IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Webinar

Hydrogen Production with Operating Nuclear Power Plants the Business Case

23 March 2023

moderator: Aliki van Heek

Outline

- Welcome remarks (Henri Paillere, IAEA)
- Introduction (Aliki van Heek, IAEA)
- Part 1: The role of hydrogen from nuclear energy to support clean energy transitions
- Part 2: Examples of nuclear hydrogen project by utilities
- Q&A

Speakers

Part 1: **The role of hydrogen from nuclear energy to support clean energy transitions**

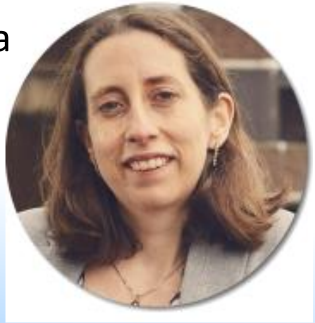
Andrei Goicea
Nucleareurope

Gilles Rodriguez
CEA
France &
IEA H2 TCP

Rupsha Bhattacharyya
HBNI/BARC
India

Part 2: **Examples of nuclear hydrogen project by utilities**

Rebecca Rosling
EDF Energy
UK



Maryam Qasem
ENEC
UAE

Uuganbayar Otgonbaatar
Constellation
USA

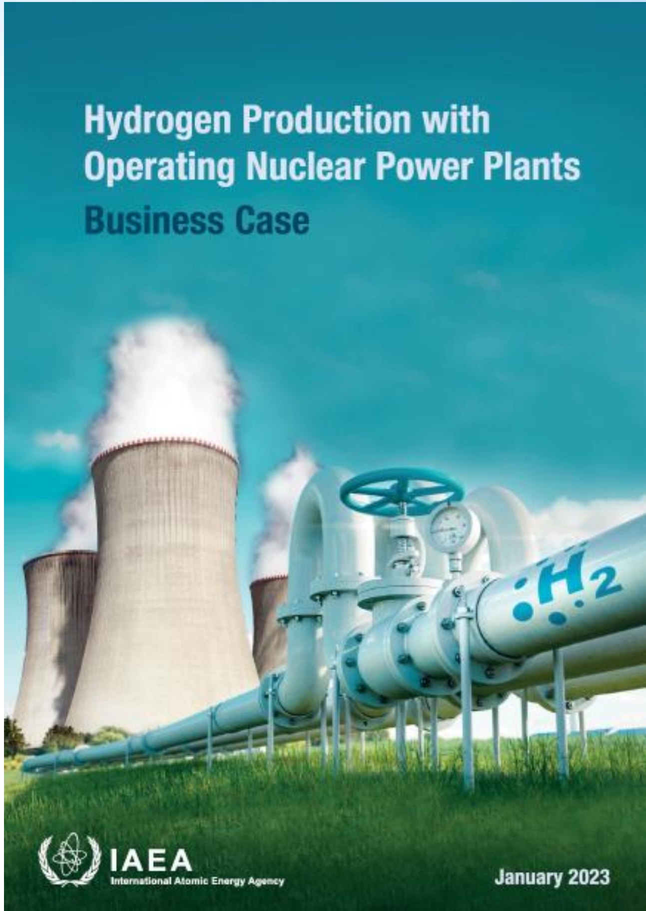
Publication Hydrogen Production with Operating Nuclear Power Plants - Business Case

Scope:

- Hydrogen production using **existing nuclear power plants and newbuild projects** as a near-term low carbon hydrogen production method and a basis for future expansion.

Objectives:

- To evaluate and compare hydrogen production demonstration projects by **nuclear utilities currently underway**,
- To identify **similarities** and **differences** and
- To extract the factors for **deployment of nuclear hydrogen business case**.



Why the interest in nuclear hydrogen as an energy carrier?

1. Reducing greenhouse gas emissions:

1) Current ways of hydrogen production using fossil fuels should be **replaced**

2) Hydrogen production using nuclear power

- is an effective way to **decarbonize** hydrogen production
- can be done **large-scale**, **stable**, **24/7** and **on-demand**

3) Hydrogen can be efficiently produced by using nuclear **heat** as well as electricity.

2. In energy systems with increasing shares of variable renewable energy:

– Option of **storing energy** and increasing **flexibility** of these energy systems.

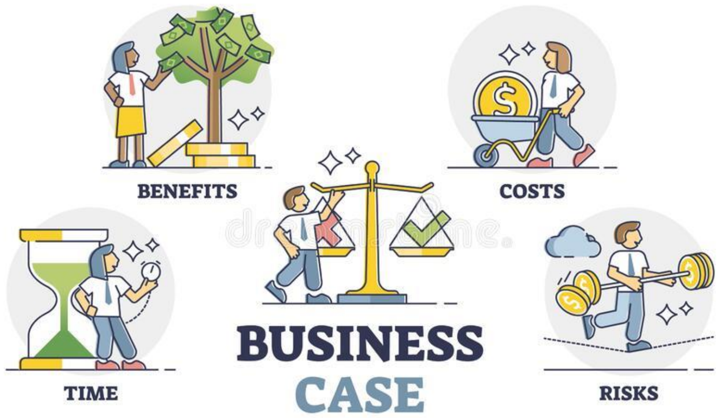
– **Alternative revenue stream** for those nuclear power plants with temporary surplus power.

Nuclear utilities participating in our study

10 projects: all in an early phase

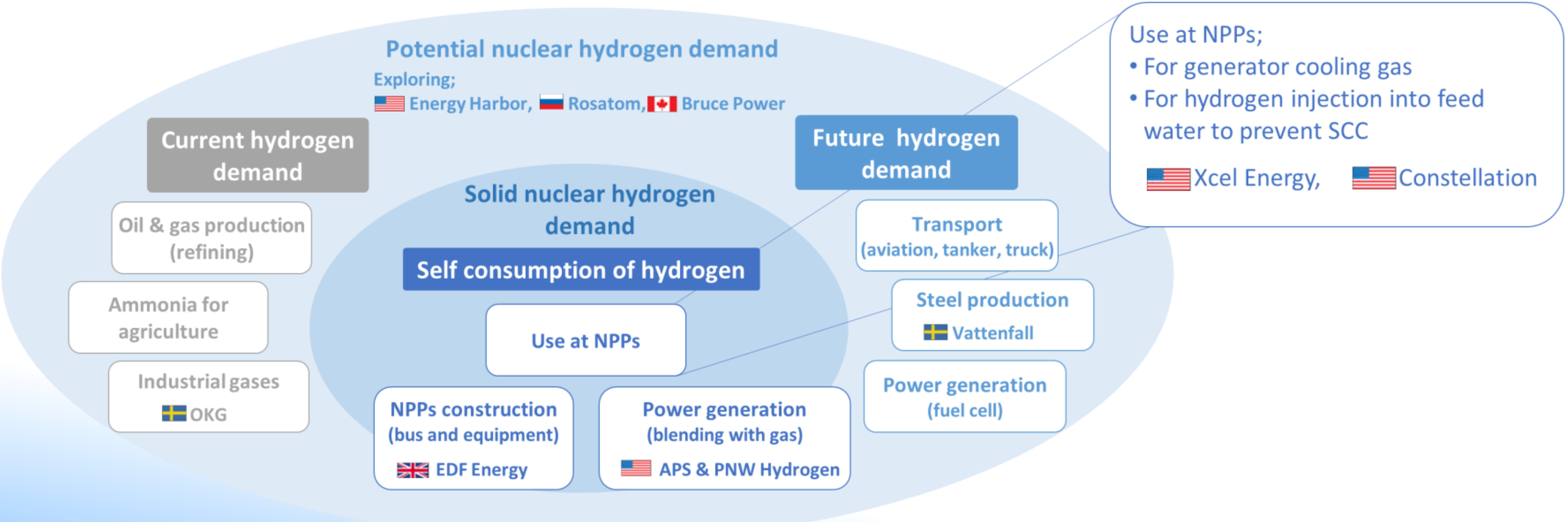
Approach

- **Utility strategy for climate targets**
  - National hydrogen strategy
  - Utility hydrogen targets
- **Demand and market**
  - Finding or creating demand for hydrogen
  - Electrolyser system location
  - Creating demand through 'clusters'
- **Minimizing costs to maximize revenue**
  - Approaches for cost reduction
  - Appropriate capacity & production
  - Government support & risk allocation



Finding demand for hydrogen

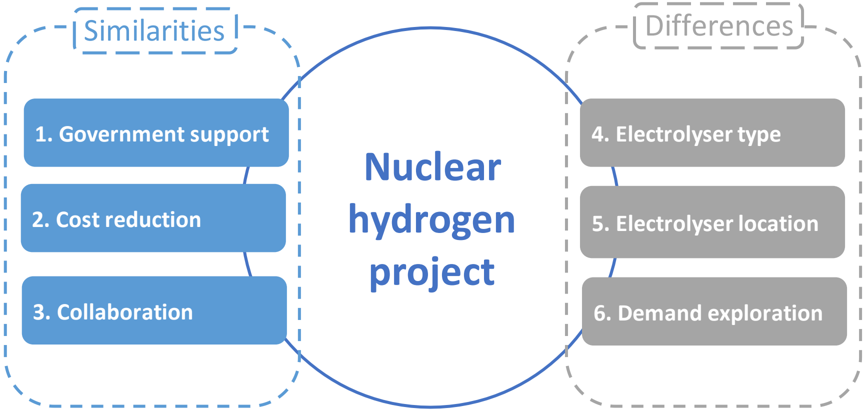
- Current demand for hydrogen: refining and ammonia for agriculture
- Future demand expansion expected to other sectors, e.g. transport, steel manufacturing and power generation
- Challenge for nuclear hydrogen demonstration projects: to find enough demand to incentivize hydrogen production
- Initial applications: nuclear power plant internal use; co-firing natural gas



Summary – Similarities and differences

- **Observed project similarities include:**
  - Government support is key to nuclear hydrogen project success.
  - Considerations order to reduce electricity costs:
    - use of surplus electricity from NPPs
    - use of HTE
  - To avoid risk, the nuclear hydrogen projects:
    - Start with a small size of electrolyser (around 1MW),
    - Include cooperation with research institutes, electrolyser manufactures, and hydrogen consumers.

- **Observed project differences include:**
  - Each utility targets different demands, but faces the same challenge of finding a market.
  - Different electrolyser technology selected for each project, with no clearly defined superior technology to date.
  - LTEs tend to be located
    - near NPPs when hydrogen is used primarily in NPPs only as step towards commercial H_2 production,
    - near hydrogen demand facilities when hydrogen is used by a large demand facility.



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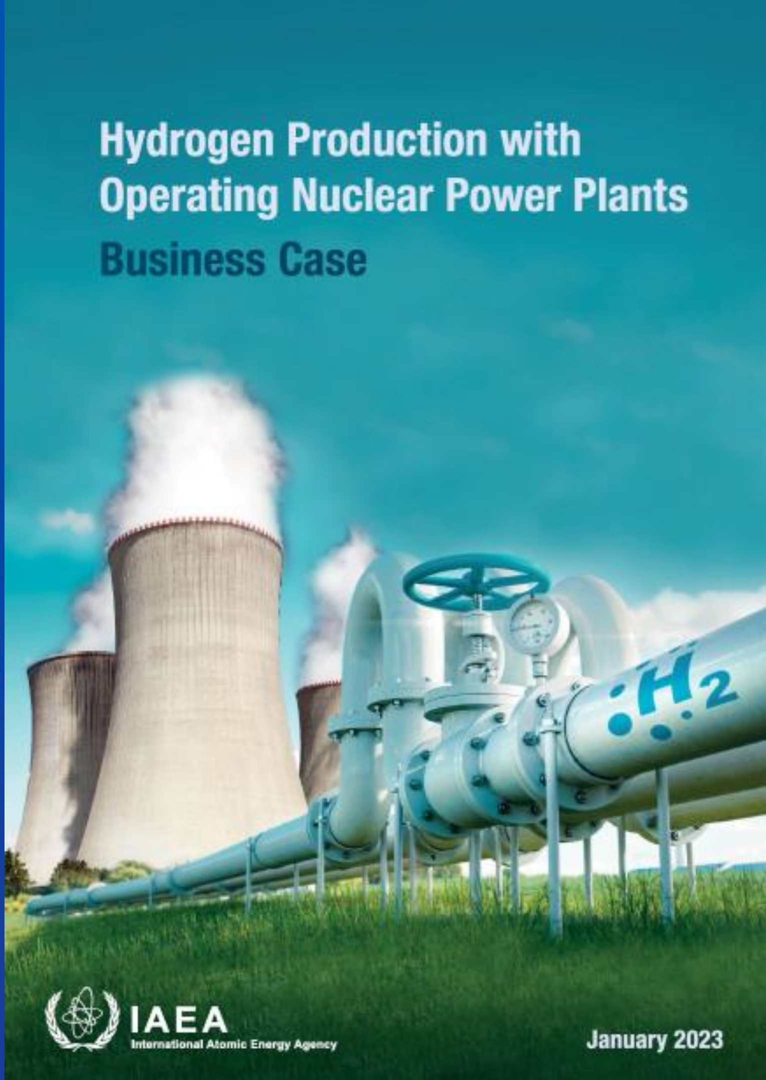
IAEA booklet "*Building the Business Case for Hydrogen Production with Currently Operating Nuclear Power Plants*"

https://www.iaea.org/sites/default/files/2023_h2_bc_booklet_web.pdf



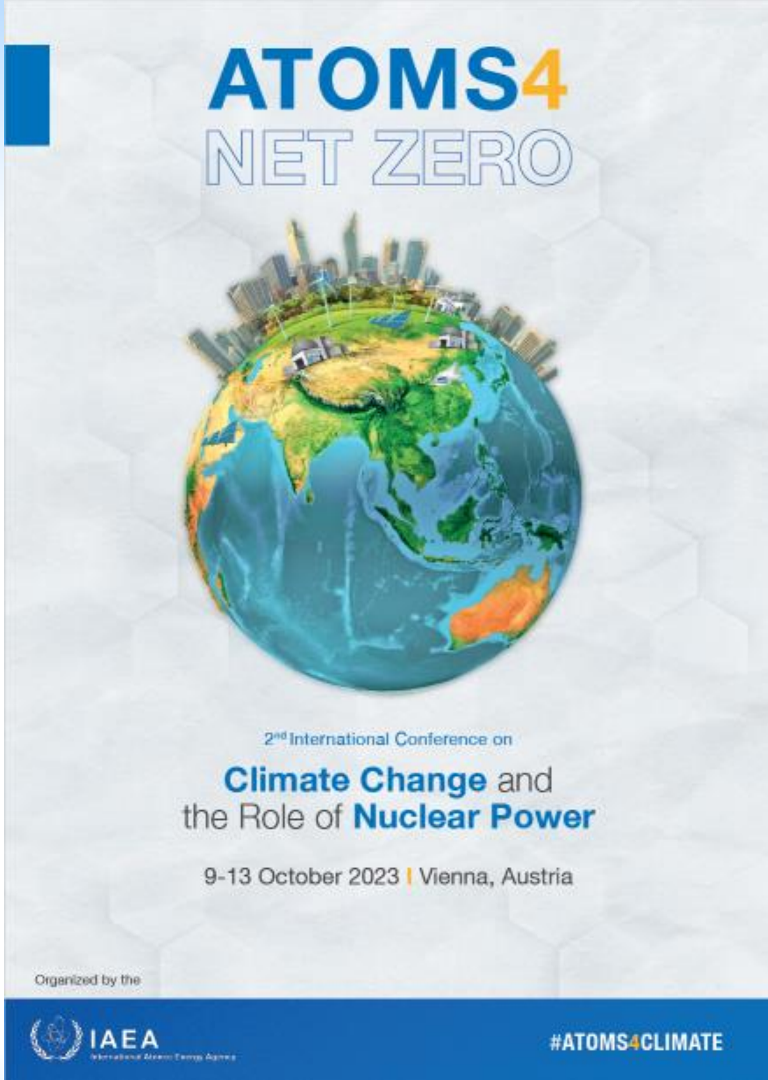
IAEA 2nd International Conference on Climate Change and the Role of Nuclear Power

Dates: 9-13 October 2023

Announcement and Call for Papers: https://www.iaea.org/events/atoms4climate-2023

Deadline for abstracts: **28 April 2023**

One of the topics: "*Releasing the full potential of nuclear energy*", including hydrogen



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thank you!

