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Competitiveness of System Integration Elements

Exploratory study

Report - Competitiveness of System Integration Elements

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Acronyms

Acronym	Full description
BACS	Building Automation Control Systems
BIPV	Building-Integrated Photovoltaics
CEC	Citizens Energy Community
CET	Clean Energy Technologies
CPR	Competitiveness Progress Report
DHC	District Heating & Cooling
DSO	Distribution System Operator
ENTSO-E	European Network of Transmission System Operators for Electricity
EPBD	Energy Performance of Buildings Directive
FDI	Foreign direct investment
GDP	Gross Domestic Product
HEMS	Home Energy Management Systems
IMF	International Monetary Fund
NZEB	Nearly zero-emission building
ORC	Organic Ranking Cycle
REC	Renewable Energy Community
RES	Renewable Energy Sources
RFNBO	Renewable fuel of non-biological origin
SIA	System Integration Areas
TSO	Transmission System Operator

Content

1 Background and aim of this exploratory study

Since 2020, as per the Energy Union Governance Regulation[1], the European Commission publishes an annual report to assess whether clean energy technology development is on track to deliver the EU's long-term energy and climate goals and to map the competitiveness of the EU clean energy industry[2].

As competitiveness is a complex and multifaceted concept, which cannot be defined by a single indicator, the Competitiveness Progress Report (CPR) proposes a set of widely accepted indicators capturing the entire energy system (generation, transmission and consumption), which is analysed at three levels (technology, value chain, and global market).

The CPR builds on the outcomes of Clean Energy Technology Observatory that publishes annual in-depth technology developments of a large number of clean energy technologies and systems. The CPR presents indicators displaying the competitiveness of clean energy technologies (CET) in two sections, i) macro section and ii) technology-specific section including the technology, value chain and the respective global market.

However, on a macro-economic level, factors that influence the competitiveness of CET are only partly captured by the current approach. Furthermore, in light of the increasing requirement to integrate different sectors and systems (sector coupling) to leverage the full potential of clean energy potentials, a concept is needed to highlight the strengths and weaknesses of the EU energy sector and its consumers regarding the intensity and progress in energy system integration.

Hence, the aim of this study is to outline a comprehensive concept on the way to integrate system integration aspects as well as further macro-economic aspects into the broad approach of assessing the competitiveness of CET. The objectives, key focus areas and approach to elaborate a comprehensive concept to assess the competitiveness of CET is outlined in the ToR. However, in the course of the elaboration of the ToR, significant challenges emerged regarding the clear definition and delineation of the suggested system integration areas (SIA), and thus we conducted an exploratory study that is considered as a preliminary and introductory research which could lead, if requested, to a detailed study on the analysis of the competitiveness of Energy System Integration Areas. As per the ToR, this exploratory work has been focusing on additional indicators on a macro-economic level and on 7 potential System Integration Areas (SIAs), suggested by the European Commission:

- SIA 1: Building-related clean energy technologies
- SIA 2: Digital infrastructure for smart energy system
- SIA 3: Industrial and District Heat & Cold Management
- SIA 4: Off-grid energy systems
- SIA 5: Transmission- and distribution-related technologies
- SIA 6: Smart Cities
- SIA 7: Innovative energy carriers and energy supply for transport needs.

In the framework of this exploratory study, we carried out some preliminary research on the scoping of the 7 SIAs, on identifying possible influencing factors, and on proposing to focus on 2 priority enablers per SIA. Moreover, we conducted a preliminary identification of macro indicators.

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1999&from=EN
[2] https://energy.ec.europa.eu/topics/research-and-technology/clean-energy-competitiveness_en

2 Common methodological framework

2.1 Overview of the common methodological framework

The aim of this common methodological framework is to guide the scoping, design and indicator identification of every System Integration Area (SIA) to be addressed within this study, through a 5 steps approach covering

- **influencing factors**: analysing all aspects that could influence the competitiveness of the CET, including the macro-economic level and broadening the scope, and support understanding the global landscape of a SIA;
- **preliminary scoping**: identifying and describing all potential elements/components, and their interactions, considering their system integration, giving a broad picture of all possibilities of SIA;
- **priority enablers**: based on the broad picture of factors and components, we look at the priorities. By enabler we understand a component in the SIA which could be a product, equipment, service, technology, regulation, infrastructure, humans (actors), and which has an integration or connection functionality between systems. To identify these priority enablers, we address the following research questions:
    - Is the enabler significantly contributing to the Fit for 55 package, by facilitating the uptake of a technology or supporting the integration of sectors, and thus making the system more efficient?
    - Is EC intervention needed to make the enabler become an actual enabler of system integration (in other words, identify areas where there is some need to act)?

Similarly, we identify indirect key enablers of CET for the macro-economic indicators, i.e. what are enablers that foster the competitiveness of an economy with respect to CET.

- **Indicators**: for each enabler, a set of indicators is identified (it can be only one) that reveals
    - whether the EU has a competitive advantage in this system integration area or on a macro-economic level?
    - and where the EU lacks competitiveness?
- **Data set:** we suggest preliminary data sources and data related to the respective indicator. Some indicators may be already covered to assess the progress of technologies, but when correlated with new indicators, they could provide a new perspective regarding the competitiveness of the system integration area.

This framework is required to ensure a certain level of coherence between all SIA, considering they are all different in concept.

2.2 Factors influencing competitiveness

There are different understandings and definitions of the notion of competitiveness. A major differentiation is made between the micro- and macro-economic perspective[3]. Understanding of competitiveness on a macro-level (task 2) could refer to different aspects that correlate with each other such as productivity, welfare and sales to external markets. In this context, the focus of competitiveness could be on the competitiveness with respect to the outcome or with respect to processes, i.e. both represent a subject of competitiveness. For both subjects on the macro-level,

[3] Delgado, Ketels, Porter, Stern 2012: The determinants of national competitiveness; NBER Working paper 18249; https://www.nber.org/system/files/working_papers/w18249/w18249.pdf

drivers of competitiveness may include ecological, social, distributional, and technical indicators as well as capabilities and trust. Key factors of competitiveness across these areas, are national infrastructures (social, physical, financial), institutions (political, social, legal), resources (human, physical), policies (fiscal, monetary).

In contrast, microeconomic aspects (according to task 3, these will be addressed partially for each SIA) focus on certain characteristics of firms competing for market shares and profits under a given business environment. The characteristics include, among others, strategies, organisation, structures management, and, of course, the business environment, i.e. supply-chain, resource/input factors and demand conditions[4]. According to Porter[5], the competitiveness of a nation is founded on microeconomic factors, while conditions on a macro-level (political, legal, social, economic and institutional aspects) are necessary to ensure the enabling framework. Therefore, microeconomic factors that could be reflected by an aggregated business indicator have to be complemented by the macro-level.

Ongoing research examines the notion of competitiveness from a third perspective, the meso-level. It encompasses competitiveness of certain sectors or areas that are affected by, for example, trade, regional, technology, education and labour policies. Overall, development takes place on multi-levels and calls for an understanding of the micro-meso-macro environment, as it reflects the interactions of actors with a subset of other agents of a system.[6]

Regarding the assessment of the competitiveness of clean energy technologies (CET) in the EU, we rely on the micro-meso-macro perspective to account for the interactions between these different levels and systems. Competitiveness of CET and system integration areas (SIA) depends on the environment in which it is developed, produced and used. The suggested approach also takes into account the existing concept of the EC's Competitiveness Progress Report (CPR), and comprises the three levels:

- **macro-level**, which accounts for the general environment of CET such as general conditions for human resources, monetary, fiscal and trade policies, overall features of the economy and society not directly linked to the energy transition. It does not explicitly focus on the CET but addresses the overall conditions under which CET and SIA are embedded. These comprise for example conditions on the demand side, policy and politics, resources etc.;
- **meso-level,** which includes the supply chain and the areas of intersection/interfaces of the CET with other systems, for example the interfaces between electricity and heat or mobility, between digitalisation and energy transition, and intersection areas (SIA) such as buildings, infrastructure, etc. It refers to the closer environment of CET, namely to their down- and upstream value chain, including the implementation areas of CET and system integration and interactions;
- **micro-level,** which includes specific focus on all aspects that are directly related to CET, including factors that have a specific influence on the competitiveness of the technology e.g. supply with specific materials, skills, i.e. all factors are directly linked to the market success of the technology. Task 3 will partially address this level, at least liaising it with the existing competitiveness assessment, and identifying remaining gaps.

Based on the above outlined drivers of competitiveness, we suggest to group them into the following main areas:

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[4] Delgado, Ketels, Porter, Stern 2012: The determinants of national competitiveness; NBER Working paper 18249; https://www.nber.org/system/files/working_papers/w18249/w18249.pdf

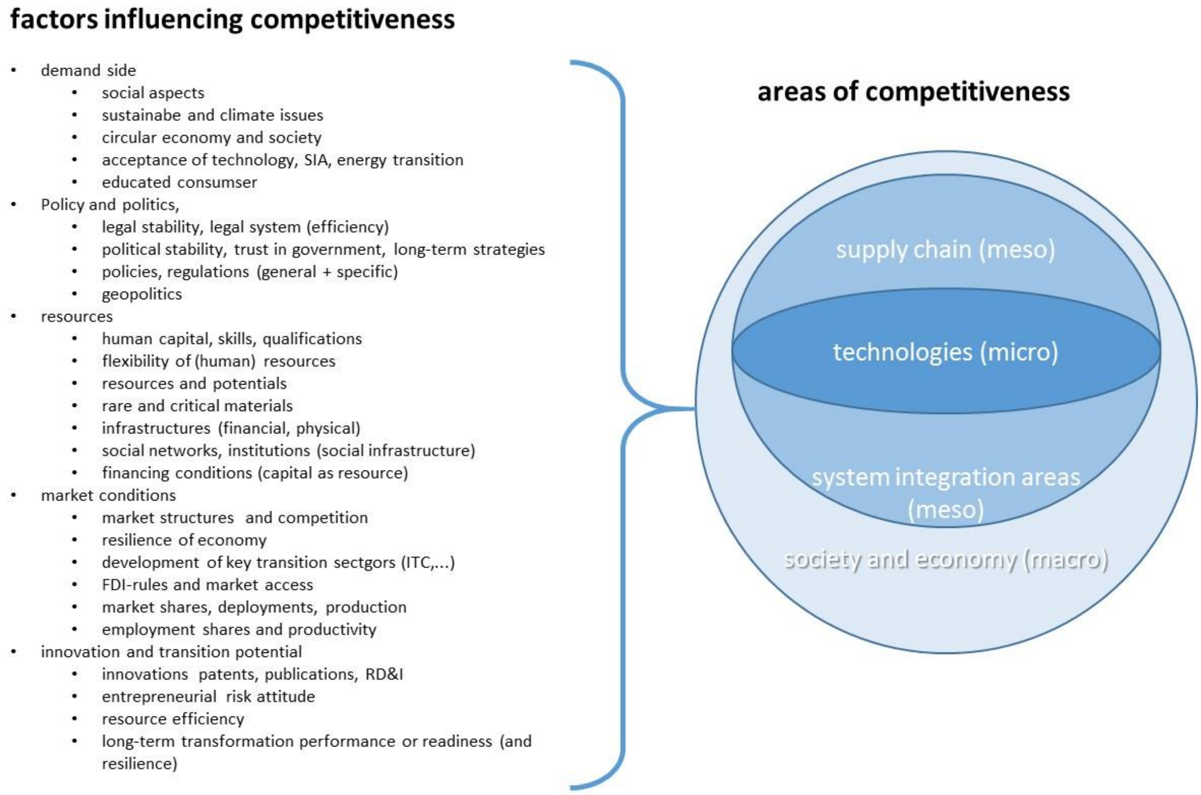
[5] Porter, M.E., Building the Microeconomic Foundations of Prosperity: Findings from the Business Competitiveness Index, in Porter, M.E. et al. (eds), Global Competitiveness Report 2003-2004 of the World Economic Forum

[6] Vlados, Chatzinikolaou, 2020: Macro-meso and micro policies for overview: Optional strengthening entrepreneurship: towards an integrated competitiveness policy; Journal of Business & Economic Policy, Vol 7, No 1, 2020, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3563453

- **demand-side factors**: include on the one hand educated and interested consumers or users that are able to use the technology and suggest potential improvements or adjustments in its design, application and further development regarding e.g. sustainability, circularity and social criteria (like ease of use) or standards, and, on the other hand acceptance of the technology and its accompanying or induced changes (transition).
- **policies and politics**: they set the action framework for companies. Thus, any uncertainty regarding the political system, the reliability of the legal system, mistrust in government, unreliable policies, strategies and target settings, weak governance and institutions increase technology, market and legal risks and value chain costs, hence, they are weakening the competitiveness of companies.
- **resources:** comprise physical and human capital, natural resources and potentials as well as social networks, qualitative, quantitative infrastructure, financial services and products, i.e. all input factors that are relevant for a successful business.
- **markets and economy:** represent the close environment and framework in which some agents, e.g. firms, negotiate and interact with other agents. They comprise market structures at EU and international levels, access rules, access to information, shares and productivity.
- **innovation and transition**: provide new or improved processes, products and organisation in production, reflect the risk attitude, the resource efficiency, the readiness for transformation, the learning curves, cost performance and expectations.

