DECARB A1.1

Report on the ex-ante economic and social impact assessment of the regions' decarbonisation

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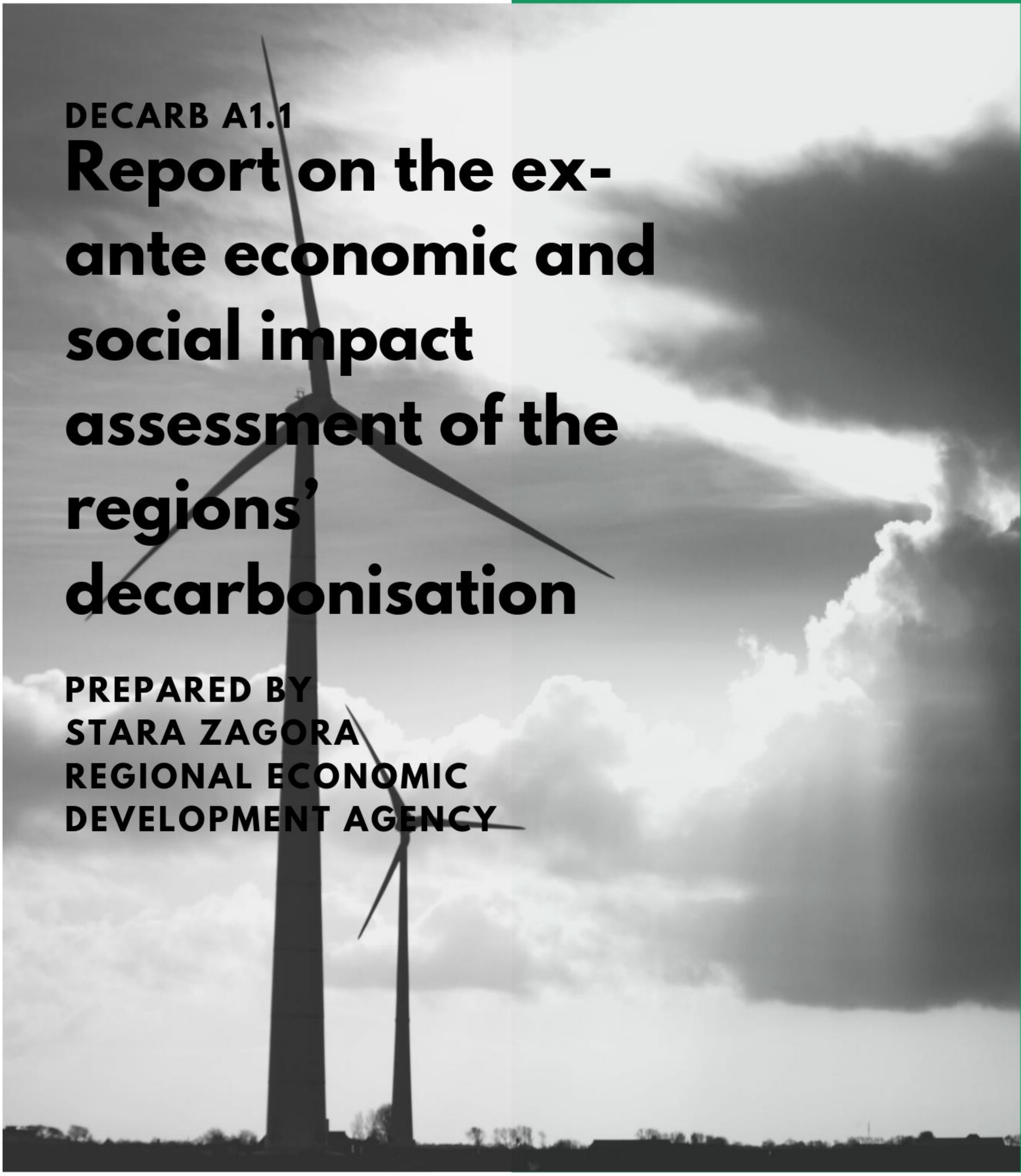

DeCarb
Interreg Europe
European Union
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Executive summary

This document is the final output of DeCarb Activity 1.1 "Ex-ante economic and social impact assessment of regions' decarbonisation". The purpose of this activity is to evaluate how the contraction of coal-driven value chains will affect existing regional economic activities and employment.

The main source of data for this activity was desk research, conducted by the project partners on the basis of a common Data Collection Form. The data collected represent different administrative levels as the majority of project partners provided energy production related evidence at a regional (NUTS 2) administrative level, yet, some participants provided evidence at country level.

The key findings and conclusions drawn from the study include the following:

- The DeCarb regions have widely divergent energy mixes, therefore, decarbonisation essentially means different things at different contexts, and it is not possible to use in a meaningful manner the same indicators for all cases.
- There appear to be direct dependencies between mines and power plants operating in each region. Furthermore, there are other companies offering a variety of services standing to be affected by the decommissioning of coal mines and power plants.
- Timely planning and public finding schemes are key in shaping a smooth transition towards the new energy mix and it is crucial that all levels of the government and all the relevant stakeholders are involved.

1. Context of the study

This section introduces decarbonisation as the main strategy of reducing GHG emissions in the EU. According to the EU's Energy Roadmap 2050, the milestones to reach the 2050 target of 80-95% reductions in total GHG emissions involve member states reducing their emissions at least by 20% compared to 1990, by 2020 (Europe 2020 strategy). In detail, the 2020 target, also referred to as '20-20-20', denotes the targets of 20% share of renewables in energy production, 20% improvement in energy efficiency and 20% cut in greenhouse gas emissions. The 2030 climate & energy framework defines the interim targets for 2030, which consist in 40% cuts in GHG emissions, 27% share of renewable energy and 27% energy efficiency improvement.[1]

The EU decarbonisation strategy is marked by intense policy and technical work to ensure not only that a reduction in emissions takes place but also that three key prerequisites of growth and development are effectively addressed: the first aspect is **sustainability**. By referring to sustainability, the necessity of resilience in the face of changing circumstances and a forward-looking approach to resource use, are effectively evoked. In the context of decarbonisation, the concept of sustainability is initially mobilized to frame uninhibited CO_2 emissions development as environmentally unsustainable. A great deal of studies at a global level ground the claim that CO_2 emissions are directly responsible for increases in global temperatures, while model future projections paint an unpleasant picture of socio-environmental impact. It is noteworthy that the great bulk of these emissions can be attributed directly to the energy sector.

Sustainability, however, is broad concept that also refers to socio-economic affairs.[2] If decarbonisation encompasses a number of actions to ensure environmental sustainability in the near future, it harbours the risk of exposing communities, regions and states to socio-economic turbulence with unpredictable flow-on effects, ranging from reduced social

[1]COM(2011) 885 of 15 December 2011 – Energy Roadmap 2050; Commission communication of 19 October 2006, COM(2006) 545 - Action Plan for Energy Efficiency: Realising the Potential; Directive 2009/28/EC of 23 April 2009; For the 2020 climate and energy package, the 2030 climate and energy framework and the 2050 long term strategy, see online sources at: https://ec.europa.eu/clima/policies/strategies/2020_en;

[2] See 2030 Agenda and Sustainable Development goals for a comprehensive account: ec.europa.eu/environment/sustainable-development/SDGs/

cohesion and unemployment to fiscal pressures (Robinson, 2017). It is, thus, imperative that decarbonisation works simultaneously at many fronts and is sustainable in socio-economic terms. In that sense, GHG reduction policies and decarbonisation in particular should be thought of as policy strategies driven primarily by environmental sustainability problems to effect change for resilience – rather than continuing with 'business as usual' – in the face of alarming socio-environmental predicaments. How decarbonisation strategies are implemented at the level of restructuring particular value chains, communities and administrative practices, is key to understanding the nature of the impact of specific decarbonisation planning trajectories. For this purpose the EU has mobilized extensive resources for simulating and quantifying various energy-economy scenarios (Capros et al., 2014).

The second node in the context of decarbonisation efforts is **security of energy supply**. Energy supply is a multi-faceted issue, as it covers for the demand of nearly all economic activities: consider electricity production, electricity supply to communities and end-users, businesses and industries; transportation of goods and people, to mention just a few of the areas affected under progressing decarbonisation implementation plans. The EU notes that the 'energy supply problem is most acute' in the transport sector,[3] characterized by heavy, nearly total, dependence on imported oil. Although, addressing the transport sector is well beyond the scope of this report, imported oil – similar to any other imported fossil fuel - is an exemplar of determinants of energy supply security: high levels of dependence of transportation on imported oil, translate into de facto energy supply 'insecurity', due to possible resource (or supply line) depletion, increased prices of oil or unpredictable fluctuations thereof, trade barriers etc. Notwithstanding differences, import coal dependency is characterized by the same features. It is intuitive to think that a territorial unit of any scale is more secure in terms of energy supply to the extent that it covers its demand for energy by own sources, be it the EU, a member-State or a single region. That said, this report excludes the consideration of oil imports as a factor of energy supply insecurity primarily because it excludes the transport sector from the analysis. The reason is twofold: what is at question in DeCarb, is the energy production sector and the key resource at play in energy production in the EU is coal. Irrespective of particular sectors, coal combustion is the principal source of GHG emissions

[3] Directive 2009/28/EC.

and, among the fossils, it accounts for the majority of emissions (it is the most CO_2 intense fossil fuel). **Hence, the decarbonisation of the energy production sector is the key action plan within this strategy**. This point resonates the previous one on sustainability. As far as energy security supply goes, the risk is considerable: a good deal of coal in the EU is imported. The research undertaken here is concerned with decarbonisation in this sense: examining a) (changes in) the dependency on coal import for energy production as means to ensure energy supply security, and b) energy production's dependency on coal value chains irrespectively of the source of carbon (e.g. import, domestic mining). In certain cases, regional economies are largely dependent altogether on coal extraction, processing, transporting and use as a raw resource for energy production.

The third key aspect that needs to be foregrounded, as it drives decarbonisation and supports the energy transition in the EU by fostering a socio-economic environment that increases the uptake of renewables, is **competitiveness**. The rationale of EU policy-making – in a nutshell – is that a turn to renewables is conducive to regional growth. In making this claim, the EU postulates a causal relationship between mandatory renewables' policies and growth of small and medium-sized enterprises, as more often than not, production of energy from renewables depends on such economic operators and decentralization of power production and supply. Contrary to electricity production from coal combustion, which presupposes large scale infrastructure, national and international-wide grids for electricity transferals, renewables' energy production is based on infrastructure developed to cover local and regional needs. This has multiple implications for local economies, and, indeed, the EU policy is premised on the 'positive impact of regional and local development opportunities, export prospects, social cohesion and employments opportunities, in particular as concerns SMEs and independent energy producers'.[4]

[4] DIRECTIVE 2009/28/EC

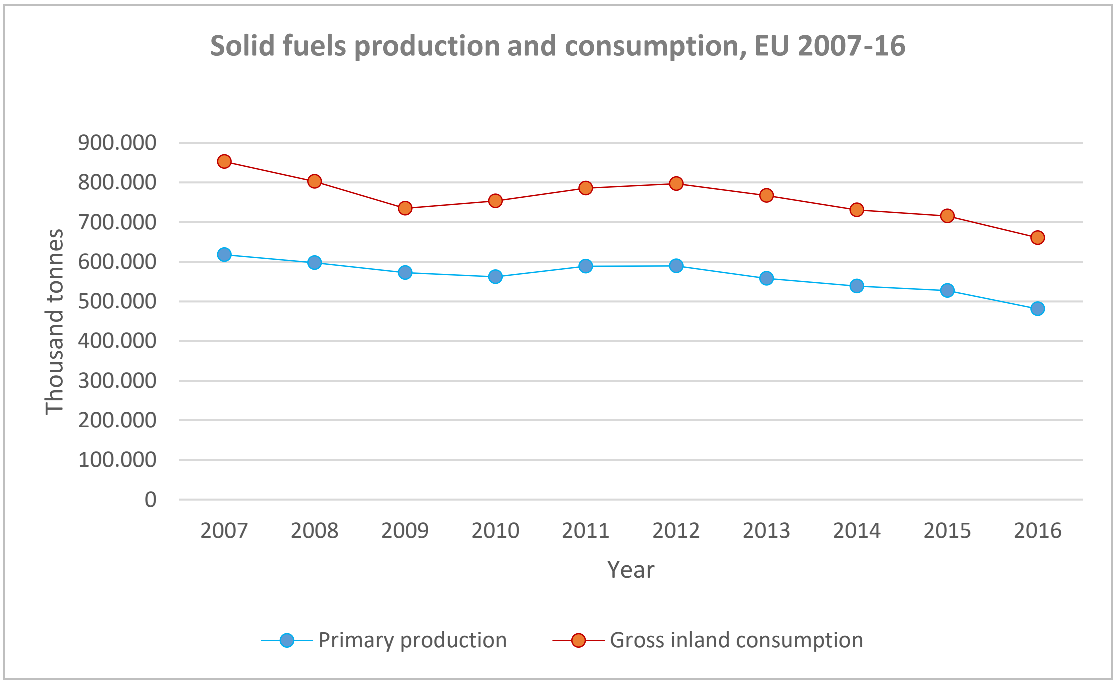
2. Research focus

In the previous section, an introduction to decarbonisation as a principal means for sustainability, energy supply security and competitiveness was discussed. This section discusses in some depth the major issues with energy production and supply in the EU, introduces the notion of 'energy mix' and then turns to coal-related activities, to conclude with a discussion of what the decoupling of energy production and coal-related activities may entail for planners, citizens and all energy consumers.

