IAEA
International Atomic Energy Agency

IAEA Activities on Nuclear Cogeneration for Non-electric Applications of Nuclear Energy

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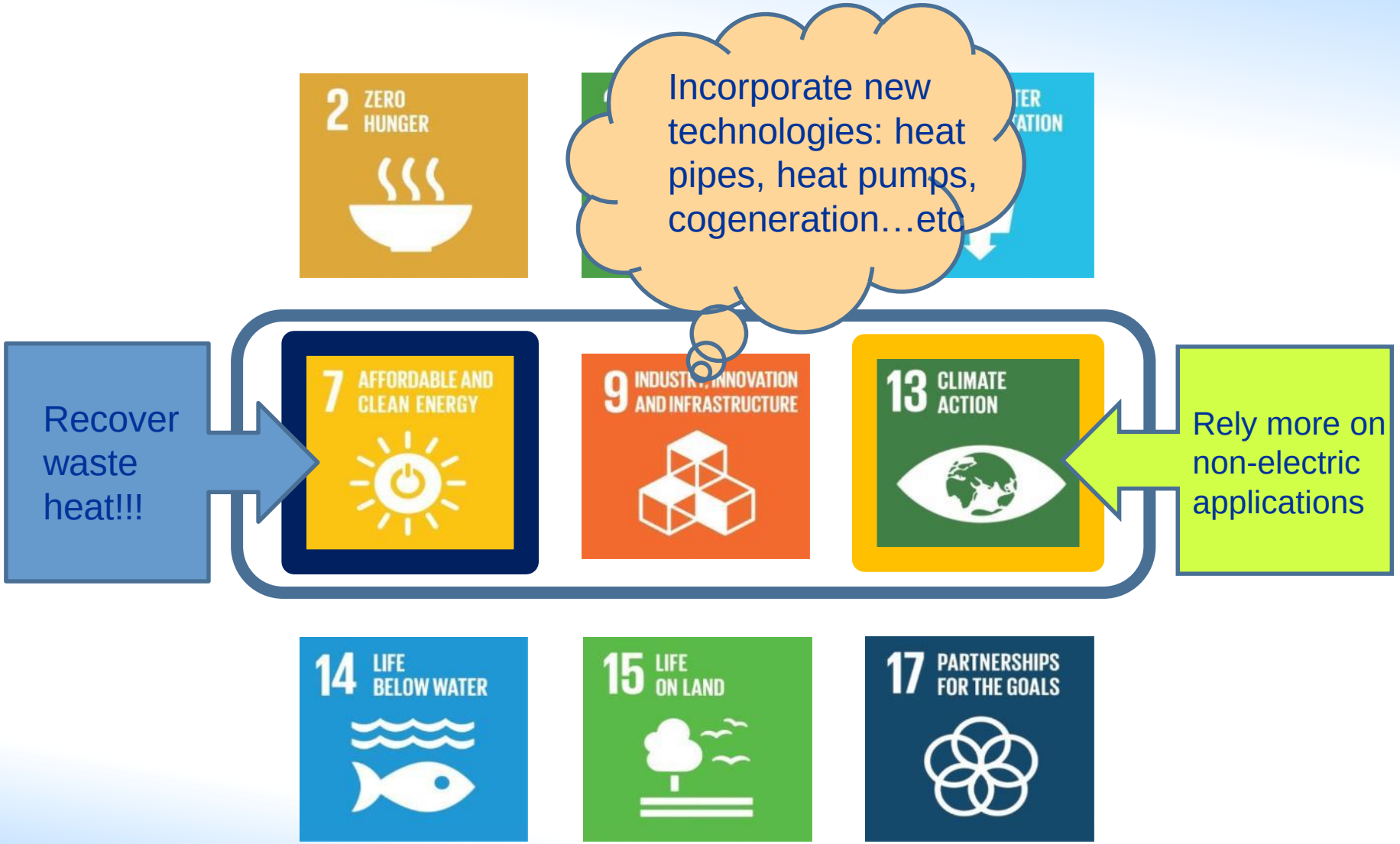
Department of Nuclear Energy

International Atomic Energy Agency


SUSTAINABLE
DEVELOPMENT
GOALS


TRANSFORMING OUR WORLD: THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

Nuclear Cogeneration & SDGs



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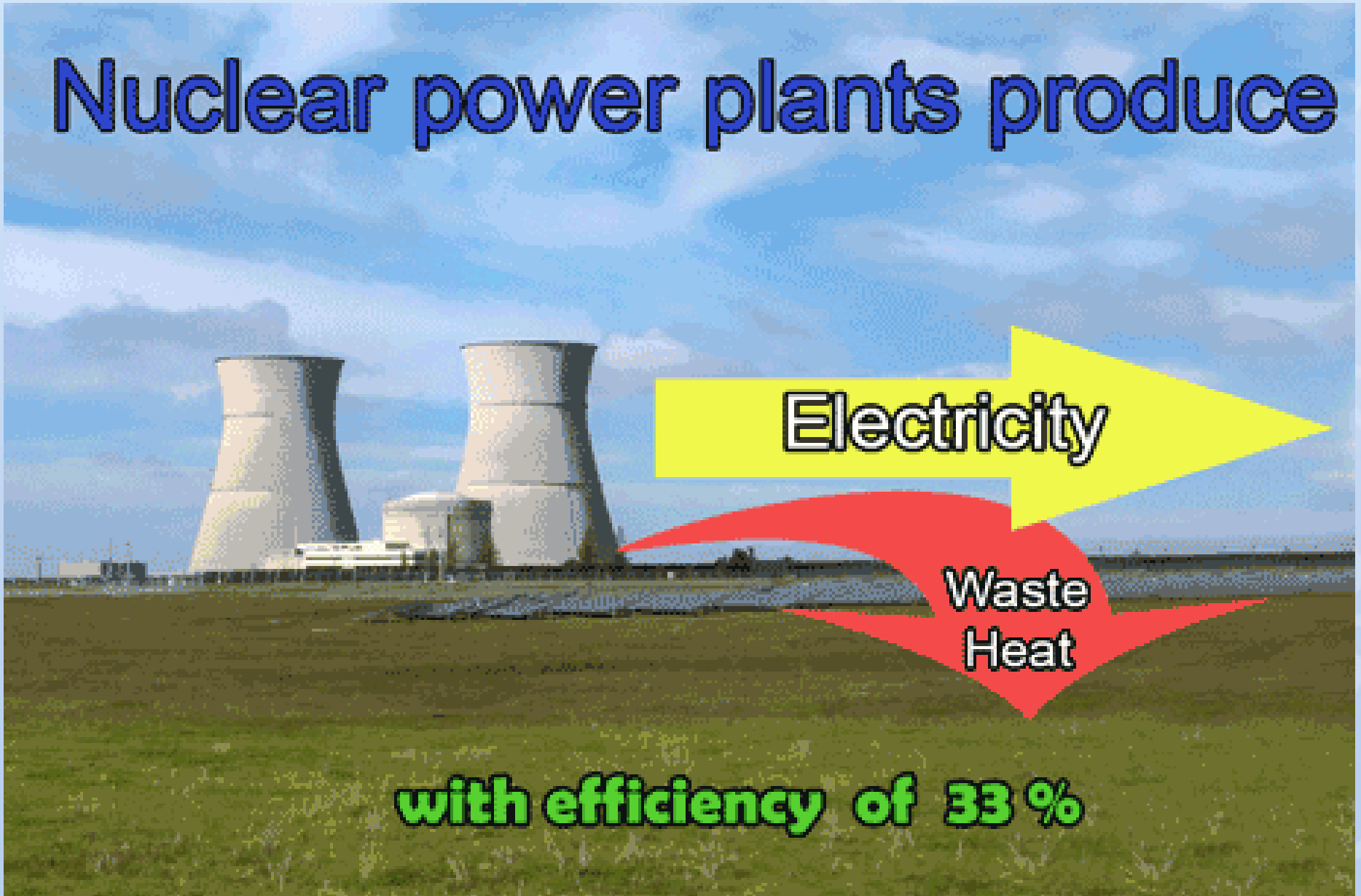
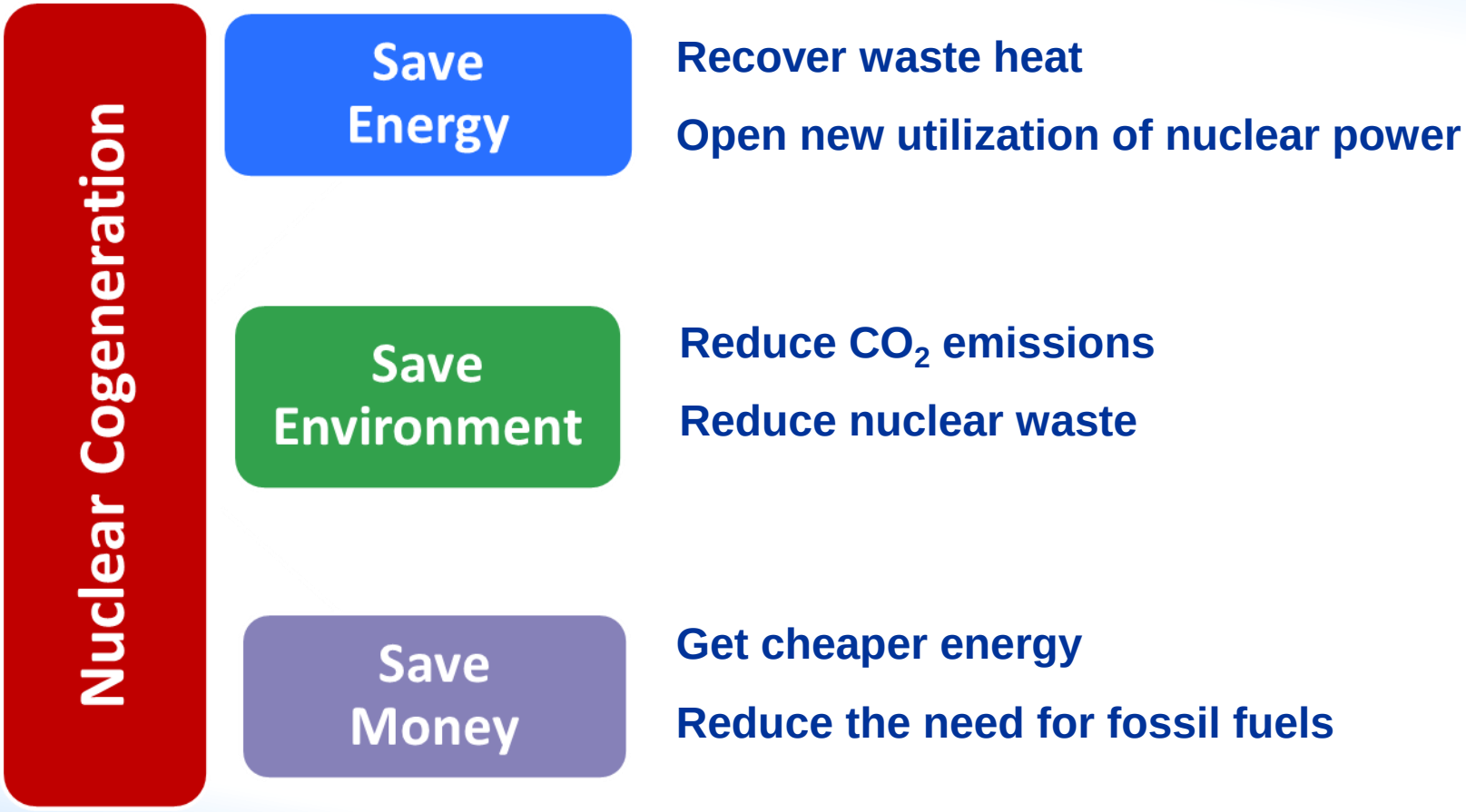
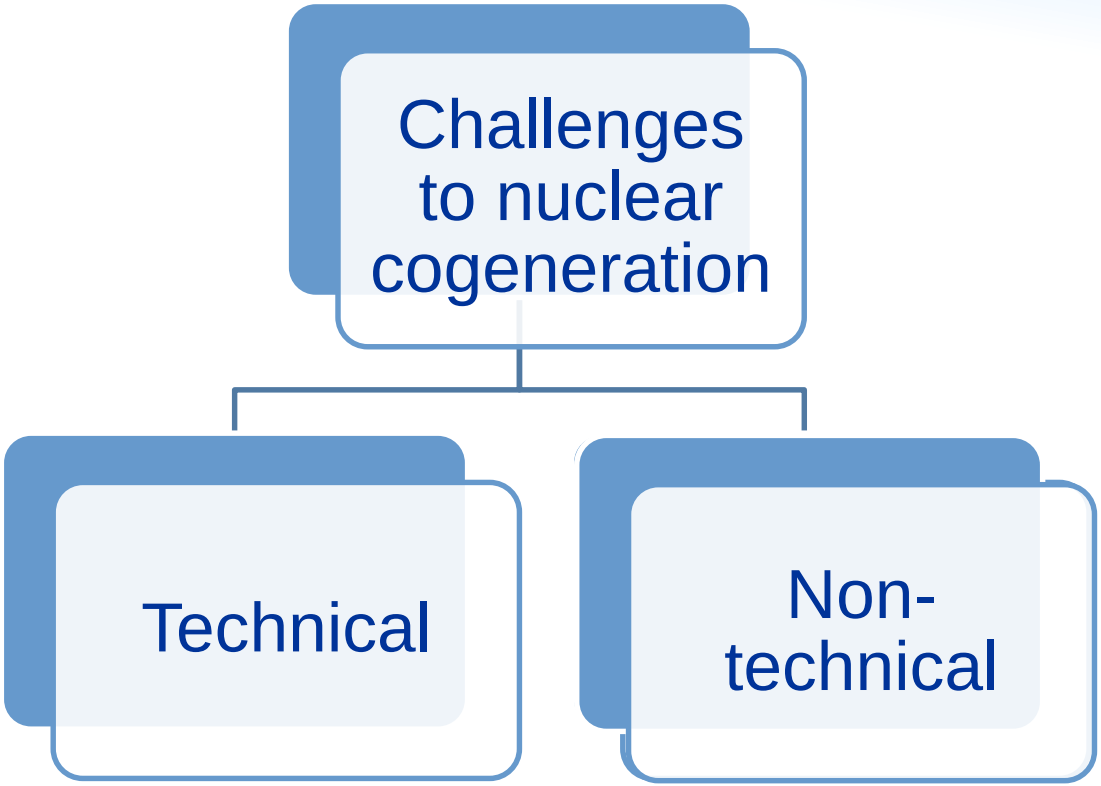