Figure 1 illustrates the factors influencing competitiveness at these three levels. These factors and areas of competitiveness span a matrix, and each cell of this matrix could (but may not) depict potential competitiveness indicators of the respective combination of level and area.

Figure 1: Illustration of the factors affecting competitiveness at the micro-meso-macro perspective



The suggested approach is comprehensive and includes the existing concept, i.e. it integrates the existing indicators and focus areas of the EC's Competitiveness Progress Report on CET. The tables provided in Annex A for 6 SIA represent an elaboration of this approach per category of influencing factors and are supposed to support the identification of the further factors and indicators. For some levels and factor categories, indicators are already included, for others the table should be completed. Having the global view from the micro-level (e.g. technologies already addressed in the CPR) to the macro level (broader considerations than the energy system and its transition), a broad range of indicators and areas is encompassed that include the SIA in Task 3 and macro-level aspects under Task 2, and allows to understand the possible linkages and potential influences between all those factors and areas. In addition, for each area we could briefly screen for technical, economic and financial, social and societal, natural, political, legal, regulatory conditions.

2.3 Preliminary scoping

This task aims to identify all components/elements of the System Integration Area.

The preliminary scoping starts by describing briefly the SIA, and the reason why it should be considered from the System Integration angle. It identifies and describes all possible elements/components it could encompass, and finally conducts a preliminary identification of the interactions between all elements/components.

Its aim is to support the identification of all potential components of the SIA that need to be analysed, considering their system integration. It should be as complete as possible to provide a broad picture of all possibilities.

The following table reflects the process structure for identifying the appropriate elements/ components along the value chain of a concept/application.

Table 1: Elements/components identification table

System Integration Area	Elements to include	Link with usual technology (considered in competitiveness study)	Link with other SIA
Step 1 in value chain (e.g. production)			
Step 2 in value chain (infrastructure)			
Step 3 in value chain (storage)			
Step 4 in value chain (monitoring/ communication)			

Exploratory results for each of the SIA are provided in Annex A. At this stage, it became obvious that it is difficult to clearly delineate SIA 6 from other technologies, because it has a large overlap with other SIAs.

The level of granularity will depend on the size & complexity of each SIA. These elements/components will

- pertain to the different influencing factor areas, e.g. if behaviour is considered as a key influencing factor in the frame of SIA 1 on building, then this should certainly be addressed in the elements/components;
- define, among others, the boundaries of the system through the different interactions, e.g. SIA 3 on DHC could include the interface with the electricity system, as provider of market/auxiliary services;
- categorise the elements/components of the SIA such as natural resources, materials, equipment, services, software, infrastructure, concerned actors, knowledge, skills, need for planning and coordination etc.

2.4 Identify and prioritise SIA enablers

Among the many factors and components, it is necessary to identify and prioritise the most relevant elements to be focused on.

By enabler we understand a component in the SIA which could be a product, equipment, service, technology, regulation, infrastructure, humans (actors) and which has an integration or connection functionality between systems. Enablers should facilitate the deployment of the surrounding or related technologies.

To identify the priority enablers, we address the following research questions:

- Is the enabler significantly contributing to the Fit for 55 package, by facilitating the uptake of a technology or supporting the integration of sectors, and thus making the system more efficient? Is it contributing at short or long-term, avoiding or contributing to lock-in effect (and lead to possible stranded assets)?
- Is EC intervention needed to make the enabler become an actual enabler of system integration? (in other words, identify areas with need for action)

The contribution to the Fit for 55 should remain the main reason for the selection of a SIA, but also for its scoping, to focus on the relevant elements of the system (e.g. addressing smart cities may lead to a very broad set of applications. To select the most appropriate elements, the process should always consider the contribution to the climate agenda).

Per definition, system integration refers to a system which interacts with other systems. As we focus on the energy transition and on clean energy technologies, we could limit our analysis to all interactions of systems or subsets of systems within energy transition.

On a macro-level, enablers are aspects within the main categories that have a strong influence on the competitiveness of an economy.

2.5 Interactions

Based on an analytical framework presented at the IST Conference 2021[7], interactions are defined along the dimensions interfaces of systems, relationships of systems through the interfaces and impacts of relationships.

- Interfaces comprise actors (individual actors such as citizens/households, organisations, businesses, municipalities, or groups and sectors comprising several individual actors), infrastructures (physical, social, financial), intermediate goods (materials, services, …), natural resources, institutions (rules, culture, policies), technology and knowledge (e.g. skills, expertise, know-how).
- Relationships are of competitive, cooperative (beneficial for both systems), integrative (one system relies on the other), spill-over (unintended one-way spill-over) or neutral nature.
- Impacts on systems or systems' components, type, direction and speed of change.

Interactions of subsystems take place within the energy system and between the energy system and other systems e.g. food system, housing system, industrial system and systems might vary by their scope depending on their boundaries. Each SIA is based on an interaction that can be described by the above outlined dimensions, that is the interactions with:

- other energy system components, e.g. DHC as technology (in a broad sense) of the heating sector possibly interacts with the electricity system, the gas and other energy carrier infrastructure;
- other system-integrated areas closely linked, e.g. SIA 1 on buildings & SIA 2 on digital infrastructure may both address the integration of EV charging infrastructure, in the built environment and in the smart infrastructure;
- with systems "outside" the energy system or other sectors where the technology is part of it, e.g. DHC interacts with industry, urban infrastructure, buildings, as it provides heat for production or consumption purposes but requires a network.

Table 2: Matrix to identify interactions of a SIA with subsystems or other sectors

Relationship / Interface	heating and electricity	Digital	E-mobility	construction	….
Actors	Flexibility provider, system responsible, …	Service providers	Automotive industry		

[7] Breitschopf et al. 2022: Understanding inter-system interactions and their impacts, https://www.isi.fraunhofer.de/content/dam/isi/dokumente/sustainability-innovation/2022/Understanding_inter_system_interactions_and_their_impacts.pdf

Relationship / Interface	heating and electricity	Digital	E-mobility	construction	....
Institutions	Electricity market regulation	Data security regulations, …		Construction, energy efficiency standards, spatial planning	
Infrastructure	Electricity grid	Data network and centres	Data network		
Technology, commodity, building	Heating technology	Digital devices	….		
Knowledge	Market experiences, technological				
Natural resources, production factors	Capital				
Intermediate goods and services					

This table only illustrates the building case, and should be adapted to each SIA.

2.6 Define indicators (designing)

Starting from the preliminary scoping of components/elements concerned by the SIA (2.1), developing further from the factors influencing competitiveness (2.2), ensuring throughout all steps the enabling character and alignment with the Fit for 55 agenda (2.3) including their interactions with other system components (2.3.1), this step aims to identify and define the indicators.

For each enabler, a set of indicators are identified (it can be only one) that reveals:

- whether the EU has a competitive advantage in this system integration area? And where does the EU lack competitiveness?

2.7 Data set

This step consists of identifying data sources, collect the data, and produce their analysis.

Some indicators may be usual/common (already covered to assess the progress of technologies), but when correlated with new indicators, they could provide a new perspective regarding the competitiveness of the system integration area.

3 Macro indicators - exploratory results

Based on the above outline on indicators and levels, the following macro indicators are identified and classified into the 5 categories:

- demand side
- policy and politics
- resources
- market conditions
- innovation and transition potential

3.1 Demand side

Social aspects

- Indicator: share of middle & high income households
- Explanation: propensity to consume clean energy technologies
- Source: https://ec.europa.eu/eurostat/documents/276524/10369740/SDG_indicator_2020.pdf

Sustainable and climate issues

- Indicator: Economic Decline Index
- Explanation: Higher decline indicates lower resilience
- Source: https://www.theglobaleconomy.com/rankings/economic_decline_index/

Circular economy and society

- Indicator: solid waste recycling rate
- Explanation: higher recycling rates indicate a higher societal familiarity with recycling technology
- Source: https://www.statista.com/statistics/1052439/rate-of-msw-recycling-worldwide-by-key-country/

Acceptance of technology, SIA, energy transition

- Indicators: share of younger population (18-29) in relation to older population (65+), median age
- Explanation: affinity towards new technology is higher among younger population
- Source: https://www.worlddata.info/average-age.php

Educated consumer

- Indicator: Education Index
- Explanation: educated consumers understand clean energy technology better than uneducated consumers
- Source: https://en.wikipedia.org/wiki/Education_Index

3.2 Policy and Politics

Legal stability, legal system efficiency

- Legal stability: Corruption Perceptions Index
- Source: https://www.theglobaleconomy.com/rankings/transparency_corruption/

- Legal efficiency: public sector employment as of total workforce
- Source: https://govdata360.worldbank.org/indicators/haa733075

Political stability, trust in government, long-term strategies

- Indicator: Political Stability Index
- Source: https://www.theglobaleconomy.com/rankings/wb_political_stability/Europe/, http://info.worldbank.org/governance/wgi/

Policies, regulations

- No indicator

Geopolitics

- Indicator: trade to GDP ratio
- Explanation: higher ratio indicates higher globalization and therefore higher risk to trade disruptions
- Source: https://web.archive.org/web/20201216193141/https://ourworldindata.org/grapher/trade-openness

3.3 Resources

Human capital, skills, qualifications

- Indicator: Human Capital Index
- Source: https://data.worldbank.org/indicator/HD.HCI.OVRL?locations=Z7

Flexibility of (human) resources (e.g. qualification or training indices)

- Indicator: investment in professional development
- Explanation: higher share indicates higher intensity of professional trainings
- Source: https://www.weforum.org/agenda/2021/06/which-countries-are-most-invested-in-professional-develeopment/

Resources and potentials

- Indicator: total natural resources rents
- Explanation: higher rents indicate higher potential by resource exploitation (and less potential for developing alternatives)
- Source: https://data.worldbank.org/indicator/NY.GDP.TOTL.RT.ZS

Rare and critical materials

- Indicator: rare earth production market share among industrial nations
- Explanation: lower production indicates higher dependency
- Source: https://ec.europa.eu/growth/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

Infrastructures (financial, physical)

- Indicator: IMF financial stability spotlight
- Source: https://data.imf.org/?sk=51B096FA-2CD2-40C2-8D09-0699CC1764DA&sId=1411569045760

- https://blogs.imf.org/2022/02/03/countries-in-the-imf-financial-stability-spotlight-in-2022/
- Literature: https://www.die-gdi.de/en/briefing-paper/article/financial-stability-as-a-precondition-for-the-financing-of-sustainable-development-in-emerging-and-developing-countries/

Social networks, institutions (social infrastructure)

- Indicator: worldwide bureaucracy index
- Source: https://www.worldbank.org/en/data/interactive/2019/05/21/worldwide-bureaucracy-indicators-dashboard

Financing conditions (capital as resource) (2 Indicators)

- Indicator: central bank interest rate (in %)
- Explanation: higher rate indicates a more costly credit environment
- Source: https://tradingeconomics.com/country-list/interest-rate
- Indicator: domestic credit to private sector (% of GDP)
- Explanation: higher share indicates a higher availability of credit
- Source: https://data.worldbank.org/indicator/FS.AST.PRVT.GD.ZS

