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Smart Specialisation Toolkit Adaptation and Development

european future
innovation system
centre

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1. Introduction

Considering the context of the project, the submitted proposal as well as discussions between the ECCI and EFIS, this report provides a basis for transition to low-carbon (zero-carbon) economy based on smart specialisation. It outlines a number of indicators that should guide the regions to measure the transition towards a low-carbon economy, using the smart specialisation methodology. Furthermore, it provides a smart specialisation zero-carbon transition roadmap as well as comments on necessary modifications of the already existing smart specialisation tools that would help support the process.

The indicators will take into consideration linking existing regional competencies and strength in the area of high-carbon technologies that have the potential to transition into low-carbon opportunities. The indicators proposed cover a wide range of metrics including current economic situation, emissions intensity and (green) jobs creation. In the development of these indicators, EFIS makes use of its experience from the Eco-Innovation Scoreboard (Eco-IS) and the Eco-Innovation Index under the Eco-innovation Action Plan (https://ec.europa.eu/environment/ecoap/_en).. Other sources for suitable indicators have been used like Green Growth Indicators by OECD (http://www.oecd.org/greengrowth/green-growth-indicators/), the United Nation 17 Sustainable Development Goals (SDG 17 - https://sustainabledevelopment.un.org/sdgs) and the High-Level Indicators for clean energy transition by the International Energy Agency (IEA) (https://www.iea.org/tcep/indicators/). Each indicator has its pros and cons as well as its level of relevance that will be described and discussed below.

The online applications (tools) presented in this report are from the Online S3 Horizon 2020 project and can be found at the Online S3 website (http://www.s3platform.eu/toolbox/). The report ranks their adaptability and applicability as well as their advantages. Furthermore, it clearly specifies how they should be modified to support the transition to low-carbon economy. Modified applications should be applied within the framework of the smart specialisation zero-carbon transition roadmap developed for the purpose of this report.

This report is structured as follows. After the Introduction, Chapter 2 describes indicators and context of transition to a low-carbon (zero-carbon) economy. Chapter 3 explains how to choose relevant indicators. Chapter 4 introduces the online applications to manage specialisation analysis, and the following chapter (Chapter 5) explains how to adapt existing tools to support the transition to a low or zero-carbon economy. The sixth and final Chapter presents a smart specialisation zero-carbon transition roadmap. Annex 1 provides an overview matrix for indicators for transition to low-carbon economy, while Annex 2 describes some details of particular indicators and scoreboards that can be used for the purpose of analysis and monitoring of transition to a low or zero-carbon economy.

2. Indicators and context

Transition to low-carbon economy for the purpose of this report is understood as a pathway to a socio-economic system that uses less materials and is emitting less carbon dioxide and other greenhouse gasses on a net basis than the baseline situation today[1]. Smart specialisation strategy may be considered as means by which the transition to low-carbon economy can be supported, as it may be considered as a governance arrangement through cooperation and coordination between government, universities and research institutes, businesses and the civil society actors in an entrepreneurial discovery process (EDP)[2]. The latter 'is about prioritising investment based on an inclusive and evidence-based process driven by stakeholders' engagement and attention to market dynamics' (Gianelle et al., 2016: 15). Hence, even though smart specialisation is currently not intended to cover transition to low-carbon economy, it can be adapted for that purpose. There is a need for the right indicators and for the transition roadmap.

To be able to develop a strategy and find the most relevant indicators to focus on, a baseline needs to be established from where the analysis can start. It is important to frame the analysis with a number of guiding questions:

- What is the current situation in the region (economic, environmental, greening, etc.)? The answer to the question depends on what can be measured at a regional basis or how detailed geographically indicators can be (i.e. at NUTS2/ NUTS3 level)?
- What authority (autonomy) does the region have in terms of policies that can influence the evolution of specific indicators?
- How to define what types of economic activities are low-carbon/resource efficient and how to define what is a green job?

In terms of mapping the current situation, there are several areas that are put forward in the literature and the current practice. OECD (2017: 15) mentions 'i) the environmental and resource productivity of the economy, ii) the natural asset base, iii) the environmental dimension of quality of life, and iv) economic opportunities and policy responses'. OECD (2015) adds the socio-economic context and skills and training ecosystems to the above categorisation. And Tapia et al., 2014) observe territorial sphere, economic sphere, econosphere, environmental sphere and social sphere. Following these examples several areas for headline indicators[3] are proposed:

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[1] What the targets should be over a certain period needs to be politically discussed with stakeholders in the region. There are several EU and international agreements, like the Paris Agreement, that could be used as benchmark.

[2] Smart specialisation strategy is currently defined in the Official Journal of the EU (2013). It represents an ex-ante conditionality for the use of European Regional Development Fund (ERDF), under thematic objective 1) Strengthening research, technological development and innovation. Hence, they have a narrower focus than it would be the case for a transition to low-carbon economy.

[3] The specific metrics varies what type of indicator is used.

1. economic outlook:
   - socio-economic context (GDP, gross value added from agriculture, industry, services and population density) – trends[4] in value added are important,
   - unemployment, e.g. if there is a high (youth) unemployment then maybe the indicator for creating 'green' jobs should become more central, as green jobs may be more important for younger workers. See for instance ILO guidelines (International Labour Organization, 2015),
   - competitiveness (compared to national and EU level),
   - R&D spending (public & private),
   - other relevant indicators on demography and society, economy and labour, structural business statistics, business demographics and the innovation system.
2. green economic outlook - what is the current level of economic activity resulting from the transition to a green economy and what is the potential
   - the most carbon-intensive industries or sectors (NACE level 2 and 3) in terms of 1) share of total CO_2 emissions, 2) share of total employment, and 3) share of total added value,
   - Number (and trend) of established eco-industries in the region (share of all industries and of SMEs)
   - share (and trend) of employment in eco-industries and circular economy (share of SMEs),
   - low-carbon investments (an indication of the trajectory for low-carbon technology deployment into the future),
   - carbon productivity, e.g.: production-based (GDP for each kg of CO_2 emitted on the national territory) or demand-based (GDP for each kg of CO_2 emitted anywhere to satisfy domestic demand)[5],
   - green early stage investment/financing of 'clean' tech (public & private),
   - governmental (regional) environmental and energy R&D appropriations and outlays (share of GDP).
3. natural assets and their use
   - environmental productivity[6] (efficient use of natural resources and environmental services).
4. energy sector
   - share and type of regionally generated electricity and energy vs energy 'imported' from other regions (this could have a significant impact in transition towards a low-carbon economy, depends what other regions' objectives are towards renewable energy and what the cooperation and coordination between regions on electricity and energy production looks like),

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[4] Nothing is decided forever in smart specialisation. Hence, part of the smart specialisation process is to continuously revisit it through dialog and interactions amongst stakeholders. For instance, every 6 months a committee or working group with representatives from key stakeholders meet to discuss the current state of the strategy and future direction. This is called the Entrepreneurial Discovery Process (EDP).

[5] Low-carbon economy presupposes a reduction in the overall emissions, for both locally produced and imported CO_2.

[6] See Table 3 for specific indicators covering the area of environmental, energy and resource productivity.

- share and type of regionally-generated electricity and energy consumed locally vs 'exported' outside the region,
- the share and type of electricity in total final energy consumption (provides a pathway for clean-energy transitions through the electrification of end-use sectors),
- energy intensity (per GDP),
- what type of energy are different sectors (GREECO project defines them as bio-economy, manufacturing, renewable energy, tourism and transport (https://www.espon.eu/programme/projects/espon-2013/applied-research/greeco-territorial-potentials-greener-economy) consuming (especially those that are most CO2 intense, this can help to focus efforts to reduce emissions while at the same time having as high impact as possible).

5. policy and regulatory issues
    - dedicated environmental and green energy objectives in place
    - current regulations in place to tackle CO2 emissions and pollution in general. How well is the region doing in fulfilling the regulations?,
    - environmental taxes & subsidies in place.
6. environmental quality of life and psychological preconditions for a transition
    - GHG emissions levels,
    - Source of GHG emissions,
    - Pollution levels (land, water, air),
    - encourage more sustainable consumption, investment and compliance decisions by individuals and firms (see http://www.oecd.org/environment/consumption-innovation/)[7].

The matrix of proposed indicators for analysing and monitoring the transition to low-carbon (zero-carbon) economy is presented in Table 3, which also ranks their availability and ranks them according to relevance for this purpose. Above mentioned areas for headline indicators have been divided in three main ones: 1) green economic outlook, 2) environmental, energy & resource productivity and 3) environmental quality of life and psychological preconditions for a transition. Furthermore, the Annex 2 presents the main datasets and scoreboards with indicators that can be consulted. In addition to the ones presented in Table 3, there may be other indicators that may be used for the purpose, and that might be available at the local level, hence not necessarily in English language.

It should be noted that every system in a region is different depending on the sectors and/or technological domains which defines the complexity and specificity of the system. Hence, the same set of indicators cannot be applied one to one to different regions due to these differences.

[7] Evidence on that should be collected through surveys. See e.g. indicator No. 81 from Table 3.

The next chapter describes how to choose relevant indicators.

3. Choosing relevant indicators

To facilitate the selection of indicators, one approach would be to grade each indicator in terms of relevance, impact, data available and (regional) 'control'. For instance, if environmental regulation is relevant and has an impact in the transition towards a low-carbon economy, but the region has no control in setting the standards, then such an indicator, even if important, might not be of great value. On the other hand, it can be used as a policy tool to show the need for change. The same can be said about data availability in terms of how accessible and collectable data is, how often the data is collected[8] or renewed. One also needs to consider 'granularity' of the data, i.e. whether the data is available at a regional level. If data is not available, it would be important that the region estimated its resources or measured and collected such data.

