D11.1: Preliminary Market Analysis: Energy efficiency and flexibility in process industries

August/2019 (M12)

D11.1:

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Technical References

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[1] PU = Public

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0 EXECUTIVE SUMMARY

EU resource and energy intensive industries face several challenges to decrease energy consumption and their dependence on fossil fuels. The BAMBOO project aims at introducing new technologies that support the energy transition towards a decarbonized system, able to adapt consumption and production patterns to the fluctuations in renewable energy supply. Focusing on steel, petrochemicals, pulp & paper, and minerals, the project will deploy full energy flexibility through the application and integration of the following innovations:

- Decision Support System (DSS) for flexibility management;
- Organic Rankine Cycle (ORC);
- High temperature heat pump;
- Flame monitoring system;
- Drying process for bio-sludge valorisation;
- Multifuel low-NOx burners.

To maximise their application and uptake, this report provides an analysis of the context impacting the market potential in the 4 industry sectors where these technologies will be demonstrated. Key takeaways from the analysis include:

- From a structural perspective, large companies are the backbone of iron & steel and petrochemicals. Despite the dominant presence of SMEs in terms of number of companies, employment, turnover and value added in these two sectors are driven by large companies. In mineral and pulp & paper, SMEs play a more important role, posing specific challenges in terms of skills and resources for the deployment of innovation. These issues will have to be considered in the design of the go-to-market strategy of the solutions in the project.
- Globalisation, innovation and digital transformation are shaping the business scenarios of companies operating in the 4 industry sectors. While these trends strengthen global competition, they can also offer opportunities for growth.
- Global energy demand keeps on increasing and energy prices remain volatile. Wholesale prices dropped in Q1 2019 (vs Q4 2018) but increased against Q1 2018. The weight of energy bills on costs is between 3% and 20% in pulp and paper, mineral, iron and steel, and concrete. Volatility has therefore a strong impact on production and operations of these energy intensive industries.
- Technologies aimed at energy flexibility help facing price volatility. Nonetheless, investment in industrial energy efficiency fell in 2018 owing to ROI issues and competition for capital with other business improvements' projects.
- BAMBOO innovative solutions can benefit from advantages proven in real demonstrations but will have to leverage appealing value propositions and effective business models for their exploitation across the EU and internationally.

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1 INTRODUCTION

This document provides the preliminary release of the market analysis foreseen in the framework of Task 11.1 ("Business Model Refinement and Business Plan Development") of the BAMBOO project. The project addresses challenges related to energy and resource efficiency in 4 energy intensive industries:

- Steel;
- Petrochemicals;
- Pulp & paper;
- Minerals.

through the development of 6 innovative technologies and processes allowing full industrial flexibility. These include:

- Decision Support System (DSS) for flexibility management, demonstrated across sectors;
- Organic Rankine Cycle (ORC), demonstrated in petrochemicals;
- High temperature heat pump, demonstrated in the steel sector;
- Flame monitoring system, demonstrated in the steel sector;
- Drying process for bio-sludge valorisation, demonstrated in pulp & paper;
- Multifuel low-NOx burners, demonstrated in the mineral sector.

The analysis is not meant to be a rigorous academic review of energy efficiency and flexibility in process industries, rather to provide insights that can support the exploitation, commercialisation and faster uptake of these technologies in the EU. To fulfil this aim, this document focuses on:

- Understanding the structure of the 4 process manufacturing sectors in the project, to provide hints on the addressable market that technologies in BAMBOO can address in the EU and on a global scale (chapters 2-5). The analysis draws on Eurostat data. Other than EU28 countries, Norway, Switzerland and Turkey are considered in the perimeter to provide a more comprehensive view of the structure and dynamics of each sector.
- Identifying key economic and business trends each sector is facing, to contextualise the go-to-market strategy and build value propositions that go beyond obvious technology benefits to cover most pressing business needs (chapters 2-5).
- Reviewing energy dynamics and in particular prices, costs and other demand issues, which may affect the uptake of BAMBOO technologies in the 4 vertical sectors (chapter 6).
- Assessing the market potential for the 6 technologies developed within the project, including drivers and barriers from both a demand and a competitive perspective (chapter 7).

Throughout the report, Nordics include Denmark, Finland, and Sweden. Other EU includes Bulgaria, Estonia, Ireland, Greece, Croatia, Cyprus, Latvia, Lithuania, Luxemburg, Hungary, Malta, Austria, Portugal, Romania and Slovenia.

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2 IRON AND STEEL

For the purpose of the analysis, NACE code "C24.1" referred to "Manufacture of basic iron and steel and of ferro-alloys" is used.

2.1 STRUCTURAL ANALYSIS: EU AND TURKEY

2.1.1 Number of Companies and Persons Employed

The European iron and steel industry (i.e. NACE C24.1) is composed by 3,000 operating companies (2017)[1], representing just 0.14% of total manufacturers in the EU. The UK, Germany, Italy and Slovakia are the countries with more operating companies and with a higher impact on the total European steel operations (63.2% adding up the countries). The UK and Slovakia stand out also in terms of iron and steel weight on total manufacturing companies. Nonetheless, the share on total manufacturing remains close to zero also in these two countries. Turkey holds a good position in the market with a total of 313 operating companies, more than one tenth of the EU total.

Table 1 – Iron & Steel. Number of companies in 2017, EU28, Norway, Switzerland and Turkey

	N. of companies	EU28 % breakdown	Share of total manufacturing
EU 28	**3,000**	**100%**	**0.14%**
Belgium	79	2.6%	0.21%
Czechia	68	2.3%	0.04%
France	44	1.5%	0.02%
Germany	515	17.2%	0.26%
Italy	429	14.3%	0.11%
Netherlands	62	2.1%	0.09%
Nordics	112	3.7%	0.13%
Poland	97	3.2%	0.05%
Spain	189	6.3%	0.11%
Slovakia	317	10.6%	0.44%
UK	635	21.2%	0.46%
Other EU	453	15.1%	0.12%
Norway	20		0.12%
Switzerland	11		0.05%
Turkey	313		0.09%

Source: Eurostat, 2019 (Data refer to 2017. Ireland, Italy: 2016; Turkey: 2014)

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The total number of persons employed in the sector is 321,765, accounting for 1% of total employment in EU manufacturing. Germany is the country with more people employed (i.e. 76,491), about twice the number of the second-ranked, Italy. Nonetheless, iron and steel are more relevant employment engines in Belgium, Slovakia and the Nordics, where their share on total manufacturing is higher than 2%.

Outside the EU, Turkey employs a relevant number of people, 49,961[1] representing 1.4% of the total persons employed in the Turkish manufacturing sector.

Table 2 – Iron & Steel. Persons employed in 2017, EU28, Norway, Switzerland and Turkey

	Persons employed	% of total manufacturing	Persons employed per company
EU 28	**321,765**	**1.0%**	**107**
Belgium	11,589	2.3%	147
Czechia	17,316	1.3%	255
France	21,959	0.8%	499
Germany	76,491	1.0%	149
Italy	42,933	1.2%	100
Netherlands	12,046	0.6%	194
Nordics	26,326	2.1%	235
Poland	19,948	0.8%	206
Spain	21,269	1.1%	113
Slovakia	11,443	2.3%	36
UK	24,162	0.9%	38
Other EU	36,283	0.9%	80
Norway	1,681	0.8%	84
Switzerland	1,211	0.2%	110
Turkey	49,961	1.4%	160

Source: Eurostat, 2019 (Data refer to 2017. Slovakia, Turkey: 2014; UK:2015)

The sector is largely composed by SMEs, with each company employing on average 107 persons. Looking into countries, some key structural facts emerge:

- The sector structure in France differs from all the other countries in the EU. Even though its number of operating companies and persons employed are rather limited, French companies are bigger in size, with an average of persons employed of 499 per company.
- Although Germany has the biggest number of persons employed in the sector, the number of persons employed per company is lower compared to France, Czechia and the Nordics

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countries, due to the smaller companies' dimension or different work management settings compared to other countries.

- Similarly, Italy and Turkey have a small number of persons employed per company despite the high number of people employed overall.

2.1.2 Turnover, Production and Value-added

The European steel industry reached a turnover of €153 billion[1] in 2017. Germany was the country with highest net sales in all Europe, reaching €36 billion, followed by Turkey, Italy, the Nordics countries and France. Germany, Turkey and Italy together have a combined turnover of €82 billion, making these countries quite attractive for players selling solutions in iron and steel. The contribution of Germany and Italy to total net sales in the EU28 is 23.5% and 14.2% respectively.

On average, iron and steel represent 2% of total turnover in manufacturing. Mirroring the trend analysed for persons employed, the sector is a stronger contributor to the economy in Belgium (4%), Slovakia (3.8%) and the Nordics (3.7%). Outside Europe, this share reaches 7.1% in Turkey, making iron and steel an important sector for the Turkish economy.

The average turnover per company is just above €50 million. Some country differences apply. Slovakia and the UK show a strong below average performance per company; French data are much higher (i.e. €343 million on average), confirming the country different structure in terms of company size. Belgium and the Nordics have also higher than average turnover per company (€136 million and €151 million respectively). On average, all the other countries behave in a similar way, with the total net sales close to the EU average.

Looking at turnover per person employed, Belgium and Norway have a higher ratio of respectively €925k and €901k. Belgium, with a total of 11,589 persons and a turnover of €11 billion seems to have a high level of productivity in the sector – double compared to the EU28 average. Outside the EU, the turnover per person employed in Turkey is very close to the European average.

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Table 3 – Iron & Steel. Turnover in 2017, €M, EU28, Norway, Switzerland and Turkey

	Total Turnover, €M	EU28 % breakdown	Share of total manufacturing	Turnover per company, €M	Turnover per person employed, €k
EU 28	**152,559**	**100.0%**	**2.0%**	**51**	**474**
Belgium	10,716	7.0%	4.0%	136	925
Czechia	3,800	2.5%	2.1%	56	219
France	15,094	9.9%	1.5%	343	687
Germany	35,877	23.5%	1.7%	70	469
Italy	21,737	14.2%	2.4%	51	506
Netherlands	3,234	2.1%	0.9%	52	268
Nordics	16,898	11.1%	3.7%	151	642
Poland	6,532	4.3%	2.0%	67	327
Spain	11,781	7.7%	2.3%	62	554
Slovakia	2,936	1.9%	3.8%	9	257
UK	7,991	5.2%	1.2%	13	331
Other EU	15,963	10.5%	1.8%	35	440
Norway	1,515		1.8%	76	901
Switzerland	713		0.2%	65	589
Turkey	14,834		4.3%	1,648	1,884

Source: Eurostat, 2019 (Data refer to 2017. Netherlands: 2009; Ireland: 2016; Turkey: 2014)

Production shows similar patterns to turnover. Mirroring higher than average turnover, Germany, Turkey and Italy have also strong production values, followed by the Nordics and France. Germany alone account for 24.3% of the total production value in the EU28.

France, together with the Nordic countries and Belgium, have the highest production values per company, due to their companies' size and different work organisation. In addition, Belgium and Norway - other than having a turnover per person employed higher than other countries - detain the highest production value per person employed (€860k and €897k respectively).

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Table 4 – Iron & Steel. Production value in 2017, €M, EU28, Norway, Switzerland and Turkey

	Production value, €M	EU28 % breakdown	Share of total manufacturing	Production value per company, €M	Production value per person employed, €k
EU 28	**149,453**	**100.0%**	**2.1%**	**50**	**464**
Belgium	9,972	6.7%	3.9%	126	860
Czechia	3,662	2.5%	2.2%	54	211
France	15,197	10.2%	1.7%	345	692
Germany	36,293	24.3%	2.0%	70	474
Italy	19,831	13.3%	2.2%	46	462
Netherlands	3,232	2.2%	1.0%	52	268
Nordics	14,702	9.8%	3.7%	131	558
Poland	6,473	4.3%	2.2%	67	325
Spain	12,205	8.2%	2.5%	65	574
Slovakia	2,928	2.0%	4.0%	9	256
UK	7,978	5.3%	1.3%	13	330
Other EU	16,979	11.4%	2.1%	37	468
Norway	1,507		2.0%	75	897
Switzerland	736		0.2%	67	608
Turkey	22,831		6.9%	73	457

Source: Eurostat, 2019 (Data refer to 2017. Netherlands: 2009; Ireland: 2016; Turkey: 2014)

Value added at factor cost was close to €24 billion in 2017, representing just 1.2% of total manufacturing (compared to 2% for turnover and 2.1% for production), stressing the challenges of the iron and steel sector when it comes to costs and productivity.

Germany has the highest value added at factor cost (i.e. €6 million) followed by Turkey and Italy. Its value added per company is rather small compared with the turnover of other countries such as France which holds the highest valued added per company (€40 million).

Considering the value added per person employed, Norway and Belgium have the most relevant ratios of respectively €157k and €135k.

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Table 5 – Iron & Steel. Value added at factor cost in 2016, €M, EU28, Norway, Switzerland and Turkey

	Value added, €M	EU28 % breakdown	Share of total manufacturing	Value added per company	Value added per person, €k
EU 28	**23,806**	**100.0%**	**1.2%**	**8**	**74**
Belgium	1,562	6.6%	2.8%	20	135
Czechia	553	2.3%	1.5%	8	32
France	1,766	7.4%	0.8%	40	80
Germany	5,988	25.2%	1.1%	12	78
Italy	2,829	11.9%	1.3%	7	66
Netherlands	729	3.1%	1.1%	12	61
Nordics	2,450	10.3%	2.1%	22	93
Poland	1,018	4.3%	1.6%	10	51
Spain	1,678	7.0%	1.6%	9	79
Slovakia	455	1.9%	3.5%	1	40
UK	1,488	6.3%	0.7%	2	62
Other EU	3,289	13.8%	1.3%	7	91
Norway	264		1.3%	13	157
Switzerland	135		0.1%	12	111
Turkey	2,945		4.6%	9	59

Source: Eurostat, 2019 (Data refer to 2016, Netherlands: 2009; Slovakia, Turkey: 2014)

2.1.3 Structural analysis by company size

As stated above, with 107 persons employed per company, the EU iron and steel sector is mainly composed by SMEs (below 250 employees). 94.6% of all companies are small or medium-sized, with micro-enterprises (0-9 employees) accounting for nearly 72%. Despite these numbers, the sector is significantly more biased to large companies than overall EU manufacturing. Large companies represent a relevant 5.5% in iron and steel versus just 0.8% in total manufacturing.

More importantly, large companies are the backbone of the iron and steel economy; employment, turnover and value added are driven by companies with more than 250 employees. In detail, large companies account for nearly 80% of persons employed, more than 86% of total turnover and nearly 91% of value added. This compares with 42.4% of persons employed, 63.4% of total turnover and 58.6% of value added of large companies in total manufacturing.

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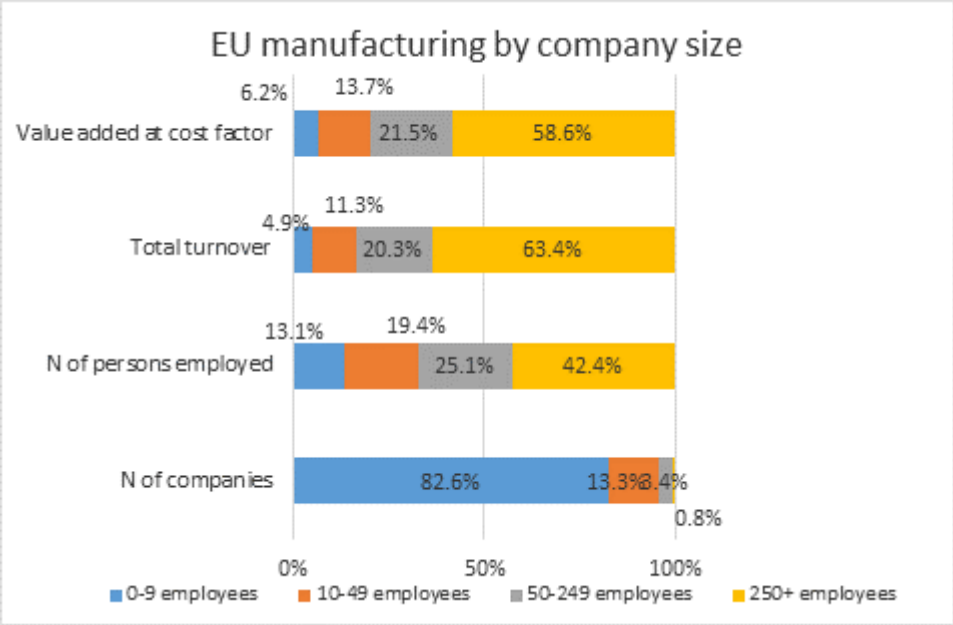
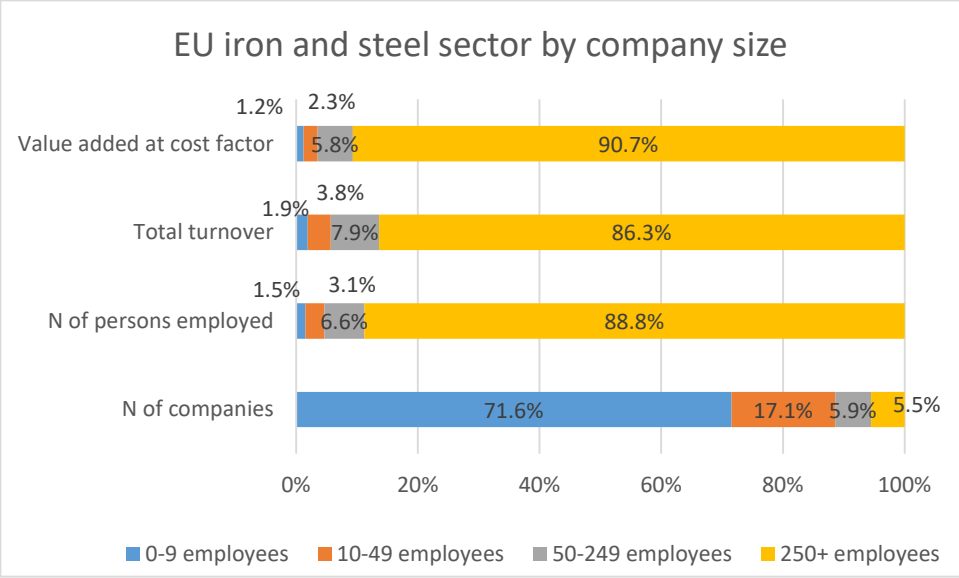
Figure 1 – EU Manufacturing by company size



Source: Eurostat

Figure 2 – EU Iron & Steel sector by company size



Source: Eurostat

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2.1.4 Gross investment in machinery and equipment

To conclude the structural analysis of the sector, it is interesting to investigate the propensity to invest in machinery and equipment at a country level. Although Eurostat data are not complete, some interesting facts emerge:

- Countries investing the most in machinery and equipment are Germany, Turkey and Italy. In absolute values the gross investment per company is higher in Belgium and Turkey. However, Italy and Slovakia show the same share of investment on total manufacturing as Belgium
- Investment in iron and steel in Turkey amount to a relevant 6.3% of total manufacturing
- Norway, Turkey, Switzerland and Belgium show a higher level of investment per person employed.

Table 6 – Iron & Steel. Gross investment in machinery and equipment in 2016, €M, EU28, Norway, Switzerland and Turkey

	Gross Investment, €M	% of total manufacturing	Gross investment per company, €M	Gross investment per person employed, €k
EU 28	na	na	na	na
Belgium	202	2.5%	2.6	17.4
Czechia	82	1.4%	1.2	4.8
France	na	na	na	na
Germany	890	1.6%	1.7	11.6
Italy	601	2.5%	1.4	14.0
Netherlands	na	na	na	na
Nordics	208	1.8%	1.9	7.9
Poland	162	1.5%	1.7	8.1
Spain	228	1.6%	1.2	10.7
Slovakia	64	2.5%	0.2	5.6
UK	206	1.0%	0.3	8.5
Other EU	na	na	na	na
Norway	28	1.5%	1.4	16.9
Switzerland	19	0.3%	1.7	15.8
Turkey	837	6.3%	2.7	16.8

Source: Eurostat, 2019 (Data refer to 2016. UK: 2015; Slovakia. Turkey: 2014)

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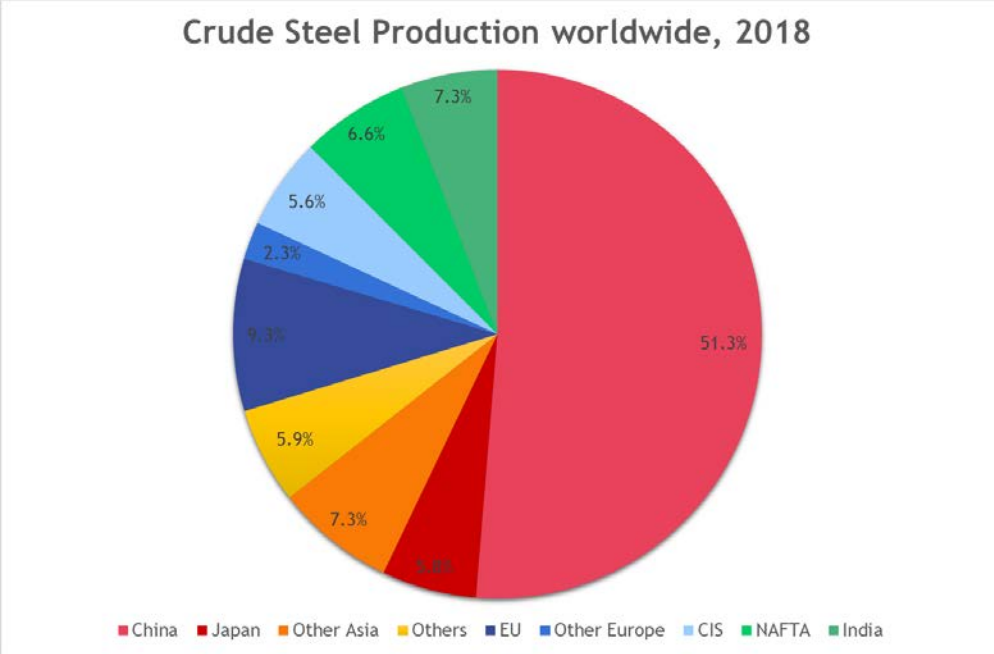
2.2 THE GLOBAL PERSPECTIVE

In order to put the EU and Turkish iron and steel sector into the right perspective, it is useful to take a look also at the global market. According to the World Steel Association, the global crude steel production was €1.51 million tonnes in 2017. EU 28 accounts for some 10%[1] and other European countries for 2.3%. Asia holds the biggest share of steel production. The major country is China which accounts for half of global production (51.3%); the other Asian countries represent 7.3%. Japan and NAFTA (i.e. US, Mexico & Canada) 5.8% and 6.6% respectively.

CIS countries (including Russia) hold 5.6% of total production. Africa, Middle East, Central and South America, Australia and New Zealand have residual shares[2].

