



# SMRs as a cornerstone of complex energy ecosystem

04 February 2021



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**INTERNAL**



**RESTRICTED**



**CONFIDENTIAL**

# Why Tractebel believes in Small Modular Reactors?

A business model that starts from the right questions



Expand role in zero-carbon **transition**?

Load-balancing capability

Deep decarbonization



Foster nuclear **investments**?

From tens to couple of billions \$ project



Alleviate concern of nuclear **waste**?

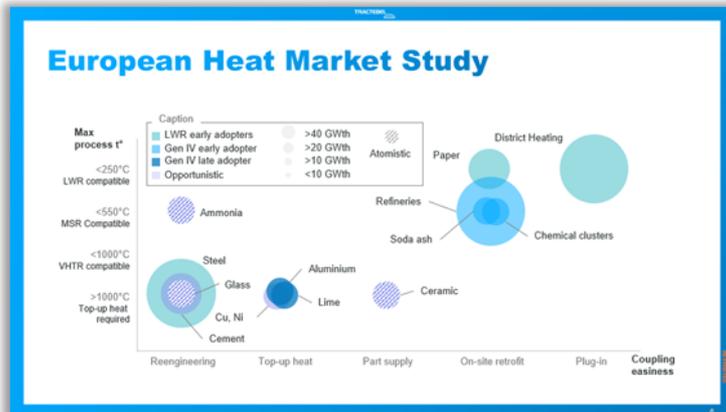
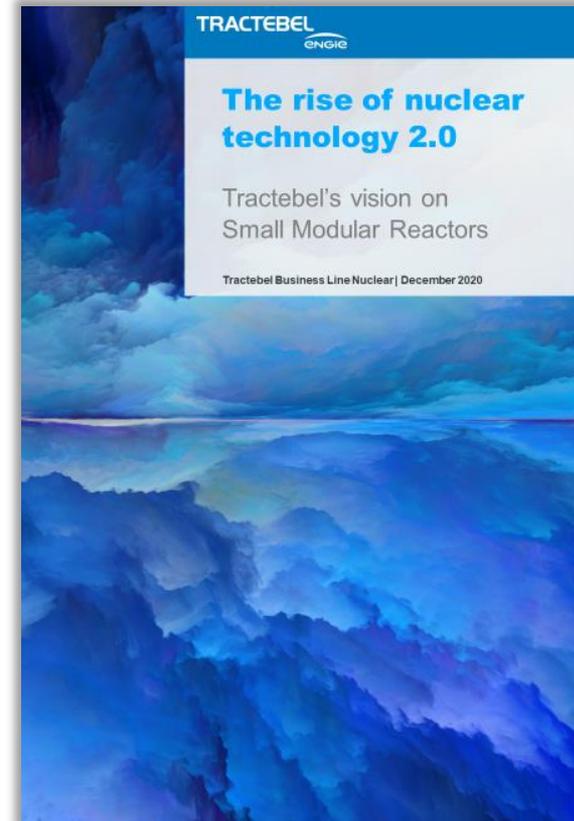
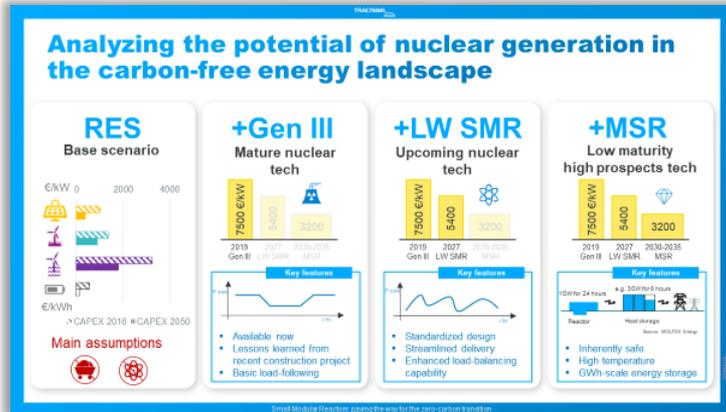
Turning wastes in watts



