Webinar on Nuclear Heat to Decarbonize the Energy Sector

Webinar Series on Nuclear Technology Breakthroughs for the 21st Century

Webinar Series on Nuclear Energy and Climate Change

13 July 2021 15:00-16:30 CET (Vienna, GMT +02:00)

Panelists:

Neva Espinoza
Vice President
Energy Supply and Low-Carbon Resources
Electric Power Research Institute
USA

Ping Zhang
Researcher
Institute of Nuclear and New Energy Technology
China

Józef Sobolewski
Plenipotentiary Director for High Temperature Reactors Development National Centre for Nuclear Research Institute of Nuclear and New Energy Technology
Poland

Moderator:

Rauli Partanen
Think Atom

PLEASE NOTE..

This is an **interactive Webinar** and we would love to hear from you, so if you have any question, please type them at any time into the **Q&A panel** and we will try to address as many of your questions during our Q&A session.

Please also use the **CHAT panel** to let us know if you're experiencing any technical problems and our technical team will help you out.

Participants will be muted for the duration of the session.

Please note that the IAEA is **not offering certifications** for the Webinars in this series.

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IAEA
International Atomic Energy Agency

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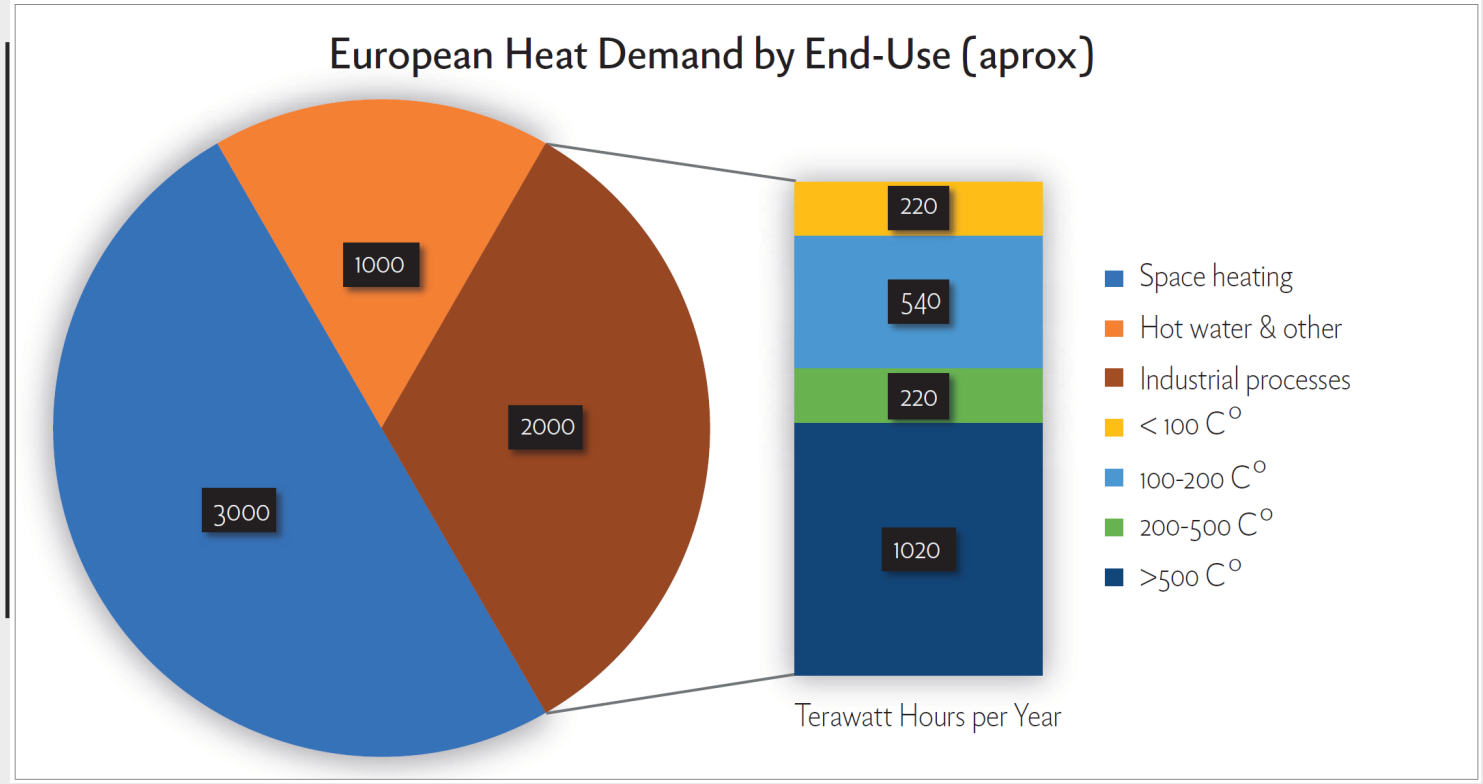
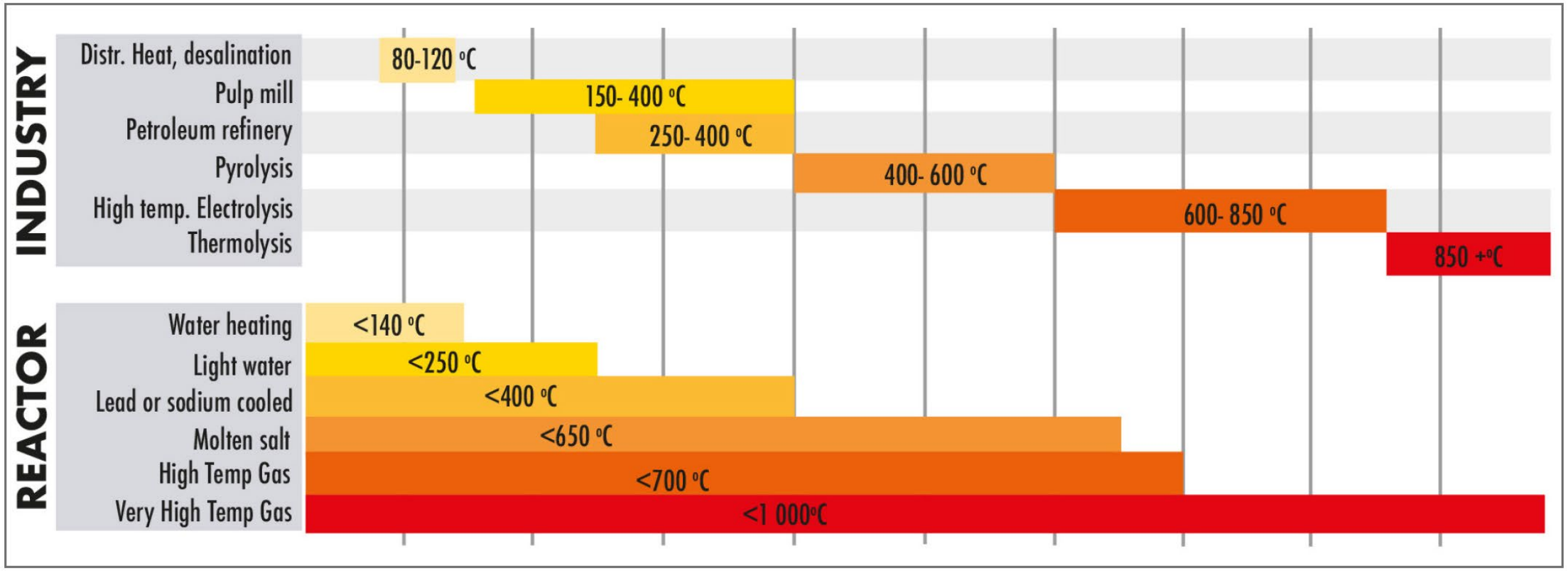
HEAT

- Half of European energy is used as heat
- Globally there is demand for tens of thousands of terawatt hours of clean heat
- Most of the demand is for local, reliable, dispatchable, low-cost heat



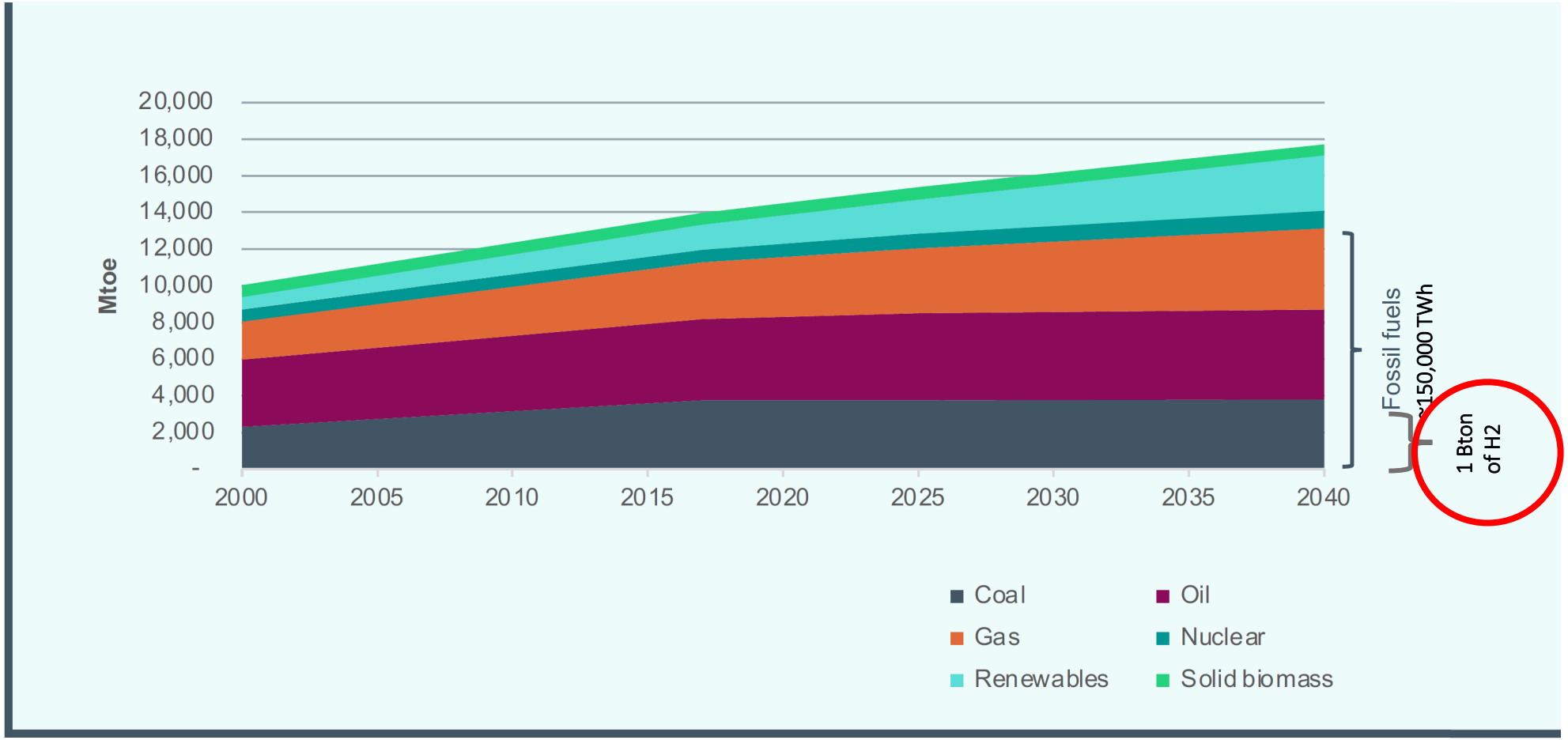
THINK ATOM

NUCLEAR IS GREAT FOR HEAT PRODUCTION



THINK ATOM

IN ADDITION TO DIRECT HEAT, A LOT OF CLEAN HYDROGEN / E-FUELS IS NEEDED



IEA 2018, Current Policies Scenario

THINK ATOM

NUCLEAR HEAT IS ESSENTIAL FOR CHEAP, SCALABLE HYDROGEN

- High capacity factor of over 90%
- High temperature, high efficiency electrolysis at 90%+