Figure 3 – Crude Steel Production worldwide, 2018



Source: World Steel Association, 2019

Considering the apparent use (finished steel products) the share of Europe increases to 9.9% and that of China decreases to 48.8%

[1] *EY, "Globalize or Customize: Finding the Right Balance Global Steel 2015–2016", 2017.*

[2] *World Steel Association, "World steel in figures 2019", 2019.*

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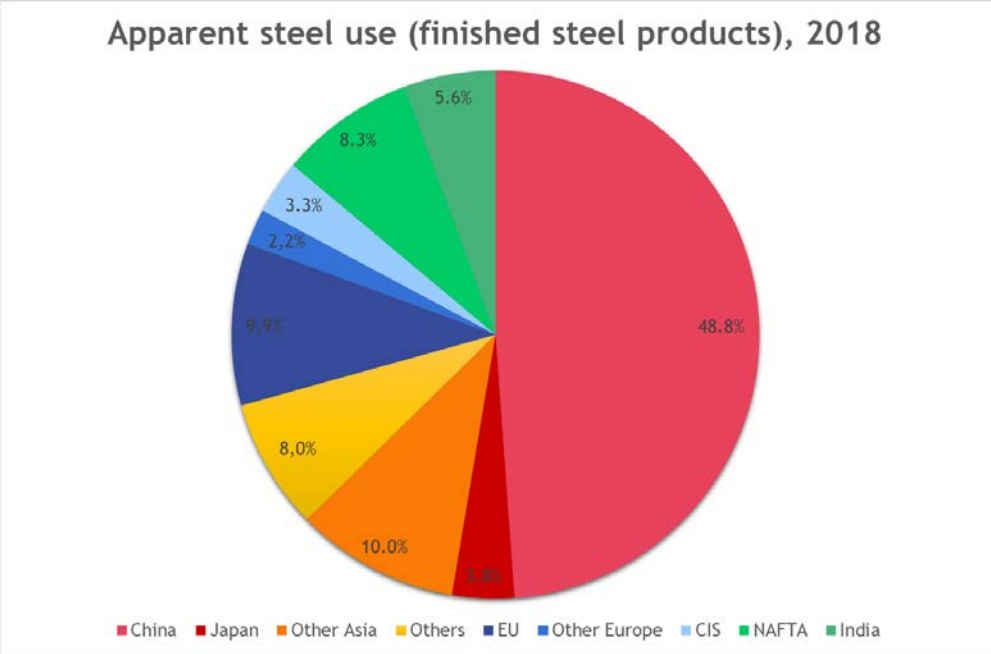
Figure 4 – Apparent steel use (finished steel products), 2018



Source: World Steel Association, 2019[2]

China leads therefore in total exports followed by Japan and Russia. The EU28 is the largest importer in absolute terms, followed by the US, and the second largest net importer, after the US.

Table 7 – Total imports of steel, Mt, 2018

Rank	Countries	Total imports, Mt
1	European Union (28)	44.9
2	United States	31.7
3	Germany	26.6
4	Italy	20.6
5	Thailand	15.5
6	South Korea	14.9
7	France	14.9
8	Belgium	14.8
9	China	14.4
10	Vietnam	14.1

Source: World Steel Association, 2019[2]

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Table 8 – Net imports of steel (imports-exports), Mt, 2018[2]

Rank	Countries	Total imports, Mt
1	United States	44.9
2	European Union (28)	31.7
3	Thailand	26.6
4	Philippines	20.6
5	Vietnam	15.5
6	Indonesia	14.9
7	Mexico	14.9
8	Malaysia	14.8
9	Poland	14.4
10	United Kingdom	14.1

Source: World Steel Association, 2018

To conclude, the table below shows the top 20 companies of the sector in 2018, an indication of Tier1 providers that could be targeted with the solutions developed within BAMBOO. ArcelorMittal, the largest steelmaker in the world, is one of the four real demonstrators within the project.

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Table 9 – Iron & Steel. Top 20 steelmakers, 2018[2]

Rank	Top companies	HQ	Tonnage, M Tonnes
1	ArcelorMittal	Luxemburg	96.42
2	China Baowu Group	China	67.43
3	Nippon Steel Corporation	Japan	49.22
4	HBIS Group	China	46.80
5	POSCO	South Korea	42.86
6	Shagang Group	China	40.66
7	Ansteel Group	China	37.36
8	JFE Steel Corporation	Japan	29.15
9	Jianlong Group	China	27.88
10	Shougang Group	China	27.34
11	Tata Steel Group	India	27.27
12	Nucor Corporation	USA	25.49
13	Shandong Steel Group	China	23.21
14	Valin Group	China	23.01
15	HYUNDAI Steel Company	South Korea	21.88
16	Maanshan Steel	China	19.64
17	Novolipetsk Steel (NLMK)	Russia	17.39
18	JSW Steel Limited	India	16.83
19	IMIDRO	Iran	16.79
20	Steel Authority of India Ltd.	India	15.93

Source: World Steel Association, 2019

2.3 ECONOMIC OUTLOOK & KEY BUSINESS TRENDS

2.3.1 Short-term economic outlook

The European steel market increased by 3.3% in 2018 according to the European Steel Association. However, the overall increase in steel demand led more benefits to suppliers outside the EU (which saw a 12.3% increase in exports), while EU domestic producers experienced just a 0.6% growth[3].

[3] *EUROFER, "Economic report economic and steel market outlook 2019-2020", 2019.*

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The introduction in 2018 of anti-dumping measures to protect the European domestic market did not block the recent increase in imports from third countries, causing a loss of market shares for European steel producers in 2018 and 2019. US protectionist measures (see Section 2.3.2) instead had a more positive impact on the US steel internal demand and allowed to partially prevent unfair practices[3].

In this context, even though the European market increased during 2018, short-term forecasts show that it will drop until the end of 2019[3].

Looking at the steel-using sectors, the construction sector was not negatively affected by recent trends and continues to expand, with an anticipated growth of 2.2% in 2019, since housing demand is positively impacted by increasing consumer confidence and improved access to finance. Automotive, mechanical engineering, steel tube and metal goods were impacted more negatively registering the most consistent slowdown[3].

For the years to come, forecasts for the overall steel-using sector are not completely positive: analysts think that even though consumption and public expenditure are growing, exports and investments are expected to be rather weak and may fall more if other protectionist measures will arise or Brexit will occur[3]. Output from steel-using sectors is expected to grow up to 1% at maximum in both 2019 and 2020.

2.3.2 Key business trends

In the past few years, several factors affected the dynamics of the iron and steel sector. Above all, a persistent excess capacity, especially in China, is having consequences worldwide, hampering both efficiency and profitability of the sector. This led to the rise of protectionist measures as a way to protect business operations and competitiveness. Recently, higher duties and anti-dumping actions spread out to a greater extent from several countries; most of the measures are directed to hamper China's behaviour. Both the United States and the European Union took measures towards China. In 2018 the United States applied 25% and 10% tariffs on specific steel and aluminium products[4]; Europe started with provisional measures in 2016 and then confirmed the imposition with definitive measures in 2018. European measures have been imposed on 26 product categories (such as hot-rolled flat steel and heavy plates) in order to control the negative effects of price pressure due to unfair trade practices by China and trade diversions caused by US tariffs[5].

Hot-rolled steel is an important input for the production of a wide range of steel applications in construction, energy pipes, gas containers, ships. Steel plates also have a substantial range of

[4] *Congressional Research Service, "Section 232 Investigations: Overview and Issues for Congress", 2019.*

[5] *European Commission, "Steel: Commission intends to impose definitive safeguard measures on imports of certain steel products", 2019*

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applications in construction, energy pipes and containers, oil platform and in general heavy equipment[6].

Under these circumstances, several M&A have been carried out recently to face increased duties, overcapacity and increased competition caused by China intensive production. Companies in Europe and worldwide opted for market consolidation to face competition and lower production costs. One of the most important actions was the acquisition of Ilva by ArcelorMittal in 2018, the largest steel producer in Europe. Negotiations are ongoing for an expected merger between Germany's ThyssenKrupp and India's Tata Steel, becoming then the second larger steel producer in Europe.

More than that, the overall steel sector has entered its final stage of the business cycle implying economic solidity but also an expected and progressive slowdown in the next few years till the end of the cycle[3]. This structured stagnation together with overcapacity and protectionism trends can hamper the stability of the EU region over the next few years.

In addition, the increase in environmental and safety regulations worldwide and the pressure caused by manufacturing competitiveness lead to a growing need for sector renovation. Moreover, the sector is facing progressively higher energy cost to sustain, especially in the EU; as analysts show, electricity tariffs in EU are twice as high and still rising compared to all the other regions of the world.

From a consumer behaviour perspective, there is an increasing demand for product differentiation. This forces companies to focus on customization and reconfiguration of the production chain.

In summary, the business phase the sector is facing brings along several challenges that can hamper the development of the EU steel industry or instead be a starting point for improvements. In this context, analysts pinpoint some opportunities and trends for the medium-term.

- Despite uncertainty linked to policies and global trade, business confidence is expected to lead investment to progressively recover in the medium-term[7]. An expected increase in general competitiveness will result in production consolidation in some world regions, such as Europe and China.
- Improvements are expected also for working capital performance, which was negatively affected in the past years due to market volatility, the need of business process transformation and some companies' failures[8].

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[6] *European Commission, "European Commission imposes anti-dumping duties on Chinese steel products", 2016.*

[7] *World Steel Association, "Global Steel Demand Continues to Show Resilience.", 2018.*

[8] *EY, "How Steelmakers Are Responding to Volatile Times", 2019.*

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- Ways in which improvements can be reached include more responsiveness to external factors, such as rethinking of manufacturing and supply solutions towards a more flexible and agile structure and more cross-functional cooperation among actors in the value chain[8].
- Factors which will increasingly become crucial for the industry are the adoption of highly innovative and technological solutions, attention to regulations related to safety, increase in capital flow and strengthening of trade across borders.

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3 PETROCHEMICALS

For the purpose of the analysis, NACE code "C19" referred to "Manufacture of coke and refined petroleum products" is used.

3.1 STRUCTURAL ANALYSIS: EU AND TURKEY

3.1.1 Number of Companies and Persons Employed

The European petrochemicals sector is composed by just 1,065 operating companies (2017). The sector represents 0.05% of total manufacturing. The country with higher impact on European operations is Italy, accounting for almost one third of total petrochemicals companies in the EU (i.e. 27.3%). Also Poland and the UK have a relevant number of operating companies, respectively 18.3% and 6.8% of total EU enterprises in the sector.

In all EU countries the share of petrochemical companies on total manufacturing is extremely low. Poland stands out in terms of petrochemicals weight on total manufacturing compared to other countries, but still it reaches just 0.1%. Italy, UK and Norway follow.

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Table 20 – Petrochemicals. Number of companies in 2017, EU28, Norway, Switzerland and Turkey

	N. of companies	EU28 % breakdown	Share of total manufacturing
EU 28	**1,065**	**100%**	**0.05%**
Belgium	12	1.1%	0.03%
Czechia	28	2.6%	0.02%
France	24	2.3%	0.01%
Germany	72	6.8%	0.04%
Italy	291	27.3%	0.08%
Netherlands	31	2.9%	0.05%
Nordics	57	5.4%	0.06%
Poland	195	18.3%	0.10%
Spain	16	1.5%	0.01%
Slovakia	na	0%	0%
UK	115	10.8%	0.08%
Other EU	224	21.0%	0.06%
Norway	14		0.08%
Switzerland	7		0.03%
Turkey	9		0.00%

Source: Eurostat, 2019 (Data refer to 2017. Italy: 2016)

The total number of persons employed in the sector is 126,499, representing 0.4% of total persons employed in manufacturing. Even though Italy has more companies than other countries, it employs less workers (i.e. 10,998). Germany, France and Poland have more people employed in the sector, respectively 19,037, 15,095 and 13,886. Belgium holds the largest share of people employed on total manufacturing in the country (0.9%).

Outside the EU, Turkey employs 7,872 people in total.

Looking at persons employed per company, Turkey stands out with the highest number (i.e. 875), mirroring the presence of large companies in the sector, followed by France and Spain with respectively 629 and 545 persons employed per company.

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Table 11 – Petrochemicals. Persons employed in 2017, EU28, Norway, Switzerland and Turkey

	Persons employed	% of total manufacturing	Persons employed per company
EU 28	**126,499**	**0.4%**	**119**
Belgium	4,559	0.9%	380
Czechia	2,053	0.2%	73
France	15,095	0.5%	629
Germany	19,037	0.3%	264
Italy	10,998	0.3%	38
Netherlands	5,577	0.3%	180
Nordics	2,879	0.2%	51
Poland	13,886	0.5%	71
Spain	8,723	0.5%	545
Slovakia	na	na	na
UK	9,756	0.4%	85
Other EU	33,936	0.8%	152
Norway	421	0.2%	30
Switzerland	624	0.1%	89
Turkey	7,872	0.2%	875

Source: Eurostat, 2019 (Data refer to 2017. France: 2010; United Kingdom: 2012; Czechia, Turkey: 2014; Slovenia, Sweden: 2015)

Beyond Turkey, France and Spain (where the average number of persons employed is above 500), in other countries the sector sees the large presence of SMEs with no production plants.

Germany, for example, accounts for more than 19,000 persons in the sector for an average of persons employed per company lower than France, Turkey and Spain (264). Italy and Poland, with respectively 10,998 and 13,886 persons employed, show an even smaller company dimension with an average of persons employed per company of respectively 38 and 71.

3.1.2 Turnover, Production and Value-added

The European petrochemicals sector reached a turnover of €443,775 million in 2017. The sector has a great impact on the total manufacturing, representing 5.7% of total turnover.

Germany and the UK are the strongest contributor to the total turnover in the sector, with a country turnover of €72,905 and €72,908 million. Belgium, Spain, and France follow.

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Looking at the petrochemicals' weight on each country's total manufacturing, it is shown that the sector in Belgium is relatively bigger than everywhere else, with a share of 15.8%. The sector is important in terms of total manufacturing impact also in other countries, such as the UK, Poland, Netherlands and Spain with a share very close to 10%.

Belgium is confirmed at the top also in terms of turnover per company with the highest value in Europe of €3,554 million followed by Spain with €2,548 million. Also, the turnover per person employed is much higher in Belgium than in other countries (i.e. €9,354K). Just after, the UK shows a relevant turnover per person employed of €7,473K and the Netherlands a value of €5,414K.

Table 12 – Petrochemicals. Turnover in 2017, €M, EU28, Norway, Switzerland and Turkey

	Total Turnover, €M	EU28 % breakdown	Share of total manufacturing	Turnover per company,	Turnover per person employed,
EU 28	**443,775**	**100.0%**	**5.7%**	**417**	**3,508**
Belgium	42,644	9.6%	15.8%	3,554	9,354
Czechia	4,943	1.1%	2.8%	177	2,408
France	38,998	8.8%	3.8%	1,625	2,584
Germany	72,905	16.4%	3.5%	1,013	3,830
Italy	34,298	7.7%	3.7%	118	3,119
Netherlands	30,197	6.8%	8.7%	974	5,414
Nordics	11,225	2.5%	2.4%	197	3,899
Poland	30,333	6.8%	9.4%	156	2,184
Spain	40,761	9.2%	8.0%	2,548	4,673
Slovakia	na	na	na	na	na
UK	72,908	16.4%	10.6%	634	7,473
Other EU	64,563	14.5%	7.3%	288	1,902
Norway	2		0.0%	0	5
Switzerland	na	na	na	na	na
Turkey	14,834		4.3%	1,648	1,884

Source: Eurostat, 2019 (Data refer to 2017. Slovenia: 2013; Czechia, Turkey: 2014; Sweden, Norway, Latvia: 2015)

Mirroring the behaviour of turnover, Germany has by far the highest production value (€70,452 million) accounting for 18.7% of the total European production in petrochemicals. The UK, Belgium, Spain, and France are also strong contributors with a production share of around 10% each.

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The impact of petrochemicals production on each country's total manufacturing is significant in several countries, above all in Belgium, accounting for 14.5% of total manufacturing.

Belgium, Spain, and France have the highest production values per company of €3,092, €2,271 and €1,519 million together with Turkey with a significant value of €1,511 million. In addition, Belgium shows a strong production value per person employed, much above all the other countries (i.e. €8,138K) followed by the UK, Spain and the Netherlands.

Table 13 – Petrochemicals. Production value in 2017, €M, EU28, Norway, Switzerland and Turkey

	Production value, €M	EU28 % breakdown	Share of total manufacturing	Production value per company, €M	Production value per person employed, €k
EU 28	**375,985**	**100.0%**	**5.4%**	**353**	**2,972**
Belgium	37,103	9.9%	14.5%	3,092	8,138
Czechia	4,911	1.3%	2.9%	175	2,392
France	36,452	9.7%	4.1%	1,519	2,415
Germany	70,452	18.7%	3.9%	979	3,701
Italy	26,526	7.1%	3.0%	91	2,412
Netherlands	22,693	6.0%	7.2%	732	4,069
Nordics	9,730	2.6%	2.4%	171	3,380
Poland	21,949	5.8%	7.5%	113	1,581
Spain	36,338	9.7%	7.6%	2,271	4,166
Slovakia	na	na	na	na	na
UK	50,677	13.5%	8.3%	441	5,194
Other EU	59,155	15.7%	7.4%	264	1,743
Norway	2		0.0%	0	5
Switzerland	na	na	Na	na	na
Turkey	13,598		4.1%	1,511	1,727

Source: Eurostat, 2019 (Data refer to 2017. Slovenia, Norway: 2013; Czechia, Turkey: 2014; Sweden, Latvia: 2015)

Value added at factor cost was closed to €31 billion in 2016, representing 1.6% of total manufacturing. Compared to turnover and production value, representing respectively 5.7% and 5.4% of total manufacturing, value added in petrochemicals presents a lower impact on total manufacturing. Belgium, Poland and Spain have an above-average impact, between 3% and 4%.

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Table 14 – Petrochemicals. Value added at factor cost in 2016, €M, EU28, Norway, Switzerland and Turkey

	Value added, €M	EU28 % breakdown	Share of total manufacturing	Value added per company, €M	Value added per person employed, €k
EU 28	**31,308**	**100.0%**	**1.6%**	**29**	**247**
Belgium	2,182	7.0%	4.0%	182	479
Czechia	116	0.4%	0.3%	4	56
France	3,025	9.7%	1.4%	126	200
Germany	4,820	15.4%	0.8%	67	253
Italy	1,964	6.3%	0.9%	7	179
Netherlands	1,517	4.8%	2.3%	49	272
Nordics	821	2.6%	0.7%	14	285
Poland	2,470	7.9%	3.8%	13	178
Spain	3,441	11.0%	3.3%	215	394
Slovakia	na	na	na	na	na
UK	4,076	13.0%	2.0%	35	418
Other EU	6,876	22.0%	2.8%	31	203
Norway	1		0.0%	0	1
Switzerland	103		0.1%	15	165
Turkey	527		0.8%	59	67

Source: Eurostat, 2019 (Data refer to 2016. Croatia :2012; Slovenia, Norway: 2013; Czechia, Turkey: 2014; Sweden, Estonia: 2015)

3.1.3 Structural analysis by company size

As shown above, even though Turkey, France, Spain and Belgium companies are bigger in size compared to other countries, the European petrochemicals sector is mainly composed by SMEs with no production plants. Indeed, the number of persons employed per company in those countries are much above the European average (i.e. respectively 875, 629, 545, and 380); most of the other countries are composed by small enterprises, resulting in an overall European average of 119 persons per company.

As shown in the following figure, 91.3% of petrochemicals companies are SMEs with micro-enterprises accounting for 59.7%. Even though the sector seems to be structurally dominated by small businesses, the presence of large companies is much higher than for the average European manufacturing (i.e. 8.7% compared to 0.8%). Indeed, the EU petrochemicals sector has a twofold structure, with few countries having large enterprises and accounting for almost all turnover of

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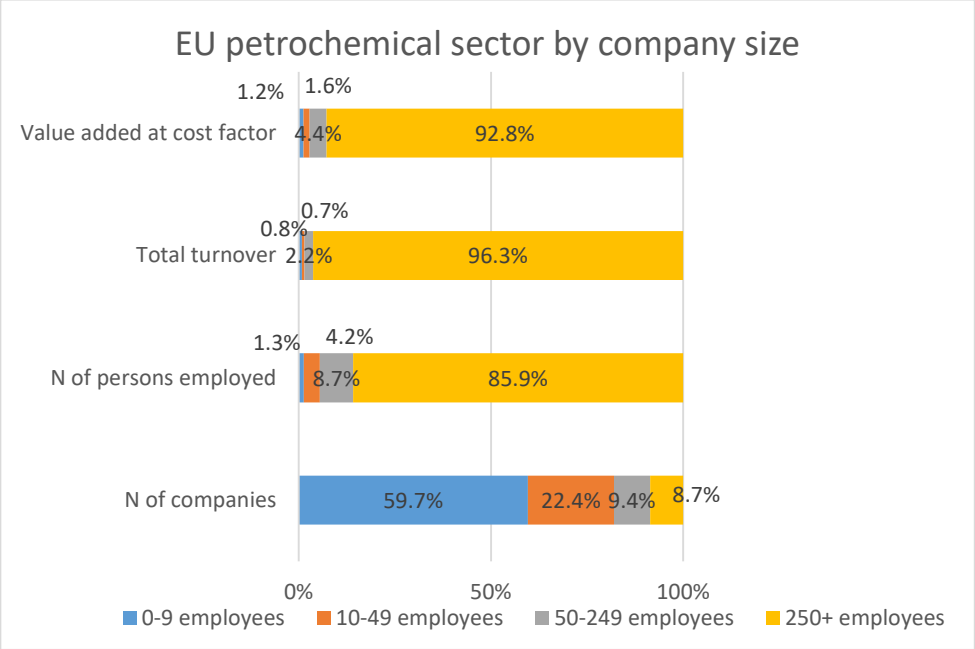
the sector, and the remaining countries with a high number of SMEs accounting for a residual turnover. Employment, turnover and value added of large companies are respectively 85.9%, 96.3% and 92.8% out of the total – much more compared to total manufacturing. As such, despite the structural prevalence of SMEs, the sector is largely dominated by large and very large companies.

Figure 5 – EU petrochemicals sector by company size



Source: Eurostat

3.1.4 Gross investment in machinery and equipment

The propensity to invest in machinery and equipment in the sector is higher in Belgium and Germany compared to all the other countries with respectively €841 and €767 Million invested in 2016. Other countries having relevant investments in the sector are Spain, the UK and Poland.

Mirroring the little presence of companies in other countries, gross investment in machinery and equipment is rather limited.

Belgium gross investment has a relatively high share on total manufacturing investment; also gross investment per company and per person employed stand out for Belgium compared to other countries: €70.1 million and €184.5 compared to the EU average of €4.3 million and €35.8.

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Table 15 – Petrochemicals. Gross investment in machinery and equipment in 2016, €M, EU28, Norway, Switzerland and Turkey

	Gross Investment, €M	% of total manufacturing	Gross investment per company, €M	Gross investment per person employed, €k
EU 28	**4.529**	**na**	**4.3**	**35.8**
Belgium	841	10.4%	70.1	184.5
Czechia	17	0.3%	0.6	8.3
France	na	na	na	na
Germany	767	1.4%	10.7	40.3
Italy	367	1.6%	1.3	33.4
Netherlands	318	4.9%	10.3	57.0
Nordics	159	1.4%	2.8	55.3
Poland	462	4.3%	2.4	33.3
Spain	614	4.4%	38.4	70.4
Slovakia	na	na	na	na
UK	568	2.8%	4.9	58.2
Other EU	416	1.8%	1.9	12.2
Norway	0	0.0%	0.0	0.0
Switzerland	17	0.3%	2.4	26.8
Turkey	27	0.2%	3.0	3.5

Source: Eurostat, 2019 (Data refer to 2016. Croatia :2012; Czechia, Turkey: 2014; Sweden, Estonia: 2015)

3.2 THE GLOBAL PERSPECTIVE

The petrochemical sector was traditionally concentrated in industrialised regions such as Europe, United States and Japan. In the past few decades, production expanded in other regions with more competitive feedstock prices, such as Middle East and Asia.

