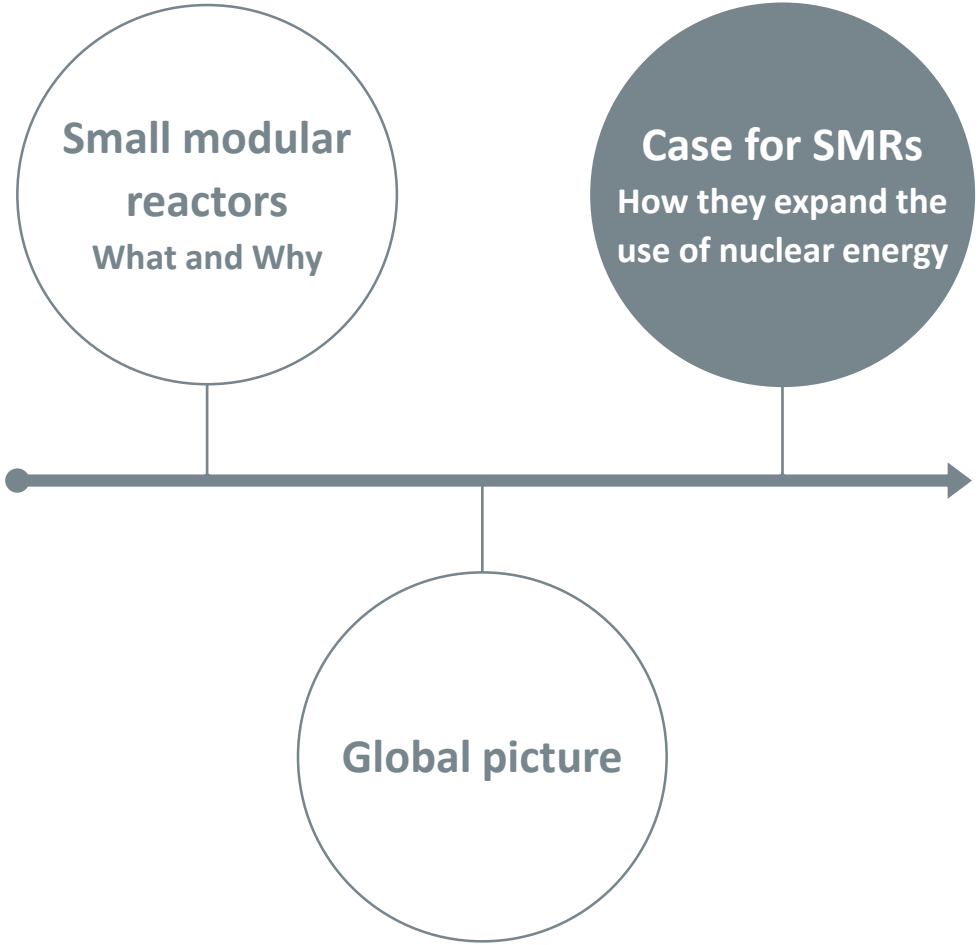
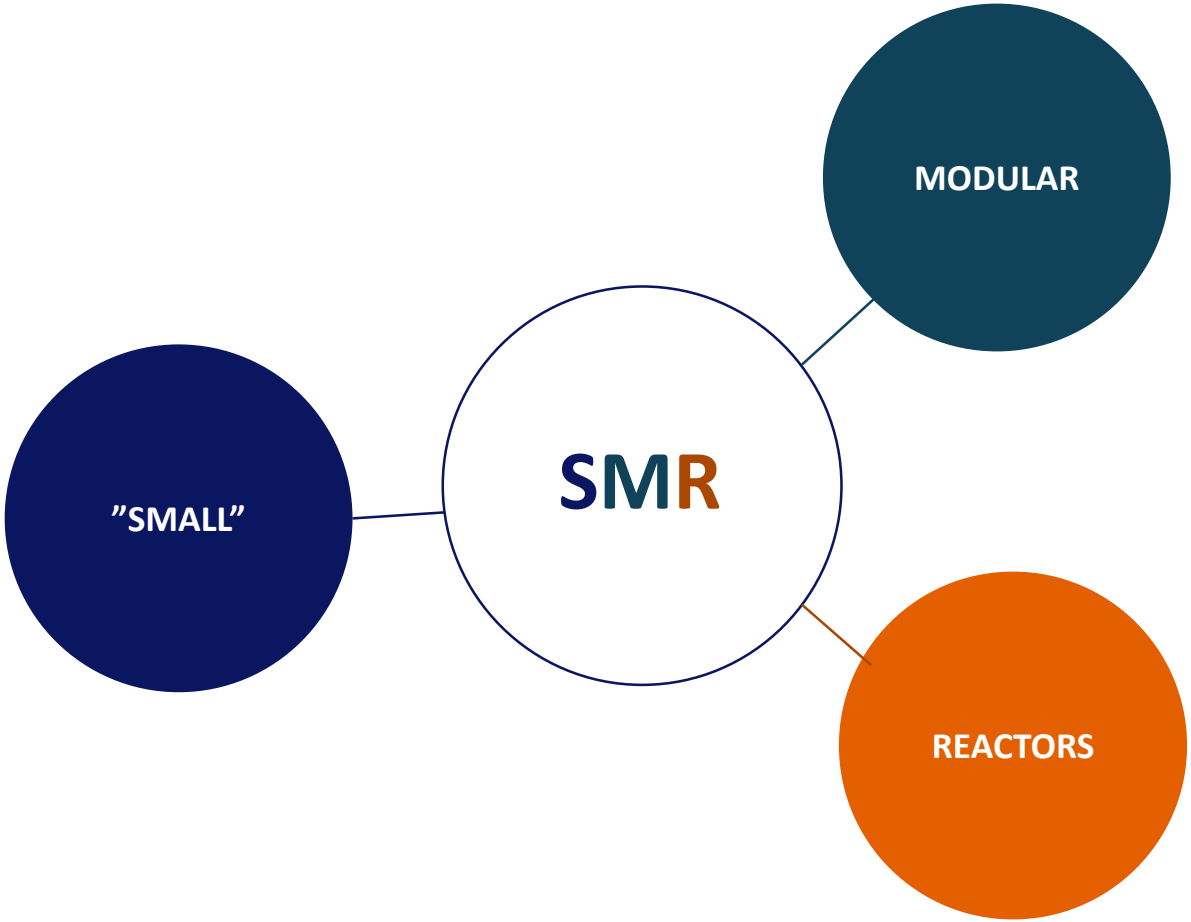
Small Modular Reactors and District Heating

