Industrial Energy Efficiency and Material Substitution in Carbon-Intensive Sectors

Including Financing, Training, and Co-Benefits Aspects of this Sector

Prepared for the thematic dialogue on industrial energy efficiency organized by the Technology Executive Committee on 29 March 2017, Bonn, Germany

About the Technology Executive Committee

The Technology Executive Committee (TEC) is the policy component of the Technology Mechanism, which was established by the Conference of the Parties in 2010 to facilitate the implementation of enhanced action on climate technology development and transfer. Along with the other component of the Technology Mechanism, the Climate Technology Centre and Network, the TEC is mandated to facilitate the effective implementation of the Technology Mechanism.

Background

In response to decision 1/CP.21 paragraph 109(c) and as per activity 6 of its workplan for 2016–2018, the TEC is to take forward the outcomes of the technical examination process (TEP), taking into account the policy options, and identify gaps and replicable best practices or enabling policy conditions. At TEC 13, the TEC agreed to continue its work in the areas of identified gaps, namely industrial energy efficiency and material substitution in carbon-intensive sectors, including financing, training and co-benefit aspects of these sectors. It further requested the task force on mitigation to prepare this technical paper and to hold a thematic dialogue at its first meeting in 2017.

This technical paper provides the context and current state of play of measures in the field of industrial energy efficiency, providing an accurate, objective, and up-to-date picture and assessment of the current situation. The paper identifies the various dimensions of, and major themes and issues surrounding industrial energy efficiency and its policies with a global perspective, as well as areas for further consideration for the TEC.

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Executive Summary

Energy is needed in industry for a number of technologies and processes, including cross-cutting technologies such as steam, motors, compressed air, pumps, heating and cooling, as well as specific processes in energy-intensive sectors (Chemicals, Iron and Steel, Cement, Pulp and Paper, Non-Ferrous Metals, and Food). Greenhouse gas emission reductions in industry can be achieved in different ways. One option is to reduce the energy consumption of processes and technologies by implementing specific EE measures and state-of-the-art energy management systems, or by generating energy reusing industrial by-products. Besides investing in energy efficiency measures, CO_2 emissions can also be reduced substantially through increased material efficiency. This includes various options such as fuel substitution as well as the substitution and reuse of production materials.

Despite the great energy and cost saving potential, there are a number of barriers that often impede the implementation of EE measures. They include particularly the lack of financing and the lack of awareness, technical knowledge and personnel resources. In order to overcome these barriers and to support the adoption of EE measures, there are different policy options. They can be classified as economic instruments, information and education, institutional creation and strategic planning, regulatory instruments, research, development and deployment, and voluntary approaches.

This paper finds that international organizations that are active in the field of EE in industry tend to be focused on the introduction of energy management systems and accompanying training measures and are mostly motivated by competitiveness improvements and environmental benefits that come along with gains in energy efficiency.

On a national level, financing instruments, institutional creation and strategic planning seem to play a more important role. Besides energy and cost saving considerations, many countries highlight the target of creating employment and securing energy supply in the country.

However, from the case studies it becomes clear that generally a mixture of different and aligned policy instruments is used, embedded in an overall long-term EE strategy and a regulatory framework. This is identified as key to successful EE policies in industry. Moreover, policy makers should consider the relevant barriers as well as targeted co-benefits when designing policies. Both influence the selection of policy options, as different policies are suited for different needs. For example, the lack of financial resources can be addressed through financial or fiscal incentives; lack of awareness or knowledge can be addressed through information campaigns, labelling schemes, access to guidance, tools and resources, and training measures, whereas a lack of motivation or low priority of EE should rather be tackled with a mix of demonstration of business value and mandatory instruments, such as minimum performance standards, or audit and monitoring obligations. Voluntary approaches can complement an effective bunch of policies.

Other recommendations include continuing to use policies that have proven successful, such as the promotion of energy management systems or financial support, to exploit locally available energy and resources, including industrial by-products, to involve technology and knowledge transfer to developing countries, and to coordinate national and regional policies.

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List of Abbreviations

AEEE	Alliance for an Energy Efficient Economy
AHK	Auslandshandelskammer (German Chamber of Commerce)
AMO	Advanced Manufacturing Office
ANME	Agence Nationale pour la Maîtrise de l'Energie (Tunisian National Agency for Energy Management)
ARPA-E	Advanced Research Projects Agency-Energy
BAFA	Bundesamt für Wirtschaft und Ausfuhrkontrolle (German Federal Office of Economics and Export Control)
BEE	Bureau of Energy Efficiency
BINGO	Business and Industry Non-Governmental Organization
BMUB	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety)
BMWi	Bundesministerium für Wirtschaft und Energie (German Federal Ministry for Economic Affairs and Energy)
CAC	Compressed Air Challenge
CEEW	Council on Energy, Environment and Water
CFL	Compact Fluorescent Lamp
CONUEE	Comisión Nacional para el Uso Eficiente de la Energía (Mexican Agency for Energy Efficiency)
COP	Conference of the Parties
DISCOM	Distribution Company
US DOE	US Department of Energy
DPR	Detailed Project Report
DRI	Direct Reduced Iron
DSM	Demand Side Management
EC Act	Energy Conservation Act
EE	Energy Efficiency
EED	Energy Efficiency Directive
EEFP	Energy Efficiency Financing Platform
EIA	United States Energy Information Administration
EJ	Exajoule
EMS	(Technical) Energy Management System
EnMS	(Organizational) Energy Management System
ENGO	Environmental Non-Governmental Organization
EPA	(United States) Environmental Protection Agency
EPI	Energy Performance Indicators
ESCerts	Energy Savings Certificates

ESCO	Energy Service Company
EU	European Union
FEEED	Framework for Energy Efficient Economic Development
FEMP	The Federal Energy Management Program
FIDE	Fideicomiso para el Ahorro de Energía Eléctrica (Mexican Foundation for Electrical Energy Saving)
FNME	Fonds National de Maîtrise de l'Energie (Tunisian National Fund for Energy Savings)
FYP	Five-Year Plan
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ) GmbH (German Technical Development Agency)
HLS	High Level Structure
HRD	Human Resource Development
IAC	Industrial Assessment Centers
IAF	International Accreditation Forum
IEA	International Energy Agency
IGO	International Governmental Organizations
ILO	International Labour Organization
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
KfW	Kreditanstalt für Wiederaufbau
kWh	Kilowatt Hour
LASE	Ley para el Aprovechamiento Sustentable de la Energía (Mexican Law for Sustainable Use of Energy)
LBNL	Lawrence Berkeley National Laboratory
LED	Light-Emitting Diode
Mcf	Thousand Cubic Feet
MDM	Motor Decisions Matter
MENA	Middle East and North Africa
MEPS	Minimum Energy Performance Standard
MTEE	Market Transformation for Energy Efficiency
Mtoe	Million tons of oil equivalent
MWth	Megawatt-thermal
NAPCC	National Action Plan on Climate Change
NDRC	National Development and Reform Commission
NEEAP	National Energy Efficiency Action Plans
NEMA	North American National Electrical Manufacturers Association
NGO	Non-Governmental Organization
NMEEE	National Mission for Enhanced Energy Efficiency

OECD	Organization for Economic Cooperation and Development
PAESE	Programa de Ahorro de Energía del Sector Eléctrico (Mexican Program for Energy Savings in the Electricity Sector)
PAT	Perform Achieve and Trade Scheme
PDCA	Plan-Do-Check-Act
PRONASGen	Programa Nacional para Sistemas de Gestión de la Energía (Mexican National Program for Energy Management)
PROSOL	Programme Solaire (Tunisian Solar Program)
RINGO	Research-oriented and Independent Non-Governmental Organization
SDA	State Designated Agency
SEC	Specific Energy Consumption
SECF	State Energy Conservation Fund
SENER	Secretaría de Energía (Mexican Ministry of Energy)
SMEs	Small and Medium-sized Enterprises
TBtu	Trillion British thermal units
TEC	Technology Executive Committee
TEM	Technical Expert Meeting
TEP	Technical Examination Process
TMIE	Ministère de l'Industrie, de l'Energie et des Petites et Moyennes Entreprises (Tunisian Ministry of Industry and Energy)
TOT	Training-of-Trainers
TRT	Top-pressure Recovery Turbine
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
US	United States
USD	US Dollars
VCFEE	Venture Capital Fund for Energy Efficiency
VSD	Variable Speed Drive

1 Introduction

This background paper provides the context and current state of play of measures in the field of industrial energy efficiency (EE). It is intended to assist the Technology Executive Committee (TEC) of the United Nations Framework Convention on Climate Change (UNFCCC) in its efforts to enhance technology development and transfer in this sector. The TEC is the policy component of the Technology Mechanism, established in 2010 to facilitate enhanced action on climate technology development and transfer.[1]

In 2016, an analysis of policy options of UNFCCC's technical examination process (TEP) on mitigation was prepared by the TEC task force on mitigation[2]. Industrial energy efficiency was identified as one major interest but with relatively little expertise so far in the implemented TEP policies. As a consequence of the analysis, the TEC decided to work on the specific area of industrial energy efficiency in the year 2017, specifically industrial EE measures, for instance programs to implement improved electricity generation technologies, industrial boilers, and other industry-specific technologies such as those for brickmaking and material substitution in carbon-intensive sectors. Deriving from the previous analysis, this paper also includes the aspects financing, training, and co-benefits with the aim to address main barriers and motivations for investments in industrial EE. Drawing on an analysis as well as outcomes of previous technical expert meetings (TEMs), the TEC agreed to hold a thematic dialogue on this very topic in 2017. This technical paper has been commissioned in advance to deepen the understanding of various means of industrial EE, its current state, and its potential as an instrument to improve the use of energy in industrial processes (UNFCCC 2016). It will thus serve as input for the thematic dialogue 2017.[3]

The paper is structured as follows: After a short introduction to energy use and emissions in industry with a description of the most energy-intensive sectors in Chapter 2, an overview of industrial EE measures and their current state is given in Chapter 3, including measures for cross-cutting technologies, sector-specific processes, energy generation technologies, and energy management systems. Different options of material substitution are discussed in Chapter 4. Chapter 5 addresses policy options to foster industrial EE, with a focus on financing, training and co-benefit aspects, including examples of implemented policies. In Chapter 6 a selection of international organizations and initiatives and an overview of their focus areas of industrial EE is given. Chapter 7 presents experiences and lessons learned with a selection of case studies from countries in different regions. Chapter 8 concludes with recommendations for international policy options to promote industrial EE.

[1] Read about the TEC's mandate, functions, modalities and rules of procedure: http://unfccc.int/ttclear/tec

[2] http://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/HOME_infobox_2/e85713f2234442878e12fd08215fd927/3c16466d1c4a4b3db5cf1dff1066ce6d.pdf

[3] http://unfccc.int/ttclear/events/2017_event1

2 Energy Consumption and Emissions in Industry

General Trends and Tendencies

The total global final energy consumption in 2014 amounted to 9,462 million tons of oil equivalent (Mtoe, normalized unit of energy expressing the amount of energy that can be generated by burning one million tons of crude oil). With a share of approximately 37%, the industrial sector consumes more energy than any other end-use sector (IEA 2016a). In developing and emerging economies the share can even be up to 50% (UNIDO n.d.). Most of the worldwide industrial energy consumption increase in 2013 was caused by China and India (62%). In those two countries energy consumption in industry grew by 3.6% in 2013 and in Africa by 3.3%, whereas industrial energy consumption declined in the Middle East by 1.9% and in Latin America by 0.1% (IEA 2016b).

Energy is needed in industry for a number of processes, such as production and assembly, steam and cogeneration, process heating and cooling, lighting, etc. Depending on economic and technological development, the composition of industries and other factors, the intensity and mix of fuels therefore differs across countries. According to the U.S. Energy Information Administration's (EIA) International Energy Outlook 2016 reference case, worldwide industrial sector energy consumption is assumed to increase on average by 1.2% per year between 2012 and 2040, where the average annual change in OECD countries is projected to be lower with around 0.5% and in non-OECD countries higher with around 1.5%. Nevertheless, in non-OECD countries the industry share of energy consumption is projected to decrease from 64% in 2012 to 59% in 2040, as many emerging countries are likely to shift their economic activities away from the energy-intensive manufacturing industry to other end-use sectors where energy use is more rapidly increasing (EIA 2016a).

The worldwide industrial CO_2 emissions were 14.39 $GtCO_2$ in 2014, comprised of direct energy-related emissions, indirect emissions from electricity and heat production, process emissions and emissions from waste / wastewater, accounting for 44.4% of total global CO_2 emissions (IEA 2016c). In industry, energy efficiency potentials exist in cross-cutting technology systems, sector-specific processes, energy generation, and control systems for performance optimization (IPCC 2014).

Energy- and Carbon-Intensive Industrial Sectors

According to IPCC's Fifth Assessment Report, the major emitting industrial sectors are Chemicals (plastics, fertilizer and others), Iron and Steel, Cement, Pulp and Paper, Non-Ferrous Metals (aluminum and others), and Food Processing (IPCC 2014).

Chemicals: The largest energy-consuming industry sector is the basic chemicals industry with a share of 14-19% of the total delivered energy consumption in industry in 2012, for non-OECD and OECD countries respectively. Petrochemical feedstocks, such as ethylene, ammonia, adipic acid and caprolactam used in producing plastics, fertilizer, and synthetic fibers, account for around 60% of the energy consumption (EIA 2016).

Iron and Steel: Iron and Steel is the second largest energy consumer in industry. With nearly half of the world's steel production, China is the world's biggest steel-producing country (49.6% in 2015), followed by EU-28 with 10.2%, Japan with 6.5%, India with 5.5% and the US with 4.9% (World Steel Association 2016). The energy intensity of the steel production varies across regions depending on the technology used. Due to the use of coal and coke, the conventional iron making process is the most emission-intensive part of steel production, accounting for 70-80% of the emissions (Global CCS Institute 2013).

Cement: As the demand for cement is correlated with the construction industry, an increase of building and infrastructure construction induces a rise in the cement industry's energy use (EIA 2016). CO_2 emissions in the cement sector are composed of emissions from fuel combustion for limestone, clay and sand heating (around 40%), of process emissions from the calcination reaction (around 50%), and of emissions arising from grinding and transport (around 10%) (IPCC 2014).

Pulp and Paper: The global demand for paper and variety of paper products is mainly driven by developing countries leading to a steadily growing worldwide paper production (IPCC 2014). Although the paper producing process is very energy-intensive, nearly half of the needed electricity is provided through co-generation in paper mills with wood waste products (EIA 2016).

Non-Ferrous Metals: The production of non-ferrous metals, primarily aluminum, is very energy-intensive because of a high electricity demand. More than 80% of total greenhouse gas (GHG) emissions in aluminum production are indirect electricity-related emissions (IPCC 2014). Aluminum can be produced from raw materials or recycling, where the latter one can save up to 95% of energy needed for primary aluminum production (International Aluminum Institute 2016). China currently produces more aluminum than any other country in the world, however, with recycling rates much lower (21% in 2012) than in the US (57%) (EIA 2016).