2.1. Carbon-intense energy production

It is instrumental to provide an overview of key descriptive statistics of coal-intense energy production and consumption. Graph 1 presents the aggregate production and gross consumption of solid fuels in the EU for the years 2007 – 2016.

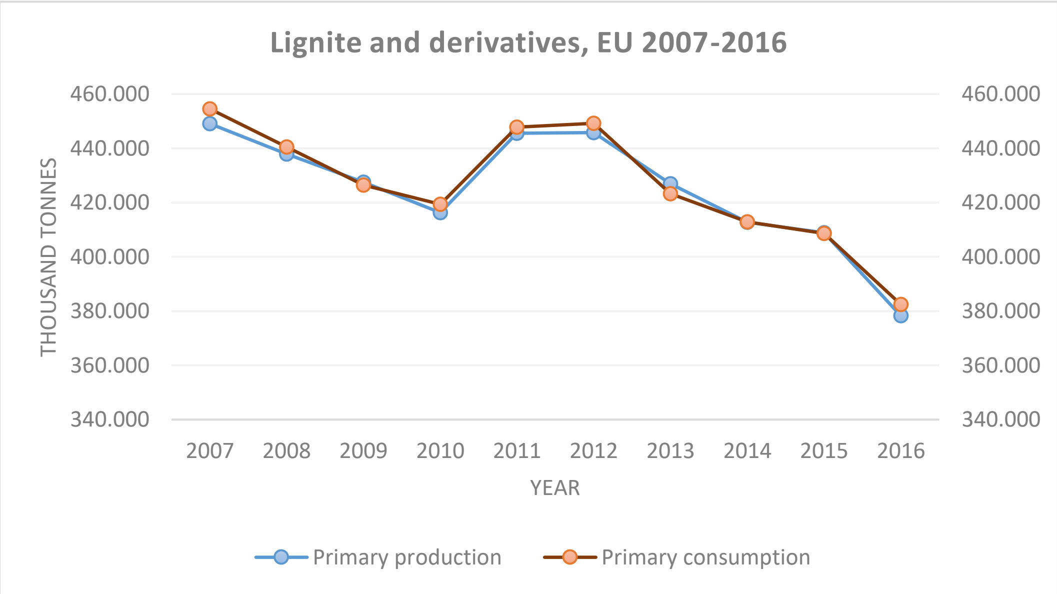
Graph 1: Production and consumption of solid fuels



Source: Eurostat

Notably, both production and consumption have significantly dropped during those years, due to the implementation of decarbonisation policies, but also due to diminishing market effectiveness of carbon compared to RES opportunities. It should also be noted that consumption is consistently higher than production. This reflects the problems around energy supply and security that were discussed in the previous section. The chart in the following page represents **lignite** production and consumption. Contrary to the aggregate of solid fuels,[5] lignite production and consumption almost overlap point to point throughout the years, which suggests that as far as lignite and derivatives go, there is little concern regarding energy supply security. Indeed, the Eurostat dataset shows that regarding other solid fuels, notably, **hard coal and derivatives**, the consumption is approximately 2 to 3 times higher than production, and the same holds for anthracite (its production dropped for the same period more sharply than its consumption). **Coking coal** presents a similar course with consistently lower production compared to consumption. Lignite and derivatives therefore present us with the problem of overall high production and consumption (nearly half of the production and half of the consumption of solid fuels is lignite and derivatives); while the rest of solid fuels that comparatively present lower levels of consumption and production, pose the problem of energy supply security, given that the consumption that exceeds production is attributed to imports.

Graph 2: Production and consumption of lignite and derivatives in the EU



Source: Eurostat

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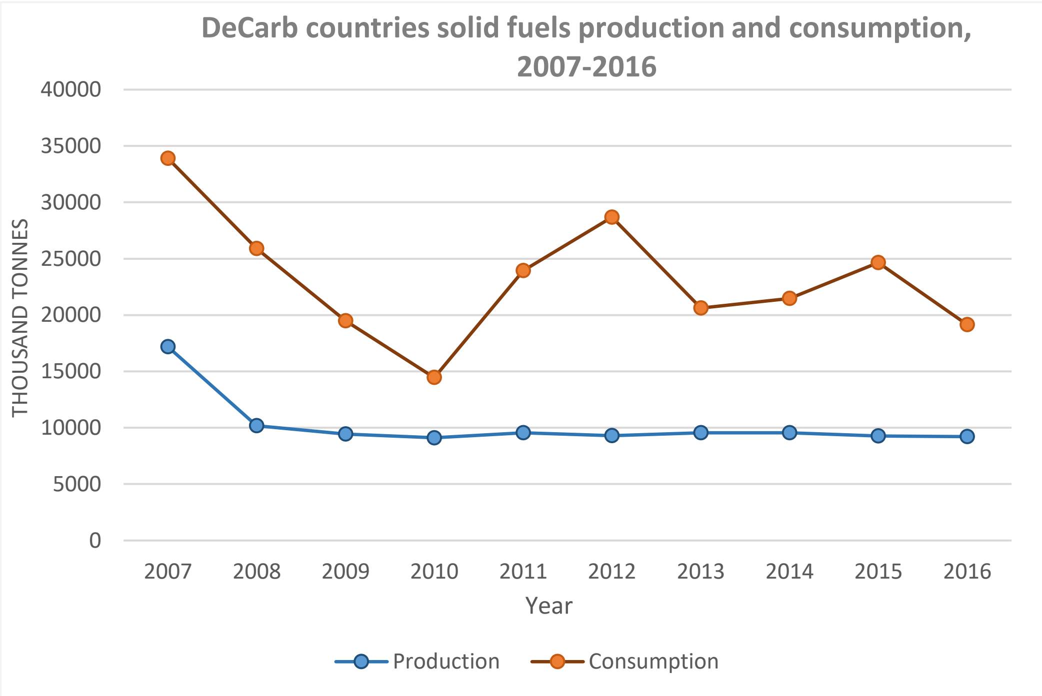
[5] By solid fuels, according to the operational Eurostat definition, we refer to 'Hard coal and derivatives', 'Anthracite', 'Coking Coal', 'Lignite and derivatives' and 'Brown Coal'. For more energy related terminology see: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Primary_production_of_energy.

2.2. Carbon-intense fuels

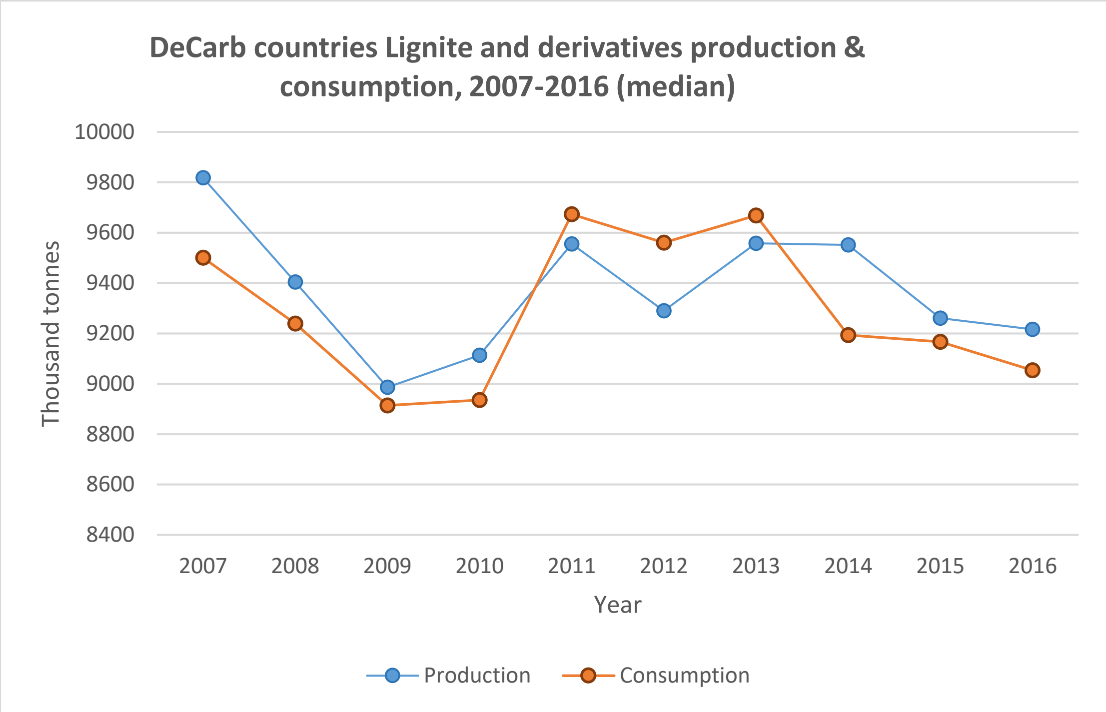
Graph 3 shows the median production and consumption of solid fuels in DeCarb territories (countries). It can be observed that median consumption in DeCarb territories is consistently higher than median production throughout the years for which there is data available. However, the average distance between the two (consumption due to trade/imports) is not consistent. This indicates that fluctuating demand is covered by trade/imports, while production is relatively stable for the years 2008-2016. Graphs 4 and 5 present an overall decline in lignite, brown coal and derivatives production and consumption. Neither of these graphs provides data on the specific DeCarb regions. However, this data can be used for benchmarking, comparisons and putting into perspective the respective regional values.

Graph 3: Solid fuels production and consumption for the years 2007-2016 in DeCarb countries



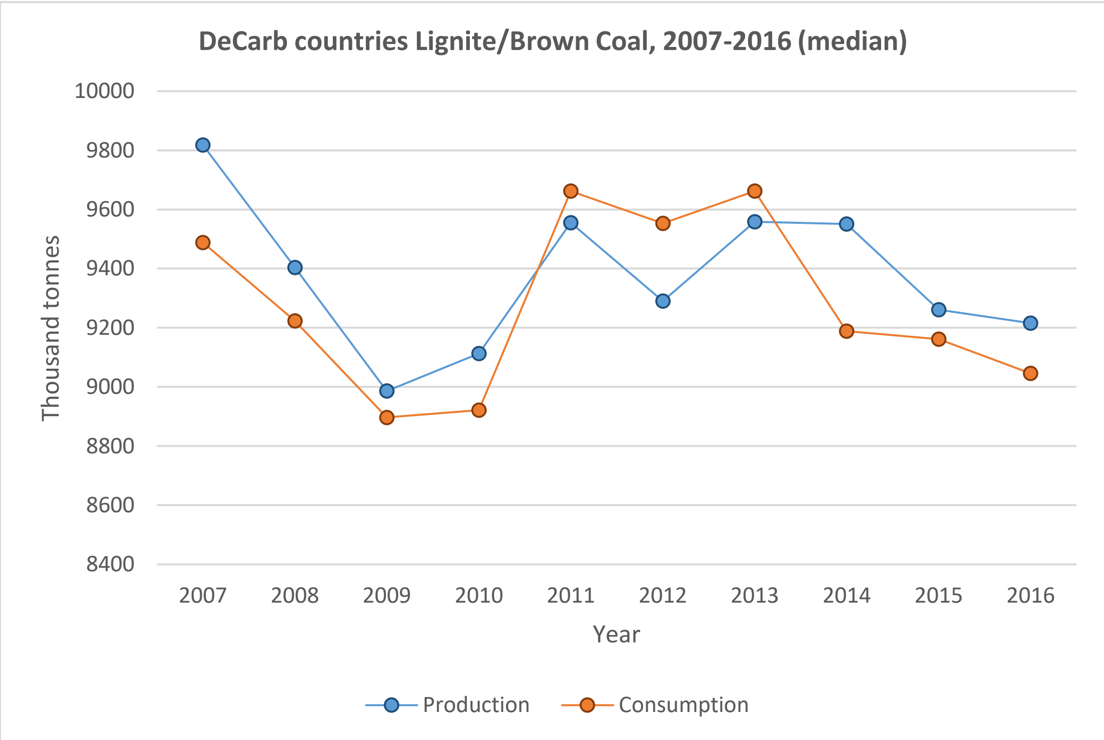
Source: Eurostat

Graph 4: Solid fuels production and consumption for the years 2007-2016 in DeCarb countries



Source: Eurostat

Graph 5: Solid fuels production and consumption for the years 2007-2016 in DeCarb countries