Ville Tulkki, D.Sc. (Tech)
Research Team Leader

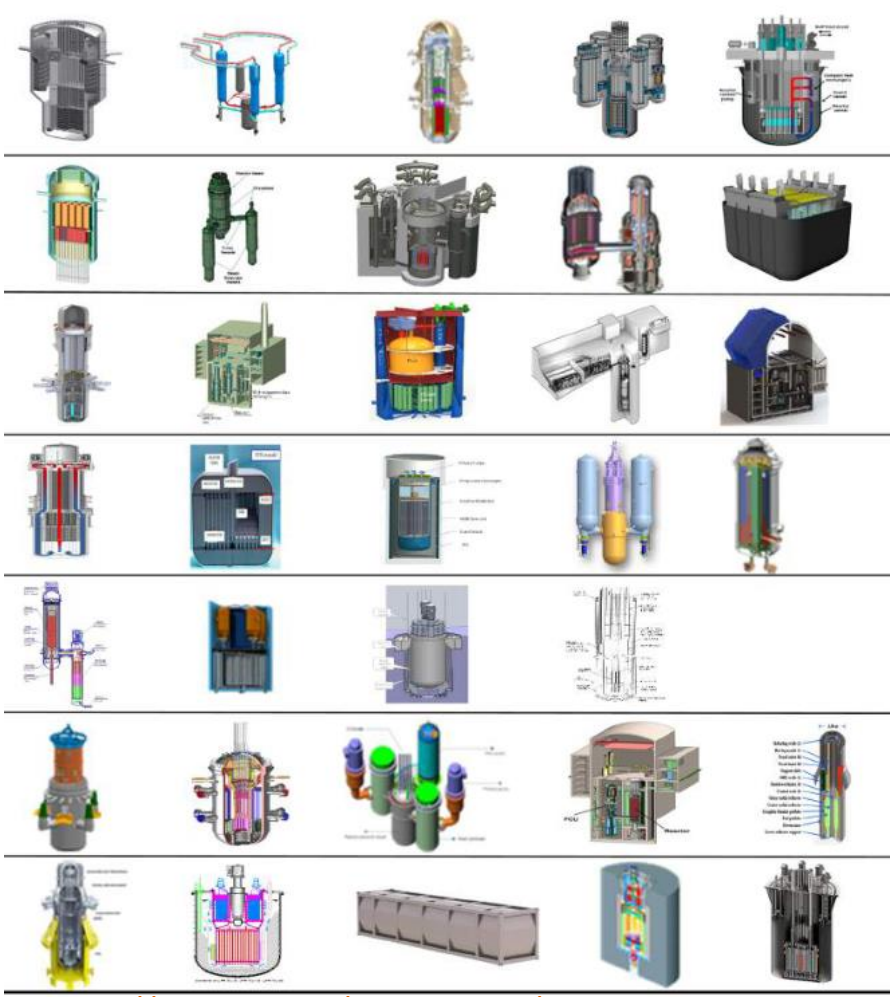
Contents


Small modular reactors
What and Why
Case for SMRs
How they expand the use of nuclear energy
Global picture


MODULAR
”SMALL”
SMR
REACTORS

Variety of designs

- Reactor size, coolant, fuel form varies
- SMR umberella term

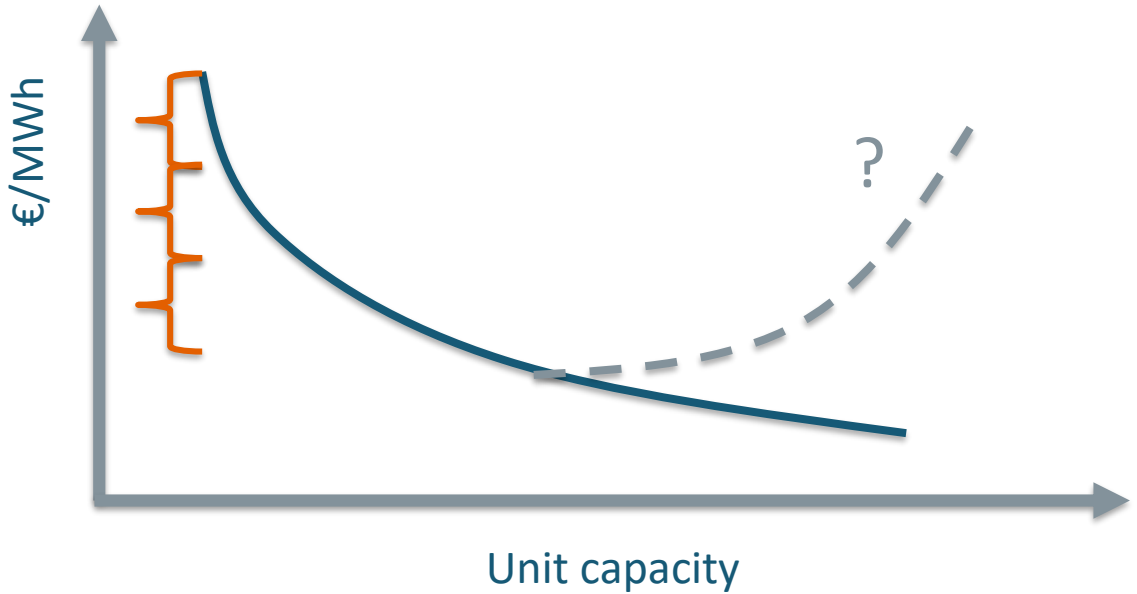


https://aris.iaea.org/Publications/SMR-Book_2018.pdf

Why?

