Realising the carbon-negative opportunity in the Energy from Waste sector

July 2025

With concerted action now, the EfW sector can go carbon-negative

1

The Energy from Waste (EfW) fleet diverts fossil and biogenic waste from landfill to produce energy

Energy from Waste (EfW) plants are power system assets within the waste sector, which **divert residual waste from landfill and use it to produce energy**, with complex emissions impacts

- Alongside taking in fossil-based waste, **EfW plants also take in biogenic waste, which includes biogenically sequestered carbon that could be stored**
- These impacts and this potential mean that **EfW is important for the UK's net zero power sector and carbon dioxide removals targets**[1]

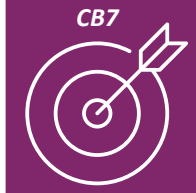
2

CCS can enable the EfW fleet to be carbon-negative in the late 2030s

Carbon Capture and Storage can enable the EfW fleet to be carbon-negative before 2040, and even by 2035 in an accelerated scenario

- **In our Base Case for EfW CCS, EfW emissions fall by more than 70% in 2035,** even net of additional emissions from replacing lost electricity output, and **the EfW fleet goes carbon-negative by 2040**
- **In our Accelerated Case, EfW fleet emission can go carbon-negative by 2035**
- **Without CCS, fossil fuel emissions from EfW will remain above 7MtCO_2**

3



With CCS, EfW can contribute significant amounts of carbon-removals

EfW CCS can contribute meaningfully to the CB7 carbon removals target, exceeding the sectoral target set for it

- **EfW CCS can permanently store millions of tonnes of biogenically captured carbon** that has ended up in residual waste streams
- At a time when the UK is not yet on track to meet its carbon budgets, nor the legally binding Net Zero 2050 target, **this contribution will be crucial**

4

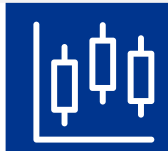
Power generation emissions[2] will be negative by 2040 only if EfW CCS is deployed

Power generation emissions[2] will be negative by 2040 only if EfW CCS is deployed, in which case they can go negative even if other decarbonisation does not accelerate

- **Without CCS, EfW emissions could be higher than the rest of power generation** by 2035
- **With EfW CCS, power generation emissions can be negative in 2040**, even on the current pathway
- **Without CCS, power generation emissions will be positive in 2040,** even if power sector decarbonisation accelerates

Notes: 1) This analysis is restricted to the GB power sector and EfW fleet, as the <1% of UK EfW capacity in Northern Ireland is part of a separate power system. 2) Power sector DAM emissions (exc EfW) + EfW emissions.
Sources: Enfinium; UK Government; Tolvik; Baringa

There are several crucial policy levers that could accelerate EfW CCS in GB, and contribute to the achievement of these decarbonisation impacts

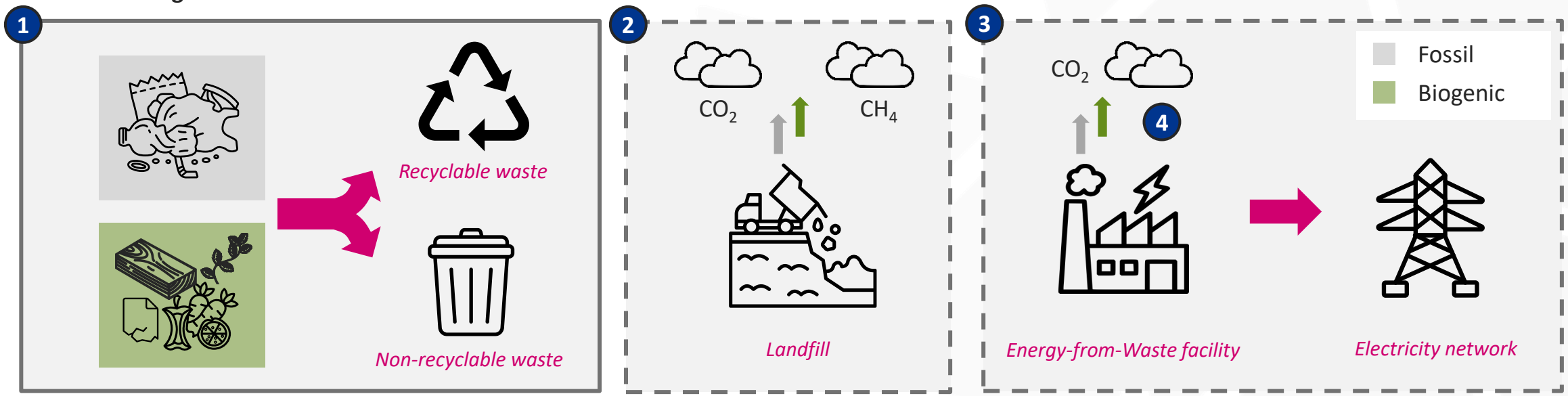
1	 **Ending biogenic waste to landfill**	The planned **near elimination of biodegradable waste in landfill** in 2028 will likely result in more biogenic waste going to EfW plants, even with an increase in waste separation, and could contribute to carbon removals if those plants are fitted with CCS.
2	 **Emissions trading scheme inclusion**	**Integration of carbon removals into the UK ETS** is planned but without a clear timeline. Early implementation would provide additional revenue for EfW CCS projects and support transition to a merchant model in the 2030s.
3	 **CCS clusters**	**The continuation of support for CCS clusters** is a necessity for EfW CCS to succeed. EfW CCS projects require clusters with which to partner, including access to a transport and storage system.
4	 **CCS allocation rounds**	If EfW CCS is to succeed, the government must **continue to expand the CCS programme** with future allocation rounds for capture support and provide early visibility for market participants to build investor confidence.
5	 **Diversity of transport options**	The government should **support access to non-pipeline transport for CO_2**, such as shipping and rail, which would be necessary for ~30% of the EfW CCS capacity identified as potentially deployable by 2040.

Sources: Enfinium; Baringa

Table of contents

EfW plants are power generation assets within the waste sector, diverting residual waste from landfill and using it to produce energy, with complex emissions impacts

Illustrative diagram



1 Non-recyclable waste contains a mixture of biogenic content including food and paper waste, and content originally derived from fossil fuels, predominantly plastic waste.
Some waste is exported, but most is dealt with in the UK.

2 Non-recyclable waste is sometimes disposed of at landfill sites. In landfill, biogenic content will decompose and release CO_2 as well as methane, a potent greenhouse gas. Whilst some of this gas is captured, landfill is still responsible for over half of UK waste sector emissions.

3 Alternatively, non-recyclable waste can be processed at Energy-from-Waste (EfW) facilities, where the waste is incinerated or gasified, producing baseload power for the electricity grid.

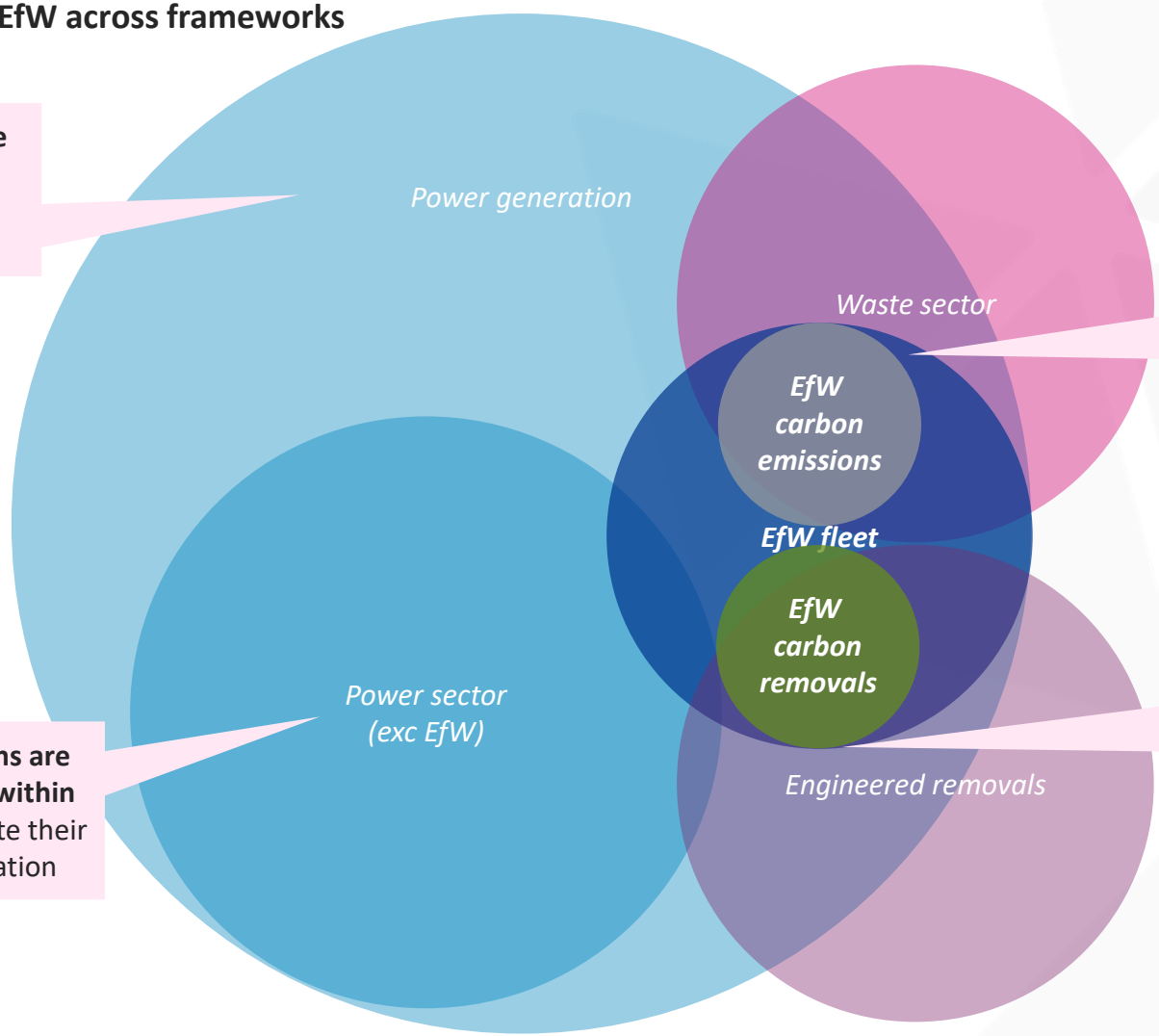
4 Energy-from-Waste facilities release CO_2. Biogenic CO_2 is considered net-zero, as carbon was sequestered during growth of the biogenic material, whilst fossil CO_2 is counted as positive emissions, like emissions from burning fossil fuels.

Source: Baringa

EfW emissions are accounted for in complex ways because the EfW fleet is part of both the waste system and the power system and with CCS, it can remove carbon

Theoretical placement of EfW across frameworks

EfW plants are part of the power system, providing reliable baseload power generation



EfW emissions are currently counted within the waste sector, where EfW is an alternative to landfill or export of unrecyclable waste

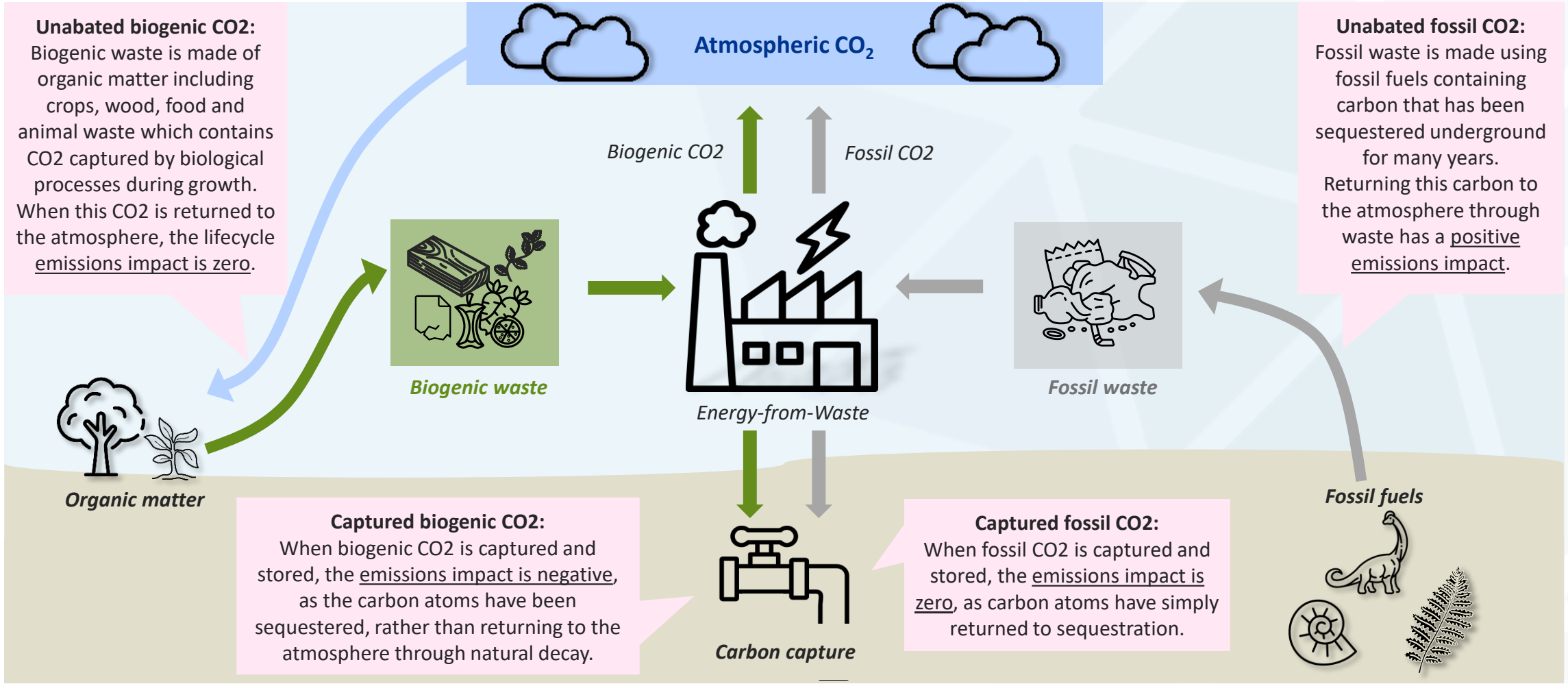
However, **EfW emissions are not currently counted within the power sector**, despite their contribution to generation

