Climate-Scale Solutions with Nuclear-Produced Hydrogen: Net-Zero Carbon Synthetic Fuels

Presented by the Clean Energy Ministerial's Nuclear Innovation: Clean Energy Future (NICE Future) initiative and the Hydrogen Initiative (H2I)

HYDROGEN INITIATIVE

AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

NICE Future

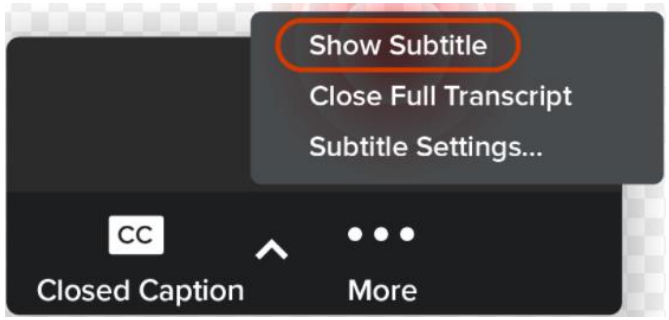
Nuclear Innovation: Clean Energy Future

An Initiative of the Clean Energy Ministerial

Today's Webinar

Audio & Video, Recording, Subtitles:

- All Attendees are in listen-only mode (no audio, no video)
- We will be recording today's webinar
- Closed captioning is enabled. Attendees may choose to turn on subtitles.



For Technical Issues during webinar:

- "Raise Hand" and Dylan Adler will respond to you directly via chat

Audience questions: Click the "Q&A" button to open the dialogue box.

International Efforts—Nuclear Innovation: Clean Energy Future (NICE Future), an initiative of the Clean Energy Ministerial (CEM)

NICE Future
Nuclear Innovation: Clean Energy Future

The NICE Future initiative explores the potential for nuclear energy uses, innovations, and greater systems integration to accelerate progress toward clean energy goals. The initiative recognizes there is no one-size-fits-all solution to energy and fosters collaboration among clean energy supporters in exploring diverse solutions.

Lead Countries


Canada


Japan


USA

Participant Countries


Argentina


Poland


Romania

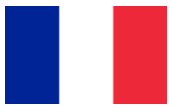

Kenya


Jordan


Russia


UAE


UK


France


Brazil

Focus Areas

Exploring innovative applications for advanced nuclear systems both electric and non-electric.

Pooling experience on economics, including valuation, market structures, and ability to finance.

Engaging policy makers and stakeholders regarding energy choices for the future.

Communicating nuclear energy's role in clean integrated energy systems and developing the nuclear workforce of the future.

External Partners

International Energy Agency
OECD Nuclear Energy Agency
International Atomic Energy Agency
International Framework for Nuclear Energy Cooperation
Generation IV International Forum
ClearPath
Third Way
Energy for Humanity
Energy Options Network
Women in Nuclear Global
International Youth Nuclear Congress
Nuclear Industry Council
Nuclear Energy Institute
World Nuclear Association
American Nuclear Society
Electricité de France

For more information, visit nice-future.org

CEM's HYDROGEN INITIATIVE (H2I)

HYDROGEN INITIATIVE
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

OBJECTIVE

To raise international ambition and advance commercial scale low-carbon hydrogen deployment in the long-term globally, across all sectors .

RATIONALE

There is a need for long term plans, vision and goals in giving direction to hydrogen uptake and to enable effective planning and development of consistent policies.

AMBITION/TARGET

To build strategic partnerships to develop and facilitate global actions on clean hydrogen and fuel cell deployment across regional, national, and municipal economies.

ACTORS

Co-Leads:

Participants:

- Around 25 governments are part of the network.
- Hydrogen Council and individual companies part of the discussion
- 50+ port association and authorities
- Coordination with other international H2 initiatives a priority.

ACTIONS

- Global aspirational goals
- Global Ports Hydrogen Coalition
- H2 Twin cities programme
- International hydrogen trade and supply-chains
- North-Western Europe hydrogen market coordination
- IEA Global Hydrogen Review tracking policies and markets

Nuclear Hydrogen Production: Opportunities and Policies for a Zero Carbon Option

Presented at the Clean Energy Ministerial (CEM)
NICE Future Webinar

Carlos Leipner
Director, Global Nuclear Energy Strategy
Clean Air Task Force

Elina Teplinsky
Partner
Pillsbury Winthrop Shaw Pittman LLP

Nuclear Hydrogen Initiative

June 29, 2022

NHI Mission Statement

The production of large-scale zero carbon hydrogen and ammonia present tremendous opportunities to achieve the levels of deep decarbonization needed to meet climate change targets. Nuclear technologies have the potential to produce hydrogen at high efficiency and capacity factors and at the scale required for deep decarbonization without the space constraints. This goal of this initiative is to:

- Further raise awareness as to the role that nuclear technologies could play in creating a large-scale zero-carbon market
- Craft and work with other stakeholders to advance policy recommendations and solutions
- Address technical and regulatory challenges and facilitate the development of nuclear hydrogen demonstrations across technologies
- Catalyze commercial partnerships to enable nuclear hydrogen demonstrations and projects
- Involve the financial community in building nuclear hydrogen solutions and innovative structures for financing new projects

Policy Working Group

Objective: Ensure that hydrogen production from nuclear power is included in hydrogen roadmaps, energy resource planning and other government energy and decarbonization policies.

Activities to Include:

- Develop policy recommendations and specific proposals
- Engage with decisionmakers at various levels of government(s) regarding these proposals to support meaningful implementation of nuclear H2 production capabilities across several jurisdictions
- Engage with other stakeholders to collaborate on advocacy initiatives

Technology, R&D and Licensing Working Group

Objective: Evaluate technical and regulatory solutions for H2 generation from nuclear technologies for low and high temperature electrolysis and thermochemical production

Activities to Include:

- Identify technical challenges, develop recommendations to address these challenges and develop recommendations and implementation plans for potential pilot programs to demonstrate the potential of the technologies available
- Identify key licensing challenges and regulatory requirement issues to be addressed through the various development phases from conceptual, testing to commercialization

Market and Commercial Partnerships Working Group

Objective: Develop a better understanding of key H2 markets including various segments (shipping, transport, industrial among others) and facilitate partnerships for nuclear H2 production in these markets

Activities to Include:

- Review and identify key global market opportunities
- Craft ideas on potential commercial partnerships and recommendations on how these can be structured
- Develop and implement strategies on informing key players in each of these markets of the potential of nuclear technologies to produce cost-efficient zero carbon hydrogen and ammonia and catalyzing commercial partnerships for nuclear zero carbon fuel production

Finance Working Group

Objective: Facilitate pathways for financing nuclear H2 generation projects including pilot/demonstration programs

Activities to Include:

- Engage stakeholders in the global financial community
- Develop recommendations to alternative models to enable practical and innovative financing of nuclear H2 generation projects including pilot/demonstration programs
- Consider different phases/stages of H2 generation projects including pilot/demonstration programs and potential different ownership/operation models

NHI PARTICIPANTS

Academia

- Ontario Tech University

Advanced Reactor Vendors

- AKME-Engineering
- Core Power
- General Fusion
- Oklo
- Terrestrial
- Ultra Safe Nuclear Corp (USNC)
- X-Energy

Consultants

- Murphy Energy Consulting & Infrastructure
- NucAdvisor
- Pillsbury Winthrop Shaw Pittman
- Qvist Consulting
- Resolute Strategies

Electric Utilities

- Arizona Public Services
- Eletronuclear
- Entergy

EPC & Engineering Service Providers

- Dominion Engineering
- Jensen Hughes
- KBR
- Sargent & Lundy
- Tecnatom
- Teledyne Brown
- Tractebel / Engie
- Worley

Government

- Canadian Nuclear Laboratories
- Idaho National Lab
- National Nuclear Laboratory

Hydrogen End-Users

- Nikola

Hydrogen Supply Chain

- Cummins
- Itochu International
- Nel Hydrogen
- Siemens

Industry Associations

- Nuclear Energy Institute
- World Nuclear Association
- ABDAN

International Organizations

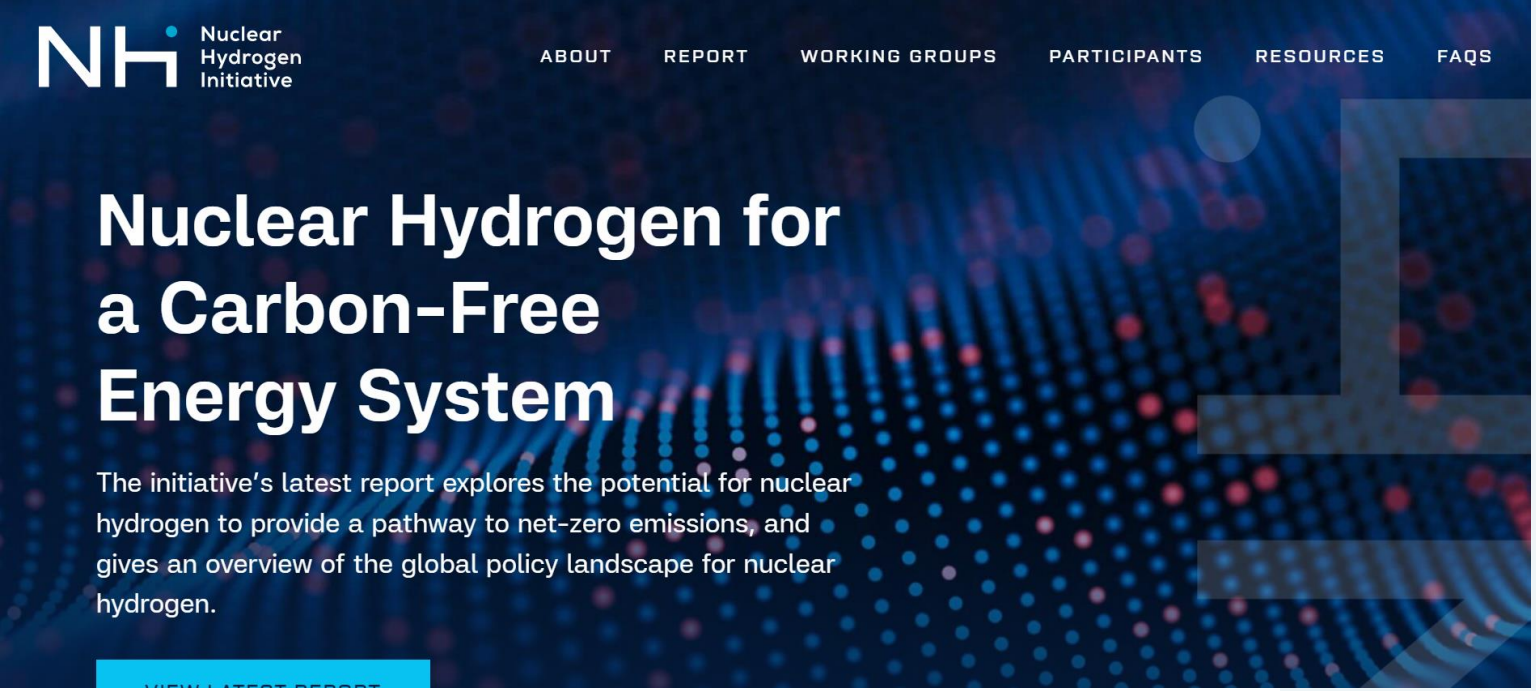
- International Atomic Energy Agency (IAEA)

NGOs / Charitable Foundations

- Clean Air Task Force
- ClearPath
- Electric Power Research Institute (EPRI)
- Global America Business Institute
- New Nuclear Watch Institute
- Nuclear Innovation Alliance
- ThinkAtom

