EUROPEAN COMMISSION
RTD - Energy
ENER - Renewables, R&I, Energy Efficiency
JRC – Institute for Energy and Transport
SET Plan Secretariat

SET-Plan ACTION n°6

DRAFT ISSUES PAPER

Continue efforts to make EU industry less energy intensive and more competitive

1. Purpose of this document

In September 2015, the European Commission adopted a Communication for an Integrated Strategic Energy Technology Plan (C(2015) 6317 final). The Communication identifies ten priority actions to accelerate the energy system transformation that should facilitate coordinated or joint investments by individual Member States, between Member States and with the EU. These actions have been defined on the basis of the Integrated Roadmap developed with stakeholders and Member States and in line with the new political priorities defined in the Energy Union. Out of the ten priorities, two are related to the development and strengthening of energy-efficient systems, namely Action 5 on the development of new materials and technologies for energy efficiency in buildings, and Action 6 on the continuation of our efforts to make EU industry less energy intensive and more competitive.

For each priority action, the services of the European Commission develop an Issues Paper which will be jointly prepared by and discussed with the representatives of EU Member States and countries forming part of the SET-Plan, working together in the SET-Plan Steering Group, as well as in other Member State and stakeholder forums. These documents will serve as a starting point for discussions with Member States and stakeholders in the development of new research and innovation activities at European, Regional and national level in order to define (a) the level of ambition (in terms of priorities and funding), (b) the modalities for the implementation and (c) the timing for achieving results and adopting expected deliverables.

This document[1] is intended to progress the implementation of Action 6 on energy efficiency solutions in industry, with a focus on the technological aspects of research and innovation. It will be used to come to an agreement on targets in a dedicated meeting of the SET-Plan Steering Group with a representation of key stakeholders planned on 15 March 2016.

Stakeholders will be invited to take positions on the proposed targets in accordance with the guidelines set out in the paper "The SET-Plan actions: implementation process and expected outcomes" that is annexed to this paper and submit their positions to SET-PLAN-SECRETARIAT@ec.europa.eu by **Monday 15 February 2016** at the latest. Relevant documents and material on the SET-Plan and Integrated roadmap are available on the SETIS website https://setis.ec.europa.eu/ and other relevant information from the Public-Private Partnership (PPP) on Sustainable Process Industry (SPIRE) is available on the EC website[2] and SPIRE website[3].

[1] This document is a working document of the European Commission services for consultation and does not prejudge the final form of any future decisions by the Commission.
[2] https://ec.europa.eu/research/industrial_technologies/sustainable-process-industry_en.html

2. Background

Energy in industry:

In 2013, the industrial sector accounted for 25.1% of the total final energy consumption in the EU-28[4]. Although industry is the third-largest end-use sector in the EU after buildings and transport, its weight is more significant in countries with more energy-intensive industries, such as Austria, Czech Republic, or Sweden where it represents more than 30% of the total final energy consumption. In Finland and Slovakia, industry accounts for even more than 40% of their total final energy consumption.[5]

Energy in industry is mostly used for process heating and cooling, which represents about 63% of the total industry final energy demand. The major heat consuming processes are furnaces (e.g. in iron and steel, cement, glass) or steam generation in boilers or in Combined Heat and Power units.

Energy and competitiveness:

The share of energy costs in sectors such as aluminium, selected chemical products, glass or cement production, goes up to 30-40% of total production costs. As a result, the export competitiveness of these companies is directly affected by high and volatile energy prices. In the past years, energy intensive industries in Europe have seen less investment and lower growth compared to other part of the world such as the United States[6] where the "shale gas revolution" resulted in plunging prices of natural gas and electricity, leading to a revival of some manufacturing sectors such as metals or the chemical industry which benefited both from lower raw material and energy costs.

In less energy-intensive industries, an increase in energy cost can also affect export competitiveness on the margin. For instance, in highly competitive sectors, if profits are not high enough to offset even an incremental increase in energy costs, export competitiveness may suffer as a result.