Source: Eurostat

2.3. Carbon-intensity of the power sector

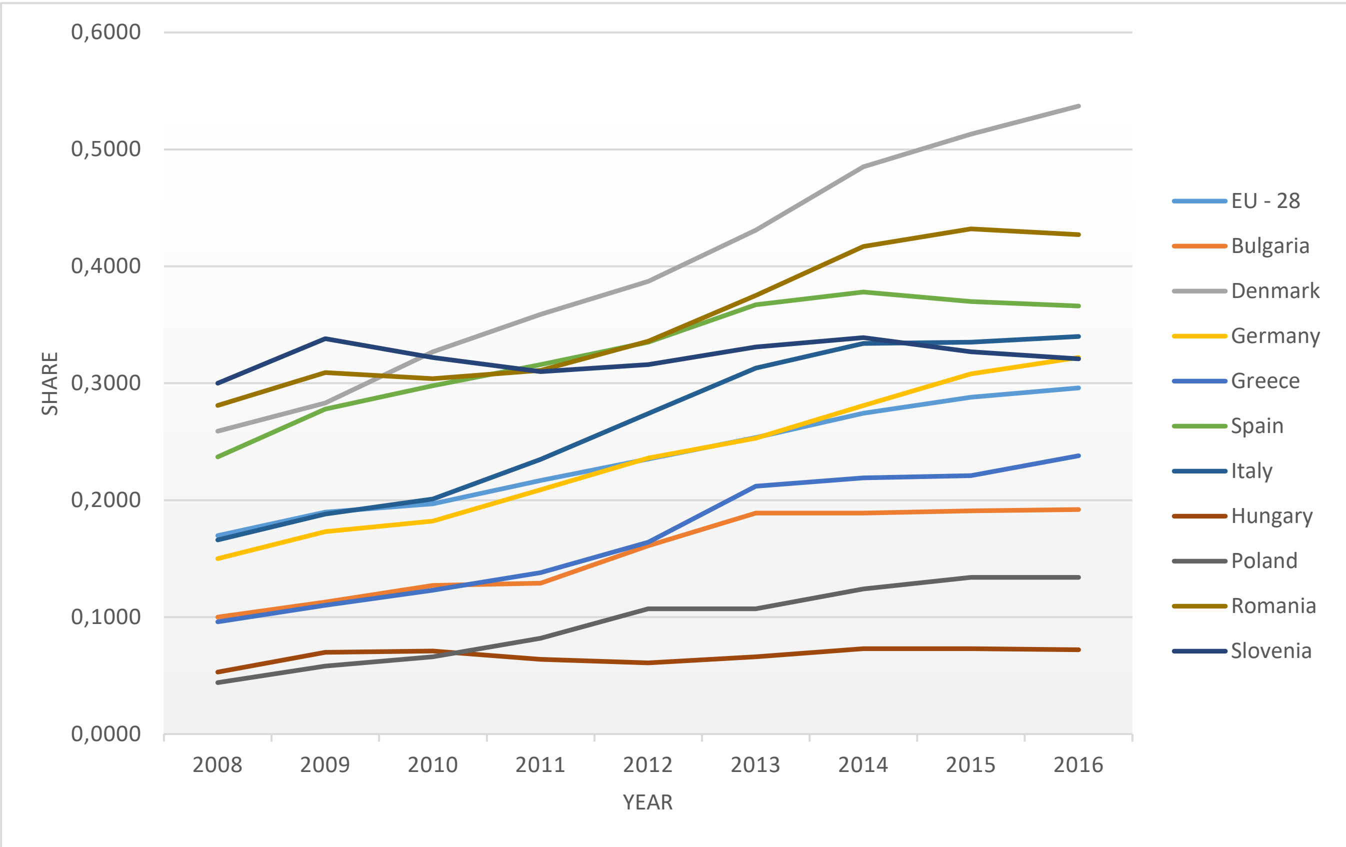
At this point it is useful to clarify the difference between the primary energy, and power generation. At this stage we will address the power sector which includes 'mining of coal and lignite' but also other inputs and associated industries. In particular, the focus is on power supply sources and, according to Behrens et al. (2014), 'supply includes all aspects related to the production and supply of energy, including the extraction of natural resources, conversion activities (mainly electricity generation) and transport (including transmission and distribution […] demand, on the other hand, covers final consumption by sector'. Power consumption is excluded from the focus of this research activity. However, electricity prices, demand for electricity and fluctuations thereof are accounted for under the label 'economic' impact for households and energy-intense industries (prices per unit of power).

Carbon-intensity of power generation is correlated to the energy mix composition. An indirect way of representing carbon-intensity is through accounting for RES share in electricity production. The assumption posits a negative correlation between RES-intensity and carbon-intensity, all other variables equal. The graph below shows the share of RES in EU -28 and in DeCarb countries for the period 2008-2016.

Through a quick glance, it is noteworthy that the EU average nearly overlaps with Germany's share of RES nearly entirely with .3 - .033 share of RES for the year 2016. Partnership countries are (almost equally) distributed on either side of the EU average, with Bulgaria, Hungary, Poland and Greece RES share per year being consistently below the EU – 28 average, and Germany, Slovenia, Spain, Romania and Denmark being consistently above the EU – 28 average.

These trends are **representative of national units** in the context of the EU and they are presented indicatively by way of introduction to the context of research. For smaller administrative and geographical units, such as the DeCarb territories, a certain degree of variability is expected compared to national average values. The questionnaire designed for data collection will precisely address these differences and how changes in this variability lead to changes in socio-economic variables.

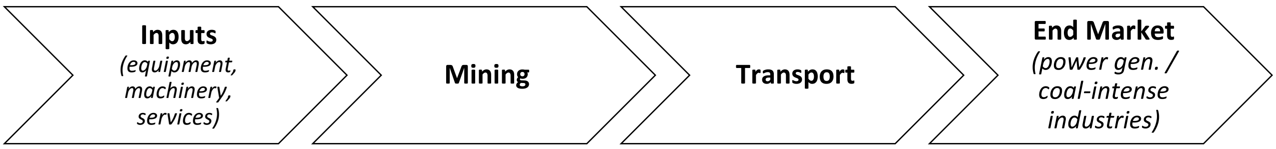
Graph 6: Solid fuels production and consumption for the years 2007-2016 in DeCarb countries
Source: Eurostat



2.4. Coal value chains

The previous section provided a brief overview of production and consumption of solid fuels in DeCarb countries. The purpose of the present section is to explain in a little more detail energy production as a coal-related sector. A very high portion of produced and consumed solid fuels quantities is for energy production, but not the entirety of it. That is, not all output of coal mining is directed to energy production, just as all energy production is not coal-dependent; therefore, it is crucial to know the extent to which the two sectors – mining and power production are co-dependent. To represent these relationships it is best to mobilize the concept of the value chain. This research activity is specifically concerned with the **'coal value chain'**. Graph 7 represents the value chain in its simplest form.[6]

Graph 7: The coal value chain



To begin with, 'Inputs' refers to coal-mining-specific industries, linked industries and production outputs used in mining (as inputs) and in intermediary coal transportation. These include special machinery, oil and rubber production (or supply), freight vehicles etc. 'End Market', on this account, includes all activities involving coal use: a) **coal for energy production** and b) **coal-intense industries (textiles, iron & steel industries)**: electricity and heat production. For each of the above categories, there correspond three options-levels of proximity, ranging from those 'directly' involved and those which are 'linked'. A dependency factor could help determine *how* coal-specific an industry is. This analytical breakdown is necessary in order to account for the impact of decarbonisation in terms of mapping employment changes and understanding in detail the coal value chain. Table 1 summarises a working typology.

[6] The schema is adapted from Donnari et al. (2018); for a more elaborate account see Baruya (2012).

Table 1: The coal value chain

	DIRECT	LINKED
INPUTS	Equipment, security	Industries: Rubber, metallurgic, Engineering, Petrochemical, Timber and processing, Transport, Food
MINING	Coal mining, surface activities, rescue station, others	
TRANSPORT	Road transport, Railway	
END MARKET	Production of heat, Electricity production, Carbon-intense industries	

There is a large number of studies discussing or modelling the impact of decarbonisation on variables of performance and size of coal value chains,[7] simultaneously factoring in the degree of dependence of local, regional and national economy on said value chain. The relevant metrics in this respect are supply chain economic measures (annual turnover per industry/ final supply chain demand, annual expenditure for inputs per industry involved and/or for the whole value chain). To evaluate the regional economic dependence on the coal value chain, a useful metric is carbon-intensity of GDP, i.e. the volume of emissions per GDP unit. Assuming that all emissions are attributed to the coal-value chain, this metric is a dependency factor indicating how much regional GDP is affected by attribute changes in the coal value chain. A hypothetical GDP unit that is 100% carbon-intense, means that a decrease by one point of emissions equals a one point decrease in GDP.

[7] Indicatively see: Alexandri et al. (2018); Alves Dias et al. (2018).

Thus, it is important to set out in advance a model that accounts for (differences in) these relations:

a) The degree of dependency of the regional economy on the coal value chain (a function of the 'energy mix')
b) The degree of dependency (the 'dependency factors') among sectors/businesses within the value chain. This degree will determine/explain both i) the agglomerations in input/output values of the sectors involved, and the number of jobs affected in one sector by changes in another.
c) The (change in) values of inputs, outputs and final demand of the value chain (expenditure, turnover)

2.5. Labour intensity of value chain

The previous tables give us a chart-like mapping of all processes and sectors that make up the coal value chain. This representation is important because a basic issue this report addresses is the **number and type of jobs affected** by transformations in coal value chains, resulting from transformations in energy mixes (reducing carbon-intensity of energy production). Regional energy-source value chains are associated with professional groups employed in each of the sectors involved. Depending on the type of work as well as the demographics of the professional groups in question, decarbonisation is variably unsettling employment patterns formed over decades of carbon-dependence.

A relevant metric in this respect is **labour-intensity of the coal value chain**. Labour-intensity should be broadly understood as both a metric of employment structure and of energy production efficiency. Indeed, it is established that novel techniques involved in mining activities have significantly increased technology-intensity (Alves Dias et al., 2018), which in turn increased efficiency and mine productivity (further indicators are based on these metrics, i.e. plants' efficiency, carbon-intensity of energy production which was previously discussed). Since, however, it is not an 'either-or' situation (i.e. *either* technology *or* labour), in general, it is claimed that in the context of decarbonisation, electricity production from low-carbon sources is comparably labour-intensive (and more so) to traditional, coal-based, electricity production, although this is a more ambiguous issue.[8] To give a comparative synthetic example, if labour intensity of *x* coal activities equals labour intensity of *y* RES activities, then from the point of view of the number of jobs the two primary energy production activities have the same impact on employment. The evaluation then turns on which of the two is less carbon-intensive, that is, which one is more environmentally sustainable.

The following relevant indicators account for labour characteristics of coal value chains (Alves Dias et al., 2018):

- Number of jobs in coal mines at each NUTS-2 region
- Overall Number of jobs in coal power plants and coal mines in NUTS2 regions

[8] Fankhauser et al. (2008) and other researchers argue that high labour-intensity of renewables reflects their still high costs and tend to decrease over time (as labour productivity increases by relevant training; see also, Fankhauser (2012)

- Share of jobs in coal mines
- Share of jobs in coal fired power plants
- Number of coal related direct jobs
- Number of persons employed in the manufacture of machinery for mining, quarrying and construction, in coal producing countries
- Number of enterprises engaged in the manufacture of machinery for mining, quarrying and construction, in coal producing countries
- Share of total jobs in countries (or regions) with coal mines
- Number of enterprises within the mining of coal and lignite NACE sector in 2015
- Types of professional groups employed in mining activities
- Share of professional groups employed in mining activities

Labour intensity is a useful metric because it allows comparisons between labour inputs of coal value chains to labour input of renewables value chain, or in other words, between a carbon-intense energy mix and a less carbon-intense energy mix. It further allows for fruitful comparisons between the employment structure associated with a coal-driven (regional) economy and that of an economy powered by more diversified means. In terms of evaluating the socio-economic impact of decarbonisation this is a key metric. The standard way of defining labour intensity of the energy sector is by correlating 'number of jobs' with 'energy output' (i.e. 'number of jobs per unit of energy'. The 'number of jobs' can be an aggregate of all jobs in all sectors involved in the coal value chain, or in primary energy production/power sector, but it can be more specific, i.e. reflecting specific employment structures (i.e. number of jobs per qualification level [low-medium-highly qualified] per energy unit (Ktoe/MW) (Behrens et al., 2014). Table 2 presents EU-level evidence on labour intensity of primary energy activities.

To put it concretely, for a given region, if labour intensity for the whole coal value chain, as well as for a high RES scenario in a low carbon energy mix are known, we can determine the number of jobs to be affected. In plotting more than one decarbonisation 'scenarios' we can compare between those and identify the scenario that optimizes the net value of decarbonisation processes.[9] Therefore, dependency factors (in essence 'coefficients') help

[9] See: http://www.oecd.org/dac/evaluation/dcdndep/37671602.pdf.

determine the change in quantities of labour and output value among the value chain, due to interindustry dependences, while labour intensity can be used as point of comparison between value chains, i.e. between existing coal value chains and future RES intense energy mixes.

Table 2: Labour intensity of Primary Energy Activities in 2011

ACTIVITY	JOBS/KTOE	DIRECT JOBS	KTOE
MINING OF COAL AND LIGNITE	1.37 – 2.06	229,000 – 345,000	167,400
OIL AND GAS EXTRACTION	0.49 – 0.81	113,000 – 187,000	229,800
OIL AND GAS OTHER ACTIVITIES	0.27 – 0.41	269,000 – 410,000	1,004,600

2.6. Carbon-intensity of GDP

Carbon-intensity of GDP (GHG intensity of the economy) is a decarbonisation indicator (EEA, 2018). However, it refers to all emissions by all fossils and for all sectors of the economy. An important adjacent measure is 'GHG per capita'. As it will also be mentioned further down in the discussion about the metrics of socio-economic development, a central aim of decarbonisation processes is the decoupling of GHG and GDP. Specifically, such decoupling consists in the inversion of the conventionally positive correlation between GHG and GDP, between emissions and growth. Decarbonisation unsettles long-standing patterns of considering growth as modernization, i.e. industrialization, with GHG emissions standing in as a proxy metric of growth. Decarbonisation, by contrast, mandates a negative correlation between the two, such that growth and GDP increase are actually dependent on adoption of RES and reduction of GHG emissions.