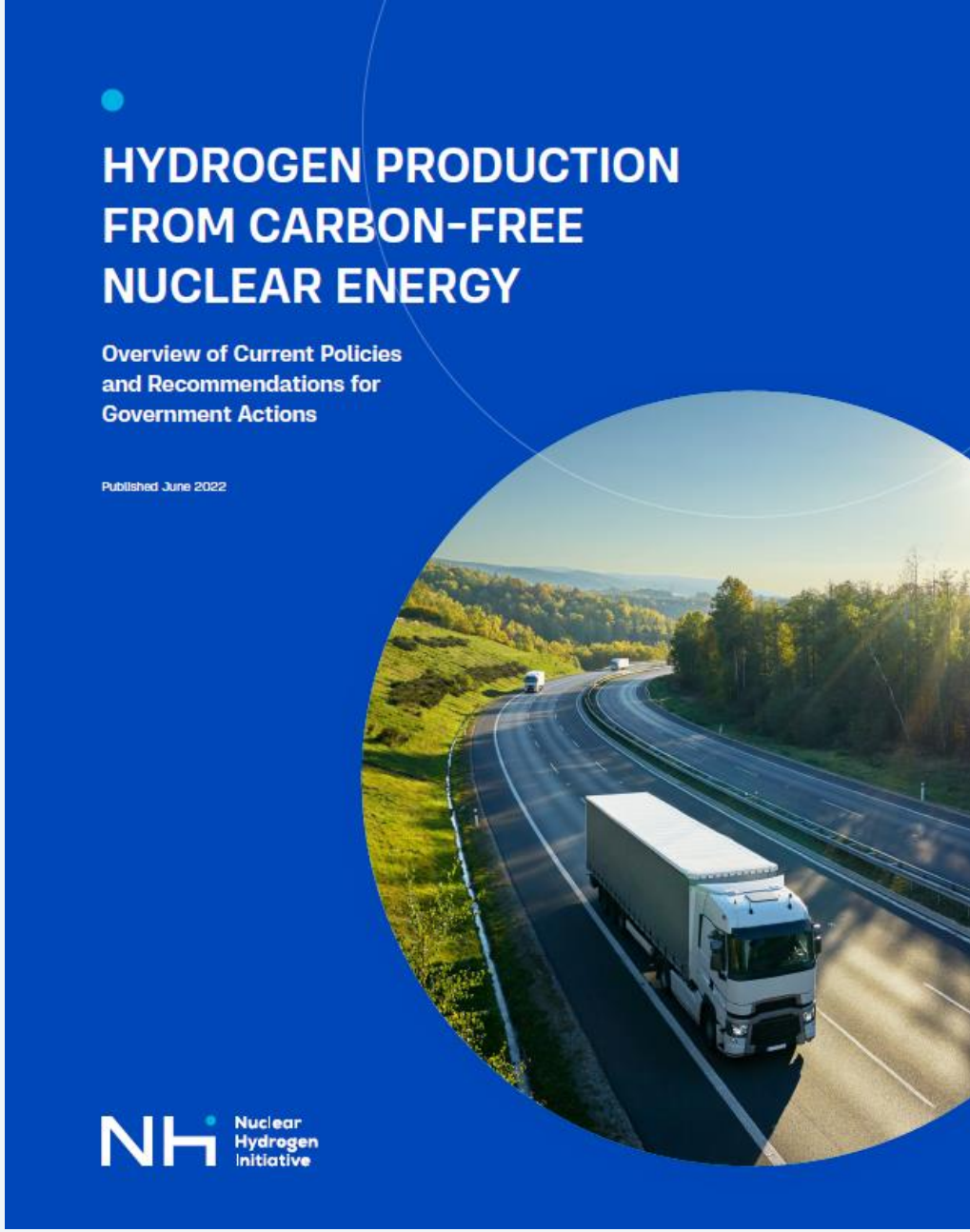
Nuclear Reactor & Equipment Suppliers

- Curtiss Wright
- Framatome

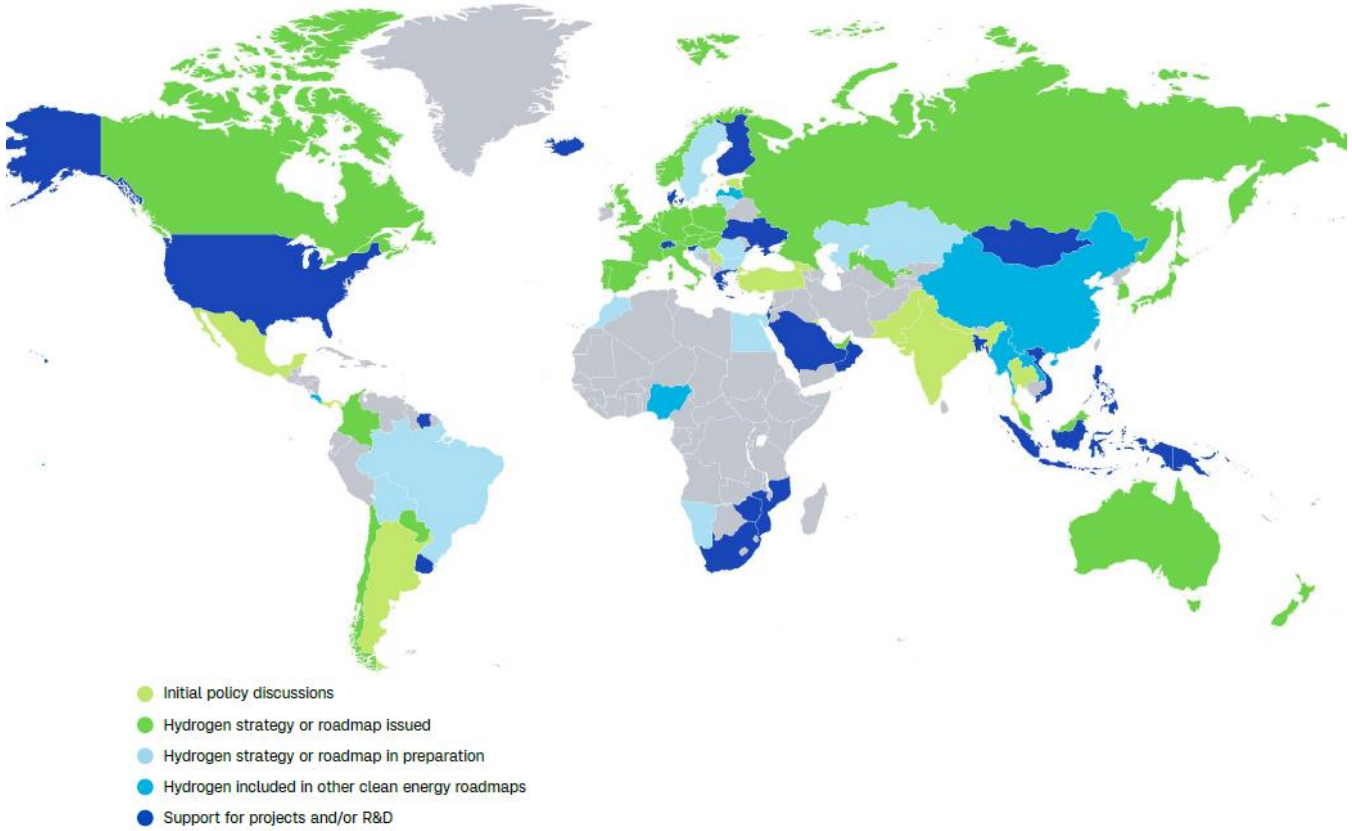


Our website: https://nuclear-hydrogen.org/

First white paper just published



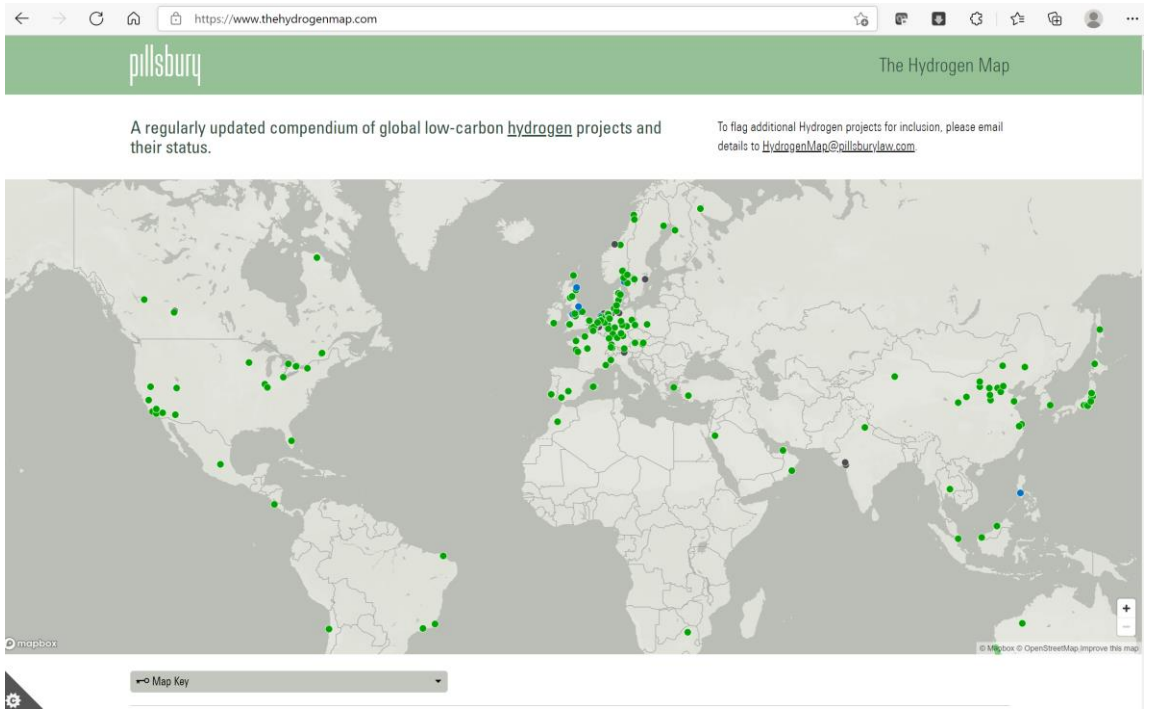
Policy Drives Projects

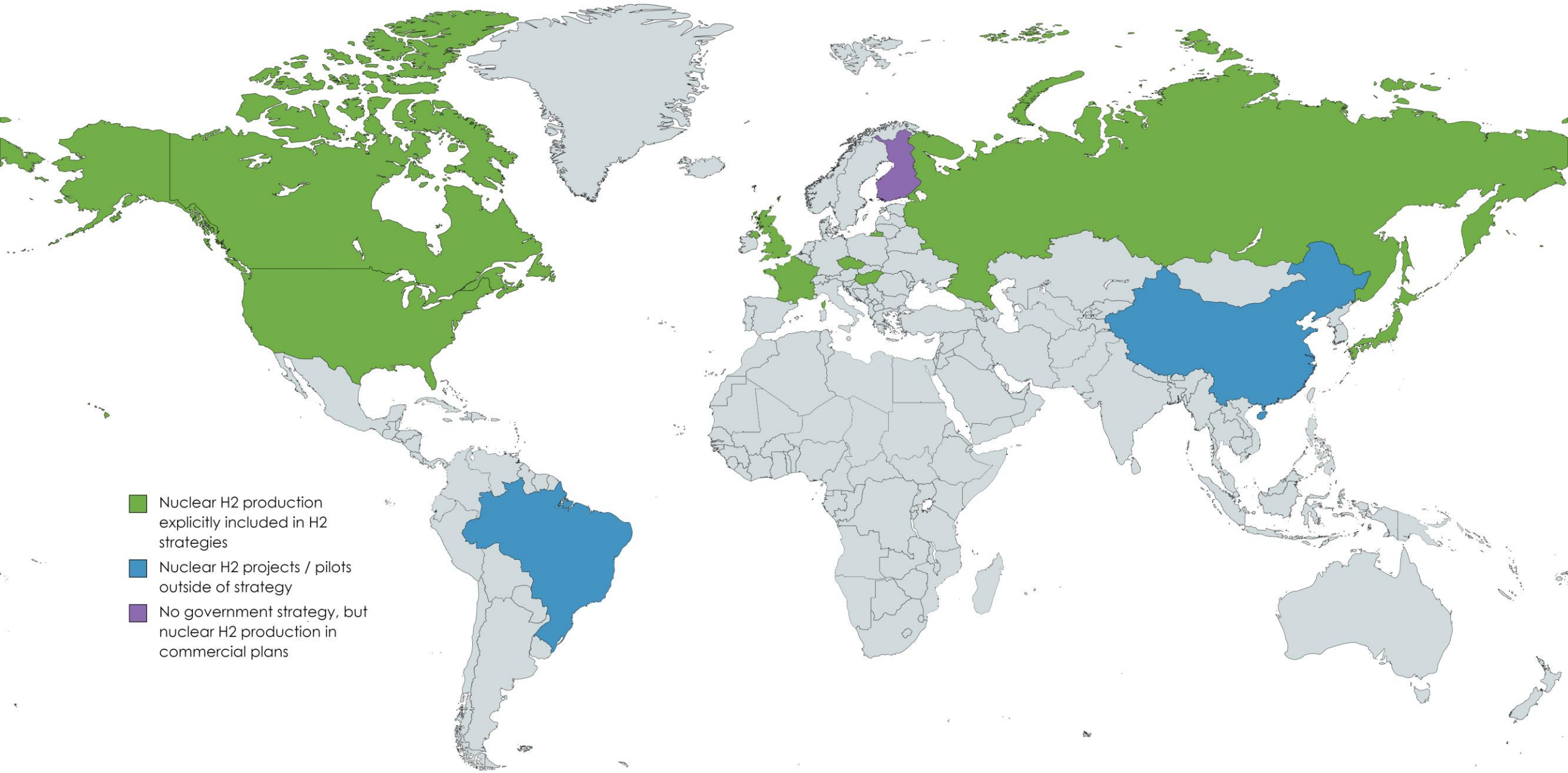


National Hydrogen Strategies as of June 2022

Over 200 low and zero carbon H2 projects globally under development

https://www.thehydrogenmap.com




Nuclear H2 production explicitly included in H2 strategies
Nuclear H2 projects / pilots outside of strategy
No government strategy, but nuclear H2 production in commercial plans

Nuclear within Hydrogen Policy Frameworks

United States: Infrastructure Investment and Jobs Act (IIJA)

- $1.2 trillion infrastructure package passed Senate on August 10, 2021
- Requires the Secretary of Energy in consultation with EPA, to develop initial standard for the carbon intensity of clean hydrogen production
  - defines "**clean hydrogen**" as hydrogen "**produced with a carbon intensity equal to or less than 2 kilograms of carbon-dioxide equivalent produced at the site of production per kilogram of hydrogen produced**."
  - Mandates that the clean hydrogen standard be applied to hydrogen produced from "renewable, fossil fuel with carbon capture, utilization and sequestration technologies, **nuclear**, and other fuel sources using any applicable production technology."
- Requires DOE to solicit proposals for regional clean hydrogen hubs 180 days after bill passage and select **four regional hubs** within one year
  - At least one hub to demonstrate H2 production from nuclear

DOE Findings from RFI: 7of 9 regional H2 hubs can include nuclear H2 production

RFI Findings: Regional clusters and geographic factors

Pacific Northwest
- Port communities
- Tribal communities
- Extensive renewables
- 8 jobs per $1M invested in H2

Central U.S.
- Ample wind
- Geological storage
- Railway transport
- Nuclear resources
- >630,000 tonnes/yr CO2 reduction

Great Lakes
- Major national corridors
- Nuclear power
- 60,000+ jobs

New England
- Offshore wind
- Fishing communities
- Backup power and winter heating
- ~120K tons CO2/year reduction

California
- Diverse populations
- Extensive infrastructure
- Emissions regulations
- 40,000+ jobs

Appalachia
- Retiring fossil plants
- Mining, refining transferable skills
- Carbon capture and sequestration
- 70,000 tons/yr H2 production

Southwest
- Tribal and Hispanic communities
- Underutilized solar
- Nuclear power
- Up to 2B tonnes/yr emission reduction potential

Gulf Coast
- Existing infrastructure
- Multiple opportunity zones
- Renewable resources
- 1,000s of jobs
- Chemical industry

Alaska and Hawaii
- Extensive renewables – geothermal, solar, ocean
- Backup power
- Isolated communities
- 86,000 tonnes/yr emission reduction

earthshots | Hydrogen

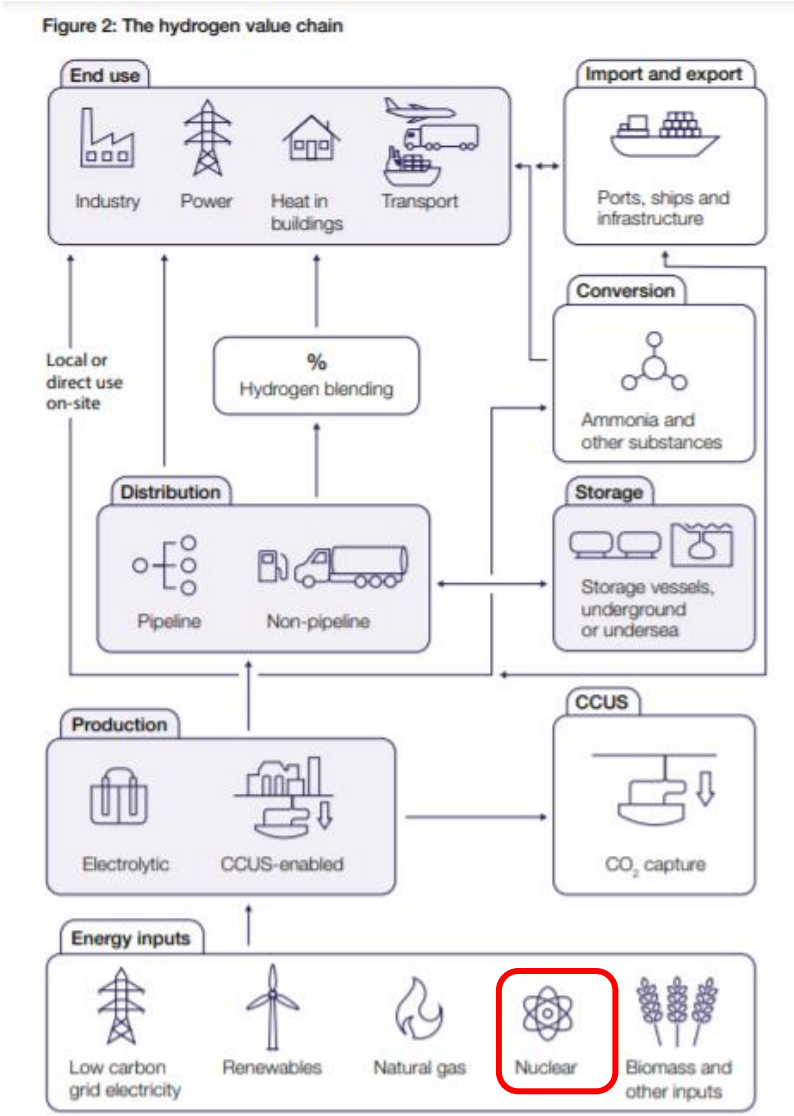
Hydrogen Shot Summit

14

Nuclear within Hydrogen Policy Frameworks

UK: Hydrogen Strategy (issued Aug. 2021)