In general, previous studies have shown that a rise in the cost share of electricity, gas, steam and hot water by 1 percentage point is statistically associated with a 1.6% decline of exports[7].

Industrial energy efficiency

For decades, EU industry responded to this threat by becoming more energy efficient. Between 2001 and 2011, the European industry has succeeded to reduce its energy intensity by 19%[8]. However, significant energy savings potential remains in many industrial sectors, e.g. surplus heat continues to be produced in large quantities in many industrial processes, which offer an untapped opportunity for heat recovery and re-use, subject to investment mobilisation. Statistics also show that there has been a much slower energy efficiency progress since the recession in 2007 (0.9%/year from 2007 to 2013 compared to 1.9%/year from 2000 to 2007), because of a slower progress in most branches and even no more energy efficiency improvement for some of others (e.g. steel, cement, machinery).[9] In fact, more than half of the reduction in energy consumption in industry since 2007 is linked to the decrease in industrial activity and one fourth only to energy savings.

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[3] http://www.spire2030.eu/projects
[4] Source: Eurostat, June 2015,
[5] Source: Odyssee Mure, http://www.odyssee-mure.eu/publications/br/energy-efficiency-trends-policies-industry.pdf
[6] Source: Reindustrialising Europe, Member States' Competitiveness Report 2014,SWD(2014) 278
[7] http://ec.europa.eu/DocsRoom/documents/7084/attachments/1/translations/en/renditions/native
[8] COM(2014)520 final, Communication on Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy.
[9] http://www.odyssee-mure.eu/publications/br/energy-efficiency-trends-policies-industry.pdf

Policy background

The issue of energy consumption and costs and their impact on industrial competitiveness has become central for EU policy making in the context of the EU ambitious energy and climate objectives and against the challenge of growing competitive pressures from emerging economies. This is all the more important given the slow recovery of the EU industrial output and employment after the crisis[7]. At the EU level, the energy efficiency of the industrial companies is mainly driven by four directives: 1) the Energy Efficiency Directive (EED) (2012/27/EU) which requires energy distributors or retail energy sales companies to achieve 1.5% energy savings per year through the implementation of energy efficiency measures, and which require large companies to make energy audits and also MS to support and foster voluntary energy audits in SMEs; 2) the Eco-design (2009/125/EC) and Energy-labelling (2010/30/EU) directives, setting minimum energy efficiency standards and energy labels to support the development and market uptake of energy efficient products such as electric motors (representing 40% of electricity consumption in industry), frequency drives, circulators, pumps or industrial fans; 3) the EU Emission Trading System (ETS); 4) the Industrial Emissions Directive (IED) (2010/75/EU) which provides that the BAT (Best Available Techniques) conclusions shall be the reference for setting the permit conditions of the installations covered by the IED. The BATs aim to reduce emissions and the impact on the environment as a whole, which includes the reduction of energy consumption.[10]

In the context of this Issues paper, it is important to underline that as part of the Energy Union Strategy[11] of 25 February 2015, the Commission announced the review of the EED and the Energy Performance of Buildings Directive (EPBD) (2010/31/EU) as one of the key strategic energy efficiency policy initiatives to contribute to moderation of demand. In addition, in order to sufficiently identify and address the role of heating and cooling as a sector in the EU energy transition towards decarbonisation, the Commission will release a strategy on Heating and Cooling which will inform and provide input to the review of some of the EU instruments described above.

Why do we need R&I for EE in industry?

R&I in energy efficiency in industry is needed to ensure industry contributes to climate change targets and further increase their export competitiveness in a situation where manufacturing companies from across the globe have more and more access to the same energy saving technologies, R&I investments is therefore necessary to further improve our technological leadership and innovation know-how. As a result, it should help EU industry companies tap into their existing technical energy saving potential and support the development and commercialisation of future disruptive technologies.

3. Drivers and means to improve EE in industry

Technology is one of the important drivers to improve energy efficiency in industry. Technologies can be grouped into sector specific technologies and cross-cutting technologies.[12]

- Sectoral technologies are tied to specific materials, processes or practices characterising a given sector, e.g. the steel or chemical industries.