In empirical terms, GPD across Europe has increased by nearly 50 % between 1990 and 2015; emissions simultaneously decreased by 22 %. **Carbon intensity of the EU economy decreased by nearly 48 %** over the same period. GHG intensity fell from 1990 in all Member States except Portugal, Spain and Cyprus, which stayed closer to initial levels.

In the context of this research activity the focus should be more specifically on the dependency of GDP on the coal value chain. The rationale of this metric is to measure a regional economy's dependency on the sum of coal-related activities, or the share of coal-related activities to the overall (regional) economy. Current GDP dependence on coal activities and coal phase out rates can be plugged in to a 'dependency function', to estimate future GDP and future dependence of GDP on coal activities.

3. Areas of socioeconomic impact

3.1. Socio-Economic impact

Given the purpose and rationale of this research activity, the 'socio-economic' needs to be conceptually delimited to ensure uniformity of understanding, as the debate on how to define the 'socio-economic' is ongoing and dynamic.[10] It is most productive to consider the socio-political in its context-sensitive variance, that is, to consider what measures to include depending on the topic one is approaching. In the context of considering development and growth, the social and economic spheres cannot easily be disentangled. However, in broad terms social development tends to refer to aspects of quality of life (health, nutrition, education, transport, communication). Respectively, economic development is normally understood as a function of (a) certain metric(s) (i.e. GDP rates of change, investments rates, public expenditure, household income etc.).

For the purposes of DeCarb A1.1, the task is to examine how a major socio-technological transformation, namely decarbonisation, brings about significant changes in the energy sector specifically, given its prominent place in the overall distribution of GHG emissions per source, and what impact the former has in terms of socio-economic development. In the following paragraphs a number of categories are discussed in order to determine which are going to be included in the analysis.

A common classification utilised in development studies and international organisations capturing comprehensively major aspects of the socio-economic sphere consists in:

- **Per capita income**
- Level of agriculture development
- **Level of industrial development**
- Level of urbanization
- **Occupational structure**
- **Level of educational development**
- **Health status**

[10] This is reflected in the various frameworks for interventions' impact assessments within the context of EU policy: indicatively see the Common monitoring and evaluation framework (CMEF) comprising discussions working classifications of socio-economic categories and indicators. See: https://ec.europa.eu/agriculture/rural-development-previous/2007-2013/monitoring-evaluation_en.

- Transport and communication
- Population characteristics

From the list above, the items in bold indicate which categories are mostly relevant and are going to be analysed. Specifically:

a) **Per capita income** and equivalent aggregate measures (GDP) are common, value-free and adequately objective indicators used to represent growth rate. However, they should be used with care in the context of comparisons between regions with different patterns of consumption and valuation;

b) **Industrial development** is included in the analysis, however, only as far as carbon and energy intense industries are concerned. That is, in examining the coal value chain, certain industries are included;[11] given their use of raw coal supplied directly from mines;[12]

c) **Occupational structure** is a cornerstone category examined: the most relevant dimension of socio-economic growth, occupational structure (number of jobs in coal/ RES value chains, knowledge & expertise intensity of coal/RES jobs respectively – rates of change) gives satisfactory evidence of a socio-technological transformation's impact.

d) Correlatively, the level and type of **education development**, provided that it is fine tuned to fit the research objectives can provide useful indicators of social impact: the expansion of RES and the increased rates of uptake of these technologies, precisely because they involve a significant increase in decentralized primary energy production, they depend on re-skilling and various types of vocational education. The occupational structure and education aspects are not independent variables. Employment levels in the course of decarbonisation are correlated with changes in technical education, however, it is not clear and at all times what is the direction of causality: it cannot be determined in the abstract whether changes in

[11] For reasons of time and resources limitations, this study includes in the value chain industries to which coal is directly supplied and combusted on site (e.g. ferrous metals, mineral industries) rather than the entirety of industry sectors in risk of carbon leakage. See EC Directive 2014/746/EU.

[12] In the course of numerous impact assessments and studies, the EU has charted a list of the industries at risk of 'carbon leakage'. Notably, among them and besides the energy production sector, the industries of production and processing of ferrous metals, the mineral industry (ceramics, tiles, bricks etc.) are in particular risk. The EU Emissions Trading System (EU ETS) is a major tool for containing both climate change and 'carbon leakage'. For more details, see: https://ec.europa.eu/clima/policies/ets_en; the full list of the sectors at risk of carbon leakage can be found in EC Directive 2014/746/EU. Please see Annex for a list of the main industries in question.

technical education for RES, CCS uptake and operation, increase the uptake of the technologies, or *vice versa*, that is, whether opportunities for uptake bring about the necessity for the corresponding training;

e) **Health** is included in the scope as a flow-on area of decarbonisation impact, albeit a very important one. Indicatively, in 2016 the number of premature deaths due to ambient air pollution has recently increased to 4.2 million (last known data 3.3 million), while 29% of lung cancer and 25% of ischemic heart disease, and 24% of stroke deaths are caused by air pollution.[13] The focus is on outdoor air quality and all other measures of health correlatives of energy efficiency measures are excluded from the scope because they are marginally irrelevant to the energy sector. By contrast, coal combustion and CO_2 level significantly affect the quality of air with grave consequences for local communities. The global rate of annual premature deaths caused by air pollution is estimated at 3.3 million (IEA, 2016). The so called 'exposure indicators' and 'health & wellbeing indicators' (number of statistical life years lost; rate of excess seasonal mortality; treatment costs), [14] as well as more common demographic indicators (mortality rate) can provide robust evidence of differences in population health.

The following two categories are excluded from analysis:

a) **Agricultural development** as such is excluded from analysis on the grounds that it is an economy sector to be affected negatively by electricity energy prices, but also positively from possible uptake of RES and decentralised energy production capacities; in addition, this research cannot focus on specific sectors of the economy with the exception of selected coal-intense industries, i.e. those that are situated within or in a close distance to the coal value chain.

b) **Urbanization, transport and communication** and most population characteristics are equally excluded from the present scope as they are not relevant to the research questions addressed.

One provision to be stated at this point is that this research is not interested *per se* in levels of development as such: the levels and types of socio-economic development indicators are approached as *broader results* (i.e. impact indicators) of a certain input (energy mix

[13] See https://www.who.int/gho/phe/outdoor_air_pollution/en/ and IEA, 2016.

components and corresponding policy implementation). It is noteworthy that standard core indicators of socio-economic development are not as such a very helpful resource in understanding the socio-economic impact of decarbonisation. For instance, the UNRISD indicators measure,[15] among others, the fraction of a population that has access to electricity. Although access to energy is not a universally solved issue, a more relevant metric to this research would be the fraction of the population producing electricity by own means through RES installations. In addition, the same indicator set defines *'energy consumption, kg. of coal equivalent per capita'* as a measure of development. This shows that these indicators are designed for different contexts of use and they are not altogether relevant to the present conjuncture where coal consumption is negatively correlated with the objective of sustainable development, i.e. energy production and consumption without CO_2 footprint. A similar point is stressed by IEA (2016) "where previously economic performance drove energy consumption upwards, reduced energy consumption now appears to have substantial positive impacts for economic development".

[15] See UNRISD, 1970. For a comprehensive analysis of the components of socio-economic development, see Baster, 1972.

3.2. Macro-economic impacts

IEA (2016) defines four major areas of macroeconomic impact:

- *Economic development, measured by GDP*
- *Employment*
- *Energy price changes*
- *Trade balance*

All four areas are components of equal macroeconomic weight in the present intervention-specific impact assessment. As indicated earlier, the reduction in coal intensity of energy production (as well as overall energy efficiency) is a driver of regional growth and sustainable development. Any decarbonisation intervention is on average expected to have **a positive impact on the economy** by strengthening SMEs' own and decentralised energy production means. In certain cases, it will allow private operators to transfer and sell amounts of energy (e.g. from biomass) on a local/regional basis. It is a matter therefore of determining increases in GDP due to RES uptake.

In terms of **employment,** a number of aspects has already been discussed, such as the labour intensity parameter of either carbon-based or RES-based energy production. Apart from labour intensity, which in itself is more of an efficiency measure (jobs/energy unit output), the actual number of jobs impacted and the nature of the impact is of significance. In this respect, there are some general empirical dimensions to be taken into account, notably, the difference between the precise levels of labour intensity of RES technologies and coal processing and combustion. Substitutions in the energy mix imply some jobs loss and some jobs gain. The overall change in the absolute number of jobs per region to be impacted is a point in question.

Table 1: Coal related jobs in EU-21

EU-21	JOBS
COAL SECTOR JOBS	237.000
COAL MINING JOBS	185.000
INDIRECT COAL-RELATED JOBS	215.000
CCS POTENTIAL UPTAKE	13% (of current capacity)

CCS retrofitting should be understood, simply put, as a means to prolong the lifetime of coal-fired power plants. Decommissioning and CCS, therefore, are opposite drivers regarding employment. CCS therefore, apart from being an energy production sustainable technology is a de facto means of transition to post-carbon economies that entails a more smooth impact on employment.

Trade balance is to be impacted, however, precisely how, is the object of research: indicatively, in certain scenarios, the reduction of imports of raw resources for energy production (coal imports) accounts for reductions in trade deficits. Yet, if simultaneously imports of other energy resources increase for that matter (e.g. import gas for decentralized heating) rather than regional energy sources output capacities increasing, the overall impact of decarbonisation on trade balances cannot be known in advance.

Table 2: Impacts on Public Budget

Investment effects		**Energy demand reduction effects**	
Tax revenue from sales of energy efficiency products and services	⇧	Public expenditure on public sector energy	⇩
Initial costs of public investment in energy efficiency products and services	⇧	Energy subsidies to final consumers	⇩
Social welfare and unemployment expenditures	⇩	Emissions trading, and carbon tax revenues	⇩
		Public health, social welfare expenditure	⇩
		Public investment in energy supply infrastructure and subsidies	⇩

Source: IEA, 2016 (modified)

A number of ‘Innovation, competitiveness and eco-efficiency’ metrics should be added to the previous metrics. As a way to gauge the broader economic impact of decarbonisation policies in terms of competitiveness and innovation, two indicators can specifically be productively modified and put into use:

- Total R&D expenditure → Total RES R&D expenditure
- Turnover from innovation → Turnover from RES innovation

RES R&D expenditure is a useful measure of RES penetration into the economy and energy production/consumption. Together with Turnover from RES innovation, the insight provided is multiplied as it is possible to gauge the efficiency of R&D activities – reflecting partly productivity of R&D labour and expertise input. If the impact of R&D and innovation on the creation of jobs is factored in, then these two measures are rather critical. By contrast, the category used to refer to carbon-related infrastructure investments is ‘locked-in’ investments. This term signifies that an investment in coal related energy production has been planned or is in a development phase that cannot be inhibited. Contrary to ‘RES R&D expenditure’, ‘locked in’ carbon investments are deterrents of decarbonisation and constitute de facto indicators of processes that stand in the way of decarbonisation.

4. Ex ante impact analysis

The EU uses impact analyses in fields as diverse as agricultural and development policy, ICT and informatics and social and fiscal policy. The ex ante impact analysis serves the purpose of assessing the future impact of a current or planned intervention, in other words to 'predict' the likely effects of several alternative interventions in order to ascertain the one(s) with the least 'cost' and the biggest 'benefit'. In different terms, the ex ante impact analysis provides a sound means to identify positive and negative impacts of an intervention in certain areas (impact areas) on the basis of certain criteria.

Such analysis should be seen under the light of the 'intervention logic' which 'establishes the logical link between programme objectives and the envisaged operational actions'. Putting it in context, Table 5 presents a version of the 'intervention logic model' for the purpose of considering the socio-economic impact of decarbonisation in the energy sector.

Table 5: The 'intervention logic' adjusted to DeCarb research scope

Intervention logic components		Description
Needs		Address climate change Sustainable regional growth
Objectives	*Overall*	Reduce CO2 emissions Increase regional competitiveness Energy security/efficiency
	Specific	**Decarbonisation of energy sector**
	Operational	Reduce coal & fossils import/ phase out coal mining, processing and combustion Increase RES objectives
Inputs		Financial/administrative resources (e.g. financing RES, taxing emissions, skills & support with RES, lift carbon subsidies)
Outputs		RES support & financing schemes, increased CCS technolog
Results		Reduced energy production CO2 emissions, increased upta RES Restructured energy production value chain

Intervention logic components	Description
Impacts	Energy prices, jobs & employment structure, fiscal policy an energy trade (im)balances

The proposed impact analysis design involves data collection from specific regions with specific energy production attributes, whose decarbonisation paths are governed by a variety of energy policy programs (e.g. regional, national). Therefore, for each region participating in the research, there is crucial information to be reported and used as 'input' in the impact analysis. The following table (Table 6), adjusted from rural development planning, is helpful in providing more content to the above mentioned categories:

Table 6. Break down of 'intervention logic' categories

Intervention logic components	*Description*
Problems/ Needs addressed by the program	• Problems, risks, needs • Driving forces, strengths, opportunities in area • Causes of disparities • Target groups (or sector) and needs • Problems not addressed
Objectives	• Overall policy objectives • General, specific and operational objectives • Baseline and impact indicators • Coherence between regional/national/EU objectives
Proposed measures	• Baseline needs and objectives • Measures applied
Positive & negative impacts	• Expected impacts (social, economic, environmental) • Impact over time • Conflicts • Stakeholders affected

There is a number of different methodologies to carry out an impact analysis. Most notably, simulation, optimization, accounting & hybrid (Mundaca & Neij, 2010). Mundaca and Neij identify these four approaches dominant in the relevant literature:

Table 7: Types of impact analyses

Intervention logic components	Description
Simulation	Descriptive and quantitative Exogenously determined scenarios Observed and expected micro-economic decision making of end-users
Optimisation	Prescriptive Least cost solutions Rational model of consumer behavior
Accounting	Prescriptive or descriptive Definition of outputs in advance General equilibrium
Hybrid	Combinations of the above

For all purposes, however, an impact analysis aims at interpreting the values of impact indicators that have been developed for specific interventions; in the words of the EU, impact indicators 'are normally expressed in "net" terms, which means subtracting effects that cannot be attributed to the intervention (e.g. double counting, deadweight), and taking into account indirect effects (displacement and multipliers).'