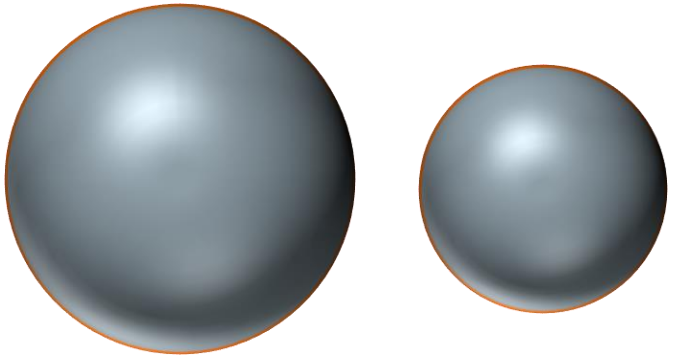
Economies of Scale

Economies of Volume



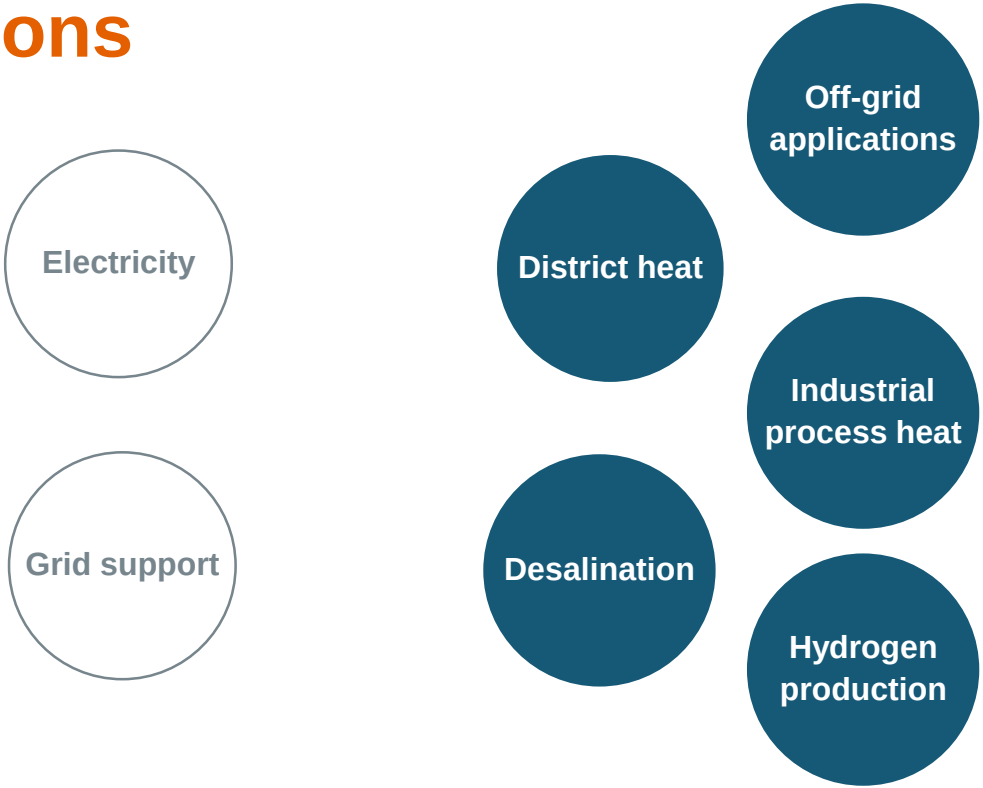
Potentially simpler systems

- Smaller unit power enables achieving required level of safety with simpler systems
  - Power produced relative to volume, conduction relative to surface area
- Innovative solutions
  - Integral pressure vessels remove LBLOCA
- New reactor technologies



$$\frac{A}{V} \sim \frac{r^2}{r^3} = \frac{1}{r}$$

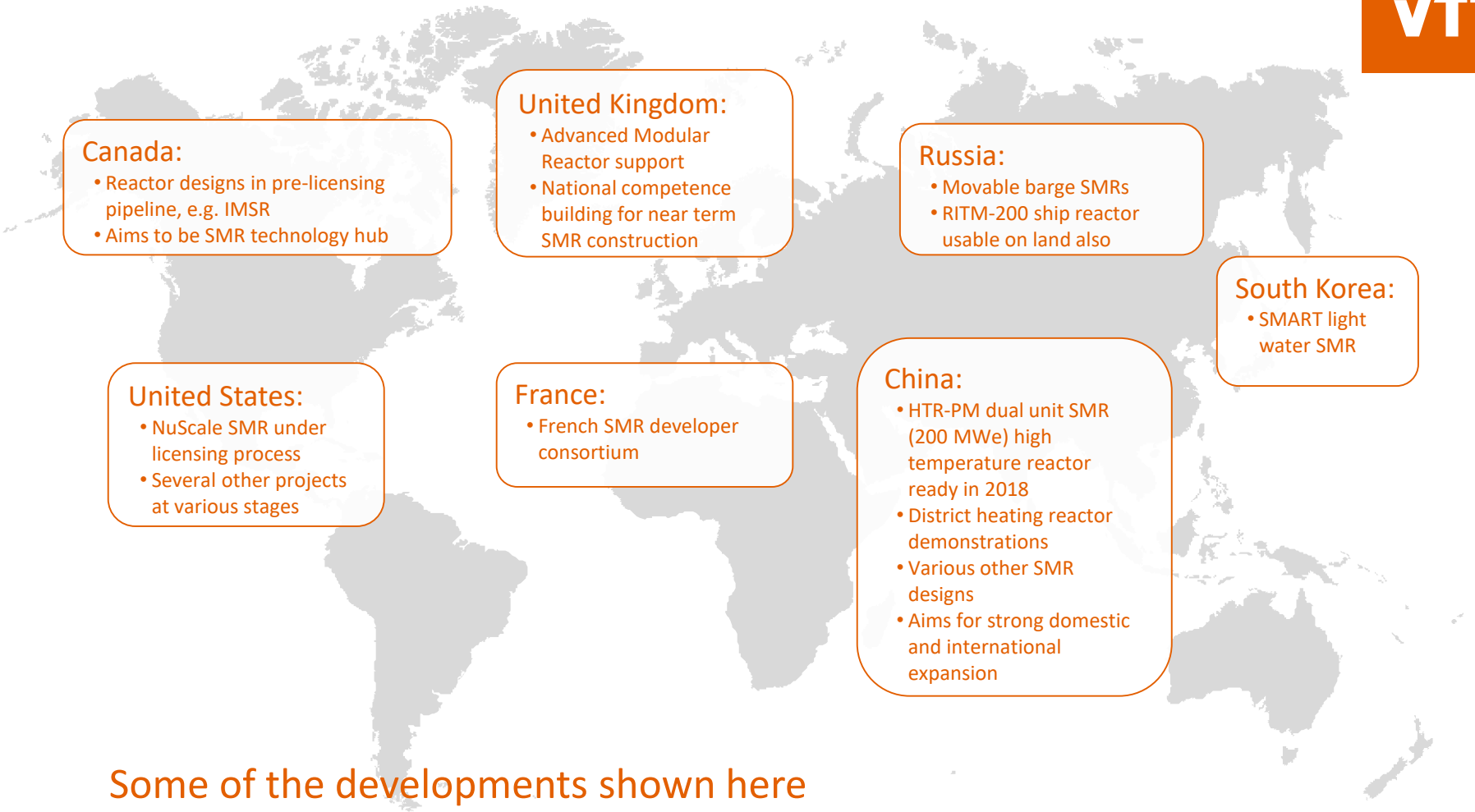
Applications



SMRs have several advantages in heat production

- Heat
  - Hard to transfer – needs to be produced locally
  - Limited in scale – no use for several GWs of heat
  - Few other low-C options
- Lower temperature heat can be produced with lighter components
  - District heat reactors