Food: In food processing, most energy is used for drying, cooling, storage, and food and beverage processing purposes (FAO 2012). Due to a growing world population the demand for food keeps rising, making the food industry one of the major GHG emitting industry sectors. However, the demand for food and hence energy use and emissions could be drastically reduced by avoiding wasted food, which is estimated at around one third of the food produced.

Table 1 provides an overview of the energy-intensive sectors with respective energy consumption shares.

Table 1: Energy consumption shares of total industrial consumption by sector

Industry Sector	**Energy consumption (2012)**	
	OECD countries	non-OECD countries
Chemicals	19%	14%
Iron & Steel	10%	18%
Non-Metallic (primarily Cement)	5%	7%
Pulp & Paper	6%	1%
Non-Ferrous (primarily Aluminum)	2%	2%
Food	4%	2%
Rest	54%	56%

Source: EIA 2016c

Looking at the company structure in energy-intensive industries, large-scale production dominates the energy-intensive sectors on a global scale. In many developing economies, however, small and medium-sized enterprises (SMEs) play an important role in this context (IPCC 2014).

3 Overview of Industrial EE Measures

The industry sector offers great potential for energy saving measures. In this chapter, an overview of a number of energy efficiency measures in industry is provided. The measures are categorized under cross-cutting technologies, sector-specific processes, energy generation technologies and state-of-the-art energy management.

3.1 EE Measures for Cross-Cutting Technologies

A number of technologies can be commonly applied across different sectors, such as steam, motors, pumps, compressed air, heating, cooling, lighting etc. Those technologies are referred to as cross-cutting technologies or systems. Technology improvements are rather small but have a high impact on energy savings as they concern many sectors. Furthermore, through optimization of cross-cutting systems (like compressed air systems) and thus fitting of supply and demand, energy efficiency improvements can be substantial. Table 2 gives an overview of cross-cutting technologies and a selection of the most important energy efficiency measures for the respective technologies. Most important measures are defined as those with highest energy savings and a high level of application worldwide.

Table 2: Overview of cross-cutting technologies and most important EE measures

Technology	Relevant Sectors	Important EE Measures
Steam	Chemicals, Petroleum Refining, Pulp & Paper	▪ Increase boiler efficiency ▪ Employing operating & control techniques ▪ Minimizing blowdown from the boiler ▪ Optimizing steam distribution systems
Motor drives	All industry plants where electricity is available	▪ Use of energy-efficient motors ▪ Use of variable speed drives ▪ Motor repairs / rewinding
Pumps / Pumping systems	Agriculture, Chemicals, Food, Waste	▪ Pumping system control & regulation ▪ Improving pipework system ▪ Optimizing motors & transmission
Compressed air systems (CAS)	All sectors	▪ Assessing actual flow/pressure/quality needs ▪ Reducing compressed air system leaks ▪ Optimizing controls & supply to meet actual needs
Heating	Chemicals, Copper & Aluminum, Food, Glass & Ceramics, Iron & Steel, Pulp & Paper, Textiles	▪ Efficient load management ▪ Use of heat exchangers and heat pumps ▪ Heat recovery & CHP / CCP generation
Cooling	Chemicals, Copper & Aluminum, Food, Glass & Ceramics, Iron & Steel, Pulp & Paper, Textiles	▪ Employing chillers & cooling systems ▪ Improving parts of the compressor ▪ Evaporative cooling
System EE	All sectors	▪ Efficient matching of supply to demand

Source: own elaboration, based on dena 2013, Compressed Air Challenge & US DOE 2015

Steam

Steam is used in many industrial processes to provide process heating, pressure control, mechanical drive, and component separation. As it has many advantages, such as high heat capacity, easy transportability, low toxicity, and cost advantage, steam is a widely used and important means of energy transportation. However, this brings along a high use of energy in industry for its production. In order to reduce the energy demand for steam, there are several EE measures available. First of all, steam should only be used where it is needed and should therefore be replaced by hot water where possible. **Boiler efficiency** can be increased by installing more efficient burners or by changing the boiler itself, e.g. in case a change in steam demand can be met with a smaller boiler or fluctuating steam demand can be followed with two or more boilers working in parallel. By employing **operation and control techniques**, such as fuel regulating valves and fuel flow meters or combustion control systems, the amount of used fuel can be efficiently regulated (EERE 2012). During the water evaporation process, energy losses can be reduced by **minimizing boiler blowdown**. Water blowdown serves to remove sediments on the walls of boiler steam drum. Too little blowdown thus leads to a decreased energy transfer, while too much blowdown results in energy loss as the water temperature would be reduced. Automatic blowdown control systems regulate the water blowdown rate to the optimal point that usually lies between 4% and 8% of the boiler feed water flow rate (AMO 2012). In order to save energy when steam is transferred from the boiler to end uses, the steam **distribution systems can be optimized**. First and foremost, this refers to prevent leaking, maintain steam traps, and ensure proper thermal insulation of the piping. To regulate steam flow, valves can be used to isolate steam from a system branch or a component (gate, globe, and swing check valves) or to control the amount of steam (pressure reducing valves) (EERE 2012).

Motor drives

According to the Institute for Industrial Productivity (IIP), with 69% of the global industrial electricity consumption, motor systems are the major electricity consumer in industrial processes (IIP n.d.). Motors are used to drive pumps, fans, compressors and a large variety of other electric equipment and are used in basically every industry sector. Nevertheless, motor systems also bear a great energy saving potential (De Almeida et al. 2011). As a measure to save energy, **energy-efficient state-of-the-art motors** can be installed. The highest standards, IE3 / NEMA “Premium Efficiency” and IE4 / NEMA “Super Premium Efficiency”, represent a substantial upgrade in terms of efficiency, compared to IE1 / NEMA “Standard Efficiency” motors. The primary improvements are made in fixed-speed motors through rotor and stator construction and materials, gears and transmissions (Waide & Brunner 2011). However, the energy-saving potential is limited due to long lifetimes of already installed (conventional) electric motors (Piper 2009). Nevertheless, for smaller motors it is worthwhile to replace IE1 and IE2 with IE4 models even if the end of its life cycle has not yet been reached. For retrofitting purposes of large electric motors that have not reached end of life, the primary approach is **installing a variable speed drive (VSD)** rather than replacing an existing motor. Besides energy savings through reduced losses additional benefits of VSDs include improved process control and system reliability. Maintenance and repair procedures, like rewinding, can restore a motor nearly to its original efficiency. Note that maintenance restores the motor’s efficiency up to a certain point, but efficiency is nonetheless decreasing. Even large motors should thus be replaced when their efficiency has decreased significantly.

Pumps / Pumping systems

The field of possible pump and pumping system application is wide: Circulation pumps are implemented in closed systems, such as heating or air conditioning systems. In open systems, like in water supply and sewage disposal, feed pumps are employed. In order to save energy it is important to consider the whole system. A high amount of energy can be saved in pumping systems as they are often oversized. With the help of **pumping system control and regulation** the actual demand can be assessed and the pump output can be adjusted accordingly and overproduction can be reduced. **Controlling the pump’s output** according to actual demand leads to avoided energy losses compared to flow or bypass control (throttling). In a next step the **pipework system can be improved** by designing the pipework monitoring system, reviewing flow rates and optimizing piping configurations. Finally, the pumps themselves offer a great efficiency potential by **optimizing motors and transmission** through either pump speed control (by installing a VSD on the motor), refurbishing to lower constant speed (if oversized) or incorporating multiple-pump arrangements (Sustainability Victoria 2015).

Compressed air systems (CAS)

Compressed air is used in almost every plant in the manufacturing industry: in pneumatic systems, as a means of transport, for parts cleaning, and for generating industrial vacuums. Since supplying compressed air is highly energy-intensive, it should only be used where it cannot be replaced (e.g. by using electric drives). The equipment operated with compressed air determines the pressure level, the volume and quality (dryness, cleanliness) of compressed air needed. The first step to save energy is therefore to identify this equipment and assess its compressed air parameters. The other system components, such as processing (drying and filtering) and generation (compressors), can be **adjusted accordingly to the needed flow, pressure, and quality**. In order to **minimize leakage**, leaks should be tagged and fixed and a leak maintenance program should be established. In addition, through the implementation of automated control systems for compressed air valves, individual and not required parts of the network can be isolated to reduce leakage losses. Modern compressed air management systems can also be used to automatically detect leaks and alert maintenance. Once existing compressed air controls have been adjusted, additional efficiency gains may be achieved by optimizing management of multiple compressors **through installation of master controls and/or variable speed drive compressors**, s to follow actual facility demand for the optimal supply at minimal no-load losses.

Heating

Heating in industry refers to heating of industrial buildings on the one hand and process heat on the other hand. Regarding space heating, an efficient and demand-based heat supply as well as a **modernized building envelope** to minimize heat losses plays an important role. Process heat is needed for a number of different processes, such as sterilizing, drying, cooking, smelting, forging, welding and for the production of steam, and therefore account for a large charge of energy consumption in industry. Besides an **efficient load management**, possible measures to increase energy efficiency include the **use of heat exchangers** and the **use of heat pumps.** Moreover, systems to **recover unexploited industrial waste heat** (see Chapter 3.3) and the possibilities of **combined heat and power (CHP)** or **combined cooling and power (CCP)** should be used as effective measures to save energy.

Cooling

Cooling technology is an inherent part of many production processes. Process cooling for example plays an important role for industries where materials have to be heated first and the cooled. Cooling is also needed in the production of food. Various technologies are deployed and the cooling system sizes differ greatly. As for the other cross-cutting technologies the starting point for increasing energy efficiency is to identify the actual demand and optimize the system based on those findings. The common method of **chiller optimization** is employing a control system (like a fuzzy logic controller) in combination with optimizing the electrical motor through employing a VSD. Further measures include the **improvement of mechanical system parts of the compressor** to reduce friction losses. If local circumstances permit, direct cooling through well or stream water is the least energy-intensive option for industrial processes. For cooling towers, **evaporative cooling** is the least energy-intensive option. While it reduces energy demand, freshwater consumption is higher than with closed circuit options. The choice of the cooling tower is often determined by local circumstances like environmental regulations and parameters like freshwater supply (VDMA 2010, Umweltbundesamt 2012).

3.2 Sector-Specific EE Measures

A number of EE measures can only be applied in single sectors due to individual and sector-specific processes and technologies. Table 3 gives a selective overview of the specific EE measures that can be applied in the energy-intensive industry sectors described in Chapter 2.

Table 3: Overview of sector-specific EE measures

Sector	Specific EE Measures
Chemicals	▪ Upgrade steam cracking plants to best practice technology ▪ Upgrade all fertilizer production plants to best practice technology
Iron & Steel	▪ Improved Furnace designs ▪ Reduced number of temperature cycles ▪ Coke dry quenching ▪ Top pressure recovery turbines
Cement	▪ Multi-stage preheater systems ▪ Addition of pre-calciner to pre-heater kilns ▪ Dry systems with preheaters & pre-calciner ▪ Fluidized bed advanced kiln systems ▪ Fuel management ▪ High-efficiency mills & classifiers
Pulp & Paper	Use of: ▪ additives, increased dew point, & improved heat recovery for drying ▪ continuous digester, washing presses & pulping aids ▪ vacuum system optimization ▪ advanced dryer controls
Non-Ferrous Metals	New process development in aluminum production: ▪ Multipolar electrolysis cells, ▪ Inert anodes ▪ Carbo-thermic reactions
Food	▪ Technical dewatering compared to rotary drying ▪ Use of reverse osmosis to further enhance thermal & mechanical vapor recompression in evaporation ▪ Improved insulation & reduced ventilation in fridges & freezers

Source: own elaboration, based on IPCC 2014

3.3 Energy Generation Technologies to Increase EE

Energy can be generated during industrial processes as a by-product using waste heat, production gases or biomass. It can thus serve to increase energy-efficiency, as original energy consumption is reduced by the amount of energy that is generated or recovered during the industrial processes. Table 4 shows the energy generation technologies to increase EE and the sectors where they can be applied.

Table 4: Overview of energy generation technologies to increase EE and most important EE measures

Energy Generation Technology as a Measure to Increase EE	Relevant Sectors
Waste heat recovery	Chemicals, Cement, Iron & Steel, Non-Ferrous Metals, Pulp & Paper
Electrification of production gases	Iron & Steel
Use of biomass	Food, Pulp & Paper
Combined heat and power (CHP)	Chemicals, Copper & Aluminum, Food, Glass & Ceramics, Iron & Steel, Pulp & Paper, Textiles

Source: own elaboration

Waste heat recovery

In almost every thermal or mechanical industrial process heat losses occur – referred to as waste heat – ranging from process exhaust air or wastewater from manufacturing plants and motors, compressed air systems, cooling and air-conditioning systems. Heat losses can be reduced through optimal insulation and operation, but not be avoided completely. Waste heat that cannot be avoided can be recovered and used either directly or indirectly in several ways: for electricity generation, refrigeration, space and water heating, but also for external usage by feeding it into local or district heating grids.

The direct use of waste heat is often the easiest and most cost-efficient way. Recovered heat can be used again in the same process or the same plant. For that, heat exchangers are needed that transfer waste heat to a transport medium. Examples for the direct use are pre-heating of combustion air, materials or water, and drying of materials. If direct use is not possible, waste heat can also be used for other processes, space or water heating. With the help of heat pumps the temperature can be increased if it is not high enough. Another indirect use of waste heat is the conversion into electricity or cooling energy. For electricity generation, the choice between systems based on a steam cycle or an Organic Rankine Cycle (ORC) depends on the temperature and quantity of available waste heat. For converting heat into cooling energy, a refrigeration machine is needed (Grahl et al. 2014). For the use of waste heat the temperature level is crucial: high-grade heat can be reused for industrial processes or power generation, whereas low-grade waste heat would rather be used for (pre-)heating purposes (IEA 2016e). Since high temperature heat is more valuable than low temperature heat, waste heat should always be used on the highest possible temperature level. A pinch-point-analysis can help to identify the best process points to integrate surplus heat.

Electrification of production gases

Power generation with the help of production gases plays mainly a role in the iron and steel sector. In a blast furnace iron is melted and collects at the bottom. The hot gases leaving the blast furnace at the top maintain a pressure of around 2 to 3 bar. The pressured blast furnace gas can be used to drive a top-pressure recovery turbine (TRT) to generate electricity (IIP n.d.). Around one third of used energy can be recovered through this technology.

Use of biomass

Biomass is the most widely used renewable energy source in industry, whereas its availability and use are dependent on the region and sector (UNIDO 2010). It can be used to provide steam, heat and electricity. For industrial heat and energy generation, biomass is mainly used in the food and pulp & paper industry, from food waste like bark or black liquor. In 2012, almost 8 exajoules (EJ) were used worldwide in industry to provide low- and medium-temperature process heat (IEA n.d.).

High-temperature process heat can be generated through biomass gasification or through co-firing of biomass with coal. Power generation installations vary from biogas digesters to large-scale biomass gasification plants that gain in importance due to the rising demand for bioenergy electricity.

