Horizon 2020 Societal challenge 5: Climate action, environment, resource efficiency and raw materials

COP21 RIPPLES

COP21: Results and Implications for Pathways and Policies for Low Emissions European Societies

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1. Changes with respect to the DoA

This task uses qualitative and also some quantitative approaches to assess employment and income effects of the mitigation trajectories developed under COP21 RIPPLES, building on the WP3 modelling outputs of UCL and CMCC instead of the use of the E3ME model (agreed on Jun-2018). In addition to these effects the task expands the analysis to health, and gender inequalities where possible and possible ways of addressing these (that were not in the DoA).

2. Dissemination and uptake

This research was presented in the last Dissemination event (EUCalc & COP21 RIPPLES Joint event) on 30th January 2019 in Brussels, and will be further disseminated via mailing list and regular communication channels of the Consortium partners.

3. Short Summary of results (<250 words)

This deliverable presents an attempt to analyze social co-impacts of climate change mitigation policies and their implications for inequality based on the COP21 RIPPLES narratives modelled by UCL and CMCC and the existing literature with some additional qualitative and quantitative analysis. Three case studies were conducted: the UK and Europe, Brazil and South Africa. It is evident that there is not enough research done on and data available for analyzing distributional and inequality impacts of a low-carbon transition at national and regional levels. The deliverable includes suggestions for further work. It also points out the weaknesses of current economy wide modelling exercises that may underestimate the challenges of just transition, such as the assumption of the perfect labor mobility.

4. Evidence of accomplishment

Deliverable report

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1. Introduction

The Paris Agreement is closely intertwined with the Sustainable Development Goals (SDGs), which list a set of 17 targets for ending poverty, protecting the planet and ensuring prosperity for all by 2030 (UN, 2015). Over the past decade or so, the potential for climate change mitigation policy to deliver outcomes that work towards these broader sustainability objectives has become widely recognised by academics and policy makers alike (e.g. Urge-Vorsatz et al, 2014; von Stechow et al., 2015). As a result, climate change mitigation policies are increasingly embedded within a larger framework of low-carbon development strategies and plans, and attempts have been made to develop conceptual frameworks to methodically capture the interactions between mitigation and other sustainability objectives (for e.g. see Dubash et al, 2013; Rio and Burguillo, 2008; O'Neill et al, 2014; UNEP, 2011; Urge-Vorsatz et al, 2014; von Stechow et al, 2015).

COP21 RIPPLES (Results and Implications for Pathways and Policies for Low Emissions European Societies) seeks to inform the ratcheting process of Nationally Determined Contributions (NDCs) by contributing to better understanding of the implications of meeting Paris goals through the use of macroeconomic modelling and combination of quantitative and qualitative analysis. The modelling component of the project focusses on three overarching questions: (1) What are the advantages and disadvantages of increasing ambition in the short term?; (2) What does it mean to pursue efforts to limit to the 1.5 degree goal?; and (3) What are the implications of specific countries and/or sectors cooperating to take the lead? The underlying logic for assessing the impacts of early action is built on an expectation that most countries are keen to avoid the high costs of accelerated action pre-2030, with a view that breakthrough technologies may reduce the cost of action in the future. However, sticking to the ambition of current NDCs would require dramatic acceleration of decarbonization processes after 2030 if the Paris climate goal is to be reached, with high risks of strongly negative socio-economic effects (Waisman et al., 2018, COP21 RIPPLES deliverable 2.2).

Considering the synergies between climate change mitigation and broader socioeconomic development, delayed action on climate change may thwart efforts to achieve the Sustainable Development Goals (SDGs), and not just in terms of the specific environmental and climate-related objectives. This section draws on some of the modelling work carried out for COP21 RIPPLES, with a specific focus on the impact that different levels of ambition and the timing of climate action may have on inequality outcomes. The need to address inequality is mentioned either implicitly or explicitly in various Sustainable Development Goals (SDGs), including commitments to eradicate poverty (SDG 1); end hunger (SDG 2); ensure healthy lives for all (SDG 3); ensure inclusive and equitable quality education (SDG4); achieve gender equality (SDG 5); promote productive employment and decent work for all (SDG8) and reduce inequalities (SDG 10). The role of distributional effects, i.e. impacts of climate change mitigation policy on different subgroups within society, is also recognised in Chapter 3 of the Working Group III contribution to the 2014 IPCC Assessment Report (Kolstad et al, 2014).

To enable the global community to achieve both the Paris Agreement target and the SDGs, economic growth will need to be more inclusive, as well as decoupled from greenhouse gas (GHG) emissions. In a previous stage of task 3.4 work, we presented the results of a comprehensive review of relevant

literature on inequality outcomes associated with climate change mitigation policies (Markkanen and Anger-Kraavi, 2019). The analysis presented in this section showed that inequality outcomes are typically influenced by various contextual factors and emerge through the co-benefits or adverse side-effects of climate change mitigation policy - for example, as a result of job losses or employment gains in specific industries, or because of area-specific activity that impacts the environment and/or local residents' access to resources or services. The localised impacts that may exacerbate or mitigate existing inequalities can easily go unnoticed in figures that refer to national or global totals, or averages.

In the present report, we move from literature-based analysis to a more empirical, case-study based approach that links macroeconomic modelling results with additional quantitative and qualitative analysis to illustrate some of the inequality outcomes that can emerge from the implementation of climate change mitigation policy. We analyse the results from two different macroeconomic models in the light of additional information and national statistics on the geographic distribution of various industry sectors across a set of case study countries. Combining data from these sources enables us to identify areas where the number or nature of available jobs may change significantly, or the local circumstances change in other ways that can have socioeconomic impacts. For example, evidence from a variety of sources is used to map out where renewable energy projects or forest conservation initiatives are likely to be implemented. We also carried out interviews and employed other qualitative and quantitative methods to allow a more in-depth analysis of the nature and extent of the inequality impacts in the case-study locations. Different modelling scenarios will provide several sets of results that enable us to see how the impacts differ depending on the targeted levels of emissions reduction and the timing of the interventions (i.e. 'accelerated early action' versus 'delayed action').

Existing literature provides examples of two established approaches to using CGE model results to estimate and analyse inequality outcomes (Bourguignon et al., 2003). These include

- Use of a representative households (RHs) in the CGE model, linked to a household module. This is typically done by integrating a social accounting matrix (SAM) and a computable general equilibrium (CGE) model. If the SAM is to support analyses of poverty and inequality, it must include a detailed disaggregation of households and the factors, activities and commodities that are important in their income generation and consumption. (e.g. Lofgren et al., 2003)
- Linking a RHGs CGE model with a microsimulation (MS) model. This can be done using a top-down, integrated or a bottom-up framework for linking the models. (e.g. Buddelmeyer et al., 2012)

In the first approach, the amount of heterogeneity that can be accounted for depends on the number of representative household groups (RHGs), characterized by different combinations of factor endowments and possibly different labour supply, saving, and consumption behavior (Bourguignon et al., 2003). However, this approach is better suited for the analysis of changes in economic inequality between RHGs rather than within-group inequalities. Yet empirical evidence from household surveys indicates that changes in overall inequality are usually due at least as much

to changes in within-group inequality as to changes in the between-group component (Bourguignon et al., 2003).

This challenge can be overcome by using the second approach, i.e. linking the CGE model with a microsimulation model that use real households, as they are observed in standard household surveys. In this integrated approach, the heterogeneity of households, reflecting differences in factor endowments, labor supply, and consumption behavior, can be taken into account and one can explore how household heterogeneity combines with market equilibrium mechanisms to produce more or less inequality in economic welfare. This approach in particularly useful when seeking to understand and estimate the inequality impacts of economic shocks or policy changes. However, an integrated microsimulation-CGE model must be quite large and raises many issues of model specification and data reconciliation, with serious cost-implications (Bourguignon et al., 2003). Different options including various degrees of complexity and integration of the models have been used in the practical application this approach exist, including a 'top-down' approach that involves taking the CGE results as given, and adapting the MS model to use all relevant inputs from the CGE model (Buddelmeyer et al, 2012).

Although both of the above-mentioned approaches have been used to estimate inequality outcomes of macro-economic shocks and policy measures (add refs), experiments comparing the results between the micro-simulation and RHG approaches to the dame data have shown quite different estimates of the distributional effects between the two approaches, leading some commentators to argue that more work is needed in order to integrate satisfactorily micro and macro approaches to distributional issues (Bourguignon et al., 2003). The theoretical underpinnings of CGE models also make them unsuitable for regional economic development analysis that would require a modelling approach that is more representative of the empirically observed regional economic setting (Partridge and Rickman, 2010).

The use of RHG approach in CGEs and integrated assessment models (IAMs) have been used primarily to analyse access to electricity and trade-offs between climate policy and energy access. By focusing solely on household energy price impacts, these models only analyse the changes in energy consumption, while ignoring changes in income. As a result, they "have very limited ability to represent the interlinkages and cascading effects between particular sectors and the rest of the economy, let alone to represent how these effects are distributed across households" (Rao et al, 2017: 857). While linking the CGE with an MS model may well be superior due to its ability to account for phenomena that are known to be important in explaining distributional changes—such as changes in types of occupation or combination of income sources and heterogeneous consumption behaviour - the problem is to know whether the representation of these phenomena is satisfactory (Bourguignon et al., 2003).

The shortcomings of the two established methodologies for analysing the poverty and inequality outcomes have led some commentators to argue that integrated assessment models (IAMs) and macroeconomic models currently used in climate research have a limited ability to represent the poor and vulnerable, or the different dimensions along which they face the climate risks – or the risks associated with lack of climate action (Rao et al., 2017; Stern, 2016). Omissions and uncertainties

regarding the extent of risks and costs, including various social impacts (and how these may be distributed across societies), mean that even models that estimate social impacts by calculating the social cost of carbon (SCC) are believed to generate misleading results (Stern, 2016; Rao et al., 2017). Although methods such as 'equity weights' and 'damage functions' can provide a clearer picture of the poverty and income inequality implications of proposed policies, studies that use future socioeconomic scenarios typically adopt simple rules such as constant income distributions, or poverty levels indexed to GDP, which hinder their ability to accurately predict long-term distributional impacts (Rao et al, 2017).

