RESEARCH PAPER

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Potential for Small Modular Reactors (SMRs) deployment in the Chemical Industry

A Challenging Transition

The chemical sector is the largest industrial electricity consumer in the EU, accounting for around 165 TWh consumed in 2021[1]. Low-carbon electricity and high temperature industrial heat (steam) are key for many chemical manufacturing facilities.

On the path towards 2050, electricity consumption is set to drastically increase[2] as the industry seeks to electrify processes and deploy critical emissions abatement technologies. However, those volumes are not available yet and renewable power sources cannot necessarily provide for them. Grids are currently not fit to deliver the capacities needed for the transition[3] and supply disruptions have significant impacts on production processes.

Moreover, the EC Communication on a 2040 climate target shows that high electricity prices are not set to decrease in the long run[4]. The Commission analysis further underlines that high energy costs expose Energy Intensive Industries (EIIs), like the chemical industry, to mounting international competition.

An efficient transition can only materialise if the sector has access to abundant and affordable low-carbon energy.

The purpose of this paper is to lay out the chemical industry's energy needs to quantify the potential role that Small Modular Reactors[5] could play in providing on-site energy generation in the chemical sector. As such, it aims to facilitate the dialogue between industry, the nuclear sector and relevant stakeholders on the energy needs of the chemical industry.

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[1] Source: Eurostat.

[2] The EU Transition Pathway for the Chemical Industry outlines how electricity consumption by the chemical industry is set to increase by up to four times today. Source: European Commission, *Transition Pathway for the Chemical Industry*, 2023.

[3] Eurelectric, *Decarbonisation Speedways study*, 2023.

[4] Commission Communication, COM(2024) 63, *Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society*, 06.02.2024.

[5] Commonly understood as small, modular nuclear reactors having usually a **power output of between 10 megawatt electric (MWe) and 300 MWe**.

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Potential Benefits for the Chemical Industry

Against this framework, there are substantial **benefits of on-site electricity and heat production** via Small Modular Reactors, among other on-site low-carbon production pathways.

On-site electricity production is also an attractive option for industrial consumers as it would abate **high electricity grid costs which are currently prohibitive to investments in electrification**[6].

Several SMRs designs are implementing a **co-generation system which allows for simultaneous production of low-carbon electricity and heat for industrial consumption**[7].

Furthermore, the chemical industry's energy-intensive production processes would benefit from SMRs low-carbon energy to **significantly abate production sites' scope 1 and scope 2 emissions**, the related CO_2 costs, and deliver lower carbon footprint products.

The technology could play a key role in **ensuring stable energy supply** that chemical plants need to operate efficiently. On-site electricity production would also free up capacities in already congested electricity grids.

In addition, the **modular nature of SMRs** allows to install on-site back-up module(s) -redundancy capacity- to address maintenance periods while maintaining a reliable system providing abundant and continuous streams of energy needed to sustain the production.

To secure seamless operation and uphold the safety standards required for SMRs, **specialized third-party entities** have to be involved. Such third-parties would be responsible for the asset management, operation, maintenance, fuel cycle and back-end of the technology installed on the chemical installation. An alternative option would be for the chemical company to purchase **SMRs' energy-as-a-service**.

To assess the potential role of SMRs in the chemical industry, two scenarios are analysed: ethylene production in the Petrochemicals industry sector and chlorine production in the Chlor Alkali industry. Petrochemicals production is a highly energy-intensive process which needs continuous electricity and steam supply resulting in the release of a significant amount of greenhouse gases. Chlor Alkali production is an electro-intensive process for which the associated power prices represent more than half of the total production costs. The sectors' specificities make them attractive for potential SMRs deployment.

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[6] The biggest share of electricity grid costs is represented by the cost of generation and access to the grid in the form of network charges, renewable taxes and levies for transmission and distribution.

[7] Installed combined heat and power (CHP) in the EU27 chemical industry, resulted in 37 TWh of electricity and 14 TWh of heat consumed by the industry in 2021 (source: Eurostat). Most CHP installations have a lifetime of around 20 years and require considerable investment for large scale maintenance of the capacity installed, which could potentially be matched by Small Modular Reactors.

