Heat Decarbonization in Industrial Sectors

Atsushi Kurosawa

kurosawa@iae.or.jp

The Institute of Applied Energy

High temperature reactors and industrial heat application
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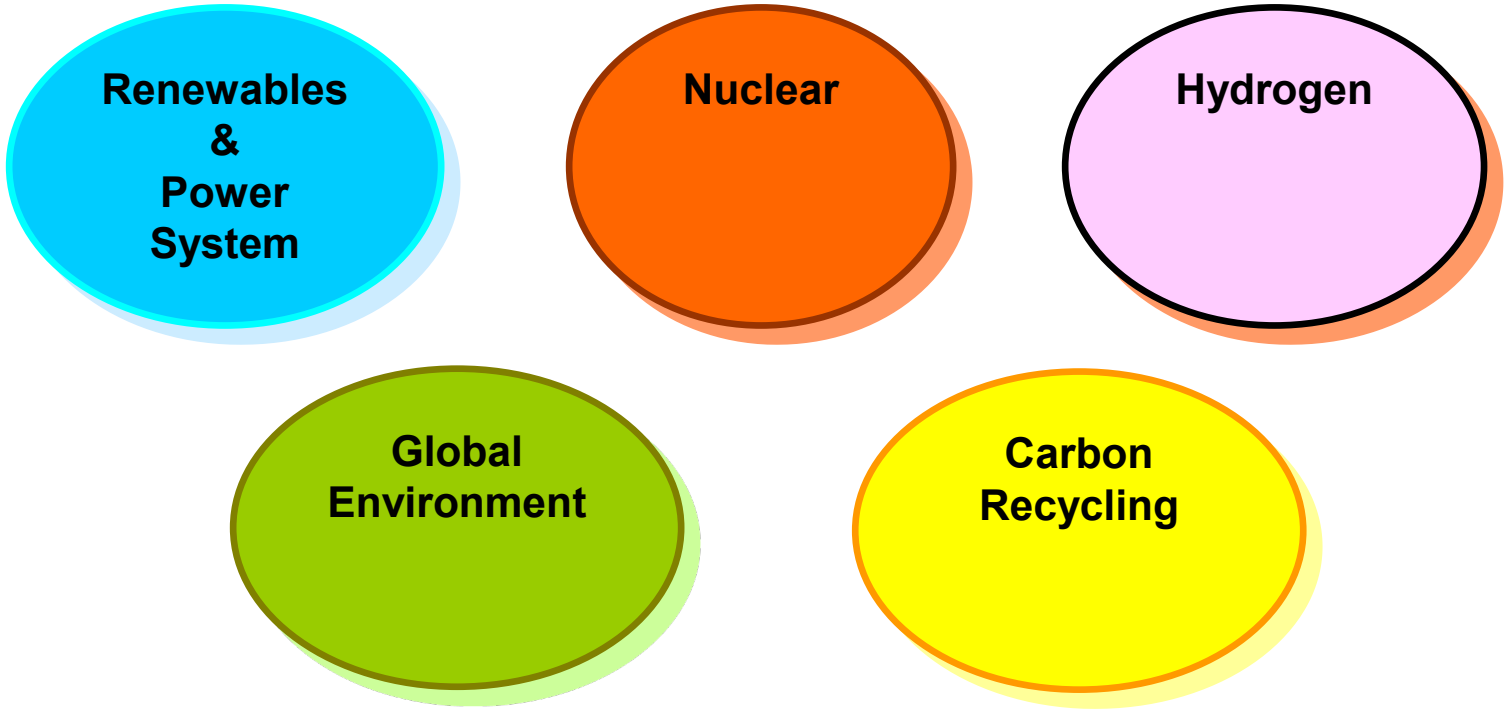
IAE overview

- Since 1978
- Non-profit organization
- Expertise - energy technology assessment
- Energy areas
- Visit http://www.iae.or.jp for further information



Nuclear Power Research Activities in IAE

☐ Fukushima Daiichi nuclear power plants accident analysis

- Computational analysis of accident progressions and fission products behaviors by SAMPSON code (NEA projects)
  - ✓ BSAF（2012-2018）Benchmark Study of the Accident at the Fukushima Daiichi NPS
  - ✓ ARC-F（2019-2021）Analysis of Information from Reactor Building and Containment Vessel and Water Sampling in Fukushima Daiichi NPS