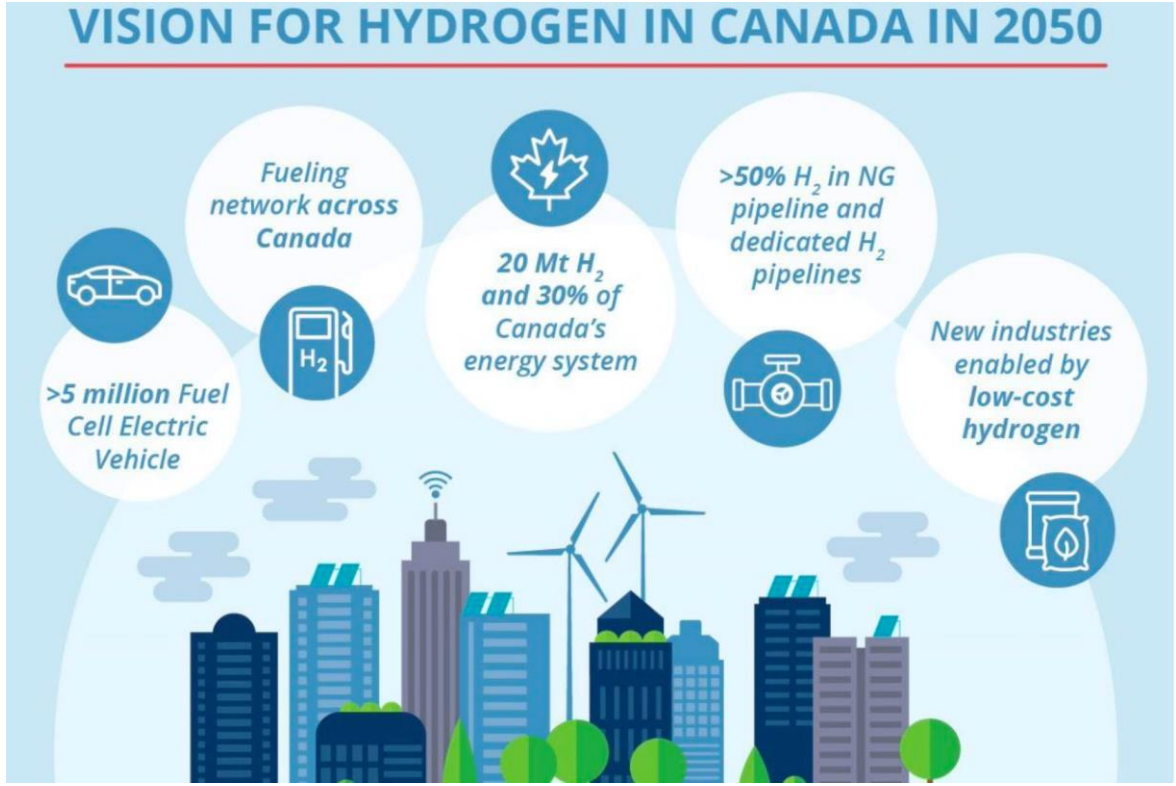
- Vision: UK will rapidly and significantly scale up hydrogen production and lay the foundations for a low-carbon hydrogen economy by 2030:
  - 5GW of low-carbon hydrogen production capacity by 2030 with potential for rapid expansion post-2030
  - 1GW production capacity as early as 2025.
- proposes development of a **UK low-carbon hydrogen standard**
  - Will define a methodology for calculating greenhouse gas emissions associated with hydrogen production and a greenhouse gas emissions threshold against which different low-carbon hydrogen production pathways would be measured
- Nuclear hydrogen production specifically mentioned as part of the approach



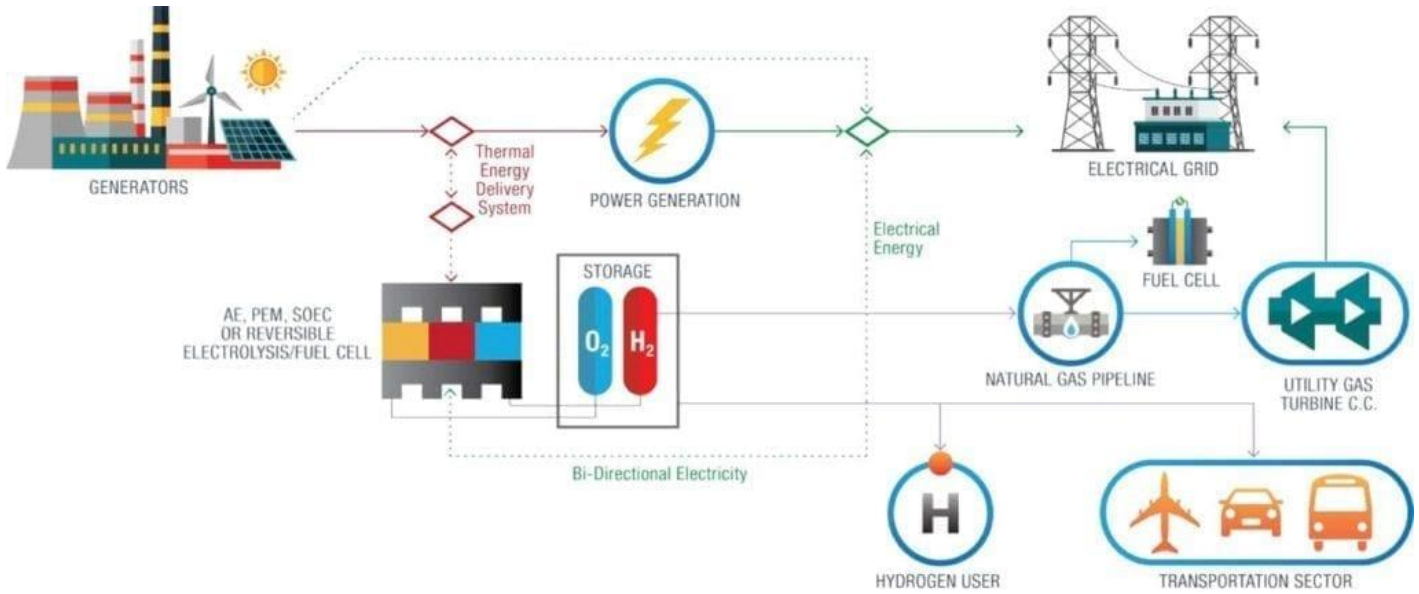
Nuclear within Hydrogen Policy Frameworks

Canada: Hydrogen Strategy (issued Dec. 2020)

- Sets out short, medium and long-term goals for H2 production in Canada
- specifically includes nuclear:
  - H2 production at existing reactors – Ontario and NB
  - H2 production from SMRs
  - Using steam produced by nuclear reactors as the reactant in the steam methane reformation process -- would eliminate the need to use natural gas to create steam and would simplify and lower the cost of carbon capture



Policies needed to support Nuclear H2 Production



- Make H2 Plans Technology Neutral
- Include Nuclear Technology in H2 Policies and Plans
- Targeted RD&D
- Set Production Incentives
- Establish End-User Incentives
- Leverage Government Procurement

Make H2 Plans Technology Neutral

- Governments preparing H2 plans and policies should include all low-carbon H2 production technologies in their plans.
- Preferably, H2 plans and policies should avoid the color scheme in favor of inclusion of technologies based on carbon footprint.

Include Nuclear Technology in H2 Policies and Plans

- Nuclear H2 production should be expressly included as a key zero-carbon H2 pathway in H2 plans and roadmaps, as well as in the "guarantee of origin" schemes.
- Explicit goals and metrics for nuclear H2 production should be set and described in the policies and plans.
- H2 hubs should include nuclear H2 production facilities.

Targeted RD&D

Governments should allocate targeted funding to nuclear energy RD&D with near, medium, and long-term goals. Specifically:
1. create a pathway for large-scale commercial H2 production from existing reactors within the next three years, starting in 2022;
2. demonstrate H2 production using high-temperature steam electrolysis from advanced reactors by 2028;
3.demonstrate pilot thermochemical production of H2 within the next five years.

Set Production Incentives

- Provide tax incentives to nuclear based H2 producers. E.g.,: Investment Tax Credits, Production Tax Credits, and exemptions from other applicable taxes (e.g., carbon taxes, electricity production taxes, grid tariffs if applicable).
- Ensure that nuclear based H2 producers are eligible for various financial incentives (e.g., loan guarantees, low-interest government loans, etc.).

Establish End-User Incentives

Subsidize during an initial period (e.g., five years) the purchase of nuclear-produced H2 through contract-for-difference schemes (e.g., government pays users the difference between the market price of fossil-fuel produced H2 and low-carbon H2).
• Provide tax incentives to H2 users for the offtake of nuclear-produced H2.
• Provide loans, grants or dedicated funds to industrial companies to decarbonize through the use of low-carbon H2, and specifically include nuclear produced H2 as eligible for the incentives.

Leverage Governmment Procurement

Governments should, through public procurement, preferentially buy products (e.g., steel) made through the use of low-carbon hydrogen, including nuclear produced hydrogen.

Thank you

Nuclear Hydrogen Initiative

Carlos Leipner
cleipner@catf.us

Elina Teplinsky

Elina.Teplinsky@pillsburylaw.com

Questions?


HYDROGEN
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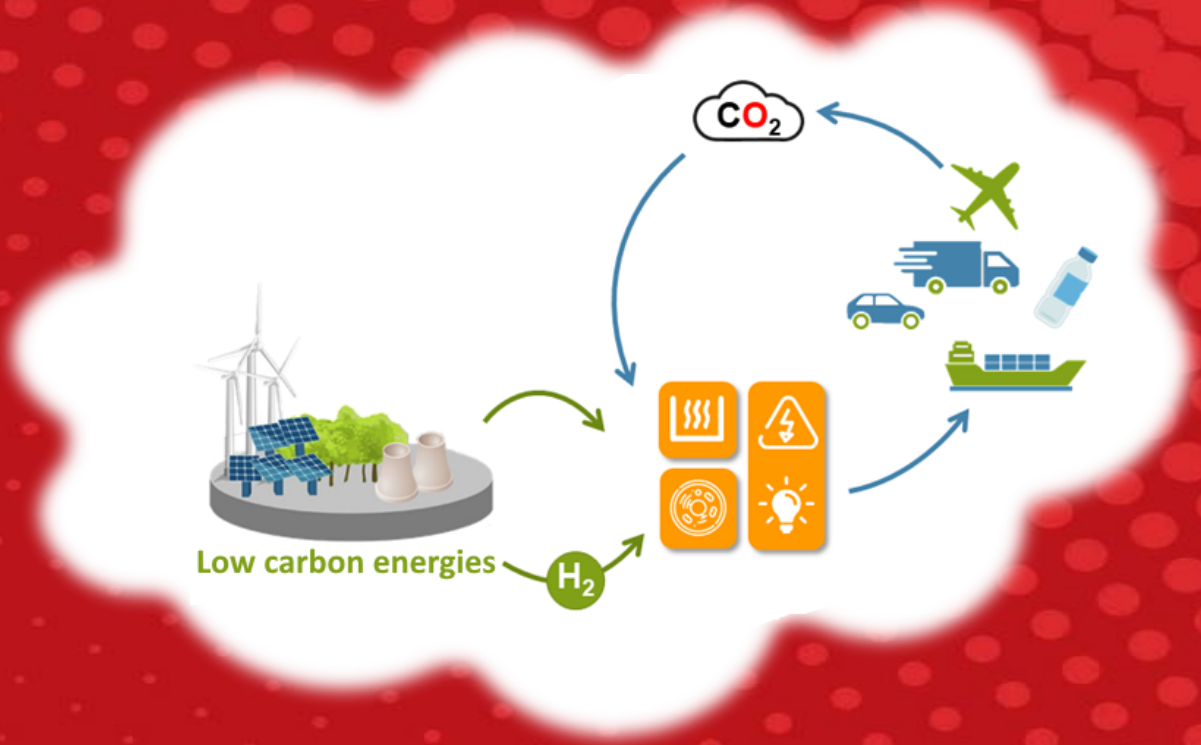
NICE Future
Nuclear Innovation: Clean Energy Future
An Initiative of the Clean Energy Ministerial



DE LA RECHERCHE A L'INDUSTRIE

TOWARDS A CARBON CIRCULAR ECONOMY…

… FRENCH NUCLEAR INDUSTRY PERSPECTIVE ON SYNTHETIC FUELS

DR. THIBAULT CANTAT

JUNE 29, 2022 – NICE FUTURE WEBINAR

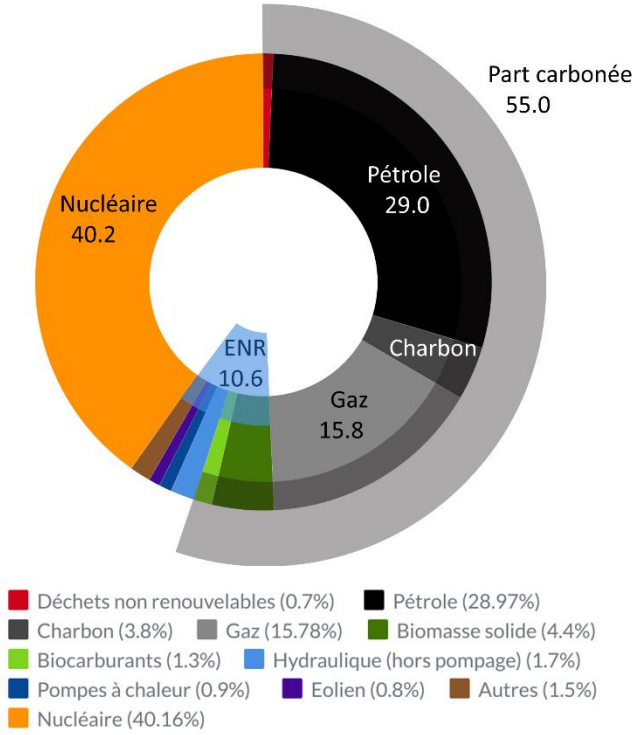
Carbon based products are at the core of energy systems

What is the place of carbon products in the French energy system?

- The consumption of primary energy in France (2900 TWh) relies for 40% on nuclear energy (for the production of electricity) and for 55% on carbon fuels

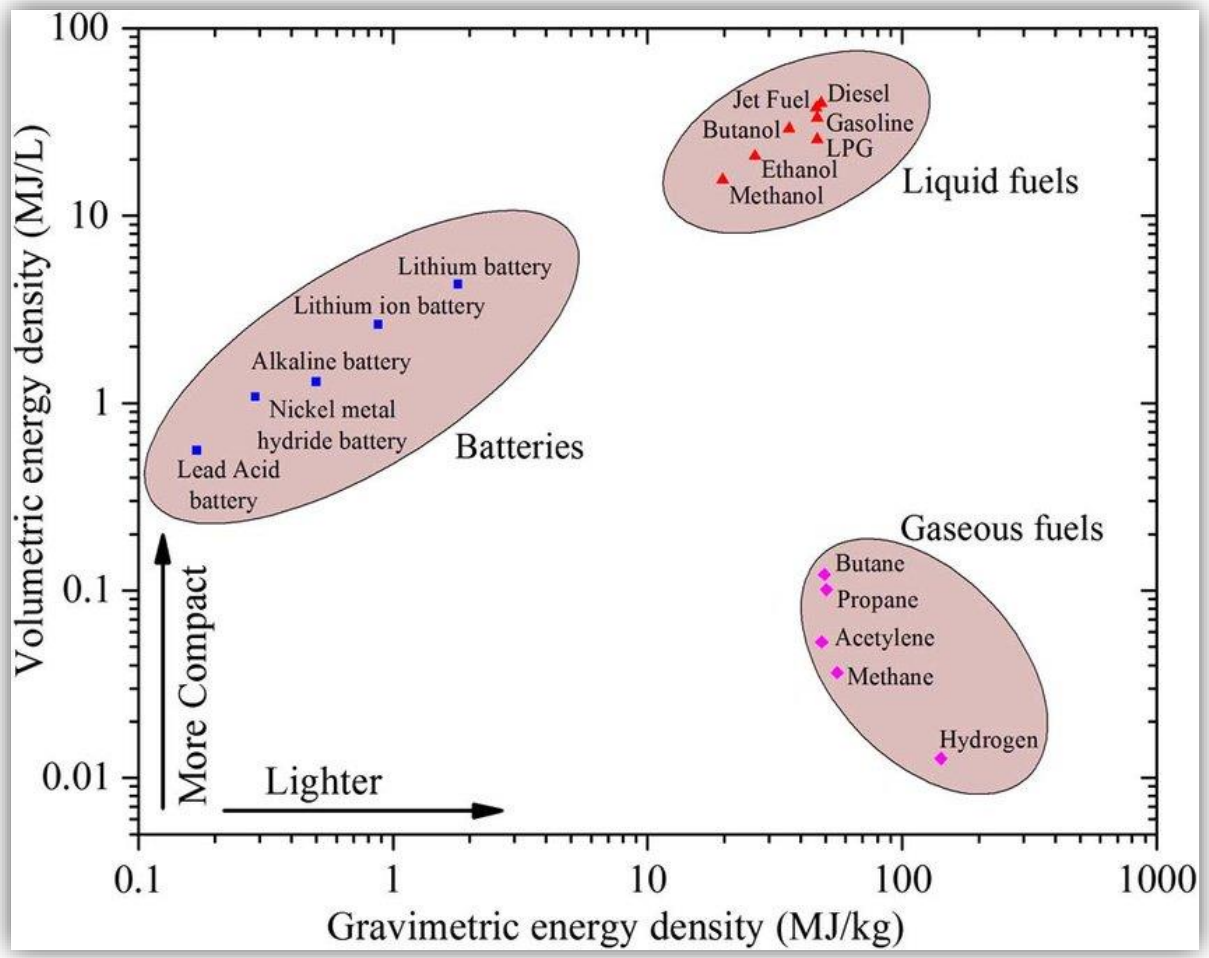
- A third (1/3) of the uses of carbon products cannot be substituted with carbon-free alternatives such as electrification, H2 or batteries technologies

- 46 Mtep (530 TWh) of carbon-based products will need to be produced from renewable energy and carbon sources to ensure services dealing with:
  - Liquid fuels for long range transportation
  - Production of materials (steel, cast iron, cements)
  - Production of chemicals (plastics, agrochemicals, solvents, etc,)



Breakdown of the primary energy consumption in France, for a total of 2900 TWh, in 2018. SDES Data in % ; ENR = Renewable energies ; d'après « Chiffres clés de l'énergie - Edition 2018 », from Commissariat général au développement durable.

