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The untold potential and rationale of industrial electrification in the United States

June 2024

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Global awareness for a more inclusive and climate-positive world is at an all-time high. This includes carbon emissions as well as preventing environmental damage and biodiversity loss.

Global awareness for a more inclusive and climate-positive world is at an all-time high. This includes carbon emissions as well as preventing environmental damage and biodiversity loss. Nation states and corporations are increasingly making climate pledges and including sustainability themes in their governance. Yet, progress is nowhere near where it should be. For global society to achieve these goals, more action and speed is needed.

How can we convert momentum into reality? By aligning action with United Nations Sustainable Development Goals. By leveraging scientific research and technology. By gaining a better understanding of the future of energy and industry, and of the social, environmental, technological and geopolitical shifts happening all around us. By reinforcing the legislative and financial drivers that can galvanize more action. And by being clear on what the private and public sectors can do to make all this happen

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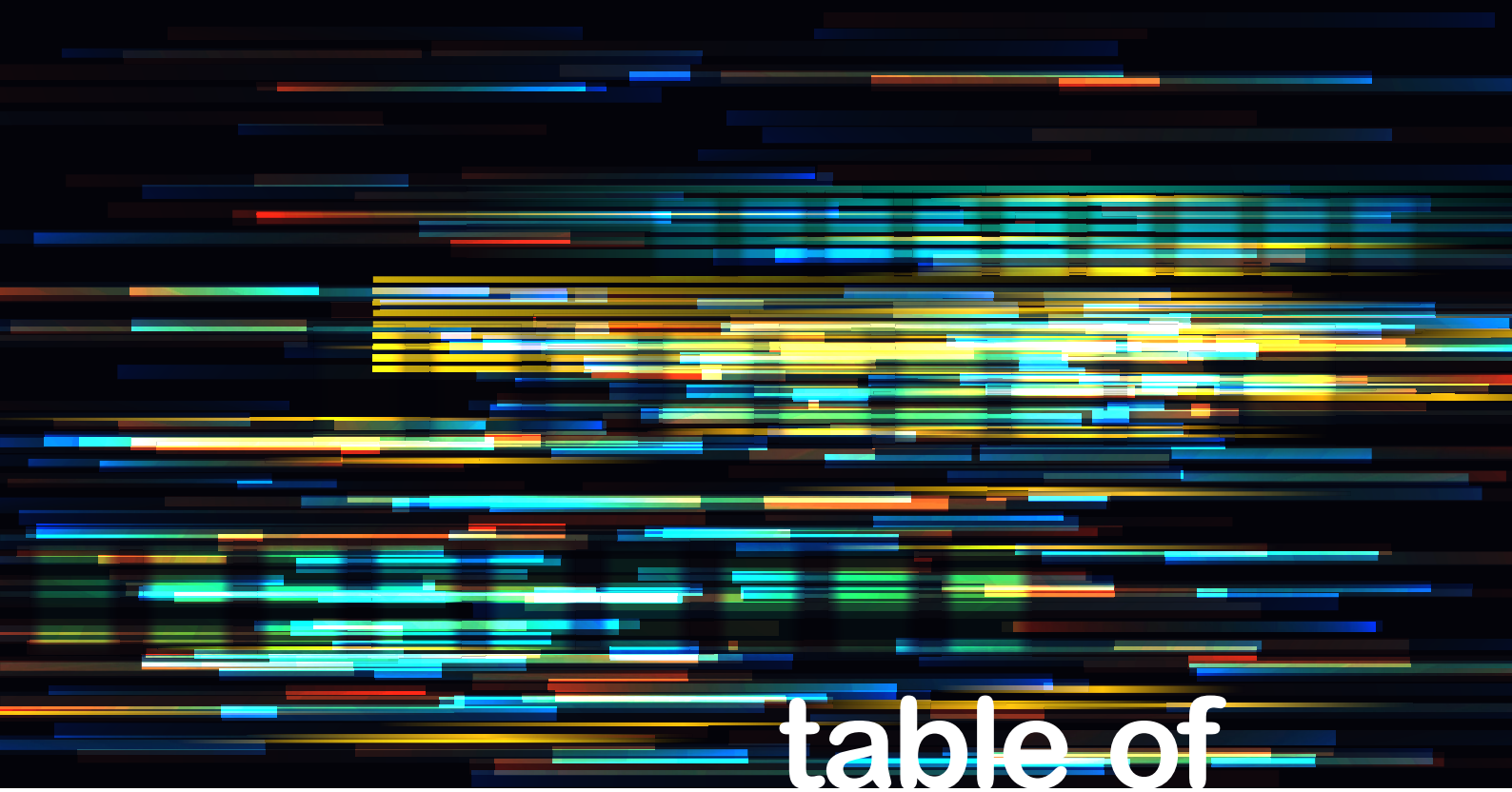
Set up in 2020, our team is part of Schneider Electric, the leader in the digital transformation of energy management and automation, whose purpose is to bridge progress and sustainability for all.

We build our work on regular exchanges with institutional, academic and research experts, collaborating with them on research projects where relevant. Our findings are publicly available online, and our experts regularly speak at forums to share their insights.

In this report, we explore to which extent the decarbonization of industry could be accelerated, a theme which has today been lacking focus compared to the transition of other sectors such as buildings and mobility. We notably explore the potential of electrification as a promising option. We find that the share of electricity in industry energy could increase by 50% in the very short run, by focusing on all these processes for which existing and compelling solutions already exist at scale, with electricity reaching nearly half of final energy demand. Such a transition would help cut emissions of the industry sector by around 100MtCO2/y, a target readily achievable before 2030.



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Executive summary

Many U.S. states have embraced addressing climate change as a priority, implementing ambitious policies to spur the U.S. economy and meet the U.S. climate pledge to reach carbon neutrality by 2050.

To date, 33 states have published a climate action plan or are in the process of doing so. While the transition is in full swing, strongly supported by recent and historical legislation such as the "Inflation Reduction Act" (IRA), current plans mostly emphasize the decarbonization of buildings and transportation.

In these two sectors, solutions exist at scale for a rapid turnaround of emissions. In this report, we argue that a significant potential also exists in industry, coupled with the need for more action. There are three reasons for this:

- Given the severity of severe weather events and other impacts of climate change, it's critical to maximize every opportunity to decarbonize segments of the economy at rapid pace. Not all emissions are equal, and those that can be abated more rapidly hold considerably more value than longer-term prospects.
- The ongoing transitions of buildings and mobility will also have ripple effects on industries, particularly regarding natural gas prices for industrial customers. A lack of focus on industrial transitions will also entail rising prices for the sector, impacting competitiveness.
- The significant increase in domestic production capabilities (notably following the IRA) represents a major opportunity to accelerate the decarbonization of industry, if done right.

In this report, we explore the potential of electrification of industry in the U.S. as one of the most promising options to achieve this goal. We look at this potential not only in terms of technical feasibility, but also in terms of practicality. We are indeed interested in understanding the extent industry could electrify in the short run, i.e., in the coming decade. We are thus voluntarily conservative in our approach.

Our analysis suggests that the share of electricity in the industry energy mix could jump rapidly from around 30% to date (on the scope covered) to 45%, or a 50% increase. This would translate into a reduction of fossil fuels demand of around 25%, and savings of around 100MtCO2 per year.

Such a transition appears readily achievable within the next decade, and represents a major opportunity to accelerate the U.S. decarbonization agenda. It requires, however, a new policy agenda, focused on those short-term opportunities and on removing the inherent barriers of adoption, which revolve around three main themes: capabilities, financials, and power grids.

1 U.S. industry needs to accelerate on decarbonization

Looking at industry in a different way reveals many decarbonization opportunities

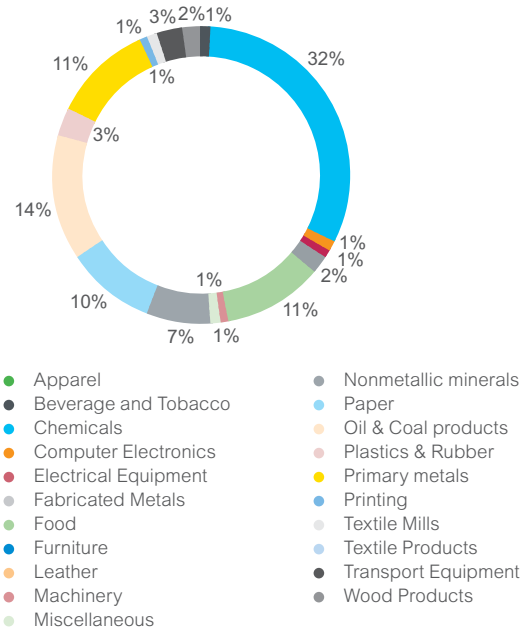
Today's U.S. industry final energy demand (with some exclusions, see footnote and annex) ranges around 10,000 trillion British thermal units (tBtu). This data is extracted from the Manufacturing Energy Consumption Survey from the Energy Information Administration (EIA, 2018)[1].

Five sectors account for around 75% of energy (hence emissions): the chemicals, petroleum and coal products, primary metals, nonmetallic minerals and paper industries (Figure 1). These are traditionally qualified as "hard to abate" sectors, because decarbonizing them at scale is difficult (EnergyTransitionsCommission, 2018). This suggests that decarbonization efforts should thus concentrate in those sectors, what has indeed been the key focus. **However, the reality is more complex.**

A deeper look within each process activity highlights three fundamental processes (Figures 2 to 5):

- Indirect energy use for boilers and co-generation (30% of total). Combined heat and power (CHP)/co-generation represents two-thirds of the total with traditional boilers (for steam) representing the rest.
- Direct energy use for processing (60% of total). This is dominated by process heating (55%) and motion (or machine drives, 30%), with the remaining 15% split between cooling and refrigeration, specific electrochemical processes, and other uses.
- Direct energy use for non-processing activities (10% of total). This is dominated by heating, ventilation, and air-conditioning (HVAC) systems (60%), lighting, and other facility support activities (e.g. IT) for around 30%, and the remaining 10% allocated between small energy uses.

Figure 1 – Share of final energy demand in industry, by sector



(1) We use in this report the perimeter defined by the MCES survey, table 5.4 (End uses of Fuel Consumption). It is representative of around two-thirds of final energy demand in industry, which ranges at around 15,000 tBtu (and excludes non-energy use). The difference is due to net steam use in certain industries for local power and heat generation purposes. 85% of this energy is used in the paper industry, the chemicals industry, and the oil and coal products industry. See annex for more details.

Figure 2 – Share of final energy demand in industry, by process

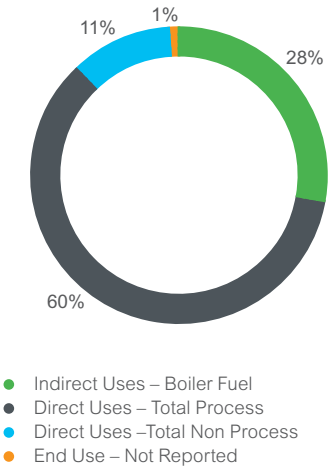


Figure 3 – Share of energy demand for indirect uses – boiler fuels

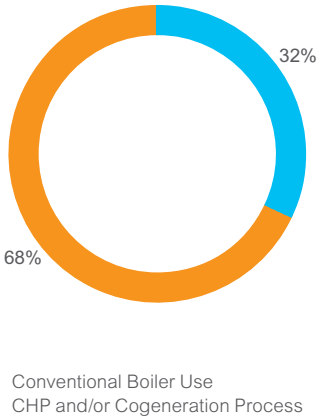


Figure 4 – Share of energy demand for direct uses – process

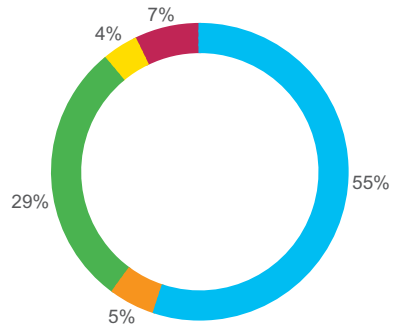


Figure 5 – Share of energy demand for direct uses – non-process

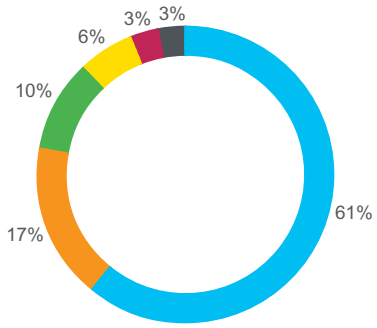
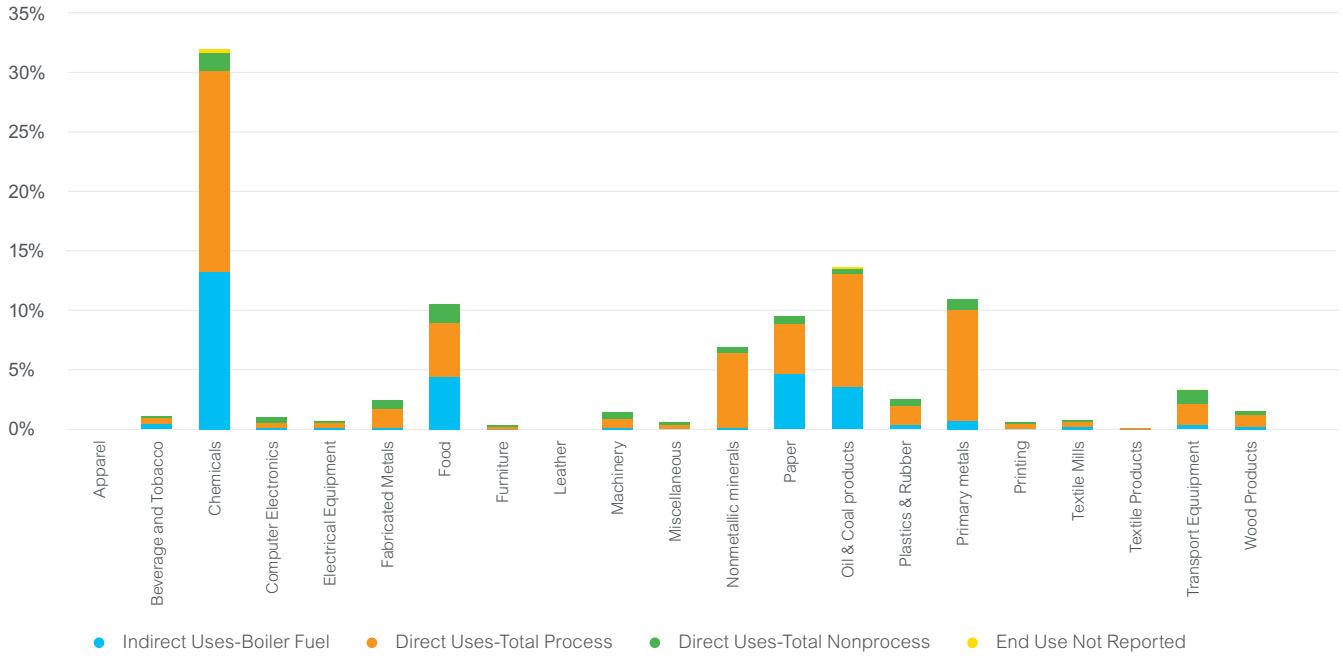


Figure 6 shows a consolidation of these breakdowns. Boiler fuels account for a significant share of final energy demand in the chemicals, paper, oil and coal products, and the food industry. Direct energy use for processing is significant in hard to abate industries, yet not negligible in other sectors such as fabricated metal products, food, transport equipment, machinery, and wood products industries. While the graph below confirms the fundamental role of hard to abate sectors, a detailed breakdown by process type also suggests another perspective. “Hard to abate” refers to those process heating systems reliant on high-temperature and complex and integrated designs. They in fact represent only around 40% of final energy demand[2], the rest coming from lower-temperature process heating systems or cooling systems, boilers, and energy stemming from facility management (e.g. HVAC). **A process-by-process approach suggests that 60% of industry energy could in fact be decarbonized at a greater pace and with greater ease.**

(2) We include here both process heating systems from hard to abate sectors as well as the energy demand for co-generation, particularly relevant in several of those sectors (chemicals, petroleum and coal products, and the paper industries). Without co-generation, those hard-to-abate process heating systems account for 27% of final energy demand.

