SYNERGETIC
NU PRIMARY ENERGY

The 2nd IAEA Conference on Fusion Enterprises

July 2022

01

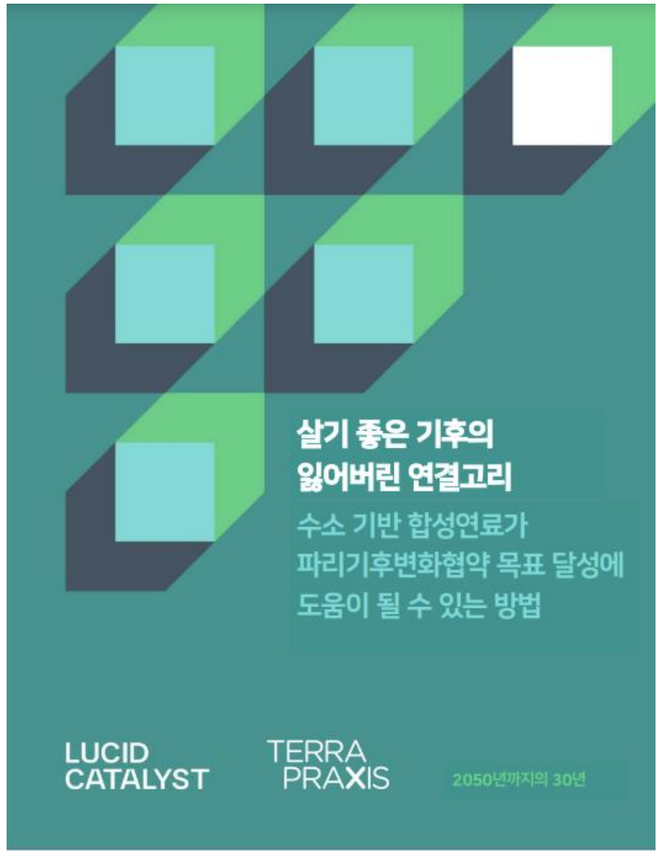
ABOUT SYNERGETIC

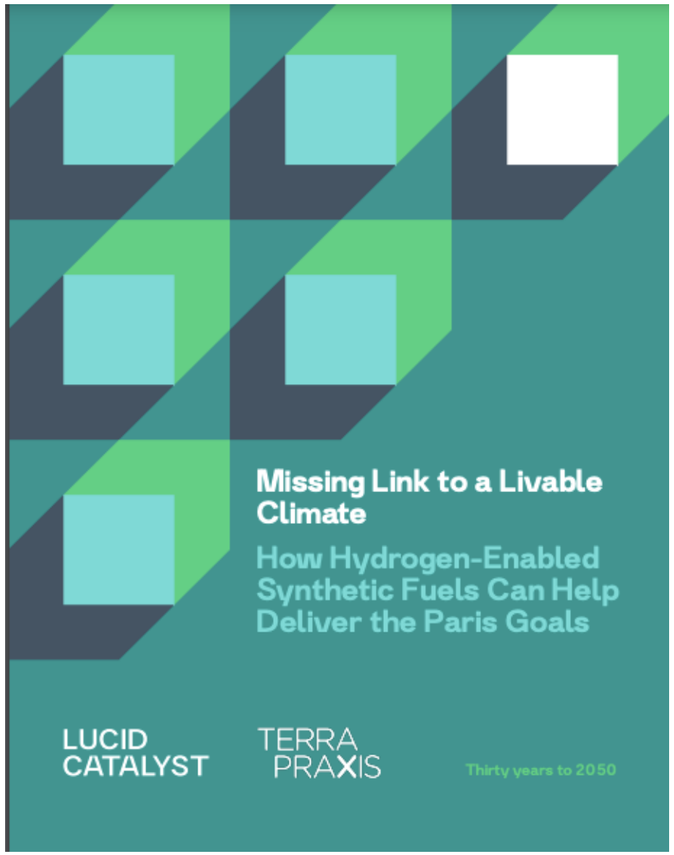
SCALING UP CLEAN HEAT AND POWER

Our Vision

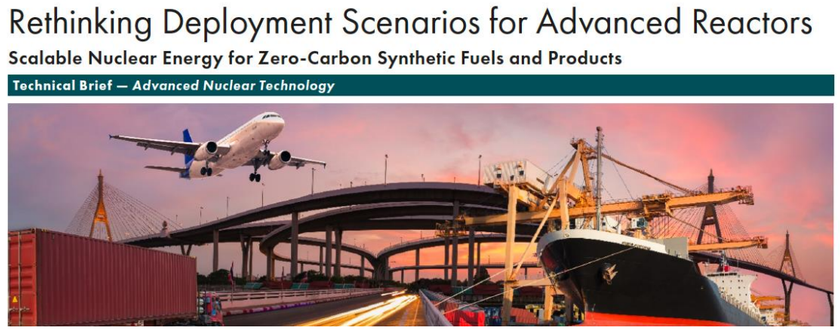
Our large, highly standardized projects – in partnership with Team Korea - will deliver zero carbon power and liquid fuels that are cost-competitive, clean and globally available.