To address the shortcomings of current models used in climate change research, Rao et al. (2017) call for more models to "move beyond representing average regional effects to quantify and project distributional effects and their complexities within countries" (pp. 857) through calibrating new model parameters to the real world, or e.g. by using multidimensional poverty metrics and equity weights. In order to provide meaningful outputs, the models should also incorporate other agents and the relevant dynamics, such as income and consumption, and social protection and other policies that influence the distributional impacts of climate policies and climate change impacts on households (Rao et al., 2017). For modelling to provide policymakers with reliable information on poverty and inequality outcomes, there is a need for not just improved analytics and model design, but also better data to support improved understanding of the mechanisms that drive income distribution. This will require a concerted effort involving researchers across disciplines as well as greater collaboration between groups working on global models and local research communities that conduct empirical studies or work with national models (Rao et al., 2017; Stern, 2016).

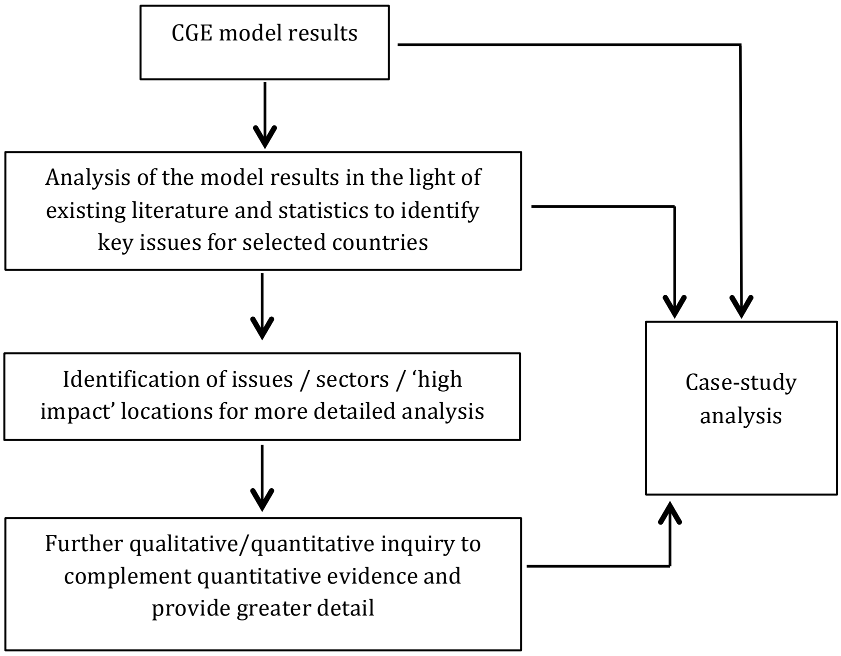
The approach employed in this research exercise seeks to overcome some of the limitations (discussed above) of purely quantitative modelling-based approaches in the assessment of poverty and inequality outcomes by combining CGE modelling with location-based mixed-method analysis. This approach includes analysing CGE model results in the light of existing literature on poverty and inequality outcomes of climate change mitigation policies. National-level datasets are used in combination with the CGE model results and literature to identify potential 'high-risk' or 'beneficiary' areas where climate change mitigation policies may result in co-benefits or unintended adverse side-effects. Attention is given especially to areas where the co-impacts result in positive or negative inequality outcomes. Qualitative methods are utilised to provide further insight into the nature of the opportunities and challenges in specific geographic locations, and action that could, has or will be taken to maximise the co-benefits or mitigate any potentially adverse outcomes.

The CGE models applied in this study cannot project impacts on income inequality. The project changes for specific measures in the sectoral composition of the economy as a result of a carbon constraint. The models projects changes in 28 sectors in the economy for specific measures including labour costs, wage indices and GDP. These changes typically constrain the sectoral output of fossil fuel intensive sectors (oil, gas and coal) for the benefit of less emissions intensive sectors (such as renewable energy, carbon capture and storage and nuclear). The models project changes for two scenarios of 'Nationally Determined Contributions' (NDCs). The main differences between these scenarios are the ambition levels: the 'current' NDC scenario and 'enhanced' NDC scenario start off

with the same emissions levels and converge 2050. The 'enhanced' introduces more 'ambitious' emissions by 2030. The results suggest that 'rapid' transitions are desirable in terms of their impact on the economy. The qualitative inquiry puts these results into the national perspectives of highly unequal societies in the Global South and Europe. The qualitative analysis show how the trade-offs between the 'fossil fuel' vs. 'clean' technology sectors evolve differently in different societies and contextualizes the low carbon technologies within the national political systems.

The results of the analysis are presented in a format of three case studies, focusing on the co-impacts of climate change mitigation policies through changes in sectoral employment and output, labour costs, consumer prices and GDP. While this approach is not suitable for large-scale analysis across multiple countries, these case studies can help generate relevant knowledge to assist in future development of modelling techniques that are better able to forecast poverty and inequality outcomes in climate change mitigation research.

Figure 1. Visual illustration of methodology



Three case studies were conducted: the UK and Europe, Brazil and South Africa. The regions were selected based on a combination of the disaggregation of the ICES and ENGAGE models and where the COP21 RIPPLES project had project partners (so we could draw on local insights). All case studies built on the modelling results of the COP21 RIPPLES projects 2°C pathways (the models used were not producing 1.5°C pathways at sufficient detail to allow for a further detailed analysis). Brazilian and South African case studies took a qualitative approach, while the UK and Europe case took a more quantitative stance than the other two case studies and the rest of the literature already present (which is reviewed by Markkanen & Anger-Kraavi (2019) that was published based on the Milestone 3.4).

The case studies are presented below as standalone studies together with their methodologies (sections 2-4) and the report then draws overarching conclusions (section 5).

2. Case Study 1: Climate Change mitigation, rapid transitions and social inequality in South Africa

Authors: Britta Rennkamp, Katrina Lehmann-Grube, Rejoice Mabhena, Annela Anger-Kraavi

1. Introduction

The linkages between the world's inequality and climate crises have become increasingly visible. New climate policies and regulation create tradeoffs between climate protection and progress in socio-economic development (Markkanen and Anger-Kraavi 2019).

Some of these trade-offs have altered with the drastic decline of prices for renewable energy, as economic growth does not necessarily have to depend on fossil fuel driven development pathways anymore (IRENA 2019). Transitions to green economies should, in principle, lead to a more equitable distribution of economic benefits, because technological change triggers economic growth and generates decent jobs (UNEP 2019). Technological change, however, creates gains in clean energy industries while and established fossil fuel sectors resist regulations, which may create losses for their industries.

How can we better understand which gains and losses are expected in the different sectors in the economy? How do these gains and losses influence poverty and social inequality? What structures are in place to collect data to understand the transition?

This section addresses the question of how a 'rapid' low-carbon economy transition may impact poverty and inequality in South Africa. It investigates the research questions through a mixed method approach which combines the quantitative analysis of the results generated by a multi-sectoral, multi-regional dynamic recursive computable general equilibrium (CGE) model with a qualitative inquiry.

The model shows two scenarios for the 'current' and 'enhanced' Nationally Determined Contributions (NDCs), which introduce an emissions constraint on the economy with the aim to limit global warming to 'well below 2 C' (UN 2015). These results, and the constraints of the model have been subject to a qualitative analysis, based on data generated by a focus group of 15 climate change and inequality experts, interviews and documents.

The analysis finds that impacts on poverty and inequalities largely vary depending on the emissions constraints in the NDC scenarios, the emissions intensities in the economic sectors and the implementation of sectoral and national policies. The research confirms that current available data and ways of collecting quantitative and qualitative data on economic sectors, climate policies, poverty and inequalities do not provide sufficient understanding of the detailed impacts of rapid transitions.

The section is organised as follows: the following section presents the results of a multi-sectoral, multi-regional computable general equilibrium model of the world economy to extract South Africa's performance in terms of different NDC scenarios and impacts on inequality. Section 3 presents the qualitative results of a focus group of climate change and poverty, inequality and labor experts. Section 4 presents an overview on data relevant to climate relevant transitions, poverty and

inequality in South Africa. The focus group of experts identified gaps for future research and data collection for a better understanding of inequality impacts of climate related transitions in the country.

2. Understanding distributional aspects of low carbon transitions in South Africa

South Africa is one of the 197 signatories of the Paris Agreement who aim to take action towards achieving the global temperature to 'well below' 2°C above pre-industrial levels (UN 2015). The South African government communicated its planned climate actions to achieving the global temperature goal in its Nationally Determined Contribution (NDC) in 2015. The sum of these actions has been largely regarded as insufficient to limit global warming to 1.5 °C (Climate Action Tracker, B2G 2019).

Unlike most countries in the region, South Africa is under pressure to rapidly reduce emissions. Per capita emissions range with 9 tons above the average of the G20, which is similar to the per capita of Germany. This high share in emissions is largely due to the high dependency on coal. South Africa has the largest share of coal of the G20, and ranks 6th in the highest of fossil fuels, behind Saudi Arabia, Australia, Russia, Mexico and Japan (Climate Transparency 2019).

The South African economy is one of the most energy intensive economies in the world, which is why the high emissions do not translate into equivalent GDP and puts the country on the OECD's Development Assistant Committee (DAC) list as a higher middle-income country (OECD 2020). The country faces enormous developmental challenges with more than half[1] of the population living in poverty, while the country's assets are concentrated in the hands of a few (StatsSA 2019). South Africa counts as the most unequal society in the world, with a GINI coefficient of 0.63 in 2015 (Stats SA, 2019).

Researchers have used linked climate, energy and economy models to analyse how these industries, sectors and processes interact with the aim to understand the relationship between climate change actions, poverty and inequality. However, this approach is not without flaws and tends to overlook many of the key drivers of poverty and inequality, their dynamics over time and how they function within countries. The benefits of future technological change are often omitted or too difficult to simulate in current climate models (Stern 2016). Qualitative data can help to contextualize the findings and provide insight into aspects, which the model may overlook, because of its simplified assumptions.

2.1. Quantitative analysis: Modeling gains and losses in multiple sectors of a low carbon transition

This section presents output data from the Intertemporal Computable Equilibrium System model (ICES) as modelled in (Parrado et al., 2019). ICES is a multi-sectoral, multi-regional dynamic recursive computable general equilibrium (CGE) model of the world economy developed for the analysis of climate change impacts and policies, decarbonisation scenarios and sustainability. ICES can be used to assess and analyse economy-wide impacts of international climate policies, including the

[1]Using South Africa's Upper Bound Poverty Line, 55,5% of households in 2015 were poor.

[2] SATIMGE combines a CGE model and a TIMES model of the energy sector (for more detail see McCall et al 2019)

development of low carbon technologies with an emphasis on competitiveness, trade, and industrial implications of the NDCs and 2°C mitigation pathways.