A LINEAR CARBON ECONOMY ASSISTED WITH CARBON CAPTURE AND STORAGE?



Energy

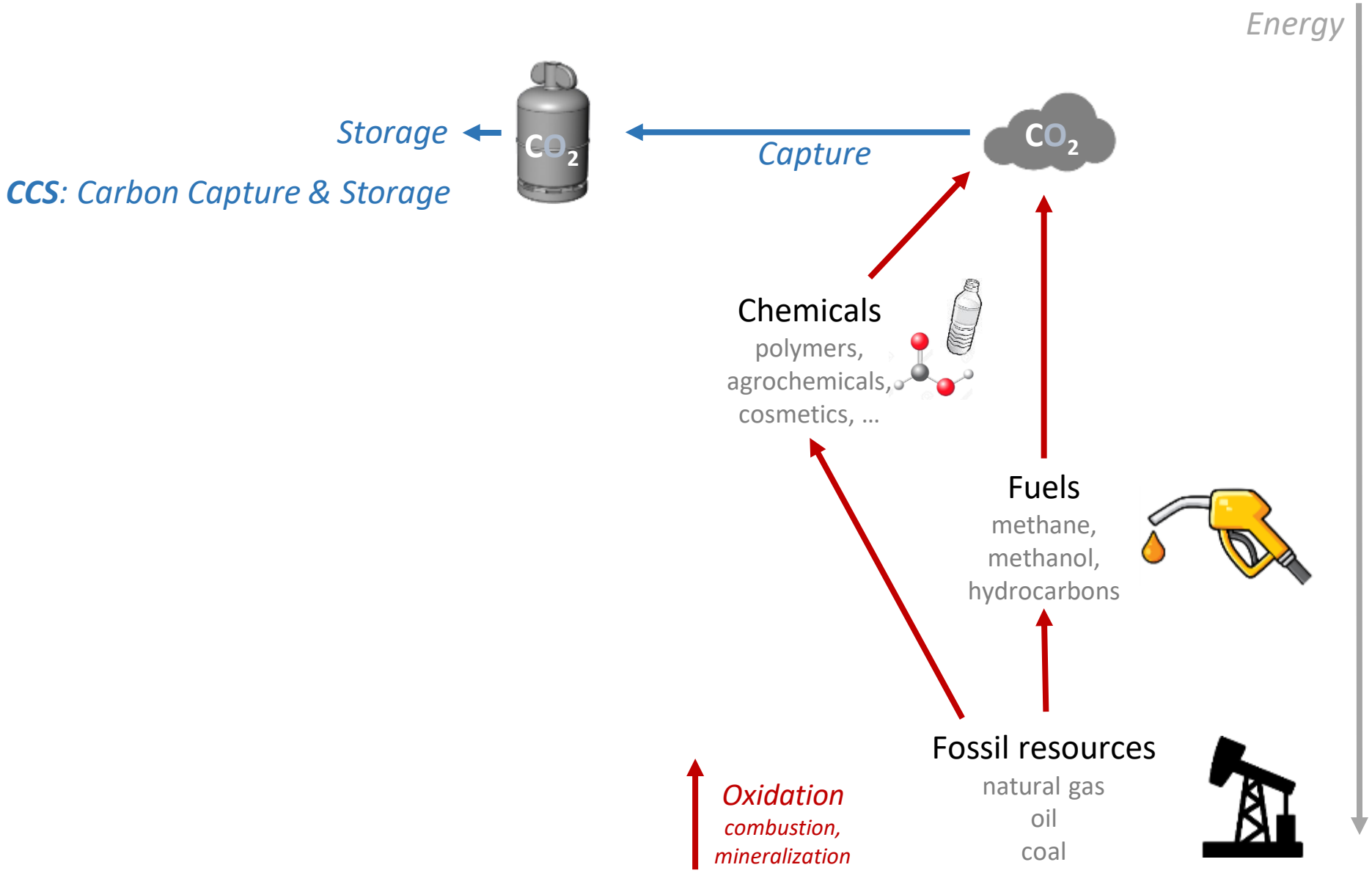
Chemicals
polymers,
agrochemicals,
cosmetics, …

Fuels
methane,
methanol,
hydrocarbons

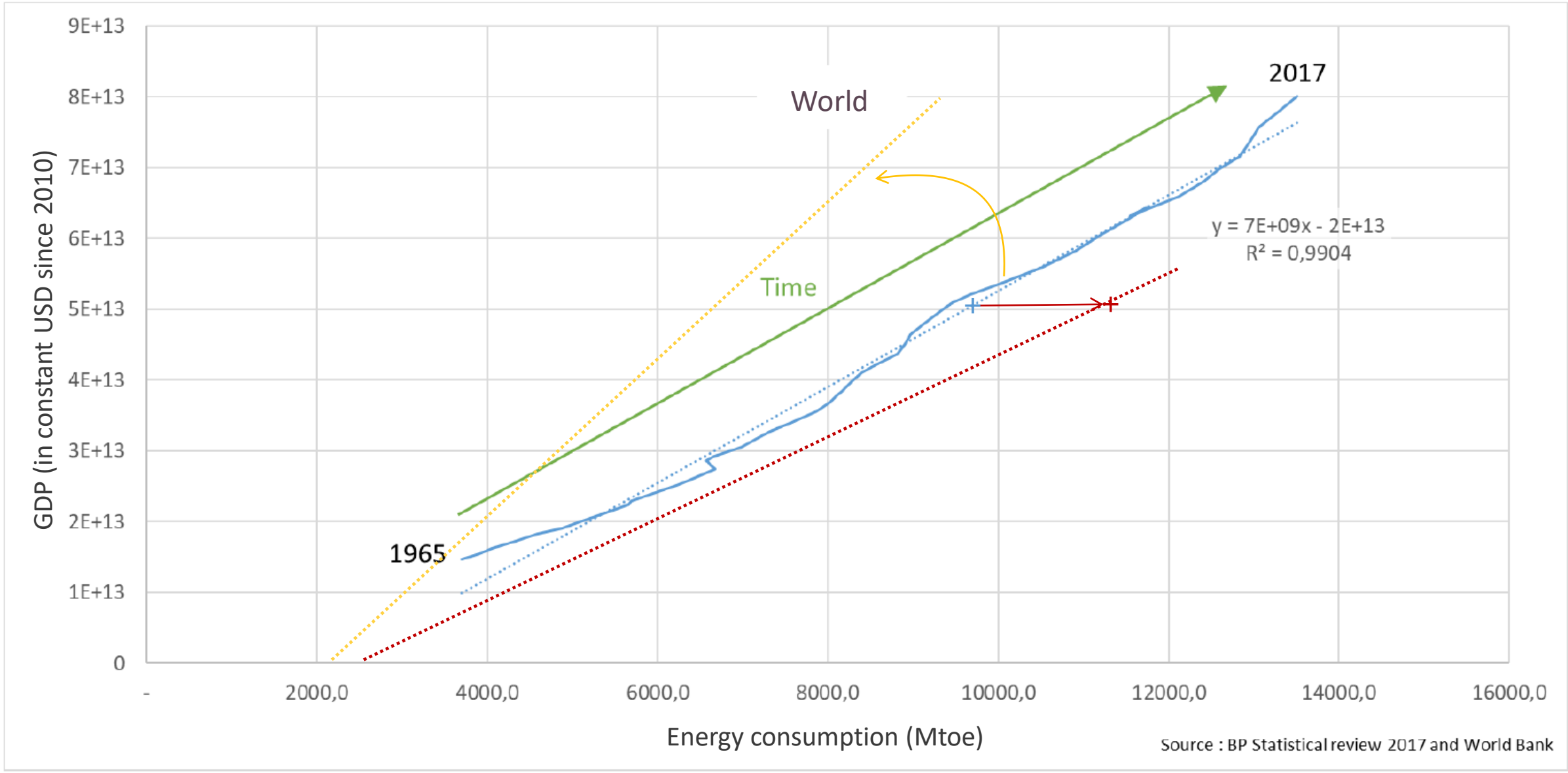
Fossil resources
natural gas
oil
coal

Oxidation
combustion,
mineralization

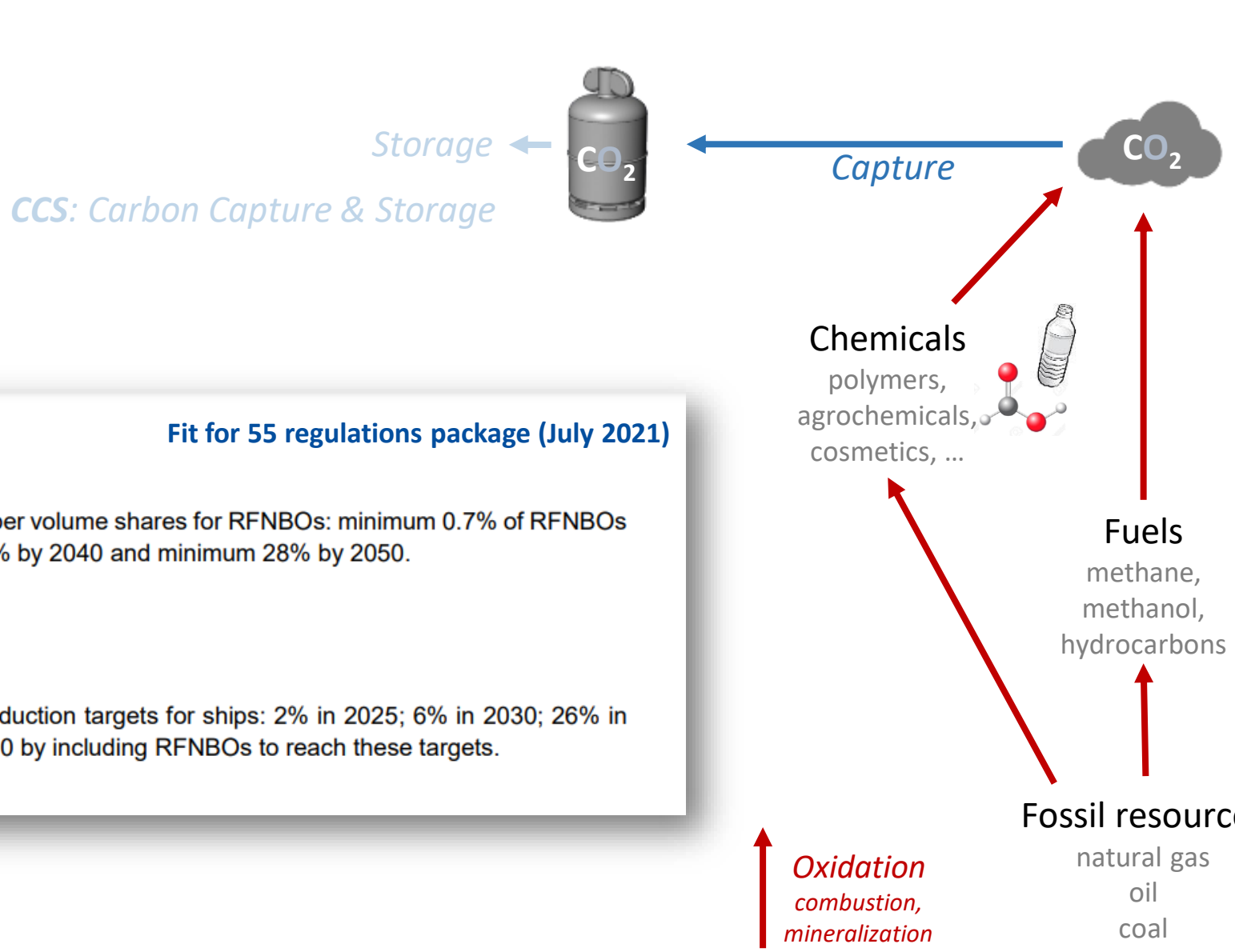
A LINEAR CARBON ECONOMY ASSISTED WITH CARBON CAPTURE AND STORAGE?



ENERGY EFFICIENCY AND CCS APPROACHES



TOWARDS A CARBON CIRCULAR ECONOMY



Fit for 55 regulations package (July 2021)

ReFuelEU Aviation:

- Sets binding targets per volume shares for RFNBOs: minimum 0.7% of RFNBOs by 2030; minimum 8% by 2040 and minimum 28% by 2050.

Fuel EU Maritime:

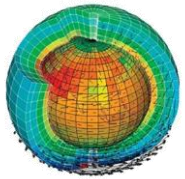
- Sets binding GHG reduction targets for ships: 2% in 2025; 6% in 2030; 26% in 2040 and 75% in 2050 by including RFNBOs to reach these targets.

TOWARDS A CARBON CIRCULAR ECONOMY

A circular carbon economy involves

A collection of technologies able to convert CO_2 and its derivatives into useful products, from low-carbon energies (incl. nuclear and renewables), to achieve carbon neutrality with a positive environmental and societal impact.