Under CB7, **EfW CCS carbon removals emissions are counted within the engineered removals sector**, along with other carbon removals technologies such as BECCS[1]

Notes: 1) Some carbon accounting includes BECCs within the power sector, including Baringa's projections of power sector carbon emissions
Source: Baringa

EfW plants take in a mix of fossil waste and biogenic waste, which means that some of their gross emissions are counted as zero due to biological carbon sequestration

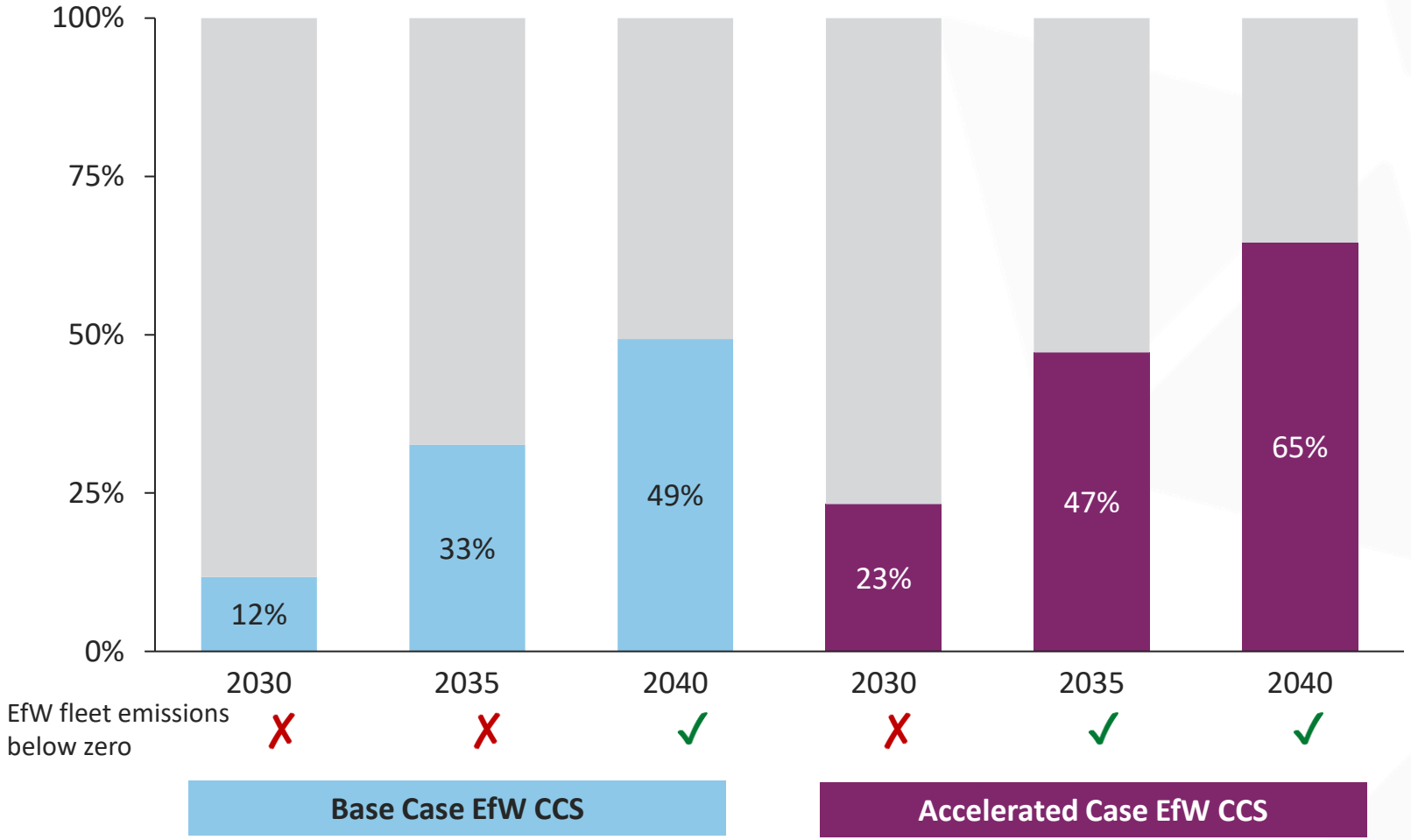
Illustrative diagram:



Source: Baringa

To achieve EfW decarbonisation, a large proportion of the fleet will need CCS, with the net zero tipping point achieved when around half the fleet has it deployed

EfW CCS deployment by scenario (% capacity)



- Our analysis shows that to achieve EfW sector decarbonisation, a significant proportion of the sector will need CCS deployment
- Our Base Case has 12% of the sector fitted with CCS by 2030, whilst the Accelerated Case has 23%
- Note that the level of CCS even in the Accelerated Case is resilient to a high ambition scenario for reducing, reusing and recycling waste – 35% of EfWs in this scenario do not have CCS in 2040

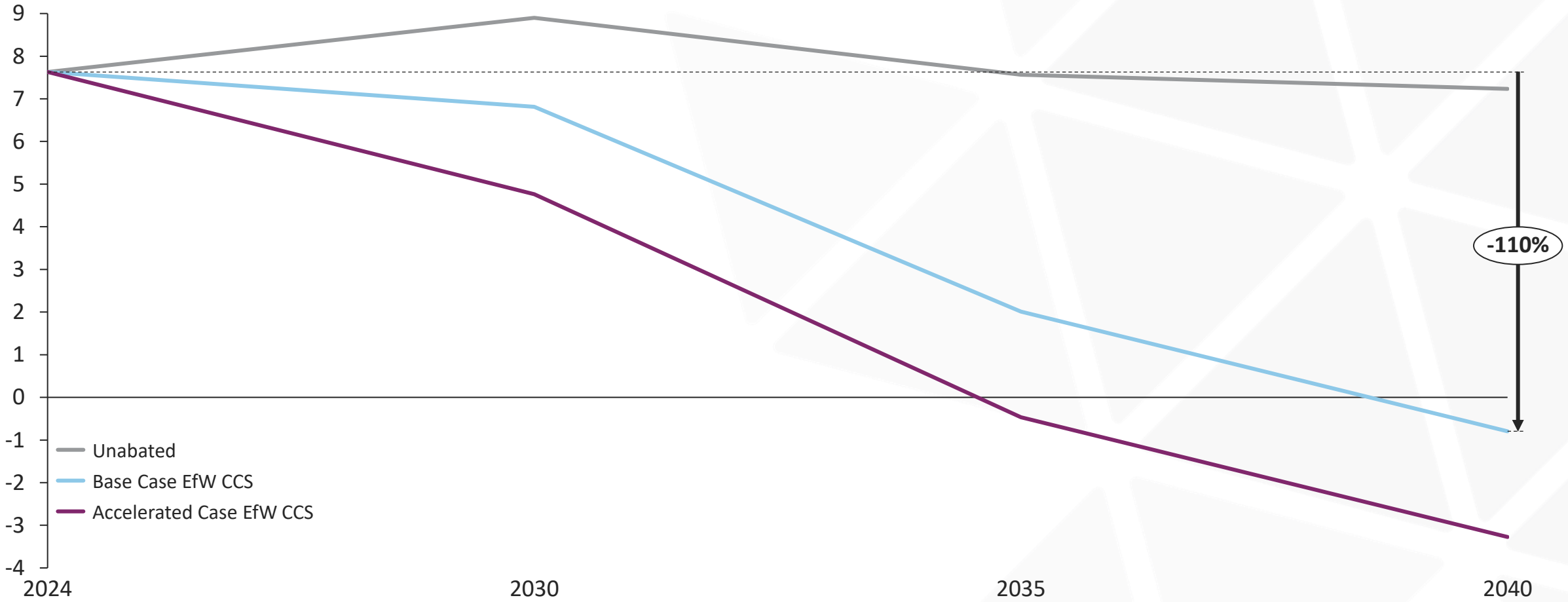
CCS deployment at this speed and scale requires significant investment by the industry and swift and clear support from government to unlock this investment

Unabated
Accelerated Case CCS
Base Case CCS

Notes: 1) 2023 emissions based on Baringa Reference Case Day Ahead Market model for purposes of comparability, not equal to actual out-turn emissions due to factors including post-DAM actions and consistent weather year in model
Sources: Tolvik; Enfinium; Baringa

CCS can enable the EfW fleet to be carbon-negative before 2040, and even by 2035 in an accelerated scenario

EfW fleet emissions under CCS deployment scenarios

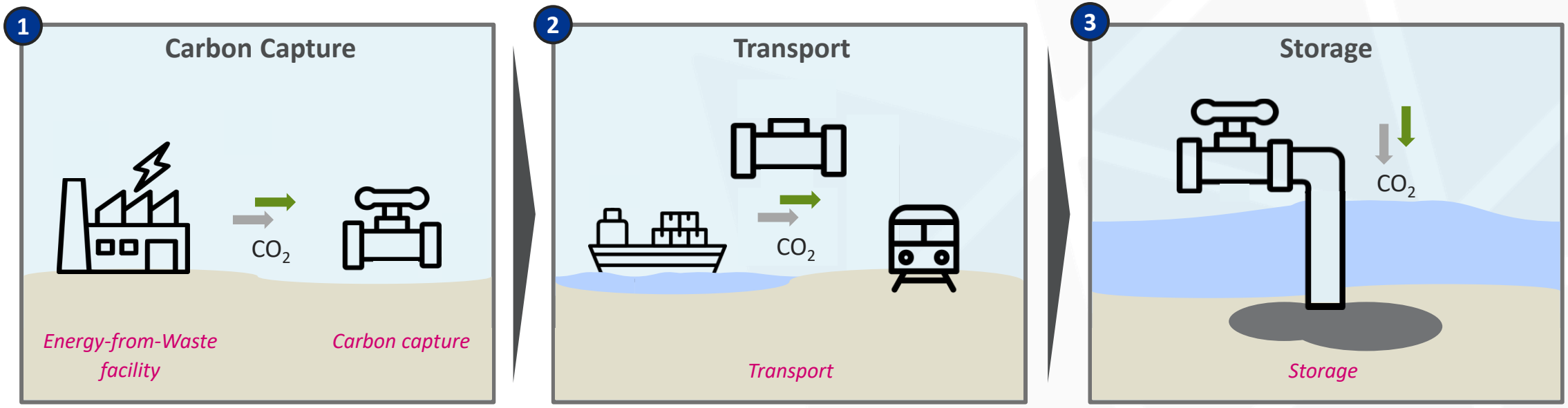


Sources: Tolvik; Enfinium; Baringa

Table of contents

CCS can decarbonise EfW plants by capturing, transporting and storing their emissions

Illustrative diagram:



- Post-combustion capture is employed to separate CO2 from flue gases
- Typically, around 90% of CO2 emissions are captured
- Energy use in the carbon capture process can reduce EfW power output significantly