Planning and Economics Studies Section

Low-carbon hydrogen policies in EU

Andrei Goicea - Policy Director
IAEA webinar on Hydrogen Production with Operating Nuclear Power Plants – the Business Case
23 March 2023

nucleareurope

The EU energy market needs

Electricity

1600 TWh/y
EU Low carbon electricity production to be deployed by 2040

80GW
European Nuclear capacity to be replaced by 2050 (end of life)

Hydrogen

>20 Mt H_2/y
REPowerEU Market Estimate for 2030

1000 TWh/y
Equivalent additional clean electricity demand

>125 GW
Equivalent nuclear capacity

Industrial heat

~1250 TWh_{th}/y
Iron – Steel, Non-metallic minerals and chemicals heat demand in EU

> 45% market
Heat < 400°C

District heat

~500 TWh_{th}/y
Current district heat demand in EU

> 2/3 fossil- fueled
Assets to be retired and replaced in the coming two decades

Source: ENGIE Tractebel

nucleareurope

Hydrogen matter at EU level

Political messages

Hydrogen Strategy (2020)

- clean hydrogen (RES)
- low-carbon hydrogen (fossil+CCS/electrolysis low-carbon electricity)

REPowerEU plan (2022)

More ambitious targets for clean hydrogen:
target of 10 million tonnes of domestic renewable hydrogen production and 10 million tonnes of imports by 2030

Legal background

RED III review

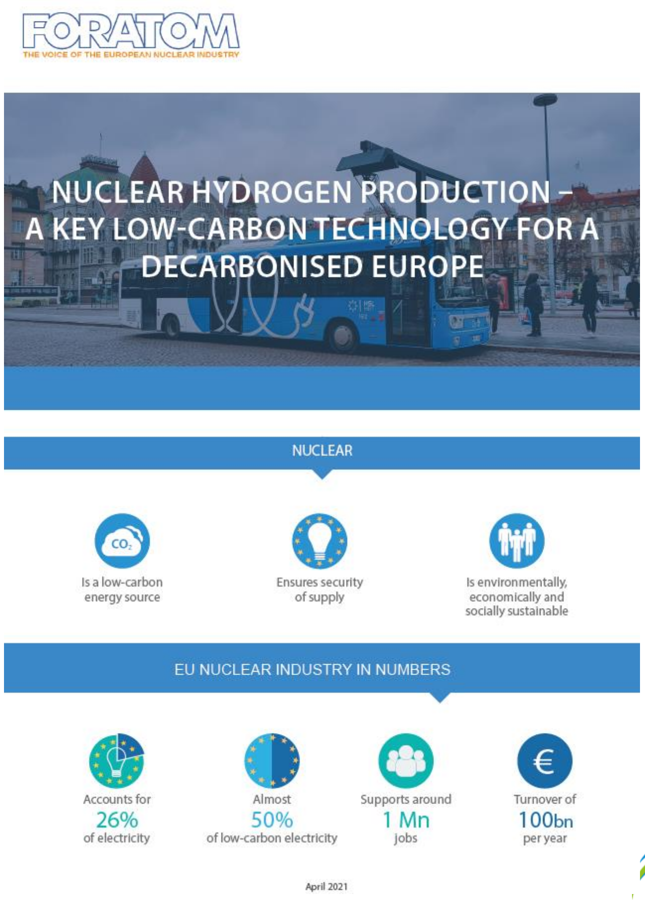
Delegated acts

- The first Delegated Act defines under which conditions hydrogen, hydrogen-based fuels or other energy carriers can be considered as an RFNBO (additionality).
- The second Delegated Act provides a methodology for calculating life-cycle greenhouse gas emissions for RFNBOs

Gas package

Delegated act expected by the end of 2024

nucleareurope's position paper on hydrogen



FORATOM

THE VOICE OF THE EUROPEAN NUCLEAR INDUSTRY

NUCLEAR HYDROGEN PRODUCTION – A KEY LOW-CARBON TECHNOLOGY FOR A DECARBONISED EUROPE

NUCLEAR

Is a low-carbon energy source

Ensures security of supply

Is environmentally, economically and socially sustainable

EU NUCLEAR INDUSTRY IN NUMBERS

Accounts for 26% of electricity

Almost 50% of low-carbon electricity

Supports around 1 Mn jobs

Turnover of 100bn per year

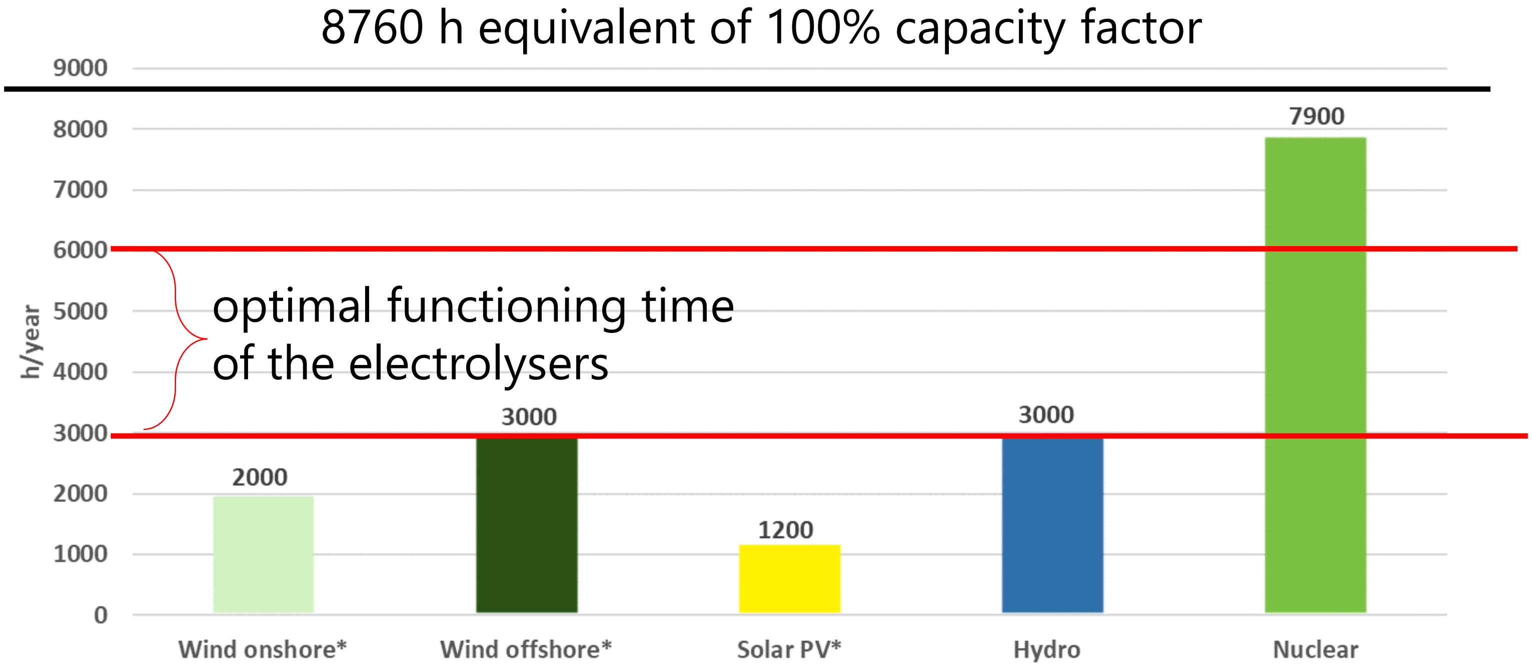
April 2021

- Position paper and background paper released in April 2021
- Main point of nucleareurope's opinion:

A sustainable and economic hydrogen economy cannot succeed without significant reliance on low-carbon category (electrolysis using nuclear power)

nucleareurope

Low-carbon generations capacity factors



- With optimal economic functioning time of **3000h-6000h/year** resting only on renewable doesn't make sense
- The carbon intensity of H2 from grid can fulfil required thresholds only w/ support of nuclear (i.e. France, Sweden or Finland)

nucleareurope

*ASSET report for EC on "Technology pathways in decarbonisation scenarios", July 2018
Note: medium capacity factors for 2030 has been considered for the selected technologies

Thank you!

andrei.goicea@nucleareurope.eu

nucleareurope

Hydrogen Value Propositions

Constellation: By the Numbers

Constellation is the #1 zero-carbon energy provider in the U.S with 90% carbon-free output, backed by more than 32,000 MW of generating capacity.

Operates in 48 States & DC

215 TWh
1600 Bcf
Customer Load Served

Scalable national platform of approximately **2 million customers** served, offering a diversity of innovative products and services, including to ¾ of Fortune 100 companies

Power Supply Mix	TWh
Nuclear	176
Conventional	20
Owned Renewable	7
Contracted Renewable	7
Purchased Power	73

13,000 Employees

Constellation is soon to be a **Fortune 200** Company

C&I Market Share Ranking **#1**

Goal of providing **100%** of business customers with custom GHG data by end of 2022

Constellation

Hydrogen Hub Funding

Expected FOA: No later than 180 days after the date of enactment of the Infrastructure Investment and Jobs Act – May 2022– the Secretary shall solicit proposals for regional clean hydrogen hubs. $8 B is authorized from the period of FY 2022-2026.

Selection criteria

- Feedstock diversity—To the maximum extent practicable— ''(i) at least 1 regional clean hydrogen hub shall demonstrate the production of clean hydrogen from fossil fuels; ''(ii) at least 1 regional clean hydrogen hub shall demonstrate the production of clean hydrogen from renewable energy; and ''(iii) at least 1 regional clean hydrogen hub shall demonstrate the production of clean hydrogen from nuclear energy.
- End-use diversity—To the maximum extent practicable— ''(i) at least 1 regional clean hydrogen hub shall demonstrate the end-use of clean hydrogen in the electric power generation sector; ''(ii) at least 1 regional clean hydrogen hub shall demonstrate the end-use of clean hydrogen in the industrial sector; ''(iii) at least 1 regional clean hydrogen hub shall demonstrate the end-use of clean hydrogen in the residential and commercial heating sector; and ''(iv) at least 1 regional clean hydrogen hub shall demonstrate the end-use of clean hydrogen in the transportation sector.
- Geographic diversity—To the maximum extent practicable, each regional clean hydrogen hub— ''(i) shall be located in a different region of the United States; and ''(ii) shall use energy resources that are abundant in that region.
- Hubs in natural gas-producing regions—To the maximum extent practicable, at least 2 regional clean hydrogen hubs shall be located in the regions of the United States with the greatest natural gas resources.

Source: IIJA final language

Constellation

Clean Hydrogen from Nuclear

Superior economics

Clean hydrogen produced using nuclear power currently beats green hydrogen produced using renewable power on a levelized cost basis in most regions of the country

Low barriers to implementation

Existing nuclear plants avoid supply chain and other development delays associated with new renewables

Scalable and iterative

Electrolyzer capacity can be modularly ramped onto nuclear assets from pilot stage to at-scale production – allowing iterative electrolyzer installation cost-downs and quick production scale-up with new offtakers

Advantageous end-uses

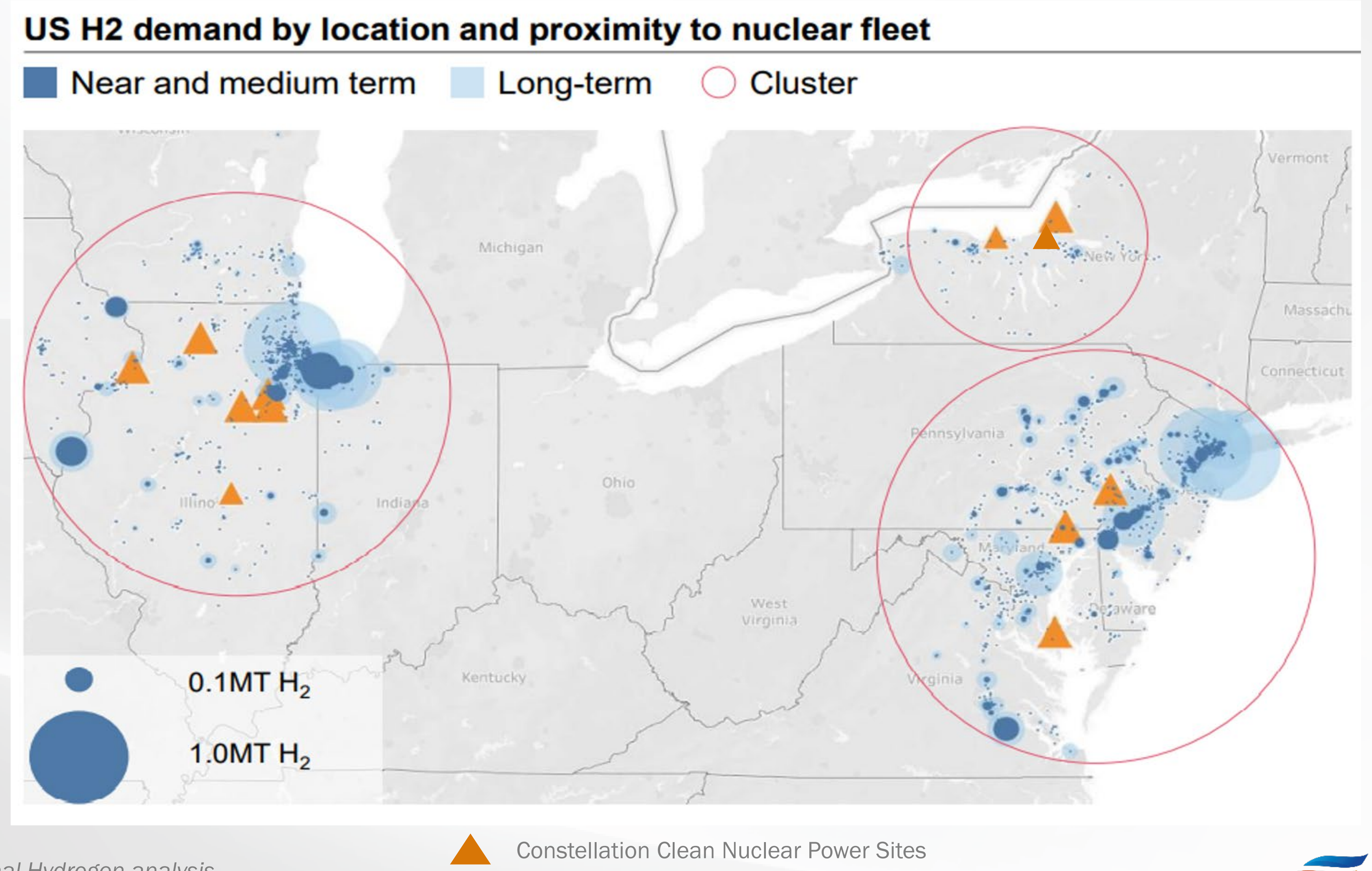
There are certain end-uses that benefit from high heat industrial processes – such as synfuels– that create a synergistic relationship with nuclear sites