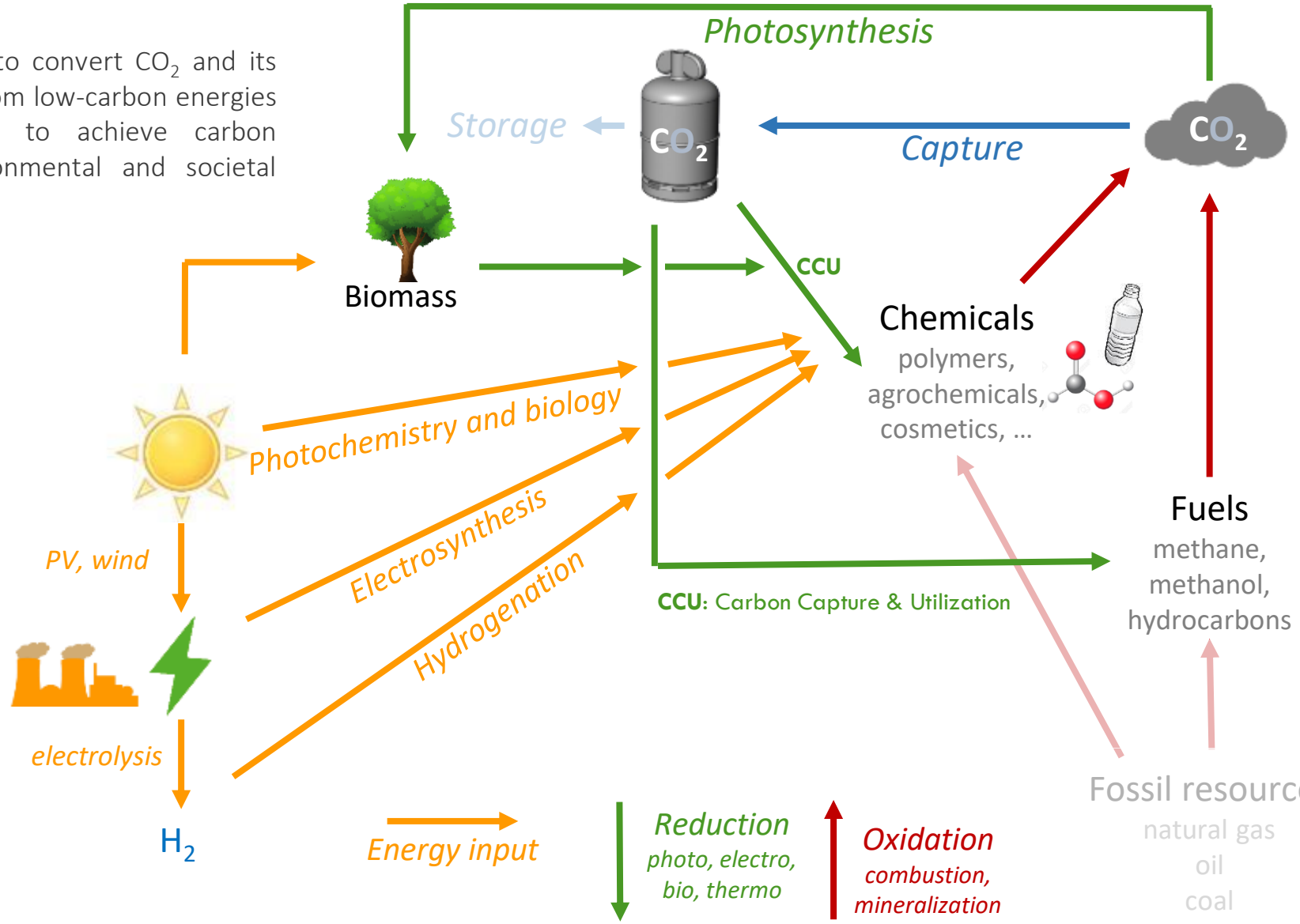
Cross-cutting challenges



Impact analysis on soils and climate

Multicriteria Life Cycle Analyses

Sustainability of resources



ENABLING A CARBON CIRCULAR ECONOMY

Value chain of molecules for energy and chemistry

Collecting resources

LOW CARBON ENERGY SOURCES
Hydroelectricity, solar, wind, nuclear, biomass

INTRANTS
CO_2; derivatives (CO…), plastics, biomass, solid wastes

CONVERSION VECTOR
Green H_2

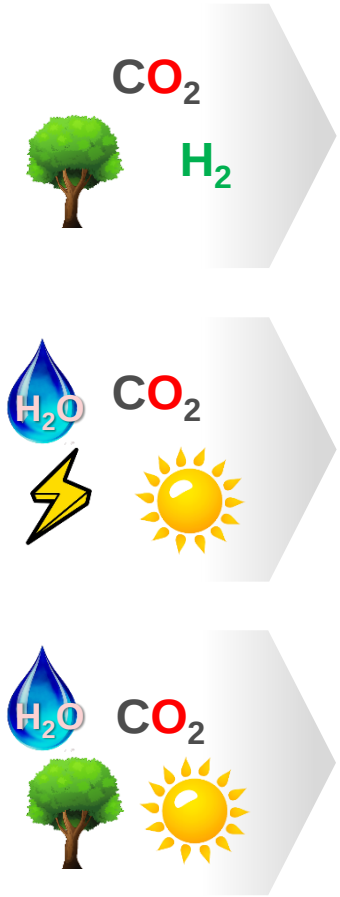
Production - Transformation

THERMOCATALYSIS
THERMOCONVERSION
Methanation; gaseification; pyrolysis; torrefaction; hydrothermal liquefaction

ELECTROCATALYSIS
Electrolysis; coelectrolysis

PHOTOELECTROCATALYSIS
Photocatalysis; artificial photosynthesis

BIOLOGY / BIOHYBRIDS
Microalgae; cyanobacteria; bacteria



Molecules

GASES
Methane; syngas ($CO+H_2$) ; ethylene

LIQUIDS
Bio-oil; methanol; formic acid; ammonia; terpenes; fatty acids

SOLIDS
Biochar, parafines; sugars; polysaccharides

Applications

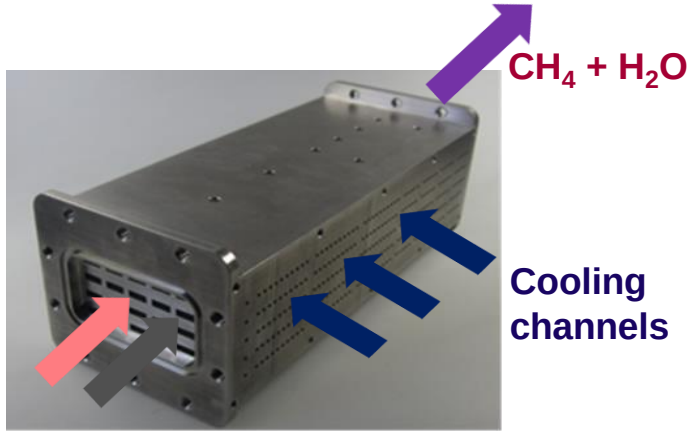
ENERGY
Alcohols; synthetic fuels or 3G biofuels (methane, kerosene and hydrocarbons); additives; lubricants

CHEMISTRY
Polymers; alcohols; fertilizers; ethylene; methanol;

TOPICAL RESEARCH AND DEVELOPMENT PROJECTS IN THERMOCATALYSIS

Thermocatalysis and thermoconversion

Methanation unit



Reactive channels: $CO_2 + H_2$

$$4\,H_2 + CO_2 \rightarrow 2\,H_2O + CH_4$$

Fluidized bed convertor

R&D ——— Commercial

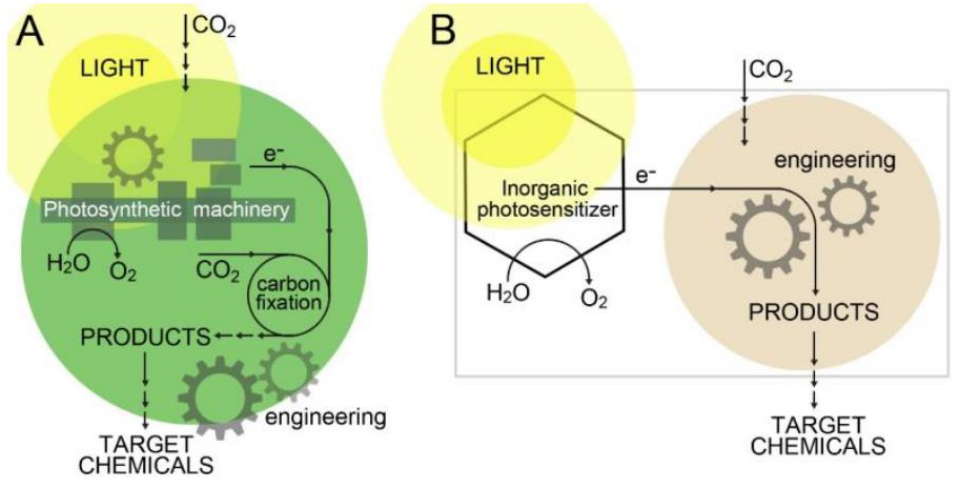
Strategies

- Develop innovative conversion paths from CO_2 and fuels and chemicals
- Explore the conversion of CO_2 from catalysts design to the reactor and the process
- Innovative reactors architectures to shorten the value chain of CO_2 conversion

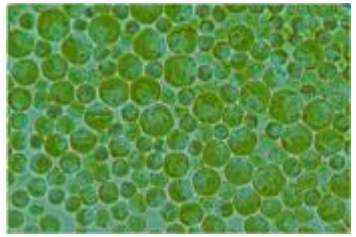
Challenges

- A difficult economic balance: competition with fossils
- Position with respect to the H_2 value chain
- Steps and costs reduction from the ressources to the fuel

Biology and biohybrids



*Photosynthetic organisms (A) and their use in biohybrids (B) for the production of fuels and chemicals



Strategies

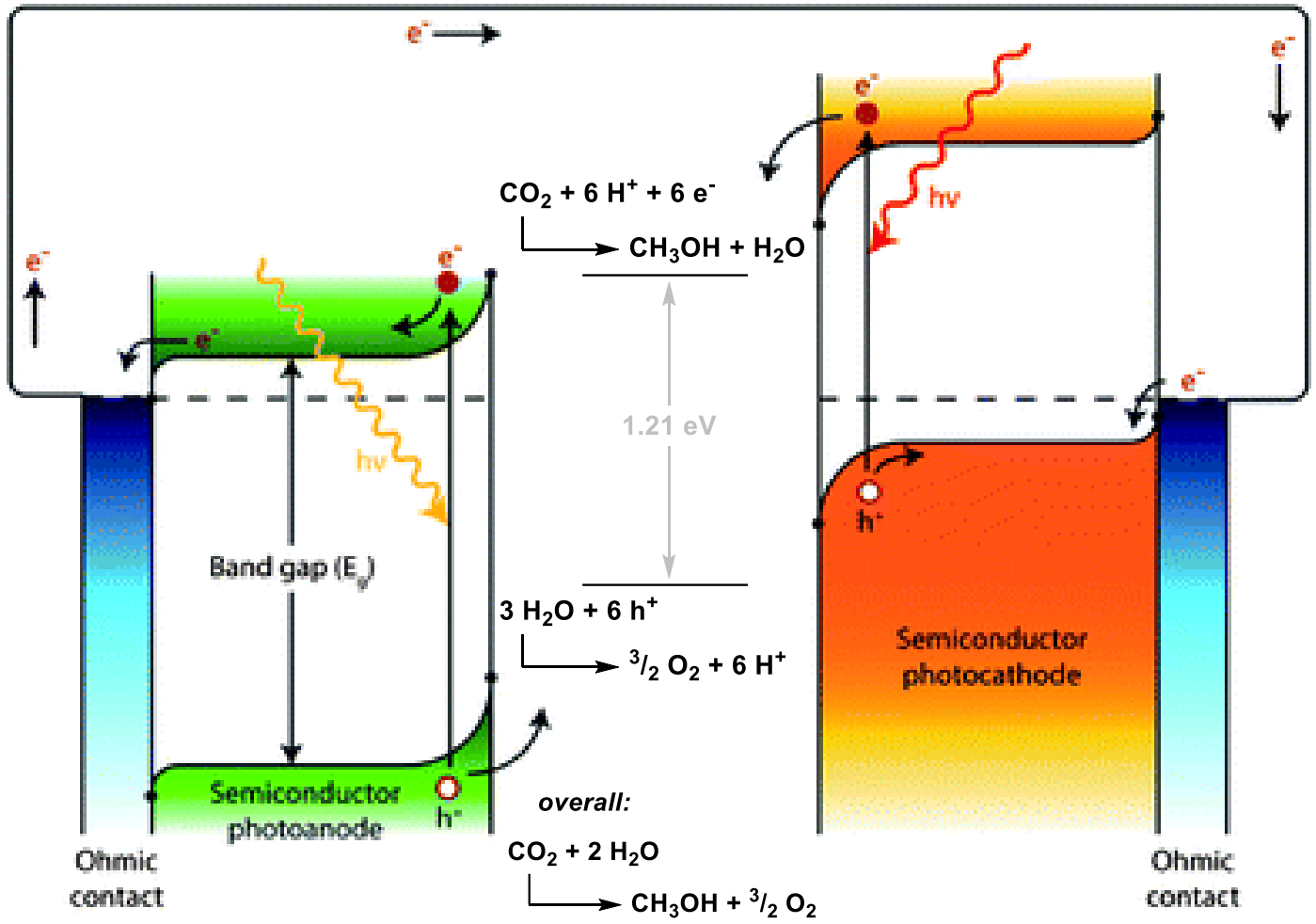
- Develop optimized strains by genetic engineering and synthetic biology
- Cultures of microalgae and cyanobacteria in open and closed reactors (photobioreactors)
- Hybridation of materials and micro-organisms to facilitate the chemical storage of solar influx to target compounds

Challenges

- Performance and robustness of the strains (salty water, industrial CO_2 sources, NO_x and SO_x comtaminants)
- High yielding strains
- Steps and costs reduction from the strains to the fuel

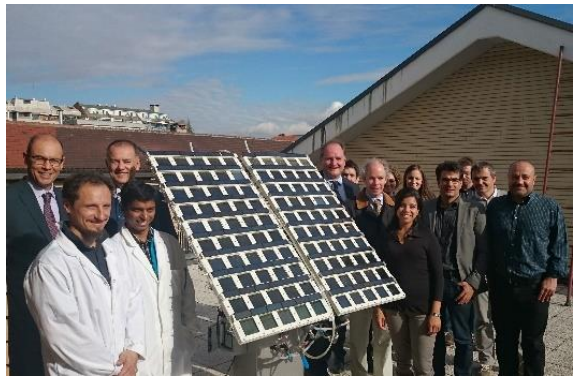
TOPICAL RESEARCH AND DEVELOPMENT PROJECTS IN PHOTOELECTROCATALYSIS

Photo(electro)catalysis



Challenges

- Performance and robustness of the materials (photo, electro, catalysis)
- Design of the cells
- Selectivity for targeted chemicals and fuels

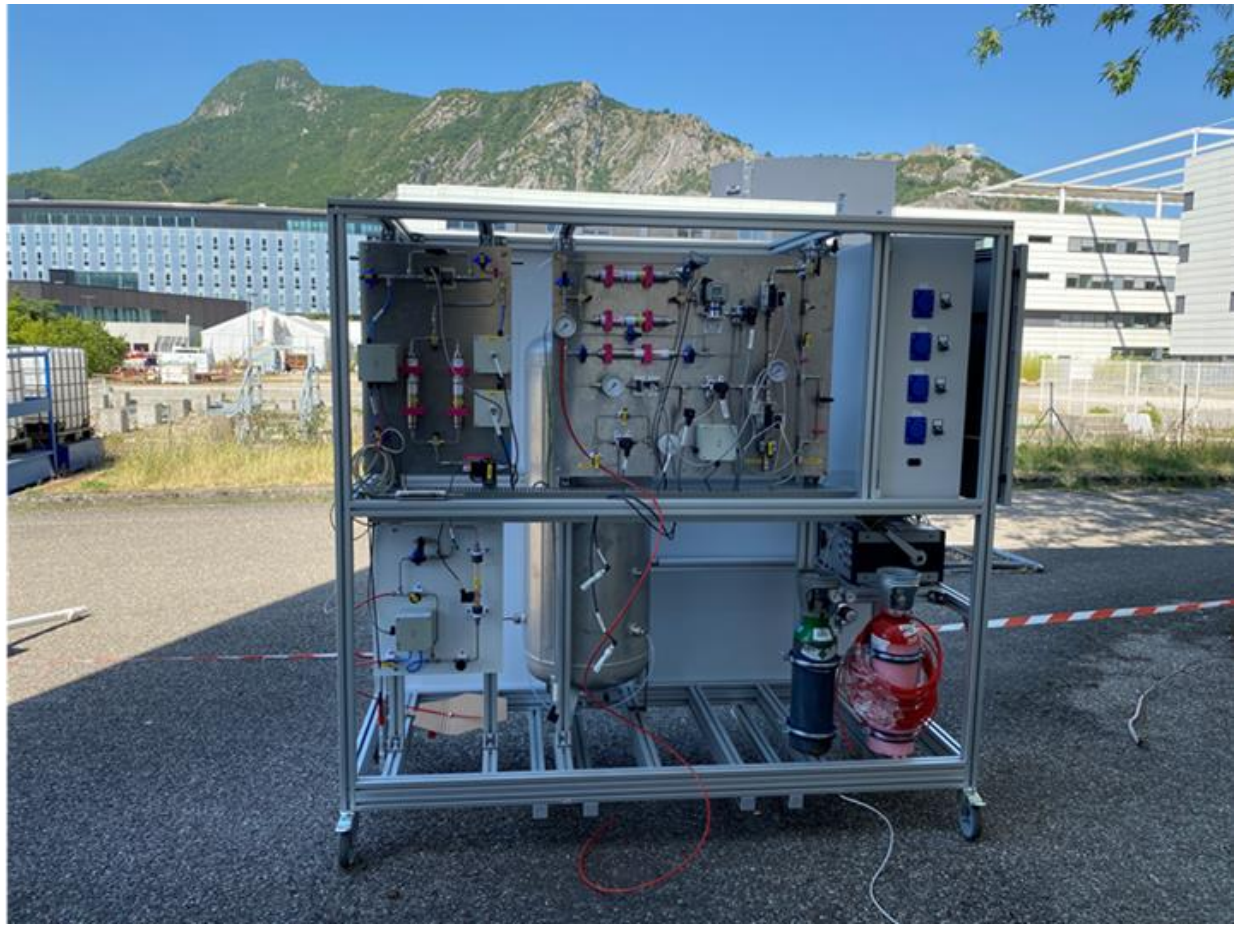


« Solar to Hydrogen » Prototype for H_2 production
Projet ArtipHyction
conversion 2%, >1000h, without nobel metals