READ ABOUT OUR VISION



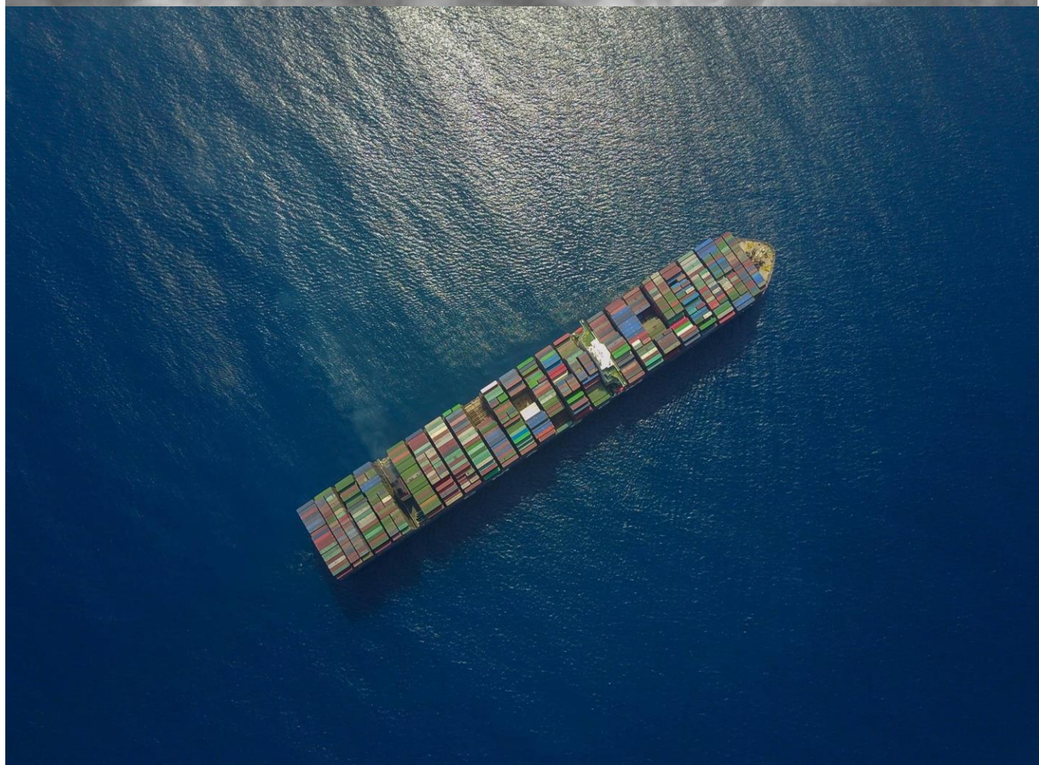


EPRI



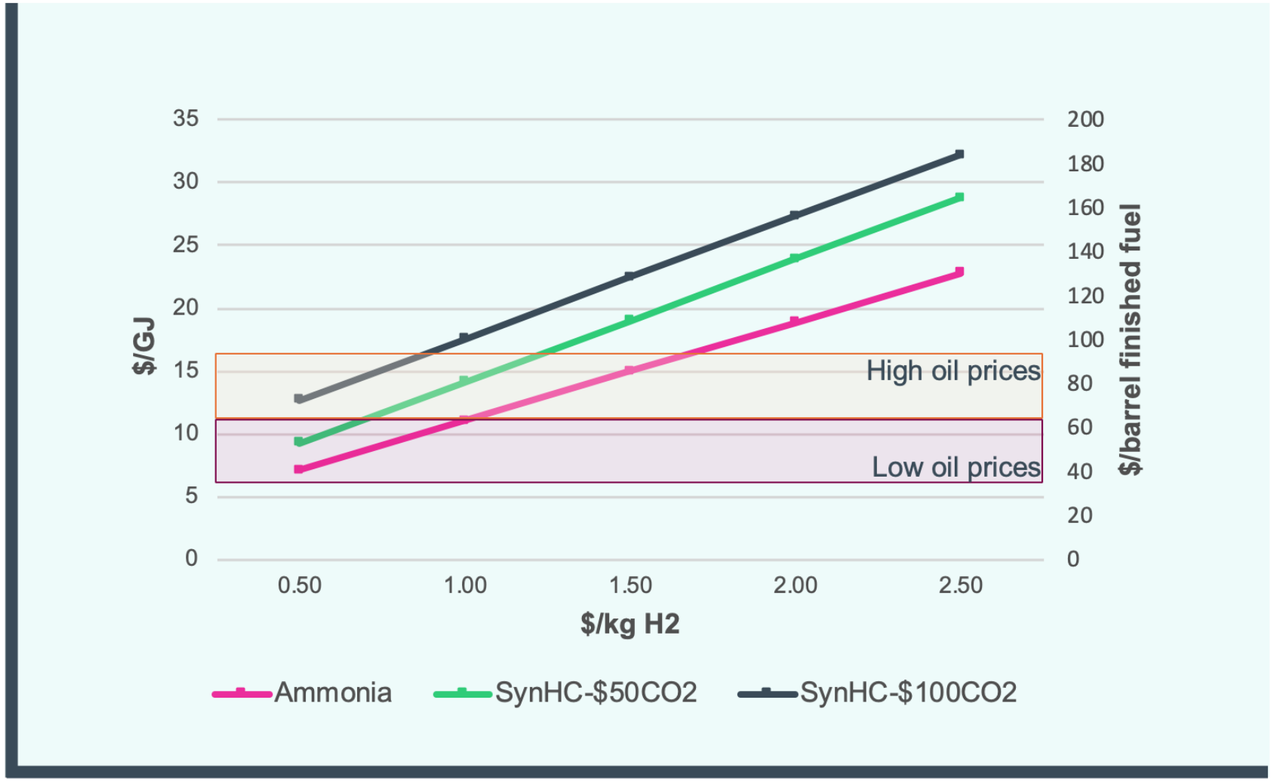
THERE IS MASSIVE PENT-UP DEMAND FOR AFFORDABLE DECARBONIZATION

- Customers want to achieve their decarbonization goals faster
- Customers want fuels that are compatible with their existing applications
- Clean fuels cannot cost 3-5x more than conventional fuels cost today
- Market share for cost competitive clean fuels will be limited by supply, not demand



COST COMPETITVE SYNTHETIC FUELS REQUIRE LOW-COST CLEAN HYDROGEN

- Achieving these hydrogen production costs (<$1.5/kg) requires very low-cost electricity
- To achieve $1.5/kg you need $30/MWh electricity and high temperature electrolysers at $400/kW
- $1500/kW capital cost
- $10/MWh O&M; $7/MWh fuel; 38kWh/kg-H



02

SYNERGETIC

DEPLOYMENT ARCHITECTURE

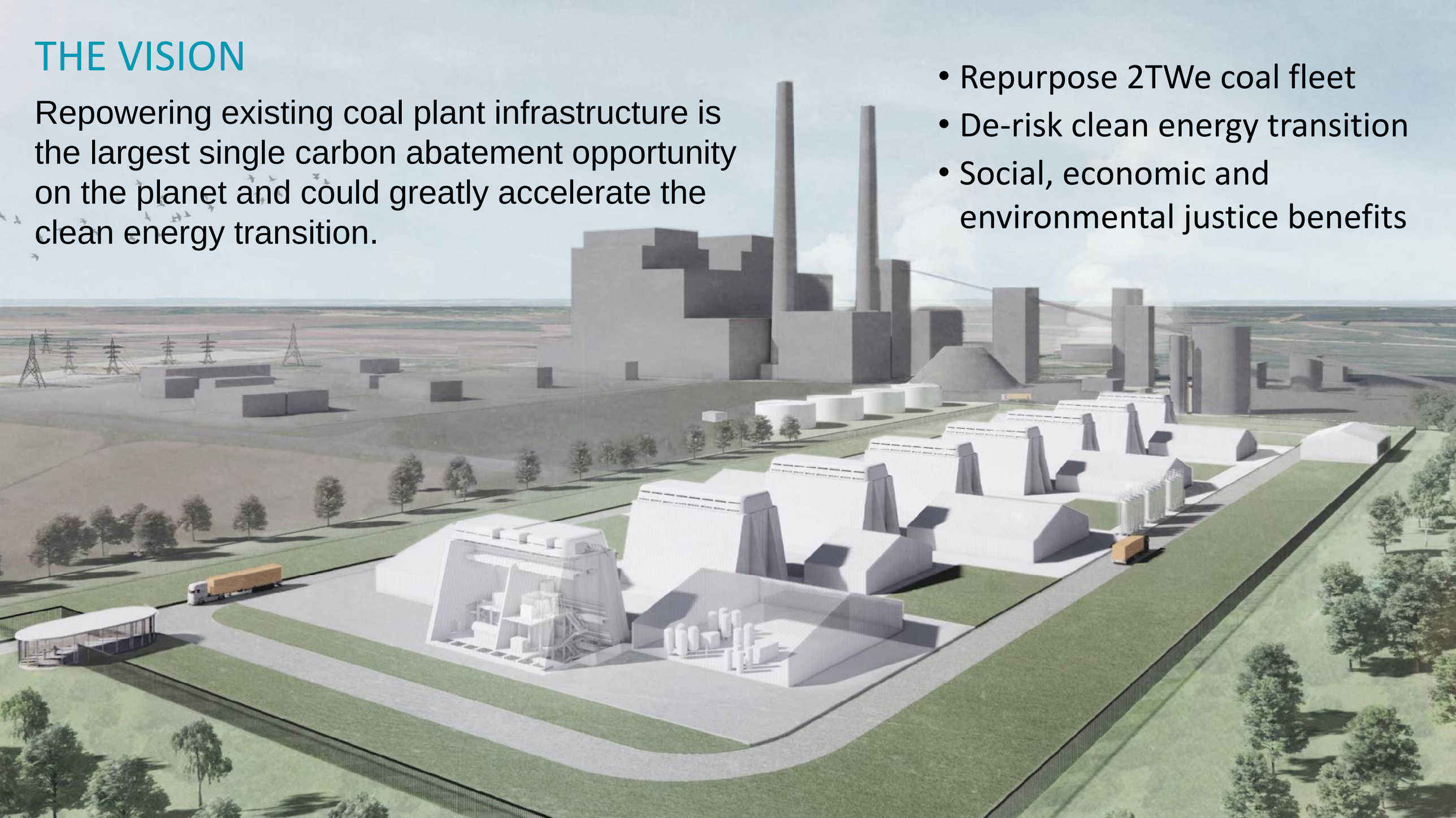
01 # REPOWERING COAL

FAST, LOW COST, REPEATABLE

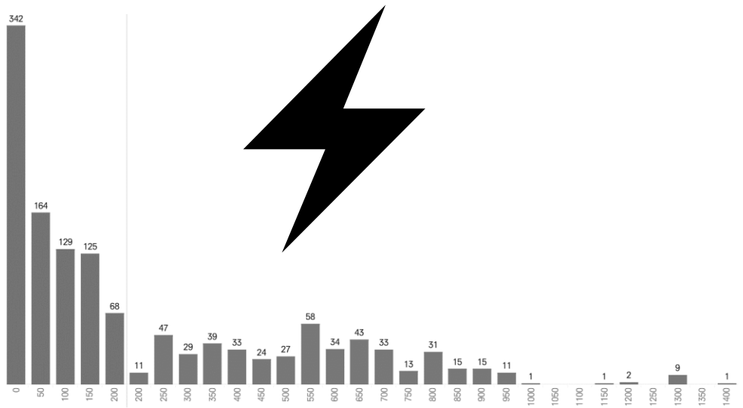
THE VISION

Repowering existing coal plant infrastructure is the largest single carbon abatement opportunity on the planet and could greatly accelerate the clean energy transition.

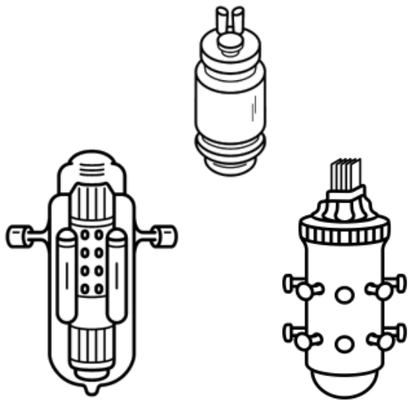
- Repurpose 2TWe coal fleet
- De-risk clean energy transition
- Social, economic and environmental justice benefits



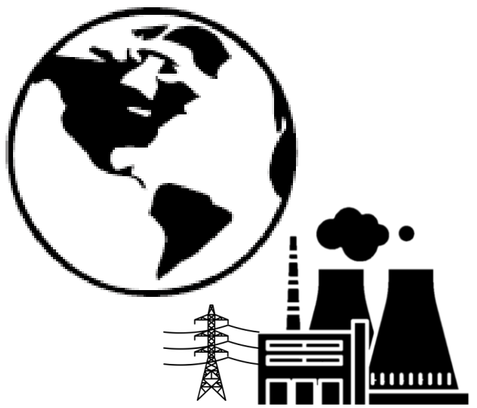
Standardization to Address Wide Variety of Requirements



