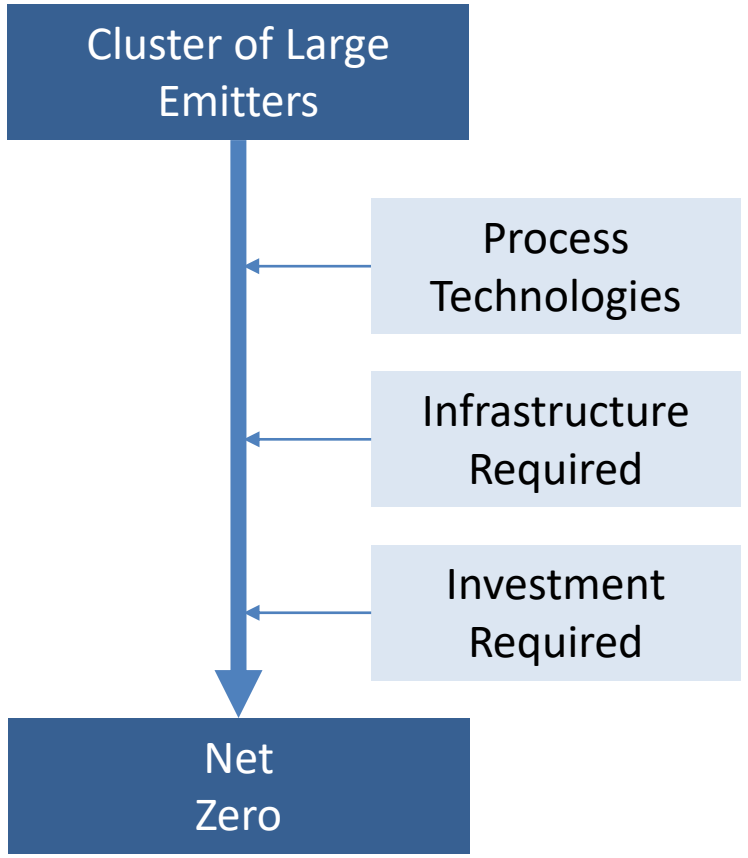
SNZR
Scottish Net Zero Roadmap

A Net Zero Roadmap for Scottish Industry

Iain Weir, Optimat Ltd

Project Objectives

- Identify a pathway for a selected cluster of large emitters to achieve net zero by 2045
  - Taking advantage of economies of scale and collective action
- Develop strategies for emitters and infrastructure that other companies can use
- Provide a route-map for emitters, infrastructure owners and government to jointly deliver a net-zero cluster



Project Partners

SNZR
Scottish Net Zero Roadmap

- **Led by NECCUS with the following partners:**

AkerSolutions, COSTAIN, ALTRAD BABCOCK, CATAPULT Energy Systems, HALLIBURTON, NECCUS, Net Zero Technology Centre Technology Driving Transition, optimat, STOREGGA, The University of Edinburgh, University of Strathclyde Glasgow, wood.

- **With significant funding provided by Innovate UK**

UKRI Innovate UK

- **Industry funding and support from the following partners:**

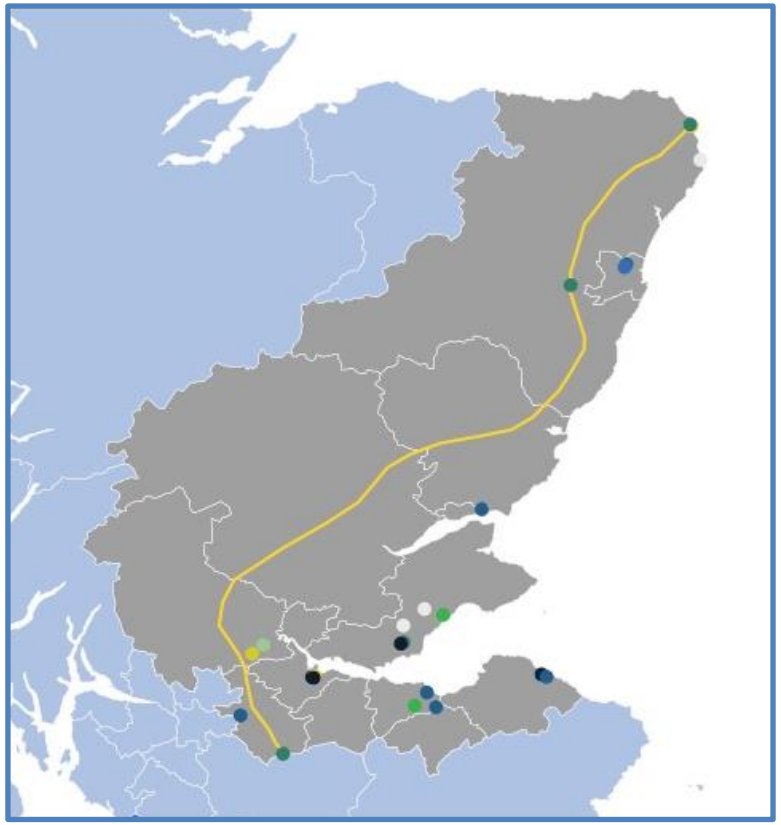
Capricorn, Harbour Energy, Crown Estate Scotland Oighreachd a' Chrùin Alba, petroineos REFINING AND TRADING, Shell, SGN, sse