Figure 6 – Share of final energy demand



U.S. industry emissions need to be abated more rapidly

The average temperature rise on the planet is now 1.2 degrees higher than pre-industrial levels (ClimateActionTracker, 2022). The change in global climate conditions is more a result of accumulated concentration of greenhouse gases in the Earth's atmosphere over time than of annual greenhouse gas emissions. In fact, it is the concentration of these emissions that drives greenhouse gas effect, as one year's emissions have limited impact overall on Earth's systems.

Although obvious, it has fundamental consequences. While many countries around the world have pledged to reach carbon neutrality by mid-century, a target confirmed by the **Intergovernmental Panel on Climate Change (IPCC, 2022), it matters more to rapidly bring emissions down than to actually meet a net-zero target in the distant future.** To account for this, the IPCC uses carbon budgets. Carbon budgets evaluate the overall amount of GHG emissions which can still be emitted to remain under a certain concentration level (hence a certain rise in temperature). The global carbon budget has been estimated to range around 500 $GtCO_2$ (from 2019) for a 50% chance to stay below 1.5˚C of global warming, and 1,350 $GtCO_2$ for a 50% chance to stay below 2˚C. More recent scientific advances suggest that the budget for 1.5˚C has in fact dropped to 250 $GtCO_2$ since the IPCC report, with the 2˚C target also dropping (Trendafilova, 2023). With an annual run rate of around 40 $GtCO_2$ per year, the 1.5˚C carbon budget will be entirely depleted by or earlier than 2030.

Emissions are thus not all equal; those that can be reduced more rapidly hold much greater value than those that could be reduced in the future (even if massive). This concept is already well understood across the U.S. with significant programs in place to decarbonize the buildings and mobility sectors at an accelerated pace, together accounting for around 70% of total emissions[3] (EIA, 2022). However, this is also very relevant for industry (30% of U.S. emissions) and challenges the current focus on hard to abate sectors. While there is a specific focus on innovation for industry decarbonization in the U.S., there is currently no known policy program across the U.S. on industry electrification (Gold, 2021; Nadel, 2019).

A deeper focus on what could be achieved rapidly in industry is required

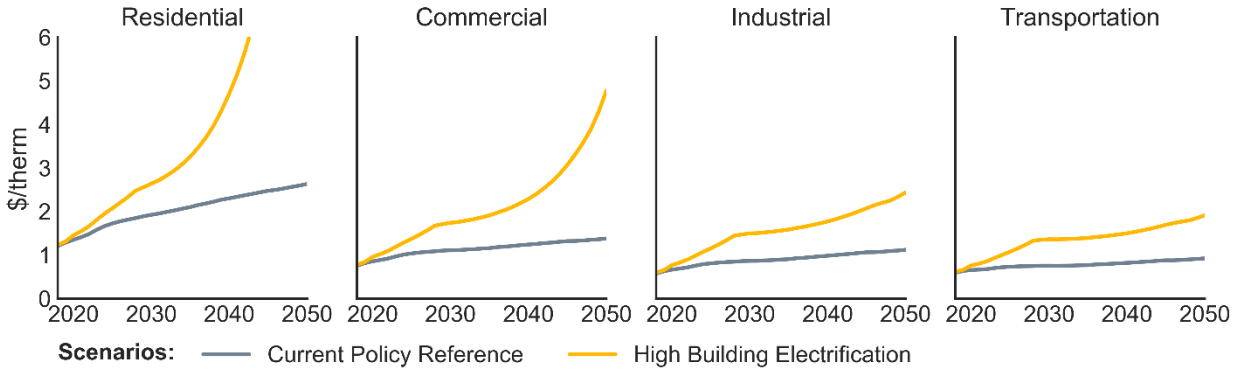
(3) Total emissions across end-use sectors, including electricity. If we exclude indirect emissions associated to electricity from this account, the shares are different. OECD/IEA. (2022). *World Energy Outlook. International Energy Agency.* https://www.iea.org/reports/world-energy-outlook-2022.

The U.S. industrial complex is caught in the line of fire

Many U.S. states have by now embraced climate change and designed ambitious policies to turn around the U.S. economy and meet the U.S. climate pledge to reach carbon neutrality by 2050. To date, 33 states have published a climate action plan or are in the process of doing so (C2ES, n.d.). And, as discussed, most these states are particularly focused, in the short term (i.e. in the coming decade to 2030), on the buildings and mobility sectors.

The California Energy Commission has published interesting insights on the second order effects of such ongoing transitions on industrial energy prices (Mahone et al., 2020). The accelerated transition of the building stock to electric solutions and the subsequent switch away from natural gas is indeed expected to yield **a strong increase of retail natural gas prices not only in buildings, but also in industry** (Figure 7). This is mainly because a lower number of consumers need to bear (largely fixed and recurring) natural gas grid costs. The effect is particularly important for industry, with a significant rise (near-doubling) in prices by the early 2030s (in a scenario where the ambitious plans on building electrification effectively materialize).

Figure 7 – Rising natural gas prices in California, retrieved from Mahone et al. (2020)



There is a critical transitional issue for industries as other sectors move away from the natural gas grid, which is generally overlooked. This is particularly relevant in the context of rapid relocalization of a number of industries in the country. Will these new facilities be built for a net-zero world, relying on alternative and sustainable energy resources, or will they be connected to the existing natural gas grid and perpetuate reliance on fossil fuels?

This not only concerns hard to abate industries (which by nature are less impacted because of contract terms and the fact they are often connected to transmission grids), but also (and more so) other segments of industry, which have been less of a priority until now.

This finding also suggests that a greater focus must be placed on industry decarbonization before 2030, for both existing and new facilities, and with a wider focus than that of hard to abate sectors.

2 An agenda for rapid electrification of U.S. industry

In this research, we focus on one solution to accelerate the decarbonization of industry: direct electrification. We explore to which extent industry segments can be electrified, and at which pace.

We leverage a methodology already used in another report (SchneiderElectric, 2022), albeit with slight modifications, and inspired by a seminal research paper from Madeddu et al. (2020).

Our methodology consists of studying subprocesses of each segment of industry, and assessing the extent these could be electrified. We look not only at the technological feasibility, but also the extent supporting industries (e.g., equipment manufacturing) exist, the cost of change, as well as the impact on existing processes. Our assessment aims to identify what can be electrified rapidly across industry, i.e., in the coming decade.

The detailed methodology is discussed in the annex. As a summary, we define three steps of electrification opportunities

- Step 1 accounts for all activities that are already feasible, with no impact on the industrial process (essentially upgrades of equipment), and leveraging products and solutions that are already in use in the ongoing transition of the building sector. This includes notably most nonprocess uses (e.g., facility HVAC), electrification of machine drives (for those not already electric), and the rapid switch of fossil fuel boilers (to produce steam) to their electric equivalent.
- Step 2 includes additional parts of industrial processes that are considered both technically and economically feasible in the short run, based on research from Madeddu et al. (2020), BeyondZeroEmissions (2018) and Hasanbeigi (2023). This includes all cooling and refrigeration processes as well as process heating in sectors deemed relevant (see annex).
- Step3 encompasses additional electrification opportunities that necessitate innovation or the upscaling of emerging technologies, and may be subject to feasibility constraints such as capex requirements, impact on operational expenses, and the need for significant process redesigns. These opportunities are not considered short-term, yet they are presented as the next round of electrification potential.

Steps 1 and 2 correspond to short-term opportunities, i.e. transitions that can materialize at scale because of products and solutions already widely available on the market, and because these do not entail major process redesigns, and can in some cases prove to be economic.

Step 3 corresponds to more distant targets of decarbonization and represents the larger potential of direct electrification in the medium term.

Overall, we have designed these steps in order to remain very conservative on the potential decarbonization of the U.S. industry in the decade to 2030 (see annex). We have imposed on ourselves several limitations and excluded a number of opportunities that could also become relevant more rapidly.

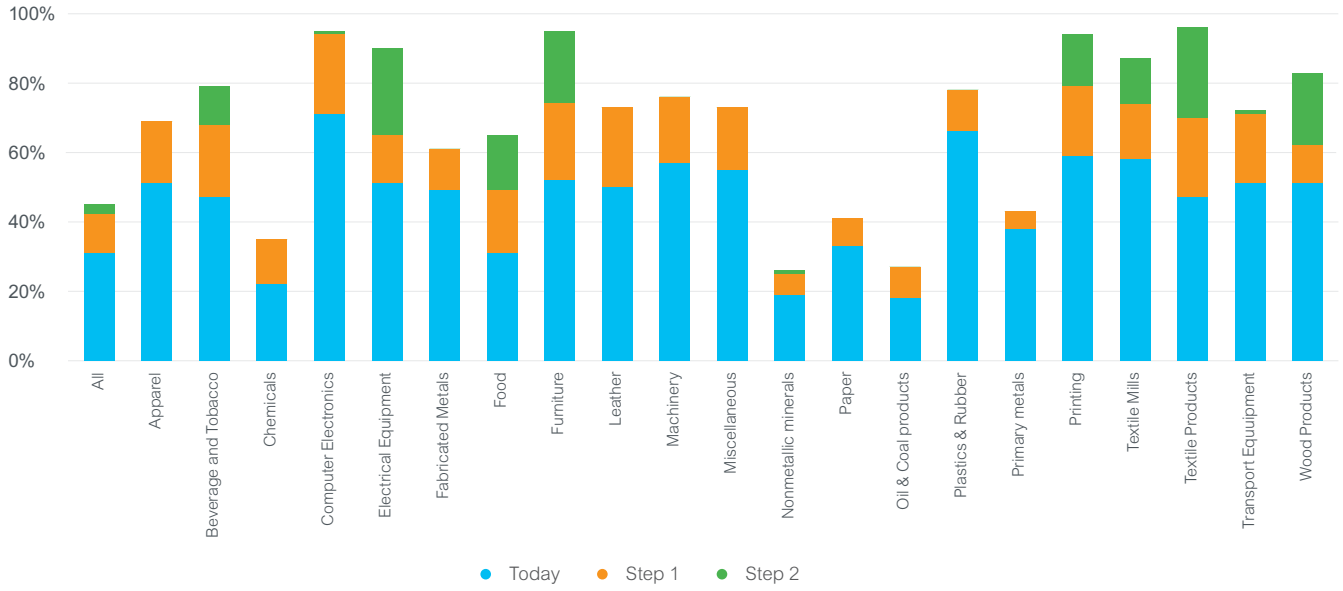
3 In the short term, nearly half of industrial energy could be electrified

The first question we try to answer is “How much of industry energy demand could we electrify in the short term?”

In this part, we focus on Steps 1 and 2 only. Overall, the level of electrification increases from 31% to 45%, a 50% increase in share (Figure 8). Eight out of 21 sectors reviewed here reach 80% electrification or more, and 16 reach a level of electrification 60% or more.

Step 1 represents the bulk of that increase and concerns all sectors of activity. Step 2 brings an additional contribution in specific sectors such as the food and beverage, textiles, electrical equipment, transport equipment, and wood product industries.

Figure 8 – Short-term electrification potential



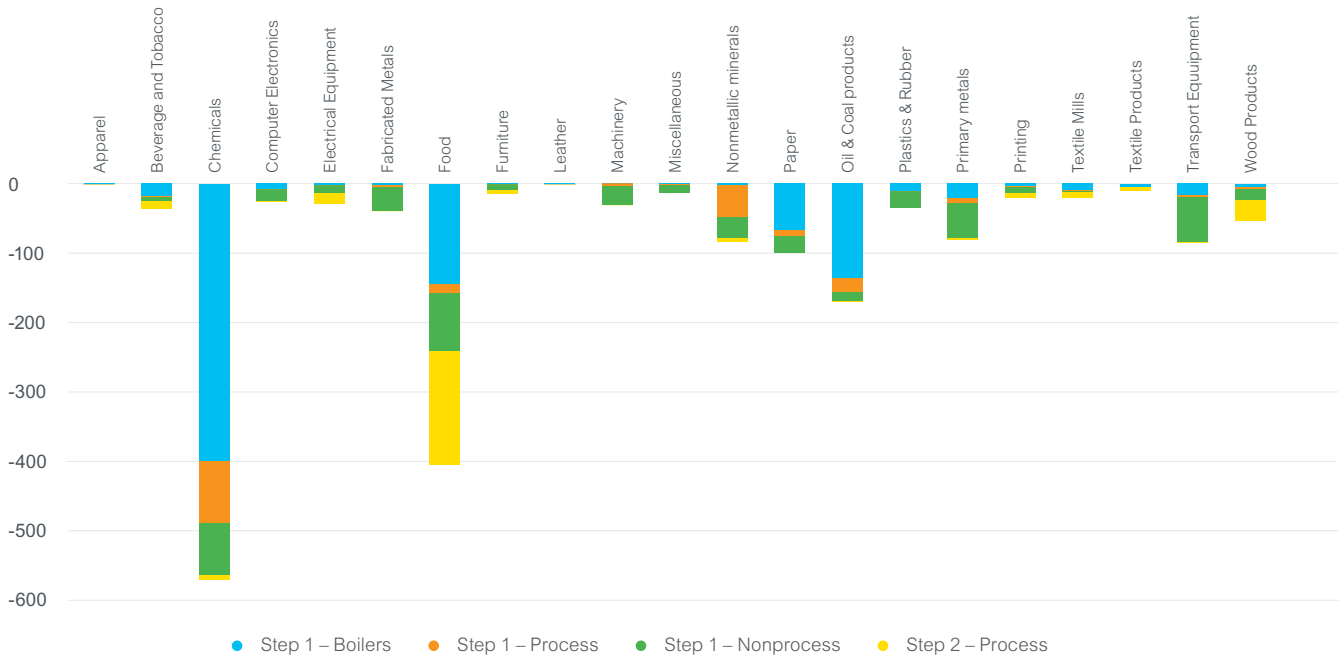
In steps 1 and 2, **fossil fuels demand drops as a result by 25%** (Figure 9). Around 50% of that drop is due to the electrification of industrial boilers across most industries. 25% comes from non process uses (e.g., facility HVAC) and another 25% from direct electrification of process uses.
More importantly, 50% of that drop comes from non-hard to abate sectors, i.e., sectors which have not been yet under the focus of policy. In hard to abate sectors, the drop is mainly centered around the chemicals industry.

