Benchmarking baseline report

E2DRIVER H2020 project

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ABBREVIATIONS

ACEA: Association des constructeurs européens d'automobiles - European Automobile Manufacturers' Association (BELGIUM)

ADEME: Agence de l'environnement et de la maîtrise de l'énergie - Environment and Energy Management Agency (FRANCE)

BAFA: Bundesamt für Wirtschaft und Ausfuhrkontrolle - Federal Office of Economics and Export Control (GERMANY)

CLEPA: European Association of Automotive Suppliers

EASC: European Automotive Skills Council

EEAP: Energy Efficiency Action Plan

EED: Energy Efficiency Directive 2012/27/EU

ENEA: Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile - Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ITALY)

FIRE: Federazione Italiana per l'uso Razionale dell'Energia - Italian Federation for the Rational use of Energy (ITALY)

GHG: Greenhouse Gases

FIRE: Federazione Italiana per l'uso Razionale dell'Energia

ENEA: Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

ADEME: Agence de l'environnement et de la maîtrise de l'énergie

BAFA: Bundesamt für Wirtschaft und Ausfuhrkontrolle

IDAE: Instituto para la Diversificación y ahorro de la Energía

JRC: Joint Research Centre, the European Commission's science and knowledge service

Mtoe: Millions of tonnes of oil equivalent

OEM: Original equipment manufacturer

OICA: Organisation Internationale des Constructeurs d'Automobiles - International Organization of Motor Vehicle Manufacturers

PROJECT PARTNERS

CIRCE: Fundación CIRCE Centro de Investigación de Recursos y Consumos Energéticos

FRAUNHOFER ISI: Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung e.V.

POLITO: Politecnico di Torino

EPROPLAN: EPROPLAN GmbH Beratende Ingenieure

SINERGIE: Sinergie Società Consortile a Responsabilità Limitata

ENGIE: ENGIE Lab CRIGEN

SERNAUTO: Asociacion Espanola de Proveedoresde Automocion

AEN: Automotive.Engineering.Network – Das Mobilitätscluser e.V.

MESAP: Centro Servizi Industrie SRL

MOV'EO: Pole Mov'eo – Mobility Competitiveness Cluster

EPC: EPC Project Corporation Climate. Sustainability. Communications. GmbH

MERIT: MERIT Consulting House

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PUBLISHABLE SUMMARY

The purpose of this deliverable is to report the state-of-the-art of energy efficiency and energy audit procedures in the automotive sector in European countries and the resources already available. The main results of this report are twofold: On the one hand a list of specific instruments set-up for the industrial sector and, on the other hand, a state-of-the-art of energy consumption values and best practices versus which project actions and outcomes can be measured. These collected data are the starting point for forthcoming tasks of the project and ensure that project outcomes add to what already exists rather than repeating it.

The study presented in this report is enrolled into working package number 2 (or WP2) called "*Benchmarking and analysis of training programmes at the automotive sector*" aimed at developing a baseline for the development and analysis of E2DRIVER training methodology and platform by gathering previous experiences on capacity building programmes and studying at what level energy audits and energy saving opportunities are implemented in the industry.

Firstly, the study is based on a deep analysis of the legislative and standard framework at different levels (international, European, national). Then a section is devoted to the presentation of the results of the research on existing "Capacity Building Programs". The performed research allowed to highlight different initiatives devoted to energy efficiency in industrial processes even if nothing specifically devised for the automotive industry. Special focus has been set on the four Countries members of the Project Germany, Spain, France and Italy.

Afterward, a study on "benchmarking of automotive sector" is reported. A review of documents about available benchmarking data across the diverse sectors has shown that only aggregated data covering the whole automotive industry including manufactures, assemblers, suppliers as well as SMEs and non-SMEs are available.

These data have then been collected using statistical data from Eurostat and data from automotive associations. The analysis of different KPIs by region that could be derived from available statistics indicates the difficulties to set up generally applicable baselines as the variation of the data across countries is considerable. Nevertheless, the deliverable clearly sets the figures on the automotive supply chain and on its main energy consumption values.

TABLE OF CONTENTS

1 INTRODUCTION

The purpose of this report is to provide a state-of-the-art of the automotive sector regarding the legislative European background and the most representative energy consumption patterns. The main framework reports on the one hand an overview of the automotive sector which also includes the legislative hierarchy supporting energy efficiency measures within European Member States. For this purpose, main points of the Energy Efficiency Directive 2012/27/EU and its national transposition into Germany, Spain, France and Italy will be analysed. Particular attention will be given to the new Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018, amending Directive 2012/27/EU on energy efficiency, giving new targets on energy savings throughout Europe.

According to the main objective of E2DRIVER project, an overview of energy efficiency training programmes will be traced to highlight how the increase of awareness and competences are managed within small and medium enterprises companies as they mostly have no obligation for energy auditing.

In addition, a characterization of the energy consumptions involved in vehicle production will be performed by combining information about typical energy usage, energy intensive processes and possible best practice actions to improve energy efficiency in the sector. To this aim, the main activities involved in production and relative share in energy consumption will be studied giving, as output, an assessed energy baseline on aggregated level based on the available data. This will be useful to have a better knowledge of the energy behaviour of automotive industry and understand how much SMEs affect energy performance of the total supply chain.

The deliverable presents the results of the activities carried out in two specific subtasks of the project:

- Subtask T2.1a "*Capacity building programmes and initiatives in the automotive supply industry*";
- Subtask T2.1b "*Benchmarking of automotive sector*".

2 STATE-OF-THE-ART OF AUTOMOTIVE SECTOR

The automotive supply chain is one of the most important lines of activity at the European level. This section is aimed at describing its structures and its peculiarities related to the issue of energy efficiency.

2.1 Economic relevance of automotive sector in EU

The automotive sector nowadays accounts on about 13.8 million workers, which are representative of 6.1% of all European jobs (ACEA, 2019). In particular, direct and indirect manufacturing in EU involves almost 31 million people and it can be observed that more than one tenth (11.4%) of Europe's work-force is enrolled in automotive sector. Within this context, SMEs represent a large share of the industrial activities involved into manufacturing accounting for 3.5 million jobs (see Table 3) with a share of 26% of the sector.

Table 3: Automotive manufacturing employees in 2017 (ACEA, 2019)

WORKING SECTOR	ACTIVITY	EMPLOYEES (million)
Direct manufacturing (2.6 million jobs)	Motor vehicles	1.130
	Bodies (coachwork), trailers and semi-trailers	0.164
	Parts and accessories	1.314
Indirect manufacturing (0.9 million jobs)	Rubber tyres and tubes, retreading and rebuilding or rubber tyres	0.121
	Computers and peripheral equipment	0.068
	Electric motor, generators and transformers	0.244
	Bearing, gears, gearing and driving elements	0.211
	Cooling and ventilation equipment	0.243

The level of manufacturing jobs is not constant throughout the years as a continuous increase is monitored since 2013 (Figure 1), mainly thanks to the direct manufacturing.

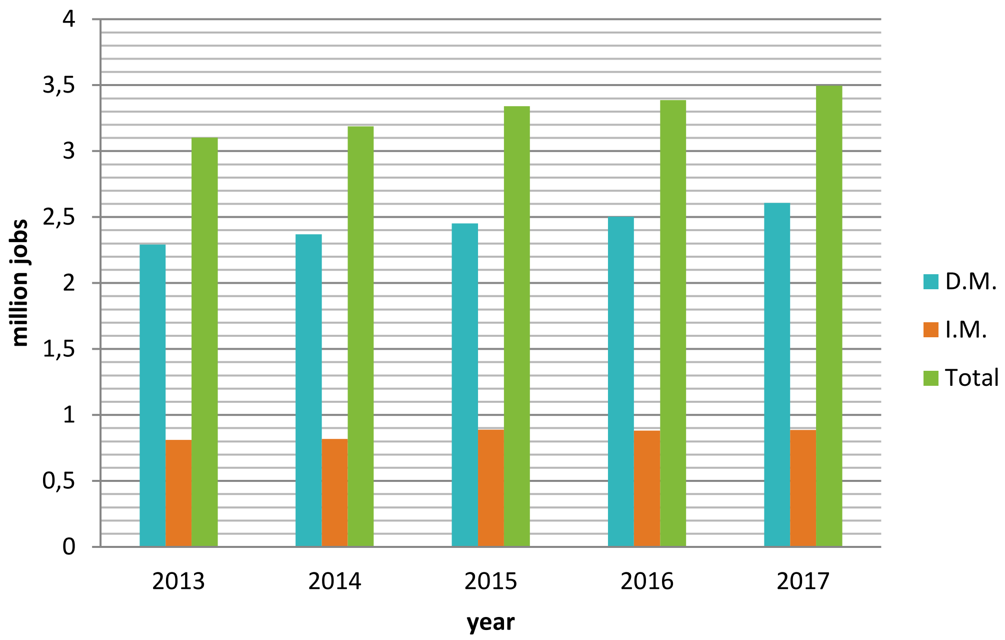

Figure 1: Employees number during years (ACEA, The Automobile Industry Pocket Guide 2019-2020, 2019) (D.M. = Direct Manufacturing, I.M. = Indirect Manufacturing)

It is apparent that the automotive sector covers a relevant part on the European economic trades. In 2018, vehicles production has overtaken the threshold of 19 million of vehicles, of which 16 are represented by passenger cars. This great production can support a huge export market mainly towards North America (31.9%) and Asia/Oceania (36.2%) accounting for about €138.4 billion in 2018. Import market represents a total of €54 billion, so the net incomes deriving by economic trading sector is 84.4 billion € (ACEA, 2019).

Following the importance of the sector, several energy efficiency measures have been applied through the years with the aim of reducing the specific energy consumption of manufacture processes. In particular, the Energy Efficiency Directive 2012/27/EU has addressed firms, classified as “large companies”, whose number of employees or turnover exceeds an established threshold. Compulsory measures have been defined to increase efficiency within their energy uses. At the same time, no measures have addressed SMEs where a lot of work to increase awareness and competences regarding energy issues has still to be done.

As a result of these actions, in 2018 the energy consumption per manufactured vehicle was 17.1 % lower with respect to 2005. By comparing to year 2012, in which EED had been issued, a reduction of about 16 % of the same indicator has been reached, corresponding to a total value of 38.72 million MWh that is reasonably lower than 2005 reference value (43.4 million MWh[1], see section 4.5.1). It can be observed that from 2016 the energy consumed for manufactured vehicle (Figure 7, section 4.5.1) almost reaches a stationary situation and further actions are needed to unlock other areas of benefits.

In the same source it can be seen that similar situation is currently undergoing for CO_2 emissions in Figure 2, in which tons carbon dioxide emitted per manufactured vehicle account for 0.55 t_{CO2} per car

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[1] https://www.acea.be/statistics/article/resource-efficient-production

in 2018. This value is 35.3% lower than the same of 2005 and 24.7% lower than it was in 2012. In 2018 9.39 million tons of CO_2 had been emitted which is significantly lower with respect to 2005 when the automotive sector was emitting into the atmosphere 13.39 million tons. As for the previous indicator, in biennium 2017-2018 a stationary condition has been achieved.

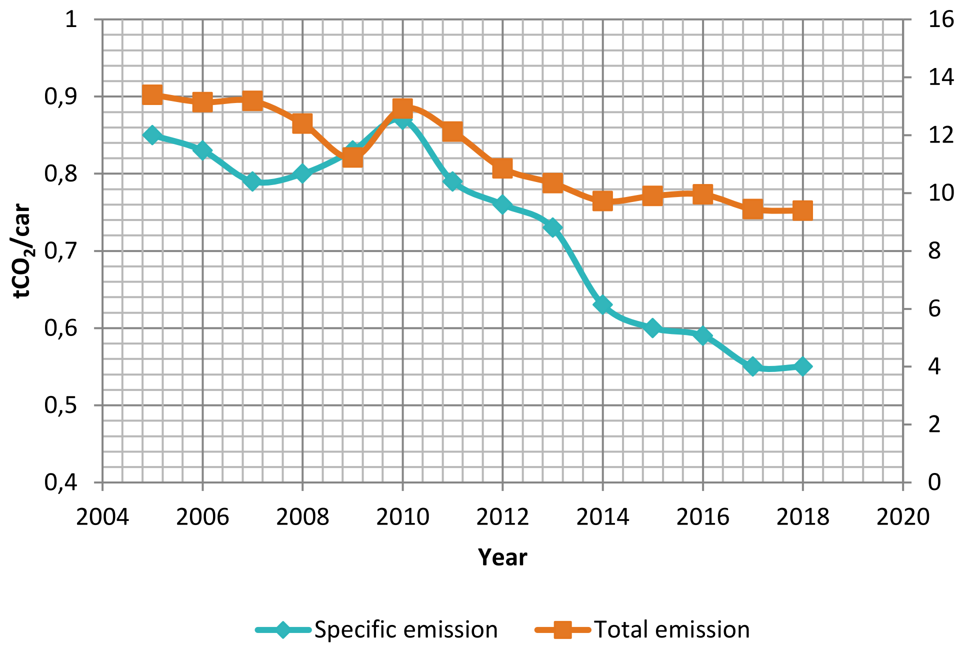

Figure 2: Automotive CO_2 emissions (ACEA, 2019)

As the previous data analysis is based on historical data, the European car manufacturing sector is currently facing a major challenge due to new emission standards for LDVs (Light Duty Vehicles), new vans and heavy trucks for 2030 (see Table 4).

