VOLTA CHEM

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Accelerating Industrial Electrification

KEY INSIGHT **#1**

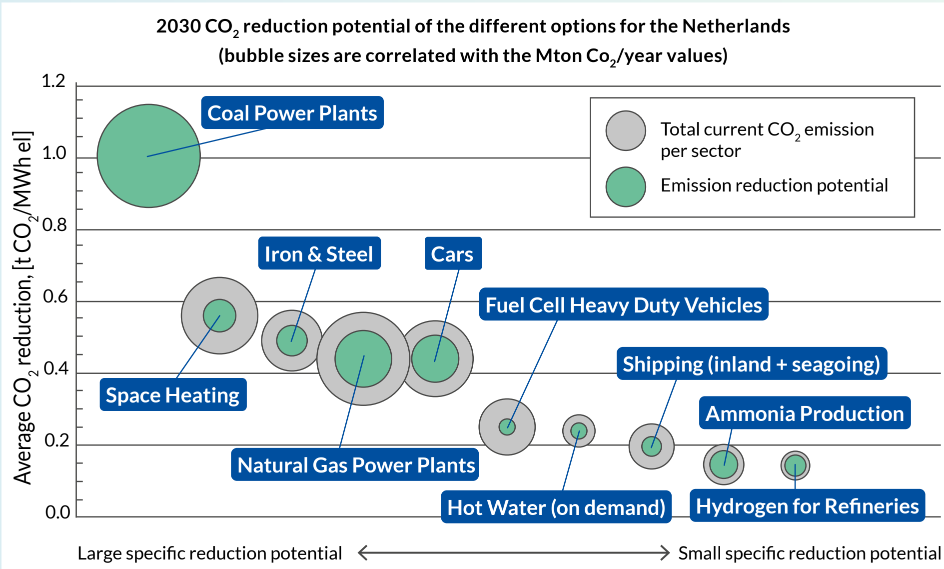
# Merit Order of Electrification

## Or how to prioritize renewable electricity to realize the highest $CO_2$ emission reduction

**KEY TAKEAWAYS**

Electrification will play a significant role in decarbonization of our economy and reaching the 2030–2050 climate goals. VoltaChem conducted a study on where electrification and associated investments have the greatest impact. The following uses of renewable power stand out in terms of their $CO_2$ reduction per MWh el: 1) displacing coal and natural gas-based power generation; 2) replacing internal combustion engine vehicles with battery electric vehicles; 3) using heat pumps for domestic/commercial heating purposes; 4) fully electrified (H-DRI) process for steel production. (See Figure 1 for the resulting merit order).

Assuming a decade would be sufficient time going from development to implementing, these options also have a large potential for reducing $CO_2$ emissions in the Netherlands up to 2030. Electrification of the industrial sector ($NH_3$ production and $H_2$ for refineries in figure 1) has a limited $CO_2$ reduction potential compared to power transport and building sector when looking at the short term (<2030). However, a decarbonized industrial sector is key in reaching the 2050 climate goals. So, due to the potential for circularity and long technology development cycles, the industry must be active in decarbonization already or at least from now on. Needless to say that investments in electrification should be aligned with the growth of renewable power generation.




| | | Coal PPs | Space heating | Iron & Steel | NG PPs | Cars | HDVs | Hot water | Shipping | Ammonia | Refinery Hydrogen | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2018 $CO_2$ emissions | [Mton $CO_2$/y] | 35.0 | 18.9 | 12.5 | 28.4 | 18.6 | 10.2 | 3.5 | 7.0 | 5.4 | 2.9 | **142.4** |
| 2030 percentage | [% 'green'] | 100.0 | 20.0 | 25.0 | 40.0 | 40.0 | 10.0 | 33.0 | 20.0 | 50.0 | 50.0 | **48.0** |
| 2030 reduction potential | [Mton $CO_2$/y] | 35.0 | 3.8 | 3.1 | 11.4 | 7.4 | 1.0 | 1.2 | 1.4 | 2.7 | 1.4 | **68.4** |
| Power demand in 2030 | [TWh/y] | 35.0 | 6.7 | 6.4 | 25.8 | 16.9 | 4.1 | 4.9 | 7.1 | 18.2 | 10.0 | **135.2** |

**Figure 1:** Comparison of current $CO_2$ emissions from various sectors and the potential impact of high-ranking decarbonization options.