3.4 Market Conditions

Market structures and competition

- No indicators found

Resilience of economy

- Indicator: Economic Decline Index
- Explanation: higher decline indicates lower resilience
- Source: https://www.theglobaleconomy.com/rankings/economic_decline_index/

Development of key transition sectors

- No indicator, since industry level

FDI-rules and market access

- Indicator 1: FDI net inflows by country
- Explanation: higher inflows indicate higher financial investment
- Source: https://data.worldbank.org/indicator/BX.KLT.DINV.CD.WD
- Indicator 2: trade to GDP ratio
- Explanation: measure for trade openness and globalisation (market access)
- Source: https://web.archive.org/web/20201216193141/https://ourworldindata.org/grapher/trade-openness

Market shares

- Indicator: installed renewable energy capacity
- Explanation: higher capacity indicates a higher share of renewable energy
- Source: https://www.eea.europa.eu/ims/share-of-energy-consumption-from

Employment shares and productivity

- Indicator: GDP per hour worked
- Explanation: per capita productivity
- Source: https://data.oecd.org/lprdty/gdp-per-hour-worked.htm

3.5 Innovation and transition potential

Innovation patents, publications, RD&I

- Indicator 1: Global Innovation Index
- Explanation: higher rank indicates higher innovative potential
- Source: https://www.globalinnovationindex.org/Home
- Indicator 2: research and development expenditure, in % of GDP
- Explanation: higher expenditures indicate higher innovative potential
- Source: https://www.theglobaleconomy.com/rankings/Research_and_development/

Entrepreneurial risk attitude

- Indicator: population-adjusted number of start-ups by country
- Explanation: more start-ups per capita indicate a risk-friendly attitude
- Source: https://2020.stateofeuropeantech.com/chart/746-3309

Resource efficiency

- Indicator: resource efficiency
- Source: https://govdata360.worldbank.org/indicators/h62ef0757?country=BRA&indicator=28773&viz=line_chart&years=2006,2020

Long-term transformation performance or readiness (and resilience)

- Indicator: Global Competitiveness Index
- Explanation: higher rank indicates a higher readiness
- Source: https://reports.weforum.org/global-competitiveness-index-2016-2017/competitiveness-rankings/#series=GCI.B.09

4 Outline of SIA indicators

Based on the methodological framework, this chapter identifies three priority enablers for each SIA.

4.1 SIA 1 - Building-related clean energy technologies

Heat pumps (as system component)

- Enabler: correct dimensioning and installation + maintenance of heat pumps (with focus on existing buildings) enables high shares of RES in buildings and an efficient usage of electricity
- Indicator: HP sales/statistics of craftsmen/heating associations

BIPV (as system component)

- Enabler: BIPV is i) a focus from the EPBD proposal of the EC (in form of high shares of on-site RES) and ii) needs to be implemented in existing buildings in order to enable HP with minimal impacts on the electricity grid (energy and peak-load)
- Indicator: BIPV sales (separate from PV sales) and capacity installed

Storage and control system (as enabler for other system components)

- Enabler: storage and intelligent control systems are needed in order to minimise grid impacts (with focus on peak load and energy) of heat pumps in the future. This will be a key requirement to prevent overloading the grid.
- Indicator: sales of storage systems (small and medium size in building context), uptake of BACS (Building Automation Control Systems) in non-residential but also in residential buildings.

4.2 SIA 2 - Digital infrastructure for smart energy systems

Addressing digital technologies that are enablers for system integration as cross-cutting applications, while digital infrastructure, which is directly connected to specific other technologies (e.g. heat pumps, electric cars, etc.), should be directly covered in other SIAs (SIA 1, SIA 3, SIA 4 and SIA 6).

Data management

- Enabler: diffusion of data-driven business models
- Indicator: useful to assess competitiveness for digital infrastructure and gain additional insights: number of start-ups with data-driven business models

Data access/exchange

- Enabler: availability and easy access to energy data could provide the basis for data-driven business models
- Indicator: number and users of platforms for data-based energy services

Control/monitoring

- Enabler: controllability of a large number of small scale generation and demand side assets can substantially improve the integration of these assets into the energy system

- Indicators: Number of HEMS/BEMS installed, number of electric cars with V2G capabilities. Indicators allow the assessment of the diffusion of digital infrastructure technology.

4.3 SIA 3 - Industrial and district heat and cold management

Modern and efficient industrial and district heat and cold management is key for the decarbonisation of the EU economy and can support in adapting operation to the precise (heating and cooling) needs; managing heat recovery and temperature/parameters optimisation in high temperature industrial processes and low temperature DHC; optimising the use of available resources (e.g. RES)[8]; and providing flexibility needs.

Regulatory and policy level

- Enabler: enabling regulatory framework & support for investment in industrial and district heating and cooling (including heat and cold management)
- Indicators: this enabler is very broad, and would need to be defined as several y/n indicators related to e.g. Subsidies for heat pumps, WHR, CHP, H&C networks, large scale heat storage, H/C management hardware and software, reinforcing skills/knowledge, support to integrated sustainable urban development (i.e. aligned policies on buildings, H&C supply and territorial/urban planning)
- Sources: National Energy and Climate Plans[9], National Resilience and Recovery Plans[10], Celsius brochure (2020)[11] – EC support to DHC, waste heat valorisation projects[12]

DHC

- Enabler: efficient and renewables-based DHC
- Share of households connected to DH networks (we could make this more specific e.g. by differentiating between type/generation of DH. It could also be instead related to heat consumption), share of RES in DHC, share of highly efficient DHC, operating DH pipelines
- Sources: IEA – Operating DH pipelines in Europe[13], DH sales by fuel source[14]

Industrial waste heat recovered

- Enabler: deployment of industrial waste heat recovery projects, addressing matching of supply and demand and contractual arrangements
- Indicator: number of pilot and demonstration projects, characteristics from the projects (e.g. recovery efficiency, payback period, barriers and success factors, contract model, scalability and replicability factors)
- Sources: REUSEHEAT, Best practices[15] & Contractual forms and business models[16], scalability and replicability[17]

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8 In many cases, DHC is also the only way to use these resources (e.g. geothermal heat)

9 https://energy.ec.europa.eu/topics/energy-strategy/national-energy-and-climate-plans-necps_en

10 https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en#national-recovery-and-resilience-plans

11 Advancing District Heating & Cooling Solutions and Uptake in European Cities D2.1 Overview of Support Activities and Projects of the European Commission on District Heating & Cooling. https://celsiuscity.eu/wp-content/uploads/2021/09/D2.1-Project-brochure_final3.pdf

12 http://publications.europa.eu/resource/cellar/688097a1-8aee-11ec-8c40-01aa75ed71a1.0001.03/DOC_1

13 https://www.iea.org/data-and-statistics/charts/total-operating-district-heat-pipelines-in-europe-2005-2019

14 https://www.iea.org/data-and-statistics/charts/district-heat-sales-in-europe-by-fuel-source-2000-2019

15 https://www.reuseheat.eu/wp-content/uploads/2018/10/D3.1-Best-practices.pdf

16 https://www.reuseheat.eu/wp-content/uploads/2021/03/D2.3-UPDATED_20210223.pdf

17 https://www.reuseheat.eu/wp-content/uploads/2021/09/D2.9-Scalability-replicability-and-modularity_Final-version_April-2021.pdf

4.4 SIA 4 - Off-grid energy system

Electrolyser integration (grid-connected)

- Enabler 1: further advances in the integration of electrolyser technologies with offshore wind parks and their market adoption as well as pilot projects targeting the integration of large-scale electrolysers in processes and value chains to scale up their (industrial) application
  - Key indicators
    - Capacity of offshore electrolysers installed (planned or installed)
    - Number/size of demonstration and RD&I projects of offshore hydrogen
- Enabler 2: Financing i.e. financial means that are available for investment expenditures
  - Key indicators
    - Share of private equity investments (risky) for new technologies (BNEF)
    - If available (for offshore electrolysis): share of CAPEX support to total investment

Self-generation & consumption (REC, CEC) and contribution to flexible energy systems with a focus on PV

- Enabler 1: smart self-consumption devices (beyond smart meter) to provide flexibility for the electricity system (technology)
  - Number of installed smart meters (as proxy) or controlling/managing devices -> align with SIA 2
- Enabler 2: market maturity for individual or aggregated flexibility services of prosumers
  - Number of contracts with aggregators/DSOs, or volume of aggregators in relation to total self-consumption or PV generation -> source tbd
- Enabler 3: regulatory issues such as requirements in tenders hindering RECs/CECs to participate, or incentives for citizens to participate in REC/CECs.
  - Share of REC/CECs in auctions (submitted and awarded)
  - Minimum size (volume) of participation in REC/CECs; administrative efforts/processes-> sources tbd

4.5 SIA 5 - Transmission- and distribution-related technologies

Regulatory framework supporting deployment of innovative TS and DS technologies

- Enabler justification: this enabling factor is crucial, as the regulatory framework substitutes market signals for the network operators operating in the natural monopoly environment. Regulatory framework should firstly enable the use of innovative technologies, mandate network operators to consider their deployment as an alternative to conventional grid enlargement investments and finally offer incentives or rewards for increasing efficiency in network management (which can be also achieved by deploying innovative technologies).
- The indicators that could be potentially sourced from ACER or CEER publications are:
  - new electricity demand areas (electro-mobility, heating), other energy sectors (NG, hydrogen), prosumers are considered in network planning
  - network planning is required to consider efficiency measures, innovative technologies

- revenue regulation includes efficiency incentives[18]
- revenue regulation includes direct incentives for research and innovation[19]
- deployed regulatory sandboxes for innovative infrastructure
- NECPs/government policies reflected in network planning and future development scenarios[20]
- network development plans existing on DS level[21]
- network development plans are coordinated between TSOs and DSOs[22]

Deployment status of assets requiring innovative approaches to network management

- Enabler justification: the deployment of many of the innovative network technologies reduces the challenge related to the shift from centralised, unidirectional electricity production and transport to a decentralised system with multiple active actors and shifting power flows. The higher the volume of such actors and activities, more sense will it make to deploy innovative technologies.
- The following indicators could point to the need for such technologies in the network:
    - volume of decentralised variable renewable energy generation connected to the distribution grid
    - volume of active consumers/prosumers
    - volume of electric vehicle charging points
    - volume of household electricity heating

Innovative network technology

- Enabler: innovative technologies deployment and human resources and expertise to introduce the innovations
- Indicator: deployment of pilot innovative network technology projects. This indicator should not only track the current level of innovative technologies deployment, but should also partially address one of the main barriers on the network operator side, which is the lack of human resources and expertise to introduce the innovations. The lack of expertise and human resources is particularly relevant on the distribution system level in some EU Member States with multiple smaller DSOs. Pilot projects are aimed at generation operating expertise and finding the right operation and business models. This experience therefore creates environment for more successful innovative technology deployment. The indicators would consider pilot projects that deploy the technologies covered in the scoping exercise, making a distinction between distribution and transmission level. The potential source for this data is however unclear so far. One example could be the ENTSO-E monitoring report on research, development and innovation projects.[23]

4.6 SIA 6 - Smart cities

As the other SIAs start from extra-technological features aiming at system integration, the approach for smart city could be different and follow the perspective of listing areas, in which enabling/supporting measures can be established to be deployed in smart city. In this context, we

[18] https://www.ceer.eu/documents/104400/-/-/8c2aace7-5601-8723-4d45-337073af38d5
[19] ibid
[20] https://documents.acer.europa.eu/Official_documents/Acts_of_the_Agency/Opinions/Opinions/ACER%20Opinion%2005-2021%20on%20the%20electricity%20national%20development%20plans.pdf
[21] ibid
[22] ibid
[23] https://rdmonitoring.entsoe.eu//wp-content/uploads/2019/05/entso-e_RDnI_MR_2019_Main_Report_190510.pdf

understand by smart city a city taking all actions that are required to achieve climate goals on its territory, by engaging all concerned parties.