The model outputs present data from 28 sectors in the economy, including industry output and prices, sectoral emissions, as well as macro-economic variables: GDP, consumption, savings, investment, imports and exports. Carbon taxes, cap and trade and border trade adjustments are included as the variables to account for changes to the policy environment regarding climate action.

2.1.1. Scenarios in ICES

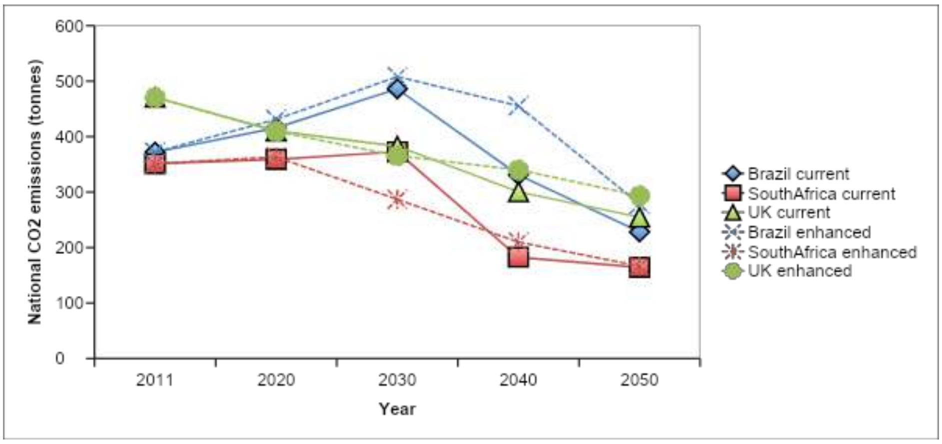
The results for the model correspond to two different scenarios: the 'Current NDC' and an 'Enhanced NDC'. The first scenario illustrates the outcome from the implementation of NDCs until 2030, with little or no increased ambition announced during the round of negotiations in 2020. This scenario requires an increased effort between 2030 and 2050 to comply with a long-term global temperature maximum increase of 2°C by the end of the century. The 'Enhanced NDC' scenario operates with the same carbon budget as the 'Current NDC' scenario between 2010 and 2050. This scenario shows a smoother, and more gradual emissions trajectory due to increased ambition *before* 2030. Both scenarios start off at the same levels in 2011, diverge thereafter, and converge again in 2050.

Importantly, the scenarios are modeled under a hypothetical assumption of global cooperation and a global carbon price, which allows for an efficient global emissions trading scheme. The assumption of a global carbon price aligns with

2.1.1.1. South Africa compared to the UK, EU and Brazil

The model produced results for South Africa, Brazil, the European Union and the UK. Population size across all countries shows a slowly increasing but decelerating population size, with no difference between the scenarios. South Africa shows the lowest GDP throughout the period between 2010 and 2050, with a slower growth rate than both Brazil and the UK, in both the current and enhanced NDC scenarios. Similarly, South Africa shows the lowest national emissions of CO_2 across the entire period. In the 'current NDC' scenario, South Africa's emissions peak in 2030 and then drop dramatically; in the 'enhanced NDC' scenario, emissions peak in 2020 and then drop more gradually, as per the scenario description. Figure 1 below illustrates the emissions pathways for all three countries and the EU, between 2011 and 2050 in both scenarios.

Figure 1: CO2 emissions in SA, Brazil, UK and EU 2011 – 2050 (ICES 2019)

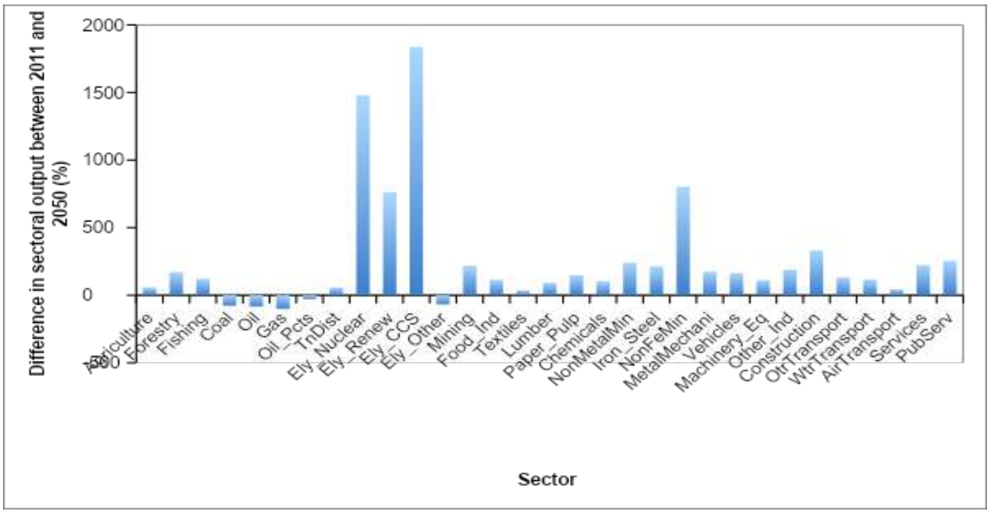


2.1.1.2. Central sectors to a low carbon energy transition

The model shows that for both Current and Enhanced NDC scenarios, South Africa is likely to see an increased sectoral output in almost all sectors covered by the model, most strikingly in the nuclear, renewables, carbon capture and storage (CCS) and non-ferrous mining sectors. The only sectors modeled to experience a decline are coal, oil, gas, oil products and other fossil fuel products in the electricity sector.

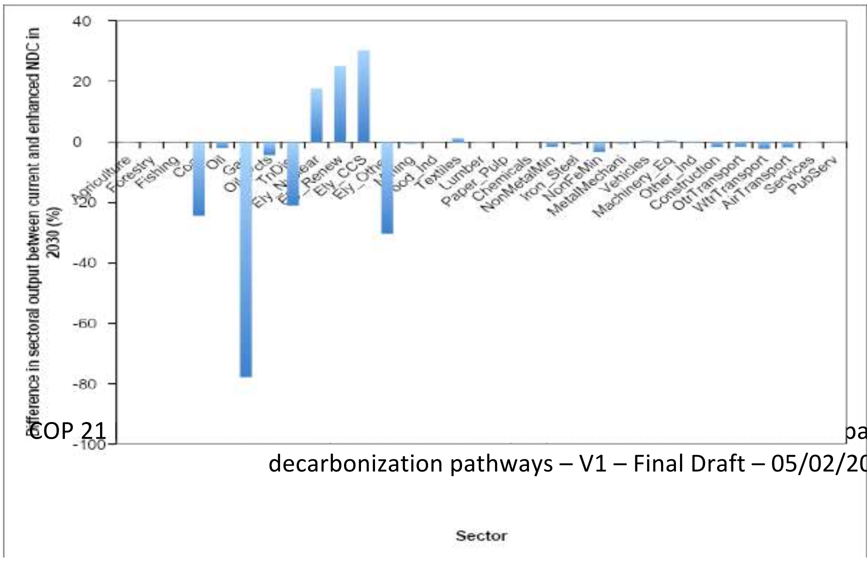
Although the differences in sectoral output between the current and enhanced scenarios are small in 2050, there are several significant differences in 2030. In the enhanced scenario, there is proportionally less coal, oil, oil products, and substantially less gas; but a higher amount of nuclear, renewables and CCS. According to the modeled scenarios, transition to low-carbon trajectories will be smoother if they start immediately rather than delay. Figure 2 below illustrates the changes in the emissions intensive sectors which are central to a transition towards a low carbon economy. Figure 3 shows the difference in sectorial output between the two scenarios, showing more losses in fossil fuel driven sectors (gas, oil and coal related products), and gains in less emissions intensive technologies (renewables, nuclear and CCS).

Figure 2: Difference in sectoral output between 2011 and 2050



Source: own compilation based on outputs of ICES 2019

Figure 3: Sectoral output in the Current and Enhanced NDC scenarios



2.1.1.3. Labour costs

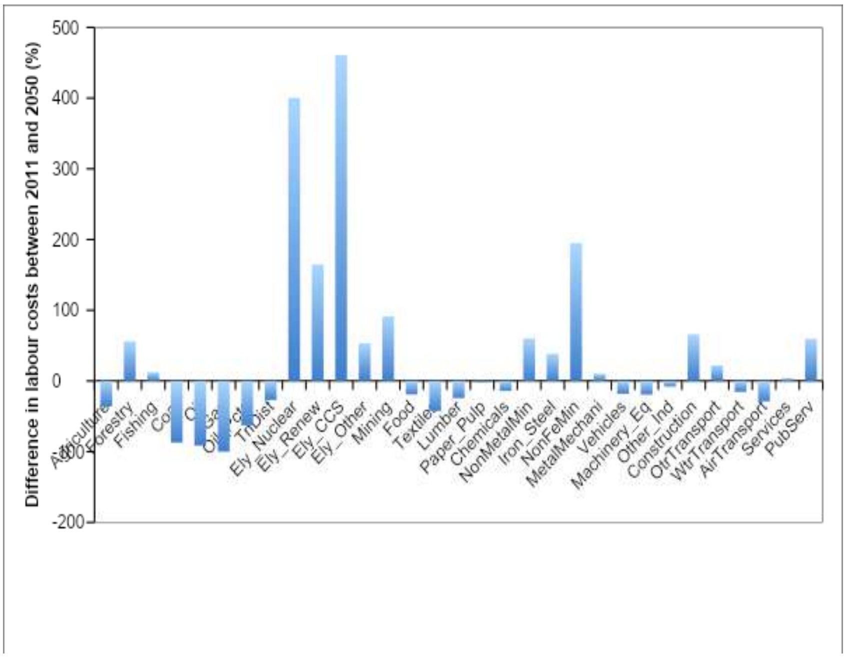
Labour costs represent the full cost of labour, including wages. The ICES model shows that labour cost increase in the sectors which the model considers as clean technologies - nuclear, renewables and CCS. This is a result of the carbon constraint introduced by the NDCs which then constrain the growth of fossil fuel intensive sectors. For this reason, labour costs in the clean energy sectors grow as the demand for labour in these sectors will grow.

In 2030, the difference between the two scenarios illustrates that the labor costs for coal, oil, gas, oil products, electricity transmission and distribution activities are considerably lower in the Enhanced NDC scenario compared to the Current NDC scenario. Clean technology sectors show the opposite effect.

In both scenarios, the labor costs of nuclear, renewables and CCS are substantially higher than those for fossil fuels, corresponding with a diminished sectoral output in the fossil fuel intensive sectors.