Global situation



Canada:
- Reactor designs in pre-licensing pipeline, e.g. IMSR
- Aims to be SMR technology hub

United Kingdom:
- Advanced Modular Reactor support
- National competence building for near term SMR construction

Russia:
- Movable barge SMRs
- RITM-200 ship reactor usable on land also

South Korea:
- SMART light water SMR

United States:
- NuScale SMR under licensing process
- Several other projects at various stages

France:
- French SMR developer consortium

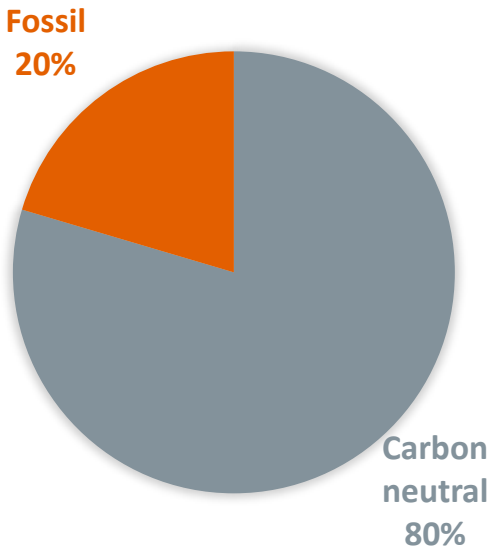
China:
- HTR-PM dual unit SMR (200 MWe) high temperature reactor ready in 2018
- District heating reactor demonstrations
- Various other SMR designs
- Aims for strong domestic and international expansion

Some of the developments shown here

Case for Finland

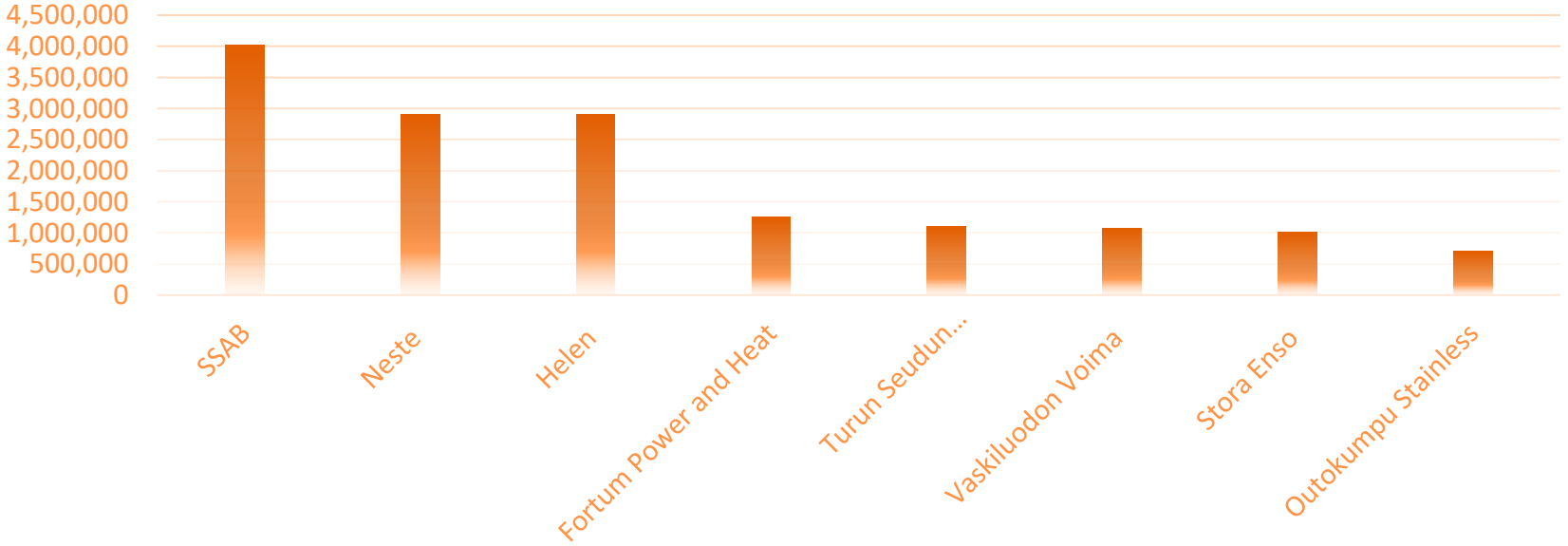
Electricity already relatively clean and getting cleaner