To summarise, the methodology developed for the purposes of DeCarb activity A1.1 focused at:

a) Determining the value chain in question
b) Determining the interdependencies between the various links of the value chains
c) Examining the policies and plans driving decarbonisation in each region

The aim of this activity is to estimate **what course of action would be more beneficial, least harmful or least risk-laden in socio-economic terms for the regions examined in the context of the implementation of decarbonisation policies**.

DeCarb project partners conducted desk research to collect data on their territories using a relevant questionnaire available in Annex.

5. Research outcomes

5.1. Extremadura (ES)

The region of Extremadura (NUTS 2 – ES43) has a population of 1.066.998 with an annual GDP of 18.520 M Euros and the regional employment rate is 76%.

5.1.1. Policy and implementation context

Besides policies and strategies at the EU and national level the region abides by, there are strategies in place for climate change at regional level: The "Estrategia de Cambio Climático en Extremadura 2013-2020" is a continuation of the previous strategy 2009-2012. In addition, the Social and Political Pact for Extremadura reflects the societal commitment to achieve a long-term development model aiming at a globalized and sustainable economy. Further, the Strategy for the Sustainable Development of Extremadura is one of the 21 specific actions defined in the pact mentioned above. Last, the Agreement for the Sustainable Energy Development of Extremadura (ADESE) promotes savings and energy efficiency in the region.

The regional government of Extremadura is committed to promoting renewable energy and is already planning a new energy market that shall not be dependent on the region's nuclear power plant, compensating its current production with RES.

In terms of monitoring and controlling regional health impacts due to air quality, a control network for air pollutants in the region has been developed and has carried out the appropriate analyses. Good practices are implemented to maintain air quality and raise awareness among the population and sectors of the region.

5.1.2. Energy production and market

The current tariff for wholesale electricity prices is at 57 €/MWh. Extremadura complies with the European regulations 2008/50, based on the cooperation of the Member States to reduce pollution.

Extremadura relies on an energy production mix of RES and Nuclear. The share of RES is 22.51%, while that of nuclear ranges at 77.15%. Energy production is therefore not entirely based on renewable energy sources, but the region is fully decarbonised, while it contributes with nuclear energy exports. The total energy production capacity is 21,185 GWh, while regional consumption is 4,800 GWh. As indicated, Extremadura produces more energy than it consumes, so no imports are necessary. In fact, its consumption is covered with the renewable production in the region (approximately 4,768 GWh in 2017).

Carbon capture and storage is nevertheless operative in Extremadura, with net carbon capture having increased in recent years. While in the period 1990-2000, a total of 1.349.417 tC per year were removed from the atmosphere, in the period 2000-2006, the amount raised to 2.548.661 tC per year.

5.1.3. RES investments

Extremadura is a net interregional exporter of energy, and the coal intensity of its energy production is null, therefore, decarbonisation in this case consists not in decommissioning coal-fired plants and/or ceasing operations of coal mines, but in increasing RES uptake. Increasing RES uptake, requires knowledge of the labour intensity of RES energy production, the jobs to be created, the value generated (e.g. from exporting Renewable energy). Depending on the nature of funding of RES development, there might be several different outcomes produced in terms of public costs and electricity prices. Given however that RES is more labour-intensive than coal-fired energy production, it can be assumed that depending on the scope of development, RES jobs will be on the rise in the near future.

Although no targets have been set at regional level, there are already new projects to develop large-scale renewable plants:

- A 40 MW wind farm was deployed in the north of Extremadura and started operating recently. There are already provisions and studies for the deployment of another wind farm with similar installed capacity.
- A 500 MW photovoltaic plant is already under construction in the province of Badajoz.
- Additional projects for a total capacity of 1.500 MW of photovoltaic power have been approved and are under regulation procedures.

These investments are bound to bring about further employment opportunities in RES for all relevant occupational profiles, provided the necessary training. The planned FOAK solar project in Extremadura is a case in point. It is reported that, as Extremadura is the region in Spain with the lowest GDP, the FOAK project is bound to overall reduce economic inequalities. Thus, a suggested course of action is to advocate and communicate the expected socio-economic benefits for the region. Among those notably, there is a potential benefit of increased cooperation among Extremadura and EU regions. Provided the increasing interest regionally and EU-wide, the benefits to be yielded are considerable, however more advocacy at the National level is needed. Extremadura can become a key, “optimal supplier” of renewable energy in Europe.

5.2. Nordjylland (DK)

Nordjylland has a population of 587.335, an annual regional GDP is 23.148 million Euros (2015) and the employment rate is 73,5%. The regional CO_2 emissions' reduction rate targets in relation to 1990 are 60% in 2030 and 100% in 2050. The associated RES uptake rate is 60% in 2020. There are 3.700 deaths annually related to air pollution in Denmark.

5.2.1. Energy production

At the regional level the share of RES is 80% and that of fossils is 20%. Indicatively, from a 10,230 GWh total regional energy production capacity (electricity and heat), approximately 1880 GWh is dependent on coal. The current coal imports reach 765.812 tonnes/year (2016), 60.189 of which goes to private industry. This coal is obtained from various sources globally.

The Nordjyllandsværket coal-fired power plant has been operating for approximately 27 years and is due for decommissioning in 2025. It has 740 MW of installed electrical capacity and average 36% efficiency. There is no other coal power plant under construction or planned for future development. Aalborg Portland, a cement factory, is the only other workplace in Nordjylland that uses coal in its production process. Nordjyllandsværket is one of the two coal-fired plants in Denmark.

5.2.2. Jobs

The process of decarbonisation is going to affect regional socio-economic indicators as a number of jobs are going to be affected by decommissioning in 2025. More specifically, the total number of jobs in the coal-fired plant is 243 (100 low skilled, 100 medium skilled and 43 high skilled) and the total number of jobs in the coal intense industry of cement production is 335 (150 low skilled, 85 medium skilled and 100 high skilled).

Workers in the coal fired plant will re-train, or work in other adjacent sectors. It can be assumed that as reliance on coal is minimised, reliance on RES increases, and therefore, labour-intensity of energy production increases as the RES expands.

The transportation sector is also linked to coal related activities, namely shipping the coal from South Africa, Colombia and Poland to Denmark. The estimated number of jobs to be affected ranges between 100 and 200 workers. Yet, the dependency of the sector on coal is minimal and therefore the decommissioning of the power plant shall not significantly affect the transportation industry which is not, strictly speaking, a regional industry. For the input sector, there is little to no dependency. In terms of interindustry dependence, Nordjyllandsværket imports coal from various mines around the world. There is very little dependency between Nordjyllandsværket and these coal mines, as Nordjyllandsværket can equally import from other mines. The same holds for Aalborg Portland.

The cement factory (Aalborg Portland) has 100 estimated jobs. The factory utilizes input for production (coal) and is thus highly dependent on it, however it is not dependent on any specific mine, as it conventionally sources its coal from various mines. The factory uses 75-80% of the total emission allowances for Denmark. Should decarbonisation progressively entail reduced number of allowances or an increase in the price of allowances, it will bring about changes in the cement industry. These fluctuations may include, pressure on wages, numbers of jobs, product prices.

The reduction of coal imports and a general shift to the reliance on sustainable, locally produced energy, brings about multiple positive effects for trade balance and regional economy indicators.

5.3. Savinjska (SI)

Savinjska is one of the eight NUTS 3 regions of Vzhodna Slovenija. The region has a population of 254,760 (2018) and an employment rate of 68%. The annual country GDP is 45,948 million EUR and the regional annual GDP is 4,858 million EUR (2017).

5.3.1. Energy prices

The producers, suppliers and traders of electricity in the wholesale market sell and purchase electricity from each other, and trade on the basis of closed contracts. They either conclude business by the bilateral transactions or at the exchanges in Slovenia and abroad. The activity of electricity exchange in Slovenia is being carried out by BSP, Regional Energy Exchange, d.o.o. (BSP SouthPool). The information is also available from commercial providers of analytical services and market information. The average base price in power exchange in Slovenia was 49.5 EUR/MWh in 2017 and 35.6 EUR/MWh in 2016.

The company Holding Slovenske elektrarne (the HSE), which owns the Velenje coal mine and the nearby Šoštanj thermal power plant, represents the first pillar in the Slovenian wholesale market. HSE is the controlling company of the HSE Group, the largest producer and seller of electricity from domestic sources on the wholesale market in the country and the largest Slovenian producer of electricity from renewable energy sources. The HSE trades with further contracts in order to protect long-term positions against price risks. At the end of 2017, the HSE company recorded EUR 51,539,000 of open future contracts held for trading.

5.3.2. Energy mix

The energy mix of Slovenia is formed as follows: 25.5% fossils, 30.7% RES, 44.7% nuclear and 0.2% gas. Production of primary energy in Slovenia totalled 3.66 million tonnes of oil equivalent (Mtoe) in 2017. The total amount of energy supply in the country was 6.84 Mtoe in 2017, thus the dependence of Slovenia on energy imports was approximately 47.5%, with petroleum products and gas almost entirely imported. In the structure of primary energy supply of Slovenia in 2017, petroleum products predominated with 34.4% share. The share of nuclear is 21.6%, and that of solid fuels 16.7%, renewable energy sources 10.9%, natural gas 10.6%, hydro 5.2% and 0.7% came from non-renewable waste. Regional energy production is primarily dependent on local lignite supply. Moreover, in 2017, regional lignite production accounted for approximately 14% of the total country's energy supply.

The only operating coal mine in Slovenia, Premogovnik Velenje (Velenje lignite mine), is situated in Velenje and the biggest operating coal-fired power plant in the country, Termoelektrarna Šoštanj, in Šoštanj, both part of the Savinjska region. Slovenia is a relatively small country and both within the context of the Savinjska region and the country as a whole, lignite is important in terms of security of supply reasons and the Šoštanj thermal power plant is one of the largest sources of electricity production, which pose the biggest factors to consider in terms of wider impacts caused by a future phase out of coal.

The majority of all imported coal (416,000 tonnes/year) in Slovenia is used at thermal power and heating plant Termoelektrarna Toplarna Ljubljana (TE-TOL) in Ljubljana (Osrednjeslovenska region) in highly efficient cogeneration for the purposes of heat generation for the district heating system in Ljubljana and smaller share of electricity production on the country level.

Approximately 70,000 tonnes of imported coal amount, which represents ca. 18% share of the total imported amount is not used in the process of energy transformation. Assuming that a certain amount of 70,000 tonnes of imported coal is used in Savinjska region and comparing it to the Velenje lignite output (3,355,664 tonnes in 2017) used in the Thermal power plant Šoštanj, which does not run on a foreign coal, it can be concluded that solid fuels import does not play a significant role in the Savinjska region coal value chain, neither on the country level. Therefore, carbon pricing, or a reduction on imported coal as a result of the implementation of decarbonisation policies, will affect negatively coal imports and in a positive manner the regional trade balance, increasing simultaneously energy security.

The Velenje lignite mine, located in the Savinjska region, is the only operating coal mine in the country and all of its lignite output is used at the nearby Šoštanj thermal power plant, the largest power plant in the Slovenian electricity system. The plant's installed capacity amounts to approximately a quarter of the available capacity of all power units in the country and based on the local lignite productions it generates approximately 30% of the electricity produced in Slovenia. The Šoštanj thermal power represents an important energy pillar for the reliable supply of electricity in the country and, furthermore, for the Savinjska region as it provides thermal energy for the district heating system of Šaleška dolina valley which is the second largest district heating system in the country.

Unit 5 and Unit 6 of the Šoštanj Thermal Power Plant are scheduled for decommissioning in 2030 and 2054 respectively. The newest addition to the Šoštanj thermal Power Plant (TEŠ) was the construction of a modern, highly efficient (43%) BAT 600 MW unit with the intent to replace existing old, outdated and inefficient units and deliver CO_2 emission reductions of 35%. Unit 6 that has received operating permit in spring 2016 is designed to be operational until 2054. In July 2018, after 46 years of operation, 275 MW Unit 4 was permanently shut down due to the end of its service life, while in in August 2018, after almost three years of ecological rehabilitation works, revitalised Unit 5 (345 MW) started operating again.