The expansion of capacities in both regions changed the sector dynamics and forced several facilities to close in traditional markets, especially in Europe. In this context, with Middle East and Asia on the rise and North America as the only traditional market holding its position, China emerged as the major producer and consumer in the sector[9].

[9] *R.J. Clews, "Project Finance for the International Petroleum Industry", 2016.*

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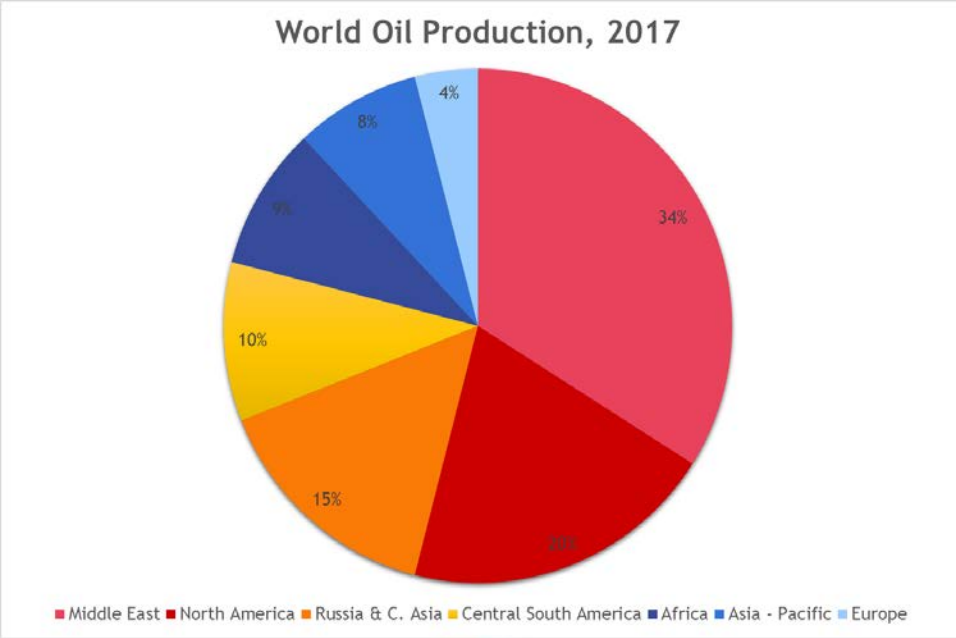
To put the petrochemical sector in the right global perspective and consider the strong dependencies between manufacturing and extraction, both upstream and downstream processes of the petroleum industry are considered in the analysis.

According to ENI, the Middle East and North America hold together half of the global oil production with shares of 34% and 20% respectively, followed by Russia & Central Asia with a share of 15%, Central South America with 10%, Africa with 9% and Asia Pacific with 9%. In this context, Europe holds only 4% of global production[8]. Data shows the relevance of North America and Middle East in the international oil equilibrium.

Figure 6 – World Oil Production, 2017[10]



Source: ENI, 2018

Looking at production by country in 2018, the United States, Saudi Arabia and Russia hold bigger shares of global oil production of respectively 18%, 12% and 11%[11]. Moreover, as shown in the following table, top 10 countries in terms of production account for 70% of the market – highlighting a high-country concentration.

Within Europe, Norway and the United Kingdom provide the biggest contribution to the European total production, holding together 80% of EU production[10]. Data include not just refining (within

[10] *Eni, "World Oil Review 2018", 2018.*

[11] *Eia, "What countries are the top producers and consumers of oil?", 2019.*

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manufacturing as presented in the structural analysis above), but also extraction of crude oil (within mining).

Table 16 – The 10 largest oil producers and share of total world oil production, 2018[11]

Country	Million barrels per day	Share of world total
United States	17.87	18%
Saudi Arabia	12.42	12%
Russia	11.40	11%
Canada	5.27	5%
China	4.82	5%
Iraq	4.62	5%
Iran	4.47	4%
United Arab Emirates	3.79	4%
Brazil	3.43	3%
Kuwait	2.87	3%
Total Top	70.96	70%
World Total	**100.66**	

Source: EIA, 2018

Looking at global oil consumption, the United States confirms its prevailing role in the sector (i.e. 20%), followed by China and India accounting respectively for 13% and 5%.

Table 17 – The 10 largest oil consumers and share of total world oil production, 2018[11]

Country	Million barrels per day	Share of world total
United States	19.69	20%
China	12.79	13%
India	4.44	5%
Japan	4.01	4%
Russia	3.63	4%
Saudi Arabia	3.30	3%
Brazil	2.98	3%
South Korea	2.61	3%
Canada	2.47	3%
Germany	2.38	2%
Total Top 10	58.31	60%
World Total	**96.92**	

Source: EIA, 2018

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With regards to global trade, major oil importers are China and the United States. Being China on the rise in petrochemical production, it shows a great increase in oil import, growing at a CAGR (Compound Annual Growth Rate) of 11.1% between 2000 and 2017[10]. In this context, also Europe has a prevailing role, with Germany, Italy, Spain, France and Netherlands as significant importers.

Table 18 – The World Top 10 Importers of Crude and non-conventional oil[10]

Country	2017 import, thousand barrels/day	CAGR (2017-2000)
China	8,413	11.1%
United	7,912	-0.8%
India	4,550	6.7%
Japan	3,158	-1.7%
South Korea	3,012	1.3%
Germany	1,815	-0.8%
Italy	1,327	-1.4%
Spain	1,318	0.8%
France	1,132	-2.4%
Netherlands	1,081	-0.1%
ROW	12,948	0.3%
World	**46,666**	1.1%

Source: ENI, 2018

Looking at exports, Saudi Arabia is by far the country exporting the most, followed by Russia and Iraq.

Table 19 – The World Top 10 Exporters of Crude and non-conventional oil[10]

Country	2017 export, thousand barrels/day	CAGR (2017-2000)
Saudi Arabia	7,178	0.8%
Russia	5,257	3.5%
Iraq	3,324	2.8%
Canada	3,318	5.3%
UAE	2,363	1.2%
Iran	2,223	-0.2%
Kuwait	2,096	3.2%
Nigeria	1,783	-1.1%
Angola	1,587	4.5%
Venezuela	1,581	-1.4%
ROW	13,568	-0.8%
World	**44,278**	0.8%

Source: ENI, 2018

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From a company perspective, the petroleum sector is composed by a high percentage of NOCs (National Oil Companies): worldwide national companies account for 58% of total companies. This is more emphasized in Russia and North America, whose NOCs hold more than 70% of total production in the countries[10].

The top 10 companies in the sector are presented below (Table 20). They represent possible targets of the BAMBOO solutions.

Table 20 –Oil & Gas. Top 10 companies worldwide[12]

Rank	Top companies	HQ	2017 Revenue
1	Sinopec	China	$362bn
2	Royal Dutch Shell Plc	Netherlands	$305bn
3	China National Petroleum Corporation	China	$269bn*
4	BP Plc	UK	$240bn
5	ExxonMobil	US	$237bn
6	Vitol Holding BV	Switzerland	$181bn
7	Total SA	France	$149bn
8	Chevron Corporation	US	$134bn
9	Gazprom	Russia	$113bn
10	Rosneft Oil Co	Russia	$104bn

Source: Hydrocarbons Technology, 2017

3.3 ECONOMIC OUTLOOK & KEY BUSINESS TRENDS

3.3.1 Short-term economic outlook

To put petrochemical sector in the right economic perspective, trends in extraction are considered. Indeed, petrochemical processes have been highly affected by global oil crises and countries with easier access to competitive feedstocks and less trade dependencies emerged as major players.

After 10 years of drastic increase in oil price between 1999 and 2008 due to demand growth in emerging economies, the price dropped dramatically during the global recession in 2008 with negative impacts on the industry as a whole, hampering both economic and political stability for several years. A recovery was registered between 2009 and 2014; during 2014 and 2015, countries that had previously driven the expansion in the industry (i.e. China, Russia, India, Brazil),

[12] *Hydrocarbons Technology, "The world's biggest oil and gas companies in 2018", 2018.*

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experienced a very much slower growth, causing another price crisis. Also, Saudi Arabia significantly contributed to this second drop, choosing not to cut its domestic production to let prices go upward again. After that, the situation recovered at a slow pace during 2016 and 2017 with an ulterior but less significant drop in 2018. From a long-term perspective, analysts state that, after several crises, the industry is now in its recovery phase.

In this context, short-term projections for the petroleum industry are positive. Oil demand growth for 2019 is projected at 1.2 mb/d and is expected to increase also in 2020 by 1.4 mb/d. Positive short-term forecast is justified by solid demand by non-OECD countries (Asia, Africa and South-Central America) and by the expansion of petrochemicals[13]. Indeed, the petrochemicals sector is considered by analysts the key driver for the next positive wave in the industry – especially in United States and China. Indeed, globalization and higher incomes in developing countries lead to a general increase in demand of consumer goods whose manufacturing is highly dependent on petrochemicals (e.g. 95% of goods are made up by petrochemicals).

With a focus on regions, Africa experienced a significant decline in the sector, due to Libya instability, the largest African producer. However, Africa is very promising in the industry for the next future also due to probable increase in investment attractiveness, recent offshore oil discoveries and more favourable tax regimes[14].

Asia is the largest oil consumer worldwide and this is expected to grow more. Even though the production level has been steady recently, the country on its own is unable to meet the internal demand (covering just 30%). Future expectations include a rise in petrochemical production and a focus on environmental and safety regulations. To the contrary, both CIS and Middle East countries are major oil exporters and produce three times their own internal demand and are expected to keep their prevailing position in the market[14].

In this context, while North America consolidated its position in the market with high investment in technologies and infrastructure, also Europe prospects are not negative. Demand recovered after the drop in 2014 and is expected to remain steady. Europe is highly dependent on trade, since it imports three quarters of the oil it needs (for both direct use and oil-based production). Even though it is unlikely that Europe will return to its dominant position in the market as during 1960s, the expansion of production in both Norway and the UK can lead in the short and medium-term to meet a bigger share of internal demand[14].

3.3.2 Key business trends

The petrochemical industry performed well in the last few years compared to other petroleum sectors and analysts expect that it will drive the global growth in oil demand between 2020 and 2030. This is due to the general increase in demand of plastic consumer goods in some emerging

[13] *International Energy Agency, "Oil Market Report", 2019.*

[14] *IOGP, "Global Production Report 2018", 2018.*

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regions and to the fact that renewable feedstocks as production input are not economically ready for many market segments[15].

In this context, petrochemical is expected to remain a pillar of the global economy in the next decade. In the longer term the sector will be more and more challenged by the substitution of oil with other energy sources.

This shift is expected to take place on a global scale and following this the petrochemicals industry is anticipated to slow down by 10% in the long-term (2050). The substitution of oil together with a progressively higher recycling rate and a general digitalization of processes will force petrochemical activities towards a substantial conversion. Companies may focus on fewer profitable segments of the market or convert the activity towards new segments such as those where some integration between new and traditional materials exists.

With the urgency to pursue a low-carbon approach, regulations play a role in setting up the new business environment[15]. Government intervention is a crucial driver expected to incentive changes in the industry, impacting on global plastic demand and forcing reconversion of activities in the long-term. In a context in which businesses already put effort in not losing margins – due to increasingly high-priced feedstock, incentives to use new materials and technological solutions can be an opportunity to create new market segments and nourish the industry[16].

Indeed, analysts forecast that in the medium-term companies will spur investments towards new approaches[16]. However, the introduction of new technologies, new materials and intra-materials solutions face several barriers and the adoption might take more time for petrochemical compared to other industries due to its high complexity.

Indeed, from a technology viewpoint, a study of KPMG[17] shows that even though innovation is already affecting oil businesses at multiple levels and executives all agree on the importance of technologies such as AI and machine learning, just half of them proceeded with such disruptive implementations. Analysts justify this with some factors that innovation brings along: the overall uncertainty on change management, workforce transition, unbalances between production and cost ratio, possible shifts on supply and demand logics, need of significant investments.

In this context, the European environment is challenging. From a competition point of view, EU industry is affected by a significant disadvantage in feedstock price and different policy costs compared to other regions[18]. Thus, the competitive pressure from the US, Middle East and Asia is high and is expected to increase.

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[15] *Petrochemicals Europe, "Petrochemicals' Production To Be Most Important Growth Driver For Global Oil Demand Up To 2030, Says Mckinsey Expert", 2018*

[16] *McKinsey Company, "Petrochemicals 2030: Reinventing the way to win in a changing industry", 2018.*

[17] KPMG, "Market Update: Oil & Gas - December 2018". 2018.

[18] *Cefic, "European chemistry for growth", 2013.*

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To unlock potentials of the European industry, analysts suggest the following actions:

- Share risks and know-how with strong partnerships and M&As, opt for plants at bigger scale that can allow lower costs, increase integration both upstream and downstream, rethink at age and technology level of factories[16]
- Invest in high differentiation of feedstock types including completely new sources to bring competitive advantage[19] and work around the difficult access to traditional feedstock
- Leverage high skilled workforce and low risk aversion to embrace innovative solutions
- Leverage EU industry cluster structure to gain competitive advantage[8]. Indeed, European production sites are often located in aggregate clusters highly integrated along the production chain with shared infrastructure, services and proximity to both raw material sources and suppliers' sites[20]. Locations are also easily connected to different transport nodes able to optimise logistic costs[20].

[19] *BCG, "The Future of Petrochemicals in Europe: Continuous Retreat or Rising Profitability?", 2014.*

[20] *Ecspp, Cefic, "Improving Competitiveness of European Chemical Industry Clusters".*

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4 NON-METALLIC MINERALS

For the purpose of the analysis, NACE code "C23" referred respectively to "Manufacture of other non-metallic mineral products" is used. Mining of minerals is not included in statistical data due to the impossibility to single out non-energy mining on Eurostat.

4.1 STRUCTURAL ANALYSIS: EU AND TURKEY

4.1.1 Number of Companies and Persons Employed

The European mineral sector is composed by 94,012 operating companies (2017) representing 4.43% of the total European manufacturing.

Italy is by far the European country with the highest number of companies (i.e. 18,973) and higher impact on total European operations (i.e. 20.2%). Also Germany, Poland, France and Spain stand out in terms of number of companies. Italy, Germany and Poland together account for 40% of the total European non-metallic mineral companies.

The impact on total manufacturing is significant for several countries and in line with the European average of 4.43%.

Outside the EU, Turkey shows a relevant number of companies (i.e. 13,888), higher than that of all European countries except for Italy.

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Table 21 – Mineral. Number of companies in 2017, EU28, Norway, Switzerland and Turkey

	N. of companies	EU28 % breakdown	Share of total manufacturing
EU 28	**94,012**	**100%**	**4.43%**
Belgium	1,617	1.7%	4.35%
Czechia	6,121	6.5%	3.45%
France	7,803	8.3%	3.89%
Germany	8,951	9.5%	4.47%
Italy	18,973	20.2%	4.89%
Netherlands	2,013	2.1%	3.02%
Nordics	3,172	3.4%	3.55%
Poland	9,140	9.7%	4.60%
Spain	7,929	8.4%	4.70%
Slovakia	2,426	2.6%	3.38%
UK	3,688	3.9%	2.70%
Other EU	22,179	23.6%	5.71%
Norway	627		3.70%
Switzerland	630		3.14%
Turkey	13,888		4.17%

Source: Eurostat, 2019 (Germany, Estonia, Spain, France, Malta, Netherlands, Slovenia: 2017; other countries: 2016)

The total number of persons employed in the sector is 1,214,503 or 4% of total persons employed in manufacturing.

Germany has more persons employed in the sector (i.e. 238,008) compared to the other EU 28 countries, followed by Italy, Poland and France. Turkey is by far the country with more persons employed: 247,024, with a great impact on the country total manufacturing (i.e. 6.8%). Other countries show a significant share on total manufacturing as well.

In general, all the countries have few persons employed per company; indeed, the European average is 13 persons per company. Just Germany and the Netherlands have a higher than average number of persons employed, still below 50. In general, even though Germany, Italy, Poland and France have a high number of persons employed, the sector in these countries is mostly composed by microenterprises just like in the other European countries.

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Table 22 –Mineral. Persons employed in 2017, EU28, Norway, Switzerland and Turkey

	Persons employed	% of total manufacturing	Persons employed per company
EU 28	**1,214,503**	**4.0%**	**13**
Belgium	28,559	5.6%	18
Czechia	58,780	4.5%	10
France	119,623	4.1%	15
Germany	238,008	3.2%	27
Italy	156,103	4.2%	8
Netherlands	64,400	3.5%	32
Nordics	47,058	3.8%	15
Poland	133,030	5.0%	15
Spain	92,208	4.8%	12
Slovakia	17,211	3.4%	7
UK	82,051	3.2%	22
Other EU	177,472	4.2%	8
Norway	11,089	5.0%	18
Switzerland	17,462	2.7%	28
Turkey	247,024	6.8%	18

Source: Eurostat, 2019 (Germany, Estonia, Spain, France, Malta, Netherlands, Slovenia: 2017; other countries: 2016)

4.1.2 Turnover, Production and Value-added

The European mineral sector reached a turnover of €210,815 million in 2017. Germany, France and Italy are the countries with the highest net sales (i.e. €50,489 million, €30,537 million, €28,348 million), making the greatest impact on total EU net sales, 23.9%, 14.5% and 13.4% respectively.

On average, the mineral sector accounts for 2.7% of the total European manufacturing turnover. Turkey stands out compared to EU countries, with a mineral share out of total manufacturing of 6.1%.

The average turnover per company is just €2 million. Some country differences apply: Germany, Belgium, the UK and Norway present a higher than average turnover per company. It is worth reporting also the highest average turnover per company hold by Switzerland.

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Looking at turnover per persons employed, Norway and Switzerland have the highest ratios followed by Belgium.

Table 23 – Mineral. Turnover in 2017, €M, EU28, Norway, Switzerland and Turkey

	Total Turnover, €M	EU28 % breakdown	Share of total manufacturing	Turnover per company, €M	Turnover per person employed, €k
EU 28	**210,815**	**100.0%**	**2.7%**	**2**	**174**
Belgium	8,641	4.1%	3.2%	5	303
Czechia	5,220	2.5%	2.9%	1	89
France	30,537	14.5%	3.0%	4	255
Germany	50,489	23.9%	2.4%	6	212
Italy	28,348	13.4%	3.1%	1	182
Netherlands	6,311	3.0%	1.8%	3	98
Nordics	11,524	5.5%	2.5%	4	245
Poland	12,219	5.8%	3.8%	1	92
Spain	18,288	8.7%	3.6%	2	198
Slovakia	1,765	0.8%	2.3%	1	103
UK	18,990	9.0%	2.8%	5	231
Other EU	18,483	8.8%	2.1%	1	104
Norway	3,680		4.3%	6	332
Switzerland	6,436		2.2%	10	369
Turkey	21,276		6.1%	2	86

Source: Eurostat, 2019 (Germany, Estonia, Spain, France, Malta, Netherlands, Slovenia: 2017; other countries: 2016)

Production value shows similar patterns of turnover: Germany, France and Italy have the most relevant production value, followed by the UK and Spain. France, Germany and Italy together account for half of the EU mineral production value.

The overall share of mineral production on total European manufacturing is 2.9%; Norway holds a higher than average share of 4.6%.

Outside the EU, Turkey has a very relevant share out of total manufacturing of 6.2% and a total production value of €20,510 million.

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Production value per person employed is higher in Belgium, France and the Nordics countries. However, Switzerland shows a production value per person employed much higher than the European average (i.e. €370K).

Table 24 – Mineral. Production value in 2017, €M, EU28, Norway, Switzerland and Turkey

	Production value, €M	EU28 % breakdown	Share of total manufacturing	Production value per company, €M	Production value per person employed, €k
EU 28	**200,171**	**100.0%**	**2.9%**	**2**	**165**
Belgium	7,724	3.9%	3.0%	5	270
Czechia	4,983	2.5%	2.9%	1	85
France	28,075	14.0%	3.2%	4	235
Germany	47,310	23.6%	2.6%	5	199
Italy	28,693	14.3%	3.2%	2	184
Netherlands	5,757	2.9%	1.8%	3	89
Nordics	11,082	5.5%	2.8%	3	235
Poland	11,291	5.6%	3.8%	1	85
Spain	17,636	8.8%	3.7%	2	191
Slovakia	1,601	0.8%	2.2%	1	93
UK	18,244	9.1%	3.0%	5	222
Other EU	17,776	8.9%	2.2%	1	100
Norway	3,497		4.6%	6	315
Switzerland	6,456		2.2%	10	370
Turkey	20,510		6.2%	1	83

Source: Eurostat, 2019 (Germany, Estonia, Spain, France, Malta, Netherlands, Slovenia: 2017; other countries: 2016)

Value added at factor cost was €67,252 million in 2017, representing a share on total manufacturing of 3.5%, in line with turnover and production value.

Germany has the highest value added at factor cost (i.e. €16,685 million), twice the second and third-ranked countries, France and Italy. Its contribution to European value added in minerals is 24.8%. France, Italy, and Germany together hold half of the value added in the region.

Outside EU28, the sector in Turkey has a significant impact on the total country manufacturing (i.e. 8.3%)

Value added per person employed in Switzerland is much higher than the European average (€134K compared to the EU average of €55K).

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Table 25 – Mineral. Value added at factor cost in 2017, €M, EU28, Norway, Switzerland and Turkey

	Value added, €M	EU28 % breakdown	Share of total manufacturing	Value added per company, €M	Value added per person employed, €k
EU 28	**67,252**	**100.0%**	**3.5%**	**1**	**55**
Belgium	2,541	3.8%	4.6%	2	89
Czechia	1,762	2.6%	4.7%	0	30
France	8,430	12.5%	3.9%	1	70
Germany	16,685	24.8%	2.9%	2	70
Italy	8,992	13.4%	4.0%	0	58
Netherlands	1,889	2.8%	2.8%	1	29
Nordics	3,935	5.9%	3.4%	1	84
Poland	3,691	5.5%	5.7%	0	28
Spain	5,478	8.1%	5.2%	1	59
Slovakia	488	0.7%	3.8%	0	28
UK	6,376	9.5%	3.2%	2	78
Other EU	6,984	10.4%	2.9%	0	39
Norway	1,114		5.3%	2	100
Switzerland	2,337		2.4%	4	134
Turkey	5,313		8.3%	0	22

Source: Eurostat, 2019 (Germany, Estonia, Spain, France, Malta, Netherlands, Slovenia: 2017; other countries: 2016)

4.1.3 Structural analysis by company size

As shown above, even though Germany, Italy, Poland and France have a high number of persons employed, the sector is dominated by micro enterprises in most of Europe. The European average of persons employed in the sector is 13. Number of persons employed by each country are in line with the average.