FINNISH ELECTRICITY PRODUCTION 2016



Heat and industry remain challenging

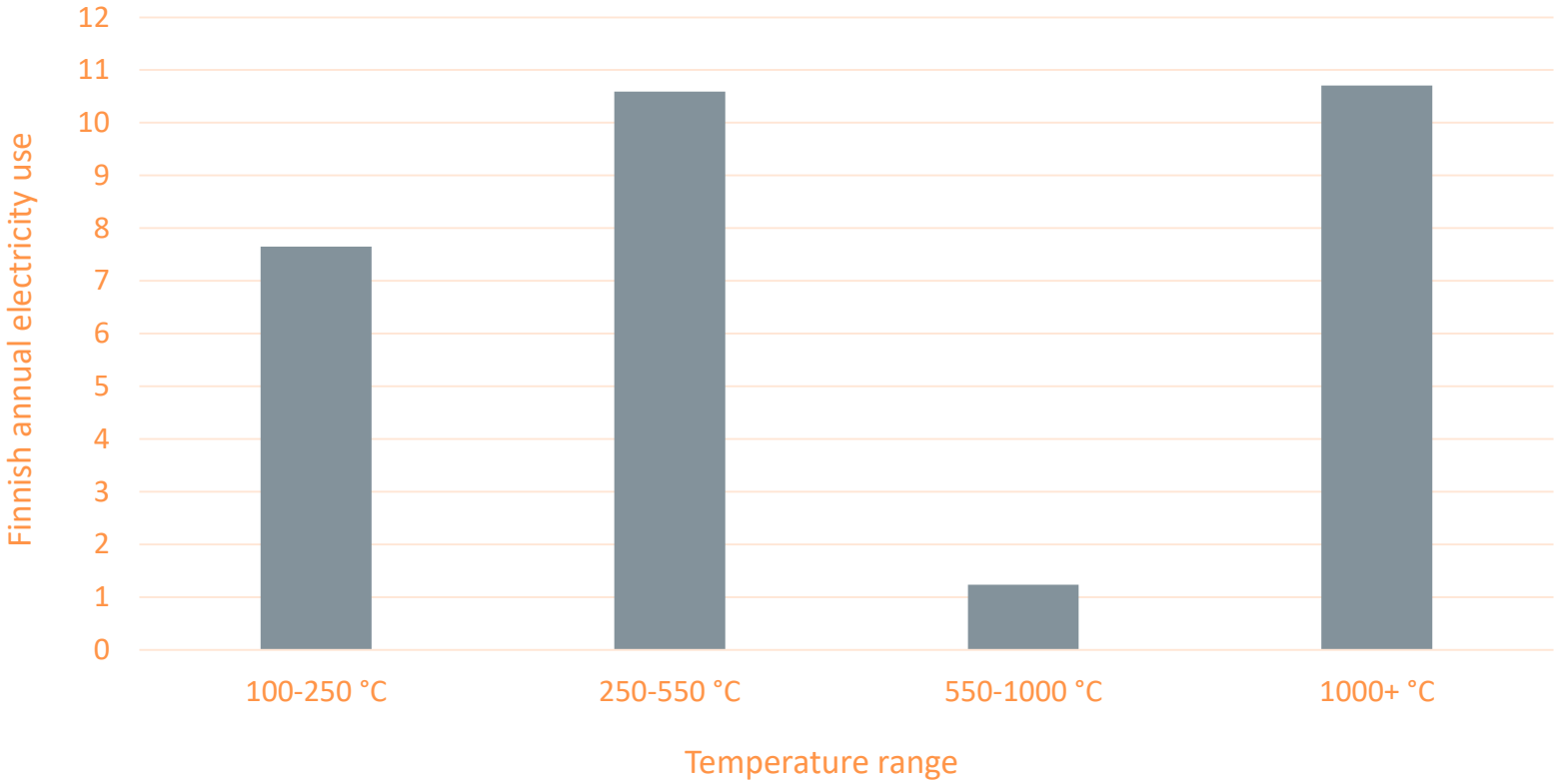
TONS OF CO2 EMITTED IN 2015

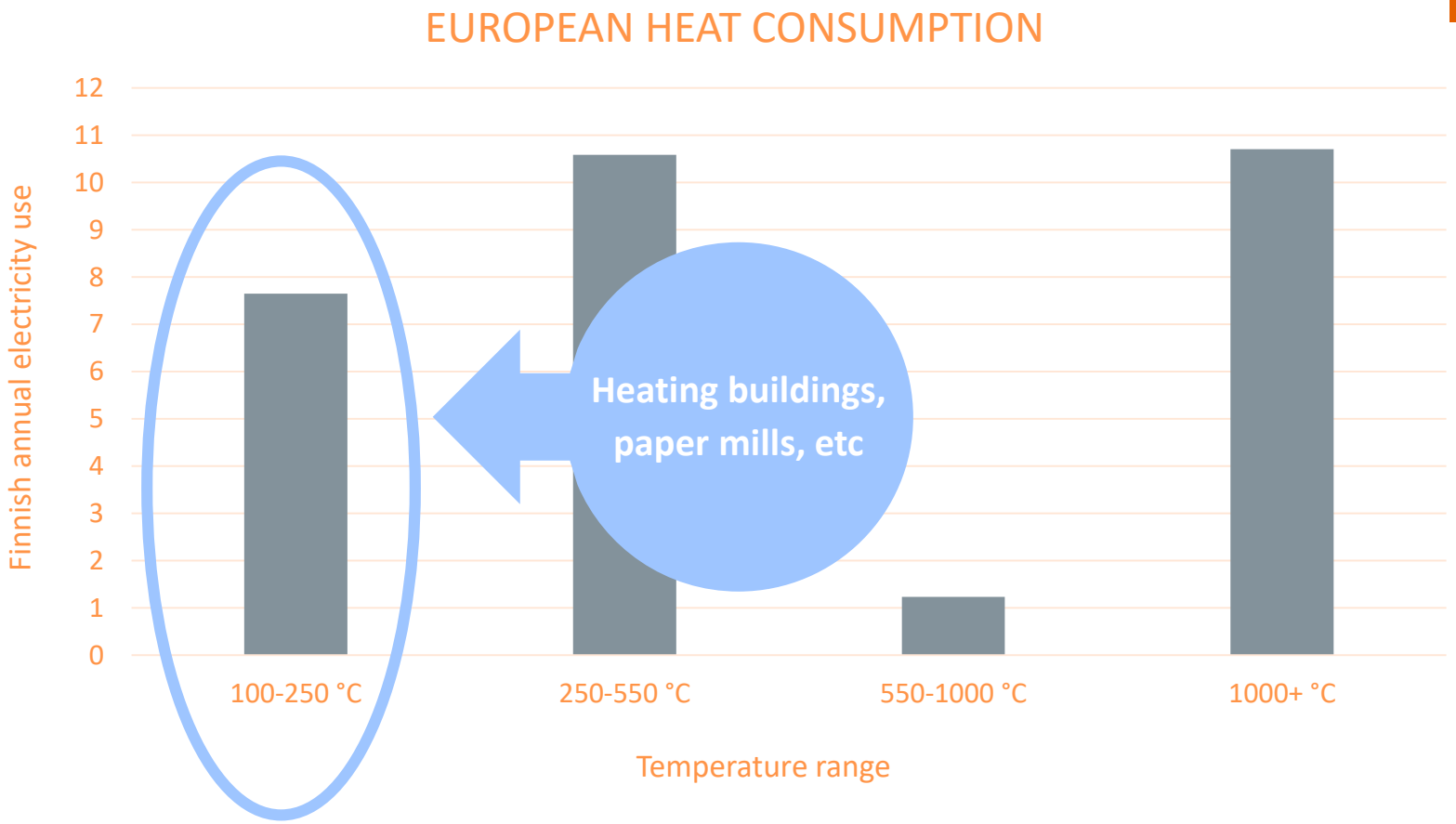