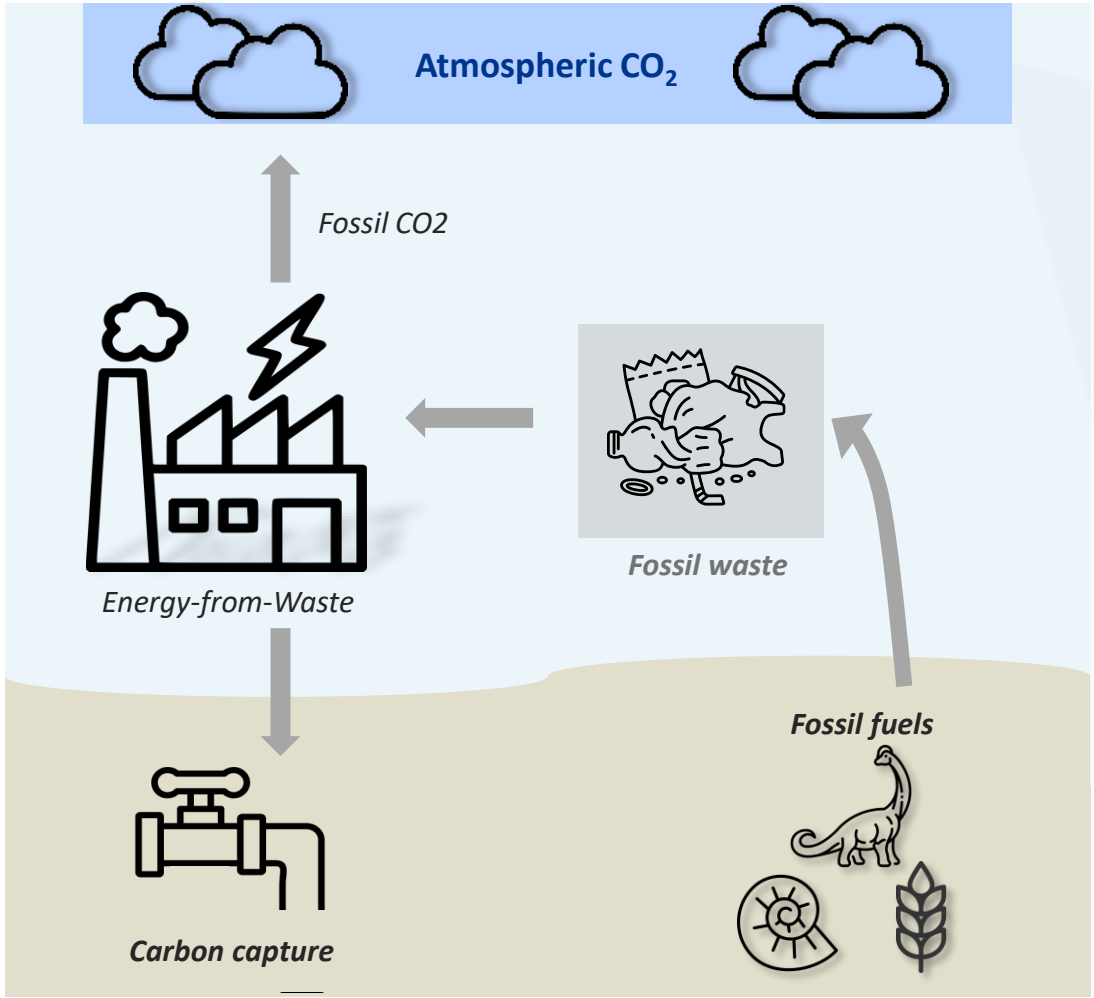
- Once captured, CO2 is compressed for transportation
- EfW sites near CCS clusters can connect to planned CO2 pipeline networks for storage
- EfW sites near rail or shipping infrastructure can use non-pipeline transport

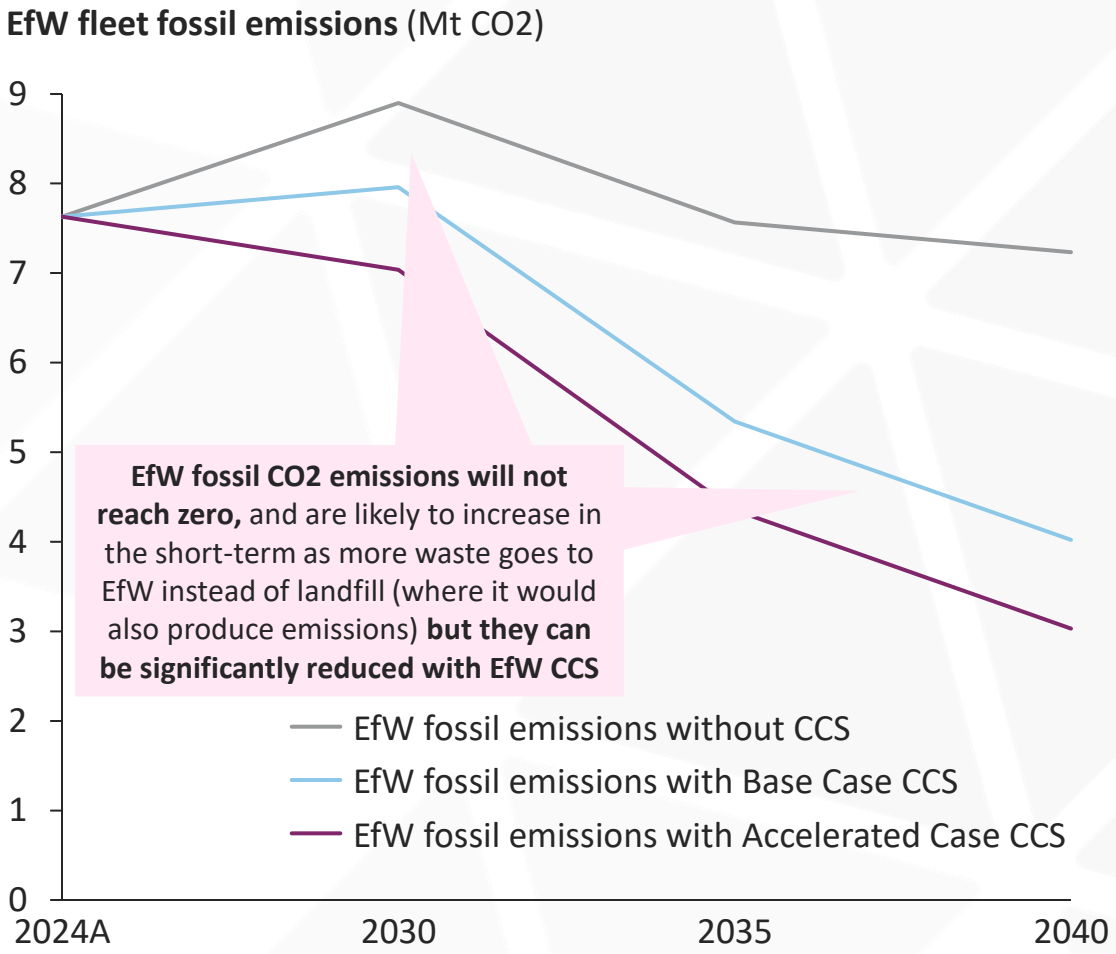
- CO2 is permanently stored in saline aquifers or depleted offshore gas fields
- These sites are monitored to ensure the CO2 stays safely contained
- The UK continental shelf has a projected 78 billion tonnes of carbon storage capacity

Sources: Enfinium; DESNZ; Baringa

Without CCS, EfW fleet fossil emissions will remain above 7MtCO2/yr, with increases in the short term, but with CCS these emissions can fall significantly

EfW fleet fossil emissions diagram and emissions trajectories:

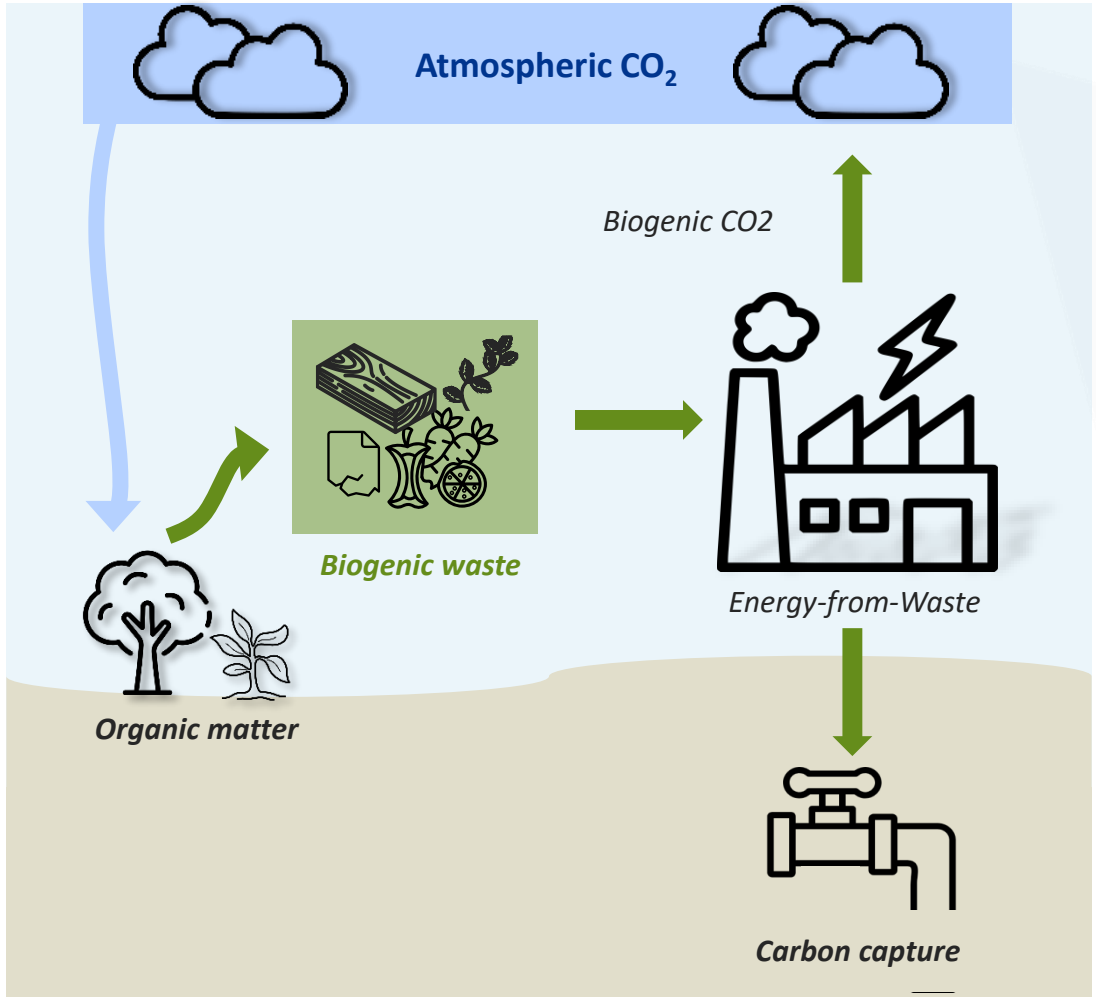


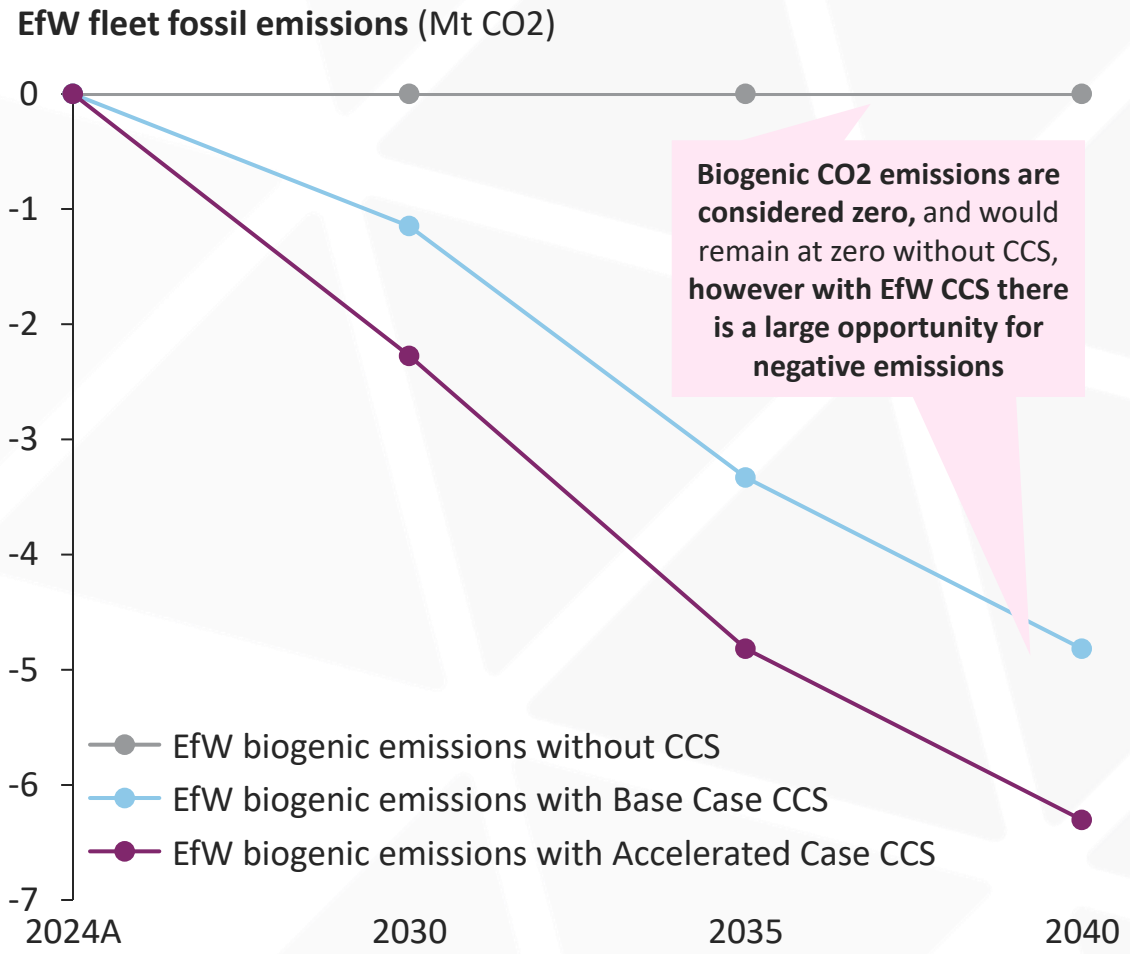


Sources: Tolvik; Enfinium; Baringa

And with CCS, EfW can permanently store millions of tonnes of biogenically captured carbon that has ended up in residual waste streams