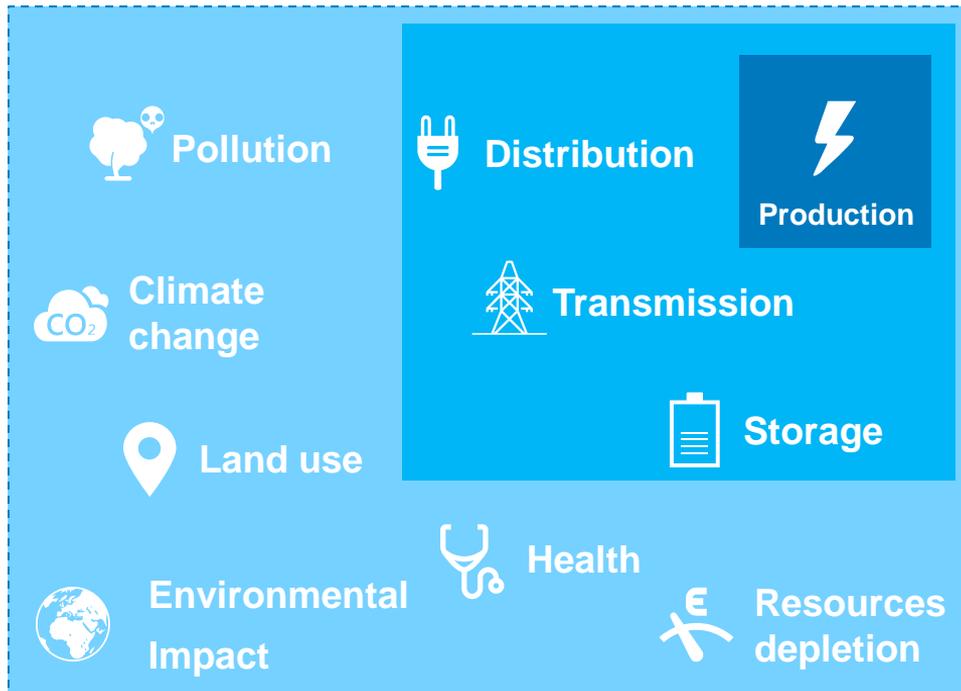
Recreate public trust in nuclear **safety**?

Eliminate the off-site radiological risk of severe accident

# Our recent SMR white paper



# Integrated view of the electricity market



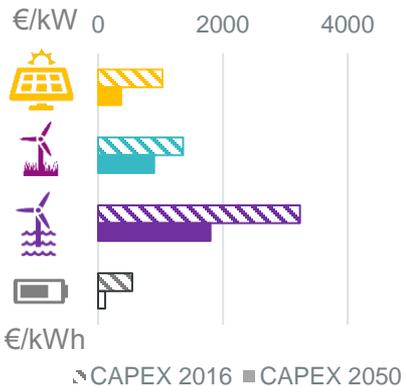
## Societal-level

Full cost including external & social costs

# Analyzing the potential of nuclear generation in the carbon-free energy landscape...

## RES

Base scenario

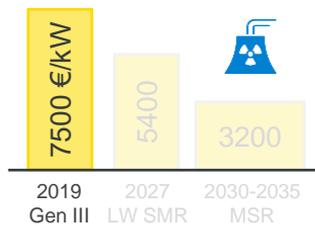


Main assumptions



## +Gen III

Mature nuclear tech



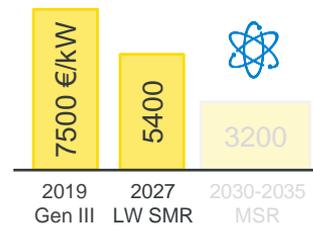
Key features



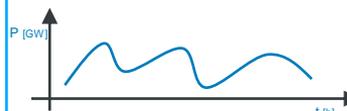
- Available now
- Lessons learned from recent construction project
- Basic load-following