Table 4: CO_2 emission targets per vehicle class (IEA, 2019)

Vehicle	Reference	Target
Light Duty Vehicles	95 gCO_2/km (2021 requirement)	- 37.5%
New Vans	147 gCO_2/km (2020 requirement)	- 31.0%
Heavy Trucks	2019 emission (not specified)	1. -15.0% for 2025 2. -30.0% for 2030

These emission targets are specific for each manufacturer and an exceed in production is rewarded with a reduction of respective CO_2 target. EU also promotes zero- and low-emission vehicles through encouragement in public sector with established minimum targets in terms of clean vehicles, different from each country (for LDVs, the expected share is between 17.6% and 38.5%). Electric mobility is also funded by incentive schemes in 33 European countries states, 26 within European Union. In addition, EU countries shall set specific objectives regarding development of charging infrastructure for 2020, 2025 and 2030 according to EU Alternative Fuels Infrastructure Directive. Energy Performance Building Directive (EPBD) states to establish minimum requirements for charging infrastructures within new or renovated buildings and its effectiveness is achieved if properly implemented within national building codes (IEA, 2019). Thanks to all these actions and according to European Commission, almost 2.8 million (20 times higher current situation) ECV charging point should be available by 2030 to increase the market penetration (ACEA, September 2019).

As a consequence, reshaping of the industrial activities and of the supply chains can be foreseen in the next few years in the car manufacturing sector. While some activities will remain unchanged, for instance car body, painting etc., others will undergo a deep transformation as the power train manufacture. As competition among different producers at world level is likely to increase, the issue of energy efficiency at any step of the supply chain will become surely more needed and urgent.

2.2 Overview of the automotive supply chain

Automotive supply chain is complex and results by the interaction of many stakeholders. The average vehicle composition of about 30 thousand parts (referring to lighting, electrical and electronics, body and main parts, powertrain and chassis and interior) highlights the complexity and diversity of its supporting supply chain.

The sector is historically dominated by a hierarchical structure with a small number of main manufacturers or firms at the top of the pyramid and a deep branching of smaller collaborators. The structure shows at first level tier suppliers producing subsystems with strong relationships and communication with lower tier suppliers, with a huge sectorial global dissemination. First tier suppliers increased their specific weight through the years even in design process at global level increasing connections with car assemblers (De Backer & Miroudot, 2013). In a nut, a first classification can be outlined (Gaudillat, Antonopoulos, Dri, Canfora, & Traverso, 2017):

- *Original Equipment Manufacturers (OEMs)*: firms involved into design, marketing and assembly of final product;
- *Tier 1 suppliers*: companies working close to OEMs, producing mainly automotive-grade hardware, doors, bumpers, brakes, wheels, gear boxes, powertrain, transmission and steering systems, etc.;
- *Tier 2 suppliers*: companies providing electrical and/or electronic machinery and equipment, metal products, machinery and communication equipment, bearing assemblies and pump units not directly to OEMs;
- *Tier 3 suppliers*: providing supply of raw materials (metals, plastics and glasses).

E2DRIVER will focus mainly on tier 1 and tier 2 suppliers. Companies often are involved in different supply chains at the same time, so that one Company category changes with the market, so that it could be belonging to Tier 1 in automotive chain and be a lower level supplier in another sector (Research Triangle Institute, 1999). Automotive suppliers represent an interesting area within automotive production chain since they produce 75% of the vehicle value, with an annual turnover of 600 billion euros[2]. Notwithstanding this production share, it must be pointed out that in the past Research and Innovation (R&I) expenditures were covered only by 1/3 by suppliers in 2007 with the remaining part sustained by OEMs. Situation got reversed during years and it is projected that suppliers' effort will reach 2/3 of the total amount as reported by the European Association of Automotive Suppliers

[2] https://clepa.eu/wp-content/uploads/2018/03/CLEPA-DNA_infographic-A4_FLYER_V14_PRESS-final_SMALL.pdf

(CLEPA[3]). CLEPA, which represents more than 3000 SMEs, also estimates that European supply industry yearly invests more than €20 billion for research and innovation by several patents registration and introduction of a wide range of products and solutions into the market.

Looking at the composition of the final product, the production of a car mainly consists on body shop, paint shop and final assembly in which the vehicle is built by its body, chassis and powertrain system (Oh & Hildreth, 2014) using electricity and fuel as energy carriers. Fuel is used for direct heating or to produce the steam employed in painting, space heating and car wash. Electricity is used during assembling stages in painting, HVAC (Heating, Ventilation and Air Conditioning), lighting, compressed air systems, welding and generic materials handling. More specifically, production processes can be summarized as follows (Galitsky & Worrell, 2008):

1. **Engines and parts manufacturing**: Aluminum and iron are main common materials used for engines and parts through metal casting, which is an energy intensive process. Final engine is obtained after an assembly stage;
2. **Vehicle body production**: Automobiles are generally formed by metal sheets, although some parts may be formed by plastic materials (such as doors or bumpers) because of their faster and more economic tooling steps with respect to metal ones;
3. **Chassis**: In most applications it is a metal-pressed frame on which further components are mounted (engines, wheels, transmission, brakes, suspensions, etc.);
4. **Painting**: Processes aimed to provide to the vehicle bodies proper resistance to corrosion. First step requires a cleaning bath of the body and series of painting processes to maintain paint quality and hardness. Uniform painting over the whole body is assured through electrostatic painting and a final drying process into an oven or using infrared-curing is performed;
5. **Assembly**: body and chassis are assembled in two parallel lines. First one requires assembly of body panels, doors, windows and painted body. On the other hand, wheels, steering gear, springs and the powertrain are installed in the frame. These lines converge into body bolting steps to the chassis. Historically this section replaced manual operations with automatic control systems and transfer machines.

Even if automotive supply chain is difficult to describe and characterize, as above stated, it is possible to identify main areas of interest by proper and in-depth analysis of national and regional enterprises with the aim to check their involvement, if any, in the vehicle production sector. If a huge data collection process is performed, it is possible to group such activities within companies into main categories of intervention, obtaining clusterization of activities as a final result (Pavone & Russo, 2017), where the Italian case is classified in 20 labels grouped into 6 aggregations (Table 5).

After this overview, a more detailed description of the automotive supply chain structure is given in section 4.2.1.

[3] https://clepa.eu/who-and-what-we-represent/ri-forerunner-2/

Table 5: Automotive supply chain – Italian case study (Pavone & Russo, 2017)

Design	Design studies
	Industrial design
	Research and experimentation
Electrical equipment	Electrical electronic equipment and software
	Electrical equipment, batteries, engines
	Electronics for refrigeration and heating
Parts, components, machining	Machining and surface treatments
	Metal hardware & taps
	Metal profiling
	Moulding and surface treatments
	Moulds and shapes
	Parts for motor vehicles
	Surface treatments
	Transmission organs
	Washer & hardware
Spare parts	Parts
	Vehicle spare parts
Windows and car interiors	Glasses
	Windows and car interiors
Miscellany	Miscellaneous business

3 SUBTASK T2.1A: “CAPACITY BUILDING PROGRAMMES AND INITIATIVES IN AUTOMOTIVE SUPPLY INDUSTRY”

Starting point of WP2 is Task 2.1.A “Capacity building programmes and initiatives in the automotive supply industry”. The purpose is to analyze the legislative framework behind European implementation of energy audits and energy management systems to highlight how countries enrolled in E2DRIVER project support energy saving practices within national boundary. In addition, an overview of existing capacity building programmes is listed to understand education and training level of energy efficiency in automotive sector. As will be seen in section 3.3, national implementation of EED requires the knowledge of main international and European standards.

Task 2.1A is structured into three main topics:

- Overview of European Energy Efficiency Directive and each national implementation of involved countries;
- Analysis of standards regarding energy efficiency;
- Analysis of existing capacity building programmes implemented at global, European and national level.

3.1 Legislative framework: Directive 2012/27

Regarding energy efficiency related issues, on 25 October 2012 the Energy Efficiency Directive (EED) 2012/27/EU had been approved by European Parliament and Council. Structured into a list of articles, this directive established common guidelines and frameworks to be implemented into European Member States to achieve 2020 energy target (20% reduction of its amount) in terms of energy consumption (Official Journal of the European Union, 2012). It had been amended by Directive 2018/2002/EU to establish future energy saving target of 32.5% for 2030 and a set possible rise of the threshold in 2023. Member states targets are set as minimum requirements, but they are forced to achieve annual 0.8% energy saving in the 2021-2030 period (Official Journal of the European Union, 2018).

Some particularly important sections can be highlighted:

- *Art. 1 “Subject, matter, scope”:* This section provides common frameworks regarding energy efficiency promotion to achieve 2020 20% reduction target and to set up a base for future initiatives. Several rules to overcome barriers in energy efficiency market are suggested and Member States national energy targets are established in terms of minimum requirements;
- *Art.3 “Energy efficiency targets”:* Specific target for European energy consumption had been established as 1474 Mtoe for primary energy consumption and 1078 for final energy for 2020;
- *Art.7 “Energy efficiency obligations schemes”:* This article promotes obligation schemes to identify organizations amongst energy distributors and/or retail energy sales companies to achieve 2020 targets. Obligations can be alternatively implemented by the definition of other policy measures or national energy efficiency programmes reflecting EED requirements;
- *Art.8 “Energy audits and energy management systems*”: Customers must pass through energy audits held by qualified experts or authorities under national legislation. In addition, each

Member State shall encourage initiatives to diffuse energy efficiency practices into small-medium enterprises (SMEs)[4].

By considering E2DRIVER programme purposes, particular attention should be devoted to art.8 of above-mentioned directive. As a consequence, European countries have been compelled to transpose energy efficiency practices into national directives and to first establish national energy targets and afterward frameworks for the promotion of implementation measures to achieve respective objectives.

For what concerns energy audits, national implementations properly classify non SMEs companies that shall undergo mandatory energy audits, whereas small-medium enterprises sector (even classified as microenterprises into national directives) represents an area into which each country is left free to encourage voluntary action and initiatives to boost energy audits implementation (European Commission, 2016). Nowadays the main tools to disseminate competencies in SMEs are information platforms and subsiding systems or financial support by regional or national bodies, such as national Energy Efficiency funds, able to cover part of required costs. This should allow the introduction of a stable policy fully oriented towards rational and efficient use of energy, from which, in a revolving economy concept, savings are the main economic driving force for its sustaining and continuous improvement.

3.1.1 Italian framework

Italian President of the Republic and Italian Government enacted Legislative Decree n.102/2014 on 4 July 2014 as the transposition of the Energy Efficiency Directive. The document establishes national frameworks and energy targets to reach 2020 energy consumption reduction goals according to the EED requirements (Decreto Legislativo n.102, 4 luglio 2014).

In particular, Italy shall reduce by 2020 its energy consumption of 20 Mtoe for primary energy consumption or 15.5 of final energy uses taking as a reference the value of the year 2010, with a quantitative target of 158 Mtoe (Italian Energy Efficiency Action Plan, 2014). In addition, GHG shall be reduced by 13% with respect to 2005 and achieve 17% of renewable share in gross final energy consumption[5]. To achieve this objective the law provides several tools to promote energy efficiency measures, to overcome obstacles in energy efficiency market and obligation schemes to identify energy-intensive companies.

Article n.8 is focused on energy audits and energy management systems implementation into national context. According to Decree n.102, large enterprises must undergo mandatory energy audits performed by qualified experts (European Commission, 2016). Energy audits are as well mandatory for energy-intensive companies listed in CSEA[6] (Cassa per I Servizi Energetici e Ambientali, or Energy and

[4] SMEs definition in EED: "enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million" (Official Journal of the European Union, 2012)

[5] https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/eu-economic-governance-monitoring-prevention-correction/european-semester/european-semester-your-country/italy/europe-2020-targets-statistics-and-indicators-italy_en#greenhouse-gas-emissions

[6] http://energivori.ccse.cc/Energivori/#

Environmental Services Fund) portal, classified according to minimum energy consumption level and incidence of energy cost on the value of business activity as specified in 5 April 2013 Decree[7].