**INTRODUCTION**

Achieving 2030–2050 targets, to avoid the worst consequences of climate change, requires a rapid decline of emissions to stabilize the concentration of $CO_2$ in the atmosphere. This entails drastic changes to our energy systems. Tackling the problem relies on a combination of behavioural changes (e.g., in line with Reduce / Reuse / Recycle/ Recover principles) and the implementation of a wide range of technical solutions, spanning across multiple domains such as: Increased energy efficiency & fuel switching, Direct & indirect electrification (e.g., through the use of green $H_2$ produced by electrolysis), Carbon Capture Storage and Utilization. These areas are also interrelated. For instance, producing synthetic fuels via $CO_2$, utilization requires large amounts of clean energy, which can be delivered in the form of green electrons or an energy carrier such as green $H_2$. This is of key interest within the VoltaChem Shared Innovation Program, which aims to develop technologies to accelerate industrial electrification in order to create a fully sustainable chemical industry.

There are many solutions in the form of electrification options, not only for industry but also for transport and the built environment. However, emissions will be significantly reduced only if low-carbon electricity is used from renewable sources such as wind and solar power plants. Their use is rapidly expanding, yet biomass and renewables combined still only account for a relatively small fraction (<10%) of final energy use in the Netherlands. Considering the urgency of reducing $CO_2$ emissions, the challenge for the coming decades is making the best use of these scarcely available sources of low-carbon energy. But how to prioritize between different ways of using renewable electricity across different sectors to realize our emission reduction targets most effectively?

## APPROACH

This study provides a partial answer to these questions by evaluating a key dimension of the comparison between available options: the $CO_2$ emissions reduction potential per unit of energy. The starting point is a base unit of 1MWh of renewable power, which was not assumed to be 100% carbon-free. Instead, an intensity factor of 50 kg $CO_2$/MWh was used as a conservative estimate, to factor in additional emissions from hardware installation, embedded emissions, and grid balancing, etc. A broad range of electrification options across multiple sectors was used (Power sector, Transport and Buildings), ranging from electric resistance furnaces for high temperature heat in industry to battery-electric vehicles. Each electrification option was compared against a fossil-based reference (counterfactual), using literature data and average efficiency estimates, see Figure 2. Please note that this study doesn't account for other important factors such as costs and implementation-related challenges, cost per ton of $CO_2$ abated, technology maturity and ease of deployment, implications for the national power grid. An additional dimension to study could be to also evaluate how the electrification option compares to other decarbonization solutions.

## RESULTS

The measure of $CO_2$ reduction potential per MWh is a common denominator, so all the (direct & indirect) electrification options can be compared to each other, see Figure 3.
Displacing coal-based power generation for existing demand stands out as a high-priority option, but this will likely require grid adaptations and also the addition of power storage solutions. Because the use of coal results in high $CO_2$ emissions per unit of energy used, the electrification of steel production also ranks highly in this comparison. Options which inherently use electricity in an efficient manner also stand out, for instance heat pumps with a high coefficient of performance (heat to power ratio). Battery electric vehicles also have a very good $CO_2$ reduction potential, as they replace cars with internal combustion engines, which are comparatively inefficient at converting fuel energy into motion. The energy needed for charging the batteries can be generated by green energy sources.

Aside from the specific $CO_2$ reduction potential (per MWh of renewable energy), it's also important to consider the overall scale of emissions and the corresponding emissions reduction potential for various decarbonization options, in absolute terms. These are compared in Figure 1, using indicative assumptions for the potential of various options to be deployed in the Netherlands by 2030 (for comparison purposes, the percentages don't represent actual decarbonization scenarios). The following uses of renewable power stand out in terms of their $CO_2$ reduction per MWh el: 1) displacing coal and natural gas-based power generation; 2) replacing internal combustion engine vehicles with battery electric vehicles; 3) using heat pumps for domestic/commercial heating purposes; 4) fully electrified (H-DRI) process for steel production. Assuming a decade would be sufficient time for development and implementation, these options can offer a substantial contribution to the realization of the 2030 $CO_2$ emissions reduction target of the Netherlands.