Relevant indicators should be chosen on the basis of the aforementioned guiding questions: 1) What is the current situation in the region (economic, environmental, greening, etc.)?, 2) What authority (autonomy) does the region have in terms of policies that can influence the evolution of specific indicators?, 3) How to define what types of economic activities are low-carbon/resource efficient and how to define what is a green job. To answer the first question, availability of indicators at a regional level should be checked. Having listed the main suggested areas of measurement above, indicators' availability should also be checked with different projects and databases (see Annex 1 and 2). In order to extract the most useful indicators, available studies should be reviewed, and possibilities for disaggregating data should be looked into, to analyse a region to a proper level of detail. In parallel to this, questions two and three should be answered, so as to help support the choice of the most relevant indicators. A result of this process is a selection of readily available (tier 1) indicators and those that require additional research and/or sources at the local level (tier 2 indicators).

In Annex 1, Table 3 below there is a collection of the most prominent indicators that can be used in this analysis. However, they are mostly available at the national level, and only two are available at a regional level (Nuts 2 or Nuts 3 levels). Notable exceptions are also the GREECO system of indicators, partially the RECREATE and the Green Horizons Scoreboard as well as OECD.Stat data on environmental indicators for metropolitan areas of some countries and certain European Environment Agency data (see Annex 2 for details). Some data for the regional level could potentially be estimated from the national level data, which is the case with indicators such as Mortality from exposure to PM2.5 or municipal waste generated, as the value of both indexes depends on the number of inhabitants. Furthermore, data could be obtained through experts' surveys as well as from the secondary sources.

[8] To determine how often data is collected is very difficult, especially if data is not regularly reported in one source, compared with some of the most established indicators, like national R&D spending, economic growth, etc.

Some of these indicators are already produced by different Online S3 applications (tools), so the applications will be first presented (Chapter 4) and then reviewed (Chapter 5) below. In Chapter 5 key advantages and applicability as well as the need for adaptation and adaptability of the online applications that are needed are clearly indicated.

4. Online applications to manage specialisation analysis

The project proposal suggested to review applications of the Online S3 project[9] that can be used to analyse specialisation of a country or a region. A brief description of each application is given below[10].

Application 2.1 Regional assets mapping. This application works as a dashboard, providing information on seven different domains: geography, demography, economy, sectoral structure, business characteristics, and innovation system at NUTS II level and for a number of years. The output generated by the application can be organised either based on the variable or based on the region. It can be presented as a table (downloadable in a .xlsx format). They can also be shown in a form of a line graph or a bar chart and subsequently export the graphs in the .png format. As noted by Griniece et al. (2017: 25), mapping regional assets is crucial and serves as a basis for other methods. Next two applications provide information on innovation infrastructure (Griniece et al., 2017: 26). These are application 2.2. (Research infrastructure mapping) and 2.3 (Clusters, incubators & innovation ecosystem mapping).

Application 2.2 Research infrastructure mapping. This application provides information on research infrastructures in the EU and Norway, Turkey and Switzerland. Research infrastructures are all those physical and human resources that provide services for research in science or technology fields. The application draws on the European Strategy Forum on Research Infrastructures (RI) data, and from the MERIL database. Additionally, the users can update the information themselves. The users first need to select which RI they would like to search for, and it will be shown on a map. The users can then zoom in for the most pertinent information regarding the RI. The application can also export the results to a report in .docx format.

Application 2.3 Clusters, incubators & innovation ecosystem mapping. This guide provides a link to: 1) The European Cluster Mapping Tool, 2) Regional Ecosystem Scoreboard, and 3) Cluster Collaboration Platform. The instructions how to use them are provided in the guide itself. The first tool visually shows cluster analysis from a sectoral or a cross-sectoral perspective. The second scoreboard provides analysis of conditions affecting entrepreneurship and innovation either in NUTS I or NUTS II regions, depending on the country. The Cluster Collaboration Platform serves for mapping cluster organisations, and it shows them on a map of Europe (and the World).

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[9] For the tools developed by the Online S3 project see http://www.s3platform.eu/toolbox/.

[10] Description of the applications is taken from Komninos et al. (2018: 50-52).

Application 2.4 Benchmarking. This application provides regional comparisons based on either a .xls file that can be uploaded or on the generation of a new table. Data could also be imported from the application 2.1 Regional assets mapping. A reference region will be compared to selected regions. The data can be exported to a .xslx or a .csv format. The analysis thereby made can also be visualised on a diagram. Benchmarking "method will foster analysis that places regions in international comparative perspective" (Griniece et al., 2017: 26). For example, share of human resources in the fields of science and technology can be analysed with this application.

Application 2.5 Regional scientific production profile. The application enables users to carry out bibliometric analysis of scientific performance at the national, regional and the city level. The data are based on Scopus database, and the application's three tools can provide a subject area analysis, an affiliation analysis or an annual analysis. The results are available as charts, and a Word document report is generated at request. "There is a need to increase understanding of knowledge produced and available in regions. This is relevant for linking it later to the demand for knowledge and identifying emerging areas of activity" (Griniece et al., 2017: 27). An analysis of the number of publications by scientific field and by region, of academic organisations by publishing activity, and an analysis of scientific production in a region over time can all be done with this application.

Application 2.6 Specialisation indexes. This application generates technological (RTA), scientific (AI), and economic indexes (RCA) that enable users to analyse how regional activities fare in global value chains. The scientific profile data obtained in the Application 2.5 (Regional scientific production profile) need to be uploaded in order to calculate the Scientific Specialisation Index. For the Economic Specialisation Index (i.e. RCA), export data of the region need to be provided. The results can be visualised in a dashboard and a report can be generated as a textual file.

Application 4.2 Extroversion analysis. This tool provides a link to two external apps: The EU trade Tool and the Trade Competitiveness Map. The former helps visualise inter-regional trade flows (exports and imports), and see competitors of the region, the competitiveness scores, and trade network scores. The latter enables analysis of country and product competitiveness on the basis of many different indicators, with the help of graphs.

Application 4.3 Related variety analysis. The application analyses sectors by the number of employees, unveils sectoral specialisation (that shows whether an industry at the regional level is performing relatively better than at the national level), technological specialisation (concerning patents), and correlated sectors (if any). The images thereby produced can be exported to a file. As this method was not used in cases examined by Griniece et al. (2017), the application serves an important purpose of providing an important and a user-friendly means of analysis.

Application 5.3 Budgeting. The budgeting application helps users visualise and manage budgeting data for the NUTS 0, NUTS I and NUTS II regions through an online dashboard. It produces an overview of the RIS3 financial plan. Users need to provide initial data, as well as define the time period of the financial plan and the RIS3 priorities. The application enables extraction of tables and graphics. As RIS3 background analysis has thus far lacked a standard budgeting analysis that would help the process of RIS3 design.

Application 5.6 Innovation maps. This application uses grant data on innovative programmes in different regions. Data could either be inserted manually or imported (also from the application 5.7 Open data tool), enabling more detailed analysis. Data can subsequently be visualised (through a heat map or a bubble map), as well as extracted.

Specialisation analysis can then be performed as a circular process that can be described in brief as follows (Komninos et al., 2018: 52-54):
set the baseline situation (by using all ten of the aforementioned applications),
analyse situation in the sphere of investments (using the 'budgeting' and 'innovation maps' applications),
analyse outcomes (using the following applications: 'extroversion analysis', 'specialisation indexes', 'related variety analysis' and 'regional scientific production profile'.
compare with the baseline situation.

The process described above is intended for the specialisation analysis in the field of research and innovation that has been proposed with the Specialisation Roadmap (http://www.s3platform.eu/specialisation/). A similar process will be described below, in Chapter 6. Before that the next chapter shows how these 10 Online S3 tools can be adapted to support the transition to a low or zero-carbon economy. It also briefly reviews and ranks the remaining 19 Online S3 tools.

5. Adapting existing tools to support the transition to a low or zero-carbon economy

Online S3 tools are ready-made applications that help support the smart specialization process using widely accepted classification of sectors and fields of science, technology and economy. However, some of them would need to be adapted for the smart specialisation process supporting transition to a low or zero-carbon economy. We took a subset of ten tools from the Specialisation roadmap described in Komninos et al. (2018) and have ranked their adaptability and applicability. A summary Table 1 with key advantages and specified need for adaptation of different applications is below. The table also specifies which indicators should ideally be included in which tool.

Table 1: Adapting existing tools to support the transition to a low or zero-carbon economy

Application No.	Name of the application	Key advantages	Applicability (highly applicable, somewhat applicable or not applicable)	Need for adaptation	Adaptability (adaptable or not adaptable)	Rank	Indicators to be included in the application*
1	Regional assets mapping	- comprehensive information on NUTS 2 level on a variety of domains	- highly applicable	- other relevant indicators on demography and society, economy and labour, structural business statistics, business demographics and the innovation system should be added - in particular the indicators on youth unemployment, green jobs, gross value added from different sectors and on competitiveness - include NUTS 1 and NUTS 3 regions - indicators should be made available for 3-digit level of the NACE classification	- adaptable	- 1	- 1-11 - 21-23 - 25-26 - 29-37 - 41-58 - 60-65 - 68-70 - 72 - 74-76 - 79
2	Research infrastructure mapping	- pertinent information on various research infrastructures	- somewhat applicable	- no need for adaptation	- not adaptable (as the tool relies on an	- 2	- none

					external application)		
3	Clusters, incubators & innovation ecosystem mapping	- three background tools supplement the economic outlook analysis and the regional assets mapping with data on clusters and regional entrepreneurial ecosystems, all at regional levels of EU member states	- highly applicable	- no need for adaptation	- not adaptable (as the tool relies on external applications)	- 2	- none
4	Benchmarking	- comparison of different regions' performance	- highly applicable	- see above, under Regional assets mapping tool (the application draws on that application)	- adaptable	- 1	- see Regional assets mapping
5	Regional scientific production profile	- comparison of different regions' scientific production	- highly applicable	- no need for adaptation	- adaptable (but depends on Scopus database)	- 1	- none
6	Specialisation indexes	- comparison of different regions' technological specialisation,	- highly applicable	- there is a need to better indicate specialisation in green technologies and sectors of science of economy that	- adaptable (but depends on availability	- 1	- 6-8

		scientific specialisation and economic specialisation in a clear manner		contribute to transition to low or zero-carbon economy - include NUTS 1 and NUTS 3 regions	of information from the OECD patent database, information on patent applications to the EPO and WIPO)		
7	Extroversion analysis	- two background tools offer an analysis of trade from different perspectives: geographical, quantitative, qualitative, by using different indicators	- highly applicable	- it would be helpful if the external tools would include NUTS 1 and NUTS 3 regions	- not adaptable (as the tool relies on external applications)	- 2	- none
8	Related variety analysis	- calculation of a sectoral, technological specialisation as well as analysis of correlated sectors	- highly applicable	- include data on NUTS 1 and NUTS 3 regions - employment data on a more detailed level than the NACE 1 are not available for NUTS 2 and NUTS 3 regions, data on	- adaptable	- 1	- 6-8

				patents depend on the PATSTAT database)			
9	Budgeting	- the only existing smart specialisation budgeting application	- highly applicable	- include data and options for NUTS 3 regions	- adaptable	- 1	- 1-4
10	Innovation maps	- tool that helps visualising and managing grant data on a regional level	- highly applicable	- the visualisation tool needs to be adapted	- adaptable	- 1	- none