Combined heat and power (CHP)

Combined heat and power refers to electricity generation with the simultaneous use of available heat. This way, up to 90% of the energy content of fuels can be used. The waste heat generated during electricity production is used for process heating, space heating or water heating purposes. For an economic operation of a co-generation plant, a perennial heat demand is necessary that allows for a high runtime of at least 5,000 hours per year. In order to compensate for the fluctuations in heat demand, combined heat, power and cooling systems can be implemented that use waste heat for cooling applications during the summer months.

3.4 State-of-the-Art Energy Management

Against the backdrop of volatile global energy markets – and later as an effort to mitigate climate change – energy consumption, efficiency, optimization and security have all been issues that have gained recognition over last three or four decades. The set of strategies, approaches and activities to address them, particularly in the industrial and service sector, has been termed energy management. Over time, best practices have matured into national codes and standards in many industrialized countries. In 2007, the United Nations Industrial Development Organization (UNIDO) recognized the need and value of harmonizing them, while the International Organization for Standardization (ISO) had already identified energy management as one of the priority areas to be standardized. The work started in 2008 under the leadership of four ISO member countries, with the participation of 41 members and 14 members acting as observers. Drawing from existing national codes and standards, in 2011, the international energy management system (EnMS) specification ISO50001:2011 *Energy management systems – Requirements with guidance for use* was published, providing a framework of requirements.

Although an implementation of energy management system as specified in the standard is strongly based on qualitative data to drive its processes, the specification does not prescribe performance criteria. It rather

> *“specifies requirements for establishing, implementing, maintaining and improving an energy management system, whose purpose is to enable an organization to follow a systematic approach in achieving continual improvement of energy performance, including energy efficiency, energy use and consumption”* (ISO 2017a).

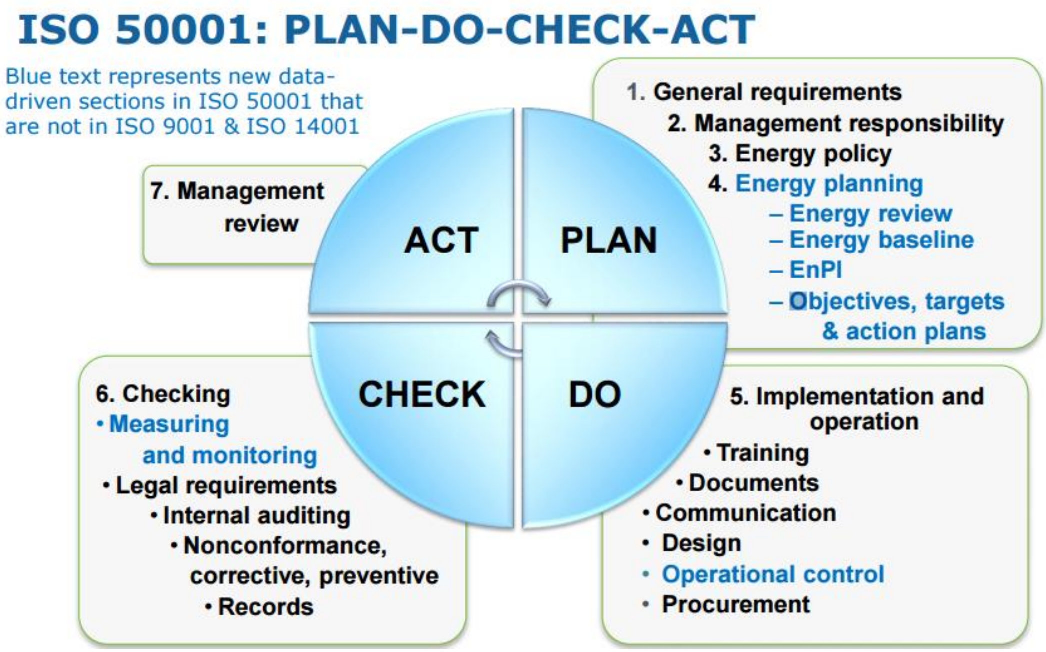
The management system framework of ISO 50001:2011 resembles those of ISO 9001 and ISO 14001. This simplifies its implementation and integration with those two standards for the organizations that have already implemented them. ISO 50001:2011 is a management system standard that is not specifically sector-oriented and can be adopted by SMEs as well as large enterprises (adelphi 2012). The framework of ISO 50001:2011 is as follows:

1. Scope
2. Normative references
3. Terms and definitions
4. Energy management system requirements
    - 4.1 General requirements
    - 4.2 Management responsibility
    - 4.3 Energy policy
    - 4.4 Energy planning

4.5 Implementation and operation
4.6 Checking
4.7 Management review

The last four requirements combined represent the four-phase Plan-Do-Check-Act (PDCA) cycle, which ensures a continuous improvement of energy management as practiced in an organization. The PDCA cycle is illustrated in Figure 1.

Figure 1: The seven main components of the ISO 50001:2011 PDCA cycle



Source: Clean Energy Ministerial, 2014

The first step for an organization that wants to implement an energy management system according to ISO 50001:2011 is to fulfill the requirements the standard specifies, i.e.

> *"requirements applicable to energy use and consumption, including measurement, documentation and reporting, design and procurement practices for equipment, systems, processes and personnel that contribute to energy performance"* (ISO 2017a).

Subsequently, an organization can choose to obtain a certification confirming that it meets the standards for energy management set by the ISO norm. Advantages of a certification include: (1) ensuring through an independent party that energy management is fully functional, (2) distinguishing the organization in front of their customers, partners and general public, (3) fulfilling legal requirements and/or (4) qualifying for incentives. The certification is valid for three years and usually consists of at least the following steps:

- Assessment of meeting the standard's formal requirements on implementing the required procedures, documentation, responsibilities etc.,
- Assessment of continual improvement of the EnMS and of energy performance,
- Elaboration of instructions for closing the gaps (if necessary) and recommendations for improvement,
- Review of the documentation provided by the organization, and

- Issuing of the certificate and communication.

Certification can be provided by one of the International Accreditation Forum (IAF) accredited bodies, guaranteeing that the certifier and the certification procedure adhere to the globally universal standards laid out by the IAF. The requirements concerning audits and subsequent certification of energy systems are specified in the standard ISO 50003:2014 (ISO 2017b).

ISO 50001:2011 principally remains a voluntary standard. Nonetheless, it has proven its value, and many governments have adopted it into their energy efficiency programs and strategies. Some countries demand large energy consumers to implement an EnMS according to ISO 50001:2011 (e.g. Kazakhstan), some have developed voluntary agreements with energy-intensive industrial sectors for the implementation (e.g. Sweden), or provide incentives in terms of subsidies or tax reliefs (e.g. Germany). In some countries technical assistance is provided in the form of training, tools, and workforce certification to support implementation and to recognize certification (e.g. the US).

In 2015, the most recent year for which data is available, 5,220 new certificates for ISO 50001:2011 were issued, which represents an increase of 77% compared to 2014. The certificates were issued mostly in Europe (84.7%) and East Asia and Pacific (8.6%). 20,562 individual sites have been covered by ISO 50001:2011 certificates in 82 countries. The top five industrial sectors for ISO 50001 certificates in 2015 were Metal, Food, Rubber and Plastics, Chemicals, and Electrical Equipment (ISO 2016). Figure 2 shows the worldwide dispersion of issued ISO 50001 certificates in 2014. Under an assumption of 50% uptake by the industrial and service sector, the Lawrence Berkeley National Laboratory (LBNL), estimates cumulative global impacts of ISO 50001 EnMS until 2030 to amount to primary energy savings of around 105 EJ and emission savings of around 6,8 $GtCO_2$ (LBNL 2016).

Figure 2: Worldwide issued ISO 50001 certificates in 2014

Argentina	14
Brazil	38
Cameroon	0
China	65
Egypt	15
India	443
Indonesia	28
Kazakhstan	35
Mexico	21
Mongolia	0
Myanmar	0
Nigeria	0
Peru	1
Russia	115
Serbia	14
South Africa	7
Sri Lanka	8
Tunisia	0
Turkey	136
UK	853
Ukraine	34
US	80
Uzbekistan	0
Venezuela	1
Vietnam	23

Source: IEA 2016d

The year 2019 should see a revised version of the ISO 50001 standard. ISO 50001:2019 is expected to completely harmonize its high level structure with other standards and further facilitate its integration with other management systems, to stress even more the importance of stakeholders, to demand a more hands-on engagement from the leadership, to emphasize risk identification and management, etc.

Technical Energy Management

Energy management systems (EMS) as in technical systems (software, hardware) support the organizational EnMS according to ISO 50001. EMS collect, analyze and communicate data as actionable information These technical systems are intended for collecting, storing, monitoring and analyzing parameters of complex energy systems in order to assist with energy management activities, including those carried out including those carried out as part of an EnMS. Based on experiences in Germany, through the introduction of EnMS and EMS and resulting non-investment-related measures energy savings of up to 10% and additionally through investment-related measures of up to 25% can be achieved (Barckhausen et al. 2015).

3.5 Current Situation of EE in Industry

According to the International Energy Agency (IEA), in 2015, EE investments in industry were estimated at USD 39 billion, of which only USD 19 billion were in energy-intensive industry. In China alone, USD 8 billion were invested in EE measures in industry in 2015 (IEA 2016e). To reach international climate goals, however, annual EE investments in this sector of around USD 35 billion would be needed until 2020. This indicates an increase of 84% compared to 2015 levels.

Although the total worldwide energy consumption in industry rose, the overall industrial energy intensity – defined as energy used per unit of GDP – has declined/improved in the last years, however, to various extents in different regions. In emerging and developing countries it improved more rapidly in 2015 (2.5%) than in industrialized countries (2%). In China, energy intensity improved by even 5.6% in 2015. Nevertheless, even higher improvements are needed in order to reach the 2°C target (IEA 2016e).

Regarding differences in large enterprises and SMEs, it can be observed that large enterprises have made significant progress in the last years in increasing their energy efficiency. SMEs account for a high share of industry worldwide and thus their collective energy use is considerable, although individual energy consumption is low. SMEs have had difficulties so far in exploiting their EE potential due to a number of reasons, including limited financial and time resources, and the lack of awareness and technical expertise. However, simple measures, such as switching off unused equipment and better maintenance, could have a high impact on their energy consumption. Experience with implementing EnMS in large enterprises has shown that energy savings of up to 10% through organizational measures and up to 25% through capital investments can be realized. SMEs could achieve similar savings with the implementation of an EnMS (IEA 2015).

Investments in connection to industrial energy management are estimated by IEA to have been around USD 14 billion globally in 2015. Despite high investments in efficient motor technologies of around USD 8.5 billion in 2015, a significant potential for energy savings still exists for electric motor systems, which consume the largest share of industrial electricity (IEA 2016e). Also industrial waste heat recovery still bears a large untapped potential. In both the European Union and China, heat recovery is moving more and more into the focus of attention, especially as a source for district heating. In China, 55% of industrial waste heat (mostly high- and medium-grade) is already recovered and used for energy generation and other industrial processes (IEA 2016e).

The investment amounts stated above indicate that so far especially investments in cross-cutting technologies have been made, while adequate investment is still needed in the field of energy-intensive processes and generally in SMEs. Besides initial financing of EE measures as a major barrier to energy efficiency in industry, long technical and economic lifetimes of industrial facilities pose the risk of a technology lock-in situation that impedes progress on energy efficiency (IEA 2015). As investments in industrial processes are very high, the equipment is typically used for many years, sometimes for decades. Even if the actual exchange of equipment was economically worthwhile, resulting downtimes might be too long and transaction expenditures too high. These additional hurdles can therefore hamper investment in energy-efficient equipment and lead to a continuation with the outdated equipment.

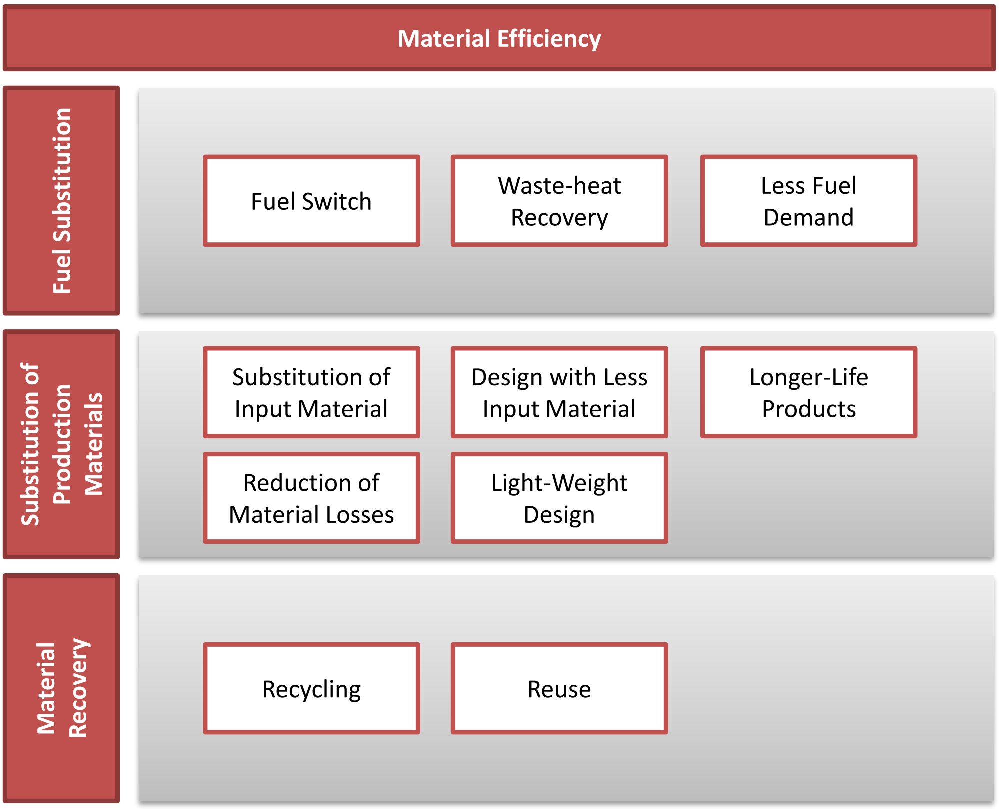
4 Overview of Material Substitution Possibilities

Since material production and processing requires a lot of energy, it is a main driver of GHG emissions in industry. Hence, there are different possibilities to cut down carbon emissions, including a change of type and amount of fuel and material input as well as recycling or re-use of waste energy and material. Besides implementing energy efficiency measures, the material efficiency in carbon-intensive sectors plays an important role to contribute to a reduction of GHG emissions. Material efficiency is a relatively broad field that includes different replacement measures or process changes. This paper therefore distinguishes between:

1) Fuel substitution
2) Substitution of production materials
3) Material recovery

The following Figure gives an overview of possible measures under the different types of material substitution.

Figure 3: Overview of material substitution possibilities



Source: own elaboration

1) Fuel substitution

One way to reduce GHG emissions in production processes is to address the energy use. According to an analysis by the International Renewable Energy Agency (IRENA), 128 EJ of final energy were consumed by industry worldwide in 2009, of which 61% were used for the generation of process heat (steam and direct heat), 7% for the production of iron and steel (in blast furnaces and coke ovens), 13% for the production of chemicals and polymers, and 19% to cover electricity demand, e.g. for electrolysis, motor drives, cooling or refrigeration (IRENA 2015).

