Nuclear R&D – the future of nuclear energy

Aalto Energy Forum 2021

Eero Vesaoja, 11 November 2021

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Agenda

- Introduction
- Overview to nuclear energy now
- Areas in nuclear research and development
- SMR’s, basics and topical
- Fortum and SMR’s

Introduction

- Eero Vesaoja
  - Role: Senior Manager, Strategy and Development at Fortum Co-owned Assets and Nuclear Services, Generation
  - Responsibilities: Nuclear R&D, Nuclear Strategy, Interest promotion

- M.Sc Engineering, Aalto University, Finland, 2012
  - Major: Automation and Control Engineering
  - Minor: Information Technology, Mathematics

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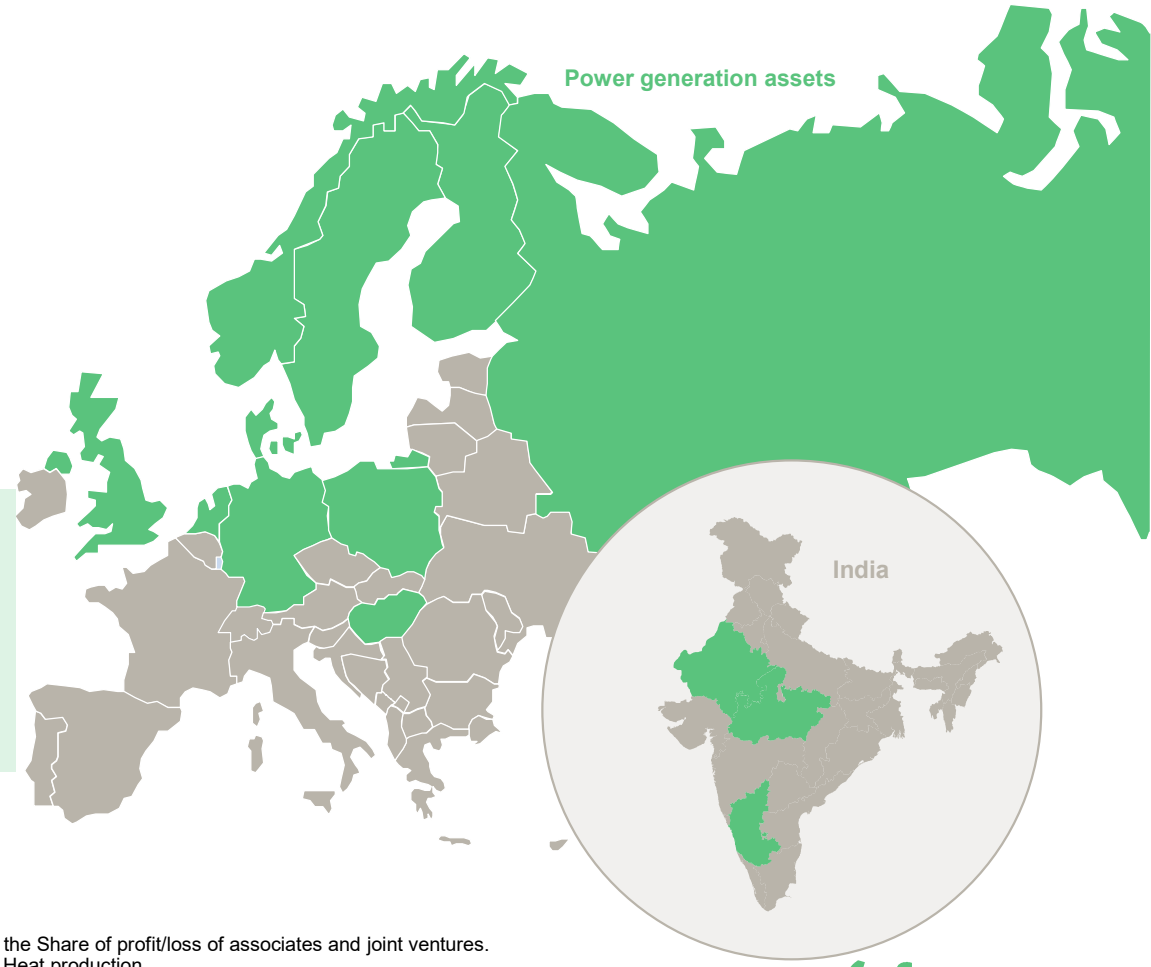
Fortum in brief