Note: * Full list of indicators with can be seen in Table 3, to which these numbers refer. The applications are ranked on the following scale - 4 = not useful, 3 = useful to a certain extent, 2 = quite useful, 1 = very useful.

The remaining set of applications developed by the Online S3 project can be seen in the Table 2. The applications were ranked from 4 (note useful) to 1 (very useful).

Table 2: The rest of the Online S3 applications with a summary of key characteristics and a rating

Application No.	Name of the application	Key characteristics	Rating
1	Vision Sharing	It is a set of external applications and templates that may be useful. However, this tool is not good enough as a standalone application.	4
2	Stakeholder engagement	It offers relatively useful functionalities for discussions among stakeholders. However, it would need more functions to make it more useful. Potentially the tool should be merged with the 'Collaborative vision building',	3
3	Debate at a glance	It is essentially a placeholder for external applications that are useful. However, the tool is not good enough as a standalone application.	4
4	RIS3 Legal and administrative framework related to ESIF	It is of value as it provides legal and administrative information, but it does not have added value above that.	4
5	SWOT analysis	It is not smart specialization-specific.	4
6	Collaborative vision building	As a standalone tool it offers very little value. The tool should be merged with 'Stakeholder engagement' to provide fuller functionalities.	3

7	Scenario building	It is useful as guidance for stakeholders of the smart specialization process, especially in terms of guidance on scenario development process. But it does not have all functionalities an application should have.	2
8	Delphi – Foresight	It serves as a signpost for an external application rather than as a standalone application.	4
9	EDP focus groups	By using this tool, public authorities can communicate with shareholders, but it does not have a distinctive value in comparison to other similar applications. The tool can be merged with 'Collaborative vision building' and 'Stakeholder engagement' to make it more comprehensive.	2
10	Intervention logic	It does not offer the full intervention logic, but still quite helpful.	2
11	Action plan co-design	A complex tool with fragmented user experience, but still quite helpful.	2
12	State aid law compliance for implementation	It is rather an online guidance and as such it may be useful. It does not have any bigger value as an application though.	3
13	Calls consultation	Users can assess operational programmes' calls for proposals, discuss different topics and suggest selection criteria for projects.	1
14	Open data tool	It tracks projects and initiatives region by region. However, it does not contain detailed data.	1
15	Monitoring	It lets the users get the information on results and policy measures. However, the other data that would be useful (from 'Definition of output and result indicators', 'Beneficiaries and end users' satisfaction online survey' and 'Budgeting') should also be included in this tool.	3
16	Definition of output and result indicators	The tool is quite complex and not easy to use despite the importance of output and results indicators that the tool helps analyse.	3

17	Balanced scorecard	Advantages of this application that should trace activities vis-à-vis the vision and strategy are diminished through issues impeding its functionalities.	4
18	Beneficiaries and end user satisfaction online survey	The tool takes users to a collection of links to online survey platforms. Hence it does not function as a proper tool in itself.	4
19	Social media analysis	It is user friendly, but with limited options of analysis that enable social media analysis.	3

Note: The applications are ranked on the following scale - 4 = not useful, 3 = useful to a certain extent, 2 = quite useful, 1 = very useful.

After modifications, 10 Online S3 tools reviewed above would be able to cover the most important fields of analysis sketched in this Report (see Chapter 2 and Chapter 3). However, some of the modifications may increase the complexity of the applications as they would have to include much more detailed data geographically and in terms of economic sectors.

The next Chapter will present a smart specialisation zero-carbon transition roadmap that explains the pathway to zero-carbon economy with the help of online tools and indicators supporting this transition.

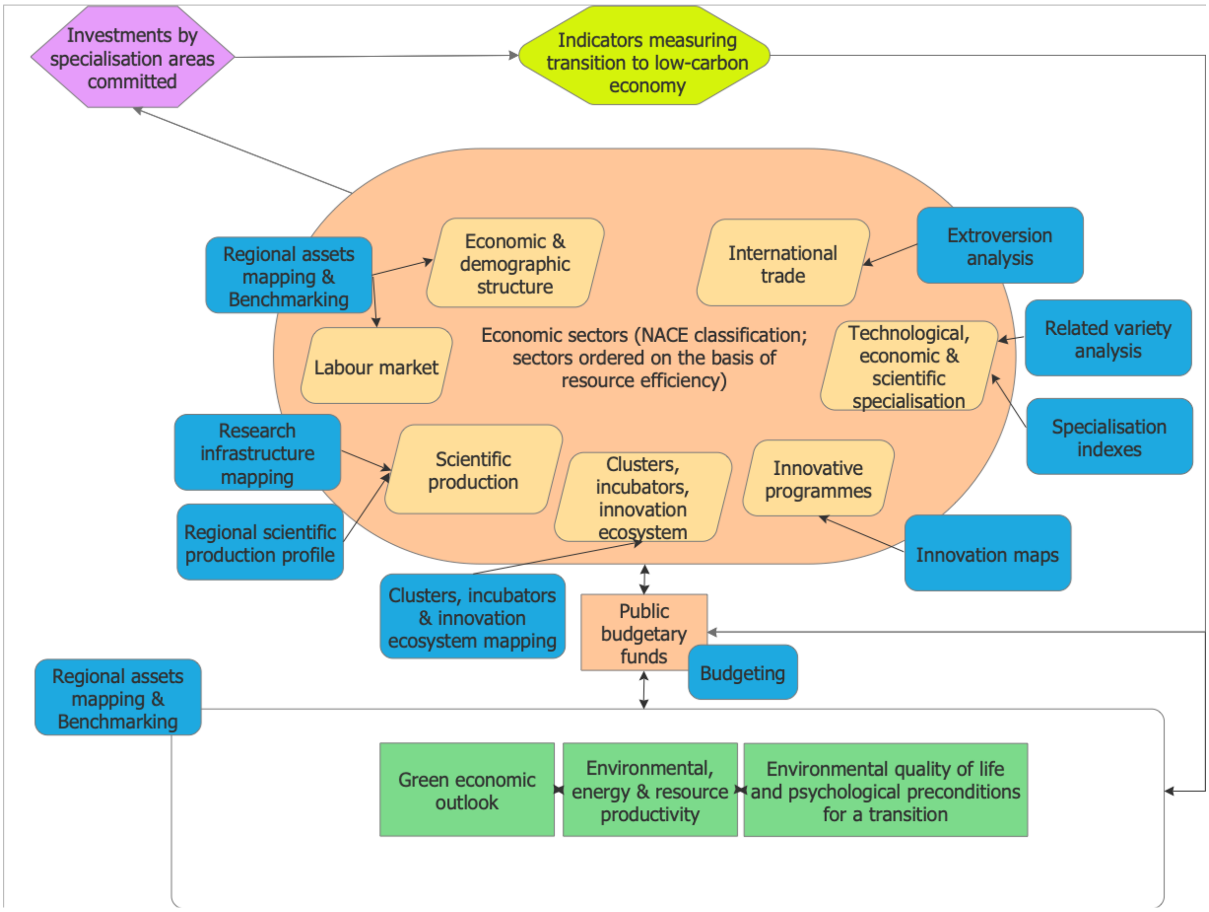
6. Smart Specialisation Zero-Carbon Transition Roadmap

This chapter describes the Smart specialisation zero-carbon transition roadmap. It can be used to answer questions that the participants of the entrepreneurial discovery process may ask, such as:

- What is the baseline socio-economic, environmental, energy and cultural context for the transition?
- How is our region positioned in key technologies necessary to support the transition to a low/zero carbon future and/or in specific 'eco-innovations' that can provide an environmentally sustainable but globally competitive future economic base for high value-added service and products ?
- How can public/private investments be channelled so as mitigate existing negative environmental effects or enhance specialisation in technologies and applicable solutions/products that tackle specific challenges?

Smart specialisation zero-carbon transition roadmap is shown in Figure 1. The roadmap is grounded in analysis of socio-economic and ecological areas of a country or a region (henceforth: region) on a path towards a zero-carbon economy. In the diagram the areas providing the socio-economic, environmental, energy and cultural context for the transition (highlighted dark green in the diagram) are analysed together with economic areas and public budgetary funds (marked orange). The analysis serves as a backbone for the entrepreneurial discovery process that should determine specialisation areas and direct investment (hexagon marked purple) towards purposes corresponding to the goal of reaching a zero-carbon economy. The investments will affect a number of sectors and activities in the region, which can be measured by changes in the indicators measuring transition to low-carbon economy (rounded hexagon highlighted light green in the diagram). Eventually, this process will make an impact on not just the baseline context, but also on public budgetary funds in turn allowing the process to start again.