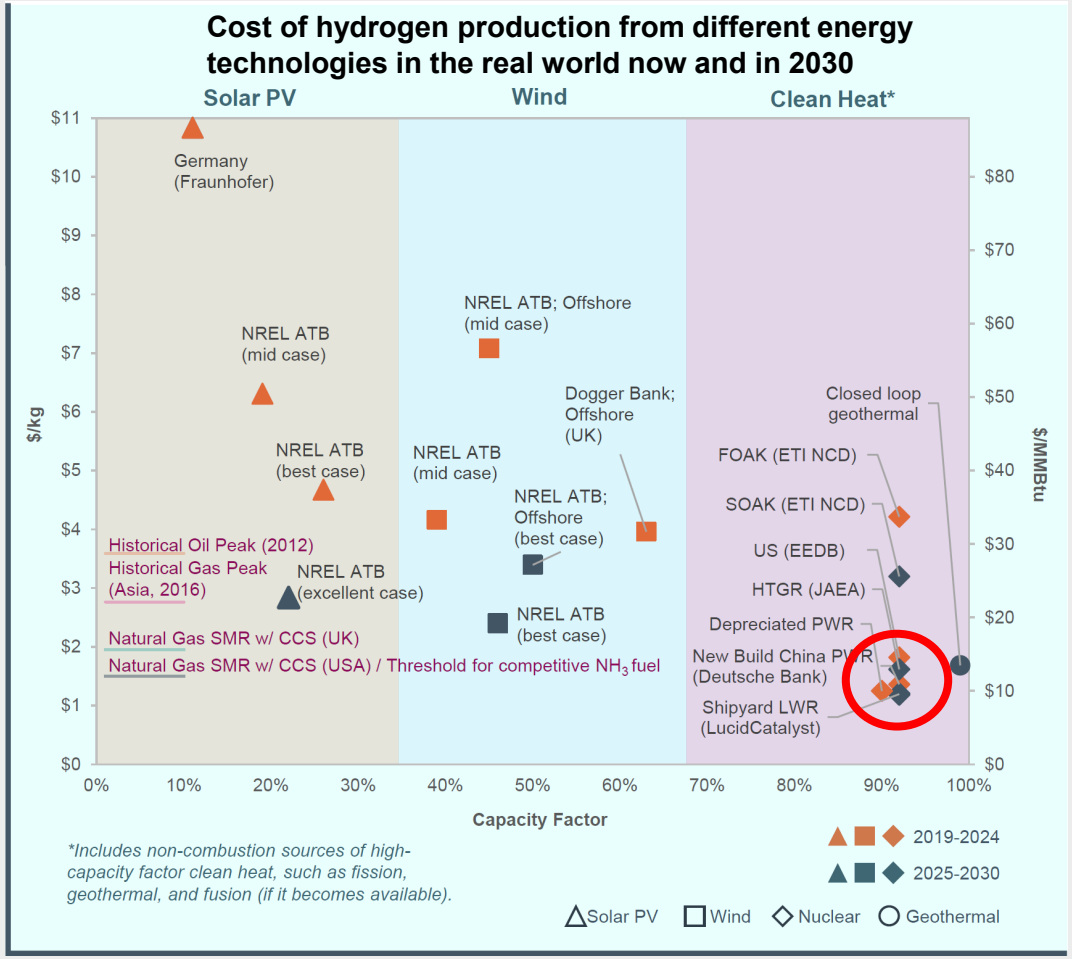
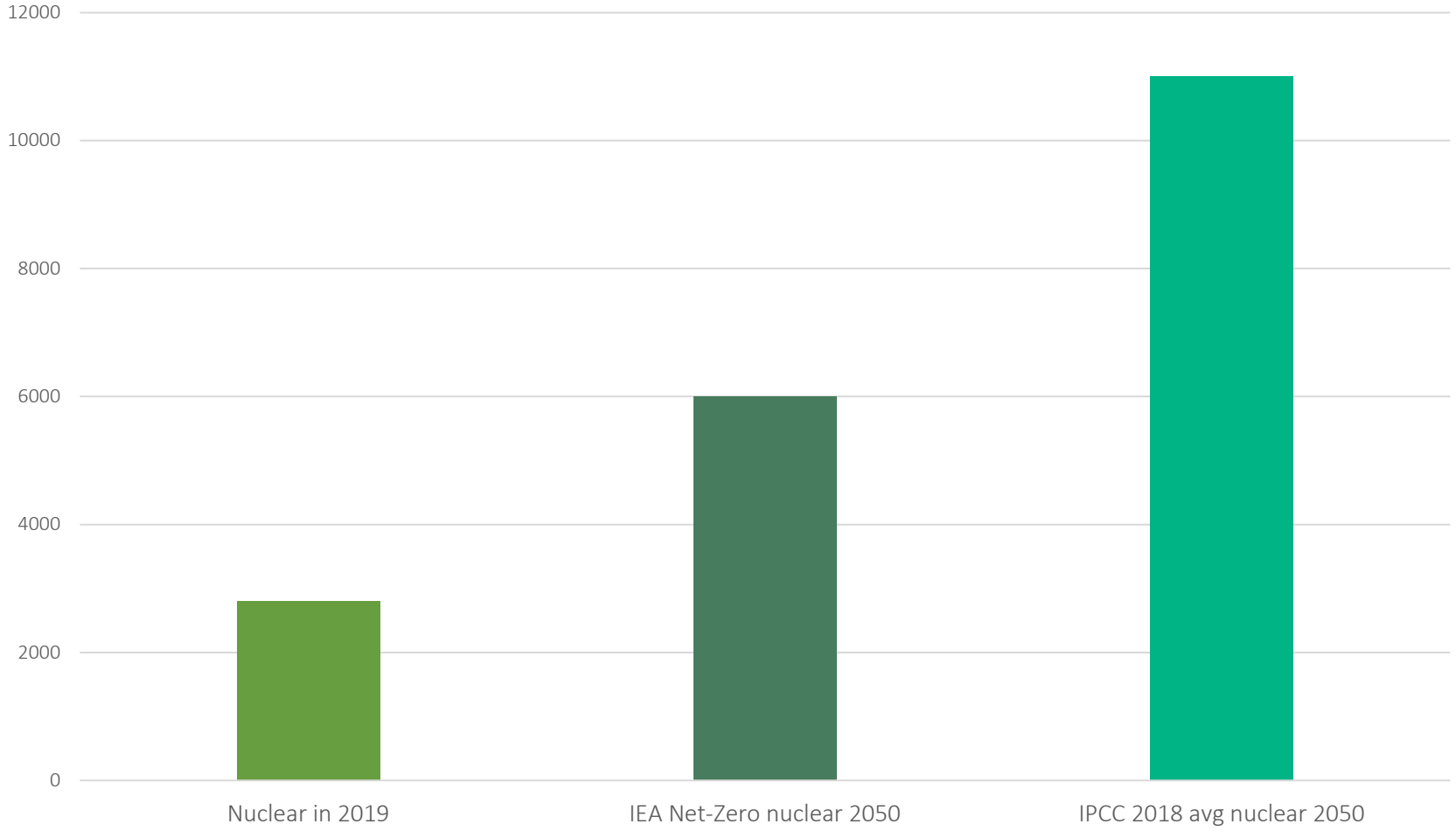


Image Source: Lucid Catalyst 2020

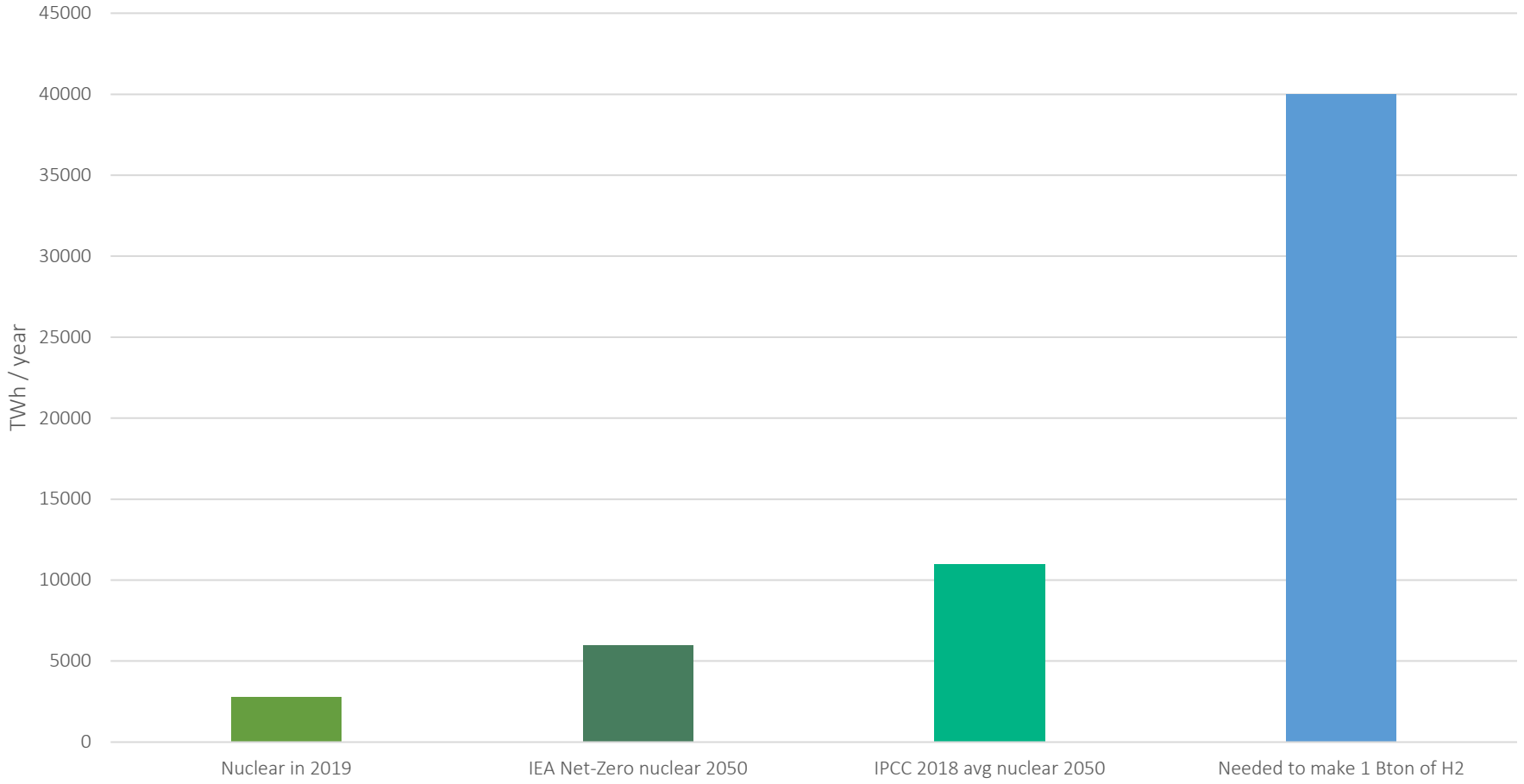
THINK ATOM

Nuclear 2050 Production in IEA and IPCC Scenarios



THINK ATOM

Nuclear 2050 Production in IEA and IPCC Scenarios, and One Billion Ton of Hydrogen



THINK ATOM

NUCLEAR - THE MISSING LINK

- Why is nuclear not growing nearly enough in mainstream scenarios?
  - Lack of information?
  - Lack of evidence?
  - Lack of interest in nuclear technology, or even ideological opposition?
  - Lack of political acceptance and courage?
  - Incompatibility and lack of flexibility in regulations?

NUCLEAR - THE MISSING LINK

- I think it's all of these.
  - We need more academic publications on the role of nuclear
  - We need more nuclear-inclusive scenario-modelling
  - We need more technology neutral policies
  - We need better regulation
  - We need successful projects and examples
  - We need better communications in nuclear

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Neva Espinoza

Ms Neva Espinoza is the Vice President, Energy Supply and Low-Carbon Resources at the Electric Power Research Institute (EPRI).

In this role she is leading a team focused on R&D on a range of energy supply technologies, including both existing and future generating assets and how they can be best leveraged in a deeply decarbonized power system. In addition, Ms Espinoza is leading the Low-Carbon Resources Initiative, in partnership with Gas Technology Institute, to accelerate development and deployment of low-carbon technologies.