Cluster Scope & Profile (2019)

Scottish Net Zero Roadmap

- Large geographical area
- High percentage of Scotland's industrial CO_2 emissions
- Multiple sectors
- Aligned with existing and/or near-term gas transport and infrastructure options

- 28 sites
- 11 industrial sectors
- 14 local authority areas
- 8.6Mt (76%) of Scotland's industrial CO_2 emissions (2019)

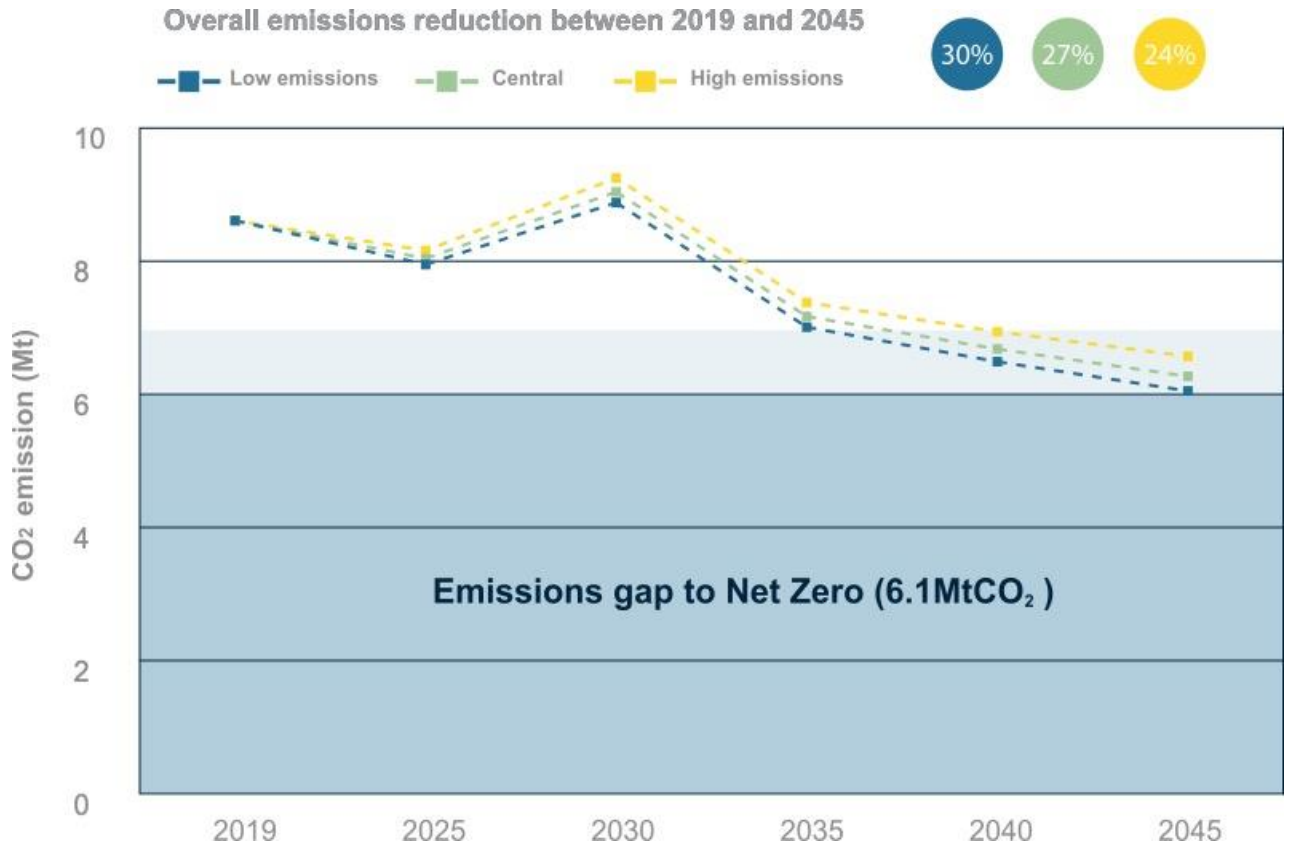


	Company / Industrial Site	2019 Emissions (kt)
1	SSE Generation Limited	1,579
2	Petroineos Manufacturing Scotland Limited	1,343
3	ExxonMobil Chemical Ltd	680
4	Grangemouth CHP Ltd	641
5	Tarmac Cement & Lime Limited	559
6	INEOS Chemicals	522
7	RWE Markinch Limited	487
8	Ineos Infrastructure (Grangemouth) Limited	429
9	Ineos FPS Limited (Kinneil Terminal)	345
10	Shell UK Limited (St Fergus)	303
11	Viridor Waste Management Ltd. Dunbar ERF Dunbar	274
12	Shell UK Limited. Fife NGL Plant Cowdenbeath	250
13	Norbord Europe Limited	210
14	O - I Manufacturing UK Ltd	149
15	FCC Waste Services (UK) Limited.	132
16	MVV Environmental (Dundee Energy Recycling)	102
17	SAGE Gas Terminal (Wood Group UK Limited)	94
18	EPR Scotland Limited	86
19	Diageo Distilling Limited	68
20	Versalis UK Limited	58
21	Arjo Wiggins Fine Papers Ltd	58
22	PX Limited (St Fergus Gas Terminal)	52
23	National Grid Gas Plc - Bathgate	41
24	The North British Distillery Company Limited	35
25	Energen Biogas Limited. Energen Biogas Ltd	29
26	Veolia Water Outsourcing Limited	27
27	National Grid Gas Plc - Aberdeen	27
28	National Grid Gas plc - Gas Terminal	26