Figure 7 confirms this, showing that the percentage of micro-enterprises in the sector is 83.3%, in line with the percentage of total manufacturing.

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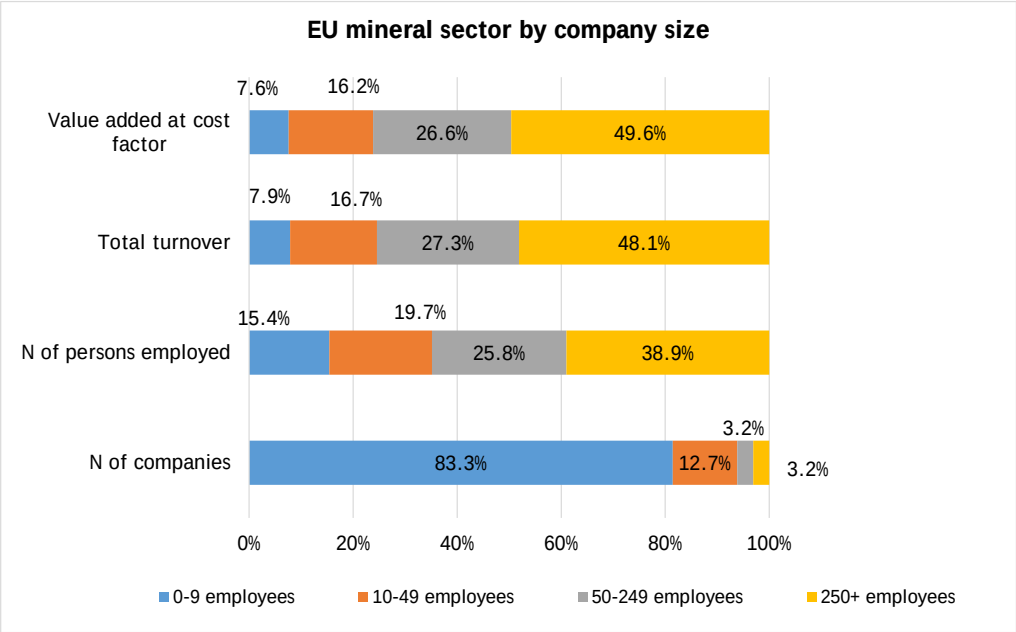
Figure 7 – EU mineral sector by company size



Source: Eurostat

Considering SMEs, the percentage is much higher, reaching 96.2%. Even though the sector mostly comprises SMEs, impact on turnover, value added and employment comes from both SMEs and large enterprises. Half of turnover and value added is driven by SMEs and the other half from large companies.

In details, turnover, value added and employment coming from large companies are respectively 48.1%, 49.6% and 38.9%. Compared to other sectors in the analysis (steel and petrochemicals), SMEs have therefore a relevant role and this should be considered when building value propositions to target the EU mineral sector.

4.1.4 Gross investment in machinery and equipment

The propensity to invest in machinery and equipment is higher in Germany and Italy compared to all the other countries with respectively €1,805 and €1,190 million invested in 2016.

The total value invested by countries over the total manufacturing has a greater impact in Poland and Norway.

Gross investment per company is rather limited due to the high presence of small enterprises.

Belgium, Norway and Switzerland present a higher gross investment per person employed.

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Table 26 – Mineral. Gross investment in machinery and equipment in 2016, €M, EU28, Norway, Switzerland and Turkey

	Gross Investment, €M	% of total manufacturing	Gross investment per company, €M	Gross investment per person employed, €k
EU 28	**7,332**	**na**	**0.1**	**6.0**
Belgium	382	4.7%	0.2	13.4
Czechia	259	4.4%	0.0	4.4
France	na	na	na	na
Germany	1,805	3.2%	0.2	7.6
Italy	1,190	5.0%	0.1	7.6
Netherlands	150	2.3%	0.1	2.3
Nordics	401	3.5%	0.1	8.5
Poland	796	7.4%	0.1	6.0
Spain	600	4.3%	0.1	6.5
Slovakia	61	2.4%	0.0	3.6
UK	564	2.8%	0.2	6.9
Other EU	1,125	5.0%	0.1	6.3
Norway	116	6.1%	0.2	10.5
Switzerland	183	2.9%	0.3	10.5
Turkey	na	na	na	na

Source: Eurostat, 2019 (Data refer to 2016. Turkey: 2014)

4.2 THE GLOBAL PERSPECTIVE

The mineral sector is the source of many manufacturing and construction industries worldwide.

Economic development in China and other countries such as Brazil, Russia, India, Mexico, Indonesia, Nigeria, drives the sector trends in the past 2 decades[7]. China, above all, expands in

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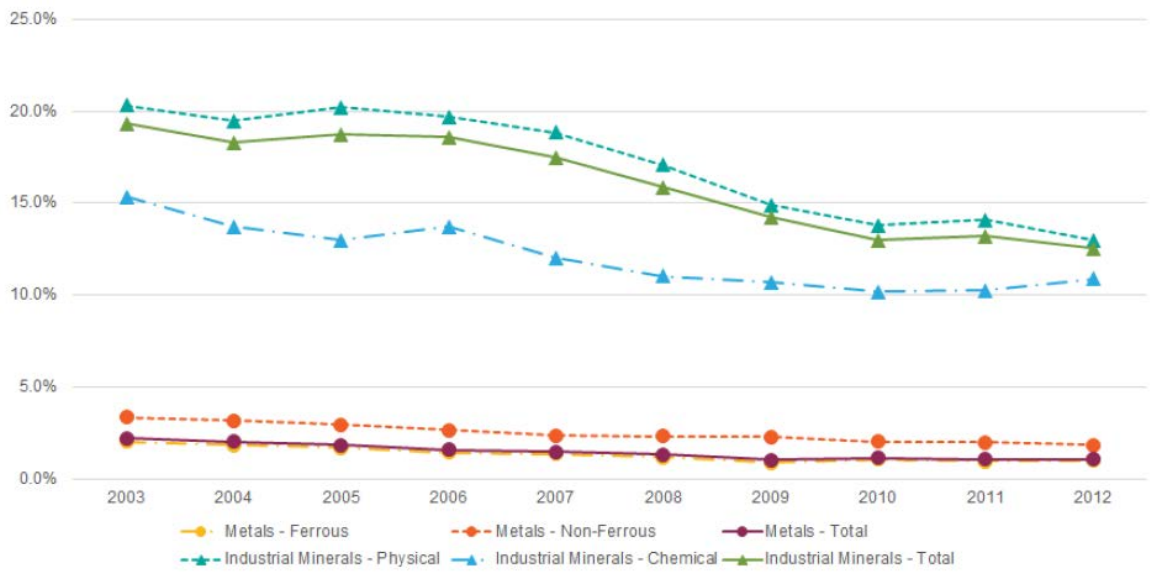
both consumption and production developing its own extractive and processing domestic industry, increasing its internal production capacity[21].

Traditionally Europe holds an important role in the sector: being one of the first industrialised regions, investments occurred before than elsewhere. Even though Europe has more limited access to raw sources compared to other regions, it early became a top producer for a few specific minerals.

In the current situation in which new players are expanding their position in the market, it seems that the European impact on global mineral activities is declining in recent years registering a drop in total mineral production[21].

EC data can suggest that Europe is becoming less competitive for both metals and minerals compared to other regions.

Figure 8 – EU28 Share of Global Output by Sub-Group, 2003-2012[21]



Source: EC, 2015

In this regard, it is useful to look at performance production of Europe for non-energy extractive industries compared to the rest of the world. Even though data are not updated to recent years, a trend can be highlight and some indications on competitiveness can be provided.

Table 27 – Performance of EU28 Production Compared to Global Markets, 2003-2012[21]

[21] *European Commission, "Study on the Competitiveness of the EU Primary and Secondary Mineral Raw Materials Sectors", 2015.*

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Sub-group	Change in production EU28	Change in production Global	Change in EU 28 share of global output
Metals - Ferrous	16%	139%	-1.4%
Metals - Non-Ferrous	-17%	51%	-1.5%
Industrial Minerals - Physical	-31%	8%	-7.32%
Industrial Minerals - Chemical	-17%	17%	-4.46%

Source: EC, 2015

Table 27 shows clearly that a global expansion occurs, especially for metals but also for industrial mineral with an 8% and 17% of increase. In this context, EU 28 industrial minerals shows a significant decline.

Looking at the structure of the sector, it is composed by few large players (especially for cement, glass and brick) and a high number of small and medium enterprises (as for cement and lime) making the market highly fragmented[22]. Bigger players, holding in Europe half of turnover and production value of the sector, usually operate at a global scale. Smaller companies, with a relevant impact on net sale and total European production, act more locally[21].

Table 28 provides an overview of the top 10 companies in metals and mining from a PwC analysis[23]. Most of them focus on the extraction of a broad range of products, both energy and non-energy. This leads to broaden the scope of the analysis and include players which are partially in scope of BAMBOO.

Table 28 – Metals and Mining. Top 10 companies worldwide[23]

Rank	Top companies	Country
1	BHP Billiton Limited	Australia/UK
2	Rio Tinto Limited	Australia/UK
3	Glencore plc	Switzerland
4	Vale S.A.	Brazil
5	MMC Norilsk Nickel	Russia
6	Freeport-McMoRan Copper & Gold	United States
7	China Molybdenum Co. Limited	China/Hong Kong

[22] *European Commission, "Minerals and non-energy extractive industries"*

[23] *PwC, "Mine 2018 - Tempting times", 2018.*

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8	Potash Corporation of Saskatchewan	Canada
9	Zijin Mining Group Co. Limited	China/Hong Kong
10	South32 Limited	Australia

Source: PwC, 2018

4.3 ECONOMIC OUTLOOK & KEY BUSINESS TRENDS

4.3.1 Short-term economic outlook

To put the non-metallic mineral sector in the right perspective, the non-energy extractive industry in its entirety is considered in the analysis.

As anticipated, new players from developing countries and China enter the market (especially downstream), rising its competitiveness[21]. The phenomenon is expected to persist in the short-term along with the progressive expansion of infrastructures and production capacity in those regions. Indeed, analysts state that the overall market is expected to continue growing together with an increasing competitiveness.

In this context, Europe hold a progressively smaller share of global activities and its difficulties seem to persist in the short-term, caused especially by difficult access of raw sources and high operations costs.

However, the region will hold its position in some downstream activities and for the production of a specific set of minerals. Indeed, the EU is the world largest producer of some types of minerals such as magnesite, fluorspar, kaolin, and potash[22].

4.3.2 Key business trends

The sector represents a pillar of the global economy. Industrial minerals, comprising non-metallic non-energy minerals are widely used as inputs for several production industries, such as chemical, electronics, fertiliser production, paper, plastic, glass, ceramics, hygiene and detergents[21].

As anticipated, even though the non-energy extractive sector is on a positive wave, it presents several challenges.

Recently, the rise of developing countries and China in the market are mining the sector structure and leveraging competitive pressure. Businesses are facing difficulties related to resource cost pressure, increasing operating costs and dramatically increase in tax contribution[1]. In response, several actions are undertaken by companies, such as vertical integrations and M&As to share infrastructure and increase access to finance[21].

The increase in operating cost is highly affected by energy costs needed for both extraction and processing. Even though energy cost differs among minerals extracted and type of processing, its impact on the total operating costs is significant among regions, above all Europe. As shown in Table 29 industrial minerals reflect a high percentage of energy cost over total operating costs.

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Table 29 – Comparison of the Relative Costs of Energy (electricity and fuel) as a Proportion of Overall Operating Costs[21]

Sub-sector	Estimated energy costs in the EU as a proportion of overall site operating cost
Metallic minerals	15%-17%
Construction minerals	3%
Industrial minerals	11%-19%

Source: EC, 2015

Also government intervention affects to a great extent operations. In most of the countries, policies rise in importance in order to increase benefits on the exported extraction minerals and for environmental issues. Regulations focus on both access to resources and processing methods[21].

From an environmental point of view, the transition towards a more sustainable management of resources in respect to biodiversity, forces the sector into a transition phase[2]. The phase brings along significant changes on mineral value chain in its entirety[23].

Indeed, as further explained in section 6.4, the sector represents a significant portion of total industry energy consumption. The adoption of energy efficiency paradigms will lead to a significant optimization of energy consumption resulting in a lower dependency of operations on energy costs.

In this context, analysts highlight some key success factors for European players:

- To work around the limited access to raw sources for some specific minerals, European countries can leverage recycling processes and reuse of waste. Positive effects can include avoiding disposal costs, decreasing energy extraction and processing costs, increasing supply capacity[21].
- Focus on energy cost, addressing methods to share costs or decrease energy dependency. Improve efficiency leads to decrease energy dependency and to provide positive responses to environmental concerns.
- Foster innovation and R&D to boost competitiveness, improve productivity and increase raw sources supply. Technological development requires upfront cost to sustain but in the longer term it allows to optimise processes without rising costs.
- For smaller companies, investments in flexibility and technological solutions can allow to be more competitive towards larger players.

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5 PULP & PAPER

For the purpose of the analysis, NACE codes "C17" referred to "Manufacture of paper and paper products" is used.

5.1 STRUCTURAL ANALYSIS: EU AND TURKEY

5.1.1 Number of Companies and Persons Employed

The European pulp & paper sector is composed by 19,562 operating companies (2017) representing just 0.92% of total companies in European manufacturing.

Italy is the European country with more operating companies (i.e. 3,763), accounting for 19.2% of total EU 28 operations. Other countries with relevant shares are Poland with 2,864 companies (i.e. 14.6%), Germany and France with respectively 1,678 and 1,343 companies and an aggregate share of 15.5%.

Turkey holds a good position in the market with a total of 2,501 companies, more than most of EU 28 countries.

The share of pulp & paper companies on total manufacturing is between 0.5% and 1% for most of the countries, except for Poland that stands at 1.44%. The total contribution of pulp & paper companies to European manufacturing is 0.92%.

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Table 30 – Pulp & Paper. Number of companies in 2017, EU28, Norway, Switzerland and Turkey

	N. of companies	EU28 % breakdown	Share of total manufacturing
EU 28	**19,562**	**100%**	**0.92%**
Belgium	222	1.1%	0.60%
Czechia	986	5.0%	0.56%
France	1,343	6.9%	0.67%
Germany	1,678	8.6%	0.84%
Italy	3,763	19.2%	0.97%
Netherlands	359	1.8%	0.54%
Nordics	699	3.6%	0.78%
Poland	2,864	14.6%	1.44%
Spain	1,661	8.5%	0.98%
Slovakia	370	1.9%	0.52%
UK	1,406	7.2%	1.03%
Other EU	4,211	21.5%	1.08%
Norway	64		0.38%
Switzerland	136		0.68%
Turkey	2,501		0.75%

Source: Eurostat, 2019 (Data refer to 2017. Turkey: 2014; Italy: 2016)

The total number of persons employed in pulp & paper sector is 660,000 with an average of 34 persons employed per company.

Germany is by far the country with more persons employed in the sector – about twice the number of the second-ranked, Italy with 72,378 persons employed. Several other countries follow with a total number of persons employed between 40,000 and 65,000 each: France, Netherlands, Nordics, Poland, Spain, UK, and Turkey.

Even though Germany is more relevant than other countries in term of number of persons employed, Nordics countries are by far the ones with the highest impact on the country's total manufacturing (i.e. 4.9%). More generally, no countries have a below 1% share on total manufacturing.

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Table 31 –Pulp & Paper. Persons employed in 2017, EU28, Norway, Switzerland and Turkey

	Persons employed	% of total manufacturing	Persons employed per company
EU 28	**660,000**	**2.1%**	**34**
Belgium	10,743	2.1%	48
Czechia	21,190	1.6%	21
France	64,655	2.2%	48
Germany	142,702	1.9%	85
Italy	72,378	2.0%	19
Netherlands	42,050	2.3%	117
Nordics	60,676	4.9%	87
Poland	60,641	2.3%	21
Spain	45,034	2.4%	27
Slovakia	7,316	1.5%	20
UK	56,903	2.2%	40
Other EU	75,712	1.8%	18
Norway	2,748	1.2%	43
Switzerland	7,929	1.2%	58
Turkey	62,875	1.7%	25

Source: Eurostat, 2019 (Data refer to 2017. Turkey: 2014; France: 2016)

The sector is mainly composed by small-medium enterprises, with an average number of persons employed ranging from 18 in some countries to 87 in Nordics.

5.1.2 Turnover, Production and Value-added

The European pulp & paper sector reached a turnover of €200 billion in 2017. Germany, Nordics countries, Italy and France are the most relevant. Germany has the highest net sales, reaching €42 billion, followed by the Nordics with €39 billion. Italy and France account respectively for €23 and €22 billion. Germany and Nordics countries together have a combined contribution to total European net sales of 40%. Adding Italy and France, the share increases to 60%.

On average, pulp & paper turnover represents 2.6% of the total turnover of European manufacturing. Mirroring the trend of persons employed, the sector is a strong contributor in Nordics countries, where pulp & paper represents 8.5% of total turnover in manufacturing. Contribution is quite similar among other European countries and in line with the European average.

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The average turnover per company is €10 million. Czechia, Poland, Slovakia and Turkey show a below average performance per company. Several countries have a higher than average turnover per company: Belgium, France, Germany, Netherlands, Nordics, the UK, Norway, and Switzerland. In particular, Nordics countries are strongly above the average with a turnover per company of €56 million in 2017.

Looking at turnover per person employed, Nordics countries, Norway and Belgium show a higher ratio compared to other European countries.

Table 32 – Pulp & Paper. Turnover in 2017, €M, EU28, Norway, Switzerland and Turkey

	Total Turnover, €M	EU28 % breakdown	Share of total manufacturing	Turnover per company, €M	Turnover per person employed, €k
EU 28	**200,000**	**100.0%**	**2.6%**	**10**	**303**
Belgium	5,092	2.5%	1.9%	23	474
Czechia	3,199	1.6%	1.8%	3	151
France	21,657	10.8%	2.1%	16	335
Germany	41,650	20.8%	2.0%	25	292
Italy	23,099	11.5%	2.5%	6	319
Netherlands	7,679	3.8%	2.2%	21	183
Nordics	39,001	19.5%	8.5%	56	643
Poland	9,792	4.9%	3.0%	3	161
Spain	13,385	6.7%	2.6%	8	297
Slovakia	1,359	0.7%	1.8%	4	186
UK	15,701	7.9%	2.3%	11	276
Other EU	18,387	9.2%	2.1%	4	243
Norway	1,408		1.6%	22	512
Switzerland	2,633		0.9%	19	332
Turkey	8,125		2.3%	3	129

Source: Eurostat, 2019 (Data refer to 2017. Turkey: 2014)

Production presents a behaviour similar to turnover. Indeed, Germany and Nordics countries have the strongest production values of respectively €38,527 million and €30,570 million. Other countries such as France and Italy have also a relevant pulp & paper production. Germany, the Nordic countries, France and Italy together account for more than half of the European total production.

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Like for turnover, Nordic countries show the highest share of total manufacturing over production (7.6%), making pulp & paper a very relevant industry in the region. All other countries are in line with the European average of 2.6%.

Also looking at the production value per company, Nordic countries show the highest value (i.e. €44 million) very much above the European average of €9 million. Other countries above the EU average are Belgium, France, Germany, Netherlands, Norway and Switzerland. Czechia and Poland show instead a below average value of €3 million and €4 million respectively.

Production value per person employed is strong for Nordic Countries and Norway with values of €504k and €503k per person.

Table 33 – Pulp & Paper. Production value in 2017, €M, EU28, Norway, Switzerland and Turkey

	Production value, €M	EU28 % breakdown	Share of total manufacturing	Production value per company, €M	Production value per person employed, €k
EU 28	**180,000**	**100.0%**	**2.6%**	**9**	**273**
Belgium	4,267	2.4%	1.7%	19	397
Czechia	3,009	1.7%	1.8%	3	142
France	18,213	10.1%	2.0%	14	282
Germany	38,527	21.4%	2.1%	23	270
Italy	22,731	12.6%	2.6%	6	314
Netherlands	7,138	4.0%	2.3%	20	170
Nordics	30,570	17.0%	7.6%	44	504
Poland	9,500	5.3%	3.2%	3	157
Spain	13,011	7.2%	2.7%	8	289
Slovakia	1,268	0.7%	1.8%	3	173
UK	13,778	7.7%	2.3%	10	242
Other EU	17,987	10.0%	2.3%	4	238
Norway	1,381		1.8%	22	503
Switzerland	2,468		0.8%	18	311
Turkey	44		0.0%	0	1

Source: Eurostat, 2019 (Data refer to 2017. Turkey: 2014)

Value added at factor cost was close to €24 billion in 2016. It represents just 1.2% of total manufacturing, compared to both turnover and production which have an impact on manufacturing of some 2.6% each.

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Germany has by far the highest value added, reaching €6 billion and representing 25.2% of the total value added in EU pulp & paper. It is followed by Italy and Nordics countries, which account for 11.9% and 8.9% respectively.

Even though Slovakia has a rather limited value added at factor cost compared to other countries, the pulp & paper sector represents a relatively relevant share of the country's manufacturing (i.e. 3.5%). Pulp & paper has a significant impact also in Belgium, with value added representing 2.8% of total manufacturing, and in Turkey (4.6%). Most of other countries are in line with the European average of 1.2%.

Value added per company is rather small for all countries, with just Belgium presenting a higher value added per company of €7 million.

Considering the value added per person employed, Belgium is the country with the most relevant ratio of €145k – much higher than the European average. Other countries are in line with the European average (i.e. €36K) except for Norway and Slovakia with a value of respectively €96K and €62K per person.

