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BEYOND FEASIBILITY: CAPTURING THE ENERGY TRANSITION'S HYDROGEN OPPORTUNITY

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Claire Mack

Chief Executive

Scottish Renewables

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Cromarty Firth and beyond: stepping stones to a new energy system

Chaired by Claire Mack

Chief Executive, Scottish Renewables

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Joanne Allday

Strategic Business Development Manager

Port of Cromarty Firth

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NORTH OF SCOTLAND **HYDROGEN** PROGRAMME

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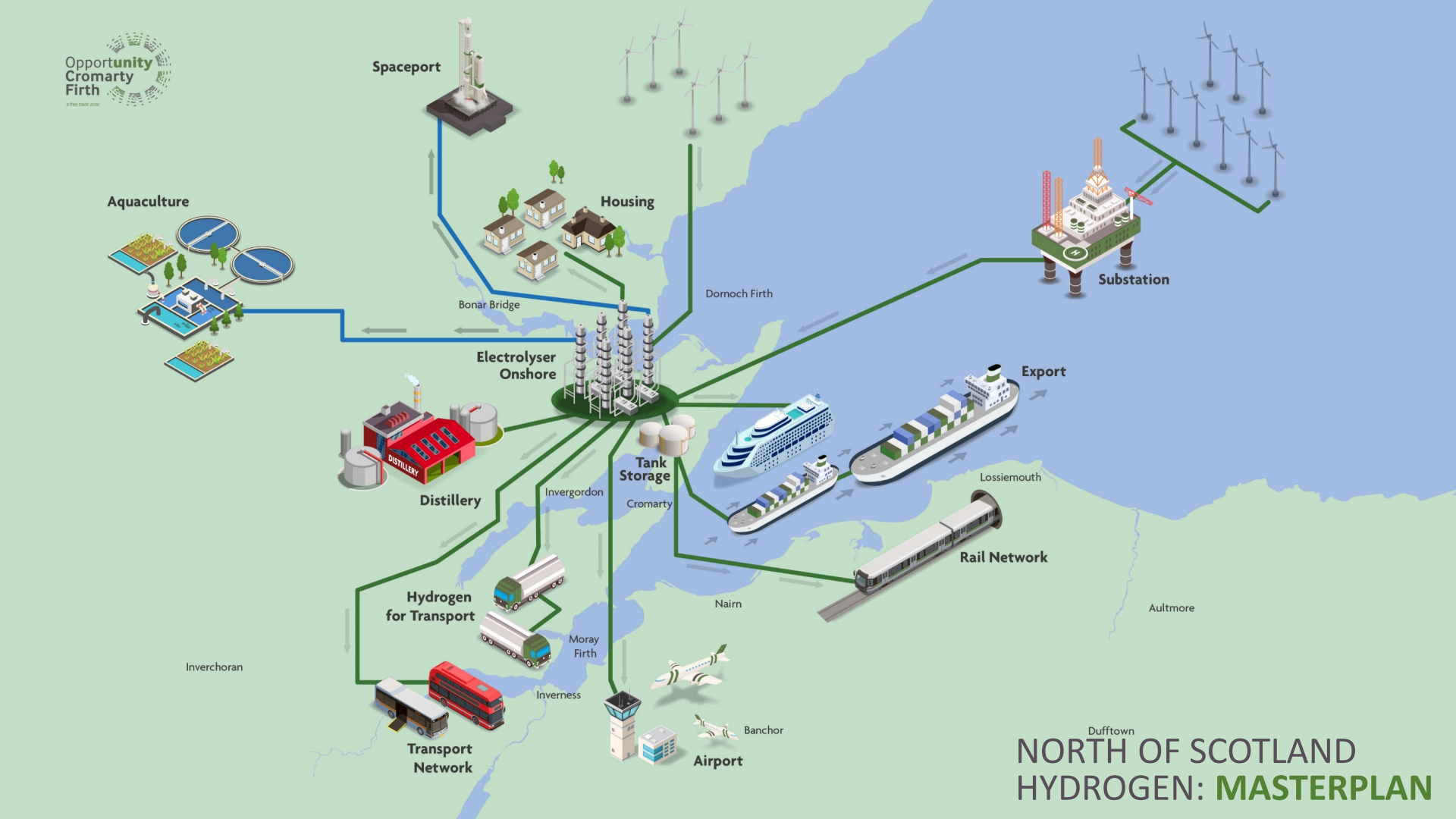
Port of Cromarty Firth, Port Office, Shore Road, Invergordon, IV18 0HD. | Email: info@opportunitycromartyfirth.co.uk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Spaceport
Aquaculture
Housing
Bonar Bridge
Dornoch Firth
Substation
Electrolyser Onshore
Export
DISTILLERY
Distillery
Tank Storage
Invergordon
Cromarty
Lossiemouth
Rail Network
Hydrogen for Transport
Nairn
Aultmore
Moray Firth
Inverchoran
Inverness
Transport Network
Banchor
Airport
Dufftown
NORTH OF SCOTLAND HYDROGEN: MASTERPLAN

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PROOF OF CONCEPT: DISTILLERIES PROJECT

- Principal Project – develop a large scale, on-shore electrolysis facility in the Cromarty Firth to produce, store and supply green hydrogen from renewable power for competitively priced local use and export to other areas/ countries.
- Aim: secure jobs and manufacturing and position Scotland at the forefront of the green hydrogen sector
- Partners are ScottishPower, Glenmorangie, Whyte & Mackay, Diageo, Pale Blue Dot and Port of Cromarty Firth
- Feasibility study privately funded. Sites and technologies short-listed
- Engineering & Design Phase to begin July followed hopefully by phased construction. Aim is production of green hydrogen from 2024.
- Kick-starter for North of Scotland Hydrogen Programme; producing the hydrogen needed (at scale) to supply many of the other projects

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COMPLEMENTARY PROJECTS

- ERM & OGTC Study into the Bulk Marine Transport of Hydrogen
- Hydrogen working group meeting regularly (~40 members)
- GEN2 Energy MoU to provide containerised green hydrogen from 2023
- SGN plans to decarbonise the gas grid and move to 100% hydrogen
- H3: Highland Hydrogen Highway: Refuelling infrastructure for HGVs
- NS HyMap – Hydrogen bunkering and export across the North Sea
- The PowerHouse – R&D and skills / education centre of excellence focused on Floating Offshore Wind (FOW) and Green Hydrogen technologies
- Electrification Projects – Oil & Gas decarbonisation using FOW & hydrogen

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HOW YOU CAN GET INVOLVED

- Hydrogen working group meeting regularly ~40 members
- DeepWind Cluster, inc. Power 2X Sub Group
- PowerHouse working group, including industry workshop to consider gaps in R&D and training provision to accelerate the FOW & Green H2 sectors
  - All of these are free to join and provide opportunities to meet like-minded people and businesses
- Invest in the region – we have a 50-70 year pipeline of offshore wind and hydrogen construction projects. How could you take advantage and create Scottish content and jobs?