Enhanced criticality of nuclear assets

As increasing renewables create more intermittency, electrolyzer loads can also be used to add flexibility to nuclear assets to improve value in a decarbonizing world

Source: Internal Hydrogen analysis

Constellation's Nuclear fleet is within 100-mile range of ~14 MT H2



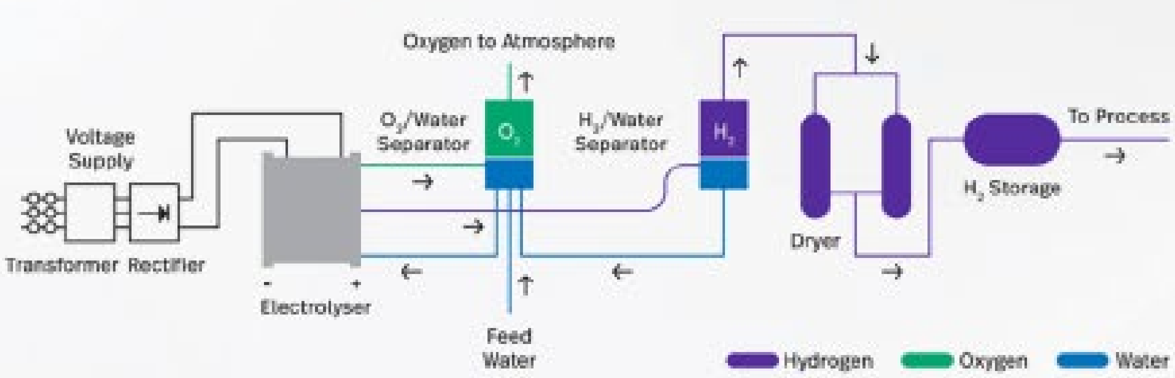
Source: Internal Hydrogen analysis

Constellation

Nine Mile Point Hydrogen Pilot

- Constellation has been awarded a DOE grant in partnership with Nel Hydrogen and 3 national laboratories to demonstrate an integrated hydrogen production strategy
- Nine Mile Point was selected as the site to install a Proton Exchange Membrane (PEM) electrolyzer
- Budget Period 1 concluded in August 2021

Electrolysis is the process of splitting the water molecule into hydrogen and oxygen using electricity. The inputs to this process are simply feed water and the current supplied to the electrolyser.



Budget Period 1:

Complete 30% Design

Demonstrate dynamics operation

Budget Period 2:

Finish 100% design, install, operate at steady state

Demonstrate dynamic operation, simulate scaleup

Year 1 (April 2020 – March 2021)
- Site selection and 30% engineering design
- Engineering specification for electrolyzer
- Environmental review
- Regulatory review
- Installation cost estimate and plan

Year 2 (April 2021 – March 2022)
- 100% engineering design
- Complete manufacture, test of electrolyzer

Year 3 (April 2022 – March 2023)
- Start of steady state operation of electrolyzer
- Simulation of scale-up electrolyzer operation
- Demonstration of dynamic operation on site

Constellation

Start of Production at Nation's First One Megawatt Demonstration Scale Nuclear-Powered Clean Hydrogen Facility

- On March 7th, hydrogen production started clean hydrogen production facility at Constellation's Nine Mile Point Nuclear Plant in Oswego, New York
- The project leverages DOE grant of $5.8 million to demonstrate hydrogen production and end use for the plant's own consumption of hydrogen
- The PEM electrolyzer uses 1.25 MW of power behind the meter to produce 560kg/Day of clean hydrogen, more than enough to meet the plant's hydrogen use.
- The additional hydrogen production is being explored as a long duration energy storage system in a separate grant project supported by NYSERDA.
- Constellation has committed to invest $900 million through 2025 for commercial clean hydrogen production using nuclear energy. This includes participation in the Midwest Alliance for Clean Hydrogen (MachH2)

Constellation

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Constellation

HyNE - Hydrogen from Nuclear Energy
A new IEA Task

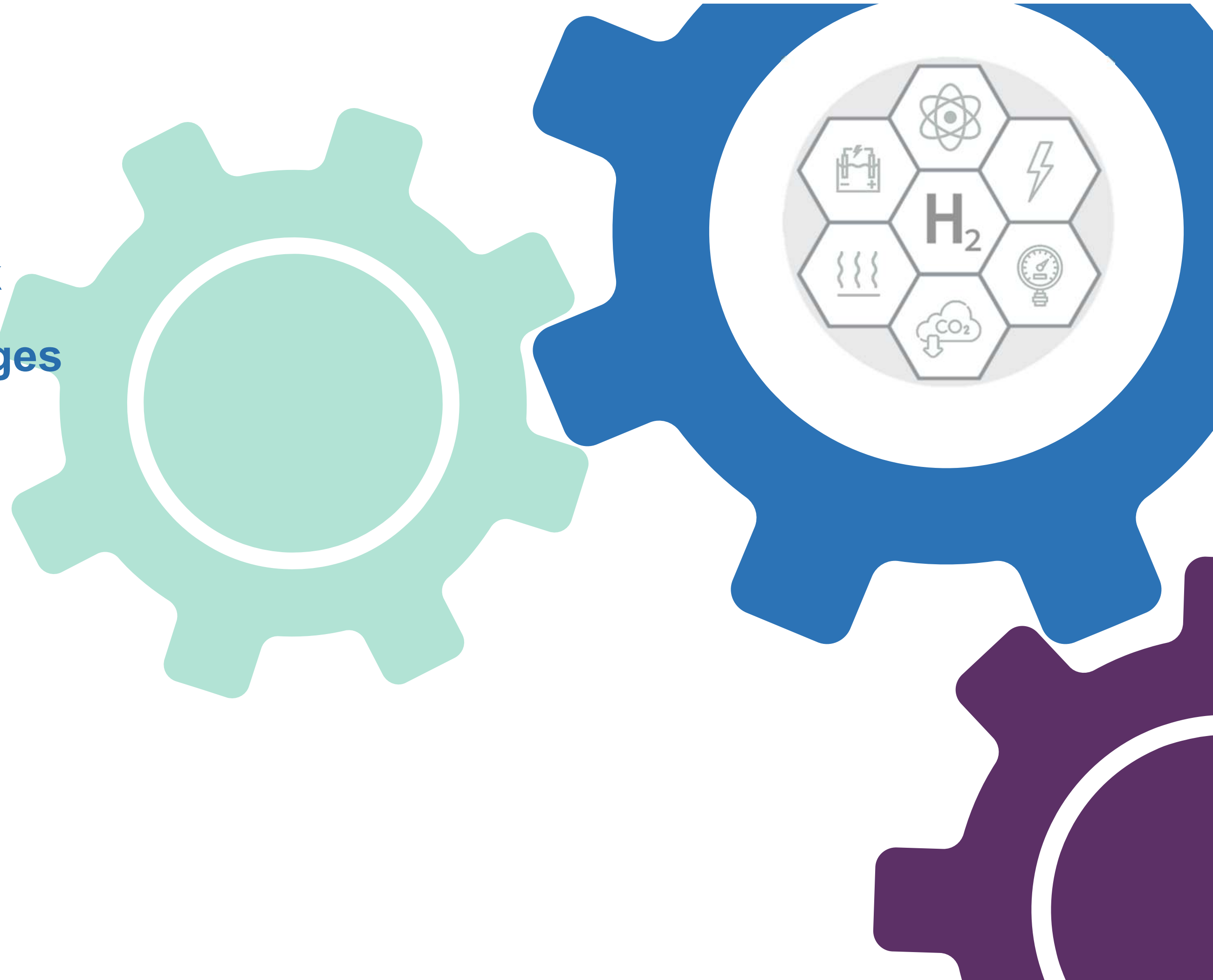
IAEA Webinar : Hydrogen Production with operating nuclear plant

23rd March

Gilles RODRIGUEZ – CEA/France

Presentation

1) What is IEA HYDROGEN TCP
2) Description of the HYNE Task
3) Some objectives and challenges
4) Conclusion



What is IEA HYDROGEN TCP ?

IEA: A three pillar organization
An unprecendented Modernization Plan

An Influent expert international organizations

CLEAN ENERGY MINISTERIAL

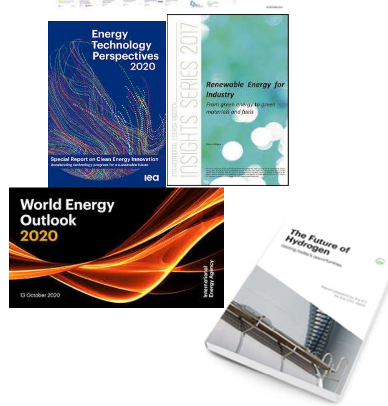
G20 2019 JAPAN

G7 FRANCE BIARRITZ 2019

MISSION INNOVATION
Accelerating the Clean Energy Revolution

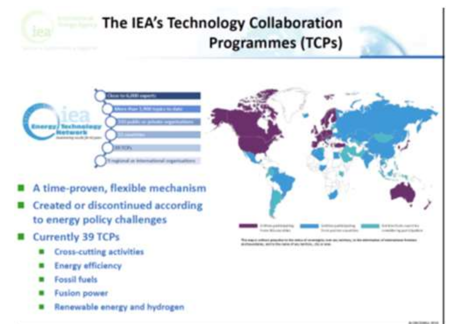
PARIS Secretariat Team (300 people)leaded by Fatih Birol

A referent expert
in Energy analysis Scenarios
Plus advisory or strategic bodies



Network of 39 TCPs
6000 expert's network

iea Energy Technology Network



Renewables, Smart Grid, oil gas, CCS, **Hydrogen**, Fuel cells, Electric vehicle, combustion, ICE, Fusion, Heat and Cooling, storage, heat pump…

IRENA International Renewable Energy Agency

H2 Hydrogen TCP

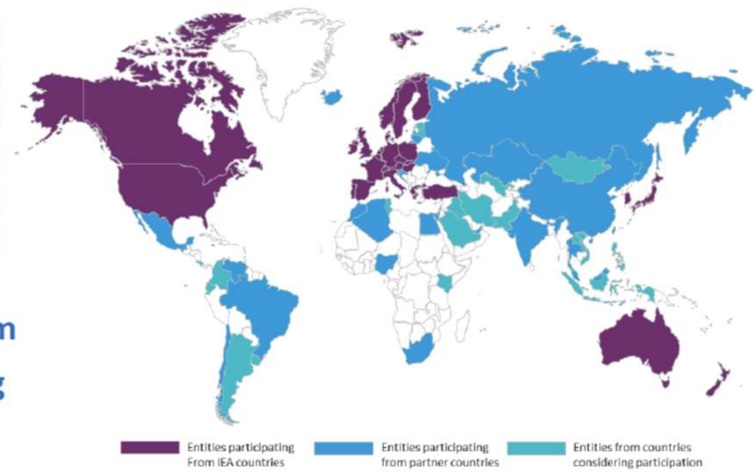
What is IEA HYDROGEN TCP ?

The IEA's Technology Collaboration Programmes (TCPs)

International Energy Agency
Secure • Sustainable • Together

IEA Energy Technology Network 1975-2015
Accelerating results for 40 years

- Close to 6,000 experts
- More than 1,900 topics to date
- 310 public or private organisations
- 51 countries
- 39 TCPs
- 9 regional or international organisations



This map is without prejudice to the status of sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

- A time-proven, flexible mechanism
- Created or discontinued according to energy policy challenges
- Currently 39 TCPs
  - Cross-cutting activities
  - Energy efficiency
  - Fossil fuels
  - Fusion power
  - Renewable energy and hydrogen

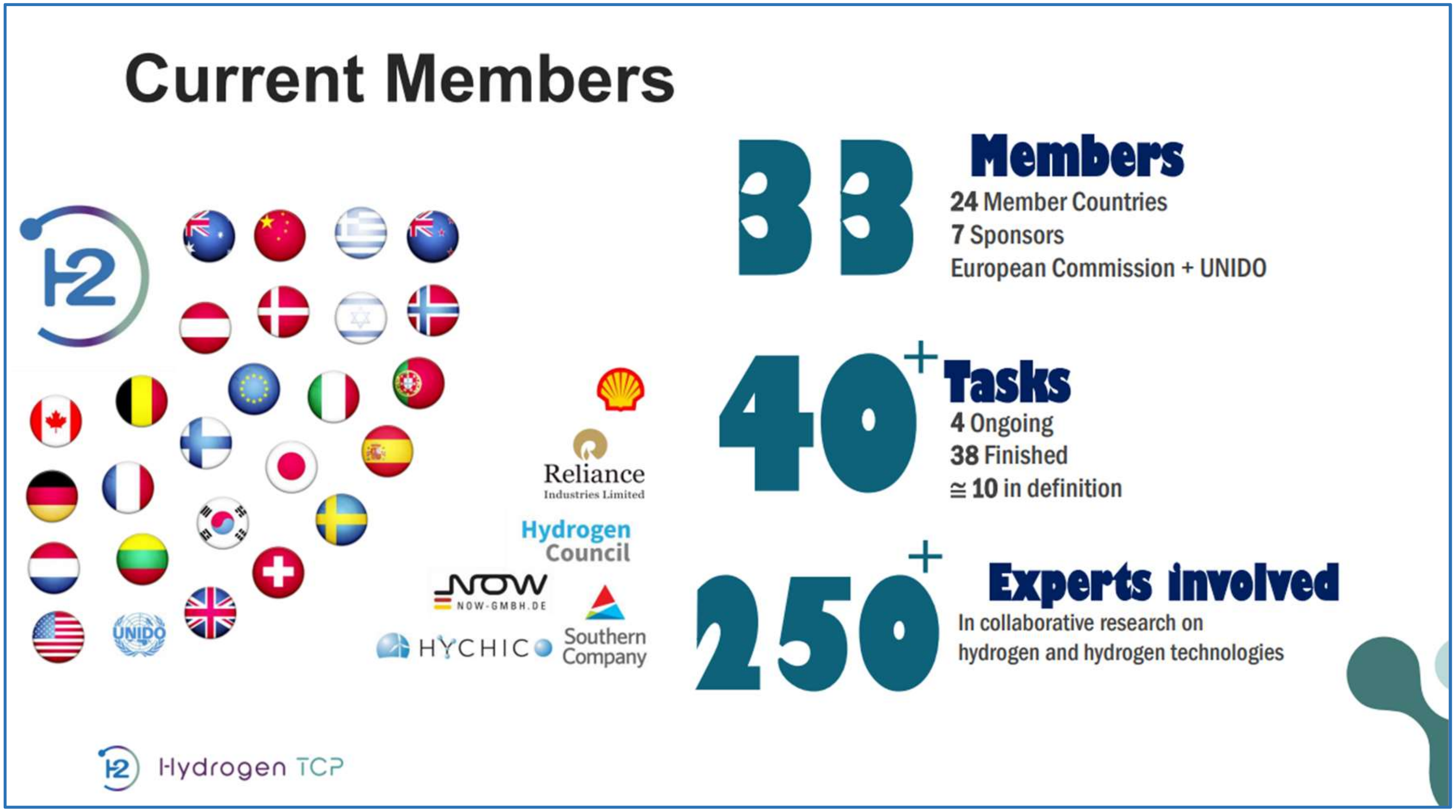
iea Energy Technology Network

H2 Hydrogen TCP

What is IEA HYDROGEN TCP ?