R&D — Commercial

SOLAR FUELS DEMONSTRATION IN 2022

- **Going faster: Horizon prize, a competition for the production of solar fuels**



Biology and biohybrids

Photo(electro)catalysis

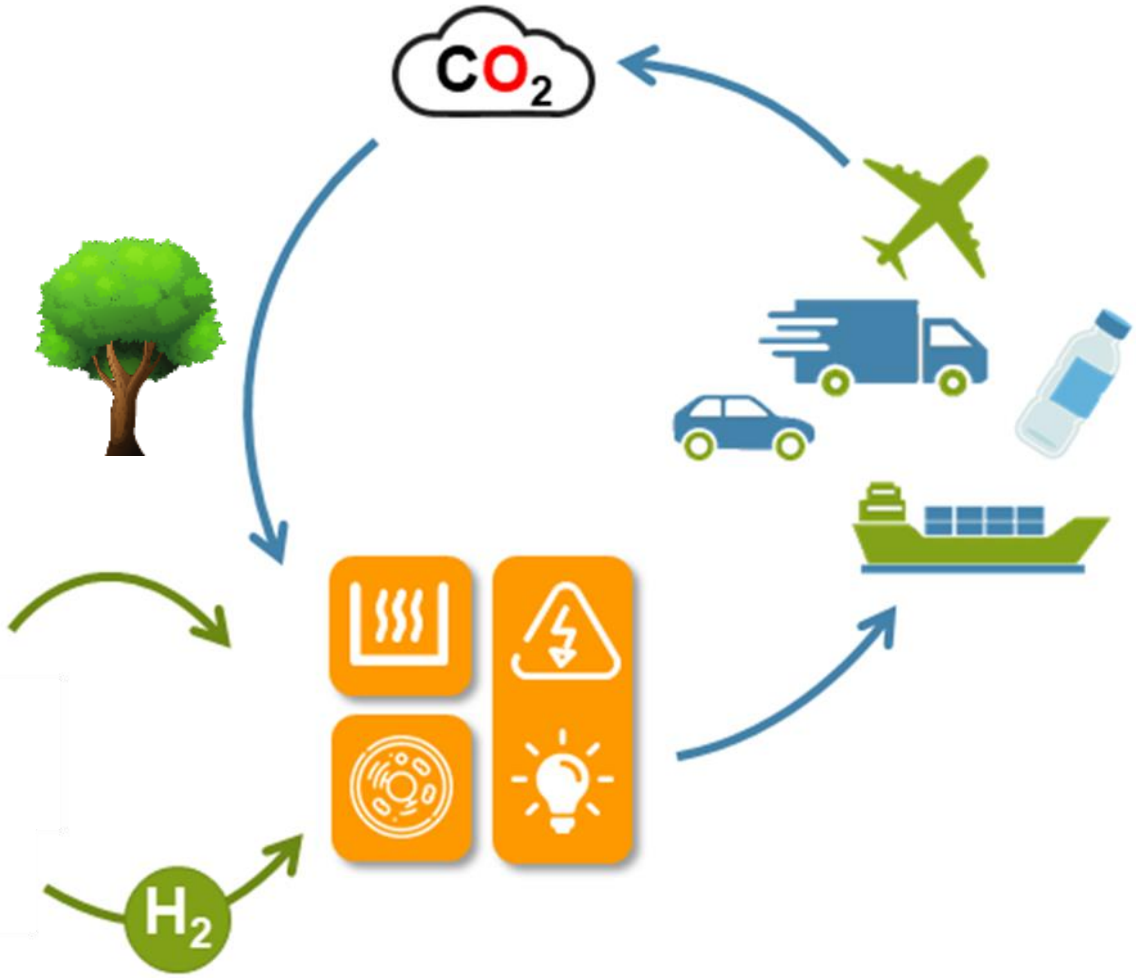
R&D — Commercial

COUPLING NUCLEAR ENERGY PRODUCTION TO SUSTAINABLE FUELS

- **Nuclear energy for the production of sustainable fuels (NeoFuels)**

- **Two research lines:**
  - Case studies for low carbon industrial complexes
  - Optimized chain values for the production of sustainable fuels

- **Numerous questions:**
  - From the nuclear reactor
  - To the energy mix:
    dedicated reactor +/- grid +/- renewables
  - And the carbon source:
    fossil CO_2, atmospheric CO_2, biomass
  - To the output:
    utilities (heat, electricity, C and H, molecules)



Questions?

HYDROGEN INITIATIVE

AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

NICE Future

Nuclear Innovation: Clean Energy Future

An Initiative of the Clean Energy Ministerial

SEABORG

Rethinking nuclear

2022

SOUTHEAST ASIA BUILDS COAL & GAS; NO ALTERNATIVES

In Southeast Asia:

- Rapidly growing economy
- 3-month monsoon season, unsuited for wind and solar power
- Limited hydro power
- Limited geothermal power

Result:

Exponentially scaling fossil power

We will only reach our goals for **decarbonisation** if the alternative is **cheap** enough and scales **fast**.

VISION

Transform energy markets and **out-compete fossil fuels** to create a bright future with abundant clean energy for everyone.

UNPRECEDENTED OPPORTUNITY

Executing a rapid **world-wide deployment** of the Compact Molten Salt Reactor via **shipyard serial production** of power barges.

SEASALT GROUP IN A NUTSHELL

Privately held and
privately funded company

Founded in **2015**

100+ employees

Scaling to **150 employees** in current funding

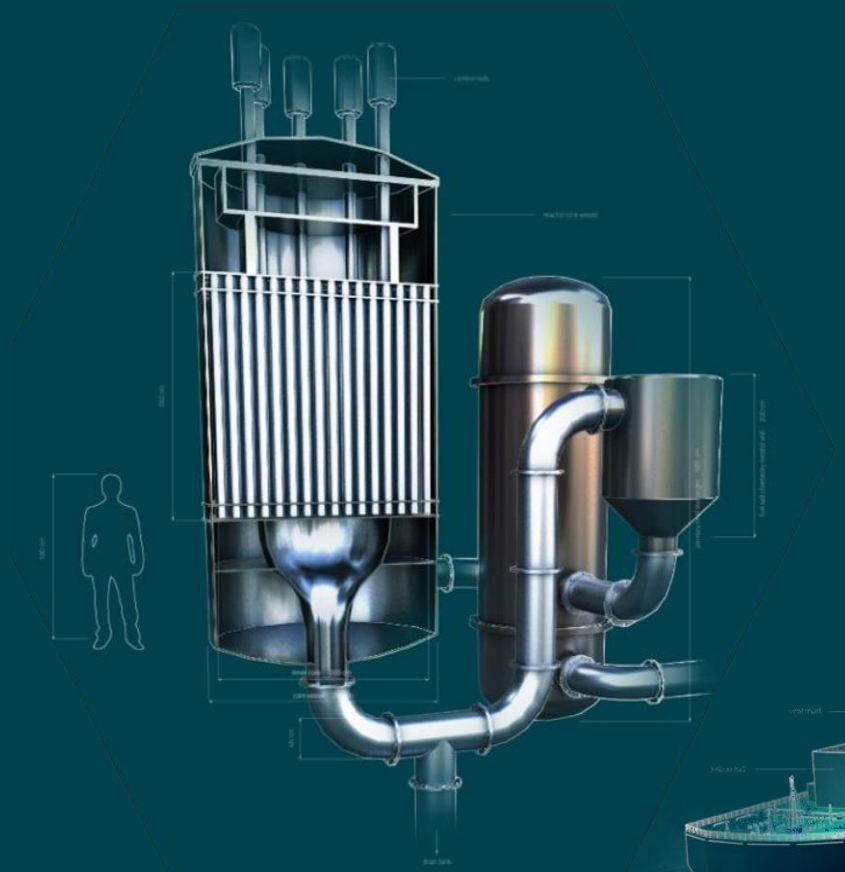
Employees from **24 countries**

HQ and laboratories in Copenhagen, Denmark

Business office in South Korea & Singapore

Partnerships with shipyards, nuclear players, heavy industry and academia

THE CMSR POWER BARGE



- 200, 400, 600 or 800 MWe units
- Mass produced
- 3 years from order to grid
- Fully commissioned at Samsung shipyard

SAFETY BY THE LAWS OF NATURE

Molten fluoride salt makes nuclear inherently safe

State of the art labs to perform fluoride and hydroxide salt experiments

The fluoride salt contains the radioactive elements

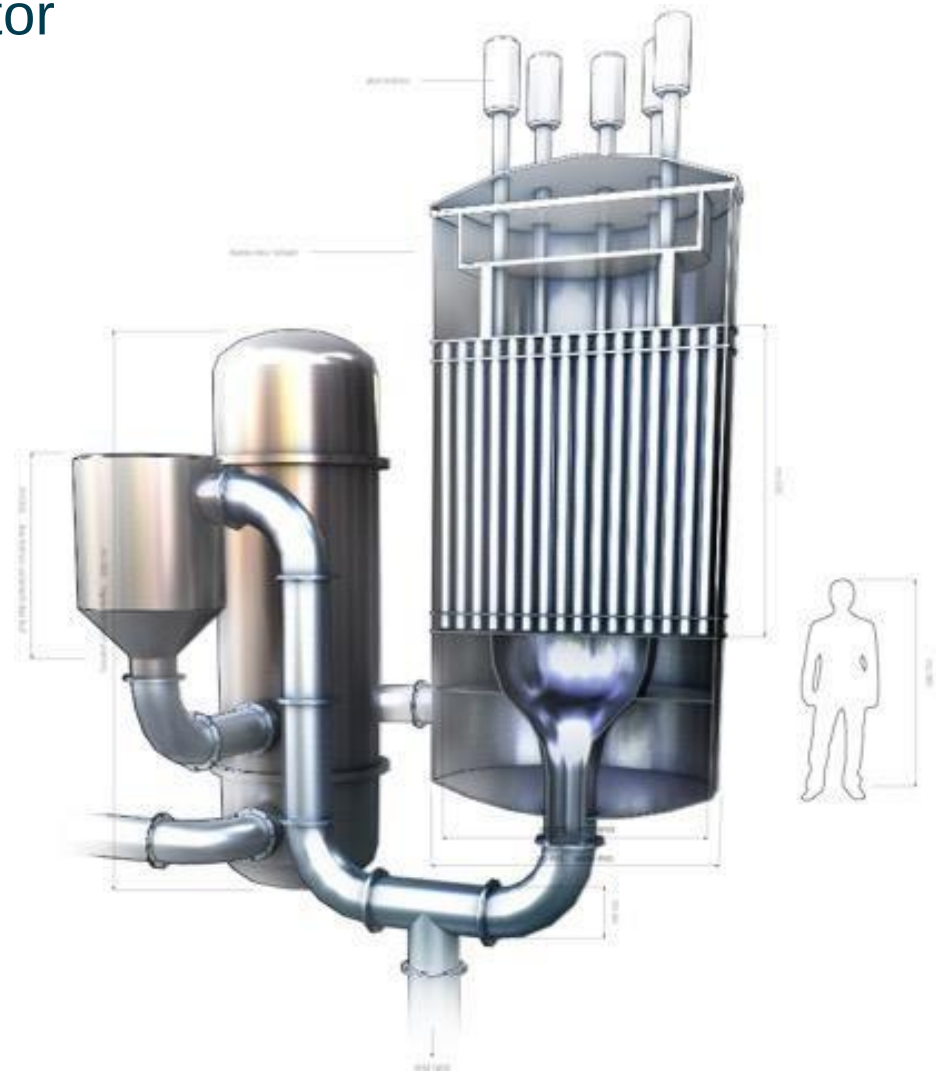
- No release of gases
- Very low solubility in water
- Below 490 °C, it is a rock
- Boils at 1500 °C
- CMSR operates at 600 °C – 700 °C

SAFE, CHEAP AND CLEAN NUCLEAR

Seaborg's modular Compact Molten Salt Reactor

The Seaborg CMSR is inherently safe. It:

- **Cannot** melt down or explode
- **Cannot** release radioactive gases to air or water
- **Cannot** be used for nuclear weapons
- Operates for **12 years without refuelling**