This suggests that a considerable potential exists for rapid abatement of industry emissions. A 25% reduction of fossil fuels demand in industry accounts for 1,800 tBtu per year, or around 100MtCO2 per year . Obviously electrification substitutes this demand in part (there are efficiency gains associated with electrification), but we argue that, since most of this electricity demand is additional, it will be zero-carbon, as the bulk of new capacities installed in the U.S. are already compliant with a net-zero carbon future power system.

(4) As discussed above, this is based on energy-related end-uses, hence excludes feedstocks.
(5) This raw estimate is based on standard emission intensities per source. We have used data from the Energy Information Administration: for coal, 100 $kgCO_2$/MMBtu; for oil, 75 $kgCO_2$/MMBtu; and for natural gas, 50 $kgCO_2$/MMBtu.

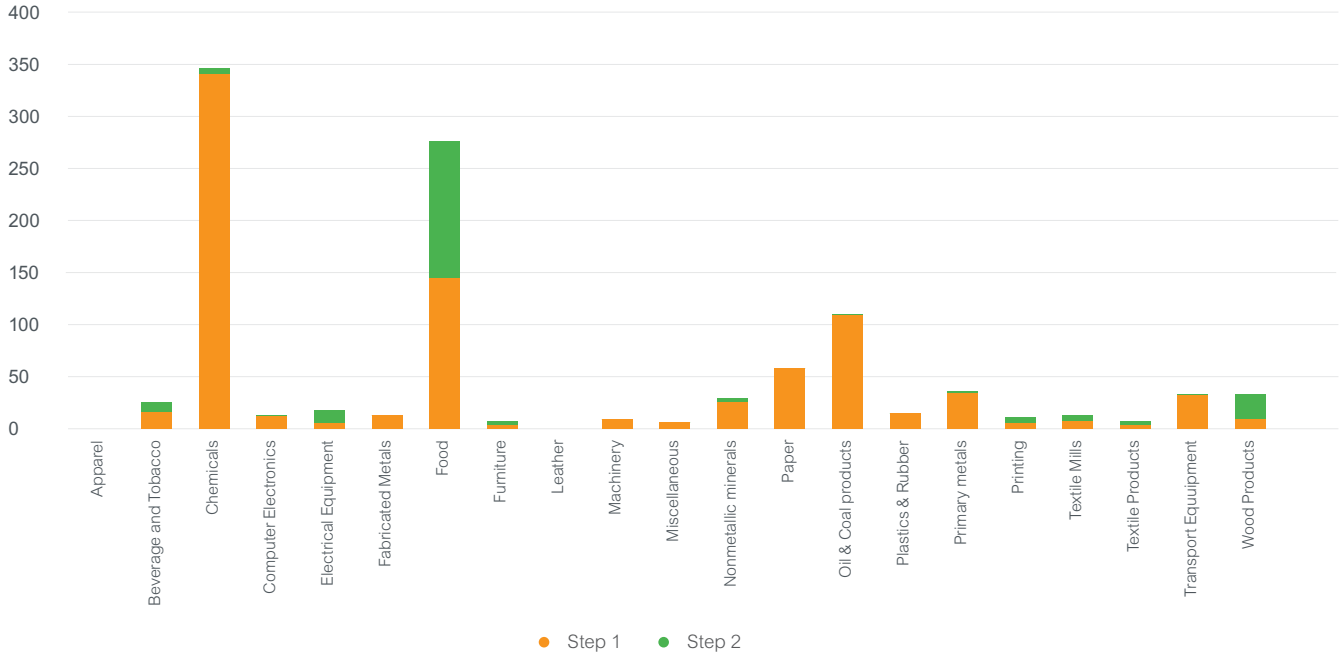
In the short term, nearly half of industrial energy could be electrified

Figure 9 – Short-term impact on fossil fuels demand, tBtu



This substitution of fossil fuels will lead to additional electricity demand, which would increase by around 1,000 tBtu (or 300 TWh/y). The difference between the rise in electricity demand and the drop in fossil fuels demand corresponds to the expected efficiency gains in total energy demand from switching from one to the other. The main impact will concern chemical and food facilities (60% of total). These facilities in particular are likely to be primarily concerned with issues of grid accessibility and grid reinforcements.

Figure 10 – Short-term impact on electricity demand, tBtu

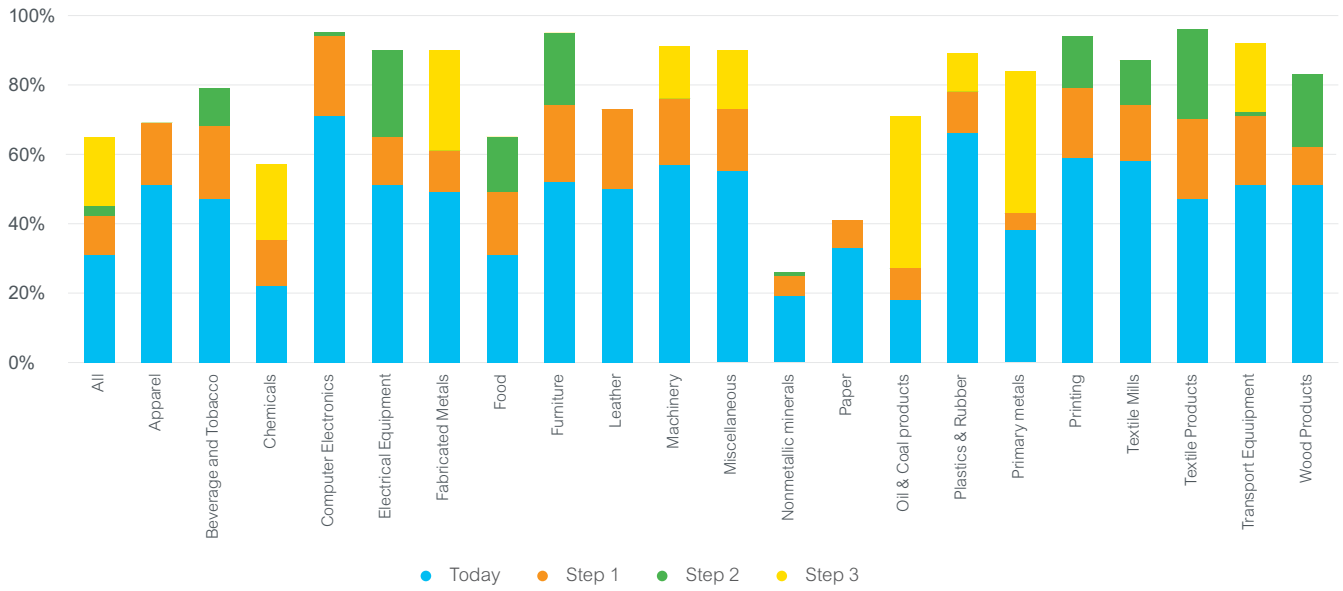


4 In the medium term, nearly two-thirds of industrial energy could be electrified

Nearly half of industrial energy demand could be electrified rapidly in the short term. This forecast, as promising as it may seem, remains conservative. In this chapter, we also integrate the effects of Step 3 in our projections.

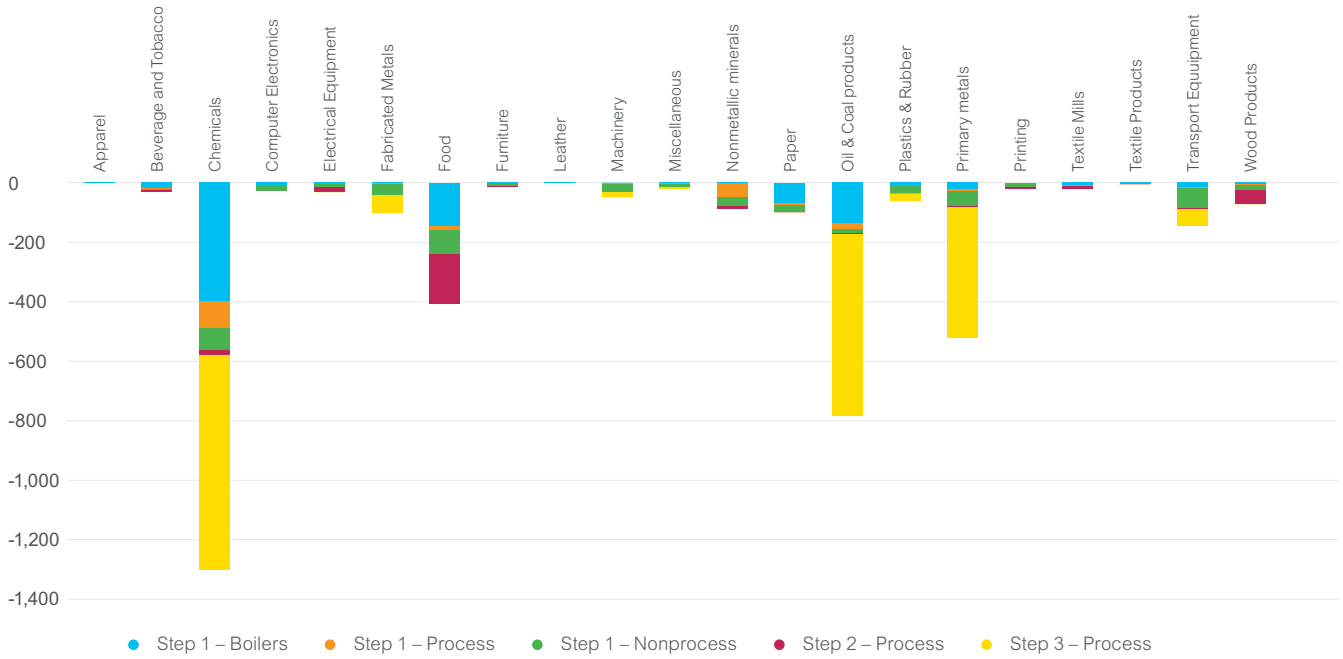
Step 3 represents all opportunities that may require some level of innovation (pilot stage technologies), some scaling up of new and crucial value chains, as well as tackling some feasibility constraints (primarily necessary process redesigns). Step 3 therefore represents a longer-term perspective, one that could begin to materialize before 2030 and scale up in the 2030s. We estimate the corresponding level of **electrification of industry to reach 64%**. With the exception of three (hard to abate) sectors, all parts of industry reach a level of electrification 60% or above, and among them, 14 sectors hit the 80% mark.

Figure 11 – Total electrification potential



The consequence of such level of electrification would be a reduction of 50% in fossil fuels use (as an energy resource) in industry (3,800 tBtu), or an estimated drop in emissions of around 200 $MtCO_2/y$. The bulk of that drop would primarily occur in hard to abate sectors and concerns the deployment of electric cracking and electric furnace technologies. Significant budget has already been allocated to support the scaling up of such new technologies in the U.S. (DOE, 2023).

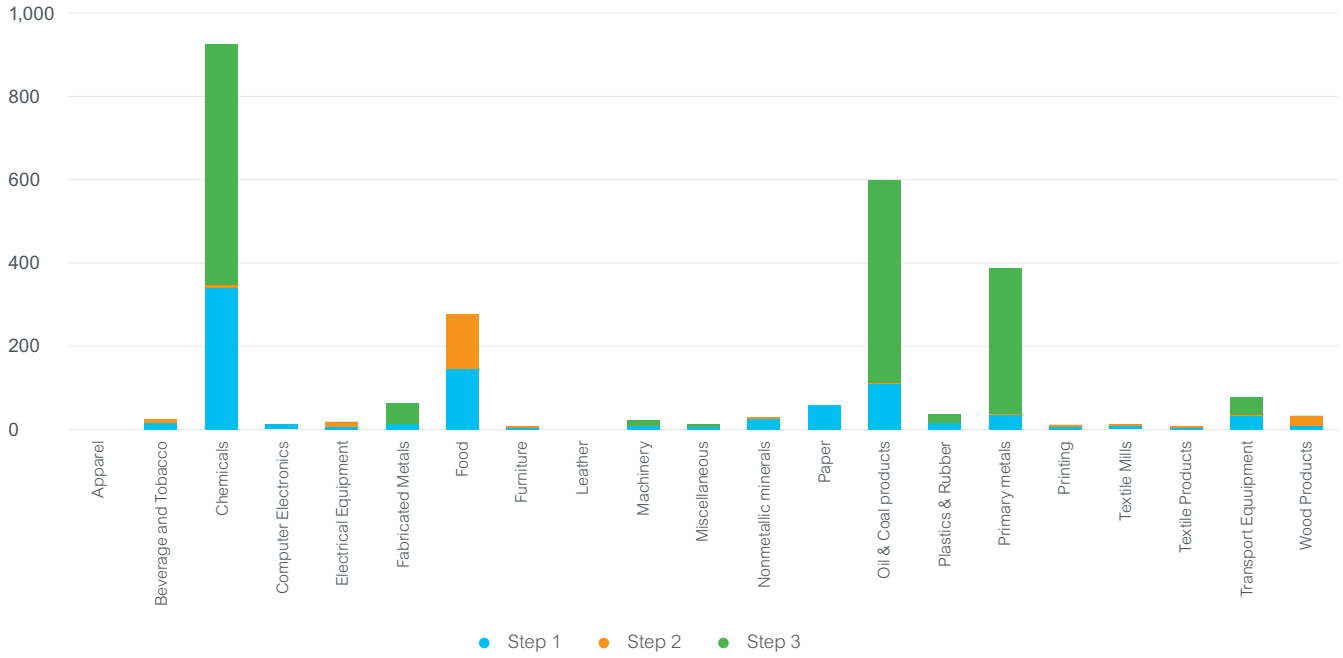
Figure 12 – Total fossil fuels demand impact, tBtu



The impact in terms of electricity demand would be significant with an additional 2,600 tBtu (or 760 TWh/y) required, and significant grid reinforcement and extension issues around key sectors of activity.

In the medium term, nearly two-thirds of industrial energy could be electrified

Figure 13 – Total additional electricity demand impact, tBtu



Why do we not reach 100% electrification in Step 3?