Nuclear Cogeneration for Sustainability



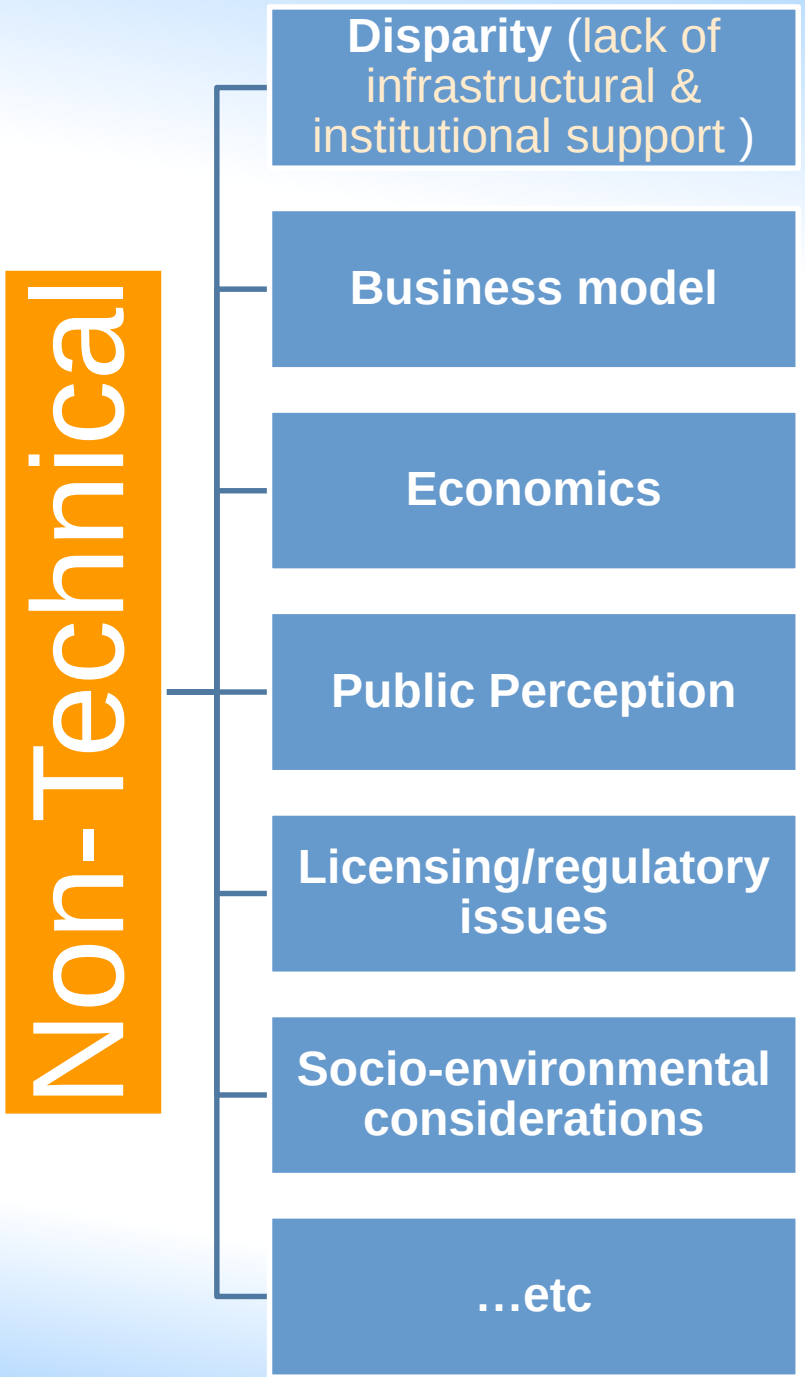
Why nuclear cogeneration is not commonly deployed?