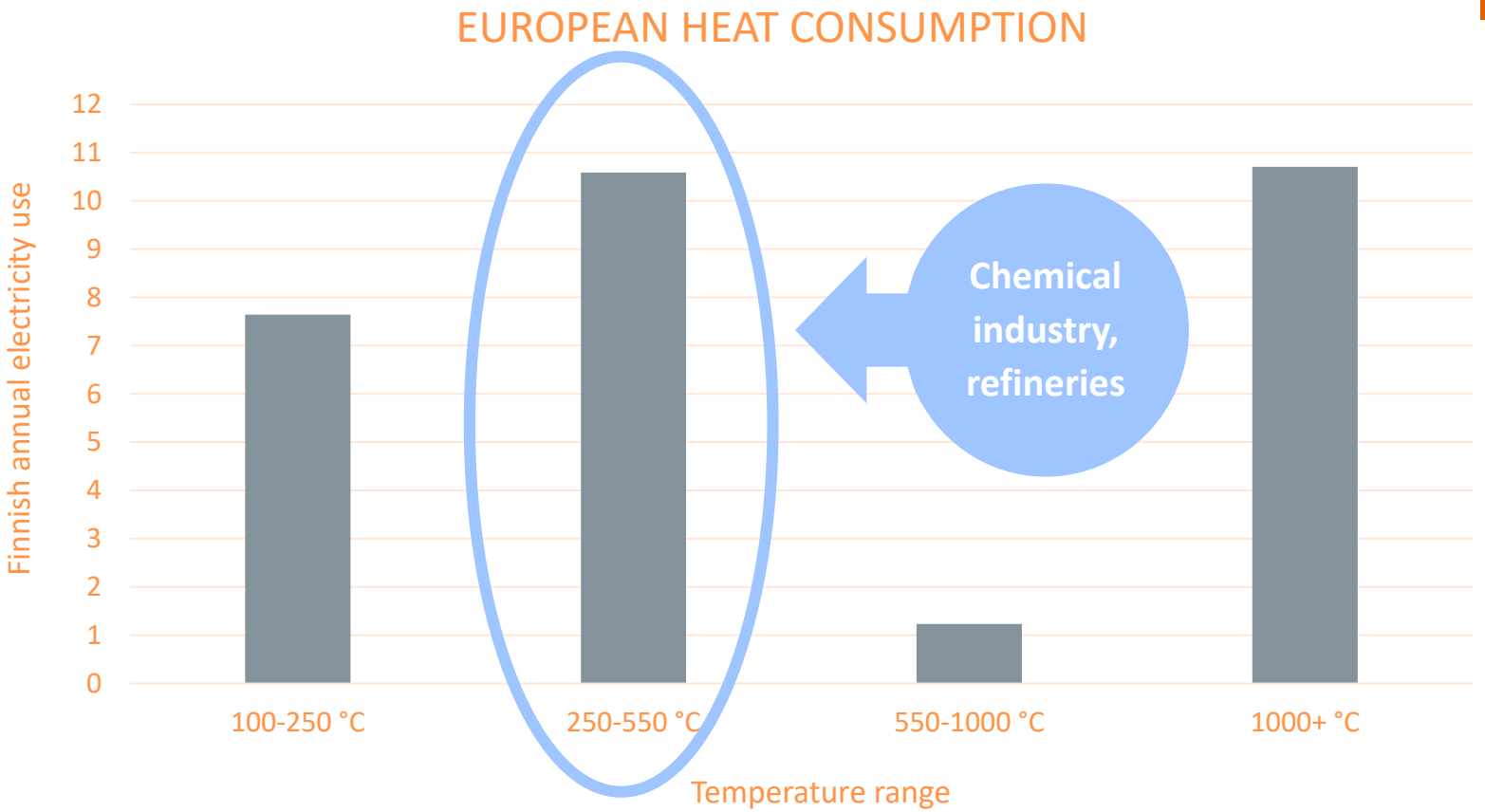
Not just a Finnish challenge
- we are just a bit ahead of the rest

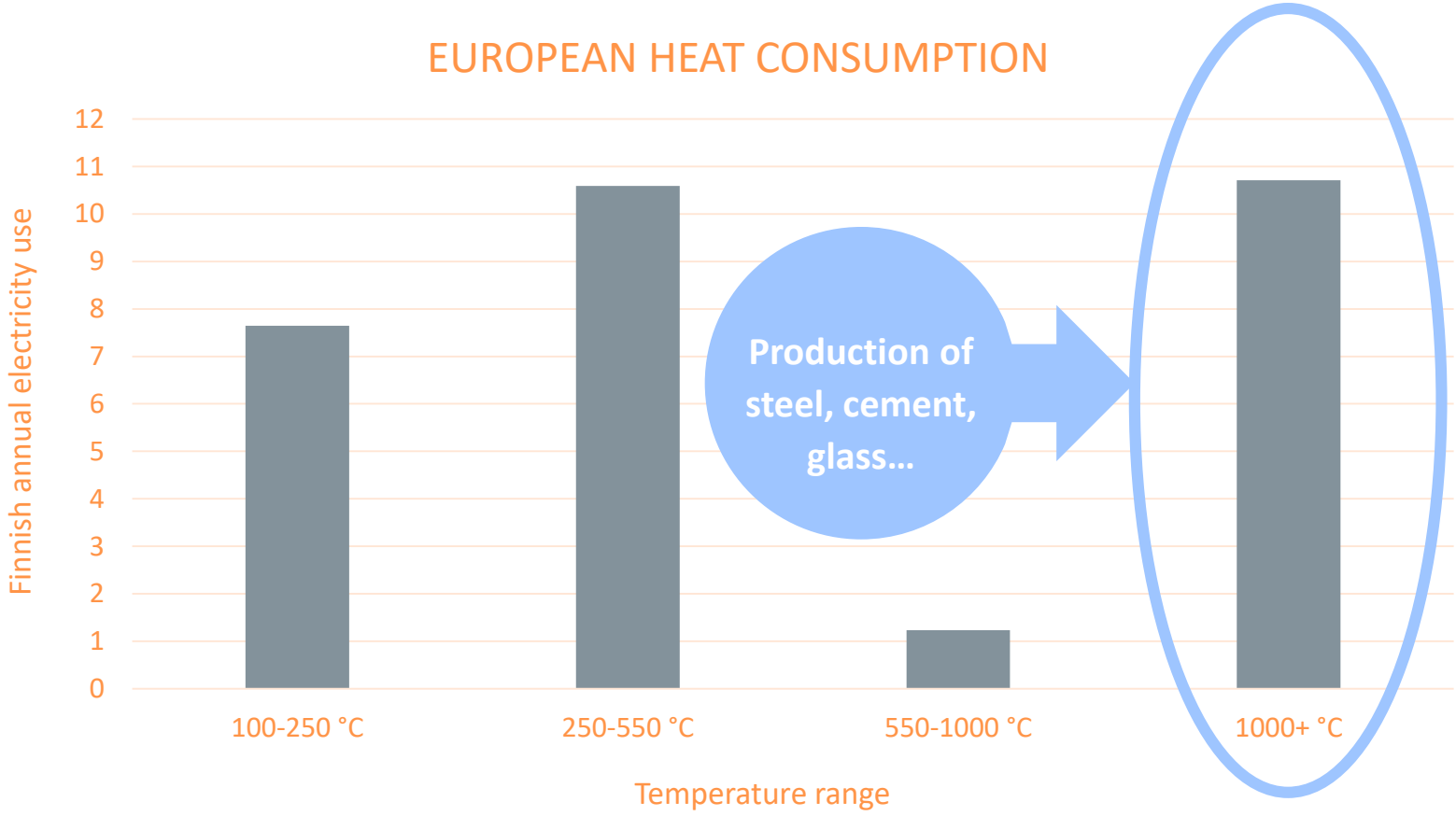
Residential and industrial heat
will be an issue in everywhere