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Operations Director, Glenmorangie

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Hydrogen in the real world

Chaired by Nick Sharpe

Director of Communications and Strategy
Scottish Renewables

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Dr Richard Kemp-Harper

Strategy Director

Arcola Energy

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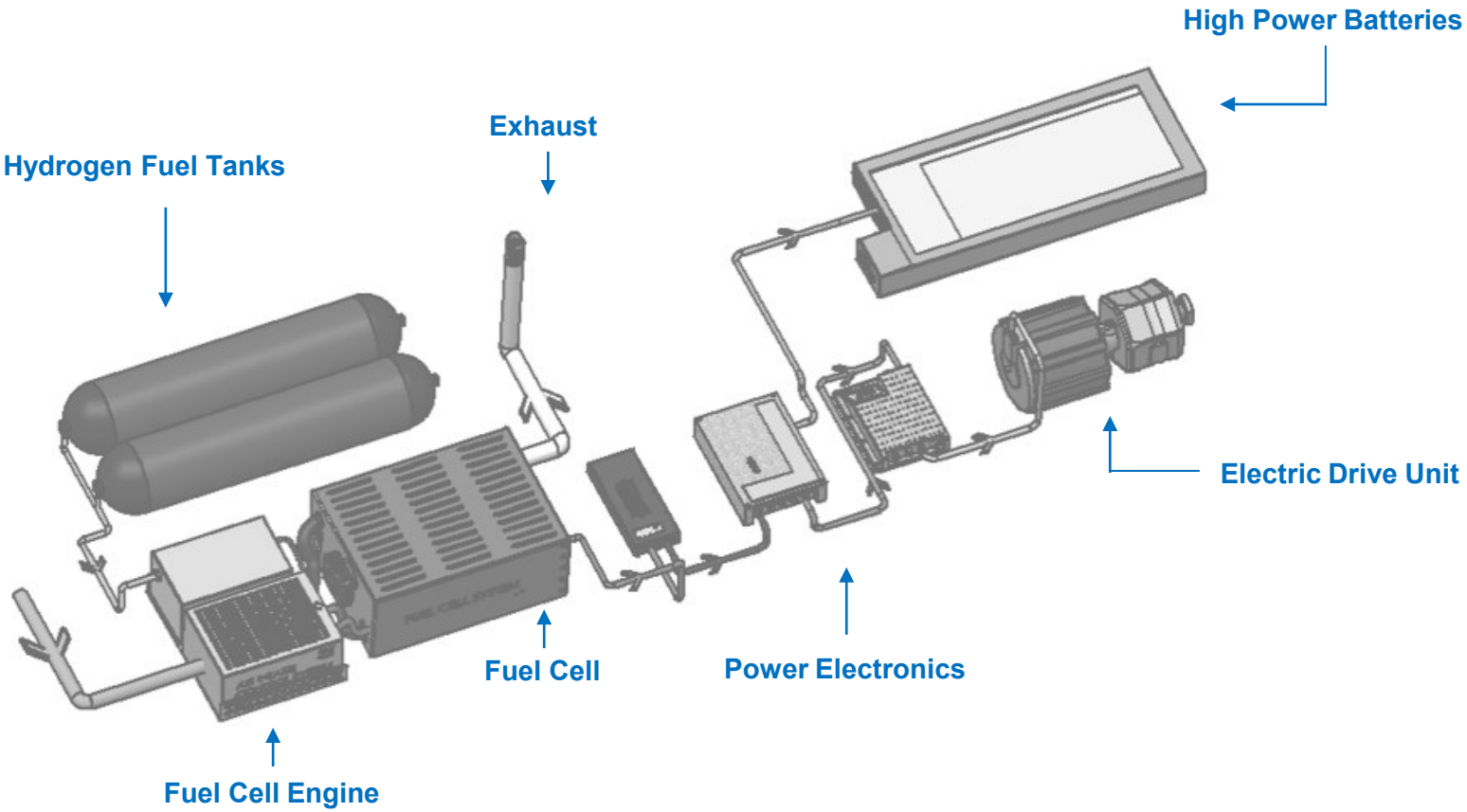
Arcola Energy

A leading UK specialist in hydrogen and fuel cell integration, focused on zero-emission heavy-duty vehicles

A-Drive Technology Platform



Arcola Hydrogen Fuel Cell Powered Double Decker Bus

- Better acceleration than diesel
- >40% more efficient than diesel on an energy basis
- Refuelling in 5–10 minutes
- Efficiency 6–7kg H_2/100km (route dependant)
- 180–240 miles of zero emission range
- Thermal integration with bus heating

ADL adds hydrogen fuel cell tech to the market's widest range of low and zero emission busses

Arcola Hydrogen Fuel Cell Powered RCV

Arcola's RCV solution offers several advantages over electric battery RCVs:

- 100 percent zero-emissions for Low Emission Zones (LEZs) and Clear Air Zones (CAZs)
- Production-ready solution
- Operational range up to 125km, shift duration up to 11 hours between fills
- 10 minute refuelling
- 10 tonne payload
- Max. speed of 90 km/h does not decrease when battery runs down
- Waste heat is recycled for cab heating
- Zero noise pollution

Fully hydrogen powered RCV solution

Arcola Hydrogen Fuel Cell Powered Train

- Scottish Enterprise, Transport Scotland and Hydrogen Accelerator project to support zero-emission railways by 2035
- Arcola Energy and leading rail engineering and safety experts will deliver full system design and integration based on Arcola's A-Drive technology platform.
- A-Drive platform will be extended to meet rail safety and compliance requirements
- Significantly reduces development time and cost to deliver a complete hydrogen powered solution in just 10 months.