Given our assumptions in Step 3, a key question worth asking is whether or not higher electrification levels could be reached. We develop this in the annex, but there are several assumptions that we have made which limit this potential:

- First, we have excluded from our analysis the potential to convert existing CHP/co-generation and local electricity generation systems. Together, they account for around 22% of industry final energy demand (in Step 3). About 80% of these systems are in use in the chemicals, paper, food, and petroleum/coal products industries. Our rationale to exclude these is their significant integration with existing processes. Any transition of these systems would significantly reshuffle those. A further switch away from these end-uses is thus likely to require further research and take more time.
- Second, we have by design excluded all process uses that were not properly defined (category "others") or not reported upon. They represent around 5% of industrial energy demand (in Step 3).
- Lastly, when determining a process eligible for electrification (heat or cooling), we have assumed a maximum penetration rate of 90%. Our rationale for this choice was to adopt a more conservative perspective regarding what could be realistically achieved within a short timeframe, as opposed to the full technical potential. This approach allows for consideration of existing sites where transitions may prove more complex than initially anticipated. This assumption could also be subject to further debate in subsequent research

We can also look at how our study compares to the seminal research from Madeddu et al. (2020). Madeddu looked at the electrification potential of various industries and split the technical opportunity in stages, as we have done here. This report has been a source of inspiration for our own study. Our analysis however differs in two ways

- Roughly speaking, Madeddu's stages correspond to the approach we have used here: stage 1 corresponds to technologies already available at scale, stage 2 to technologies that will require a more "substantial upgrade", and stage 3 to the maximum achievable potential, involving innovation. In our study, we also follow the same approach, albeit with less a focus on heating temperature levels, and rather on technological availability.
- We also integrate in our study a "feasibility" parameter, to account for those changes that may require significant process upgrades, or be highly capex- or opex-intensive (see annex).

Both are sufficiently close in their approach to be compared, however. They also confirm the significant potential of electrification. And if Madeddu's study focused on the European energy system, other studies have also confirmed this potential for the U.S. (Deason et al., 2018; Hasanbeigi, 2023). For Hasanbeigi (2023), our results are comparatively close, even if the methodological approach is slightly different.

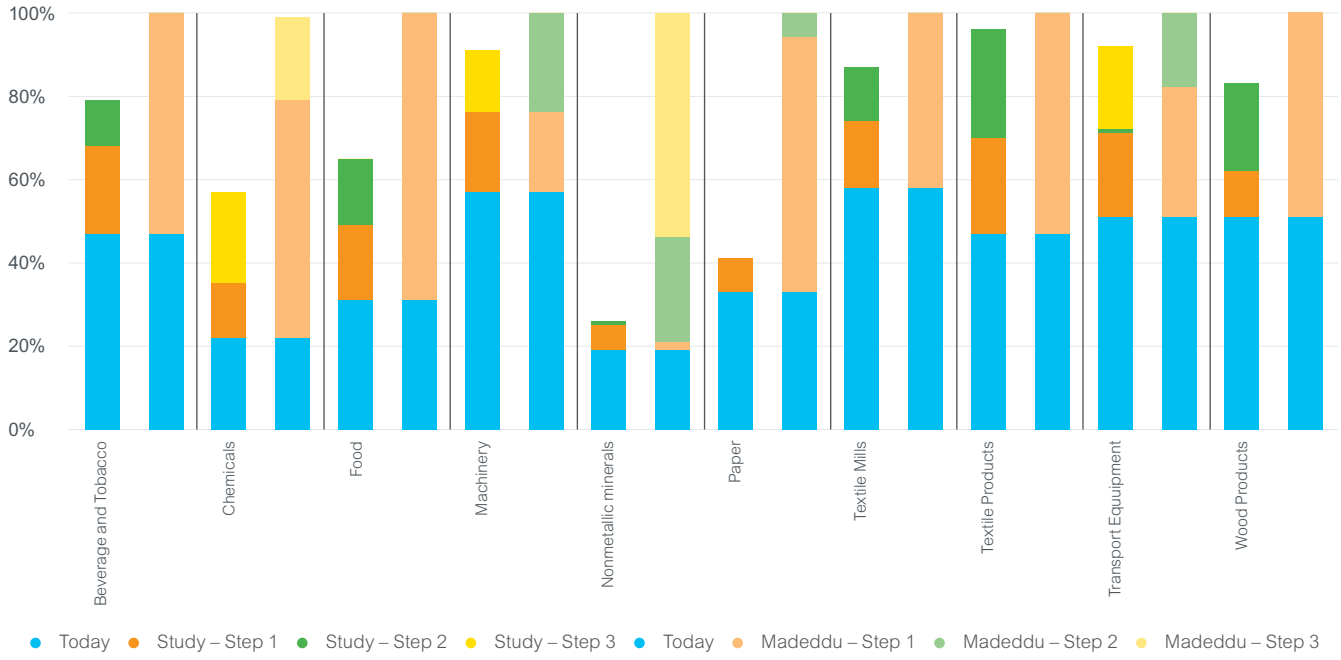
Figure 14 summarizes the key differences between Madeddu's study and this report:

- If we focus first on steps 1 and 2 (short run potential), we find that we consistently fall below the maximum potential identified by Madeddu et al. (2020), which confirms our generally conservative approach. Most sectors indeed exhibit a technical potential well above 80%, to the exception of the nonmetallic minerals sector. We are notably extremely conservative in the food and the paper industries. For the paper industry at least, this is due to the precautions we took given the integrated level of existing processes.
- For Step 3, we also remain well below the estimated potentials, in part for the reasons we have discussed above. We can note that we have not considered any Step 3 potential for non-metallic minerals or the paper industry, given the very low level of actual technological readiness.

The key to these differences is one of approach: rather than a focus on the technical potential, we have tried to focus on what could be achieved pragmatically within a specific time frame, hence the differences. **These also confirm the fact that more will be achievable in the long run.**

In the medium term, nearly two-thirds of industrial energy could be electrified

Figure 14 – Comparisons across two studies



5 A new agenda is needed

The decarbonization of industry in the U.S. must accelerate, and electrification offers a promising avenue to do so. In the short term, the level of electrification of industry could jump from 31% today (based on our scope) up to 45%. This could represent a rapid decline in fossil fuels demand of 25%, and emission savings of 100 $MtCO_2$/y.

A key finding of this report is also that around half of this reduction will not come from traditionally hard to abate sectors, but rather from sectors that one could qualify as "easy to abate". The electrification of steam boilers could provide for 50% of these savings, with another 25% coming from facility management, and the remaining 25% process equipment changes for industrial heating and cooling and machine drive electrification.

Over time, this potential is even more significant, with a target of 64% electrification in a not-distant future, and a 50% reduction in fossil fuels demand in industry, yet this time more concentrated in hard to abate sectors.

This major opportunity challenges the current hard to abate-centric approach to industry decarbonization, which suggests little is achievable until new innovations deploy at scale. On the contrary, **we find that adopting a process-per-process approach offers significant benefits in the short run.** Such evolution of the industry energy system will however face key roadblocks that require a complementary policy focus around industry electrification. We identify three critical avenues to consider.

Awareness and capabilities

There is overall a lack of awareness of this potential among industry actors, which would call for more information, as well as the possible development of a dedicated office or information clearinghouse per state to support the transition.

Accessing to the right level of capabilities might also prove to be an issue. While industries should benefit from the ongoing transition in buildings (regarding the electrification of facilities for instance, e.g., facility HVAC), key questions remain regarding the electrification of boilers and various process heating and cooling systems. The ramp up of performing value chains will prove critical and should be the object of dedicated policy support.

The current rise in domestic production capabilities in the U.S. following the "Inflation Reduction Act" (IRA) should also serve as a key enabler. Mandates to build "net zero" could be widely adopted to foster the ramp up of these value chains as well as industry-wide awareness, which could then benefit other actors.

Financials

Capital expenses required to transition and upgrade equipment will be a main barrier of adoption if this transition is to happen in the short run. This could be alleviated by a combination of mandates, targets as well as grants and/or investment tax incentives to foster a more rapid adoption than that which would be witnessed if every single upgrade were to happen at the normal refurbishment rate of industry. Additional policy would also be required to prevent those refurbishments be done with conventional solutions, what would further perpetuate the reliance on fossil fuels in the long run.

Operational expenses (opex) are also a main issue, given today's low cost of natural gas relative to electricity (although, as discussed above, this trend is set to evolve by 2030).

- Hasanbeigi (2023) mentions that a ratio of 1:2 (price of natural gas over price of electricity) is required to make electrification competitive. While trends suggest we are likely to converge toward such ratios over time (as we switch from one "dominant design" to another, Suarez et al. (2015)), this is unlikely to be the case in the short run. Production tax incentives could here support the shift, alongside support to adopt alternative electricity purchase options such as long-term PPAs (which would also incentivize the power sector to further decarbonize). This may however not need to apply on non process uses, which follow similar patterns than buildings electrification.
- In addition, to the exception of specific energy-intensive sectors (which do not form the bulk of the savings in the early steps), the share of energy costs is a minor part of total costs of goods sold, what makes electrification less problematic. Moreover, co-benefits associated with electrification (e.g., increased products quality or processing speed) could also prove essential in fostering the switch over time, although it will require gradual improvements in understanding technology benefits.
- Finally, a state-by-state approach to retail electricity schemes would also be needed, given the significant energy storage potential of some technologies, notably industrial boilers. Given the rising need for flexibility on the power system with the rapid penetration of intermittent renewable energies, such provisions could offer significant benefits to the grid, which could be best put at use leveraging modern (e.g., Time of Use) tariff schemes.

Grid reinforcements and the utility equation

As industries electrify, the demand for electricity will also increase significantly. In steps 1 + 2, we estimate this rise to be about 300TWh per year. On the one hand, this will call for additional investments in power generation, but more so in grid reinforcements, which take several years to materialize. In fact, the lack of power grid could prevent a more rapid transition on the demand side, for the lack of network to connect to. This is already a problem witnessed in France for instance, as requests to connect to the power system from various industrial players has doubled in 18 months (Raynal, 2023). Digital solutions could also provide for better use of power grids and mitigate needed reinforcement in some areas.

While electrification of industry will also present several opportunities for utilities to develop new services to industrial customers (including, as discussed above, on flexibility), such a rapid change will require major investments in power grids (that will need to be recouped), and will also come at the expense of natural gas grids and their associated revenues. This also requires a specific policy focus to ensure a smooth transition from a utility standpoint.

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Annex

Initial dataset

We are leveraging the data from the Energy Information Administration (EIA) gathered during the last Manufacturing Energy Consumption Survey (MECS) (EIA, 2018). Through this thorough survey (the last one was in 2014), the EIA has been able to collect, for each sector of the U.S. industry, the energy consumption, per type of source, and for each process within each sector, with the following split (table 5.4 of the MECS):

- Indirect uses for boilers (steam production)
  - Conventional boilers
  - CHP and other co-generation methods
- Direct uses for process
  - Process heating
  - Process cooling and refrigeration
  - Machine drives
  - Electro-chemical processes (e.g. electrolysis)
  - Other process uses
- Direct uses for non-process
  - Facility HVAC
  - Facility lighting
  - Other facility support (e.g. IT)
  - Onsite transportation
  - Conventional electricity generation (e.g. gensets)
  - Other non-process uses
- End-use not reported

Some data being not available, very small, or not disclosed, and existing uncertainties (standard deviations) in the statistical collection existing in the dataset, have caused us to retreat the file in order to produce accurate aggregations. This only marginally changes the overall energy demand levels (by less than 0.5% overall); hence, we consider it acceptable given the level of aggregation of our research.

The retreated dataset that we use is presented below (in red the retreated figures).