Figure 1: Smart specialisation zero-carbon transition roadmap



Source: authors

All 10 of the modified applications that are highlighted in blue (see Table 1) would support the transition. It is important to note that different economic sectors in the middle of the diagram are based on NACE classification. As policy makers and analysts want to understand how difficult it will be to achieve a low-carbon or zero-carbon economy there is a need to distinguish different sectors from that perspective and to analyse the changes in them. The modified applications would include information at 3 digit level of the NACE classification and from NUTS 1-3 levels in order to provide information on the resource efficiency – as measured by available indicators on emission intensity of manufacturing industries[11] and energy consumption percentage (see indicators 42-46 from Table 3)[12]. Areas marked yellow/ochre would then be analysed by the tools as marked in the diagram.

[11] The source of this information is the European Environment Agency. Emission intensity of manufacturing industries is calculated as 'the amount of pollutant discharged in water per unit of production of the manufacturing industries (expressed as one million Euro gross value added)' (European Environment Agency, 2015: 6).

[12] This data is produced by the OECD, and it covers energy consumption in agriculture, services, industry, transport and other sectors, as a percentage of total energy consumption (see OECD, 2018a).

7. Annex 1

Indicators for transition to low-carbon economy

The International Energy Agency (IEA) has made comprehensive analysis and created a scenario towards a low-carbon[13] economy calling it the Sustainable Development Scenario (SDS) and outlines how a major transformation of the global energy system should take place. According to IEA decarbonising the power sector is the fundamental step to reducing emissions and must be complemented by significant efficiency improvements in buildings, to meet growing demand from cooling, heating and powered devices. The transport sector also needs to undergo a major transformation, which includes shifting from oil to electricity to gain the benefits of clean power generation. It would be more difficult to tackle are industrial processes that cannot be easily electrified, but in which emissions still need to be cut – through efficiency, aggressive innovation and Carbon Capture and Storage technology (CCS). Energy integration technologies and updates to the electricity network will become increasingly important as shares of variable renewables rise.

According to the International Energy Agency (IEA - www.iea.org/tcep/power/) low-carbon generation must become the preferred option in order to meet SDS targets: "[L]ow-carbon generation must become the preferred option for meeting new electricity demand, displacing fossil-fuelled generation. The falling cost of clean energy technologies can reshape electricity supply but the current state of national electricity systems and local resources will greatly influence the preferred objectives and outcomes. There are also wide regional differences in the carbon intensity, depending on the reliance on fossil fuels, especially coal, for power generation" (www.iea.org).

IEA recommends a set of key indicators that reflect the most important short-term actions that policymakers should focus on to drive the clean energy transition, and they are:

- Energy-related CO2 emissions - Total CO2 emissions from energy (Gt)
- Energy intensity – Primary energy demand per unit GDP (Mtoe/1000)
- Energy system carbon intensity – CO2 emissions per unit of total final consumption (TFC) (MtCO2/Mtoe)

One mayor issue that needs to be considered when selecting indicators, is that one cannot only focus, for instance, on one source of energy generation that might generate the largest share of CO2. An increase in renewable energy sources, with its variable output (wind and solar photovoltaic), will have an impact on the electricity network that needs to be adjusted both in terms of handling these variations as well as transporting it to the right place at the right time. This means investing in the

[13] The term low-carbon power can include power that uses natural gas and coal, but only when techniques are employed that reduce carbon dioxide emissions from these sources when burning them for fuel.

network itself but also in integration of energy needs though smart grids and energy storage. Another way to lower the need for energy is by making buildings more energy efficient, both commercial and residential. To maximise a positive impact of a solution towards a low-carbon economy, one has to integrate a number of solutions. In other words, there is a need for a comprehensive and holistic approach with a long-term policy plan that all involved and affected stakeholders agree upon. Hence, it is from this point of view a selection of indicators should be made.

Another aspect is that each region is different when it comes sources of CO_2 emissions. While some regions have heavy industry and fossil fuel generating energy, another maybe has a more diverse range of CO_2 emitting sources.

Hence, it is important to provide a range of indicators that are suitable and useful for a specific region to guide its efforts towards a low-carbon economy. A selection of the most important ones is provided in Table 3 with their importance ranked and availability indicated. It should be noted that some indicators exist as a concept, but do not have data readily available. However, that has not influenced the rating of indicators. Furthermore, there are only two indicators for which data are available at Nuts 2 and Nuts 3 levels (see indicators 80 and 81) and three indicators which are available at national and Nuts 2 levels (see indicators on waste management, No. 29-31). Sometimes, the indicators are not even available at the national level, but at the world level.

In addition, there are 11 indicators among them that would be especially valuable for the regions to follow. These are the following ones:

1. Governments environmental and energy R&D appropriations and outlays of total R&D spending [% of total R&D public spending]
2. Renewable energy public RD&D budget [% of total energy public RD&D]
3. Public and private investment in clean energy RD&D [Share of total investments in RD&D]
4. Share of new low-carbon power generation investment in overall power generation investment (public & private) [% of total]
5. Renewable energy supply [% of TPES]
6. Energy CO_2 - supply - Of domestic origin [Million tonnes]
7. CO_2 intensity of electricity generation [gCO_2/kWh]
8. Share of renewable electricity total electricity generation [% of total electricity generation]
9. Power sector CO_2 emissions (Total, Gas, Coal) [GtCO_2]
10. Share of low-carbon power generation in overall power generation [% of total]
11. Mean population exposure to $PM_{2.5}$ [micrograms per cubic meter (µg/m3)].

Table 3: Indicators for transition to low-carbon economy

					Data available at level:				
No.	Indicator area / indicator	Explanation	Unit	Rank[1]	National	Nuts 2	Nuts 3	Source[4]	Application to be updated[3]
	Green economic outlook								
	R&D spending								
1	Governments environmental and energy R&D appropriations and outlays	The relative priority given by governments to investing in research and development in the areas of energy, including renewables, and environment	% GDP	1	X			https://ec.europa.eu/environment/ecoap/sites/ecoap_stayconnected/files/inputs_b1.xlsx	Regional assets mapping, Benchmarking, Budgeting
2	Environment-related government R&D budget	Refers to Government Budget Appropriations or Outlays for Research and Development (GBAORD), measuring the funds that government allocates. Includes research directed at the control of pollution and on developing monitoring facilities to measure, eliminate and prevent pollution.	% total government R&D	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking, Budgeting
3	Environment-related R&D expenditure	Refers to Gross domestic Expenditure on Research and Development (GERD) measured as total intramural (= business enterprise + government + higher education + private non-profit) R&D	% GDP	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking, Budgeting

		expenditure. Includes research directed at the control of pollution and on developing monitoring facilities to measure, eliminate and prevent pollution.							
4	Renewable energy public RD&D budget	Directed at research, development and demonstration (RD&D) related to renewable energy, including hydro, geothermal, solar (thermal and PV), wind and tide/wave/ocean energy, as well as combustible renewables (solid biomass, liquid biomass, biogas) and other renewable energy technologies (all supporting measuring, monitoring and verifying technologies in renewable energies).	% total energy public RD&D	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking, Budgeting
5	Fossil fuel public RD&D budget	Public budget directed at research, development and demonstration (RD&D) related to fossil fuels, including oil, gas and coal and excluding RD&D related to CO_2 capture and storage (CCS). Important indicator to be compared with Renewable energy public RD&D budget.	% total energy public RD&D	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
	Investments								
6	Investment share of low carbon in overall energy investment	High Level Energy Indicators - Aggregate energy sector (Transport, Industry, Buildings, Power Generation) - Energy Investment	%	1	X			https://www.iea.org/media/publications/tcep/High_Level_Indicators_for_Clean_Energy_Transition.pdf	Regional assets mapping, Benchmarking, Specialisation

									indexes, Related variety analysis
7	Public and private investment in clean energy RD&D	High Level Energy Indicators - Aggregate energy sector (Transport, Industry, Buildings, Power Generation) - Energy Investment	Share of total investments in RD&D	1	X			https://www.iea.org/media/publications/tcep/High_Level_Indicators_for_Clean_Energy_Transition.pdf	Regional assets mapping, Benchmarking, Specialisation indexes, Related variety analysis
8	Share of new low-carbon power generation investment in overall power generation investment (public & private)	High Level Energy Indicators - Power Generation sector - Energy Investment	%	1	X			https://www.iea.org/media/publications/tcep/High_Level_Indicators_for_Clean_Energy_Transition.pdf	Regional assets mapping, Benchmarking, Specialisation indexes, Related variety analysis
9	Public and private investment in clean energy research	Is a critical indicator for tracking overall trends, especially for long-term progress.	Trend in %	2	X			https://www.iea.org/media/publications/tcep/High_Level_Indicators_for_Clean_Energy_Transition.pdf	Regional assets mapping, Benchmarking
10	Total value of green early stage investments	The value of early stage investments in eco-industries	USD/capita	1	X			www.cleantech.com (access to data is available upon subscription)	Regional assets mapping, Benchmarking
11	Low-carbon investment in clean energy transition	Fossil fuel, Renewables, Other low carbon, Electricity networks	USD	2	X			https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking

	Environmental certification								
12	ISO 14001 (Environmental management systems) registered organisations	ISO 14001 is an internationally agreed standard that sets out the requirements for an environmental management system. It helps organizations improve their environmental performance through more efficient use of resources and reduction of waste.	Number per mln population	3	X			https://www.iso.org/iso-14001-environmental-management.html	
13	ISO 50001 (Energy management) registrations	ISO 50001 supports organizations in all sectors to use energy more efficiently, through the development of an energy management system (EnMS).	Number per mln population	3	X			https://www.iso.org/iso-50001-energy-management.html	
14	Other environmental certifications used	There are a number of EU, European, national and cross-sectoral eco labels around Europe that are more common on certain countries. Voluntary energy efficiency policies also exist in many regions.	Number per mln population	3	X			Various sources, depending on the country.	
	Environmental, energy & resource productivity								
	Carbon Productivity (economic output per unit of CO_2 emitted)								
15	Production-based CO_2 productivity	Is calculated as real GDP generated per unit of CO_2 emitted (USD/kg). Included are	GDP per unit of	2	X			http://www.oecd.org/greengrowth/green-growth-indicators/	