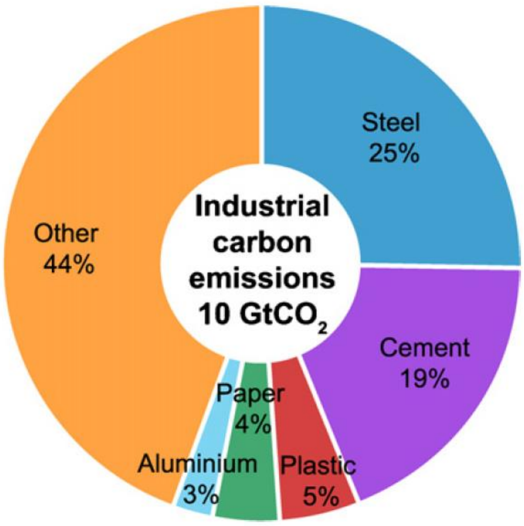
Carbon-intensive fossil fuels (coal and oil) can be replaced either by energy from renewable resources (solar thermal, biomass, heat pumps, geothermal) or by less carbon-intensive fossil fuels, such as natural gas. The possibilities of fuel switching, however, depend on the availability of alternative fuel in a country. For ammonia production in the chemicals industry, fuel switching from oil to natural gas can save up to 47% emissions, from coal to natural gas even up to 58% (IPCC 2014). In order to reduce the demand of newly generated energy, industrial waste heat can be recovered and reused for industrial processes (see Chapter 3.3).

In addition to that, the overall energy demand for industrial processes can be cut down by redesigning products and processes.

2) Substitution of production materials

Another possibility of reducing GHG emissions is the substitution and more efficient use of production materials and end-products. Figure 4 shows the five most carbon-intensive materials produced in industry.

Figure 4: Global CO_2 emissions of key materials in industry, 2006



Source: Allwood et al. 2011

In the framework of production material substitution, carbon-intensive input materials are being replaced by environmentally sounder ones, while producing identical or equivalent outputs. The substitution potential, however, depends on the properties of the material and the availability of sufficient amounts of alternative material. For example more than 200 kg steel and 380 kg cement are produced each year worldwide per capita. No other material is currently available that could replace them in such quantities (IPCC 2014). An example of input material substitution is the use of decarbonized feedstocks (steel slag or fly ash) instead of limestone for production of calcium, which is needed in cement industry (EPA 2010).

In addition to substituting carbon-intensive materials, the total use of production material can be reduced in two ways. One possibility is to reduce the amount of input material by re-designing products and another possibility is to reduce material losses along the supply chain. This is especially important for blanking processes in the sheet metal industry, where near-net-shape fabrication can reduce the amount of wasted input material significantly.

Moreover, emission reductions can also be achieved at the end-product stage. For example through a light weight design of products additional down-stream energy savings can be achieved. An example of downstream emission reductions is passenger-car light-weighting, where the substitution of heavier steel with the lighter aluminum (and with polymer-based materials) has been one of the primary approaches car manufacturers have been using in order to comply with ever-stricter emissions regulations. Producing longer-life products can also contribute to emission savings as production cycles become less frequent and thereby a lot of material can be saved. However, it must be considered that a longer product life reduces opportunities to sell products that are redesigned according to innovative and energy-saving technologies. Therefore this could lead to comparable amounts of excess energy use (Allwood et al. 2013).

3) Material Recovery

Looking at the last part of the product life cycle, material substitution through the recycling of products and the re-use of materials is an effective way to reduced energy demand and GHG emissions. This is especially true, if the reused material does not need to be augmented by new material and if further energy-intensive chemical reactions can be avoided. Particularly, bulk metals (steel, aluminum, and copper), paper, and plastics can be recycled easily and to a great extent. However, in many cases the quality of recycled products or reused material is lower than the original one, as impurities reduce the properties of the recycled material (IPCC 2014). Moreover, the recycling potential is limited to the available amount of reusable material. According to an analysis by Turner et al. (2015), with 8,143 kg CO_2e per ton, highest GHG emission reductions through recycling can be achieved for aluminum. Depending on the material, between 25% and 97% (on average 70%) of overall GHG emissions can be avoided through recycling compared to primary production.

Table 5 gives an overview of concrete material substitution possibilities in different carbon-intensive sectors.

Table 5: Overview of sector-specific potentials for material substitution

Sector	Examples of Material Substitution		
	Fuel substitution	Substitution of Production Materials	Material Recovery
Chemicals	Fuel switch from coal & oil derivatives ▪ to gas or electricity as source of process heat ▪ to natural gas in ammonia production	▪ Substitution of lead stabilized phthalate-containing PVC with one without for the application in electric cable coatings ▪ Modification of chemical composition in the synthesis loop in ammonia production	
Iron & Steel	▪ Fuel switch from coal & oil derivatives to gas or electricity as source of process heat ▪ Partial replacement of fossil fuels with charcoal in blast furnace for iron-making	▪ Use of gas-based direct reduced iron (DRI) ▪ Use of ferro-coke as a reductant ▪ Use of biomass & waste plastics to displace coal ▪ Use of CFRP, durable polymers, aluminum alloys etc. materials in automotive applications to save energy in manufacturing process & down-stream	▪ Recycling of steel

Cement	▪ Fuel switch from coal & oil derivatives to gas or electricity as source of process heat in cement kilns	▪ Use of additives to reduce clinker need (blast furnace slag, fly ash from power plants, limestone, natural / artificial pozzolana) ▪ Use of decarbonized feedstocks (steel slag or fly ash) instead of limestone for production of calcium	▪ Reuse of concrete components
Pulp & Paper		▪ Manufacturing of lighter paper ▪ Design of easy-to-remove inks & adhesives & less harmful de-inking chemicals	▪ Wood fiber recovery and reuse ▪ Recycling of paper
Non-Ferrous Metals	▪ Fuel switch from coal & oil derivatives to gas or electricity as source of process heat	▪ Near-net-shape fabrication ▪ Use of CFRP, durable polymers, aluminum alloys etc. materials in automotive applications to save energy in manufacturing process & down-stream	Recycling of ▪ precious metals from small appliances & compute devices ▪ copper, aluminum & other metals
Food	▪ Fuel switch from coal & oil derivatives to gas or electricity as source of process heat	▪ Use of emulsifier based on acetic acid & vegetable oils as replacement for phthalates ▪ Use of citric- & acetic acid as substitution for nitric acid in sugar production	

Source: own elaboration

5 Policies to Foster EE in Industry

According to an analysis of planned and implemented policies under UNFCCC, energy efficiency in industry is an often stated target in national technology action plans. On the contrary, a much lower number of policies have actually been implemented to date, leaving a gap with high interest and low experience (Komor & Wolton 2016). The following section therefore addresses various supportive policy options to increase the actual implementation of EE in industry, considering financing, training and co-benefits aspects.

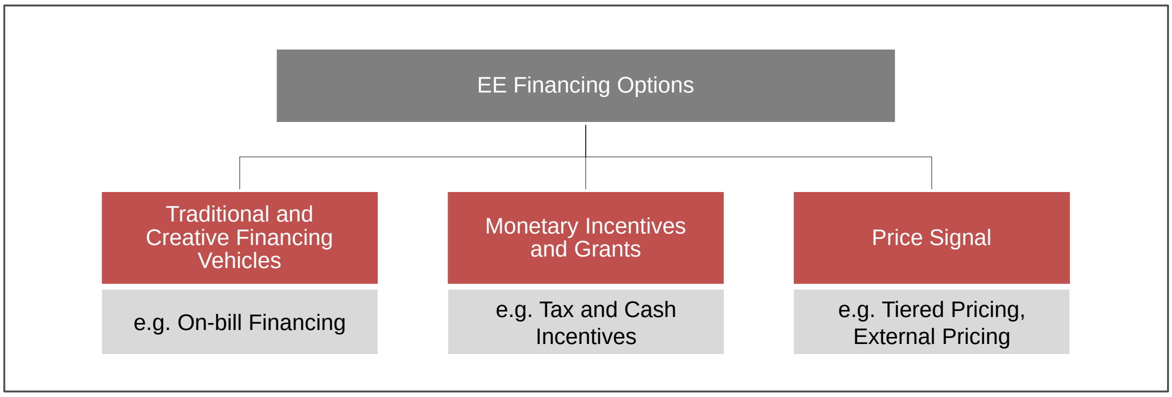
5.1 Financing, Training and Co-Benefit Aspects of EE in Industry

Since financing, training and co-benefits aspects play an important role for the sustainability of an EE policy, they are crucial for selecting the appropriate policy. In the following, all three aspects will be discussed briefly concerning their relevance and use of the terms, especially for co-benefits.

Financing as a main hurdle for SMEs in implementing EE measures in industry

While some energy efficiency measures can be realized with little or no cost, most measures require (large) upfront investments to capture the EE potential, particularly in the energy-intensive industry. Financing is therefore one of the major challenges to realize EE projects. This is especially the case for SMEs, as profitability and competitiveness considerations often impede the implementation of EE measures due to limited financial resources. Although EE actions tend to be very cost-effective and can lead to strong financial returns, some require large initial investments and therefore access to effective financial products and solutions is needed. With financiers being concerned about SMEs' collateral and vulnerability to market changes, SMEs often face difficulties in accessing capital (IEA, 2015). In addition, many banks and financiers are not aware of EE programs and the benefits they can bring – not only for climate change mitigation, but also for the banks themselves, such as increasing revenues and the creation of a positive brand. Whereas in industrialized countries the EE financing landscape is already more advanced, in developing countries there is still a big need. Figure 5 provides a general overview of EE financing options for industry.

Figure 5: EE Financing Options for Industry



Source: own elaboration, based on McKinsey & Company 2010

Training as a main need for enhancing EE in industry

Another important aspect for raising energy efficiency in industry is the awareness of saving opportunities and the capability to identify appropriate EE measures. If expertise on energy saving potential is limited, profitable efficiency opportunities can be missed out on, which is – like with financing – especially for SMEs a challenge due to their limited resources (IEA 2015). Therefore training as well as awareness-raising constitute main needs for driving energy efficiency in industry forward.

In order to exploit the maximum EE potential, trainings are necessary for different targets groups. On the one hand, training and education is needed for technical personnel, like engineers, auditors, certifiers, energy managers, to be able to identify, implement, maintain and monitor energy saving measures and technology. Especially for the implementation of an ISO 50001-conformant EnMS, specific trainings are indispensable as a combination of technical and business process know-how is required for EnMS experts. Establishing training centers as well as providing Training-of-Trainers (TOT) courses also plays an important role for the creation of a sustainable training landscape. On the other hand, enablers, such as financial institutions and policy-makers, need to be trained in order to be able to build the regulatory and policy framework for EE in industry and to provide support to enterprises, e.g. in the form of project financing, consulting services, etc. (Schleich 2011).

Definition of co-benefits of EE in industry

Economic benefits, in the form of energy cost savings, and climate change mitigation are put forward as the key decision factors for applying energy efficiency measures in industry. Nevertheless, there are significant impacts beyond cost-saving and climate protection that can be reached through EE measures and that gain increasing importance in the selection and design of EE policies for the industry as they contribute to a sustainable development. Moreover, co-benefits help to achieve greater acceptance of policies and to overcome barriers for implementation. Co-benefits are expressed in non-monetary units. Hence, quantifying the corresponding welfare is rather difficult as it also depends on other factors, actions, programs, etc. According to IPCC (2007), important co-benefits include:

- Environmental benefits and air-quality improvements
- Energy supply security
- Improved competitiveness and technology innovation
- Employment creation

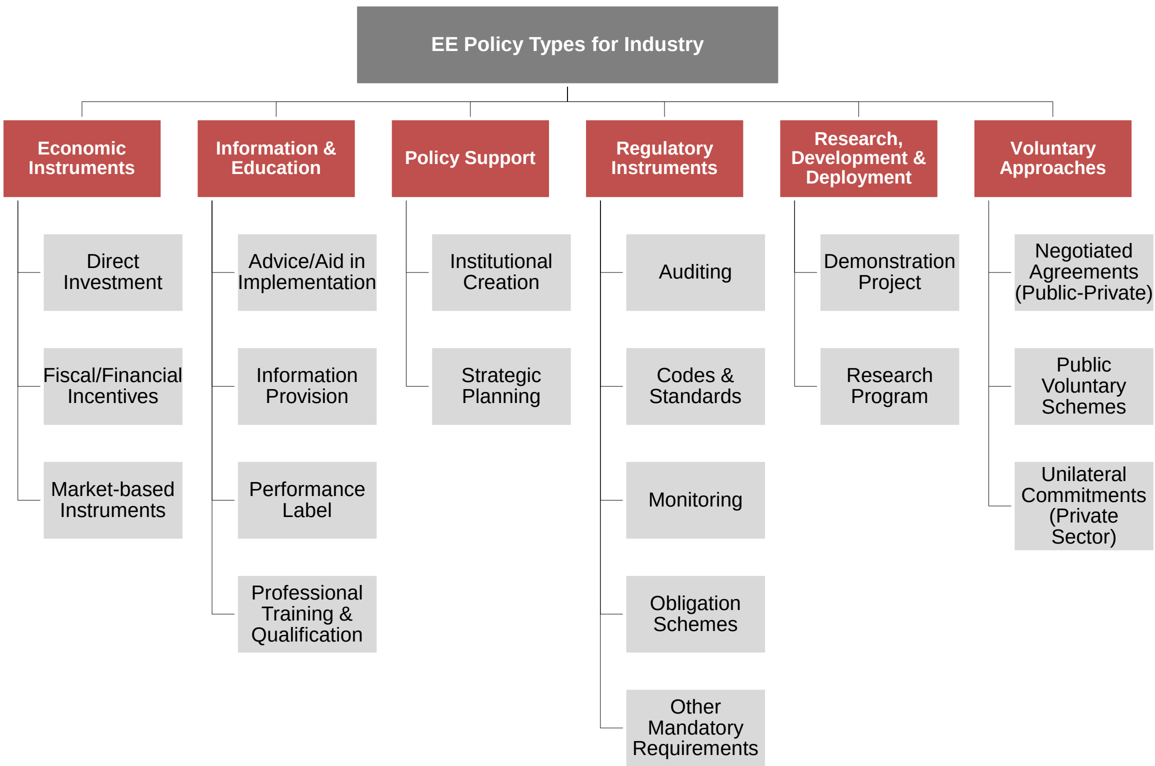
Whereas the reduction of GHG emissions as one major target of increasing energy efficiency has worldwide impacts, co-benefits usually arise on a local or regional level (IPPC 2007).