Hydrogen TCP president P. Lucchese

https://www.ieahydrogen.org/



Description of the HYNE Task

What is the context ? Why proposing this Task?

In a decarbonized society, the future energy is still centered around two primary energy sectors : **Electricity** and **Heat**

But the intermittency of the VRE (Variable Renewable Energy) is changing the specifications of electricity production

But producing cheap heat without emitting CO_2 remains challenging

In these two options **Hydrogen** is appealed to get a promising future as energy vector in storage, energy regulator, and as chemical product to decarbonized the society

In this context Nuclear could have a key position in this energy mix because it can supply these future energy needs.

Thus in the future, the nuclear energy must not be only considered as a massive electricity supplier. **Its portfolio of services is significantly increasing.**

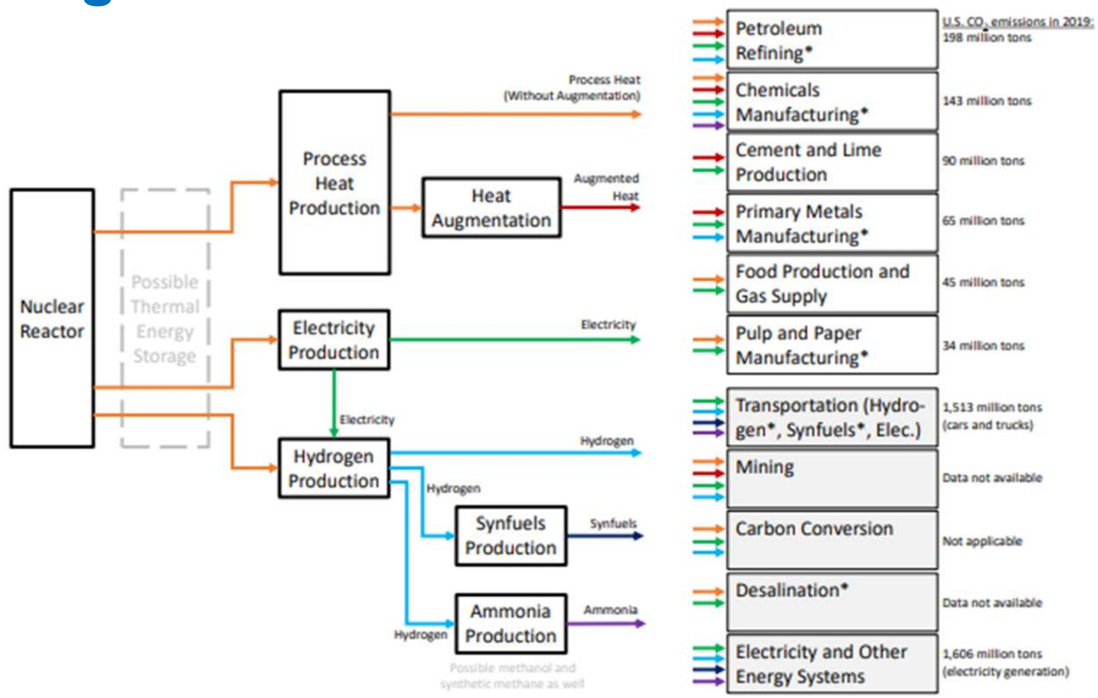


Figure Source :

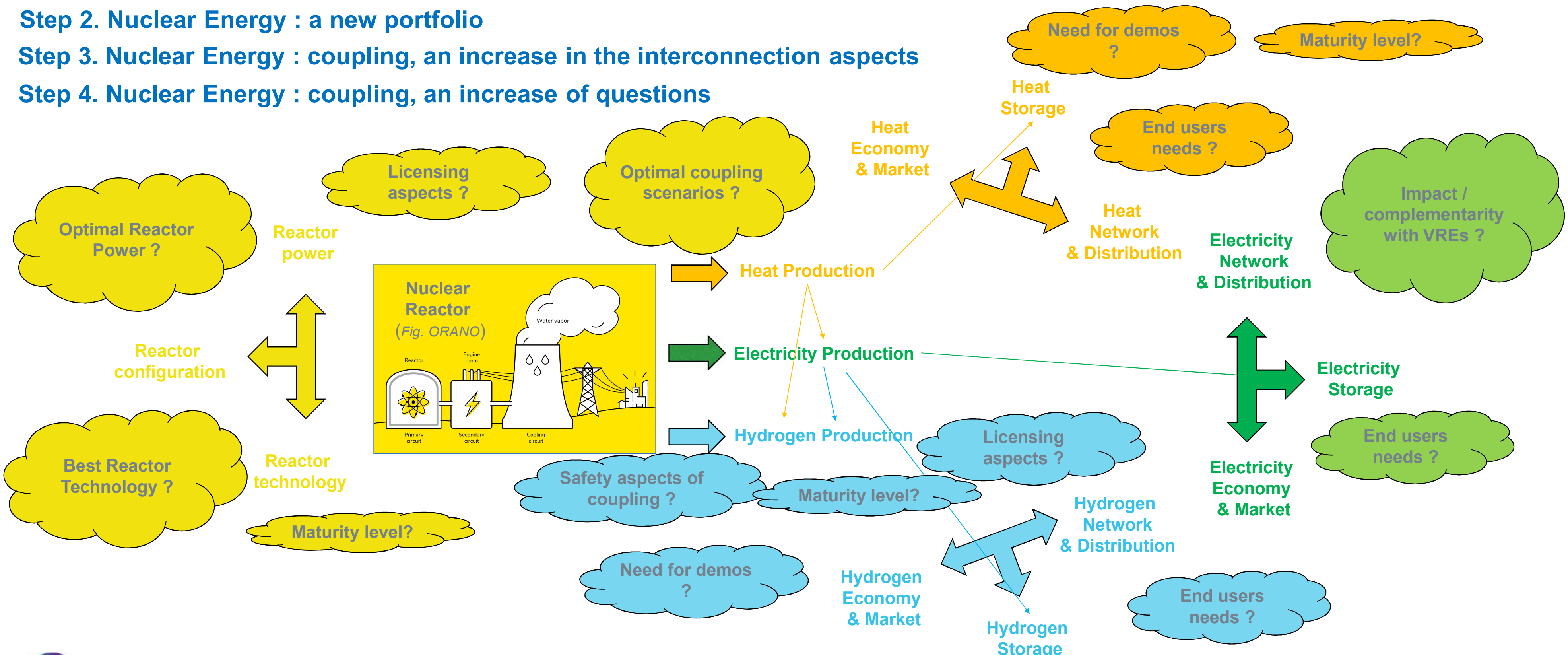
NRIC Integrated Energy Systems Demonstration Pre-Conceptual Designs

APRIL 2021

Report for Project RC-21IN020701

Challenges: Hydrogen from Nuclear Energy Task = an interconnected Task because this subject is highly complex

Step 1. Nuclear Energy : the today reference scenario
Step 2. Nuclear Energy : a new portfolio
Step 3. Nuclear Energy : coupling, an increase in the interconnection aspects
Step 4. Nuclear Energy : coupling, an increase of questions



Challenge: Hydrogen from Nuclear Energy: an IEA Task, highly connected with other Intl organisations

- *GEN II & III Systems*
- *SMRs & AMRs**
- *Tech-eco Modelling & Codes*
- *Intl approach*

** SMR: Small Modular Reactor | AMR: Advanced Modular Reactor*

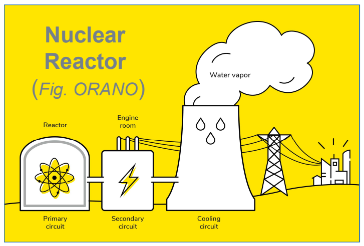
NEA
Nuclear Energy Agency

- *Data*
- *Technico-Economy approach*

Reactor power

Reactor nfiguration

Reactor technology



Heat Production

Electricity Production

Hydrogen Production

Heat Storage

Heat Economy & Market

Heat Network & Distribution

Electricity Network & Distribution

Electricity Storage

Electricity Economy & Market

Hydrogen Network & Distribution

Hydrogen Economy & Market

Hydrogen Storage

- *Organization and country interested and involved in that scheme (Private or public Org., Country, Think Tank, …) signing a collaboration agreement with IEA Hydrogen TCP*

GENIV International Forum
Expertise | Collaboration | Excellence

- *GENIV Systems*
- *NEaNH* Task Force*
- *R&D on Hydrogen massive production*

** NEaNH: Non Electric applications of Nuclear Heat*

iea
International Energy Agency

- *Data*
- *Network*
- *Global Energy scenarios*
- *Complementary approach with other energy sources*

H2 Hydrogen TCP

- *Hydrogen storage*
- *Hydrogen safety*
- *Hydrogen distribution*
- *Hydrogen to X*
- *… see next slide*

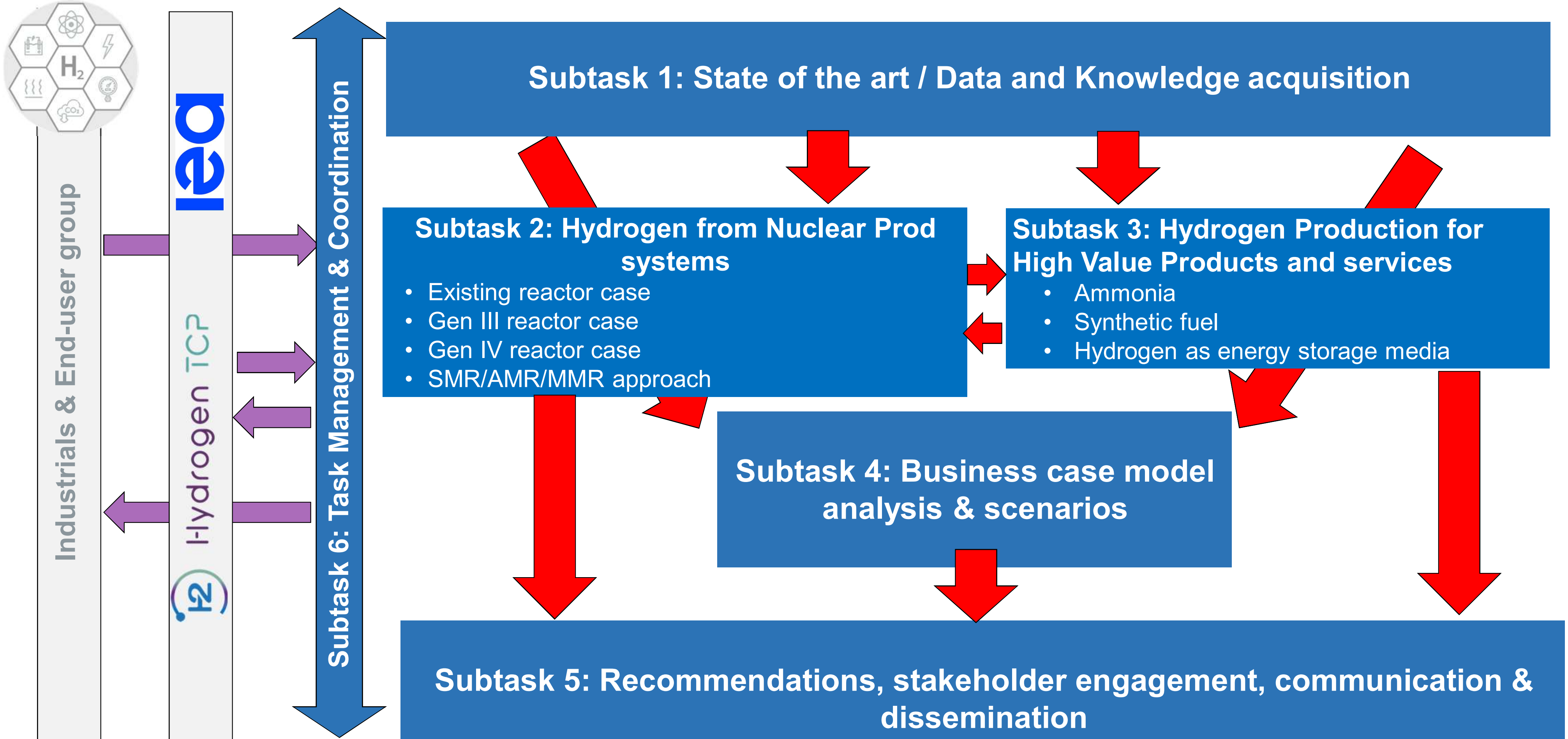
Task Description (*coming from the draft HYNE Work plan*)

Started in Feb. 2023, Task n°44 = Hydrogen from Nuclear Energy
Duration 3 years, 1 virtual meeting / month + 2 in-persons meetings / y
Around 40 members worldwide from Intl org (IAEA, OECD), industry (EDF, John Cockerill), NGO (Terrapraxis), Intl research org (ASME, CEA, JAEA, UKNNL, TECNATOM,…)

“This Task will serve as a platform and framework for sharing and contributing information one the different possibilities of Hydrogen production from Nuclear Energy by:

- identifying the on-going and planned activities in this subject,
- providing an holistic analysis of the situation, context and constraints to identify all conditions to fulfill for this technology to be deployed.
- Identifying the specificities and the scenario cases where nuclear energy will have a specific role compared to current low carbon electricity

The Hydrogen from Nuclear Energy Task structuration: 6 Subtasks



HYNE Challenges

The major objectives of the HyNE Task (Hydrogen from Nuclear Energy)