☐ Decommissioning of existing nuclear power plants

- Improvement of processes, technique and institutions
- Teaching materials and systems for human resource development, and examination of the training
- Optimization of radioactive waste treatment and disposal
- Utilization of digital technologies

☐ Nuclear power operations and designs

- Technical development support on further improved safety
- Enabling technologies for advanced nuclear reactors (incl. SMR, HTGR and offshore floating)
- Improvement of safety systems (incl. investigation of safety systems in other countries and support on international safety standards development)
- Nuclear power role under deregulated electric power sector and renewable energies expansion

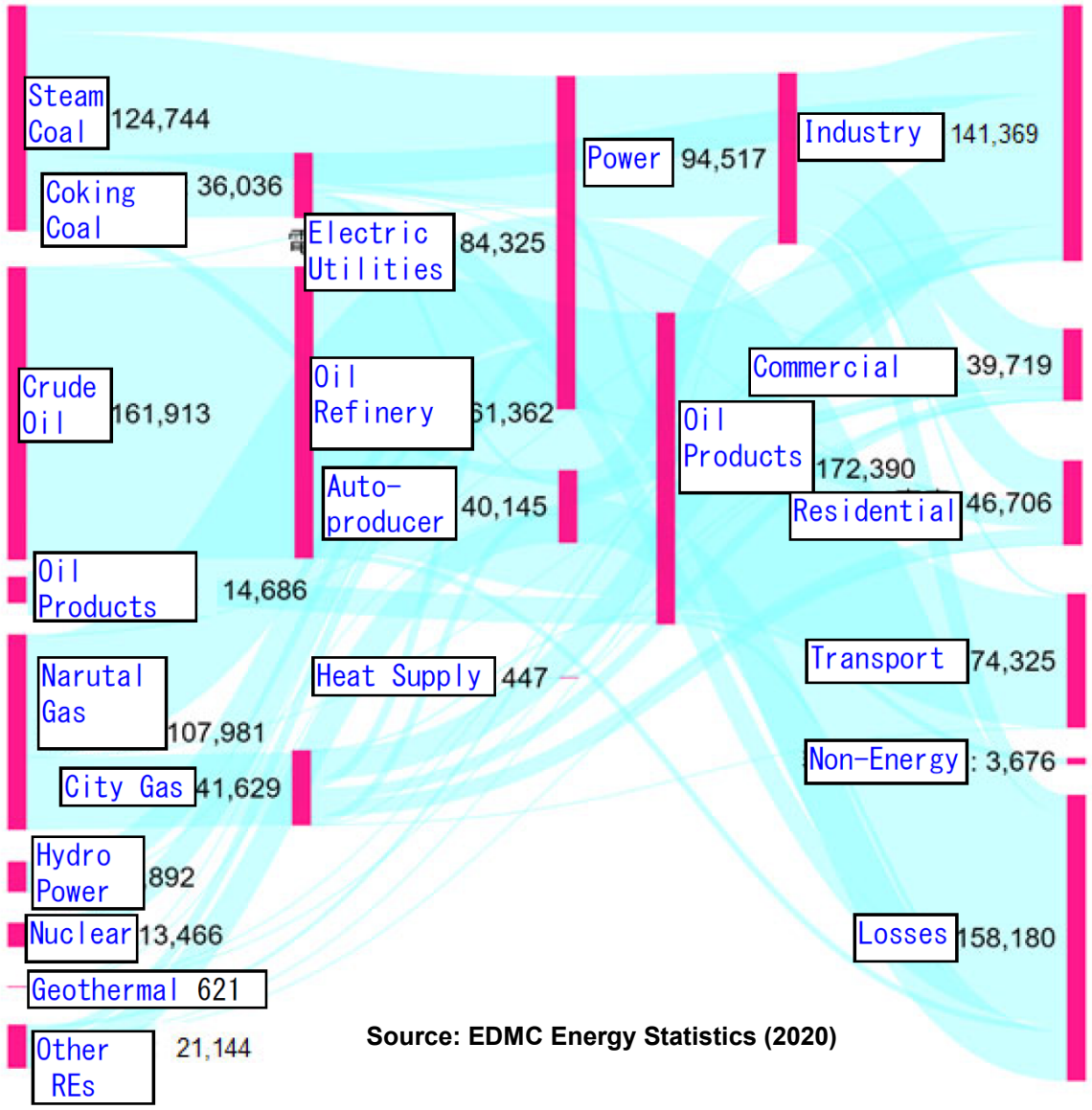
☐ Others

- Public surveys on energy including nuclear power
- Computational fluid dynamics (CFD) analysis application to other energy areas