Challenges to nuclear cogeneration
Technical
Non-technical

TECHNICAL

Depends on the non-application

- No impediment for District heating, desalination, and other low temp process heat
- For hydrogen: demonstration of large scale production/storage
- Introduction of waste heat recovery systems
- Characteristics of heat and transportation markets (Large vs. SMRs)


Non-Technical
Disparity (lack of infrastructural & institutional support)
Business model
Economics
Public Perception
Licensing/regulatory issues
Socio-environmental considerations
…etc

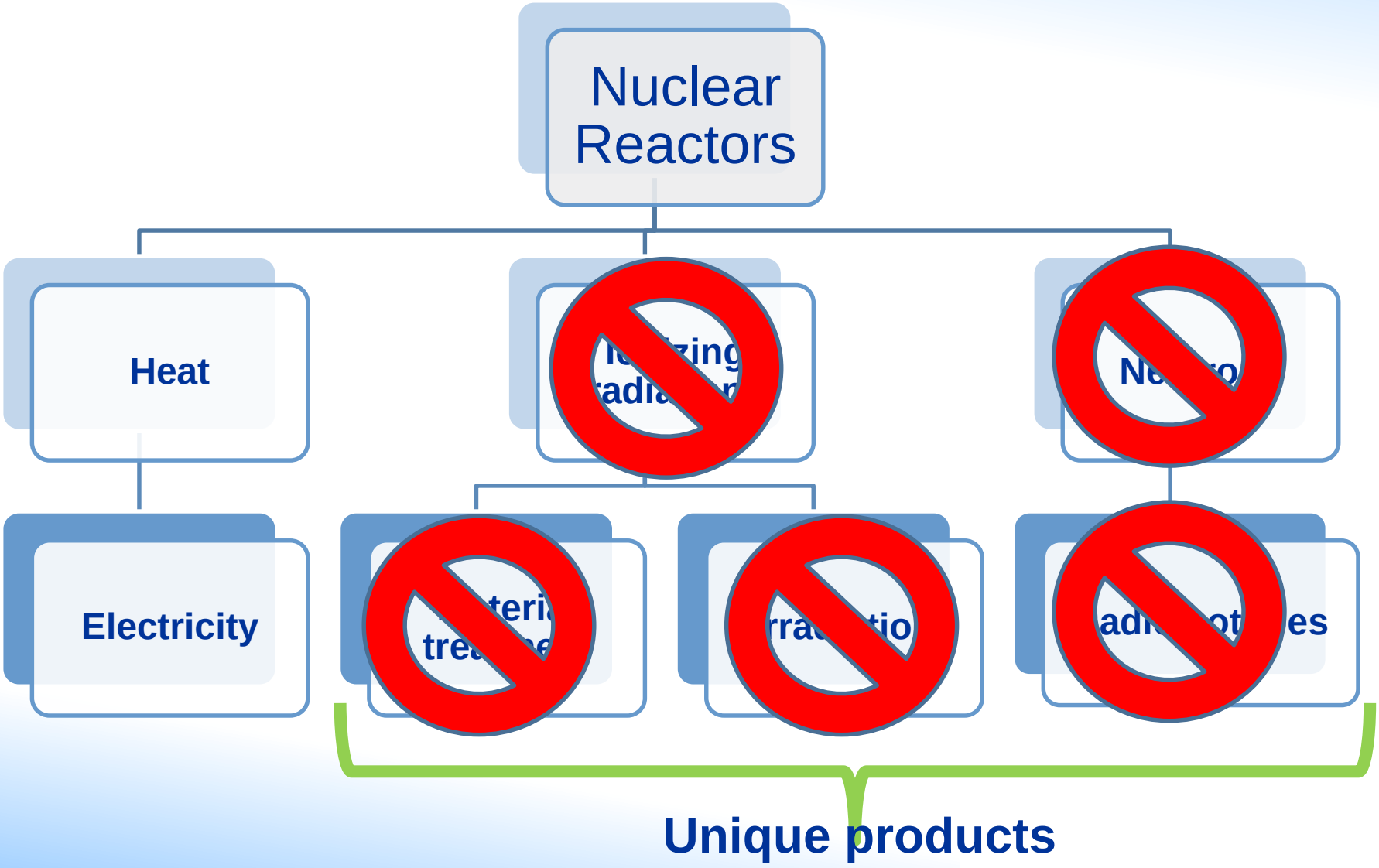
How could Stand-alone Nuclear NPPs Compete vs Coal/gas?

Power plants	Type	Nominal power MW(e)	Estimated cost of construction	Capital Cost/Watt
Nuclear Sanmen I & II	Westinghouse AP 1000x2	2x 1100	$5.9 B	~ $ 3/Watt
Nuclear Taishan I & II	Areva French EPR	2x 1660	$7.5 B	~ $ 2.5/Watt
Nuclear SMR Ref. Nucleonic Week Copyright © 2015 McGraw Hill Financial March 26, 2015	FOK NuScale	600	$ 3 B	~ $ 5/Watt
	12th NuScale	600	$ 2.5 B	
Coal & Gas			**$200 M- 1.5 B**	**$ 0.6-1.5/Watt**

Nuclear Reactors

- Subcritical Assemblies
- Research Reactors
- Power reactors

Nuclear Cogeneration has the potential to Compete vs Coal/gas



Other fields of non-electric applications

- Industry (using isotopes & Radiations)
- Hydrology (various nuclear techniques & tracers)
- Mining (isotopic dating)
- Agriculture & Food (radiations & Tracers)
- Medicine (diagnosis through radioisotopes, radiography, radio-pharmaceuticals, gammagraphy, sterilization…etc)
- Art (dating, non-destructive examination)
- Environment (analysis using nuclear techniques)
- Space exploration (nuclear batteries, space navigation)
- Etc..

Nuclear Power & Non-electric Applications (Past)

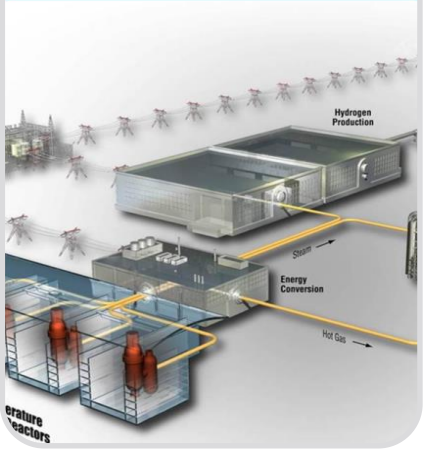
- ✓ **Proven technology:**
  - 1956: Calder Hall plant in UK provided electricity and heat to nearby fuel processing plant
  - 1963: Agesta NPP in Sweden provided hot water for district heating to a suburb of Stockholm
  - 1972: Aktau in Kazakhstan provided heat and electricity for seawater desalination to supply 120000 m3/day fresh water for the city of Aktau
  - 1979: Bruce in Canada heat to heavy-water production and industrial & agricultural users
  - 2009/2010: India & Pakistan (Desalination)

IAEA Project on Non-Electric Applications

Support for Non-electrical Applications of Nuclear Power

Nuclear seawater desalination

Nuclear hydrogen production



Nuclear energy heat for industry

+

Support to Near-Term Deployment

Website: http://www.iaea.org/NuclearPower/NEA/

Nuclear Reactors & Applications

- Industry (using isotopes & Radiations)
- Hydrology (various nuclear techniques & tracers)
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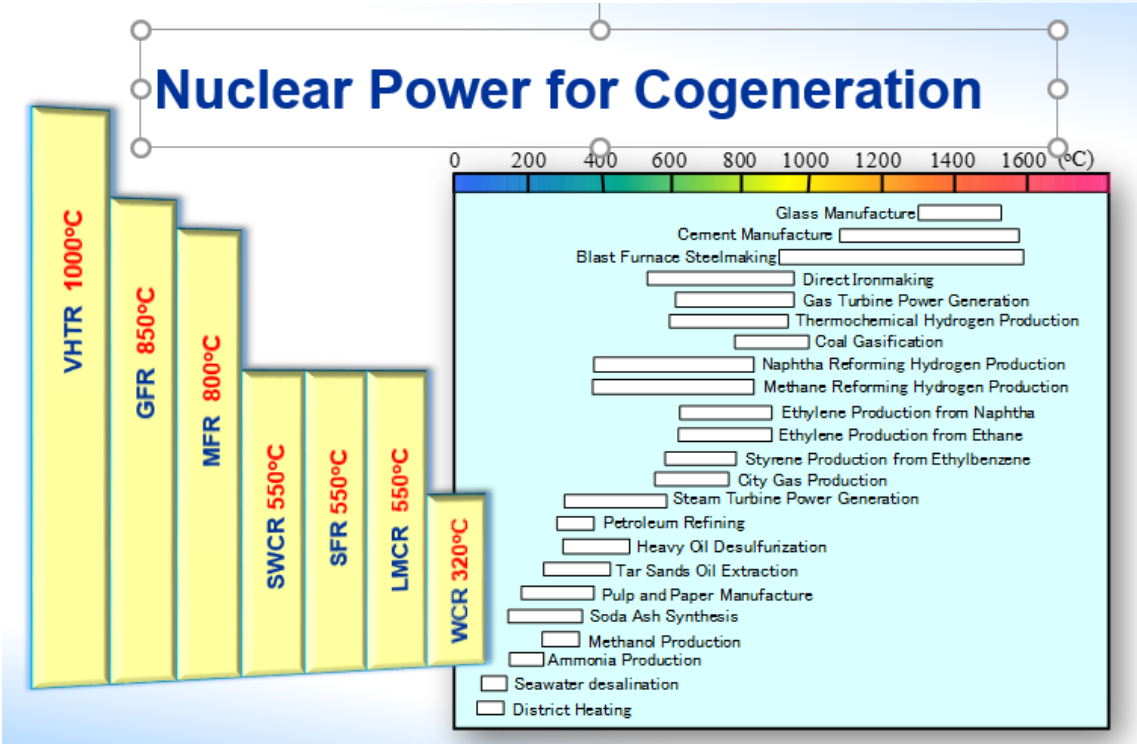
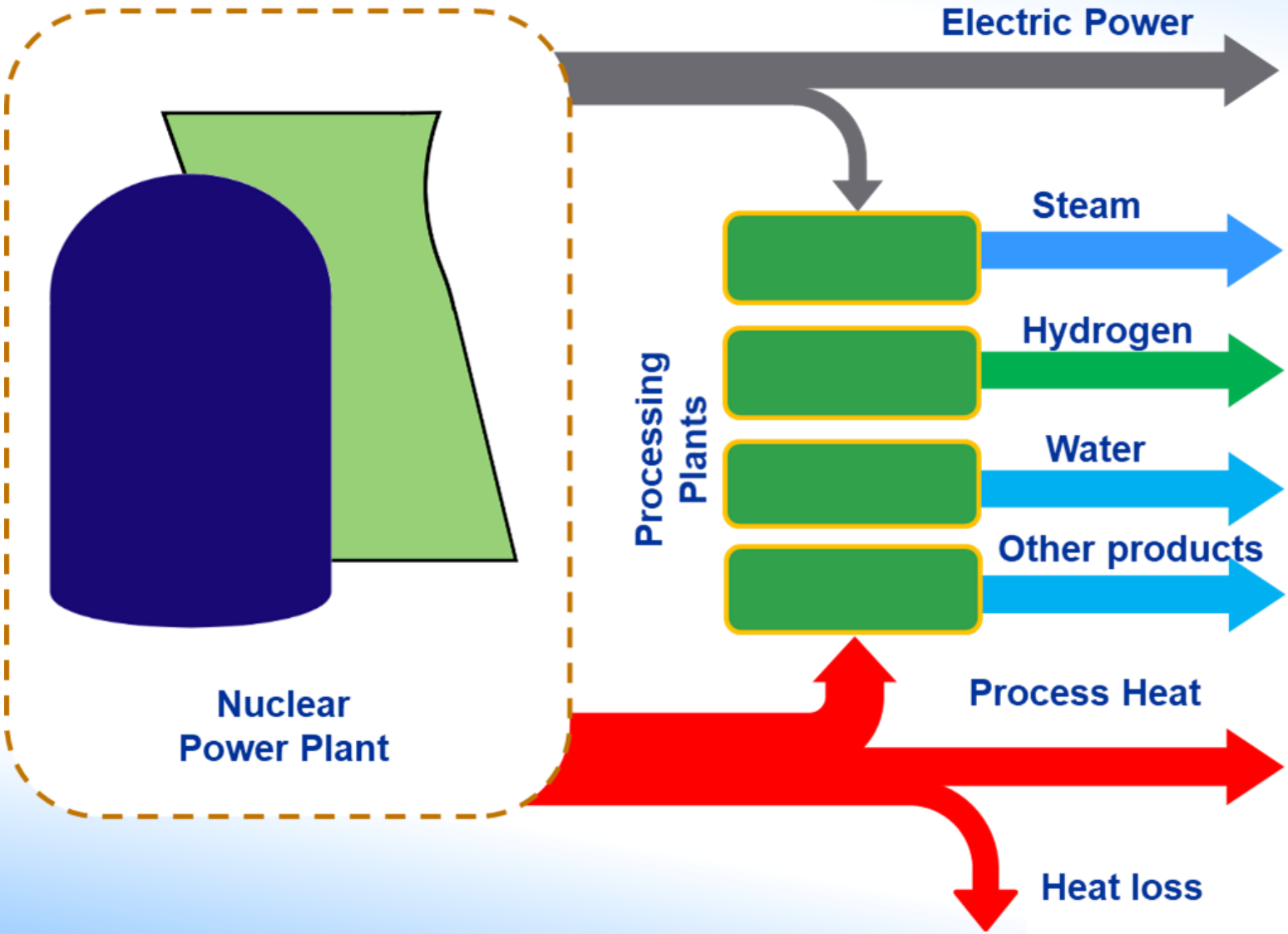