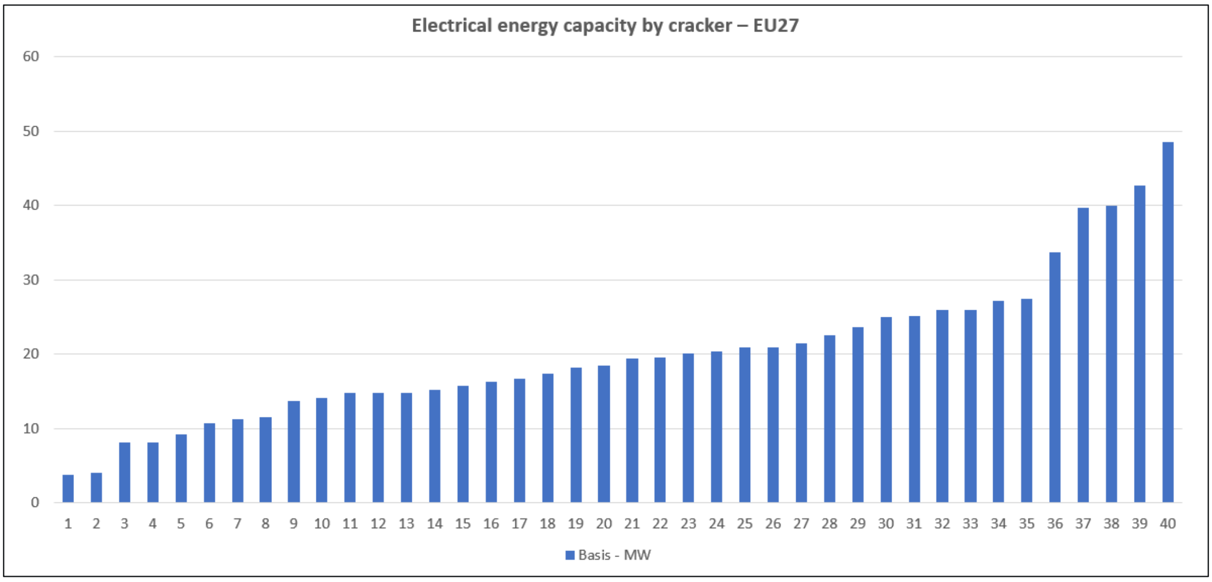
Sectoral application – Petrochemicals

Ethylene and the total High-Value Chemicals (HVCs)[8] production in the EU is used as a proxy for the petrochemicals industry sector's[9] energy needs.

The assumptions considered are:

- EU27 scope;
- Total of 40 crackers in operation;
- Average cracker production of 500-550 Kt ethylene/year;
- Ethylene represents on average 50% of HVC production;
- Average cracker primary energy consumption (furnaces, pumps and compressors) is 16,4 GJ/t HVC:
  - Electrical consumption: 9.5% of total energy consumption;
  - Fuel consumption: 87.6% of total energy consumption;
  - Steam consumption: 2.9% of total energy consumption.
- High pressure steam required (>40 Bar, up to 100 Bar) above 400°C;
- Process temperature up to 900°C;
- Installations running 24/7.

Considering the above assumptions and an efficiency rate of 37.5%, the electrical capacity needed is 19-20 MW to supply the average ethylene cracker with a production capacity of 500-550 Kt/year, with a range spanning from 4 MW up to almost 50 MW, as shown in graph 1. The figure about electrical consumption in a cracker can considerably differ depending on the units electrified e.g. pumps (for water cooling, water pumps), and compressors (cracked gas compressor, propylene refrigerant compressor, ethylene refrigerant compressor).