5.3.3. Coal chain value structure and interdependencies

As indicated above, Šoštanj Thermal Power Plant is fully dependent on the Velenje Coal Mine, thus the decommissioning of the Velenje coal mine coincides with the scheduled decommissioning of the Šoštanj Thermal Power Plant last operating unit in 2054. According to the data provided, the following sectors are likely to be affected at national scale:

- Equipment production/supply/trading
- Machinery production/supply/trading
- Production/supply of other goods
- Material processing/supply/trading
- Maintenance of machinery and technological equipment
- Ecological monitoring
- Information system software maintenance
- Insurance and banking services
- Legal services
- Security services
- Consulting services
- Food services
- Research and development

Services of maintenance of machinery and equipment have a very important role in the regional and national coal value chain, from both the perspective of possible economical and employment changes due to the decarbonization and the perspective of ensuring occupational safety, health of employees and reliable operation of machinery/equipment. In Velenje coal mine, services, which are predominately related to the maintenance of machinery and technological equipment, are performed by the subsidiary that provides employment to 785 workers. Analysis of the two key participants within the regional coal value chain (Velenje coal mine and Šoštanj thermal power plant) shows that in most cases maintenance services were performed by regional and national companies, thus this sector is fully dependent on coal .

Supply of various materials and other goods used as inputs in mining is essential for coal production as well as coal-based energy production. As Velenje coal mine and Šoštanj power plant are dependent on the processing and supply of materials from regional/national companies, it is evaluated that processing/supply/trading of material and other goods has a significant role in a coal value chain structure.

A great share of equipment and machinery used in regional coal value chain is manufactured by foreign producers or suppliers due to limited number of specialised companies in domestic market, however there is a share of the equipment that is manufactured or supplied by local, regional and national companies that have achieved an appropriate technological development level. It is, thus, evaluated that regional and national energy transition would, to a certain extent, affect indirect jobs as well as the amount of produced/distributed outputs of equipment industry.

Food services were in the past provided by the subsidiary of Velenje coal mine, however, due to the intensive restructuring and primarily focusing on coal production, since 2016 these services have been provided by another local company. Through the implementation of business restructuring, the Velenje coal mine has assured that all employees within this sector were transferred to a new company at the time, yet there is a possibility that in the process of decarbonisation these jobs could be affected in the future.

Decarbonisation of the region/country is not expected to significantly affect the linked sectors providing insurance and bank services, as these are performed by the bigger national enterprises that do not in any way depend on the coal production or processing.

5.3.4. Jobs

According to the European Association for Coal and Lignite – EURACOAL, 2015, the indirect lignite-related employment in Slovenia amounts to 2.467 jobs. In 2018, the Joint research Centre (JRC) prepared the publication “EU coal regions: opportunities and challenges ahead”

(Alves Dias et al., 2018) which provides an estimation of indirect jobs in coal-related activities on an intra- and inter-regional level:

- Intra-regional: 1.270[16]
- Inter-regional: 1.833[17]

The main sector linked to coal mining is the energy production sector (electricity and heat production). No share of regional lignite is used in non-energy applications, and all lignite is headed towards the Šoštanj thermal Power Plant. The number of jobs involved is 311, and they are all direct jobs in the Šoštanj thermal power plant.

5.3.5. Decarbonisation process

The issue of phasing out coal in Slovenia, as in the majority of coal intensive regions located in East European countries, is controversial in the sense that feasible alternatives that could realistically substitute the energy source without having a profound impact on the economy and an economically viable energy supply to households and industry are yet to be defined. To date, there is no overarching framework defining restructuring support instruments for coal-fired energy producers neither on the regional nor on the national level. Each operation is specific in terms of its role and importance to the domestic economy and national energy system.

The long-term strategic outlook for the country is however well defined and structured so as to support the sustainable energy transition on the national level across various fields of energy supply and use. Slovenia's binding national targets for greenhouse gas emissions and the annual binding national limits are pursuant to Regulation (EU) 2018/842. Under the Burden Sharing Regulation, the national targets of reducing GHG emissions were set for each EU Member State in a range between 0 and 40 %. According to the Regulation, Slovenia is required to reduce its GHG emissions by 15 % by 2030 in relation to 2005 levels.

Long-term targets and goals will be determined in National energy and climate plan, which will combine the existing action plans with individual areas. The National targets according to the Operational programme for limiting greenhouse gas emissions until 2020 are:

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[16]NUTS 2 level: Vzhodna Slovenija

[17] Inter-regional supply-chains consider the interregional trade between NUTS 2 regions. In the case of Slovenia, that has only two regions at NUTS 2 level, this number applies for the country level as well.

- Below 4% increase in greenhouse gas emissions compared with 2005. (Non-ETS emission sector)
- Reduction of greenhouse gas emission below 12.117 kt CO2 ekv3 until 2020. (Non-ETS emission sector).

Regarding RES uptake it is noteworthy that there are several funding sources including state and municipal sources and private capital, private-public partnerships, EU funds and EIB funds. Besides their potential for significant return on investments and increasing regional GDP, investments in RES are also expected to create new employment positions and increase employment figures since, RES production, installation, operation, and maintenance are more labour-intensive compared to coal-intensive energy production.

5.4. Lodzkie Region (PL)

Lodzkie Region has a population of 2.476 million inhabitants. The annual GDP per capita is PLN 48,380. In the case of Lodzkie, fossils account for 90% of energy production and only 4.3% is attributable to RES.

The main source of input for coal-based energy production is coal from the Brown coal mine Bełchatów. It is an open cast mine (surface) operating two mining fields: Bełchatów (coal mining will end in 2026) and Szczerców (coal mining will end in 2040). The coal is transported by belt conveyors directly to the adjacent power plant. The power plant is further supplied with an additional 19.67 tonnes of imported coal per year.

There is full dependency between the Bełchatów Brown Coal Mine and the Bełchatów Power Plant. The plant is scheduled for decommissioning in 2040. With the exception of the Zloczew open-pit which is to be operational until 2060, considered to be a locked- in investment, the impact of decommissioning of both the power plant and the mining pits is significant.

5.4.1. Jobs

There are no available data on the number of jobs in input businesses (equipment for mining, equipment for coal-fired plants). Data on direct jobs however show that there are 5 976 employed by Section I groups (Section B – mining and quarrying) and 9 613 working in Section I of the groups (Section D – production and supply of electricity, gas, steam and hot water). Significantly, the number of jobs in coal-intense industries ranges at 124.800 (57.5 thousand in textiles production and 67.3 thousand in the production of metals). All of these sectors are will be variably affected. Especially regarding the coal-intense industries just mentioned, it is certain that carbon pricing, as well as changes in the EU ETS allocation scheme to induce accelerated RES uptake and disincentivise the continuation of production of energy from coal, and achieve emission reduction targets, will have repercussions for these industries.

5.4.2. Decarbonisation process

The scope of the Regional Operational Programme for the Lodzkie Region for the years 2014-2020 is a response to the development challenges that have been identified in the main strategic documents and includes those areas of intervention whose implementation will bring the greatest effects.

The programme under Priority Axis IV Low-Emission Economy will contribute to the achievement of the Partnership Agreement "Increasing the competitiveness of the economy". The key challenges of the voivodeship in the field of low-carbon economy are: effective use of the potential of the possessed resources and conditions for the development of low-carbon energy and an increase in the use of renewable energy sources.

Projects implemented under OP IV will directly contribute to the reduction of the emissions of the economy, improvement of air quality, improvement of the state of the environment in cities and rural areas, which will affect sustainable development: supporting an economy which uses resources more efficiently, is more environmentally friendly and more competitive, which is the essence of the Europe 2020 Strategy. The intervention planned in OP IV will aim at reducing air pollution by reducing emissions of pollutants.

Further important measures are summarised below:

- The CO_2 reduction targets for power generation sources are 30.200.000 Mg/year.
- A statutory ban on the sale of solid fuels not adapted for combustion in households, i.e. sludge and flotoconcentrates.
- A statutory ban on importing unsorted coal into Poland, the so-called "unsorted" coal, introduction of a consumer awareness-building tool, not yet existing in the Polish legal system, i.e. certificates of quality of solid fuels, which customers will receive from coal sellers upon request, thus receiving information on the calorific value of purchased fuels.
- The construction of an institutional system for quality control of solid fuels by the National Treasury Administration, the Office of Competition and Consumer Protection and the Trade Inspection, which have been equipped with appropriate control powers and are provided with budget funds for the implementation of these tasks until 2027 in the total amount of over PLN 78 million.

Although not imminent, the decommissioning of the Bełchatów Power Plant will make a significant land restoration project possible, such that it will be possible to create revenue, occupy workers and bring about significant environmental benefits.

It can be safely assumed that the necessary RES investments to offset decarbonisation energy deficits will entail an increase in RES training and will create more job positions compared to those available in the coal-based energy production process.

The significant measures to be taken in order to substitute a 90% share of coal in the energy mix with clean energy, will bring about considerable effects for the economy and the society, as carbon pricing will crucially affect electricity prices, however, if RES funding draws on such revenue sources, the negative consequences can be manageable.

5.5. Brandenburg (DE)

The region of Brandenburg has a population of 2.494.648 (Eurostat, 2017), an annual regional GDP of 69,13 million EUR and an employment rate of 94% of the active population (15-74). The regional energy mix is 45% lignite coal, 5% hard coal, 30% oil, 15% gas, 18% RES (wind, solar, biomass). The energy production capacity amounts to 10.025 MW and 1,55 MW thermal. The regional energy needs exceed regional production capacity by far. More specifically, consumption is at 185.000 GWh (coal, oil, gases, RES, others), while regional imports of energy amount to 55.000 GWh (coal, gas, biomass). In terms of coal, imports are 9.2 million tonnes/year. Another 1.3 million tonnes/year coal is annually exported.

5.5.1. Coal value chain structure and interdependencies

There are two mines operating in Brandenburg: Jänschwalde and Welzow-Sud. The coal extracted from the current mine (Subsection I), supplying the Schwarze Pumpe power plant, is estimated to last until 2027-2030. A further expansion of the Welzow-Süd mine into Subsection II would enable mining to continue until 2045-2050. A decision on further expansion will have to be made by 2020. Based on German Government rulings, mining activities have to stop by 2038.

The power plants aggregate energy production is 4600 MW and have a 34% efficiency in transforming the energy of fossils into electricity. At present, there is no carbon-related investment planned by LEAG (the companies running the mines and plants). The energy strategy for the Brandenburg region is planning the coal sector phase out, particularly in the affected Lausitz-Spreewald state, until 2038. 3,000 MW out of total currently operated 4,300 MW power blocks is about to reach its lifespan and shut down by 2025, which entails over 700 redundancies. The reduction and eventually the cut-off of lignite mining activities will affect nearly 3,500 work places, which, based on the assessment of the performance of mining regions in comparison to other European regions, places Brandenburg at medium risk level.

Regarding input sectors, it can be ascertained that the industry producing machinery for coal mining is significantly dependent on the continuation of mining. Indeed, the majority of such machinery is currently produced and supplied locally. Machinery for power plants is equally significantly dependent on the operation of the local coal-fired plants. Finally, the steel industry is also significantly dependent on the operation of the mines.

5.5.2. Jobs

The Brandenburg NUTS-2 region (DE40) is one of the regions most affected by the energy mix transition, with 4500 jobs directly linked to coal mining and energy production. This number represents a share of 1107 plant jobs and 3402 mining jobs. According to the local statistics demonstrated in the Fact Sheet on Economic Development in the Brandenburg part of Lusatia, the total number of employees in the mining and manufacturing industry amounts to nearly 28,500 people (2017).

5.5.3. Decarbonisation

The German government is committed to the national, European and Paris climate protection targets for the period up to 2050. The 2016 climate protection plan of the German government describes the gradual path towards a largely greenhouse gas-neutral economy and society in Germany by the middle of the century. The German government is pursuing the triangle of supply security, environmental compatibility and economic viability. The implementation of the climate protection plan will accelerate structural change in many regions and economic sectors, especially in the energy generation sector. The associated changes must not be at the expense of the coal-producing regions on one side, but must rather open up opportunities for sustainable economic dynamism with high-quality employment. The Federal Government's aim is to preserve the regions as energy regions of the future and to avoid structural breaks and restrictions on international competitiveness.

Launched in June 2018, a multi-stakeholder government coal commission was challenged with proposing a new date and measures for ceasing the coal power industry. In February 2019, the commission presented its final report which foresees a phase-out of coal in Germany by 2038 with the option for revision in 2035. This also states a short-term closures of 12,5 GW by 2022 and review points in 2023, 2026, 2029 and 2032.

Current local and national programs and schemes related to coal conversion and implementation of carbon emission mitigating measures include:

- On a National level:
    - National Climate protection plan
    - National Sustainability Strategy of Germany

- On a Regional level:
    - Sustainability Strategy of Brandenburg (from 2014) and its updating 2019 (concrete goals and indicators)
    - Energy Strategy 2030 Brandenburg (Nuts 2 level), was reviewed, new measurements were decided by federal government, will be overworked beginning and of 2019, Ministry of Economic Affairs and Energy
    - Regional Energy Concept Spreewald –Lausitz (from 2013, regional Nuts 3-Level)

Politicians and policy makers that take the lead in the coal transition express a very high degree of willingness towards the structural change. Given the predominant dependence on coal to provide energy security, the expansion of renewables will require significant modifications in internal and cross-border grids. Electricity prices due to renewables surcharge are going to continue rising.

To support low-carbon and efficient energy production various grant schemes[18] have been developed as well as a number of key innovation and research activities related to buildings, heating and cooling and industry undertaken in Lausitz-Spreewald.

[18] Namely EFRE/RENplus, EFRE/Technology transfer and EFRE/Profit.