[10] These Best Available Techniques conclusions are included in the so-called BAT reference documents (BREFs), one of which is dedicated to energy efficiency (http://eippcb.jrc.ec.europa.eu/reference/BREF/ENE_Adopted_02-2009.pdf). In addition, most of sectorial BREFs (see list of BREFs in http://eippcb.jrc.ec.europa.eu/reference/) contain BAT conclusions about energy efficiency as well as a section on emerging technologies

[11] COM(2015) 80 final

[12] ICF 2015a "Study on energy efficiency and energy saving potential in industry and on possible policy mechanisms", 1 December 2015, https://ec.europa.eu/energy/sites/ener/files/documents/151201%20DG%20ENER%20Industrial%20EE%20study%20-%20final%20report_clean_stc.pdf

- Cross-cutting technologies can lead to energy savings and energy efficiency improvements across many sectors when applied. They include e.g. heat recovery, energy efficient components (motors, electric drive…); enhanced process control and industrial symbiosis.

Beyond technologies, innovations related to industry organisation, management and design are also important ways of increasing energy efficiency of production and operation, as well as behavioural changes from employees to decision makers. However, this issues paper focuses on the technological aspects related to energy efficiency in industry and therefore it does not address these important drivers.

4. How R&I on sector-specific technologies could contribute to higher efficiency in industry?

To maximise impact of R&I, there is a need to prioritise sector-specific technologies with the highest potential. For that purpose, eight industrial sector groups have been analysed which account for 98% of the industrial final energy consumption in EU28. The table1 below provides energy and economic metrics for each sector as a basis for identifying where the R&I is most needed, according to the following criteria:

- Final energy consumption
- Energy Efficiency (EE) Saving potential of Economic technologies, i.e. energy saving potential considering technologies which are already economically viable with a payback period not longer than 5 year[illegible]
- Full Technical Saving potential, i.e. the maximum energy saving potential which is technically feasible, regardless of the economic constraints on implementing these opportunities.
- Energy cost intensity, i.e. the proportion of the energy cost in the value added of the product
- Number of persons employed in the sector
- Value added of the sector

Table1: Industrial sectors metrics[13][14]

Sector	Final energy consumption	EE Economic potential (payback <=5 year)	EE Technical Potential	Energy cost/ Value Added	No. of employed	Value added, gross
	Mtoe	Mtoe	Mtoe		Million	€ billion
Pulp and paper	34.3	1.4	7.2	16%	1.43	79.0
Iron and steel	50.8	3.1	16.3	36%	0.63	39.7
Non-metallic mineral	34.2	1.3	7.1	23%	1.29	63.9
Chemical and pharmaceutical	51.5	3.2	16.5	12%	1.72	229.8
Non-ferrous metal	9.4	0.5	1.9	23%	0.46	23.7
Petroleum refineries	44.7	1.9	10.6	44%	0.12	24.3
Food and beverage	28.4	1.7	6.8	10%	4.53	251.4
Machinery	19.3	1.3	5.3	3%	9.03	579.8
Total	**272.5**	**14.4**	**71.7**			

Three sectors Iron & Steel , Chemical & Pharmaceutical and Petroleum & refineries account for 54% of the final energy consumption and 6[illegible] of the technical saving potential.

[13] Final energy consumption, EE potential, Energy intensity: ICF 2015a, based on Eurostat 2013 data for EU28
[14] No of employed (2012), Value added (2013): Eurostat

For Iron & Steel and Petroleum & refineries, the cost of energy is a high share of the value added and therefore significantly affects their competitiveness.

The sectors with the highest economic weight in terms of employment and value added are Chemical & Pharmaceutical, Food & Beverage and Machinery, but the last two sectors are not energy intensive.

According to these criteria, it is proposed to focus the EU's sector-specific R&I efforts on cooperating on three sectors, which have the greatest potential for energy savings and enhanced competitiveness: Iron & Steel, Chemicals & Pharmaceuticals and Petroleum refineries. This prioritisation does not preclude a number of Member States and/or stakeholders to identify and agree on cooperation on actions in other sectors. The other sectors will also benefit from actions addressing the cross-cutting technologies identified in section 5.