Hydrogen TCP

- Explain
- Clarify
- Anticipate
- Analyse
- Recommend
- Advise

Creation of a multidisciplinary network of international experts

Hydrogen from Nuclear Energy Task: an IEA integrative Task

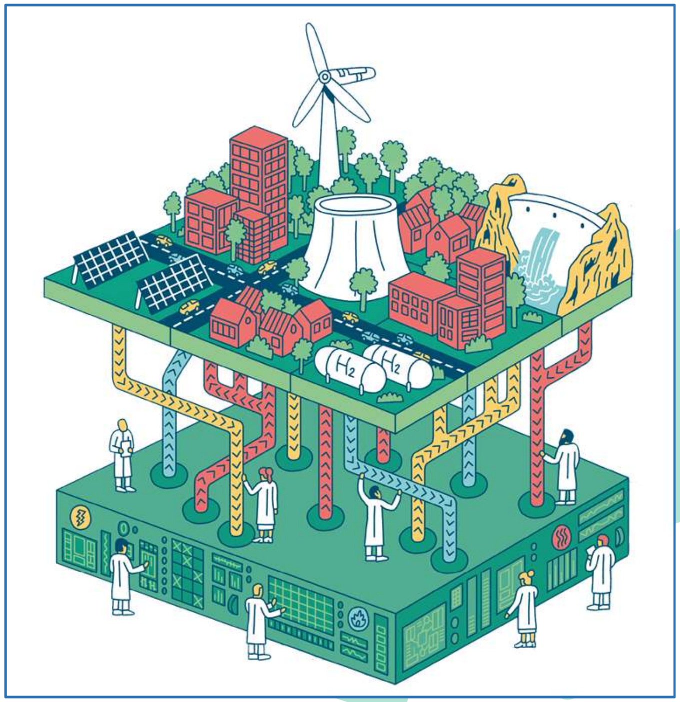
What we want to achieve :

- Be an integration of Nuclear Hydrogen studies carried out worldwide
- Be a well-balance Task between:
  - the Nuclear development, Hydrogen process production, and the coupling aspects
  - The techniques / The economy / The market approach
- Be a recognized Task of experts able to:
  - Assess scenarios with a fair analysis
  - Advice IEA in all scenarios for a future decarbonized society
  - Provide key data and recommendations to accelerate the time to market
  - Underline what could be specific regarding nuclear energy (and what is not specific)
- Provide regular and sharp notes rather than one unique heavy document at the end of the three year-time
- Being efficient with a regular work, well balanced among all partners
- All experts opinion will be taken into consideration, and all specific aspects (local, geographical) will be investigated
- An agile organization suited for any situation

What we want to avoid :

- Duplicate actions and roles provided by other International organization
- Too much overlapping of this Tasks with the other IEA TCP Task
- Poor reactivity according to IEA request

Thank You!



For more informations or if you wish to join HYNE:
please contact me at gilles.rodriguez@cea.fr or paul.lucchese@cea.fr
Or olmar.rubio@ieahydrogen.org

IAEA Webinar

23rd March 2023

Bay Hydrogen Hub – Hydrogen4Hanson Project

Vision and Partners

Department for Energy Security & Net Zero

Our vision is to demonstrate solid-oxide electrolysis integrated with nuclear heat and electricity, providing low-carbon, low-cost hydrogen via novel, next generation composite storage tankers to dispersed asphalt and cement sites

Partners and key subcontractors

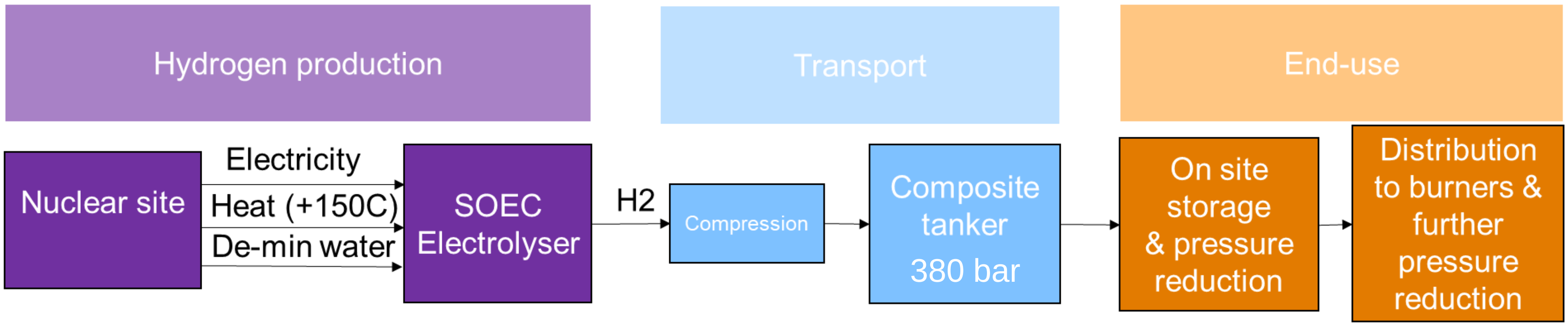
EDF R&D | EDF Generation | Hanson | National Nuclear Laboratory | hynamics | ceres | NPROXX

- **EDF**: Consortium lead, bid and project management, nuclear site feasibility, H2 production and distribution engineering design, technology evaluation, economic modelling.
- **Hanson**: Industrial partner, asphalt and cement fuel switching feasibility and engineering design.
- **Ceres**: SOEC electrolyser technology, economic evaluation, site integration.
- **NNL**: Future nuclear industry impact, wider social impact, development concept.
- **NPROXX**: Hydrogen transport technology provider, site interface, business case, routes.

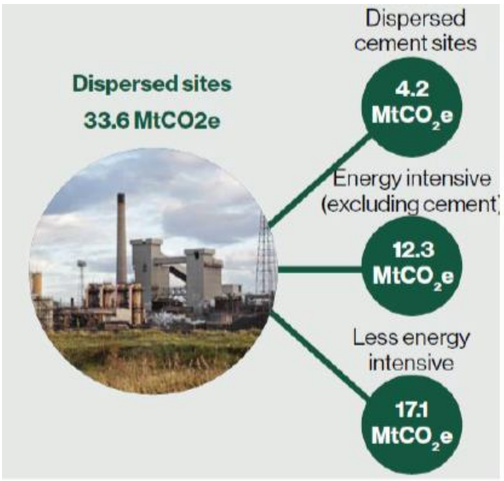
Feasibility study completed March 2023 - possible demonstrator in 2024

Nuclear derived SOEC hydrogen to the asphalt and cement industry

- **Innovative end to end H_2 production to end-use project** showcasing novel technologies along the supply chain



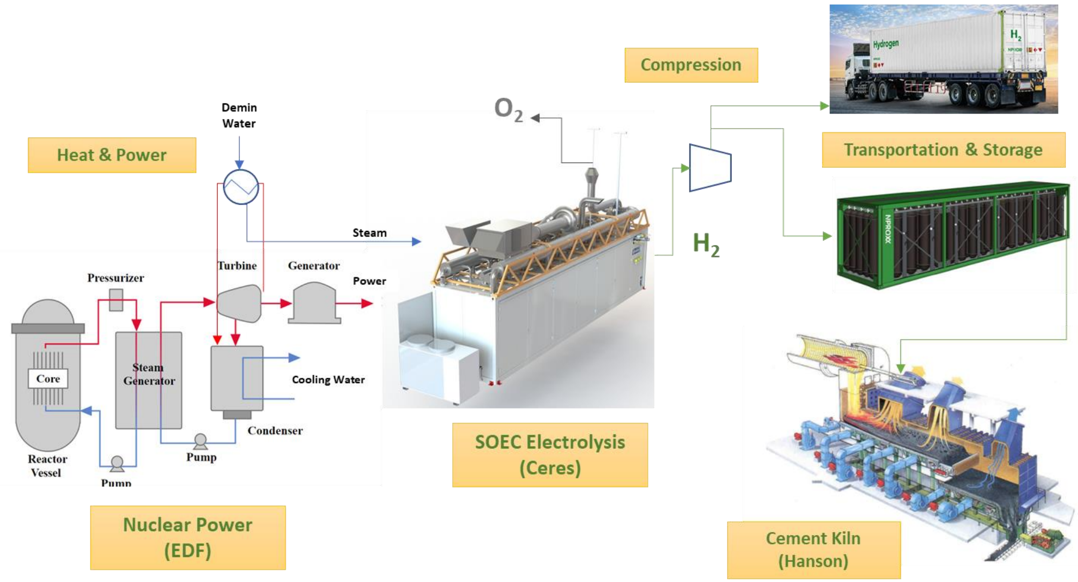
- MW scale SOEC plant to demonstrate **nuclear hydrogen production to industrial cement & asphalt decarbonisation**
- **H_2 fuel switch** demonstrating decarbonisation of critical UK industry infrastructure.
- Support development of H_2 fuel delivery to **dispersed end use sites that generate c.50% of total industrial emissions**



Project scope

The “Bay Hydrogen Hub – Hydrogen4Hanson” project is a key stepping stone towards the decarbonisation of the cement and asphalt industry, developing nuclear hydrogen production and investigating technologies to deliver hydrogen to dispersed industrial sites.

- Supplying heat (steam 190ºC, 9 bar) and electricity to a SOEC electrolyser to produce low carbon hydrogen
- Hydrogen production efficiency >20% vs PEM technology
- Composite storage tankers can transport 6-8 x more hydrogen than existing tube trailers
- **Use of hydrogen as a fuel at asphalt sites has also not been demonstrated before**

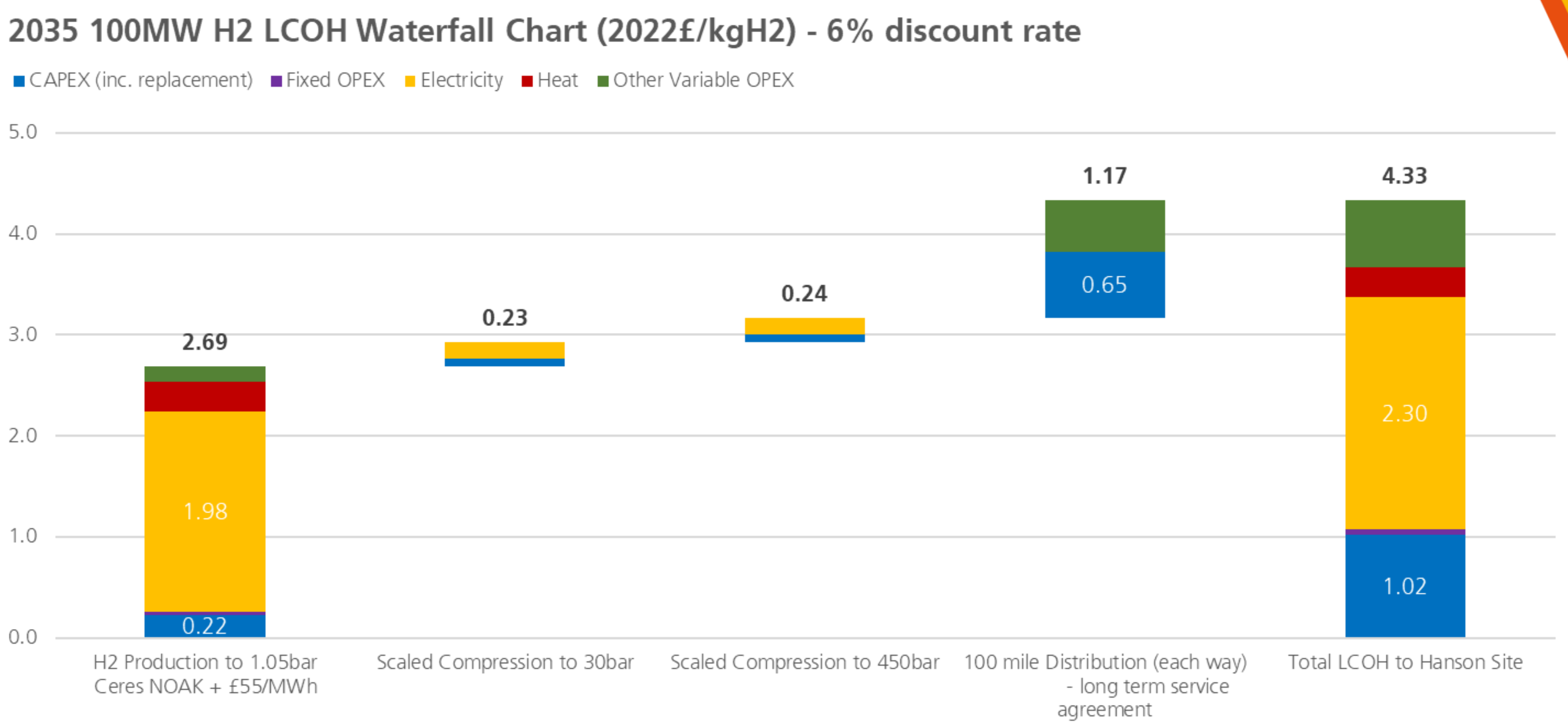


Hydrogen end-use

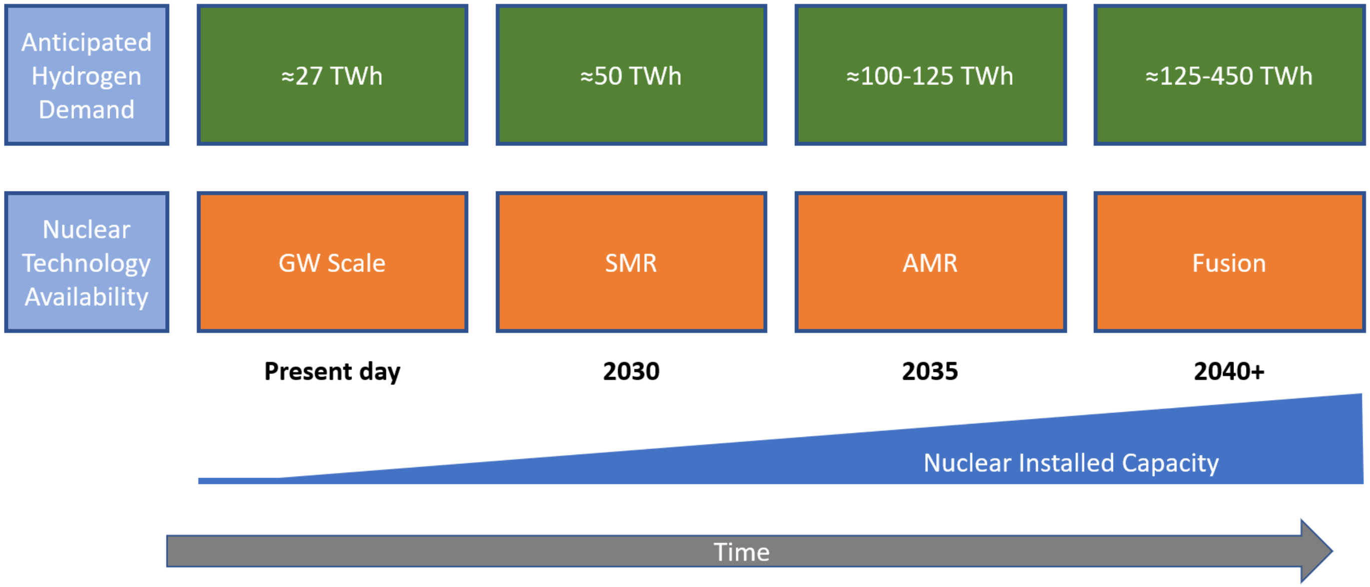
- Focus on Asphalt plant drying process (H_2 world first)
- Building on previous learnings from trial in cement process (earlier H_2 world first)
- Assess feasibility of 100% fuel substitution ahead of demonstration phase

- UK hot mix asphalt demand c. 27 million tonnes every year
- 270+ plants nationally
- 90-100 kWh per tonne heating /drying
- Circa 2.5 TWh annual consumption

Economics of Hydrogen from Nuclear



Replicability and scalability in other industries



While for some processes electrification might be the most optimal solution, for others there is still requirement for heating furnaces where hydrogen can play an important role.