EfW fleet biogenic emissions diagram and emissions trajectories:



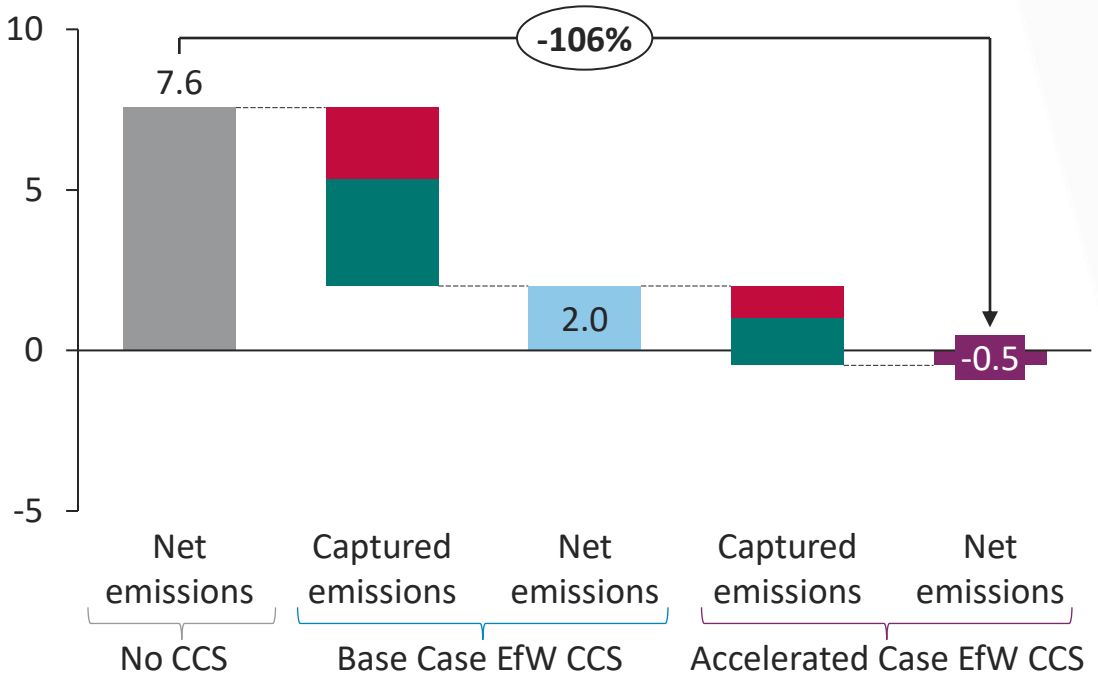


Sources: Tolvik; Enfinium; Baringa

The net result is that capturing emissions from EfW with CCS can deliver a carbon-negative EfW fleet by 2040, or by 2035 if deployment is accelerated

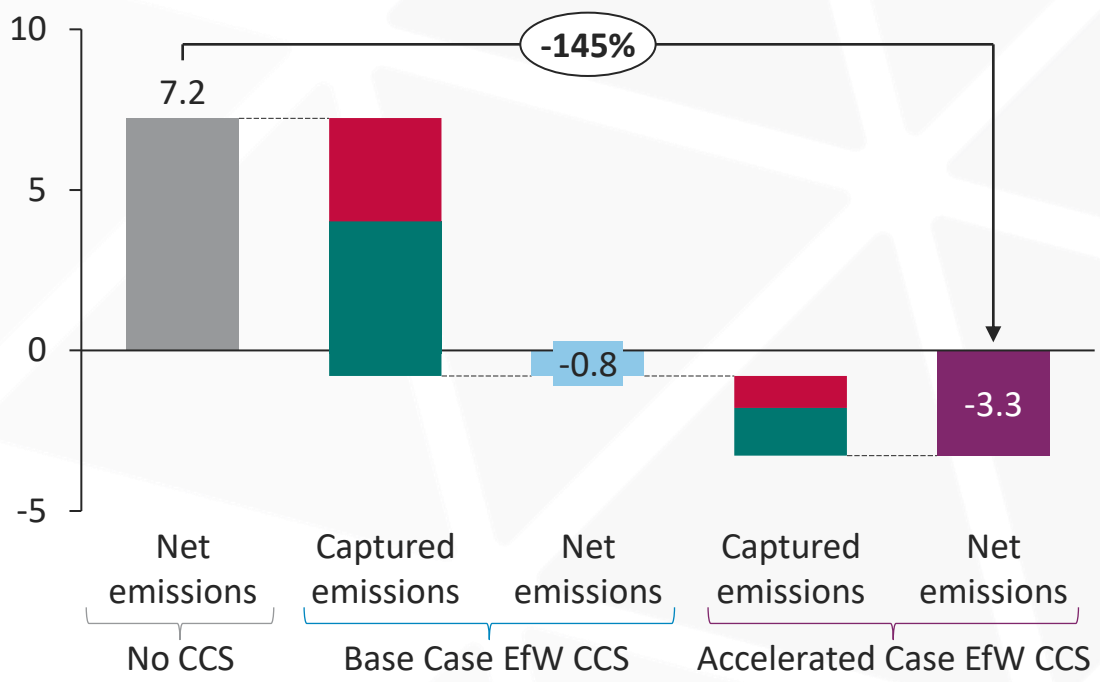
By 2035, CCS can reduce EfW emissions by 5.5 Mt (73%) in the Base Case scenario and 8.0 Mt (106%) in the Accelerated Case scenario

EfW fleet emissions, 2035 (Mt)



By 2040, CCS can reduce EfW emissions by 5.5 Mt (73%) in the Base Case scenario and 10.5 Mt (145%) in the Accelerated Case scenario

EfW fleet emissions, 2040 (Mt)



Sources: Tolvik; Enfinium; Baringa

Table of contents

The CCC's seventh carbon budget (CB7) extends its target-setting to the early 2040s, but the UK is not on track to reach it or the legally binding net zero 2050 target

Under the 2019 amendment to the Climate Change Act, the UK must hit Net Zero by 2050

UK legally binding climate change legislation

Climate Change Act 2008

2008 CHAPTER 27

PART 1

CARBON TARGET AND BUDGETING

The target for 2050

1 The target for 2050

(1) It is the duty of the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least [F1100%] lower than the 1990 baseline.

(2) "The 1990 baseline" means the aggregate amount of—

(a) net UK emissions of carbon dioxide for that year, and

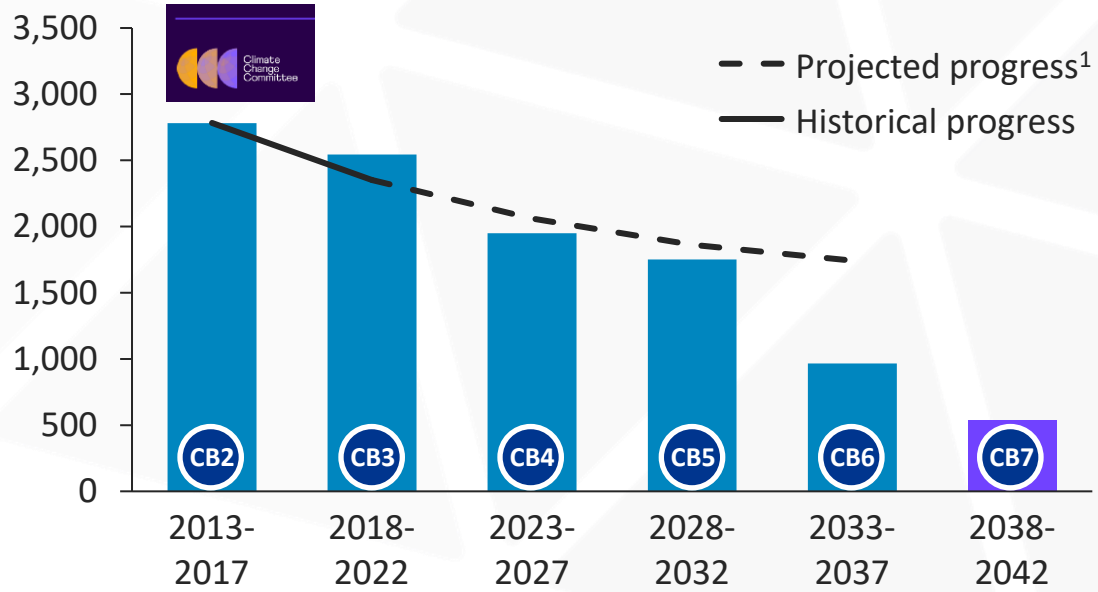
(b) net UK emissions of each of the other targeted greenhouse gases for the year that is the base year for that gas.

Textual Amendments

F1 Word in s. 1(1) substituted (27.6.2019) by The Climate Change Act 2008 (2050 Target Amendment) Order 2019 (S.I. 2019/1056), arts. 1, 2

CCC carbon budgets lay out recommendations to get there, with the new CB7 covering 2040 - but the UK is not on track to meet it

UK progress against carbon budgets (Mt CO2e)



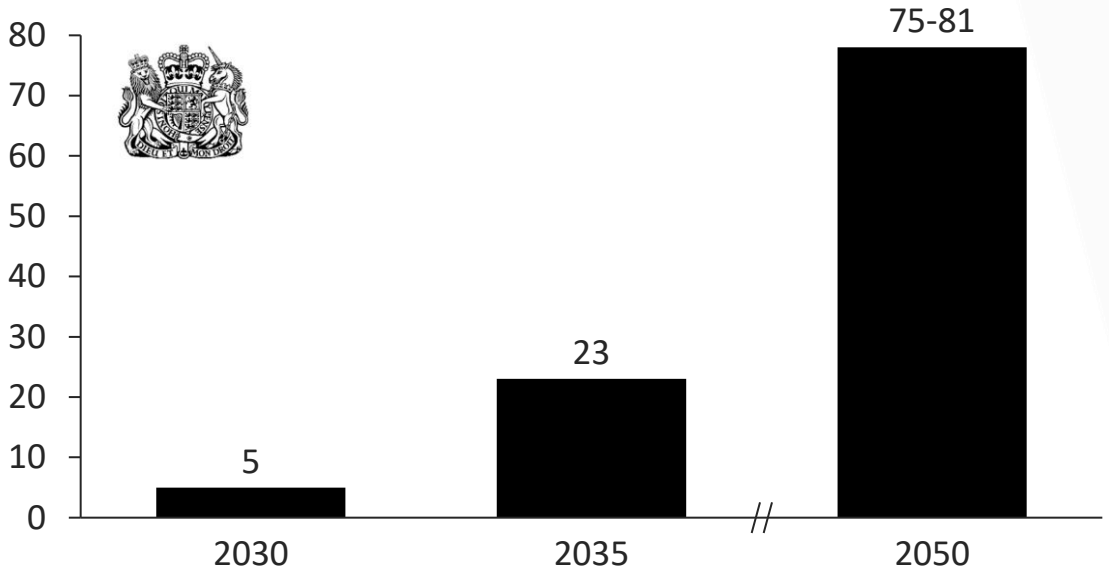
- The Climate Change Committee (CCC) regularly reports to the Government, providing recommendations on overall carbon budgets and how to achieve them
- The UK has achieved recent carbon budgets, but is not on track to achieve the next three according to government projections
- The CCC recommendation for Carbon Budget 7 is that by 2038-2042, the UK should reduce its emissions by 87% compared to 1990 levels

Notes: 1) DESNZ – Energy and emissions projections: 2023 to 2050 (Reference)
Sources: DESNZ, CCC, legislation.gov.uk

The UK has ambitious targets for carbon removals and the CB7's Balanced Pathway requires carbon removals of 4MtCO2e per annum from EfW CCS by 2040