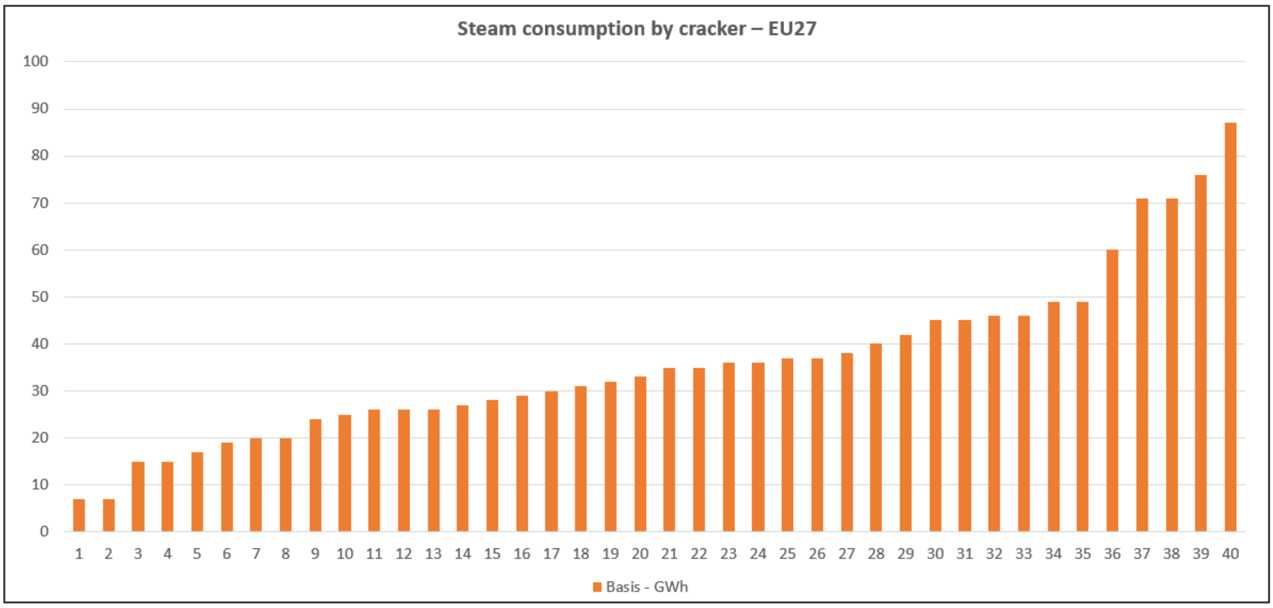


Graph 1: Electrical energy capacity by cracker, EU27 (2021). Source: Petrochemicals Europe, Cefic calculations.

[8] High Value Chemicals (HVCs) include ethylene, propylene, butadiene, benzene, hydrogen and acetylene which are summarised for benchmarking reasons. HVCs represent a cracker's output products.

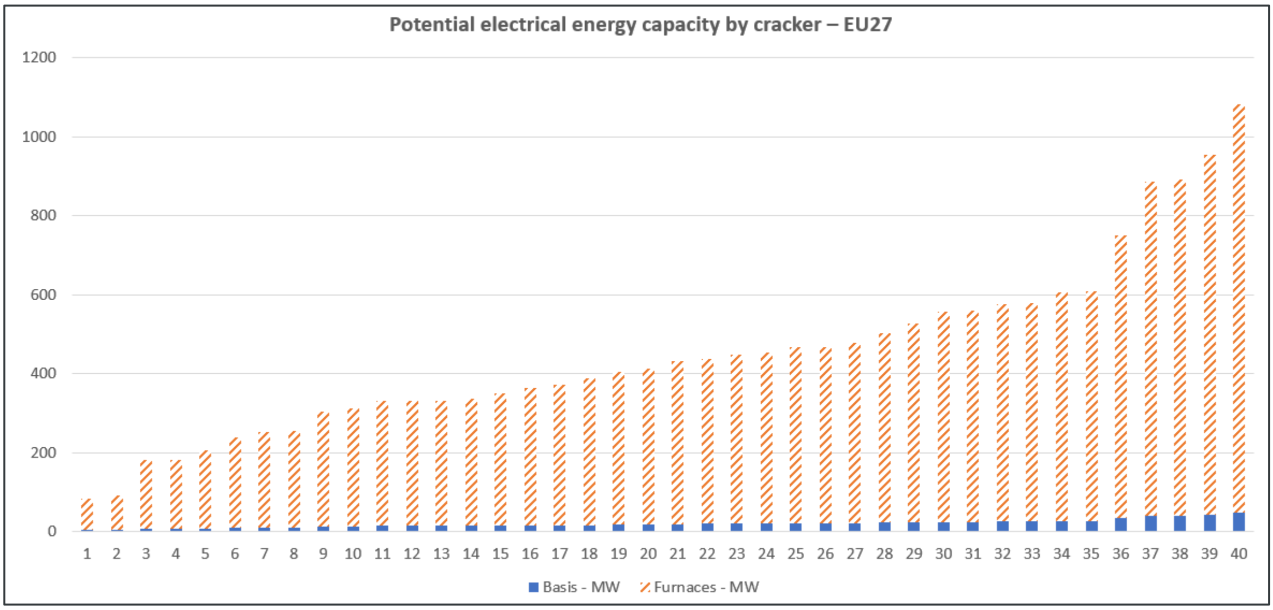
[9] Petrochemistry in Europe - Petrochemicals Europe - Petrochemicals Europe