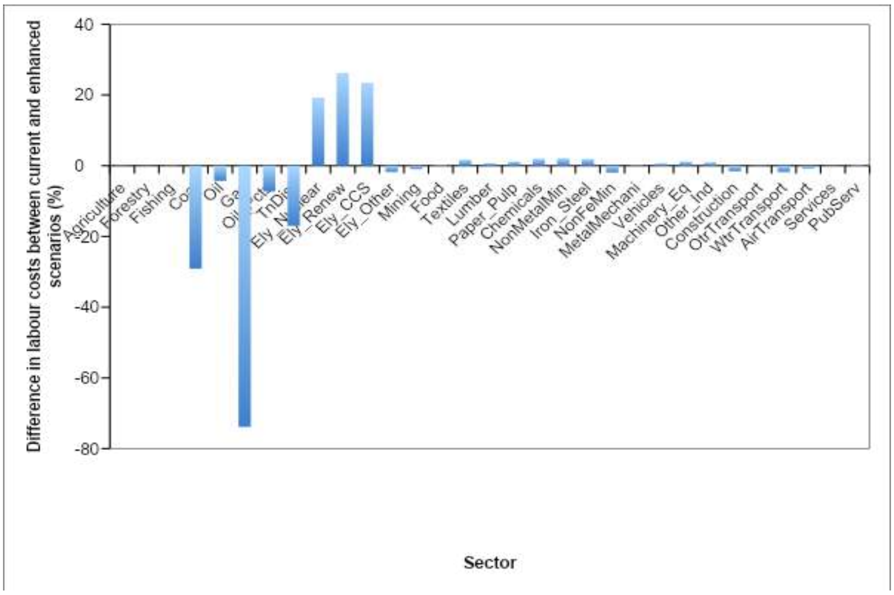
There is no substantive difference between the changes in labor costs of skilled and unskilled labor. The wage index is uniform between sectors and shows no significant difference between scenarios, or between skilled and unskilled labor. Even if fossil fuel (FF) sectors shrink, there is no significant difference between skilled and unskilled labor in both scenarios according to the model.

Figure 4 Differences in labor cost 2011 &2050



Source: own compilation based on outputs of ICES 2019

Figure 5: Difference in labour costs between Current and Enhanced NDC scenarios



Source: own compilation based on outputs of ICES 2019

The differences in the labor cost between the 2011 and 2050 show losses in fossil fuel intensive sectors. Gains occur in nuclear, renewable energy, carbon capture and storage and public services, according to ICES.

2.1.1.4. Consumer prices

The model provides consumer prices for a subset of sectors: agriculture, coal, oil, gas, oil products, eletectricity generated with fossil fuel sources such as coal, gas, oil and oil products (Ely_Other), electricity transmission and distribution activities (Tn_Dist, in Figure 6). Prices experience a decrease in agriculture, nuclear, renewables, CCS and the food industry. Oil and gas products show a relatively small increase in prices. Coal shows the largest increase, with prices growing to 20-fold over the period 2011 to 2050. There is no difference in consumer prices between the Current and Enhanced NDC scenarios.

Figure 6: Consumer price index: South Africa

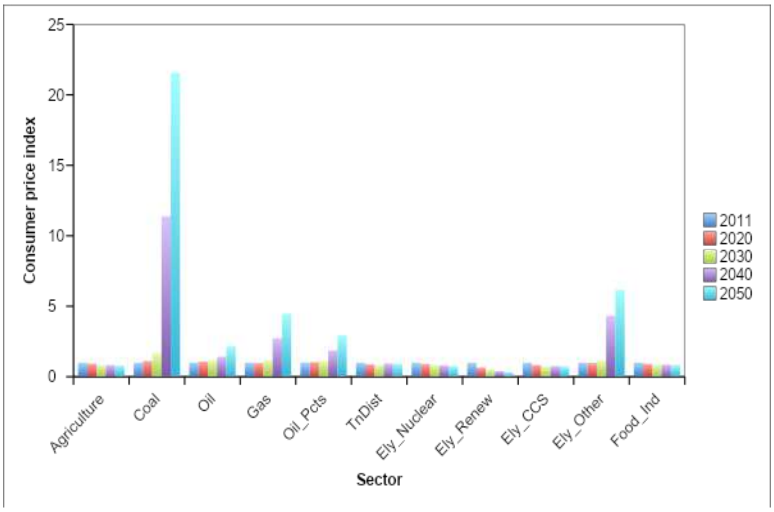
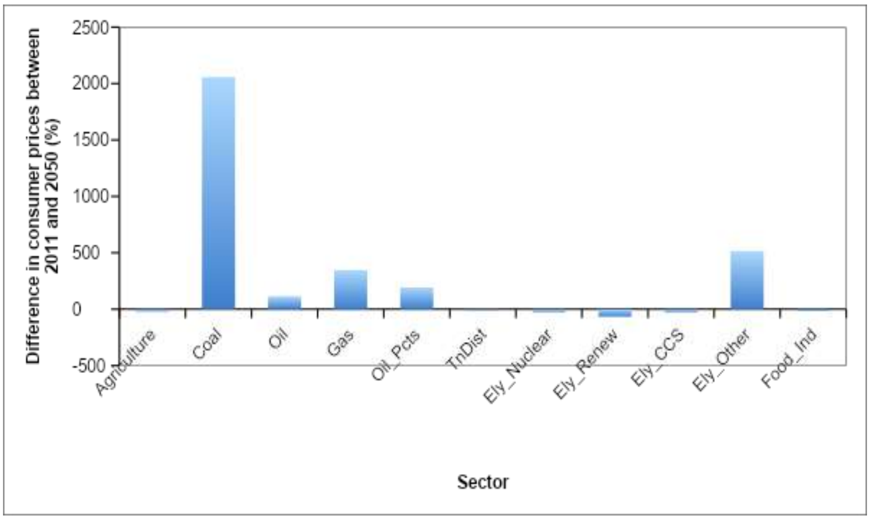


Figure 7: Differences in the consumer price index between 2011 and 2050 in the Current NDC scenario



Source: own compilation based on outputs of ICES 2019

2.2. Contextualising the results in South African climate policy and inequality

This section puts the modeling results into South Africa's political and economic context. The country's emissions emerge largely from its energy sector, which constitutes 80% of total emissions. Approximately half of the energy comes from electricity generation (GHG inventory 2010). Approximately 14% of emissions derive from industrial processes, and 10% from transportation and 10% from energy use in industrial processes. Unlike most developing countries, emissions from land-use change and agriculture contribute only a small proportion, approximately 5% (NCCRWP, 2011). As a result, the central challenge in decarbonizing the economy sits with the energy intensive industries.

The emissions-intensive nature of energy and electricity-use is due to South Africa's dependence on coal, which produces 30% more emissions than gasoline (EIA, 2019). Approximately, 92% of South Africa's electricity is coal-generated. About a third of South Africa's transport fuels derive from coal, in a relatively unique, highly emissions intensive coal-to-liquid process, which is the core business at SASOL, the country's second biggest emitter (Burton et al., 2019).

Since 2009 South Africa's emissions have plateaued (Greenhouse Gas National Inventory Report 2010). This trend can be attributed to slow economic growth that has occurred since 2009 and to an increase in energy efficiency, rather than effective mitigation policy (Expert 1). The panel of experts confirmed these principal challenges in the economic structure, which trends were adequately reflected in the ICES model.

2.2.1. South Africa's Nationally Determined Contribution

The South African government communicated its Intended Nationally Determined Contribution (INDC) to the UNFCCC in 2015 and subsequently ratified the Paris Agreement a year later. There was no further submission to the UNFCCC since 2015, which turned the same text of the INDC into the Nationally Determined Contribution (NDC). South Africa's NDCs outlines a strategy of an emissions trajectory to 'peak, plateau and decline' (PPD). This is planned in 5-year cycles, with the 2016-2020 cycle focused on developing and demonstrating its mitigation policies, with a planned peak in emissions between 2021 and 2025 of between 398 and 614 Mt CO_2-eq, followed by a decade of a plateau in emissions and then an absolute decline afterwards (UNFCCC 2015). The Paris Agreement requires all Parties to submit updates of the NDC which reflect increases in the ambition to reduce emissions. The first South African NDC already communicates its contributions for 2025 and 2030 and will not submit an additional NDC in 2020 to cover the period from 2026 to 2030 (see Marquard 2020 for more detail, in COP21 RIPPLES).

The South African NDC states explicitly the premise to adopt a 'comprehensive, ambitious, fair, effective and binding multilateral rules-based agreement under the UNFCCC at the 21st Conference of the Parties (COP21) in Paris' (UNFCCC 2015, p. 3). This comes from the importance of international equity with regard to climate mitigation, adaptation and financing, particularly between developed and developing nations (Expert 2). South Africa used a carbon budget approach, based on the principles of "responsibility, capability and access", as evidence to illustrate why the given NDCs are both fair and ambitious. The government states in the NDC explicitly that the 'PPD trajectory range is an ambitious and fair effort in the context of national circumstances, and priorities to eliminate poverty and inequality, promote inclusive economic growth and reduce unemployment. It presents a trajectory that is consistent with a just transition to a low carbon and climate-resilient future.' (UNFCCC 2015, p 8)

However, the extent to which this is an accurate depiction is debatable (Cunliffe et al., 2019, Marquard 2020 in COP21 RIPPLES D.2.5.). The NDC has been regarded as insufficient in in terms of its contribution to emissions reduction in international comparisons (CAT 2020). Its impacts of the PPD on the poverty and inequality and equitable distribution of economic benefits have not been studied systematically. The most comprehensive research on socio-economic impacts of decarbonisation of the economy focuses on the electricity sector.

2.2.2. Electricity planning until 2030: The Integrated Resource Plan and the NDC

Decarbonising the electricity and liquid fuels sectors are central to achieving South Africa's NDC. The government has released a plan for future infrastructure development in the electricity sector until 2030: The Integrated Resource Plan (IRP RSA, 2019). The plan prioritises electricity generation technology on a least cost basis while ensure that there is a balance of all technologies to ensure security in demand. In this way, coal will still remain dominant in South Africa's electricity sector until 2030, while the share of renewable energy is allowed to increase. The IRP aligns with National Development Plan's vision of a "reliable and efficient energy service at competitive rates; that is socially equitable through expanded access to energy at affordable tariffs" as well as environmental considerations and South Africa's commitment to climate mitigation as stipulated in the NDCs.