Chemical | Iron & steel | Aluminium | Glass | Ceramics

Conclusions

Hydrogen produced from nuclear power plants can play a crucial role in decarbonising the UK's carbon intensive industrial sectors, including cement and asphalt sites that are often not connected to the grid.

- It is technically possible to integrate hydrogen production with nuclear
- Nuclear stations can provide low carbon heat and electricity to a solid oxide electrolyser (SOE) to produce 20-30% more hydrogen for the same overall energy input than conventional PEM and Alkaline electrolysis
- Nuclear backed hydrogen production has the potential to be competitive in a future low carbon hydrogen market
- H_2 produced can be distributed by high-capacity next generation composite type IV storage tankers to dispersed asphalt and cement sites.
- Use of H_2 as a fuel could reduce asphalt industry direct emissions by c. 560kT
- The use of hydrogen as a fuel enhancer for cement could broaden the use of lower grade, lower cost and higher biomass waste derived fuels

Thank You

Nuclear Hydrogen Production in Indian NPPs: Current Initiatives and Insights

Rupsha Bhattacharyya
Homi Bhabha National Institute, DAE, Mumbai
UPD&FS, ChEG, Bhabha Atomic Research Centre, Mumbai

IAEA Webinar on "Hydrogen Production with Operating Nuclear Power Plants - The Business Case"

23rd March 2023

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Hydrogen Energy in India: Current Scenario

- Hydrogen Roadmap (2006): Focus on R&D and demonstration/pilot projects across entire hydrogen value chain
- National Green Hydrogen Mission, Phase I (Feb. 2022): Focus on renewable and biomass derived hydrogen/ammonia for commercial scale applications
- Focus on hydrogen in India's Long Term Low Carbon Development Strategy (submitted to UNFCCC, Nov 2022)
- National Green Hydrogen Mission Document, Jan. 2023
- Fertilizers, petroleum refining, petrochemicals are the first target sectors – drop-in grey H_2 substitute, reducing dependence on imported natural gas
- Important component of India's energy transition, energy security climate change commitments and Net Zero ambitions by 2070

Nuclear Hydrogen Production in India: Current Scenario

- Nuclear industry working on advanced reactor systems and technology development for hydrogen production (water/steam electrolysis, thermo-chemical cycles), storage, purification, techno-economics, hydrogen safety and combustion phenomena – know-how being shared with public sector and private industry; Technology transfer, incubation with Industry co-operation for scale up

- Demonstration projects on water electrolysers coupled to currently operational nuclear power reactors planned at select sites – vendor selection and techno-commercial analyses in progress

The Telegraph online

Friday, 25 March 2022 • E-paper

BPCL teams up with BARC to scale up alkaline electrolyser technology

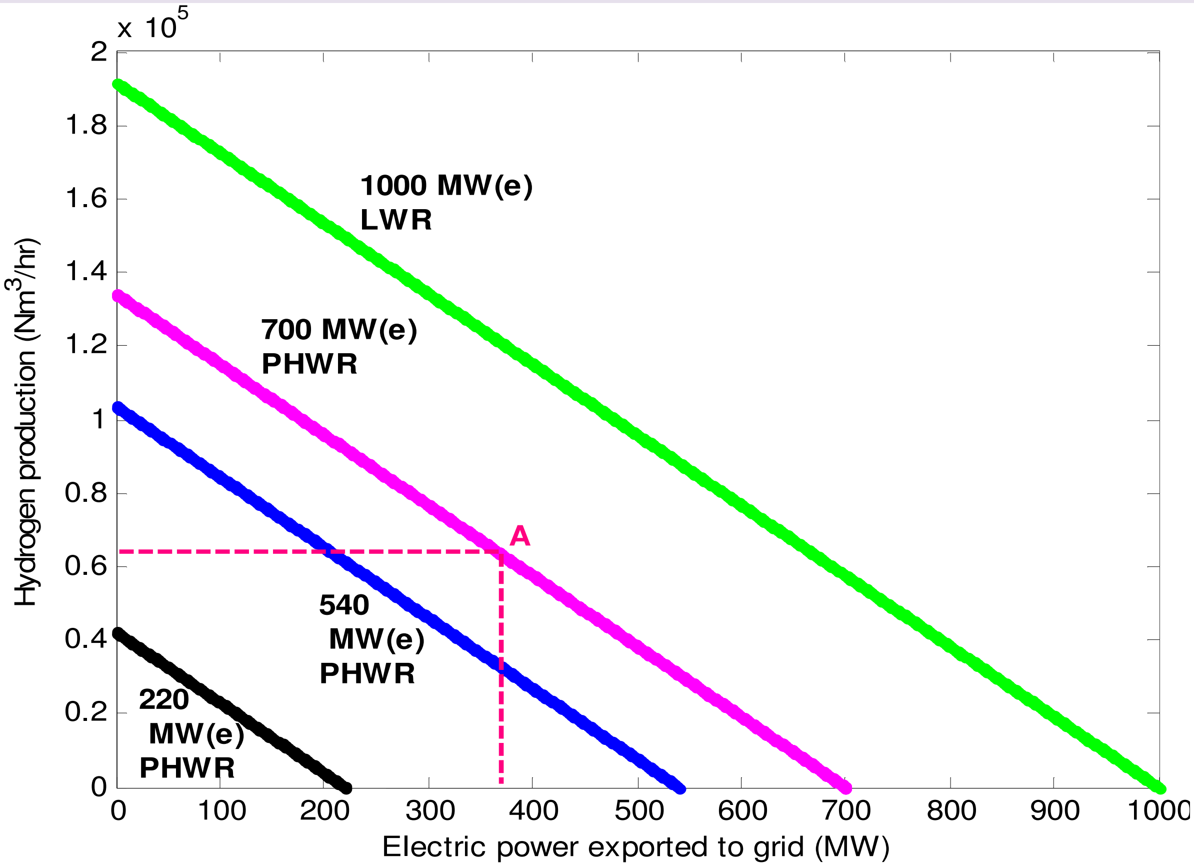
Ondia is aiming to reach net zero emissions by 2070 and wants to raise the share of renewables in its energy mix to 50 per cent by 2030 rom 38 per cent at present

Representational image.
File photo

Our Special Correspondent | New Delhi | Published 14.12.21, 02:13 AM

Privatisation bound BPCL has collaborated with Bhabha Atomic Research Centre (BARC) to scale up alkaline electrolyser technology for green hydrogen production as part of the country's effort to reduce greenhouse gas emissions.

Hydrogen production possibilities frontier in Indian NPPs



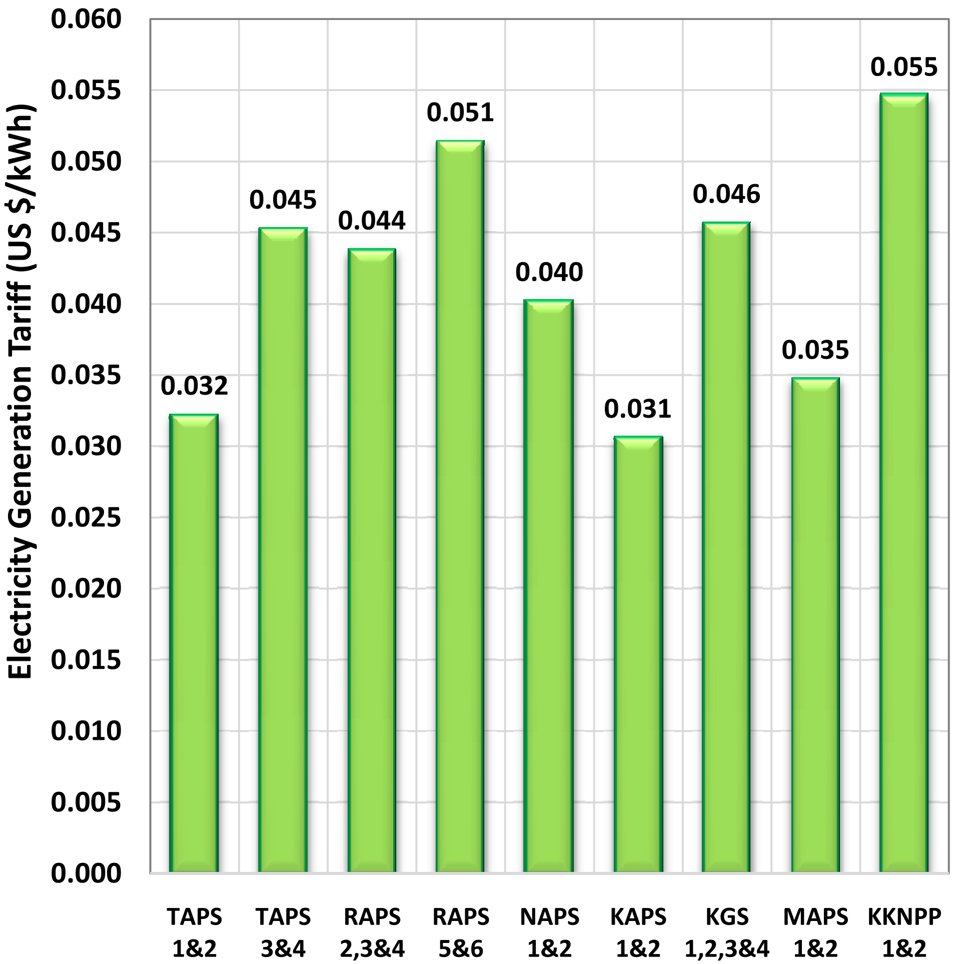
Nuclear power-to-hydrogen production possibilities frontier at typical nuclear power plants in India

Findings

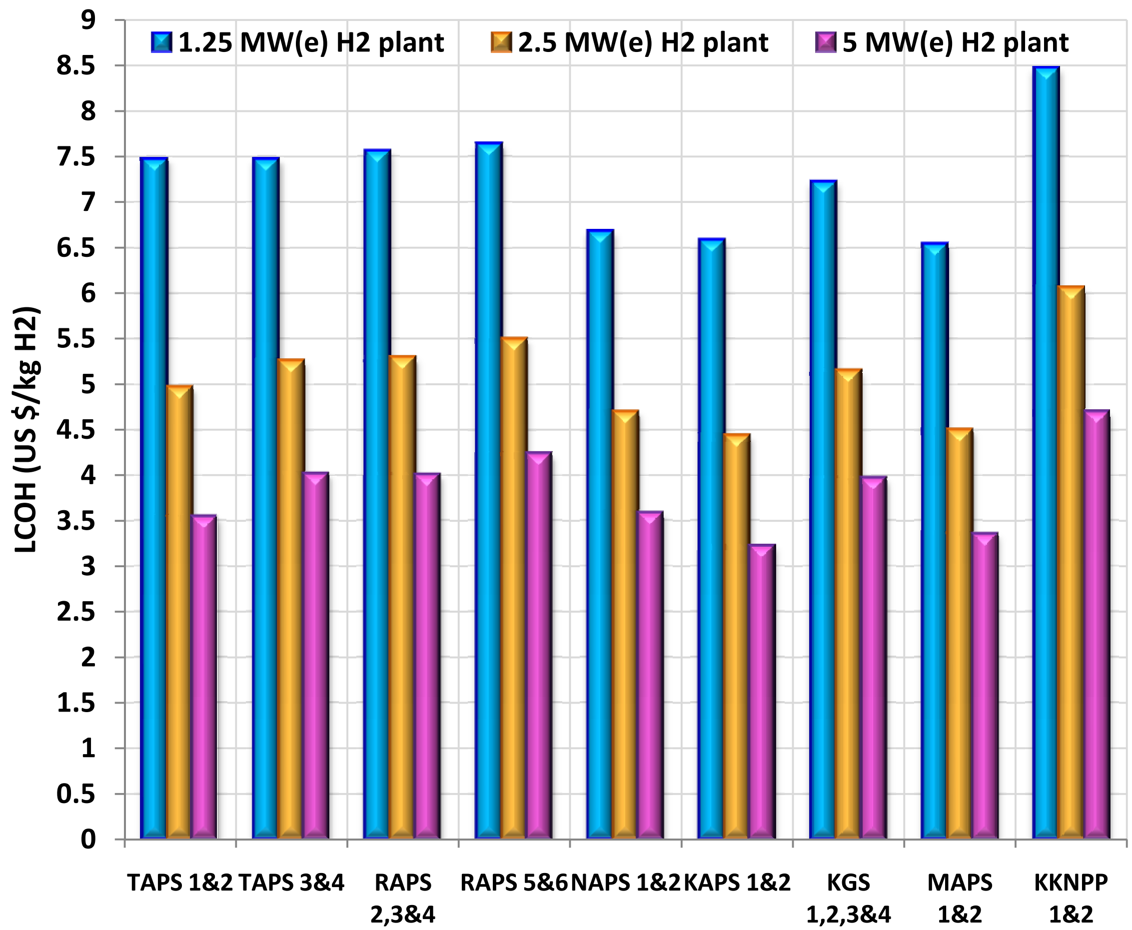
I. **Maximum nuclear hydrogen production potential of 1.8 to 4 million ton/y**

Leveraging Nuclear Power-to-Green Hydrogen Production Potential in India: A Country Perspective", Bhattacharyya R, et al., International Journal of Energy Research, 46(13):18901-18918, DOI:10.1002/er.8348