Considering current steam consumption, the median is 34 GWh, spanning from 7 GWh up to around 90 GWh (graph 2). Should this consumption be met by electricity such a figure can potentially be much higher since pumps and compressors can be driven by both electricity and steam.



Graph 2: Steam consumption by cracker, EU27 (2021). Source: Petrochemicals Europe, Cefic calculations.

Against this background, graph 3 shows the electrical capacity needed if all furnaces were electrified on top of the current electrical consumption. Such figure reaches up to around 1080 MW, with an average in the range of 430-475 MW.



Graph 3: Potential electrical energy capacity by cracker, EU27. Source: Petrochemicals Europe, Cefic calculations.

Sectoral application – Chlor Alkali

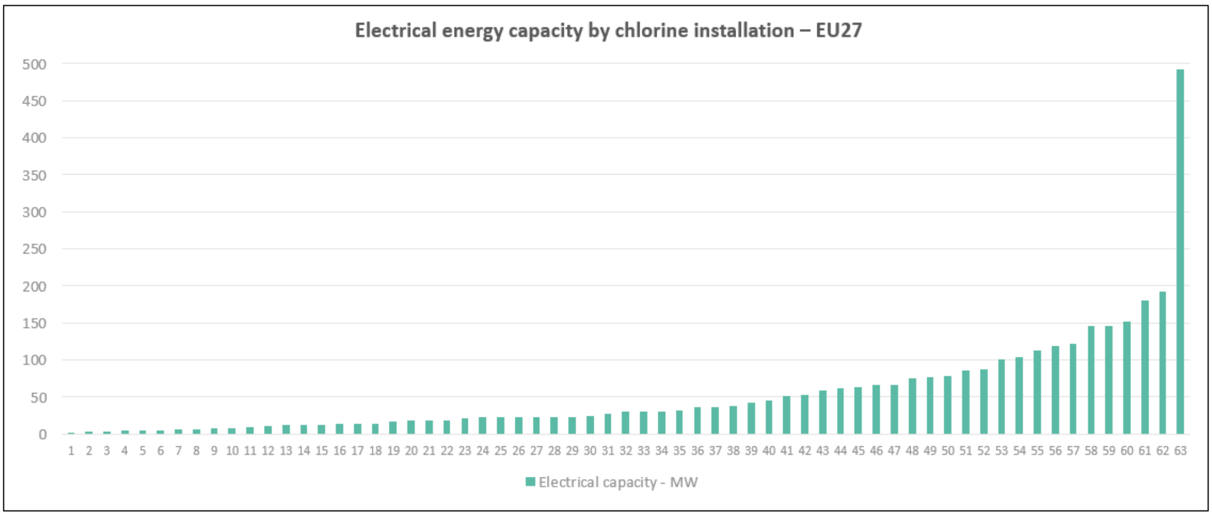
Energy needs for chlorine production in the Chlor Alkali sector[10] have been quantified for this analysis.

The assumptions considered are:

- EU27 scope;
- Total of 63 chlorine production sites are operational;
- Average chlorine production output of 181 Kt Cl_2/year;
- Total average primary electricity consumption is approx. 2660 kWh/t Cl_2 (2022);
- Steam consumption: 0.76 t/ t Cl_2;
- Steam pressure required (<15 Bar) at around 180°C;
- Process temperature up to 200°C[11];
- Installations running 24/7.