Business As Usual

Scottish Net Zero Roadmap

- Emissions reduction by 2045 (best case): 2.6MtCO_2/yr
- Emissions gap to net zero in 2045 (best case): 6.1MtCO_2/yr
- Key changes by sector:
  - Power: -44%
  - Chemicals: -74%
  - Refining: -14%
  - Waste (Energy-from-Waste): +138%



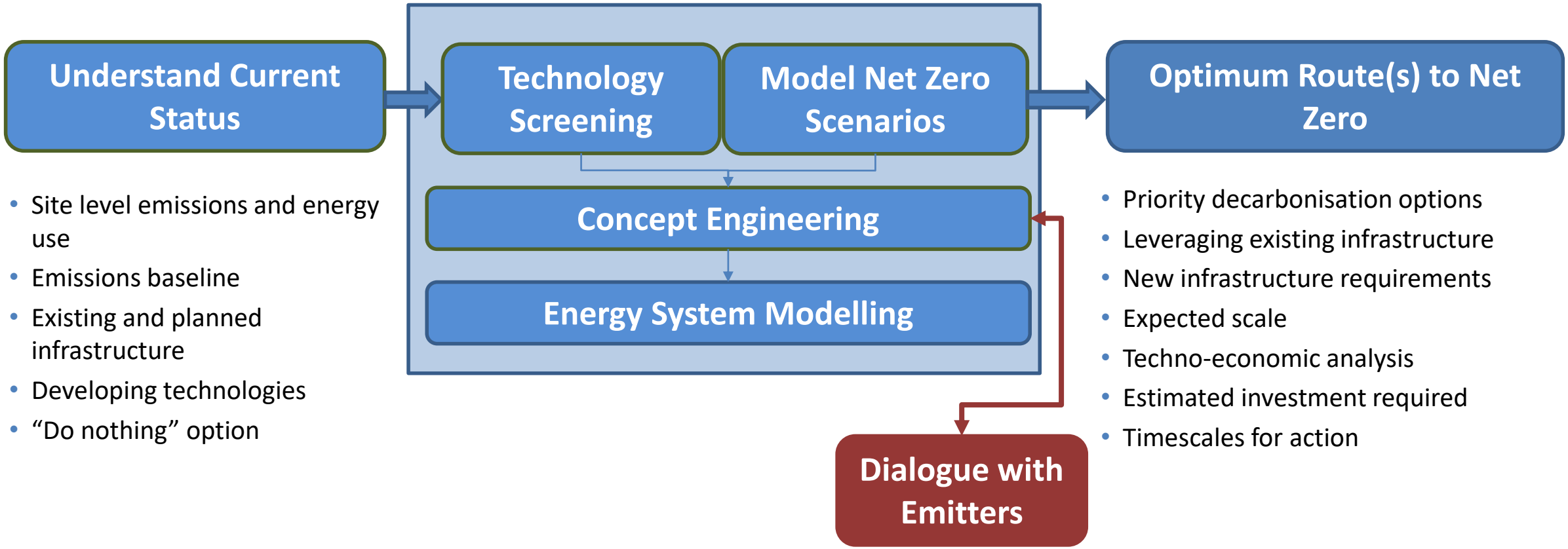
Our Approach

Scottish Net Zero Roadmap

Months 1 to 6

Months 3 – 15

Months 15 - end

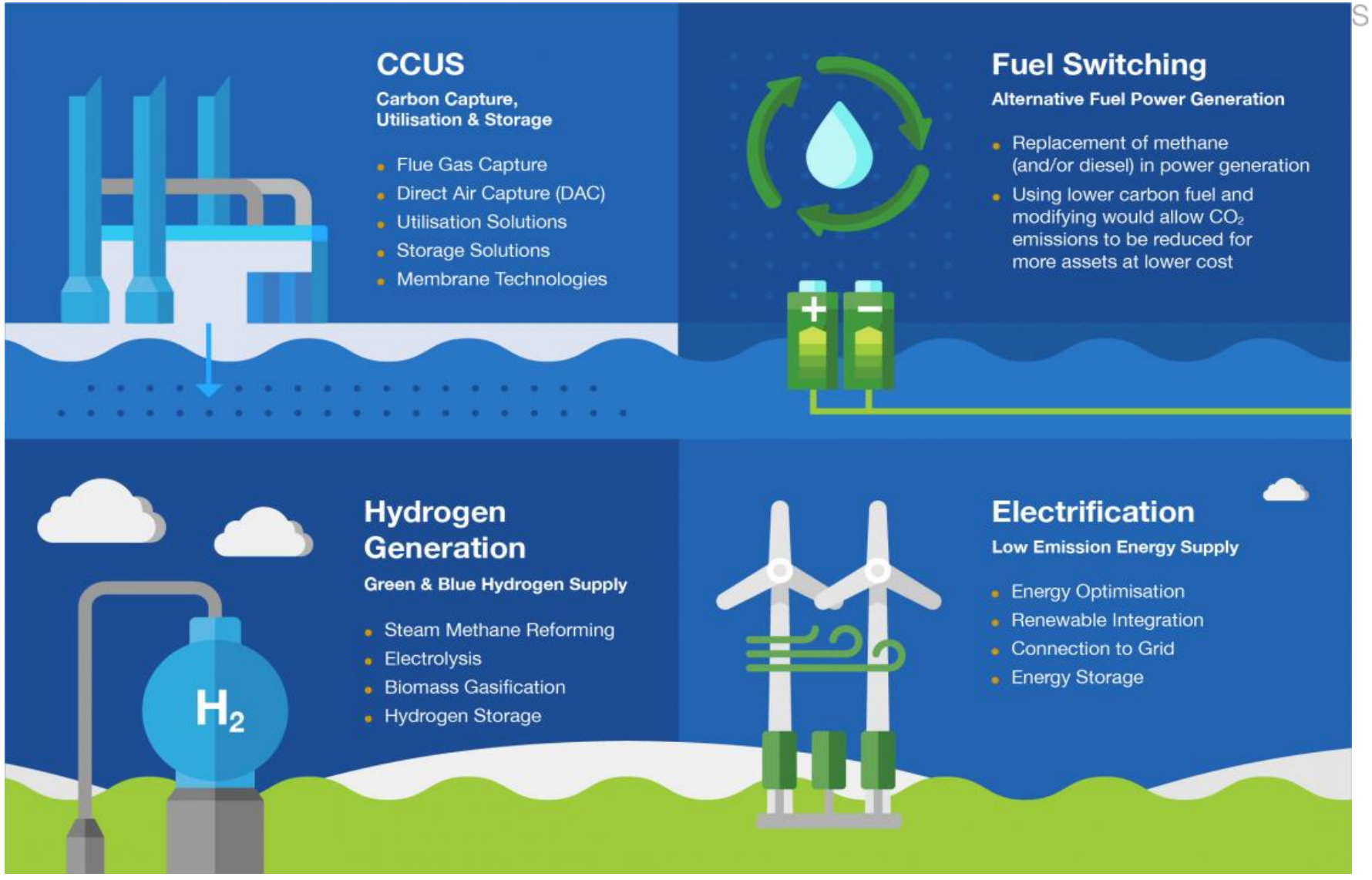