Decarbonization Challenge

- Toward net-zero emissions
  - Low dependence on fossil resources
  - Renewable energy integration in energy supply
  - Decarbonization of non-power demand (heat, transport)

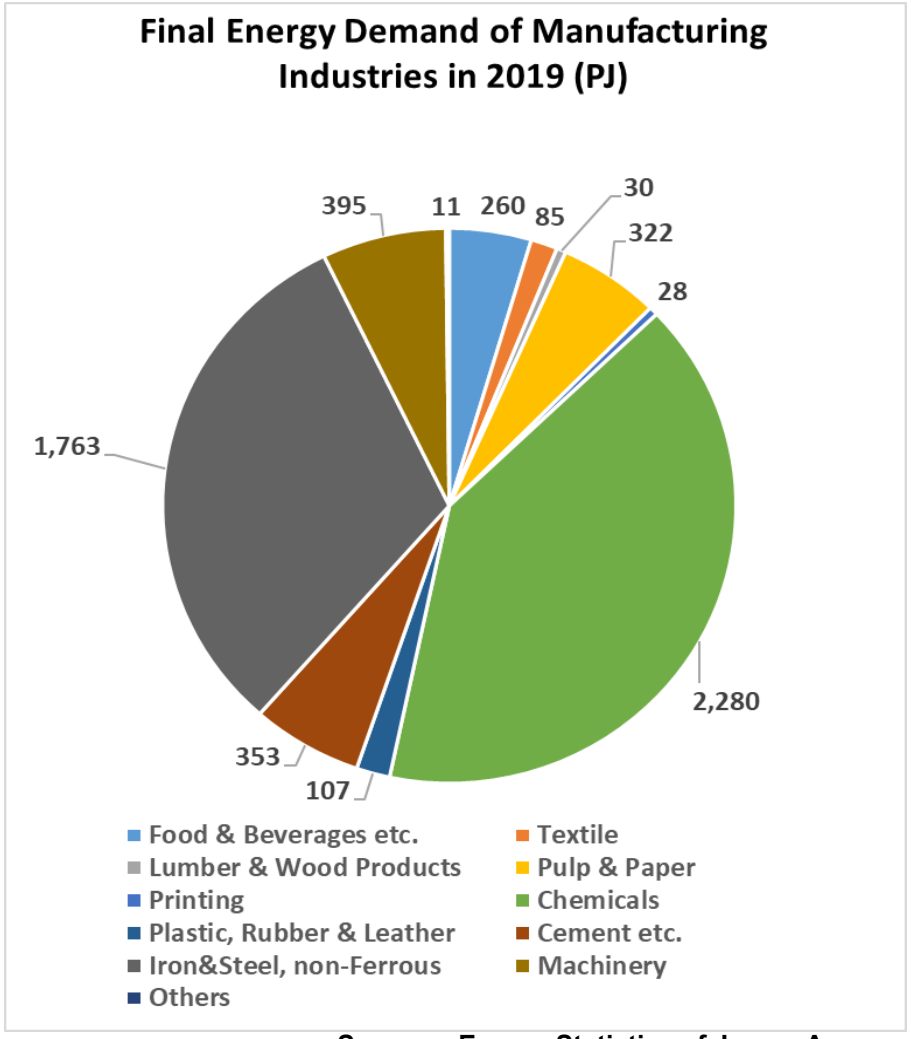
Energy Flow of Japan (2018, 10^{10}kcal)