According to IPPC (2014), local air pollution, for example in areas close to industry sites, has led to strict emission regulations in almost every country. Through **air quality improvements** caused by increased EE in industry, significant health benefits for the population can be achieved. These benefits can lead to other economic impacts, such as reduced public health spending. Reduced requirements for fuel consumption, imported fuels, and for new electricity generation capacity **increase the energy supply security** of a country and reduce the risks of fuel availability, accessibility, affordability, and acceptability (IEA 2014e). Energy security through increased EE therefore ranks high on the agenda of many policy-makers. For companies, implementing EE measures has an important role in **improving competitiveness and technology innovation,** owing to cost-efficient production, mitigation of risks related to volatile fuel prices, improved processes, better environmental compliance, improved working-conditions, and a better reputation and corporate image (IPCC 2014). Furthermore, investment in EE can **generate direct and indirect jobs**, bringing along a number of other social and monetary benefits. Direct jobs refer to those created for manufacturing, installing, maintaining and repairing EE equipment or monitoring and measurement systems, and those for EE-related services like energy audits and EnMS implementation and certification auditing. Additionally, indirect jobs result from effects in the supply chain. For directs jobs in the field of EE in industry, education and trainings are necessary to build a competent workforce.

5.2 EE Policies in Industry

An IEA recommendation paper from 2011 indicates a worldwide energy saving potential in industry of at least 26 EJ per year from 2010 to 2030, which is equivalent to the total 2010 annual electricity consumption of China and the US together (IEA 2011). However, there are a number of barriers that impede the implementation of EE measures, although they would be technically and economically feasible. These include for example the failure to understand the positive impacts of EE on profitability, limited access to capital, low public acceptance of unconventional manufacturing methods, market failures such as split incentives, limited information access, distorted fiscal and regulatory policies, and energy subsidies (IEA 2014f). The choice of the right policies can make an important contribution to exploit most of the energy-saving potential in industry. There are many different policy options to enhance EE in industry. IEA provides a database for EE policies and measures for industry and other sectors, including an overview of implemented policies from all around the world. Figure 6 presents an overview of EE policy types in industry according to the IEA database. Financing and training aspects of policies can be sorted under *Economic Instruments* and *Information & Education*, respectively.

Figure 6: Classification of EE policies for industry



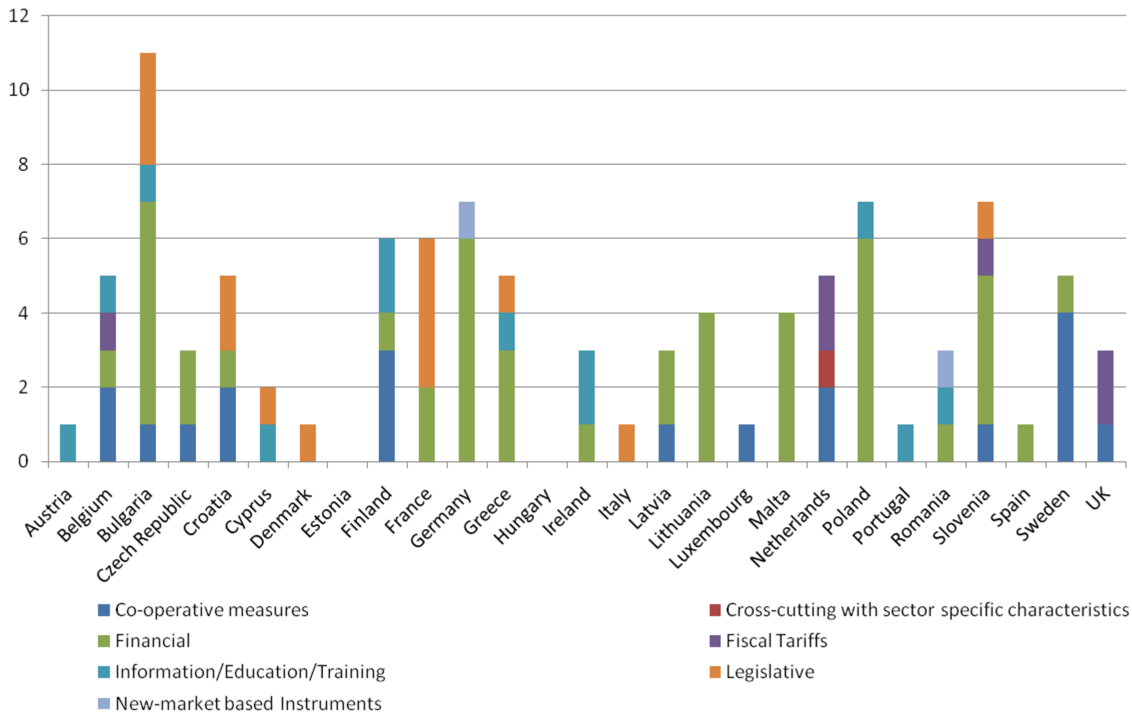
Source: own elaboration, based on http://www.iea.org/policiesandmeasures/energyefficiency/

Policy Support

The basis for an effective and sustainable EE policy development and implementation is the establishment of an institutional framework, e.g. the set-up of a national EE agency responsible for

EE policies in industry. Likewise, strategic planning plays an important role as it defines targets as well as planned measures and policies to achieve them. The development of a National Energy Efficiency Action Plan (NEEAP) for example has become mandatory in many countries, e.g. under the EU Energy Efficiency Directive or the League of Arab States' Guidelines for Improving Energy Efficiency. Figure 7 illustrates the targeted measures in NEEAPs of European countries, which indicate a focus on finance-related policies.

Figure 7: Envisaged policies in NEEAPs of European countries, by type (June 2015)



Source: ODYSSEE-MURE 2015, data from June 2015

Economic Instruments

Economic incentives are aimed at encouraging investment in EE measures. They can be of financial nature (direct incentive) or of fiscal nature (indirect incentive) and can be defined as a fixed amount, a percentage of the investment sum, or proportionally to the amount of saved energy (WEC 2016). Economic instruments include government grants or soft loans, the establishment of EE funds, the removal of energy subsidies and the implementation of subsidies for energy audits, tax rebates, risk-sharing or loan guarantees with private financial institutions, internalizing of external energy cost through policies such as carbon pricing, and market-based instruments like emission trading schemes.

Information & Education

Information and education are key components of an effective EE policy to foster motivation to improve energy efficiency and increase knowledge of technical and financial solutions. In order to support the application of EE measures, the provision of high-quality and relevant information, e.g. on equipment energy performance, training possibilities, audits, proven practice etc. is crucial. Information can for example be provided through platforms, campaigns and information centers, certification, or through mandatory or voluntary EE labels. In addition to information provision, technical assistance is important to successfully and sustainably implement EE measures or projects. This includes for example guidance of project implementers and the provision of supporting tools. When it comes to capacity building, policies must ensure that energy audits are carried out by qualified and trained engineers, widely promoted and easily accessible, also for SMEs. Likewise, trainings of EnMS experts are crucial for a sustainable implementation of energy management systems (IEA 2014f).

Regulatory Instruments

As incentive-oriented policies in some cases do not suffice to achieve the maximum implementation of EE measures, they should be accompanied by regulatory instruments. Besides national or regional EE laws that build the legal framework for energy efficiency, as for example the EU Energy Efficiency Directive (EED), there are different obligation schemes to enforce action on EE in industry. Those include mandatory auditing, monitoring and other requirements, codes and standards like minimum energy performance standards (MEPS) for industrial equipment such as electric motors, transformers, compressors, boilers, and pumps. In addition to obligatory standards, there is also the possibility of employing voluntary standards. Even if standards are voluntary they often serve to define standards in regulatory instruments.

Research, Development & Deployment (RD&D)

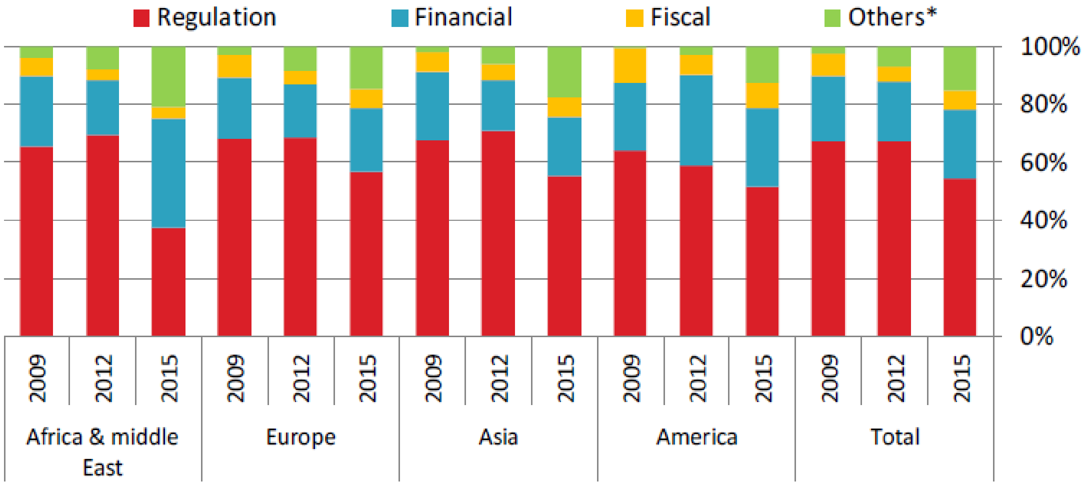
In order to drive technology and process innovation forward and to test and promote new developments that promote the efficient use of energy in industry, research, development and deployment is crucial and should be addressed by policies, e.g. in the form of research programs and demonstration projects. Demonstration projects can be aimed at demonstrating efficient technology, but also the business value.

Voluntary Approaches

Additionally, voluntary agreements between the public and the private sector, such as EE networks or partnerships, public voluntary schemes and private sector agreements (initiatives, programs, energy service companies (ESCOs), etc.) can accompany and increase the impact of EE policies.

Figure 8 illustrates the distribution of implemented EE policy measures by type in 2009, 2012 and 2015.

Figure 8: Distribution of implemented policy measures by type and region (2015)



Source: WEC 2016, *others correspond to voluntary agreements, ESCO and certification

As it can be seen, regulatory and fiscal instruments played a more important role in the past to initiate action on EE, whereas today other instruments like voluntary agreements and certification, gain in importance. Detailed information on implemented policies and their performance will be given in the case studies in Chapter 7.1 for the following countries and regions: China, EU, Germany, India, Mexico, Tunisia and the United States.

6 International Organizations and Initiatives

A number of international organizations active in the field of energy included industrial EE in their agenda. Many international networks and initiatives specifically focusing on this topic were established in the last years. Table 6 presents a rough overview of them including an indication of which of the aspects described in Chapter 5.1 are targeted. Concerning the co-benefits aspects, these reflect the organizations' main motivation or justification for energy efficiency deliberations. The letters a) – d) refer to

a) environmental / air-quality improvements
b) energy-supply security
c) Improved competitiveness / technological innovation
d) employment creation

Table 6: International organizations and initiatives active in the field of EE in industry

Organization / Initiative	Key Topics / Activities	Targeted aspect(s)		
		Financing	Training	Co-Benefits
AEE: Association of Energy Engineers	▪ EnMS ▪ Energy certification programs		x	
CEC: Commission for Environmental Cooperation	▪ EnMs / ISO 50001 ▪ Strategies / regulatory standards		x	a), c)
CEM: Clean Energy Ministerial	▪ Clean energy policy ▪ EE policies and practices ▪ EnMS			a)
CTCN: Climate Technology Centre & Network	▪ Technology transfer & low-carbon development of developing countries	x	x	a), c)
EMAK: Energy Management Action Network	▪ EnMS ▪ Role of governments ▪ Public-private networks		x	
EMWG: Energy Management Working Group	▪ EnMS international government best practice dialogue ▪ EnMS policies and data collection Focus on countries that drive industrial demand		x	c)
EnR: European Energy Network	▪ EE in SMEs & large industry ▪ Policies / common EE targets			c)
EUREM: European Energy Manager	▪ EnMS		x	c)
GSEP: Global Superior Energy Performance Partnership	▪ EE policies and practices ▪ EnMS			b), c)
IEA E4: Energy Efficiency in Emerging Economies	▪ EE activities scale-up ▪ Data collection & policy design		x	b), c)
IEA 4E: Energy-Efficient End-Use Equipment	▪ Non-transport energy using equipment & systems		x	a), b), c)

	▪ EE policies & practices			
IPEEC: International Partnership for Energy Efficiency Cooperation	▪ EnMS ▪ Efficient equipment ▪ EE policies and practices	x		a), b), c)
SEAD: Super-Efficient Equipment and Appliance Deployment Initiative	▪ Design & implementation of appliance EE policies		x	a), b), c)
SE4All Global Energy Efficiency Accelerator Platform	▪ Prepare integrated policy & investment roadmaps			c)
UNEP U4E: United for Efficiency	▪ Strategies for sustainable market transformation in developing & emerging economies			a), c)
UNIDO IEE: Industrial Energy Efficiency	▪ Energy system optimization ▪ EnMS / standards		x	a), b), c)
UNIDO RECPnet: Global Network for Resource-Efficient and Cleaner Production	▪ Technology transfer ▪ Strategies & policies ▪ Focus on developing and transition economies		x	a), c)
WEC: World Energy Council	▪ Support decision-making process in policies & industry strategy		x	a), b), c)

Source: own elaboration (list is not exhaustive)

From the table it can be noticed that half of the international organizations listed work in the field of energy management systems. Likewise half of the organizations focus on EE policy design and/or implementation. Two organizations address technology transfer to developing (and emerging) countries.

The targeted aspects as illustrated in the table refer to those that are explicitly mentioned on the main pages of the website. That means that possibly other aspects not indicated in the table are also relevant for the organizations, which would, however, need a more in-depth analysis.

As can be seen, around two thirds of the above listed organizations involve capacity building aspects at some point, in the form of technical trainings, workshops or webinars for different target groups. On the contrary, financing aspects seem not to be as often treated in the organizations. An explanation for this could be that financial support is rather developed and provided on a national level, than on an international level, or in the framework of special programs.

From the first rough analysis of co-benefits aspects, as indicated in the table, it can be said that the majority of organizations focuses on innovation and competitiveness aspects, as well as on environmental improvements, whereas some arguments also relate to energy security. None of the organizations explicitly points to employment creation. However, 12 of the 18 listed organizations involve EE trainings, which are indirectly related to employment, though not necessarily to employment creation.

7 Lessons Learned

A large number of energy efficiency programs have been implemented in industry across the globe so far. Detailed examples as well as general observations and conclusions are addressed in this chapter to provide insights in the actual implementation of policies.

7.1 Case Studies

In this section seven Case Studies from different regions and countries with detailed information on the energy situation in industry and the regulatory framework for industrial EE are presented. For each Case Study a flagship program and its impacts are highlighted and a selection of other EE programs is listed. Case Studies are selected considering:

- global coverage: developing, emerging and developed countries from different regions,
- SMEs and large enterprises as target groups,
- financing, training and co-benefit aspects.

7.1.1 China: Inter alia energy audits

China is the world's largest emitter of CO_2 emissions with 10,250 Mt in 2013 (World Bank 2016e). Energy efficiency in China is not on the agenda for most industries. However, leading industrial actors operate as flag ships to inspire in others the benefits of energy efficiency (McKinsey & Company 2013). China is an example of a system where industry obligations and sanctions are promoted in large industry enterprises and then broken down to SMEs.