Figure A1 – Initial dataset

SECTOR	SOURCE	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	**TOTAL**	**9,947**	**2,825**	**891**	**1,935**	**6,006**	**3,315**	**281**	**1,771**	**249**	**390**	**1,059**	**650**	**180**	**108**	**63**	**29**	**29**	**57**
ALL	Electricity	**3,034**	**43**	43	1	**2,450**	296	255	1,573	249	77	**520**	258	180	57	13	0	12	**21**
ALL	Oil + HGL	**135**	**24**	12	13	**47**	31	0	14	0	1	**63**	6	0	0	50	2	5	**1**
ALL	Natural Gas	**6,347**	**2,569**	823	1,747	**3,267**	2,810	22	168	0	266	**476**	386	0	51	0	27	12	**35**
ALL	Coal	**431**	**189**	14	175	**242**	178	3	15	0	46	**0**	0	0	0	0	0	0	**0**
APPAREL	**TOTAL**	**4**	**1**	**1**	**1**	**2**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
APPAREL	Electricity	**2**	**0**	0	0	**1**	0	0	1	0	0	**1**	1	0	0	0	0	0	**0**
APPAREL	Oil + HGL	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
APPAREL	Natural Gas	**2**	**1**	1	1	**1**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
APPAREL	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
BEVERAGE AND TOBACCO PRODUCTS	**TOTAL**	**104**	**36**	**19**	**17**	**51**	**13**	**10**	**26**	**0**	**2**	**17**	**9**	**4**	**2**	**1**	**0**	**0**	**0**
BEVERAGE AND TOBACCO PRODUCTS	Electricity	**49**	**1**	1	0	**37**	1	10	25	0	1	**11**	5	4	1	1	0	0	**0**
BEVERAGE AND TOBACCO PRODUCTS	Oil + HGL	**1**	**0**	0	0	**0**	0	0	0	0	0	**1**	0	0	0	0	0	0	**0**
BEVERAGE AND TOBACCO PRODUCTS	Natural Gas	**54**	**35**	18	17	**14**	12	0	1	0	1	**5**	4	0	1	0	0	0	**0**
BEVERAGE AND TOBACCO PRODUCTS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
CHEMICALS	**TOTAL**	**3,176**	**1,313**	**407**	**906**	**1,684**	**827**	**77**	**462**	**135**	**183**	**152**	**96**	**25**	**20**	**5**	**1**	**5**	**27**
CHEMICALS	Electricity	**707**	**8**	8	0	**613**	22	68	373	135	15	**76**	39	25	9	1	0	2	**10**
CHEMICALS	Oil + HGL	**11**	**5**	3	2	**1**	1	0	0	0	0	**4**	0	0	0	4	0	0	**1**
CHEMICALS	Natural Gas	**2,345**	**1,202**	389	813	**1,055**	797	9	89	0	160	**72**	57	0	11	0	1	3	**16**
CHEMICALS	Coal	**113**	**98**	7	91	**15**	7	0	0	0	8	**0**	0	0	0	0	0	0	**0**
COMPUTER AND ELECTRONIC PRODUCTS	**TOTAL**	**105**	**12**	**9**	**3**	**44**	**8**	**12**	**14**	**2**	**8**	**46**	**34**	**6**	**4**	**0**	**0**	**2**	**3**
COMPUTER AND ELECTRONIC PRODUCTS	Electricity	**75**	**1**	1	0	**42**	7	12	14	2	7	**29**	19	6	3	0	0	1	**3**
COMPUTER AND ELECTRONIC PRODUCTS	Oil + HGL	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
COMPUTER AND ELECTRONIC PRODUCTS	Natural Gas	**30**	**11**	8	3	**2**	1	0	0	0	1	**17**	15	0	1	0	0	1	**0**
COMPUTER AND ELECTRONIC PRODUCTS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
ELEC. EQUIP., APPLIANCES, COMPONENTS	**TOTAL**	**71**	**6**	**2**	**4**	**43**	**26**	**2**	**13**	**0**	**2**	**22**	**16**	**3**	**2**	**1**	**0**	**0**	**0**
ELEC. EQUIP., APPLIANCES, COMPONENTS	Electricity	**36**	**0**	0	0	**25**	8	2	13	0	2	**11**	7	3	1	0	0	0	**0**
ELEC. EQUIP., APPLIANCES, COMPONENTS	Oil + HGL	**1**	**0**	0	0	**0**	0	0	0	0	0	**1**	0	0	0	1	0	0	**0**
ELEC. EQUIP., APPLIANCES, COMPONENTS	Natural Gas	**34**	**6**	2	4	**18**	18	0	0	0	0	**10**	9	0	1	0	0	0	**0**
ELEC. EQUIP., APPLIANCES, COMPONENTS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
FABRICATED METAL PRODUCTS	**TOTAL**	**242**	**14**	**3**	**11**	**158**	**90**	**5**	**53**	**6**	**4**	**70**	**49**	**13**	**5**	**3**	**0**	**0**	**0**
FABRICATED METAL PRODUCTS	Electricity	**119**	**1**	1	0	**84**	20	5	51	6	2	**34**	17	13	3	1	0	0	**0**
FABRICATED METAL PRODUCTS	Oil + HGL	**3**	**0**	0	0	**0**	0	0	0	0	0	**3**	1	0	0	2	0	0	**0**
FABRICATED METAL PRODUCTS	Natural Gas	**120**	**13**	2	11	**74**	70	0	2	0	2	**33**	31	0	2	0	0	0	**0**
FABRICATED METAL PRODUCTS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
FOOD	**TOTAL**	**1,054**	**439**	**153**	**286**	**448**	**189**	**89**	**149**	**2**	**18**	**157**	**90**	**28**	**29**	**6**	**2**	**2**	**10**
FOOD	Electricity	**323**	**9**	9	0	**237**	11	85	135	2	4	**72**	34	28	6	3	0	1	**5**
FOOD	Oil + HGL	**16**	**5**	3	2	**2**	1	0	0	0	0	**9**	3	0	0	3	2	1	**0**
FOOD	Natural Gas	**668**	**388**	136	252	**199**	167	4	14	0	14	**76**	53	0	23	0	0	0	**5**
FOOD	Coal	**47**	**37**	5	32	**10**	10	0	0	0	0	**0**	0	0	0	0	0	0	**0**
FURNITURE AND RELATED PRODUCTS	**TOTAL**	**31**	**1**	**1**	**1**	**16**	**7**	**0**	**9**	**0**	**0**	**14**	**10**	**2**	**1**	**0**	**0**	**0**	**0**
FURNITURE AND RELATED PRODUCTS	Electricity	**16**	**0**	0	0	**10**	1	0	9	0	0	**6**	3	2	1	0	0	0	**0**
FURNITURE AND RELATED PRODUCTS	Oil + HGL	**1**	**0**	0	0	**0**	0	0	0	0	0	**1**	0	0	0	0	0	0	**0**
FURNITURE AND RELATED PRODUCTS	Natural Gas	**14**	**1**	1	1	**6**	6	0	0	0	0	**7**	7	0	0	0	0	0	**0**
FURNITURE AND RELATED PRODUCTS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
LEATHER AND ALLIED PRODUCTS	**TOTAL**	**2**	**2**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
LEATHER AND ALLIED PRODUCTS	Electricity	**1**	**1**	1	1	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
LEATHER AND ALLIED PRODUCTS	Oil + HGL	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
LEATHER AND ALLIED PRODUCTS	Natural Gas	**1**	**1**	1	1	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
LEATHER AND ALLIED PRODUCTS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
MACHINERY	**TOTAL**	**136**	**6**	**1**	**5**	**74**	**23**	**3**	**44**	**0**	**4**	**56**	**40**	**10**	**4**	**2**	**0**	**0**	**0**
MACHINERY	Electricity	**78**	**1**	1	0	**49**	4	3	41	0	1	**28**	14	10	3	1	0	0	**0**
MACHINERY	Oil + HGL	**3**	**0**	0	0	**1**	0	0	0	0	1	**2**	1	0	0	1	0	0	**0**
MACHINERY	Natural Gas	**55**	**5**	0	5	**24**	19	0	3	0	2	**26**	25	0	1	0	0	0	**0**
MACHINERY	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
MISCELLANEOUS	**TOTAL**	**60**	**3**	**1**	**2**	**30**	**12**	**2**	**12**	**0**	**4**	**27**	**16**	**4**	**1**	**0**	**0**	**5**	**0**
MISCELLANEOUS	Electricity	**33**	**0**	0	0	**17**	2	2	11	0	2	**16**	8	4	1	0	0	3	**0**
MISCELLANEOUS	Oil + HGL	**1**	**0**	0	0	**0**	0	0	0	0	0	**1**	0	0	0	0	0	0	**0**
MISCELLANEOUS	Natural Gas	**26**	**3**	1	2	**13**	10	0	1	0	2	**10**	8	0	0	0	0	2	**0**
MISCELLANEOUS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
NONMETALLIC MINERAL PRODUCTS	**TOTAL**	**690**	**12**	**2**	**10**	**629**	**467**	**12**	**116**	**3**	**31**	**47**	**23**	**6**	**4**	**10**	**0**	**4**	**2**
NONMETALLIC MINERAL PRODUCTS	Electricity	**130**	**0**	0	0	**113**	26	6	71	3	7	**16**	7	6	2	0	0	1	**1**
NONMETALLIC MINERAL PRODUCTS	Oil + HGL	**22**	**0**	0	0	**10**	4	0	6	0	0	**12**	0	0	0	10	0	2	**0**
NONMETALLIC MINERAL PRODUCTS	Natural Gas	**349**	**12**	2	10	**317**	283	3	25	0	6	**19**	16	0	2	0	0	1	**1**
NONMETALLIC MINERAL PRODUCTS	Coal	**189**	**0**	0	0	**189**	154	3	14	0	18	**0**	0	0	0	0	0	0	**0**

Annex

SECTOR	SOURCE	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
PAPER	**TOTAL**	**946**	**459**	**80**	**379**	**421**	**156**	**9**	**244**	**3**	**9**	**66**	**34**	**14**	**7**	**5**	**6**	**0**	**0**
PAPER	Electricity	**310**	**13**	13	0	**261**	11	9	236	3	2	**36**	16	14	5	1	0	0	**0**
PAPER	Oil + HGL	**14**	**8**	1	7	**2**	2	0	0	0	0	**4**	0	0	0	4	0	0	**0**
PAPER	Natural Gas	**569**	**386**	65	321	**157**	143	0	7	0	7	**26**	18	0	2	0	6	0	**0**
PAPER	Coal	**53**	**52**	1	51	**1**	0	0	1	0	0	**0**	0	0	0	0	0	0	**0**
PETROLEUM AND COAL PRODUCTS	**TOTAL**	**1,357**	**347**	**138**	**209**	**949**	**687**	**12**	**220**	**4**	**26**	**51**	**15**	**6**	**4**	**4**	**20**	**2**	**10**
PETROLEUM AND COAL PRODUCTS	Electricity	**246**	**2**	2	0	**227**	9	11	201	4	2	**17**	8	6	3	0	0	0	**0**
PETROLEUM AND COAL PRODUCTS	Oil + HGL	**34**	**3**	2	1	**26**	22	0	4	0	0	**5**	0	0	0	4	0	1	**0**
PETROLEUM AND COAL PRODUCTS	Natural Gas	**1,077**	**342**	134	208	**696**	656	1	15	0	24	**29**	7	0	1	0	20	1	**10**
PETROLEUM AND COAL PRODUCTS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
PLASTICS AND RUBBER PRODUCTS	**TOTAL**	**251**	**31**	**11**	**20**	**157**	**48**	**14**	**86**	**2**	**7**	**63**	**38**	**13**	**6**	**4**	**0**	**2**	**0**
PLASTICS AND RUBBER PRODUCTS	Electricity	**165**	**0**	0	0	**126**	19	14	86	2	5	**39**	17	13	5	2	0	2	**0**
PLASTICS AND RUBBER PRODUCTS	Oil + HGL	**2**	**0**	0	0	**0**	0	0	0	0	0	**2**	0	0	0	2	0	0	**0**
PLASTICS AND RUBBER PRODUCTS	Natural Gas	**84**	**31**	11	20	**31**	29	0	0	0	2	**22**	21	0	1	0	0	0	**0**
PLASTICS AND RUBBER PRODUCTS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
PRIMARY METALS	**TOTAL**	**1,089**	**70**	**23**	**47**	**929**	**618**	**14**	**132**	**91**	**74**	**87**	**54**	**15**	**8**	**7**	**0**	**3**	**3**
PRIMARY METALS	Electricity	**415**	**2**	2	0	**376**	130	11	126	91	18	**36**	14	15	5	1	0	1	**1**
PRIMARY METALS	Oil + HGL	**8**	**0**	0	0	**2**	1	0	1	0	0	**6**	0	0	0	6	0	0	**0**
PRIMARY METALS	Natural Gas	**639**	**68**	21	47	**524**	480	3	5	0	36	**45**	40	0	3	0	0	2	**2**
PRIMARY METALS	Coal	**27**	**0**	0	0	**27**	7	0	0	0	20	**0**	0	0	0	0	0	0	**0**
PRINTING AND RELATED SUPPORT	**TOTAL**	**56**	**3**	**3**	**0**	**35**	**9**	**2**	**21**	**0**	**3**	**18**	**14**	**3**	**1**	**0**	**0**	**0**	**0**
PRINTING AND RELATED SUPPORT	Electricity	**33**	**0**	0	0	**23**	1	2	19	0	1	**10**	6	3	1	0	0	0	**0**
PRINTING AND RELATED SUPPORT	Oil + HGL	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
PRINTING AND RELATED SUPPORT	Natural Gas	**23**	**3**	3	0	**12**	8	0	2	0	2	**8**	8	0	0	0	0	0	**0**
PRINTING AND RELATED SUPPORT	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
TEXTILE MILLS	**TOTAL**	**64**	**16**	**10**	**7**	**37**	**12**	**2**	**22**	**0**	**1**	**11**	**8**	**2**	**1**	**0**	**0**	**0**	**0**
TEXTILE MILLS	Electricity	**37**	**1**	1	0	**27**	3	2	21	0	1	**9**	6	2	1	0	0	0	**0**
TEXTILE MILLS	Oil + HGL	**1**	**1**	1	1	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
TEXTILE MILLS	Natural Gas	**24**	**12**	7	5	**10**	9	0	1	0	0	**2**	2	0	0	0	0	0	**0**
TEXTILE MILLS	Coal	**2**	**2**	1	1	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
TEXTILE PRODUCT MILLS	**TOTAL**	**19**	**4**	**4**	**0**	**12**	**6**	**0**	**6**	**0**	**0**	**3**	**2**	**1**	**0**	**0**	**0**	**0**	**0**
TEXTILE PRODUCT MILLS	Electricity	**9**	**0**	0	0	**7**	1	0	6	0	0	**2**	1	1	0	0	0	0	**0**
TEXTILE PRODUCT MILLS	Oil + HGL	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
TEXTILE PRODUCT MILLS	Natural Gas	**10**	**4**	4	0	**5**	5	0	0	0	0	**1**	1	0	0	0	0	0	**0**
TEXTILE PRODUCT MILLS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
TRANSPORTATION EQUIPMENT	**TOTAL**	**336**	**29**	**17**	**12**	**183**	**79**	**14**	**79**	**1**	**10**	**123**	**89**	**20**	**7**	**5**	**0**	**2**	**1**
TRANSPORTATION EQUIPMENT	Electricity	**172**	**1**	1	0	**112**	16	12	76	1	7	**59**	31	20	5	2	0	1	**0**
TRANSPORTATION EQUIPMENT	Oil + HGL	**7**	**2**	2	0	**2**	0	0	2	0	0	**3**	0	0	0	3	0	0	**0**
TRANSPORTATION EQUIPMENT	Natural Gas	**157**	**26**	14	12	**69**	63	2	1	0	3	**61**	58	0	2	0	0	1	**1**
TRANSPORTATION EQUIPMENT	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
WOOD PRODUCTS	**TOTAL**	**154**	**21**	**6**	**15**	**104**	**38**	**1**	**61**	**0**	**4**	**28**	**11**	**5**	**2**	**9**	**0**	**1**	**1**
WOOD PRODUCTS	Electricity	**78**	**2**	2	0	**63**	4	1	58	0	0	**12**	5	5	2	0	0	0	**1**
WOOD PRODUCTS	Oil + HGL	**10**	**0**	0	0	**1**	0	0	1	0	0	**9**	0	0	0	9	0	0	**0**
WOOD PRODUCTS	Natural Gas	**66**	**19**	4	15	**40**	34	0	2	0	4	**7**	6	0	0	0	0	1	**0**
WOOD PRODUCTS	Coal	**0**	**0**	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**

Analysis of existing energy mix

Using this dataset, we can make several interesting consolidations for analysis. The key conclusions and summarizing graphs are presented in the body of the report. The following tables show the underlying data.