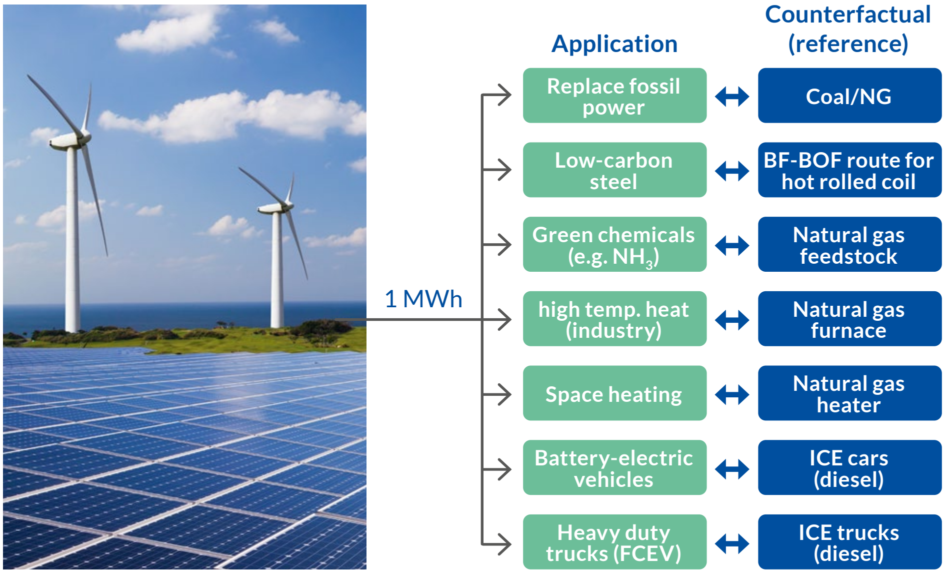



**Figure 2:** Overview of the electrification options which were evaluated as part of this study, and the conventional technologies against which their $CO_2$ reduction potential was benchmarked.

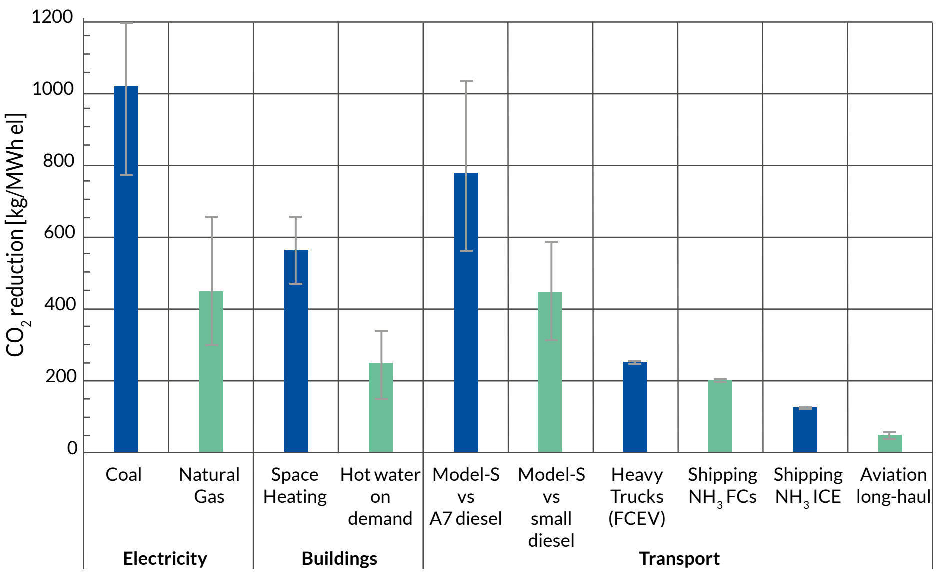



**Figure 3:** Comparison between the $CO_2$ reduction potential of various electrification solutions, across three major sectors (power generation, buildings and transport)

## WANT TO KNOW MORE?


**Contact**
**Martijn de Graaff**
*Program director VoltaChem*
+31 (0) 6 22 26 08 71
martijn.degraaff@voltachem.com


**Or visit**
www.voltachem.com