- Site level emissions and energy use
- Emissions baseline
- Existing and planned infrastructure
- Developing technologies
- “Do nothing” option

- Priority decarbonisation options
- Leveraging existing infrastructure
- New infrastructure requirements
- Expected scale
- Techno-economic analysis
- Estimated investment required
- Timescales for action

Key Technologies

Scottish Net Zero Roadmap



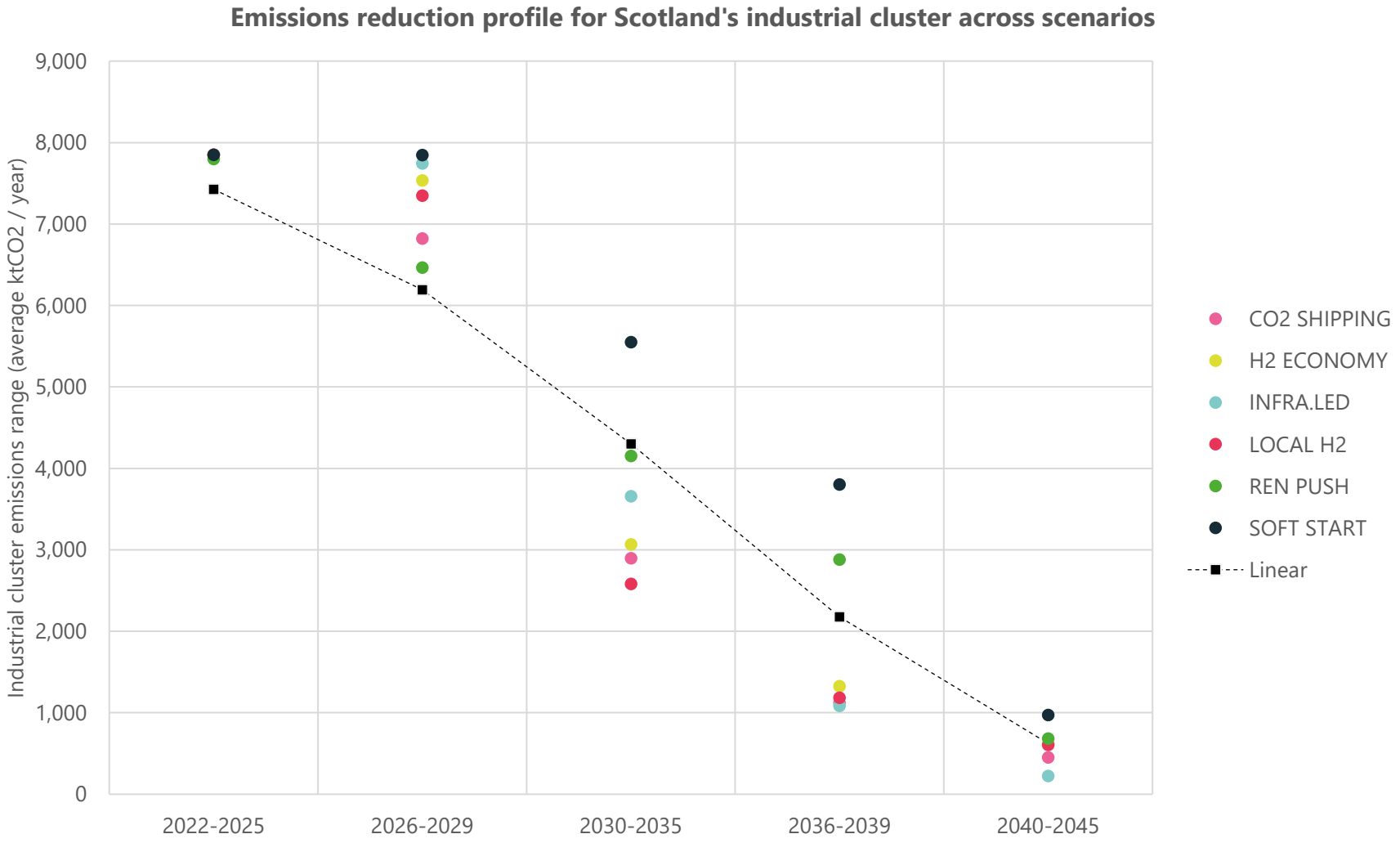
Net Zero Scenarios (Deployment Paths)