Figure A2 – Share of each process step in each sector versus total energy demand

SHARE OF EACH PROCESS STEP VS TOTAL	TOTAL	ALL	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	TOTAL	9,947	28.4%	9.0%	19.4%	60.4%	33.3%	2.8%	17.8%	2.5%	3.9%	10.6%	6.5%	1.8%	1.1%	0.6%	0.3%	0.3%	0.6%
Apparel	TOTAL	0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Beverage and Tobacco	TOTAL	1%	0.4%	0.2%	0.2%	0.5%	0.1%	0.1%	0.3%	0.0%	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Chemicals	TOTAL	32%	13.2%	4.1%	9.1%	16.9%	8.3%	0.8%	4.6%	1.4%	1.8%	1.5%	1.0%	0.3%	0.2%	0.1%	0.0%	0.1%	0.3%
Computer Electronics	TOTAL	1%	0.1%	0.1%	0.0%	0.4%	0.1%	0.1%	0.1%	0.0%	0.1%	0.5%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Electrical Equipment	TOTAL	1%	0.1%	0.0%	0.0%	0.4%	0.3%	0.0%	0.1%	0.0%	0.0%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fabricated Metals	TOTAL	2%	0.1%	0.0%	0.1%	1.6%	0.9%	0.1%	0.5%	0.1%	0.0%	0.7%	0.5%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
Food	TOTAL	11%	4.4%	1.5%	2.9%	4.5%	1.9%	0.9%	1.5%	0.0%	0.2%	1.6%	0.9%	0.3%	0.3%	0.1%	0.0%	0.0%	0.1%
Furniture	TOTAL	0%	0.0%	0.0%	0.0%	0.2%	0.1%	0.0%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Leather	TOTAL	0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Machinery	TOTAL	1%	0.1%	0.0%	0.1%	0.7%	0.2%	0.0%	0.4%	0.0%	0.0%	0.6%	0.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Miscellaneous	TOTAL	1%	0.0%	0.0%	0.0%	0.3%	0.1%	0.0%	0.1%	0.0%	0.0%	0.3%	0.2%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Nonmetallic minerals	TOTAL	7%	0.1%	0.0%	0.1%	6.3%	4.7%	0.1%	1.2%	0.0%	0.3%	0.5%	0.2%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
Paper	TOTAL	10%	4.6%	0.8%	3.8%	4.2%	1.6%	0.1%	2.5%	0.0%	0.1%	0.7%	0.3%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
Oil & Coal products	TOTAL	14%	3.5%	1.4%	2.1%	9.5%	6.9%	0.1%	2.2%	0.0%	0.3%	0.5%	0.2%	0.1%	0.0%	0.0%	0.2%	0.0%	0.1%
Plastics & Rubber	TOTAL	3%	0.3%	0.1%	0.2%	1.6%	0.5%	0.1%	0.9%	0.0%	0.1%	0.6%	0.4%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
Primary metals	TOTAL	11%	0.7%	0.2%	0.5%	9.3%	6.2%	0.1%	1.3%	0.9%	0.7%	0.9%	0.5%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%
Printing	TOTAL	1%	0.0%	0.0%	0.0%	0.4%	0.1%	0.0%	0.2%	0.0%	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Textile Mills	TOTAL	1%	0.2%	0.1%	0.1%	0.4%	0.1%	0.0%	0.2%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Textile Products	TOTAL	0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Transport Equipment	TOTAL	3%	0.3%	0.2%	0.1%	1.8%	0.8%	0.1%	0.8%	0.0%	0.1%	1.2%	0.9%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%
Wood Products	TOTAL	2%	0.2%	0.1%	0.2%	1.0%	0.4%	0.0%	0.6%	0.0%	0.0%	0.3%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%

Figure A3 – Share of electricity in final energy demand

SHARES OF ELECTRICITY	ELECTRICITY	ALL	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	TOTAL	9,947	2,825	891	1,935	6,006	3,315	281	1,771	249	390	1,059	650	180	108	63	29	29	57
ALL	ELECTRICITY	31%	2%	5%	0%	41%	9%	91%	89%	100%	20%	49%	40%	100%	53%	21%	0%	42%	37%
Apparel	ELECTRICITY	51%	0.0%	0.0%	0.0%	52.6%	0.0%	0.0%	76.9%	N/A	N/A	100.0%	100.0%	N/A	N/A	N/A	N/A	N/A	N/A
Beverage and Tobacco	ELECTRICITY	47%	2.8%	5.3%	0.0%	72.5%	7.7%	100.0%	96.2%	N/A	50.0%	64.7%	54.1%	100.0%	50.0%	80.0%	0.0%	0.0%	N/A
Chemicals	ELECTRICITY	22%	0.6%	2.0%	0.0%	36.4%	2.7%	88.3%	80.7%	100.0%	8.2%	50.0%	40.6%	100.0%	45.0%	20.0%	0.0%	40.0%	37.0%
Computer Electronics	ELECTRICITY	71%	8.3%	11.1%	0.0%	95.5%	87.5%	100.0%	100.0%	100.0%	87.5%	63.0%	55.9%	100.0%	75.0%	N/A	N/A	50.0%	100.0%
Electrical Equipment	ELECTRICITY	51%	0.0%	0.0%	0.0%	58.1%	30.8%	100.0%	100.0%	N/A	100.0%	50.0%	43.8%	100.0%	50.0%	0.0%	N/A	N/A	N/A
Fabricated Metals	ELECTRICITY	49%	7.1%	33.3%	0.0%	53.2%	22.2%	100.0%	96.2%	100.0%	50.0%	48.6%	34.7%	100.0%	60.0%	33.3%	N/A	N/A	N/A
Food	ELECTRICITY	31%	2.1%	5.9%	0.0%	52.9%	5.8%	95.2%	90.4%	100.0%	21.9%	45.9%	37.8%	100.0%	20.7%	50.0%	0.0%	50.0%	50.0%
Furniture	ELECTRICITY	52%	0.0%	0.0%	0.0%	62.5%	14.3%	N/A	100.0%	N/A	N/A	42.9%	29.4%	100.0%	83.3%	0.0%	0.0%	0.0%	N/A
Leather	ELECTRICITY	50%	50.0%	50.0%	50.0%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Machinery	ELECTRICITY	57%	16.7%	100.0%	0.0%	66.2%	17.4%	100.0%	93.2%	N/A	25.0%	50.0%	35.0%	100.0%	75.0%	50.0%	N/A	N/A	N/A
Miscellaneous	ELECTRICITY	55%	0.0%	0.0%	0.0%	56.7%	16.7%	100.0%	91.7%	N/A	50.0%	59.3%	49.2%	100.0%	80.0%	0.0%	N/A	57.1%	N/A
Nonmetallic minerals	ELECTRICITY	19%	0.0%	0.0%	0.0%	18.0%	5.6%	50.0%	61.2%	100.0%	22.6%	34.0%	30.4%	100.0%	50.0%	0.0%	N/A	25.0%	50.0%
Paper	ELECTRICITY	33%	2.8%	16.3%	0.0%	62.0%	7.1%	100.0%	96.7%	100.0%	22.2%	54.5%	47.1%	100.0%	71.4%	20.0%	0.0%	N/A	N/A
Oil & Coal products	ELECTRICITY	18%	0.6%	1.4%	0.0%	23.9%	1.3%	91.7%	91.4%	100.0%	7.7%	33.3%	53.3%	100.0%	75.0%	0.0%	0.0%	0.0%	0.0%
Plastics & Rubber	ELECTRICITY	66%	0.0%	0.0%	0.0%	80.3%	39.6%	100.0%	100.0%	100.0%	71.4%	61.9%	44.7%	100.0%	83.3%	50.0%	N/A	100.0%	N/A
Primary metals	ELECTRICITY	38%	2.9%	8.7%	0.0%	40.5%	21.0%	78.6%	95.5%	100.0%	24.3%	41.4%	25.9%	100.0%	62.5%	14.3%	N/A	33.3%	33.3%
Printing	ELECTRICITY	59%	0.0%	0.0%	N/A	65.7%	11.1%	100.0%	90.5%	N/A	33.3%	55.6%	42.9%	100.0%	100.0%	N/A	N/A	N/A	N/A
Textile Mills	ELECTRICITY	58%	6.3%	10.5%	0.0%	73.0%	25.0%	100.0%	95.5%	N/A	100.0%	81.8%	75.0%	100.0%	100.0%	N/A	N/A	N/A	N/A
Textile Products	ELECTRICITY	47%	0.0%	0.0%	N/A	58.3%	16.7%	N/A	100.0%	N/A	N/A	66.7%	50.0%	100.0%	N/A	N/A	N/A	N/A	N/A
Transport Equipment	ELECTRICITY	51%	3.4%	5.9%	0.0%	61.2%	20.3%	85.7%	96.2%	100.0%	70.0%	48.0%	34.8%	100.0%	71.4%	40.0%	N/A	50.0%	0.0%
Wood Products	ELECTRICITY	51%	9.5%	33.3%	0.0%	60.6%	10.5%	100.0%	95.1%	N/A	0.0%	42.9%	45.5%	100.0%	100.0%	0.0%	N/A	0.0%	100.0%

Methodology

Our methodology is strongly inspired from previous research on Europe (Madeddu et al., 2020; Schneider Electric, 2022). We apply a similar methodology devising a three-step approach to electrification:

- Step 1: corresponds to the electrification of all activities that are already feasible, with no impact on the industrial process (essentially, upgrades of equipment) and leveraging products and solutions that are adjacent to the ongoing transition of the buildings sector, which is the object of strong policy efforts across the country. This includes:
  - All non-process uses such as facility HVAC, other facility support, onsite transportation, and other non-process uses.
  - The convergence of machine drives (i.e. motors) to electric ones.
  - The switch to e-boilers across all activities.
- Step 2: corresponds to the electrification of parts of the industrial process, deemed technically and economically feasible, based notably on research from Madeddu et al. (2020), Beyond Zero Emissions (2018), and Hasanbeigi (2023). This includes the following:
  - All cooling and refrigeration processes (use of electric chillers for instance).
  - For process heating in the following sectors (because of low-temperature process heating): beverage and tobacco, computer electronics, electrical equipment, food, furniture, printing, textile (mills and products), and wood products.
- Step 3: corresponds to additional electrification opportunities, that may require specific innovations to scale up (low technological readiness levels), face economic feasibility constraints (capex levels, but more importantly operational cost impacts) which could require significant policy support, or face practical implementation roadblocks with significant process changes that may make adoption extremely difficult. Step 3 sectors are not considered short-term opportunities. They include:
  - Most hard to abate sectors, notably chemicals (e-crackers), primary metals (e.g. iron and steel), oil and coal products, and plastics and rubber.
  - Sectors which have potential for electrification on parts of their processes, but which also include the use of high-temperature furnaces and other high-temperature processes, such as: fabricated metal products, machinery, transport equipment, as well as the miscellaneous category, which we cannot explore in detail because of lack of information on exact content.

Figure 4 summarizes our selection process.

We have excluded a number of subprocesses and segments:
- CHP/co-generation and conventional electricity generation are considered out of scope. Often, these provisions (particularly for CHP/co-generation) are highly integrated into existing processes, hence difficult to switch.
- Other process uses and unreported end-uses are also excluded because of lack of data.
- Non-metallic minerals are also excluded because of the very early-stage innovation on electrification of the processes, while the paper industry is also excluded given the intricate aspects of local energy generation in the industry process.

Figure A4 – Key assumptions

Stepwise Electrification	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
Apparel		step1	NA		0	0	step1	0	NA		step1	already	step1	step1	NA	step1	NA
Beverage and Tobacco		step1	NA		step2	already	step1	0	NA		step1	already	step1	step1	NA	step1	NA
Chemicals		step1	NA		step3	step2	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Computer Electronics		step1	NA		step2	already	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Electrical Equipment		step1	NA		step2	already	step1	0	NA		step1	already	step1	step1	NA	step1	NA
Fabricated Metals		step1	NA		step3	already	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Food		step1	NA		step2	step2	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Furniture		step1	NA		step2	0	step1	0	NA		step1	already	step1	step1	NA	step1	NA
Leather		step1	NA		0	0	step1	0	NA		step1	already	step1	step1	NA	step1	NA
Machinery		step1	NA		step3	already	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Miscellaneous		step1	NA		step3	already	step1	0	NA		step1	already	step1	step1	NA	step1	NA
Nonmetallic minerals		step1	NA		NA	step2	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Paper		step1	NA		NA	already	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Oil & Coal products		step1	NA		step3	step2	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Plastics & Rubber		step1	NA		step3	already	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Primary metals		step1	NA		step3	step2	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Printing		step1	NA		step2	already	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Textile Mills		step1	NA		step2	already	step1	0	NA		step1	already	step1	step1	NA	step1	NA
Textile Products		step1	NA		step2	0	step1	0	NA		step1	already	step1	step1	NA	step1	NA
Transport Equipment		step1	NA		step3	step2	step1	already	NA		step1	already	step1	step1	NA	step1	NA
Wood Products		step1	NA		step2	already	step1	0	NA		step1	already	step1	step1	NA	step1	NA

When we consider one of these subprocesses within a segment of activity to be eligible for electrification, we also consider the maximum reachable rate of electrification to be 90% across the U.S. That way, we also account for residual fossil fuels demand in specific locations that may prove impossible to turn around over time.

When a process is electrified, the resulting energy demand changes. Indeed, there are different efficiency ratios between conventional (i.e. fossil fuel based) and electric processes. We take the following assumptions, once again based on previous research cited above:

- For facility HVAC: we assume a switch to heat pump (HP) with an average coefficient of performance (COP) of 3, which yields three times less electricity demand than fossil fuels demand.
- For machine drives and onsite transportation: we assume that the switch to electric motors yields three times more efficiency (i.e. diesel engines running at c.20% efficiency compared to electric motors typically running above 70%). Our assumption of a 300% gain in efficiency is conservative.
- For boilers and other process-related solutions: we assume electric solutions are 20% more efficient.
- For unrelated energy services such as other facility support and other non-process uses: we simply consider a 1-to-1 conversion, with no efficiency gain (another conservative assumption, but necessary given the lack of precision on data).

By applying these ratios, we recompute corresponding electricity and total energy demand, which helps us to provide an accurate perspective of the rate of electrification within a given sector/subprocess.

Overall, our analysis remains conservative, as a result of:

- The assumptions on conversion efficiencies between fossil fuels and electricity (as discussed above).
- The sectors/subprocesses we have not accounted for in the analysis:
  - The lack of details prevents us from proving that there are opportunities for electrification in other process use or in end-uses that are not reported (Figure 4), therefore we have excluded these, however, further opportunity may exist. Together, they represent around 350 tBtu of fossil fuels demand.
  - We have excluded CHP/co-generation and conventional electricity generation on site, however, solutions exist there too. Distributed generation could play a very significant role, although it will not change the entire perspective, given its limited level. CHP/co-generation is a much harder case (1,900 tBtu), but also intrinsically linked to the process in place, hence much harder to substitute.
  - Finally, we have placed several segments in Step 3 (under process heating, Figure 4) that could be eligible for some level of electrification, notably the fabricated metal products, machinery, transport equipment, and miscellaneous industries. Together, this extra opportunity represents around 200 tBtu of fossil fuels demand, out of a total of around 7,000 tBtu, or around 3% of fossil fuel demand in industry. We have excluded them from Steps 1 and 2 as in each sector there are process steps that involve high temperature melting, thermal treatment, foundries, and other activities that we consider more difficult to electrify in the short term. The potential of a number of technological solutions has been demonstrated, however, but we consider the applicability in the short term more debatable, hence our decision to exclude them from our analysis.

The sum of these arbitrary exclusions accounts for 2,500 tBtu, or around 35% of total fossil fuels demand in industry. Although this appears a significant uncertainty, this only accounts for around 500 tBtu, or 8% of fossil fuels demand, when we exclude CHP/co-generation.

As indicated in the first chapter, we also exclude net steam used locally to produce power and heat, accounting for around 5,000 Btu, mainly used in the paper, chemicals, and oil and coal products industries. Given these figures, it is clear that an exhaustive agenda on electrification should include the overall topic of local power and heat generation including steam and CHP/co-generation, accounting for a total of around 7,000 tBtu, and that further research of these processes be undertaken given the key intricacies of these with existing industrial processes.

Step 1 data

In this part and the following, we present the result tables for evolutions of final energy, electricity demand, and fossil fuels demand for each step of change. For fossil fuels demand, details per category of products (liquids, natural gas, coal) is available upon request.