Arcola Energy will lead consortium to deliver Scotland's first hydrogen powered train

Repair & Maintenance of Fuel Cell Vehicles

- Specialist technical support and training for early deployments
- Arcola managers and technicians have many years of experience in fleet services and fuel cell vehicle maintenance

Arcola Energy supports the largest fleet of fuel cell commercial vehicles in the UK

Supply Chain Opportunities

Vehicle Opportunities

- Arcola Energy specific supply chain for core powertrain systems
- Arcola Energy and general supply chain for fabrications and ancillary equipment to support repowering
- General supply chain for train refit not associated with repowering

www.arcolaenergy.com

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Judith Balfour

Programme Manager

First Group

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Aberdeen Hydrogen Buses

June 2021

The Project

- 15 hydrogen fuel cell vehicles
- Vehicles leased and operated by First Bus
- Funded by The Scottish Government, Joint Initiative for Hydrogen Vehicles (JIVE), Fuel Cells and Hydrogen Joint Undertaking (FCH) and Aberdeen City Council
- Fuelled off site at Council refueling facility

Hydrogen-specific requirements

- Hydrogen availability
- Depot alterations
- Risk assessments
- Operational procedures
- Schedules
- Freeze protection
- Connectivity
- Training Qualifications
- Blue light services

Achievements

- 15 hydrogen vehicles running in Aberdeen
- Switching to zero emission bus saves 1 kg of CO2 per km
- Guaranteed price per kg of hydrogen
- Integrated approach
- New technology and enhanced training for employees
- Digital launch

Future

- Vehicle monitoring
- JIVE Customer survey commenced
- More vehicles?
    I. Driving a lower unit cost
    II. Public sector support
    III. Hydrogen supply

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Ed Macfarlane

Principal Consultant

Abbot Risk Consulting

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Scottish Renewables – 17th June 2021

An Introduction to Hydrogen Safety

Ed Macfarlane

Lessons Learned and Challenges

- General points are:
  - Hydrogen is not ‘new’, has had wide use historically, what is new is the areas of application
  - Legislation, standards and guidance are developing in parallel to deployments. The sector is learning by doing
  - ‘Just working to the standard / best practice’ is not a viable apart from for very simple systems
  - Sector specific standards may not exist, considered use of nearest comparable sector is a frequent approach
  - Three broad categories to think of (onshore!):
    - > 2 tonne hazardous planning limit
    - > 5 tonne lower tier COMAH limit
    - > 50 tonne upper tier COMAH limit
  - All appropriate general Health and Safety at Work legislation will still apply

Lessons Learned and Challenges

- Hydrogen Specific Safety Considerations
  - Low density - most practical systems are 350 bar to 750 bar range
  - Low viscosity – it leaks really easily
  - High diffusivity – can migrate through volumes and materials
  - Embrittlement – can affect materials it is contained/transferred in
  - High buoyancy – it will go up!
  - Wide flammability range – 4% to 75% by volume
  - Low ignition energy – it will probably ignite, just a matter of whether it is delayed
  - Invisible flame – burns in the UV range BUT doesn't radiate much heat
  - Rapid burning rate – delayed ignition can undergo Deflagration to Detonation Transition (DDT) – avoid Congestion and Confinement
  - Liquid hydrogen – cryogenic hazards, including potential for LOX
  - Liquid Organic Hydrogen Carriers (LOHC) – have specific chemical considerations

Lessons Learned and Challenges

- Hydrogen Systems
  - Plenty of standards for individual items of kit / components
  - But need to consider ‘whole system’ and the integration of components / kit AND how they will be operated and maintained
  - Supply chain challenges
    - Installers / maintainers are sparse and often based in geographical locations remote from items
    - Deployments are spread out and often remotely monitored
    - Skills from adjacent sectors (e.g. O&G) whilst relevant are not directly transferrable, need training and familiarisation


Gangneung,
Korea
23rd May 2019

Principal Legislation and Standards

- NB this is not a complete list
- Legislation (UK) – NB not complete and would need to be reviewed for specific application and most current updates/versions. Just a sample!
  - Pressurised gas
    - Pressure Equipment (Safety) Regulations 2016
    - Pressure Systems Safety Regulations 2000
    - Pressure Equipment Regulations 1999 (As Amended)
    - Transportable Pressure Vessels Regs 2001
  - Flammable / Explosive Materials
    - Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002
    - Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016

Principal Legislation and Standards

- Legislation (UK) – NB not complete and would need to be reviewed for specific application and most current updates/versions
  - Chemicals
    - Control of Substances Hazardous to Health Regulations 2004 (As Amended)
    - Amending Regulation (EC) No 1907/2006 Registration, Evaluation, Authorisation and Restriction of Chemical Substances (REACH)
  - Transport
    - Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009
    - Dangerous Goods in Harbour Areas Regulations 2016

Principal Legislation and Standards

- Standards – NB these are hydrogen specific ones, other generic gas standards, and other appropriate safety standards, are still applicable
  - BS EN 62282-6-100:2010+A1:2012 Fuel cell technologies. Micro fuel cell power systems. Safety
  - BS ISO 16110-1:2007. Hydrogen generators using fuel processing technologies. Safety
  - BS EN 62282-3-300:2012 Fuel cell technologies. Stationary fuel cell power systems. Installation
  - BCGA – CP33 – Bulk Storage of Hydrogen
  - BCGA – CP46 – The Storage of Cyrogenic Flamable Liquids
  - NFPA 853: 2020. Standard for the Installation of Stationary Fuel Cell Power Plants. National Fire Protection Association.
  - CGA G-5.4. Standard for Hydrogen Piping Systems at Consumer Sites. Compressed Gas Association.
  - CGA G-5.5. Hydrogen Vent Systems. Compressed Gas Association.
  - ASME B31.12 - 2019 Hydrogen Piping and Pipelines. American Society of Mechanical Engineers.
  - IGC Doc 100/03/E. Hydrogen cylinders and transport vessels. European Industrial Gases Association.
  - ANSI/AIAA G-095-2004. Guide to Safety of Hydrogen and Hydrogen System. American National Standards Institute/American Institute of Aeronautics and Astronautics.
  - ISO/TR 15916:2015 Basic considerations for the safety of hydrogen systems
  - NFPA 50A. Standard for gaseous hydrogen system at consumer sites. National Fire Protection Association
  - IGC Doc 15/06/E. Gaseous Hydrogen Stations. European Industrial Gases Association.