Table 7: Economic and energy-related data for the industrial sector of China

Country Data	
GDP / annual growth (2015) **Energy intensity (2014)**	USD 11,008 Billion (World Bank 2016b) / 6.9% (World Bank 2016c) 0.37 toe/thousand 2010 USD (OECD/IEA 2017a)
Industrial sector ▪ GDP share (2014) ▪ Share of energy consumption (2014) ▪ Energy supply (2014) ▪ SME share (2013) ▪ Energy prices: electricity, diesel, natural gas (2016)	 ▪ 43.1% (World Bank 2016d) ▪ 49.5% (OCBC 2014) ▪ mostly from coal (IEA 2014b) ▪ 80% of urban employment; contribute 60% to GDP (OCBC 2014) ▪ 0.05 – 0.22 USD/kWh, 3.38 USD/gallon, 0.18 – 0.32 USD/m3 (AHK China 2016, GlobalPetrolPrices 2017)

Table 7 provides data on economic and energy indicators. The industry is responsible for almost half of China's energy consumption. Coal is the main source of energy being supplied to industry and energy is primarily used for electricity generation (almost 50%) and steel and building materials production. In comparison to large enterprises, SMEs are on average nearly 40% less energy-efficient and therefore offer a great potential for energy savings (IEA 2015). Energy Prices in China are subsidized, whereby the industry receives higher subsidies than households.

The main barriers to energy efficiency in industry in China are

- **Energy price subsidies**

- **Lack of financing** (OCBC 2014) and
- **Lack of information / understanding** (Lin 2016).

Government's focus and approach

As China has a big air pollution problem, the main motivation and targeted co-benefit of EE in industry is the improvement of air quality. The 13th Five-Year Plan (FYP 2016-2020) therefore sets ambitious targets for the progress in air quality (ChinaFAQs, 2016).

Energy efficiency in China is largely governed by the National Peoples' Congress and NDRC, where the latter one is responsible for developing the Five-Year Plans. The 11th FYP (2006-2010) already addressed energy-efficient industrial processes, especially through equipment renovation as well as the design and implementation of process optimization and management measures (IEA 2017). The regulation is specifically targeted at the metal and chemicals industries, for which China has set the target of an 18% reduction in carbon-intensity compared to 2015 levels (WRI 2016, IEA 2017). Industrial energy-saving standards include:

- **Aluminum Industry Permitting Standards**, incl. energy consumption standards
- NDRC's order of **Retirement of Inefficient Plants** in a variety of industrial sub-sectors (2007)

The Top-1,000 Energy-Consuming Enterprises Program

One of the most significant Chinese EE programs in industry is the Top-1,000 Energy-Consuming Enterprises Program, including inter alia energy audits, the training of energy managers, and the phasing-out of backward technologies. The idea of the program that started in 2006 was to achieve an energy-saving target of 1,000 Mtoe through the 1,000 largest enterprises in China during the 11th FYP. To achieve energy savings the program used both incentives and disincentives, accompanied by supporting policies, such as facility audits, assessments, benchmarking, monitoring, information dissemination, and financial incentives, to help the participants understand managing their energy use. The program was in great demand and in the end, a total of 1,008 enterprises participated and thousands of energy-saving contracts were signed with key energy-using enterprises. In total, energy savings of 150 Mtoe and CO_2 emission savings of 400 Mt could be realized between 2006 and 2010.

Due to the great demand, the program was increased to a Top 10,000 program under the 12th FYP targeting at a total of 17,000 enterprises. The 10,000 Program includes the following elements: the introduction of energy management systems following China's energy management system standard (GB/T 23331) accompanied by trainings for energy managers, the development of Energy Auditing Guides for industrial enterprises, the improvement of energy measures, the introduction of energy conservation incentive mechanisms, and online monitoring of key energy-using enterprises. Online monitoring comprises data collection to understand energy use and CO_2 emissions by province and industry and to develop measures that can address these trends (IEPD n.d.).

If companies cannot adhere to the annual energy-saving target, mandatory energy audits have to be conducted and retrofit measures must be taken within a limited time period (IEPD, n.d.).

Other programs and policies

- **Closing of Small Plants and Phasing Out of Outdated Capacity**
- **Energy Efficiency Appraisals for New Large Industrial Projects**
- **Ten Key Projects Program**

7.1.2 EU: National EE targets and action plans

The EU is included as a case study in order to demonstrate the coordination of energy efficiency measures in a supranational constellation. It is important to note how EU-law is implemented into national law, as is shown in the example of Germany. The 28 member states of the European Union (EU) coordinate their national economic policies and have adopted a framework of a single market with free movement of goods, services and capital (CIA 2017).

Table 8: Economic and energy-related data for the industrial sector of the EU

Country Data	
GDP / annual growth (2015) **Energy intensity**	USD 16,312 Billion / 2.2% (World Bank 2016b) 0.09 toe/thousand 2010 USD (OECD/IEA 2017g)
Industrial sector ▪ GDP share (2015) ▪ Share of energy consumption (2014) ▪ Energy supply ▪ SME share ▪ Av. energy prices: electricity, diesel, natural gas (2015)	 ▪ 19.2% (EC 2016) ▪ 28.8% (Eurostat 2016a); Chemicals 19% and Steel 18% of total energy consumption in industry in 2013 (ODYSSEE-MURE 2015) ▪ mostly from natural gas (IEA 2014b) ▪ 99% (EC 2015) ▪ 0.13 USD/kWh, 0,14 USD/l, 0.04 USD/kWh (Eurostat 2016b)

Table 8 provides data on economic and energy indicators. Industrial energy consumption in the EU accounts for around 29% of total energy consumption and is mainly driven by the chemicals and steel industries. Most of energy used is supplied by natural gas. The SME share in industry is very high with 99%. Main barriers to implement industrial EE were identified as (ODYSSEE-MURE, 2015):

- Information and knowledge deficits with respect to saving potentials and existing support programs
- Concern that efficiency measures could affect quality of processes and products negatively
- Low priority for energy efficiency measures as the share of energy costs in total company costs is low
- High transaction costs of EE measures
- Uncertain economic and legal framework and uncertainty in planning.
- Lack of own capital to undertake the measures

<u>EU's focus and approach</u>

Besides the overall climate protection goal, the main target of the EU's promotion of EE in industry is to increase the GDP and employment as well as to improve competitiveness. The EU also stresses the importance of reducing dependence on imported energy and thus increasing energy security (ODYSSEE-MURE, 2015).

The EU 2030 target for energy efficiency aims at a reduction of primary energy consumption by 27% compared to a business-as-usual scenario (ODYSSEE-MURE, 2015). Until 2020 energy efficiency should improve by 20% as decided in the 2020 package. Measures for reaching the goals are defined in the Energy Efficiency Plan and the EU Energy Efficiency Directive (EED) (European Commission 2017).

The national energy efficiency policy instruments for the industry of EU Member States are dominated by financial instruments that shall support investment in energy-efficient technologies. Around half of the policies addressing EE in industry can be included in this type. The role of energy management is also becoming very important and is being increasingly addressed by national policies and by the EU EED (ODYSSEE-MURE 2015).

Energy Efficiency Directive

The EU EED implemented in October 2012, obliges the Member States to set national energy saving targets in order to achieve the overall EU efficiency target of 20% until 2020. The directive also comprises binding national measures that support Member States to reach their targets and that ensure energy savings for industry, the public sector as well as for private consumers (European Parliament 2017). An important component of national measures included in the EED are energy obligation schemes that obligate retail energy sales companies and energy distributers to implement energy efficiency measures that lead to yearly energy savings of 1.5%. Other measures comprise energy efficient renovations for buildings or empowerment of consumers for improved consumption management via free access to energy consumption data by individual metering. (European Commission 2017b)

The regulations for the industrial sector are focusing on energy management and auditing (European Commission 2013):

- Member States have to develop incentives for SME to undertake energy audits and the implementation of outcomes of these audits. Therefore SMEs should be provided with required information and technical assistance as well as examples and best practices for the positive effects of energy management systems for business.
- Member States have to promote training programs that serve the qualification of energy auditors and they have to implement certification schemes for providers of energy audits.
- Large companies are obligated to conduct audits of their energy consumption and thereby identify possibilities for the reduction of energy consumption. Companies that have implemented or plan to implement an energy management (ISO 50001) or eco management (EMAS) system are exempt from conducting an additional audit.

Due to an impact assessment of the EED, current policies implemented in Member states will only lead to a reduction of energy consumption of 23.9% until 2030. Therefore, on 30 November 2016, the European Commission presented a proposal for a revision of the EED proposing an energy efficiency target of 30% for 2030 which has to be reached by the national targets. The revised version suggests amongst others an extension of the time period for energy obligation schemes and clearer rules for energy metering and billing (European Parliament 2017)

Other programs and policies

- **EU Emission Trading System** (ETS)
- **Voluntary labelling of electric motors** (CEMEP/EU Agreement)
- **Motor Challenge Program**
- **Energy Efficiency Management and Audit Scheme** (E2MAS)
- **Community framework for the taxation of energy products an electricity**
- **Combined Heat Power**
- **Efficiency reference values for electricity and heat production**
- **European Green Light Program**
- **Integrated Pollution Prevention and Control IPPC** (ODYSSEE-MURE 2015).

7.1.3 Germany: KfW Financing Instruments for Different EE Measures

The German government estimates a saving potential in industry of up to 40% (BMUB 2013) and the country is considered by many to be a pioneer in the field of energy efficiency with its National Action Plan on Energy Efficiency (NAPE 2014). Especially governmental financing mechanisms like KfW's *Energy Efficiency Programs* are of importance here, targeting production processes and industrial waste heat.

Table 9: Economic and energy-related data for the industrial sector of Germany

Country Data	
GDP / annual growth (2015) **Energy intensity**	USD 2,243 Billion / 1.7% (World Bank 2016b) 0.08 toe/thousand 2010 USD (OECD/IEA 2017d)
Industrial sector ▪ GDP share (2014) ▪ Share of energy consumption (2014) ▪ Energy supply ▪ SME share ▪ Energy prices: electricity, diesel, natural gas (2016)	 ▪ 32.2% (Statistisches Bundesamt 2015) ▪ 29.1% (Eurostat 2016a) ▪ mostly from natural gas (IEA 2014d) ▪ 99.3% (Statistisches Bundesamt 2014) ▪ 0.14 USD/kWh, 4.77 USD/gallon, 0.03 USD/kWh (Eurostat 2016b, GlobalPetrolPrices 2017)

Table 9 provides data on economic and energy indicators. In comparison with indicators for overall EU, the GDP share of the industrial sector is higher in Germany, i.e. nearly a third of GDP value added in 2014. The relative share of energy consumption is with roughly 29% similar to the EU and as the main source of energy supply in the industrial sector also is natural gas. The manufacturing sector accounts for 97% of total industrial energy consumption in Germany. Barriers to implement industrial EE were identified as (Fraunhofer ISI 2015):

- **Information deficits** and **insufficient market overview**
- **Low priority** for energy efficiency measures as the share of energy costs in total company costs is low

Government's focus and approach

For the far-reaching energy-transition targets, the Federal Government of Germany has implemented a set of regulatory measures to reduce energy consumption by increasing energy efficiency. The most important institutions for industrial energy efficiency in Germany are ministries at the federal level, most notably, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the Federal Ministry for Economic Affairs and Energy (BMWi). In order to implement the EU EED into German legislation, the most important German laws on energy supply have been amended, such as the Energy Service Act (EDL-G) in 2015. Large companies are obligated to carry out regular energy audits as part of the national legislation.

Germany must also comply with the EU EED in publishing a National Energy Efficiency Action Plan (NEEAP), which sets out estimates on energy consumption, planned energy efficiency measures and expected improvements in energy efficiency.

The most discussed co-benefits for Germany are of economic nature, mainly with regards to employment creation. The research institute Fraunhofer ISI found that an ambitious EE policy in Germany, including industrial energy efficiency, would have considerable positive effects on GDP and employment (Fraunhofer ISI 2015).

KfW Energy Efficiency Financing Programs

KfW offers different programs to increase energy efficiency in industry and to reduce a company's fixed costs[4].

The program **Production Facilities and Processes** aims to achieve substantial energy savings of at least 10% compared to the average consumption of the last three years for replacement investments and at least 10% compared to the industry average for new investments in the area of manufacturing plants and processes in companies located in Germany and abroad.

[4] https://www.kfw.de/inlandsfoerderung/Unternehmen/Energie-Umwelt/Energieeffizienz/

The program **Waste Heat** is targeted at investments in technologies that recover or avoid waste heat. Promoted are, for instance, measures for process optimization, the switching to technologies that create less waste heat and the insulation of plants.

The program **Energy-Efficient Construction and Refurbishment** addresses enterprises that plan to build or modernize their premises. Constructions and refurbishments are promoted by KfW if they do not exceed the energy requirements of specific "KfW Efficiency House" standards (KfW Efficiency House 55, 70, 100, Monument). For all three programs KfW provides loans of up to EUR 25 million per project at favorable interest rates and in some cases also with a repayment bonus (of 17.5-40%).

In 2012, 2,117 energy efficiency projects in the industrial sector were supported by KfW leading to a yearly reduction of final energy consumption by around 900 gigawatt hours and a decline in GHG emissions by 545,000 tons of CO_2e. Furthermore, the measures led to a reduction of annual energy costs for the participating companies by around EUR 150 million and to the creation of about 51,000 jobs for the period of a year with most of them in SMEs (Prognos 2014).

Other programs and policies

- Incentives for increasing energy efficiency within the **special equalization scheme under the EEG** as well as the **peak equalization for electricity and energy taxes**
- **Investment grants for the application of highly efficient cross-cutting technologies in SMEs,** for single measures or measures for an entire system optimization
- **Energy-Efficient Network Initiative** (information/ education/ training)
- **Energy Audit Obligations for Non-SMEs** (legislation / information)
- **Promotion of energy management systems under the Energy Efficiency Fund** of the BMWi (support of initial certification of energy management systems (DIN EN ISO 50001) and energy monitoring systems) (Fraunhofer ISI 2015)
- **Promotion of energy consultation in SME** (BMWi)
- **Support Program for energy efficient production processes** (BMWi)
- Efficiency Measures for refrigeration and air-conditioning in companies (BMUB) (dena 2014)

7.1.4 India: Energy Efficiency Certificate Trading Scheme

As one of the biggest emerging economies, India is the third largest producer of CO_2 emissions worldwide after China and the United States, with 2,035 Mt emitted in 2013 (World Bank 2016e). However, the country is striving for a sustainable industrial growth. Under the National Mission for Enhanced Energy Efficiency (NMEEE), India is amongst other measures employing the Perform Achieve and Trade Scheme (PAT) which is a trading system of energy saving certificates in energy-intensive industries.

Table 10: Economic and energy-related data for the industrial sector of India

Country Data	
GDP / annual growth (2015) **Energy intensity**	USD 2,095 Billion (World Bank 2016b) / 7.6% (World Bank 2016c) 0.38 toe/thousand 2010 USD (OECD/IEA 2017c)
Industrial sector ▪ GDP share (2014) ▪ Share of energy consumption (2014) ▪ Energy supply ▪ SME share	 ▪ 22% (GTAI 2016a) ▪ 34.3% (EIA 2014b) ▪ mostly from coal (EIA 2014b) ▪ 90% of total industrial units, 45% of industrial output, 40% of total exports (IBEF n.d.)