5.6. Oltenia (RO)

The Region of Oltenia has a population of 1.949.940 (according to the 2018 census), it has an annual regional GDP of 55335,1 (EUR, 2016) and an employment rate of 50%. The current energy mix of Oltenia is formed as follows: 44.5% Fossils, 37.2% RES, and 18.3% Nuclear. In 2017, the share of primary energy resources in electricity production had the following structure:

- Electricity produced from coal (lignite and coal) 27.5% (17.3 TWh)
- Electricity produced in 23% hydro power plants (14.4TWh)
- Electricity produced in the Cernavoda nuclear power plant 18.3% (11.5 TWh)
- Electricity produced from hydrocarbons (oil and gas) 17% (10.7TWh)
- Electricity produced in wind and photovoltaic installations 13.5% (8.5TWh)
- Electricity produced from biomass 0.7% (0.4 TWh)

The national energy production capacity is 25.416 thousand TOE (2017) and the respective regional is 3.710,7MW produced by:

- Turceni Electrocentrale Substation 1.320 MW
- Rovinari Electrocentrale Substation 1.320 MW
- Isalnita Electrocentrale Substation – 630 MW
- Craiova Electrocentrale Substation – 300 MW si 160 Gcal with co-generation on lignite
- UATA Motru – 12,5 MW si 6 Gcal with co-generation on lignite
- Small hydro power plant of Turceni Power Plant – 9,9 MW
- Chemp Novaci 18,3 MW – produced with 6 micro-plants (CHEMP 1bis, 1.2.3.4 si 5)
- Govora thermal power plant 100 MW

Primary energy consumption at the regional level is 333,96 (MW), representing its own technological consumption. Consumption is estimated at a maximum of 9%. The domestic production amounted to 21303.5 thousand toe, increasing by 814.3 thousand toe versus the previous year, and the import was 12987.9 thousand toe at national level.

The tables bellow present information on the mines and power plants of Oltenia:

Table 8: information on Oltenian mines

Mine	Type	Decommissioning
Jilțu Sud	Over ground Lignite	2050
Jilțu Nord	Over ground Lignite	2050
Peșteana	Over ground Lignite	2050
Roșia	Over ground Lignite	2050
Husnicioara	Over ground Lignite	2022
Rovinari	Over ground Lignite	2050
Tismana	Over ground Lignite	2050
Pinoasa	Over ground Lignite	2022
Rosiuta	Over ground Lignite	2050
Lupoaia	Over ground Lignite	2022
Berbesti	Over ground Lignite	2022
Tehomir	Underground Lignite	2020
Motru	Underground Lignite	2020

Table 9: information on Oltenian mines

Plant	Capacity	Decommissioning
Turceni Electrocentrale	Substation: 1.320 MW 4 ENERGY GROUPS * 330 MW	2050

Plant	Capacity	Decommissioning
Rovinari Electrocentrale	Substation: 1.320 MW 4 ENERGY GROUPS * 330 MW	2050
Isalnita Electrocentrale	Substation: 630 MW 2 ENERGY GROUPS * 315 MQ	2050
Craiova Electrocentrale	Substation: 300 MW 2 ENERGY GROUPS * 150 MW	2050
UATA Motru	Substation: 12,5 MW 1 ENERGY GROUP * 6.5 MW & 1 ENERGY GROUP * 6 MW	2025
Govora thermal power plant (CET Govora)	Substation: 100 MW 2 ENERGY GROUPS * 100 MW	2030

There are approximately 13.500 jobs directly associated to mining and power generation: 9860 jobs in coal mines (230 in Motru and Tehomir) and 4.997 jobs in coal-fired plants (Turceni, Rovinari, Isalnita, Craiova, UATA Motru, CET Govora).

In the end of 2018 (31/12/2018), the number of jobs linked to mining were 14.640. Some of the sectors associated to mining and coal-fired energy production concern the rental of machinery, maintenance services, freight and passenger transportation services (to and from the workplace), cleaning services, security services, medical services - occupational medicine, design and cadastre services. The total number of companies to be affected are 76 (excluding micro-enterprises)[19].

Based on the collected data, the supply, machinery rental, security services and cleaning services are significantly dependent on coal-related activities as this is a mono-industrial area. Regarding interindustry dependence between mining and coal-fired plants, specifically

[19] Specifically: 16 rental machinery companies, 27 companies maintenance services, 21 goods and personnel transport services (to and from the workplace) companies, 1 leaning services company, 6 security services companies, 1 medical services/occupational medicine company, 6 design and cadastre services companies.

between Jilt Nord and Sud Pesteana, Rosia, Husnicoara and SE Turceni, and between Rosia, Pinoasa, Tismana, Rovinari and SE Rovinari is full, meaning that all fossils extracted are used in the regional power plants.

Sud-Vest Oltenia is one of the most affected regions to lose more than 1000 jobs, reaching 2000-2500 by 2050. Unemployment may increase to reach 11.1%, compared to the current rate of 9.9%.

5.7. Western Macedonia (GR)

The region of Western Macedonia has a population of 283.700 (according to the 2011 census). The annual GDP is 3.849 million and the current employment rate is at 53%. The energy mix in Western Macedonia is 87.6% fossils and 12.4 RES. Renewable energy sources include a large hydroelectric unit with installed capacity of 375 MW.

The regional energy production capacity is 4.309 MW and the primary energy consumption is 0.9 TWh per annum. Net regional primary energy imports amount to 214.120 metric tons of oil products (2017). There is no coal imported or exported.

5.7.1. The coal value chain

There are 2000 jobs[20] associated to coal extraction (equipment). The estimated number of direct coal jobs is 2500[21] and the number of jobs in coal-fired plants is 1400[22]. A 660 MW lignite power plant, Ptolemaida V, is currently under construction and planned to be commissioned in 2021.The following tables (Table 10 & 11) present the mines and power plants scheduled for decommissioning:

Table 10: Mines scheduled for decommissioning

Mine	Decommissioning
Main Field Over ground Lignite	2035
Kardia Field Over ground Lignite	2055
South Field Over ground Lignite	2043
Amynteo Field Over ground Lignite	2022
Three mines of limited production in Florina area, private and owned by the Public Power Cooperation (PPC), supplying the Meliti TPP	2036

[20] 300 low skilled, 1500 medium killed and 200 high skilled.
[21] 50 low skilled, 2300 medium killed and 150 high skilled.
[22] 50 low skilled, 1250 medium killed and 100 high skilled.

Table 11: Power plants scheduled for decommissioning

Power plant	Decommissioning
Kardia	2019-2021
Amyntaio	2021
Agios Dimitrios	Units 1-4: 2029-2030, Unit 5: 2043
Meliti	2036
Ptolemaida V	2055

It should be noted that there is a significant dependency between the mines and the power plants.

Regarding the Agios Dimitrios TPP, the largest lignite power plant with 5 units, the following environmental upgrades have been launched:

- Construction of wet desulphurization of unit V, a project already commissioned
- Upgrading the boilers of all 5 units to reduce nitrogen oxide (NOx) emissions by primary measures.

Furthermore, there are several services and sectors involved in coal extraction including:

- Rock moving sub-contractors
- Owners of trucks, excavators, dozers, etc. who rent their equipment to PPC SA
- Mechanical – electrical equipment repair and maintenance sub-contractors
- Companies producing concrete and asphalt and sub-contractors of steel and concrete construction works
- Suppliers of equipment and parts, conveyor belts, explosives, etc.
- Small sub-contractors providing several services (e.g. catering, cleaning, waste disposal)

5.7.2. Decarbonisation process

According to the National Planning for Energy and Climate (NPEC) that was submitted by the Greek Ministry of Energy and Environment on November 2018, the lignite industry is expected to be continuously declining, reaching less than 10% of net electricity production of Greece in 2030. For the region of Western Macedonia it is foreseen that the Greek government intends to keep the lignite industry alive and active, well beyond 2030.

The National Just Transition Fund announced by the Greek Government for the lignite areas, is expected to finance sustainable development actions in Western Macedonia, providing a budget of 60 M€ (20 M€ per year) during the period of 2018-2020. The funding priorities are related to the Region's Smart Specialization Strategy, as well as past development plans and proposals, promoting the development of clean energy, energy saving, circular economy, primary sector, exploitation of industrial heritage and integrated intervention programs. The main aim of the program is job creation and entrepreneurship support.

The Regional Development Fund of Western Macedonia established in 2016 by the Western Macedonian Regional Council, reached its operational status in 2018. It is co-funded by the Public Power Corporation, through compensatory supporting actions, and the Hellenic Fund for Entrepreneurship and Development. The regional fund aims to support local SMEs at regional level in the form of small low interest loans. Strong emphasis is being given on projects with substantial added value to the local economy. The Fund will invest 10 M€ in a minimum of 200 innovative business plans.

Furthermore, taking into account the fact that Western Macedonia is participating in the European initiative "Coal Regions in Transition Platform" as a pilot region, a Working Group was created in late 2017, to support the technical and administrative work to be carried out throughout its participation in the Coal Regions in Transition Platform.

In addition, through the European Structural Reform Support Programme (SRSP), a total budget of 500.000 € was approved for the region in order to develop support measures for establishing the transition procedures framework in management, governance and the institutional / financial field.

With the funding of the Region of Western Macedonia, all the municipalities in the region will be participating in the European Initiative of the Covenant of Mayors. The proposed action requirements, planned to be completed in July 2019, with Western Macedonia being the first region in Greece in which all its municipalities have Sustainable Energy (and Climate) Action Plans until 2030.

The Greek National Energy and Climate Plan foresees major RES penetration, to be driven by reduced electricity generation costs in the sector, especially photovoltaic (PV) and wind energy technology, and a withdrawal of old lignite and diesel-fired power stations, whose production costs are expected to increase as a result of higher CO_2 emission right costs. Under the plan, the investments in electricity production from RES are expected to add over EUR 12 billion in value to the economy from 2020 to 2030. Wind energy installed capacity is seen almost tripling to 6.4 GW in 2030 from 2.4 GW in 2016, as is PV capacity, to 6.9 GW from 2.6 GW in 2016, while hydropower capacity, including the main power utility PPC's large units, is forecast to achieve a milder increase to 3.9 GW from 3.4 GW in 2016.

Especially for Western Macedonia, a total of 12 companies or joint ventures have expressed interest in a tender launched by PPC Renewables to build and operate a biomass CHP plant to produce renewable heat and electricity in Amyntaio, a city in Western Macedonia. PPC Renewables is seeking a strategic partner who will hold a majority stake and take over the planning, funding, construction and operation of the unit. The unit will have a power of 25 MW (electric) and 45 MWth (thermal energy).

In addition, a prospective 200-MW photovoltaic park is planned to be developed in Western Macedonia by PPC Renewables. The 200-MW solar park will produce around 260,000 MWh a year, offsetting 300,000 tons of carbon dioxide emissions. Some EUR 600 million will be invested in the project, which will be developed by PPC Renewables SA and the company's future partner.

Furthermore, small decentralised biomass units are planned to be installed in order to provide district heating to the remote settlements. These actions will be implemented through the Regional Operational Programme 2014-2020.

5.8. Stara Zagora (BL)

The region of Stara Zagora has a population of 1.046.125 with annual GDP 6692.86 million and employment rate 66.8%. The region's energy mix is composed of fossils (50%), RES (18%) and nuclear (38%). The region imports 0.8% of the total coal it uses.

There are three over ground lignite coal mines operating in the region, namely Troyanovo 1, Troyanovo 2 and Troyanovo 3. Respectively, three coal power plants are operating in the region, namely:

1. TPP Maritsa East 1 (AES Galabavo)
2. TPP Maritsa East 2
3. TPP Maritsa East 3 (Contour Global)

The three main power plants of the Maritsa Iztok energy complex provide 25-35% of the electricity used in the country. The total number of persons employed in the area's mines and power plants is estimated at approximately 12.000. Furthermore, there are several companies whose activities are directly linked to the Maritsa Iztok energy complex providing raw materials, materials and equipment, repair, installation and maintenance, transport services, and other goods and services (Za Zemiata, 2018).

According to Za Zemiata (2018), a successful transition is feasible for the region as long as a proper preparation takes place with the participation of all the relevant stakeholders, namely national, regional and local institutions, business, trade unions and the public. The available funding sources may offer a good basis for the implementation of the transition. Furthermore, the area is expected to expand in the development of high-tech manufactures and services, leading to higher incomes, rather than returning to traditional economic sectors.

5.9. Észak-Alföld (HU)

Észak-Alföld has a population of 1468088. The annual GDP is 17066.48 million with an employment rate 58.2%. The current energy mix is composed of Fossils (89%) and RES (11%). The RES fuel mix in the electricity generation process indicates that the biomass and renewable wastes outnumber other energy sources as 60% of total electricity production from RES comes from biomass and renewable wastes. The regional energy production capacity is 289 MW, while the primary energy consumption exceeds 4000 GWh.

Hungary is a country poor in fossil fuels. There are predominantly low quality lignite (approx. 6 billion tonnes) brown coal (approx. 3 billion tonnes) and black coal (approx.1.6 billion tons) totalling 10.5 billion tons in our country. Most coal reserves are depleted or are no longer economically exploitable. Only low-grade lignite is found in the North Central Mountains, which is currently mined in Visonta and Bükkábrány. The country's last underground mine at Márkushegy closed in 2014, and the Vértes Power Plant in Oroszlány, in 2015.