The same national laws establish the "qualified" expert category represented by Energy Services Companies (ESCOs), energy management experts and energy auditors which have to be certified according respectively to UNI CEI EN 11352, UNI CEI EN 11339 and EN 16247-5 laws. Deadline for mandatory audit and/or implementation of energy management system was set for 5 December 2015. After this date an energy audit must be performed at least every 4 years. These obligations can be avoided if companies adopt an energy management system.

White Certificates ("Certificati Bianchi") trade mechanism is the main tool devised to achieve energy targets. In this scheme, each company has an energy target equivalent to an amount of energy efficiency titles (White Certificates) to be yearly owned by implementing energy efficiency measures within organization's activities and processes. These titles are negotiable and can be traded so that companies that do not reach their energy goals can purchase them and accomplish their objectives.

Art.8 of the Decree also aims to promote energy efficiency practices into SMEs. In 2013 European Regional Development funded "Trend Programme" to support energy audit in 100 SMEs and increase their awareness (European Commission, 2016). In addition, the Italian Ministry of Economic Development, in agreement with Ministry of Environment and Protection of Natural Resources and Sea, promoted a call for the period 2014-2020 to support Regional programmes for implementation of energy audits and energy management systems for SMEs funding about 50% of their expenditure (European Commission, 2016).

3.1.2 Spanish framework

The article n. 8 of the Energy Efficiency Directive had been transposed into Spanish context through the adoption of the Royal Decree 56/2016 of 12 February 2016. In terms of energy consumption, target was set up in 2013 as 119.9 Mtoe equal to a reduction of 2007 baseline of 25.2% into the national plan of Ministerio de Energía, Turismo y Agenda Digital (Ministry of Energy, Tourism and Digital Agenda, 2017). Furthermore, renewable sources into energy consumption shall cover 20% of the total amount and GHG emission must be lower of 10% with respect to 2005 baseline[8].

According to the law, large enterprises are identified if their number of employees is higher than 250 and the annual turnover exceed €50 million threshold and/or the balance sheet exceed €43 million (European Commission, 2016); the group that does not take part to this category is representative of small-medium enterprises sector. Mandatory energy audit have to be performed by proper experts (certified by European or international standards) at least every 4 years and the adoption of an energy/environmental management system under ISO 50001 or ISO 14001 standards allows to overcome these obligations, given that energy audits are already planned within them (Ministry of Energy, Tourism and Digital Agenda, 2017). Obligation schemes had been set for gas and electricity retailers, and gas and wholesalers involved into gas, liquified petroleum and petroleum products market. Minimum requirements for energy audits are established considering necessary operational and

[7] https://www.gazzettaufficiale.it/eli/id/2013/04/18/13A03398/sg

[8] https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/eu-economic-governance-monitoring-prevention-correction/european-semester/european-semester-your-country/spain/europe-2020-targets-statistics-and-indicators-spain_en#greenhouse-gas-emissions.

measurable data, detailed energy consumption examination of the enrolled activity, adoption of a Life Cycle Cost approach and criteria to improve its representativeness of the current situation.

Currently energy management systems implementation as well as energy efficiency measures within SMEs and large companies are promoted by the National Energy Efficiency Fund with economic support following a programme set up by IDAE (which is the Spanish Government's Instituto para la Diversificación y Ahorro de la Energía or Institute for the Diversification and Saving of Energy, or). This national body also carry out information sharing function using its website as a platform with databases, publication, reports, etc.

3.1.3 German framework

EED transposition into German context had been delivered by German Parliament with the amendment to the Act on Energy Services and Energy Efficiency Measures (EDL-G) on March 2015 (European Commission, 2016) to highlight objectives to be satisfied within national boundaries.

The legislation provides guidelines to identify SMEs and large companies and it can be observed that the regulation in terms of exceptions and deadlines to undergo mandatory energy audit or implement an ISO 50001 energy management system is the same as of other European countries: by 5_{th} of December 2015 an audit shall be performed and then every 4 years thereafter. For this purpose, the national law directly refers to EED definition to identify SMEs and not SMEs (European Commission, 2016). Germany is looking to reduce GHG emission by 14% with respect to 2005[9], increase renewable share in energy consumption to 18% and a national energy consumption target of 276.6 Mtoe (Bundesministerium fur Wirtschaft und Energie, 2017).

Similarly to other countries, mandatory audits are defined, but Germany can also supports energy management system implementation with multiple channels such as a reduction in electricity tax burdens to be obtained and maintained with continuous achievement of energy target, reduction of the renewable surcharge and funding for energy management system provided by BAFA (Federal Office for Economic Affairs and Export Control) regarding its cost, technology purchasing, external consultation and employees training costs. First two above mentioned channels are addressed to large companies with proper energy and/or environmental management system and small-medium enterprises adopting EN 16247 series (European Commission, 2016). Energy efficiency measures are not promoted by means of a trading scheme as in Italy and France.

Audits in SMEs are promoted by a programme currently administered by BAFA which points to overcome lack of knowledge in energy usage and meets requirements of EED art. 8 and Annex VI. The programme consists in financial support for audit costs in small-medium enterprises by qualified experts. Strong importance is given to information sharing thanks to the creation of local Learning Energy Efficiency Networks (LEEN). These networks look to group at least 5 companies by a two-three years plan of information and best practices sharing about energy efficiency[10]. It is strongly believed that an increase of communication level between companies can provide to all of them continuously

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[9] https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/eu-economic-governance-monitoring-prevention-correction/european-semester/european-semester-your-country/germany/europe-2020-targets-statistics-and-indicators-germany_en#energy-efficiency.

[10] See also http://publica.fraunhofer.de/dokumente/N-503271.html

innovative and updated solutions for energy efficiency measures and discover new investment sectors. Federal Government is pushing for development of 500 new energy efficiency networks within 2020[11].

3.1.4 French framework

In France the National Energy Code (from L.233-1 to L.233-4 also known as the law 2013-619) had been adopted by the French Government to specifically transpose Article 8 of EED into national legislation, on 27 November 2014 (European Commission, 2016).

National energy target for 2020 is set 219.9 Mtoe for primary energy consumption or 236.3 also accounting final non-energy consumption in the national energy efficiency action plan developed by Ministère de l'écologie, du Développement durable et de l'Energie (Ministry of Ecology, Sust. Development and Energy, 2014). The expected share of renewable energy in gross final energy consumption is 23% by 2020 and GHG emissions is deemed to be 14% lower with respect to 2005 value[12]. Mandatory energy audits had been programmed by Laws 233 and regulated into Legal Notice 2014-1393 and follow EN 16247 and EED Annex VI specifications. Large companies, which are forced to perform mandatory energy audits with the standard European time schedule (within 5 December 2015 and then each 4 years thereafter), are defined accordingly to the usual European scheme (European Commission, 2016). Companies not belonging to the previous set are classified as SMEs. Enterprises with an energy management system structured according to ISO 50001 requirements can avoid this obligation (European Commission, 2016).

The main framework to promote energy efficiency is represented by Energy Saving Certificates (CEE in French, Certificats d'Economies d'Energie), which are tradable personal property whose unit of account is the kilowatthour of energy saved. Interested actors shall hold energy saving certificates either by carrying out energy saving measures or by purchasing certificates. Obligatory regime is applied for legal entities using automotive fuels and bodies who sell electricity, gas, domestic fuel, heat or cold exceeding certain thresholds. According to their production volumes obligation are defined through multi-year target to be accomplished by holding an amount of energy saving certificates.

ADEME (French Environment & Energy Management Agency, or Agence de l'environnement et de la maîtrise de l'énergie) promotes both energy audit and energy management system implementation funding up to 70% of audits' costs and energy efficiency measures implementation. This measure applies also to SMEs. In addition, local and regional bodies focused on energy efficiency related issues are finalized to increase awareness and best practices information sharing (European Commission, 2016).

3.2 International and European Standards

Energy efficiency topic is world-wide discussed due to its direct link with fossil fuels and GHG emissions. These principles are expressed into global standards by ISO (International Standardization Organization[13]) to pave further international directives' implementation each one regarding a specific area.

[11] https://www.effizienznetzwerke.org/

[12] https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/eu-economic-governance-monitoring-prevention-correction/european-semester/european-semester-your-country/france/europe-2020-targets-statistics-and-indicators-france_en

[13] https://www.iso.org/home.html

European standards are identified with EN abbreviation, approved by CEN (Comité européen de normalisation) or CENELEC (Comité européen de normalisation en électronique et en électrotechnique) and at the end transposed into national contexts. Some of these regulations regarding energy efficiency and energy management systems can be outlined as follow:

1. **ISO 50001** is the International standard for energy management systems (ISO 50001:2018 "Energy management systems - Requirements with guidance for use", 2018). The aim of the standard is to enable organization to develop systems and actions finalized to increase their energy performance by supporting energy efficiency and decreasing energy consumption, giving requirements for methodologies implementation. According to the PDCA (Plan-Do-Check - Act) model, energy management system requires detailed explanation of the interested boundaries to be managed in terms of energy and organization top management main commitments. Risks and opportunities shall be outlined as well as measurable targets to be monitored in energy reviewing processes and a proper operational controlling plan. Measurable data are the base to evaluate system performance with possible internal audit and energy saving opportunities.

2. **ISO 50002** is the International Standard about energy audits. (ISO 50002:2014 "Energy audits - Requirements with guidance for use", 2014) It provides general requirements to be satisfied by auditors towards organizations, i.e. professional skills regarding energy issues and communication and/or project management abilities. In addition, a general structure of energy audit process is stated starting by definition of interested energy consumption areas to be analyzed with the company, data measurement and analysis of past and current situation until the final reporting of possible improvement actions. Steps to be followed are planning and opening meeting with organization, data collection, measurement plan, on-site visits, analysis, audit reporting and closing meeting.

3. **EN 16247 series** is a European standard that provides sets of requirements and guidelines to the identifications of measures leading to energy efficiency improvement of an organization through energy audits. It is subdivided into 5 parts regarding general requirements to perform an auditing process (EN 16247-1:2012 "Energy audits Part 1: General requirements", 2012) and guidelines to perform an audit respectively in buildings, industrial processes and transport sector (in order, (EN 16247-2:2014 "Energy audits Part 2: Buildings", 2014), (EN 16247-3:2014 "Energy audits Part 3: Processes", 2014) and (EN 16247-4:2014 "Energy audits Part 4: Transport", 2014)). In 2015 the document was updated with a section regarding required competences of an energy auditor (EN 16247-5:2015 "Energy audits Part 5: Competence of energy auditors", 2015).

3.3 Capacity building programmes

Obligation schemes within each national legislation develop a competitive market in which each large or energy-intensive company is called to achieve pre-established energy targets by optimizing their energy usage into specific processes. In parallel, the increase of the competitiveness of organizations requires more and more people to be trained to have sufficient qualifications in energy matters. In fact, the workstaff need to know the general rational use of energy principles and their application into specific processes of the organization. As above stated, automotive industry is hierarchically structured with a small number of firms on the top and a huge quantity of smaller tiers below, in which SMEs play an important role. It is apparent that the development of specific training programmes within small and medium enterprises could boost implementation of energy saving measures to reduce energy consumption, increasing energy efficiency and reducing GHG emissions in a sector where currently there are no obligations schemes. An improvement of capacity building programmes could act as a driving force to increase awareness and competitiveness in this reality. As pointed out before, no actions are specifically devised for the automotive sector.

At global level some initiatives are ongoing:

- IEA (International Energy Agency[14]) is an International organization which deals with renewable energies diffusion, fossil fuel consumption reduction and energy efficiency measures and is represented by 30 member states, providing useful material in terms of resources and training programmes[15]. Energy efficiency is treated with energy statistics weeks, online webinars and online statistics training programme, available on YouTube. CO_2 emission, energy policies, energy efficiency indicators, energy prices and taxes and renewables are main topics under analysis;
- IPEEC (International Partnership for Energy Efficiency Cooperation[16]) is another important worldwide organization providing information and material regarding energy. It is composed of 17 member states of G20 accounting for 80% of global energy consumption and 80% of global GHG emissions. Currently a proposal for a framework regarding a globally integrated platform (Energy Efficiency Knowledge Sharing Framework or KSF) had been delivered by G20 to disseminate energy efficiency and best practices information with the aim to accelerate sectorial energy savings (IPEEC, 2019);
- In addition, the IIET (International Institute for Energy Efficiency[17]) is an international energy training center regarding energy related topics and offers a wide range of training material with different course approaches (from multiple in-person days courses to 1-2 hours online training). Training involved into TIER 1: "*Certification Programs*" provides in person courses for 3-9 days; TIER 2: "*Short thematic courses*" takes 1-2 days and are held by experts; TIER 3 "*Thematic online training*" offers online platform to attend 1-2 hours courses. Online training about energy topics refers to energy audits and instrumentation, energy financing, energy monitoring and targeting, energy tariffs, energy performance contracting, etc.