▪ Energy prices: electricity, diesel, natural gas (2014/16)	▪ 0.0892 USD/kWh, 3.42 USD/gallon, 3.06 USD/MBtu (AHK India 2016, GlobalPetrolPrices 2017, Bloomberg 2016)

Table 10 provides data on economic and energy indicators. Approximately a third of the energy use in India is caused by the industrial sector. As in China, coal is the main source of energy in industry. Electricity production in India is subsidized. The SME share accounts for 90% of total industrial units and produces 45% of industrial output. Barriers to implement industrial EE were identified as

- **Financing**
- **Subsidies for electricity**
- **Lack of information** (Bhattacharya and Cropper 2010)

Government's focus and approach

Koshy Cherail, president of India's Alliance for an Energy Efficient Economy (AEEE), sees energy efficiency as the first step for energy security and stresses that energy efficiency provides three important benefits: reducing emissions, economic benefits as a result of the profitability of energy-efficiency investments and social benefits, when policies and investments can be for social goals (India Climate Dialogue 2015).

The center piece of India's energy policy is the Energy Conservation Act (EC Act) of 2001, amended in 2010, which has the goal of reducing energy intensity in the Indian economy. For this reason, the Bureau of Energy Efficiency (BEE) was set up as the statutory body in March 2002. The most important regulatory mandates that stem from the act are: standards and labeling of equipment and appliances, energy conservation building codes for commercial buildings, and energy consumption norms for energy-intensive industries. In 2006, the BEE initiated the Standards and Labeling program for 19 equipment types and appliances (Ministry of Power 2017).

The Perform Achieve and Trade Scheme (PAT)

The PAT was set up in 2011 as a market-based mechanism that includes a trading scheme for energy-saving certificates in energy-intensive industries. In its first phase that ended 2014-2015, PAT was applied in eight sectors: Aluminum, Cement, Chlor-Alkali, Fertilizer, Iron & Steel, Paper & Pulp, Thermal Power, and Textile. The aim of PAT is to reduce the specific energy consumption (SEC). The average SEC target for the mentioned industries is a reduction of 4.05% in energy consumption. The specific targets of companies are based on current levels of their energy efficiencies. If a company achieves savings beyond its specific target, it receives energy savings certificates (ESCerts) for the excess savings. These can be traded on the market, where other companies can use them to meet their targets. To evaluate the performance, BEE started the accreditation of energy auditors (IIP 2012). According to the last available information, India now has 12,228 certified energy managers and 8,536 certified energy auditors. However, only 150 energy auditors were accredited so far through the Accreditation Advisory Committee (BEE 2014).

Other programs and policies

Through the BEE, the Indian Ministry of Power has started a few energy efficiency initiatives especially for SMEs and large industries. A few of these are listed below:

- **Demand Side Management (DSM) Scheme**
- **Capacity Building of DISCOMS**
- **Energy Efficiency in the SME sector:** development of studies, cluster-specific EE manuals, detailed project reports, capacity building for employees of SMEs
- **Strengthening Institutional Capacity of States**
- **Strengthening of State Designated Agencies (SDAs)**
- Contribution to **State Energy Conservation Fund (SECF) Scheme**
- **School Education Program**

- **Human Resource Development (HRD)**
- **National Mission for Enhanced Energy Efficiency (NMEEE)**: regulatory framework, promotion of innovative business models
    - Perform Achieve and Trade Scheme (PAT)
    - Market Transformation for Energy Efficiency (MTEE)
    - Energy Efficiency Financing Platform (EEFP) for SMEs
    - Framework for Energy-Efficient Economic Development (FEEED)

By unlocking the market for energy efficiency, the government envisions fuel savings of around 23 million tons per year as well as GHG emissions reductions of 98.55 million tons per year at the full implementation stage of NMEEE (BEE 2012). India's achievements in the field of energy efficiency are demonstrated at the National Energy Conservation Awards each year, where the Ministry of Power recognizes innovation in energy conservation in industries and other sectors. The participation level in the commercial and industrial units has risen from 123 in 1999 to 1,010 in 2014 (Ministry of Power 2017).

7.1.5 Mexico: National Program for Energy Management ISO 50001

Mexico is the second largest economy (AHK Mexico 2016) as well as the second largest emitter of CO_2 in Latin America (489 Mt CO_2 in 2013) (World Bank 2016e). The Mexican industry is predominantly shaped by small enterprises *(*94% in 2014). In 2015, the government introduced the national program for energy management system (PRONASGEn) in order to support energy-intensive companies in introducing EE measures.

Table 11: Economic and energy-related data for the industrial sector of Mexico

Country Data	
GDP / annual growth (2015) **Energy intensity**	USD 1,144 Billion (World Bank 2016b) / 2.5% (World Bank 2016c) 0.16 toe/thousand 2010 USD (OECD/IEA 2017e)
Industrial sector ▪ GDP share (2015) ▪ Share of energy consumption (2014) ▪ Energy supply (2014) ▪ SME share ▪ Energy prices: electricity, diesel, natural gas (2016)	 ▪ 16.8% (GTAI 2016b) ▪ 31.4% (SENER 2016a) ▪ mostly from natural gas (IEA 2014c) ▪ 94% (AHK 2016); contribute to 52% of GDP (IPEEC 2016). ▪ 0.0602 – 0.0806 USD/kWh, 3.03 USD/gallon, 3.419 USD/MMBtu (AHK Mexico 2016, GlobalPetrolPrices 2017, SE 2017)

Table 11 provides data on economic and energy indicators. The industrial sector accounts for 31% of energy consumption in Mexico. Thereby gas is the main source of energy supply. Compared to international standards, the cost of energy is relatively high in Mexico, which makes energy efficiency an important application to increase global competitiveness of Mexican companies (IPEEC 2016). With the end of government subsidies for gasoline in 2016, the gasoline prices have increased around 20% on New Year's Day 2017 (Semple & Malkin 2017). Challenges for the employment of energy efficiency measures in Mexico have been categorized into three subsections:

- **Structural issues** on the technological as on the legislative side
- **Issues of financing** with regards to the availability of capital to engage EE measures and
- **An information and knowledge gap** in industry concerning the availability and the usefulness of EE measures (Energíahoy 2016n).

<u>Government's focus and approach</u>

In Mexico, the targeted co-benefits of employing EE measures are mainly job creation (World Economic Forum 2016) as well as environmental protection and health (FIDE 2016). According to Crawford-Brown et al. (2012), a policy of 77% GHG reduction compared to a baseline scenario would result in a reduced mortality loss of about 3,000 lives per year and savings of about USD 0.6 billion in cost of illness.

The Mexican government has been supporting energy efficiency since 1989. CONUEE, the Agency for Energy Efficiency, was founded in the same year (AHK Mexico 2016). In its strategy for an energy transition, Mexico has targeted to reduce energy intensity (measured as final energy consumption) by 1.9% from 2016 to 2030 and by 3.7% from 2031 to 2050 (SENER 2016b). The most important laws and strategies concerning climate change and a more sustainable use of energy are the following (CONUEE 2016):

- **Law for Sustainable Use of Energy** from 1989 (Ley para el Aprovechamiento Sustentable de la Energía)
- **Energy Transition Law** from 2015 (Ley de Transición Energética),
- **Law on Climate Change** from 2012 (Ley General de Cambio Climático)
- **National Development Plan** 2015-2021 (Plan Nacional de Desarollo)

For the industrial sector, the focus is on energy management, use of high efficiency components and systems, services for SME and policies to enhance EE in industry.

National Program for Systems to Save Energy - PRONASGEn

The PRONASGEn program (Programa National para Sistemas de Gestion de la Energia) was initiated in August 2015 (AHK Mexico 2016) and financed by the German development agency (GIZ) together with CONUEE (IPEEC 2016). PRONASGEn is supposed to build EE networks in order to introduce energy management systems in accordance with ISO 50001 in energy-intensive SMEs. The focus of the initiative is at Mexican SMEs due to their high share in the landscape of Mexican companies (IPEEC 2016). The implementation process is accompanied by European consultants, mostly from Denmark and Germany (AHK Mexico 2016) as well as by a significant number of certified ISO 50001 experts from Mexico. PRONASGEn offers energy audits as well as a knowledge exchange between companies. In each of the participating companies, an energy manager is identified, trained and supported. The first set of workshops has taken place in October 2015. Eleven companies participated in the first workshop, which was presided over by the Energy Secretariat (SENER), CONUEE and GIZ (IPEEC 2016).

From the companies that participated in the PRONASGEn workshop, three have started the process to receive their ISO 50001 certification after the training. The eight others have committed to continue maintaining their EnMS and investing in energy management measures. In this context, more than 30 EE initiatives have been identified and are very likely to be put into practice. The Mexican media has quoted one of the participants to point out the following challenges for the companies (Energíahoy 2016b):

1) Continuation of the process on companies' own resources,
2) Promotion of new networks in order to generate and communicate more success stories,
3) Enabling applicability of EnMS in other sectors and segments (especially for small enterprises, considering their individual circumstances),
4) The existence of a critical mass of energy experts and EnMS experts to allow the application of EnMS.

Other programs and policies

Moreover, Mexico has some other interesting programs in place to foster a sustainable use of energy, including:

- **Foundation for Electrical Energy Saving** (FIDE)
- **National Program on Sustainable Energy Consumption** (PAESE)

- **Sectoral Energy Program**
- **Sectoral Program of Environment and Natural Resources**

7.1.6 Tunisia: Training for energy auditors

The socio-economic growth of Tunisia combined with subsidies for nearly all kinds of energy led to a high increase of energy demand over the last decades (GIZ & ANME 2012). Accordingly, CO_2 emissions also have been steadily growing from 1.7 Mt in 1960 to 27.7 Mt in 2013 (World Bank 2016e). Tunisia presents an interesting example of how energy efficiency promotion tools such as funding programs for technology and the introduction of auditing schemes can lead directly to traceable impacts in achieving a specific co-benefit, in this case employment creation.

Table 12: Economic and energy-related data for the industrial sector of Tunisia

Country Data	
GDP / annual growth (2015) **Energy intensity**	USD 43,015 Million(World Bank 2016b)/ 1.0% (World Bank 2016c) 0.22 toe/thousand 2010 USD (OECD/IEA 2017f)
Industrial sector ▪ GHG emissions share (2014) ▪ GDP share (2014) ▪ Share of energy consumption (2014) ▪ Energy supply ▪ SME share ▪ Energy prices: electricity, diesel, natural gas (2016)	 ▪ 20% (GIZ 2017) ▪ 29.3% (World Bank 2016d) ▪ 29% (IEA 2014g) ▪ Mostly from oil and natural gas (IEA 2014g) ▪ 97.8% (across all sectors) (World Bank 2009) ▪ 0.29 USD/kWh EUR/kWh, 0.71 USD/l, 0.02 – 0.03 USD/th (AHK Tunisia 2016, GlobalPetrolPrices 2017)

Table 12 provides data on economic and energy indicators. The Tunisian industry is the country's largest energy consumer (29% of total energy consumption). Thereby, main sources for energy are oil and natural gas. Electricity prices in industry differ greatly and are highest in the cement industry. In 2014, the government discarded the energy subsidies for the cement industry. Other subsidies for electricity and gas also are planned to be reduced adjusting pricing to global market prices. At present electricity prices are subsidized by 20% through the price for natural gas (AHK-Tunisia, 2016, p. 19-21).

Main barriers to implement EE were identified as (ANME, Ecofys and Alcor 2015):

- **Financial barriers**
- **Lack of awareness**

<u>Government's focus and approach</u>

The Ministry of Industry and is responsible for the national energy policy in Tunisia. Founded in 1985, the Tunisian National Agency for Energy Management (Agence Nationale pour la Maîtrise de l'Énergie, ANME) is the designated agency for formulating, promoting, and implementing energy efficiency measures and policies (RCREEE, 2013).

The government fosters energy efficiency by subsidizing investments in EE projects. Through national energy funds obligatory energy audits are financed. Companies that apply EE measures also receive specific direct support (RCREEE, 2013). The most important co-benefit that Tunisia strives for is job creation. The Tunisian government sets an emphasis on improvement of skills through human resources development and promotes education and professional training. From 2005 and 2010 jobs were created especially in the field of energy management and audits as well as in the solar thermal sector. By the end 2010, 500 energy manager and 152 auditor positions were filled in various business sectors and more than 420 energy audits were carried out in industrial, tertiary and transportation sectors. In the solar thermal sector around 1,480 jobs were created (GIZ & ANME, 2012, p. 42-55).

Promoting innovative energy efficiency measures in Tunisian industry

Between 2015 and 2017, in cooperation with ANME, the German federal development agency GIZ is implementing a program for the promotion of energy efficiency in Tunisia on behalf of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). The program aims at reducing greenhouse gas emissions through EE measures that include introduction of new technology as well as training for Tunisian specialists.

The program has the following sub-targets (GIZ, 2017):

- Technology advancement for energy efficiency: At least one industrial company shall receive assistance with implementing an innovative energy measure. To reach this aim, specific energy audits have to be conducted in a specific number of companies.
- Improving the performance of cogeneration plants: Co-generation shall be optimized in Tunisia. In a first step, the country-wide potential will be defined. Furthermore, the implementation of a monitoring system is planned to supply information on co-generation plants to ANME anytime.
- Training: Through training courses and workshops, the project aims at enhancing the skills of technical experts in Tunisia. These trainings also include the specific requirements of the ISO 50001 standard for energy management systems.

Results of the program were not yet available at the time of writing.

Other programs and policies (GIZ & ANME 2012)

- **Three-year program (2005-2007)** (sustainable energy program; in this framework: around 230 energy efficiency program contracts made between industrial sector and the government)
- **Four-year program (2008-2011)** (sustainable energy program; institutional and regulatory measures to increase use of renewable energy and EE)
- **PROSOL Program for Solar Water Heaters** (funding mechanism)
- **Photovoltaic solar pumping program** (funding mechanism)
- **Refrigeration appliance labelling program**

7.1.7 US: Better Plant Program to foster technological Innovation

The US is one of the largest GHG emitters globally with 16.4 tCO_2 per capita in 2013 (World Bank, 2016a). The industrial sector accounts for 21.4% (2014) of the country's GHG emissions (EPA 2015). Although due to the results of the 2016 presidential election, the future of energy efficiency policies in the US is uncertain, market experts are confident that new administration will continue to build on the premise of the economic advantages of energy efficiency (Piria et al. 2016).