Key figures 2020[1]	
Sales	EUR 49.0 bn
Comparable EBITDA	EUR 2.4 bn
Total assets	EUR 57.8 bn
Personnel	19,933

Main businesses[1]	Sales (€)	Volume[2]	Capacity
Power	20.8 bn	142 TWh	50.3 GW
Gas	22.4 bn	~370 TWh	7.6 bcm[3]
Heat	0.8 bn	30 TWh	19.5 GW



1) Until 31 of March 2020 Uniper's contribution to the income statement was recognised in the Share of profit/loss of associates and joint ventures.
2) For Power - Power generation, for Gas - Long-term gas supply contracts and for Heat – Heat production
3) Gas storage capacity, billion cubic meters

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Strong position to drive the energy transition in Europe

3rd largest
power generator
in Europe and Russia

3rd largest
CO_2-free power
generator in Europe

3rd largest
nuclear generator
in Europe

4th largest
gas storage operator
in Europe

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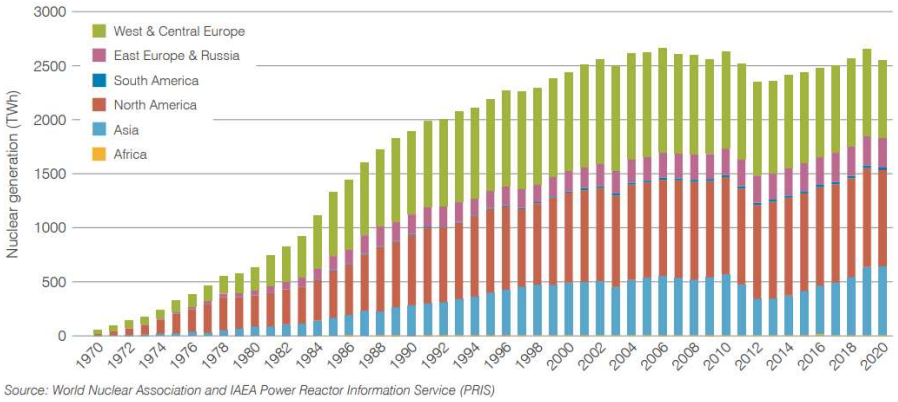
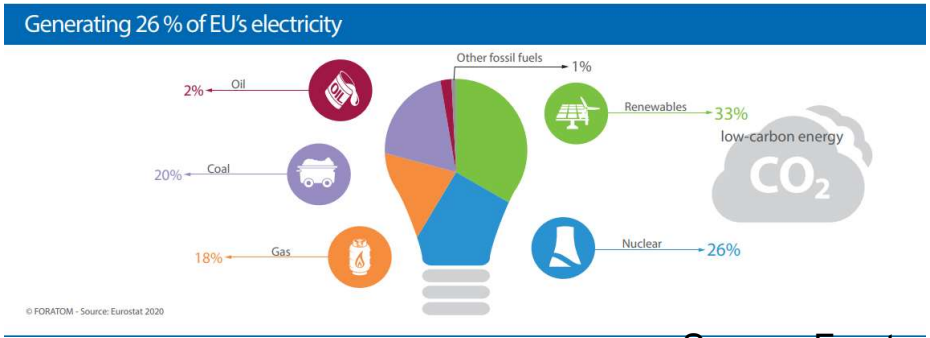
Overview to nuclear energy now

- From the 1970s to 2000s growth from ~0TWh/a to ~2500TWh/a (total generation in Finland 66TWh)
- Since 2000 flat development
- About 10% of global generation, second largest low-carbon source after hydropower
- Contributes about ¼ of the electricity in the EU, slightly under half of the low-carbon production
- One third of Finnish power generation
- 4 reactors operational in Finland, 1 on commissioning and 1 applying construction licence



Source: World Nuclear Association



Source: Foratom

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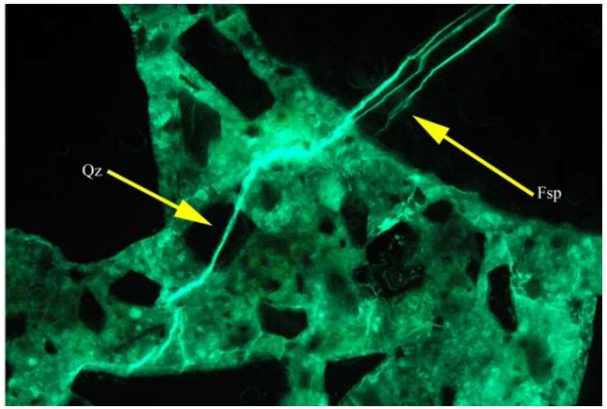
Areas in nuclear research and development, operating plants