Central components of the IRP 2019 are:

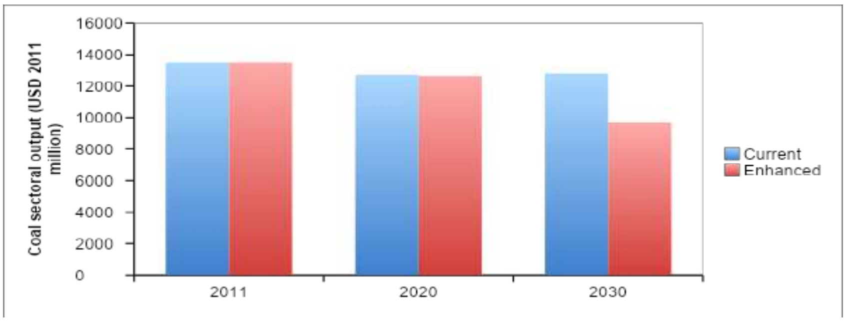
- an absolute reduction in coal, from 37 149 MW to 33 364 MW due to a mix of additional capacity and the decommissioning of 10 173 MW before 2030. Nonetheless, coal remains the main source of electricity, comprising 43% of total production in 2030.
- an additional 6000 MW of new solar PV capacity, bringing the proportion of solar power up to approximately 11% of total capacity
- an additional 14 400MW for wind, bringing wind up to approximately 23% of total capacity
- an increase in use of natural gas from 3830 to 6380 MW between now and 2030
- no extra nuclear capacity, only an extension of the life of the Koeberg power facility resulting in nuclear remaining at 1860 MW in 2030 (RSA 2019).

The general trend of an increase in renewables and a decrease in fossil fuels in the model is consistent with the plans of the IRP 2019. There are differences in the details and the assumptions.

2.2.3.Coal & Renewable energy

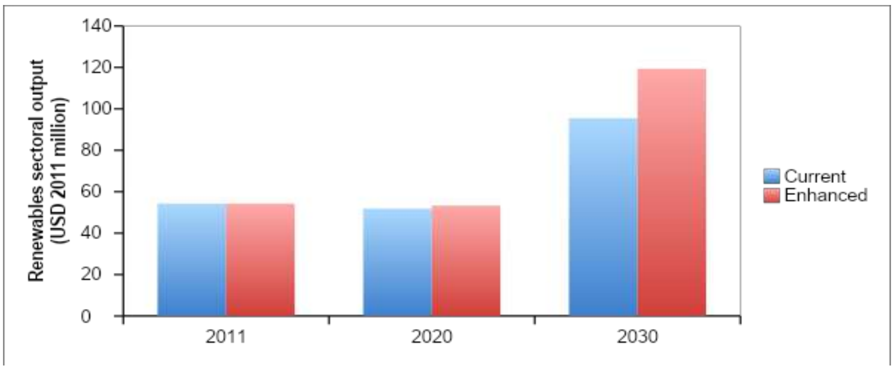
The ICES model suggests a small decrease in coal output by 2030 (accelerated under the enhanced scenario). Coal for electricity production is becoming increasingly uncompetitive in South Africa, because the cost for new coal plants are increasing. while the cost for renewable energy technology is decreasing (Burton et al 2019).

Figure 8: Coal output in the Current and Enhanced NDC scenarios



Source: own compilation based on outputs of ICES 2019

Figure 9: Renewable energy output in the Current and Enhanced NDC



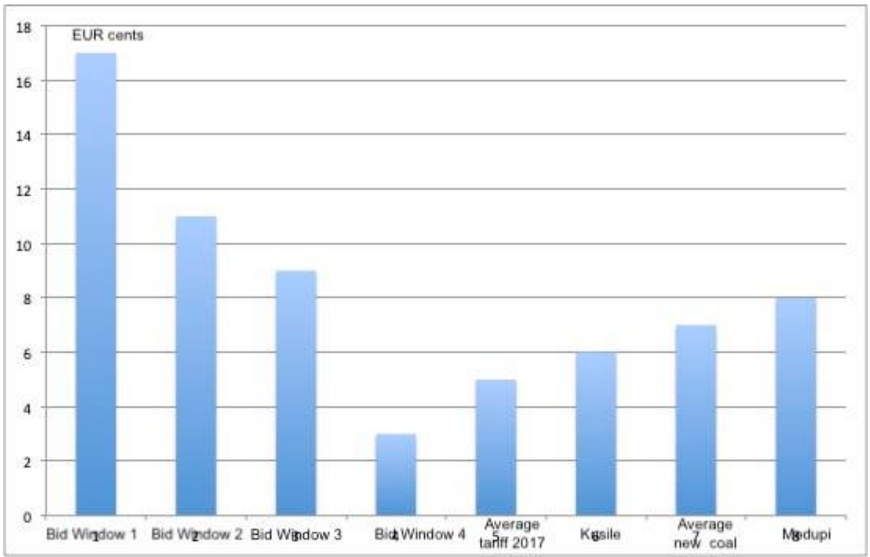
Source: own compilation based on outputs of ICES 2019

The model shows an increase in renewables, particularly under the enhanced scenario, however while the model suggests only an approximate doubling in sectoral output by 2030, the IRP suggests a more than 4-fold increase in renewables by 2030.

The proposed changes in the IRP are yet to be implemented. As mentioned above, the South African government has introduced its first renewable energy programme in 2011. Initially designed as a system of feed-in tariffs, it was changed to a competitive bidding process where private companies bid to produce electricity and sell it to Eskom, the state electricity utility. This was done in four rounds, conducted between 2011 and 2015. The outcome was the contracting of 6 422 megawatts (MW) of power forming the bulk of the Integrated Resource Plan's renewable energy commitment in the short term. The Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) has attracted 16 billion US dollars in investment in developing renewable energy between 2011 and 2015 (UNFCCC 2015, DoE 2011).

The price for electricity from South Africa's most recently built coal plants, Medupi and Kusile, ranges at levelized costs of electricity (LCOE) between approximately 12.7 US cents/kWh and 14,2 US cents/kWh. New build coal plants, as they are suggested in the new IRP (2019), will likely be 40% more expensive than renewable technologies as the cost for new built coal are increasing while the prices for renewable energy technologies continue to fall (Steyn et al 2017, Burton, Marquard, McCall 2019, Burton and Ireland 2019).

Figure 10: Price trends in renewable energy and coal generated electricity in EUR cents



source: CSIR 2017

Medupi and Kusile are coal plants that are currently under construction in the North of South Africa.Figure 10 illustrates how prices for renewable energy technologies have been decreasing, while electricity from coal is increasingly more expensive.

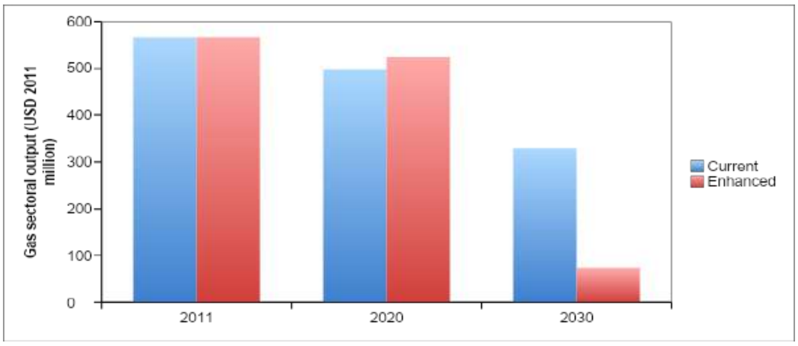
Pricing alone is not the only factor in democratic energy policy decision-making processes, as the power balances between political coalitions ultimately determine the policy outcomes (Rennkamp et al 2017). The current supply crisis in the electricity sector triggered a disadvantageous discourse

between renewable energy vs. coal-generated electricity which echoes the debates between public vs. private generation of electricity. The REIPPP program generated influx of renewable energy into the South African electricity system for the first time. The programme also allowed private companies, Independent Power Producers (IPP), to generate electricity and sell to the State Owned Enterprise (SOE) Eskom, for the first time in history of the country. Eskom, the electricity utility, had historically operated as a monopoly, with coal powered electricity generation as its core business and expertise. The obligation to purchase renewable energy from the IPP generated resistance to the program, within Eskom, the coal mining industries and the unions that aim to protect mining jobs (Malema 2019). Historically grown carbon-intensive electricity generation and associated industries in South Africa have created “lock-in” situations and stubborn coalitions who protect the status quo and hinder change towards progressive climate and energy policy (see Rennkamp 2019, D.4.4 in COP21 RIPPLES, Baker (2018), for more detail).

2.2.4. Natural Gas

The ICES model indicates an opposite trend for gas, showing a decrease between 2011 and 2030, while the IRP plans for an almost doubling of gas-powered capacity for electricity by 2030 (see figure 12 below). There were recent discoveries outside South Africa’s coastline. Plans for hydraulic fracking of shale gas in the Karoo desert have successfully been opposed by NGOs and environmental groups, because of the negative environmental impact of fracking technologies in the soil. The Supreme Court ruled in favor of civil society’s application and did not grant the necessary rights to Ministry of Minerals and Energy (Brandt 2019). Gas discoveries in Mozambique and Namibia create opportunities for growing influx of natural gas into South Africa’s energy system. Sasol, one of South Africa’s major emitters, increasingly explores natural gas for replacing its polluting coal to liquid technology with cleaner gas to liquid technologies. Sasol has a base in Mozambique and runs gas through its pipeline from Temane, Mozambique, to its Secunda plants in the North of the country. The dynamics in the gas sector are relevant for the future South Africa’s transport and electricity sector, there are significant uncertainties with regards to the pricing of future gas resources, which require further research (Marquard 2020).

Figure 12: Gas sectoral output

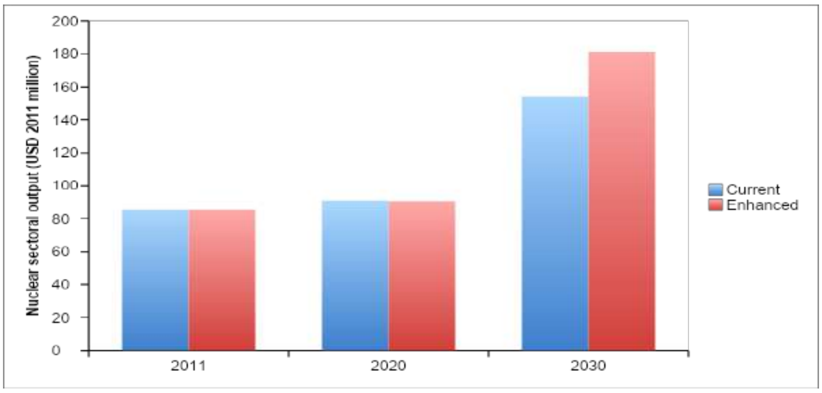


Source: own compilation based on outputs of ICES 2019

2.2.5. Nuclear power

While the model suggests a considerable increase in nuclear power between 2011 and 2030, the IRP shows no indication of a growth in nuclear output. The aim is to maintain the current capacity through an extension of the life of the Koeberg power facility.