Table 34 – Pulp & Paper. Value added at factor cost in 2016, €M, EU28, Norway, Switzerland and Turkey

	Value added, €M	EU28 % breakdown	Share of total manufacturing	Value added per company, €M	Value added per person employed, €k
EU 28	**23,806**	**100.0%**	**1.2%**	**1**	**36**
Belgium	1,562	6.6%	2.8%	7	145
Czechia	553	2.3%	1.5%	1	26
France	1,766	7.4%	0.8%	1	27
Germany	5,988	25.2%	1.1%	4	42
Italy	2,829	11.9%	1.3%	1	39
Netherlands	729	3.1%	1.1%	2	17
Nordics	2,113	8.9%	1.8%	3	35
Poland	1,018	4.3%	1.6%	0	17
Spain	1,678	7.0%	1.6%	1	37
Slovakia	455	1.9%	3.5%	1	62
UK	1,488	6.3%	0.7%	1	26
Other EU	3,626	15.2%	1.5%	1	48
Norway	264		1.3%	4	96
Switzerland	135		0.1%	1	17
Turkey	2,945		4.6%	1	47

Source: Eurostat, 2019 (Data refer to 2016. Turkey: 2014)

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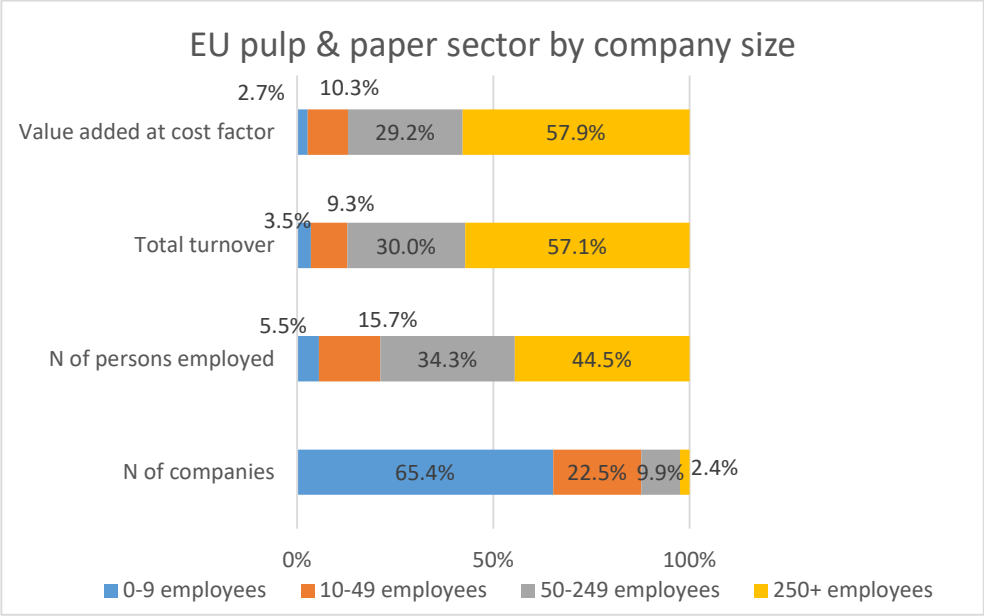
5.1.3 Structural analysis by company size

As shown above, the pulp & paper industry is composed mainly by SMEs. Data on number of persons employed per company shows that on average a European pulp & paper company has 34 persons employed.

As shown in the figure, 65.4% of companies are micro-enterprises having between 0 and 9 employees. Another 22.5% have between 10 and 49 employees. The residual 12.3% is shared between medium and large companies. The share of large companies is 2.4%, still higher than that of total manufacturing, but lower compared to that of other sectors in the report (steel and petrochemicals).

Looking at value added, turnover and persons employed by company size, it is clear that companies with more than 250 employees play a crucial role in the sector - holding respectively 57.9%, 57.1% and 44.5% of value added, turnover and persons employed. This shows a quite similar pattern to total manufacturing in which value added, turnover and persons employed of large enterprises represent 42.4% of persons employed, 63.4% of total turnover and of 58.6% of value added. Also with this respect, though, the contribution of large companies to the sector is less significant compared to other industries in the report and SMEs play a more relevant role.

Figure 9 – EU Pulp & Paper sector by company size



Source: Eurostat

5.1.4 Gross investment in machinery and equipment

The propensity to invest in machinery and equipment in the sector is much higher in the Nordics and Germany. The total value invested by Nordic countries and Germany (i.e. €1,561 and €1,357

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million respectively) is double the gross investment of third-ranked, Italy, which invests €831 million. Other countries have a smaller propensity to invest with Poland, Spain and the UK showing stronger investments than all other remaining countries.

Nordics countries' gross investment in machinery and equipment represents a high share of total investment in manufacturing (i.e. 13.5%) and has a high value of €2.2 million per company. This is reflected also into the gross investment per person employed with Nordics showing again a higher than average value (i.e. €25.7K).

Table 35 – Pulp & Paper. Gross investment in machinery and equipment in 2016, €M, EU28, Norway, Switzerland and Turkey

	Gross Investment, €M	% of total manufacturing	Gross investment per company, €M	Gross investment per person employed, €k
EU 28	na	na	na	na
Belgium	142	1.8%	0.6	13.2
Czechia	129	2.2%	0.1	6.1
France	na	na	na	na
Germany	1,357	2.4%	0.8	9.5
Italy	831	3.5%	0.2	11.5
Netherlands	na	na	na	na
Nordics	1,561	13.5%	2.2	25.7
Poland	518	4.8%	0.2	8.5
Spain	531	3.8%	0.3	11.8
Slovakia	51	1.9%	0.1	6.9
UK	567	2.8%	0.4	10.0
Other EU	na	na	na	na
Norway	14	0.7%	0.2	5.1
Switzerland	104	1.7%	0.8	13.1
Turkey	2	0.0%	0.0	0.0

Source: Eurostat, 2019 (Data refer to 2016. Turkey: 2014)

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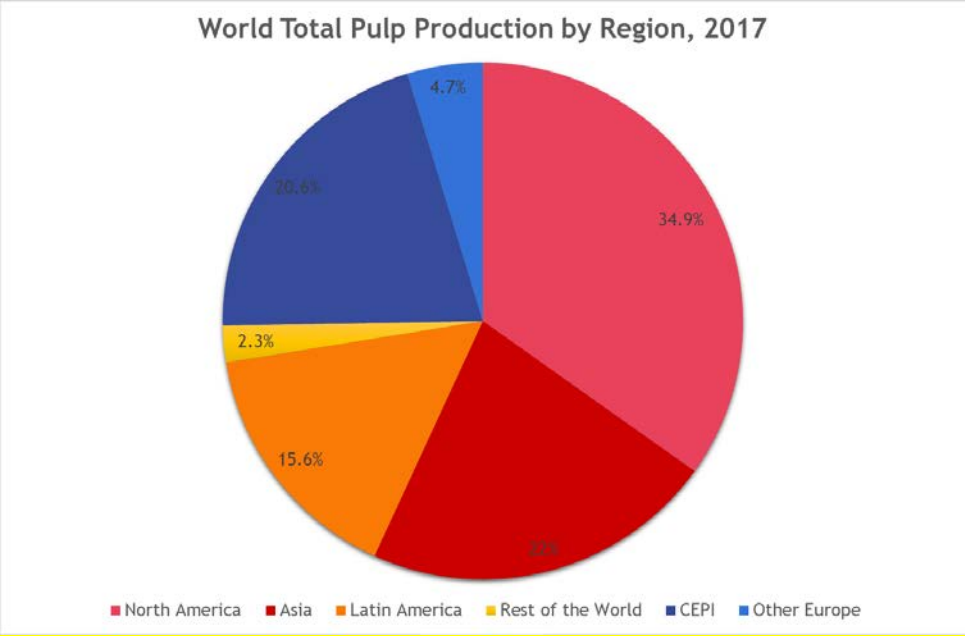
5.2 THE GLOBAL PERSEPCTIVE

Globally, Asia is the largest producer of pulp & paper accounting for 22% of world total pulp production and 47% of total paper & board production[24].

Looking at pulp production, North America and Europe have a relevant percentage compared to other countries of respectively 34.9% and 25.3%. Other regions represent a smaller percentage of production: Latin America holds a share of 15.6% and the rest of the world just the remaining 2.3%[24].

Figure 10 – World Total Pulp Production by Region, 2017[24]



Source: CEPI, 2018

Looking at paper and board production, Asian countries, which, as said, hold mostly half of the global production (i.e. 47%), are followed by Europe, which accounts for 24.1%, and North America, which represents 19.6%. Latin America accounts for 5.3% of the production and the remaining residual countries for 2%.

[24] *CEPI, "Key statistics 2018 European pulp & paper industry", 2018.*

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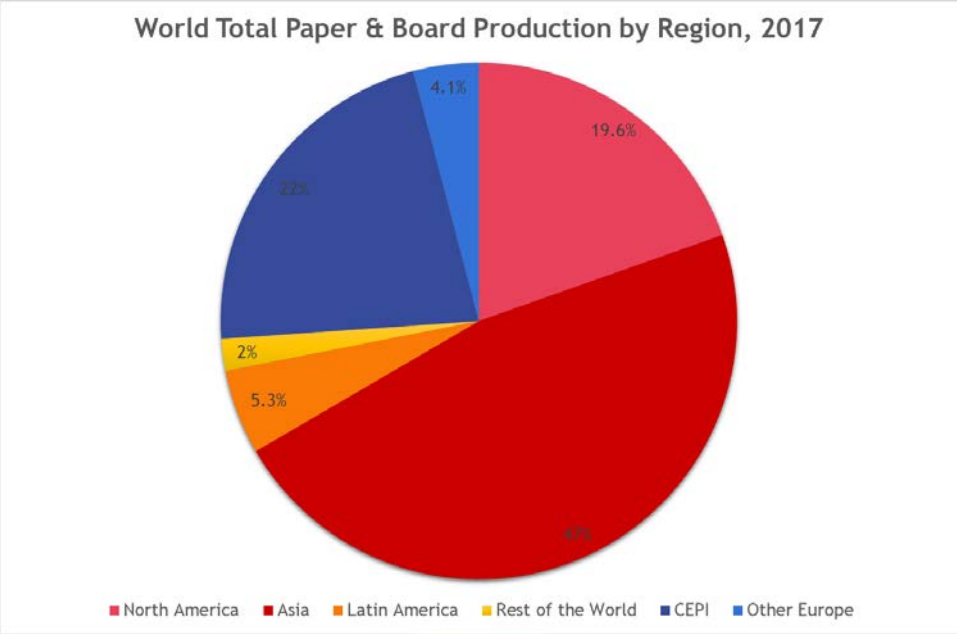
Figure 11 – World Total Paper & Board Production by Region, 2017[24]



Source: CEPI, 2018

Looking at European countries, the main players in the pulp market are from Sweden and Finland, holding respectively 31.2% and 30.2% of the total EU pulp production. The other countries have residual shares: 7.3% Portugal, 6.4% Germany, Spain 4.5%, France and Austria 4.2%.

For paper and board, shares are more equally distributed among European countries. Germany holds the biggest share of 24.6% out of the total European production, followed by Finland with 11.4% and Sweden 11% of the total. Italy and France have a fairly relevant share of respectively 9.9% and 8.5%.

With regards to European trade with other countries, Europe have significant trade relations with Latin America and Asia for pulp. European pulp import from Latin America is 75.5% out of the total; the share of total European export to Asia is 69.1%. Other countries have residual shares. For paper and board, the situation is different: European countries trade shares are more equally distributed. European countries import the most within Europe (i.e. roughly half of the total import, 2018) and from North America (30%). From an export perspective, European countries export 36% of the total export within Europe; a relevant amount of goods are exported to Asia, 25.6% share of total[24].

Concerning the overall industry's structure, analysts state that it has been consolidating over the years. The major players have progressively gained shares in their specific market segments[25].

[25] *McKinsey&Company, "Pulp, paper, and packaging in the next decade: Transformational change", 2017.*

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Some companies have reduced their presence in some market segments and decided to focus their investments on fewer segments of the industry. This resulted in a higher concentration at the segment level, but not at the aggregate level[25].

Even though the structure of the industry is stabilized, some changes may still occur due to some new companies entering the market and expecting to gain shares due to their larger financial resources available (for capex potentially 5 to 10 time bigger than already established industry players).

Top 20 Global Forest, Paper and Packaging Industry Companies[26] are provided in the table below.

Table 36 – Pulp & Paper. Top 20 companies worldwide

Rank	Top companies	Country	Sales, US $M
1	International Paper	US	22,365
2	Kimberly-Clark	US	18,591
3	Svenska Cellulosa (SCA)	Sweden	13,653
4	Oji Paper	Japan	11,916
5	Rock-Tenn	US	11,381
6	UPM–Kymmene	Finland	11,016
7	Stora Enso	Finland	10,969
8	Smurfit Kappa	Ireland	8,812
9	Sumitomo Forestry	Japan	8,649
10	Nippon Paper Group	Japan	8,371
11	Mondi Group	UK	7,410
12	Weyerhaeuser	US	7,061
13	Unicharm	Japan	6,140
14	Packaging Corp of America	US	5,742
15	DS Smith	UK	5,640
16	Sappi	South Africa	5,390
17	Domtar	Canada	5,264
18	Arauco	Chile	5,146
19	Sonoco	US	4,964
20	CMPC	Chile	4,841

Source: PwC, 2

[26] *PwC, "Pulp, paper, and packaging in the next decade: Transformational change", 2016*

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5.3 ECONOMIC OUTLOOK & KEY BUSINESS TRENDS

5.3.1 Short-term economic outlook

Even if the sector is affected by disruptive changes caused by digital transformation, the European pulp & paper industry remains fairly stable compared to other regions. Indeed, the global production decreased by -0.6% from 2017 to 2018, mainly due to China drastic production drop (i.e. -4% in a year). Other countries such as US, North Korea and Japan have also decreased their production[5]. Instead, the European pulp production increased at a rate of 0.8% between 2017 and 2018, and consumption remained positive as well, with a change of +2.2% in a year. Looking at paper and board, the situation is stable, with no changes in both European production and consumption between 2017 and 2018 (i.e. 0.0% and -0.1% respectively)[24].

Substantial market transformations have forced the industry to change with businesses focusing on newer or fewer market segments and with completely new production paradigms. Nonetheless, the overall European paper industry seems to be stable. Hygiene products, tissue papers, packaging have compensated the losses from digitalization and the decline of graphic-paper products. Graphic papers fell globally by 3.6% in 2018 compared to the previous year and it is expected to continue to decline; the highest decrease is registered for newsprint, -8.9%. The instability in specific segments is expected to persist. However, due to the increase in packaging production that balances the fall in graphic papers, the overall European production is expected to remain slightly positive in the near future[27].

At global level, the situation is quite different. Analysts expect that the global industry will be negatively affected by these changes, and the global operating income will decline by approximately 2-4%, as the decline of traditional paper products will be not offset by other segments' growth (e.g. packaging, tissues, hygiene products). Moreover, increasing paper packaging prices and production input costs are also expected as well as a certain reduction in capacity caused by forced conversion of factories and machines[28].

Looking at market segments, packaging and tissues are anticipated to remain positive in the next future even though the recent rise in packaging prices negatively affects the market. Concerning the pulp sector, the recent drop in prices after the peak during 2018, will lead to more consolidation in the segment.

5.3.2 Key business trends

The paper industry is traditionally both energy and raw materials intensive. It is also highly sensitive to feedstock costs and needs high and long investment cycles to ensure the continuity in

[27] *CEPI, "Preliminary Statistics 2018", 2018.*

[28] *Moody's, "Moody's - Outlook for the global paper and forest products industry changed to negative", 2019.*

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the production and meet global demand. In recent years, some new challenges have emerged due to the rise of digitalization, which has caused a drop in the global demand for paper products. However, the industry has been not drastically affected by this, since the negative trend was compensated by the increasing demand for packaging and hygiene materials, at least in the EU.

In this context, investments in the paper industry switched from traditional paper products, largely replaced by digital products, to new types of products, whose demand has increased thanks to new market trends such as the replacement of plastic packaging and the increased demand for hygiene commodities. Major players, which have progressively consolidated their position in the market[2], have therefore started to focus their investments on fewer segments of the industry.

From a trade perspective, trade relations have been negatively affected by increased taxes and duties on wood, creating significant trade barriers; furthermore, an overall rising of energy prices, especially in Europe, had a negative impact on competitiveness[29].

Under these circumstances, innovation is playing and is going to play a crucial role in the next decades also in the paper industry; innovation in products, process & organization along with completely new business models will grow in relevance[2]. In addition, analysts anticipate that the paper industry will increasingly switch its focus from a sales volume perspective to a value creation perspective[2]. In order to follow this path, resource efficiency and bio economy approaches will play a central role not only towards a more sustainable global market but also to find cost-effective solutions able to compete in the new challenging environment[2].

A value creation perspective in the industry can lead to a significant optimization of the use of resources such as raw materials, energy and water, other than reducing environmental impact. The research and exploitation of innovative processes can result in the introduction into the market of entirely new applications, which could generate a bigger value added to the industry and the society[29]. New applications will facilitate then paper products to potentially enter entirely new market such as cosmetics, textile, food, chemicals and pharmaceutical[3].

Although the change in market needs hampered the traditional paper products' business, it lays also the basis for exploring new business opportunities.

However, energy and resource renovation will pose several challenges. Companies have to rethink their production processes and the level of cost optimization. Even though rethinking business processes goes together with an overall level uncertainty, the renovation of the production chain can lead to embrace more sustainable operating models focused on a different cost structure and more flexibility[25].

[29] *European Commission, "Pulp and paper industry".*

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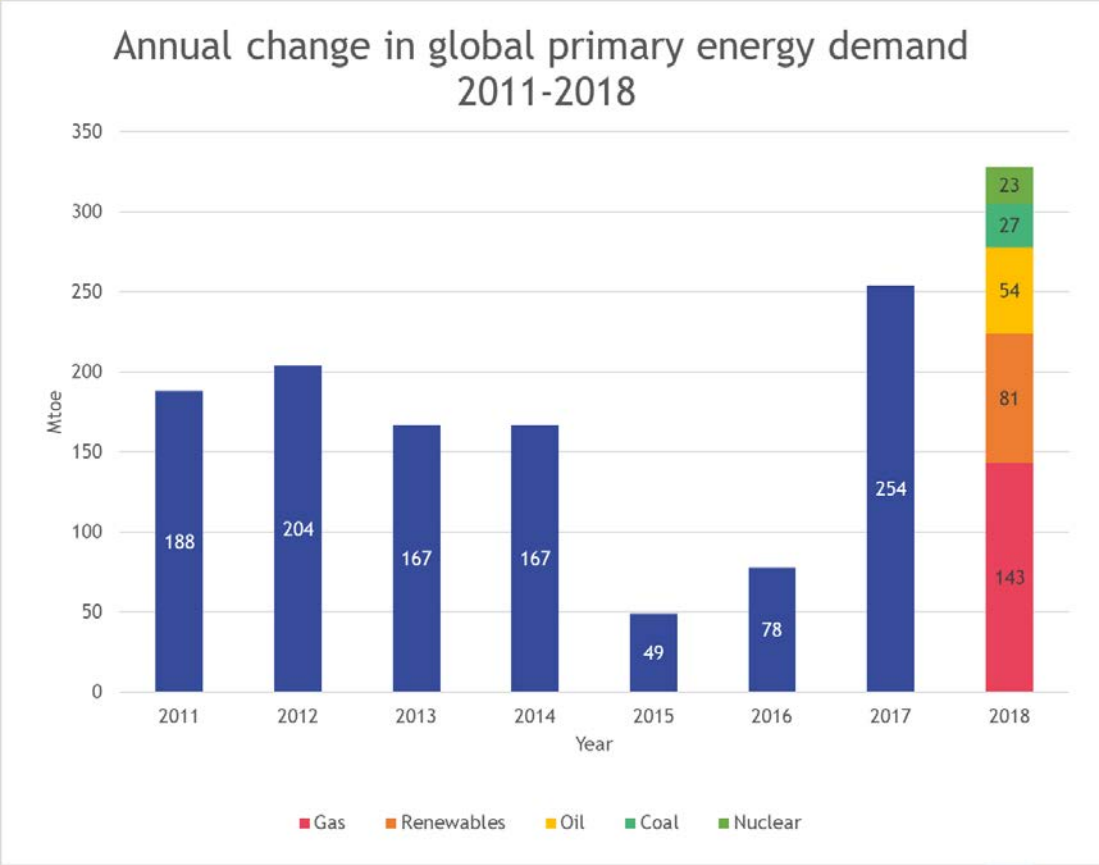
6 ENERGY DYNAMICS

6.1 Energy demand outlook

Global energy demand increased by 2.3% in 2018, twice the average growth registered since 2010. The International Energy Association states that this is due to the solid and growing global economy, population growth and economic development leading to increasing demand of energy appliances; moreover, heating and cooling demand is expanding as well since temperatures reach extremes never recorded so far[30].

Figure 12 – Annual change in global primary energy demand, 2011-2018[31]



Source: IEA, 2018

[30] *IEA, "Global energy demand rose by 2.3% in 2018, its fastest pace in the last decade", 2019.*

[31] *IEA, "Global Energy & CO2 Status Report", 2019*

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Demand increases for most of fuels, driven by natural gas which accounted for 45% of the total increase in 2018. Demand for gas expands at a year on year rate of 4.6% for both 2017 and 2018, caused by the increasing use of gas as coal substitute. The growth is registered especially in the United States and China[31].

Electricity, leading half of energy demand growth and registering 4% of net growth in 2018, is considered by analysts the main source of energy to rely on in the future. By now, electricity accounts for 20% of total energy consumption worldwide[31].

Oil demand rises as well (by 1.3% globally) due mainly to its expansion in the United States, continuously investing in petrochemicals and developing its industrial production[30].

Renewables account for half of the energy demand growth, with China as prevailing country with a strong wind and solar industry, followed by Europe and the United States. Even though solar and wind are not able to meet a significantly high portion of electricity demand by now, they progress as well, with solar growing by 31%.

Increase in energy consumption – especially in China, U.S and India, caused also energy CO2 emissions to rise by 1.7% in 2018. The main source of energy-related emission remains coal for power generation, accounting for roughly 30% of the total emissions. Indeed, global coal consumption increased in 2018 by 0.7% mainly driven by Asian countries: China, India, South and Southeast Asia[30].

Also, nuclear grows by 3.3% due to the start of new activities in both China and Japan.

Looking at energy demand growth by regions and technologies, some interesting facts emerge.

The increase in gas and oil demand is lead mainly by the United States and China. Even though China expands gas consumption as coal substitute, coal demand gets bigger anyway and contributed to a high share of global coal demand in 2018. Other than gas, oil, and coal, the increase in energy demand in China is registered among all fuels, nuclear and renewables[31].

Other than making a substantial contribution to global gas demand, the United States contribute also for both oil and coal growth in 2018. Instead, US contribution to renewables is rather limited compared to other regions, such as Europe which registers a 4% growth.

European contribution to other segments of energy demand is rather limited for most of fuels. Indeed, even though world demand grows almost everywhere along with economic expansion, Europe energy demand increases just by 0.2%, with oil decreasing by 6% in a year.

It should be reported that India contributed to coal demand growth for power generation, with an increase of 20 Mtoe.