Fuel and reactor

- New and improved types of nuclear fuel
- Reactor physics analysis

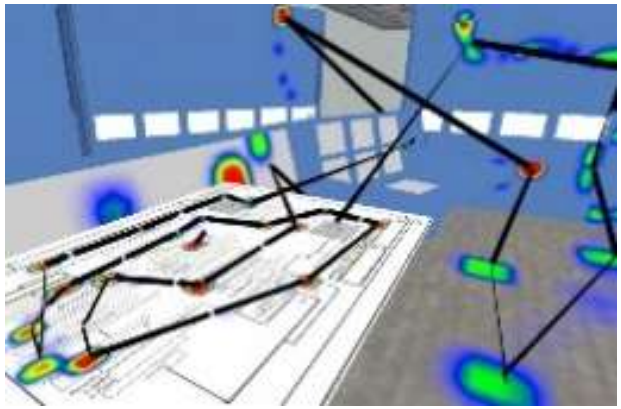
Long term operation

- Thermal and radiation aging of metals, concrete and polymers
- Efficient ways to refurbish



Digitalization

- Digital twins, advanced modelling
- Utilization of AI, machine learning



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Areas in nuclear research and development, safety related

Nuclear safety

- Systemic approach to safety
- Human factors
- Physics of severe accidents

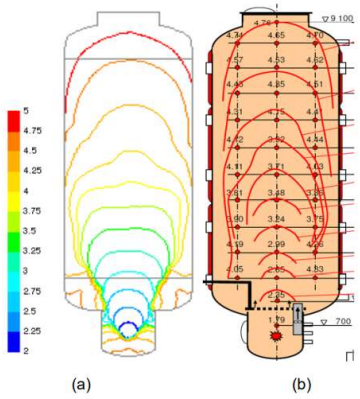


Figure 3. Computational (a) and experimental (b) first flame arrival time on a vertical cross-section for Test HD-3 with 9.01 vol-% for H_2.

Source: VTT, SAFIR2022 ANSA project

Waste management

- Physics, chemistry, geology and biology of spent nuclear fuel final disposal

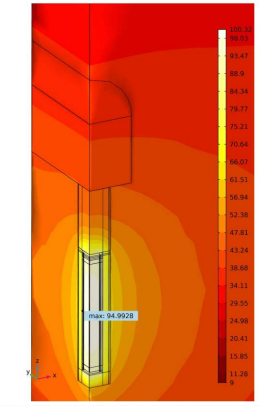
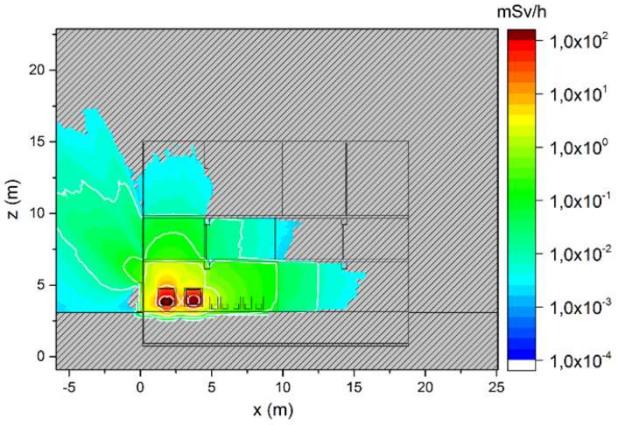


Figure 7. Temperature field in the disposal area at the hottest time point in °C.

Source: VTT, KYT2022 BROCTIO project

Radiation safety

- Modelling of radiation and shielding
- Fission product transport



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Areas in nuclear research and development, SMR's

- Small Modular Reactors, an umbrella term
  - From 1MW to almost Loviisa NPP sized reactors at hundreds of MW
  - From mature LWR technology to experimental fast neutron spectrum designs, AMRs (advanced modular reactors)
  - From small start-ups innovating to national nuclear suppliers building
  - One factoid about SMRs rarely covers all
- Unifying factors
  - Smaller size (still industrial facilities!) -> simplified design
  - Simplified designs -> Easier licensing
  - Standardized designs -> Faster learning by doing
  - Factory fabricated -> Less project risk at the site
  - Modular construction -> Shorter deployment projects
  - ...all leading to more competitive projects?