There are two lignite mines, Matra and Bükkalja, and three coal and lignite fired power plants, the Mátrai Power Plant, the Oroszlány Thermal Power Plant and the Tatabánya Thermal Power Plant, operating in Hungary. Tatabánya and Oroszlány power plants are licensed to produce energy until 2020 and Mátra Power Plant until 2025.

The number of jobs in coal power plants in Hungary is 900 and the respective number in coal mines is 1700, totalling 2500 jobs. The number of indirect jobs at an intra-regional and an inter-regional level is 2255 and 4735 respectively. Furthermore, approximately 20 enterprises in Hungary were operating within the coal and lignite mining sector in 2015.

It should further be noted that there is potential for CCS in large coalfields. Therefore, there is potential for value generation and new associated employment positions through the development of the appropriate infrastructures.

6. Conclusions

The participating regions have widely divergent energy mixes, therefore, decarbonisation essentially means different things at different contexts, and it is not possible to use in a meaningful manner the same indicators for all cases. For instance, there is no point in evaluating carbon-intensity of energy production in Extremadura, it is more meaningful to assess RES labour intensity. Furthermore, not all regions have similar, and thus comparable, coal value chains.

The following table (Table 12) recapitulates the key findings derived by the input provided by the project partners.

Table 12: DeCarb A1.1 key findings by Region

REGION	KEY FINDINGS
EXTREMADURA (ES)	Investments in large-scale renewable plants are bound to bring about further employment opportunities in RES for all relevant occupational profiles, provided the necessary training. A suggested course of action is to advocate and communicate the expected socio-economic benefits for the region. Extremadura can become a key, “optimal supplier” of renewable energy in Europe.

REGION	KEY FINDINGS
NORDJYLLAND (DK)	Power plant workers are expected to re-train, or work in other adjacent sectors. Should decarbonisation progressively entail reduced number of allowances or an increase in the price of allowances, it will bring about changes in the cement industry. These fluctuations may include, pressure on wages, numbers of jobs, product prices. It can be assumed that as reliance on coal is minimised, reliance on RES increases, and therefore, labour-intensity of energy production increases as the RES expands.
SAVINJSKA (SI)	It is noteworthy that there are several funding sources available regarding RES uptake, including state and municipal sources and private capital, private-public partnerships, EU funds and EIB funds. Besides their potential for significant return on investments and increasing regional GDP, investments in RES are also expected to create new employment positions and increase employment figures since, RES production, installation, operation, and maintenance are more labour-intensive compared to coal-intensive energy production.

REGION	KEY FINDINGS
LODZKIE REGION (PL)	Although not imminent, the decommissioning of the Bełchatów Power Plant will make a significant land restoration project possible, such that it will be possible to create revenue, occupy workers and bring about significant environmental benefits. It can be safely assumed that the necessary RES investments to offset decarbonisation energy deficits will entail an increase in RES training and will create more job positions compared to those available in the coal-based energy production process. The significant measures to be taken in order to substitute a 90% share of coal in the energy mix with clean energy, will bring about considerable effects for the economy and the society, as carbon pricing will crucially affect electricity prices, however, if RES funding draws on such revenue sources, the negative consequences can be manageable.
BRANDENBURG (DE)	The Brandenburg region is one of the regions most affected by the energy mix transition, with 4500 jobs directly linked to coal mining and energy production. Various grant schemes as well as a number of key innovation and research activities have been developed to support low-carbon and efficient energy production.

REGION	KEY FINDINGS
OLTENIA (RO)	Sud-Vest Oltenia is one of the most affected regions, standing to lose more than 1000 jobs, reaching 2000-2500 by 2050. Unemployment may increase to reach 11.1%, compared to the current rate of 9.9%. Based on the collected data, the supply, machinery rental, security services and cleaning services are significantly dependent on coal-related activities as this is a mono-industrial area.
WESTERN MACEDONIA (GR)	The lignite industry is expected to be continuously declining, reaching less than 10% of net electricity production of Greece in 2030. The Greek government intends to keep the lignite industry alive and active, well beyond 2030 for the region of Western Macedonia. The National Just Transition Fund announced by the Greek Government for the lignite areas, is expected to finance sustainable development actions in the region, providing a budget of 60 M€. The funding priorities are related to the Region's Smart Specialization Strategy, as well as past development plans and proposals, promoting the development of clean energy, energy saving, circular economy, primary sector, exploitation of industrial heritage and integrated intervention programs. The main aim of the program is job creation and entrepreneurship support.

REGION	KEY FINDINGS
STARA ZAGORA (BL)	A successful transition is feasible for the region as long as a proper preparation takes place with the participation of all the relevant stakeholders. The available funding sources may offer a good basis for the implementation of the transition. The area is expected to expand in the development of high-tech manufactures and services, leading to higher incomes, rather than returning to traditional economic sectors.
ÉSZAK-ALFÖLD (HU)	There is potential for CCS in large coalfields and, thus, potential for value generation and new associated employment positions through the development of the appropriate infrastructures.

The progressive reduction of allowances and increase in the price of allowances brought about as part of the decarbonisation process are expected to affect various industries. These fluctuations may include, pressure on wages, employment positions and product prices. On the other hand, substituting the share of coal in the energy mix with clean energy, can bring about considerable effects for the economy and the society, as if RES funding draws on revenue sources, the negative consequences can be manageable.

With the sole exception of Nordjylland (DK), where the coal-fired power plant, due for decommissioning in 2025, processes imported coal, there are direct dependencies between mines and power plants operating in each region. Furthermore, there are other companies offering a variety of services standing to be affected by the decommissioning of coal mines and power plants. However, in most cases the decommissioning timeframe allows for planning the appropriate adjustments and restructuring.

Land restoration projects themselves may create revenue, occupy workers and bear significant environmental benefits. Investments in renewable energy plants are bound to bring about further employment opportunities in RES for all relevant occupational profiles, provided the necessary training. In fact, it can be safely assumed that the necessary RES investments to offset decarbonisation energy deficits will entail an increase in RES training and will create more job positions compared to those available in the coal-based energy production process.

Shifting towards renewable energy yields numerous benefits, in terms of energy sufficiency, employment and environmental protection. Generally speaking, timely planning and public finding schemes are key in shaping a smooth transition towards the new energy mix and it is crucial that all levels of the government and all the relevant stakeholders, namely national, regional and local institutions, business, trade unions and the public, are involved.

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DeCarb A1.1

Ex ante socio-economic impact assessment of regions' decarbonisation pathways

DATA COLLECTION FORM

The present form is intended to facilitate DeCarb partners with data collection on regional decarbonisation parameters. In order to be effectively completed, project partners are advised to consult with the accompanying methodology report as well as with external sources of information.

Section 1

This section collects socio-demographic data & data related to regional energy characteristics.

Regional socio-demographics & economic data *(Please fill in the boxes below providing the latest available national statistical data)*	
a. Administrative unit:	Click here to enter text. *(NUTS 1,2 or 3)*
b. Population:	Click here to enter text.
c. GDP at specified NUTS level:	Click here to enter text. *(EUR)*
d. Employment rate (regional):	Click here to enter text. *(as % of total unit population, 20-64)*
e. Wholesale electricity prices (regional average):	Click here to enter text. (EURO/mWh)
f. Notable population health or air quality figures (if available and relevant):	Click here to enter text.

Regional energy production outlook		
e. Primary energy production mix: *(please tick the applicable boxes and provide further data if necessary in the space below)*	**Type** ☐ Fossils ☐ CCS ☐ RES ☐ Nuclear	**Share (%)** Click here to enter text. Click here to enter text. Click here to enter text. Click here to enter text.
Click here to enter text.		
f. Regional energy production capacity:	Click here to enter text. *(mW)*	
g. Primary energy consumption:	Click here to enter text. *(mW)*	
h. Regional net imports of primary energy :	Click here to enter text. (mW)	
i. Coal imports (share):	Click here to enter text. (Tones/year)	
j. Coal exports (where applicable):	Click here to enter text. (Tones/year)	

Section 2

This section gathers information on regional coal value chains:

Number and characteristics of coal mines in region			
Coal mine:	**Over ground, underground**	**Type of solid fuel**	**Scheduled closure**
1. Click here to enter text.		Click here to enter text.	Click here to enter text.
2. Click here to enter text.		Click here to enter text.	Click here to enter text.
3. Click here to enter text.		Click here to enter text.	Click here to enter text.
n.		Click here to enter text.	Click here to enter text.
		Click here to enter text.	Click here to enter text.
		Click here to enter text.	Click here to enter text.

Number and characteristics of coal-fired plants		
Plant ID	b. CCS capacity:	c. Scheduled decommissioning (provide year i possible):
1. Click here to enter text.	☐	☐ Click here to enter text.
2. Click here to enter text.	☐	☐ Click here to enter text.
3. Click here to enter text.	☐	☐ Click here to enter text.
Add lines as per requirements		

d. 'Locked in' carbon-related investments[23]	Click here to enter text.
d. Other relevant details	Click here to enter text.
Please provide any further details:	Click here to enter text.

Upstream in the chain *(including transport and various input enterprises)*	
a. Type/sector(s) of enterprises linked to coal extraction:	
b. Number	
c. Estimated number of jobs involved	
Downstream in the chain *(coal intense industries, e.g. textiles, steel, non-ferous minerals)*	
a. Type/sector(s) of enterprises linked to coal processing	
b. Number	
c. Estimated number of jobs	
EU ETS allowances *(provide detailed information on regional coal value chain related ETS allowances[24])*	

[23] Please provide information regarding any investments on coal-coal related technologies, processes and plans that are in the stage of development and implementation and as such are obstacles to efficient decarbonisation.

[24] Concerns mostly energy activities, Production and processing of ferrous metals and the mineral industry. Please see methodology report ANNEX.

Click here to enter text.

Section 3 Coal value chain structure

Inter-industry dependence (input & linked industries and services) (I)	
Please choose and rank up to 5 'input & linked industries & services' (e.g. machinery, equipment, security) in the boxes below and assign a 'dependency factor' (*0 = '**No Dependency'**; 0.25 = '**Little Dependency**' 0.5 = '**Moderate Dependency'**; 0.75 = '**Significant Dependency'**; 1 = '**Full Dependency**'*), on the basis of an informed estimate (justify & explain choice). For each entry please use the 'criteria' space to indicate the exact value of input and input destination (mines/ plants).	
Input Sectors	**Dependency factor (est.)**
1. Click here to enter text.	Choose an item.
Please justify/describe criteria:	Click here to enter text.
2. Click here to enter text.	Choose an item.
Please justify/describe criteria:	Click here to enter text.
3. Click here to enter text.	Choose an item.
Please justify/describe criteria:	Click here to enter text.
4. Click here to enter text.	Choose an item.
Please justify/describe criteria:	Click here to enter text.
5. Click here to enter text.	Choose an item.

Inter-industry dependence (mines, transport, coal plants, coal-intense industry) (II)		
To what extend are coal mining activities linked to coal processing for energy production? *(Please provide an estimate for each existing combination of power plant / supply mine, providing nominal details and justification of your choice)*		
Mine	**Plant**	***Dependency factor (est.)***
1. Click here to enter text.	1. Click here to enter text.	Choose an item.
Please justify your choice of dependency factor:	Click here to enter text.	
n. Click here to enter text.	n. Click here to enter text.	Choose an item.
(Add lines as per reporting requirements)		

Inter-industry Dependence (mines, transport, coal plants, coal-intense industry) (III)		
To what extent are coal-intense industries linked to coal mining (supply) for production uses? *(Please provide an estimate for each existing combination of supply mine / carbon – intense industry, providing nominal details and justification of your choice)*		
Mine	**Carbon-intense industry**	**Dependency factor**
1. Click here to enter text.	1. Click here to enter text.	Choose an item.
Please justify your choice of dependency factor:	Click here to enter text.	
n. Click here to enter text.	n. Click here to enter text.	Choose an item.
(Add lines as per reporting requirements)	Click here to enter text.	

Section 4 Value Chain Employment Structure

Jobs in input, mining, coal transport and processing/combustion	
Number of jobs in linked businesses manufacturing equipment for mining:	
Number of jobs in linked businesses manufacturing equipment for coal-fired plants:	
Number of jobs in coal mines:	
Number of jobs in coal-fired plants:	
Number of jobs in coal-intense industries:	

Coal-related jobs (numbers)			
Value chain sector	**Occupational profile**		
	Low Skilled	**Medium Skilled**	**High Skilled**
Input			
Coal Mines			
Coal Plants			
Coal-intense industries (specify):			
1.Click here to enter text.			
2.Click here to enter text.			

Section 5 Decarbonisation

Please provide information on the policies driving decarbonisation in you region: (in case of several known instruments, please choose the most relevant ones (i.e. those with specific provisions on energy production decarbonisation), and provide basic information on them (name and reference, scope [regional, national], Issuing authority; Implementation date, review schedule)
Please provide information regarding the targets of the existing policy driving decarbonisation in your region:

CO_2 reduction targets (Power generation sources):	Click here to enter text.
Timeline:	Click here to enter text.
RES uptake targets:	Click here to enter text.
Timeline:	Click here to enter text.
CCS retrofitting targets:	Click here to enter text.
Timeline:	Click here to enter text.
Energy imports targets:	Click here to enter text.
Timeline:	Click here to enter text.

RES investment landscape: Please use the space below to provide any relevant information on current or scheduled RES investments (e.g. indicative relevant metrics include RES research and development (R&D) expenditure; turnover from RES innovation)

Please use the space below to provide additional comments, details and crucial information regarding decarbonisation planning in your region:

Thank you for your contribution!