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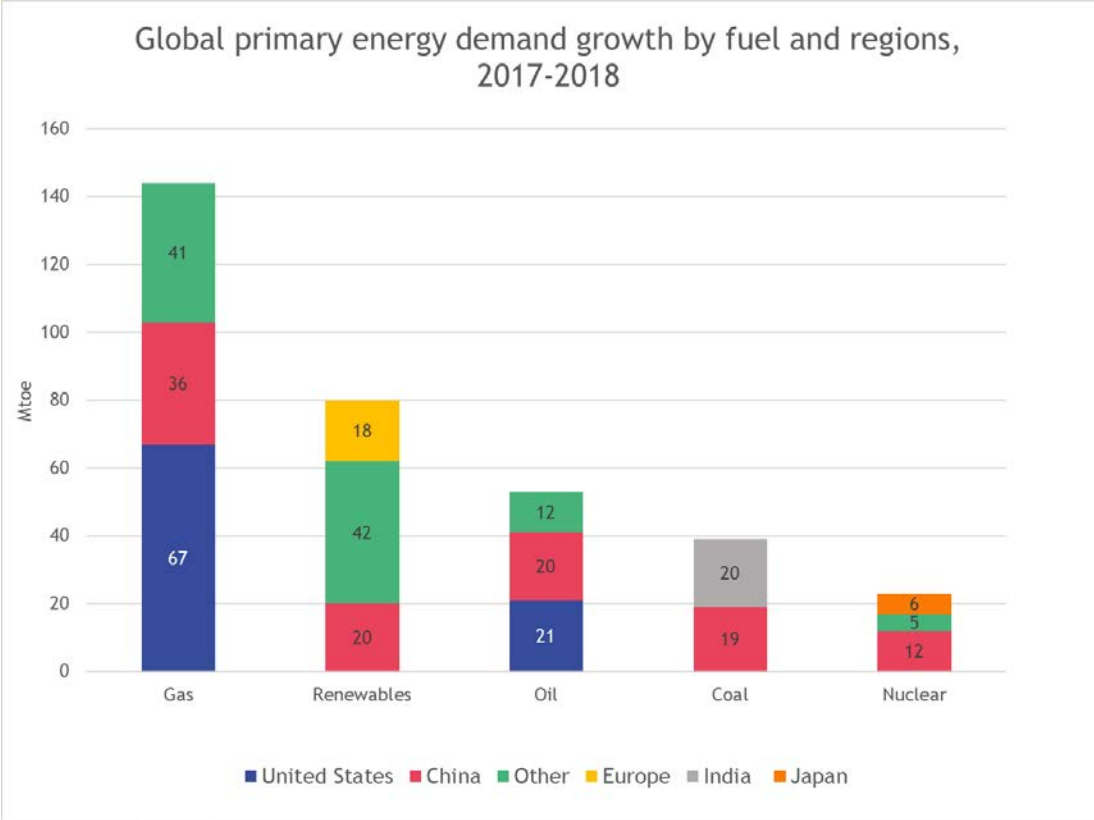
Figure 13 – Global primary energy demand growth by fuel and regions, 2011-2018[31]



Source: IEA, 2018

6.2 Energy Price & Cost in Europe

6.2.1 Electricity Price in Europe

Energy prices present a high volatility impacting global and European energy bills and economy.

In general, European prices are higher than the US, Russia and Canada but lower than other countries, such as China. Even though development of renewables is expected to lower electricity prices, the market is still dominated by coal and gas which set market margins and cause prices to rise. Average European prices are also significantly affected by taxes, making 40% of total average price in the region[32].

[32] *EC, "Energy prices and costs in Europe", 2019.*

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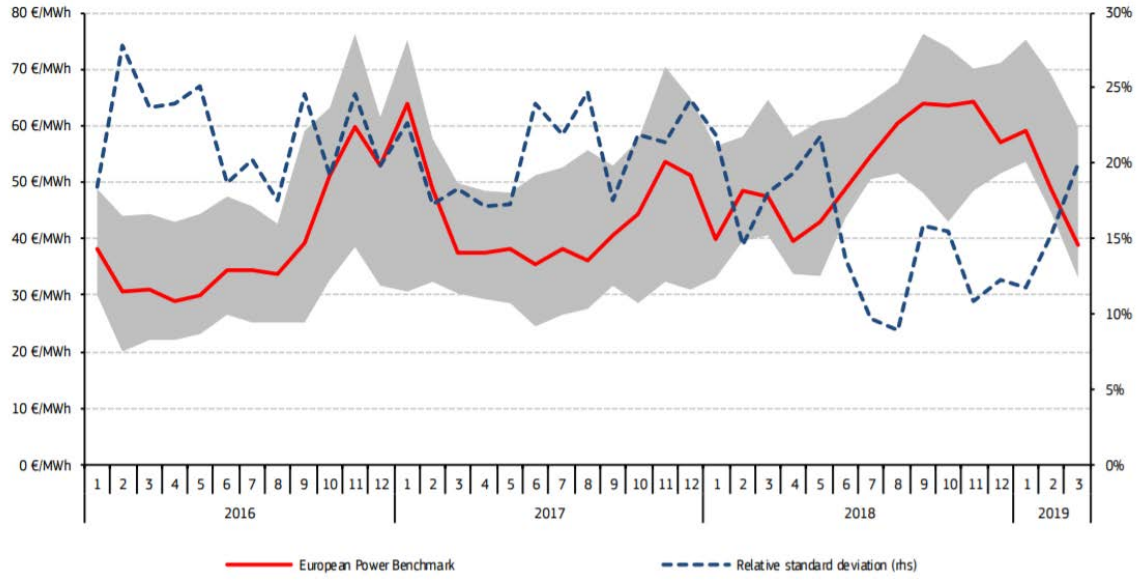
To understand short-term trends in Europe, analysts consider wholesale and retail separately. In general, prices are more volatile in the wholesale market; retail prices are instead less dependent from market dynamics since retail contracts have fixed prices and do not usually follow energy supply's cost.

Wholesale price drops in EU in Q1 2019; comparing Q1 2019 price to Q4 2018, average price falls by 20.7%; compared to Q1 2018 price goes up by 7.7%.

Figure 14 – The evolution of the lowest and the highest regional wholesale electricity prices in the EU and the relative standard deviation of the regional prices[32]



Source: EC; Platts, 2019

Significant differences are registered in 2019 for wholesale prices among regions. In the first quarter, Greece displays highest electricity prices, together with Ireland, Italy and the United Kingdom – which are traditionally importers of electricity or have complicated and limited geographical access for energy transmission. UK's higher price is caused by higher CO2 prices for power generation set up by the government[33]. Q1 2019 lower prices are registered in Germany, Luxembourg and Denmark, all facilitated by higher renewables and fossil fuel capacity.

Looking at trends by different electricity producers, decrease of nuclear and increase of both fossil fuels and renewables are registered in Q1 2019.

Compared to Q1 2018, fossil fuel rises from 34% to 35%. Renewables rises from 31% to 32% in a year, due to better weather conditions, but especially due to an increase of both wind and solar

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capacity across the region. Wind energy generation registers the best Q1 ever, gaining a share of 16% out of the total mix. Nuclear drops from 28.6% to 28.2%[33].

It is worth reporting an interesting switch in energy dynamics in Germany: gas-fired generation shows higher competitiveness compared to coal, due mainly to lower gas prices and increase in CO2 prices. The transition from coal to gas is expected to flourish in all Europe following the UK approach, where coal competitiveness has been drastically reduced over the recent past years. The EC analysis of electricity in Q1 2019 shows however that this transition could be limited in the short-term by the expansion of renewables and usual lower power demand in summertime.

Looking at retail market, prices are less volatile than wholesale since characterized by higher taxes and fixed contracts. Prices in Europe, compared to other regions, remain high, second only to Brazil. In both regions retail prices significantly increase over the last three years - by 21% in Brazil and by 8% in Europe. The highest decrease is registered in China (i.e. 14%).

Trends in Q1 2019 show that prices among all levels of consumer types converge in January and February 2019, registering in the following months a price increase for small consumers and a stabilization for industrial consumers[33].

Median industrial consumers register a high price in both Italy and Germany; lowest prices are in Sweden and Finland. Industrial highest price is registered in the UK and the lowest in Luxemburg.

6.2.2 Energy cost in Europe

To put Europe in the right perspective in terms of competitiveness and trade dependency with other regions, the paragraph focuses on energy cost.

Trends in energy cost significantly affect Europe due to its relevant import bills. Europe is exposed to price volatility since half of the energy demand of the region is met by imports and increase in prices directly exposes Europe to economic difficulties. In 2017, the European import bill increased by 26% compared to the previous year, mainly caused by higher oil prices – accounting for 68% of the total bill[32].

Looking at the impact of energy cost for industries, Eurostat shows that energy effects on bills significantly vary across sectors. Weight of energy bills on costs of European businesses accounts on average for 0-3%. However, some sectors have a much higher share. In energy intensive sectors such as paper and pulp, mineral, iron and steel, and concrete, energy represents between 3 and 20% of total costs. In these sectors, changes in energy costs significantly affect production and operations. However, increase in energy prices does not affect all energy intensive sectors in the same way due to different reasons, such as the different level of energy intensity of single processes[32].

[33] *EC, "Quarterly Report on European Electricity Market", 2019.*

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From a global perspective, energy cost share in Europe is higher than Asia and similar to the US, with aluminium and steel as exception since they present much higher costs in Europe. Energy intensity in Europe is lower than China and similar to the US. Indeed, improvements in terms of energy intensity are registered in Europe. However, the level of dependency to energy cost remains high in the region and it may push companies to take actions towards lower energy dependency and to focus on energy efficiency solutions[32].

6.3 Energy market by regions & EU Energy dependency rate

World energy production increased from 9,263 Mtoe in 1995 to 13,764 in 2016 according to Eurostat. Looking at production by region, energy production is spread almost equally among regions. However, China, United States and Middle East hold a bigger share than other countries, accounting respectively for 17.2%, 13.9% and 14.8%. Russia holds 10% of the global energy production, Africa 8% and other Asian countries 11.7%.

In this context, EU28 holds 5.5% of total production[34].

[34] *EC, "EU energy statistical pocketbook and country datasheets", 2019.*

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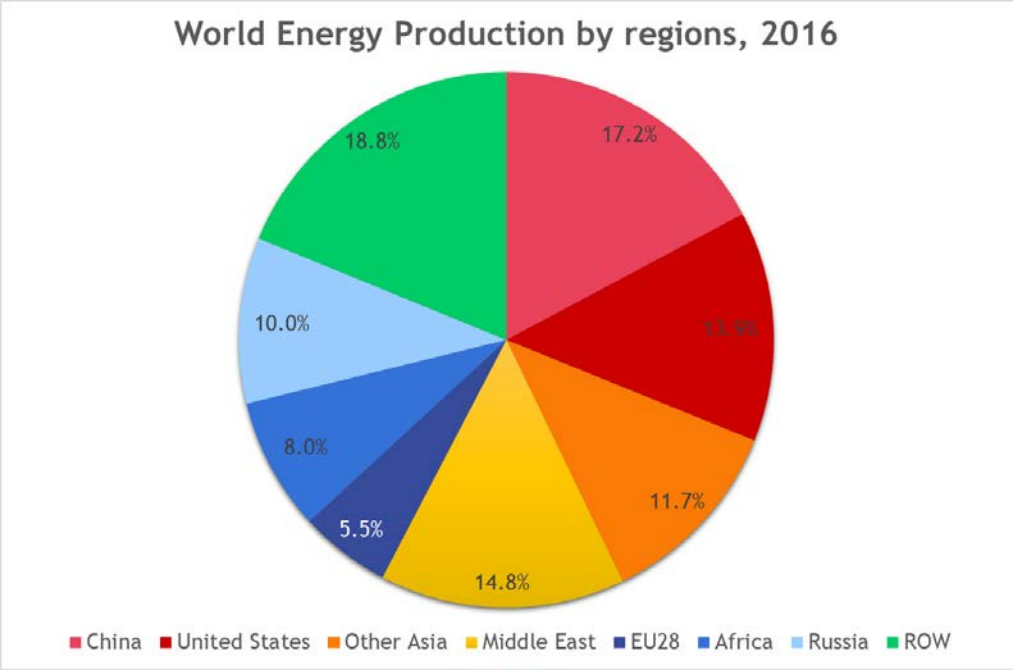
Figure 15 – World Energy Production by regions, 2016[34]



Source: EC, 2018

Consumption by region shows that China, rest of Asia (i.e. both OECD and non OCED countries) and the United States have bigger share of consumption compared to other regions. All together they hold 55.8% of global consumption[4]. EU28 has a share of 11.6%.

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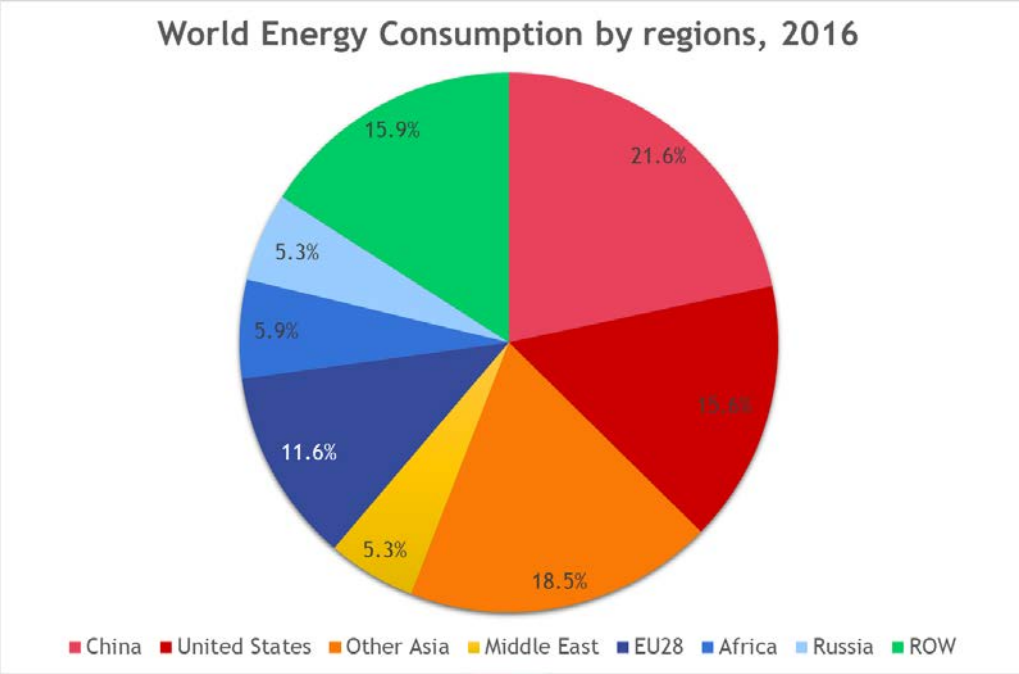
Figure 16 – World Energy Consumption by regions, 2016[34]



Source: EC, 2018

To meet consumption, EU needs to import a significant portion of energy from third countries. Main products imported in Europe are oil (i.e. accounting for 58.6% of total European import), gas (i.e. 29.8%) and solid fossil fuels (i.e. 10.7%)[34]. In the past years, imports of primary energy increased, in particular gas imports doubled in the last 30 years[35].

[35] *Eurostat, "Energy statistics - an overview", 2018.*

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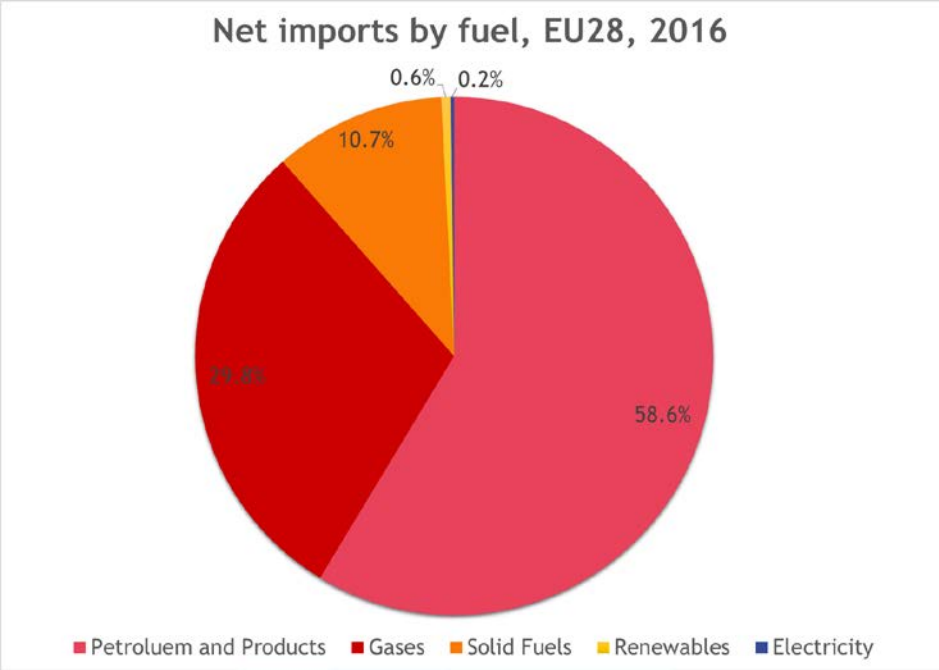
Figure 17 – Net imports by fuel, EU28, 2016[34]



Source: EC, 2018

Europe has a strong trade relation with Russia, exporting towards European countries a significant amount of oil, gas and solid fuel. Indeed in 2017, European crude oil demand was mainly filled by Russia (i.e. 30%); remaining shares are held by Norway (i.e. 11%), Iraq (i.e. 8%), Kazakhstan and Saudi Arabia. Main gas provider is again Russia accounting for 40% of total gas imported in Europe, followed by Norway (i.e. 26%) and Algeria (i.e. 11%). Solid fuel, mainly coal, is imported for 39% by Russia, followed by Colombia and United States[36].

Looking at the energy dependency rate of EU, it shows that 55.1% of the total European energy need is met by imports – but significant country differences apply. Even though the dependency rate is relevant for most of the European countries, the rate is highest in smaller countries such as Malta (i.e. over 102.8%), Luxemburg (i.e. 95.4%) and Cyprus (i.e. 96.3%), but also in Italy (i.e. 77.0%), Lithuania (i.e. 75.6%), Belgium (i.e. 74.8%) and Portugal (i.e. 79.9). The rate is lowest in Estonia (i.e. 4.1%) and Denmark (i.e. 11.7%).

More than 80% of total imports respond to petroleum needs from Cyprus, Malta, Greece, Sweden and Romania and one third of gas import is for Hungary, Italy, Austria and Germany.

[36] *Eurostat, "2.3 From where do we import energy and how dependent are we?", 2018.*

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Table 37 – Energy import dependency, EU-28, 2012-2017[36]

	2012	2013	2014	2015	2016	2017
EU 28	**53.7**	**53.3**	**53.6**	**53.9**	**53.8**	**55.1**
Belgium	75.8	77.1	79.8	83.9	75.4	74.8
Bulgaria	36.9	38.5	35.3	36.5	38.6	39.5
Czechia	25.3	27.4	30.1	31.9	32.6	37.4
Denmark	-2.7	12.4	12.3	13.0	13.4	11.7
Germany	61.9	63.0	61.9	62.2	63.7	63.9
Estonia	19.8	13.9	11.1	9.6	7.9	4.1
Ireland	83.8	91.7	86.2	88.9	69.1	67.1
Greece	65.8	61.7	65.4	71.0	72.9	71.1
Spain	73.0	70.2	72.7	72.9	71.5	73.9
France	48.4	48.1	46.2	46.0	47.4	48.6
Croatia	49.9	47.5	44.3	48.9	48.5	53.3
Italy	79.1	76.7	75.8	77.0	77.7	77.0
Cyprus	97.0	96.3	93.2	97.7	96.2	96.3
Latvia	56.4	55.9	40.6	51.2	47.2	44.1
Lithuania	80.5	78.5	78.3	78.4	77.6	75.6
Luxembourg	97.5	97.1	96.5	95.9	96.1	95.4
Hungary	50.1	50.1	59.8	53.9	55.8	62.6
Malta	101.0	104.2	97.7	97.0	100.6	102.8
Netherlands	30.6	23.7	30.9	48.4	45.9	51.8
Austria	64.5	61.5	65.7	60.6	62.5	64.4
Poland	31.8	26.4	29.5	29.9	30.8	38.3
Portugal	79.5	73.3	72.1	78.2	74.0	79.9
Romania	22.3	18.1	16.4	16.4	21.6	23.1
Slovenia	52.1	47.8	45.5	49.7	49.3	50.4
Slovakia	61.6	60.8	62.1	60.1	60.6	64.8
Finland	47.2	50.0	50.2	48.2	46.0	44.0
Sweden	29.8	32.5	31.9	28.9	31.9	26.4
United Kingdom	43.4	47.8	46.8	37.5	35.7	35.4
Norway	-549.3	-482.4	-575.4	-575.1	-631.9	-603.3
Turkey	75.6	75.4	76.3	77.9	75.5	77.1

Source: Eurostat, 2018

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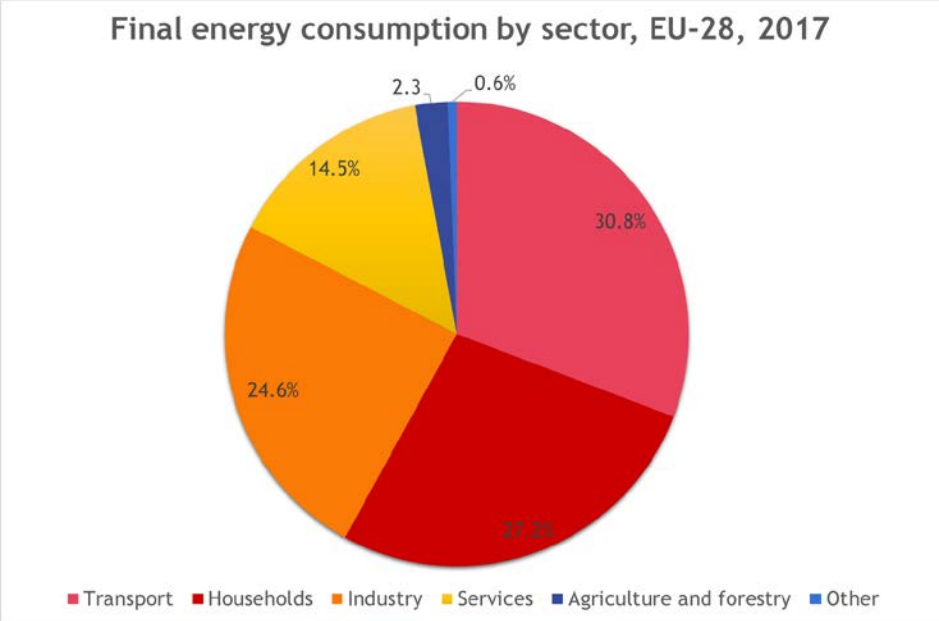
6.4 Energy consumption by EU sectors

Final energy consumption in EU 28 in 2017 accounts for 1,060 Mtoe. The three main segments using more energy are transport, households and industry, accounting respectively for 30.8%, 27.2% and 24.6%[7] out of the total energy consumption.

Figure 18 – Final energy consumption by sector, EU-28, 2017[35]



Source: Eurostat, 2018

At industry-level, final energy consumption fell by 14.1% between 2007 and 2017, reaching in 2017 261,037 Toe. The highest contribution to industrial energy consumption comes from Germany, which in 2017 consumed 56.273 Toe of energy, followed by Turkey, France, Italy and the United Kingdom.

Looking in deep into industries, the sector consuming the most in 2017 is chemicals and petrochemicals with 52.692 Toe, followed by paper, pulp & printing with 34,356 Toe and non-metallic minerals with 34,184. Other most-consuming sectors are food, beverage & tobacco and iron & steel with respectively 29,948 and 27,860 Toe of energy consumed in a year.

BAMBOO sectors, as per the data, are among the most energy-consuming ones.

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Table 38 – Final Energy consumption by industrial sectors, Toe, EU-28, 2017

Industrial sectors	EU-28 Consumption, 2017
Iron & steel	27,860
Chemicals and petrochemicals	52,696
Non-ferrous metal	10,323
Non-metallic minerals	34,184
Transport equipment	8,697
Machinery	19,565
Mining and quarrying	3,516
Food, Beverages & Tobacco	29,948
Paper, Pulp & Printing	34,356
Wood and wood products	8,859
Construction	7,505
Textile & leather	4,245
Other	18,988

Source: Eurostat, 2018

Specifically, iron & steel, chemical and petrochemical, paper & pulp and mining and quarrying with non-metallic minerals account together for 56.6% of total energy consumption by European industries.