For the three identified sectors, we have classified their technologies according to their maturity and economic viability:

a) the emerging technologies, which still need to be validated in pilot or demonstration plants (see Table 3) (sources: ICF 2015a, BREF-CWW-Chemical[15], BREF-Iron&Steel[16])
b) the existing technologies which have been demonstrated but are not (yet) economically viable[17] , i.e. with payback period longer than 5 years (see Table 2)

Only technologies with a significant energy saving potential were retained.

R&I should:

a) progress the maturity of emerging sector-specific technologies;
b) increase the performance and reduce the costs of existing technologies (which have a pay-back period longer than 5 years) to reduce the payback period and make them attractive for the industrial players.

Table 2: Examples of existing but not (yet) economically viable sector-specific technologies (with pay-back period longer than 5 years)

Sector	Sector Specific Energy Efficiency Opportunity Description	Potential savings 2030 ktoe/a[18]
Chemical	Improved distillation column design	373
Chemical	Improved reactor design	261
Chemical	Improved Catalysts	1627
Chemical	Oxygen-depolarised cathodes (chlorine production)	1437[19]
Petroleum Refineries	Improved distillation column design (incl. for crude: fouling mitigation and progressive distillation)	635

15 BREF-CWW in Chemical: http://eippcb.jrc.ec.europa.eu/reference/BREF/CWW_Final_Draft_07_2014.pdf
16 BREF-Iron&Steel http://eippcb.jrc.ec.europa.eu/reference/BREF/IS_Adopted_03_2012.pdf
17 Investment decisions depend on the Internal Rate of Return (IRR) calculated on the life cycle costs and benefits of the technologies. In this paper, we have used the simplified payback period criterion. Investments with an IRR of 30% (calculated over 10 years) or Payback of 3 years are generally considered as "Low hanging fruits" while an IRR of 15-12% or Payback period of 5-6 years is a typical threshold of economic viability.
18 ICF 2015a
19 Calculated as 30% reduction of the energy needed (27.4GJ/t) to produce 7.2 Mton of chlorine with membrane cell technique

Table 3: Examples of emerging sector-specific technologies

Sector	Sector Specific Energy Efficiency Opportunity Description	Potential savings[20][21] 2030 ktoe/a
Iron and Steel	Top gas recycling blast furnace	4331
Iron and Steel	HIsarna (combination of preheating of coal and partial pyrolysis)	5774
Iron and Steel	ULCORED (advanced Direct Reduction without CCS)	1444
Iron and Steel	ULCOWIN (electrolysis process) [22]	8661
Chemical	Novel separation techniques: membrane separation, membrane distillation[23]	
Chemical	Improved Naphtha Cracking Technologies	
Chemical	Integrated Gasification Combined Cycle (IGCC)	
Petroleum Refineries	Integrated Gasification Combined Cycle (IGCC)	257
Petroleum Refineries	Improved Catalysts (Emerging)	989
Petroleum Refineries	Waste cold recovery from (imported) LNG gasification	

Note 1: the Food & Beverages sector was also analysed, due to its very large employment and value added. It appeared that most energy savings in this sector are related to cross-cutting technologies such as high efficiency components, heat/cold recovery and integrated control systems (see table 4).

5. How R&I on crosscutting technologies could contribute to higher efficiency in industry?

Due to their applicability to all sectors, there is a large energy savings potential in cross-cutting technologies. Table 4 lists the existing cross-cutting technologies which have presently a pay-back period of more than 5 years (Source ICF 2015a). Table 5 lists the emerging cross-cutting technologies. (Sources: BREF-ENE[24], IEA-IETS[25])