This approach addresses the capacities a smart city could provide as support:

Capacity to plan, install and operate (political/administrative municipal level)

- Enabler: capacity of the city to develop and employ integrated energy planning
- Indicators: potentially qualifications and trainings of municipal employees

Capacity balancing and combining (technical level/infrastructure)

- Enabler: capacity of the city to develop the required integrated energy infrastructure (electricity grid, district heating, local storage, VE chargers, …) considering all challenges and needs
- Indicators: potentially density of grids, intensity of storage, etc.

Capacity to drive local participation/incentives (awareness, commitment, incentives)

- Enabler: to engage consumers (energy & goods) and citizens, incentives/awareness should be created
- Indicators: number of meetings and information platforms for citizens, potentially number of cooperatives, number of citizens per total population involved in initiatives, energy communities

4.7 SIA 7 - Innovative energy carriers and energy supply for transport needs

Major enablers of the system integration of innovative energy carriers and energy supply for transport needs are not yet addressed in the 2020 and 2021 report on "Progress on competitiveness of clean energy technologies" as listed below. The SIA need to be supported by technological and organisational advances, which improve the technology readiness and therefore decrease investments risks, contribute to scale-up and economies of scale (cost reduction, learning curve, eventually finally lower financial risks again), and by policies (e.g. mandates/subsidies that obligate certain storage/transport volumes, with a long-term view to ensure that projects have a solid long-term business case):

Infrastructure availability for storage, transport and distribution of alternative fuels (scope: alternative fuels (liquid and H_2) for shipping and aviation)

- Indicators:
  - network development plans [km] for **transport and distribution** of alternative fuels
  - network development plans for **storage** of alternative fuels [number]
  - **transport** capacity of alternative fuels installed [PJ/day]
  - **storage** capacity of alternative fuels installed [PJ]
  - number of EU ports/airports equipped with alternative fuel delivery and storage capacity
  - number of workers with qualification to handle hydrogen/ammonia

Adapted engine availability to withstand alternative fuels (scope alternative fuels (liquid and H_2) for shipping and aviation)

- Indicators:
  - number of EU patents for sales of jet engines allowing for > 50% alternative fuel blend

- number of ships (new and retrofit) adapted to the use of alternative fuels (fuel cell, H_2/ammonia storage for fuel cell or direct combustion, biofuel-adapted engine)

Aggregators for the management of vehicle charge and optimisation of vehicle-grid integration (scope EVs)

- Indicators:
    - number of aggregating services/businesses across the EU
    - average yearly revenue per vehicle (and share of OPEX of vehicle)
    - number of EV models with V2G capability

5 Conclusions and next steps

From this preliminary research, we can draw the following main conclusions:

The overall approach analysing competitiveness of CET should differentiate between different levels: the macro-level that encompasses rather general aspects of a nations' competitiveness, such as education and qualification of workers and employees, reliability and efficiency of legal systems, and thus, has an indirect impact on the CET as well. The meso-level encompassing the surroundings or environment of a CET, including the supply chain and system integration, and the micro-level with a focus on the technology as element of a system.

Addressing the competitiveness of system integration areas, we identified several challenges, calling for a clear definition and delineation of system integration areas. These challenges are:

- SIA or enablers remain highly complex, as SIA comprises an important number of potential components, highly interconnected and not always representing a system[24];
- narrowing down to identify the most relevant components to focus on, requires many iterations, with a clear understanding of their impact (on the climate transition, on the uptake of different technologies or low carbon solutions);
- some of the SIAs where encompassing too many concepts or applications (e.g. off-grid and smart cities), while others were so narrow that they were almost associated to technology supply chain components;
- the “enabling” character of these SIAs and their components should be streamlined to continuously remind the main goal of this competitiveness analysis.

Regarding the macro-level indicators, we suggest to create a set of indicators for each of the main categories of factors. They provide an insight into the general competitiveness of an economy with a slight focus on CET. In this phase of the study, the final macro-level analysis is not conducted.

To conclude, we recommend to set up a joint workgroup with DG ENER, JRC and EnTEC to identify, delineate and select SIA in a joint process as the identification of the system borders and components of the suggested SIA has proved to be very complex. Further, the suggested indicators at the macro-level should also be discussed. This workgroup could then define the terms of reference for an in-depth study.

[24] Socio-technical system is understood as a set of components (institutions, actors, technologies…) embedded in a technological context and social networks, which together fulfil a societal function, such as the energy system providing heat for certain purposes with specific technologies.

A.1 Annex 1 - Preliminary Scoping and Influencing Factors

A.1.1 SIA 1 - Building-related clean energy technologies

A.1.1.1 Preliminary scoping

The scope of the SIA 1 is on heating and cooling systems and sector-coupling technologies (heat pumps/hybrid heat pumps) and other energy consumption elements as well as on-site renewable energy generation (building integrated solar PV and solar thermal). In addition, a possible expansion could also cover building envelope and electric vehicle charging if time and budget allows.

In addition, the scope has synergies and overlaps with the following CETO areas:

- Heat pumps (CETO 2022)
- Photovoltaics (CETO 2022)
- Batteries (CETO 2022)

Therefore, the analysis should provide new and additional knowledge to the ongoing CETO and CPR activities, mainly in the fields of Buildings Automation and Control Systems (BACS), energy flexibility solutions, grid integration with the focus revolving around overall system integration. In addition to synergies with CETO and CPR, this SIA synergies and overlaps with other SIA's namely SIA 2 ''Digital infrastructure for smart energy system'' under home energy management systems.

Tables 3 and 4 provide a scoping overview of the addressed elements in this SIA.

Table 3: Elements to include

SIA 1	Elements	Link with CET	Link with other SIA
HVAC systems	Heat pumps + Hybrid heat pumps BACS (load-shifting/demand response/ price demand + grid flex)	Heat pumps covered in 2022 CETO	Home energy management system (SIA 2)
Other energy consumption	Energy-efficient lighting		
On-site generation	PV (incl. battery?) => focus on BIPV	Photovoltaics & batteries covered in 2022 CETO	

Table 4: Optional elements - TBD

SIA 1	Elements	Link with CET	Link with other SIA
Building Shell	Energy Efficiency of building shell Thermal inertia/storage Solar shading of windows Low temperature heating systems to enable heat pumps		

SIA 1	Elements	Link with CET	Link with other SIA
EVs	EL charging incl. battery (out of building scope?)	Batteries covered in 2022 CETO	
On-site generation	Solar-thermal		

A.1.1.2 Influencing factors

Table 5: Overview demand side

Demand side	Meso/Micro level	Potential Indicators
Social aspects	Investment costs are higher than gas boilers	
Sustainable and climate issues	Energy efficiency improvements are needed for heat pumps (higher COPs esp. at low temperatures), climate friendly refrigerant (such as R290: propane) are needed to minimize GWP through leakages of systems	
Circular economy and society	Production capacity (a ramp-up is needed), considering the embodied energy/GHG-emissions of manufacturing	
Acceptance of technology	Acceptance of HP, BIPV and Co. (noise, energy costs, etc.)	
Educated consumer	Ability to remotely control/maintain the heat pump/ PV/ storage and control system	

Table 6: Topics for indicators: Technology penetration rate (e.g. share of households with HP systems), compatibility with current infrastructure, investment costs, Efficiencies of systems (COPs), typical leakages of systems, noise levels of air heat-pumps

Policies and politics	Meso level	Micro level
Legal stability and efficiency of system	Enforcement/ implementation deficits to be minimised, laws/rules need to be followed	
Long-term strategies	Mid- and long-term targets set, share of building sector for decarbonisation compared to power sector reduction targets	

Policies and politics	Meso level	Micro level
Policies and regulations	Enabling framework and financial incentives needed for private investments	
Geopolitics	Energy import dependency (prio1: gas, also oil and coal), re	

Table 7: Topics for indicators: Renewable energy in buildings targets, emissions reduction targets, enabling regulatory framework, energy mix and import dependency rates + targets

Resources	Meso level	Micro level
Human capital, skills, qualifications	Focus on energy advisors (for planning and issuing EPCs) and craftsmen to install all the systems	
Flexibility of HR	Qualification and life-long education needed	
Resources and potentials	Economies of scale: Heat-pump and BIPV prices should drop in price in case a mass-market is established	
Rare and critical materials	Computer chips and heat-pump components imports/exports to/from EU	
Infrastructure (financial, physical)	Electricity infrastructure (transmission and distribution) as well as generation capacity is crucial, especially in critical windless winter week with heat pump demand peak	
Social networks, institutions	See educations and HR	
Financing conditions	Financing of relatively high investments in heat-pumps and BIPV needs to be very easy => low entry barrier	

Table 8: Topics for indicators: Human capital (number of skilled installers, renovation experts, graduates), heat-pump prices, imports/exports of chips and heat pump elements, generation and transmission/distribution capacity

Markets and economy	Meso level	Micro level
Market structure and competition	Average installer firm size, e.g. number of firms with >10 employees	
Resilience of economy		
Development of key transition pathways	Positive or rather negative opinion within installation firms on growing/high heat-pump shares in existing buildings?	
Market access	Qualifications needed to enter market	
Market shares, productivity	Market shares per manufacturer of heat pumps, BIPV and BACS installed	
Employment shares and productivity	Employment figures in production within EU and for installation of technology	

Table 9: Topics for indicators: emerging markets (annual growth or market share), surveys within installer companies

Innovation and transition	Meso level	Micro level
Innovation patents, publications, RD&I	Number of patents and publications, investments in R&D	
Entrepreneurial risks attitude	Risk capital given to the market	
Resource efficiency	Energy/GHG/material input e.g. per kW of heat-pump output (kW of system power)	
Long-term transformation performance	Ability to adapt to market needs and developments	

A.1.1.3 Enabler and contribution to Fit for 55 package

The building sector plays a significant role in the decarbonisation of the EU economy and energy sector, as it currently accounts for 40% of the total energy consumption and 36% of the total energy-related greenhouse gas emissions. Decarbonising the building sector is a complex process and requires significant actions on the technology side as well as the current policy and regulatory framework. This SIA contributes to the fulfilment of the FIT for 55 targets, goals and aims of decarbonising the buildings sectors; for instance, the focus on BIPV, solar thermal as well as heat pumps contributes to the achievement of the renewables in buildings benchmarks and the increased use of renewables for heating and cooling purposes.

Sector coupling elements are a critical success factor for the decarbonisation of the built environment, as heat pumps will be the core element of heating buildings in Europe. They need to be integrated properly in existing buildings also with on-site PV and BACS but also with hybrid heat pumps (also using gas/H_2 in condensing boilers to supply peak loads). Energy storage on-site (batteries) also represent an important element to enable high shares of heat pumps and avoid extreme peaks in the electricity generation and transmission/distribution. Therefore, all systems need to be integrated and, as a consequence, have minimal impact on the electricity grid. Communication of buildings HVAC and BACS systems with the grid is essential to be able to balance regional renewable electricity generation and consumption.

A.1.2 SIA 2 - Digital infrastructure for smart energy system

A.1.2.1 Preliminary scoping

The focus for this SIA is to address digital technologies that are enablers for system integration as cross-cutting applications. Digital infrastructure that is directly connected to specific other technologies (e.g. heat pumps, electric cars, etc.) should be directly covered in other SIA (SIA 1, SIA 3, SIA 4 and SIA 6).

The scope encompasses enabling technologies and infrastructures facilitating data access and data exchange across the energy system by integrating smart meters, home energy management systems, smart charging and V2G as well as smart heating.

In the assessment and analyses, we will identify enabling conditions to support system integration and allow innovations to reach the Fit for 55 goals. Underlying technologies and stakeholders should be identified to monitor the competitiveness of EU industries in this area. Core elements of this study are therefore upcoming solutions for data economies and related platforms that can build the nucleus of a digital energy ecosystem. Core fields to be analysed are flexibility provision to the energy system and optimised operation of energy assets and network infrastructure.

The analysis should provide new and additional knowledge to ongoing CETO and CPR activities, mainly in the field of extended data usage and related business opportunities. This covers new service-oriented business models (e.g. charging as a service, heating as a service, etc.) as well as extended data exchange between stakeholders in sectors within and outside the energy industry. If needed, new indicators to assess current competitiveness in this field are suggested, for example participation and usage of platforms or ecosystems, amount of data shared or others.