Figure 13: Nuclear sectoral output

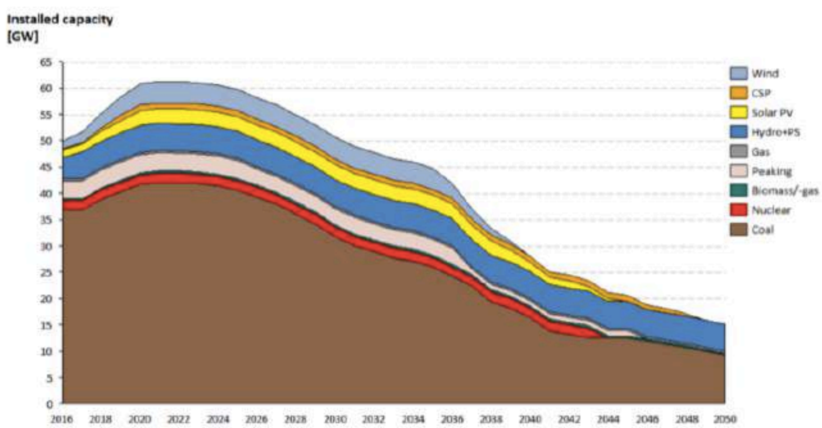


Source: own compilation based on outputs of ICES 2019

The section on Nuclear Energy in the IRP leaves an option for future nuclear energy, which has been put on hold at the moment. The South African president Jacob Zuma had tried for years to advance a nuclear build program, which foresaw building new nuclear capacity of 9,6 GW through six new plants (DOE 2008). This plan was eventually dropped. Cost and safety were the central controversies in this program (Rennkamp and Bhuyan 2018). Building new nuclear energy is currently not an option for South Africa, mainly because of its cost, which is a factor that the ICES model did not fully cater for.

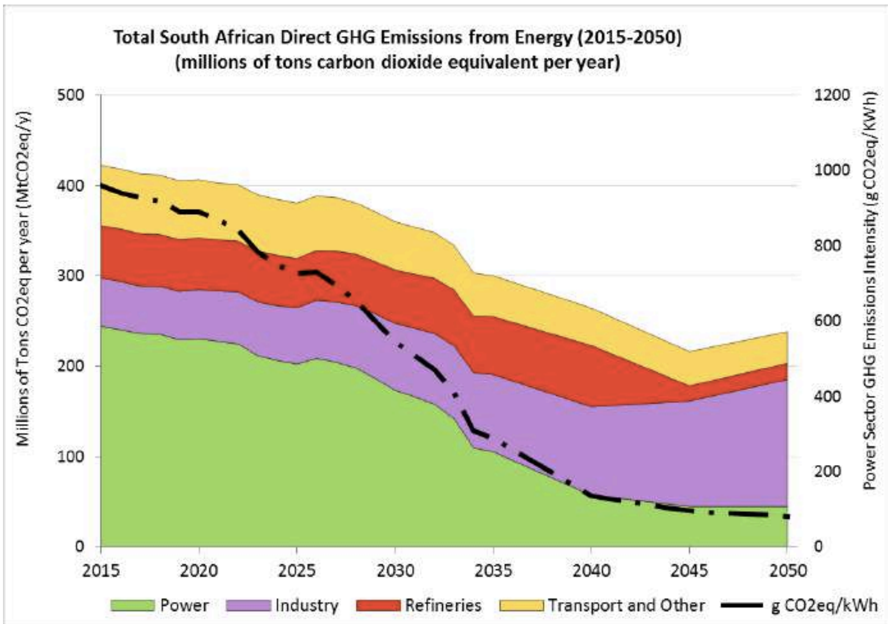
As a result, it very much depends on the future energy policy decisions whether South Africa can achieve changing towards less emissions intensive trajectories. The aging coal and nuclear infrastructure supply require urgent action to secure security in supply. Figure 14 illustrates the decommission timeline for South Africa's electricity supply infrastructure which shows a big opportunity for introducing clean energy technologies.

Figure 14 Timeline for decommissioning South Africa's electricity infrastructure (CSIR 2018)



The current trajectory of the IRP has been largely considered incompatible with the current NDC scenario (Marquard 2020). For this reason, the energy systems modeling group at the University of Cape Town explored an “alternative IRP”, which reflects more ambitious decarbonisation in the power sector (McCall et al 2019 cit in Marquard 2020). The group uses a linked energy-economic model, SATIMGE[2], which represents the whole economy. The study proposes a least-cost reference case under the assumption existing policy and regulation will be implemented. Further uncertainties regard the costs of batteries vs natural gas.

Figure 15 Reference case GHG emissions for energy and IPPU emissions



source: McCall et al 2019

The results of the modeling exercise for the electricity sector are significantly different from the IRP 2019. The assumed compliance with air pollution legislation leads to earlier retirement of existing coal capacity and no new coal plants will have to be built. As a result, emissions from the electricity sector decline more rapidly in the 2020s, which increases the chances to reach the national contribution to the global temperature goal (Marquard 2020).

2.2.6.Other mechanisms to reduce emissions

The South African government implemented a tax on carbon emissions in June 1, 2019. The tax structure proposes to affect only those emitters who own or control direct sources of emissions in a first phase until 2022. The standard tax rate is R120 (EUR 7.5) per tonne of CO2e (Presidency 2019). Exemptions, discounts and minimum thresholds have been negotiated over the lengthy policy processes, which lower the effective rate substantially. Slate levies tax petrol and diesel at 13.6 ZAR/ 0.84 EUR cents per liter (RSA 2019).

[2] SATIMGE combines a CGE model and a TIMES model of the energy sector (for more detail see McCall et al 2019)

The South African government proposed carbon budget approach for reducing national emissions in a parallel process to the tax as part of its National Response to Climate Change White Paper, in 2011. The budget approach grounds in the principle of setting a national target for emissions, in accordance with what is economically feasible and climate change commitments. Then sectors, sub-sectors and individuals are allocated proportions of this budget which may not be overreached. This approach forms one of the key foundations of the Climate Change Bill, a draft of which was released in August for public comment in 2018. This Bill will provide the legal basis for the Minister of Environmental Affairs, together with a Ministerial Committee on Climate Change, to establish, monitor and enforce carbon budgets and sectoral emissions targets for those companies/individuals who exceed a particular threshold. If the Bill is approved, it will likely affect a relatively small number of companies, approximately 30, due to the high level of concentration of emissions within the South African economy (Expert 2).

A number of the focus group participants raised the problem of data scarcity with regard to corporate emissions. Governmental attempts to implement coherent measurement, reporting and verification (MRV) have been resisted by a coalition of companies unwilling to disclose their emissions. Resistance to reporting mechanisms on emissions reductions makes it difficult to monitor the impacts of the carbon tax and carbon budget approaches.

3. Attempts and constraint to assessing impacts on poverty and inequality

The following section presents an overview of the current data sets and surveys to assess the state of poverty and inequality in South Africa. We investigated how these data may or may not be useful for understanding the social impacts on rapid transitions towards climate compatible development with inputs from a panel of experts in climate change, poverty and inequality at the University of Cape Town.

3.1. The state of poverty and inequality in SA

Poverty and inequality trends in South Africa have been well documented in the post-1994 period, partly a result of the availability of a number of nationally representative household survey data in the country. Table 1 below shows the existence of both panel and cross-sectional surveys in South Africa after 1995. The table illustrates the different household surveys that have been used in the analysis of poverty and inequality in South Africa, highlighting on their years of availability, on their type and on the coverage of the data. A majority of the household surveys in South Africa are cross-sectional with surveys such as the Income and Expenditure Survey (IES), the Living Conditions Survey (LCS), the General Household Survey (GHS) and the Community Survey (CS) contributing significantly to our knowledge of poverty and inequality trends in the country in the period after 1994.
However, South Africa as is the case with a majority of countries in the developing world, has a limited number of panel household surveys that can be used to analyze poverty dynamics, with the National Income Dynamics Study (NIDS) as the only nationally representative panel survey in the country since 2008. Other research on poverty dynamics used the Kwa-Zulu Natal Income Dynamics Study (KIDS) to understand poverty dynamics in KwaZulu Natal province.

Table 1: Survey availability for poverty and inequality analysis in South Africa

Survey	Years of availability	Type of survey	Coverage
Income and Expenditure Survey (IES)	1995 2000 2005 2010/11	Cross sectional household survey	Nationally representative
General Household Survey (GHS)	2002-2017 (Annual)	Cross sectional household survey	Nationally representative
Community Surveys (CS)	2007 2016	Cross sectional household survey	Nationally representative
KwaZulu Natal Income Dynamics Survey (KIDS)	1993 1998 2004	Panel survey	Covers KwaZulu Natal province only
Living Conditions Survey (LCS)	2008 2014/15	Cross sectional household survey	Nationally representative
Labor Force Survey (LFS)	2000-2007 (Bi-annual)	Rotating panel household survey developed to replace the OHS	Nationally representative
National Income Dynamics Survey (NIDS)	2008 2010 2012 2014 2016	Panel survey	Nationally representative
October Household Survey (OHS)	1993-1999	Cross sectional household survey	Nationally representative
Quarterly Labor Force Survey (QLFS)	2008-2017 (Quarterly)	Rotating panel household survey	Nationally representative
Cape Area Panel Study (CAPS)	2002 2003/4 2005 2006 2009	Panel	The sample is restricted to the metropolitan area of Cape Town

All Media Products Survey (AMPS)	1974-2015 (Annual and semi-annual)	Cross sectional	Data collected only from metropolitan areas

(source: own compilation)

The listed household surveys in table 1, above, have enabled an extensive analysis of poverty and inequality in South Africa in the period after apartheid. Despite this availability of a seemingly comprehensive number of cross sectional household surveys, the poverty story in the country is less straightforward. For instance, there is contention on poverty trends in South Africa between 1994 and 2000. Whereas findings from Hogeven and Ozler (2006), Simkins (2005), Stats SA (2002) found that poverty between 1994 and 2000 increased, other research findings from UNDP (2004), van der Berg and Louw (2004) and van der Berg et al (2006) show that poverty either stabilised or declined in a similar period. These disagreements resulted from the use of different methodologies and poverty lines.