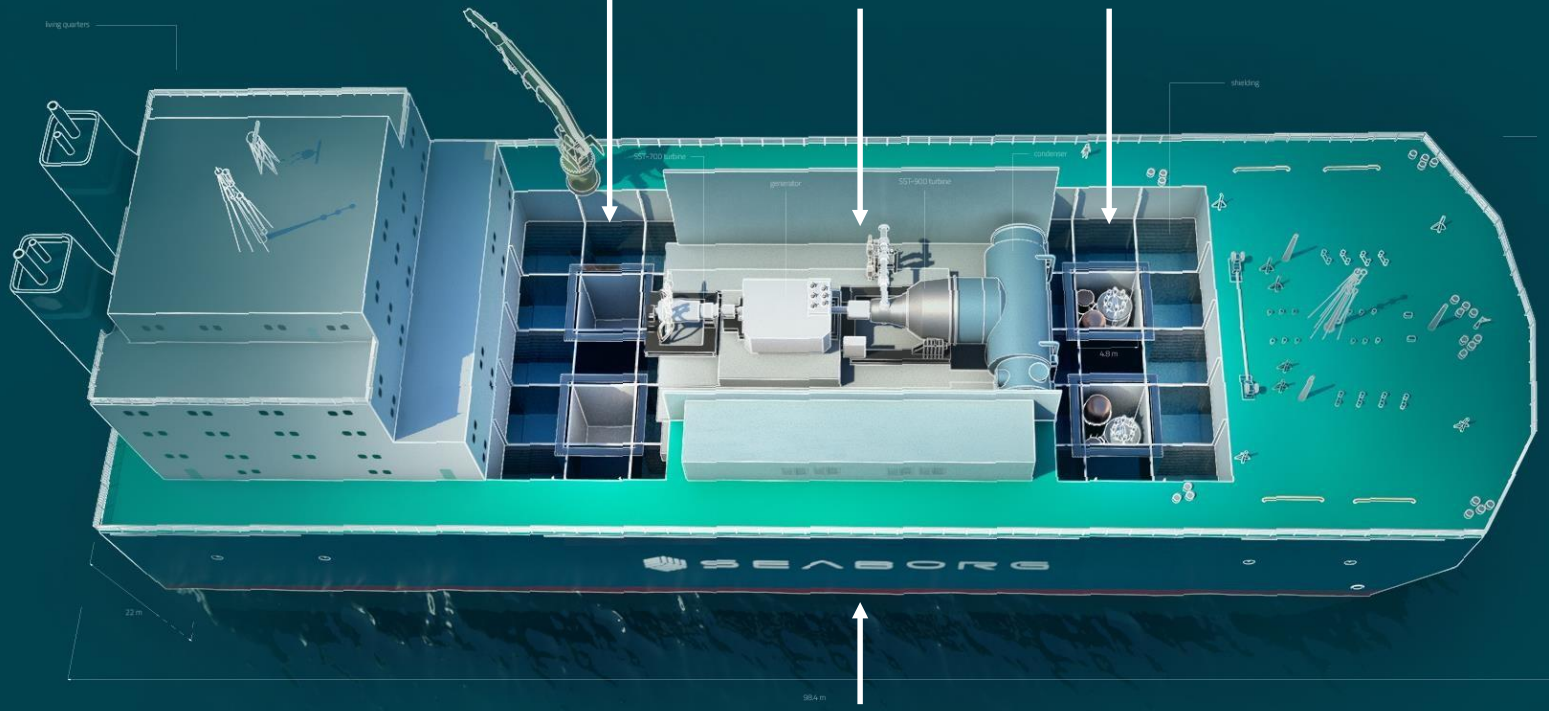
MODULAR CMSR POWER BARGE

24 years operational life time

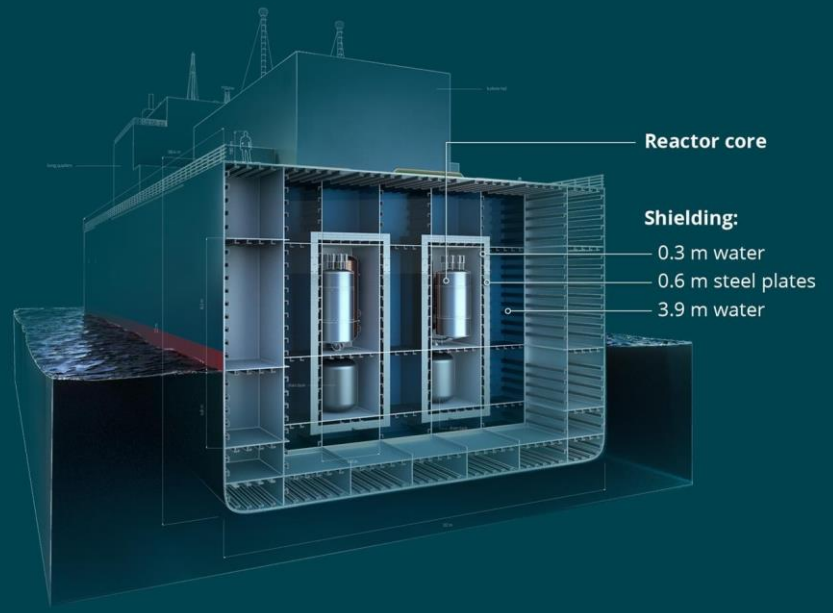
2 empty CMSR compartments for the second 12-year fuel cycle

Steam turbine with generator and condenser

2 CMSRs for the first 12-year fuel cycle

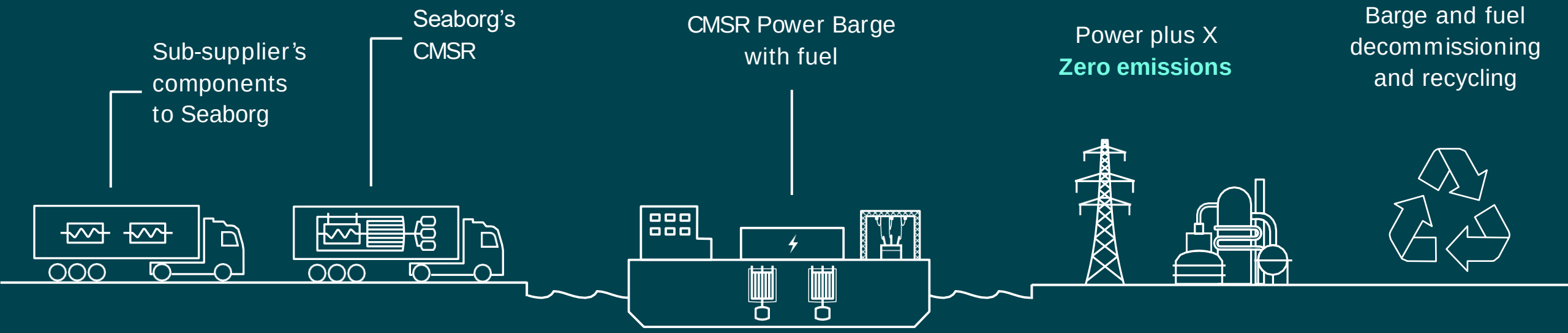


Compartments below turbine with auxiliaries for steam generation, power transmission and the CMSR



DELIVERING ENERGY

Centralised construction, worldwide distribution



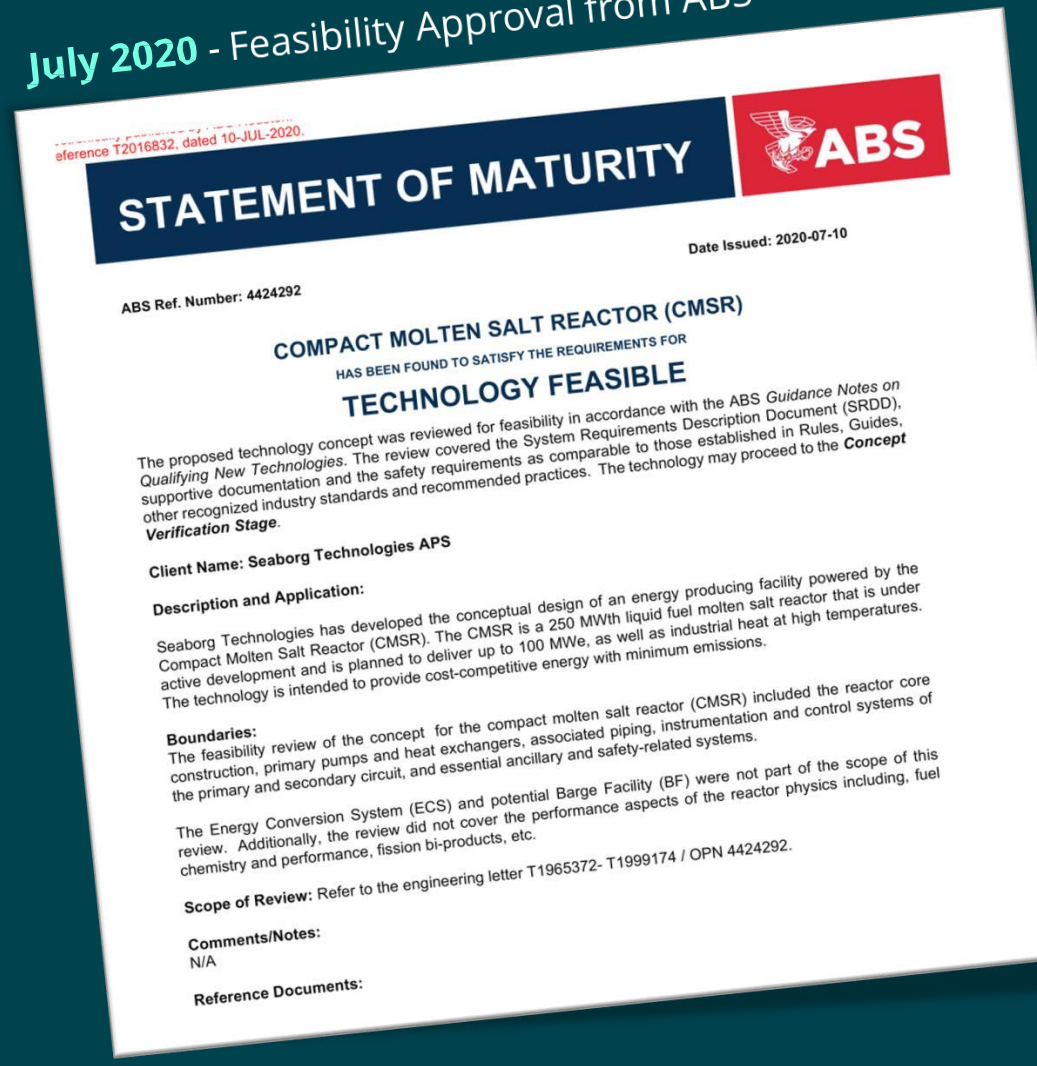
Supplier network	Facility for CMSR assembly	Supply of CMSRs for the Power Barge construction	Fully commissioned Power Barge for the customer	Decommissioning

GLOBAL LICENSING APPROACH

IAEA and Maritime Framework

- Global licensing approach
- IAEA Guidelines combined with maritime framework IMO
- Classification of the CMSR Power Barge under ABS on behalf of Flag State
- Site specific regulations controlled by Port State

July 2020 - Feasibility Approval from ABS



eference T2016832, dated 10-JUL-2020.

STATEMENT OF MATURITY

ABS

Date Issued: 2020-07-10

ABS Ref. Number: 4424292

COMPACT MOLTEN SALT REACTOR (CMSR)

HAS BEEN FOUND TO SATISFY THE REQUIREMENTS FOR

TECHNOLOGY FEASIBLE

The proposed technology concept was reviewed for feasibility in accordance with the ABS *Guidance Notes on Qualifying New Technologies*. The review covered the System Requirements Description Document (SRDD), supportive documentation and the safety requirements as comparable to those established in Rules, Guides, other recognized industry standards and recommended practices. The technology may proceed to the ***Concept Verification Stage***.

Client Name: Seaborg Technologies APS

Description and Application:

Seaborg Technologies has developed the conceptual design of an energy producing facility powered by the Compact Molten Salt Reactor (CMSR). The CMSR is a 250 MWth liquid fuel molten salt reactor that is under active development and is planned to deliver up to 100 MWe, as well as industrial heat at high temperatures. The technology is intended to provide cost-competitive energy with minimum emissions.

Boundaries:
The feasibility review of the concept for the compact molten salt reactor (CMSR) included the reactor core construction, primary pumps and heat exchangers, associated piping, instrumentation and control systems of the primary and secondary circuit, and essential ancillary and safety-related systems.

The Energy Conversion System (ECS) and potential Barge Facility (BF) were not part of the scope of this review. Additionally, the review did not cover the performance aspects of the reactor physics including, fuel chemistry and performance, fission bi-products, etc.

Scope of Review: Refer to the engineering letter T1965372- T1999174 / OPN 4424292.

Comments/Notes:
N/A

Reference Documents:

ABUNDANT, CHEAP AND CLEAN ENERGY

200 Power Barges per year by 2035

Develop in Denmark

Build in South Korea

Power the World

Electricity

- Replacing coal and gas power
- Solving grid stability
- **Powering hydrogen production**

Heat

- **Process heat for industry**
- Production of ammonia
- Production of fresh water

Thank you!

Questions?

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Advancing H2 Production Using Nuclear

NICE Future / Hydrogen Initiative Webinar

June 2022

Bruce Power Centre for New Nuclear & Net Zero Partnerships

CENTRE FOR NEW NUCLEAR + NETZERO PARTNERSHIPS

Demonstrate nuclear's role as an enabler of and supportive partner in a net zero future by:

- Developing and managing regional and community-drive decarbonization projects;
- Raising awareness and leading original research to support the case for new nuclear builds, from small modular reactors to large-scale facilities; and
- Forging ties between nuclear and other clean energy sectors from **hydrogen** to renewables and fusion energy, building upon the work of the former Centre for Next Generation Nuclear.

NUCLEAR INNOVATION INSTITUTE

Thought leadership and original research.

BRUCE POWER CENTRE FOR
NEXT GENERATION NUCLEAR

NUCLEAR INTELLIGENCE REPORT | SEPT 2021

TAKEAWAYS

- Canada's hydrogen targets will require a massive increase in electricity generation—436 TWh or more
- Meeting this demand with one generation source would require nine new nuclear plants, 196 SMRs, 26,000 new wind turbines, or 5,500 utility-scale solar farms
- To support a hydrogen economy, Canada should start building significant new generation this decade
- Nuclear will be a key source for hydrogen, given its reliability and modest land use requirements

Source: Shutterstock

Why hydrogen needs nuclear

This issue of the monthly Nuclear Intelligence Report shows how nuclear power generation is essential to achieving the federal government's proposed 2050 hydrogen targets. Canada has set ambitious goals for replacing dirty fuels with hydrogen made from low-emissions sources. This report demonstrates why nuclear power is vital to meeting that anticipated demand.

Hydrogen fuel has incredible potential for helping decarbonize our economy. When burned for energy it reacts with oxygen in the air, creating only water as a by-product. If hydrogen is produced in a clean way—such as through electrolysis powered by clean electricity—it provides a completely carbon-free source of energy that can reduce our dependence on fossil fuels.

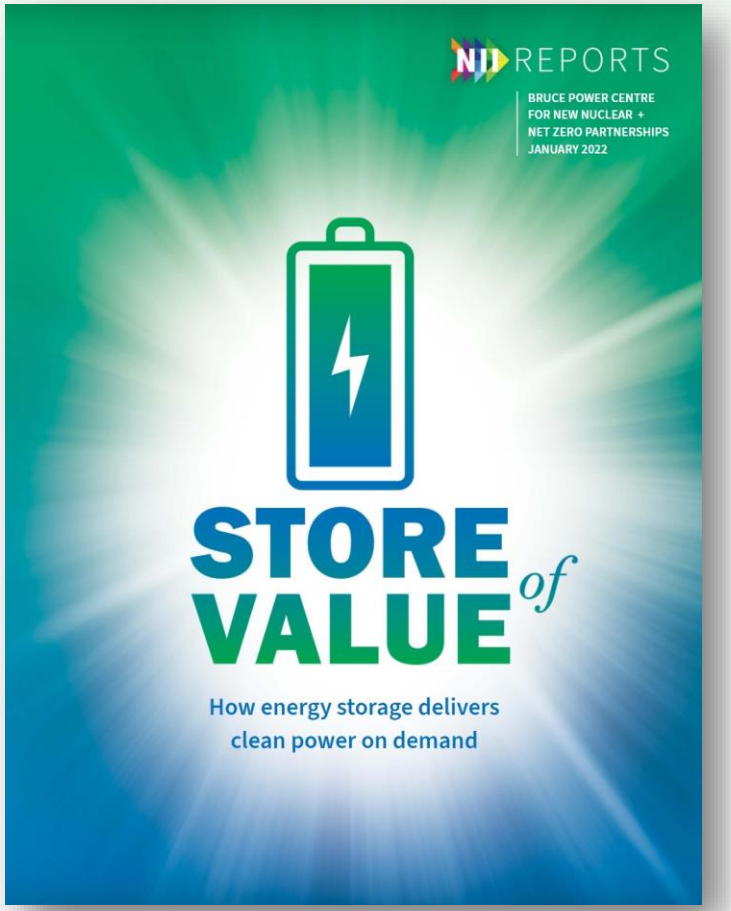
Canada's federal government, recognizing hydrogen's potential, released a National Hydrogen Strategy in December 2020. The Strategy lays out a path for further hydrogen development across the country.

As part of this Strategy, the government made an ambitious projection: by 2050, hydrogen will account for between 13% to 31% of all end use energy in Canada. But this prompts a difficult question: *how will we generate that much hydrogen?*

CANADA'S END USE ENERGY PROFILE

If Canada meets its targets, hydrogen will replace large portions of the energy currently sourced from petroleum products and natural gas.