## +LW SMR

Upcoming nuclear tech



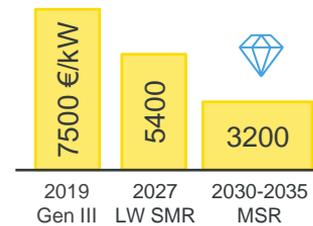
Key features



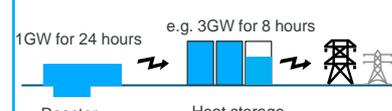
- Standardized design
- Streamlined delivery
- Enhanced load-balancing capability

## +MSR

Low maturity high prospects tech



Key features

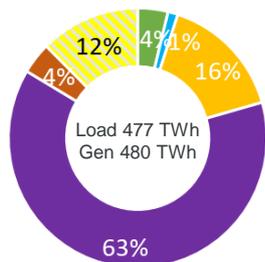


- Inherently safe
- High temperature
- GWh-scale energy storage

# ... from the perspective of countries with different profiles

## Great Britain

A country in the West of Europe which has high wind potential

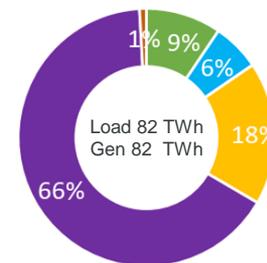


*Projected 2050 Zero-Carbon Generation Mix without new nuclear*

(\*) Poland was modelled based on surrogate data from Germany. Market potential results are shown for PL, but system impacts are measured with a modified DE

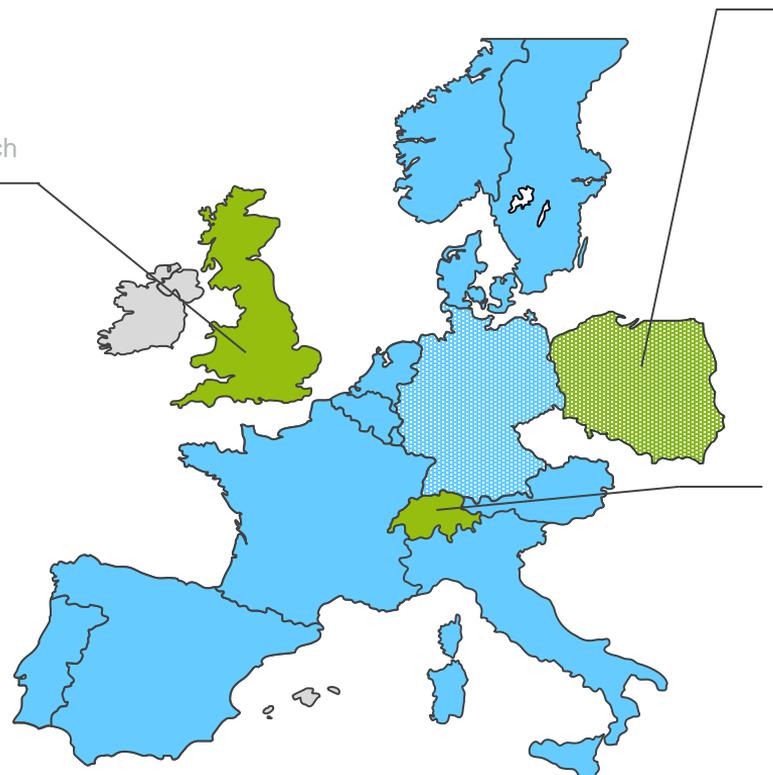
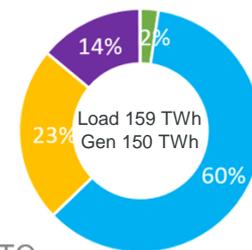
## Poland\*

A country in the east of Europe with a high carbon-emissions footprint



## Switzerland

A country well interconnected in the middle of Europe with a lot of hydropower



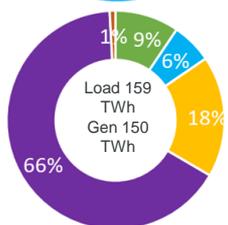
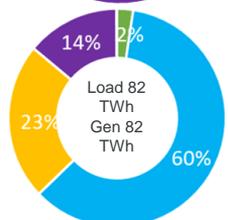
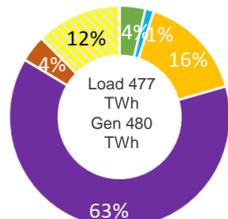
■ BIOGAS ■ BIOMASS ■ HYDRO ■ SOLAR ■ WIND ■ H2 / SNG ■ NUC New Build ■ NUC LTO