Routes of Nuclear Cogeneration



Nuclear Cogeneration for Climate Change

Current Status:

Total N

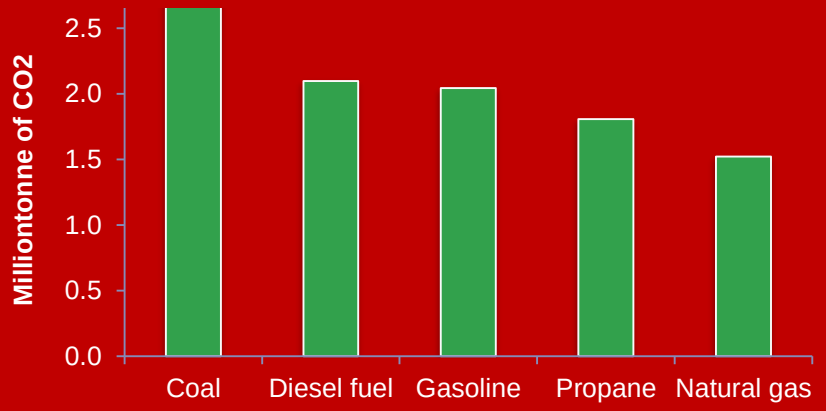
w

Imagine: the waste heat from these reactors: ~ 1 000 000 MW(th)!!

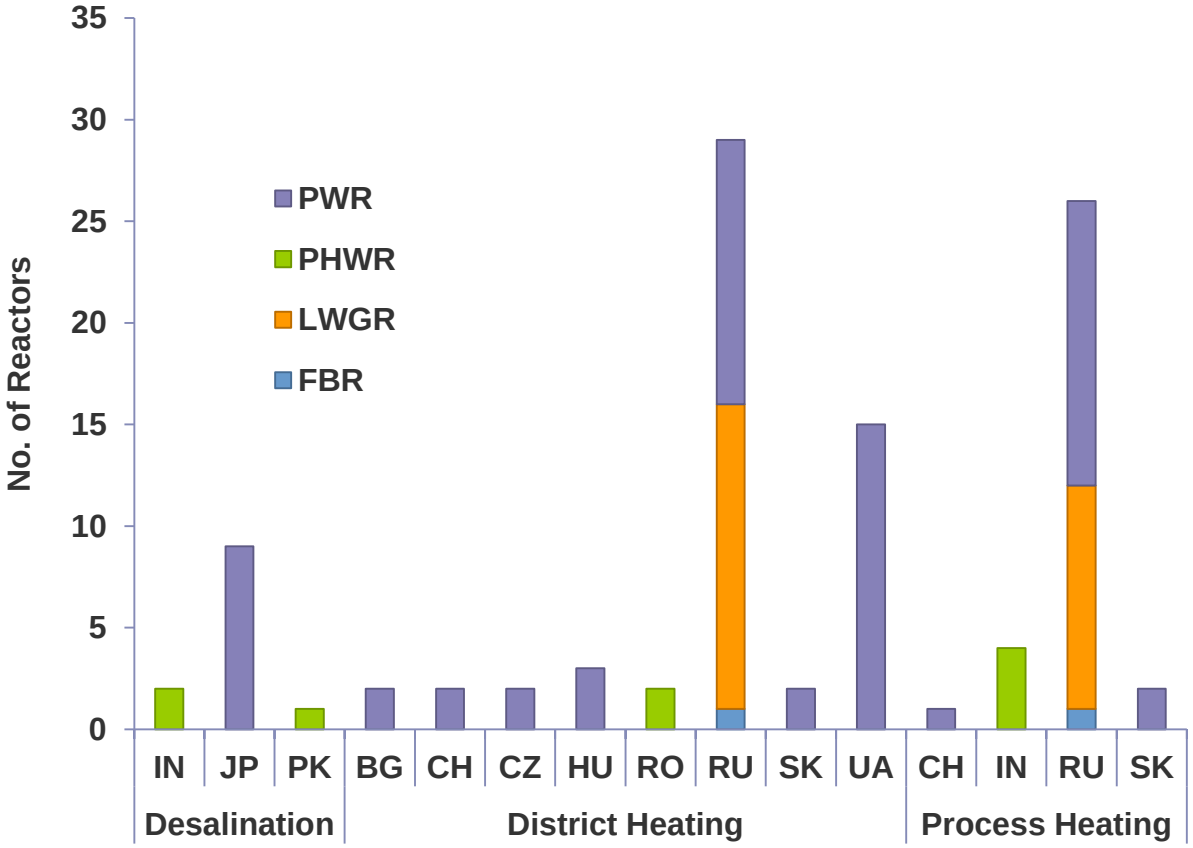
Assume: ~ 25% recovery of waste heat i.e. **re-use of 250 000 MW(th)**

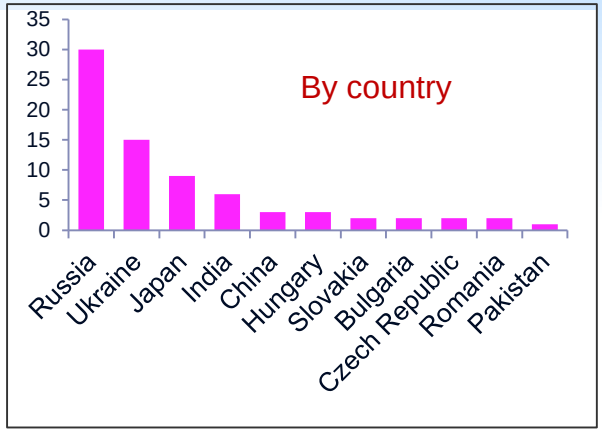
This is equivalent to daily reduction of 1 - 2 Million tonnes of CO_2 emissions

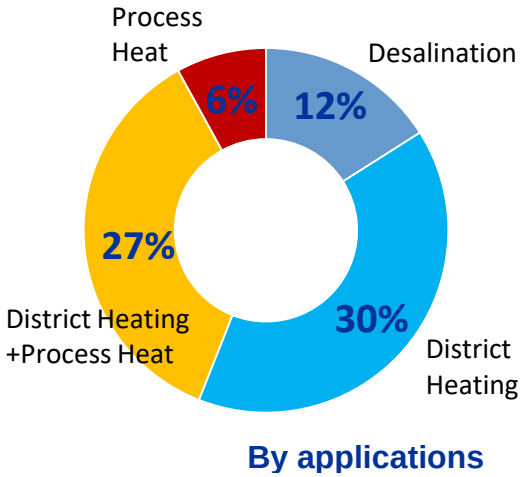
Based on the type of fossil fuel would be used to cover this thermal demand