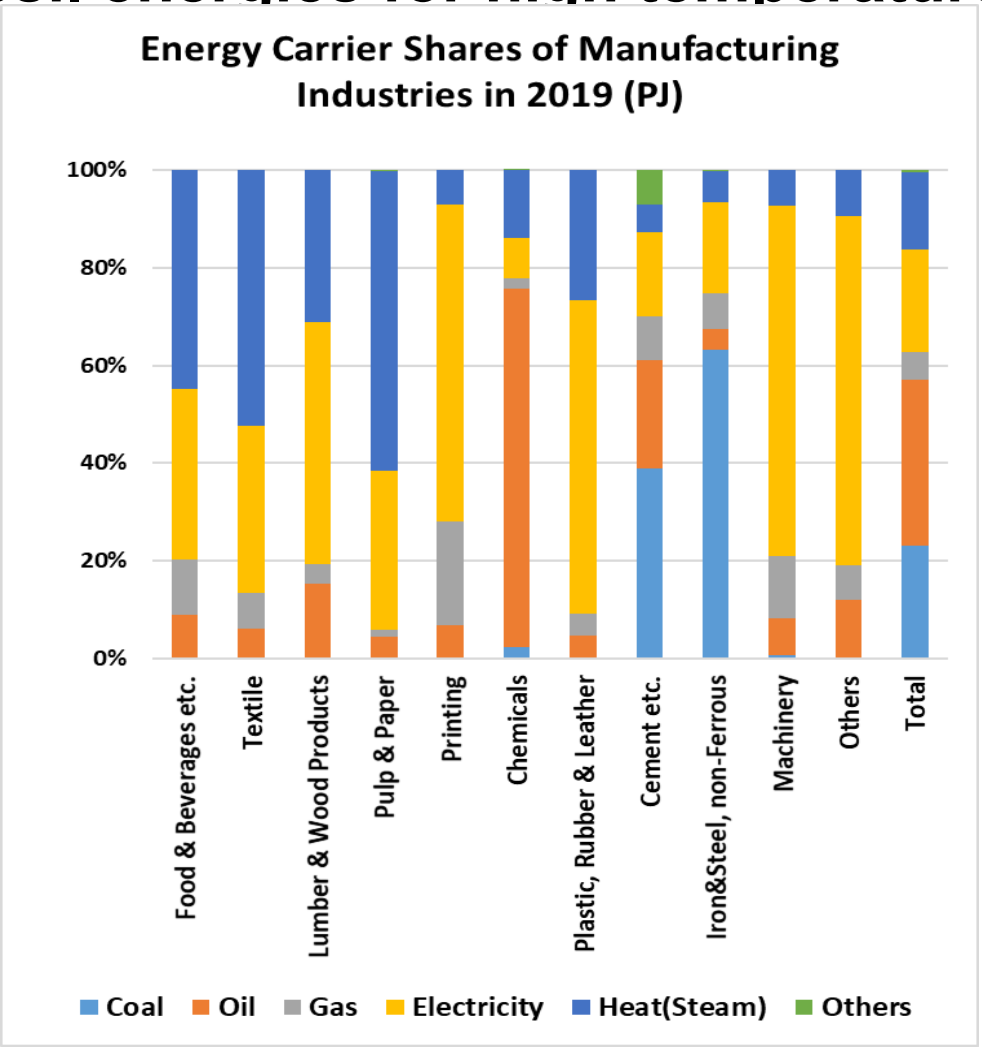


Source: EDMC Energy Statistics (2020)

Manufacturing Industry Energy Demand in Japan

- Chemicals and metals – Big 2
- Steam for low temperature, fossil energies for high temperature