At the European level, the European Commission set up EASME (Executive Agency for Small-Medium Enterprises[18]) to manage energy related supporting programmes within SMEs. In particular, Horizon 2020 Energy Efficiency[19] programme supports innovation and research of more energy-efficiency

[14] https://www.iea.org/

[15] https://www.iea.org/statistics/#training

[16] https://ipeec.org/

[17] http://iiet.com/

[18] https://ec.europa.eu/easme/en/

[19] https://ec.europa.eu/easme/en/section/horizon-2020-energy-efficiency/h2020-programme

technologies and aim to increase skilled-people and knowledge about energy related issues, with nearly €80 billion available from 2014 to 2020. From 2003 to 2013, energy sustainability topic was held by IEE[20] with €730 million available to fund projects finalized to improve sectorial energy efficiency according to 2020 European targets. Some initiatives can be listed:

- BUILD UP Skills project started within IEE aiming to increase knowledge level about energy topics in building sector through education and training programmes targeting construction workers and systems installers. Building energy efficiency and renovation is a channel to promote nZEB (nearly-Zero Energy Buildings) construction. Training material is available at BUILD UP initiative website as webinars, training, tools and experts' consultation[21];
- PROF-TRAC initiative developed an online platform with high quality training material for architects, engineers and building managers about nZEB[22];
- EPC Plus project has received funding from the European Union's Horizon 2020 and is co-funded by European Commission, representing 11 European countries. Its purpose is to reduce transaction costs of energy services to facilitate the investment in SMEs through proper standardization of technical and contractual issues of energy services. It also provides on-line training material [23] to clusters of companies, mainly SMEs, for each enrolled country so that they can offer energy services to SMEs market. Energy Efficiency Network Europe[24] is used to disseminate information about energy services, where exchange valuable know-how between each member is possible;
- STEEEP (Support and Training for an Excellent Energy Efficiency Performance) was a 3-year European project which helped 600 European cross-sector SMEs to reduce their energy consumption and become more energy-efficient (i.e. also providing training material[25]), co-funded by IEE. Energy Management and best practices tools are provided by a network of energy advisors of Chambers of Commerce and Industry (CCIs) from 10 different countries.

In addition, some national initiatives by Project Member States had already been taken:

- In Italy, an educational platform has been created by FIRE ("Federazione Italiana per l'uso Razionale dell'Energia" Italian Federation for the Rational use of Energy) allows workers to attend classrooms and/or online courses through the GOToWebinar platform, mainly to develop or update Energy Management Experts skills. It is structured into training packages to be purchased on need. ENEA (Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile, National Agency for new technologies, energy and sustainable development) also organizes and implements e-learning courses[26] regarding energy diagnosis using the Enea Matrix Platform;

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[20] https://ec.europa.eu/easme/en/section/energy/intelligent-energy-europe

[21] https://www.buildup.eu/en/learn

[22] http://proftrac.eu/training-material/search-training-material.html

[23] http://epcplus.org/upload/ue/wp3/D3_04_PRO.pdf

[24] http://www.energyefficiencynetwork.eu/

[25] http://www.steeep.eu/assets/Uploads/D4.3-Training-Material-for-SMEs.pdf

[26] http://www.agenziaefficienzaenergetica.it

- In Germany an important initiative is Mittelstandsinitiative Energiewende und Klimaschutz (SME Initiative for Energy Transition and Climate Protection)[27] .It offers a wide range of information and training programmes, in particular several modules are implemented to apprentices within companies about energy efficiency related issues and by teaching modules introducing them the topic, project work and measuring instruments usage. In addition, the Competence Centre for Sustainable Procurement (Kompetenzstelle fur Nachhaltige Beschaffung, KNB[28]) offers web services and online training courses;
- In France, FEE Bat (Formation aux Economies d'Energie des Enterprises- Training in Energy Savings of Companies [29]) develop training courses for energy saving in buildings and artisans (Ministry of Ecology, Sust. Development and Energy, 2014);
- In Spain, IDAE (Instituto para la Diversificación y Ahorro de la Energía) provides an e-learning platform[30] with courses about best practices for energy efficiency during personal working activities, domestic equipment purchasing, driving, domestic heating and water systems, energy efficiency certification for existing buildings, energy saving measures for interior lighting and energy saving measures in heating, domestic hot water and solar thermal energy systems (Ministry of Energy, Tourism and Digital Agenda, 2017). In addition, an e-learning tool is provided by AEE in Spain (Association of Energy Engineers)[31]. On the other hand, these institutions, as well as other national federations of companies (e.g. CEOE or CEPYME), develop specific guidelines related to the use of energy according to industrial sectors or processes.

All above mentioned national initiatives can be briefly summarized in Table 6:

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[27] https://www.mittelstand-energiewende.de

[28] http://www.nachhaltige-beschaffung.info/DE/Home/home_node.html

[29] http://www.feebat.org/

[30] http://www.aprendecomoahorrarenergia.es

[31] https://www.aeespain.org/cursos/

Table 6: National initiatives summary

	Italy	Germany	France	Spain
National transposition of EED	Legislative Decree n.102/2014	Amendment to the Act on Energy Services and Energy Efficiency Measures (EDL-G) 2015	National Energy Code (from L.233-1 to L.233-4 also known as the law 2013-619)	Royal Decree 56/2016
Energy targets for 2020[32]	158 Mtoe[33], 13% of GHG emission reduction and 17% of renewables share[34]	276.6 Mtoe, 14% of GHG emission reduction and 18% of renewables share	219.9 Mtoe, 14% of GHG emission reduction and 23% of renewables share	119.9 Mtoe, 10% of GHG emission reduction and 20% of renewables share
SMEs initiatives	Funding programmes for audits and EnMS[35] implementation	BAFA funding programmes for audits costs and EnMS and Learning Energy Efficiency Networks	ADEME funding programmes for audits and EnMS implementation	National Energy Efficiency Fund funding for EnMS implementation by IDEA programme
Capacity building programmes	FIRE and ENEA on-line/classroom courses	Mittelstandsinitiative Energiewende und Klimaschutz and KNB on-line training courses	FEE Bat training courses	IDEA e-learning platform

[32] 2014 Countries reports also available at https://ec.europa.eu/clima/sites/clima/files/strategies/progress/reporting/docs/it_2014_en.pdf (Italy), https://ec.europa.eu/clima/sites/clima/files/strategies/progress/reporting/docs/de_2014_en.pdf (Germany), https://ec.europa.eu/clima/sites/clima/files/strategies/progress/reporting/docs/fr_2014_en.pdf (France), https://ec.europa.eu/clima/sites/clima/files/strategies/progress/reporting/docs/es_2014_en.pdf (Spain).

[33] Values refer to national primary energy consumption target

[34] In gross final energy consumption

[35] Energy Management Systems (EnMS)

4 SUBTASK T2.1B: “BENCHMARKING OF AUTOMOTIVE SECTOR”

The subtask 2.1B “Benchmarking of automotive sector” is carried out under Work Package 2. Its specific goal is to develop a baseline for benchmarking in the automotive sector and, as far as possible, in particular in the automotive supply industry. This shall help to determine the potential impacts leveraged by the E2DIVER project and to identify potential measures for achieving energy savings in the automotive supply industry.

The task addresses the following points of investigation:

- Overview of energy consumption in the automotive sector for the four focus countries (Germany, Spain, France, Italy)
- Development of a benchmarking baseline
- Measures for achieving energy savings in the automotive sector

The results of this task will be used as a baseline to estimate the (potential) impacts leveraged by the E2DRIVER project. This will be part of the work carried out in WP5 “E2DRIVER evaluation and exploitation”.

4.1 The energy baseline in E2DRIVER project

As mentioned in the proposal E2DRIVER will establish links with previous EU projects related to capacity building programmes on energy audits and saving measures in industry. Thus, the benchmarking approach of E2DRIVER is based on the methodology applied in the INDUCE project which deals with capacity building programmes in energy efficiency in the food and beverage sector.[36]

Energy benchmarking, or energy efficiency benchmarking, is as special type of benchmarking activity focusing on energy performance. The purpose of energy benchmarking generally is to establish and to compare the energy efficiency within or between entities and to contribute to a reduction in energy use and related costs and emissions.

As the concept of an energy baseline can be perceived in different ways, some clarification is needed on the understanding of the baseline in the E2DRIVER project. The discussion of this understanding follows several questions (Sontag, et al., 2014) which are briefly interpreted with regard to energy benchmarking in the E2DRIVER project:

- **Aim and user:** Why to introduce energy benchmarking? What purpose is the information used for?

  A starting point for setting up energy benchmarks is to clarify the purpose and the user of information gained from the benchmarks. Being clear about this is important as it will affect the subsequent design of a benchmark. Furthermore, it will influence what is benchmarked, how it is benchmarked, what data is used and how this data is collected.

  ➔ In the specific case of the E2DRIVER project, the primary user group of the benchmarking baseline is the project team. The intended purpose is to use benchmarking information to get insights on the impact of the E2DRIVER project.

[36] see https://www.energyefficientfoodindustry.eu/

- **Object:** Which activities or entities are analysed in the benchmarks?

  Many objects or entities can be analysed using energy benchmarks, e.g. products, processes, machines, equipment, technical installations, buildings, areas or sites. The selection of the objects depends on the users and their aims. The benchmarking object also influences the type of benchmark that is used. These types include benchmarks based on past performance, based on reference values and on comparisons of multiple objects (Mattes, Jäger, Nabitz, Hirzel, Rohde, & Som, 2016).[37]

  ➔ As the goal of the E2DRIVER project is to achieve improvements in energy performance over the entire site and the aim of benchmarking is impact assessment of the E2DRIVER intervention, the benchmarking objects are the pilot companies. With regard to the benchmarking type, the performance of the pilot companies can be monitored against past values. Yet to ensure that autonomous progress of the sector is taken into consideration, there is a need to establish a benchmarking baseline in E2DRIVER which allows to characterize the autonomous improvement in energy efficiency and to remove it from the quantitative result from the impact assessment. As a consequence, the benchmarking baseline will provide an indication of the macroeconomic development of the sector while a more detailed analysis on the level of the companies will yield the microeconomic achievements of the individual pilot companies.

- **Performance indicators and factors of influence:** What energy performance indicators or metrics to use in benchmarks? How are they influenced by other factors and how to deal with this influence?

  Performance indicators should allow users to analyse the energy performance of the considered entities or objects as transparently and objectively as possible. The main challenge is to separate actual development of energy performance from other information that might affect benchmarking results (e.g. weather, operating time, process parameters, etc.).

  ➔ The benchmarking baseline of the E2DRIVER project should indicate average improvements in energy efficiency in the automotive sector. Usually, this data is only available on an aggregate level without indications about specific factors of influence potentially affecting benchmarking results. Due to these limits and assuming that most of the factors will even themselves out across the variety of companies in the sector due to statistical effects and across several years, factors of influence will not be considered for the baseline data. Yet for the analysis of progress of individual pilot companies, such factors of influence will have to be taken into consideration for determining their overall progress.

- **Data acquisition and analysis:** How often is it necessary to sample data? Where and how often does it have to be collected and analysed?

  As the questions point out, the sources for and the frequency of data acquisition are closely linked to the purpose of the benchmarking approach.

  ➔ Specifically, for the E2DRIVER project, both data acquisition and analysis have to compare the status before the benchmarking intervention and sometime after the E2DRIVER

[37] For more details on methodological issues of such comparisons, see for example Mattes et al. (2016).

intervention. As official statistics on energy consumption as a main source of information usually lag behind by several years, it is necessary to rely on average sectoral improvements over the past years. On the level of pilot companies, the most recent data should to be used.

The energy benchmarking baseline is to investigate on the autonomous improvement of the automotive sector. As it has been already mentioned in previous sections, the automotive sector is composed by a small number of large original equipment manufacturers (OEMs) and a tiered structure of suppliers dominated by a large number of SMEs all working closely together. Since there are limitations with regard to data availability of the automotive sector as described in section 4.4, only a general assessment of the automotive industry in terms of on an aggregated level seems reasonable.

4.2 Automotive supply industry

4.2.1 Sectoral definition and relevance

According to the official statistical classification of the economic activities in the European Community (NACE), the automotive sector is attributed to the manufacturing section (Section C) of the statistical classification. It generally refers to the manufacture of motor vehicles, trailer and semi-trailers (NACE C29) which includes the manufacture of motor vehicles (NACE C29.1), of bodies (coachwork) for motor vehicles (NACE C29.2) and of parts and accessories for motor vehicles (NACE C29.3) and is shown in Table 7. In this context it is important to note that original equipment manufacturers (OEMs) which are operating as assemblers as well as large number of suppliers (SMEs and non-SMEs) involved in the automotive sector are included here. However, since the suppliers are part of the whole supply chain the underlying Eurostat Data is suited for a general benchmarking analysis.