Different
Energy and heat requirements

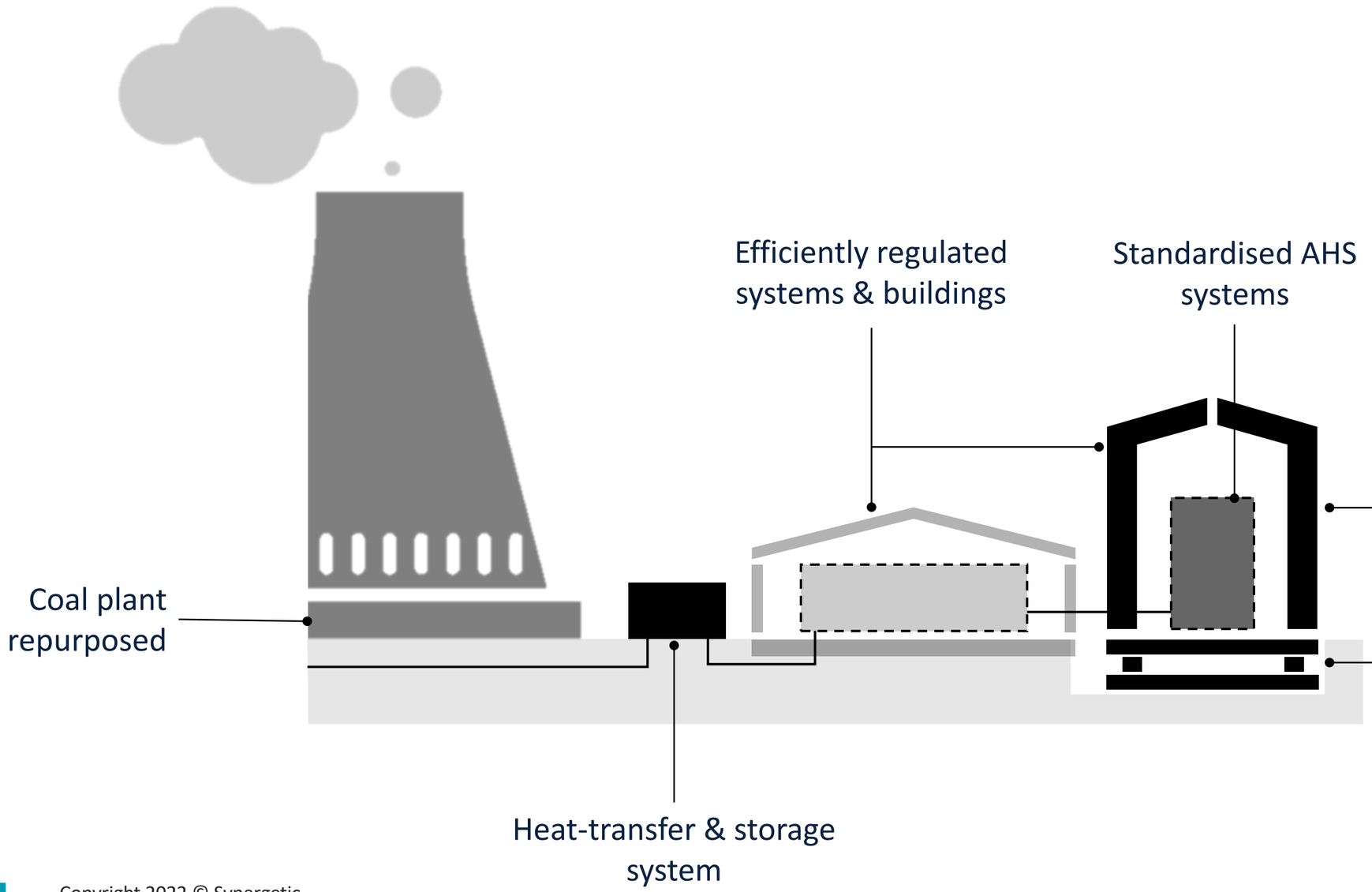


Different
Advanced heat-source (AHS) technologies (fission or fusion)



Different
Site layouts and local requirements

Built Systems Must Enable Scale and Speed



2TWe
2050

Thermal energy storage de-links the nuclear heat island safety case from the existing coal plant power island. This enables flexible generation and continued use of the existing plant.

TerraPraxis has assembled a world-class team to deliver Repowering Coal

Microsoft

Bryden Wood

SIMPSON GUMPERTZ & HEGER

Engineering of Structures and Building Enclosures

TERRA PRAXIS

University at Buffalo

Southern Company

Tennessee Valley Authority

Learn more at
www.terrapraxis.org

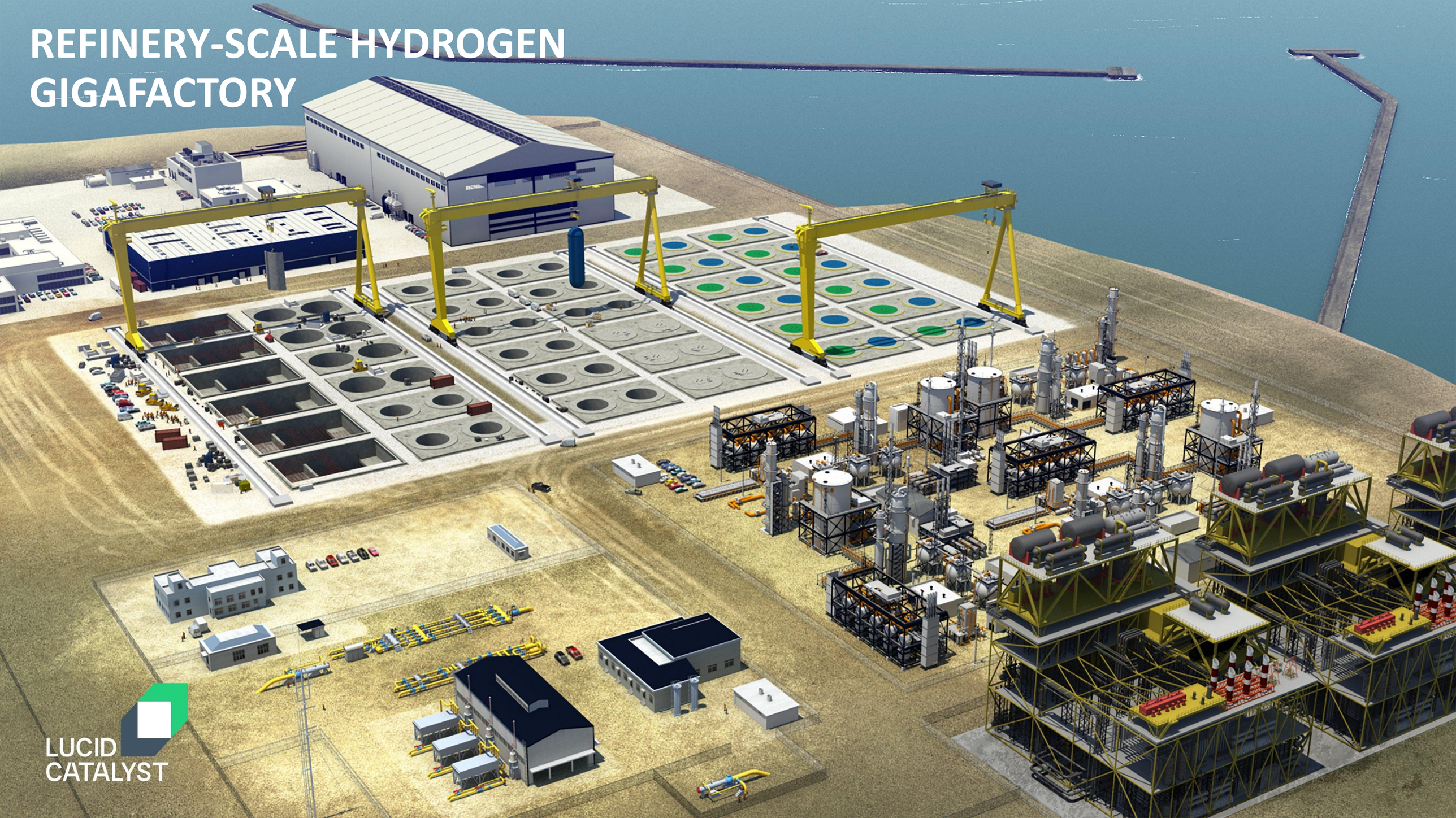
Repowered coal plants can protect jobs and energy security by continuing to operate for decades, supplying emissions-free, reliable, flexible, and cost-competitive electricity.