EUROPEAN HEAT CONSUMPTION

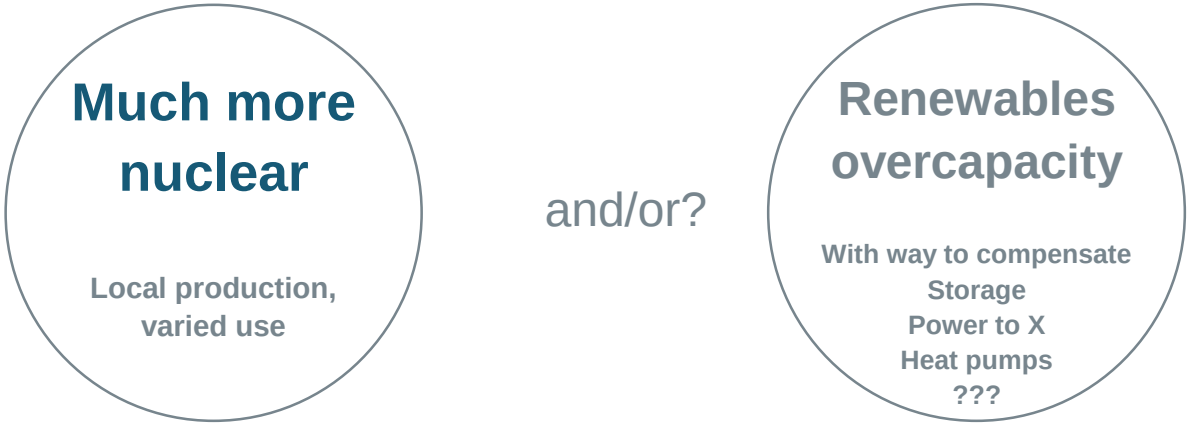



EUROPEAN HEAT CONSUMPTION
Finnish annual electricity use
12
11
10
9
8
7
6
5
4
3
2
1
0
Heating buildings, paper mills, etc
100-250 °C
250-550 °C
550-1000 °C
1000+ °C
Temperature range


EUROPEAN HEAT CONSUMPTION
Finnish annual electricity use
12
11
10
9
8
7
6
5
4
3
2
1
0
Chemical industry, refineries
100-250 °C
250-550 °C
550-1000 °C
1000+ °C
Temperature range


EUROPEAN HEAT CONSUMPTION
Finnish annual electricity use
12
11
10
9
8
7
6
5
4
3
2
1
0
Production of steel, cement, glass…
100-250 °C
250-550 °C
550-1000 °C
1000+ °C
Temperature range

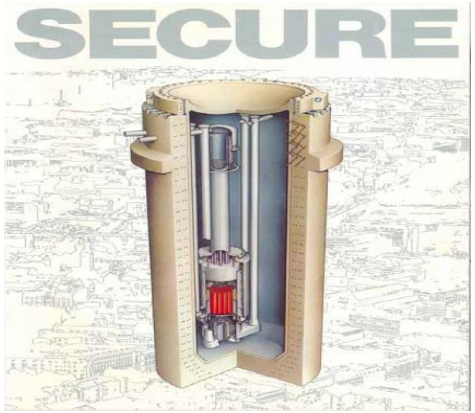
How is future energy supply guaranteed?



Nobody knows, yet – most likely ”it depends”