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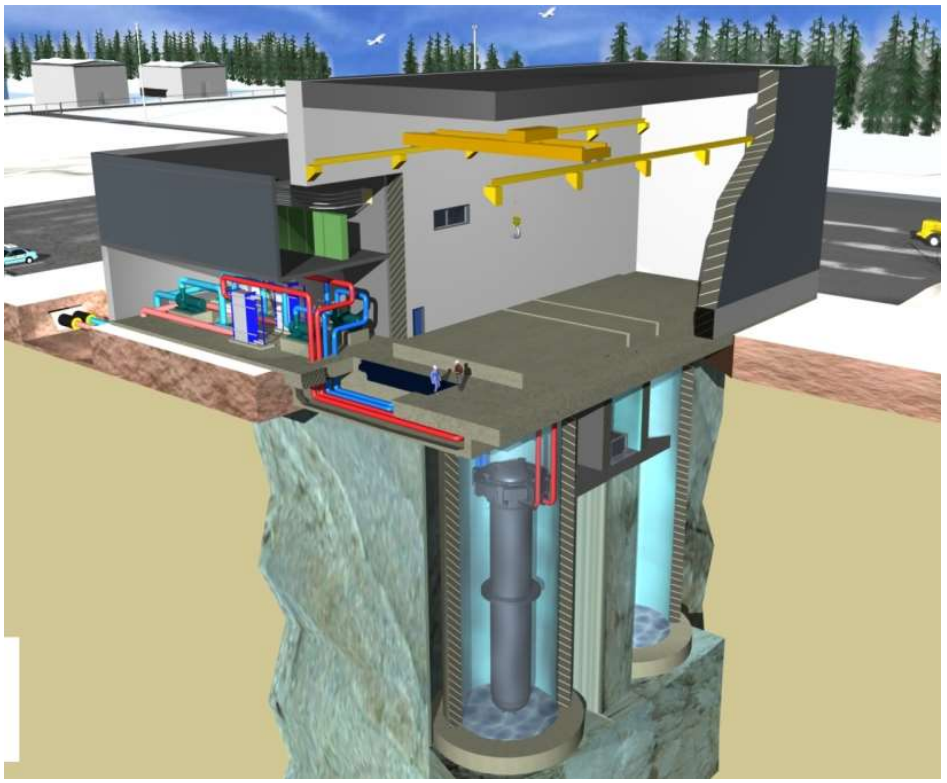
Areas in nuclear research and development, novel products

- Heating reactors
  - Providing low temperature heat for district heating, sea water desalination or industry
  - Simplifies design
  - Improves efficiency compared to electricity by a factor of three

- Hydrogen cogeneration
  - Supporting the grid during low RES production
  - Producing hydrogen during low electricity prices
  - Ideally utilizing both heat and electricity from the NPP



Source: VTT

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European SMR projects get funded

Rolls-Royce secures funding for SMR deployment

09 November 2021

Share

British engineering group Rolls-Royce has announced the establishment of a new business - Rolls-Royce SMR Limited - for the deployment and commercialisation of its small modular reactor (SMR) technology. The announcement follows the securing of GBP210 million (USD285 million) in funding from the UK government, matched by more than GBP250 million of private investment.

A rendering of a plant based on the Rolls-Royce SMR (Image: Rolls-Royce)

Source: World Nuclear News

France / Macron Announces Plans For First SMR And Green Hydrogen From Nuclear Plants By 2030

By David Dalton
12 October 2021

President says Europe 'will never have' enough renewable energy capacity

Mr Macron said France's nuclear plants are a major asset for producing clean hydrogen. Courtesy Elysée Palace.

Source: Nucnet

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In the east, new technologies and use cases for SMR's

China's HTR-PM reactor achieves first criticality

13 September 2021

Share

The first of the two high-temperature gas-cooled reactors of the demonstration HTR-PM plant at Shidaowan, in China's Shandong province, attained a sustained chain reaction for the first time yesterday. The reactor is scheduled to be connected to the electricity grid before the end of this year.

Workers in the HTR-PM control room bring the first reactor to first criticality (Image: China Huaneng)

Source: World Nuclear News

Akademik Lomonosov / Russian Port Town To Switch To District Heating Powered By Floating Nuclear Plant

By David Dalton
6 April 2021

The Akademik Lomonosov floating nuclear power station in the Russian port town of Pevek. Courtesy Rosatom.