02

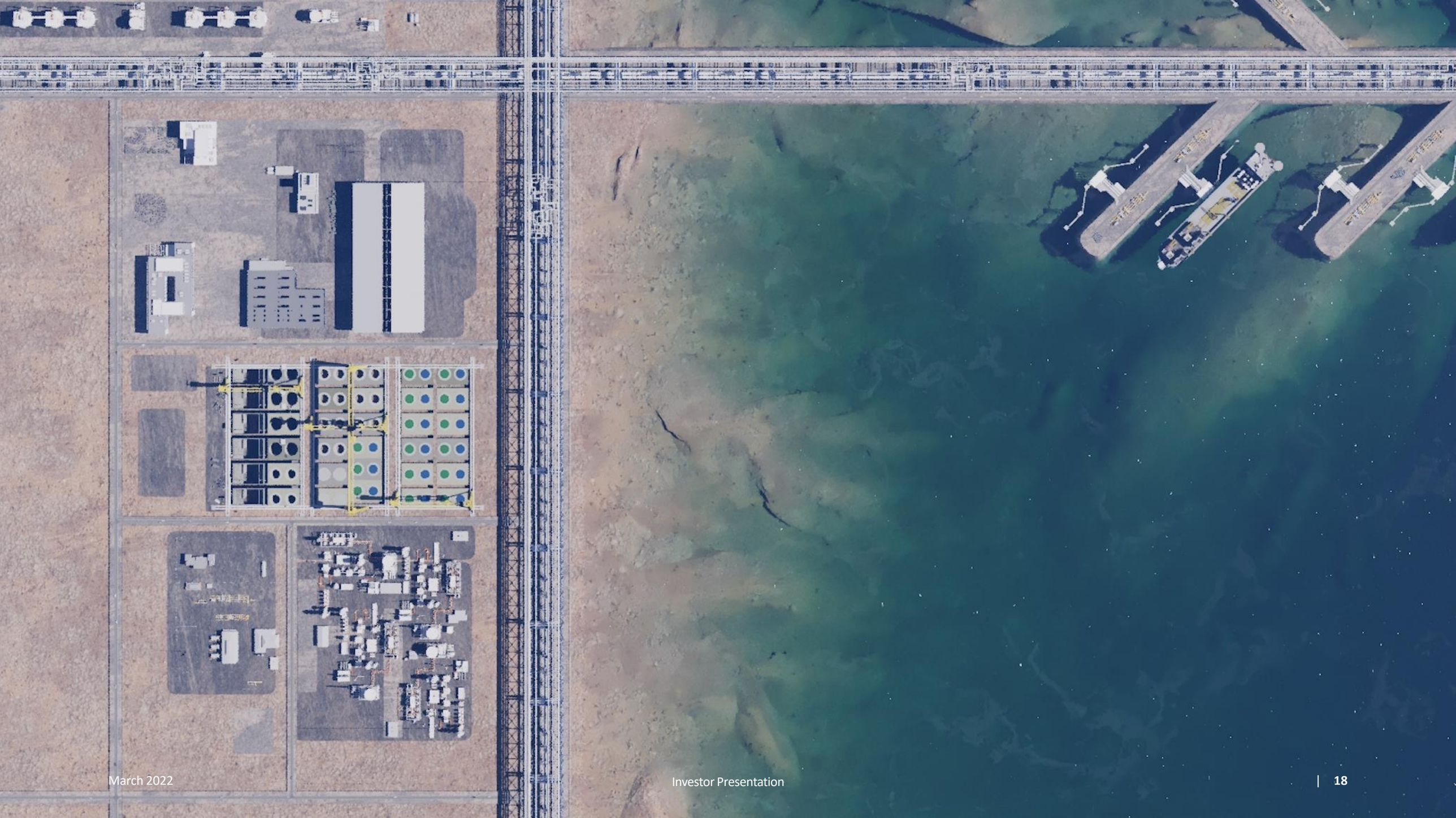
REFINERY-SCALE HYDROGEN GIGAFACTORY

BRING THE FACTORY TO THE PROJECT

REFINERY-SCALE HYDROGEN GIGAFACTORY



LUCID CATALYST



03

SHIPYARD-MANUFACTURED CLEAN SYNTHETIC FUELS

BRING THE PROJECT TO THE FACTORY

SYNERGETIC AMMONIA FPSO

12k boe/d
1.2 GWe

FLEET FACILITIES

200k boe/d

SYNERGETIC: ACHIEVING SCALE

Seven FPSO platforms each producing 1.2 million tonnes per year of the world's lowest cost zero-carbon ammonia would be the equivalent to 5% of total global ammonia production.

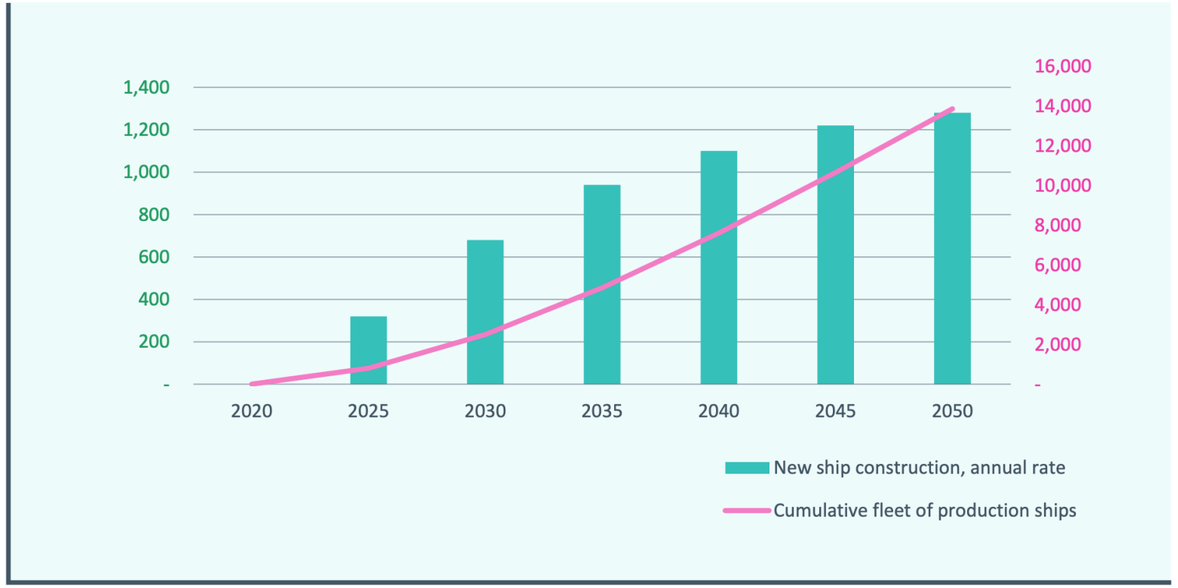
03

SYNERGETIC

TRANSFORMING OIL PRODUCERS INTO CLEAN FUELS SUPPLIERS

TRANSFORMING MAJOR OIL PRODUCERS INTO GLOBAL SUPPLIERS OF CLEAN LIQUID FUELS

- 100 million Barrels of Oil per day = ~10,000 FPSOs
- Currently ~ 60,000 large ships operating
- Shipyards: 281 operating in 2019



EXXON/Mobil	4,000,000	334
Shell	3,700,000	308
ADNOC	3,000,000	250
Equinor	2,000,000	167

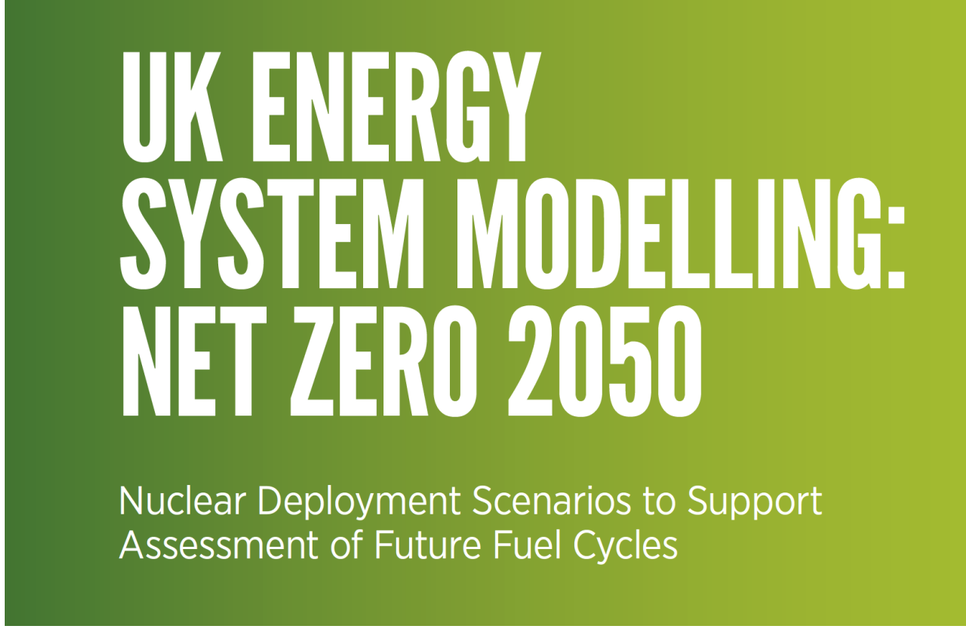
04

SYNERGETIC

MODELLING THE VALUE PROPOSITION

HYDROGEN SYNFUELS GIGAFACTORY TO SUPPORT UK NET ZERO BY 2050

- **Considers the role of nuclear providing not only electricity but also heat and hydrogen, giving a range of nuclear deployment scenarios from 14 GWe to over 60 GWe in 2050**
- This study included analysis of the potential for:
  - The concept of a **Hydrogen Gigafactory** for dedicated production of high-volume low-cost hydrogen with a low carbon footprint
  - Production of **liquid synthetic hydrocarbon fuel**, or Jet A, for “drop-in” application within the aviation sector as an alternative fuel with no net carbon emissions.