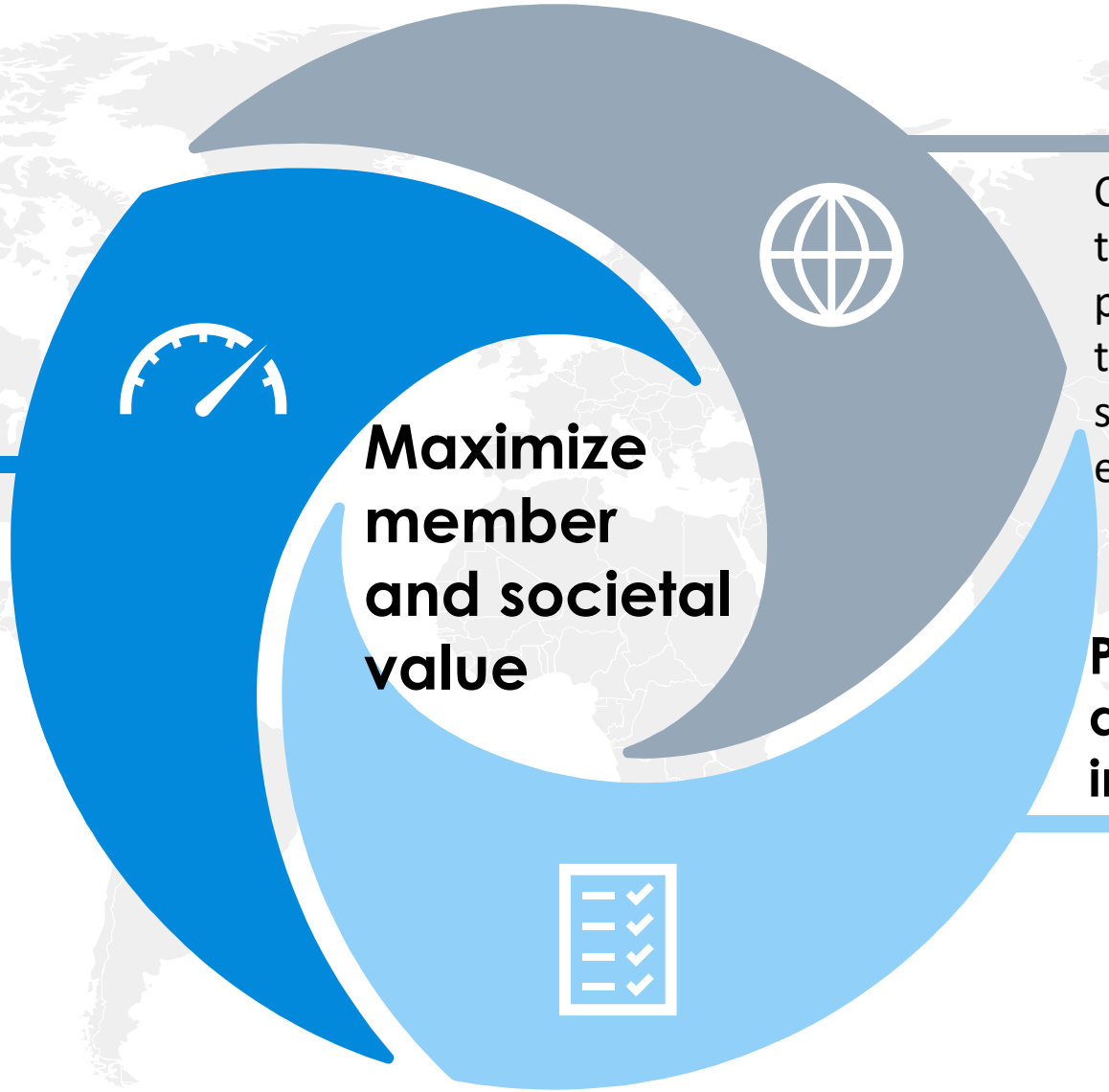
Ms Espinoza previously served as the Director of R&D for EPRI's Generation Sector. Prior to EPRI, Espinoza served in technical and leadership positions at NRG's Arthur Kill Power Station, Exelon's Oyster Creek Power Station and Knolls Atomic Power Laboratory.

Enabling Economywide Decarbonization

The Role of Nuclear Heat

Neva Espinoza
Vice President
Energy Supply and Low-Carbon Resources
Electric Power Research Institute

EPRI



Accelerate technology innovation

Develop and evaluate energy system solutions through broad global engagement with technical partners and other stakeholders

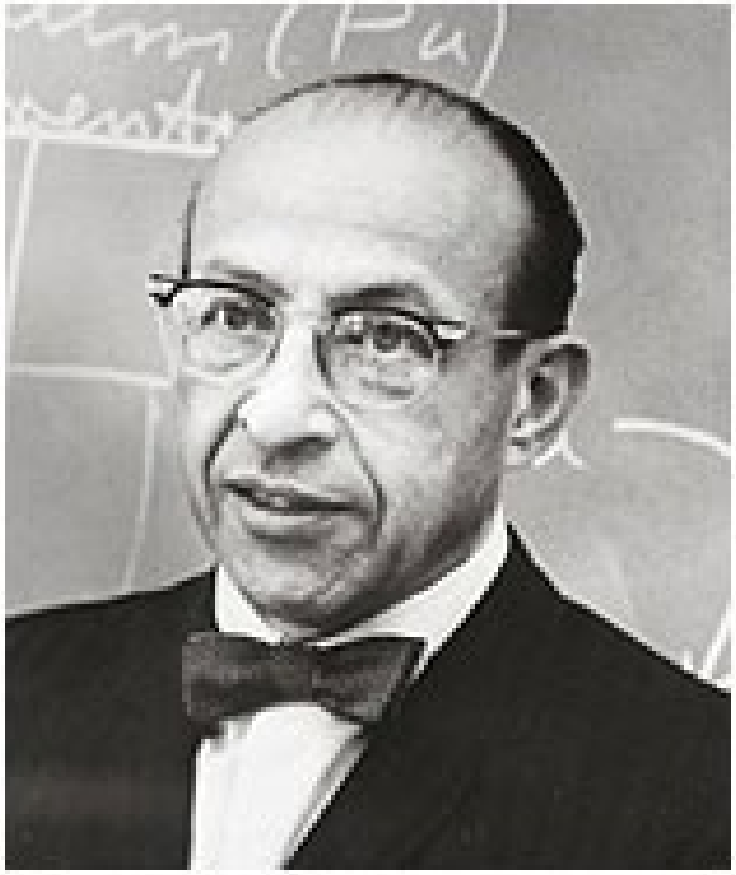
Enable the future energy system

Conduct economy-wide technology, economic, and policy analyses and research to make an affordable, sustainable, and resilient energy future possible

Provide independent and objective information

Inform investment, policy, and regulatory decisions, deliver intelligence on the energy system, and train the industry workforce

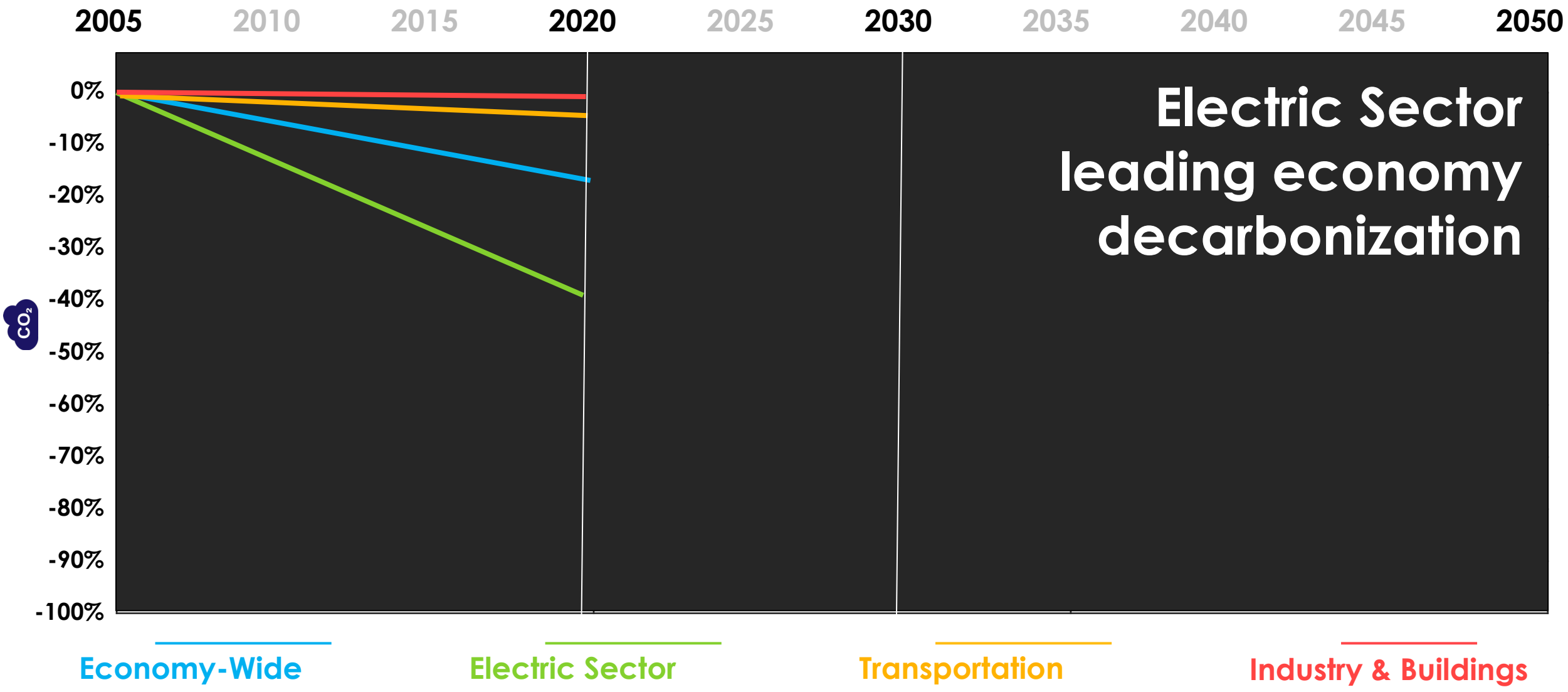
Our Role



Chauncey Starr
EPRI Founder

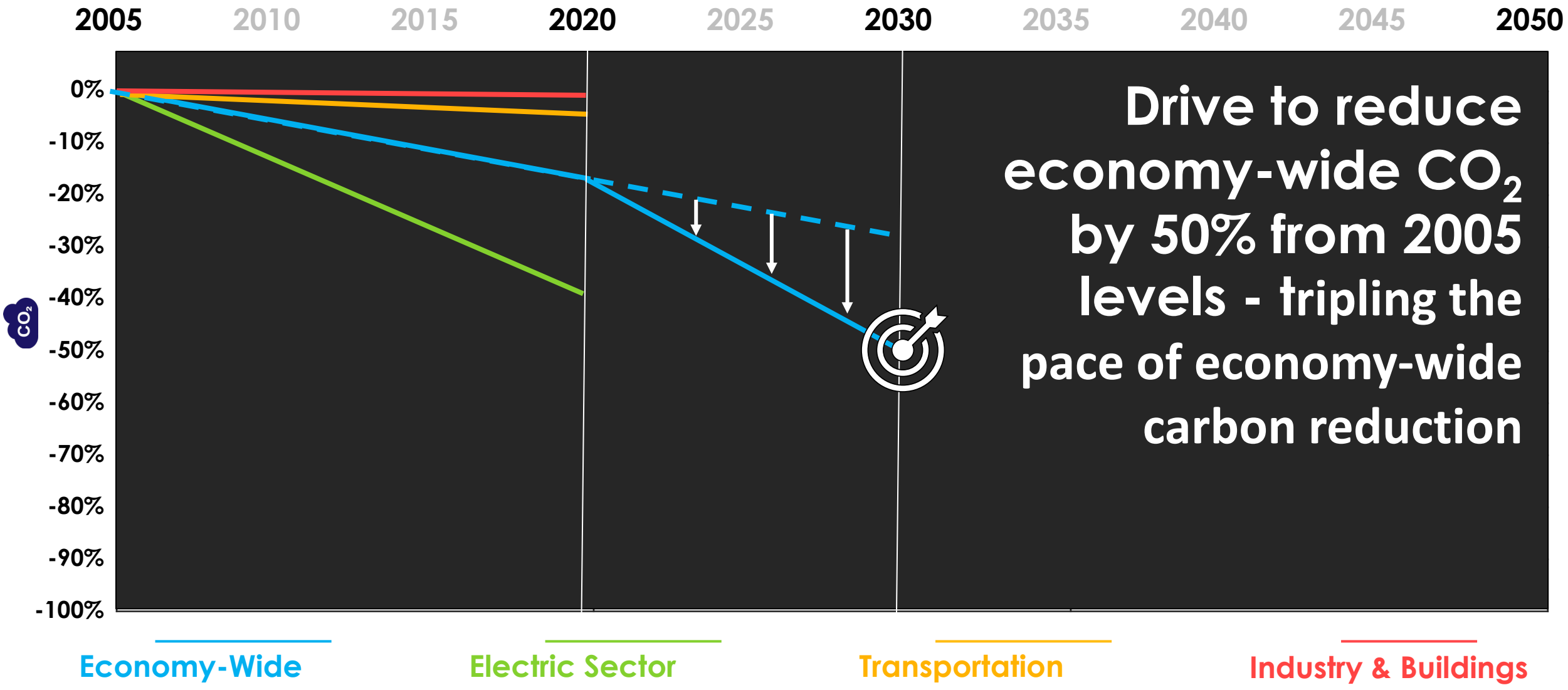
"You can't wipe out society and make a whole new society. You have to deal with the society that exists. But you have to figure out how you're going to change it to something that's better."