Scottish Net Zero Roadmap

Scenario	Fuel Switching	Efficiency	Process emissions	H_2 production	CO2 transport	Non-industry: heat	Non-industry: transport
Infrastructure-led	Baseline	Moderate	CCUS Early	Blue, local, early	Feeder 10, early	Electricity, Hydrogen, DHN	Electric cars, H_2 trucks
Soft Start	Biomass, electricity	High	CCUS Later	Blue, local, early	Feeder 10, later	Electricity, Hydrogen, DHN	Electric
Local H_2 network	Hydrogen	Low	CCUS Later	Blue, local, early	Feeder 10, early	Electricity, Hydrogen, DHN	Electric cars, H_2 trucks
H_2 economy	Hydrogen	High	CCUS Early	Blue, national, early	Feeder 10, early	Hydrogen	H2
Renewables push	Biomass, Electricity, Hydrogen	Low	CCUS Early	Green, national, early	Feeder 10, later	Hydrogen, Electricity, Biomass	Electric
CO_2 shipping	Baseline	Moderate	CCUS Early	Blue, local, early	Shipping, No Feeder 10	Electricity, Hydrogen, DHN	Electric cars, H_2 trucks

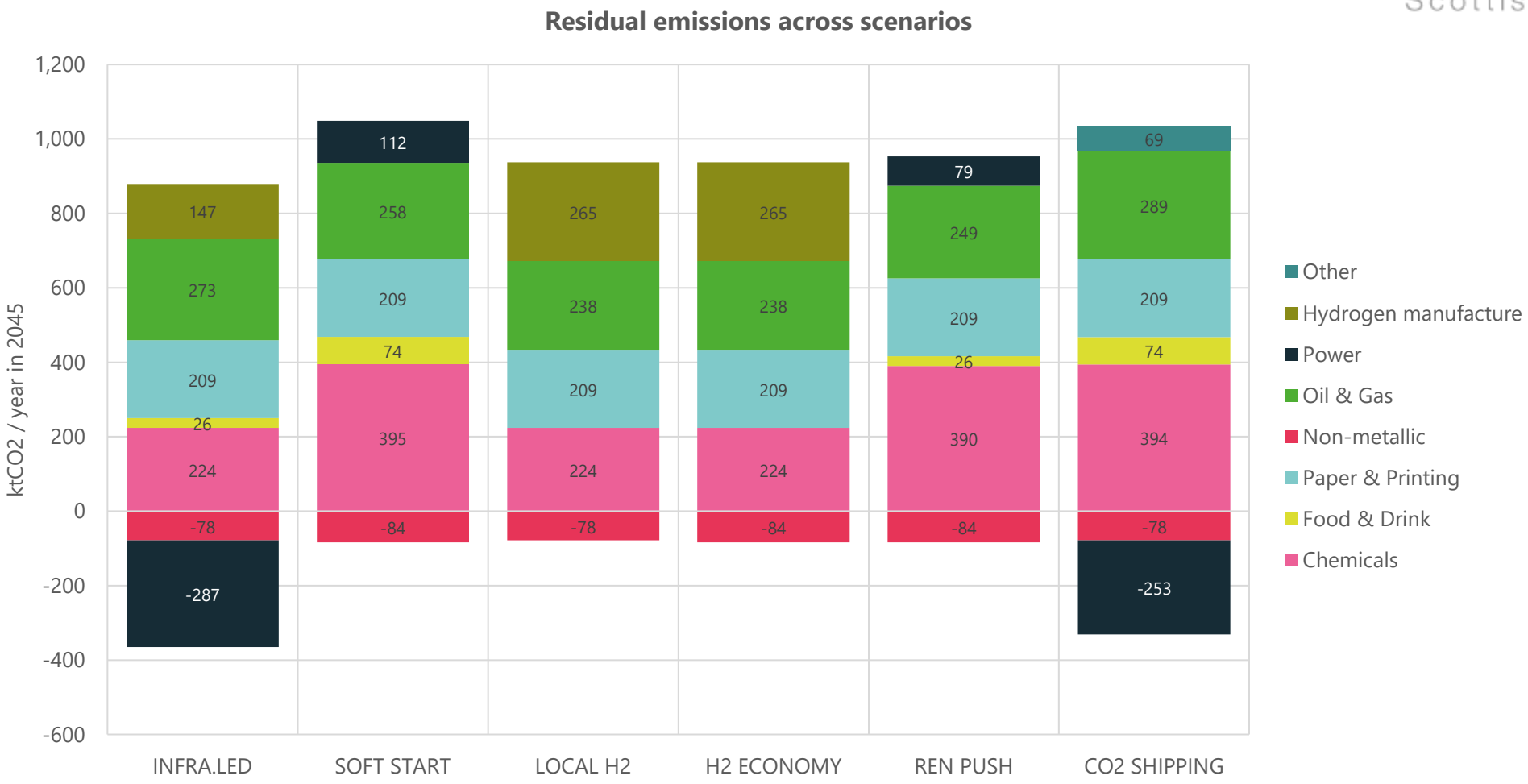
Key Scenario Outcomes

Scottish Net Zero Roadmap



- **Philosophy of scenarios** – and implied infrastructure requirements – informs speed of transition and alignment with economy-wide greenhouse gas targets. E.g. RENEWABLES PUSH scenario delivers early carbon savings via electrification; exclusion of hydrogen as fuel switch in some sectors increases residual emissions
- **In all scenarios**: cluster emissions reduced by at least 92% compared with baseline. DACC required to eliminate last 100-500 $ktCO_2$

Residual Emissions