Table 13: Economic and energy-related data for the industrial sector of the US

Country Data	
GDP / annual growth (2015) **Energy intensity**	USD 18,037 Billion (World Bank 2016b) / 2.6% (World Bank 2016c) 0.14 toe/thousand 2010 USD (OECD/IEA 2017b)
Industrial sector ▪ GHG emissions share (2014) ▪ GDP share (2014) ▪ Share of energy consumption	 ▪ 21.4% ▪ 27.2% (World Bank 2016d) ▪ 32.2% (EIA 2016a), of which aluminum, chemicals, wood, glass,

(2015)	casting metal, mining and steel: 75% (AHK USA-Chicago 2015)
▪ Energy supply	▪ largely from oil and natural gas (AHK USA-Chicago 2015)
▪ SME share	▪ 99%; over 50% of private sector employees (TradeUp Capital Fund & Nextrade Group LLC 2015)
▪ Energy prices: electricity, diesel, natural gas (10/2016)	▪ 0.0672 USD/kWh, 2.454 USD/gallon, 3.78 USD/Mcf (EIA 2016b)

Table 13 provides data on economic and energy indicators. The industrial sector makes up the largest share of energy consumption in the US. In 2015, the industrial sector was responsible for 32.2% of all energy consumption, and by 2025 this share is expected to exceed 36% according to the U.S. Department of Energy (US DOE 2015). Although there have already been significant improvements on energy efficiency over the past decades, US DOE also estimates that there is still potential to reduce energy consumption in the industrial sector by further 15-32% by 2025. Main barriers to implement industrial EE were identified as:

- **Economic and financial**,
- **Regulatory**, and
- **Informational** barriers.

Government's focus and approach

On the federal as well as on the state level, the EE funding is especially targeted at the creation of new jobs and innovation in the sector. The existing industries shall be strengthened in their competitiveness through efficient use of energy. Other important driving forces in this context are health and economic aspects, such as reduced costs for healthcare through improved air quality (Piria et al. 2016).

In the area of industry, federal agencies are responsible for

- **Policy-making**: incl. labeling and promotion of EE technologies
- **Financial and non-financial incentives**
- **Research, development and demonstration**
- **Regulatory framework**: Energy Policy Act (1992, updated 2005): loan guarantees for entities that develop or use innovative technologies avoiding GHG (EPA 2017); EE Obligations (since 1970ies): saving targets for a fixed period

The Better Plants Program

The Better Plants program of the Advanced Manufacturing Office (AMO) of the U.S. Department of Energy was introduced in 2009 and aims for reducing the energy intensity in industry by 25% within ten years. Partner companies of the program that have committed to a specific target (usually the 25% target) are required to develop an energy management plan and nominate an energy manager. The plan is to be realized in seven steps and includes regular reporting about energy intensity and consumption to US DOE. To support the partner companies, AMO provides trainings on energy management, a technical account manager for each company, and access to supportive instruments, resources and other training opportunities (AHK USA-Chicago 2015). A number of leading partners have joined the higher-level *Better Plants Challenge* and are openly sharing their energy performance data and innovative EE solutions in addition to setting an energy-saving goal. US DOE provides all Better Plants Challenge partners with technical assistance to achieve their goals and national recognition for their leadership (US DOE 2016).

By fall 2016, a total of 179 Better Plants Program partners achieved cumulated energy savings of roughly 600 TBtu and energy cost savings of around USD 3.1 billion. The average annual energy-intensity improvement rate currently lies at 3% (US DOE 2016). The Better Plants initiative can serve as an example of a voluntary program that supports specifically the introduction of innovative technologies while complementing a scheme of norms and standards.

The Better Plants program leverages technical tools and approaches from other government-led programs focusing on EnMS/ISO 50001, including those listed in the section below. The US DOE's ISO 50001 programs provide resources, tools, guidance, training and technical assistance for companies looking to implement ISO 50001 best practices. This includes recognition for companies that implement an EnMS consistent with ISO 50001 (the 50001 Ready Program) and those who seek third party certification to ISO 50001 and validation of energy performance improvements (the Superior Energy Performance Certification Program).

Other programs and policies

- **Energy Star Program**
- **Advanced Research Projects Agency – Energy** (ARPA-E)
- **Industrial Assessment Centers** (IACs)
- **50001 Ready Program** (by US DOE)
- **Superior Energy Performance (SEP) Certification Program** (by US DOE)
- **Federal Energy Management Program** (FEMP)
- Cross-cutting technology programs:
    - Combined Heat and Power Program
    - **Compressed Air Challenge** (CAC) Initiative
    - National **Motor Decisions Matter** (MDM) campaign
    - Education initiative **Pump Systems Matter**
    - **Process Heat Best Practices** publication (by DOE)

It must be acknowledged that, in addition to the above mentioned programs and policies, significant approaches and incentives to promote efficiency exist at the state and local level. Examples thereof are utility-based EE obligations and programs directed at end-users. Those programs focus on a range of EE measures, including technological support and knowledge sharing, to incentivize the introduction of efficient technologies and energy management systems.

7.2 General Observations

This chapter summarizes general results from the Case Studies presented in Chapter 7.1 and adds information of findings on EE policies in industry from the literature.

Barriers to implement industrial EE identified in the Case Studies include mainly the subsidization of energy prices, the lack of financing and the lack of information / understanding, a low priority of EE and the uncertainty of economic and legal framework. The countries have used different approaches to address these barriers.

As Table 14 shows, a broad range of the approaches and instruments listed in Chapter 5.2 has been implemented in the described programs. Measures range from financial instruments such as low-interest loans (KfW Energy Efficiency Financing), over market-based instruments (PAT/certificate trading in India), to regulatory instruments with a strong focus on the implementation of environmental management, auditing and monitoring systems. Besides mandatory interventions, also voluntary tools have been used, such as in the Better Plant Program in the US. Looking at each program separately, it becomes obvious that nearly all programs are composed of different policy types and measures that are implemented as a package to achieve EE goals.

Table 14: EE policies realized in Case Studies

Country	China	EU	Germany	India	Mexico	Tunisia	US
Program	Top-1,000 Energy-Consuming Enterprises Program	Energy Efficiency Directive (EED)	KfW EE Financing Programs	Perform Achieve & Trade Scheme (PAT)	National Program for Systems to Save Energy - PRONASGEn	Promoting Innovative EE Measures in Industry	Better Plants Program
Fiscal / Financial Instruments	x		x				
Market-based Instruments				x	x		x
Information	x	x			x	x	x
Training	x				x	x	x
Regulatory Instruments	x	x	x		x	x	x
RD&D						x	x
Voluntary Approaches					x		x

Source: own elaboration

Most programs are embedded in national policy strategy and all programs are accompanied by policy support as the government or public institutions take part in the launching, implementation and/or monitoring of measures. The impacts of the programs differ and hint at the different stages of efforts already taken to improve EE in the past. While some programs are focused on a nationwide application of EE tools, as in Germany or the EU, others rather have the character of pilot projects. An example for the latter is Mexico, where training programs, so far, are only implemented at a smaller scale.

Findings from other studies support the lessons learned from the Case Studies, especially with regards to the importance and effectiveness of implementing a bundle of different and well-matched policies. EE labels and minimum energy performance standards (e.g. for electric motors, transformers and compressors) have been important to increase the supply and use of energy-efficient products (Fawkes et al. 2016; WEC 2016). According to IEA, governments should remove energy subsidies and internalize external costs of energy (e.g. through carbon pricing) to increase industrial EE. Moreover, a special focus should be put on SMEs, developing and implementing tailored measures, including systems for energy audits, capacity building, and information on energy performance benchmarks. (IEA 2011). Policies should comprise a mixture of regulatory and institutional tools, information and capacity building as well as financial and fiscal measures for encouraging investment (Fawkes et al. 2016). Furthermore, policies should be coordinated such that various barriers across different sectors are addressed. Therefore, governments should embed policy measures in national strategies and action plans that are monitored, enforced and evaluated regularly (IEA 2011).

In summary, for increasing EE in the industrial sector, a legal framework with a well-coordinated strategy that allows reliable long-term planning is needed. Interlocking measures that enhance education, financing and access to technologies should be implemented.

8 International Policy Options to Foster Industrial EE

This chapter provides suggestions related to policies that effectively address EE in industry. The recommendations mainly follow from experiences linked to existing initiatives as shown under Chapter 6 and the identified lessons learned in Chapter 7. The term “international policy options” here refers to policies that can be implemented in various countries. The emphasis is therefore on policy options that have proven successful in different country or regional contexts.

Barriers and Suitable Policies

Table 15 provides an overview of typical barriers that impede the implementation of EE measures as well as policy options that help to overcome these barriers.

Table 15: Overview of barriers to EE in industry and policies to address them

Barriers	Policies	
Lack of Financial Resources / Capital Access, Transaction Costs	Economic Instruments	Financial Incentives
		Direct Investment
		Market-based Instruments (e.g. certificates trading)
Lack of Awareness / Understanding	Information	Information Campaigns
		Performance Label
	Deployment	Demonstration Projects
Lack of Technical Know-How	Education	Professional Training
		Aid in Implementation
Lack of Motivation, Low Priority	Regulatory Instruments	Auditing
		Codes & Standards
		Monitoring
		Obligation Schemes
	Deployment	Demonstration Projects (demonstration of business value)
Energy Price Subsidies	Economic Instruments	Fiscal Instruments (fading out of subsidies / carbon pricing)
Structural	Policy Support	Institutional Creation
		Strategic Planning
Access to Technology	Economic Instruments	Market-based Instruments (incl. technology transfer)
	Research & Development	Research Programs
Equipment Downtimes, Technology Lock-In	Economic Instruments	Financial Incentives
	Regulatory Instruments	Codes & Standards

Source: own elaboration

As illustrated in the table, there are a number of barriers that must be considered when designing an effective policy. These barriers concern different situations, country conditions, technologies and actors. For example, financing barriers are rather a problem for SMEs and rather in developing countries, lack of motivation is often related to a lack of awareness or subsidized energy prices and therefore rather occurs in enterprises or sectors with low energy costs, access to technology is more likely a problem for developing countries, and the problem of equipment downtimes or technology lock-in situations occurs especially when it comes to replacing whole systems. Therefore, the first step of designing a policy must be to identify the relevant barriers to be overcome. In addition to policies targeted at specific barriers, voluntary approaches of the private or public sector or as a collaboration between both of them can be implemented to complement an effective policy system.

National and International Policy Options

Policies can be adopted on an international as well as a national level. On an international level, especially programs including information, knowledge or technology transfer are reasonable, since countries not having much expertise in EE in industry so far can benefit most from the know-how and innovations from more advanced countries. Those types of policies are also the focus of many international organizations active in the field. Likewise, uniform codes and standards facilitate a technology transfer between countries and are therefore also likely to be implemented on an international level. The technology and knowledge transfer focus of international organizations can be explained by the target of increased competitiveness for companies and of environmental improvements through GHG emission reductions. On the contrary, fiscal and financial policies as well as institutional creation and strategic planning take rather place on a national level and are designed to fit the countries' conditions and needs. The main motivation of national policies includes energy security and employment creation. Both are co-benefits directly affecting the countries' economy.

EE Focus Areas

So far, many initiatives and policies were targeted at implementing energy management systems. The policies and initiatives turned out promising as a significant amount has been invested in EnMS implementation purposes in the last years. Also efficient cross-cutting technologies have been strongly promoted and implemented. What is still needed, are policies addressing energy-intensive processes and policies designed to support SMEs. SMEs that account for a very large share of companies around the globe often face a number of barriers that can be addressed with different policy measures including particularly financial assistance and capacity building. In several countries, financial instruments to support SMEs are already implemented. In Germany for example the EE programs for SMEs are in strong demand and achieved great energy savings since their implementation. These programs can be taken as an example of an effective EE financing policy. Concerning capacity building policies, especially international organizations often include trainings for energy auditors and energy managers. Due to the high number of international initiatives, many parts of the world are already covered with EE training offers (e.g. Europe, Asia-Pacific, MENA, South Africa, and Latin America).

Employment Generation through EE in Industry

One of an often targeted co-benefit when it comes to increasing EE in industry is job creation. Those jobs are for example related to energy auditing and energy management services as well as to manufacturing, installing, maintaining and repairing EE equipment and other parts of the value chain. Through the implementation of energy-saving measures indeed a significant number of jobs can be created as experienced in practice and analyzed in many different studies. Through the KfW EE programs for industry for example around 51,000 were created in Germany in one year, mostly in SMEs (Prognos 2014). According to Cambridge Econometrics (2015), 800,000 additional direct jobs could be created by 2020 in the industry, wholesale and retail sector in EU-28 through eco-design and energy labelling services. However, as definitions of jobs vary greatly (direct vs. indirect jobs, gross vs. net jobs, employment displacement considerations) the estimated or reported numbers are difficult to compare. Nevertheless, the numbers suggest a great potential of employment creation through EE improvements in industry. Besides the positive impacts for the individuals, employment creation also entails the advantage of reduced unemployment payments, which influences public budgets positively.

Success Factors

- **Long-term Planning**: As identified in this paper, a long-term and reliable planning builds the basis for effective EE policies in industry. Only if the overall strategy, targets and framework remain reliable in the long term and emission reduction targets are legally binding, companies are encouraged and willing to invest in EE measures and convinced that investments will pay off.
- **Addressing Barriers**: As already mentioned above, it is important to consider which barriers are actually impeding energy-saving measures. Based on the identification of measures, the most effective policies can be chosen and designed.
- **Bunch of Aligned Policies**: In order to cover different aspects and needs of companies, it is recommended to implement several policies that are aligned and build on each other. For example, awareness-raising campaigns have more impact if they are accompanied by consulting services and adequate financing instruments. Through the provision of accompanying trainings and capacity building measures, policies can be made more sustainable as expertise is transferred to the persons who actually work in the companies or financial institutions and who are then able to identify further EE (financing) potentials.
- **Focus on Co-Benefits**: While designing policies, targeted co-benefits should be kept in mind and whenever possible policies should be designed to correspond to them. For example, if technology innovation and improved competitiveness are targeted, programs including capacity building, research and development and/or technology transfer should be focused. If employment creation is targeted, a qualified workforce is needed.
- **Proven Policies**: The promotion of EnMS, financial and fiscal incentives including the phase-out of energy price subsidies, the introduction of MEPS, training programs, and the promotion of efficient technologies and practices have turned out to be successful measures. Therefore policy makers should continue to follow these approaches.
- **Locally Available Resources**: Effective policies should always concentrate on exploiting locally available energy and material resources as far as possible. This also includes the promotion of waste heat recovering technologies and the reuse of other industrial by-products as well as material and product recycling.
- **Technology Transfer**: If efficient and innovative technology is not available locally, technology transfer should be fostered through policies. Developing countries can benefit in a number of ways of technology transfers: Besides energy savings, innovative technologies make the companies more competitive, increase their own know-how and skills, improve their economic situation and finally contribute to a country's development.
- **Coordination of National and Regional Policies**: In order to achieve highest possible impacts of a policy, it should be designed in line with other national and regional policies. This helps especially for a long-term planning.

Role of the paper in the UNFCCC process

This paper serves an input to the TEC, who is to discuss what can be done to enhance the development and transfer of technologies for energy efficiency in industries and what can be **relevant policy work and recommendation areas for the TEC**, in accordance with its functions, to bring added-value to this specific sector.

Recommended policies should consider industrialized as well as developing countries, which is taken account of in this paper. During the thematic dialogue in March 2017, the insights of this paper can be used as a basis for further discussions. Moreover, the results and insights of this paper might serve as an additional input for the Technical Expert Meetings on mitigation, especially concerning the specific country experiences covered in the case studies and actions of international organizations.

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