Examining U.S. Carbon Reduction Goals



https://www.youtube.com/watch?v=42UqxqCCYs4

Examining U.S. Carbon Reduction Goals



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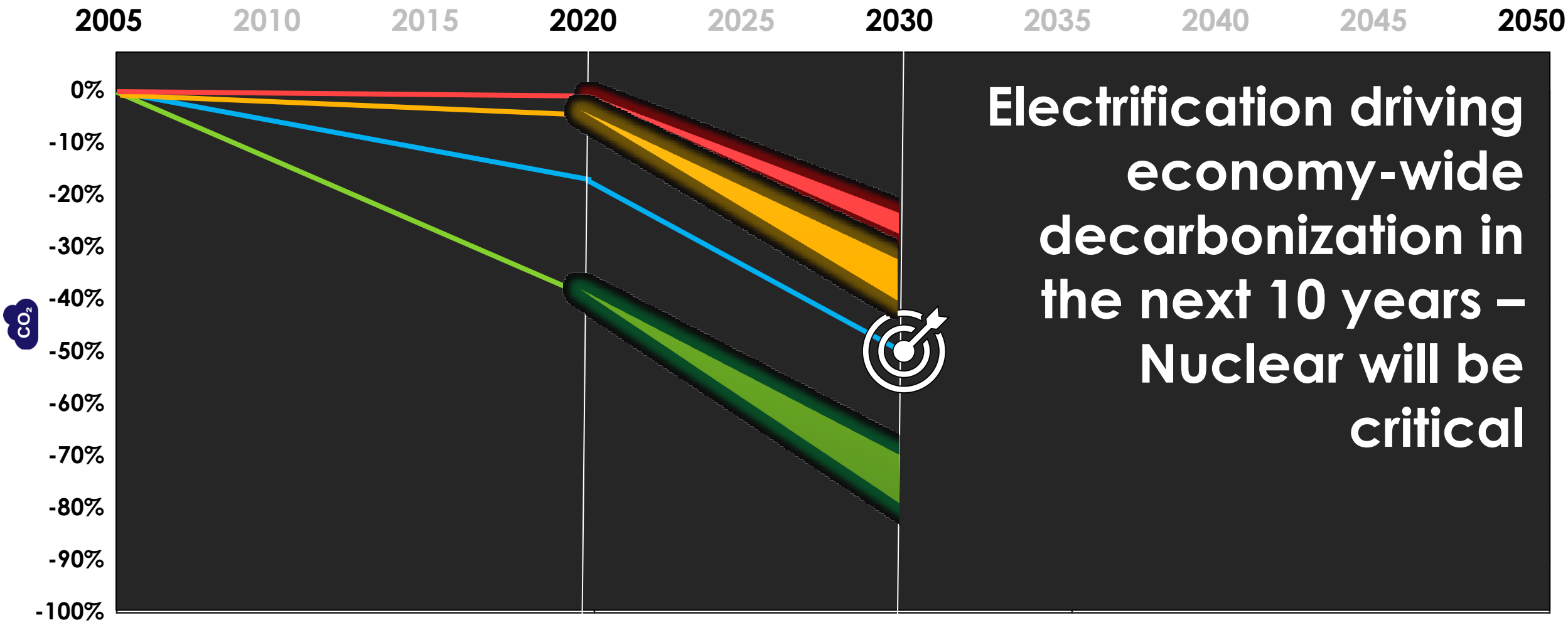

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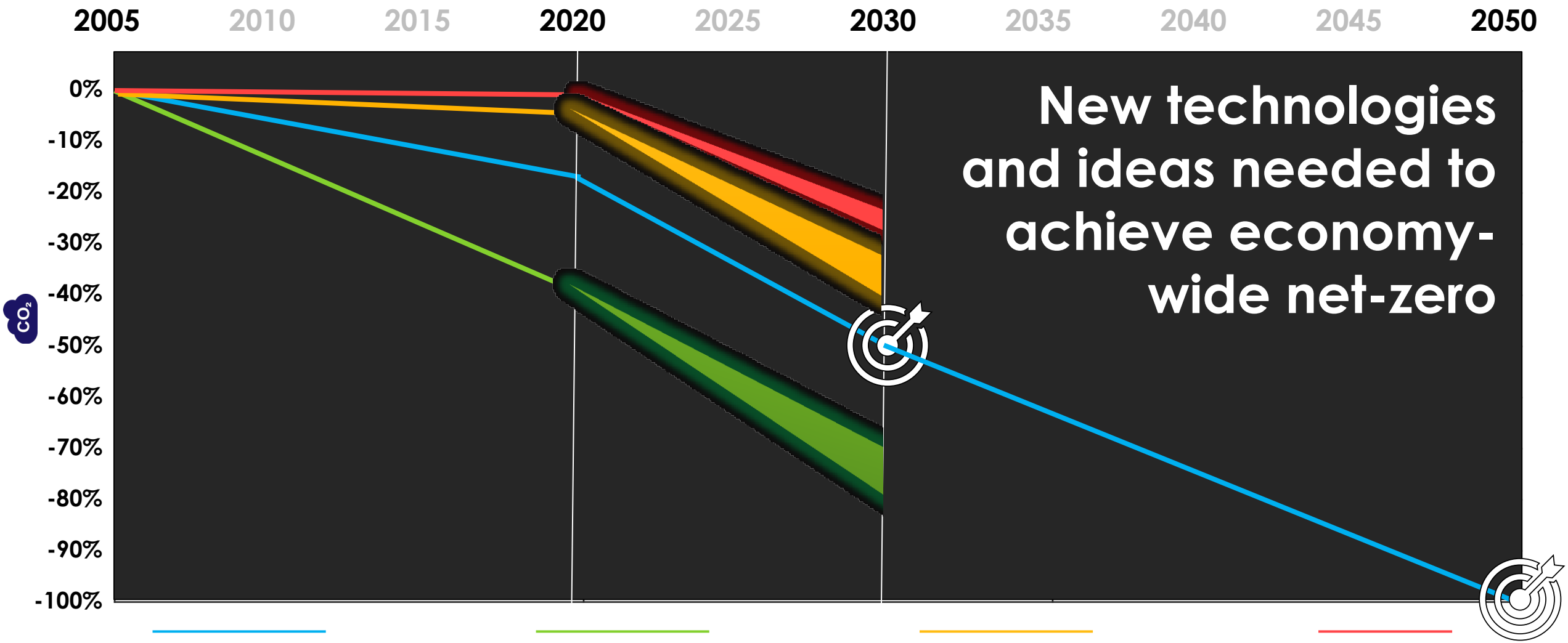

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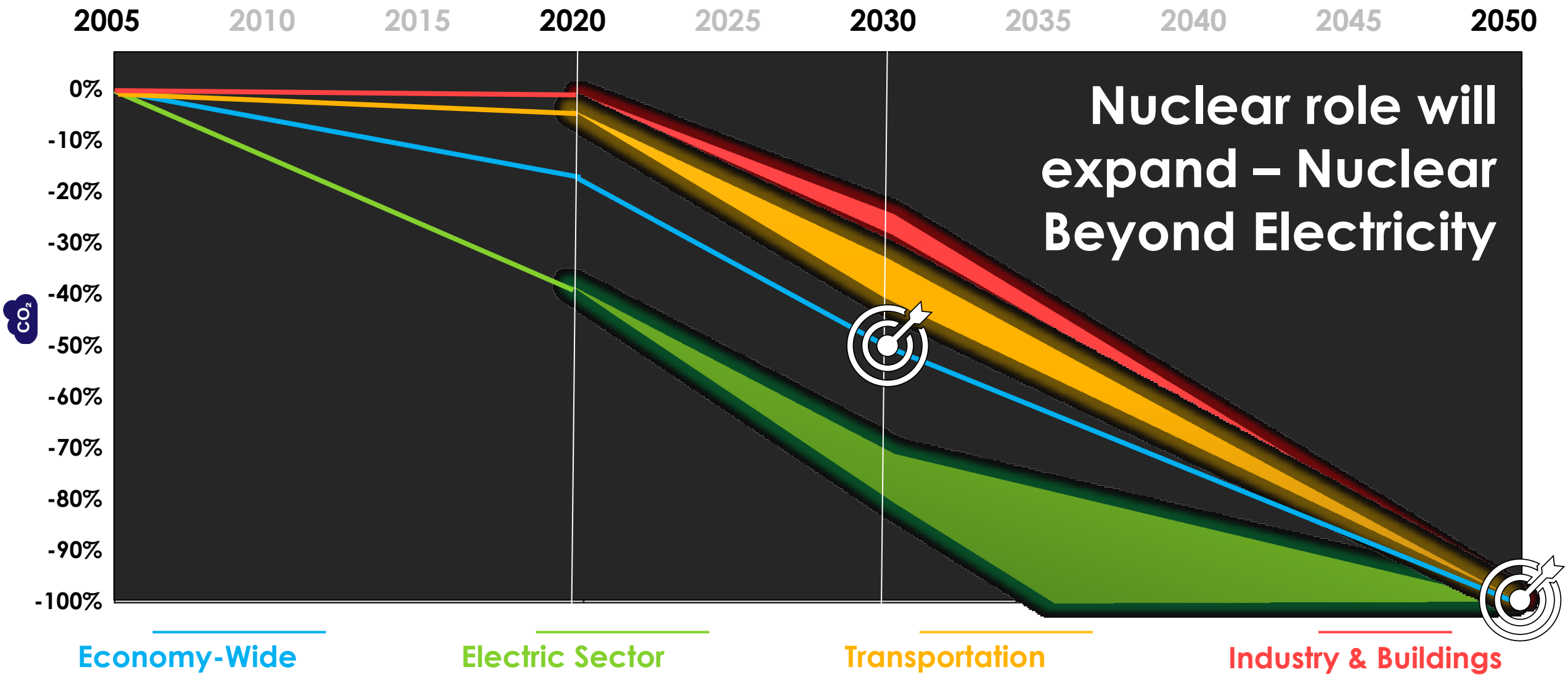

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4 Markets and 7 Strategies of Nuclear Beyond Electricity

Grid

Nuclear Operational Flexibility (Flex ops)

Grid Services

Energy

Energy Storage

Hydrogen and other Energy Carriers

Industrial

Water Desalination

Industrial Applications

Medical

Radioisotopes Production

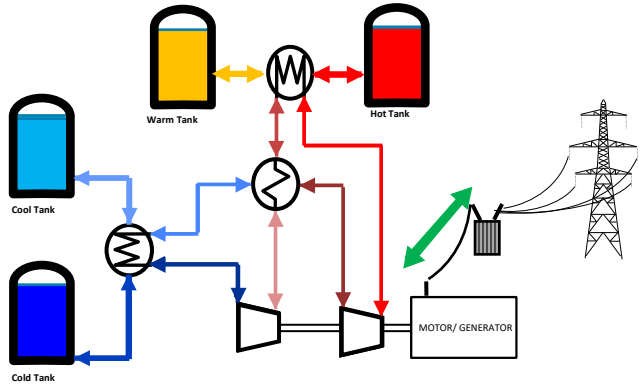
Thermal Energy Storage Critical

Energy storage achieved by heating a bulk media

SALT

CERAMICS

SAND



sCO2

CONCRETE

NUCLEAR BEYOND ELECTRICITY:

LANDSCAPE OF OPPORTUNITIES

Released in March 2021

Initial Survey and Near-Term Actions

Learn more:
EPRI product: 3002020437
Publicly Available

Ping Zhang

Dr. Ping ZHANG is a nuclear researcher with a PhD in Chemical Engineering from the Tsinghua University. Since 2001 he has been working in the Institute of Nuclear and New Energy Technology (INET) of Tsinghua University where he is a professor and in charge of R&D focused on nuclear hydrogen production through water splitting process.

Dr Zhang worked also in the Japan Atomic Energy Agency as a visiting scientist. He has published more than 70 peer reviewed papers, and owned more than 30 Chinese patent of invention.