[20] For Iron & Steel, energy savings of the four technologies were estimated by the formula: (energy consumption of BF process)*(CO2 reduction potential in %, ICF fig A1.18, Eurofer, 2013b) assuming full deployment of the technology. These four technologies are mutually exclusive and competing with each other.
[21] For Chemical and Petroleum, ICF 2015a study
[22] ULCOWIN technology will not be ready before 2040
[23] BREF-CWW in Chemical: http://eippcb.jrc.ec.europa.eu/reference/BREF/CWW_Final_Draft_07_2014.pdf
[24] BREF-Energy Efficiency: http://eippcb.jrc.ec.europa.eu/reference/BREF/ENE_Adopted_02-2009.pdf
[25] IEA-IETS 2014 Annual Report and Annexes http://www.iea-industry.org/86-ietsar2014.html

Table 4: Examples of existing cross-cutting technologies with pay-back period longer than 5 years

End Use	Energy Efficiency Improvement Opportunity Description
Chillers & Compressors	Premium Efficiency Refrigeration Control System
Compressor for Pneumatic Systems	Compressor heat recovery
Compressor for Pneumatic Systems	Premium efficiency ASD compressor
Fans / Blowers	High/Premium Efficiency Motors (Fans)
Indirect Heating (Boilers)	Automated Blowdown Control
Indirect Heating (Boilers)	Condensate Return
Indirect Heating (Boilers)	Heat exchanger optimization
Indirect Heating (Boilers)	Minimize De-aerator Vent Losses
Machine Drive	High/Premium Efficiency Motors
Pumps	High/Premium Efficiency Motors (Pumps)
Pumps	Premium Efficiency Control with ASDs (Pumps)
System	Electricity demand management control system
System	Power Factor Correction

Table 5: Examples of emerging Cross-cutting technologies

End Use	Energy Efficiency Improvement Opportunity Description
Heat recovery	Organic Rankine Cycle, Supercritical Rankine Cycle
Heat recovery	More efficient low grade waste heat recovery Technologies, e.g. high temperature heat pump
Integrated Control Systems	Process integration for EE optimisation, including dynamic modelling to allow real-time process control and optimisation

The main cross-cutting technologies can be grouped as follows:

1. **High efficiency components**: motors, adjustable speed drives, pumps, fans, machines, compressors
2. **Heat or cold recovery technologies**: condensers, exchangers, carriers, storage, heat pumps
3. **Integrated control systems**: static modelling for process integration and energy efficiency optimisation at design stage, but also dynamic modelling to allow real-time process control and optimisation. It includes also: monitoring and sub-metering; demand response management; integration of renewables.

Heat Recovery and Integrated Control Systems technologies have a large energy saving potential in the three sectors selected above, but also in the Pulp & Paper and Non-metallic Minerals sectors[26].

	Pulp & Paper	Iron & Steel	Non-metallic minerals	Chemical & Pharma	Petroleum	Sum
	ktoe/a	ktoe/a	ktoe/a	ktoe/a	ktoe/a	ktoe/a
Heat recovery (high and low grade)	820	2200	1880	1950	890	7740
Integrated Control Systems and sub-metering	1350	2560	1450	2620	1470	9450

[26] ICF 2015a

The last two groups of technologies are instrumental for **inter-plant integration** (industrial symbiosis), to enable energy flows between industries or plants in industrial parks, and with district heating/cooling networks.

R&I should increase the performance and cost effectiveness of these existing cross-cutting technologies and demonstrate them in real life, so as to remove the barriers and ensure they are widely deployed across all sectors.

6. Targets

Building on the Integrated Roadmap (IR) of the SET Plan[27] and SPIRE, public (EC and Member States/Regions) and private investment must focus on targeted R&I actions to make the EU industry more energy efficient:

Priorities	Targets	Indicators
Sector specific R&I: Increasing the energy efficiency of our most energy consuming industries by increasing the cost effectiveness of existing technologies	*By 2030, the energy saving potential related to economically viable technologies (i.e. payback not longer than 5 years) is increased by 30% compared to the potential identified in 2015*	*Economic energy savings potential (payback not longer than 5 years)*
Sector specific R&I: Increasing the energy efficiency of our most energy consuming industries by progressing emerging technologies	*By 2030, 1/3 of the currently promising emerging technologies are becoming commercially available*	*R&I Maturity progress (lab, pilot, demonstration)*
Cross-cutting R&I: maximising the economic returns of waste heat recovery	*By 2025, develop and demonstrate waste heat recovery solutions (heat exchanger, storage, distribution, and industrial symbiosis)*	*Evolution of BAT for heat recovery (IED), monitoring of industrial excess heat*
Cross-cutting R&I: maximising the economic returns of high-efficiency components.	*By 2025, improve energy performance of components by 15%*	*Minimum energy performance standards for relevant industrial products (EcoDesign Directive) / evolution of BAT (IED)*
Cross-cutting R&I: Enhancing operational improvements with ICT and intelligent operating systems	*By 2020, cost-effective continuous process optimisation technologies help small and large industries reduce their energy consumption by 15%*	*% of savings related to operational improvements*

For monitoring the industrial excess/waste heat, an action is recommended to develop industrial excess/waste heat inventory methods and to perform the inventory (also suggested by IEA-IETS[28])

27 https://setis.ec.europa.eu/system/files/IR_Annex%20I_Part%20I_Energy%20Efficiency.pdf

28 IEA-IETS- Annex XV: Industrial Heat Recovery http://www.iea-industry.org/ongoing-annexes/annex-15.html

7. Ideas for concrete cooperation

The first stage in the SET plan process is to agree on specific recommendations on the priorities/targets proposed in the issues paper. Then we will move to the second stage where the relevant stakeholders will be asked to contribute to a joint implementation plan in order to deliver the priorities/targets set by the Steering Group, including concrete implementation actions, related funding, expected deliverables and timeline for achieving results.

For information: In a questionnaire to Member States organised during the first half of 2014 a large number of countries (AT, BE, CZ, DE, DK, ES, FI, FR, GR, IE, IT, LT, MT, RO, SI, SK, CH, IS, NO, TR) indicated Energy Efficiency in Industry as an important area for R&I at national level. 22 of them (AT, BE, CY, CZ, DE, DK, ES, FI, GR, HU, IT, MT, NL, PT, RO, SE, SI, UK, CH, IS, NO, TR) indicated their willingness to exchange information on this topic, of which 16 are willing to define a common R&I agenda (AT, BE, CZ, DE, ES, FI, GR, IT, MT, NL, RO, SE, SI, UK, IS, TR) and 15 countries indicated their interest in establishing joint R&I projects or programmes (AT, BE, CZ, DE, DK, ES, FI, GR, MT, NL, RO, SE, SI, UK, TR). In their replies to this questionnaire, several countries indicated specific topics of interest[29].

8. List of Stakeholders to be consulted

- CEFIC (Conseil Européen des Fédérations de l'Industrie Chimique - European Chemical Industry Council)
- BUSINESSEUROPE (European National Business Federations)
- COGEN Europe (European Association for the Promotion of Cogeneration)
- CONCAWE (European Petroleum Refiners Association)
- EEIP (Energy Efficiency in Industrial Processes)
- EERA (European Energy Research Alliance)
- EUA – European University Association
- Eurofer (European Confederation of Iron and Steel Industries)
- Euroheat & Power (District Heating & Cooling and Combined Heat & Power Association)