Table 7: Overview of the activities of manufacturing motor vehicles according to NACE rev. 2 (Eurostat, 2008)

29		MANUFACTURE OF MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS
29.1		Manufacture of motor vehicles
29.2		Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
29.3		Manufacture of parts and accessories for motor vehicles
	29.31	Manufacture of electrical and electronic equipment for motor vehicles
	29.32	Manufacture of other parts and accessories for motor vehicles

The activities of division 29 include the direct manufacturing of motor vehicles for transporting passengers or freight. The manufacture of various parts and accessories, as well as the manufacture of trailers and semi-trailers, is included here[38]. The maintenance and repair of vehicles produced in this division, which is not included in the benchmarking analysis, is classified in 45.20. Since E2DRIVER will be focused mainly on tier 1 and tier 2 suppliers (as shown in Figure 3 and described in section 2.2) the manufacture of rubber tires and tubes (NACE C22.11) which is allocated within tier 3 is not included in the benchmarking analysis.

[38] Note: All indirect manufacturing like the manufacture of lighting equipment, pumps and engines, batteries and electric motors, computers and peripheral equipment or bearings and gears is for instance not included here.

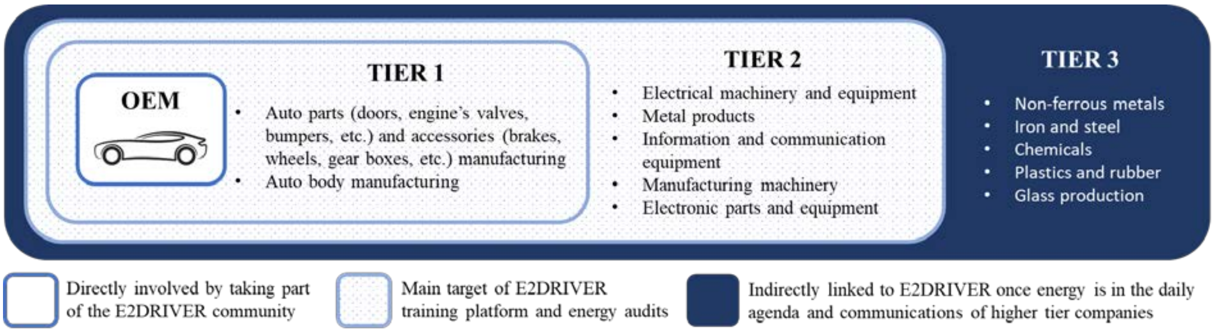

Figure 3: Automotive value chain structure and E2DRIVER representativeness

It should be stressed that the classification and statistics provided by Eurostat do not differentiate SME and non-SME or supplier and OEM. Even industry associations[39] do not have such data (see section 4.4**)**. Therefore, figures specific to SME of the car supplier industry are almost not available, alternatively a broader scope has to be considered in the figures presented in this task.

An overview on the relevance of the different sectors following the NACE classification is given in Table 8. For this analysis, the number of employees, the number of enterprises, the value-added and the turnover are shown. According to statistics, there are approximately 20 160 enterprises with 2.5 million employees active in the manufacture of motor vehicles in the European Union.

*Table 8: Relevance of automotive sector by employees, enterprises, value-added and turnover in 2017 for the European Union (source: Eurostat data tables: sbs_na_ind_r2) *for some countries only data from 2016 available, for some countries no data published*

NACE Code	NACE Description	Employees [number]*	Enterprises [number]	Value-added [Mio EUR]*	Turnover [Mio EUR]
C29	**Manufacture of motor vehicles, trailers and semi-trailers**	**2 585 977**	**20 161**	**210 664**	**1 099 648**
C29.10	Manufacture of motor vehicles	1 039 780	2 700	137 082	800 000
C29.20	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	160 763	6 922	8 472	- [40]
C29.30	Manufacture of parts and accessories for motor vehicles	1 240 646	10 500	65 110	278 888
C29.31	Manufacture of electrical and electronic equipment for motor vehicles	259 748	1 700*	8 939	36 470*
C29.32	Manufacture of other parts and accessories for motor vehicles	973 821	8 759*	56 171	226 605*

A breakdown of employees and companies by country for 2017 shows that Germany has about 865 000 employees and thus the largest number in Europe (Figure 4). By comparison in terms of enterprises, however, Germany is only the second largest country with some 2500 companies. Leading in terms of

[39] e.g. European Association of Automotive Suppliers (CLEPA)

[40] values confidential, 2015: 31 000 Mio EUR turnover

companies is the United Kingdom, followed by the focus countries of the project (Germany, Spain, France and Italy). This implies that even average values are quite heterogeneous across the EU-28 Member States, ranging from 2-3 employees per company in Cyprus and Greece to 350-390 in Germany and Romania (Figure 5).

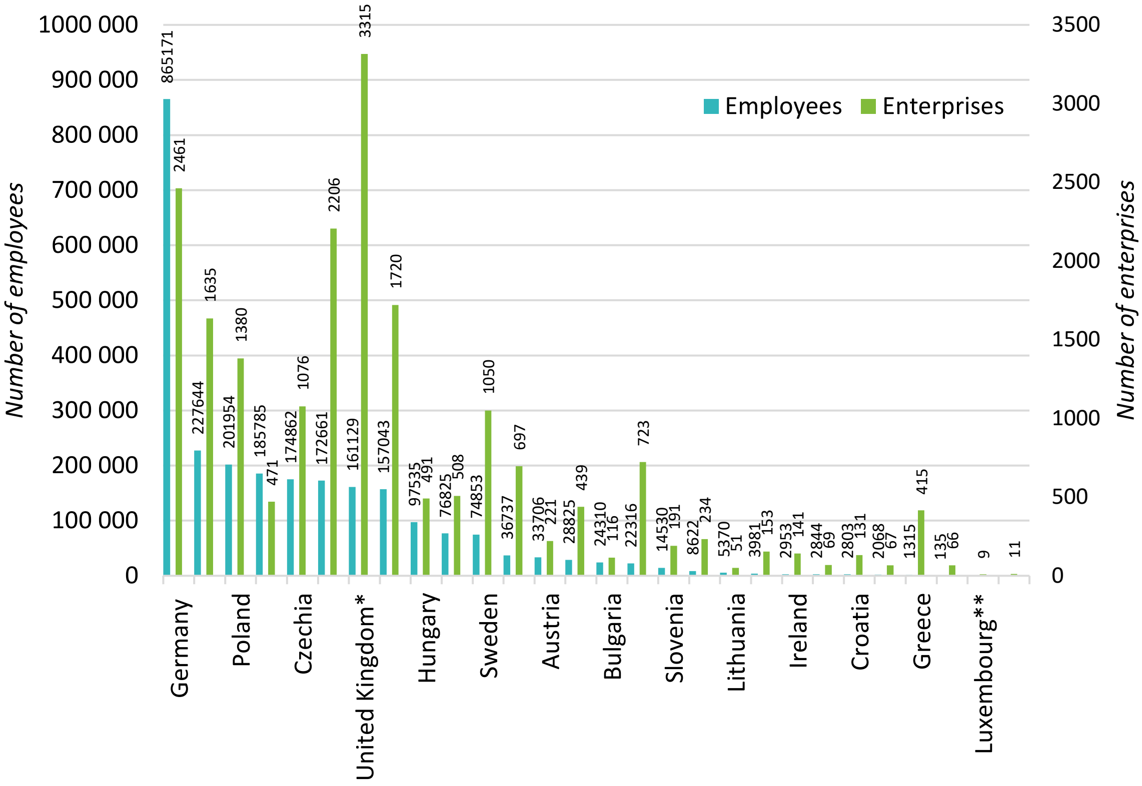

Figure 4: Number of Employees and enterprises in the automotive sector by Member State of the EU-28 in 2017 (source: Eurostat data table sbs_na_ind_r2; * value only available for 2016; ** no value available).

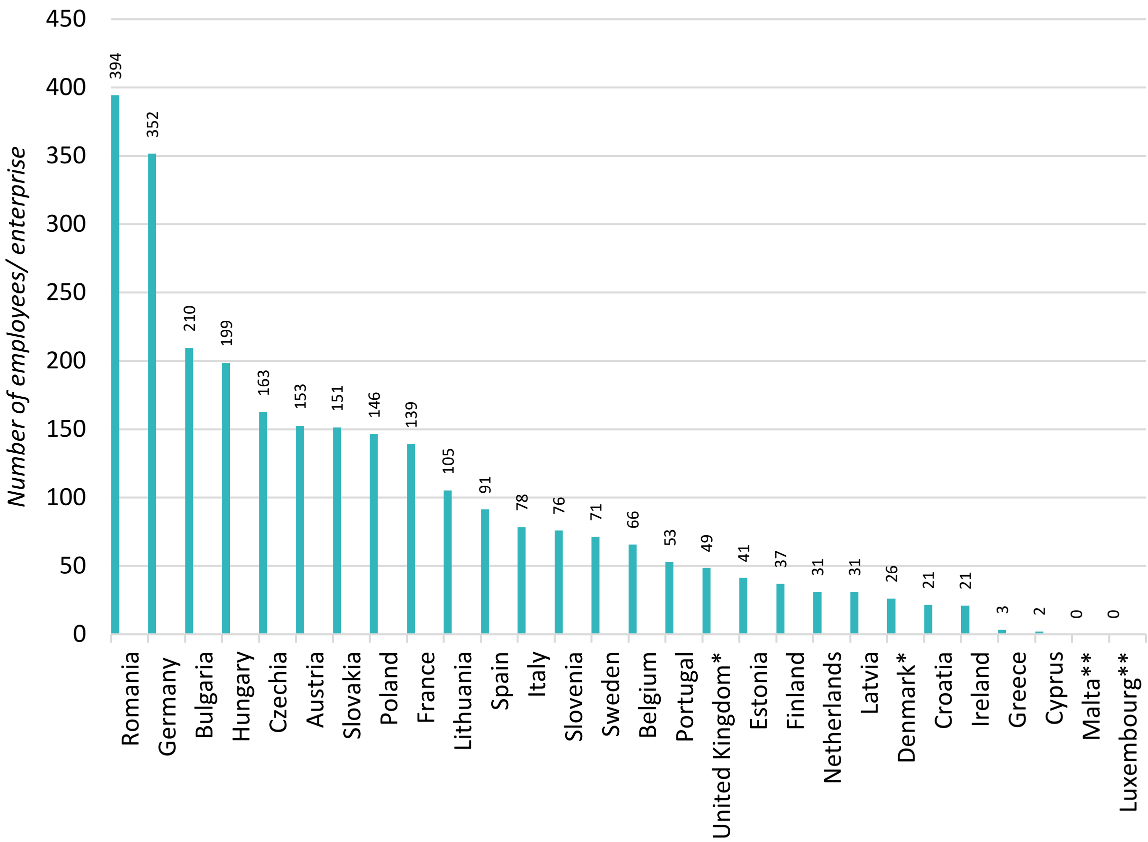

*Figure 5: Employees per enterprise in the automotive sector by Member State of the EU-28 in 2017 (source: Eurostat data table sbs_na_ind_r2; * value only available for 2016; ** no value available)*

Looking at the total motor vehicle production in the EU in the year 2018 (Table 9) Germany is the largest producer of the four focus countries followed by Spain, France and Italy. This includes the production of passenger cars (PC), light commercial vehicles (LCV), medium commercial vehicles (MCV) as well as heavy commercial vehicle (HCV). The diagram in Figure 6 visualizes the distribution of the different vehicle types amongst the EU production.

Table 9: Total motor vehicle production for 2018 including production of passenger cars (PC), light commercial vehicles (LCV), medium commercial vehicles (MCV) as well as heavy commercial vehicle (HCV) (ACEA, 2019)

	Total motor vehicle production in the EU 2018 [Mio]	Share of PC [%]	Share of LCV [%]	Share of MCV [%]	Share of HCV [%]
EU 28	19.2	86	11	1	2
Germany	5.6	91	6	0	2
Spain	2.9	77	22	0	1
France	2.3	75	22	1	2
Italy	1.0	65	31	3	1

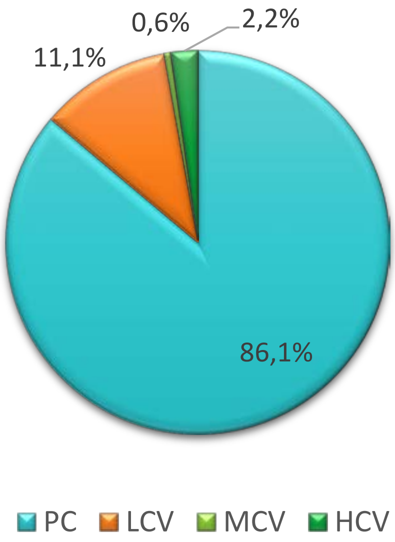

Figure 6: Share of different vehicles types on total motor vehicle production in the EU-28 including production of passenger cars (PC), light commercial vehicles (LCV), medium commercial vehicles (MCV) as well as heavy commercial vehicle (HCV) (ACEA, 2019)

4.3 Methodology for obtaining a benchmarking baseline

The provision of the benchmarking baseline focuses on the four "focus countries" with pilot companies in the E2DRIVER project, i.e. Germany, Italy, Spain and France. For the purpose of comparison, the analysis also includes data for the European Union (EU28) as a whole, where available.