Guidance Sources

- HSE – dedicated hydrogen pages and multiple Research Reports:
  - HSE: Current issues - Hydrogen economy - Horizon scanning
  - Health and Safety Laboratory - Hydrogen Safety
  - Safe Net Zero 2021 – Hydrogen - Online (hsl.gov.uk)
  - RR715 - Guidance for hydrogen and fuel cell stationary applications
  - RR1047 - Injecting hydrogen into the gas network
  - RR1159 - Research Priorities Workshop
  - RR769 - Hazards of liquid hydrogen: Position paper
  - RR987 - Ignited Releases of Liquid Hydrogen
  - RR985 - Modelling of liquid hydrogen spills
  - RR986 - Releases of unignited liquid hydrogen

Guidance Sources

- UK
  - SHFCA
  - Home - British Compressed Gases Association (BCGA)
- Europe
  - Hydrogen Europe | H2: enabling a zero-emission society
  - www.fch.europa.eu
  - Welcome to the HyResponse project's website
  - Home | HyLAW Online Database
  - Introduction to Hydrogen Safety Engineering
- International / US
  - Fuel Cell & Hydrogen Energy Association (fchea.org)
    - Hydrogen Fuel Cell Codes & Standards (fuelcellstandards.com) (FCHEA)
  - International Association for Hydrogen Safety – focussed on integrated research and information
  - The International Association for Hydrogen Safety (hysafe.org)

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Matt Bird

CEO & Co-Founder

Supercritical

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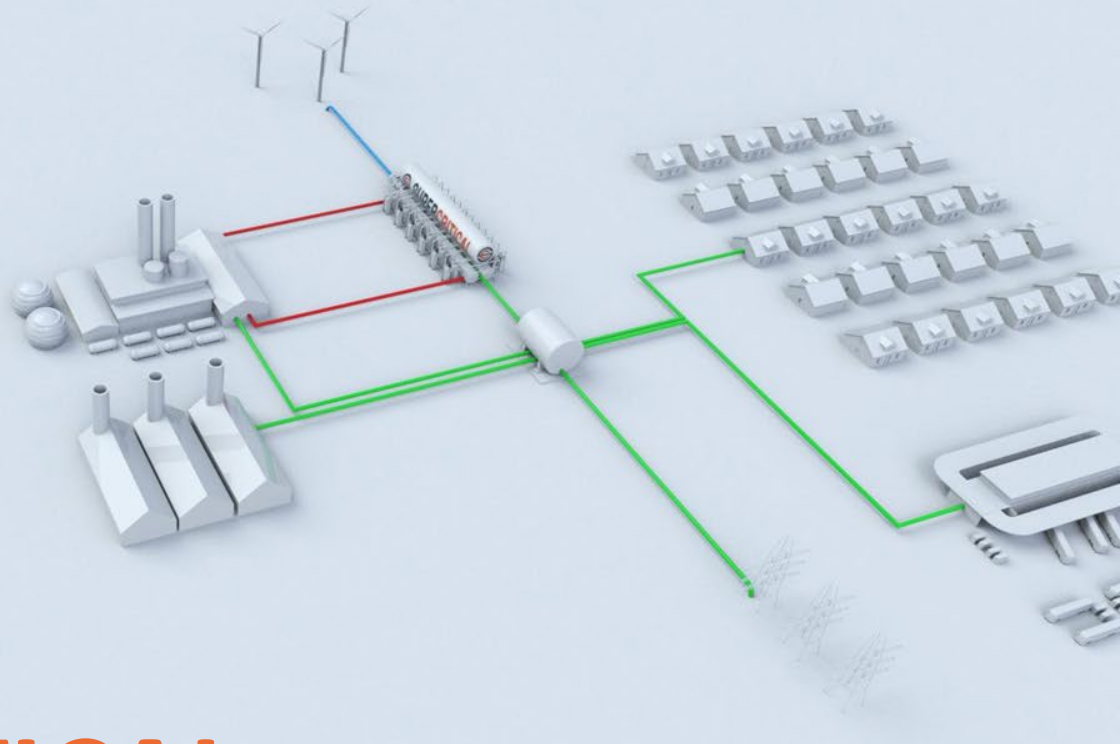


SUPERCRITICAL

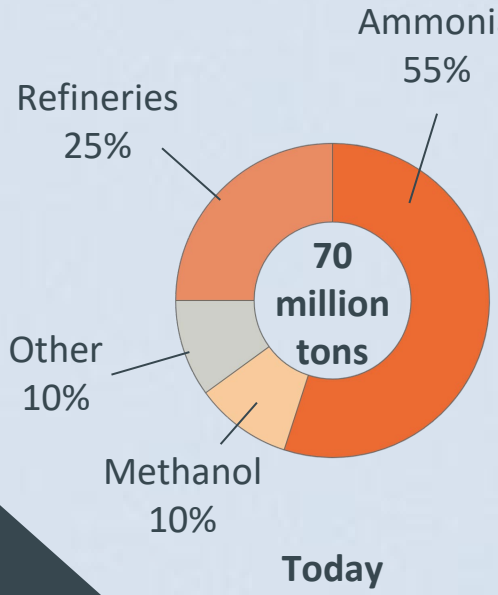
Developing the world's first high pressure, ultra-efficient electrolyser

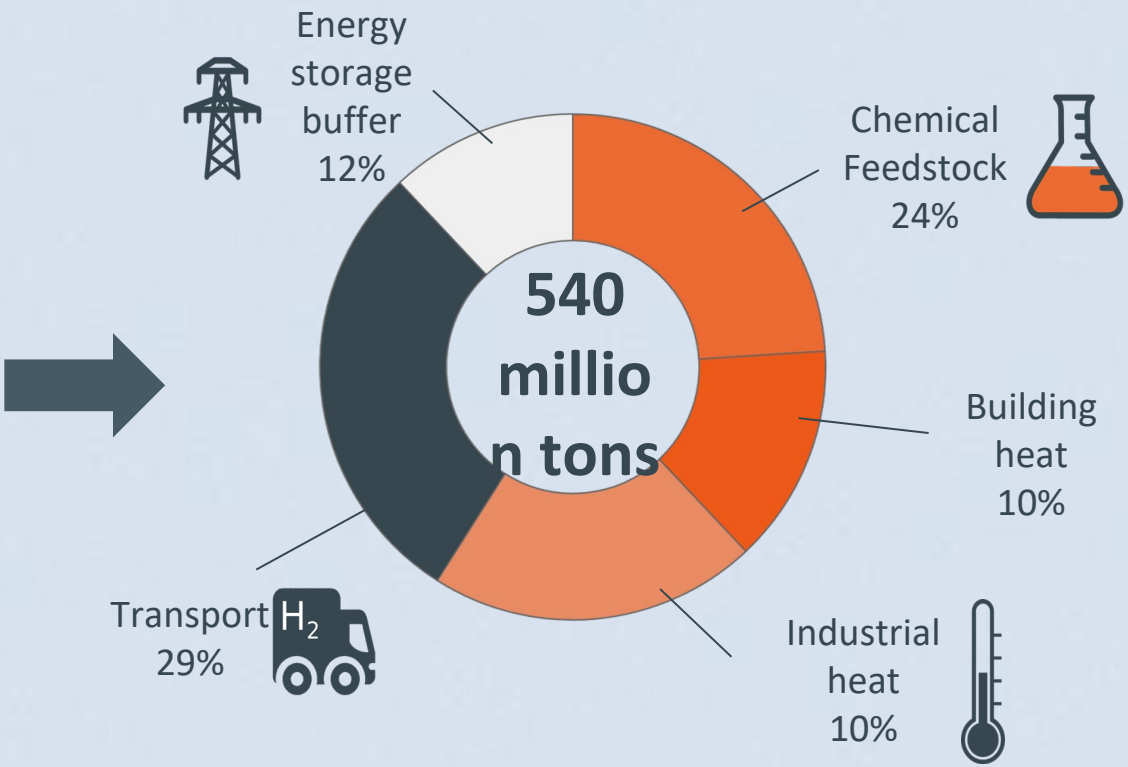
VISION

Affordable clean Hydrogen would eliminate the 742 million tonnes of CO_2 emitted by Fossil Hydrogen each year and could completely decarbonise the world's hard to abate industrial, chemical and heavy transport sectors, who emit more than 10 billion tonnes of CO_2 each year.