清華大學

Institute of Nuclear & New Energy Technology (INET), Tsinghua University

HTGR and Its Potential to Decarbonize the Industrial Sector by Nuclear Heat Application/hydrogen production

Dr./Prof. Ping ZHANG

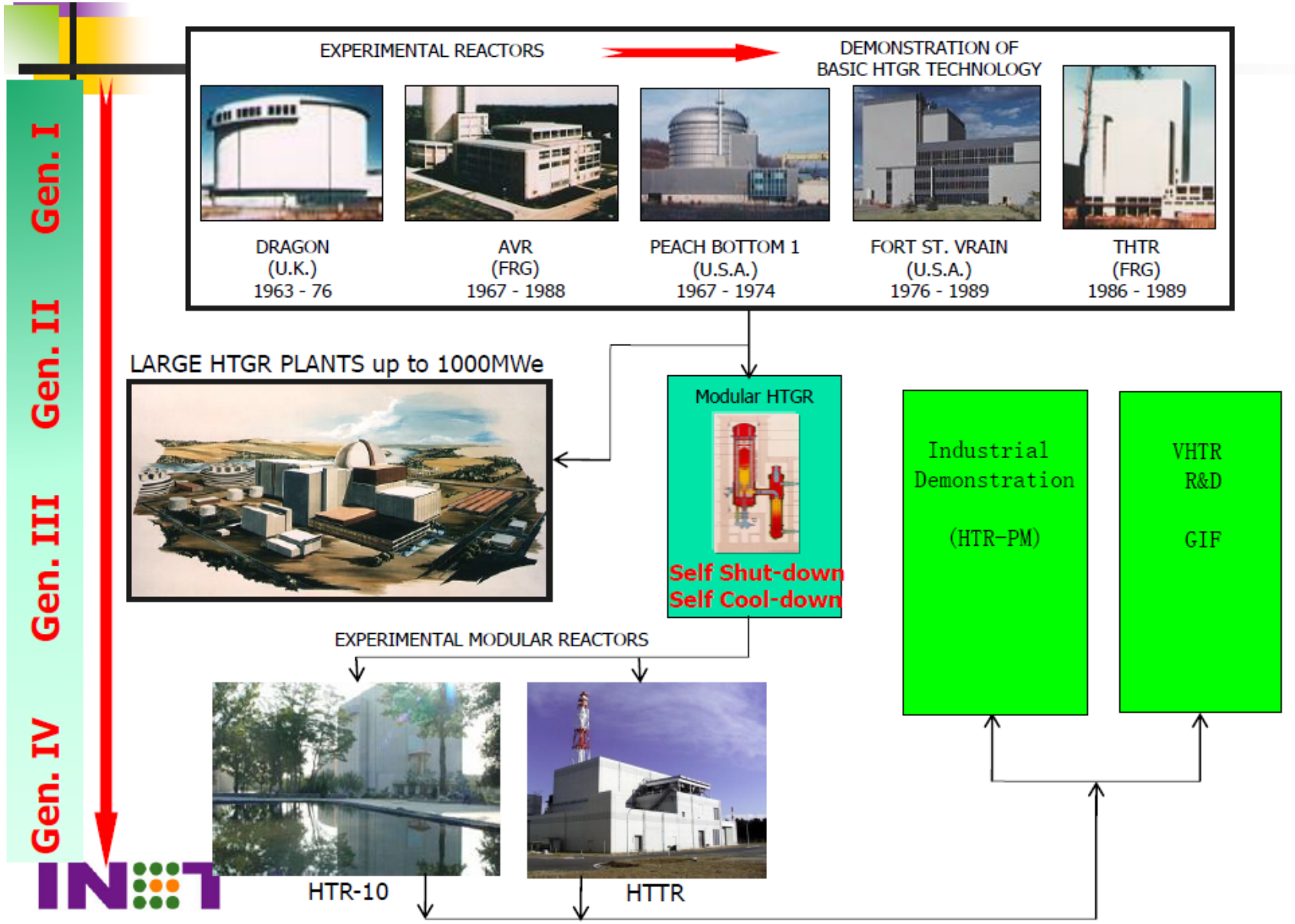
INET, Tsinghua University, China

IAEA Webinar, 13 July 2021

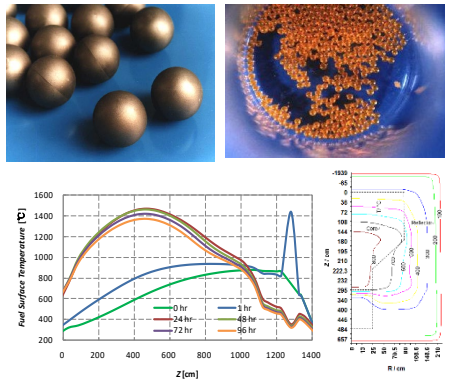
Outline

- *HTGRs development worldwide and in China*
- *The advantages of HTGR for process heat/H2 production*
- *Applications of HTGR in heat process and hydrogen production for decarbonization*
- *Cooperation between technology developer and industry*

Worldwide HTGR development



Development of HTGR in China



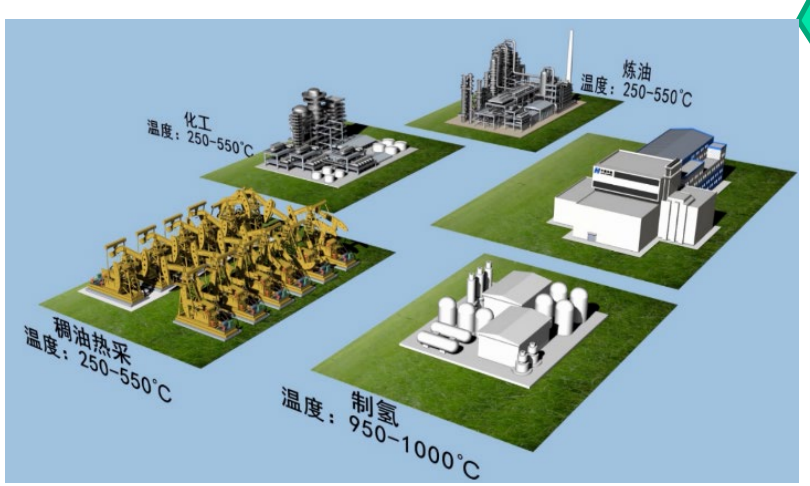
1.R&D on key tech

2.Test reactor (HTR-10)

3.Industrial demonstration(HTR-PM)

Pebble bed modular HTGR

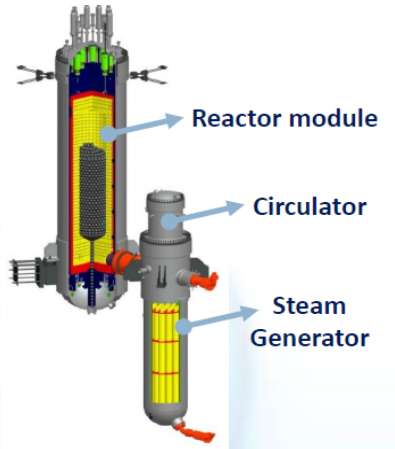
- *Electricity generation,*
- *cogeneration,*
- *process heat*
- *Hydrogen production*



4.Large scale application

HTR-PM

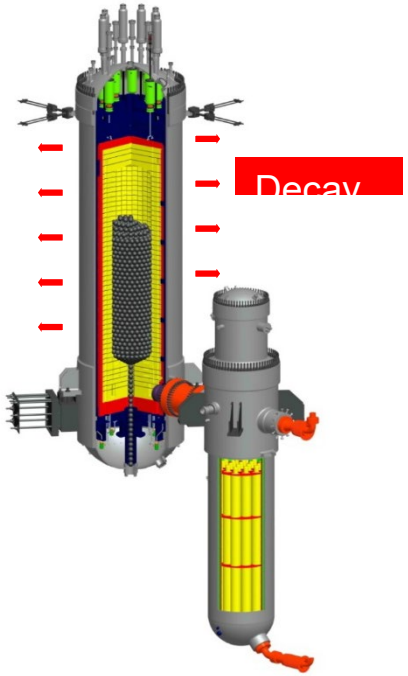
- **Basic info.**
  - *A 211MW$_e$ commercial demonstration NPP with two 250MW$_{th}$ pebble-bed HTGR modules coupling one stem turbine*
- **Milestones**
  - *2006: HTR-PM was approved as one of the top state level S&T projects*
  - *Dec 2012: Construction started*
  - *Up to now*
    - *All systems& components on site*
    - *Installation finished*



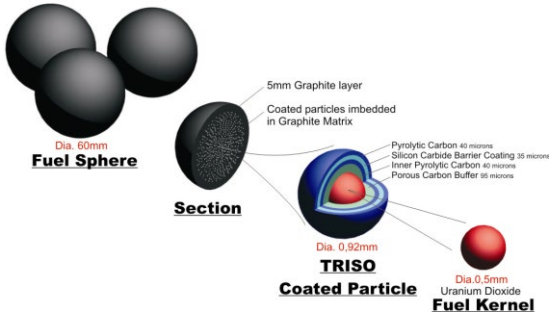
Parameters	Values
Helium Pressure (MPa)	7.0
Core inlet/outlet Temp. (°C)	250 / 750
Fuel enrichment (%)	8.5
Steam Temp. (°C)	566
Steam Pressure (MPa)	13.24

Modular HTGR: Inherent safe and catastrophe-free

- ***How nuclear safety is achieved by modular designs***
  - ***Reactor self-shutdown: strong negative temperature feedback, large span of allowable temperature increase of fuel***
  - ***Self-acting decay heat removal: low power density; selected slim configuration of reactor core***
  - ***Retention of radionuclides: strong coating; limiting temperature by material selection and core configuration.***
  - ***Safety goal: no off-site nuclear emergency (safety feature of Gen-IV systems)***

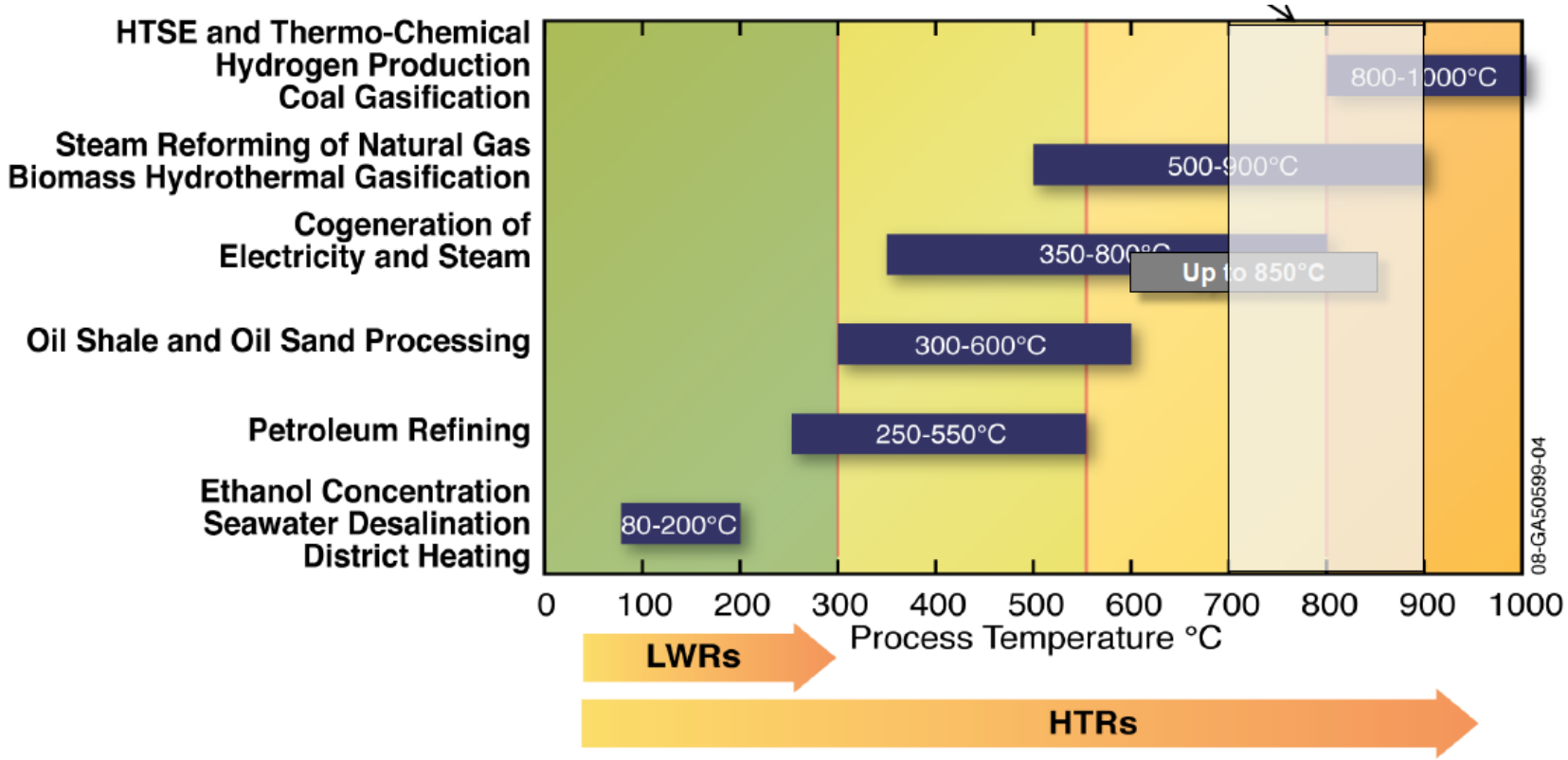


- ***Inherent safety, which permits close arrangement of heat-demanding factories or chemical plants, e.g., a hydrogen plant can be placed several hundred meters away from HTGR, increase the efficiency.***