Table 10: Scoping overview: element to include

SIA 2	Elements to include	Link with CET	Link with other SIA
Data access/exchange	Data spaces Cloud solutions	non	Buildings (SIA 1), Heating & Cooling (SIA 3), Prosumers (SIA 4), Smart Cities (SIA 6)
Control, Monitoring	V2G components	Electric vehicles	Buildings (SIA 1), Heating & Cooling (SIA 3), Prosumers (SIA 4), Smart Cities (SIA 6)
Data management	Virtual power plants, Operational management platforms	Asset performance management and IOT devices (CETO)	Buildings (SIA 1), Heating & Cooling (SIA 3), Prosumers (SIA 4), Smart Cities (SIA 6)

Table 11: Scoping overview: optional elements

SIA 2	Elements to include	Link with CET	Link with other SIA
Energy management	Update to HEMS/BEMS, Smart Meter to be discussed	HEMS/BEMS, Smart Meter Software, Services, Platforms (CETO and CPR)	Buildings (SIA 1), Heating & Cooling (SIA 3), Prosumers (SIA 4), Smart Cities (SIA 6)
Grid management	Update to CEPO on DERMS, ADMS, VPP to be discussed	DERMS, ADMS, VPP (CEPO)	Buildings (SIA 1), Heating & Cooling (SIA 3), Prosumers (SIA 4), Smart Cities (SIA 6)
Smart Grids	Update to CPR to be discussed	distribution grid automation, smart metering, Home Energy Management Systems and smart EV charging	Transmission and distribution (SIA 5)

A.1.2.2 Influencing factors

Main Factors influencing Competitiveness of digital infrastructures:

- **Digital and data policy:** Overarching policy with regard to digitalisation and implementation of underlying communication technology plays a crucial role. Furthermore, the availability of data as well as the conditions for the usage of data is strongly dependent on government policies. Policies address digital strategies in general, but also specific policies with regard to data usage, data governance and data protection policies.
- **IT and data security:** Another highly influential factor are IT and data security requirements that are defined by policy actors and standardization bodies.
- **Energy and environmental impact:** Digital infrastructure itself consumes energy and causes other environmental impacts e.g. via using materials and resources. These direct impacts resulting from the usage of the technology must be offset or compensated via enabling positive environmental impacts in the energy system. Low direct environmental impacts of digital infrastructures increase competitiveness of the technology.
- **Investment and costs:** Additional investment in digital infrastructure must be compensated by cost savings in the energy system to make the technology profitable.
- **Skills:** The usage of digital infrastructures and the implementation of related business models increases complexity and interactions between stakeholders. Digital skills to handle data needs, underlying processes and data analytics and algorithms are needed.

Table 12: Defining indicators for digital infrastructures

Demand side	Factor	SIA 2/potential indicators
Social aspects	Investment costs are high	Investment costs
Sustainability and climate issues	High energy and resource use	Energy and resource efficiency
Circular economy and society	Not interoperable and compatible with future needs	Interoperability, future proof (update ready)

Demand side	Factor	SIA 2/potential indicators
Acceptance of technology	Installation of infrastructure and provision of data by users	Share of users; penetration rate
Educated consumer	Understanding of energy markets	Active market participants
Indicators: number of controllable devices, participants on digital platforms, customers providing data, investment costs, service fees		

Policies	Factor	SIA 2/potential indicators
Legal stability and efficiency of system	Address implementation deficits	Monitor implementation deficits
Long-term strategies	Goal setting for availability of digital infrastructure	Technology installed
Policies and regulations	Requirements to allow remote monitoring and control, Support for ICT investments, Consideration of digital infrastructure in incentive regulation for grid operators	Enabling regulatory framework & support for investment, Grid regulation
Geopolitics	Availability of digital technologies (microchips, semiconductors), AI technologies	Market share, number of companies
Indicators: monitor implementation numbers and barriers for digital infrastructure		

Resources	Factor	SIA 2/potential indicators
Human capital, skills, qualifications	IT and data specialist are available	Number of skilled/certified IT and data specialists
Flexibility of HR		
Resources and potentials	Data availability, scalability of platforms	Number of platforms, market places
Rare and critical materials	Microchips, semiconductors, AI technology,	Imports/exports of chips and components
Infrastructure (financial, physical)	infrastructure in place (smart meters, HEMS, BEMS, DERMS, ADMS)	Diffusion of digital infrastructure (market size, turnover)
Social networks, institutions		RDI, EU/national networks
Financing conditions	Sufficient incentives, cost recognition	Eligibility & access to loans/funding
Indicators: available market places, platforms, market size and turnover for digital infrastructure		

Markets and economy	Factor	SIA 2/potential indicators
Market structure and competition	Several actors are active to set up digital infrastructure	Number and size of companies
Resilience of economy	Broad implementation across several actors	
Development of key transition pathways	Transformation strategies and roadmaps are developed	Monitor key factors for transformation pathway e.g. ICT skills
Market access		
Market shares, productivity	New emerging business models and markets	Growth/Market shares per business model
Employment shares and productivity		Employment figures within EU for installation/operation
Indicators: emerging business models and participants, e.g. on data driven platforms		

Innovation and transition	Factor	SIA 2/potential indicators
Innovation patents, publications, RD&I		Number of patents and publications, investments in R&D
Entrepreneurial risks attitude	Start-up ecosystem	Number of start-ups
Resource efficiency	Energy and resource demand of digital infrastructure	Specific energy/resource consumption related to number of users
Long-term transformation performance		
Indicators: number of start-ups		

A.1.2.3 Enabler and contribution to Fit for 55 package

Digital infrastructure can contribute to the energy and climate transition via support of an increased energy efficiency and an easier electrification of several energy demand sectors (e.g. transport, mobility, buildings or process heat). Furthermore, digital infrastructure provides the basis for a flexible operation of the energy system and an increased utilization of energy infrastructure.

Specifically, digital infrastructure can support and enable the energy transformation in the following ways:

- provide the needed information and data to optimise decision making for investment in energy assets and energy infrastructure (e.g. charging infrastructure);
- foresee and optimise efficient ways to operate energy generation and energy demand applications
- identify, control and coordinate several applications to provide flexibility for the energy system
- optimise the usage of energy infrastructures by avoiding congestions and coordinate priorities for users
- enables easy usage and access to energy markets to increase end customer participation

To successfully use digital infrastructure for the energy transformation, the following steps and activities are needed:

- low cost and secure sensors, communication and control technologies.
- easy access and availability of information on the energy system and underlying data.
- standardised frameworks to collect and share information across several stakeholders.
- regulations to make information and data publicly available.
- framework conditions and market incentives to respond to energy system needs and provide tailored services to different stakeholders and end-customers.

A.1.3 SIA 3 - Industrial and District Heat and Cold management

A.1.3.1 Preliminary scoping

This strategic integration area should cover the **management** or handling of large volumes of heat and cold flows from the recovery/production of heat (heating sources), to its end use (heating needs). This spans over different dimensions:

- **temperature**: ranging from ambient – for district heating, to high temperature – for industry, heat production
- **quantity**: Focused on large volumes of heat, for industry or DH
- **temporal**: ranging from intra-day to seasonal storage
- **integration** of the heat and power sectors (storage, CHP and heat pumps are key here)

The focus for this SIA is to address the use of the different technologies in a heat system, connecting the different elements.

Table 13: Scoping overview: element to include

SIA 3	Elements to include	Link with CET	Link with other SIAs
H&C production (focus on the interface with the DHC)	Large HP (H&C) WHR equipment (e.g. from data centre, industry) CHP (focus on gas, but H_2, biogas, biofuels could be considered)	HP buildings & industry NA NA	SIA 1 (building heat demand & HP)
H/C transport Infrastructure	Pipes & insulation (for 4th and 5th G heat networks), pumps Heat exchangers (demand side)	NA NA	SIA 5 (CHP connexion to electricity grid)
Storage	Large scale (ID to seasonal)	Other storage Novel storage for electricity & heat (in CETO from 2023 onwards)	
Monitoring/communication	Hardware to manage H/C fluxes (temperature, quantity and temporality) for production, distribution and demand (like meters, control system, wires, …)	NA	SIA 2 (data management)

Table 14: Scoping overview: optional elements

SIA 3	Elements to include	Link with CET	Link with other SIAs
H&C production	Bioenergy CHP Solar heat Direct geothermal heat	Bioenergy (biomass, biogas) and Advanced biofuels Concentrated Solar Power and Heat Geothermal heat (Scope to be finalised for CETO)	
Infrastructure	/		
Storage	Middle size storage	Novel storage for electricity & heat (in CETO from 2023 onwards)	
Monitoring/communication			

A.1.3.2 Influencing factors

Factors influencing Competitiveness of Industrial and District Heat & Cold Management:

- **Government policy:** Carbon neutrality targets, coal phase-out, feed-in tariffs, disconnection from gas network, NZEB support, integrated territorial/urban policy and planning
- **Government support for investment:** Subsidies for heat pumps, WHR, CHP, H&C networks, large scale heat storage, H/C management hardware and software, reinforcing skills/knowledge, support to integrated sustainable urban development
- **Investment costs & pay-back period:** Influence of outside/required temperature in HP performance
- **Heat generation costs & predictability**
- **Demand:** Secure demand (contracts before construction, prices)
- **Supply:** Secure supply for biogas/biomass (feedstock), depends on geography (solar thermal)
- **Skills:** Large scale systems and their integration in complex industrial and district systems, especially for 5th generation DHC where heat/cold management is the main parameter
- **Infrastructure:** DH infrastructure availability, potential extensions and improvements to existing DHC networks, integration of new sources (WHR or RES) to replace incumbent fossil fuels, installation of new infrastructure (new areas)

Table 15: Defining indicators for Industrial and District Heat & Cold Management

Demand side	Factor	SIA 3/potential indicators
Social aspects	Investment costs are high	Investment costs
Sustainable and climate issues	Efficiency improvements of DHC (from 1st generation to 4th/5th) and WHR	Efficiencies of systems (COPs)
Circular economy and society		Compatibility with current infrastructure

Demand side	Factor	SIA 3/potential indicators
Acceptance of technology	Acceptance regarding DHC and WHR	Share of users; penetration rate
Educated consumer	Education regarding DHC and WHR	

Policies	Factor	SIA 3/potential indicators
Legal stability and efficiency of system		
Long-term strategies	Carbon neutrality targets, coal phase-out, disconnection from gas network, NZEB targets, integrated territorial/urban policy and planning	H&C targets; Emissions reduction targets; Coal phase-out
Policies and regulations	Subsidies for heat pumps, WHR, CHP, H&C networks, large scale heat storage, H/C management hardware and software, reinforcing skills/knowledge, support to integrated sustainable urban development	Enabling regulatory framework & support for investment.
Geopolitics	Energy import dependency (gas)	Energy mix and import dependency rates + targets

Resources	Factor	SIA 3/potential indicators
Human capital, skills, qualifications	Large scale systems and their integration in complex industrial and district systems., especially for 5th generation DHC where heat/cold management is the main parameter	Number of skilled/certified installers/operators
Flexibility of HR		
Resources and potentials		Training centres, certifications and recognitions
Rare and critical materials	Computer chips and heat-pump components imports/exports to/from EU	Imports/exports of chips and components
Infrastructure (financial, physical)	DH infrastructure availability, potential extensions and improvements to existing DHC networks, integration of new sources (WHR or RES) to replace incumbent fossil fuels,	Pipes & insulation for 4/5th G heat networks Eligibility & access to loans/funding

Resources	Factor	SIA 3/potential indicators
	installation of new infrastructure (new areas)	
Social networks, institutions		RDI, EU/national networks
Financing conditions		

Markets and economy	Factor	SIA 3/potential indicators
Market structure and competition		
Resilience of economy		
Development of key transition pathways		ICT skills
Market access		
Market shares, productivity	New emerging markets	Growth/Market shares per manufacturer
Employment shares and productivity		Employment figures within EU for installation/operation

Innovation and transition	Factor	SIA 3/potential indicators
Innovation patents, publications, RD&I		Number of patents and publications, investments in R&D
Entrepreneurial risks attitude		
Resource efficiency		
Long-term transformation performance		

A.1.3.3 Enabler and contribution to Fit for 55 package

The H&C sector will play a key role in the decarbonisation of the EU economy and the energy and climate transition, as identified by the Energy System Integration Strategy, the Renovation Wave Initiative and the 2030 Target Plan. DHC represents today ~10-12% of total heat supply in EU, though some studies estimate it could cover up to 50%. However, H&C decarbonisation is particularly complex given the need to link together energy sources, energy carriers, infrastructure, the characteristics and patterns of demand and technologies. This is particularly the case for DHC, which is at the center of the energy system, interfacing with electricity, gas, buildings, and industry. Therefore, modern and efficient industrial and district heat and cold management is key, and can support in:

- adapting operations to the precise (heating and cooling) needs;
- managing heat recovery and temperature/parameters optimization in high temperature industrial processes and low temperature DHC;

- optimising the use of available resources (e.g. RES)[25];
- providing flexibility needs.