# Snapshot of results for 2050

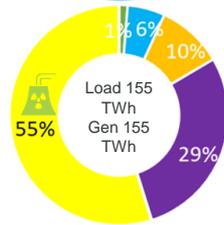
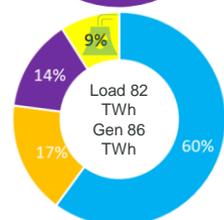
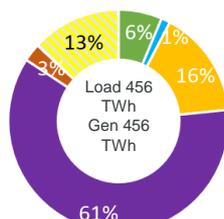
## Great economic prospects for SMRs



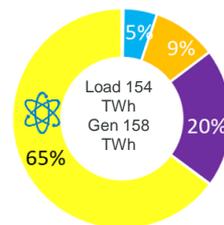
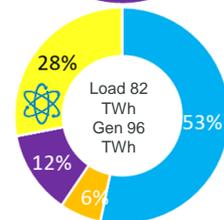
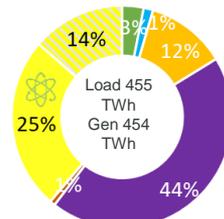
### RES



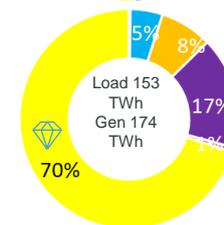
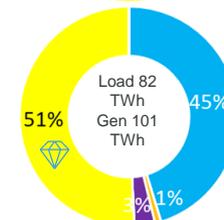
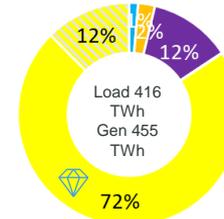
### +Gen III



### +LW SMR

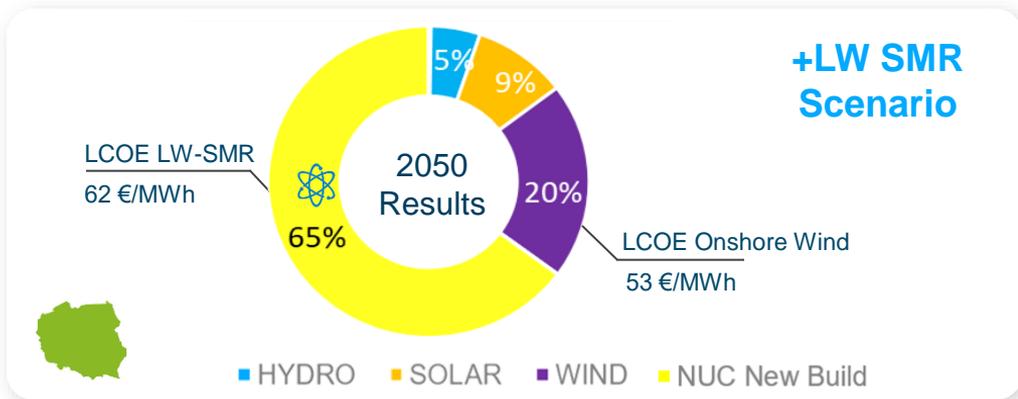


### +MSR



■ BIOGAS ■ BIOMASS ■ HYDRO ■ SOLAR ■ WIND ■ H2 / SNG ■ NUC New Build ■ NUC LTO

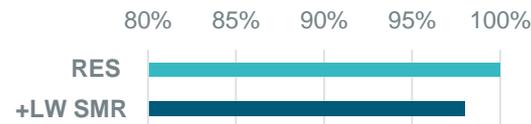
# LCOE is not the whole story



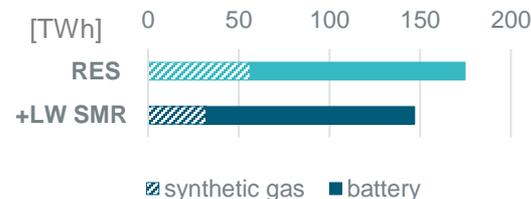
## Key insights

- Higher penetration of NUC projected despite WIND lower **LCOE**
- **Grid-level generation cost** is lower with **NUC** than 100% **RES**
  - Lower amount of storage required
  - Lower yearly electricity price
- Lower grid infrastructural transformation (storage, T&D) with flexible nuclear