Higher outlet temperature

- ***High temperature reactors can provide energy production that supports wide spectrum of industrial applications***



- ***High core outlet temperature, currently 750 ℃ and possibly 950 ℃, capable of high-efficiency power generation, heat supply, and chemical production.***

Application of HTGR

Key feature of HTGR: *extend the application of nuclear energy to process heat, a similar market volume to nuclear power*

HTGR Roles in China

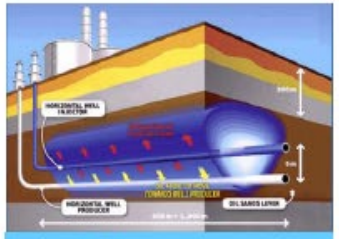
Supplement to LWR for power generation

Hydrogen production as next step

Co-generation to supply steam

Water desalination

District heating

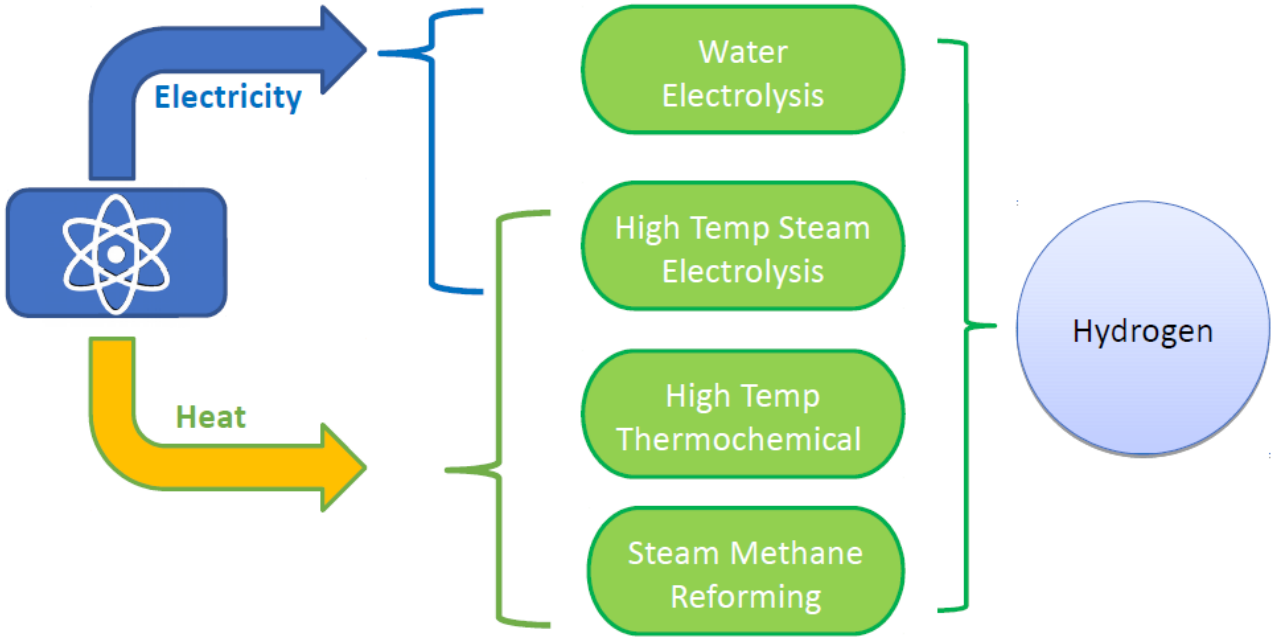


Oil recovery

Petroleum refinery

Coal liquefaction

HTGR for hydrogen production



- ***Advantages***
  - *No GHG emission*
  - *H_2 is produced from water, which is more comprehensive than fossil fuel.*
  - *Higher hydrogen production efficiency, large scale hydrogen production method*

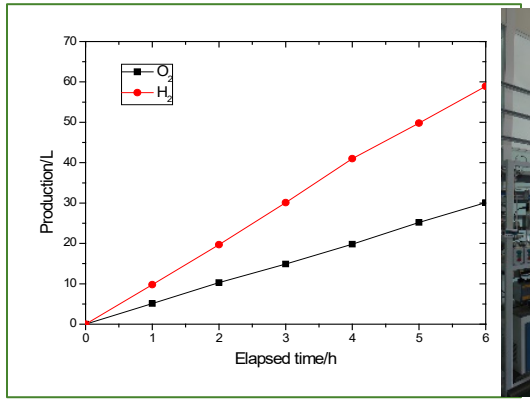
---nuclear hydrogen production is one of the best options in terms of mass production, CO2 emission and sustainability

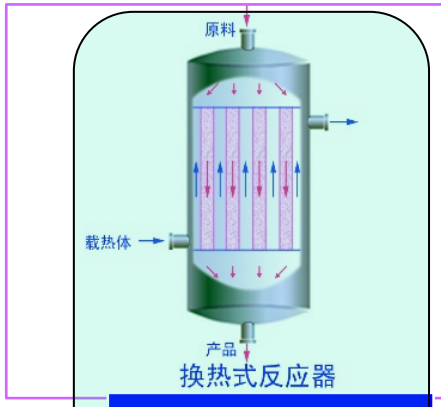
H2 in industrial sector and merits of nuclear hydrogen

In the long run, nuclear hydrogen production is a prospective massive , efficient , and CO2 – free hydrogen production.

Method	*Power density*	*Conversion /%*	*CO2 emission /Kg/GJ*
SMR	*Very high*	*75*	*69*
Coal to hydrogen	*Very high*	*59*	*193*
Electricity	*high*	*70*	*15-27*
Solar hydrogen from biomass	*low*	*24*	*25*
Solar hydrogen by light catalysis	*low*	*4*	*28*
Nuclear hydrogen	*Very high*	*50*	*25*

Roadmap of nuclear hydrogen production at INET





100-1000Nm³/h

Key tech. process

Closed-cycle

Verification of feasibility

0.01Nm³/h

Simulation and continuous operation

0.1Nm³/h

Engineering materials

Key components

1-10Nm³/h

Coupling tech.

Scaling-up

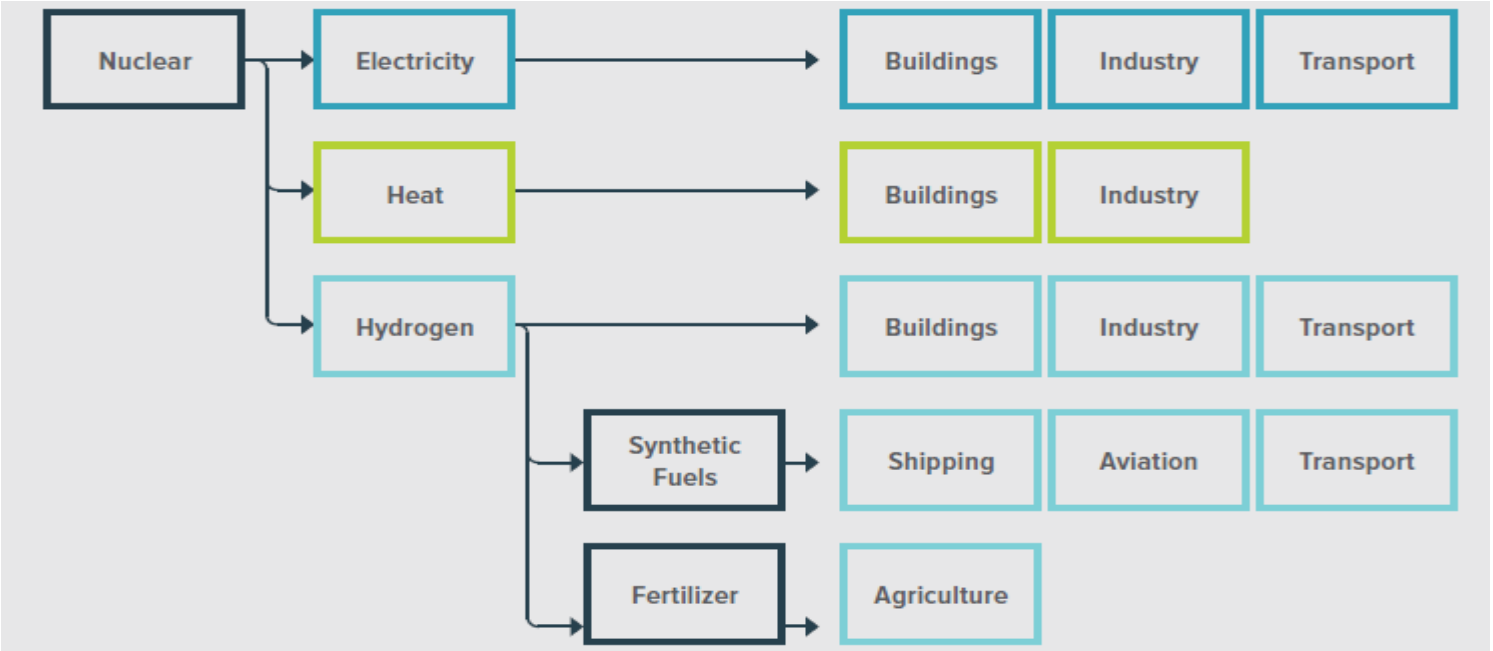
Safety

Fundamental study	System integration	Key components	Pilot demo
2005-2010	2010-2015	2016-2020	2021-2025

P Zhang, et al. ***Renewable & Sustainable Energy Reviews,.*** *https://doi.org/10.1016/j.rser.2017.05.275*

Nuclear heat/hydrogen for decarbonization of the industry sector

- *Industry is often termed "hard to decarbonize" because a vast, inhomogeneous array of processes comprise the sector, developing new, decarbonized process heating technologies represents a broadly applicable pathway to eliminate a large portion of sectoral emissions.*
- *Nuclear heat is extremely energy dense, not intermittent, and without GHG emission, will play an important role in the decorbonizaton of industry sector.*
  - *Commercial nuclear reactor (PWR) could supply steam for heating*
  - *V/HTR with outlet temperature of 750-950 would used for cogeneration of hydrogen, electricity, and heat, as well as desalination.*