The starting point for the analysis is identifying sources of information for establishing a benchmarking baseline and on measures to improve energy efficiency in the automotive sector. More specifically, the goal is a) to identify energy-related data on the EU automotive sector and more specifically the automotive supply industry that could be used to define a benchmarking baseline, b) to collect information about best practices to improve energy efficiency in the sector.

Various sources of information were scanned for this type of information. These include statistical offices, reports from academia and practice and public documents issued by private and public bodies including reports from former projects. The data found was reviewed and clustered in terms of information regarding energy efficiency benchmarks in the automotive industry.

The data sources for the energy benchmarking baseline and the energy efficiency measures can generally be structured as primary and secondary data sources:

- **Primary data sources** include the Eurostat database, which is a main source of statistical information for the European Union. The data provided by Eurostat is collected by individual Member States and transferred to the European statistical office. Eurostat covers a wide range of topics concerning all societal areas including energy, finance and economy. Specifically concerning the automotive industry, Eurostat offers data on general economic parameters like turnover and value added in the individual member states or in the EU in general for the industry (including OEMs, manufactures, assemblers and suppliers). Data on energy consumption of the automotive industry on member state level, however, is only available for the manufacture of transport equipment in general (including motor vehicles, ships, railway and airplanes). Furthermore, data availability is sometimes limited for confidentiality reasons.

- **Secondary data sources** include reports. There are three groups of reports relating to energy efficiency in the food and beverage sector. The first group includes reports published by industry associations (ACEA, CLEPA, etc.). The second group is reports provided by other interest groups and national and international authorities (EASC, etc.). Finally, the last group are reports from other national and international institutions (e. g. JRC, etc.).

There are several EU-wide and national associations representing the automotive industry and its specific subclasses. The umbrella association of the European automotive suppliers representing over 3.000 companies is CLEPA (European Association of Automotive suppliers).

Table 10 shows a summary of sources for benchmarking data. Each source was evaluated in terms of what kind of benchmarking data is covered. The goal is to provide a non-exhaustive overview of the available data. Especially the main official statistics and the most important reports only provide very general data of the automotive sector on energy benchmarking. General data describes key economic indicators for the automotive industry. NACE class means that the data covers the automotive industry on the level NACE rev.2 code C29. Finally, it is also evaluated if energy-related data or information about best practices is given.

Table 10: Description of the data availability in specific sources (selection of most relevant documents) (own compilation)

Source	Category	Topic/Content	Focus and categories covered			
			General	NACE Class	Energy-related data	Best practices
Eurostat	Official statistics	Structural Business Statistics & Energy Statistics	X	X	X	
OICA	Official statistics	International Organization of Motor Vehicle Manufacturers: Production statistics	X			
ACEA (2019)	Report	Pocket Guide of data and trends in the EU automobile industry	X	X	X	
EASC (2016)	Report	European skills council to address the automotive sector changes	X	X	X	
Lawrence Berkeley National Laboratory (2008)	Report	Energy Efficiency Improvement and Cost Saving Opportunities for the Vehicle Assembly Industry (U.S.)	X		X	X
Natural Resources Canada (2005)	Report	Best practice benchmarking in energy efficiency: Canadian automotive parts industry	X		X	X
JRC (2017)	Report	Best Environmental Management Practice in the Car Manufacturing Sector	X			X

4.4 Limitations of the benchmarking analysis

With regard to KPIs as energy benchmarking baselines, unfortunately it can be observed that for the automotive sector and in particular the automotive supply industry, only scarce data is available. This limits the possibility for obtaining a substantive benchmarking of the automotive (supply) industry - especially on country level - and is described in the following. Given these circumstances, the automotive sector will be assessed in terms of energy on a general basis by means of the data available.

4.4.1 Limitations due to data availability

While there is EU and also country specific structural annual business data of employment, productivity or profitability available for the manufacturing of motor vehicles (for example in the Eurostat database), there is no specific energy data publicly available for this sector. In the energy statistics of Eurostat, the only available country specific data refers to final energy consumption of the manufacture of transport equipment. Since this includes motor vehicles, as well as the manufacture of ships, railway and airplanes it is not suited to solely benchmark the automotive industry.

Consultations with sector experts from the European Association of Automotive Suppliers (CLEPA) have shown that specific energy-data for the automotive supply industry is at least not publicly available. This particularly makes sense when taking into account that the automotive suppliers are often SMEs where, as pointed out in the previous sections, energy audits are not mandatory. Moreover, due to the high competition in the supply chain, energy consumption data are often treated confidentially by the companies.

4.4.2 Limitations due to aggregation level of data

Concerning the aggregation level of existing data for the automotive sector it has to be mentioned that most of this data covers the whole automotive industry including manufactures, assemblers, suppliers as well as SMEs and non-SMEs. As a consequence, the benchmarking will be conducted on a more aggregated level including the whole automotive sector, although the focus target group of E2DRIVER will be Tier 1 and Tier 2 suppliers.

Nevertheless it has to be stated that the automotive suppliers, which consume about 88-92 % of the total energy required in the manufacturing process, dominate the energy consumption of the whole sector while assemblers are less energy intensive (G. Azevedo, Govindan, Carvalho, & Cruz-Machado, 2013). Hence, the benchmarking activities and data acquisition within the E2DRIVER project also tend to gain specific energy-data of the automotive supply industry to identify needs, requirements and motivation in this sector that could foster energy audits and the successful implementation of energy efficiency measures in the incorporated pilot companies.

4.5 Typical energy consumption patterns

In this section, the energy consumption in the automotive sector is further analysed with focus on the training material of the sub-sectors and processes influencing the most the final energy intensity of the product.

4.5.1 Energy consumed per manufactured car

Considering the latest data provided by the European Automobile Manufacturers' Association (ACEA) it can be seen that car manufacturers steadily reduced the environmental impact of manufacturing over the last decade, even though the number of cars produced increased.

As the complexity of vehicle production has increased with the increasing demand for safer, cleaner and smarter cars, this also affects the energy demand during the production. Nevertheless, the energy consumption per car produced has been decreased by 16.9 % since 2005 (Figure 7) showing that the automotive industry continuously is working to improve the energy efficiency of the production (ACEA, 2019). The reported value of 2.3 MWh of energy consumed per car produced in 2018 is in line with the values published by Oh et al. in 2014 (Oh & Hildreth, 2014).[41] However, if a complex supply chain is included in the contribution, the total energy consumption related to the car manufacturing industry will be considerably greater: Energy intensive processes of the supply chain are for example the production of raw materials, such as steel, aluminium, plastics, and glass; forming and fabrication of parts, components, and subsystems; assembly of hundreds of these elements to manufacture the vehicles; and distribution and sale of the vehicles (Oh & Hildreth, 2014).

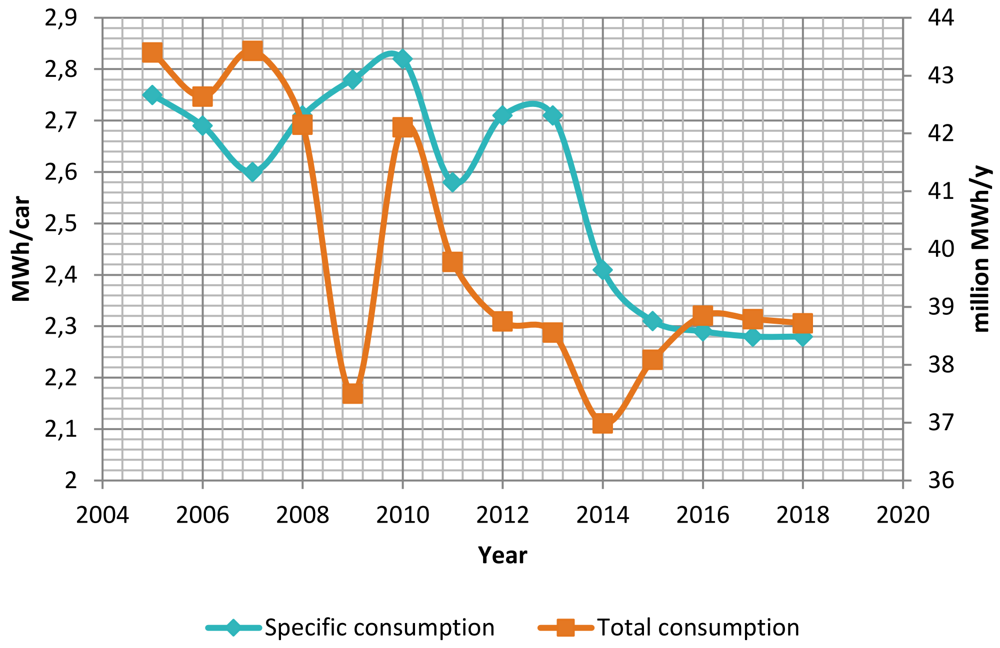

Figure 7: Energy consumption during car production in automotive industry (ACEA, 2019)

The same trend can be seen in Figure 2 in section 2.1 for CO_2 emissions which dropped by 34.7 % between 2005 and 2018, while the overall CO_2 emissions in total went down by 29.9 %. This reflects the industry's efforts to decouple CO_2 emissions from production growth by increasingly sourcing from renewable and/ or low-carbon sources (ACEA, 2019).

4.5.2 Energy consumption in the EU28 and the focus countries

Based on the ACEA data for energy consumption per manufactured car and the number of produced motor vehicles per country the total final energy consumption of the vehicle production can be

[41] 2.21 – 2.45 MWh/ vehicle manufactured (electricity + fuel) among major car companies

specified on country level for 2018. This is shown in Figure 8 for the EU-28 and the four focus countries. Germany as the largest car producer accordingly has the highest energy consumption. It is important to note, that such a country specific allocation of final energy consumption is difficult to assess: the country specific data is of low reliability because it does not take into account that some parts of the produced vehicles in a specific country are coming from other and even non-EU countries.

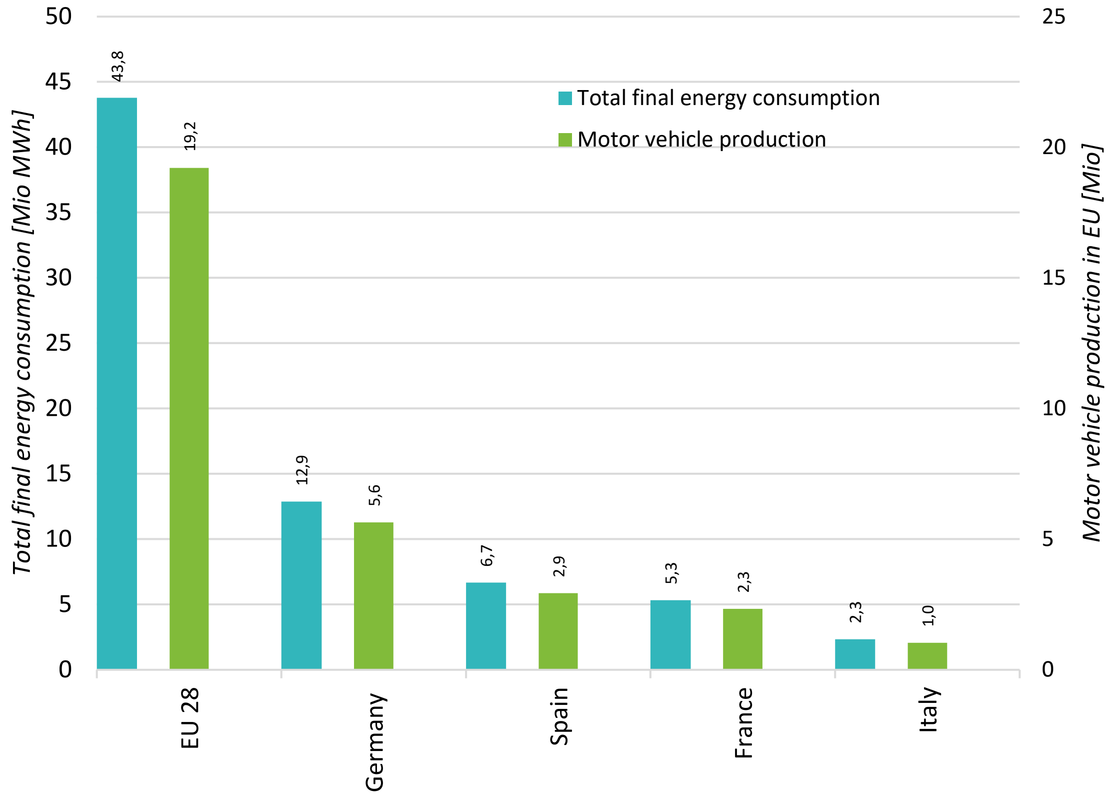

Figure 8: Total final energy consumption of the vehicle production for the EU-28 and the four focus countries

The analysis results in a total final energy consumption of the motor vehicle production in the EU-28 of about 43.8 Mio MWh[42]. This value seems reasonable when comparing it to the evaluated EUROSTAT data for the whole manufacturing of transport equipment (NACE C29 & C30, including motor vehicles, ships, airplanes and railway) as shown in Figure 9. Figure 9 shows the final energy consumption of the transport equipment manufacturing by the different energy carriers for the EU-28 and the four focus countries in 2017. In comparison to the vehicle production's total final energy consumption with 43.8 Mio MWh the energy consumption of all transport equipment in the EU-28 accounts for ca. 101.1 Mio MWh.