		CO_2 emissions from combustion of coal, oil, natural gas and other fuels.	energy-related CO_2 emissions						
16	Production-based CO_2 intensity	Is calculated as CO_2 emissions per capita (tonnes/person). Included are CO_2 emissions from combustion of coal, oil, natural gas and other fuels.	energy-related CO_2 per capita	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	
17	Production-based CO_2 emissions	Can be expressed in million metric tonnes or as an index with values in year XXXX normalised to equal 100. Included are CO_2 emissions from combustion of coal, oil, natural gas and other fuels	million metric tonnes (or index)	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	
18	Demand-based CO_2 productivity	Reflects the CO_2 from energy use emitted during the various stages of production of goods and services consumed in domestic final demand, irrespective of where the stages of production occurred. Trends in emissions on this basis thus complement the more conventional production-based measures.	GDP per unit of energy-related CO_2 emissions	2	X			http://www.oecd.org/greengrowth/green-growth-indicators/	
19	Demand-based CO_2 intensity	Reflect the CO_2 from energy use emitted during the various stages of production of goods and services consumed in domestic final demand, irrespective of where the stages of production occurred. Trends in	energy-related CO_2 emissio	2	X			http://www.oecd.org/greengrowth/green-growth-indicators/	

		emissions on this basis thus complement the more conventional production-based measures.	ns per capita							
20	Demand-based CO2 emissions	Also expressed as an index with values in year XXXX normalised to equal 100. Demand-based emissions reflect the CO2 from energy use emitted during the various stages of production of goods and services consumed in domestic final demand, irrespective of where the stages of production occurred. Trends in emissions on this basis thus complement the more conventional production-based measures.	million metric tonnes (or indexed)	2	X				http://www.oecd.org/greengrowth/green-growth-indicators/	
	Land resources									
21	Land use: (housing and transport area, agricultural land, forests, water surface)	Baseline	% of total	2	X				http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
22	Land resources: land use changes (housing and transport area, agricultural land, forests, water surface)	Loss of natural and semi-natural vegetated land is presented as a proxy for pressures on biodiversity and ecosystems.	% change to reference year	2	X				http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking

	Resource productivity								
23	Material productivity	Illustrates the GDP generated by material consumption of a country	GDP/ Domestic Material Consumption	2	X			http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_mfa&lang=en	Regional assets mapping, Benchmarking
24	Water productivity	Illustrates the GDP generated by domestic water consumption	GDP / total fresh water abstraction	3	X			http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wat_abs&lang=en	
25	Energy productivity	See below Energy generation & Energy productivity	GDP/ gross inland energy consumption	2	X			http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tsdcc120	Regional assets mapping, Benchmarking
26	GHG emissions intensity	Illustrates the amounts of GHG emissions generated per unit of GDP	CO2e/GDP	1	X			http://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer	Regional assets mapping, Benchmarking
27	Low air pollution exposure	See subheading 'Environmental quality of life and psychological preconditions for a transition'	PM2.5	2	X			http://www.oecd.org/greengrowth/green-growth-indicators/	

28	Environmentally adjusted multifactor productivity (EAMFP) growth	EAMFP growth measures the change in productivity at the macroeconomic (country) level encompassing e.g. technological change, institutional and organisational improvements.	EAMFP	3	X			http://www.oecd.org/greengrowth/green-growth-indicators/	
	Waste management								
29	Municipal waste generated	Includes household waste originating from households (i.e. waste generated by the domestic activity of households) and similar waste from small commercial activities, office buildings, institutions such as schools and government buildings, and small businesses that treat or dispose of waste at the same facilities used for municipally collected waste	kg per capita	2	X	X		https://www.oecd-ilibrary.org/environment/data/oecd-environment-statistics_env-data-en and https://ec.europa.eu/eurostat/web/waste/transboundary-waste-shipments/key-waste-streams/municipal-waste	Regional assets mapping, Benchmarking
30	Municipal waste recycling and backfilling (recovery)	Recycling is defined as any reprocessing of material in a production process that diverts it from the waste stream, except reuse as fuel. Both reprocessing as the same type of product, and for different purposes are included. Direct recycling within industrial plants at the place of generation is excluded. Composting is defined as a biological process that submits biodegradable waste to anaerobic or aerobic decomposition, and that results	% waste treated	2	X	X		https://www.oecd-ilibrary.org/environment/data/oecd-environment-statistics_env-data-en and https://ec.europa.eu/eurostat/web/waste/transboundary-waste-shipments/key-waste-streams/municipal-waste	Regional assets mapping, Benchmarking

		in a product that is recovered. Waste treated includes recycling, composting, incineration and landfill disposal.							
31	Municipal waste incinerated with energy recovery ('Waste-to-Energy') (recovery)	Incineration with and without energy recovery is included. Waste treated includes recycling, composting, incineration and landfill disposal.	% waste treated	2	X	X		https://www.oecd-ilibrary.org/environment/data/oecd-environment-statistics_env-data-en and https://ec.europa.eu/eurostat/web/waste/transboundary-waste-shipments/key-waste-streams/municipal-waste	Regional assets mapping, Benchmarking
	Energy generation & Energy productivity								
32	Energy productivity	It reflects, at least partly, efforts to improve energy efficiency and to reduce carbon and other atmospheric emissions. Together with Energy intensity, these indicators also reflect structural and climatic factors.	GDP per unit of TPES	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
33	Energy intensity	Reflects, at least partly, efforts to improve energy efficiency and to reduce carbon and other atmospheric emissions. Together with Energy productivity, these indicators also reflect structural and climatic factors. (SDG indicator 7.3.1)	TPES per capita	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking

34	Total primary energy supply	Total primary energy supply (TPES) is expressed in million tonnes of oil equivalent. TPES is also expressed as an index with values in year XXXX normalised to equal 100. TPES comprises production + imports - exports - international marine bunkers - international aviation bunkers ± stock changes. Provides the baseline.	TPES	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
35	Renewable energy supply	Renewables include hydro, geothermal, solar (thermal and PV), wind and tide/wave/ocean energy, as well as combustible renewables (solid biomass, liquid biomass, biogas) and waste (renewable municipal waste).	% of TPES	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
36	Modern renewable energy share in total final energy consumption	(SDG Indicator 7.2.1)	% of total final energy consumption	1	X			https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking
	Energy related CO2								
37	Energy CO2 - supply - Of domestic origin	Energy-related CO2 emissions depending on supply and use	Million tonnes	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
38	Energy CO2 - supply - Imports	Energy-related CO2 emissions depending on supply and use	Million tonnes	2	X			http://www.oecd.org/greengrowth/green-growth-indicators/	

39	Energy CO_2 - use - Exports	Energy-related CO_2 emissions depending on supply and use	Million tonnes	2	X			http://www.oecd.org/greengrowth/green-growth-indicators/	
40	Energy CO_2 - use – Final domestic use	Energy-related CO_2 emissions depending on supply and use	Million tonnes	2	X			http://www.oecd.org/greengrowth/green-growth-indicators/	
41	Energy sector carbon intensity	The energy sector carbon intensity indicator tracks the amount of carbon emissions from fuel combustion. It shows the net impact of policy changes, shifts in investment and technology developments on CO_2 emissions in the energy sector and gives a measure of how "clean" the energy supply is from a climate perspective.	tCO_2/(Total Final Energy Consumption)	1				https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking
	Energy consumption per sector								
42	Energy consumption in agriculture	Final consumption reflects for the most part deliveries to consumers. It excludes energy used for transformation processes and for own use of the energy-producing industries. Energy consumption in agriculture includes deliveries to users classified as agriculture, hunting and forestry by the International Standard Industrial Classification (ISIC).	% total energy consumption	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
43	Energy consumption in services	It excludes energy used for transformation processes and for own use of the energy-producing industries. Energy consumption	% total energy	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking

		in services includes both commercial and public services.	consumption						
44	Energy consumption in transport	It excludes energy used for transformation processes and for own use of the energy-producing industries. Energy consumption in transport covers all transport activity (in mobile engines) regardless of the economic sector to which it is contributing.	% total energy consumption	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
45	Energy consumption in industry	Final consumption reflects for the most part deliveries to consumers. It excludes energy used for transformation processes and for own use of the energy-producing industries. Energy consumption in industry includes the following sub-sectors: iron and steel, chemical and petrochemical, non-ferrous metals, non-metallic minerals, transport equipment, machinery, mining and quarrying, food and tobacco, paper, pulp and print, wood and wood products, construction, textile and leather together with any manufacturing industry not included above.	% total energy consumption	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
46	Energy consumption in other sectors	Final consumption reflects for the most part deliveries to consumers. It excludes energy used for transformation processes	% total energy consumption	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking

		and for own use of the energy-producing industries. Energy consumption in other sectors includes residential consumption and all fuel use not elsewhere specified.							
	Energy intensity								
47	CO_2 intensity of electricity generation	Low-carbon generation must become the preferred option for meeting new electricity demand, displacing fossil-fuelled generation to meet SDS/SDGs - outcome metric.	gCO_2/kWh	1	X			https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking
48	CO_2 intensity of power generation from new investments	This would show efforts made towards low-carbon economy in the energy sector - a driver metric.	gCO_2/kWh	1	X			https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking
49(5	Share of electricity in total final energy consumption	The share of electricity in total final energy consumption provides a pathway for clean-energy transitions through the electrification of end use sectors, with increasing shares of electrified transport (electric vehicles and freight) and buildings, with more challenges in industry.	% of total	1				https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking
50	Share of electricity generation from power technologies	The share of electricity produced from low-carbon technologies – including renewables, nuclear and carbon capture and storage – is an effective measure of the overall impact on the system.	% per technology	2	X			https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking

51	Share of renewable electricity total electricity generation.	Renewables include hydro, geothermal, solar (thermal and PV), wind and tide/wave/ocean energy, as well as combustible renewables (solid biomass, liquid biomass, biogas) and waste (renewable municipal waste) - Shows current state.	% of total electricity generation	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
52	CO_2 intensity per sector	Residential, services, industry and transport	CO_2 emissions per sector	1	X			https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking
	Power								
53(5	Power sector CO_2 emissions (Total, Gas, Coal)	The power sector plays a central role in the clean energy transition, because it is the largest source of energy-related CO_2 emissions and because the share of electricity in final energy consumption is rising.	$GtCO_2$	1				https://www.iea.org/tcep/power/	Regional assets mapping, Benchmarking
54	Share of low-carbon power generation in overall power generation	Energy Supply - High Level Energy Indicators	%	1	X			https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking
55	Average CO_2 intensity of electricity generation	Energy Supply - High Level Energy Indicators	gCO_2/kWh	1	X			https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking

56	CO_2 intensity of power generation from new investments	Energy Supply - High Level Energy Indicators	gCO_2/kWh	1	X			https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking
	Buildings								
57	Buildings sector CO_2 emissions	Indirect emissions due to energy use from upstream power generation need to be taken into account (28% of global energy-related CO_2 emissions came from buildings in 2017 – IEA.org)	$GtCO_2$	2	X			https://www.iea.org/tcep/buildings/	Regional assets mapping, Benchmarking
58	Building sector energy intensity	Change in total final energy used per m2 in the buildings sector.	Index (year xxxx = 100)	2	X			https://www.iea.org/tcep/buildings/	Regional assets mapping, Benchmarking
59	Policy coverage of total final energy consumption in buildings	Percent of buildings energy use covered by policies, e.g.: lightning, space cooling, space heating, water heating, appliances, Total coverage. Figures for policy coverage do not indicate how stringent polices are.	%	2	X			https://www.iea.org/tcep/buildings/	
60	Buildings sector energy efficiency investments	Investment in sustainable buildings: Building envelope measures, heating and cooling equipment, Lightning and appliances, Other building investments (e.g. Digitalization, Data centres and networks and energy efficiency)	USD / EUR	2	X			https://www.iea.org/tcep/buildings/	Regional assets mapping, Benchmarking

61	Type of heating used in residential buildings	Fossil fuel equipment, heat pumps, district heating & cooling, conventional electric equipment, renewables	% share per source	2	X			https://www.iea.org/tcep/buildings/	Regional assets mapping, Benchmarking
	Transport								
62	Transport sector CO_2 emissions	Total, Other, Rail, Shipping, Aviation, Road freight vehicles, Passenger and road vehicles.	$GtCO_2$	2	X			https://www.iea.org/tcep/transport/	Regional assets mapping, Benchmarking
63	Transport sector energy intensity	BOE = barrel of oil equivalent	boe/ thousand USD	2	X			https://www.iea.org/tcep/transport/	Regional assets mapping, Benchmarking
	Industry								
64(5	CO_2 emissions from direct industrial energy use	Decoupling of industrial activity from CO_2 emission is critical to meet SDS/SDG targets	$GtCO_2$	1				https://www.iea.org/tcep/industry/	Regional assets mapping, Benchmarking
65(5	Total final industrial energy consumption by fuel	Total, Other renewables, Bioenergy, Heat, Electricity, Gas, Oil, Coal	EJ	1				https://www.iea.org/tcep/industry/	Regional assets mapping, Benchmarking
66	Electricity consumption of electric motor systems by efficiency standard level	Improving energy efficiency and shifting towards best available technologies can help reduce energy demand. Under the IEC 60034-30-1 standard for induction motors, there are five International Efficiency (IE) classes as follows: IE 1 = standard efficiency, IE2 = high efficiency, IE3 = premium	Twh	2	X			https://www.iea.org/tcep/industry/	

		efficiency, IE4 = super premium efficiency, IE5 = ultra premium efficiency (United Nations Environment Programme, 2017).							
67	Industrial productivity by region	Industrial productivity is defined as industrial value-added per unit of energy used.	USD/Gj	2	X			https://www.iea.org/tcep/industry/	
68	Mandatory policy coverage of industrial energy use by region	Proportion of industrial total energy use covered by mandatory policies.	%	2	X			https://www.iea.org/tcep/industry/	Regional assets mapping, Benchmarking
	Energy Integration								
69	Energy storage	Storage capacity, excluding pumped hydro	GW	2	X			https://www.iea.org/tcep/energyintegration/	Regional assets mapping, Benchmarking
70	Smart grids	Investment in smart distribution networks	USD	1				https://www.iea.org/tcep/energyintegration/	Regional assets mapping, Benchmarking
71	Demand response (Industry & Agriculture, Buildings, Transport)	Electricity supply and demand must be balanced at all times but is an issue as the share of power generation from variable rises. Demand-side response is one of several measures that can help integrate higher shares of variable renewables, including electricity storage, greater interconnection and more flexible power plants.	Twh + Share of demand	2	X			https://www.iea.org/tcep/energyintegration/	

72	Digitalization	Digitalized energy systems can identify energy needs and deliver it at the right time, in the right place and at the lowest cost. Investment in Data storage, Internet bandwidth, Sensors	USD	2	X			https://www.iea.org/tcep/energyintegration/	Regional assets mapping, Benchmarking
73	Hydrogen and fuel cells	Hydrogen can link different energy sectors and energy transmission and distribution networks, and thus increase the operational flexibility of future low-carbon energy systems. Heat network, Electricity grid, Liquid and gaseous fuels and feed-stocks T&D, Hydrogen	USD	3	X			https://www.iea.org/tcep/energyintegration/	
74	Renewable heat	Bioenergy (excluding traditional biomass), Solar, Geothermal, Renewable district heating, Renewable electricity.	Mtoe / year	1				https://www.iea.org/tcep/energyintegration/	Regional assets mapping, Benchmarking
	Environmental quality of life and psychological preconditions for a transition								
75	Modern renewable energy share in total final energy consumption (SDG Indicator 7.2.1)		Percentage (%) of total	2	X			https://www.iea.org/tcep/indicators/	Regional assets mapping, Benchmarking
76	Mean population exposure to PM2.5	Defined as the average level of exposure of a nation's population to concentrations of suspended particles measuring less than 2.5 microns in aerodynamic diameter, which are capable of penetrating deep into	micrograms per cubic meter (µg/m3)	1	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking

		the respiratory tract and causing severe health damage. Exposure is calculated by weighting mean annual concentrations of PM2.5 by population in living areas.							
77	Percentage of population exposed to more than 10 µg/m3	(WHO Air Quality Guideline (AQG)	µg/m3	2	X			http://www.oecd.org/greengrowth/green-growth-indicators/	
78	Percentage of population exposed to more than µg/m35	(WHO Air Quality Guideline (AQG)	µg/m3	2	X			http://www.oecd.org/greengrowth/green-growth-indicators/	
79	Mortality from exposure to PM2.5		deaths per million inhabitants	2	X			http://www.oecd.org/greengrowth/green-growth-indicators/	Regional assets mapping, Benchmarking
	Individual Psychological Characteristics								
80	Norm perception, Attitudes, Identity, Efficacy	Collected through surveys		2	X	X	X	(2)	
	Household-level behaviour								
81	Recourse consumption,	Collected through surveys		2	X	X	X	(2)	

	Conservation/efficiency, Food procurement, Waste management								

Note: (1) 3 = somewhat relevant, 2 = quite relevant, 1 = relevant. (2) Cook et al. (2014: 70-78). (3) Applications to be updated are specified for those indexes that are relevant (ranked 1) and sometimes for those that are quite relevant (ranked 2). (4) Source is a reference in which the indicator is either mentioned and/or in which data for the indicator can be found.

Source: authors on the basis of the sources quoted in the table.

8. Annex 2

Green Growth Indicators (OECD)

As a starting point in the selection of indicators, or to have a few questions that guide towards the objective of a low-carbon economy, one can take inspiration from OECD Green Growth Indicators informed by 'four questions that are at the heart of green growth' (OECD, 2017):

- Is the region becoming more efficient in using natural resources and environmental services?
- How does greening the regional economy generate opportunities for growth and development?
  a. Taxes & subsidies (shifting taxes away from labour and capital and towards sources that harm the environment and phasing out harmful subsidies) – it completely depends if regions have any control over this.
  b. R&D (eco-innovation) (what is the share of dedicated government R&D spending on dedicated environment and energy objectives)
  c. Is the natural asset base of the regional economy maintained?
  d. Pressure on natural resources (land development and the resulting changes in land cover lead to a loss of natural resources and agricultural land)
  e. Does greening growth generate benefits for people in the region?
  f. Simply measuring emissions, especially air pollution. As reference can be used the 'WHO Air Quality Guideline' (World Health Organization, & UNAIDS, 2006) and the 'Ambient Air Quality Directive' (Directive 2008/50/EC) and the 'Air Quality Standards' (http://ec.europa.eu/environment/air/quality/standards.htm) by the European Union.

Below, in Table 4 are the OECD headline indicators for its Green Growth Indicators.