Direct reduction iron by H2 for decarbonization of steelmaking

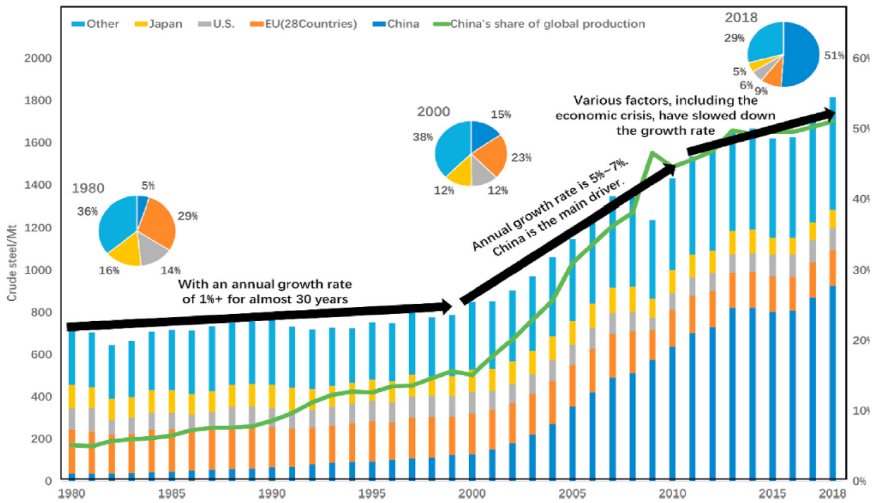


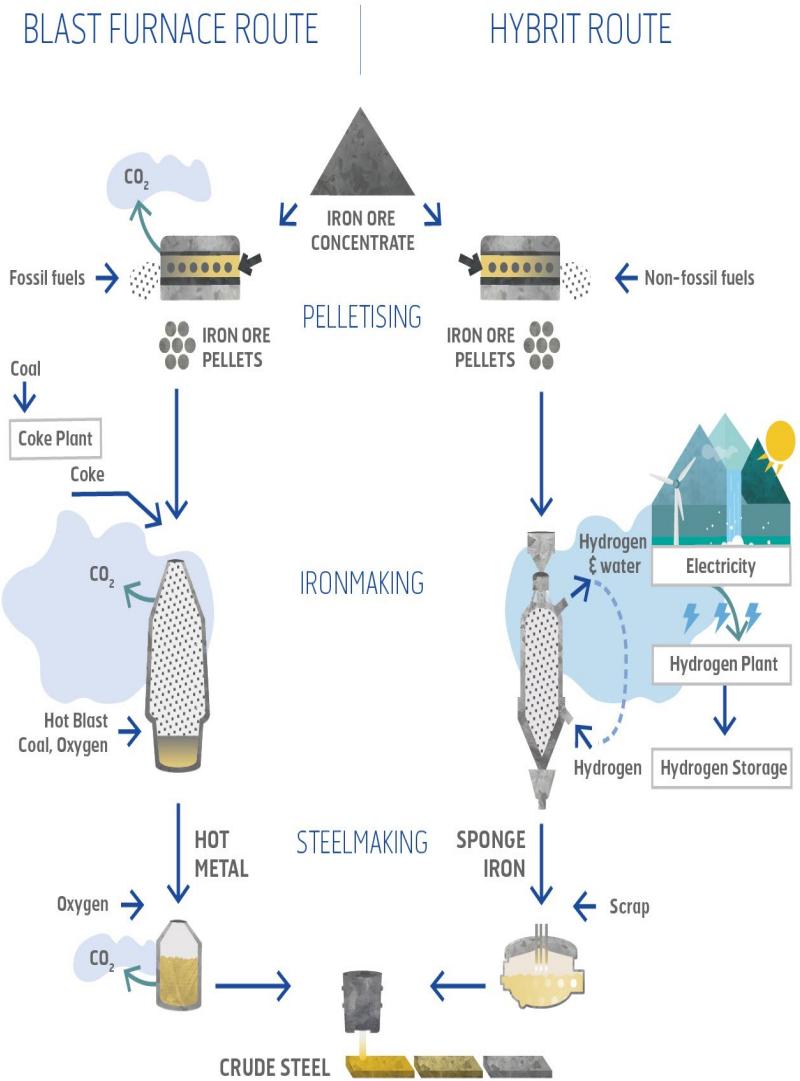
Fig. 1. Global crude steel production from 1980 to 2018, highlighting China's proportion (units: Mt) [2,32–34].

$2Fe_2O_3$（ore） + 3C →4 Fe + $3CO_2$

- The 83% of CO_2 is emitted in Ironmaking process (making pig iron)
- ~2 ton of CO_2 emitted per ton of steel product

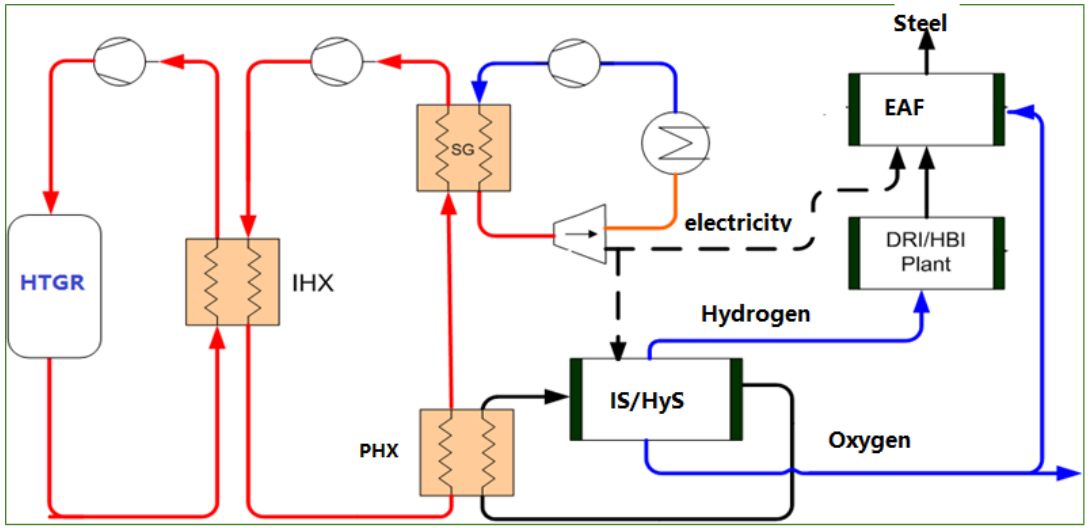
Fe_2O_3（ore）+3 H_2 → 2Fe + $3H_2O$

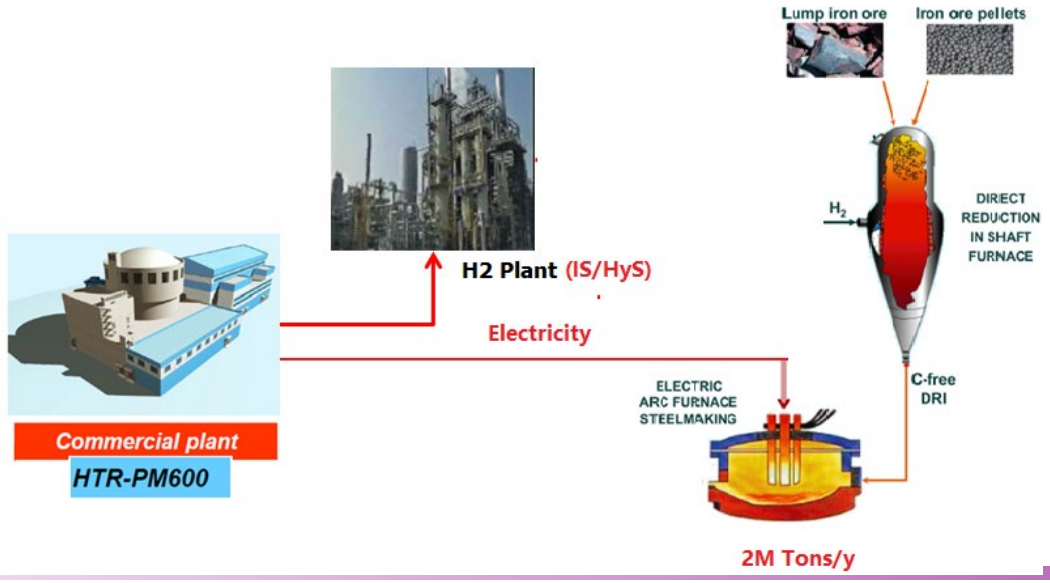
The CO2 emission from steelmaking industry account for 12-15% of the total emission



Nuclear Hydrogen production + Steelmaking

- ***1500MW$_{th}$ VHTR (Power equivalent to HTR-PM600): Meet all the energy demand and hydrogen of a 2 Million tons/y steelmaking company***





- ***CO2 emission: 14kg/T steel <1% of conventional process***
- ***Near zero emission technology***

Industrial Activities

- *Industrial-University collaboration*

- *Tsinghua Univ.*
  - ***Shanghai Electric on collaboration of key component manufacture***
  - ***China Nuclear E&C Group(CNEC) on commercialization of HTGR***
  - ***China General Nuclear Power Corporation (CCN) on commercialization of HTGR***
  - ***China National Nuclear Corporation(CNNC) joined Collaborative Innovation Center of Advanced Nuclear Energy Technology leaded by Tsinghua University***

Thanks for Your Attention!

Józef Sobolewski

Dr Józef Sobolewski is a nuclear physicist with a PhD at Physics Faculty of Johannes Gutenberg University of Mainz in Germany and an MBA at Warsaw University of Business.

Since June 2020 he is Plenipotentiary Director for High Temperature Reactors Development at National Centre for Nuclear Research. He is also Member of the Euratom Scientific and Technical Committee, Chairman of the European Nuclear Cogeneration Industry Initiative (NC2I) and a Member of the Governing Board of the Sustainable Nuclear Energy Technology Platform (SNETP).
In 2020 entrusted with the function of Adviser to the Minister of Climate and Environment of Poland on new nuclear technologies and their application.

IAEA International Atomic Energy Agency

Nuclear Heat to Decarbonize the Energy Sector
13 July 2021
- IAEA Webinar -

Recent HTR Developments in Poland and in the European Union

Dr Józef Sobolewski
National Centre for Nuclear Research, Poland
Chairman of Nuclear Cogeneration Industrial Initiative (NC2I), Europe

Narodowe Centrum Badań Jądrowych
National Centre for Nuclear Research
ŚWIERK

NC2I
Nuclear Cogeneration
Industrial Initiative

The European Green Deal - an assembly of political initiatives of the European Commission with the overarching goal of achieving climate neutrality in Europe by 2050.

In the EU, the choice of energy mix is a national responsibility. Not for all EU countries climate neutrality up to 2050 means emission reduction with all possible tools. Some countries firmly reject nuclear energy.

There are now 2 important documents discussed in EU: Taxonomy (sustainable investment) and Hydrogen (strategy). In both documents, nuclear energy is absent.

BUT

The revived cooperation of pro-nuclear countries in the EU and the determined efforts of many countries to have nuclear energy recognized as sustainable allows for optimism in the further development of nuclear energy for both electricity generation and non-electric applications.

This activity (e.g. letter from 7 pro-nuclear countries to EC) will probably achieve that the basic document for sustainable investment may include nuclear energy as a sustainable source of energy.

The EU Hydrogen strategy still does not consider nuclear energy, but several individual member state strategies do.

Heat market for nuclear technologies in EU

No competition between LWR & HTGR;

need for both

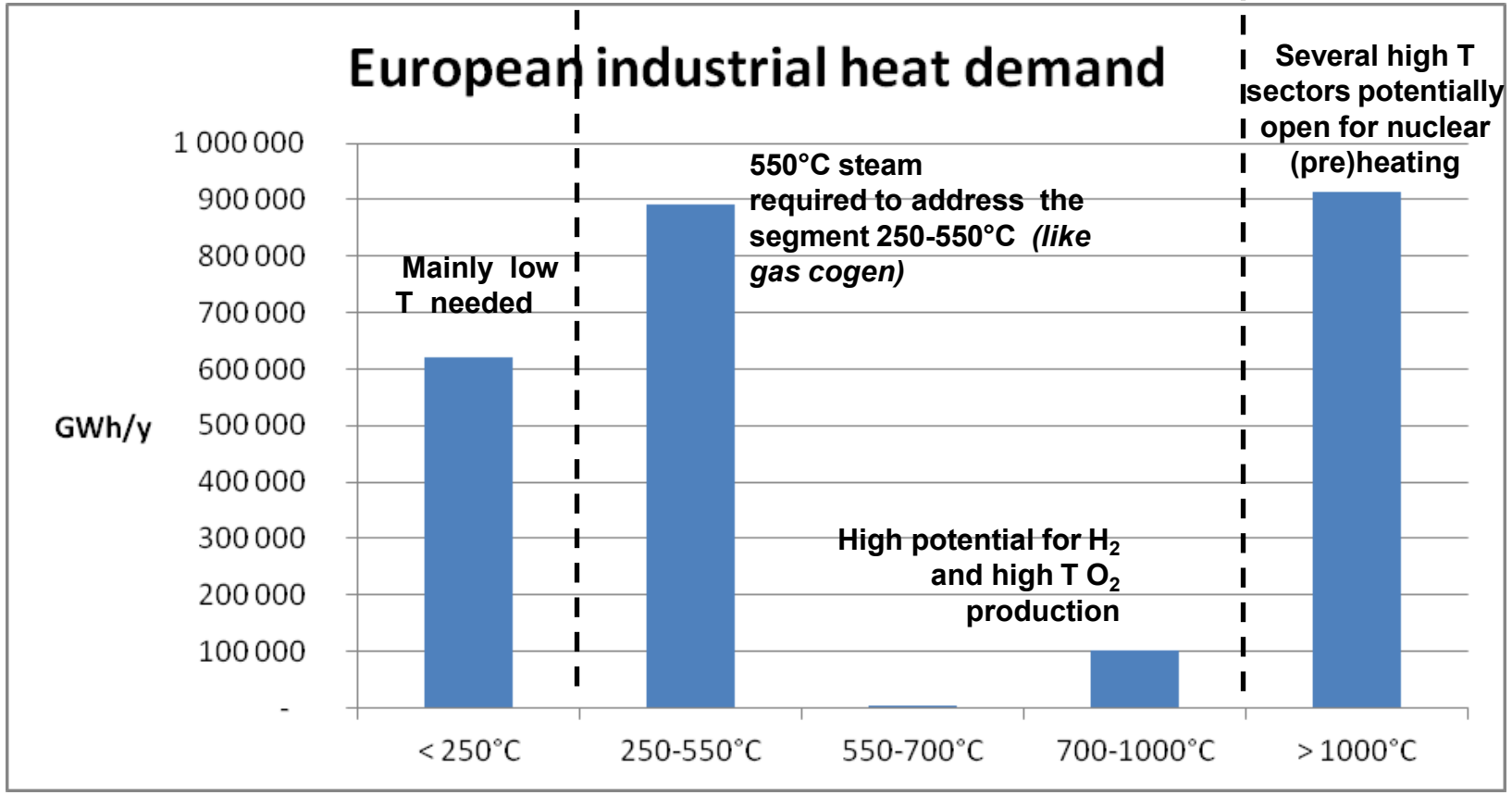
LWR

District heating, pulp & paper, desalination

HTGR

Chemicals, refining, H_2, steelmaking, soda ash, lime, glassmaking, industrial gases, etc.