- **Oil / gas** and **chemicals** sectors contribute more to residual emissions (typically CCS residuals), with bioenergy injection into power and non-metallic (cement / glass) sectors providing offset

Scenario Analysis - Critical Insights

Scottish Net Zero Roadmap

- **There are multiple possible routes to Net Zero for industry in Scotland**
  - CCS is mandatory for some sectors
  - A viable choice of electrification, hydrogen or CCS is present at many sites
  - Removals via DACC are highly likely to be required
- **Early decarbonisation is particularly challenging**
  - Ahead of major infrastructure availability (H_2 / CO_2 pipelines) options such as electrification are limited
  - Shipping of CO_2 could be impactful in terms of acceleration of capture
- **Activity in the late 2020s / early 2030s is vital**
  - CO_2 / H_2 pipeline development (or vehicular rollout) allows emissions removal first in Grangemouth and then in Fife. Extensive site and infrastructure projects
- **Strong synergies with out-of-cluster decarbonisation in hydrogen-focused scenarios**
  - Industrial demand for hydrogen can help underpin the economic case for hydrogen usage in other demand sectors nearby
- **Opportunity for multi-billions of capital investment in all scenarios**

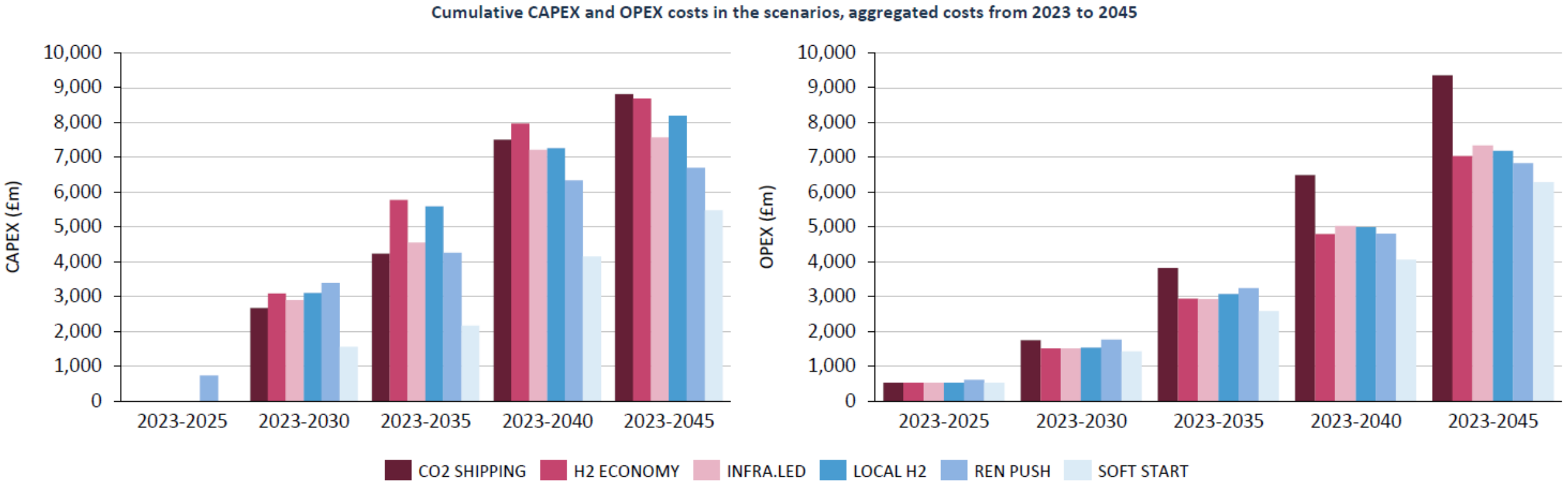
Metric	Value
Emissions in 2045 (without DACC)	90 – 500 $ktCO_2$ / year
Cumulative 2022-2045 emissions	83 – 120 $MtCO_2$
Capital investment	£5-9bn
Approximate cost of decarbonisation	£130-170 / tCO_2
Hydrogen consumed	0 – 25 TWh / year
Carbon captured	4 – 9 $MtCO_2$ / year
Emissions offset through NETs	0 – 1 $MtCO_2$ / year