Table 4: Headline OECD Green Growth Indicators

Environmental and resource productivity	
Carbon productivity	1. CO_2 productivity
Resource productivity	2. Non-energy material productivity
Multifactor productivity	3. Multifactor productivity including environmental services
The natural asset base	
Renewable and non-renewable stocks	4. Natural resource index.
Biodiversity and ecosystems	5. Changes in land use and cover
Environmental quality of life	
Environmental health and risks	6. Air pollution (population exposure to PM 2.5)

Economic opportunities and policy responses	
Technology and innovation, environmental goods and services, prices and transfers, etc.	No indicator specified

Environmental and resource productivity: indicates whether economic growth is becoming greener with more efficient use of natural capital and to capture aspects of production which are rarely quantified in economic models and accounting frameworks (OECD, 2017): carbon productivity, energy productivity, material productivity and waste, nutrient flows and balances, environmentally adjusted multifactor productivity.

The natural asset base: indicate the risks to growth from a declining natural asset base: land resources, forest resources, freshwater resources, biodiversity, ecosystems and wildlife resources.

Environmental dimension of quality of life: indicate how environmental conditions affect the quality of life and well-being of people: air pollution, health risks and costs, access to water supply, sanitation and sewage treatment.

Economic opportunities and policy responses: indicate the effectiveness of policies in delivering green growth and describe the societal responses needed to secure business and employment opportunities: technology and innovation, markets for environmental related products, international financial flows, taxes and subsidies.

However, the Green Growth indicators are very comprehensive counting 138 variables in total, and many are aggregated to create one composite indicator. They are practical to use though, as all the Green Growth Indicators are accessible in OECD.Stat (OECD, 2018a). However, they are only disposable at the national level, and not at the regional level.

In addition, OECD (2017) uses the environmentally adjusted multifactor productivity (EAMFP). The EAMFP is a development of the Multifactor Productivity (MFP) which has been used for more than 50 years to better understand drivers behind economic growth. MFP measures the part of output growth that cannot be explained by changes in inputs such as labour and capital. The idea is that by comparing changes in the contribution of labour and capital with changes in GDP, you can understand how technological improvements or efficiency gains help a country become wealthier and improve material living standards. However, MFP does not take into account pollution emissions and the use of natural resources. Traditionally, the increase in the extraction of natural recourses has been interpreted as an increase in productivity while at the same time GDP is the only measured economic output. The issues are that within this framework, efforts to reduce negative impact have not been considered as an economic benefit. Not considering the negative environmental impacts and the use of natural resources when measuring economic growth gives a misleading picture of the potential growth prospects and can lead to inappropriate policy decisions (OECD, 2018b).

Growth in environmentally adjusted multifactor productivity (EAMFP) measures a country's ability to generate income from a given set of inputs while accounting for the consumption of natural resources and the production of undesirable environmental outputs (e.g. CO_2 emission, pollution).

EAMFP provides the opportunity to develop two related indicators that could be useful for green growth analysis: the growth contribution of natural capital which measures how much current income growth depends on natural resource use, and the growth adjustment for pollution abatement which measures to what extent economic growth has been achieved at the expense of environmental quality.

The idea is that growth is measured as the residual growth in the joint production of both the desirable and the undesirable outputs that cannot be explained by changes in the consumption of factor inputs (including labour, produced capital and natural capital). Therefore, for a given growth of input use, EAMFP increases when GDP increases or when pollution decreases.

The methodology is available in the OECD paper Environmentally Adjusted Multifactor Productivity: Methodology and Empirical results for OECD and G20 countries (Cárdenas Rodríguez, Haščič, & Souchier, 2018).

Pros and cons of the Green Growth Indicators:
(+) Established indicators that measure across a wide spectrum of issues.
(-) Indicators collected on a national level only
(-) Different sources for the indicators.
(-) Indicators not regularly updated.
(-) Difficult to get information on the unit of indicators and how they are calculated
(+/-) There are 138 indicators/variables (OECD, 2018a)

The Eco-innovation Action plan

The Eco-innovation Action plan has been adopted by the European Commission in order to support faster market absorption of eco-innovation (https://ec.europa.eu/environment/ecoap/about-action-plan/objectives-methodology_en). Eco-innovation scoreboard and eco-innovation index are an important part of these efforts.

Eco-Innovation index (see Table 5) - The Eco-Innovation Scoreboard (Eco-IS) and the Eco-innovation Index illustrate eco-innovation performance across the EU Member States by capturing different aspects of eco-innovation by applying 16 indicators grouped into five dimensions: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency and socio-economic outcomes. The Eco-IS and the Eco-innovation Index are intended to complement other measurement approaches of innovativeness of EU countries and with the aim to promote a holistic view on economic, environmental and social performance.

Eco-IS and the Eco-Innovation Index are used in the preparation of the country reports, published since 2010 (See https://ec.europa.eu/environment/ecoap/country_profiles_en). Not all 16 indicators are relevant, especially where data is difficult to access and collect and are based on surveys. On the other hand, surveys made on a regional level might be easier to carry out than on a national level.

There are some eco-innovation indicators that are available upon subscription only: 1.3. Total value of green early stage investments, 3.1. Eco-innovation related patents, 3.2. Eco-innovation related academic publications, 3.3. Eco-innovation related media coverage, 5.2. Employment in eco-industries and circular economy, 5.3. Revenue in eco-industries and circular economy,

In the case of Denmark and the Eco-innovation Index, there are discrepancies in figures related to that the NAICS codes selected for eco-industry and circular economy do exclude a number of industries. For instance, the indicator does not include renewable energy companies, a field that Denmark is particularly strong in, especially in the field of manufacturing, selling, installation and service of wind turbines.

According to the Green National Accounts for Denmark 2015-2016 - Environmental goods and services "[t]he accounts for the environmental goods and services sector (EGSS) provide a picture of the economic activity resulting from the transition to a green economy. This economic activity is measured in terms of output, employment, value added and exports, i.e. figures that can be compared with figures for the total economy".

Economic activities within the area of environmental goods and services are compiled according to environmental purpose (environmental protection and resource management purposes) as well as industry. Calculating according to environmental purpose helps show e.g. whether concrete environmental targets are being met, while compiling by industry can help show the potential in an industrial policy context.

The environmental goods and services accounts describe the economic aspects of the production of environmentally friendly goods and services. In accordance with the international guidelines for these accounts, environmental goods and services refer to goods and services that protect the environment directly and goods and services designed for natural resource management. Research and development in these fields is also included.

Furthermore, a distinction is made between goods and services with a specific environmental purpose (e.g. wind turbines) and products that are cleaner and more resource-efficient compared to other products with the same primary purpose (e.g. water-saving taps). It can be difficult to accurately identify environmental goods and services and these reports are therefore subject to significant uncertainty" (Statistics Denmark, 2018).

Pros and cons of the Eco-Innovation index:
(+) Established indicators that measure across a wide spectrum of issues.
(+) Indicators used on a regular basis (biannually) in reports.
(+) Indicators linked to measure specific outcomes
(-) Indicators collected on a national level only
(-) Different sources for the indicators.
(-) Not all indicators are regularly updated.
(-) Some indicators are based on surveys.
(-) Some indicators are not publicly available.
(-) What defines or measured as part of an indicator is different between Eco-index and national definitions, e.g. what is a 'green job' or employment in eco-industries? Example: NAICS: 221115 - Wind electric power generation, and NAICS 33361 - Wind turbines (i.e., windmills), manufacturing, are not included in the ORBIS list of eco-industries (Eco-innovation indicator) but it is in the Danish national green accounts.
(+/-) Difficult to accurately identify what defines environmental goods and services, hence when used in comparison with national reports subject to significant uncertainty.
(+/-) There are alternative sources for indicators. Take ISO 14001 registered organisations, in some countries maybe not so popular because they use other types of (national/regional) standards and certifications, i.e. in Denmark apply a strong environmental regulation and have preferred to implement the European Eco Management and Audit Scheme (EMAS) and Danish companies have also been successful in Environmental Technology Verification (ETV)

Table 5: Eco-innovation Index 2017 – list of indicators

Name of indicator	**Unit of measurement**
1. Eco-innovation inputs	
1.1. Governments environmental and energy R&D appropriations and outlays	Percentage (of GDP)
1.2. Total R&D personnel and researchers	Percentage (of total employment)
1.3. Total value of green early stage investments	USD/capita
2. Eco-innovation activities	

2.1. Enterprises that introduced an innovation with environmental benefits obtained within the enterprise	Percentage (of total firms)
2.2. Enterprises that introduced an innovation with environmental benefits obtained by the end user	Percentage (of total firms)
2.3. ISO 14001 registered organisations	Number per mln population
3. Eco-innovation outputs	
3.1. Eco-innovation related patents	Number per mln population
3.2. Eco-innovation related academic publications	Number per mln population
3.3. Eco-innovation related media coverage	(per numbers of electronic media)
4. Resource efficiency outcomes	
4.1. Material productivity	GDP/Domestic Material Consumption
4.2. Water productivity	GDP / total fresh water abstraction
4.3. Energy productivity	GDP/gross inland energy consumption
4.4. GHG emissions intensity	CO2e/GDP
5. Socio-economic outcomes	
5.1. Exports of products from eco-industries	Percentage (of total exports)
5.2. Employment in eco-industries and circular economy	Percentage (% of total employment across all companies)
5.3. Revenue in eco-industries and circular economy	Percentage (% of total revenue across all companies)

International Energy Agency (IEA)

IEA has developed the High-Level Indicators for a clean energy transition. The idea behind them is to "reflect the most important short-term actions that policymakers can focus on to drive long-term clean-energy transitions" (International Energy Agency, 2018). There are CO2 emission indicators on the aggregate level as well as subdivided into sectors (transport, industry, buildings, power generation). Furthermore, the indicators are divided into Energy End-Use Efficiency and Access, Energy Supply and Energy Investment (see Table 6 below). For instance, if the industry sector emits a large share of CO2 in the region it makes sense to use those indicators if data collection is feasible. One sector that is recommended to include is the building sector as it is a well-known fact that a large part of Europe's building stock is energy inefficient and a large impact can be achieved towards a low-carbon economy by making buildings more energy efficient.