Nuclear Power & Non-electric Applications

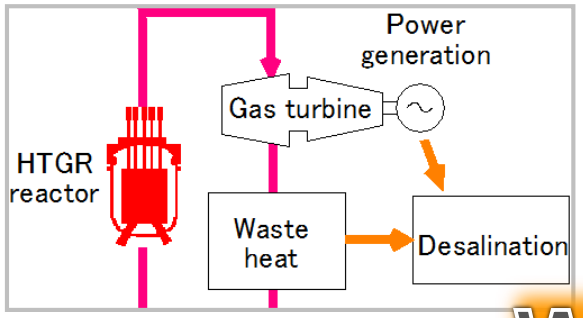






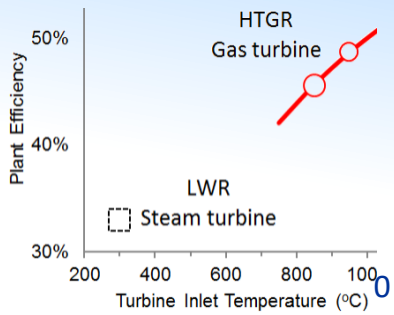
Proven technology: with **79** operative reactors and **750** reactor-years experience

Optimizing the use of nuclear reactors: Cogeneration/Multigeneration

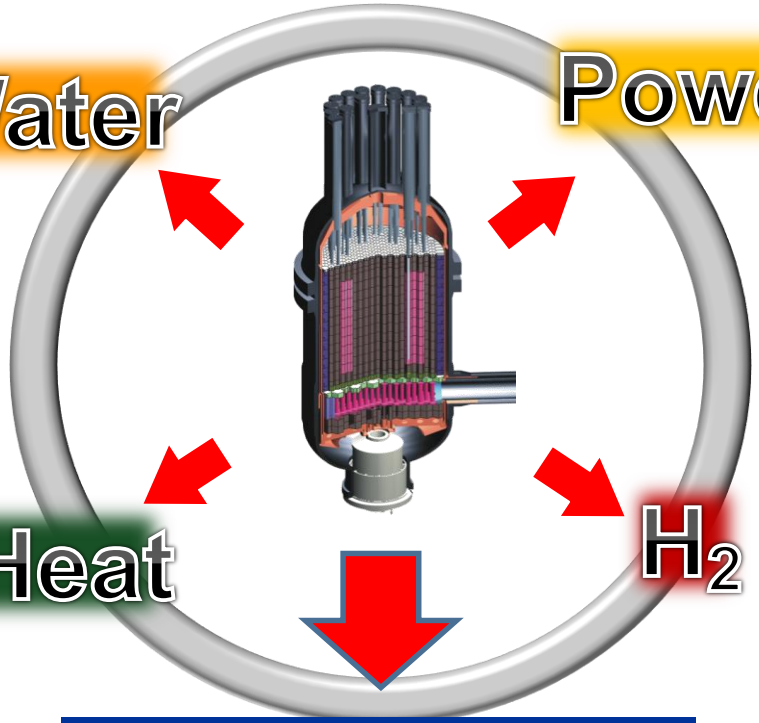


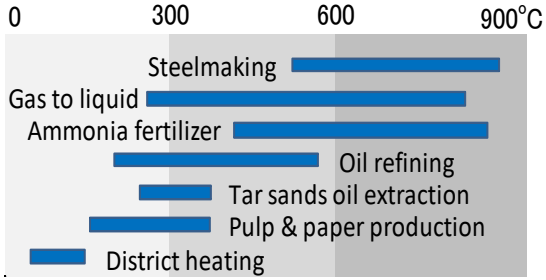
50 000 m³/day Seawater desalination

Reactor outlet coolant 850-950ºC

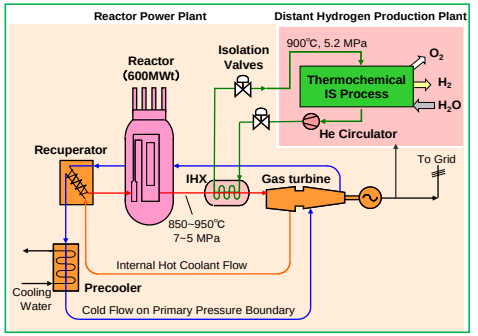


High efficiency power generation





Industrial heat applications

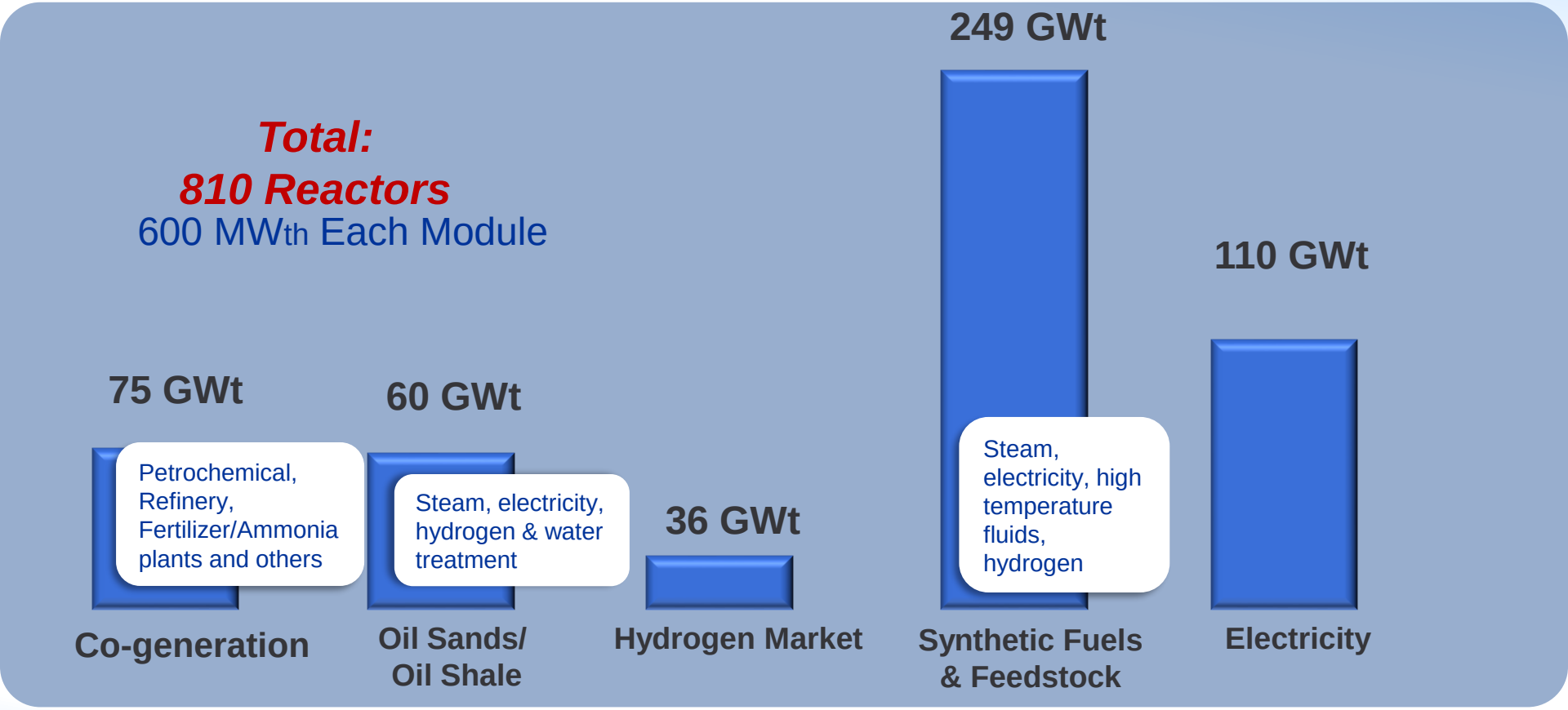


Hydrogen cogeneration

Material processing (Co-60)

Market Opportunities for HTRs in North America (future)

For petroleum industry, synthetic fuel, ammonia and hydrogen production



125 Reactor Modules* | 30 Reactor Modules | 60 Reactor modules | 415 Reactor Modules | 180 Reactor Modules

Assuming conservative market penetration.

*All module #s assume only 25% of market

Source: **Lewis Lommers,** AREVA US

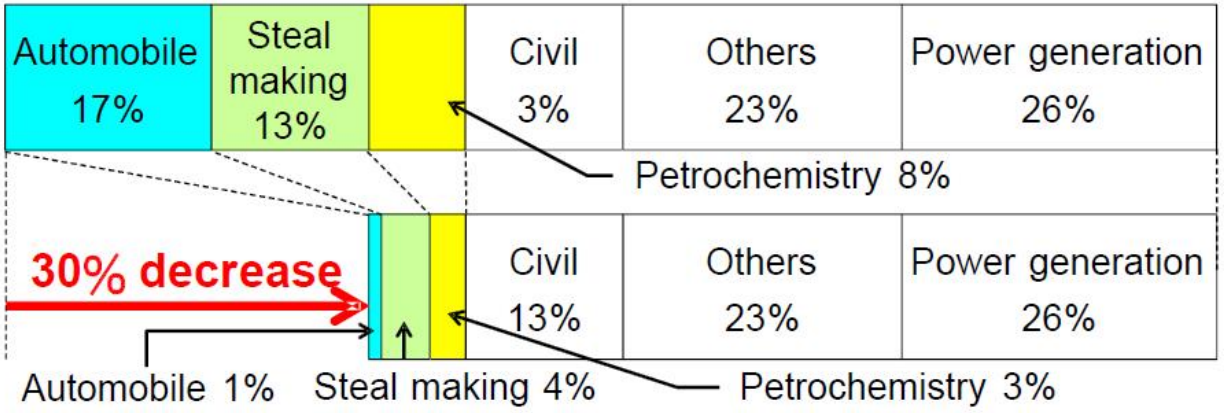
Market Opportunities for HTRs in North America (future)