The UK has large ambitions for 'engineered' greenhouse gas removals

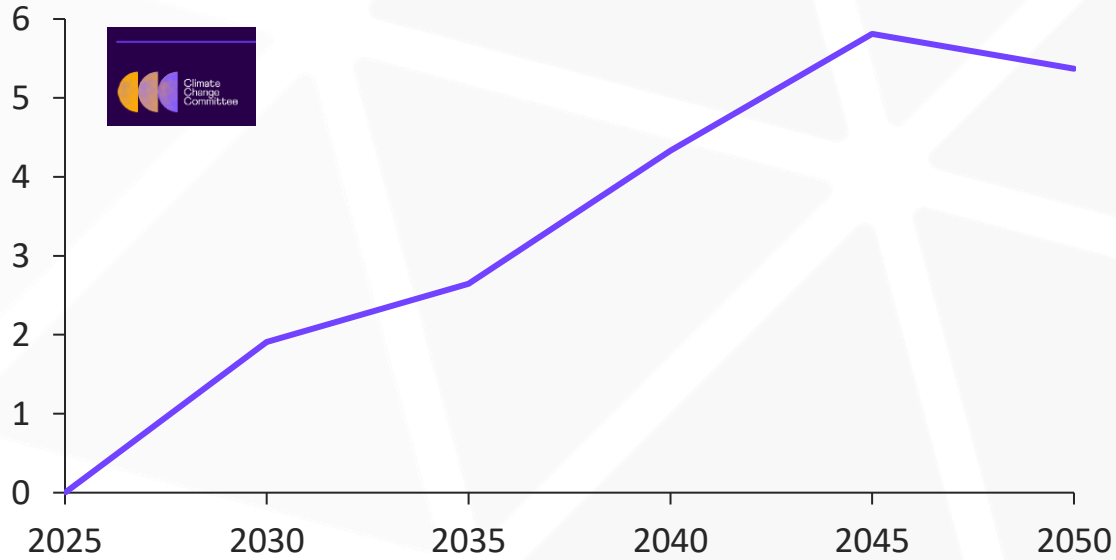
UK Government GHG Removal ambitions ($MtCO_2$)



- The UK Government set out GHG removal ambitions in its 2021 Net Zero Strategy, in line with the CCC's 2021 progress report
- Engineered removals refer to technologies that capture greenhouse gases from the atmosphere and store them permanently

And CB7 envisages a large amount of these removals coming from EfW CCS

EfW sub-sector removals, CB7 Balanced Pathway (Mt CO2e)

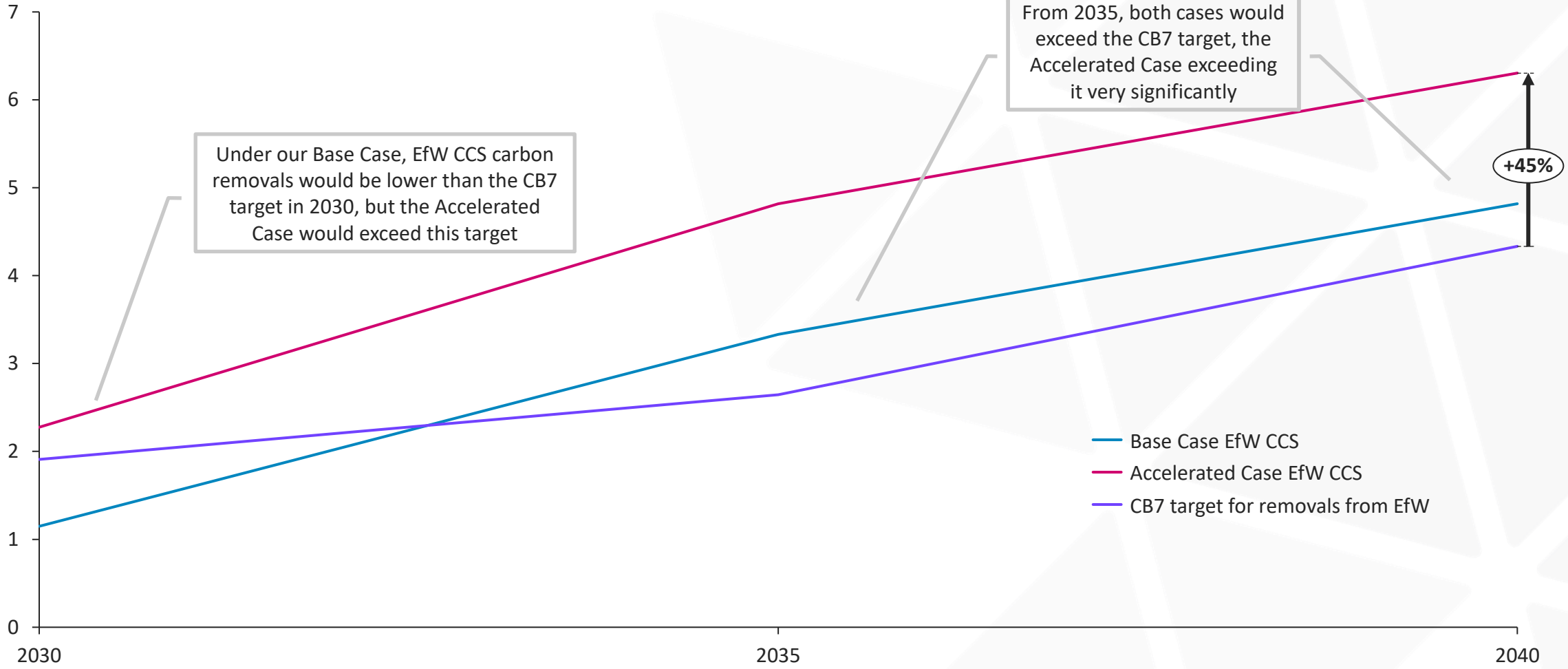


- EfW with CCS can contribute to removals by capturing and storing biogenic CO2 from the biogenic share of waste
- This technology can make a significant contribution to the government's GHG removal ambitions

Sources: UK Government, CCC

CCS can enable EfW to contribute meaningfully to the CB7 carbon removals target, exceeding the sectoral target set for EfW

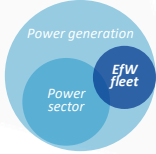
Carbon dioxide removals from EfW CCS
(MtCO2 per annum)



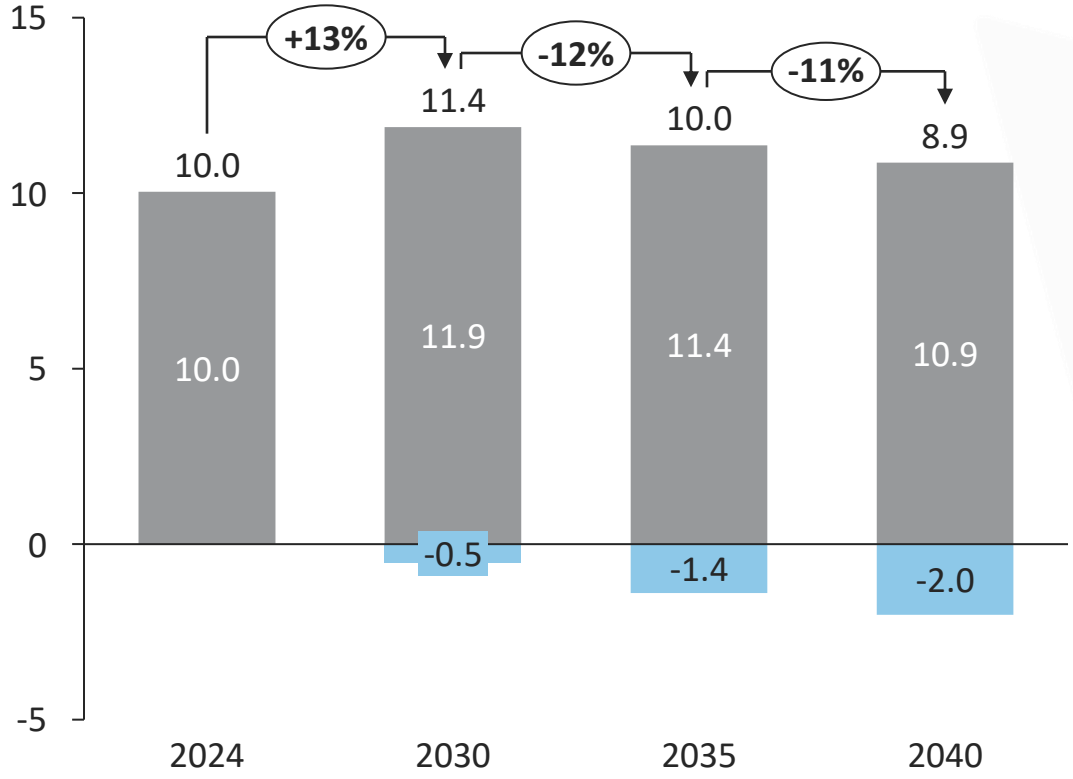
Note: we did not assess cost effectiveness in this study, but EfW CCS is expected to be relatively low cost compared with other decarbonisation options to reach CB7
Sources: Tolvik; Enfinium; Baringa; CCC

Table of contents

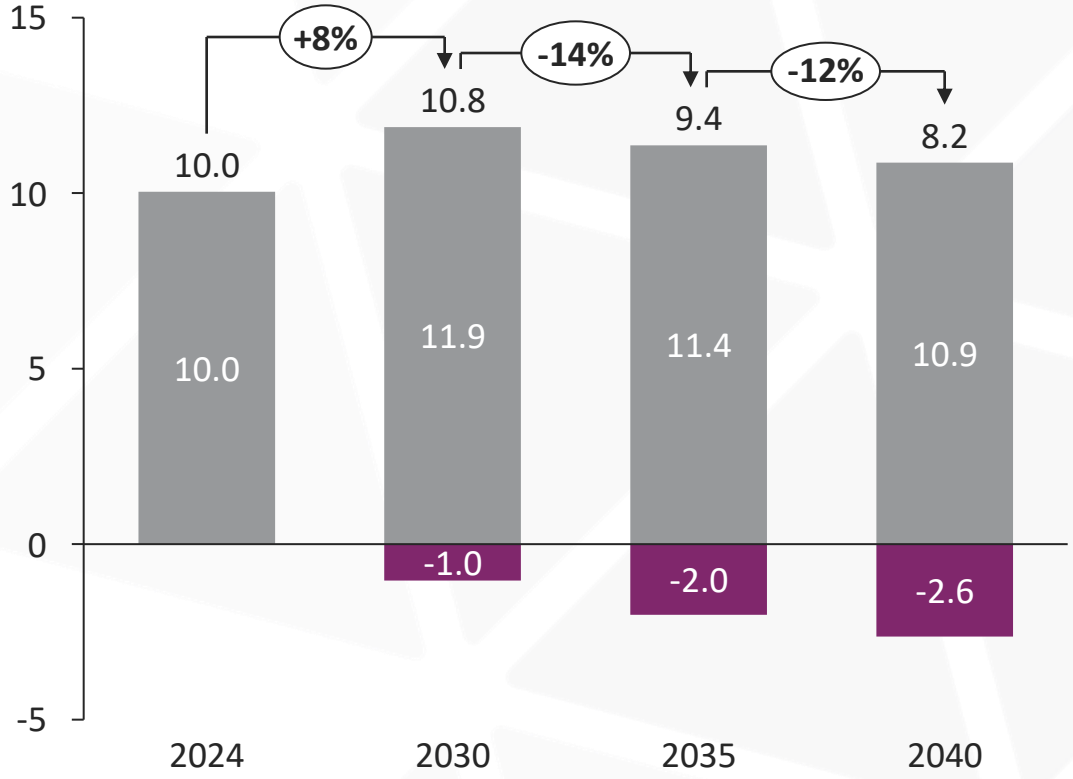
CCS requires energy, and will reduce net electricity output from EfW plants, meaning that other forms of generation will need to replace up to 3 TWh of output



EfW fleet electricity exports, Base Case CCS (TWh)



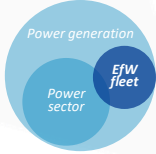
EfW fleet electricity exports, Accelerated Case CCS (TWh)



Pre-CCS electricity output | CCS parasitic load (Base Case EfW CCS) | CCS parasitic load (Accelerated Case EfW CCS)