Criterion	Promising scenario(s)
Low decarbonisation costs	INFRA LED / LOCAL H2
Successful delivery of Net Zero	INFRA LED
Low cumulative emissions	CO2 SHIPPING
Early progress	RENEWABLES PUSH
Site retained optionality	INFRA LED / LOCAL H2 / H2 ECONOMY
Synergy with non-industrial transition (e.g. transport, agri)	LOCAL H2 / H2 ECONOMY / INFRA LED

Potential Economic Impact (1)

Scottish Net Zero Roadmap

- **Capex** – varies by scenario, ranging from £5.5 to almost £9 billion
- **Opex** – varies between £6.2 to £7.3 billion except for one scenario where it is close to £9.5 billion



elementenergy an ERM Group company

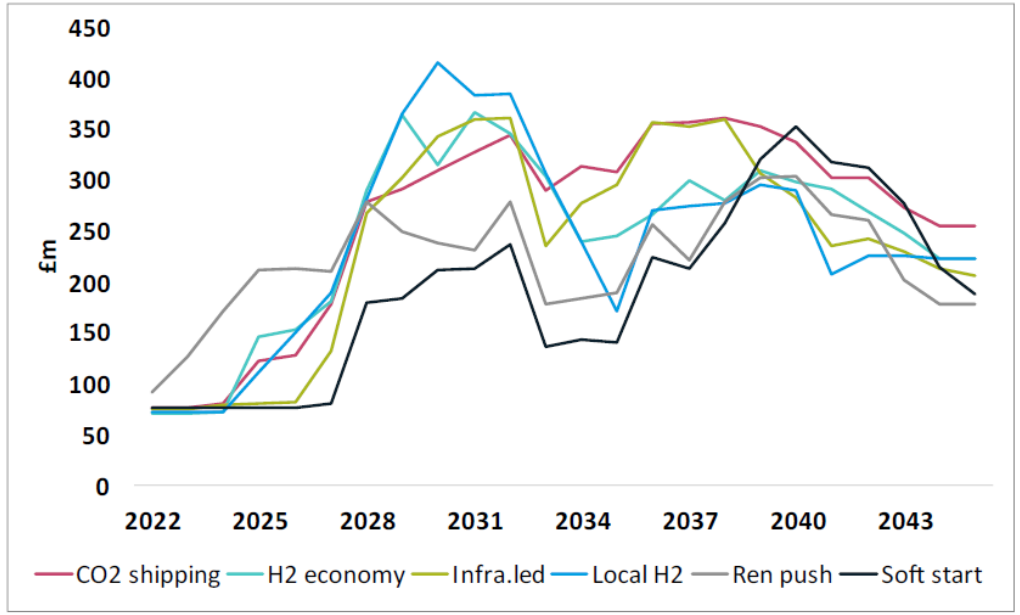
cambridge econometrics

Potential Economic Impact (2)

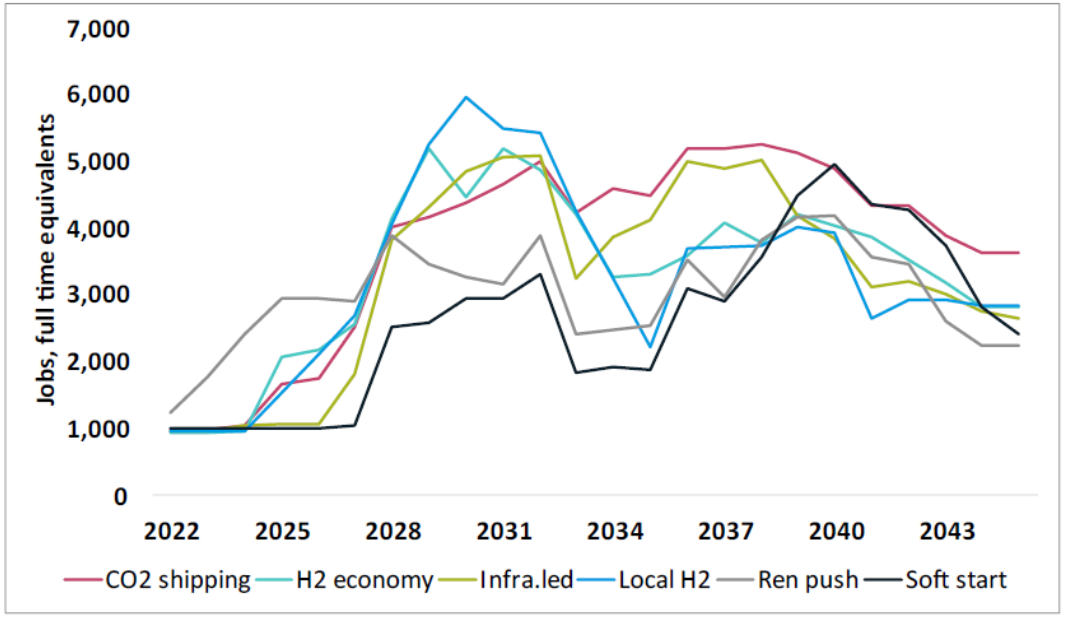
Scottish Net Zero Roadmap

- **GVA -** Varies by scenario
- **Employment**
  - Different scenarios will create an average of between 2,600 to 3,800 jobs per annum
  - Peak jobs varies up to 6,000 per annum

Type II (direct, indirect and induced jointly) GVA impact of different scenarios, by years (2022-2045), in million GBP



Type II (direct, indirect and induced jointly) employment impacts in different scenarios between 2022-2045 (in full time equivalents).