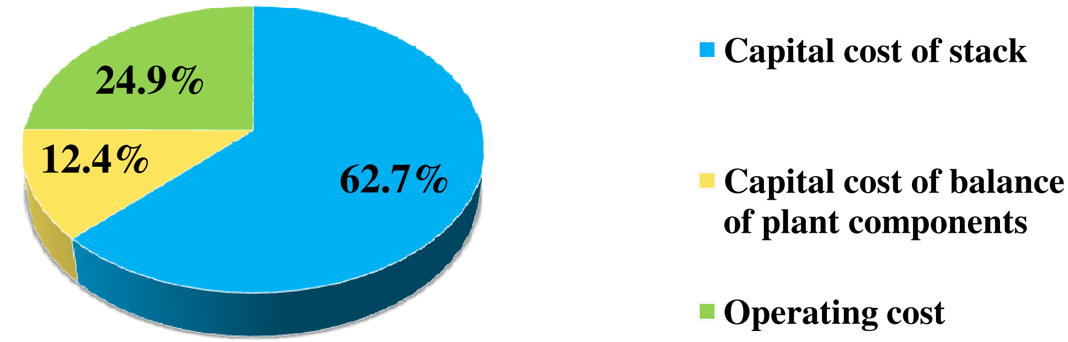
Site wise H_2 production cost in Indian NPPs: Alkaline Water Electrolysis



Nuclear electricity tariffs in India, DAE (2021)

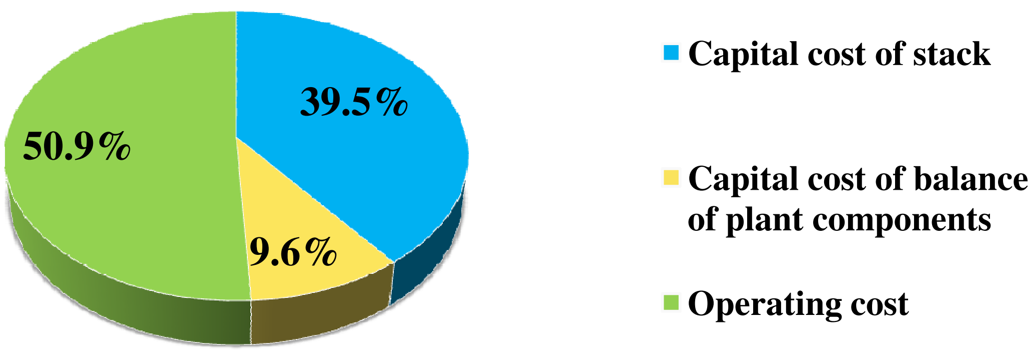


Author calculations (2022)



(a) Hydrogen cost = $ 6.58/kg H_2

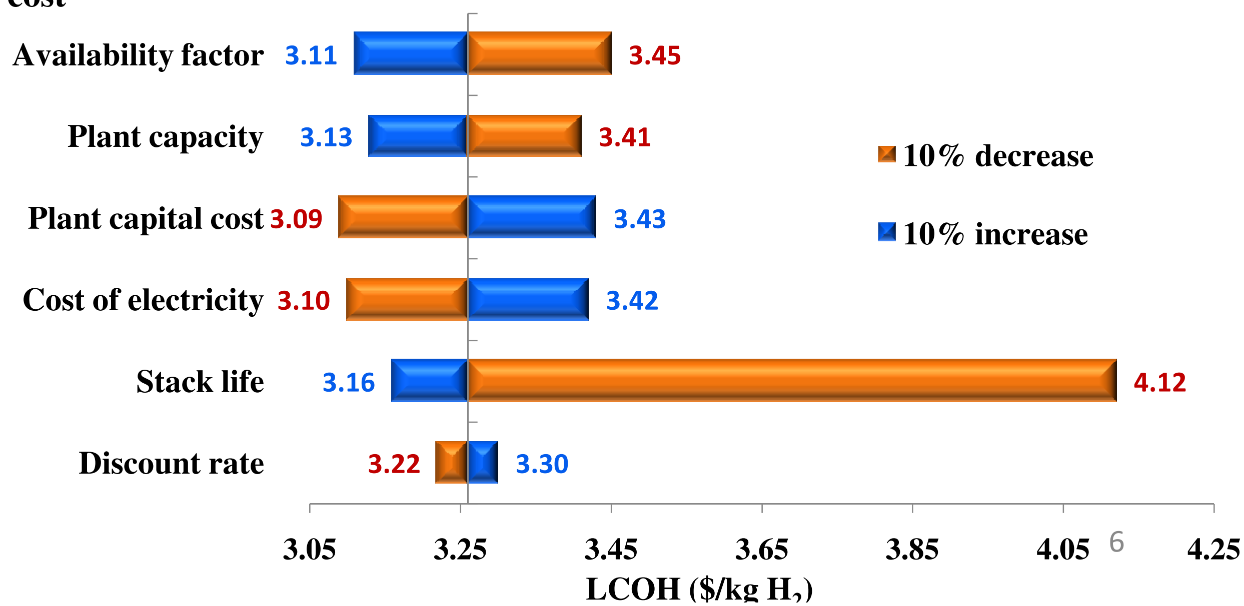
(a) 1.25 MW(e) H2 plant at KAPS 1,2



(b) Hydrogen cost = $ 3.22/kg H_2

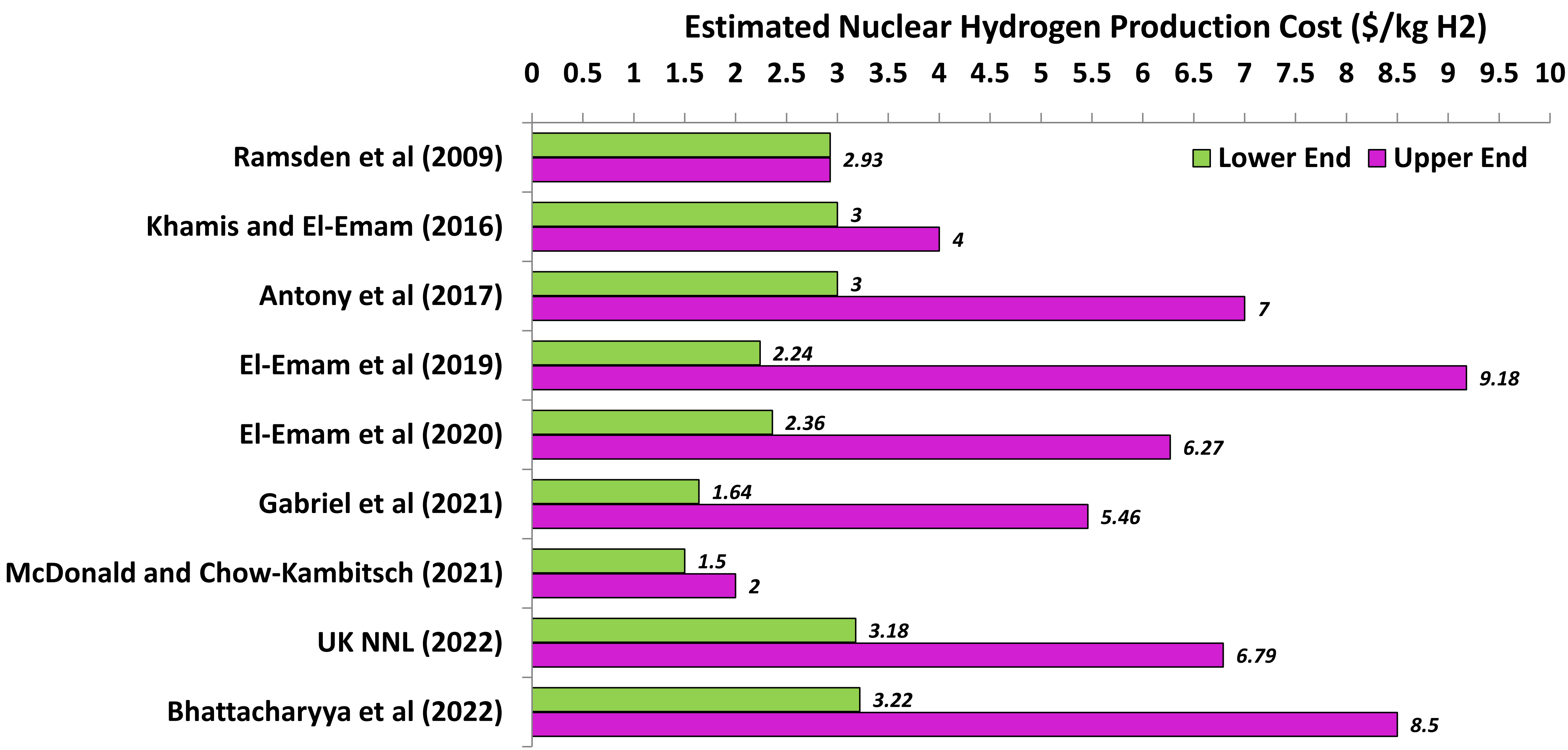
(b) 5 MW(e) H2 plant at KAPS 1,2

Sensitivity analysis



Leveraging Nuclear Power-to-Green Hydrogen Production Potential in India: A Country Perspective", Bhattacharyya R, et al., International Journal of Energy Research, 46(13):18901-18918, DOI:10.1002/er.8348

Comparison with other estimates of nuclear hydrogen production costs



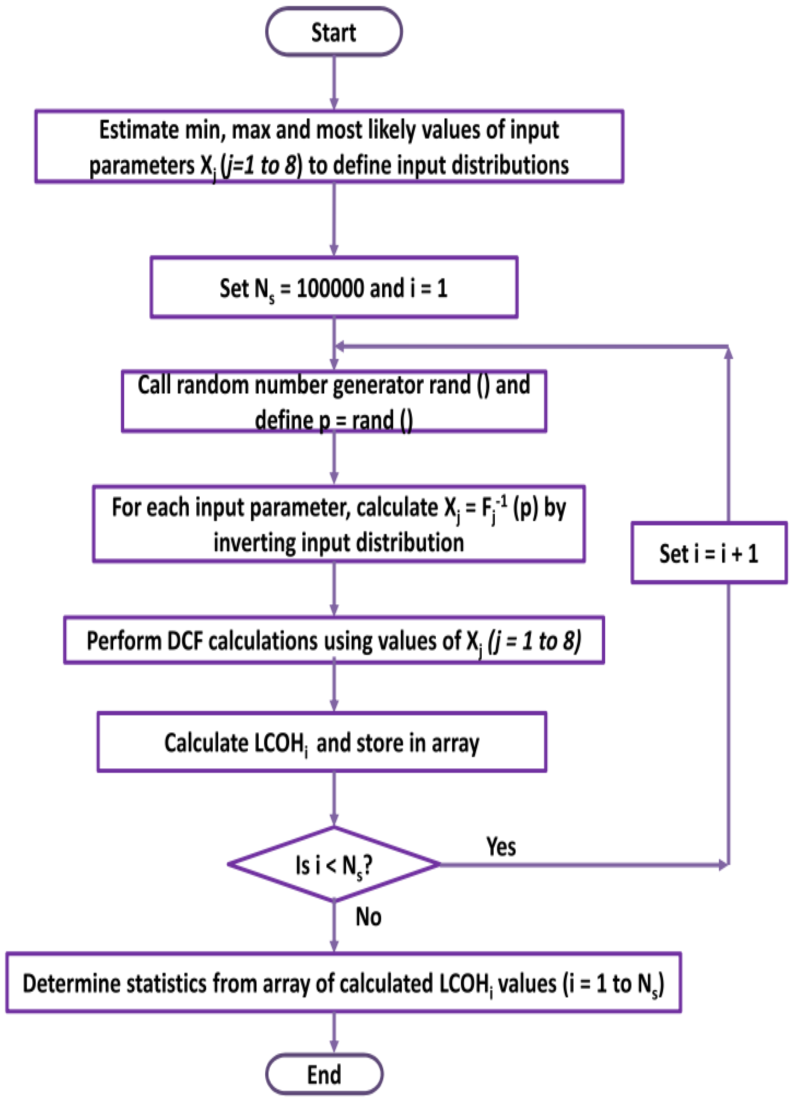
Uncertainty analysis of techno-economics of nuclear H_2

A. Focus Area and Methodology

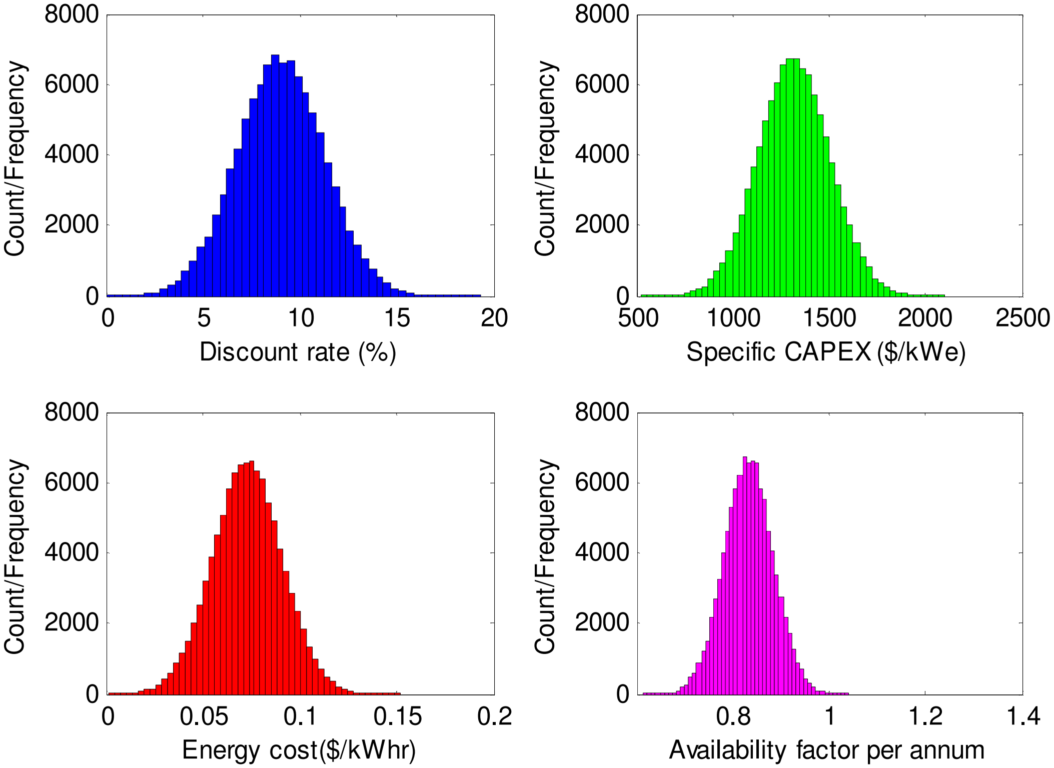
I. Defining probability distributions of input parameters
II. Developing a Monte Carlo simulation scheme and coupling it to discounted cash flow calculations for estimation of levelized costs under uncertainty
III. Sensitivity studies and regression analysis

B. Findings

I. Producing hydrogen using electricity from large water-cooled nuclear reactors costs US $ 12.205 ± 1.342, 8.384 ± 1.148 and 6.385 ± 1.051/kg H_2 from alkaline water electrolysers of rated capacities of 1.25 MW(e), 2.5 MW(e) and 5 MW(e) respectively.
II. The corresponding values for pure water electrolysers are US $ 13.162 ± 1.356, 8.891 ± 1.141 and 6.663 ± 1.057/kg H_2.
III. There appears to be less than 0.1 % probability of attaining the widely reported long-term cost target of $ 1 to 2/kg H_2 under the present techno-commercial scenario