AFCP Advanced Fuel Cycle Programme

CATAPULT Energy Systems

LUCID CATALYST

Supported by

Department for Business, Energy & Industrial Strategy

KEY PARAMETERS FOR THE HYDROGEN GIGAFACTORY

LucidCatalyst developed the technical and economic parameters for the Hydrogen Gigafactory based on existing component studies.

Hydrogen Gigafactory (NOAK)	Greater Nuclear Ambition Baseline
First Operations date	2030
Construction Duration (years)	2
Build Out Rate	5 GW/year initially ramping up to 10 GW*/year by 2040 ** [where 1 GW represents instantaneous production of 1 GW of hydrogen]*
Overnight Capital Cost	£1000/kW at 2030 reducing to £750/kW by 2050
Notes: (1) Economic life 60 years (2) Design capacity factor 92% (3) Data values reflect aspirational NOAK rather than FOAK as per consistent treatment within ESME alongside other low carbon technologies	

KEY PARAMETERS FOR THE SYNTHETIC FUEL PLANT

The total plant capex is £600/kWe higher than the Hydrogen Gigafactory because it includes the reformer and Fischer-Tropsch reactor for combining hydrogen and carbon to produce synthetic liquid fuel.

Synthetic Aviation Fuel Plant (NOAK)	Greater Nuclear Ambition Baseline
First Operations date	2030
Construction Duration (years)	4
Build Out Rate	1 GW/year in 2030 ramping up to 10 GW*/year from 2040 onwards ** [where 1 GW represents instantaneous production of 1 GW of synthetic liquid fuel]*
Overnight Capital Cost	£1600/kW at 2030 reducing to £1200/kW by 2050: • Nuclear to hydrogen: £1,200/kW.H_2 in 2030 • Carbon treatment to process ready CO_2: £160/kW.*(synthetic fuel)* in 2030 • Hydrogen to aviation fuel: £240/kW.*(synthetic fuel)* in 2030 • Total plant: £1,600 in 2030 Capital costs decrease 25% by 2050 (total plant: £1,200/kW in 2050). Alternative representation for 2050 era plant: • Hydrogen and high-temperature heat production module: £900/kW.H_2 • CO_2 processing module: Equivalent to £13/tCO_2 • Aviation fuel synthesis module: £180/kW.*(synthetic fuel)*
Notes: (1) Economic life 60 years (2) Design capacity factor 92% (3) Data values reflect aspirational NOAK rather than FOAK as per consistent treatment within ESME alongside other low carbon technologies	

05

SYNERGETIC

FAST, LOW-COST DECARBONISATION AT SCALE

HYDROGEN PRODUCTION WITHOUT THE GIGAFACTORY OR SYNFUEL PLANT

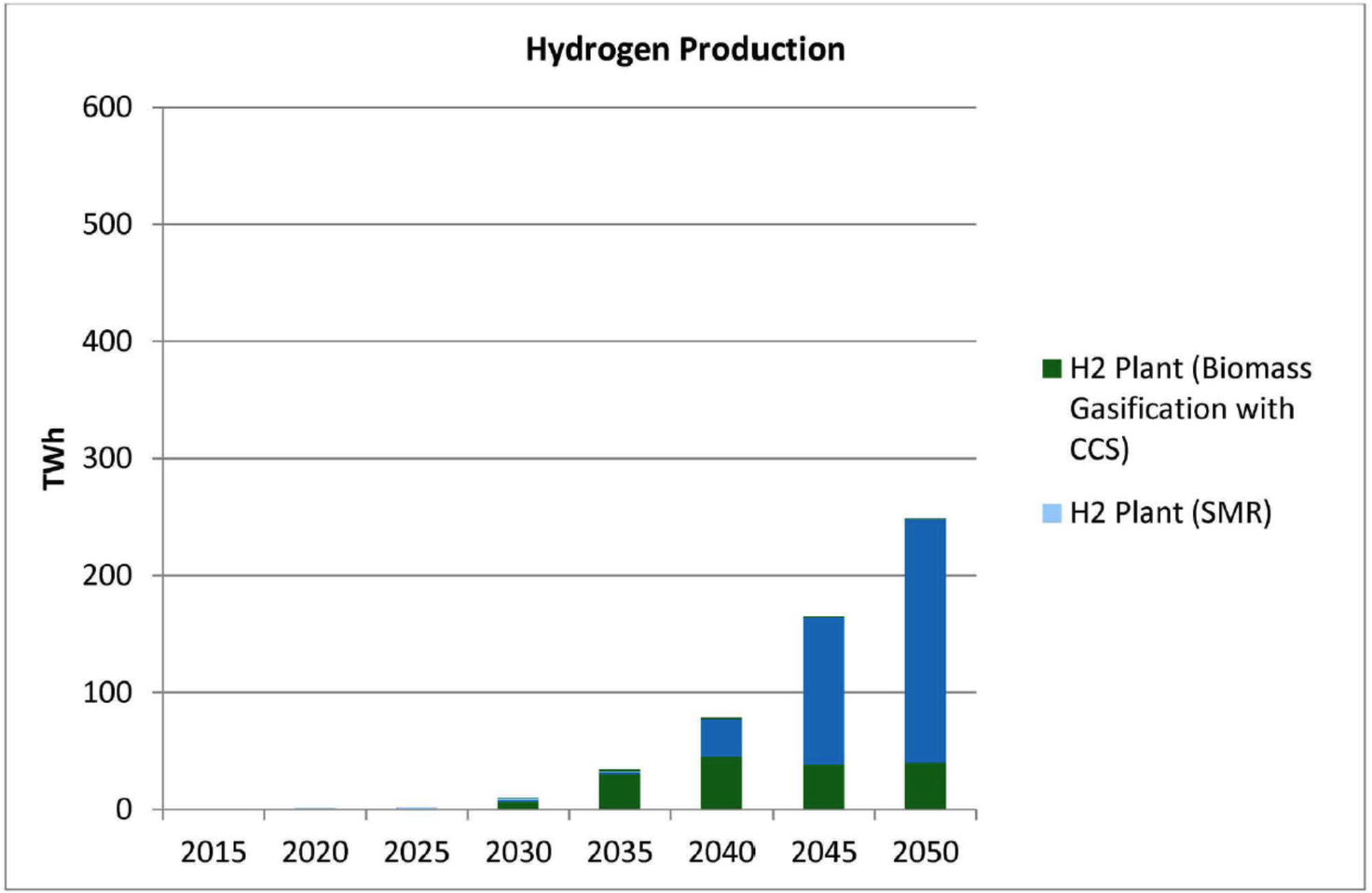


Figure 10 – Hydrogen production – Run 301 without hydrogen gigafactory or synthetic fuel plant (TECH100)