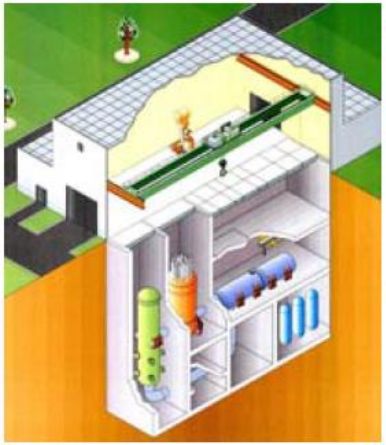
Japan Markets for HTGR (for CO2 reduction)

CO_2 emission

11.9 hundred million tone (2010)

30% Decrease with HTGR





HTGR (600 MW)

Hi. temp. heat

Steam

H_2

Fuel-cell powered automobile	Steal making with H_2 reduction	Petrochemical plant
		
H_2 (Fuel)	Hi. temp. heat, H_2 (reductant)	Hi. temp. heat, Steam
16% decrease	9% decrease	5% decrease
HTGR : 30 plants	HTGR : 20 plants	HTGR : 15 plants

1 plant : 4x 600 MWt HTGRs

Japanese Markets : 180 HTGRs (600MWt/reactor)

Cogeneration: for hydrogen production
Use of off-peak power (from currently operation NPPs)

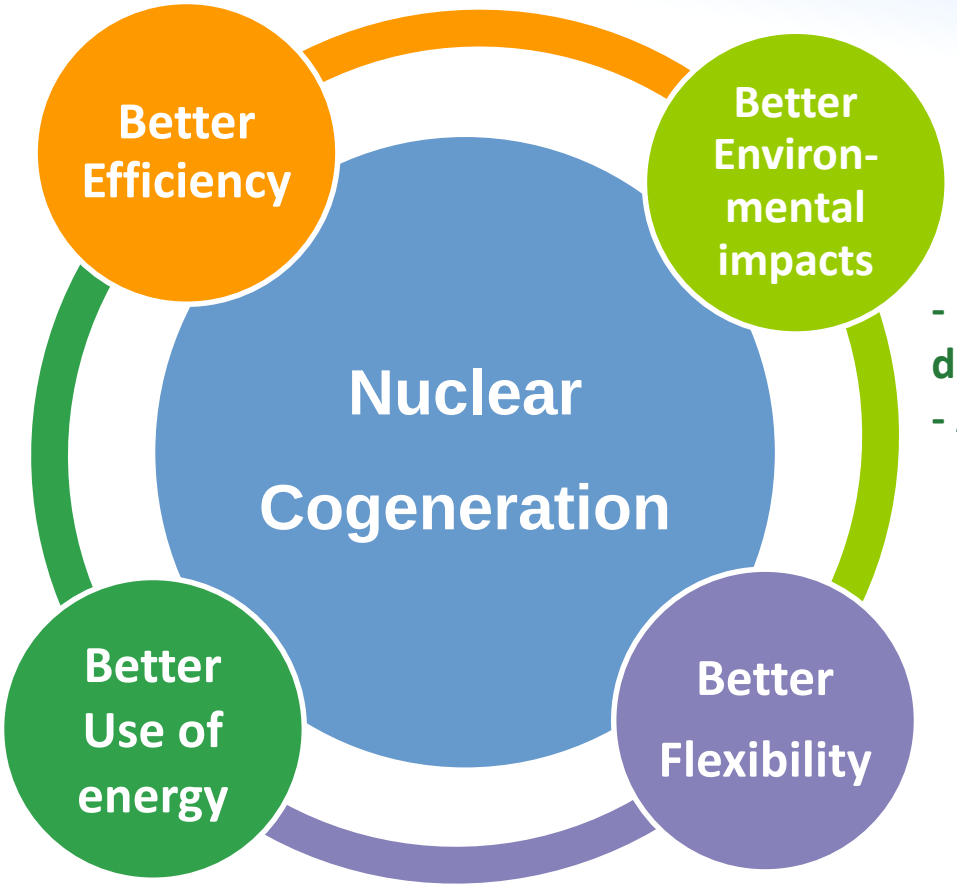
	$/kg
Conventional Electrolysis ($0.05/kW hr &> 1000 kg/day)	4.15
Dedicated nuclear HT Steam Electrolysis HTSE plant	3.23
Off-peak grid electricity ($0.05/kW hr), HTSE	2.5
Large-scale Steam Methane Reforming	2.5

First-of-a-kind Project, announced in September 2019:

- DOE selected INL & (Akron & Xcel Energy & APS) utilities to partner on Integrated Energy Systems to Pair Carbon-Free Nuclear Energy in Hybrid Applications to Produce Hydrogen.
- "The two-year project led by FirstEnergy Solutions will initially demonstrate and deploy a 1- to 3-MWe low-temperature electrolysis unit to produce commercial quantities of hydrogen. The first site, planned for 2020, is FirstEnergy Solution's Davis-Besse Nuclear Power Station near Toledo, Ohio". INL News Release

Values of Nuclear Cogeneration

- Up to 80% energy efficiency
- Open new sectors for nuclear power



- Reduce the waste heat dumped to environment,
- Additional heat sink

- Optimize energy efficiency
- Match industrial application needs at the right temperature

- In future energy planning
- In operating nuclear power plants & Grid
- In diversifying energy outputs

Challenges for Cogeneration (1)

- Public acceptance
- Disparity between characteristics of nuclear reactors & heat markets
- National position& Regulations (political will, Government commitment..etc) on cogeneration
- Availability of qualified human resources
- Selecting the most appropriate NPP (based on demand and grid capacity)

Challenges for Cogeneration (2)

- Industry trends:
  - ✓ Require small amount of heat 1-300 MWth, majority < 10 MWth,
  - ✓ Buy energy but not risk build it
  - ✓ Demonstrate newly (HTR) NPPs tailored for industry
- ✓ Economics
- Licenseability of tailored cogeneration NPPs with ensured safety
- Siting
- Business model
- Etc..

HTR=High Temperature Reactor

Typical Areas of activities

- *Info Exchange & Training Forums*
- *Coordinated Research Projects*
- *Tools development, Maintenance & upgrade*
- *Publications: Technical Reports/papers*

2019 IAEA Events on Non-Electric Applications of Nuclear Energy

February 11-14 (Prague, Czech Rep.)	Regional Workshop on Non-Electric Nuclear Applications: Options, Technology Readiness and Available IAEA Toolkits
April 08 - 10 (Vienna)	Technical Meeting on the Role of Nuclear Hydrogen Production in a Low Carbon Economy
July 22 – 24 (Vienna)	Technical Meeting on Specific Considerations for the Deployment of Nuclear Cogeneration Projects
September 02 – 04 (Vienna)	Technical Meeting on Assessing the Deployment of Small and Medium Sized or Modular Reactors and High Temperature Reactors for Cogeneration Applications
October 12 – 16 (Trieste, Italy)	ICTP-IAEA Workshop on Physics and Technology of Innovative High Temperature Nuclear Energy Systems
18 September 2019 Vienna	**General Conference Side Event on:** Reactor Technology Innovation to Support Integration of Renewable Energy Systems and Nuclear Installations

Info Exchange Forums (2020)

○ Technical Meeting on Assessing Technologies that Enable Nuclear Power to Produce Hydrogen	22-24 June	**Vienna**
○ Technical Meeting on Potential Schemes for Licensing Nuclear Cogeneration Plants	1-3 September	**Vienna**
○ Second Research Coordination Meeting on Assessing Technical and Economic Aspects of Nuclear Hydrogen Production for Near-Term Deployment	1-3 April	**Vienna**

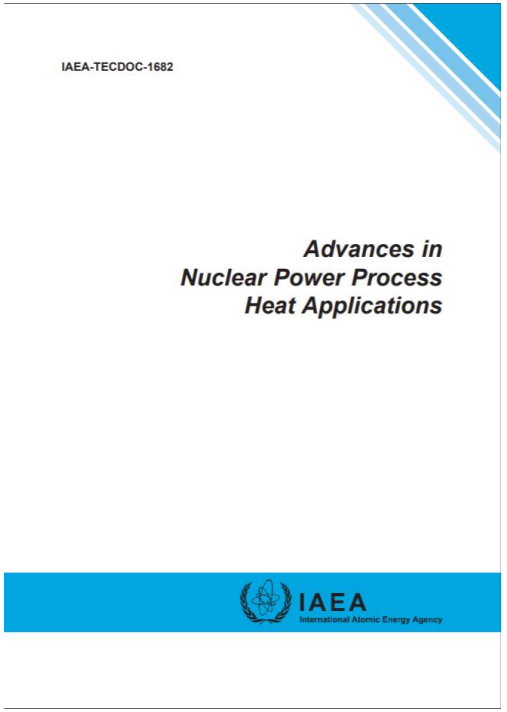
IAEA Coordinated Research Projects (CRP)

Title: Advances in Nuclear Process Heat Applications

Duration: 2007-2009

Objective:

- Investigate the prospects of using waste heat generated in High Temperature Reactors .
- Evaluate the potential of all advanced reactor designs for process heat applications.



Results: published in 2012 as an IAEA-TECDOC-1682

IAEA Coordinated Research Projects (CRP)

Title: Examining the Techno-Economics of Nuclear Hydrogen Production and Benchmark Analysis of the IAEA HEEP Software

Duration: 2011-2015

Objective:

- Examine aspects of nuclear hydrogen production
- Validate HEEP through benchmarking exercises
- Promote international collaboration among IAEA Member States.