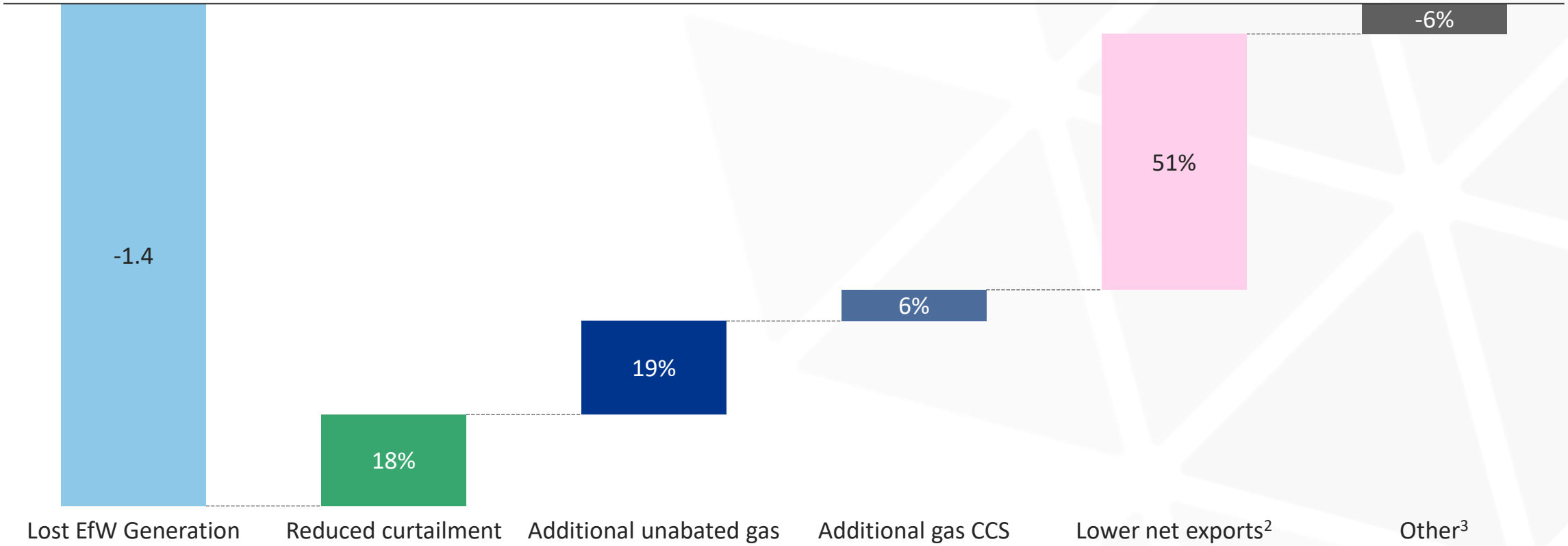
Sources: Tolvik; Enfinium; Baringa

Baringa



However, most of the replacement power is projected to come from reducing net exports of electricity via interconnectors, not burning more fossil fuels

Replacement of lost EfW generation due to CCS, Reference Case[1] with Base Case CCS, 2035 (TWh, %)

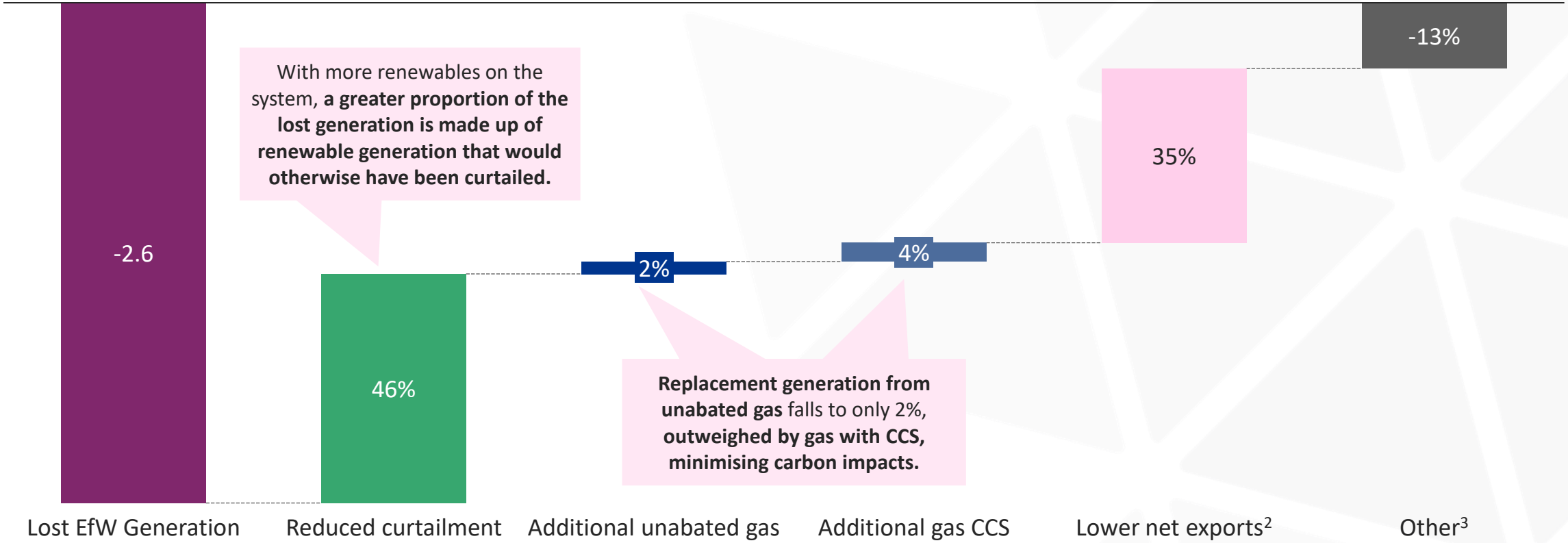


Notes: 1) Baringa Reference Case Q2 2024. 2) Interconnector exports and imports will be from a mix of sources. 3) Other includes changes in demand from storage, heat-pumps, electric vehicles and hydrogen electrolysis.
Source: Tolvik; Enfinium; Baringa

Baringa

And with greater decarbonisation an increasing portion of the replacement generation comes from reducing curtailment of renewables.

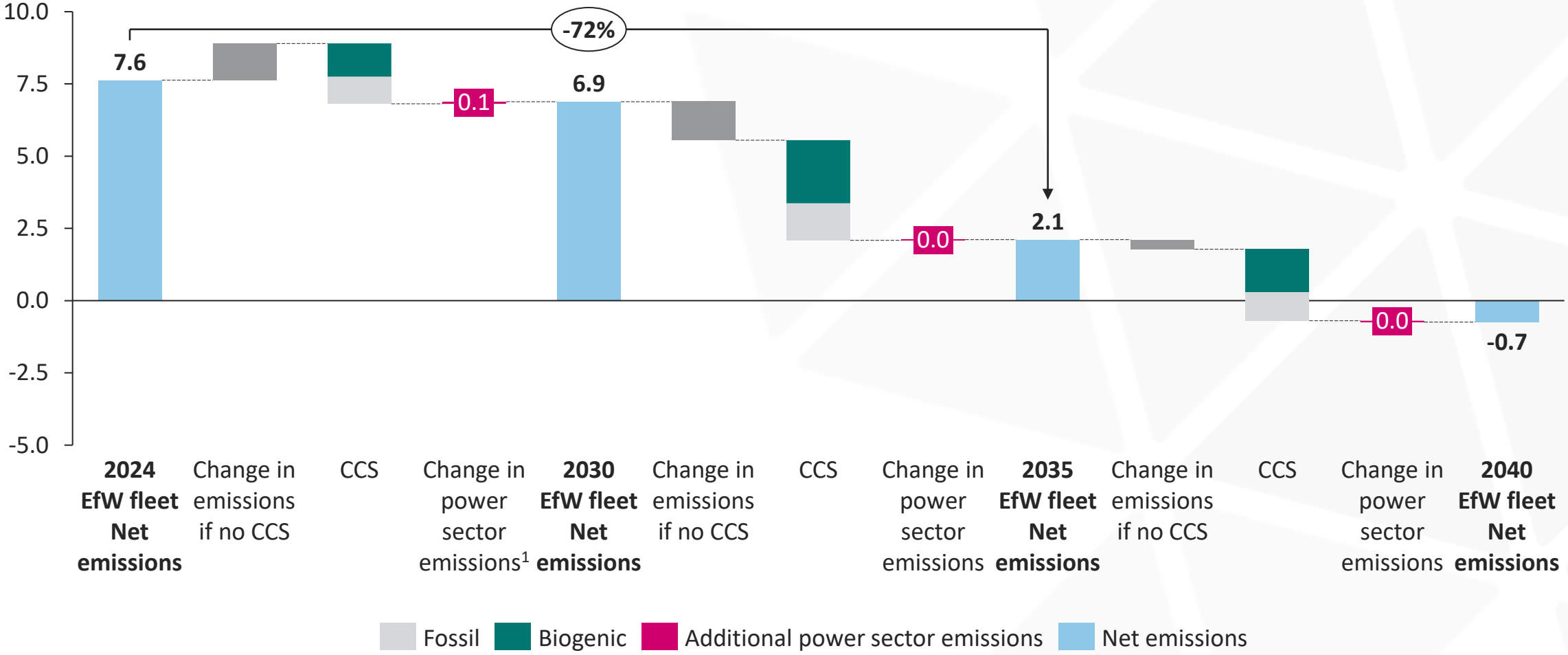
Replacement of lost EfW generation due to CCS, Accelerated Net Zero[1] with Accelerated Case CCS, 2040 (TWh, %)



Notes: 1) Baringa Accelerated Net Zero scenario Q2 2024. 2) Interconnector exports and imports will be from a mix of sources. 3) Other includes changes in demand from storage, heat-pumps, electric vehicles and hydrogen electrolysis.
Source: Tolvik; Enfinium; Baringa

Even net of additional emissions from replacing lost electricity output, the Base Case cuts EfW emissions by more than 70% in 2035 and is carbon-negative by 2040

EfW fleet emissions net of change in other power generation emissions, Reference Case and Base Case CCS (MtCO2)

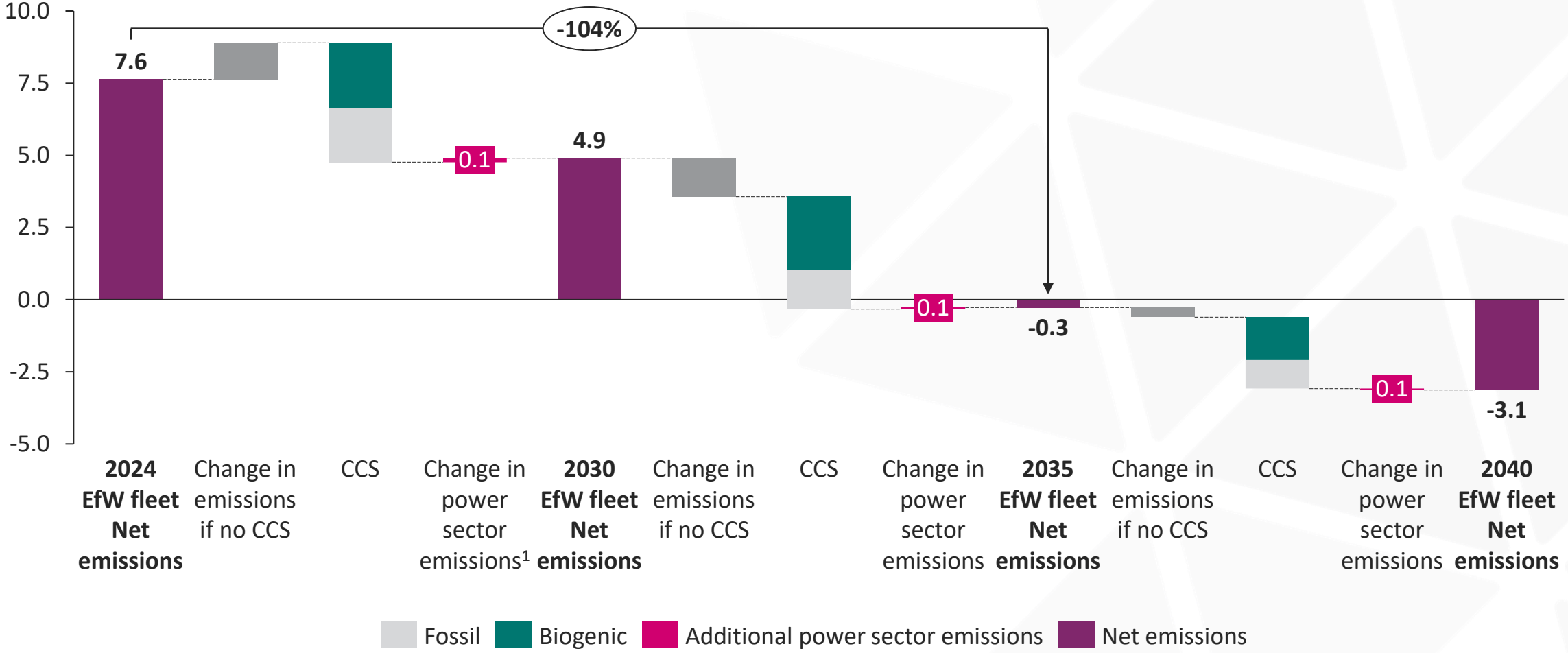


Notes: 1) Modelled using Baringa Reference Case Q2 2024 power scenario
Sources: Tolvik; Enfinium; Baringa

 |

In the Accelerated Case, EfW fleet emissions are negative from 2035, even net of emissions from replacing lost electricity output, and fall to negative 3MtCO2 by 2040