In the post 2000 period, poverty trends are clearer and the most recent poverty estimates in the country show that poverty reduced from a poverty headcount index of 52.1 in 2006 to 38.3 in 2011. In 2015 this trend reversed and poverty increased (40.0). Table 2 below illustrates the poverty trends in South Africa in the post-2000 period.

Table 2: Overview of household poverty by province

	FGT Headcount				**SAPHI Headcount**		
Province	**2006**	**2009**	**2011**	**2015**	**2001**	**2011**	**2016**
Western Cape	38.3	29.8	23.9	25.3	6.7	3.6	2.7
Eastern Cape	64.9	60.5	52.1	54.3	30.2	14.4	12.7
Northern Cape	58.3	54.8	45.2	45.6	11.3	7.1	6.6
Free State	48.6	54.3	41.7	43.1	17.4	5.5	5.5
KwaZulu Natal	59.7	54.4	47.0	48.4	22.3	10.9	7.7
North West	55.6	54.7	43.9	49.0	18.8	9.2	8.8
Gauteng	33.2	30.1	23.0	26.0	10.5	4.8	4.6
Mpumalanga	63.1	59.1	48.2	46.0	18.8	7.9	7.8
Limpopo	70.2	71.2	55.8	55.4	21.8	10.1	11.5
South Africa	**52.1**	**47.2**	**38.3**	**40.0**	**17.9**	**8.0**	**7.0**

Source: Statistics South Africa 2017:86,32

Table 2 shows high poverty rates for the Eastern Cape, Mpumalanga and Limpopo provinces. These provinces are of interest in the South African energy transition, Mpumalanga and Limpopo are mining areas which create many jobs in coal and other mining businesses, which will be affected by an energy transition. The Eastern Cape, in turn, has benefited from the transition, so far, due to its favourable wind energy resources.

The table incorporates the South African Multidimensional Poverty Index (SAMPI), a multidimensional poverty index that includes variables that capture education, health, living standards and economic activity used by Stats SA. Using the SAMPI, multidimensional poverty reduced between 2001 and 2016, partly a result of improvements in the access to basic services in South Africa (Stats SA 2017). However, using the Foster Greer Thornbecke (FGT) poverty headcount that uses consumption, poverty between 2006 and 2011 reduced from 52.1 to 38.3, but increased to 40.0 in 2015. This partly reflects the unequal consumption patterns of South Africans.

Multidimensional inequality measures like those using asset indices might reflect a decline in inequality as a result of the improvement in the access to basic services, however, an analysis of the GINI coefficient in the country between 1993 and 2015, shows that the country's Gini co-efficient has remained above 0.6 during this period (Stats SA 2019).

3.2. Impacts on regional distribution of poverty and inequality

The changes in the energy sector as illustrated by the model and the IRP will have serious socio-economic implications on poverty and inequality, due to their impact on employment in different regions.

South Africa's unemployment rate is extremely high, with narrow estimates placing it at 27.6%. Broader definitions of unemployment, which include discouraged job seekers, suggest a much higher rate of 38% (StatsSA, 2019). The ICES model assumes full employment, which does not correspond to the reality in South Africa's labour market. The model assumes that skills are fully transferrable between sectors and shows job losses in one sector as gains in other sectors.

In reality, there is some transferability between jobs in the energy sectors, but it is not perfect. The coal sector will most likely experience losses in employment, while jobs in renewable energy are likely to increase, according to a study by the CSIR (CSIR 2018). In 2018, the coal sector employed approximately 82 000 workers according to information of the Minerals Council (Minerals Council, 2018). This information needs to be looked at with caution, as the Council has its own political agenda for protecting jobs and subsidies in the sector (Expert 1).

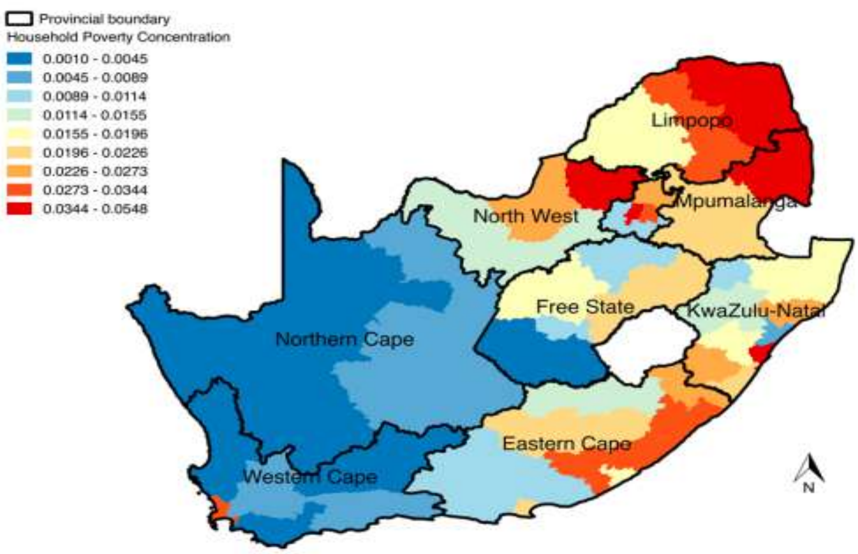
Most of the coal mining jobs are located in the Northern provinces, Limpopo and Mpumalanga. Figure 14 shows the distribution of household poverty across the country, which is particularly high in the Northern Provinces. The importance of the coal sector in these regions is striking, given the high unemployment rates and poverty headcounts, even relative to the South African total. For example, in Mpumalanga, the narrow and broad estimates of unemployment range at 34.2% and 43% respectively (StatsSA, 2019).

Within these provinces, the mines are located in only a few districts. In Mpumalanga, the sector clusters the districts Nkangala and Gert Sibande; Limpopo's coal mining operations centre in the Waterberg district. Mpumalanga hosts Sasol's liquid fuel plants, the Secunda Plant. Coal mining jobs are historically well protected by active unions. The high poverty and unemployment rates in the mining regions makes it politically even more difficult to actively phase out coal.

Employment from renewable energy is much more widely distributed geographically relative to coal, because of the prevalence of renewable energy resources. So far, solar PV and Concentrated Solar

Power (CSP) plants mainly occur in the Northern Cape, which has the country's highest radiance intensity. Wind farms spread along the coastline of the Western and Eastern Capes (DoE, 2019). Of the 112 projects that have been procured so far, only 2 occur in Mpumalanga (biomass power plants) and 2 in Limpopo (PV solar). However, it has also been noted that given the high incidence of radiance intensity throughout the country, in theory it is possible to have solar projects within all provinces (Expert 1).

Figure 14: Household poverty at the district level



Source: StatsSA, 2011

National modeling exercises have looked more generally at the net impact of the low-carbon transition on jobs. Renewable energy technologies are expected to provide a net increase of 150 000 job years by 2050, even accounting for a 35-40% decline in jobs in the coal sector (COBENEFITS 2019). This reduction in jobs is attributed to a reduction in demand globally, rather than an outcome of climate action policies. In the economy more broadly, it is estimated that 1.3 million jobs could be created by 2050. Based on an estimate of the lowest-cost scenario, which is characterized by a much higher proportion of renewables, an additional 300 000 jobs could be created, relative to the IRP 2018 scenario (COBENEFITS 2019).

In all scenarios, the majority (~70%) of these jobs will be made in the high-skill labour market, which includes all those who have tertiary qualifications. This is due to the fact that the majority of jobs that are created in the economy more broadly are within the service sector. These are likely to occur in the main economic centres, Gauteng and Cape Town, the areas of the country with the lowest poverty rates. Within the value chain of renewable energy production, job creation occurs mainly during the construction and installation phases, particularly within the wind and solar industries, accounting for close to half of the number of jobs (COBENEFITS 2019, Expert 2). These job opportunities require a highly skilled, specialized workforce, which are rare in South Africa. The skills shortage in the country counts to the main causes for poverty and unemployment across the country (Expert 1).

Other studies, however, have shown differing results. Modeled scenarios by Caetano and Thurlow (2014) suggest an overall drop in employment under the 2010 version of the IRP, due to the net loss of low-skilled jobs. This in turn results in an increase in inequality (as well as a slight drop in GDP).

Apart from these two studies using slightly different models, and based on different IRP versions, they are also based on different input values for the number of jobs within the coal and renewable industries, and differing values for each during construction, manufacturing and operations and maintenance. This has a substantial impact on the total number of jobs estimated, illustrating the importance of the underlying assumptions of the different models used and the quality of the input data. In order to address this, actual employment data from IPPs and the coal sector would be required, which are not accessible for research or to the public (Expert 1).

Regardless of the net impact on jobs nationally, the stark contrast between the regions suggests that certain provinces and districts are likely to see a growth in jobs while others are likely to see a decrease. While a lot of focus has been placed on retraining within the energy sector (from coal to renewables), (Expert 1) also noted the need to think beyond these constraints and make provisions for retraining beyond sectoral boundaries. This would be necessary if there continued to be limited geographical overlap between sectors. The ability for retraining is highly dependent on skill levels; however, this remains ambiguous as the skills-profile of miners is not available. Some have noted that miners are in fact relatively well-educated (generally having passed matric, the South African high school degree) and skilled. Therefore the opportunities for retraining are high (Expert 1) however better data is required. The feasibility of retraining both within the energy sector and beyond it, and the costs that this entails, will be extremely important in moderating the socio-economic impacts of the low-carbon transition.

The model does not provide a general price for electricity production. It indicates that there will be a substantial drop in the consumer price of renewable energy, by approximately half, by 2050. Declining price of renewable technology costs have already been witnessed in South Africa and globally. The REIPPP programme reached parity with coal prices in the third round. The cost per GW to Eskom is cheaper compared to its current supply, even from already established coal power stations (Eberhard and Naude 2016). The current dynamics in the coal sector, drop in international demand, the reduction in mining resources and a lack of investment are likely to result in price increases. The South African government plans to build additional 1.5 GW of new coal by 2030, which will most likely put an additional burden on the economy (Burton et al 2019).

The low technology cost of renewable energy has not fully translated into consumer prices. The determination of the cost of electricity takes several factors into account (including the high cost of coal which is retained in the energy matrix). Electricity tariffs result from a negotiation process between Eskom, the electricity utility, and NERSA, the National Energy Regulator of South Africa. The methodology for determining the price is known as the Multi-Year Price Determination (MYPD).