In order for industrial and district heat and cold management to play these roles, several aspects need to be addressed to successfully enable their deployment. In particular:

- improving the performance of existing DHC stock (from 1st generation – with large losses - to 4th or 5th generation at low temperature levels), putting in place the necessary hardware and software;
- aligning policies on buildings, H&C supply and territorial/urban planning;
- developing the necessary skills and knowledge to support this;
- generating awareness and acceptance towards DHC and WHR.

A.1.3.4 Relevant references

- EC (2020), Strategy on Energy System Integration[26]
- Heat Roadmap Europe[27] including Guidelines For Policy Makers To Facilitate The Integration Of Low-Temperature Renewables In District Energy Systems[28]
- EC (forthcoming), H&C decarbonisation roadmap (*ongoing project – draft report internally available)*
- EC (2017), Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables). Work Package 3: Scenarios for heating & cooling demand and supply until 2020 and 2030 & Work package 4: Economic Analysis[29]
- IRENA (2020), Renewable Energy Policies in a Time of Transition: Heating and Cooling[30]
- RHC (2020), Strategic Research and Innovation Agenda for Climate-Neutral Heating and Cooling in Europe[31]
- Eurocities (2019), Cities Leading the Way on Climate Action[32]
- Scottish Futures Trust (2018), Guidance on the development of Heat Supply Agreements for District Heating schemes[33]
- CERRE (2021), Data centres & the grid – Greening ICT in Europe[34]
- COWI, CEPS (2019), Competitiveness of the heating and cooling industry and services

[25] In many cases, DHC is also the only way to use these resources (e.g. geothermal heat)
[26] https://ec.europa.eu/energy/sites/ener/files/energy_system_integration_strategy_.pdf
[27] https://heatroadmap.eu/
[28] https://heatroadmap.eu/guidelines-for-policy-makers-to-facilitate-the-integration-of-low-temperature-renewables-in-district-energy-systems/
[29] https://ec.europa.eu/energy/sites/default/files/documents/mapping-hc-final_report-wp3-wp4.pdf
[30] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Nov/IRENA_IEA_REN21_Policies_Heating_Cooling_2020.pd
[31] https://www.rhc-platform.org/content/uploads/2020/10/RHC-ETIP-SRIA-2020-WEB.pdf
[32] https://eurocities.eu/wp-content/uploads/2020/08/EUROCITIES_cities_climate_action_2019-1.pdf
[33] https://www.districtheatingscotland.com/wp-content/uploads/2018/02/HSA-guidance-final-Feb-18.pdf
[34] https://cerre.eu/wp-content/uploads/2021/10/211013_CERRE_Report_Data-Centres-Greening-ICT_FINAL.pdf

A.1.4 SIA 4 - Off-grid energy systems

A.1.4.1 Preliminary scoping

The system integration area (SIA) 4 encompasses the following dimensions:

- offshore renewables not connected to the grid producing hydrogen or derivates
- energy self-generation and self-consumption, i.e. prosumers - feeding in the remaining energy (connected to the grid)

Offshore renewables not connected to the grid producing hydrogen or derivates

As for the first dimension, the scope suggested is to focus on renewable offshore assets, i.e. offshore wind parks, not connected to the grid producing hydrogen. To ensure complementarity with SIA 7 on Innovative energy carriers and energy supply for transport needs, the emphasis is put on the upstream (production) rather than downstream (distribution, delivery, final use) part of this specific hydrogen value chain which has potential to enable the generation of green hydrogen at scale achieving competitive levelised costs of hydrogen (LCOH). The focus is not on hydrogen derivates, such as ammonia or methanol, to keep the scope of the study manageable.

In terms of infrastructure and equipment, the analysis will look at suitable offshore electrolyser deployment and integration options, namely platform/island solutions and integration of electrolysers in the wind farm towers itself. Another significant element concerns the treatment and desalination of sea water which has to be ensured via dedicated filtering and desalination process steps (with direct sea water electrolysis still being at rather low technology readiness levels).

Synergies with the following CETO and CPR areas have been detected:

- offshore renewables - wind
- renewable hydrogen production through electrolysis

Energy self-generation and self-consumption

As for the second dimension on energy prosumption, the focus is on self-consumers in the form of households and commercial/industry actors and their market/system integration. Emphasis is put on integrated PV solutions for buildings (private/residential, commercial (offices, stores, etc.) or industrial (factory or warehouse). Public buildings (administration, school/university campuses, hospitals, etc.) are left out as the main integration issues can be expected to be similar. As renewable energy self-generation and consumption have triggered the design and deployment of smart solutions for storage, balancing and demand/response planning as well as new business models, SIA 4 will look at their ability to foster system integration. On the regulatory side, questions in focus of the study shall be the market integration of self-consumption and barriers to it as well as the design of applicable legal frameworks.

This SIA does not focus on off-grid solutions (micro-grids) and other self-sufficiency concepts for remote areas, such as islands, due to their limited contribution to the Fit for 55 package in the EU.

Synergies with the following CET areas have been detected:

- batteries
- novel electricity and heat storage technologies
- photovoltaics
- smart grids (distribution grid automation, smart metering, home energy management systems and smart EV charging)

Table 16: Elements to include – offshore renewables not connected to the grid producing H_2 or derivates and offshore in general (with the more complicated grid connection)

SIA 4	Elements to include	Link with CET	Link with other SIA
Power-to-gas/power-to-X technologies	Green hydrogen production	Renewable hydrogen production through electrolysis (CPR and CETO)	SIA 7: Innovative energy carriers and energy supply for transport needs
Infrastructure and equipment	Electrolyser integration (platform/island solutions, integrated solutions) Seawater treatment plants, esp. desalination		
Supply chain (value chain) actors	Wind farm developers and operators Electrolysers Relevant R&D projects/efforts	Offshore renewables - wind (CPR and CETO)	

Table 17: Elements to include – Energy Prosumption (feeding in the remaining energy, connected to the grid)

SIA 4	Elements to include	Link with CET	Link with other SIA
Prosumer types	Households Commercial sector and industry		
Regulatory frameworks	Legal frameworks (definition of prosumers) Market integration (Fees, levies, taxes)		
Building integration	Building-integrated PV	Photovoltaics (CETO)	SIA 1: Building-related clean energy technologies (SIA 6: Smart Cities)
Smart (grid) technologies and appliances	Smart metering and smart consumption and usage Dynamic demand/response planning	Smart grids (distribution grid automation, smart metering, Home Energy Management Systems and smart EV charging) (CPR)	SIA 2: Digital infrastructure for smart energy system
Business models/ value chains	Flexibility: storage (long-term or short-term, via batteries or electric vehicles) and balancing (shift load, react to prices) Consumption (self-consumption, feeding of remaining energy back to grid)	Batteries (CETO) Novel Electricity and Heat Storage technologies (CETO)	

A.1.4.2 Influencing factors

Matrices of influencing factors and levels of competitiveness "Offshore renewables not connected to the grid producing hydrogen or derivate"

Demand side	**Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition**	
	value chain	**SIA**
Social aspects	networks of value chain actors	sector agreements and partnerships with other countries, e.g. via cross-border cooperation using the available mechanisms under RED II
Sustainability and climate issues	Industry regulations, standards and practices	EU Climate and Energy policy, Fit for 55, RED II, etc. National legislation and regulation
Demand, acceptance of SIA		
Educated consumer		Industrial consumers

Policy and politics	**Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition**	
	value chain	**SIA**
Legal stability, legal system, efficiency of the legal system		Coherence between long-term policy and “technology options” framework
Political stability, trust in government, long-term strategies/policies	Long-term industry development plans and strategies (influencing investor perspectives)	
Policies and regulations	Industry regulations, standards and practices	EU Climate and Energy policy, Fit for 55, RED II, etc. National legislation and regulation
Geopolitics	Competition over resources, e.g. rare, critical materials needed	Geopolitical rivalries over strategic deployment areas for offshore wind or alternative deployment options Energy commodity prices

Resources	**Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition**	
	value chain	**SIA**
Human capital, qualifications	Share of graduates in engineering, ICT, energy market services, installers, etc.	

Resources	Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition	
Flexibility of resources (human capital)	Diffusion of work force within the value chain, movements between companies	Reskilling, capacity built from other activities/sectors
Resources and potentials	Training centers, certification and recognition	Training and certification options along the value chain
Raw and critical materials	platinum, iridium, titanium, scandium, yttrium (depending on electrolysis type)	
Infrastructures: physical and financing	Offshore platforms & technologies (bottom-fixed, floating), sensors, pipelines, terminals, … Eligibility and access to loans, funding, guarantees, …	Re-use/repurposing of assets and infrastructure, e.g. natural gas pipelines, storage systems, compressors, … Eligibility and access to loans, funding, guarantees, …
(Social) networks and institutions	Value-chain specific national & EU networks, RD&I	National & EU networks, RD&I, along the supply chain

Market & economy	Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition	
	value chain	**SIA**
Market structures and competition, new emerging markets	number of companies in the supply chain	new/emerging markets or areas (growth, share)
Resilience of economy	contributes to local/regional activity	
Development of key transition sectors (use or share of ITC/digitalisation)	digital monitoring, diagnosis and surveillance (failure management), digital twins	
FDI rules, market access	manage EU added value - cross-border cooperation	
Market shares/ deployments/ production	turnover, GVA growth, production shares	
Employment shares and productivity	employment , labour productivity	

Innovation & transition	**Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition**	
	value chain	**SIA**
Innovations (patents, publications, RD&I)	innovative projects & RD&I	Offshore electrolyser systems and advances in integration (offshore platforms, in-turbine), digital solutions Innovative projects & RD&I
Entrepreneurial risk attitude	number of spin-offs and start-ups in the supply chain	
Long-term transformation performance/ readiness	upgrade of infrastructure and broadening access to ICT	
Resilience	production drops/declines in times of shock Ability to harness existing assets to their full potential Ability to substitute for critical inputs	
Efficiency	energy intensity, resource efficiency of sectors or supply chains	

Matrices of influencing factors and levels of competitiveness "Energy self-generation and self-consumption"

Demand side	**Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition**	
	value chain	**SIA**
Social aspects	Networks of citizens and consumers, buildings and other "sectorial" associations	Networks of prosumers
Sustainability and climate issues	Electricity market regulations, regulation on H&C	Legislation and regulation on prosumerism, incl. support instruments and incentives
Circularity	Reuse, recycling and dismantling practices and regulations in the electricity sector and H&C	
Demand, acceptance of SIA	Social acceptance and interest in self-consumption and self-generation	
Educated consumer	Households, companies, industry, public sector	Individual prosumers Energy communities

Policy and politics	**Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition**	
	value chain	**SIA**
Legal stability, legal system, efficiency of the legal system	Coherence between long-term policy and "technology options" framework	Changes (and frequency thereof) in framework and regulations for self-consumption (long-term stability of legal framework