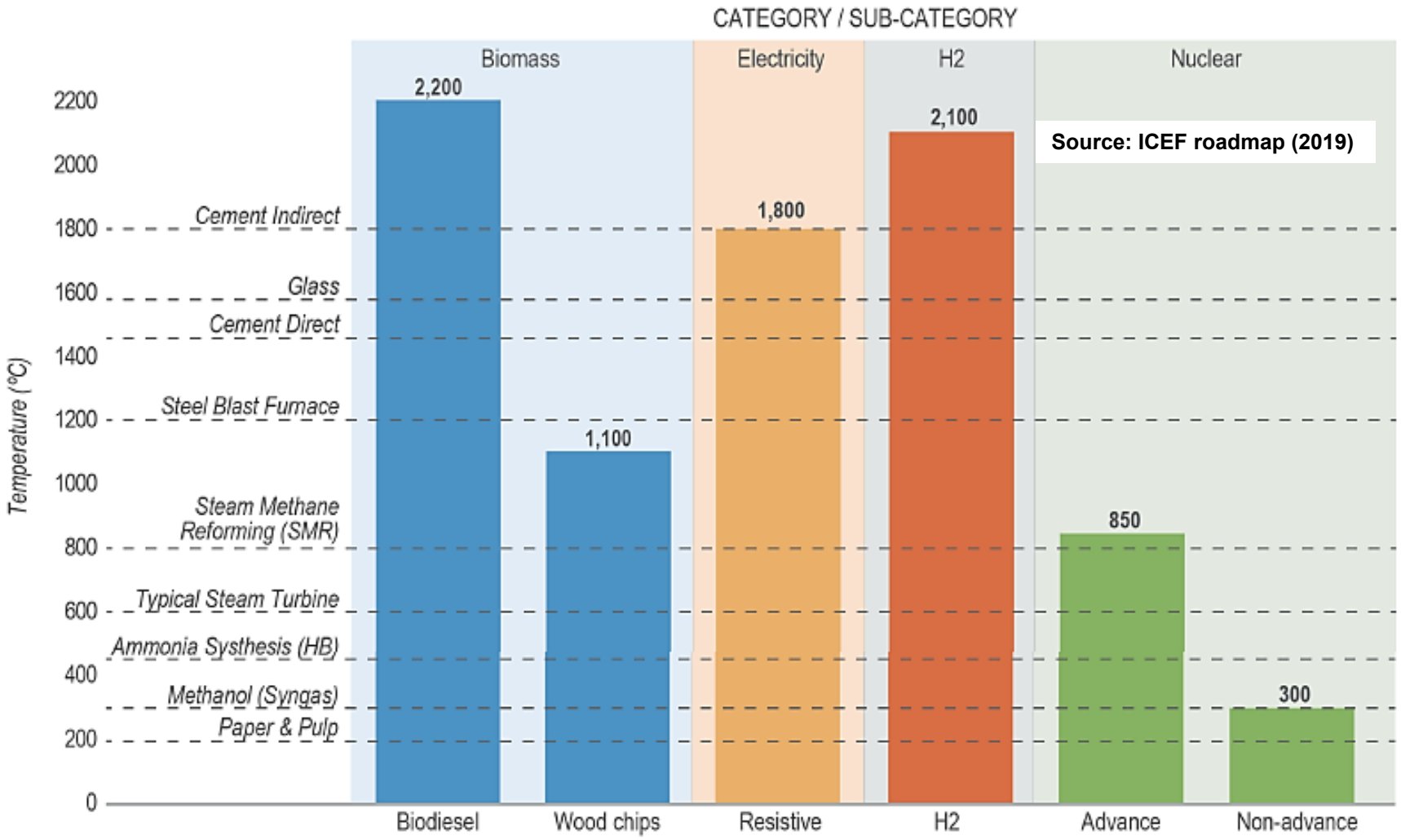
Sources: Energy Statistics of Japan, Agency of Natural Resources and Energy (2021)

Industrial Decarbonization

- Typical energy intensive and hard-to-abate sector (e.g. iron & steel, cement, chemicals)
- Fossil resources
  - High temperature heat source
  - Feedstocks (e.g. reducing agent and/or carbon source)
- Around 30% of energy related CO2 emissions from industries and processes
- Options
  - Energy efficiency (incl. heat recovery)
  - Electrification
  - Non-power zero emission energy source (e.g. hydrogen)
  - CO2 capture utilization and storage

Low CO_2 Heat Source Replacement (ICEF Roadmap)

- Biomass, electricity, hydrogen and nuclear
- Process heat and temperature range