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[29] BE: e.g. life cycle assessment within the framework of energy related issues (both industry and services)
CZ: Increasing of the primary energy sources transformation efficiency in industry; HVAC strategies and overall energy management for commercial buildings; Absorption of excess electricity (e.g. from intermittent renewables) in cooling/freezing systems.
DE: Berliner Model DE-FI
ES: Energy recovery in industrial processes; CHP processes and distributed systems; Industrial waste residues and re-use; ICT based solutions for industrial energy efficiency
FI: Technologies, services, new business models.
GR: Smart energy management solutions, cost optimisation, Life Cycle Cost optimisation
IT: New and optimised solutions for waste heat, residues and resources re-use. (e.g. for cogeneration).
MT: energy efficiency solutions for hotels and hospitality industry. Also in other services sectors.
NL: Exploring the possibility of coming to an ERA-Net Cofund on this topic in 2016 (in JAWG). Fields of interest:
EE in the Process Industries; energy efficient technologies for water treatment processes, for drying and dewatering, intensification of processes, next generation of separation technologies as a replacement for distillation (energy intensive), new modes and technologies for energy use and heat generation, integration of process industries in the renewable energy system, electrification of the process industry.
RO: Intensive use of energy recovery systems and use of waste energy for other needs. Improvement of workers skills to install and operate such systems. Energy monitoring and optimized energy management with clear targets for fossil energy savings.
SI: Thermal analysis of electric machines design, industry, services, ...; Enhance energy efficiency investments and support the implementation of energy saving measures in the Industrial sector and SMEs, which are often not implemented due to combination of factors and barriers faced by the actors involved

- Orgalime (Mechanical, Electrical & Electronic, Metalworking & Metal articles industries)
- SPIRE community
- ULCOS consortium

ANNEXE 1: Link of proposed actions with the Integrated Roadmap (Heading/Challenge/Actions)[30]

For Cross-cutting technologies:

High efficiency components: Heading 4, Challenge 1 (Develop innovative and highly efficient energy-related products and systems), Action 4.1.1 "Research on the next generation of highly efficient energy-related products and systems"

Heat recovery: Heading 3, Challenge 1 "Need to address industry's resource and energy efficiency in a systematic way, Action 3.1.1: "Development and demonstration of new technologies for heat recovery in industrial systems and optimisation of the existing recovery technologies."

Enhanced control systems: Heading 3, Challenge 2 (ICT related issues), actions 1 to 4:

- Action 3.2.1: "Development and demonstration of standard and open ICT systems and improved control concepts for energy monitoring and control of consumption in industry and SMEs"
- Action 3.2.2: "Development and demonstration of advanced energy monitoring visualization techniques and tools"
- Action 3.2.3: "Creating and demonstrating predictable models for process energy consumption and demand"
- Action 3.2.4: "Development and demonstration of advanced simulation and modelling methods and tools for the design and operational phase of manufacturing processes and systems"

Enhanced control systems: Heading 3, Challenge 3 (Value chain optimisation and factory design), action 3.3.1: "Developing industrial symbiosis and the creation of symbiotic eco-systems for more energy efficiency"

For Sector-specific technologies:

Iron&Steel, Chemical, Petroleum technologies: partly related to Heading 3, Challenge 3 (Value chain optimisation and factory design):

- action 3.3.2 - Title: "Collective cross-sectorial actions to develop, demonstrate and optimise new and existing industrial processes"
- action 3.3.2 – KPI : "By 2020, new innovative processes may allow the production of short series at the same cost as present large ones by development of more efficient melting, holding and sintering processes. In the chemical sector, new solutions in this field will enable higher reaction rates leading to low-temperature processes and smaller equipment size, better selectivity leading to minimization or elimination of waste, reduced requirements for separation which are responsible for ~40% of energy consumption in chemical and related industries.

[30] https://setis.ec.europa.eu/system/files/IR_Annex%20I_Part%20I_Energy%20Efficiency.pdf

ANNEXE 2: Complementary information on some technologies

Sector specific technologies for Chemical & Pharmaceutical and Petroleum & Refineries – emerging technologies:

- **Integrated gasification combined cycle** (IGCC) Gasification is an efficient means of converting into a syngas low-value fuels and residuals (fossil fuels - coal or oil - biomass - wood, agricultural waste or various crops - manure, asphalt, sewage sludge, plastics – especially the plastic waste not recyclable). Basically, the plants transform all the organic substances in methane, hydrogen and carbon monoxide. Metals and pollutants (including halogenated acids) are separated with a cleaning step.
  The "energy" product result can be:
    - heat recovery from the gasification
    - electricity by burning the syngas
    - fuel