Source: Nucnet

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Interest from private capital

Bill Gates and Warren Buffett to build new kind of nuclear reactor in Wyoming

The project in Wyoming – the country's top coal-producing state – is a small advanced reactor with salt-based storage that could boost output

Warren Buffett's Pacific Corp and Bill Gates's TerraPower have joined forces on a plan to launch an advanced Natrium nuclear reactor in Wyoming. Photograph: Jason Lee/Reuters

Source: The Guardian

Markets

Danish Nuclear Startup Taps Billionaire for Asian Reactor

By Jesper Starn +Get Alerts

25. marraskuuta 2020 klo 7.00 UTC+2 *Updated on 25. marraskuuta 2020 klo 20.11 UTC+2*

- Maritime reactor developer Seaborg raised $24 million
- Denmark's fashion billionaire Povlsen among investors

Seaborg is planning three variations of its molten fluoride salt reactors *Image Credit: Seaborg Technology*

Source: Bloomberg

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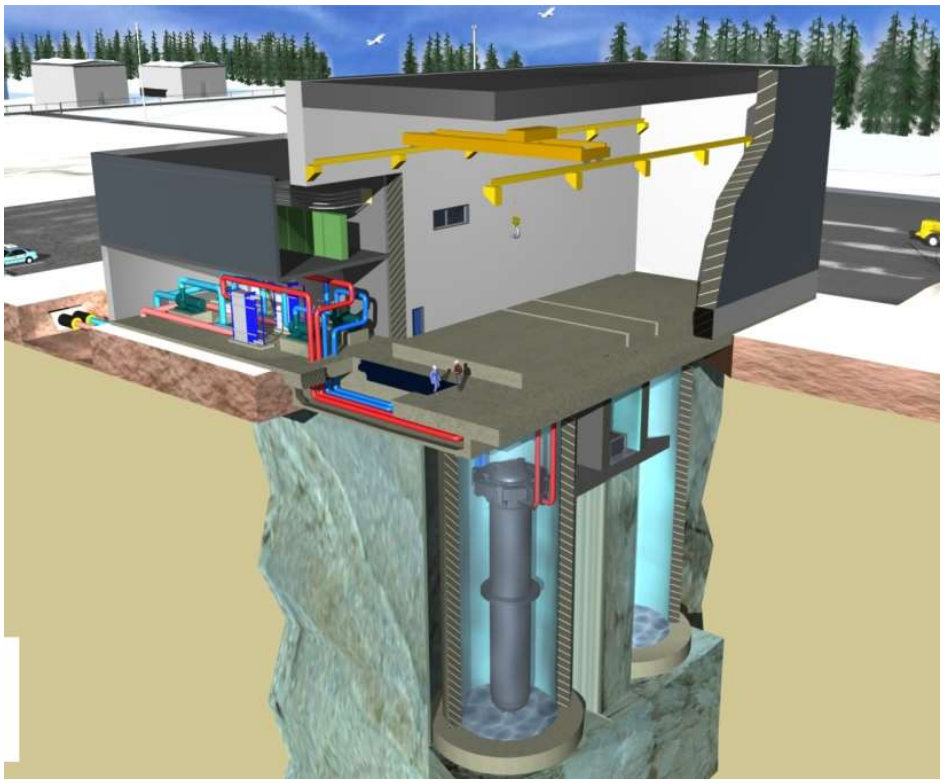
Fortum on SMR's

- Development of Nuclear Heat as a Service
  - Part of the Business Finland funded ecoSMR-project
  - Municipal heating companies as customers
  - Finding / codeveloping the suitable technology
  - Investigating the needed legal structures
  - Interviewing possible customers on their expectations
  - Advising on the necessary legislation and regulation updates



Source: VTT

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Fortum on SMR's

- Business development for cogeneration SMR's
  - Background:
    - Decarbonization of the industry and mobility will require huge amount of CO_2-free electricity, heat and hydrogen
  - Actions:
    - Business case building and evaluation
    - Project and design evaluation
    - Site evaluation
    - Commenting legislation and regulation development
  - The future:
    - Can we build sufficiently good business cases to invest in SMR's?

Strengths:
CO_2-free
Security of supply
Dispatchable
Suitable size

Weaknesses:
Higher LCOE than RES
Projects still unproven
BEUR level CAPEX

Opportunities:
Utilization of heat x3
Early on learning curve
High barrier of entry

Threats:
Regulatory risk
Public acceptance

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Thank you for your attention!

Questions and comments?