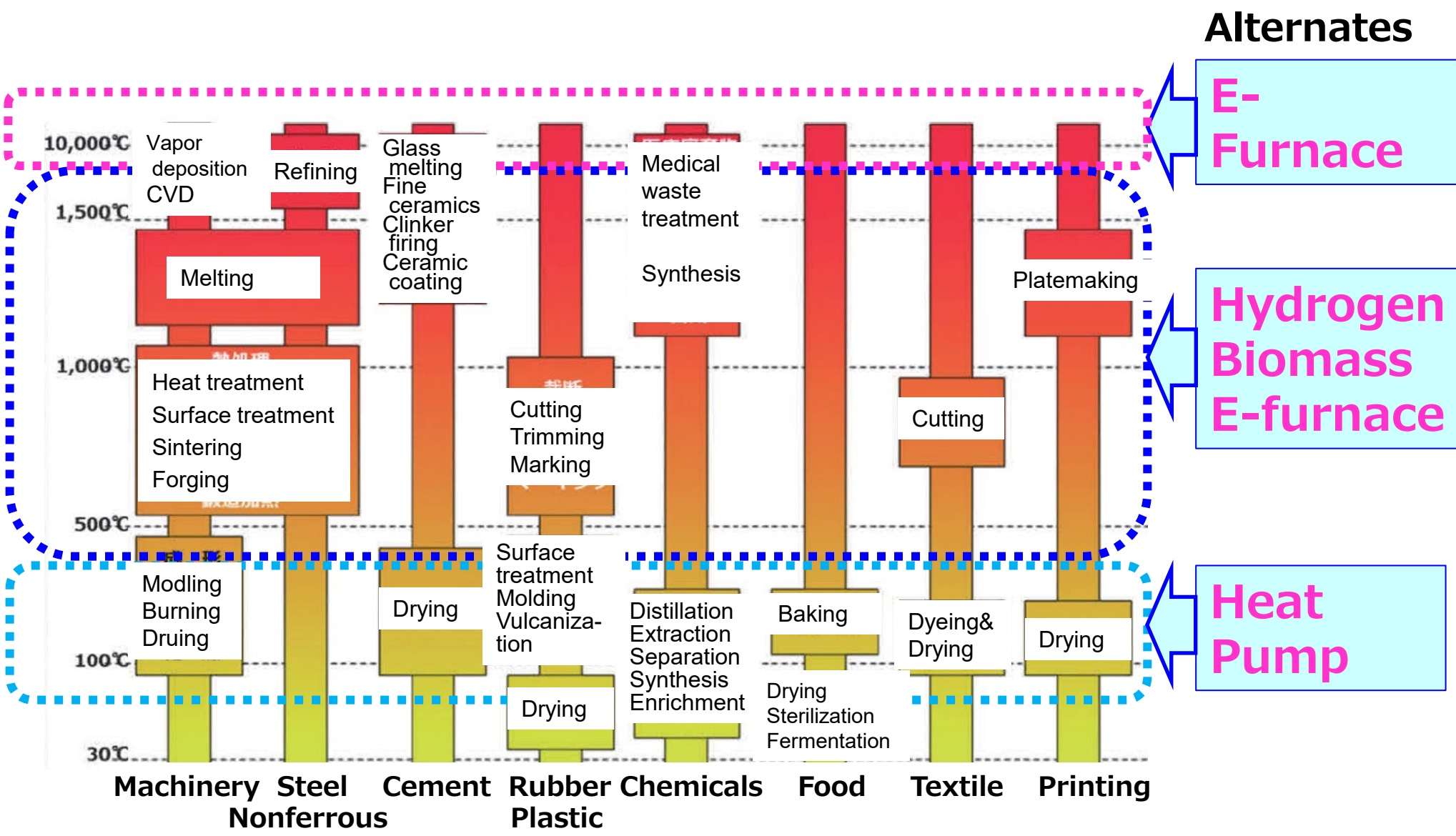
Decarbonization Potentials and Technology Readiness (ARENA)

- Non-ferrous, iron&steel, oil&gas, chemical, cement etc. in Australia
- Hydrogen and electrification

Source: Renewable energy options for industrial process heat (ARENA, 2019)