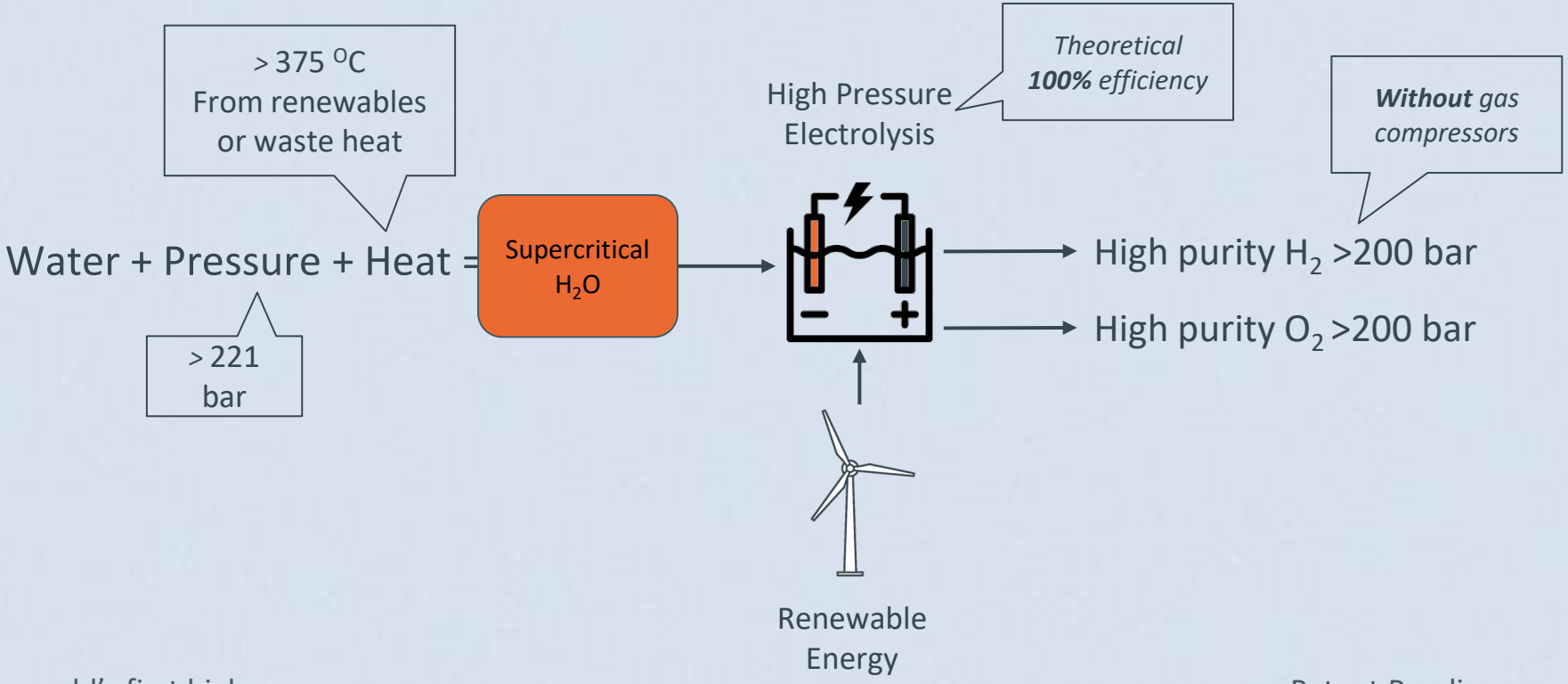
HYDROGEN MARKET

-70 million tons of hydrogen is produced annually worldwide, worth -**£144 billion** but forecast to grow 8 fold over the next 30 years, driven by a global need to decarbonise.





WHAT IS SUPERCRITICAL DEVELOPING?



The world's first high pressure, ultra-efficient electrolyser

Patent Pending on cell design

ELECTROLYSER SUPPLY CHAIN

Components

- Pumps
- Heaters
- Heat Exchangers
- Instruments
- Sensors
- Valves
- Storage Tanks
- Catalysts
- Water Treatment
- Electrical
- Control Systems

Solution Design

- Engineering design and sizing
- Storage sizing
- Renewable evaluation
- Hazid Identification
- Hazop System design

Manufacturing and Assembly

- Welding
- Bending/Forming
- Precision machining
- Testing & QA
- Control Systems
- Electrical Systems

Installation and Commissioning

- Logistics
- Ground Works
- High Voltage Electrical
- High Pressure
- Medium Temperatures
- H_2 and O_2

Operation and Maintenance

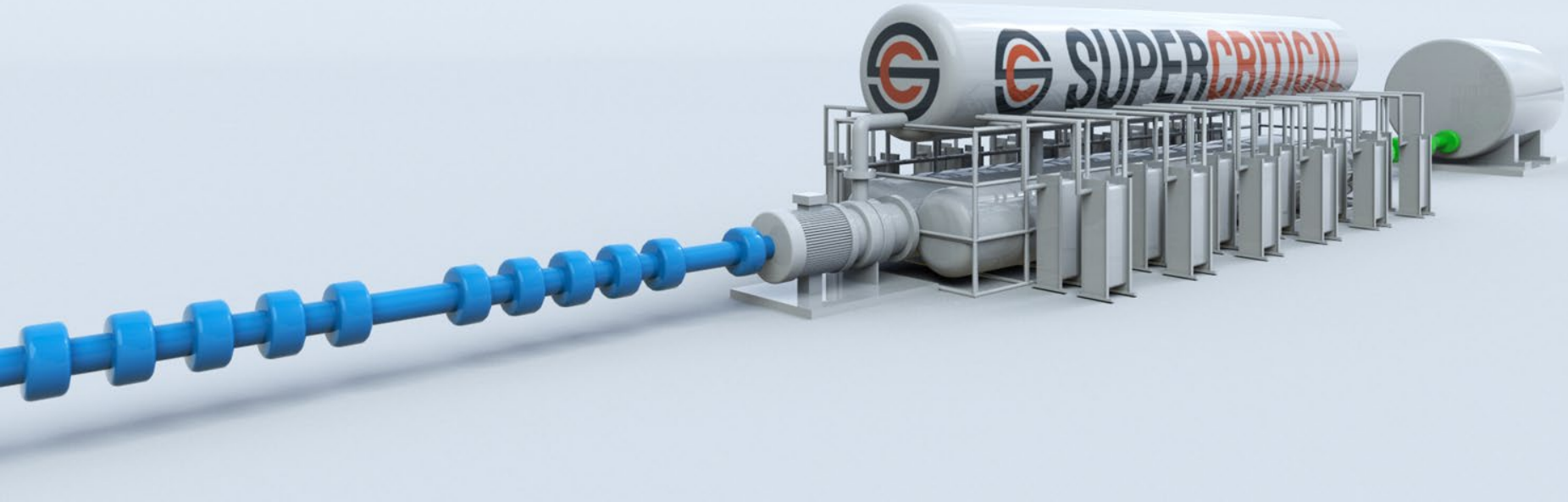
- Inspection
- Remote Monitoring
- H&S
- Emergency Response
- Offtaker logistics