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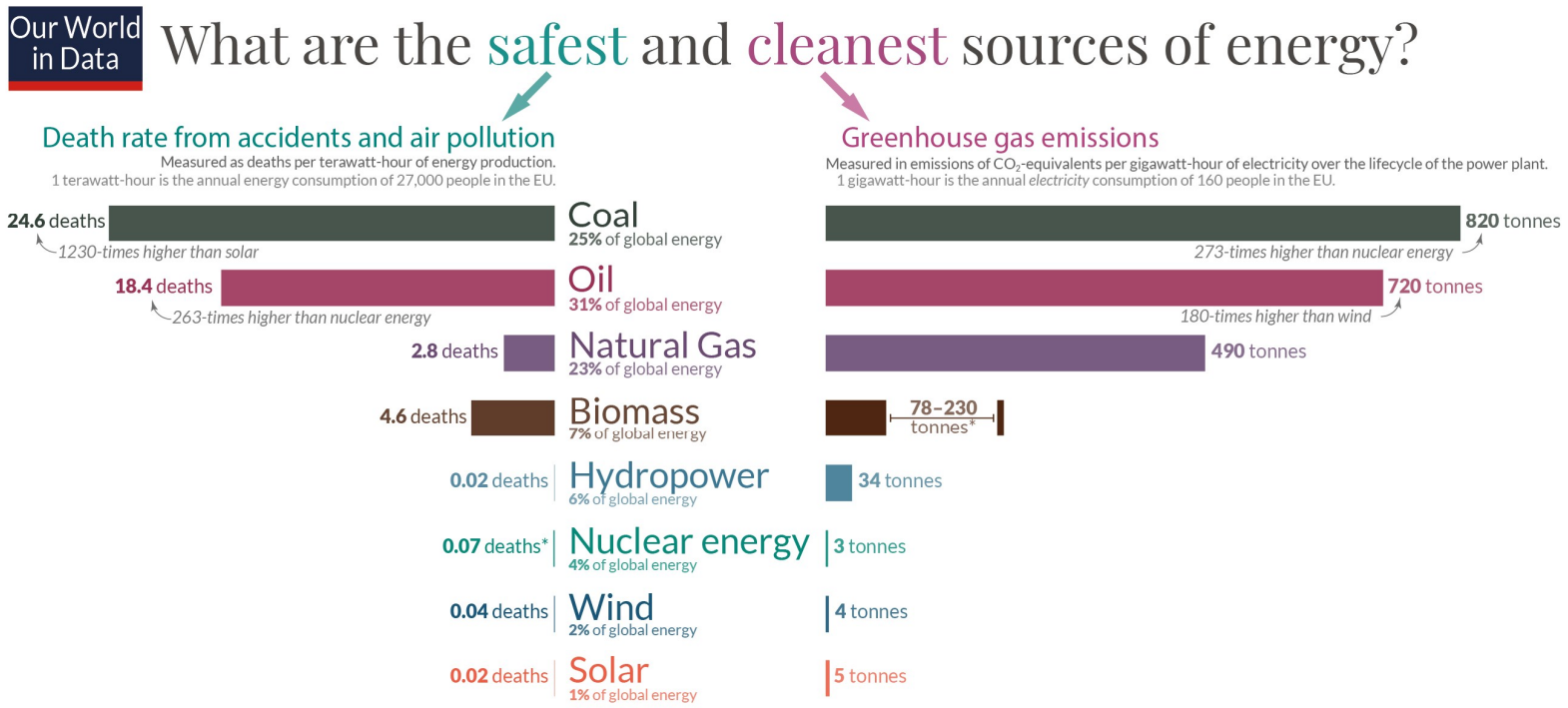
Backup

Safety and sustainability



*Life-cycle emissions from biomass vary significantly depending on fuel (e.g. crop resides vs. forestry) and the treatment of biogenic sources.
*The death rate for nuclear energy includes deaths from the Fukushima and Chernobyl disasters as well as the deaths from occupational accidents (largely mining and milling).
Energy shares refer to 2019 and are shown in primary energy substitution equivalents to correct for inefficiencies of fossil fuel combustion. Traditional biomass is taken into account.
Data sources: Death rates from Markandya & Wilkinson (2007) in *The Lancet*, and Sovacool et al. (2016) in *Journal of Cleaner Production*;
Greenhouse gas emission factors from IPCC AR5 (2014) and Pehl et al. (2017) in *Nature*; Energy shares from BP (2019) and Smil (2017).
OurWorldinData.org – Research and data to make progress against the world's largest problems.

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