Looking at the impacts of each country into sector's energy consumption, for iron and steel Germany consumed the most, followed by Turkey and Italy. For chemical and petrochemical, Germany accounts for 15,116 Toe, followed by the Netherlands with 7,306 Toe.

For non-metallic minerals, Turkey contributed with 9,620 Toe of consumed energy, followed by Germany. Nordics account for a high share in paper, pulp and printing.

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Table 39 – Final energy consumption by sectors and EU regions, Toe, EU-28, 2017

GEO/TIME	Iron & steel	chemical and petrochemical	Non-metallic minerals	Mining and quarrying	Paper, Pulp & Printing
EU-28	**27,860**	**52,696**	**34,184**	**3,516**	**34,356**
Belgium	1,081	4,020	1,331	49	740
Czechia	1,021	1,046	1,148	89	599
Nordics	1,757	1,912	1,165	767	11,946
Germany	7,630	15,116	6,710	356	5,692
Spain	2,532	2,925	3,376	484	1,765
France	1,950	4,152	3,366	379	2,398
Italy	3,597	3,654	4,193	113	2,286
Netherlands	987	7,306	588	119	590
Poland	1,970	2,765	2,995	431	1,755
Romania	1,353	1,329	1,015	41	170
Slovakia	1,055	368	468	11	478
United Kingdom	843	3,354	2,371	3	1,818
Turkey	4,532	2,694	9,620	489	727
Other EU	2,085	4,748	5,458	674	4,118

Source: Eurostat, 2018

Looking at the average energy consumption over time, overall it decreased by 1.3% between 2007 and 2017. In this context, energy consumption by industry fell by 14.1%. Industry sub-sectors decrease at different paces, except for non-ferrous metals, mining and quarrying, food, beverages and tobacco, paper and pulp which remain fairly stable. The wood sector and construction increased their final energy consumption in the same timeframe[35].

Final energy consumption in Europe is getting more efficient due to the introduction of energy efficiency technologies and flexibility measures. Between 1990 and 2015 energy efficiency in industry has increased by 38% in EU 28 at a yearly rate of 1.8%. Most of the sub-sectors followed the trend, even though energy-intensive ones at a slower pace. Within energy-intensive industries, steel is one of the sectors which drives this trend together with chemicals, cement and paper[37].

[37] *European Environment Agency, "Progress on Energy Efficiency in Europe", 2019.*

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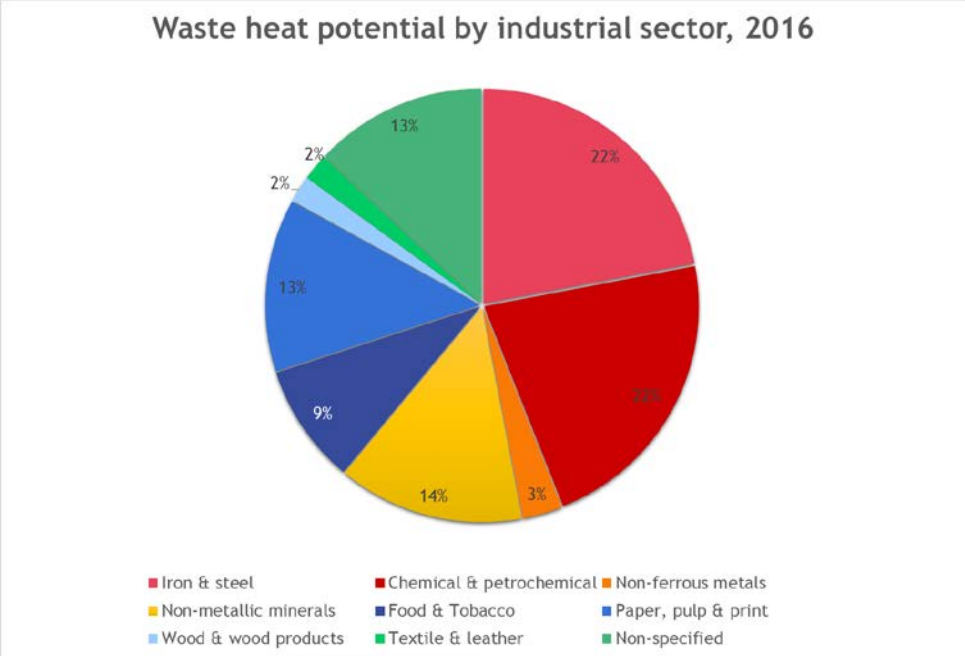
To increase energy efficiency in industrial sectors, waste heat recovery is very promising, especially for the iron & steel industry and chemicals & petrochemicals holding both 22% of the total waste heat usable by intensive industries[38].

Figure 19 – Waste heat potential by industry sectors, EU, 2016[38]



Source: Energy Procedia, 2017

Total waste heat in all SPIRE sectors exceeds 10% of sector consumption: margins for heat recovery subsist therefore for most of the industry sectors[39].

[38] *G. P. Panayiotou et al, "Preliminary Assessment of Waste Heat Potential in Major European Industries.", 2017*

[39] *I-ThERM, "Literature review of energy use and potential for heat recovery in the EU28 Report", 2016*

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Table 40 – Waste heat potential by industrial sector, EU, 2016[38]

Industrial sectors	Waste heat potential
Iron & steel	11.4%
Chemicals & petrochemicals	11.0%
Non-ferrous metals	9.59%
Non-metallic minerals	11.4%
Food & Tobacco	8.64%
Paper, pulp & print	10.56%
Wood & wood products	6.0%
Textile & leather	11.0%
Non-specified industries	10.4%

Source: Energy Procedia, 2017

Electrical flexibility is also promising, even though analysts state that it will have more impacts once global adoption of renewable power resources at industry level will occur. By now, room for improving electrical flexibility is quite limited in energy-intensive industries since the share of electricity in the overall energy consumption is lower compared to others and it is used mainly for complementary apparatus[40].

Table 41 – % of electricity on primary energy consumption in REII, EU, 2014[40]

REII	% of electricity on primary consumption
Paper	31%
Steel	20%
Oil refining	7%
Minerals	17%
Chemicals	56%
Non-ferrous	63%

Source: ICF, 2015

Additional actions towards energy efficiency in industry include the introduction of flexible schemes in raw materials consumption. New valorisation schemes of raw materials in industry can

[40] *ICF International, "Study on energy efficiency and energy saving potential in industry and on possible policy mechanisms", 2015.*

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introduce low-value materials in the production chain allowing a significant cost reduction[41] and to move towards circular economy schemes.

6.5 Energy global perspective

Even though the economy is expected to expand and population to grow, a slowdown in energy demand is foreseen in the next decades. GDP (Gross Domestic Product) is expected to double within 2050 and energy demand growth in the same timeframe will rise just by 14%. The main reason analysts identify is the development and global adoption of renewables, which are progressively gaining shares in the energy mix and substituting fossil fuels with more efficient solutions[42].

Analysts anticipate that renewables will double within 2050 (i.e. from 17% to 34%) contributing for half of the electricity demand within 2035. Wind and solar will progressively gain energy mix shares reaching by 2035 half of energy capacity worldwide. The trend will speed up in the next years due to the development in infrastructure in both China and India and due to a general decrease of renewable cost compared to coal and gas. Indeed, renewable costs will be lower than fossil fuels' in most of countries within the next 10 years – even though most of the regions will reach the even-point before, approximatively in the next 5 years. The adoption of renewables will be driven by cost competitiveness and production development in Asia and Europe.

Looking at energy demand by product, electricity is forecasted to double within 2050, gas will hold its position until 2035 with an increase in capacity in North America and China and then progressively decrease its share. Other fossil fuels and oil are expected to lose shares more and more in the next decades. Coal will also slow down reaching a share of 20% in the energy mix in 2035 and going down by 14% in 2050[10]. Analysts point out that the estimations will vary depending on technological adoption and market responses[42].

Electricity is expected to grow in most of the sectors – above all transport and buildings. Transport will rise due to the development in EVs and expected drop in battery costs, halving in the next 10 years. Electricity expansion in buildings will be led by the increase in demand of heating/cooling and building applications – especially in Asia. Electricity is expected to increase its share in industry as well, but at a slower pace since high temperature heat needs low electricity prices[10].

Gas will hold its position until 2035 with an increase in industrial capacity in the US and China (the latter accounting for half of the expected growth worldwide). Gas is the only fossil fuel holding out against changing market dynamics: this is due to still competitive cost in some regions and by the development of gas-based energy alternatives with contained costs and lower emissions

[41] *European Commission SETIS, "Energy Efficiency in the Iron and Steel Industry", 2019.*

[42] *McKinsey, "Over half of EU's energy consumption from imports", 2019.*

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(becoming substitutes to coal and oil). The only sectors in which gas could even increase will be transport (i.e. marine market segment) and chemicals (due to lower feedstock prices in the US, Russia and Iran). However, gas expansion will be narrow in the long-term (i.e. CAGR at -0.2% between 2035 and 2050) due to high competitiveness gained by renewables[42].

In summary, energy dynamics are drastically changing, mainly caused by the substitution of traditional fossil fuels by renewables and natural gas which are increasingly gaining shares in the energy mix. Energy efficiency is a key driver in the sector to reduce costs and limit emissions. Analysts believe that the expected increase in energy demand for the next 2 decades will be twice as large if improvements in terms of energy efficiency were not carried out[43]. In particular, in a new policies scenario (NPS) strengthening the move to energy efficiency, IEA estimates that manufacturing industries could improve energy efficiency by 36% between now and 2040, a rate 20% higher than the average annual intensity improvement in the countries analysed since 2000. An Efficient World Scenario (EWS) shows even greater gains (+44%). By 2040, in this second scenario, energy intensity could fall

- by 25% in iron and steel (only 5% since 2000)
- by 28% in the aluminium sector (16% since 2000)
- by 25% in pulp & paper thanks also to the increased levels of paper recycling (just over 20% since 2000)
- by 14% in chemicals and petrochemicals

BAMBOO is set to contribute to the development of this scenario in energy intensive industries.

[43] *IEA, "World Energy Outlook 2018", 2018.*

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7 TECHNOLOGIES FOR ENERGY FLEXIBILITY IN PROCESS INDUSTRIES

In general, high energy prices spur adoption of energy efficiency solutions as ROI is still mainly calculated on energy savings alone[44]. In the first months of 2019, wholesale energy prices remained volatile, while retail prices to industrial consumers were almost stable. Beyond price dynamics, the financial attractiveness of investing in energy efficiency remains robust in the medium term due to several factors[45], including increasingly stringent policies that recognise energy efficiency measures as being among the most cost-effective means of helping to tackle energy security, productivity, local air pollution and climate change challenges. In this context, investments in energy efficiency projects kept on progressing, despite at a slower pace compared to the past few years. In 2017, the global investment in industrial energy efficiency fell by 8% to $35 billion, with China accounting for the bulk of spending. Projects are mainly financed with companies' own funds. As a result, energy efficiency investments compete for the capital with other business improvements' projects and long-term ROI creates a competitive environment for funding.[46] Therefore, fostering energy efficiency projects calls for innovative finance methods, but also requires:

- The leverage of new business models that can result from the launch of new business processes and services
- The development of appealing value propositions related not only to general energy savings and cost reduction but also to improved business, new revenue streams and better working conditions for employees
- New ROI calculations considering other business improvements beyond energy savings

[44] *International Energy Agency, "World Energy Investment Outlook – Special Report", 2018.*

[45] *International Energy Agency, "Energy Efficiency Market Report 2015 – Market Trends and Medium-Term Prospects", 2015.*

[46] *International Energy Agency, "World Energy Investment Outlook – Special Report", 2018.*

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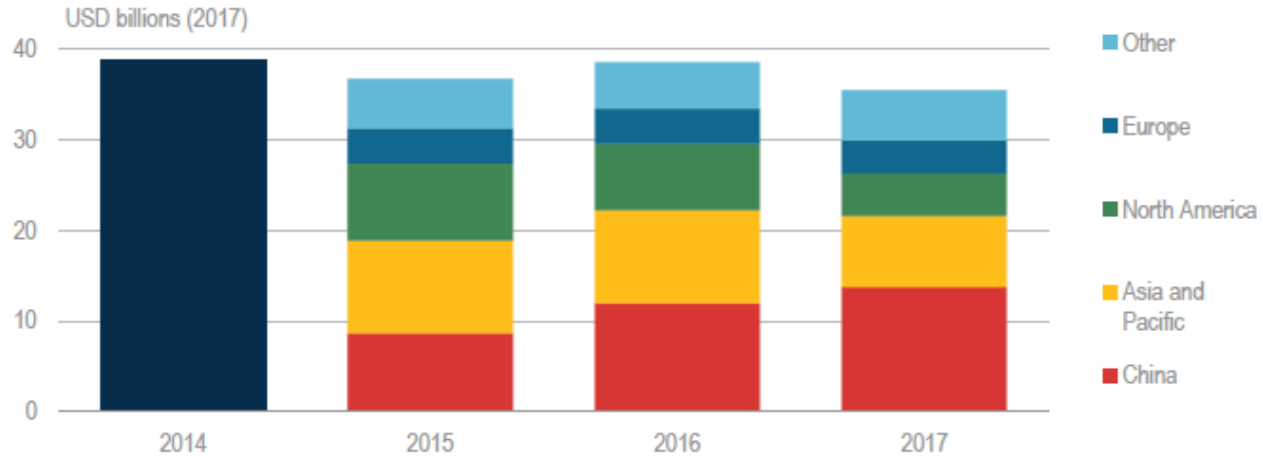
Figure 20. Global Investment in industrial energy efficiency, 2014-2017



Source: IEA

Moreover, as the European Union has the lowest industrial energy intensity[47], further reductions in energy consumption will imply major innovations to be deployed in the industry. The European Union has also the biggest share of global export market for energy-intensive goods (36%), but it is expected to decrease in 10% until 2035[48]. For this reason, focus should be placed on the potential increase in the competitiveness of EU energy intensive industry, which can be seen as an opportunity for implementing new solutions that provide significant benefits to the companies.

To this aim, the BAMBOO project will deploy and demonstrate 6 new technologies:

1. *DSS for flexibility management*: DSS able to forecast energy prices and generation (demonstrated across sectors).
2. *ORC:* flexible ORC system for the recovery of low to medium temperature waste heat and the production of electricity and upgraded heat for feeding other processes (demonstrated in petrochemicals).
3. *High temperature heat pump*: adaptation of industrial heat pumps working with low temperature waste heat sources for the production of hot water and/or steam (demonstrated in the steel sector).
4. *Flame monitoring system*: image-based flame monitoring system, able to provide the furnace operator with reliable information about the performance of the combustion and potential anomalies that may lead to increased emissions (demonstrated in the steel sector).

[47] *International Energy Agency, "Tracking Clean Energy Progress 2015 – Energy Technology Perspectives 2015 Excerpt IEA Input to the Clean Energy Ministerial", 2015.*

[48] *International Energy Agency, "Energy efficiency in the World Energy Outlook", Energy Efficiency Training Week, 2015.*

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5. *Drying process for bio-sludge valorisation*: a drying process for sludge able to use electricity or steam according to the flexibility needs of the plant while integrating waste heat recovery solutions (demonstrated in pulp & paper).
6. *Multi-fuel low NOx burner*: an adapted burner designed to feed multiple fuels and reduce NOx emissions (demonstrated in the mineral sector).

The following paragraphs provide an analysis for each of them, with a focus on trends, drivers and barriers to their market potential.

7.1 DSS for flexibility management

A decision support system (DSS) is a software system used to support decision-making in a company. A DSS allows to analyse huge amount of data in real time, and compile information that can be leveraged to solve problems and make informed, fact-based decisions.

The increasing reliance on Analytics, Big Data and IoT has dramatically increased the amount of data that manufacturers can leverage to improve their decision making. Detailed information is available regarding processes, customers and their preferences, equipment & devices and their defaults, suppliers, etc. To capitalize on this abundance of data, manufacturers have started building real-time decision-making environments for management, operations, demand forecasting and supply planning. Traditional ERP, CRM, SRM, SCM, MES solutions (just to name a few) have been complemented with analytics and/or predictive functionalities, while advanced solutions addressing vertical specific needs have been launched on the market. Within energy, the market has seen the emergence of Energy Management Systems (EMS), which are solutions able to collect real-time information on energy consumption by monitoring, controlling, assessing, and visualising energy consumption.

The market for energy management system is posed for solid growth. According to a recent study from Allied Market Research[49], the market for EMS was valued $25.9 billion in 2016 and will grow to $62.3 billion by 2023, growing at a CAGR of 13.5% over the forecast period (2017-2023).

Data refer to the global market across industries and the residential segment, and cover ICT spending for all the hardware, sensors, software and services needed to implement the system. Industrial EMSs account for the bulk of investment and will hold the largest share along the forecast period, driven by the need to reduce energy consumption of various equipment and machinery within the plant. The cost of the system coupled with long term ROI is expected to hinder growth especially among SMEs in manufacturing, which lack the resources for its implementation.

Through a factory EMS, manufacturers can not only monitor and control energy usage, but also:

[49] *Global Energy Management System Market, Opportunities and Forecasts 2017-2023.*

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- Assess problems related to energy consumption and opportunities to lower it;
- Identify the solution to the problems;
- Implement the solution and gather all feedback, enabling a virtuous cycle able to maximize the impact on energy consumption.

An EMS, though, doesn't have the functionality of a comprehensive DSS for energy flexibility management, allowing to change generation or demand in response to external signals and consumption forecasts. These tools for energy flexibility are at the early stage of development and in most cases lack features for assessing waste stream valorisation. The BAMBOO project will deploy and demonstrate an energy flexibility management tool that is able to forecast electricity prices, plant energy consumption, fuel consumption and related by-products prices and RES generation.

Scaling up the benefits provided by a factory EMS, DSS for energy flexibility allows not only to enhance control on the energy behaviour of the plant, but also the overall optimisation of energy acquisition, generation and consumption. In details:

- Optimal use of off-gases and waste streams depending on market scenarios
- Adaptation to the fluctuating supply from RES, facilitating their integration
- Reaction to real time information allowing to benefit from lower prices in energy supply
- Increased reliability and efficiency of the integrated energy system
- Reduced energy consumption and plant operational costs and potential new revenue streams

While these benefits are clear and expected to drive solid demand, some barriers may inhibit fast uptake in the short term. They include:

Technology:

- Lack of standards in several areas including sensor-rich machine tools, data models and analytical tools, advanced M2M and inter-device communication protocols.
- Costs of the technology.
- Perceived security issues around data.
- Pervasive broadband infrastructure, a prerequisite for interconnection.

Business paradigm:

- Process manufacturers' lack of familiarity and awareness of innovative technologies and their potential for energy and process optimisation.
- SMEs' delays. Similarly to what happened in other technology areas, access to finance, limited resources and skills, Return on Investment (ROI) issues, lack of best practices for small and medium-sized players, costs and complexity of technology may hamper adoption in the SME segment.
- Changing working culture and executives' buy-in.

Societal:

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- Lack of skills.
- Companies' trust, a typical issue when it comes to new concepts, and technologies.

The DSS tool can be applied in all key SPIRE sectors and represent the overarching management system integrating all the other technologies in the BAMBOO project and beyond to realise full flexibility of operations.

7.2 ORC

Concerns for energy storage, surging energy prices and global warming have fostered interested for combined heat recovery and power generation from low-medium temperature. One of the most appealing solutions in this area is ORC. Compared to a traditional Rankine Cycle using water to generate steam, ORC vaporises an organic fluid, whose features may depend on the available heat sources and the size of the plant. ORC principles are not new. Introduced back in the 70s, they are gaining traction thanks to a number of applications either connected to renewable energy (biomass, solar plant, and geothermal) or to industrial energy efficiency.

While environmental concerns and energy savings trigger adoption, there are a number of other factors that support demand for ORC. They include:

- Its modularity: the same system, with little modification can be used in conjunction with different heat sources[50].
- High technology maturity of its components already widely adopted in refrigeration applications[51].
- High overall efficiency and capacity to operate at partial load conditions (down to 10% of nominal power) making it very suitable for waste heat recovery from low to medium temperature sources[52].
- Flexibility in the selection of the fluid to be adopted resulting in more efficient turbomachinery, limited vacuum at condensers, and higher performance compared to traditional Rankine cycles especially for temperatures below 400 ºC[53].
- Organic fluid allowing slower rotation of the turbine and lower pressures, resulting in high stability of the system, and no erosion of the metal parts and blades[54], resulting in lower maintenance costs.
- Ease of installation (compact standard modules).

[50] *Technological and Economical Survey of Organic Rankine Cycle Systems, April 2009*

[51] *Technological and Economical Survey of Organic Rankine Cycle Systems, April 2009*

[52] *ORC Waste Heat Recovery in European Energy Intensive Industries: Energy and GHG savings, 2013*

[53] *A World Overview of the Organic Rankine Cycle market, 2017*

[54] *Turboden*

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- Long working life of the system (20+ years), with low need for maintenance

Still some factors may hamper adoption. In particular

- Safety concerns over the organic fluid (toxicity, flammability, etc) compared to water.
- Application limited to large corporations. Adoption for small to medium operations is not cost-effective compared to traditional Rankine systems.
- Space limitation and cost of the heat exchanger, considering that the ORC system is strongly influenced by its design[55].
- Shrinking industrial capital budgets (often devoted to other priority areas), cost of the solution and long-term ROI.

Considering industrial processes and equipment, many applications produce heat at low-medium level temperatures. A case study developed in 2004 by Engin showed that the cement industry rejects 40% of the heat used at temperature between 215 and 315 ºC, which, for economic reasons, cannot be recovered with traditional steam cycles. Energy is a critical input to any industrial process; application for industrial heat recovery is therefore posed to provide solid market potential[56]. Nonetheless the market is still at its early stage of development, with most of ORC implementations in the geothermal area.

According to a recent study presented at the IV International Seminar on ORC Power Systems in September 2017[57], as of end 2016 ORC represents a total installed capacity of around 2701 MW distributed over 705 projects and over 1754 ORC units globally. The US leads the market, followed by Turkey and New Zealand. From a competition perspective, ORMAT (US) is the leading player with 1701 MW installed capacity, followed by Turboden (Italy, 363MW), and Exergy (Italy,300MW).

Considering the 4 main application areas:

- Geothermal accounts for 74.9% of total installed capacity;
- Biomass represents 11%;
- Waste heat recovery is an interesting emerging field, accounting for 13.9%;
- Solar is negligible

Drilling down into waste heat, most applications relate to recovery from diesel or gas engines and turbines (65% of global installed capacity in heat waste recovery). Waste of energy is the second market (8.8%), driven by projects in France and Turkey since 2013. Metals (7.5%) and cement & lime (6.6%) follow.