Decommissioning

linkedin.com/company/supercritical-solutions

contact@supercritical.solutions

www.supercritical.solutions



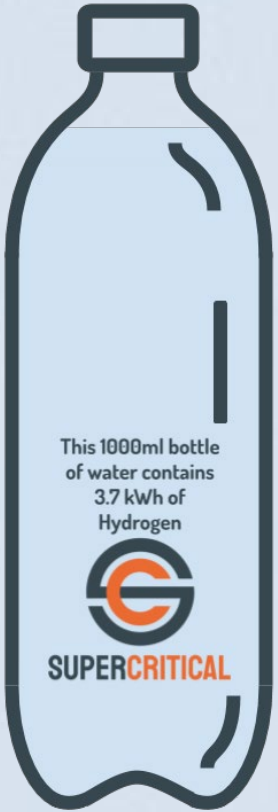
SINGLE LITRE OF WATER

1 Litre of water contains 111.11g of hydrogen, which has **3.7kWh of energy!**

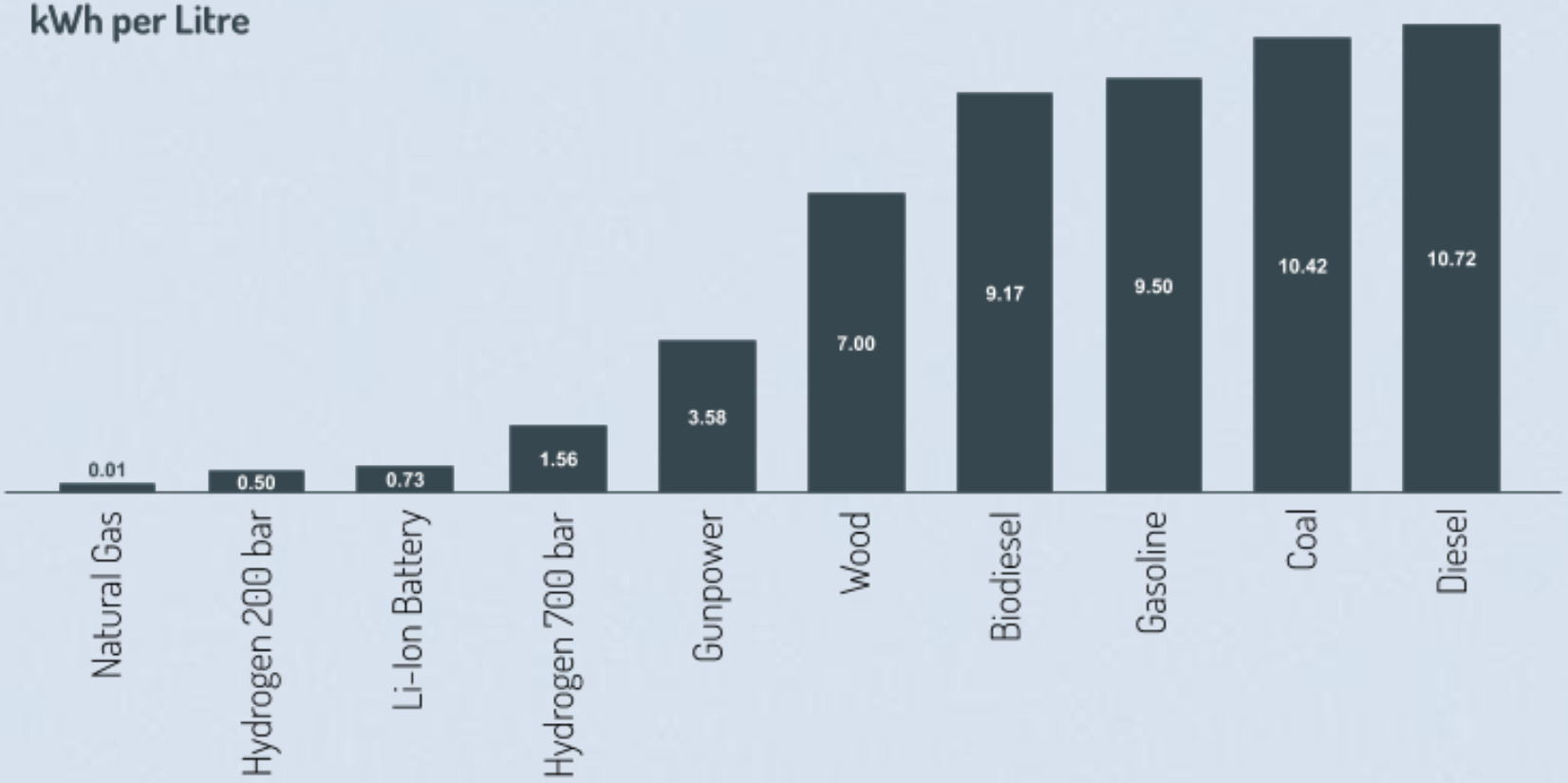
If you could get all that energy out, that would be enough energy to travel 7 miles in a fuel cell electric vehicle (double the distance of your traditional petrol/diesel car).

The equivalent water used in a 2 minute shower in the morning, contains enough hydrogen for a whole day's hot water and heating in the average natural gas powered home (80% of UK homes use natural gas for heating and hot water).