Source: Canada Energy Regulator, EF2020 Report, 2018 statistics



NII REPORTS

BRUCE POWER CENTRE
FOR NEW NUCLEAR +
NET ZERO PARTNERSHIPS
JANUARY 2022

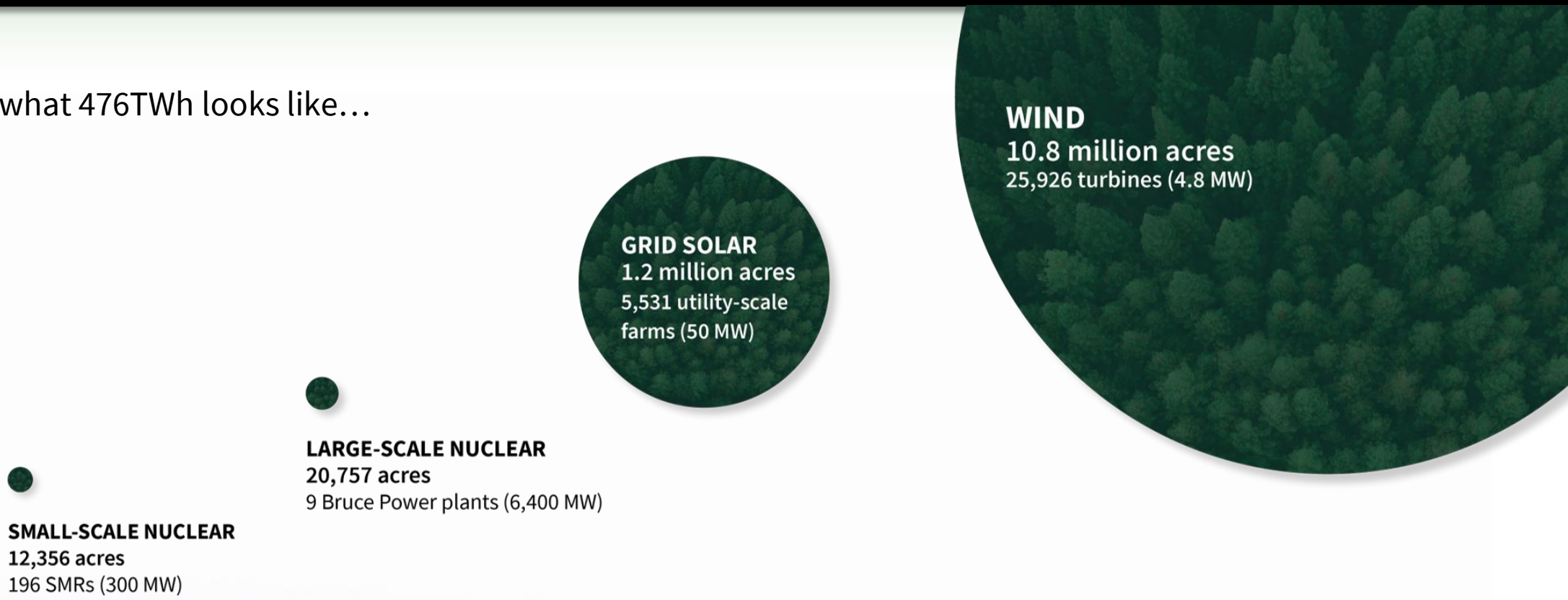
STORE of VALUE

How energy storage delivers clean power on demand

NUCLEAR INNOVATION INSTITUTE

Ex. Why hydrogen needs nuclear.

Here's what 476TWh looks like…



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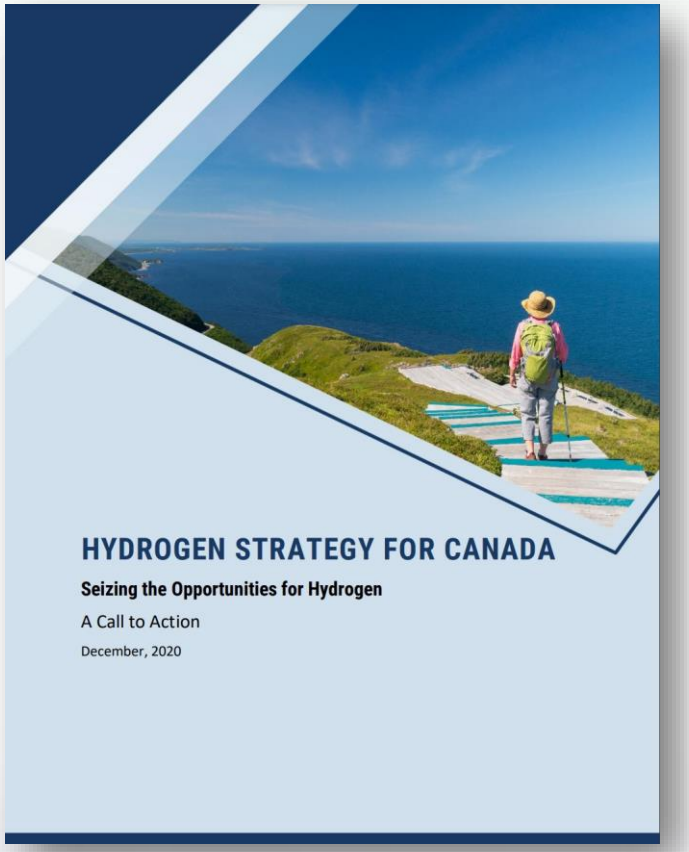
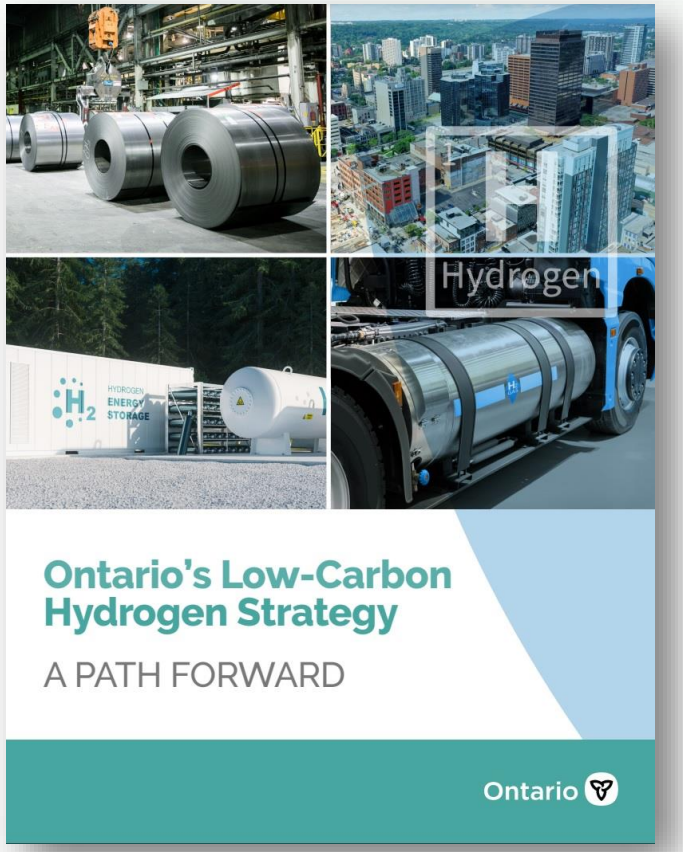
What are governments doing to advance H2 production using nuclear?





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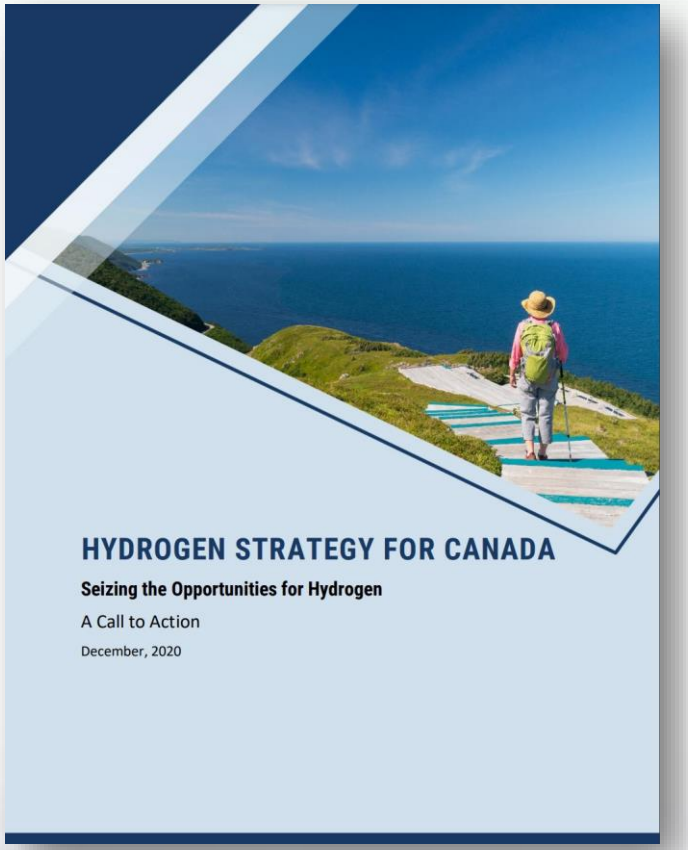
Federal Government – Hydrogen Strategy



The Government of Canada has created subject matter 'Working Groups' within the framework of the *Hydrogen Strategy for Canada.* One of those groups is the Nuclear Working Group – tasked specifically with exploring hydrogen production from nuclear assets.

- Individual 'Task Forces' have been created to explore specific focus areas including:
    - Production Opportunities;
    - Economics, Finance, Business Models and Policy;
    - Production Processes
    - Equipment & Infrastructure

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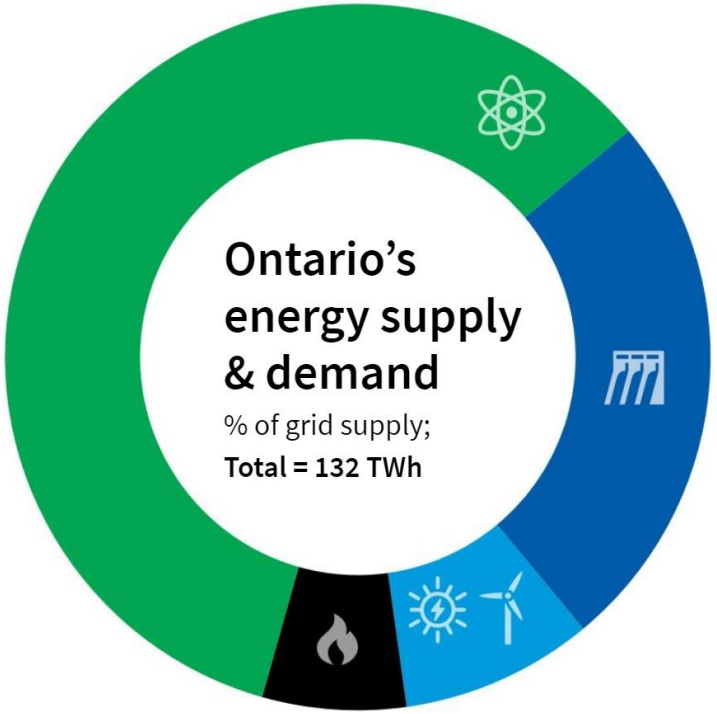
Production Opportunities – Nuclear contributes to a clean grid



60% NUCLEAR
87.8 TWh

25% HYDRO
36.9 TWh

8% WIND & SOLAR
11.8 TWh - wind
0.8 TWh - solar

7% GAS
9.7 TWh

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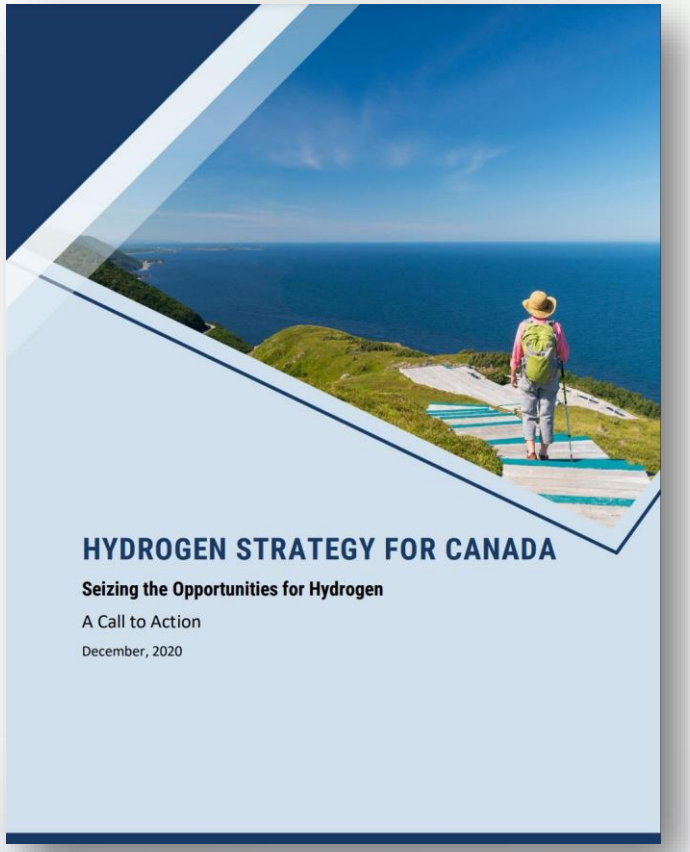
Production Opportunities – But nuclear can do more.

Low-Temperature electrochemical

High-Temperature Steam Electrolysers

Thermo-chemical Processes

Production Opportunities – Advancing opportunities.



- Industry and Government are collectively advancing specific opportunities in the near-,medium-, and long-term for further review to create a supportive policy and regulatory environment for H2 production from nuclear in Canada.

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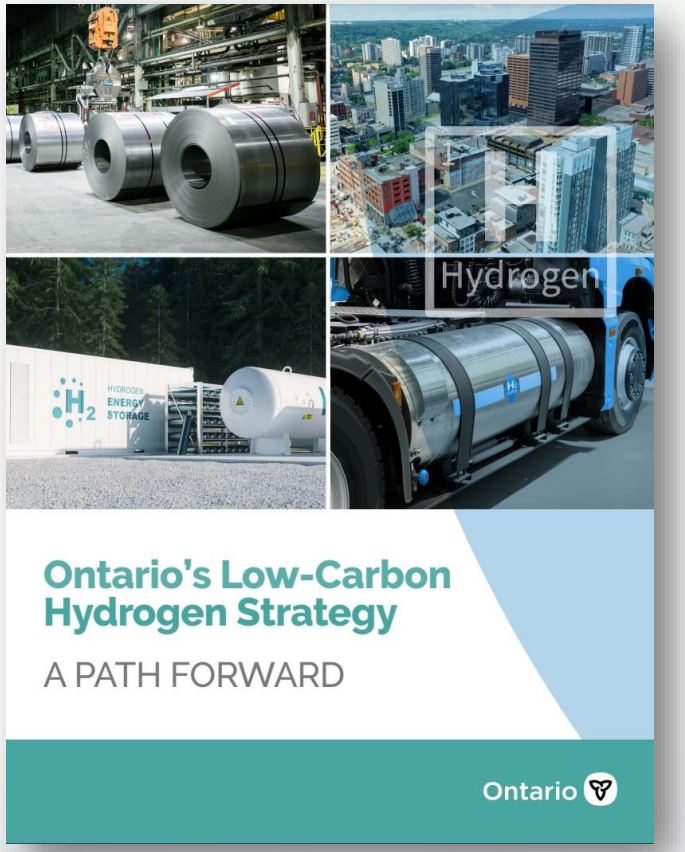
Provincial Government – Hydrogen Strategy



Ontario's Low-Carbon Hydrogen Strategy **contains 8 specific 'actions'. 1 of which is as follows:**

- ***Assessing the Feasibility of Hydrogen Opportunities at Bruce Power****: Bruce Power will launch a feasibility study to explore opportunities to leverage excess energy from the Bruce Nuclear Generating Station for hydrogen production and support a centre of excellence in the region.*

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Industry – Advancing H2 Opportunities at Current Assets

Bruce Power to explore feasibility of using excess energy for hydrogen production

2022-04-07

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Thank you.

Chad Richards
Director (New Nuclear & Net Zero)
Chad.Richards@nii.ca

Questions?

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Thank you for joining!

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