	Sector	Total fossil heat use in PJ/year	Opportunity potential: ST - 0 to 5 yrs potential; MT - 5 to 10 yrs potential; LT- 10 to 20+ yrs	Key process	Key renewable technologies: Bioenergy	Geothermal	Heat pump	Other electric	Solar thermal	Hydrogen	Comments
Non-ferrous	Alumina and other non-ferrous	169	ST 9 MT 67 LT 93	Alumina digestion, calcination			✓ ✓ ✓		✓ ✓ ✓	 ✓	Low temperature portion is accessible in medium term if barriers overcome. High temperature processes need R&D and global demand for zero emissions product
Iron & Steel	Iron and steel	94	ST 0 MT 5 LT 89	Iron ore reduction, steel production	✓			 ✓		 ✓	Needs global demand for zero emissions products, will require major investment in new plants
Oil & Gas	Oil and gas extraction	87	ST 4 MT 18 LT 65	CO2 scrubbing regeneration, steam			 ✓		 ✓	 ✓	If drives are electrified, low temperature heat can be addressed by other techs. In LT, linked to future of transport fuels
Oil refinery	Petroleum refining	65	ST 3 MT 13 LT 49	Distillation, hydrogen use	 ✓		 ✓	 ✓	 ✓	 ✓	Some MT opportunities at medium temperatures. LT linked to future of transport fuels
Chemicals	Ammonia and other chemicals	42	ST MT 8 LT 34	Steam reforming of methane, steam					✓	 ✓	Needs global demand for zero emissions products, could be first segment to adopt renewable hydrogen as energy input.
	Food and beverage	37	ST 7 MT 19 LT 11	Hot water, frying, steam, baking	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	 ✓	Low temperatures first, all RE technologies have a role
Cement	Cement, lime products	34	ST 10 MT 16 LT 8	Calcining, roasting	✓ ✓					 ✓	Strong existing use of bio waste can grow. Long term future of the sector unknown
	Commercial and services	18	ST 9 MT 9 LT	Steam	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	 ✓	Low temperatures first, all RE technologies have a role
	Bricks and ceramics	16	ST 3 MT 8 LT 5	Kiln heating	✓ ✓ ✓					 ✓	Well suited to bioenergy if resource is available. Some electrification potential also
	Pulp and paper	14	ST 2 MT 6.3 LT 6	Hot water, process steam	✓	 ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓		Strong use of bioenergy already, Progress may be limited by biomass supply, leverage other RE technologies for lower temperature processes
	Other mining	14	ST 3 MT 4 LT 7	-	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	 ✓	Low temperatures first, all RE technologies have a role
	Glass and glass products	7	ST 0 MT 3 LT 4	Glass melting	✓			✓ ✓		 ✓	Progressive switch to electric resistance heating plus bioenergy
	Other sectors	31	ST 6 MT 9 LT 16	-	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	 ✓	Low temperatures first, all RE technologies have a role

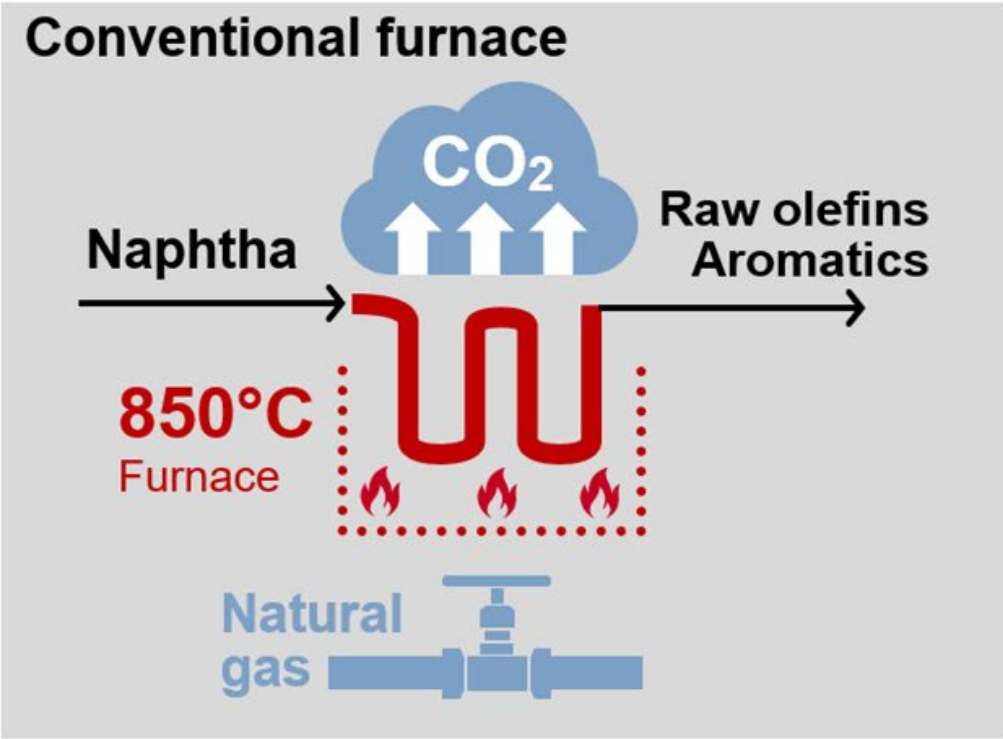
Ind. Heating Processes and Temperature Ranges