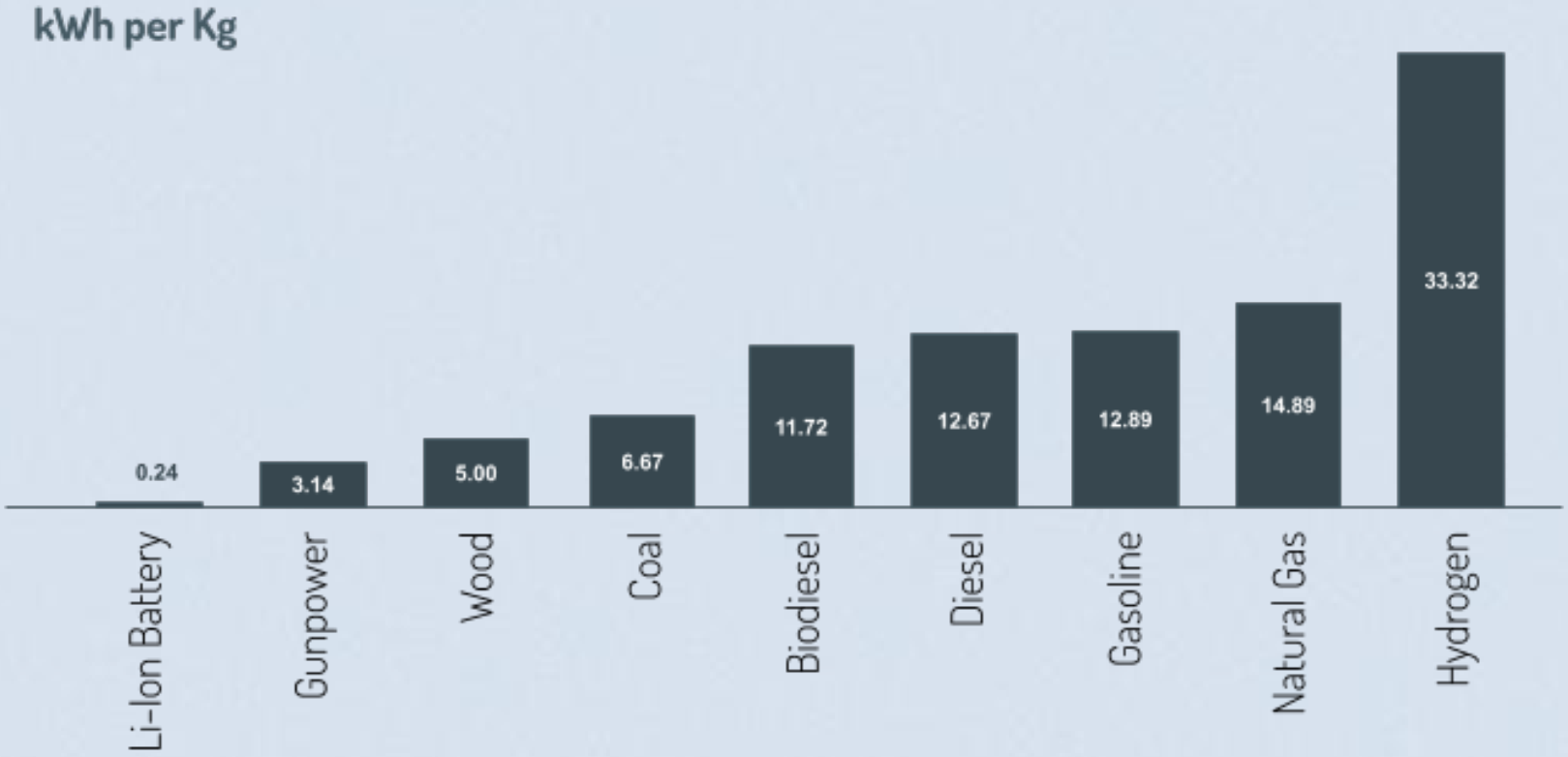
However, traditional electrolysers are inefficient. They effectively convert 3.7kWh of electricity into 2.27KWh of hydrogen.