Meetings: 17-18 October 2013
17-19 December 2013
16-18 Dec 2014
15-17 Dec 2015 Final

Participants: Algeria, Argentina, Canada, China, Germany, India, Indonesia, USA/Japan, Rep. of Korea, USA/Rep. of Korea

IAEA Coordinated Research Projects (CRP)

Title:

Assessing Technical and Economic Aspects of Nuclear Hydrogen Production for Near-Term Deployment (2018-2020)

Objectives:

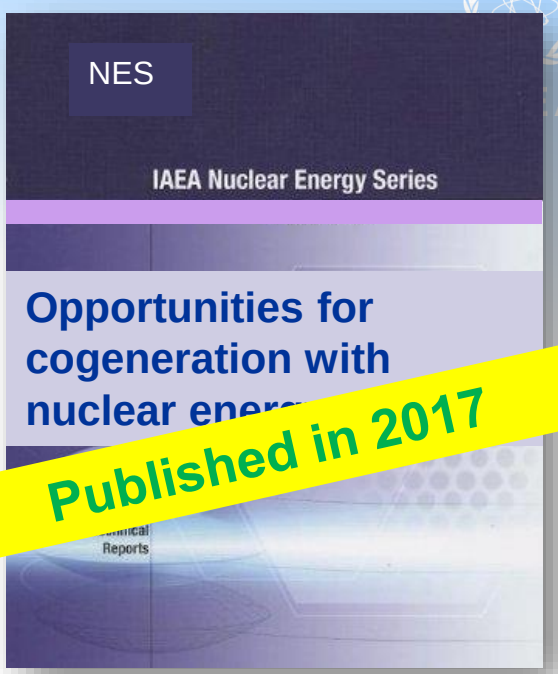
- **Assess gained experience from R&D on nuclear hydrogen production in MSs.**
- **Assess potential near-term deployment of nuclear hydrogen production.**

Algeria	Argentina	China	India	Japan
Greece	Rep. of Korea	Russia	Saudi Arabia	Turkey
				USA

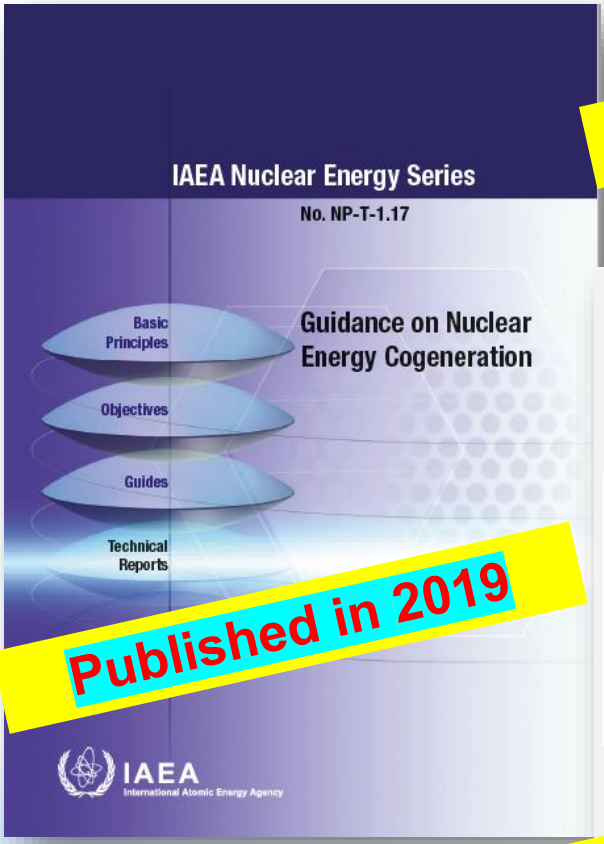
1st RCM Meeting: 03-05 December 2018

IAEA Publications

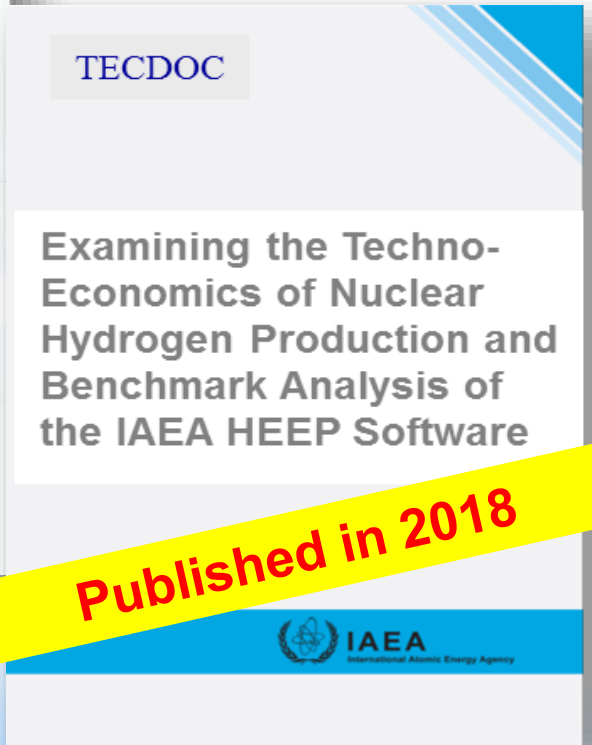
Published in 2017



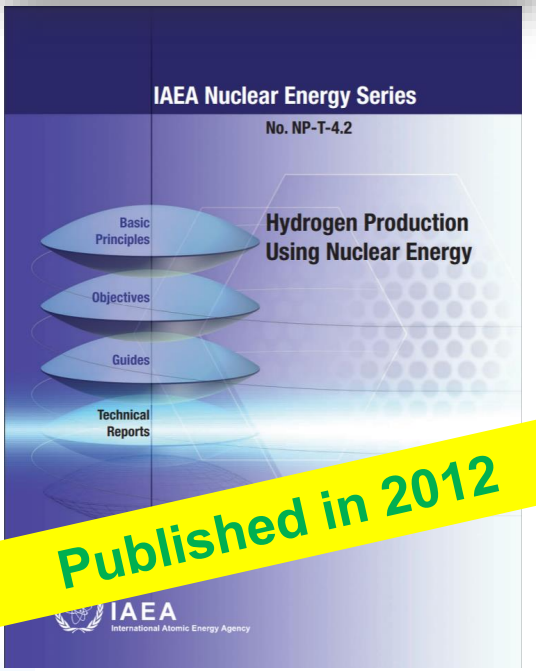
Published in 2017



Published in 2019



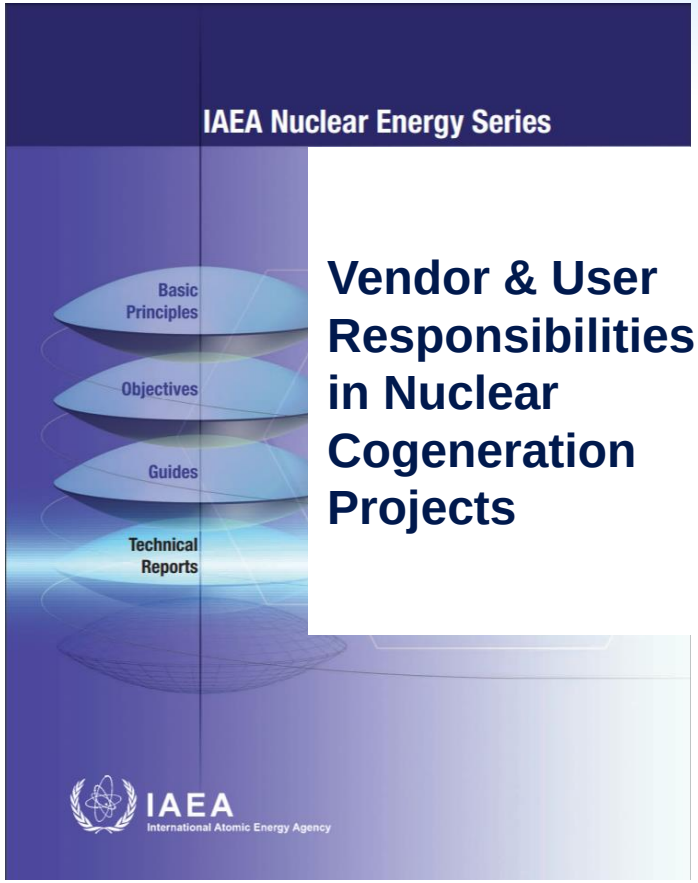
Published in 2018



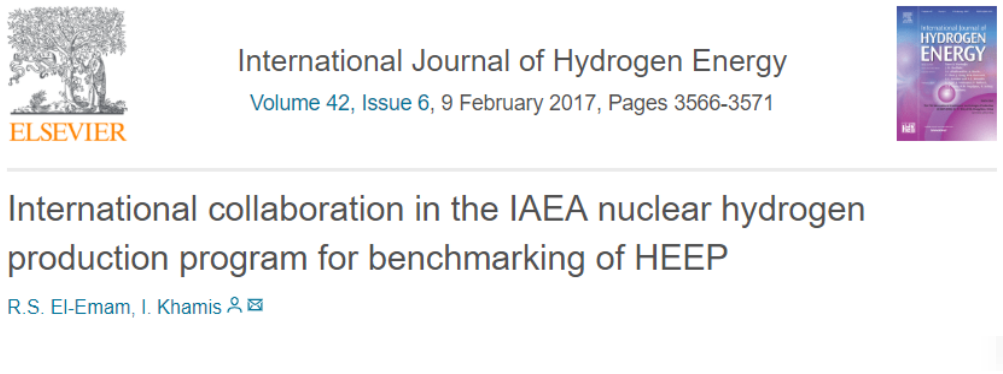
Published in 2012

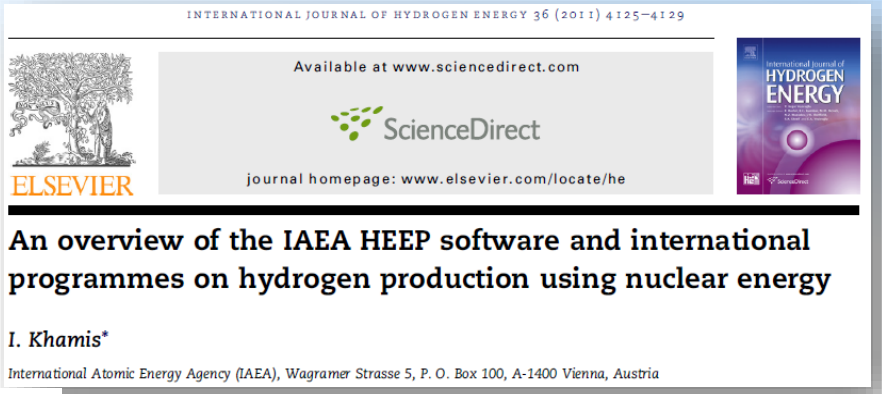
Forthcoming Publication!