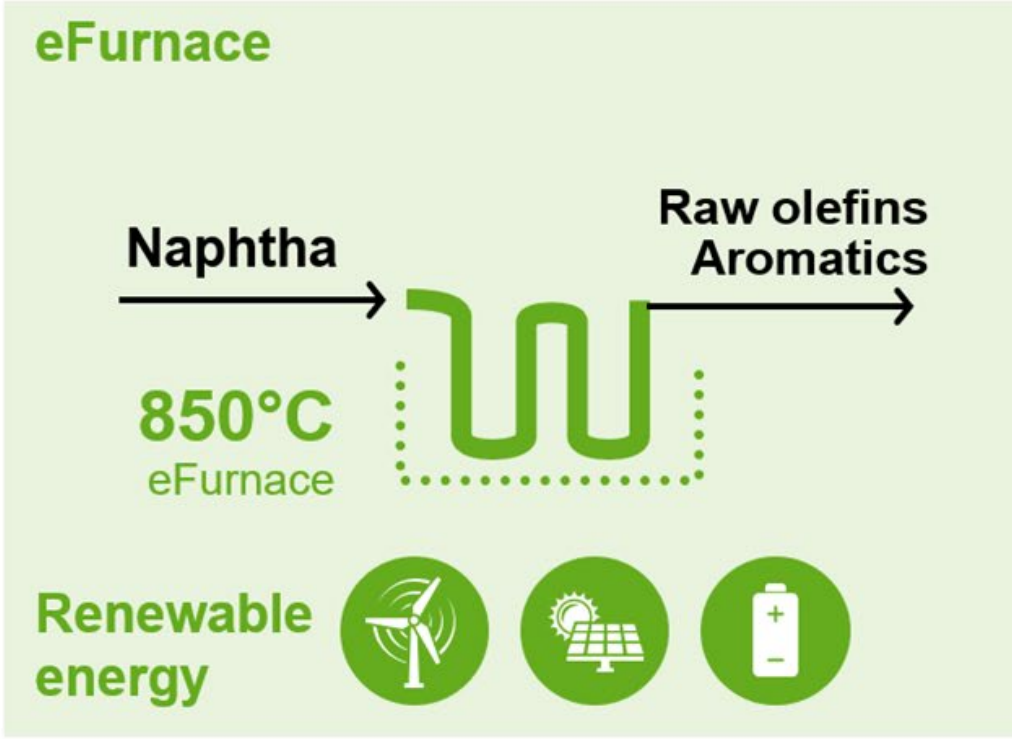


(Source: Modified from Japan Electric Heat Center (2019)

Example / E-furnace Naphtha Cracking

- BASF, SABIC and Linde - new steam cracker furnace
- Financial grants from EU Innovation Fund and German Federal Ministry for the Environment
- Demonstration will start at Ludwigshafen as early as 2023, subject to a funding decision





Source: BASF Web page
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Summaries

- Industrial decarbonization is an essential element of energy system decarbonization.
  - Affordable CO2-free electricity and hydrogen
  - Systematic energy management with IoT
- Various approaches are required because both industrial heating requirements and technology seeds are diverse.
  - Temperature range and technology choice
- Low temperature range solutions are relatively easy compared to high temperature heating issues.
- Policy support is critical to overcome technology, economy, and market barriers.