Policy and politics	**Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition**	
		conditions, e.g. feed-in tariffs, taxation, fees and levies)
Political stability, trust in government, long-term strategies/policies	Long-term electricity and H&C market regulation, strategies and targets	Targets for self-consumption
Policies and regulations	Electricity and H&C market regulation, strategies and targets	Policies and regulations incentivising self-consumption, support schemes
Geopolitics	Energy commodity prices, retail prices	Energy commodity prices - high electricity prices inducing self-consumption

Resources	**Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition**	
	value chain	**SIA**
Human capital, qualifications	Share of graduates in engineering, ICT, energy market services, installers, advisors (e.g. architects)	Energy-literacy, energy citizenship (active public participation in the energy system), informed consumers, share of knowledgeable installers, etc.
Flexibility of resources (human capital)	Reskilling, capacity built from other activities/sectors	Capacity-building to increase energy literacy and energy citizenship
Resources and potentials	Training centers, certification and recognition	availability of information and consulting (e.g. energy agencies or similar institutions as one-stop-shop providers), e-learning, availability of online resources
Raw and critical materials	Lithium, graphite, cobalt (batteries) Silicon (solar PV), others rare earths used in wind turbines	
Infrastructures: physical and financing	Transmission & distribution, storage, buildings, … Eligibility and access to loans, funding, guarantees, …	Storage systems Smart metering and monitoring devices Eligibility and access to loans, funding, guarantees, …
(Social) networks and institutions	National & EU networks, RD&I, along the supply chain	National & EU networks of prosumers and energy communities

Market & economy	**Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition**	
	value chain	**SIA**
Market structures and competition, new emerging markets	Number of companies in the supply chain (electricity suppliers, suppliers of H&C), market maturity and competitiveness, congestion	Market segments open to self-production and self-consumption of electricity/H&C, new/emerging markets, market segments or areas (growth, share) for prosumers, restrictions (e.g. capacity limits)
Resilience of economy	Resilience of the power/H&C market	Contributes to local/regional activity, spill-over effects into other segments/markets
Development of key transition sectors (use or share of ITC/digitalisation)	Development and deployment of smart metering and monitoring devices, diffusion of new technologies	
FDI rules, market access	Number of switches of providers per year per customer segment (power sector, H&C)	Rules to engage in prosumption, accessibility to different segments of the population
Market shares/ deployments/ production	Turnover, GVA growth, production shares	Market share of prosumers
Employment shares and productivity	Employment , labour productivity	Volume of electricity/heat/cold generated and self-consumed

Innovation & transition	**Meso-level: environment of technologies (supply, demand and system integration), all linked to the energy transition**	
	value chain	**SIA**
Innovations (patents, publications, RD&I)	Innovative projects & RD&I	
Entrepreneurial risk attitude	Number of spin-offs and start-ups in the supply chain, number of new business models	Number of new business models
Long-term transformation performance/ readiness	Upgrade of infrastructure and broadening access to ICT	Access to/deployment of ICT
Resilience	Resilience to fluctuating renewable sources, ability to withstand/absorb shocks, changes or shifts in performance during crisis or shocks	
Efficiency	Resource efficiency	Resource efficiency of self-produced energy/H&C

A.1.4.3 Enabler and contribution to Fit for 55 package

Both dimensions of SIA 4 show strong synergies with the Fit-for-55 package, mainly via the RED II revision proposal 1) fostering renewable hydrogen for hard-to-decarbonise sectors and 2) re-emphasising the central role of renewable energy prosumers.

Offshore renewables not connected to the grid producing hydrogen or derivates

Green hydrogen, i.e. hydrogen produced via electrolysis of water using electricity produced from renewable sources, is a key enabler of the pursuit of climate neutrality. In fact, it features prominently in the long-term strategy options laid out in the European Commission's net zero emissions scenarios for 2050. As stated in the explanatory memorandum amending Directive (EU) 2018/2001 regarding the promotion of energy from renewable sources, reaching the increased 2030 target, new targets for hydrogen, amongst others, will become necessary. This is reflected, for example in the newly proposed article 22a on mainstreaming renewable energy in industry, calling on Member States to endeavour the increase of the share of renewable energy sources in the industry sector. In concrete terms, Member States are to ensure that, by 2030, 50 percent of the hydrogen used by industry is green hydrogen, or more specifically, a renewable fuel of non-biological origin (RFNBO) as defined in RED II.

Energy self-generation and self-consumption

As for renewable energy self-generation and self-consumption, no major changes or additions are proposed under Fit for 55, but the role of consumers continues to be a central one, being covered both via RED II as well as Directive (EU) 2019/944 on common rules for the internal market for electricity (IMED). One new element proposed in order to increase the share of renewables in electricity, heating and cooling in the buildings sector, self-consumption of renewable energies, renewable energy communities and local storage solutions shall be explicitly strengthened.

Self-generators of renewable electricity are an important actor group in the decarbonisation of the energy system and complement the transition with bottom-up approaches. Collectively, prosumers who invest in renewable energy technologies might be able to trigger a shift in the diffusion and governance of sustainable energy services and could help finance and speed up the decarbonisation of the energy sector, and act as catalysts for the transition from centrally generated, conventional energy services (mainly from fossil fuels) to services provided by decentralised, more volatile, local renewable energy sources. It is also a way to involve citizens in the energy transition, which can contribute to greater awareness and public acceptance of renewable energy projects and enable a "just transition". Prosumers that also self-consume part of their own-produced energy might cause spill-over effects, drive the electrification of other sectors such as heating and cooling or transport. However, renewable energy self-consumption, with no appropriate regulation in place, can also have negative impacts on the energy system as a whole, potentially posing challenges to incumbent actors (e.g. conventional, centralised electricity generators) and for transmission and distribution network operators. Hence, when assessing and adapting framework conditions for self-consumption, both the positive and the negative implications of self-consumption need to be taken into account.

A.1.5 SIA 5 - Transmission- and distribution-related technologies

A.1.5.1 Preliminary scoping

Table 18: Elements to include – transmission level

SIA 3	AC	DC
Transport elements	Underground lines Gas-insulated lines (AC) High-temperature super conductors (AC)	HVDC cables Gas-insulated lines (DC) High-temperature superconductors (DC)
Conversion facilities	AC/AC (voltage) transformers Converters (DC/AC)	Gas-insulated substation DC/DC transformers Converters (DC/AC)
Grid control equipment	Reactive power control AC/AC phase shifting transformers Voltage control Frequency control – system rotating inertia	Voltage control
Safety equipment	Circuit breakers	HVDC circuit breakers
Monitoring equipment	Dynamic line rating	Dynamic line rating

Table 19: Elements to include – distribution level

SIA 3	AC	DC
Transport elements		DC lines
Conversion facilities	AC/AC transformers Converters (DC/AC)	DC/DC transformers Converters (DC/AC)
Grid control equipment	Reactive power control Voltage control	Voltage control
Safety equipment	Fault Current Limiter	
Monitoring equipment		

Note on terminology: in these tables, transformers are understood as devices transforming the properties of either AC or DC electricity, while converters are understood as devices converting direct to alternating current or vice versa.

A.1.5.2 Influencing factors

The TS and DS technologies are deployed by network operators that maintain a legal monopoly over the operation of their networks, but also a monopoly on network planning. This means that the decision whether to deploy a particular technology (innovative or not) is taken by the network operator. Therefore, regulatory framework design can create incentives for network operators to deploy innovative technologies (rather than e.g. market forces);

The market conditions for TS and DS technologies are therefore determined by regulatory frameworks, enabling or facilitating their use. The network operators are also a specific type of technology users, with specific problems such as lack of human resources to deploy new, innovative technologies.

The following table presents the categorisation of potential factors influencing the competitiveness of TS and DS technologies.

Table 20: Factors influencing competitiveness

	Aspect	Influencing factor
Demand side	Social aspects	
	Sustainable and climate issues	
	Circular economy and society	
	Acceptance of technology	Public opposition to new infrastructure build-up
	Educated consumers	
Policy	Long-term strategies/policies	NECPs/government policies reflected in network planning and future development scenarios
	Policies and regulations	New electricity demand areas (electro-mobility, heating), other energy sectors (NG, hydrogen), prosumers are considered in network planning Network planning is required to consider efficiency measures, innovative technologies Revenue regulation includes efficiency incentives Regulatory sandboxes for innovative infrastructure
	Legal system efficiency	permitting procedures – duration; complexity
	Geopolitics	Dependence on imported technologies
Resources	Human capital, skills, qualifications	Network operators have the expertise to deploy/use the innovative technologies Network operators have the human resources to deploy/use innovative technologies
	Flexibility of (human) resources	
	Resources and potentials	Revenue regulation allows/incentivises use of innovative technologies
	Rare and critical materials	Specific to electricity networks[35]: Aluminium; Cobalt; Magnesium; Silicon Composite polymers; Dicumyl peroxide; Ethylene propylene rubber; Fibre glass; Grain-oriented steel; Low-density polyethylene; Mineral oil; Porcelain; Stainless steel.
	Infrastructures	Share of connected variable and/or distributed energy resources (that require network upgrades/innovative management)
	Networks and institutions	ENTSO-E; EU DSO; CEER
	Financing conditions	
Market and economy	Market structures and competition	Market shares of EU companies in the value chain Domestic production capacities
	Resilience of economy	
	Development of key transition sectors	
	FDI rules and market access	
	New emerging markets	Deployment of flexibility market

[35] Trinomics, Artelys, 2021. Study on the resilience of critical supply chains for energy security and clean energy transition during and after the COVID-19 crisis. Available at: https://op.europa.eu/en/publication-detail/-/publication/b80d77b6-2a3b-11ec-bd8e-01aa75ed71a1/language-en/format-PDF/source-search

	Aspect	Influencing factor
Innovation and transition	Market shares, deployment, production	
	Employment shares and productivity	
	Innovations (patents, publications, RD&I)	Role of EU companies in development of new TS and DS technologies Intellectual property: know-how ownership
	Entrepreneurial risk attitude	
	Resource efficiency	
	Long-term transformation performance/ readiness	Readiness of network operators to deploy the innovative network technologies

A.1.5.3 Enabler and contribution to Fit for 55 package

The draft recast of the Energy Efficiency Directive introduces stronger measures to deploy energy efficiency measures in electricity (and gas) transmission and distribution networks. Article 25 of the proposed directive stipulates, among others, that transmission and distribution system operators apply the energy efficiency first principle in network planning and in network development and investment decisions. Moreover, "MSs shall encourage transmission and distribution network operators to develop innovative solutions to improve the energy efficiency of existing systems through incentive based regulations".[36]

In this context, the "innovative solutions" (and associated technologies) can:

- reduce energy losses in networks;
- new equipment with more advanced network management capabilities will allow to utilise the already available resources and network assets more efficiently, but can also unlock further potential for efficient resource use both on the supply and on demand side.[37]

The definition of innovation as developments increasing grid efficiency (and bringing additional benefits to consumers) is largely in line with the understanding of National Regulatory Authorities on this topic.[38]

Building new infrastructure faces many challenges, such as long permitting periods and public opposition, that can be avoided when existing assets could be upgraded.

The Fit for 55 package introduces measures to facilitate the development of new electricity demand sectors, such as electro-mobility or heating. These applications can be potentially utilised for network management as well. Similarly, increased renewable electricity feed-in on the distribution level creates additional challenges for network management. The current equipment was not designed with that in view, so it needs to be upgraded.

[36] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on energy efficiency (recast). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0558
[37] This SIA however focuses on the enabler role of network infrastructure technologies, not on the demand and supply side innovations.
[38] EER, 2020. CEER Status Review Report on Regulatory Frameworks for Innovation in Electricity Transmission Infrastructure. Available at: https://www.ceer.eu/documents/104400/-/-/8c2aace7-5601-8723-4d45-337073af38d5

A.1.5.4 Potential literature sources

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- Ecorys, 2019. Do current regulatory frameworks in the EU support innovation and security of supply in electricity and gas infrastructure? Available at: https://op.europa.eu/en/publication-detail/-/publication/6700ba89-713f-11e9-9f05-01aa75ed71a1/language-en
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A.1.6 SIA 6 - Smart cities

A.1.6.1 Preliminary scoping

This strategic integration area should cover the extent to which cities, as sub-national entities, have local strategies for transforming the energy system, addressing items in SIA 1,2,3,4 and other relevant matters in sub-national jurisdictions. From the standpoint of competitiveness, integrated energy systems are a new competitive advantage and further encourage the extension in smart city construction and vice versa. In contrast to the previous SIAs, the Smart Cities integration area is more located on a meso- rather than a micro-level in terms of system integration. We concentrate on specific aspects of integrating renewable energies into the system in the context of Smart Cities. Hereby we refer to a "Smart City" as the administrative level of a municipality, hence including both, its urban and rural coverage.