[42] own calculation according to data from ACEA (ACEA, 2019)

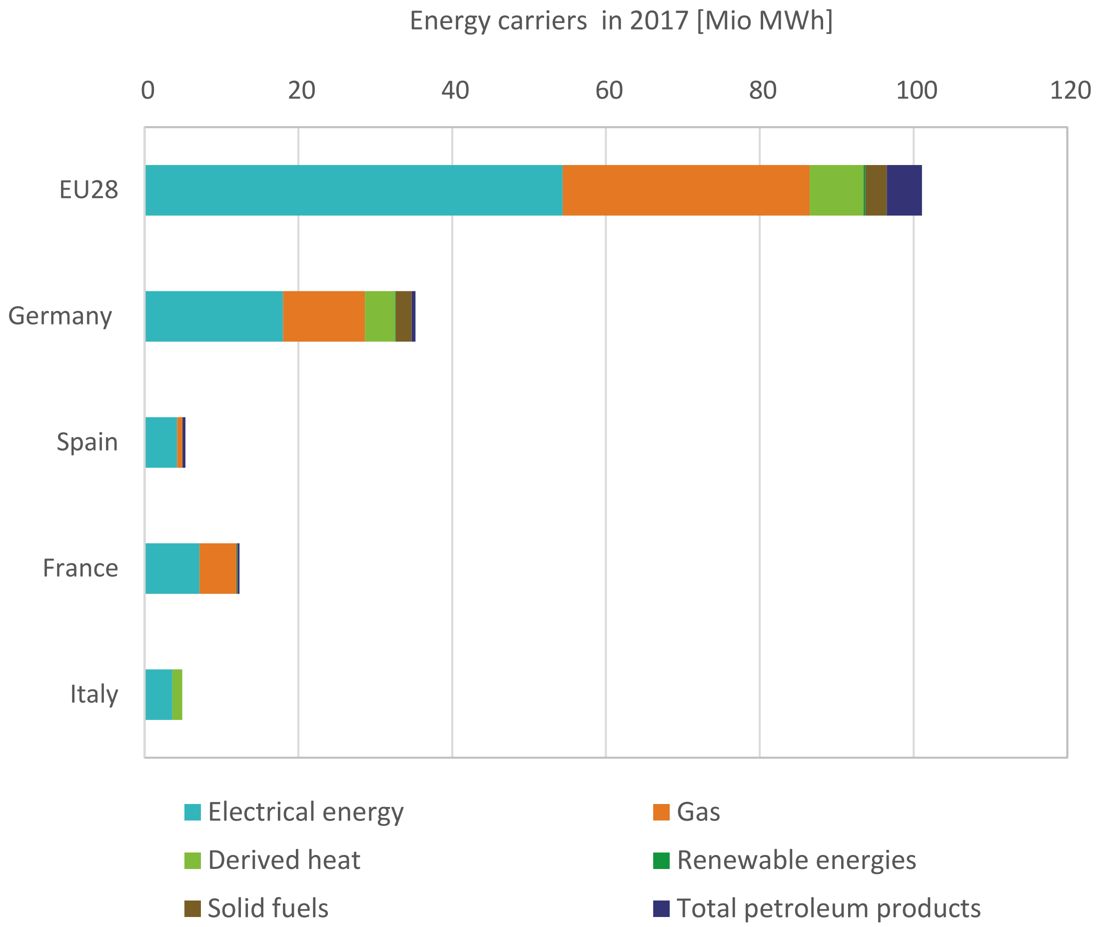

Figure 9: Final energy consumption of the transport equipment manufacturing (including motor vehicle, ship, airplane and railway manufacturing) by different energy-carriers for the EU-28 and the four focus countries

As it can be seen in Figure 9 on EU-level about half of the total final energy consumption of transport equipment manufacturing is electricity-based, while the other half consists predominantly of gas and also other energy carriers like derived heat, petroleum products and a tiny percentage of renewable energy.

Concerning a more specific energy use distribution solely for the car production only data of vehicle assembly plants[43] published by Berkeley National Laboratory in 2008 could be found (Galitsky & Worrell, 2008). Automobile assembly plants are the final step in the manufacturing of passenger vehicles and light trucks. Vehicles are assembled from components produced in, and transferred from, other plants, painted, and prepared for shipping. Assembly plants employ energy for many different end-uses ranging from space heating to steam production, compressed air, metal forming, lighting, ventilation, air conditioning, painting, materials handling and welding. According to Galitsky et al. assembly plants consume the most energy of all plant types within the motor vehicle sector, which includes casting, stamping, engine and transmission plants (Galitsky & Worrell, 2008). As shown in Figure 10 the predominant energy sources in assembly plant are fuels (mainly natural gas) and electricity.

[43] focus of the study were vehicle assembly plants in the U.S and Europe.; some of the plants also have other manufacturing facilities on site (e. g. stamping plant, engine plant, body plant).

While fuels typically account for two-third of total energy use, electricity accounts for about one-third (United States Environmental Protection Agency, 2015). This distribution of fuels and electricity is also in line with the numbers published in a study of Oh et al. (Oh & Hildreth, 2014) where the average electricity consumption per car is assumed to be 0.86 MWh/car which makes up 37 % in comparison to the total energy consumption (electricity and fuels) of 2.3 MWh/car published by ACEA. A bench-marking study of the Canadian automotive parts industry[44] provides a slightly different distribution of energy carriers for the year 2003 with about 47% electricity use and 45% use of natural gas (8% other) (Norup & Taylor, 2005).

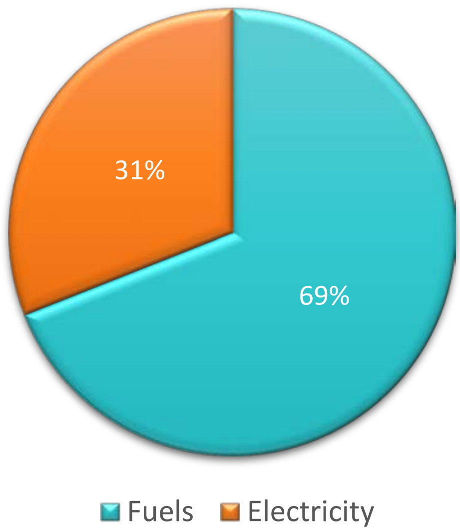

Figure 10: Typical total energy use distribution in automobile assembly plants (United States Environmental Protection Agency, 2015)

4.5.3 Share of different processes on energy consumption

Because of the diversity of manufacturing processes found in the automotive sector, there are many processes that are the major energy consumers. Data of the typical electricity end-use distribution in vehicle assembly plants can be for example found in a study published by Berkeley National Laboratory in 2008 (Galitsky & Worrell, 2008) in the scope of the EPA Energy Star program and is shown in Table 11. Nevertheless, estimates of the distribution of energy use in vehicle assembly plants are rare and may vary among plants based on the processes used in the facility. Also, not many plants have separate metering of energy use at different locations and processes in the plants.

According to the study around 70% of all electricity is used in motors to drive the different pieces of equipment in the plant, underlining the importance of motor system optimization in energy efficiency improvement strategies. Fuel is mainly consumed for space heating and for drying and conditioning the air in the painting line (although IR drying may have partially replaced it). According to Leven and Weber in Germany, paint shops use 50 to 60% of the fuel in the plants (Leven and Weber, 2001).

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[44] Including air-conditioning systems, fuel tanks and filters, exhaust systems, wheels, airbags, automobile body parts and other auto parts.

Some plants have engine and stamping plants onsite, and so may use extra electricity for machining metal. Besides the assembly large amounts of energy may be used in the manufacture of automotive (or other vehicle) parts and should be also part of a comprehensive energy efficiency strategy for a vehicle maker.

Table 11: Distribution of electricity use in vehicle assembly plants (Galitsky & Worrell, 2008).

Use/ Process	Share of electricity use (%)
Paint Booths	30-50
HVAC	11-20
Lighting	15
Compressed Air	9-14
Welding	9-10
Material handling/ tools	7-8
Metal forming	2-9
Miscellaneous/ other	4-5

4.5.4 Energy consumption per economic indicator

Based on the results of energy consumption per manufactures car and the total final energy consumption per country in section 4.5.1, three structural indicators have been selected from official Eurostat statistics to further analyze the energy consumption in the automotive industry[45]: The number of enterprises, the number of employees and the turnover (Table 12). These indicators are put in relation with information on energy consumption in the EU-28 and the four focus countries. Again, it is important to mention, that the country specific allocation of final energy consumption is of low reliability because it does not take into account that some parts of the produced vehicles in a specific country are coming from other and even non-EU countries. With regard to the structural economic data, values for the NACE division 29 "manufacture of motor vehicles, trailer and semi-trailers" is used in the calculation. Within the scope of the calculated values the limitations of the benchmarking analysis as described in section 4.4 have to be taken into account.

Table 12: Description of economic indicators

Definition of economic indicators	
Number of enterprises	"[…] a count of the number of enterprises active during at least a part of the reference period."
Number of employees	"[…] persons who work for an employer and who have a contract of employment and receive compensation […]."
Turnover	"[…] totals invoiced by the observation unit during the reference period, and this corresponds to market sales of goods or services supplied to third parties […]"

[45] Please note: The energy consumption per car as well as the production of motor vehicles is based on ACEA data from 2018, while the Eurostat data with the economic indicators is only available for 2017. Since the values were more or less stable between 2017 and 2018 there is no major error in doing so.

Figure 11 shows the specific energy consumption as compared to the number of enterprises in 2017. The average energy consumption per enterprise varies considerably between 1060 and 5230 MWh/enterprise, i.e. by a factor of about 5 between the extremes. According to the analysis, demand by enterprise is highest in Germany (5230 MWh/enterprise), followed by Spain (3880 MWh/enterprise) and France (3260 MWh/enterprise). The lowest specific value is calculated for Italy (1060 MWh/enterprise). A possible explanation for the high energy consumption per enterprise in Germany might be the larger company sizes as depicted in Figure 5.

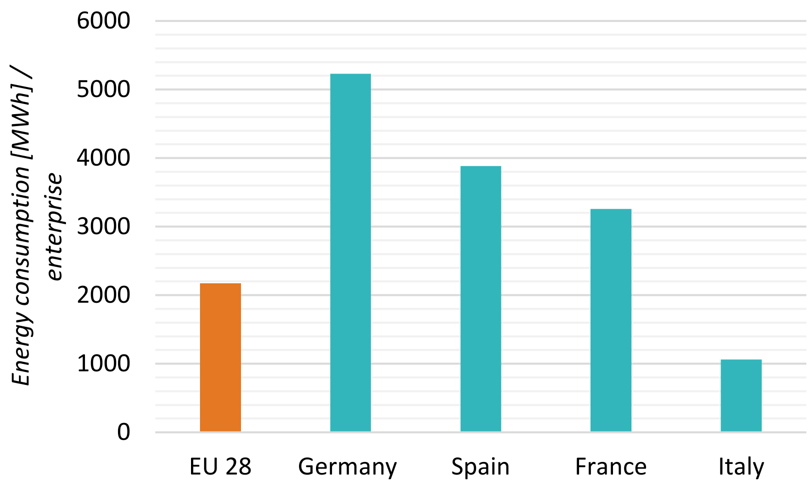

Figure 11: Energy consumption [MWh] per enterprise in the automotive sector in 2017

In Figure 12 the specific energy consumption per employee in 2017 is depicted. The weighted European average energy consumption per employee corresponds to 17 MWh/employee. Again, there is a considerable variation across the different countries. Seven countries surpass this average. Both Spain (43 MWh/employee) and France (23 MWh/employee) have comparatively high values whereas Germany (15 MWh/employee) and Italy (14 MWh/employee) show the lowest overall consumption per employee. As compared to the number of enterprises, the overall spread across the countries is slightly smaller: It has a factor of about 3 between the extremes.