VHTR



Reactors mature + experience in cogen

Proven reactor technology, high potential for cogen

Long-term

Source: EUROPAIRS study on the European industrial heat market

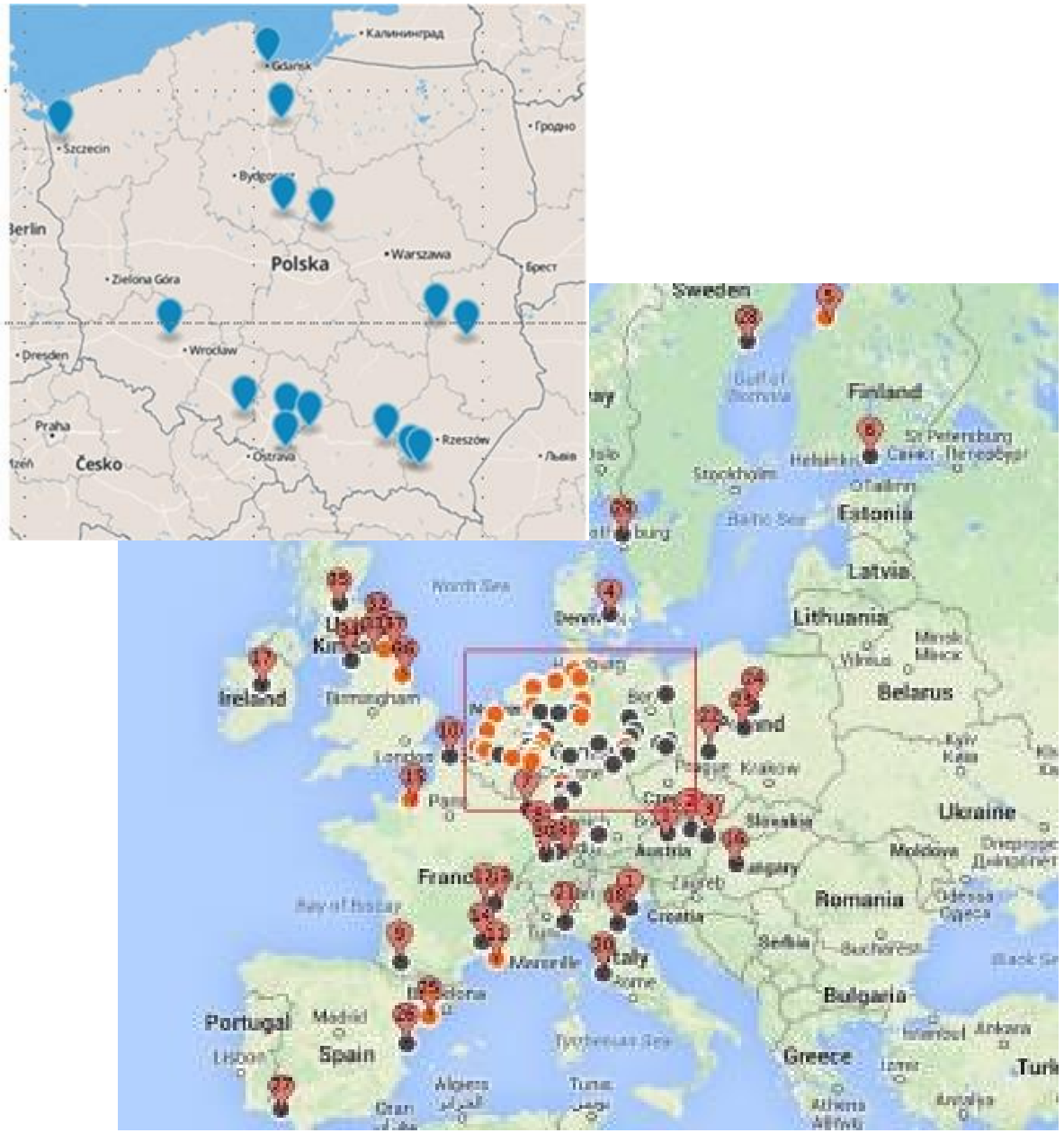
End-user needs in EU and Poland

In the range 250-550℃, the European heat market represents more than 100 GWth.

Primary target for HTGR is the Polish heat market.

- Today, 100% of the heat market is served by fossil fuels; mostly coal in district heating, and coal and gas in industrial heat generation.
- 13 largest chemical plants need 6500 MWth at T=400-550°C.

Secondary target is hydrogen production.



Narodowe Centrum Badań Jądrowych
National Centre for Nuclear Research
ŚWIERK

Advanced nuclear technologies in Poland – new opportunities for climate change mitigation

Although priority of Poland is to implement nuclear power programme based on large scale reactors we are aware of potential future benefits of HTR. As a result we initiated the scientific project on HTGR's (especially for industrial cogeneration) with the following objectives:

Decreasing dependence on fossil fuel import

HTGR may be an alternative to replace fossil fuels for industrial heat production. With expected growth of CO_2 tax and low discount rate, the cost of the steam from HTGR could be comparable to that from gas, while having more secure availability and more predictable prices.

Decreasing sensitivity of economy to environmental regulations

Industry dependent on fossil fuels might become less competitive in case of stronger environmental regulations (CO_2 tax, emission limits, etc.). HTGR being a zero emission technology is immune to that.

Synergy with multi-GW LWR programme.

Increasing scientific and industrial potential, upgrading the regulatory framework, developing human resources and creating a supply chain, will be beneficial for both HTGR and LWR projects.

Status of nuclear cogeneration activities

Formal basis for HTR technology

- Minister of Energy appointed Committee for deployment of high-temperature nuclear reactors in Poland in July 2016. Report with results of the Committee's works published in January 2018. Minister accepted the report, took note that deployment of HTGR reactors in Poland is desirable and requested Ministry to prepare further steps.
- Strategy for Responsible Development - the governmental program for Polish economic development - adopted in February 2017, contain e.g.: Deployment of HTR for industrial heat production. The project for this action is: Nuclear cogeneration – preparation for construction of the first HTR of 200-350 MWth supplying technological heat for industrial installation.

Status of nuclear cogeneration activities

Technical activities

- GEMINI+ (2017 – 2021). The main design options for HTGR fitting the requirements for cogeneration use in Europe (cogeneration use will be presented separately).
- The NOMATEN Centre of Excellence has received 7 years (2018-2025) of joint financial support (€37M) from the Foundation for Polish Science (FNP) and the European Commission. NOMATEN focus on the studies and development of novel materials, specifically those designed to work under harsh conditions – radiation, high temperatures and corrosive environments.
- In the frame of national strategy program GOSPOSTRATEG the National Centre for Research and Development accepted the grant of about $5M for joint project of MoE, NCNR and INChT for preparation of law, organization and technical instruments to deploy the HTR reactors in years 2019 – 2022.
- The largest Polish private chemical company SYNTHOS has started cooperation with American nuclear companies working on solutions related to the generation of electricity (BWR-SMR) and industrial steam (HTR-MMR).

GEMINI+

NOMATEN

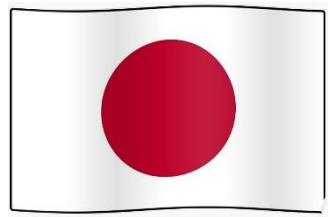
G HTR

synthos green energy

Status of nuclear cogeneration activities

Now

- National Centre of Nuclear Research is gaining knowledge on HTGR technology by strengthening collaboration with Japan Atomic Energy Agency.
- Action Plan for the Implementation of the Strategic Partnership between the Government of the Republic of Poland and the Government of Japan for the years 2021-2025 seeks cooperation in the field of High Temperature Gas-cooled Reactors (HTGR) between the National Centre For Nuclear Research of Poland and Japan Atomic Energy Agency, and cooperation between METI of Japan and Ministry of Climate of Poland, as well as other relevant entities towards possible deployment of industrial HTGR's.
- We start the first phase of EUHTER (EUropean High Temperature Experimental Reactor) program (design and construction of small experimental HTGR, being also the technology demonstrator). Financing will be based on national resources.
  - Phase I – design + start licencing (2021-2024)
  - Phase II – construction (2024 – 2029)
  - Start preparation for commercialization (2023)



Ministerstwo Edukacji i Nauki

EUHTER Programme – Phase I

The National Centre for Nuclear Research (NCBJ) and the Ministry of Education and Science have signed a contract for the implementation of another batch of design works for the research HTGR, being also the technology demonstrator. The event took place on May 12, 2021 in Świerk.

The contract determines that the conditions for the construction of a high-temperature research reactor in Poland will be created within three years at NCBJ and that the so-called “basic design” of such a device will be prepared. The reactor will be a prismatic type HTGR using TRISO fuel producing approximately 30 MWth at an outlet temperature of 750 ^{o}C.

Time: 1.06.2021 – 1.06.2024.

Value: 60 million PLN, approximately 17 million USD

EUHTER Programme – Phase I

Scope of the project:

- Preparation of laboratory facilities with the necessary accreditations and a quality management system necessary to perform research work in the process of licensing materials for HTGR technology.
- Performing tests of materials that can be used for the construction of HTGR, in terms of compliance with the requirements of HTGR technology.
- Development of the basic HTGR reactor design (basic / preliminary design according to IAEA-TECDOC-881, Fig. 4.1, page 36, LOD = Level Of Details according to BIM = Building Information Modeling; PN-EN ISO 19650 standard).
- Performing verification simulations for the project and preliminary HTGR safety report in accordance with the requirements of the Regulation of the Council of Ministers (2012).
- Preparation of selected elements of the preliminary safety report (CSR) for HTGR in accordance with the Regulation of the Council of Ministers (2012) on the scope and method of conducting safety analyzes conducted before applying for a license to build a nuclear facility, and the scope of the preliminary safety report for a nuclear facility.

HORIZON-EURATOM-2021-NRT-01-05: Safety of High Temperature Reactors

Expected Outcome: Project results are expected to contribute to all of the following outcomes:

- Validation of safety features of High Temperature Reactors (HTRs) as candidate reactors for cogeneration initiatives for high energy-consuming industries.
- Confirmation, with an early involvement of regulators, if a generic design for HTR can be proposed for licensing and how a licensing process can be launched at the European level.
- Demonstration of the feasibility of coupled nuclear cogeneration technologies and installations at industrial scale.
- Socio-economic evaluation of introducing cogeneration with temperatures relevant to HTR in the industrial landscape of European regions with high energy-consuming industries.

Recent HTR Developments in Poland and in the European Union

Thank you

Webinar on Nuclear Heat to Decarbonize the Energy Sector

Webinar Series on Nuclear Technology Breakthroughs for the 21st Century

Webinar Series on Nuclear Energy and Climate Change

13 July 2021 15:00-16:30 CET (Vienna, GMT +02:00)

IAEA
International Atomic Energy Agency

Q&A