[55] *Recent Trends in the Development of Heat Exchangers for Geothermal Systems, 2017*

[56] *Technological and Economical Survey of Organic Rankine Cycle Systems, April 2009*

[57] *A World Overview of the Organic Rankine Cycle market, 2017*

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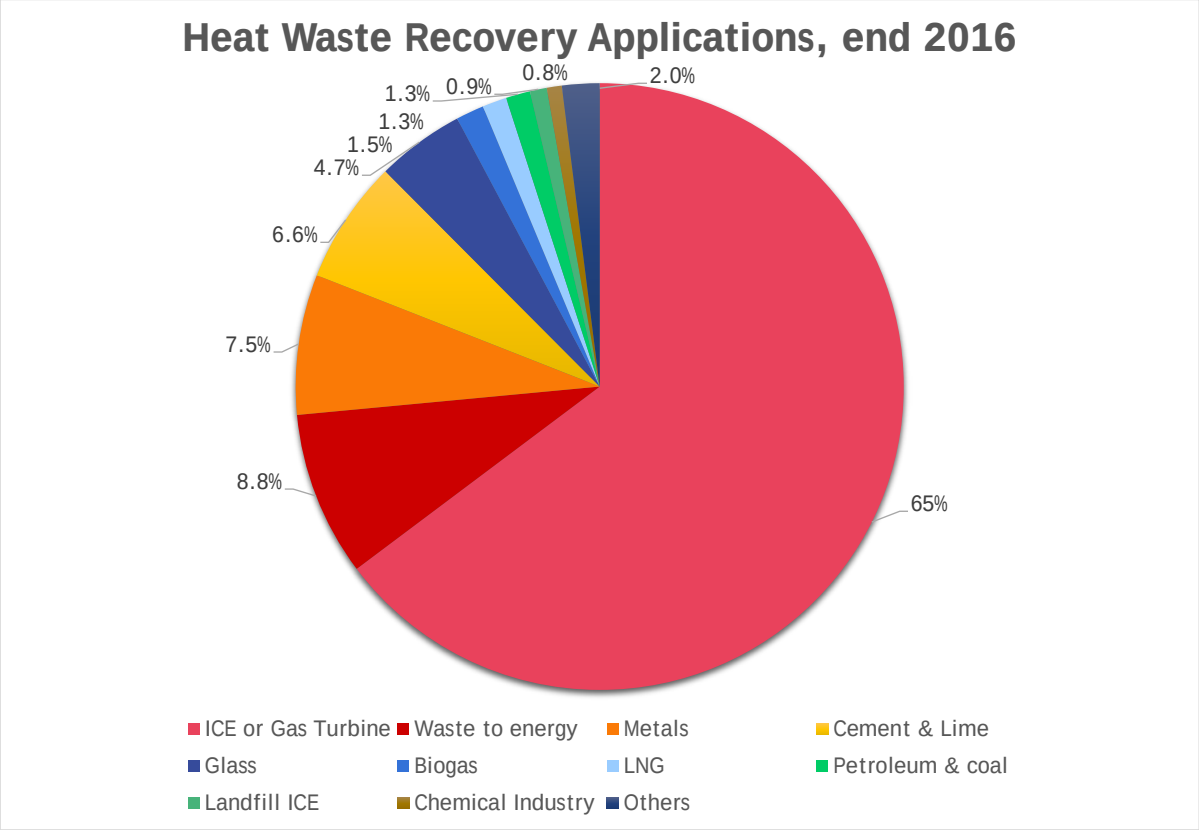
Figure 21. Heat Recovery Applications, end 2016



Source: A World Overview of the Organic Rankine Cycle market, 2017

Despite the strong potential, the share of petrochemicals (the sector where the BAMBOO project will demonstrate ORC for waste recovery) is limited to 1.3% of the global heat waste recovery capacity. Nonetheless the sector is expected to offer good opportunities in the years to come as:

- It can benefit from all drivers highlighted above.
- It is a highly energy intensive sector, especially the oil refining subsegment. In Central and Southern Europe for instance, energy costs accounted for 64% of total pre-tax revenue in 2010.[58]
- It is dominated by large players with big production capacity, making the solution cost-effective.
- Key large players have also the financial resources needed. Not only they are expected to launch or expand new petrochemicals projects over the next 10 years, thus extending the potential addressable market.

[58] *Towards an energy efficient oil&gas sector, 2015*

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- Players can profit from a positive Return on Image, by effectively leveraging the investment in their marketing activities.

Of course, safety concerns over the fluid remain. For application in the sector it is obviously crucial the fluid is not flammable. Also the low-end of the market (small and mid oil&gas companies) may prove a difficult segment to target as it faces several challenges related both to cash flow and the need to rethink their strategy in a context of an increasingly fast move to RES.

7.3 High Temperature Heat Pumps

Heat pumps uses electricity to produce hot water, air or steam. While their usage is well known in the building and residential segment, they are less recognised for their contribution to the industrial and commercial sectors. According to a recent market study, commercial and industrial installations accounted for just some 14% of the global market share.[59] However it is in these sectors where they provide more benefits in terms of more efficient use of energy, air quality and reduction in emissions[60]. Industrial heat pumps can produce more thermal energy than they use in electrical energy, leading to efficiencies of 300 to 700%, while enabling the reuse of sources which are otherwise wasted. Industrial gas-fuelled systems are never more than 90% efficient[61].

Industrial processes reject vast amounts of low temperature waste heat (exhaust gases and waste water). High temperature heat pumps allow using these waste streams as they provide heat at a higher temperature.

Heat pumps are an established technology. However most of currently available heat pumps can provide heat up to 100Cº with a spread between source and sink temperature of some 50k per stage. Although there are different examples of heat pumps dealing with higher temperatures, the use for application above 100Cº is still a challenge.[62]

Table 42 – Industrial HTHPs with heat sink temperatures above 90°C

Manufacturer	Product	Refrigerant	Max. heat sink temperature	Heating capacity	Compressor type
Kobe Steel (Kobelco steam grow heat pump)	SGH 165 SGH 120 HEM-HR90, -90A	R134a/R245fa R245fa R134a/R245fa	165°C 120°C 90°C	70 to 660 kW 70 to 370 kW 70 to 230 kW	Twin screw
Vicking Heating Engines AS	HeatBooster S4	R1336mzz(Z) R245fa	150°C	28 to 188 kW	Piston

[59] *Global Market Insights, 2019*

[60] *EHPA, Large scale heat pumps in Europe*

[61] *Beyond Zero Emissions Inc., Electrifying industry, 2018*

[62] *EHPA, Large scale heat pumps in Europe*

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Ochsner Energie Technik GmbH	IWWDSS R2R3b IWWDS ER3b IWWHS ER3b	R134a/ÖKO1 ÖKO (R245fa) ÖKO (R245fa)	130°C 130°C 95°C	170 to 750 kW 170 to 750 kW 60 to 850 kW	Screw
Hybrid Energy	Hybrid Heat Pump	R717/R718 (NH3/H2O)	120°C	0.25 to 2.5 MW	Piston
Mayekawa	Eco Sirocco Eco Cute Unimo	R744 (CO2) R744 (CO2)	120°C 90°C	65 to 90 kW 45 to 110 kW	Screw
Combitherm	HWW 245fa HWW R1234ze	R245fa R1234ze(E)	120°C 95°C	62 to 252 kW 85 to 1'301 kW	Piston
Dürr thermea GmbH	thermeco2	R744 (CO2)	110°C	51 to 2'200 kW	Piston (up to 6 in parallel)
Friotherm	Unitop 22 Unitop 50	R1234ze(E) R134a	95°C 90°C	0.6 to 3.6 MW 9 to 20 MW	Turbo (two-stage)
Star Refrigeration	Neatpump	R717 (NH3)	90°C	0.35 to 15 MW	Screw (Vilter VSSH 76 bar)
GEA Refrigeration	GEA Grasso FX P 63 bar	R717 (NH3)	90°C	2 to 4.5 MW	Twin screw (63 bar)
Johnson Controls	HeatPAC HPX HeatPAC Screw Titan OM	R717 (NH3) R717 (NH3) R134a	90°C	326 to 1'324 kW 230 to 1'315 kW 5 to 20 MW	Piston (60 bar) Screw Turbo
Mitsubishi	ETW-L	R134a	90°C	340 to 600 kW	Turbo (two-stage)
Viessmann	Vitocal 350-HT Pro	R1234ze(E)	90°C	148 to 390 kW	Piston (2 to 3 in parallel)

Source: High Temperature Heat pumps: market overview, state of the art, research status, refrigerants and application potential, 2018

This limits the adoption of industrial heat pumps across industries and in particular in the steel sector, which has higher than average demand for process heat above 100Cº. Considering ranges between 100-150Cº, industries with higher demand are all in process manufacturing and include:

- Food and tobacco
- Chemicals
- Non-metallic mineral
- Paper
- Iron and steel

Increase in the supply temperature of heat pumps can therefore prove very effective in serving heat processes in these industries.

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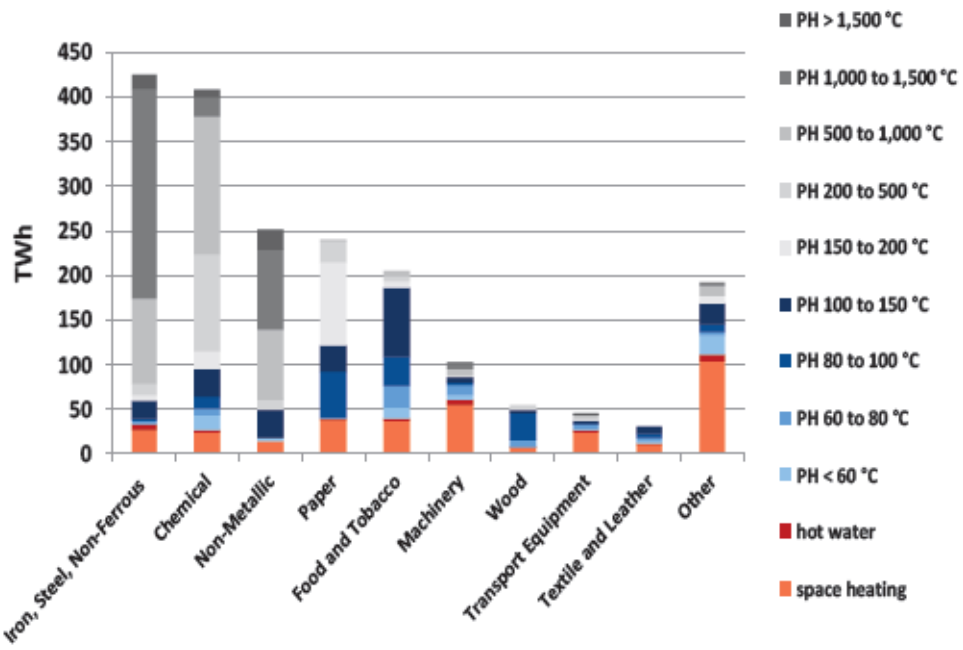
Figure 22 – Distinction of heat demand in industry by sector and temperature range



Source: EHPA

Argapaus et all looked into specific processes that require temperatures up to 200 Cº. Results are shown below in Table 43:

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Table 43 – Required temperature for specific processes, 2018

Sector	Process	Temperature	°C
		20 40 60 80 100 120 140 160 180 200	
Paper	Drying		90 to 240
	Boiling		110 to 180
	Bleaching		40 to 150
	De-inking		50 to 70
Food & beverages	Drying		40 to 250
	Evaporation		40 to 170
	Pasteurization		60 to 150
	Sterilization		100 to 140
	Boiling		70 to 120
	Distillation		40 to 100
	Bianching		60 to 90
	Scalding		50 to 90
	Concentration		60 to 80
	Tempering		40 to 80
	Smoking		20 to 80
Chemicals	Destillation		100 to 300
	Compression		110 to 170
	Thermoforming		130 to 160
	Concentration		120 to 140
	Boiling		80 to 110
	Bioreactions		20 to 60
Automotive	Resin molding		70 to 130
Metal	Drying		60 to 200
	Pickling		20 to 100
	Degreasing		20 to 100
	Electroplating		30 to 90
	Phosphating		30 to 90
	Chromating		20 to 80
	Purging		40 to 70
Plastic	Injection modling		90 to 300
	Pellets drying		40 to 150
	Preheating		50 to 70
Mechanical engineering	Surface treatment		20 to 120
	Cleaning		40 to 90
Textiles	Coloring		40 to 160
	Drying		60 to 130
	Washing		40 to 110
	Bleaching		40 to 100
Wood	Glueing		120 to 180
	Pressing		120 to 170
	Drying		40 to 150
	Steaming		70 to 100
	Cocking		80 to 90
	Staining		50 to 80
	Pickling		40 to 70
Several sectors	Hot water		20 to 110
	Preheating		20 to 100
	Washing/Cleaning		30 to 90
	Space heating		20 to 80

Source: Arpagus et all, 2018

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Beyond specific industry processes, in general steam production requires temperature up to 150Cº. The BAMBOO project will develop and demonstrate a new heat pump prototype, which provides low-pressure steam with up to 5 bar (152ºC) for industrial steam networks. The new heat pump will be demonstrated in the steel sector but use cases in other sectors and related processes will be also analysed.

If technical developments are needed to increase the temperature and allow new applications, other barriers are hampering adoption. They include:[63]

- Lack of awareness of high temperature heat pumps and their application to achieve industry benefits
- ROI in 2 years or more
- Risk aversion for new technologies and executives' buy-in
- Change management and conversion of processes
- Lack of skills (technical and business skills required for the integration of high temperature heat pumps in industrial processes)
- Competing heating technologies generating high temperature with fossil fuel at lower cost
- Lack of demonstration and standardisation for application in selected processes of the EU industries

BAMBOO will leverage the demonstration to build an effective business case and value proposition to foster the adoption across the EU.

7.4Flame monitoring system

Poor flame stability, low combustion efficiency and high pollutant emissions call for an effective monitoring of combustion processes. One traditional way to monitor the process is flame watch by experienced workers, with evident drawbacks in the quantification of the combustion performance and the poor working environment. [64]

The advent of IoT and intelligent sensors has completely revolutionised monitoring and control of combustion processes. Intelligent sensors are embedded in a computing system that monitors combustion quality and flame temperature. In particular, a flame image monitoring system involves capturing the flame image in different instants of time to check the quality of combustion[65]. The different colours of the flame image depict its temperature. The reliance on

63 Argapaus, Bless, Uhlmann, Schiffmann, Bertsch, High Temperature Heat pumps: market overview, state of the art, research status, refrigerants and application potential, 2018; EHPA, Large scale heat pumps in Europe

64 J. Chen and Y. /Y. Hsu, Image based monitoring of combustions systems, 2010

[65] *Mame,M.C., and Kulkarni,J.S.(2018). Flame Monitoring System of Power Station Plant - A Surveyi-manager's Journal on Image Processing, 5(1), 33-37. https://doi.org/10.26634/jip.5.1.14289*

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IoT and intelligent temperature sensors allows monitoring the fluctuation in flame temperature with respect to colour changes, enabling stability and reliability of the combustion process. There are several examples of early demonstrations, in particular in power plants, but no evidence of applications in co-firing of off-gases and natural gas in the steel sector, which is the area of focus in the BAMBOO project.

Given the strong innovation, there are not existing estimates on the market potential. Nonetheless, it is possible to anticipate strong interest from plants in the EU and international steel sector.

Demand is expected to be driven by:

- Reduction in emissions and better adherence to regulatory requirements
- Correction of flame instabilities and more stable combustion by using alternative fuels with lower heating values
- Improved working environment for furnace operators

The new technology will scale these benefits up to add those specifically related to the monitoring and control of co-firing of off-gases and natural gas in the steel sector. They include:

- Improved use of process gases as alternative fuels reducing natural gas consumption
- Reduced O2 and lower operating costs as the fuel-air mixture is controlled
- Prevention of unsafe fuel rich consumption as the fuel is limited to the available air
- Control over CO and NOx concentrations
- Enhancement of process efficiency and environmental performance

Moreover the new technology (to be patented by research organisation CIRCE) could be of interest to various companies with an offer in industrial flame monitoring to extend their portfolio and benefit from upsell and crossell opportunities.

7.5 Drying process for bio-sludge valorisation

According to IEA[66], paper and cardboard recycling could combine with process and equipment level efficiency gains to deliver improvements in energy intensity of some 25% by 2040. Eleven million tonnes of waste are indeed produced yearly by the European pulp & paper industry[67]. Currently, before waste sludge from paper mills can be disposed, it undergoes a mechanical

[66] *International Energy Agency, "World Energy Investment Outlook – Special Report", 2018.*

[67] *M. C. Monte et al, "Waste management from pulp and paper production in the European Union", Waste Management, Vol 29, 2009.*

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dewatering, aiming at a reduction of its moisture content[68]. However, the product thus obtained still present high humidity levels, resulting in poor combustible[69] properties and potentially high emissions[70]. A drying process by thermal means accomplishes several goals. First, reduced humidity turns into better combustible properties[71], allowing higher substitutions in co-combustion, and presents lower emissions respect to the dewatered product. Second, a solid bio-fuel obtained by drying is upgraded, presenting similar composition to that of coal, as regard to the hydrogen and oxygen ratios respect to carbon[72]. It has been shown that a thermal treatment can also reduce the content of nitrogen[73], thus reducing NOx emissions in subsequent combustion. In line with the activities of the BAMBOO project, waste-heat from the paper production can be recovered through the installation of a heat-pump and used as energy source in the drying process.[74]. Additionally, tests in fluidized beds[75] used for drying sludge, have shown some success in partial gas desulfurization, thus contributing to further reduced emissions. Technologies such as cyclone dryers appear frequently in the literature of paper sludge[76], while fluidized beds, a related technology, is also applied for drying as well as combustion of sludge[77].
The new drying facility will be further optimized trough integration with other solutions developed in the BAMBOO project:

1. Recovering waste stream from the plant, to be used in the drying process.
2. Use the flexibility tool to decide when is optimum to get electricity from the grid or switch to the low energy stream, as well as to predict the sludge amount.

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[68] *Biofiore, "Enhancing the utilization degree of sludge by improving fuel value and mapping out new applications", 10/11/2016; G.R. Hovey, "Drying characteristics of biosludge from pulp and paper mills", Master thesis, University of Toronto, 2016.*

[69] *F. J. Colomer, "Viabilidad de la valorización energética de lodos procedentes de distintos tipos de depuradoras", Residuos Vol 110, 2009.*

[70] *E. Cartmell et al., "Biosolids – A fuel or a waste?" Environ. Sci. Technol. Vol 40, Pages 649-658, 2006; S. Brown et al., "Calculator tool for determining greenhouse gas emissions for biosolids processing and end use", Environ. Sci. Technol. Vol 44, Pages 9509-9515, 2010.*

[71] *S. Budzyń and B. Tora, "Biomass fuel based on wastes from the paper industry", E3S Web of Conferences Vol 10, Pages 00083, 2016.*

[72] *C. Areeprasert et al. "Alternative Solid Fuel Production from Paper Sludge Employing Hydrothermal Treatment", Energy & Fuels, Vol 28, Pages 1198-1206, 2014.*

[73] *C. Areeprasert et al. "Fluidized bed co-combustion of hydrothermally treated paper sludge with two coals of different rank", Fuel Processing Technology, Vol 144, Pages 230-238, 2016.*

[74] *M. Mäkelä et al., "Low-temperature drying of industrial biosludge with simulated secondary heat", Applied Thermal Engineering, Vol 116, Pages 792-798, 2017.*

[75] *L. Yanfen et al., "Design of Co-combustion & Drying Integrative Process of Paper Sludge and Experimental Study", IEEE 15 April 2010.*

[76] J-E. Lee, E-M. Cho, "A study on air jet drying for water content reduction of sludge", Korean J. Chem. Eng. Vol 27(6), Pages 1822-1825, 2010; M. Mäkelä et al., "Pretreatment of recycled paper sludge with a novel high-velocity pilot cyclone", Applied Energy, Vol 131, Pages 490-498, 2014; T. J. Jamaleddine and M. B. Ray, "The drying of sludge in a cyclone dryer using computational fluid dynamics", Drying Technology, Vol 29:12, Pages 1365-1377, 2011.

[77] D. Shin et al., "Combustion characteristics of paper mill sludge in a lab-scale combustor with internally circulated fluidized bed", Waste Management, Vol 25, Pages 680-685, 2005; See also note 48.

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The value characterisation of the solutions, which is expected to drive its demand therefore relies in:

- Enabling new revenue streams from sludge thanks to an optimised drying process. Drying is an energy intensive pre-treatment. The new solution makes it cost-effective
- Integrating the drying process with the other operations of the plant (see point 1 above)
- Enabling full flexibility and fast reaction to change external conditions to benefit from competitive prices (see point 2 above)

Compared to the other sectors in the analysis, more SMEs operate on average in the EU pulp & paper sector, and this could inhibit strong adoption due to financial and human resource issues. ROI and talents (technical but also related to the integration of processes the new solution can leverage) will be crucial for the success of the solution. First targets will be therefore Tier 1 companies, but full benefits to the EU pulp & paper industry could be achieved if also the low-end of the market turns to innovative solutions.

7.6 Multifuel low-NOx burner

Low NOx burners are designed to control fuel and air mixing at each burner in order to create larger and more branched flames. Peak flame temperature is reduced and produces less NOx. The improved flame structure also reduces the amount of oxygen available in the hottest part of the flame thus improving burner efficiency[78].

According to recent report from Persistence Market Research[79], the industrial burner market amounted to nearly $5.4 billion in 2018 and will reach more than $8.4 billion in 2028, growing at CAGR of 4.4% along the forecast period. Boilers and furnaces/forges hold a significant share of the market. Growth is stronger in Asia Pacific, driven by the ongoing industrialization process of the region, and for dual-fuel burners compared to gas burners. According to the study, competition is low to medium. Although there is a large number of small players, tier 1 players hold some 35% of the market. Their current strategy is focused on low NOx and ultra-low NOx burners in response to industry demand.

Multifuel solid fuel combustion and low NOx burners are therefore maturing markets. Nonetheless applications have been so far limited to specific manufacturing segments such as cement, clay and lime. The application in the mineral sector and in particular in magnesite calcination faces several challenges due to the very high temperature (1600-2000 Cº). Existing technologies cannot

[78] IEA, Clean Coal Centre

[79] *Persistence Market Research, The Global Industrial Burner Market, 2019*

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be applied. The only way to reduce NOx at these temperatures is the modification of conventional burners' design and/or operating conditions.

The new BAMBOO solution will reduce locally the peak temperatures, maintaining the heat transfer and global flame temperature, making it suitable for the magnesium oxide sector. Drivers of the solution are expected to include:

- Application in a sector which is not covered by a commercial offer
- Reduction of NOx
- Reliance on alternative fuel, bringing flexibility in fuel usage
- Better control of the recirculation of exhaust gases and the mixing of fuel and air
- Ability to adjust and optimize the swirling angle depending on the properties of the fuel
- Ability to monitor, control and predict behaviour thanks to the integration with intelligent sensors and advanced analytics

With no existing offers available on the market, the solution could benefit from a strong competitive advantage. Nonetheless some barriers may hamper its uptake. If costs, ROI and skills already highlighted for other solutions will affect demand, other barriers will be strictly connected to its early development. This may influence companies' trust and willingness to invest and more demonstrations could be needed to ensure mass market uptake.

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8 CONCLUSIONS

This report provides a preliminary analysis of the market context for an effective exploitation of the technologies developed within BAMBOO. Focus was understanding the sectors where the 6 innovative solutions will be demonstrated from a structural, economic and business perspectives; monitoring energy demand, cost and prices; and understanding drivers and barriers specific to each solution. A final release of the market analysis including use cases will be provided at month 32.

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