Pros and cons of the High-Level Indicators for a clean energy transition:
(+) Established 'expert' source for energy indicators
(+) Indicators dedicated for monitoring clean energy process
(+) Wide range of indicators that cover different aspects of clean energy transition
(+) Tackles the main issues towards a low-carbon economy
(-) Limited to energy and emissions
(-) Not available at the regional level

Table 6: IEA – High-level indicators for clean energy transition

Sector	**CO2 totals**	**High-Level Energy Indicators**		
		Energy End-Use Efficiency and Access	**Energy Supply**	**Energy Investment**
Aggregate energy sector	Global fuel combustion-related CO_2 emissions	Energy efficiency improvement rate Primary energy intensity (TPES/GDP)	Energy sector carbon intensity [tCO_2/(Total Final Energy Consumption)] Electricity share of total final energy consumption	Investment share of low carbon in overall energy investment Public and private investment in clean energy RD&D
Transport	Transport CO_2 emissions	Total transport-related final energy consumption per GDP Energy efficiency policy coverage in transport Share of EVs in new vehicles sales	Share of biofuels use in transport (of total liquid fuels)	
Industry	Industry CO_2 emissions	Industrial productivity: industrial value added/final industrial energy use [USD thousand/GJ] Mandatory policy coverage of industrial energy use	CO_2 intensity of industrial energy supply (CO_2 per unit of energy used)	

Buildings	Buildings CO_2 emissions	Buildings sector energy performance, total final energy per m2 Energy efficiency policy coverage of buildings	Buildings sector decarbonisation, change in CO_2 per m2	
Power Generation	Power Generation CO_2 emissions		Share of low-carbon power generation in overall power generation Average CO_2 intensity of electricity generation (gCO_2/kWh) CO_2 intensity of power generation from new investments (gCO_2/kWh)	Share of new low-carbon power generation investment in overall power generation investment
Sustainable Development Goals (SDG) Indicators		Energy intensity (TPES/GDP) (SDG 7.3.1) Percentage of population with access to electricity (SDG 7.1.1) Proportion of population with primary reliance on clean cooking facilities (SDG 7.1.2)	Modern renewable energy share in total final energy consumption (SDG Indicator 7.2.1)	

Sustainable Development Goals (SDG 17)

Even if the SDG (https://sustainabledevelopment.un.org/sdgs) address universal and global issues, like access to clean water and sanitation, there are a number of goals and sub-targets that are applicable to developed countries. For instance, the target 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix uses the indicator 7.2.1 Renewable energy share in the total final energy consumption which is useful in moving towards a low-carbon economy.

Another useful target with indicators can be '11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management' with the indicator '11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)'.

Example of SDG goals and targets being used can be seen in the High-Level Indicators for a clean energy transition by the IEA (see Table 6 above). SDGs are also being connected to the circular economy model and can be used as policy goal to show achievement and contribution on an international level towards global challenges.

Pros and cons of the Sustainable Development Goals indicators:
(+) Globally accepted indicators
(+) Politically "in" but can be good to show that a region works towards global challenges
(+) Wide range of indicators
(-) Many indicators not relevant for developed regions
(-) Indicators on national level
(+/-) Some indicators could be adapted to be used at regional level

GREECO – Territorial Potentials for a Greener Economy

An interesting project is GRECCO (https://www.espon.eu/programme/projects/espon-2013/applied-research/greeco-territorial-potentials-greener-economy) that looked into territorial aspects and the potentials related to a greener economy in order to highlight areas that have particular opportunities for contributing to a greener economy through successful territorial development and cohesion policy actions (Tapia, et al., 2014), hence applicable and directly relevant to regions moving towards a low-carbon economy. What is very interesting with this report is that it discusses the linkages and interdependencies between the sectors.

The project also aimed a number of relevant research questions, like:

- What are key areas of green economic activities seen from a territorial point of view, and which key policy areas need to be considered when dealing with the green economy?
- How can regional/local territorial policy strategies and actions contribute to a greener economy?

GREECO uses headline indicators for regional green economic performance as in Table 7.

Table 7: GREECO headline indicators for regional green economic performance of economic sectors

Economic Sector	**Headline indicator**
Agriculture	Organic area
Building and construction	Energy consumption in residential buildings
Energy production	Renewable energy
Green research and eco-innovation	Eco-innovation scoreboard
Manufacturing	Environmental protection expenditure
Tourism	Tourist overnight stay density
Transport	Motorisation rate
Waste management	Waste recycling
Water management	Waste water treatment

In turn the indicators for the regional green economic performance are based on the spheres of the green economy and are organised along five spheres defined in GREECO project (see Table 8).

Table 8: Green economy spheres of the GREECO project

Green economy spheres	**Component**	**Headline indicator**
Environmental sphere	Source function	Environmental and natural assets (EEA)
	Sink function	Emission of air pollutants
Social sphere	Health	Life expectancy
	Environmental risk	Exposure to air pollution
Territorial sphere	Territorial capacity	Renewable energy production
	Spatial efficiency	Land take per GDP unit
Economic sphere	Green supply	Green products and services offered
	Green technology	Green patents
Econosphere	Energy productivity	GVA per energy unit
	CO2 Productivity	GDP per CO2 unit

The GREECO analysis of regional green economic performance is based on following indicators presented (Tapia et al., 2014: 37):

- The environmental sphere: ”[t]he first headline indicator is a comprehensive indicator developed by the EEA on environmental and natural assets, which describes the overall situation of the environment in terms of availability of open space, biodiversity etc. (EEA, 2010)”.
- The social sphere: ”the first indicator reflects the impact of the economy on the well-being of population”.
- The territorial sphere: ”the concept of territorial keys developed in the background document of the Polish Presidency are used (Bȯhme et al., 2011)”.
- The economic sphere: ”GREECO‘s intention was to address the ‘greenness of economic activities’ as far as possible”.
- The econosphere: ”is covered by environmental and resource productivity indicators”.

The report addresses an issue that should be kept in mind when choosing and working with indicators: that data scarcity can limit the analysis, i.e when an indicator is selected, sometimes a compromise between what would be desirable and what is available is made.

RECREATE and the Green Horizons Scoreboard

RECREATE stands for “REsearch network for forward-looking activities and assessment of research and innovation prospects in the fields of Climate, Resource Efficiency and raw mATErials” (www.recreate-net.eu/dweb/). It was a project funded by the European Commission in the context of its FP7 programme. One of its activities was to compare European innovation systems, i.e. the RECREATE Green Horizons Scoreboard (https://green-horizons.eu/).

What is special about the RECREATE scoreboard is that it compares Technological Innovation Systems (TIS) vis-à-vis existing scoreboards. The RECREATE Green Horizons Scoreboard (green-horizons.eu) provides time series indicators on eleven TIS that are relevant for innovations for sustainable development.

RECREATE was built around the following objectives:

1. Assessing the impact of potential break-through innovations in the relevant fields,
2. Developing scenarios and analysing trends that help to define research and innovation priorities,
3. Benchmarking Member States’ performance in the relevant fields,
4. Creating and maintaining a broad network of stakeholders that get involved in the above activities and
5. Transmitting the knowledge produced by the project effectively to policy-makers and other target groups.

One of the outputs of the project was a report on Indicators and methodology for EU R&I cooperation impact assessment (Fischer, et al., 2014) that provides a comprehensive list of useful indicators. However, only few of those are disposable at the regional level.

Definition of 'Green' Jobs

As mentioned above under the Eco-Innovation Action Plan, one of the issues that comes across when creating indicators measuring green jobs is the question what exactly a green job entails. Different organisations and countries define them differently.

The international Labour Organisation (ILO) defines them as follows. "Green jobs are decent jobs that contribute to preserve or restore the environment, be they in traditional sectors such as manufacturing and construction, or in new, emerging green sectors such as renewable energy and energy efficiency." ILO's definition of green job can also help to guide how to define green jobs. They are defined as those that (International Labour Organization (ILO), 2018):

1. Improve energy and raw materials efficiency
2. Limit greenhouse gas emissions
3. Minimize waste and pollution
4. Protect and restore ecosystems
5. Support adaptation to the effects of climate change

One option could be to focus on a few of these criteria and select those industries and sectors that match these.

Eco-innovation index: some of the information comes from Orbis, a data resource on private companies. This data is available on free trial and subscription. The technical note to the Eco-Innovation Index describes methodology of the 'Employment in eco-industries and circular economy' index: "Eco-industry company population was selected based on NAICS codes for eco-industries, including waste treatment, water sector, environmental technologies, recycling, reuse and recovery. The selection excludes companies engaged in energy generation and storage." (Giljum, Lieber, Gözet, & Doranova, 2018).

Denmark Green National Accounts: "In accordance with the international guidelines for these accounts, environmentally goods and services refer to goods and services that protect the environment directly and goods and services designed for natural resource management. Research and development in these fields is also included. Furthermore, a distinction is made between goods and services with a specific environmental purpose (e.g. wind turbines) and products that are cleaner and more resource-efficient compared to other products with the same primary purpose (e.g. water-saving taps)" (Statistics Denmark, 2018).

U.S. Bureau of Labor Statistics (NAICS): Extremely broad definition of 'Green Goods and Services (GGS)'. GGS is based on yearly surveys that to cover the need for data on the size and scope of the United States' green economy. Their definition is that green jobs are "jobs in businesses that produce goods and provide services that benefit the environment or conserve natural resources" (U.S. Bureau of Labor Statistics, 2013). For GGS Data see https://www.bls.gov/ggs/data.htm.

Some of the issues are that most sectors are actually included in the indicators because they are being 'associated' with circular economy and eco-industries. It is often difficult to extract data on turnover and employment directly related to green jobs, because no specific sectors exist for this.

Other data sources

OECD.Stat may be helpful with data on environmental indicators for metropolitan areas of certain countries (https://stats.oecd.org). In addition, the European Environment Agency (https://www.eea.europa.eu/data-and-maps) offers certain data on a regional basis.

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