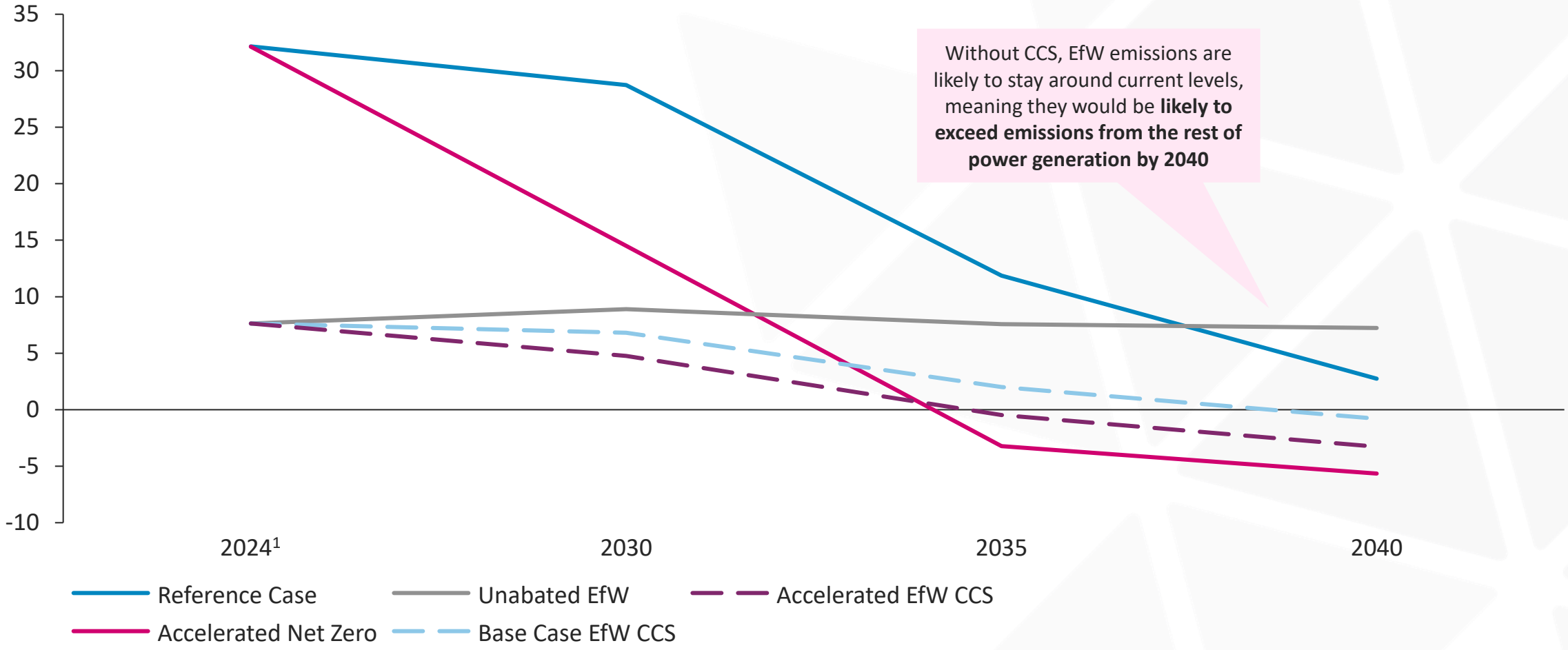
EfW fleet emissions net of change in other power generation emissions, Reference Case and Accelerated Case CCS (MtCO2)



Notes: 1) Modelled using Baringa Reference Case Q2 2024 power scenario
Sources: Tolvik; Enfinium; Baringa

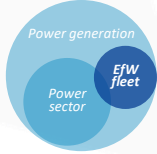
Though EfW fleet emissions are currently lower than emissions from the rest of power generation, in the absence of CCS they could be higher by 2035

Power sector emissions[1] and Energy-from-Waste fleet emissions without CCS (Mt)

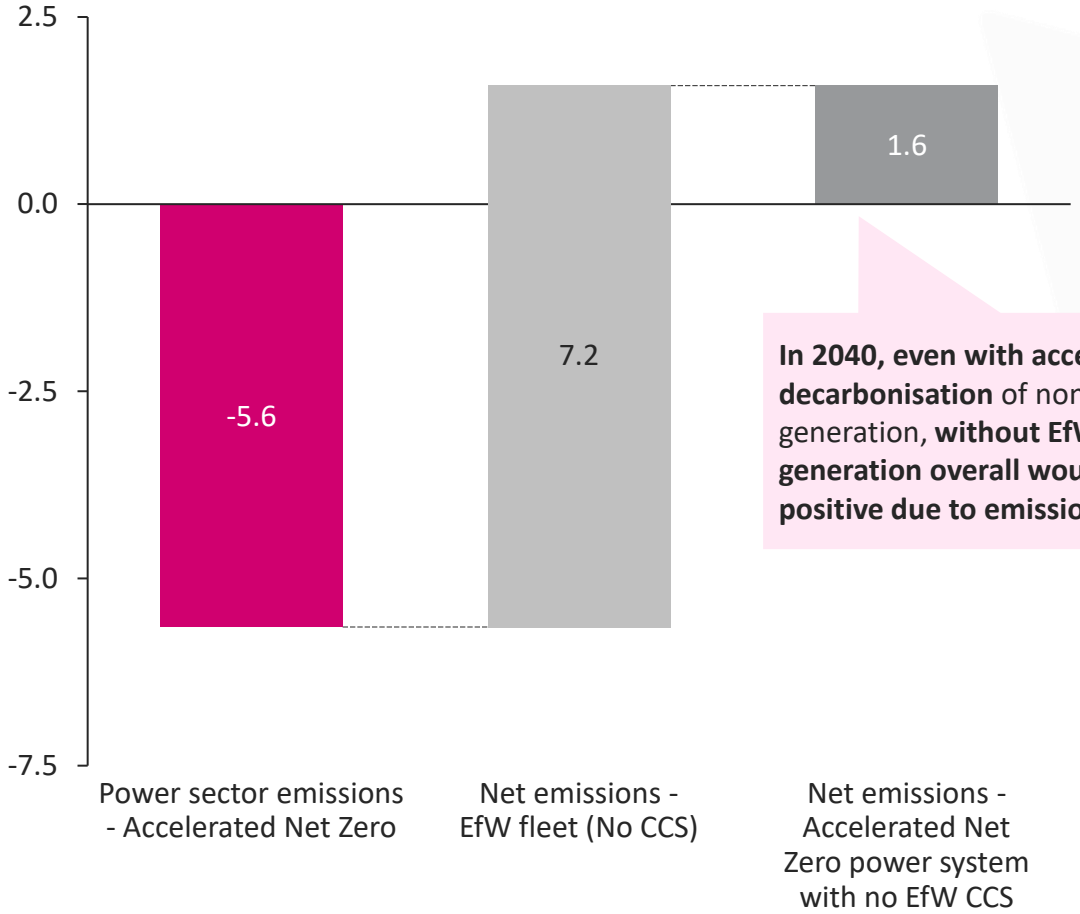


Notes: 1) 2023 emissions based on Baringa Reference Case Day Ahead Market model Q2 2024 for purposes of comparability, not equal to actual out-turn emissions due to factors including post-DAM actions and consistent weather year in model
Sources: Tolvik; Enfinium; Baringa

Power generation emissions will be negative by 2040 only if EfW CCS is deployed, and with it they can be negative even if other decarbonisation does not accelerate

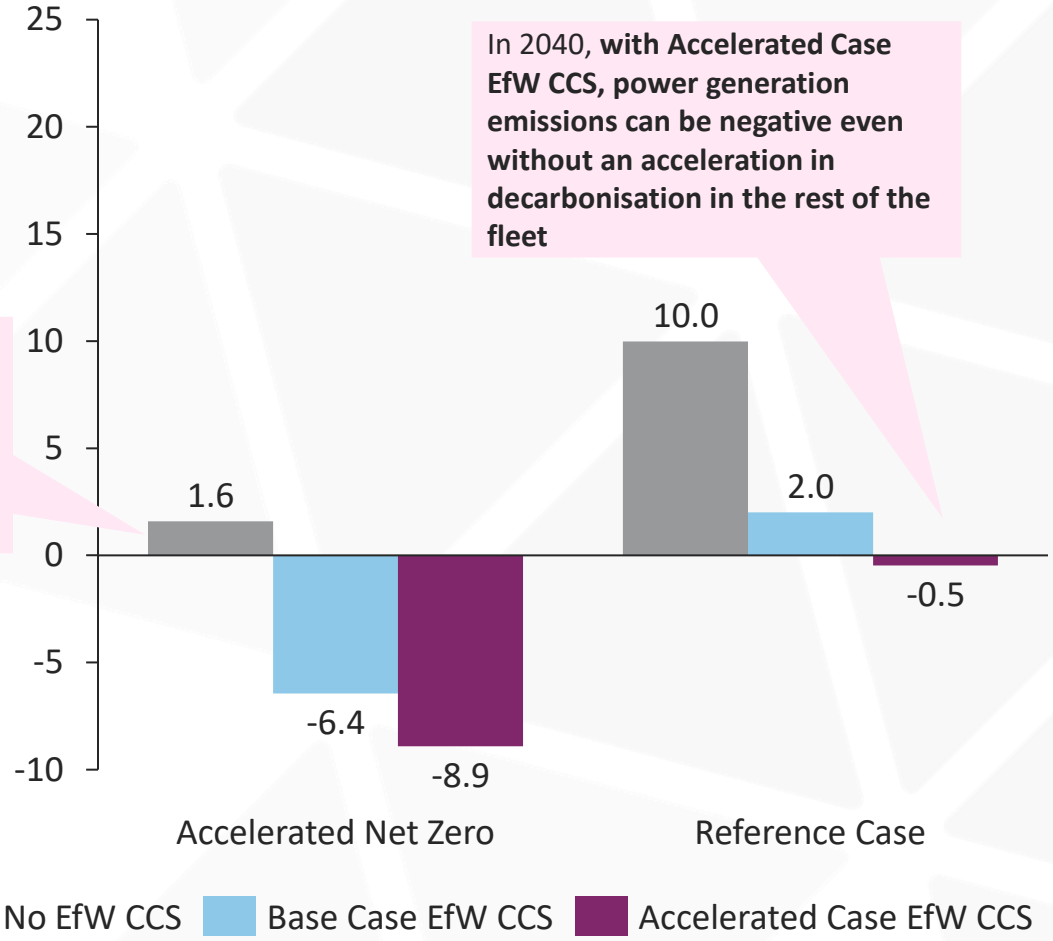


Power generation emissions, 2040 in Accelerated Net Zero scenario (MtCO2)



In 2040, even with accelerated decarbonisation of non-EfW power generation, **without EfW CCS power generation overall would still be carbon-positive due to emissions from EfW**

Power generation[1,2] emissions, 2040 (Mt)



In 2040, **with Accelerated Case EfW CCS, power generation emissions can be negative even without an acceleration in decarbonisation in the rest of the fleet**

Notes: 1) Power sector + EfW fleet 2) Modelled using Baringa Q2 2024 power scenarios
Sources: Tolvik; Enfinium; Baringa

Baringa

Table of contents

There are several crucial policy levers that could accelerate EfW CCS in GB, and contribute to the achievement of these decarbonisation impacts