HYDROGEN PRODUCTION WITH THE GIGAFACTORY AND SYNFUEL PLANT

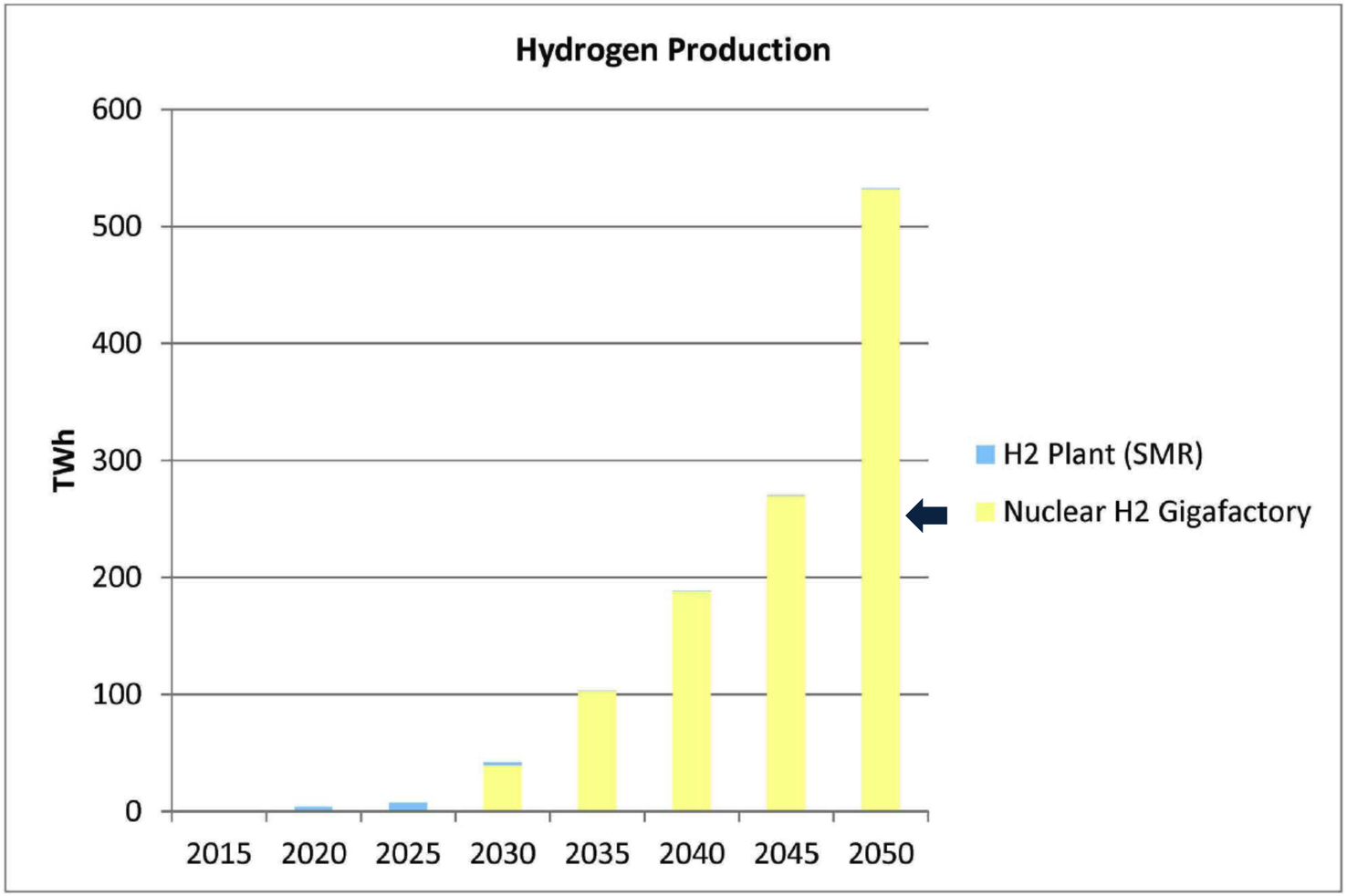


Figure 11 – Hydrogen production – Run 310 with hydrogen gigafactory and synthetic fuel plant (TECH100)

HYDROGEN CONSUMPTION WITHOUT THE GIGAFACTORY OR SYNFUEL PLANT

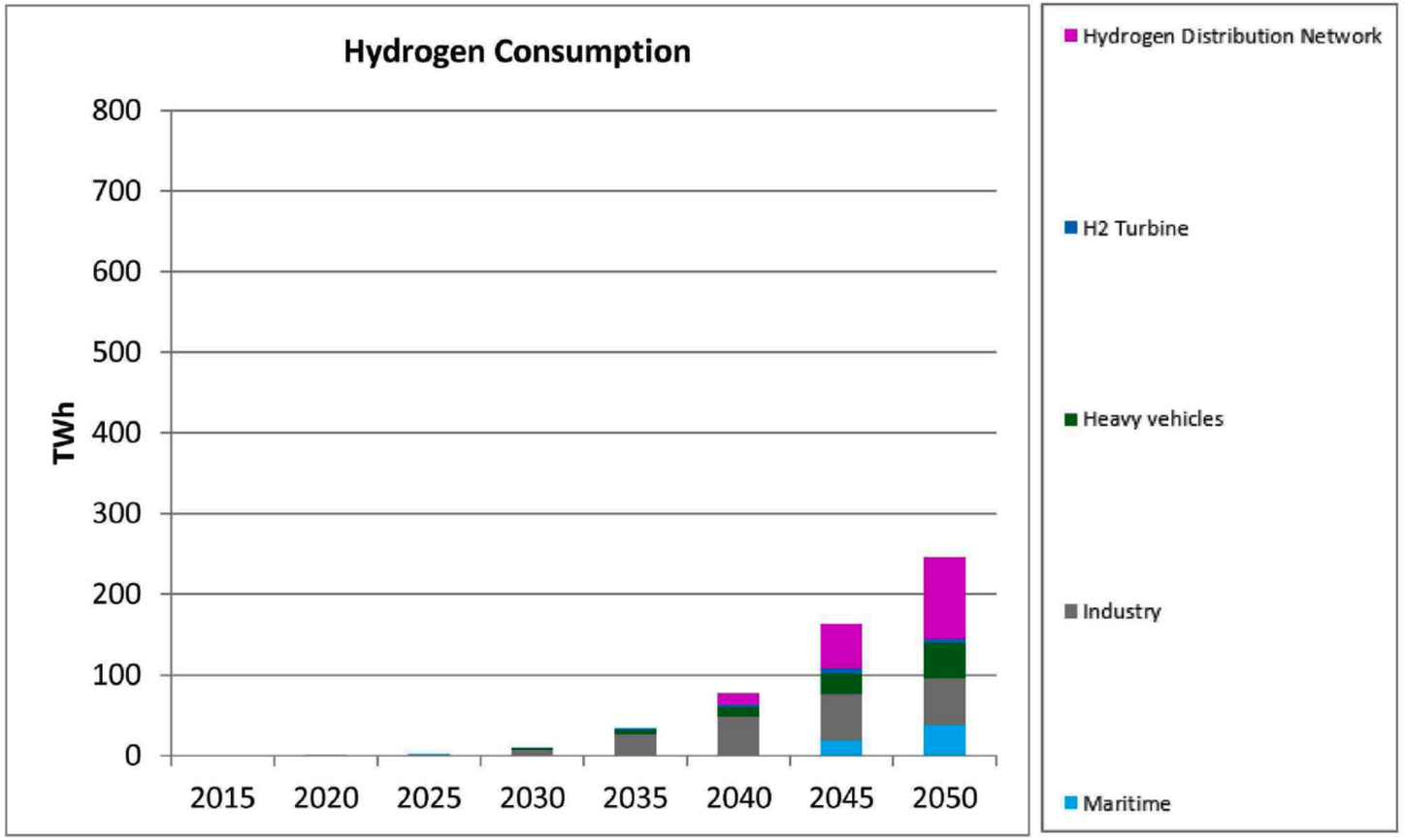


Figure 13 – Hydrogen production – Run 301 without hydrogen gigafactory or synthetic fuel plant (TECH100)

HYDROGEN CONSUMPTION WITH THE GIGAFACTORY AND SYNFUEL PLANT

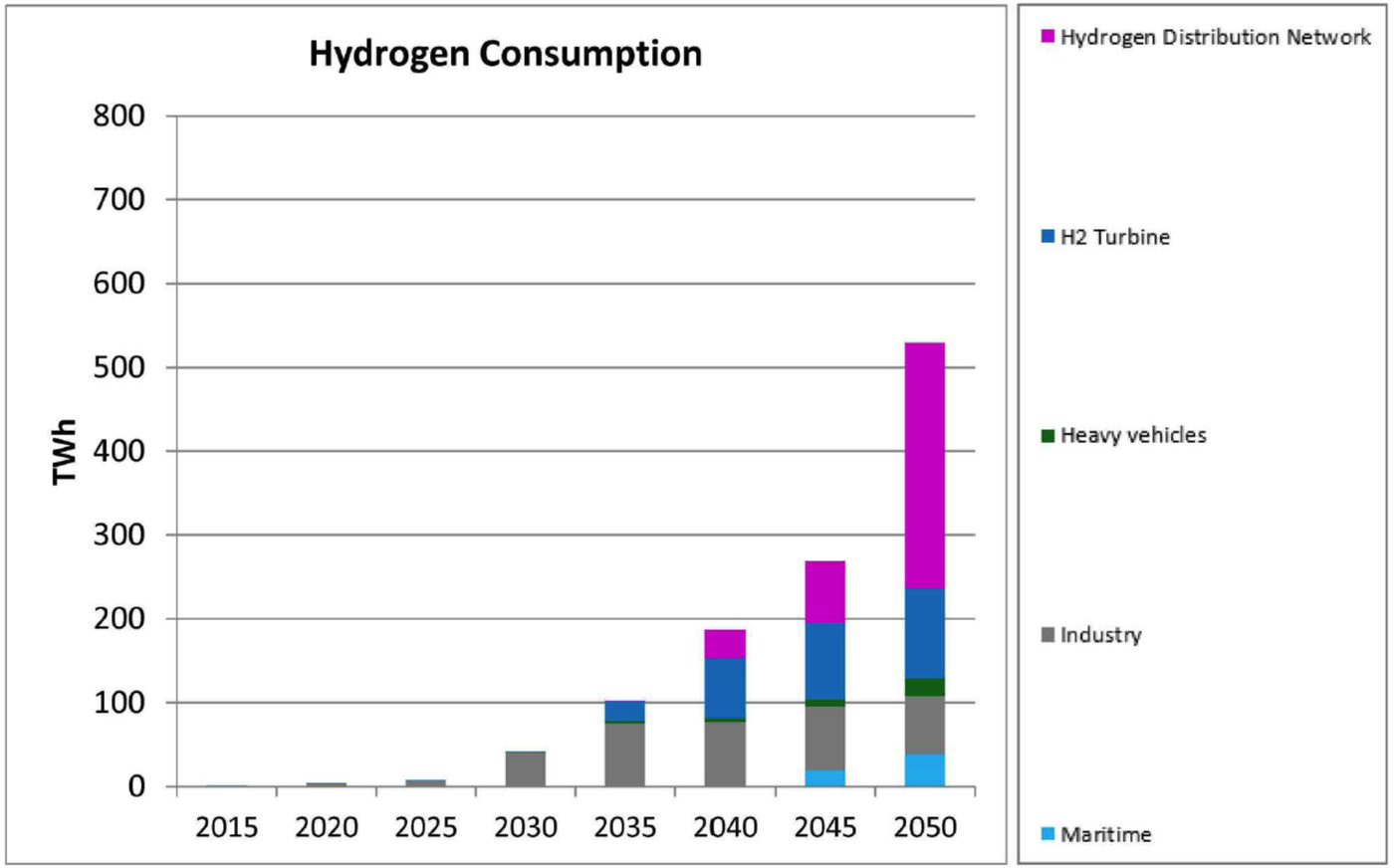


Figure 14 – Hydrogen consumption – Run 310 with hydrogen gigafactory and synthetic fuel plant (TECH100)