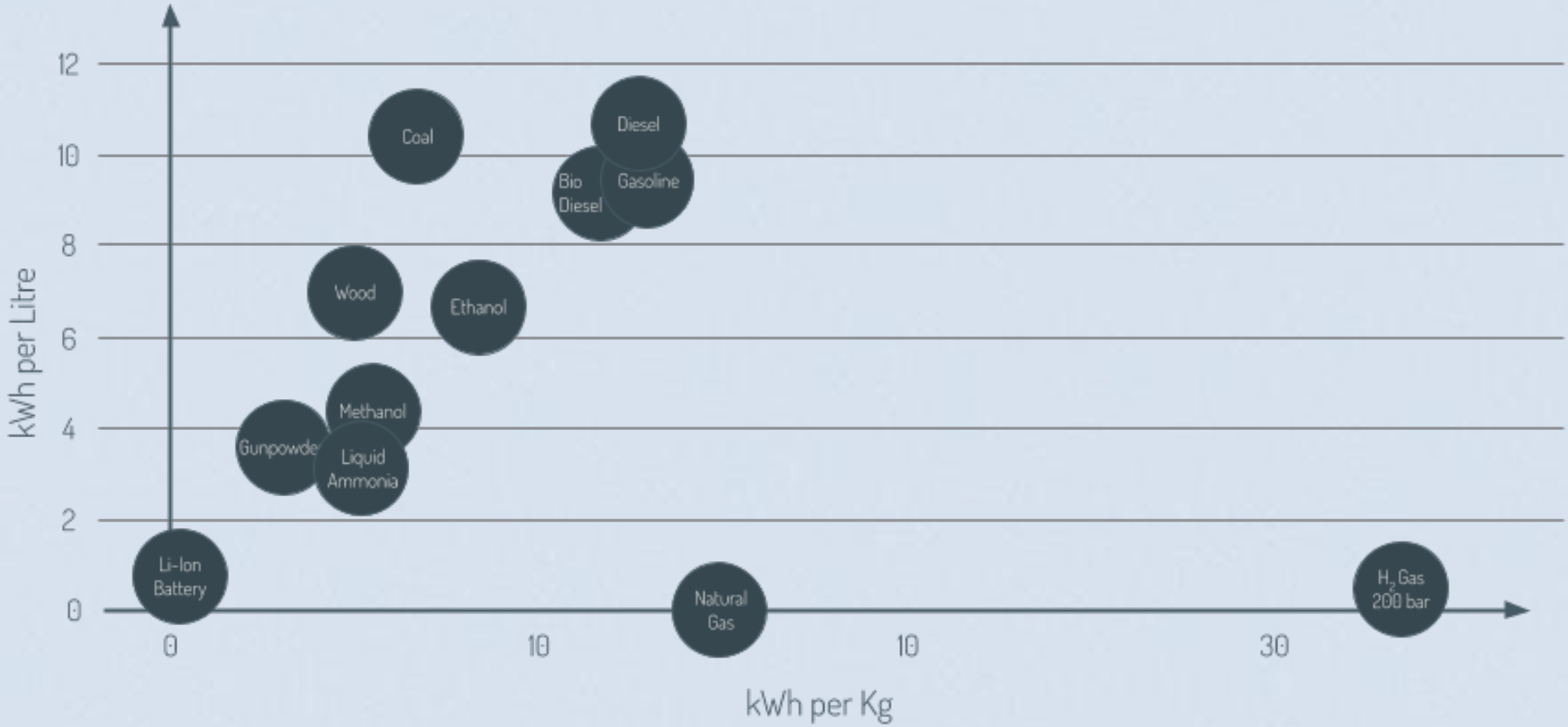
ENERGY DENSITY BY VOLUME



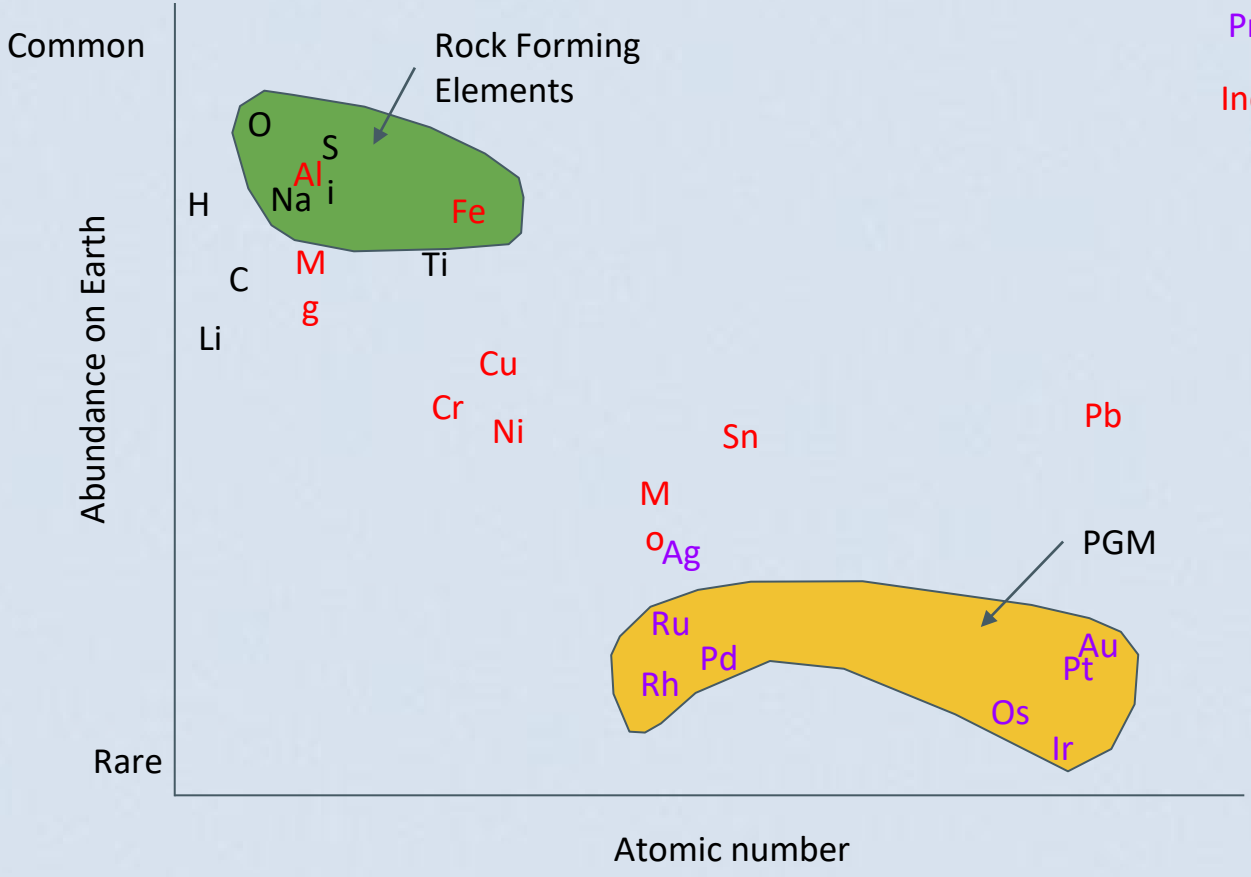
ENERGY DENSITY BY WEIGHT



ENERGY DENSITY



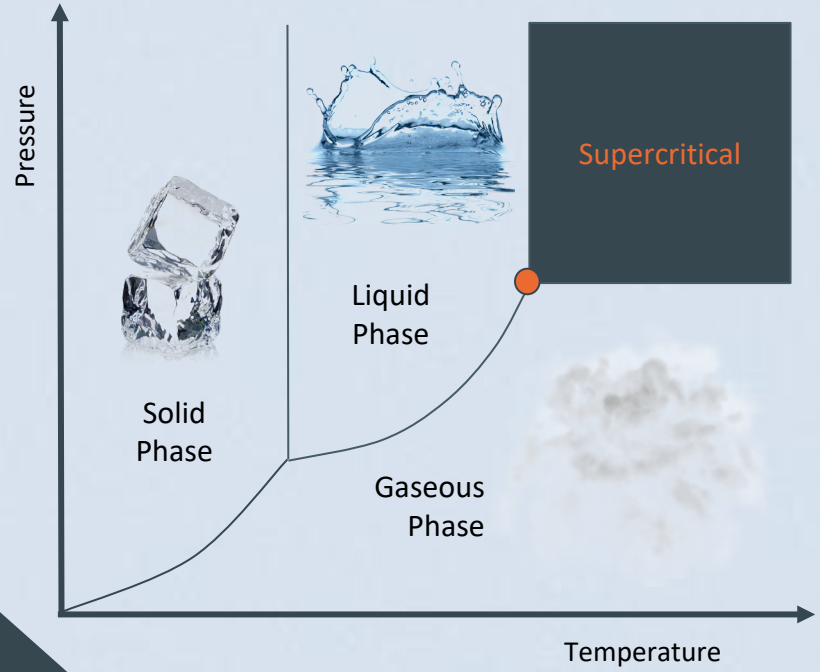
ELEMENTS IN THE EARTH'S CRUST



Precious metals

Industrial metals

SUPERCRITICAL WATER



Supercritical is the fourth state of water, not gas, liquid or solid…

In this state the properties change and if you have the right knowhow you can exploit these.

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