  Some petrochemical installations already have a gasification session and refineries too. This technology would deserve further R&I to make it both technologically and commercially viable. Gasification is normally more energy efficient than ordinary combustion; further R&I would help improve this.
  Examples:
  http://www.energy.siemens.com/mx/en/fossil-power-generation/power-plants/integrated-gasification-combined-cycle/integrated-gasification-combined-cycle.htm
  http://www.power-technology.com/projects/sarlux/
  http://www.power-technology.com/projects/isab/
  http://www.rite.or.jp/Japanese/labo/choryu/workshop/futuregenws2008/2008FGWS_MrHIGMAN.pdf

Sector specific technologies for Chemical & Pharmaceutical – for inorganic chemicals (especially chlor-alkali)

Source: http://eippcb.jrc.ec.europa.eu/reference/BREF/CAK_BREF_102014.pdf
IPPC Bureau – JRC IPTS Institute, Sevilla: Best Available Techniques (BAT) Reference Document for the Production of Chlor-alkali

- **Oxygen-depolarised cathodes**
  This technique consists in replacing the common metal cathodes in membrane cells with oxygen-depolarised cathodes that reduce oxygen to produce hydroxide, instead of converting water to hydrogen and hydroxide.

Sector specific technologies for Iron & Steel – emerging technologies:

- The **top gas recycling blast furnace** is based on the separation of the off-gases so that the useful components can be recycled back into the furnace and used as a reducing agent. Meanwhile, oxygen is injected into the furnace instead of preheated air to facilitate CO2 capture and storage (CCS). To experimentally test this concept a gas separation pilot plant was constructed next to LKAB's Experimental Blast Furnace in Luleå, Sweden. Plans are currently being developed to test this principle on a commercial scale blast furnace. This will take place in the next phase of the ULCOS project, ULCOS II requiring an initial R&D investment of several hundred million Euros.

- The **HIsarna process** produces liquid hot metal from iron ore fines using (non-coking) coal as a reductant. There is no need for ore agglomeration or coking. The HIsarna process reduces the ironmaking route presently consisting of 3 steps to a single step. The technologies associated with HIsarna have been proven independently at small scale within the ULCOS project. The work is continuing with a pilot plant in Tata Steel's IJmuiden in the Netherlands, with a budget of €25m, and €7.4m funding under the Horizon 2020 SILC-II programme[31][32]. Expected CO2 (and energy) reduction by 20% (without CCS).
- The **ULCORED** (advanced Direct Reduction with CCS) involves the direct reduction of iron ore by a reducing gas produced from natural gas. The reduced iron is in a solid state and will need an electric arc furnace to melt the iron. (ULCOS project)
- The experimental process, known as **ULCOWIN**, is an **electrolysis processes** to be tested on a laboratory scale. (ULCOS project)

Fig A1.18 Abatement potentials of the ULCOS technologies (Eurofer, 2013b) (ICF)

Technology	Expected potentials for direct CO_2 mitigation effects	Soonest expectations (from a purely technical perspective)
Top Gas Recycling Blast Furnace (ULCOS-BF)	15% without CCS 60% with CCS	Laboratory: done Pilot: done Demonstrator: tbc Deployment: > 2020 onwards
Bath smelting (HIsarna)	20% without CCS 80 % with CCS	Laboratory: done Pilot: 2011-2013 Demonstrator: 2020 Deployment: > 2030
Direct reduction (ULCORED)	5% without CCS 80% with CCS	Laboratory: done Pilot: 2013 Demonstrator: 2020 Deployment: > 2030
Electrolysis (ULCOWIN)	30% with today's electricity generation mix 98% with CO_2 free electricity generation	Laboratory: ongoing Pilot: 2020 Demonstrator: 2030 Deployment: > 2040

[31] (Tata, 2015) http://www.europe.tata.com/Section/Article/European-Union-supports-testing-of-groundbreaking-iron-production-technology-developed-by-Tata-Steel-Europe?sectid=ZACX2FP1m5c%3D

[32] (Meijer, 2015) Meijer,K., et al. The HIsarna ironmaking process http://www.metec-estad2015.com/papers2015final/P632.pdf