Figure A5 – Evolution of final energy demand: Step 1 implementation

EVOLUTION OF TOTAL ENERGY DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	-711	-237	-237	0	-144	0	0	-144	0	0	-329	-286	0	-5	-36	0	-2	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	-9	-5	-5	0	-1	0	0	-1	0	0	-3	-3	0	0	0	0	0	0
Chemicals	-223	-112	-112	0	-65	0	0	-65	0	0	-46	-42	0	-1	-3	0	0	0
Computer Electronics	-13	-2	-2	0	0	0	0	0	0	0	-11	-11	0	0	0	0	0	0
Electrical Equipment	-8	-1	-1	0	0	0	0	0	0	0	-7	-7	0	0	-1	0	0	0
Fabricated Metals	-27	-1	-1	0	-1	0	0	-1	0	0	-25	-23	0	0	-1	0	0	0
Food	-96	-40	-40	0	-10	0	0	-10	0	0	-45	-41	0	-2	-2	0	0	0
Furniture	-6	0	0	0	0	0	0	0	0	0	-5	-5	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	-22	0	0	0	-2	0	0	-2	0	0	-20	-19	0	0	-1	0	0	0
Miscellaneous	-7	0	0	0	-1	0	0	-1	0	0	-6	-6	0	0	0	0	0	0
Nonmetallic minerals	-53	-1	-1	0	-33	0	0	-33	0	0	-19	-12	0	0	-7	0	0	0
Paper	-41	-19	-19	0	-6	0	0	-6	0	0	-16	-13	0	0	-3	0	0	0
Oil & Coal products	-60	-38	-38	0	-14	0	0	-14	0	0	-8	-5	0	0	-3	0	0	0
Plastics & Rubber	-20	-3	-3	0	0	0	0	0	0	0	-17	-15	0	0	-1	0	0	0
Primary metals	-44	-6	-6	0	-4	0	0	-4	0	0	-34	-29	0	0	-4	0	0	0
Printing	-8	-1	-1	0	-1	0	0	-1	0	0	-6	-6	0	0	0	0	0	0
Textile Mills	-5	-2	-2	0	-1	0	0	-1	0	0	-1	-1	0	0	0	0	0	0
Textile Products	-2	-1	-1	0	0	0	0	0	0	0	-1	-1	0	0	0	0	0	0
Transport Equipment	-52	-4	-4	0	-2	0	0	-2	0	0	-45	-42	0	0	-2	0	0	0
Wood Products	-14	-1	-1	0	-2	0	0	-2	0	0	-11	-4	0	0	-7	0	0	0

Figure A6 – Evolution of electricity demand: Step 1 implementation

EVOLUTION OF TOTAL ELECTRICITY DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	844	611	611	0	53	0	0	53	0	0	181	106	0	46	13	0	15	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	16	13	13	0	0	0	0	0	0	0	2	1	0	1	0	0	0	0
Chemicals	340	287	287	0	24	0	0	24	0	0	29	15	0	10	1	0	3	0
Computer Electronics	12	6	6	0	0	0	0	0	0	0	6	4	0	1	0	0	1	0
Electrical Equipment	5	1	1	0	0	0	0	0	0	0	4	2	0	1	0	0	0	0
Fabricated Metals	13	1	1	0	1	0	0	1	0	0	11	9	0	2	1	0	0	0
Food	145	104	104	0	4	0	0	4	0	0	38	15	0	21	1	0	1	0
Furniture	3	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	9	0	0	0	1	0	0	1	0	0	8	7	0	1	0	0	0	0
Miscellaneous	6	1	1	0	0	0	0	0	0	0	5	2	0	0	0	0	2	0
Nonmetallic minerals	25	1	1	0	12	0	0	12	0	0	12	4	0	2	3	0	3	0
Paper	58	48	48	0	2	0	0	2	0	0	8	5	0	2	1	0	0	0
Oil & Coal products	109	98	98	0	5	0	0	5	0	0	6	2	0	1	1	0	2	0
Plastics & Rubber	15	8	8	0	0	0	0	0	0	0	7	6	0	1	1	0	0	0
Primary metals	34	15	15	0	2	0	0	2	0	0	17	11	0	3	2	0	2	0
Printing	5	2	2	0	1	0	0	1	0	0	2	2	0	0	0	0	0	0
Textile Mills	7	6	6	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Textile Products	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport Equipment	32	12	12	0	1	0	0	1	0	0	19	16	0	2	1	0	1	0
Wood Products	9	3	3	0	1	0	0	1	0	0	5	2	0	0	2	0	1	0

Figure A7 – Evolution of fossil fuels demand: Step 1 implementation

EVOLUTION OF TOTAL FOSSIL FUELS DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	-1,555	-848	-848	0	-198	0	0	-198	0	0	-510	-392	0	-51	-50	0	-17	0
Apparel	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	-25	-18	-18	0	-1	0	0	-1	0	0	-6	-4	0	-1	0	0	0	0
Chemicals	-563	-399	-399	0	-89	0	0	-89	0	0	-75	-57	0	-11	-4	0	-3	0
Computer Electronics	-25	-8	-8	0	0	0	0	0	0	0	-17	-15	0	-1	0	0	-1	0
Electrical Equipment	-13	-2	-2	0	0	0	0	0	0	0	-11	-9	0	-1	-1	0	0	0
Fabricated Metals	-40	-2	-2	0	-2	0	0	-2	0	0	-36	-32	0	-2	-2	0	0	0
Food	-241	-144	-144	0	-14	0	0	-14	0	0	-83	-56	0	-23	-3	0	-1	0
Furniture	-8	-1	-1	0	0	0	0	0	0	0	-8	-7	0	0	0	0	0	0
Leather	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	-31	0	0	0	-3	0	0	-3	0	0	-28	-26	0	-1	-1	0	0	0
Miscellaneous	-13	-1	-1	0	-1	0	0	-1	0	0	-11	-8	0	0	0	0	-2	0
Nonmetallic minerals	-78	-2	-2	0	-45	0	0	-45	0	0	-31	-16	0	-2	-10	0	-3	0
Paper	-99	-67	-67	0	-8	0	0	-8	0	0	-24	-18	0	-2	-4	0	0	0
Oil & Coal products	-169	-136	-136	0	-19	0	0	-19	0	0	-14	-7	0	-1	-4	0	-2	0
Plastics & Rubber	-35	-11	-11	0	0	0	0	0	0	0	-24	-21	0	-1	-2	0	0	0
Primary metals	-78	-21	-21	0	-6	0	0	-6	0	0	-51	-40	0	-3	-6	0	-2	0
Printing	-13	-3	-3	0	-2	0	0	-2	0	0	-8	-8	0	0	0	0	0	0
Textile Mills	-12	-9	-9	0	-1	0	0	-1	0	0	-2	-2	0	0	0	0	0	0
Textile Products	-5	-4	-4	0	0	0	0	0	0	0	-1	-1	0	0	0	0	0	0
Transport Equipment	-83	-16	-16	0	-3	0	0	-3	0	0	-64	-58	0	-2	-3	0	-1	0
Wood Products	-23	-4	-4	0	-3	0	0	-3	0	0	-16	-6	0	0	-9	0	-1	0

Step 2 data

In addition to the Step 2 tables, as presented in Step 1 data, we also provide the consolidated tables for Steps 1+2.

Figure A8 – Evolution of final energy demand: Step 2 implementation

EVOLUTION OF TOTAL ENERGY DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	-53	0	0	0	-53	-49	-5	0	0	0	0	0	0	0	0	0	0	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	-2	0	0	0	-2	-2	0	0	0	0	0	0	0	0	0	0	0	0
Chemicals	-2	0	0	0	-2	0	-2	0	0	0	0	0	0	0	0	0	0	0
Computer Electronics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electrical Equipment	-3	0	0	0	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0
Fabricated Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Food	-33	0	0	0	-33	-32	-1	0	0	0	0	0	0	0	0	0	0	0
Furniture	-1	0	0	0	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nonmetallic minerals	-1	0	0	0	-1	0	-1	0	0	0	0	0	0	0	0	0	0	0
Paper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Coal products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plastics & Rubber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Primary metals	-1	0	0	0	-1	0	-1	0	0	0	0	0	0	0	0	0	0	0
Printing	-1	0	0	0	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0
Textile Mills	-2	0	0	0	-2	-2	0	0	0	0	0	0	0	0	0	0	0	0
Textile Products	-1	0	0	0	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0
Transport Equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wood Products	-6	0	0	0	-6	-6	0	0	0	0	0	0	0	0	0	0	0	0

Figure A9 – Evolution of electricity demand: Step 2 implementation

EVOLUTION OF TOTAL ELECTRICITY DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	213	0	0	0	213	195	18	0	0	0	0	0	0	0	0	0	0	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	9	0	0	0	9	9	0	0	0	0	0	0	0	0	0	0	0	0
Chemicals	6	0	0	0	6	0	6	0	0	0	0	0	0	0	0	0	0	0
Computer Electronics	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Electrical Equipment	13	0	0	0	13	13	0	0	0	0	0	0	0	0	0	0	0	0
Fabricated Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Food	131	0	0	0	131	128	3	0	0	0	0	0	0	0	0	0	0	0
Furniture	4	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nonmetallic minerals	4	0	0	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0
Paper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Coal products	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Plastics & Rubber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Primary metals	2	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
Printing	6	0	0	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0
Textile Mills	6	0	0	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0
Textile Products	4	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0
Transport Equipment	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Wood Products	24	0	0	0	24	24	0	0	0	0	0	0	0	0	0	0	0	0

Figure A10 – Evolution of fossil fuels demand: Step 2 implementation

EVOLUTION OF TOTAL FOSSIL FUELS DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	-267	0	0	0	-267	-244	-23	0	0	0	0	0	0	0	0	0	0	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	-11	0	0	0	-11	-11	0	0	0	0	0	0	0	0	0	0	0	0
Chemicals	-8	0	0	0	-8	0	-8	0	0	0	0	0	0	0	0	0	0	0
Computer Electronics	-1	0	0	0	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0
Electrical Equipment	-16	0	0	0	-16	-16	0	0	0	0	0	0	0	0	0	0	0	0
Fabricated Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Food	-164	0	0	0	-164	-160	-4	0	0	0	0	0	0	0	0	0	0	0
Furniture	-5	0	0	0	-5	-5	0	0	0	0	0	0	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nonmetallic minerals	-5	0	0	0	-5	0	-5	0	0	0	0	0	0	0	0	0	0	0
Paper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Coal products	-1	0	0	0	-1	0	-1	0	0	0	0	0	0	0	0	0	0	0
Plastics & Rubber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Primary metals	-3	0	0	0	-3	0	-3	0	0	0	0	0	0	0	0	0	0	0
Printing	-7	0	0	0	-7	-7	0	0	0	0	0	0	0	0	0	0	0	0
Textile Mills	-8	0	0	0	-8	-8	0	0	0	0	0	0	0	0	0	0	0	0
Textile Products	-5	0	0	0	-5	-5	0	0	0	0	0	0	0	0	0	0	0	0
Transport Equipment	-2	0	0	0	-2	0	-2	0	0	0	0	0	0	0	0	0	0	0
Wood Products	-31	0	0	0	-31	-31	0	0	0	0	0	0	0	0	0	0	0	0

Figure A11 – Evolution of final energy demand: Steps 1+2 implementation

EVOLUTION OF TOTAL ENERGY DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	-764	-237	-237	0	-198	-49	-5	-144	0	0	-329	-286	0	-5	-36	0	-2	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	-11	-5	-5	0	-3	-2	0	-1	0	0	-3	-3	0	0	0	0	0	0
Chemicals	-224	-112	-112	0	-67	0	-2	-65	0	0	-46	-42	0	-1	-3	0	0	0
Computer Electronics	-14	-2	-2	0	0	0	0	0	0	0	-11	-11	0	0	0	0	0	0
Electrical Equipment	-11	-1	-1	0	-3	-3	0	0	0	0	-7	-7	0	0	-1	0	0	0
Fabricated Metals	-27	-1	-1	0	-1	0	0	-1	0	0	-25	-23	0	0	-1	0	0	0
Food	-129	-40	-40	0	-43	-32	-1	-10	0	0	-45	-41	0	-2	-2	0	0	0
Furniture	-7	0	0	0	-1	-1	0	0	0	0	-5	-5	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	-22	0	0	0	-2	0	0	-2	0	0	-20	-19	0	0	-1	0	0	0
Miscellaneous	-7	0	0	0	-1	0	0	-1	0	0	-6	-6	0	0	0	0	0	0
Nonmetallic minerals	-54	-1	-1	0	-34	0	-1	-33	0	0	-19	-12	0	0	-7	0	0	0
Paper	-41	-19	-19	0	-6	0	0	-6	0	0	-16	-13	0	0	-3	0	0	0
Oil & Coal products	-60	-38	-38	0	-14	0	0	-14	0	0	-8	-5	0	0	-3	0	0	0
Plastics & Rubber	-20	-3	-3	0	0	0	0	0	0	0	-17	-15	0	0	-1	0	0	0
Primary metals	-45	-6	-6	0	-5	0	-1	-4	0	0	-34	-29	0	0	-4	0	0	0
Printing	-10	-1	-1	0	-3	-1	0	-1	0	0	-6	-6	0	0	0	0	0	0
Textile Mills	-6	-2	-2	0	-2	-2	0	-1	0	0	-1	-1	0	0	0	0	0	0
Textile Products	-3	-1	-1	0	-1	-1	0	0	0	0	-1	-1	0	0	0	0	0	0
Transport Equipment	-52	-4	-4	0	-3	0	0	-2	0	0	-45	-42	0	0	-2	0	0	0
Wood Products	-20	-1	-1	0	-8	-6	0	-2	0	0	-11	-4	0	0	-7	0	0	0

Figure A12 – Evolution of electricity demand: Steps 1+2 implementation

EVOLUTION OF TOTAL ELECTRICITY DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	1,058	611	611	0	267	195	18	53	0	0	181	106	0	46	13	0	15	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	24	13	13	0	9	9	0	0	0	0	2	1	0	1	0	0	0	0
Chemicals	347	287	287	0	31	0	6	24	0	0	29	15	0	10	1	0	3	0
Computer Electronics	12	6	6	0	1	1	0	0	0	0	6	4	0	1	0	0	1	0
Electrical Equipment	18	1	1	0	13	13	0	0	0	0	4	2	0	1	0	0	0	0
Fabricated Metals	13	1	1	0	1	0	0	1	0	0	11	9	0	2	1	0	0	0
Food	276	104	104	0	135	128	3	4	0	0	38	15	0	21	1	0	1	0
Furniture	7	0	0	0	4	4	0	0	0	0	2	2	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	9	0	0	0	1	0	0	1	0	0	8	7	0	1	0	0	0	0
Miscellaneous	6	1	1	0	0	0	0	0	0	0	5	2	0	0	0	0	2	0
Nonmetallic minerals	29	1	1	0	16	0	4	12	0	0	12	4	0	2	3	0	3	0
Paper	58	48	48	0	2	0	0	2	0	0	8	5	0	2	1	0	0	0
Oil & Coal products	109	98	98	0	6	0	1	5	0	0	6	2	0	1	1	0	2	0
Plastics & Rubber	15	8	8	0	0	0	0	0	0	0	7	6	0	1	1	0	0	0
Primary metals	36	15	15	0	4	0	2	2	0	0	17	11	0	3	2	0	2	0
Printing	11	2	2	0	6	6	0	1	0	0	2	2	0	0	0	0	0	0
Textile Mills	13	6	6	0	7	6	0	0	0	0	1	1	0	0	0	0	0	0
Textile Products	7	3	3	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0
Transport Equipment	33	12	12	0	2	0	1	1	0	0	19	16	0	2	1	0	1	0
Wood Products	33	3	3	0	25	24	0	1	0	0	5	2	0	0	2	0	1	0