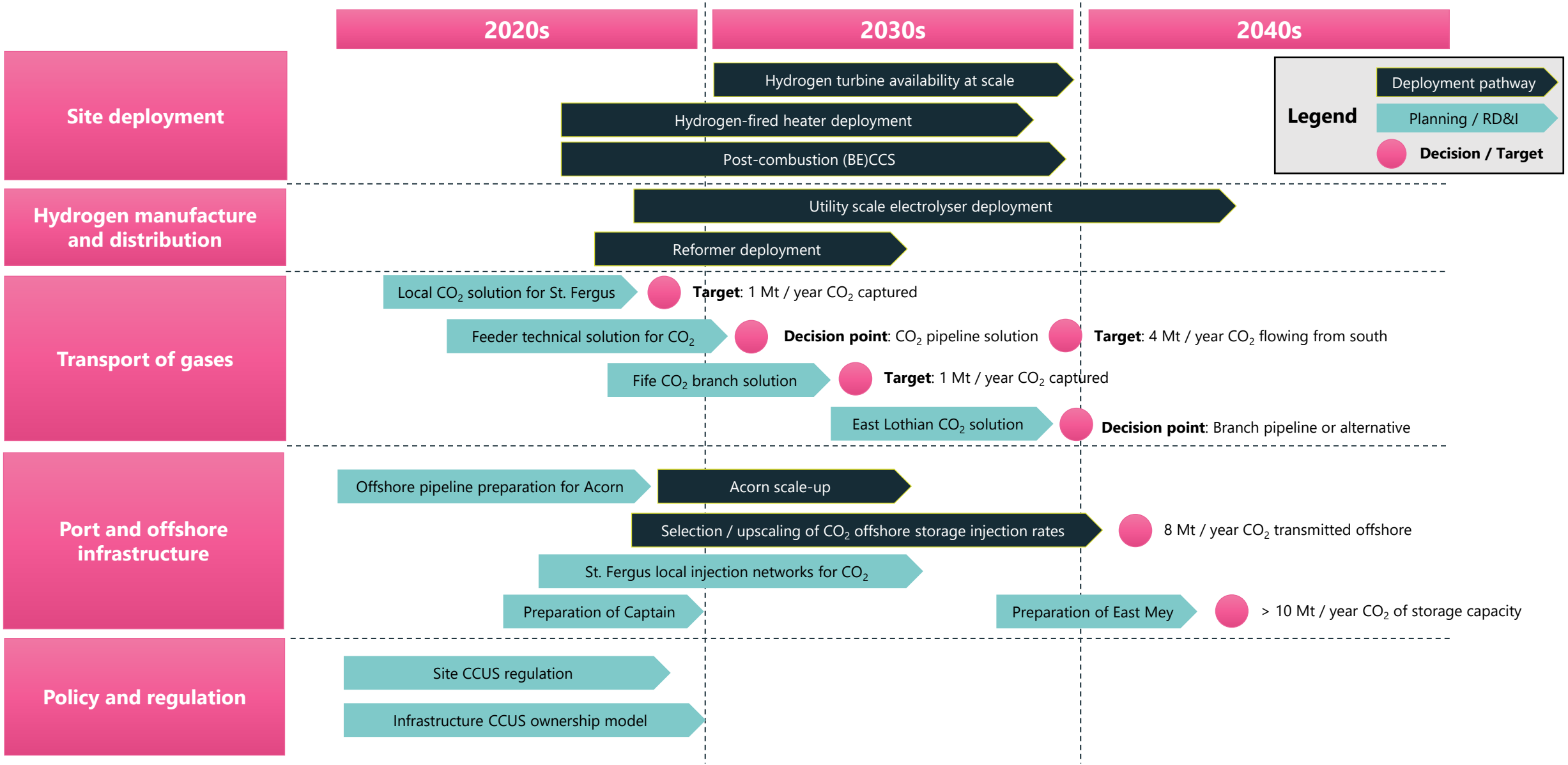


elementenergy an ERM Group company

cambridge econometrics

From Scenarios to a Roadmap

Scottish Net Zero Roadmap



Key Actions

Scottish Net Zero Roadmap

- Establish ownership and leadership of roadmap implementation
- Set-up a co-ordination mechanism
- Support ACORN projects as an initial focal point for the roadmap
- Invest in CO_2 pipeline infrastructure
- Invest in hydrogen manufacturing, transport and supply
- Invest in direct air capture capacity

THANK YOU

Iain Weir
Managing Director and Senior Consultant

Optimat Ltd.,
100 West George Street,
Glasgow,
G2 1PP

Tel: 0141 260 6260
www.optimat.co.uk

For more information, see https://snzr.co.uk/