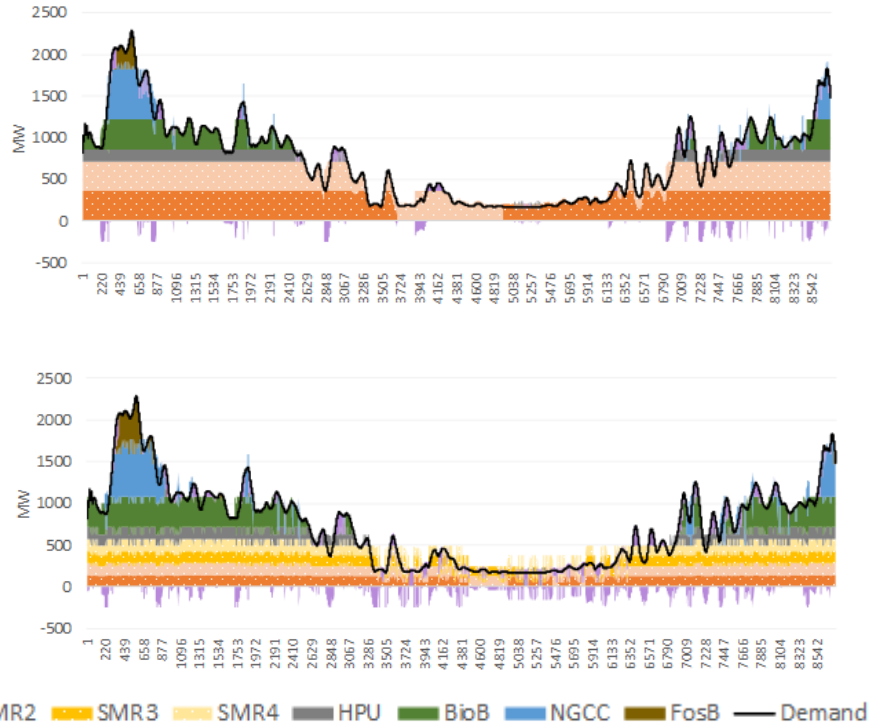
District heating with nuclear energy

- On-going discussion on emissions from heating
- Nuclear district heating not new
  - ~50 nuclear reactors supply also some heat to nearby communities
  - Plans for heat only reactors in 1970s
- Heat only reactors require lower temperatures
  - Low pressure, less demanding conditions
  - Safety easier to assure, potentially a lot cheaper to construct



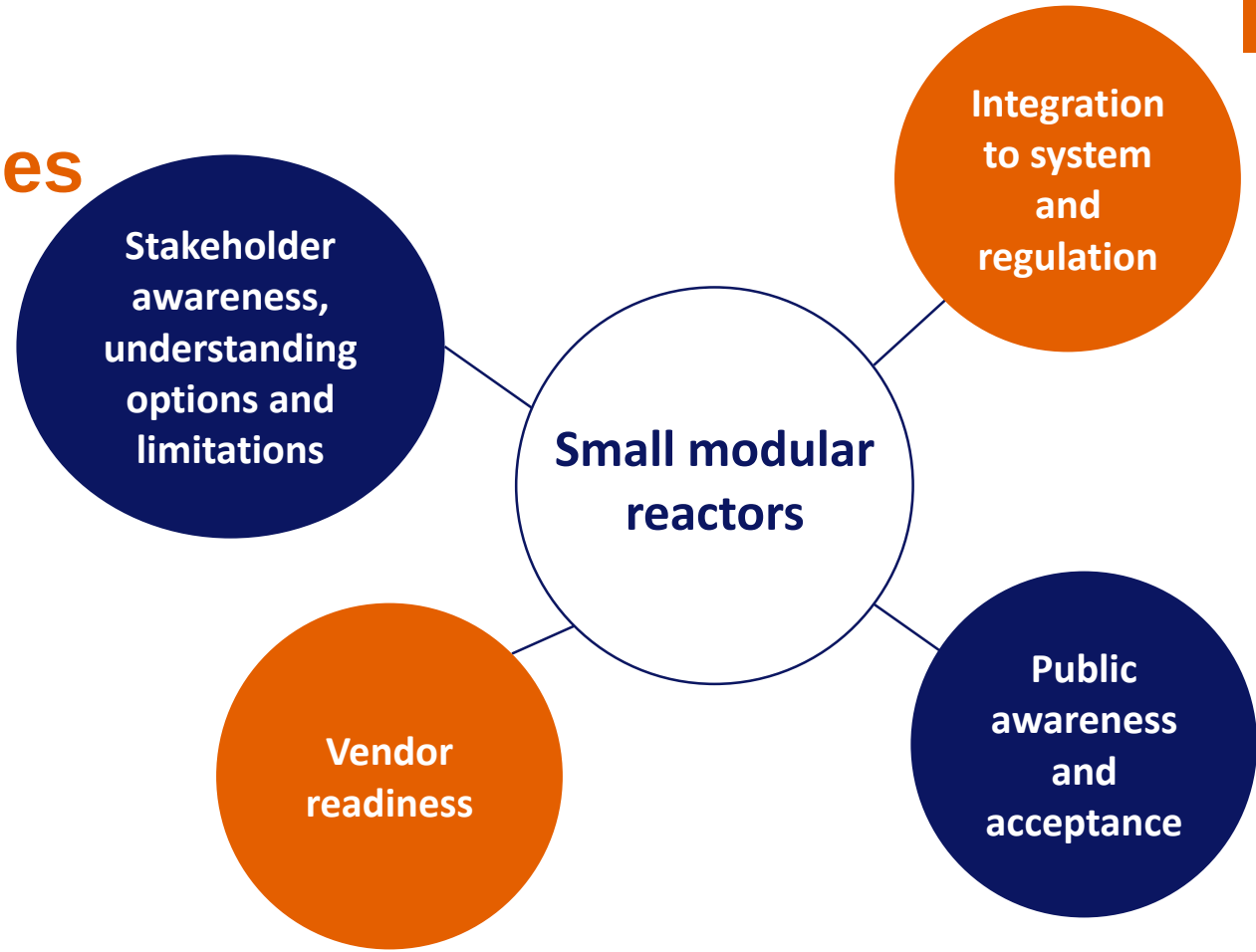
Technoeconomic studies

- Integration of nuclear heat supply to district heating network
- Summer demand low, in principle capital area would have reasonable heat demand for several 100 MWs reactor(s)
- Economics comparable with high COP heat pumps
- Heat only reactors cheaper, CHP reactors more flexible



A techno-economic assessment of NuScale and DHR-400 reactors in a district heating and cooling grid
Tomi J. Lindroos, Esa Pursiheimo, Ville Sahlberg & Ville Tulkki
Energy Sources, Part B: Economics, Planning, and Policy

Challenges


Integration to system and regulation
Stakeholder awareness, understanding options and limitations
Small modular reactors
Public awareness and acceptance
Vendor readiness

Ongoing project to collect Finnish actors into domestic SMR ecosystem

- Aim to scope near term potential for SMRs
  - Heat for various uses
  - Finnish industrial capability and willingness
  - Pave way for future business for various actors

Licencing, regulations and design criteria	SMR ecosystems
Heat use of small reactors	Dissemination and international relations
Business models and case studies	Project coordination and management

ELSMOR

Towards European Licensing of Small Modular Reactors

- Horizon2020 Euratom project on securing European capabilities to ensure the safety of SMRs
  - Coordinated by VTT, Fortum as WP lead
  - Aiming to start mid-2019
- 15 partners, with strong collaboration with the developers of French SMR design

Small modular reactors

- Expand the use of nuclear energy
  - In many places complementary to large reactors
- Variety of designs
  - Currently near the ”innovation death valley” between proof of concept and commercialization
- Would help with future’s hard challenges
  - Low-carbon flexible power, residential and industrial heat