Figure A13 – Evolution of fossil fuels demand: Steps 1+2 implementation

EVOLUTION OF TOTAL FOSSIL FUELS DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	-1,822	-848	-848	0	-464	-244	-23	-198	0	0	-510	-392	0	-51	-50	0	-17	0
Apparel	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	-36	-18	-18	0	-12	-11	0	-1	0	0	-6	-4	0	-1	0	0	0	0
Chemicals	-571	-399	-399	0	-97	0	-8	-89	0	0	-75	-57	0	-11	-4	0	-3	0
Computer Electronics	-26	-8	-8	0	-1	-1	0	0	0	0	-17	-15	0	-1	0	0	-1	0
Electrical Equipment	-29	-2	-2	0	-16	-16	0	0	0	0	-11	-9	0	-1	-1	0	0	0
Fabricated Metals	-40	-2	-2	0	-2	0	0	-2	0	0	-36	-32	0	-2	-2	0	0	0
Food	-405	-144	-144	0	-178	-160	-4	-14	0	0	-83	-56	0	-23	-3	0	-1	0
Furniture	-14	-1	-1	0	-5	-5	0	0	0	0	-8	-7	0	0	0	0	0	0
Leather	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	-31	0	0	0	-3	0	0	-3	0	0	-28	-26	0	-1	-1	0	0	0
Miscellaneous	-13	-1	-1	0	-1	0	0	-1	0	0	-11	-8	0	0	0	0	-2	0
Nonmetallic minerals	-83	-2	-2	0	-50	0	-5	-45	0	0	-31	-16	0	-2	-10	0	-3	0
Paper	-99	-67	-67	0	-8	0	0	-8	0	0	-24	-18	0	-2	-4	0	0	0
Oil & Coal products	-170	-136	-136	0	-20	0	-1	-19	0	0	-14	-7	0	-1	-4	0	-2	0
Plastics & Rubber	-35	-11	-11	0	0	0	0	0	0	0	-24	-21	0	-1	-2	0	0	0
Primary metals	-81	-21	-21	0	-9	0	-3	-6	0	0	-51	-40	0	-3	-6	0	-2	0
Printing	-20	-3	-3	0	-9	-7	0	-2	0	0	-8	-8	0	0	0	0	0	0
Textile Mills	-20	-9	-9	0	-9	-8	0	-1	0	0	-2	-2	0	0	0	0	0	0
Textile Products	-10	-4	-4	0	-5	-5	0	0	0	0	-1	-1	0	0	0	0	0	0
Transport Equipment	-85	-16	-16	0	-5	0	-2	-3	0	0	-64	-58	0	-2	-3	0	-1	0
Wood Products	-54	-4	-4	0	-34	-31	0	-3	0	0	-16	-6	0	0	-9	0	-1	0

Step 3 data

In addition to the Step 3 tables, as presented in Step 1 data and Step 2 data, we also provide the consolidated tables for Steps 1+2+3.

Figure A14 – Evolution of final energy demand: Step 3 implementation

EVOLUTION OF TOTAL ENERGY DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	-389	0	0	0	-389	-389	0	0	0	0	0	0	0	0	0	0	0	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemicals	-145	0	0	0	-145	-145	0	0	0	0	0	0	0	0	0	0	0	0
Computer Electronics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electrical Equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabricated Metals	-13	0	0	0	-13	-13	0	0	0	0	0	0	0	0	0	0	0	0
Food	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Furniture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	-3	0	0	0	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	-2	0	0	0	-2	-2	0	0	0	0	0	0	0	0	0	0	0	0
Nonmetallic minerals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Coal products	-122	0	0	0	-122	-122	0	0	0	0	0	0	0	0	0	0	0	0
Plastics & Rubber	-5	0	0	0	-5	-5	0	0	0	0	0	0	0	0	0	0	0	0
Primary metals	-88	0	0	0	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0
Printing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textile Mills	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textile Products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport Equipment	-11	0	0	0	-11	-11	0	0	0	0	0	0	0	0	0	0	0	0
Wood Products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure A15 – Evolution of electricity demand: Step 3 implementation

EVOLUTION OF TOTAL ELECTRICITY DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	1,557	0	0	0	1,557	1,557	0	0	0	0	0	0	0	0	0	0	0	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemicals	580	0	0	0	580	580	0	0	0	0	0	0	0	0	0	0	0	0
Computer Electronics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electrical Equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabricated Metals	50	0	0	0	50	50	0	0	0	0	0	0	0	0	0	0	0	0
Food	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Furniture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	14	0	0	0	14	14	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	7	0	0	0	7	7	0	0	0	0	0	0	0	0	0	0	0	0
Nonmetallic minerals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Coal products	488	0	0	0	488	488	0	0	0	0	0	0	0	0	0	0	0	0
Plastics & Rubber	21	0	0	0	21	21	0	0	0	0	0	0	0	0	0	0	0	0
Primary metals	351	0	0	0	351	351	0	0	0	0	0	0	0	0	0	0	0	0
Printing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textile Mills	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textile Products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport Equipment	45	0	0	0	45	45	0	0	0	0	0	0	0	0	0	0	0	0
Wood Products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure A16 – Evolution of fossil fuels demand: Step 3 implementation

EVOLUTION OF TOTAL FOSSIL FUELS DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	-1,946	0	0	0	-1,946	-1,946	0	0	0	0	0	0	0	0	0	0	0	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemicals	-725	0	0	0	-725	-725	0	0	0	0	0	0	0	0	0	0	0	0
Computer Electronics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electrical Equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabricated Metals	-63	0	0	0	-63	-63	0	0	0	0	0	0	0	0	0	0	0	0
Food	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Furniture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	-17	0	0	0	-17	-17	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	-9	0	0	0	-9	-9	0	0	0	0	0	0	0	0	0	0	0	0
Nonmetallic minerals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Coal products	-610	0	0	0	-610	-610	0	0	0	0	0	0	0	0	0	0	0	0
Plastics & Rubber	-26	0	0	0	-26	-26	0	0	0	0	0	0	0	0	0	0	0	0
Primary metals	-439	0	0	0	-439	-439	0	0	0	0	0	0	0	0	0	0	0	0
Printing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textile Mills	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textile Products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport Equipment	-57	0	0	0	-57	-57	0	0	0	0	0	0	0	0	0	0	0	0
Wood Products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure A17 – Evolution of final energy demand: Steps 1+2+3 implementation

EVOLUTION OF TOTAL ENERGY DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	-1,153	-237	-237	0	-587	-438	-5	-144	0	0	-329	-286	0	-5	-36	0	-2	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	-11	-5	-5	0	-3	-2	0	-1	0	0	-3	-3	0	0	0	0	0	0
Chemicals	-369	-112	-112	0	-211	-145	-2	-65	0	0	-46	-42	0	-1	-3	0	0	0
Computer Electronics	-14	-2	-2	0	0	0	0	0	0	0	-11	-11	0	0	0	0	0	0
Electrical Equipment	-11	-1	-1	0	-3	-3	0	0	0	0	-7	-7	0	0	-1	0	0	0
Fabricated Metals	-40	-1	-1	0	-14	-13	0	-1	0	0	-25	-23	0	0	-1	0	0	0
Food	-129	-40	-40	0	-43	-32	-1	-10	0	0	-45	-41	0	-2	-2	0	0	0
Furniture	-7	0	0	0	-1	-1	0	0	0	0	-5	-5	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	-25	0	0	0	-6	-3	0	-2	0	0	-20	-19	0	0	-1	0	0	0
Miscellaneous	-9	0	0	0	-3	-2	0	-1	0	0	-6	-6	0	0	0	0	0	0
Nonmetallic minerals	-54	-1	-1	0	-34	0	-1	-33	0	0	-19	-12	0	0	-7	0	0	0
Paper	-41	-19	-19	0	-6	0	0	-6	0	0	-16	-13	0	0	-3	0	0	0
Oil & Coal products	-183	-38	-38	0	-136	-122	0	-14	0	0	-8	-5	0	0	-3	0	0	0
Plastics & Rubber	-25	-3	-3	0	-5	-5	0	0	0	0	-17	-15	0	0	-1	0	0	0
Primary metals	-133	-6	-6	0	-93	-88	-1	-4	0	0	-34	-29	0	0	-4	0	0	0
Printing	-10	-1	-1	0	-3	-1	0	-1	0	0	-6	-6	0	0	0	0	0	0
Textile Mills	-6	-2	-2	0	-2	-2	0	-1	0	0	-1	-1	0	0	0	0	0	0
Textile Products	-3	-1	-1	0	-1	-1	0	0	0	0	-1	-1	0	0	0	0	0	0
Transport Equipment	-63	-4	-4	0	-14	-11	0	-2	0	0	-45	-42	0	0	-2	0	0	0
Wood Products	-20	-1	-1	0	-8	-6	0	-2	0	0	-11	-4	0	0	-7	0	0	0

Figure A18 – Evolution of electricity demand: Steps 1+2+3 implementation

EVOLUTION OF TOTAL ELECTRICITY DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	2,614	611	611	0	1,823	1,752	18	53	0	0	181	106	0	46	13	0	15	0
Apparel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	24	13	13	0	9	9	0	0	0	0	2	1	0	1	0	0	0	0
Chemicals	926	287	287	0	610	580	6	24	0	0	29	15	0	10	1	0	3	0
Computer Electronics	12	6	6	0	1	1	0	0	0	0	6	4	0	1	0	0	1	0
Electrical Equipment	18	1	1	0	13	13	0	0	0	0	4	2	0	1	0	0	0	0
Fabricated Metals	63	1	1	0	51	50	0	1	0	0	11	9	0	2	1	0	0	0
Food	276	104	104	0	135	128	3	4	0	0	38	15	0	21	1	0	1	0
Furniture	7	0	0	0	4	4	0	0	0	0	2	2	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	23	0	0	0	14	14	0	1	0	0	8	7	0	1	0	0	0	0
Miscellaneous	13	1	1	0	7	7	0	0	0	0	5	2	0	0	0	0	2	0
Nonmetallic minerals	29	1	1	0	16	0	4	12	0	0	12	4	0	2	3	0	3	0
Paper	58	48	48	0	2	0	0	2	0	0	8	5	0	2	1	0	0	0
Oil & Coal products	598	98	98	0	494	488	1	5	0	0	6	2	0	1	1	0	2	0
Plastics & Rubber	36	8	8	0	21	21	0	0	0	0	7	6	0	1	1	0	0	0
Primary metals	387	15	15	0	355	351	2	2	0	0	17	11	0	3	2	0	2	0
Printing	11	2	2	0	6	6	0	1	0	0	2	2	0	0	0	0	0	0
Textile Mills	13	6	6	0	7	6	0	0	0	0	1	1	0	0	0	0	0	0
Textile Products	7	3	3	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0
Transport Equipment	78	12	12	0	48	45	1	1	0	0	19	16	0	2	1	0	1	0
Wood Products	33	3	3	0	25	24	0	1	0	0	5	2	0	0	2	0	1	0

Figure A19 – Evolution of fossil fuels demand: Steps 1+2+3 implementation

EVOLUTION OF TOTAL FOSSIL FUELS DEMAND	TOTAL FUEL CONSUMPTION	Indirect Uses-Boiler Fuel	Conventional Boiler Use	CHP and/or Cogeneration Process	Direct Uses-Total Process	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Direct Uses-Total Nonprocess	Facility HVAC (f)	Facility Lighting	Other Facility Support	Onsite Transportation	Conventional Electricity Generation	Other Nonprocess Use	End Use Not Reported
ALL	-3,768	-848	-848	0	-2,410	-2,190	-23	-198	0	0	-510	-392	0	-51	-50	0	-17	0
Apparel	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverage and Tobacco	-36	-18	-18	0	-12	-11	0	-1	0	0	-6	-4	0	-1	0	0	0	0
Chemicals	-1,296	-399	-399	0	-822	-725	-8	-89	0	0	-75	-57	0	-11	-4	0	-3	0
Computer Electronics	-26	-8	-8	0	-1	-1	0	0	0	0	-17	-15	0	-1	0	0	-1	0
Electrical Equipment	-29	-2	-2	0	-16	-16	0	0	0	0	-11	-9	0	-1	-1	0	0	0
Fabricated Metals	-103	-2	-2	0	-65	-63	0	-2	0	0	-36	-32	0	-2	-2	0	0	0
Food	-405	-144	-144	0	-178	-160	-4	-14	0	0	-83	-56	0	-23	-3	0	-1	0
Furniture	-14	-1	-1	0	-5	-5	0	0	0	0	-8	-7	0	0	0	0	0	0
Leather	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	-48	0	0	0	-20	-17	0	-3	0	0	-28	-26	0	-1	-1	0	0	0
Miscellaneous	-22	-1	-1	0	-10	-9	0	-1	0	0	-11	-8	0	0	0	0	-2	0
Nonmetallic minerals	-83	-2	-2	0	-50	0	-5	-45	0	0	-31	-16	0	-2	-10	0	-3	0
Paper	-99	-67	-67	0	-8	0	0	-8	0	0	-24	-18	0	-2	-4	0	0	0
Oil & Coal products	-780	-136	-136	0	-630	-610	-1	-19	0	0	-14	-7	0	-1	-4	0	-2	0
Plastics & Rubber	-61	-11	-11	0	-26	-26	0	0	0	0	-24	-21	0	-1	-2	0	0	0
Primary metals	-520	-21	-21	0	-448	-439	-3	-6	0	0	-51	-40	0	-3	-6	0	-2	0
Printing	-20	-3	-3	0	-9	-7	0	-2	0	0	-8	-8	0	0	0	0	0	0
Textile Mills	-20	-9	-9	0	-9	-8	0	-1	0	0	-2	-2	0	0	0	0	0	0
Textile Products	-10	-4	-4	0	-5	-5	0	0	0	0	-1	-1	0	0	0	0	0	0
Transport Equipment	-142	-16	-16	0	-62	-57	-2	-3	0	0	-64	-58	0	-2	-3	0	-1	0
Wood Products	-54	-4	-4	0	-34	-31	0	-3	0	0	-16	-6	0	0	-9	0	-1	0

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