Based on the above assumptions, graph 4 shows chlorine production plants' (x-axis) electrical energy capacity (y-axis) needed. The results range from 1 MW up to around 500 MW[12], with the average installation requiring an electrical capacity of 55 MW. The total electricity and heat demand might increase in the future as chlorine is used in installations on the same chemical site for downstream processes, which might intensify the electrification of their processes to abate emissions.

Being a power-intensive process, the cost of electricity for chlorine production accounts for 58-62% of total production costs[13]. As such, on-site electricity production would allow us to address the challenges posed by the increased volatility of electricity production from renewable energy sources.



Graph 4: Electrical energy capacity by chlorine production plant, EU27 (2022). Source: EuroChlor, Cefic calculations.

Chlor Alkali plants consume steam alongside electricity in the production process. Steam is consumed in the evaporation process and to keep the electrolysers operational, which is required

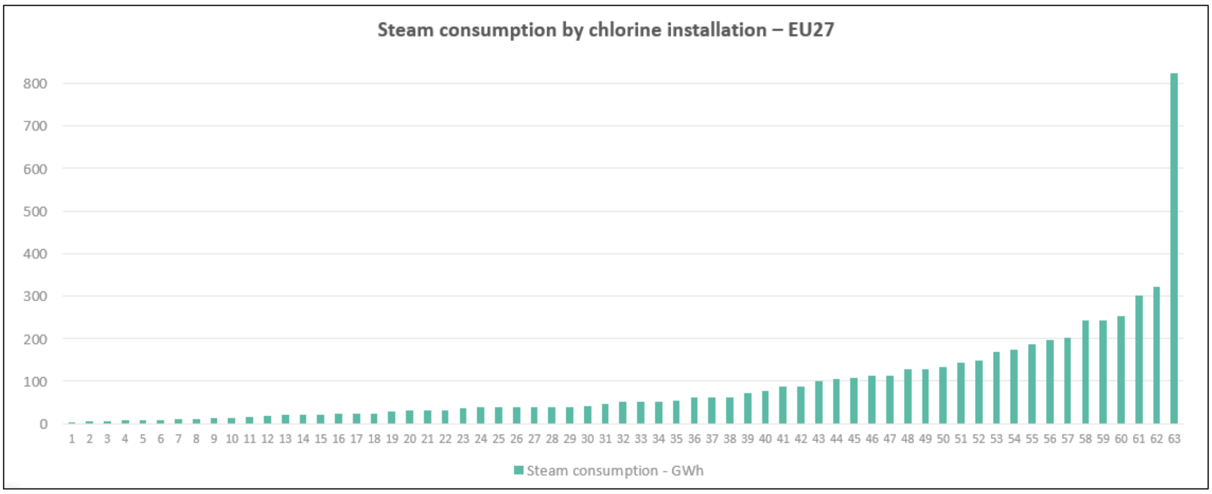
[10] Home - Eurochlor

[11] The process temperature can reach up to 200°C in caustic evaporation and up to 90°C in the rest of the installation.

[12] The last installation represented in the graph stands out due to the fact that several plants operate in the same site.

[13] Home - Eurochlor

when operating at low production rates. Graph 5 shows the volumes of steam consumed (y-axis) by the production plant (x-axis), which span from 2 GWh to 823 GWh, with a median of 50 GWh.



Graph 5: Steam consumption by chlorine production plant, EU27 (2022). Source: EuroChlor, Cefic calculations.

Next Steps to create a Business Model

The chemical industry with its long investment cycles needs regulatory clarity to be competitive in its transition.

This paper has quantified the potential role that Small Modular Reactors could play in providing on-site energy generation in the chemical sector.

Further discussions should focus on addressing the challenges ahead and should be targeted to **create a technology-positive framework**. This entails allowing for the widest possible choice of abatement technologies and solutions that contribute to reducing emissions which allow industry to thrive in Europe.

Building a business model which encompasses the industry needs and designing a supportive European regulatory framework is key.

For a comprehensive overview of the chemical industry's views on facilitating the industrial deployment of SMRs, please consult Cefic's paper '[Chemical Industry Views on Facilitating Industrial Small Modular Reactor (SMR) Deployment]'.

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About Cefic
Cefic, the European Chemical Industry Council, founded in 1972, is the voice of large, medium and small chemical companies across Europe, which provide 1.2 million jobs and account for 14% of world chemicals production.