Quantifying Uncertainties

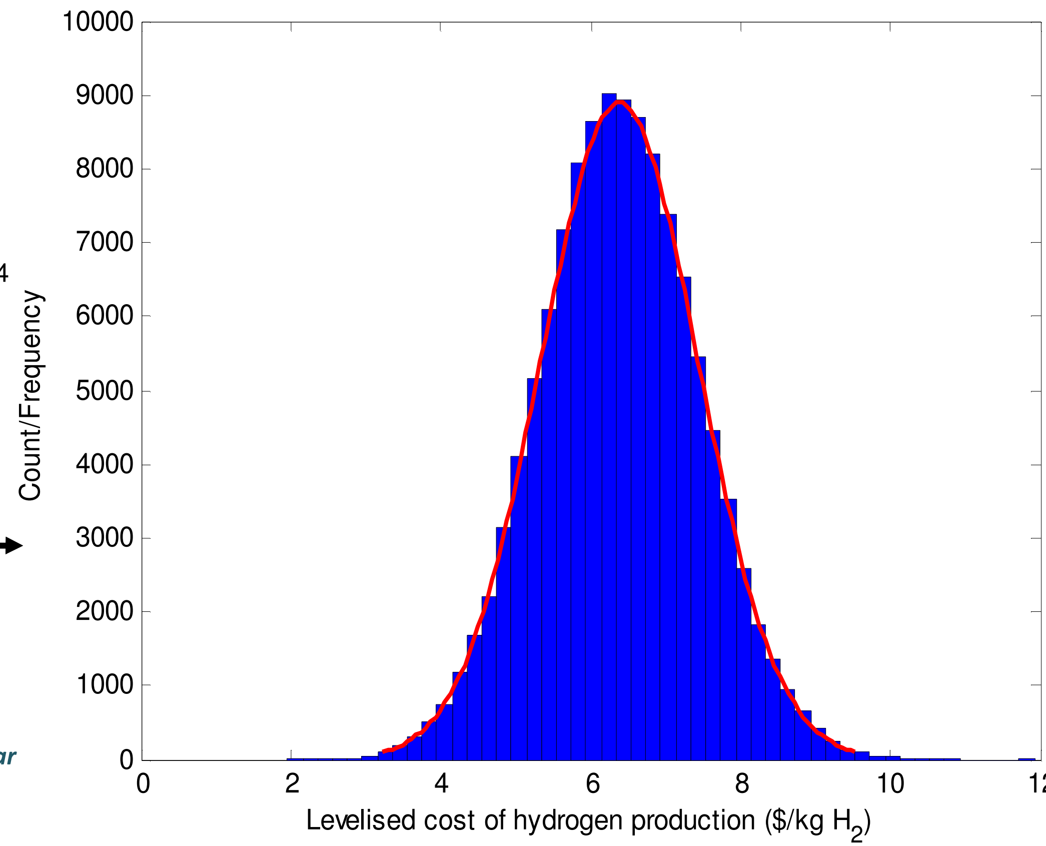


Sampled input parameter distributions affecting H_2 cost (sample size = 10^5)

Output cost distribution for a 5 MW(e) alkaline water electrolyser

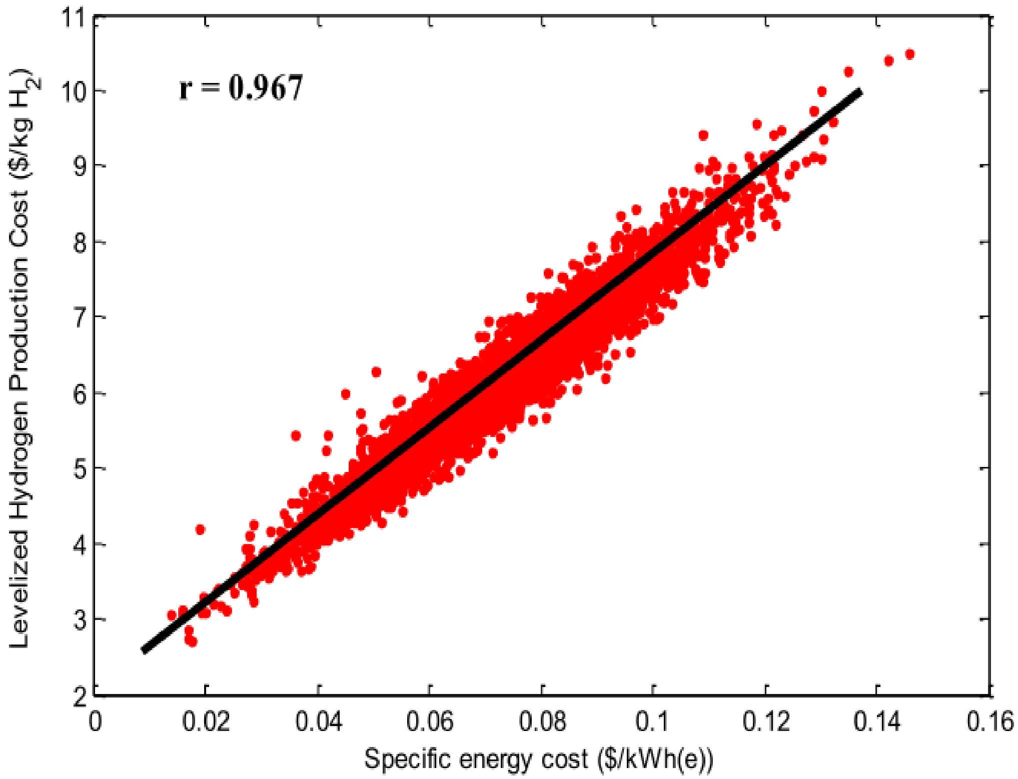
Mean = \$ 6.39/kg H_2,

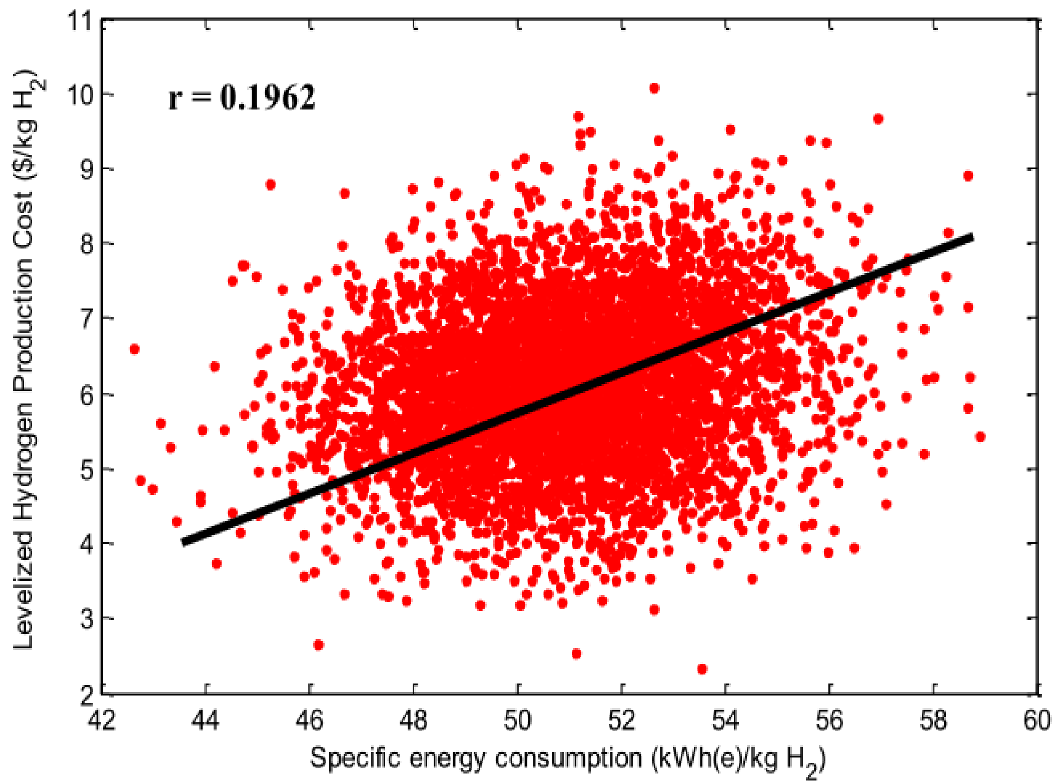
Standard deviation = \$ 1.05/kg H_2



Assessing Techno-Economic Uncertainties in Nuclear Power-to-X Processes: The Case of Nuclear Hydrogen Production via Water Electrolysis , Bhattacharyya R, et al., International Journal of Hydrogen Energy, DOI: https://doi.org/10.1016/j.ijhydene.2022.11.315

Sensitivity studies

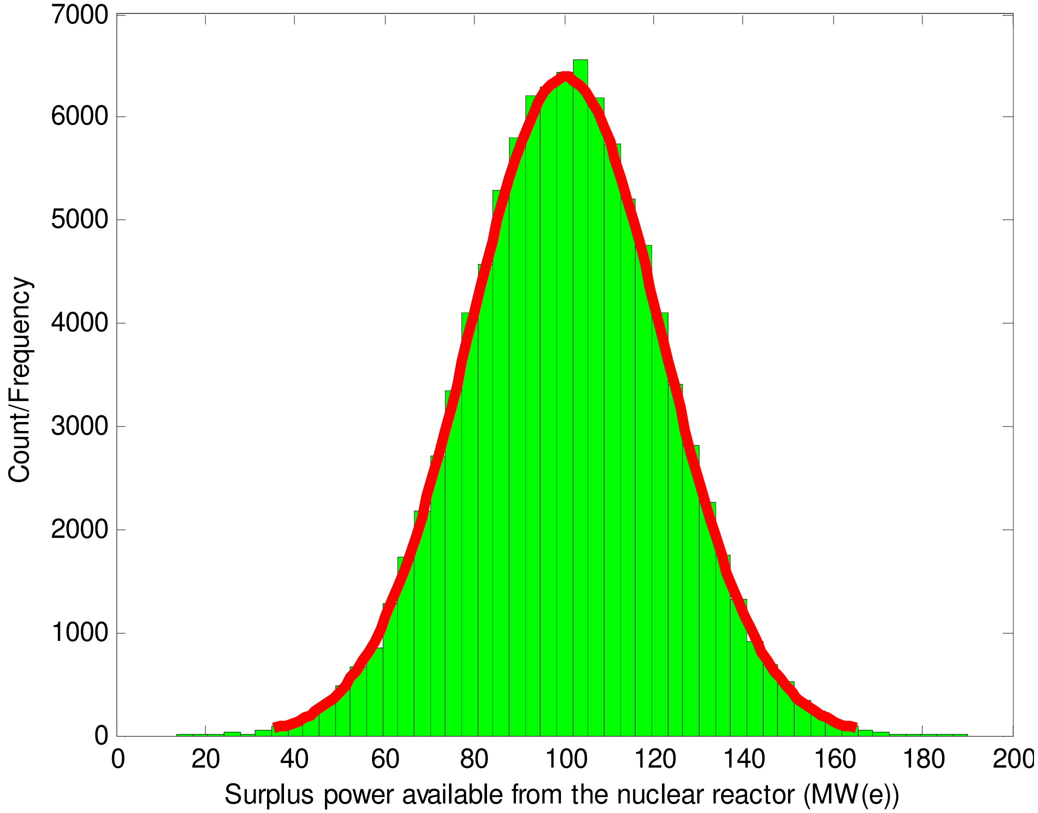




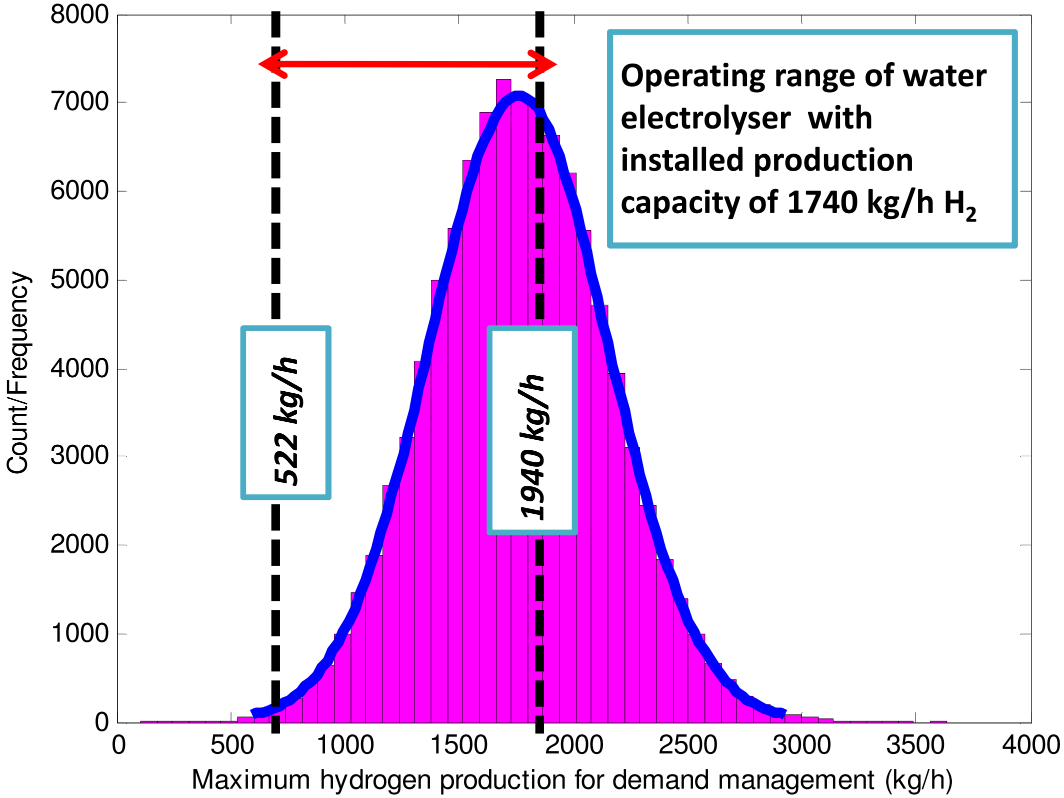
Most significant correlation of hydrogen cost observed with electricity price and electrolyser efficiency/specific power consumption

Assessing Techno-Economic Uncertainties in Nuclear Power-to-X Processes: The Case of Nuclear Hydrogen Production via Water Electrolysis , Bhattacharyya R, et al., International Journal of Hydrogen Energy, DOI: https://doi.org/10.1016/j.ijhydene.2022.11.315

Results



I. Probability distribution of surplus power available from a 700 MW(e) nuclear reactor
(100.33 ± 21.66 MW(e))



II. Probability distribution of hydrogen production rates using surplus power from a 700 MW(e) nuclear reactor
(1762 ± 21.68 kg H_2/h)

Initial Findings: A given hydrogen plant will not be able to provide perfect load following, due to its operating limits; alternatives will be needed to make full use of the surplus power and avoid curtailment

Thank you for your time !

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