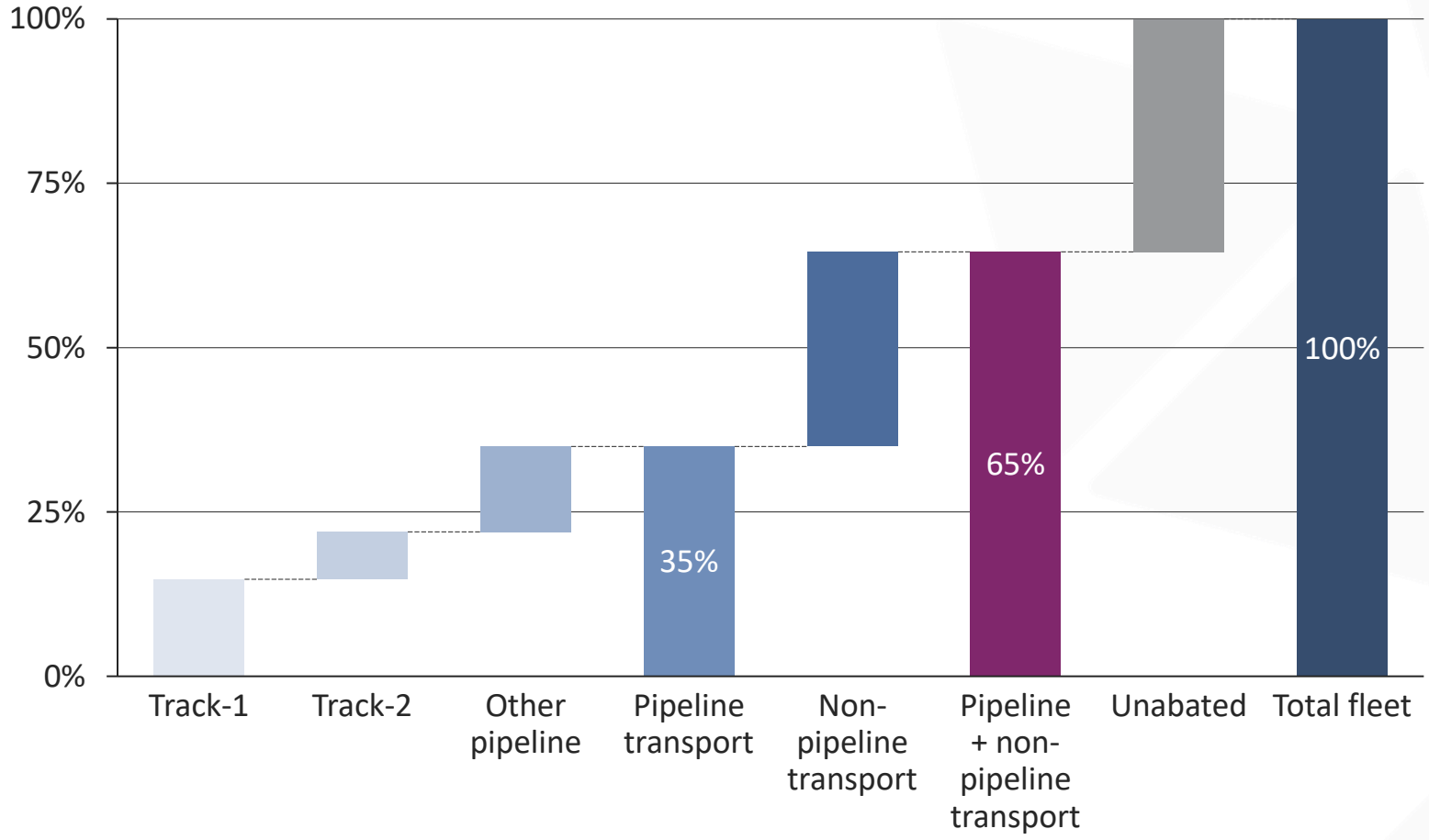
1	**Ending biogenic waste to landfill**	• Large amounts of biogenic waste continue to go to landfill, where they produce methane emissions with potent global heating impacts, 84-86× CO_2 over a 20-year timeframe. • The planned near elimination of biodegradable waste in landfill in 2028 will reduce methane emissions, and is expected to result in more biogenic waste going to EfW plants, which would deliver carbon removals with CCS
2	**Emissions trading scheme inclusion**	• EfW will be subject to the Emissions Trading Scheme (ETS) from 2028, although this alone is not likely sufficient to make CCS economic in the short-term. • Integration of carbon removals into the UK ETS is planned but without a clear timeline. Early implementation would provide additional revenue for EfW CCS projects and support transition to a merchant model in the 2030s.
3	**CCS clusters**	• The government is already supporting two CCS clusters, and the most advanced EfW CCS projects already have plans to connect to them; however, some CCS clusters have not yet secured funding. • The continuation of support for CCS clusters is a necessity for EfW CCS to succeed, as EfW CCS projects are in general unlikely to have sufficient scale in the absence of a cluster with which to partner.
4	**CCS allocation rounds**	• One EfW CCS project has already been awarded funding in the government's Industrial Carbon Capture scheme, with several others applying for funding in either Track 1 or Track 2 of the scheme. • If EfW CCS is to succeed, the government must continue to expand the scheme with future rounds and to provide early visibility for market participants.
5	**Diversity of transport options**	• Pipelines are likely to be the lowest cost and lowest-carbon[1] option for CO_2 transport, but are unlikely to be available in every case, particularly at plants located further away from CCS clusters. • The government should support access to non-pipeline transport for CO_2, such as shipping and rail, which would be necessary for ~30% of the EfW CCS capacity identified as potentially deployable by 2040.

Notes: 1) Non-pipeline transport options include trucking, rail and shipping, with trucking the most carbon-intensive; however, OIES estimate that even trucking to the nearest sequestration hub would emit <4% of captured CO_2 for all GB EfW facilities.

Sources: Enfinium; Baringa

As EfW facilities are spread around the country, getting to this point will require non-pipeline transport to enable enough plants to access carbon storage facilities

EfW CCS deployment potential by transport option (% capacity)



- To explore the impacts of EfW CCS under different scenarios of speed and scale, Enfinium provided Baringa with CCS deployment dates for individual plants across GB, along with a rationale
- In 2030, in both scenarios, only projects which have applied to participate in Track-1 or Track-2, or with potential pipeline connections, are considered
- By 2035, some projects with non-pipeline transport, which is either rail or shipping, are included in the Accelerated Case
- By 2040, projects are included in both scenarios with non-pipeline transport where there is a viable rail or shipping transport route

With only 35% of EfW capacity likely able to access pipeline transport, non-pipeline transport is necessary to enable the fleet to reach net zero

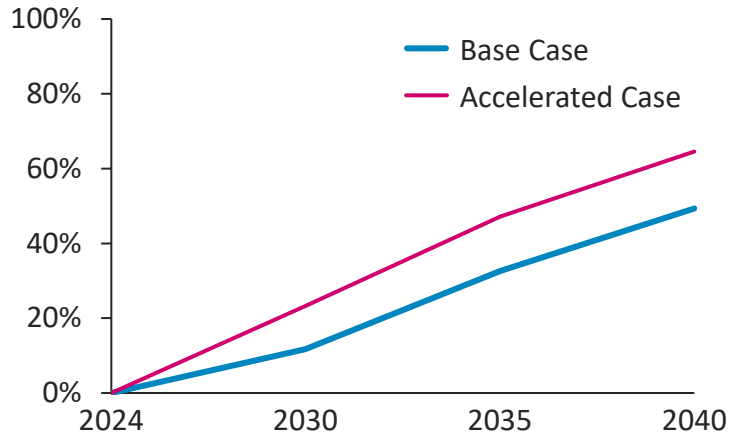
Sources: Tolvik; Enfinium; Baringa

Table of contents

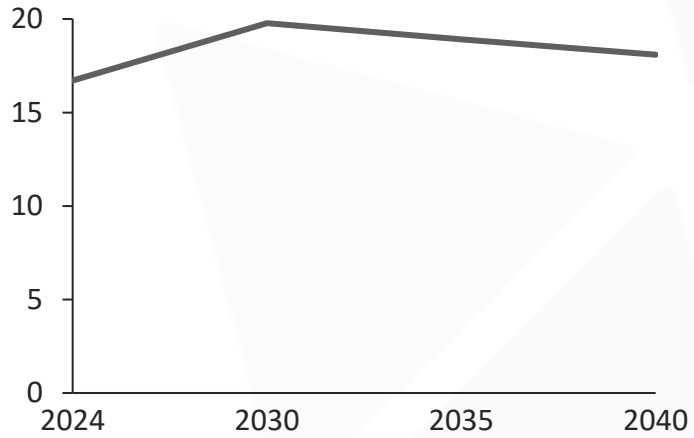
The biggest driver of change in our modelling is the rollout of CCS, but we also include expected changes in waste processed and the fossil share of waste

Assumptions:

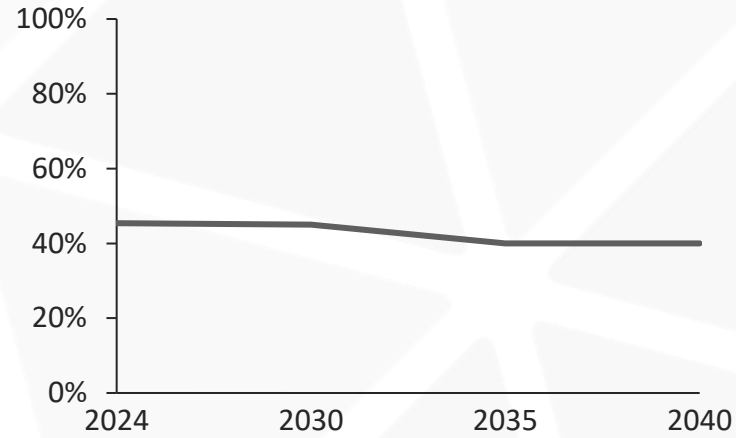
EfW fleet CCS (%)



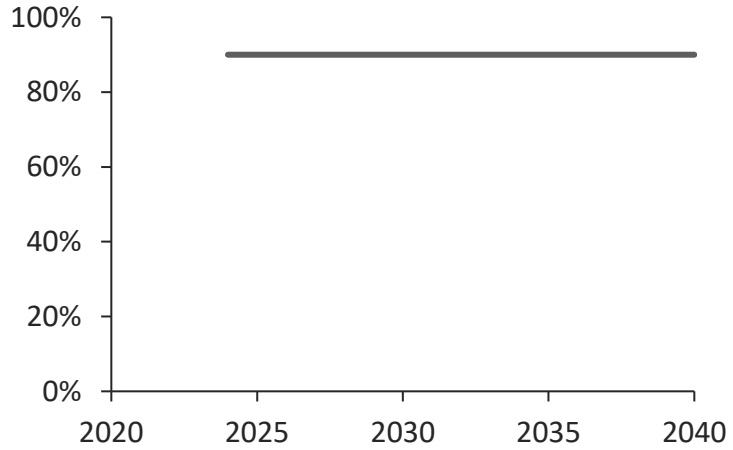
Waste processed (Mtpa)



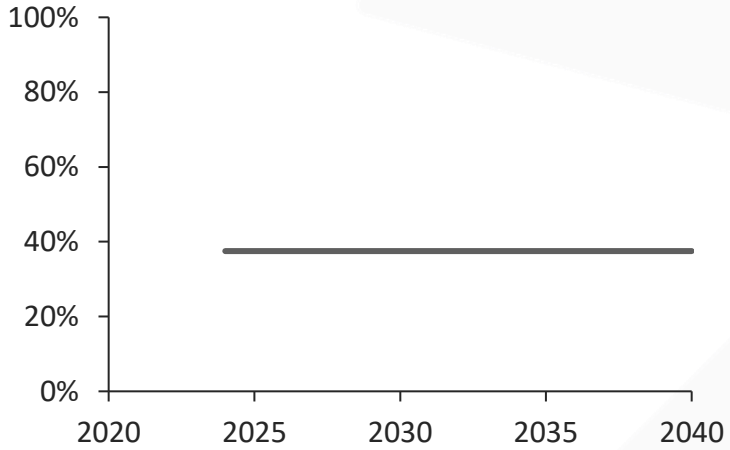
Fossil share of waste (%)



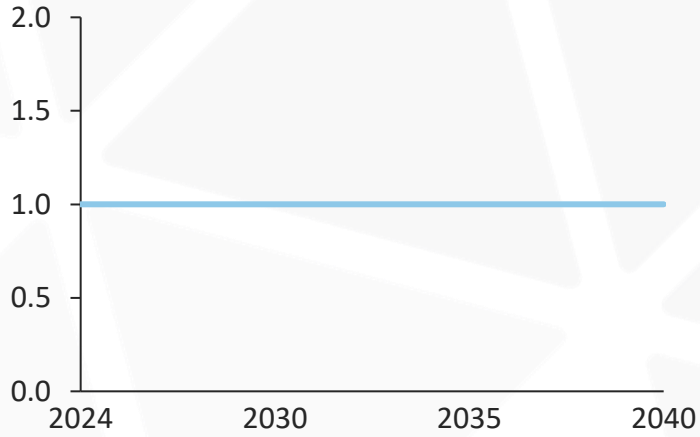
CCS emissions capture rate (%)



Parasitic load (%)



Fossil CO2 emissions factor (tCO2 / t fossil waste)[1]



Notes: 1) Same emissions factor used for negative emissions from capture of emissions from biogenic waste.
Sources: Tolvik; Enfinium; Baringa

For our analysis, we considered two scenarios for EfW CCS rollout, based on plant-level analysis of ease of CCS deployment

Rollout scenario assumptions and methodology:

Rollout scenario	Assessed ease of CCS deployment	CCS penetration assumption, by year (%)			
		2024	2030	2035	2040
Base Case EfW CCS	*****	0%	**100%**	**100%**	**100%**
	****	0%	0%	**100%**	**100%**
	***	0%	0%	**100%**	**100%**
	**	0%	0%	0%	**50%**
Accelerated Case EfW CCS	*****	0%	**100%**	**100%**	**100%**
	****	0%	**100%**	**100%**	**100%**
	***	0%	0%	**100%**	**100%**
	**	0%	0%	**50%**	**100%**

- For this analysis, two different scenarios for EfW CCS deployment were considered, based on plant-level analysis supplied by Enfinium, with rollout progressing faster and further in the Accelerated Case
- Existing plants and plants currently under construction or in commissioning were included
- Plant-level analysis took into account factors such as:
  - Status in Track-1 and Track-2
  - Affiliation to CCS clusters
  - Planning or engineering progressing
  - Potential transport solutions
  - Potential at site-level (eg sufficient space/scale)

Source: Baringa; Enfinium