HYDROGEN CONSUMPTION IN 2050 BY SECTOR AS A FUNCTION OF H2 PRODUCTION COST

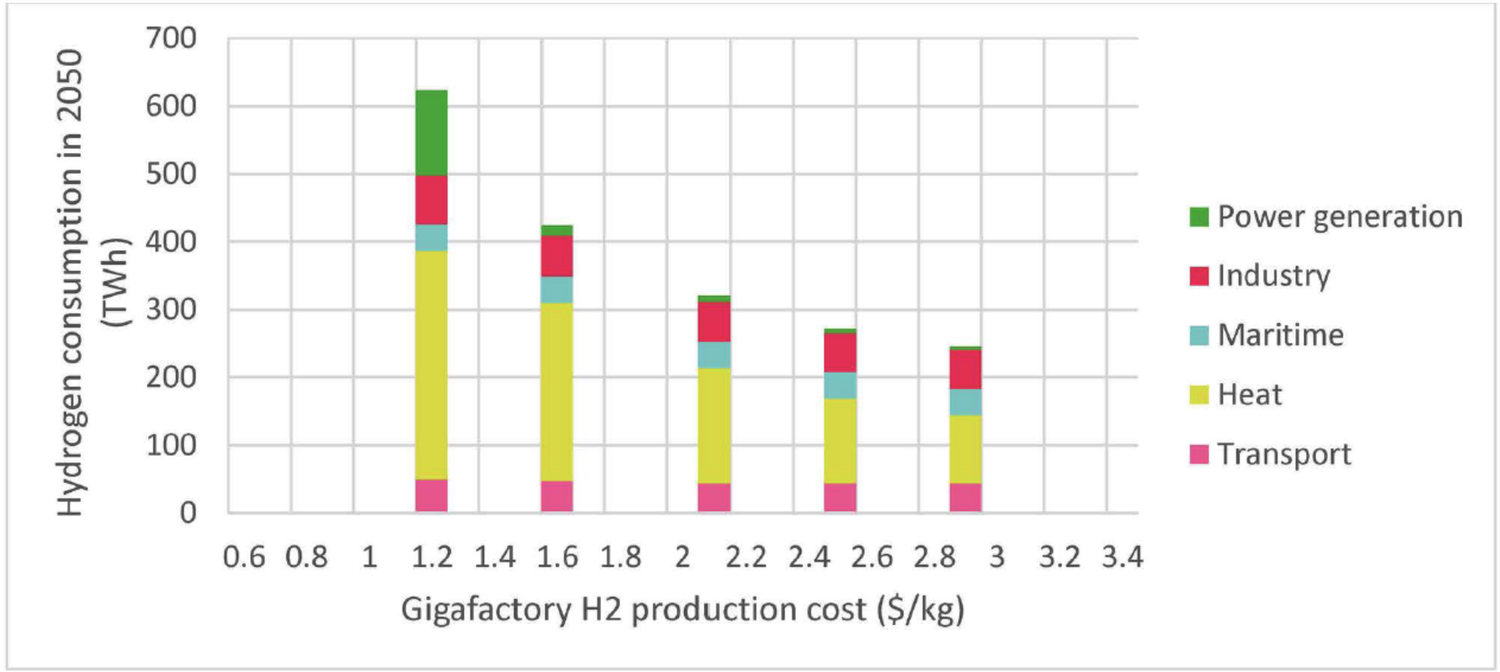


Figure 20 – Hydrogen consumption in 2050 by technology as a function of gigafactory H_2 production cost ($2017)

SYNTHETIC AVIATION FUEL ENABLES RAPID DECARBONISATION

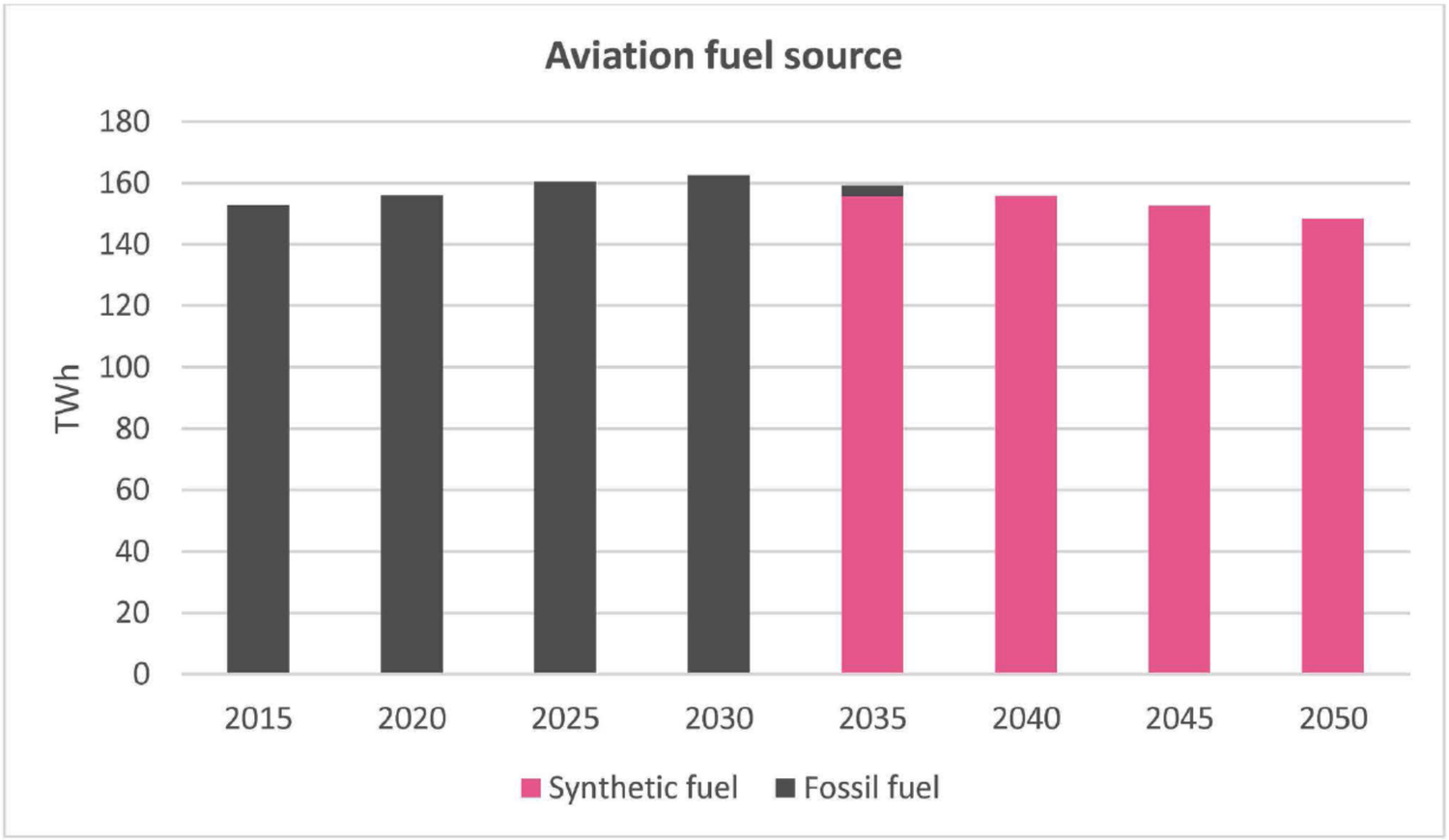


Figure 17 – Sourcing of aviation fuel – Run 310 with hydrogen gigafactory and synthetic fuel plant (TECH100)