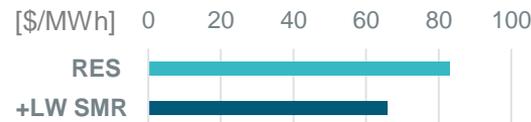
## Total generation cost



## Total Storage



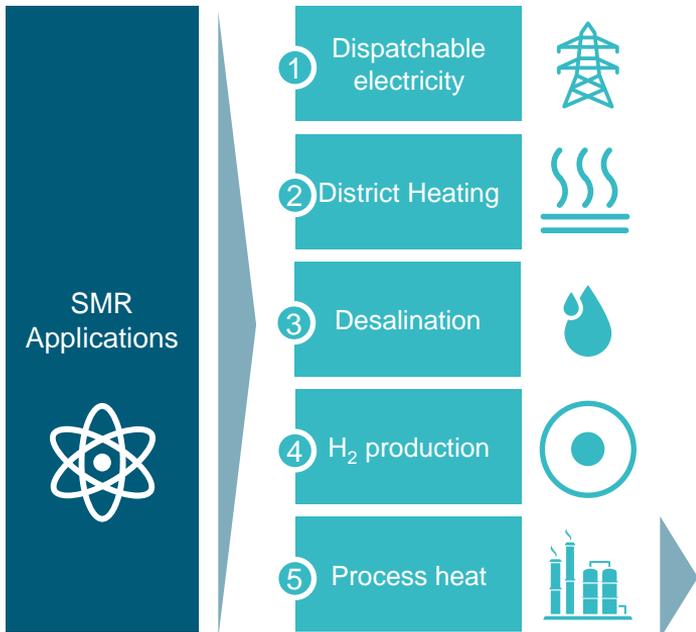
## Yearly electricity price



LCOE ≡ Levelized Cost Of Electricity

# Striving for a deep decarbonization of the economy

Expanding nuclear energy's role for the carbon-neutral transition



# Heat Market Analysis Criteria

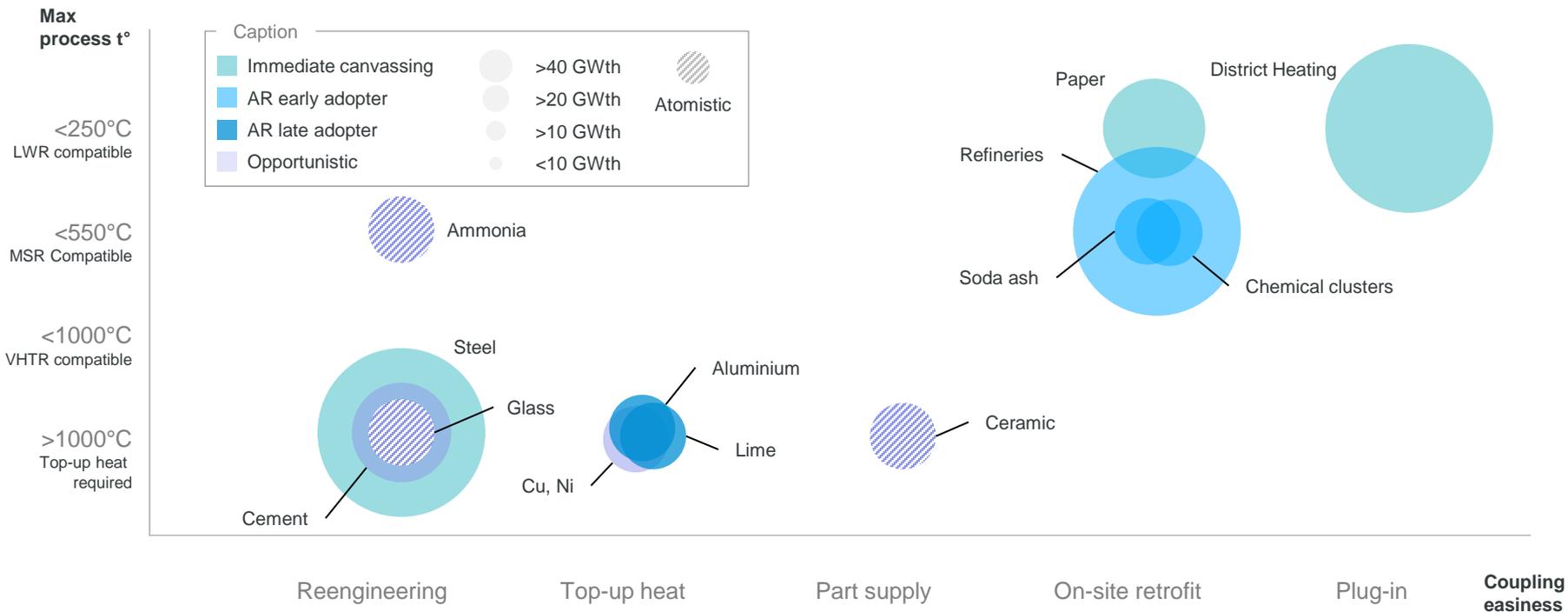


Sectorial analysis				Geographical analysis			
Max process T°	Market size	Average plant size	Coupling easiness	Nuclear industry maturity	Nuclear Appetite	Co-gen potential	Carbon footprint**
<250°C LWR* compatible	>40 GWth	>400 MWth	Plug-in retrofit of off-site plant	Tier 1 supply chain	Strong political leadership	>20 GWth	>3t CO <sub>2</sub> /toe
<550°C MSR* Compatible	>20 GWth	>200 MWth	On-site boiler/co-gen retrofit	Several sites	New build program	>10 GWth	>2t CO <sub>2</sub> /toe
<1000°C VHTR* compatible	>10 GWth	>100 MWth	Part of process supply	Single site/unit	Strong R&D and public support	> 5GWth	>1t CO <sub>2</sub> /toe
>1000°C Top-up heat required	>5 GWth	>50 MWth	Process pre-heat or top-up heat	Research lab	LTOs* + Phase-out	Sparce application	>0.5t CO <sub>2</sub> /toe
<35°C Not worth	<1 GWth	<50 MWth	Important effort to re-engineering process	No nuclear	Active opposition	No industry	<0.5t CO <sub>2</sub> /toe

\*Light Water Reactor (LWR); Molten-Salt Reactor (MSR); Very High Temperature Reactor (VHTR); Long-Term Operation (LTO)

\*\*Carbon intensity of energy carrier in industry

# Industrial affinity with SMR-based co-generation



# European heat global market potential with illustrative examples

Caption

- Early adopter country
- Huge potential at reach
- Worthwhile opportunities
- Out of scope



Gävle pulp & paper mill is worthy of an investigation on whether offsetting biomass use with nuclear co-generation is relevant



Helsinki's impressive existing district heating infrastructures could host an SMR and retrofit existing coal power plant



Wilton chemical cluster in an interesting candidate to welcome a multi-purpose SMR selected from the AMR competition



Kravów integrated steel mill would need several SMRs to cover its need in high temperature hydrogen in a Direct Reduction facility

Steel production

Refinery

Chemical cluster

Pulp & Paper



Port of Antwerp as the leading European chemical clusters could welcome a centralised solution for decentralised heat consumption



Chemelot chemical park already benefits from utility-scale high temperature steam delivery services at several pressures

