and recovery

Note, new EU F-gas regulation proposed in 2022, including more stringent HFC targets to 2050 and further equipment bans

…however countries are also going further

Spain's approach has enabled a ~65% reduction in F-gases between 2014-19. Measures used include:

- Tax scheme for highest GWP F-gases
- Permit system required to handle F-gases
- Mandatory training for technicians
- Subsidies for implementation of alternative technologies

Sweden has introduced prohibitions on the refilling of refrigerant equipment with F-gases by non-authorised persons and has strict rules and penalties regarding leakage control