SYNTHETIC AVIATION FUEL PRODUCTION AS A FUNCTION OF PRODUCTION COST

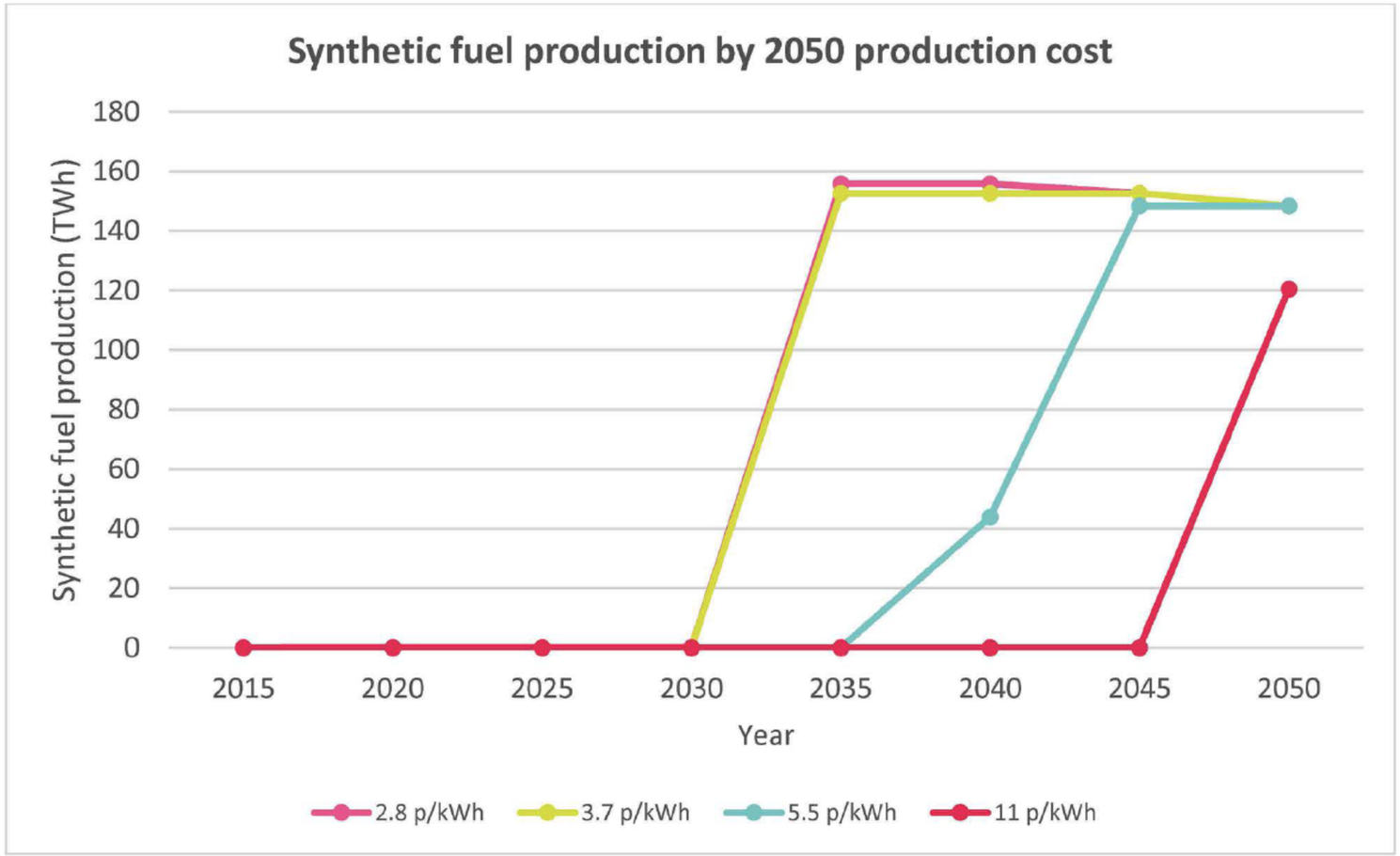
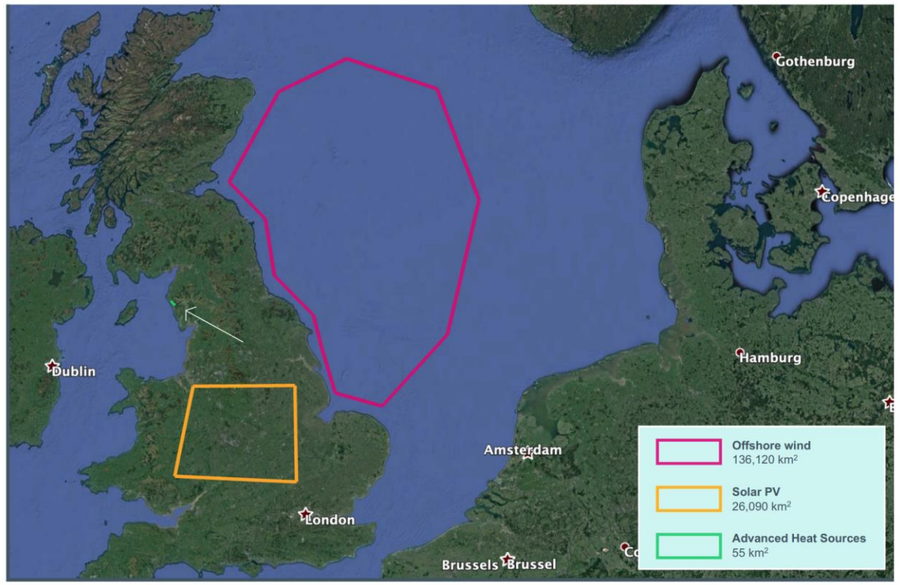
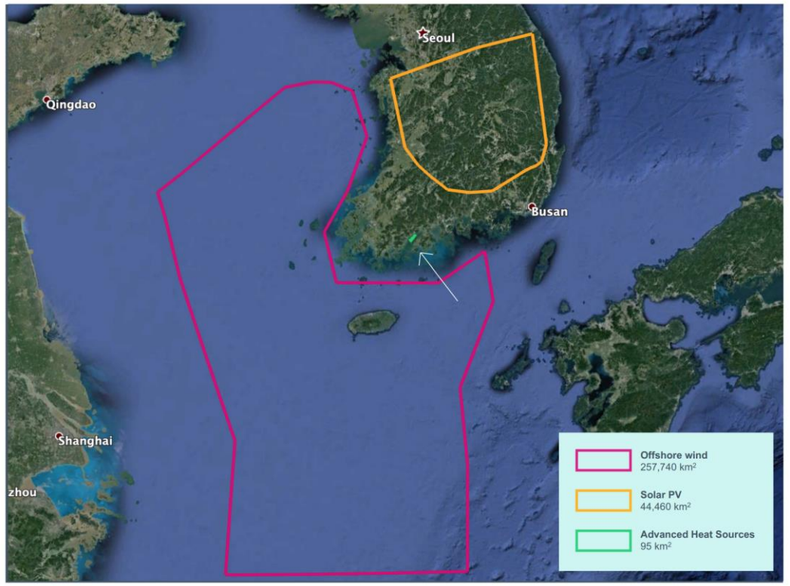


Figure 21 – Liquid synthetic aviation fuel production as a function of production cost (£2010p/kWh)

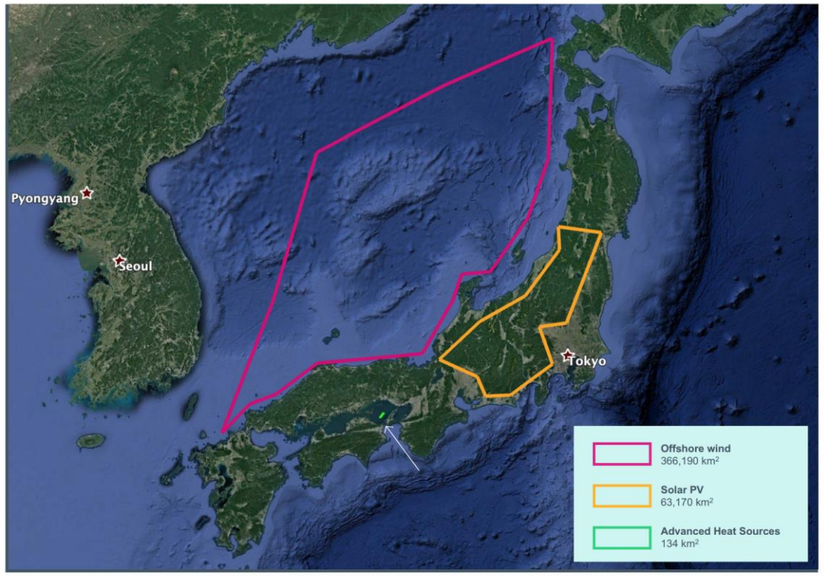
SYNERGETIC WILL DELIVER CLEAN FUELS, COST-COMPETITIVELY, AT THE SCALE OF OIL AND GAS



Each colored outline represents the total area that would be required for the siting of each type of resource if it were to be the only one used to generate enough hydrogen to replace current oil consumption in the UK.



Each colored outline represents the total area that would be required for the siting of each type of resource if it were to be the only one used to generate enough hydrogen to replace current oil consumption in South Korea.



Each colored outline represents the total area that would be required for the siting of each type of resource if it were to be the only one used to generate enough hydrogen to replace current oil consumption in Japan.

IF WE CAN:

Repower 2 TWe of coal

Deliver refinery-scale hydrogen

Substitute 100M barrels of oil per day

WHAT DO WE HAVE?

NEW (NU) PRIMARY ENERGY

FUELLING A LIVABLE CLIMATE