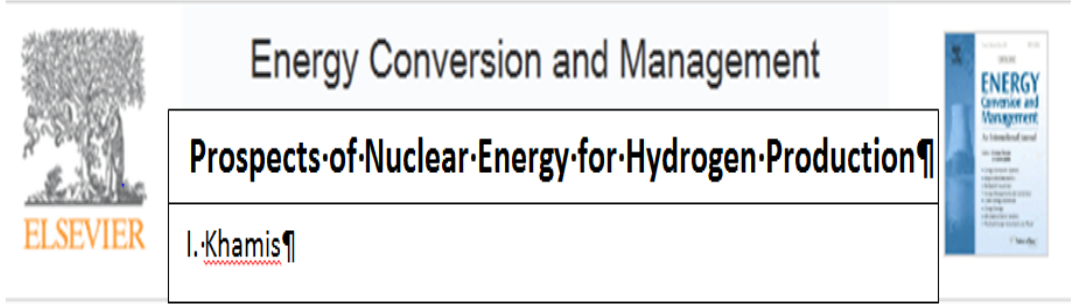
The objective of this document is to establish a common understanding of users' requirements and the terms under which vendors can supply suitable reactor designs and desalination technologies; address the common challenges and concerns related to the design and operation of nuclear cogeneration plants, with focus on nuclear desalination for near-term deployment; and identify a roadmap for implementation of such projects.

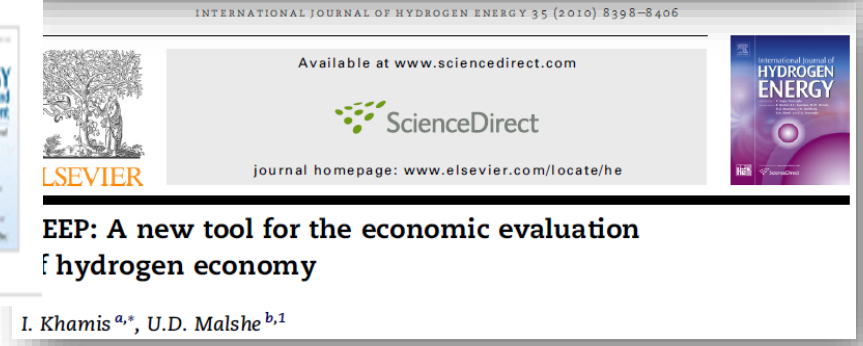


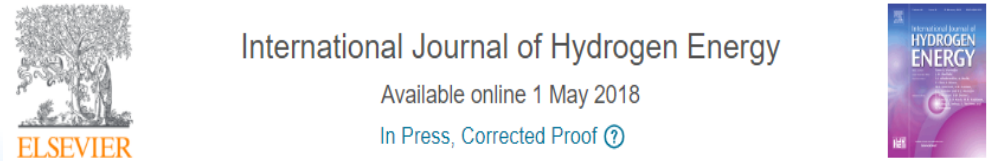
Publications











Benchmarking of Economic Models for Nuclear Hydrogen Production

Ramakant Sadhankar, Lauralee Sopczak, Donald Ryland (CNL) , Rami El-Emam, Ibrahim Khamis (IAEA)

ANS Sponsored International Conference

2018 Pacific Basin Nuclear Conference

Advancing and Sustaining Nuclear Energy

TETHYS

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Home » 7th International Symposium on Energy

7th International Symposium on Energy

This event is the Seventh International Symposium on Energy; it combines previous two symposia: ISECM - working on small scales (ECM4, ECM5); ISECM – towards a big picture (ECM3, ECM6) into one. The conference involves multiple disciplines in technology, science, management and policy-making related to energy challenges. The topics include both fossil fuels and many different forms of renewable energy. Also, it addresses issues related to energy policy and economy, energy efficiency, safety, and environment. The purpose is to gain a complete view of energy challenges and solutions among these different disciplines and from a global perspective.

Event

Title: 7th International Symp
Location: Manchester, UK
Date: August 13 - 17, 2017 UTC+01:00
Website: http://energy7.nsc
Technology Type: Marine Energy general

1st Latin American sdewes Conference RIO DE JANEIRO 2018

1ST LATIN AMERICAN CONFERENCE ON SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS

January 28-31, 2018

IEEES-9 9th International Exergy, Energy and Environment Symposium

HOME CONFERENCE COMMITTEE SUBMISSION GUIDE NEWS

9TH INTERNATIONAL EXERGY, ENERGY AND ENVIRONMENT SYMPOSIUM

14 - 17 MAY 2017 / SPLIT, CROATIA / IEEES-9

IDA 2017 World Congress on Water Reuse and Desalination

Conference

APS March Meeting Los Angeles

12-16 Mar 2018 (notify new dates)

Los Angeles, USA

Interested

About Reviews

APS physics

ANS Winter Meeting & Expo

2017

Exhibitor and Sponsorship Prospectus

Generations in Collaboration: Building for Tomorrow

ANS Annual Meeting

2018

Official Program

DRIVING THE FUTURE OF NUCLEAR TECHNOLOGY

ADVANCED ENERGY MATERIALS CONGRESS

25 - 28 MARCH 2018, STOCKHOLM, SWEDEN


THE 7th WORLD HYDROGEN TECHNOLOGY CONVENTION together with CZECH HYDROGEN DAYS 2017 9 - 12 JULY 2017
PRAGUE 2017, THE CZECH REPUBLIC
"FUTURE MIGHT BE CLOSER
WHTC
PRAGUE 2017

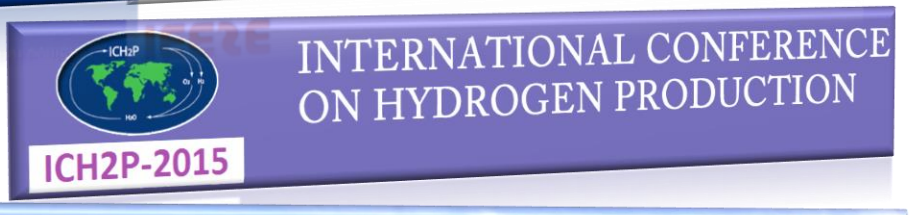

13th INTERNATIONAL CONFERENCE
ON CLEAN ENERGY (ICCE 2014)
June 8-12, 2014 /Istanbul - Turkey
WOW Istanbul Hotels & Convention Center

IAEA


ANS
PBNC 2018
Sep 30-Oct 4, 2018 | San Francisco, CA
Pacific Basin Nuclear Conference | Sponsored International Conference

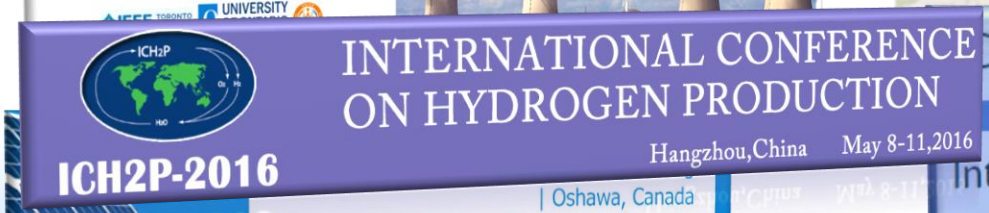

IEESE
7th INTERNATIONAL EGE ENERGY
SYMPOSIUM & EXHIBITION


INTERNATIONAL CONFERENCE ON
HYDROGEN PRODUCTION
ICH2P-12
June 24-27, 2012
Seoul, Republic of Korea


INTERNATIONAL CONFERENCE
ON HYDROGEN PRODUCTION
ICH2P-2015


SEGE 2017
August 14-17, 2017 | UOIT, Oshawa, Canada


IEEE SEGE 2016
August 21-24, 2016 | Oshawa, Canada
2016 The 4th IEEE International conference
on Smart Energy Grid Engineering


INTERNATIONAL CONFERENCE
ON HYDROGEN PRODUCTION
Hangzhou,China May 8-11,2016
ICH2P-2016


CH2P-2014
International Conference on Hydrogen Production
02 - 05 February 2014 / Japan, Fukuoka


| Oshawa, Canada
IEEE SEGE 2014
SEGE
Smart Energy Grid Engineering

Conclusions

Nuclear energy (using Large or SMRs) can:

- Penetrate major energy sectors now served by fossil fuels like:
  - seawater desalination
  - district heating
  - Hydrogen production
  - heat for industrial processes

Nuclear cogeneration is feasible and economically viable:

- Provide near-term, greenhouse gas free, energy for all energy intensive process

IAEA
International Atomic Energy Agency

Thank you!