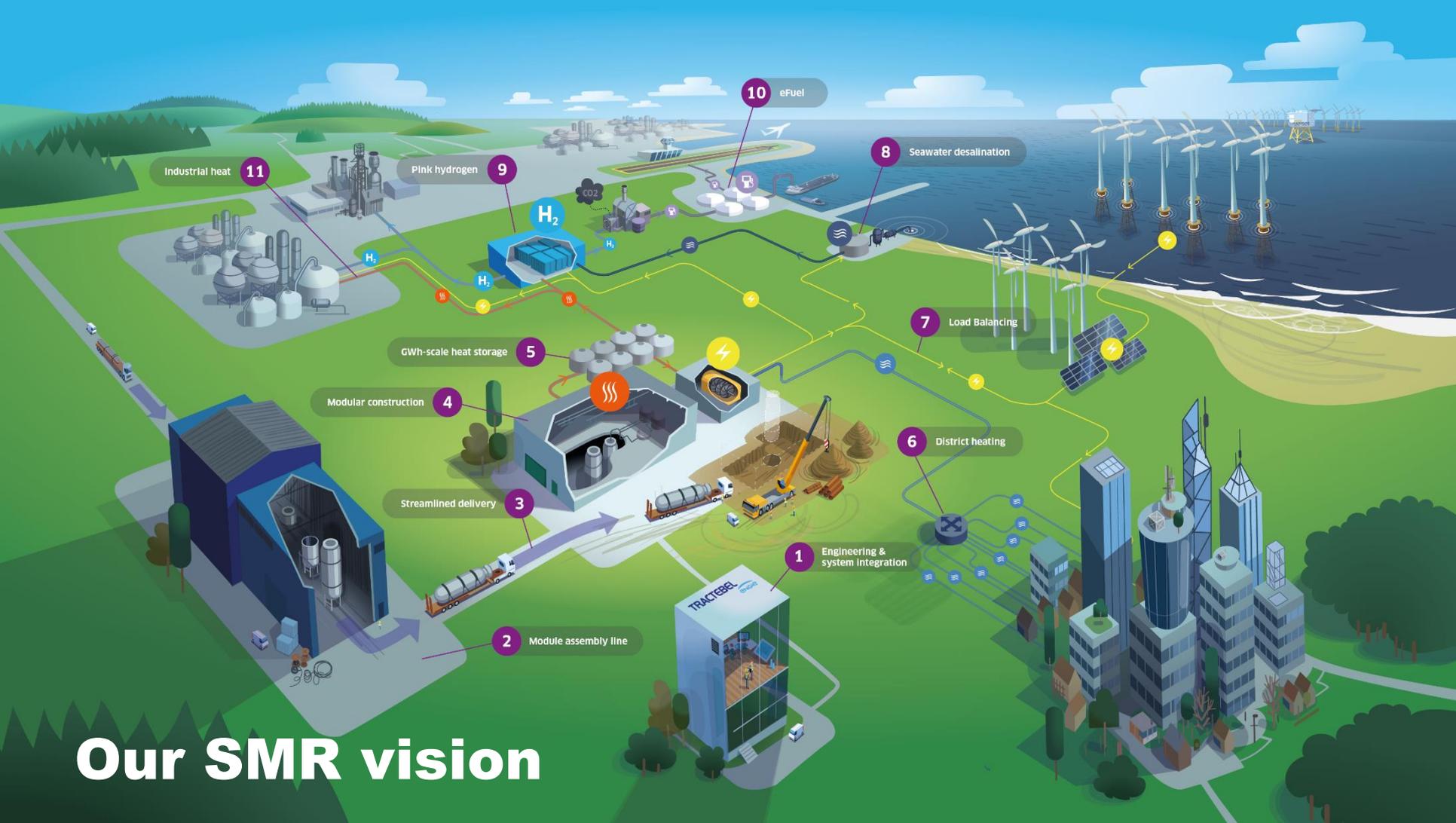
District heating



Tarragona's chemical industry could leverage region's nuclear expertise to deploy an SMR for co-generation



Dunkirk integrated steel mill is ideally suited to welcome a multi-purpose SMR demonstrator



Industrial heat 11

Pink hydrogen 9

10 eFuel

8 Seawater desalination

5 GWh-scale heat storage

4 Modular construction

7 Load Balancing

3 Streamlined delivery

6 District heating

2 Module assembly line

1 Engineering & system integration

# Our SMR vision



# Engineering a carbon-neutral future