In order to generate a list of valuable elements, we started from existing categories of various smart city approaches, selecting energy related ones and combining the approaches. For this we mainly rely on "100 Climate-Neutral and Smart Cities by 2030", resulting in the categories:

- infrastructure/technologies
- economy
- administrative support
- public participation
- politics

From here, we started to collect elements specifically important for energy system integration (e.g. EC Strategy on Energy System Integration, 2020 Strategic Foresight Report).

Since smart cities are a future concept, most European cities as yet have only small or pilot energy transition projects in that context. Therefore, we propose a twofold approach for the data collection of the elements: In a first step we will only ask for qualitative information, where appropriate: are there activities (yes/no) on the element? In a second step, we would ask for actual measurable variables.

The focus for this SIA is to identify and monitor the energy transition also for small and medium cities, connecting the different elements.

Among the list of elements, not all elements will be covered exhaustively. Within an iterative approach the most relevant ones will be elaborated.

Table 21: Scoping overview: element to include

SIA 6	Elements to include	Link with CETO/CPR	Link with other SIA
Infrastructure and Technologies	Generation of electricity from renewables	Solar PV, Wind, (CSP, geothermal power, hydropower, ocean energy)	SIA 3
	Usage of electricity from renewables	/	SIA 3
	Heat from and combined with electricity	HP buildings & industry	
	Biogas/synthetic gas/hydrogen used (in the municipality)	Biogas, advanced biofuels, Renewable Fuels of non-biological origin,	SIA 3

SIA 6	Elements to include	Link with CETO/CPR	Link with other SIA
	Amount of industrial waste heat used Seasonal heat storage capacity in use Flexibility capacity used/installed Flexibility power installed Mobility as a service	renewable hydrogen, solar fuels / (Near-surface) geothermal heat Batteries, smart grids, (pumped) hydropower, new electricity storage Batteries, smart grids /	/ SIA 1, SIA 2, SIA 3, SIA 5 SIA 1, SIA 2, SIA 3, SIA 5 /
Economy	Installers capacity CHP/HP (skills) Energy-related business models for the city (local smart energy markets)	/ /	
Administrative support	Planning capacities (governance, integrated energy buildings) Fitting narratives/communications exist	/ /	
Public participation	Citizen energy communities Renewable energy communities Lighthouse projects	/ / /	
Politics	Political support (targets etc.) (Financial) support of tailor-made concepts	/ /	

Table 22: Scoping overview: optional elements

(long list, partly included in aggregated elements on infrastructure and technologies)

SIA 3	Elements to include	Link with CETO/CPR	Link with other SIA
Infrastructure and Technologies	Heat consumed per inhabitant Electricity consumed per inhabitant Number of smart meters Smart charging Mobility as a service installed/working, 24/7? (including environmental/efficiency aspects in optimisation process)	/ / Smart grids Smart grids / / /	SIA 1 SIA 1

SIA 3	Elements to include	Link with CETO/CPR	Link with other SIA
	Share of electricity/renewables-based mobility (private and public) Private and public charging stations Grid Share of grid with installed smart grid ancillary services Grid Control and monitoring of distr. grid Number of small/large CHP Installed (rooftop vertical axis) wind turbines with energy management system heat exchangers Geothermal heat Ren based industry energy processes Electricity from heat (organic ranking cycle (ORC)) Positive/negative balancing power and capacity installed Power/capacity/Number of electricity storage in small scale Mid/large scale storage Short term/long-term storage Heat storage in buildings Disposable/controllable renewable energy applied/Electricity and heat by virtual power plants Demand side management capacity	Smart grids Smart grids / / Geothermal heat / / / / / / / / /	SIA 1, SIA 2, SIA 3, SIA 4, SIA 5 SIA 2, SIA 5 SIA 3 SIA 3 SIA 2, SIA 5 SIA 1, SIA 2, SIA 5 SIA 2, SIA 3, SIA 5 / SIA 1, SIA 4 / SIA 2, SIA 5 SIA 1, SIA 2, SIA 3, SIA 5
Economy	Producer of SIA components	/	
Administrative support	Energy agencies, climate manager, energy consultants	/	
Public participation	Participative/integrated energy concepts	/	
Politics	Political targets Local funding Local regulation	/ / /	

A.1.6.2 Relevant references

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42 https://www.niua.org/csc/assets/pdf/key-documents/indicators/energy-and-green-building.pdf
43 https://www.morgenstadt.de/content/dam/morgenstadt/de/images/loesungen1/city_index_onlinedokumentation.pdf
44 https://www.oecd.org/cfe/cities/Smart-cities-measurement-framework-scoping.pdf
45 https://ec.europa.eu/energy/sites/ener/files/energy_system_integration_strategy_.pdf
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A.1.7 SIA 7 - Innovative energy carriers and energy supply for transport needs

A.1.7.1 Preliminary scoping

The scope suggested for this SIA is to focus on a selection of fuels for the aviation and/or maritime sectors. This scope has specific synergies with the Fit-for-55 package which proposes new policy to decarbonise the aviation and maritime sectors, including internationally, namely through the ReFuelEU (aviation), FuelEUMaritime and RED II revision proposal which includes the expansion of the Directive's scope to these two sectors. With the current state of technology and the foreseeable developments to 2030, aviation will likely concentrate on bio-kerosene from advanced biofuels and e-kerosene, as there are no other alternative fuel technologies that can power current design large airliners. For shipping, fuels that do not emit carbon - hydrogen and ammonia from renewable electricity, which may be used within fuel cells or internal combustion engine powertrains – are getting most attention at the moment.

In addition, this scope has synergies with the following CET areas:

- advanced biofuels
- renewable fuels of non-biological origin (other)
- renewable hydrogen
- renewable fuels for aviation and shipping

Given the above mentioned strong synergies, we propose to leave out of the scope of this study aspects related to the road transport sector, direct transport electrification, batteries, biogas/bio-LNG, conventional biofuels, and fossil fuels. There is a question as to whether solar fuels (researched under CETO and CPR) should be within the scope of this study.

Given the potentially large diversity of the fuels to play a role in aviation and shipping in the future, we suggest to work on a selection of (1-3?) fuels for which we will carry out in-depth research on aspects relative to their value chain as described in Table 2. The list of fuels to select from, including the relevance of their application to air and maritime transport, are shown in Table 1 below.

In order to select a feasible and realistic scope within the timeframe of this study, the scope of this SIA may be framed from two ends (i.e. from the fuels selection (1.) and from the value chain segments (2.) standpoints):

1) Should the fuel selection (from the fuels listed in Table 1 and/or other fuels) cover a quite large number of fuels, the scope of the value chain elements in Table 2 may need to be further narrowed down.
2) Should value chain elements listed under Table 3 be brought into the scope, the scope of Table 2 and the number of selected fuels may need to be further narrowed down.

Table 23: Selection of renewable fuels relevant to the shipping and/or aviation sectors

Fuels:	Application:	Shipping	Aviation
Bio-based (from advanced/waste-based feedstocks)	Kerosene		++
	Biodiesel	++	
E-based	Hydrogen	+	+
	Methanol	++	
	Ammonia	++	

Fuels: / Application:	Shipping	Aviation
Kerosene		++
E-diesel	+	

"++" suggests high relevance of the fuel towards the application
"+" suggests some degree of relevance of the fuel towards the application

Table 24: Value chain aspects to be included in the competitiveness study for SIA 7

SIA 7	Elements	Link with CET	Link with other SIA
Transport	- Pipelines (new and blending/repurposing, depending on fuel) - Road, rail and maritime transport of fuels per fuel and per application	- Renewable Fuels for Aviation and Shipping (CPR) - Renewable Fuels of non-biological origin (other) (CETO) - Renewable Hydrogen (CETO) - Advanced biofuels (CETO)	
Storage	- Primary storage (at production/import terminal) per fuel - Secondary storage (at port/airport) per fuel	- Same as above	
Distribution infrastructure	- Port and/or airport storage and distribution equipment per fuel - Handling per fuel and per application		

Table 25: Value chain aspects not to be included in the competitiveness study for SIA 7

SIA 7	Elements	Link with CET	Link with other SIA
Production	- Fuel production and synthesis technologies (e.g. electrolysers) - Feedstock and materials: ▪ Renewable power ▪ Raw materials ▪ Bio-feedstocks ▪ Carbon sources	- Renewable hydrogen production through electrolysis (CPR) - Offshore and onshore wind (CPR) - Solar PV (CPR) - Batteries (CPR)	
Infrastructure	- Production/refining infrastructure: ▪ New and specific to bio- and e-based fuels ▪ Existing (repurposed/ retrofitted for bio- and e-based fuels)	Same as above	

SIA 7	Elements	Link with CET	Link with other SIA
	- Import terminals - On shore power supply for docked ships (cold-ironing)		
Transport	Electricity T&D		SIA 5: Transmission- and distribution-related technologies
Storage	Battery storage	Batteries (CPR and CETO)	
Distribution infrastructure	Electricity T&D		SIA 5: Transmission- and distribution-related technologies
Vehicle equipment	- Fuel cell technology - Engine adaptations - Electric powertrains		

A.2 Annex 2 - Additional Literature for Macro Indicators

Demand side

- EU SDG Indicator Set 2020
  https://ec.europa.eu/eurostat/documents/276524/10369740/SDG_indicator_2020.pdf
- Income inequality and willingness to pay for environmental public goods
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Policy and politics

- Sustainability Indicators: A Scientific Assessment
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- The Impact of the Government Policy on the Energy Efficient Gap: The Evidence from Ukraine
  https://www.mdpi.com/1996-1073/14/2/373/pdf

Resources

- Institutional sustainability indicators: an analysis of the institutions in agenda 21 and a draft set of indicators for monitoring their effectivity
  https://onlinelibrary.wiley.com/doi/epdf/10.1002/sd.184?saml_referrer
- Sustainability Indicators: A Scientific Assessment
  https://www.researchgate.net/publication/258261619_Sustainability_Indicators_A_Scientific_Assessment_SCOPE_67
- EU SDG Indicator Set 2020
  https://ec.europa.eu/eurostat/documents/276524/10369740/SDG_indicator_2020.pdf
- Human Capital and Environmental Sustainability https://www.mdpi.com/2071-1050/12/11/4736/pdf
- Financial stability as a precondition for the financing of sustainable development in emerging and developing countries https://www.die-gdi.de/en/briefing-paper/article/financial-stability-as-a-precondition-for-the-financing-of-sustainable-development-in-emerging-and-developing-countries/

Market conditions

- Sustainability Indicators: A Scientific Assessment
  https://www.researchgate.net/publication/258261619_Sustainability_Indicators_A_Scientific_Assessment_SCOPE_67
- EU SDG Indicator Set 2020
  https://ec.europa.eu/eurostat/documents/276524/10369740/SDG_indicator_2020.pdf
- Does FDI influence renewable energy consumption? An analysis of sectoral FDI impact on renewable and non-renewable industrial energy consumption
  https://www.sciencedirect.com/science/article/pii/S014098831500362X?via%3Dihub

Innovation and transition potential

- Institutionelle Nachhaltigkeitsindikatoren: Der institutionelle Gehalt von Agenda 21 und die Ableitung zugehöriger Indikatoren https://oes.tuwien.ac.at/article/150/galley/150/view/
- EU SDG Indicator Set 2020
  https://ec.europa.eu/eurostat/documents/276524/10369740/SDG_indicator_2020.pdf

- Technology readiness level: Guidance principles for renewable energy technologies https://op.europa.eu/de/publication-detail/-/publication/d5d8e9c8-e6d3-11e7-9749-01aa75ed71a1
- Innovation driving the energy transition https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2018-chapter3.pdf

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7 List of tables

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