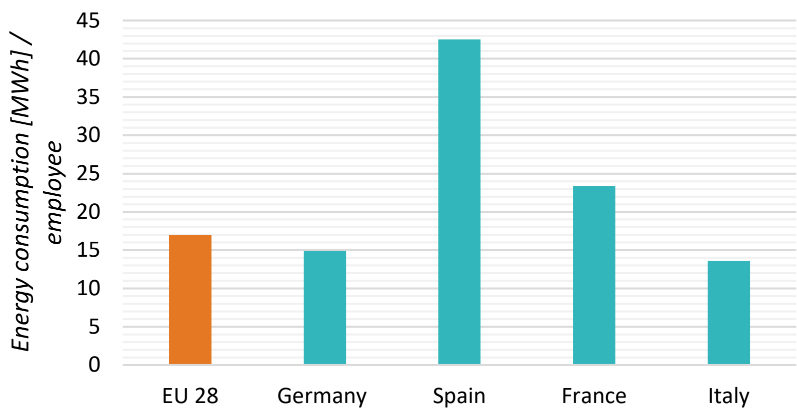

Figure 12: Energy consumption [MWh] per employee in the automotive sector in 2017

The comparison of all the European countries for the next indicator, energy consumption per turnover, is shown in Figure 13. The spread for energy consumption/ turnover is in the same range as for employees with a factor of 3.5. The weighted European average lies at 40 MWh/Mio EUR.

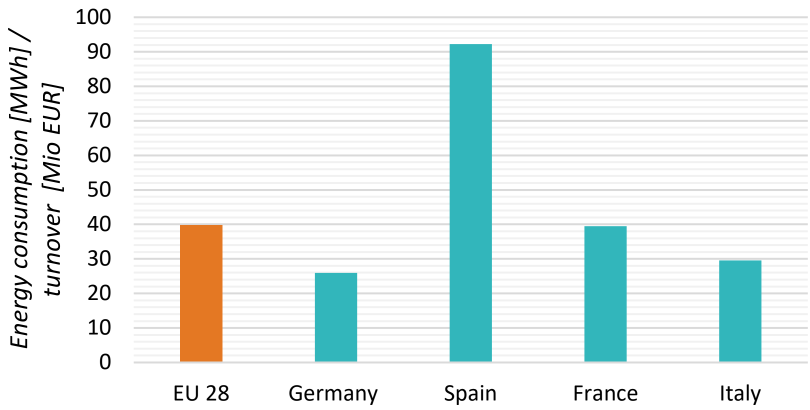

Figure 13: Energy consumption [MWh] per turnover [Mio EUR] in the automotive sector in 2017

4.6 Best practices concerning energy efficiency measures in automotive sector

After discussing benchmarking data, this section of the report deals with an overview of energy efficiency measures in the automotive industry that can help to improve benchmarking performance by energy savings. Energy savings reflect the amount of saved energy due to replacing a standard technology (or process) with improved or best available technology (or processes).

There is a large number of various energy-efficiency measures that can contribute to achieve these savings. A review of energy efficiency measures was carried out to provide a broad overview of measures for the automotive industry (no claim for completeness)[46]. In the following, an overview on these measures is given. They are structured into three categories:

- **Technical cross-cutting energy efficiency measures** are those that are usually found in many industries. They are thus usually relevant for different sector and branches of the food industry.
- **Organizational energy efficiency measures** are similar to technical cross-cutting measures, yet the focus on organizational aspects and not on technical aspects.
- **Process-specific energy efficiency measures**, on the contrary, are those that are only found in particular processes that are specific to the automotive industry.

Using synergies with other EU projects the technical cross-cutting as well as the organizational energy efficiency measures are adopted again from the INDUCE project. With regard to the empirical basis of this assessment, additional information might become available with the roll-out of the E2DRIVER training platform later in the project. This could be contrasted with these results

[46] Based on multiple sources, the most relevant sources are mentioned in Table 10

4.6.1 Technical cross-cutting energy efficiency measures

Table 1 in annexes provides an overview of cross-cutting measures that are relevant for many companies within but also beyond the automotive industry. These measures relate to typical building technologies such as the envelope, the heating system, lighting, ventilation and information and communication technology (ICT), but they also relate to support processes such as the generation of compressed air, the utilization of electric motors, the use of pumps, process heating and cooling and the power supply. Furthermore, they also include logistics.

These cross-cutting measures are mainly technological measures, i.e. they tend to be focusing on changing technologies and systems within the company.

4.6.2 Process-specific energy efficiency measures

Next to technology-oriented measures, there are various managerial measures that relate to the technological system of a company, but that are mainly aiming at changing awareness and behaviour in a company. An overview of these measures is given in table 2 in annexes.

4.6.3 Organizational energy efficiency measures

Finally, there is a group of sector-specific energy-efficiency measures (table 3 in annexes). These measures typically apply specifically to the automotive industry, though there is sometimes no clear disambiguation from cross-cutting measures. Therefore, the list given here is to be considered as a set of selected measures taken from literature as listed in Table 10. Depending on the specific plant configuration or processes, various similar and/or additional measures may apply. On the basis of the existing data for vehicle assembly plants (Galitsky & Worrell, 2008) energy efficiency measures are categorized by processes like painting, welding and stamping.

5 CONCLUSIONS

At the current situation at the European level it seems that there is not a deep characterization of the automotive supply chain regarding the structure and the specific energy consumption of each involved activity. This could derive from the strong degree of fragmentation of small and medium enterprises enrolled which may not specifically work just in this sector but be involved into further production chains. Given such considerations, it is difficult to define the working network supporting vehicle industry because most of activities are decentralized from main establishments to a wide number of SMEs that could be reluctant to make their data public and look towards proper privacy policy. Automotive market competitiveness increase integrating smaller suppliers to first tier suppliers so they can increase the final value delivered to OEMs, i.e. increasing relationships among suppliers (Research Triangle Institute, 1999), but it is further complicating supply chain structure. The lack of data regarding small and medium enterprises role within automotive industry doesn't simplify the characterization of a sectorial and detailed supply chain, so currently these ones are considered as companies providing products and services to a large number of different markets but whose each specific weight is difficult to assess. As result, from the point of view of existing capacity building programmes, several actions had been planned in terms of training in order to increase general competences of SMEs regarding proper energy usage, but it seems that nothing specific had been done for automotive sector processes.

The aim of Subtask T2.1B of this deliverable as a documentation to work package 2.1 of the E2DRIVER project was to investigate on the energy consumption in the automotive sector and if possibly in the automotive supply industry for the four focus countries (Germany, Spain, France and Italy). By trying to develop a benchmarking baseline and to review measures which contribute to improving energy efficiency the potential impacts leveraged by E2DRIVER should be determined at the end of the project.

For this purpose, an interpretation of the energy baseline for the E2DRIVER project is given first, followed by a general overview of the automotive. A review of documents about available benchmarking data across the diverse sector shows that only aggregated data covering the whole automotive industry including manufactures, assemblers, suppliers as well as SMEs and non-SMEs is available. As a consequence, the benchmarking can only be conducted on a more aggregated level including the whole automotive sector, although the focus target group of E2DRIVER will be Tier 1 and Tier 2 suppliers.

Based on this observation, a general assumption of energy consumption of the automotive sector was made using statistical data from Eurostat and data from automotive associations like ACEA. The analysis of different KPIs by region that could be derived from available statistics indicates the difficulties to set up generally applicable baselines as the variation of the data across countries is considerable. These values could serve as a general proxy based on "best-available overarching data" that allows to start better understanding the performance of companies. Yet given the high volatility in data and the multitude of processes in the automotive supply chain this comparison should only be considered as a complementary approach next to other evaluation elements to understand the impact of the E2DRIVER project or as a starting point for further analyses. This observation also stresses the need to gain more specific energy-related data of the automotive supply industry as it is one aim of the E2DRIVER project to foster energy audits and the successful implementation of energy efficiency measures in the incorporated pilot companies.

Complementing the analysis of baselines, this report provides an overview of energy efficiency measures comprising measures in cross-cutting technologies, process-specific technologies and approaches that are focused on managerial aspects. The overview of the measures indicates that many measures are available in principle. Yet the relevance for individual companies depends on the specific situation of a company.

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7 ANNEXES

ANNEX 1: TECHNICAL CROSS-CUTTING MEASURES

Area	Measure
Building envelope	Insulation of roofs
	Replacement of old windows
	Improvements of wall insulation
	Insulation of basement ceiling
	Removal of thermal bridges
Building heating	Reduction of heating temperature
	Use of smart heating systems
	Use of solar-thermal energy
	Optimized heating systems
	Use of heat pumps for buildings
Lighting	Use of LEDs
	Ensure adequate lighting
	Managing lighting
	Use of natural lighting
Ventilation	Ventilation fan-speed control
	Energy-optimized ventilation design
	Heat recovery from ventilation system
Compressed air	Waste-heat recovery from air compressor
	Acquiring energy-efficient compressors
	Minimization of leakages
	Replacing low-efficiency compressor drives
	Utilization of modern control systems
	Optimized compressed-air system design
	Avoidance of excessive air pressure losses
	Regular filter replacement
	Energy-optimized compressed air treatment
Electric drives	Use of variable speed motors
	Utilization of efficient transmission systems
	Appropriate motor sizing
	Utilization of highly efficient motors
	Regular motor lubrication
	Energy-efficient motor repair
	Energy-aware rewinding strategies
ICT	Use of highly-efficient uninterruptible power supplies
	Switching off IT equipment
Logistics	Optimization of logistics
	Vehicle optimization

	Driver training
	Tyre optimization
	Consideration of alternate means of transport
Process cooling	Decreasing cooling demand
	Adjustment of cooling temperatures
Process heating	Recovery of heat from hot processes
	Generating electricity from waste heat of hot processes
	Proper insulation of steam and condensate return pipes
	Utilization of highly efficient steam generators
	Utilization of heat pumps
	Optimized steam systems
Pumps	Energy-optimised pump selection
	Use of pump control systems
	Regular pump maintenance
	Low-losses pipework
Electric power supply	Reduction of harmonics
	Optimization of transformers
	Optimization of power supply

ANNEX 2: SECTOR-SPECIFIC MEASURES

Area	Measure	Source
Painting Systems	Maintenance and controls	1)
	Minimize stabilization period	1)
	Reduce air flow in paint booths	1)
	Insulation	1)
	Heat recovery	1)
	Efficient ventilation system	1)
	Oven type	1)
	Infrared paint curing	1)
	UV paint curing	1)
	Microwave heating	1)
	Wet on wet paint	1)
	New paint—powders	1)
	New paint—powder slurry coats	1)
	New paint—others	1)
	Ultrafiltration/reverse osmosis for wastewater cleaning	1)
	Carbon filters and other volatile organic carbon (VOC) removers	1)
	High pressure water jet system	1)
Body Weld	Computer controls	1)
	High efficiency welding/inverter technology	1)
	Multi-welding units	1)
	Frequency modulated DC-welding machine	1)
	Hydroforming	1)
	Electric robots	1)
Stamping	Variable voltage controls	1)
	Air actuators	1)
Compressed Air Systems	Using end-use management technologies, including shut-off valves, to eliminate compressed-air waste and match delivery pressure to the requirement	2)
	matching system sizing and output control to the requirement	2)
Exhaust and Make-Up Air Systems	Air is filtered and re-circulated, and flow controls are used	2)
Lighting Systems	Non-incandescent or mercury vapour lighting technologies	2)

	automated on/off controls such as occupancy sensors and photocells.	2)
Fuel-Fired Equipment Fuel-fired	Controlling the combustion efficiency of fuel-fired equipment by means of oxygen trim controls	2)
Boiler Plant Systems	Controlling the combustion efficiency of boilers by means of oxygen trim controls	2)
Cooling Systems	Chilled water treatment to control surface fouling	2)
	Using control technologies to match chilled water volume and temperature to the plant requirement	2)
Vehicle design and supply chain management	Design for sustainability using Life Cycle Analysis (LCA)	3)
	Integrating environmental requirements into supply chain management	3)

1) (Galitsky & Worrell, 2008) 2) (Norup & Taylor, 2005) 3) (Gaudillat, Antonopoulos, Dri, Canfora, & Traverso, 2017)

ANNEX 3: ORGANISATIONAL MEASURES

Area	Measure
Management	Implementation of certified energy management system
	Active engagement with energy management
	Establishing a preventive maintenance program
	Realisation of energy audits
	Raising awareness among employees for energy-related issue
	Exploitation of energy benchmarks
	Visualization of energy key performance indicators
	Training and education of employees for energy-related issues
	Usage of exchange mechanisms
	Focusing on life cycle costing
	Use of sensor technology for energy savings