Prices vary according to type and location of consumers: these differ between i) municipalities (who then go on to sell it to residents), ii) energy-intensive users who buy directly from Eskom, and iii) low-income households who are subsidised.

In terms of electricity, consumers are likely to be sheltered from the carbon tax. Eskom is exempt from paying the tax, under the rationale that it is already doing so with the electricity generation levy and a renewable energy premium for power purchased from IPPs.

However, the impact of the fuel price increase is likely to be significant. Although no studies have been conducted into this phenomenon specifically, the national response to fuel price hikes, illustrates that this is a point of much contention for particularly low-income consumers (Experts).

3.3. Just transitions: Policies to prevent the exacerbation of poverty and inequality

Concerns regarding the socio-economic impacts of a low-carbon energy transition in South Africa are widely acknowledged. The trade unions have been particularly vocal about potential employment impacts of climate policy, especially related to renewable energy as an opponent of coal. Trade unions have been active in resisting renewable energy because of the design of the renewable energy program and the role of Independent Power Producers and the potential privatisation of energy in South Africa. While they have generally been seen as opponents to renewable energy, they have argued that they are not opposed to renewable energy per se, but to the private production of energy because they argue that "private interest prioritises profit maximisation above the meeting of social needs" (COSATU, 2019). Renewable energy is the central component of the decarbonisation of South Africa's economy. Renewable energy is central to South African climate policy: the NDCs, the National Development Plan, the National Climate Change Response White Paper and the IRP. All policy documents argue for a ' just transition'.

The principles of the 'just transition for environmentally sustainable economies' include the importance of social dialogue, workers' rights, gender considerations, coherent policies across different portfolios and the promotion of decent work (ILO, 2015).

South Africa's Renewable Energy Independent Power Producer Procurement Program (REIPPPP) is probably one of the few energy programs worldwide that come closest to complying with these principles. The program makes provisions for Socio-economic Development (SED) criteria. SED criteria weigh 30% in the evaluation of bids, while the price was counted for 70%. SED criteria included job creation through local content requirements, ownership, management control, preferential procurement, enterprise development and socio-economic development in communities in proximity of the renewable energy plants (DoE 2013).

Research on the impact of the Renewable Energy Program on poverty and inequality is preliminary, because of the recent nature of most projects.

Research on the impacts of the local content requirements in the REIPPPP found positive impacts on skills and employment. As an example, local content requirements in the REIPPP have been the main reason for the development of a wind tower manufacturing industry in South Africa. In the absence of these requirements, wind farm developers would have chosen the cheaper option to simply import the towers (Rennkamp et al 2019, in D.3.3. COP21 RIPPLES, Fyvie 2017). Building a wind energy industry from scratch required high levels of science, engineering and technology (SET) skills, which were drawn from other highly skilled individuals from the energy sectors already established in South Africa. Local individuals with transferable SET skills benefited from these opportunities.

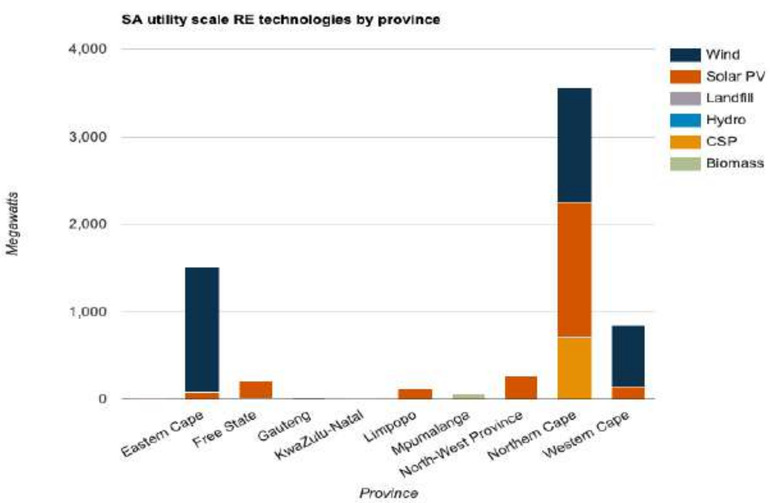
International experts train local employees, and also simply through local growth of the industry with the necessary training at post-graduate and technical and vocational level (Fyvie, 2017).

The implementation of community development requirements has been challenging as they brought three different actors together without much guidance. Wind energy developers, the national government and local communities have in practice little skills, capacity or experience to design community development projects (Wlokas, 2017).

Wlokas (2017) found that despite the good intentions of the government in designing SED for community development benefits, the policy design left a vacuum, as the rules for the implementation were not clear. As a result, community development was frequently left to the wind farm developers and community representatives to define. These relationships come with their own sets of inequalities in power and assets, which let to different outcomes. To date, the majority of the projects have established community development trusts, which accumulate the industry funds for specific projects that aim to benefit the communities within the proximity of 50km to the power plants. The spatial parameters in the policy have triggered inequality and conflict in the cases of overlap and exclusion and are currently under revision (Wlokas 2017).

So far, the REIPPP program has not been designed to address regional inequalities. Projects are built in the most favorable locations in terms of solar radiation, wind and hydro energy potential. These projects concentrate socio-economic impacts in the Eastern, Northern and Western Cape regions. The Northern regions currently benefit very little from the REIPPP program. There is an emerging debate on introducing spatial dimensions into future bidding rounds to correct these regional inequalities (Expert 8). The Department of Environmental Affairs is developing an approach for Renewable Energy Zones. The first round of these zones focused on the Northern Cape, though (DEA 2018).

Figure 15 Renewable Energy Projects in South Africa by province



source: energy blog

The regional inequalities in the current structure of the REIPPP program have raised the prospects for a change in the policy for future bidding rounds of the REIPPP. Geographic constraints could be placed on the project sites to ensure more localised employment and development (Expert 5 HVB). However, it also requires a targeted diversification of local economies where coal mining is concentrated (Strambo et al., 2019). The Department of Environmental Affairs has started a program to identify renewable energy development zones (DEA 2018). Plans are underway to expand on the integration of renewable energy plants in mines. A number of projects have been implemented on mines in Limpopo (Mining Weekly 2014). These projects reduce the carbon footprint of the electricity used for the mining operations (up to 60%) and produce additional jobs in the region.

3.4. Constraints to understanding the impacts of rapid transitions on poverty and inequality

A central constraint that we found in doing research for this project is the availability of data that can demonstrate impacts on poverty and inequality from rapid sectoral transitions towards lower carbon intensive development trajectories. The data and lack thereof results from ways that two epistemic communities – in climate change, poverty and inequality – operate. These communities do not fully understand the interactions between climate action with poverty and inequality yet. The current structures and mechanisms in collecting data are not designed to serve studies that aim to understand this problem.

Poverty data are typically collected from household surveys, conducted across the country, and even those focused on specific areas are unlikely to be nuanced or extensive enough to understand the impacts on, for example coal miners in particular (Expert 6). Poverty data typically does not include environmental variables and therefore does not take into account changes to well-being beyond the metrics measured (Expert 7). Instead data used in the analysis of poverty and inequality such as the IES and LCS are more focused on capturing welfare information to measure living standards of households and individuals (LCS) or update the consumer price index (IES).

One possibility of bringing these two fields together would be through linking surveys or models, however this raises issues on sampling frames, aggregation and the need for merging variables (Expert 8). There is a need for research to be conducted to establish if existing data from the two fields can be manipulated through survey-to-survey imputation methods. South Africa has Population Census data, but they do not have the same level of detail as household surveys. (Expert 9)

Elsewhere, there are other household survey data that were designed to analyse the interactions between climate change and poverty. Household survey data such as the Gender Household Survey from the IFPRI-CCAFS conducted in Bangladesh, Kenya, Senegal and Uganda is a good example of such data. The survey collects information that allows for analysis of the impacts of climate change on men and women, which is generally scarce.

A growing body of research that analyses the impact of climate change on poverty utilises GCMs or RGMs to project possible scenarios. Useful insights on the possible impacts on poverty and inequality of different climate actions increase our preparedness especially in decisions on the just-transition. The focus group of experts largely agreed that there is an urgent need for qualitative data to complement existing research based on fragmented quantitative data.

Ultimately, it is also a question of paradigms. While our understandings of poverty and inequality are typically from historical and current surveys, climate change generally involves modeling the future. Therefore a merging of understandings needs to happen both spatially and temporally.

And lastly, given the centrality of people to this problem and the idea of the Just Transition, it is essential that the voices of those affected are also collected and heard, to understand the complexities of what this transition would entail. This is key since climate actions do not occur in a vacuum, but affect people disproportionately given the fact that people have different vulnerabilities and adaptation is not homogenous within and across countries.

4. Ways forward in improving data collection relevant to understanding transitions and impacts

Research has increasingly become more data demanding since the advent of the Millennium Development Goals (MDGs) in the 1990's and the need for more disaggregated data has expanded under the Sustainable Development Goals (SDG) era. These demands do not necessarily come with well-executed funding mechanisms, which results in a general lack of appropriate data to meet research needs. How can existing data related to poverty and inequality be useful in complementing our existing knowledge on the impacts of climate change actions on poverty and inequality in South Africa?

Welfare survey data displayed earlier in Table 1, collects detailed information on the goods and services that people consume and this can be used to track how much carbon is associated with the production of such goods. (Expert 9) The possible drawback in using such data, however, is that consumption data are more concerned with providing national statistics, with 25000 to 30 000 households representative of the entire country. On the other hand climate change data have a more zoomed in focus. (Expert 9)

Other alternative data sources such as tax data collected by the Department of Treasury or electricity usage data from municipalities provide possibilities of linking environmental data with welfare data. In Cape Town for instance, UCT's Datafirst has data sharing agreements with the municipal administration (Expert 9). This can be extended countrywide, assuming similar collaborations exist in different provinces.

Modeling makes it possible to analyse the possible scenarios on poverty and inequality from different climate actions but there were concerns amongst some of the experts in the focus group that modeling alone in inadequate and there is a need for qualitative data to support such models (Expert 2 HW). Another expert for instance voiced that modeling tends to show how the transition would work in a perfect market but not in the real world. For in South Africa you have trade unions whose concern might not be on the other jobs to be created in the transition but seek to keep the ones their workers have in the coal sector (Expert 1 FH).

Future research also needs to consider the different pathways that can be used in the analysis of climate actions, poverty and inequality. There is need to narrow this down using specific conceptual frameworks. The possibilities of using social accounting matrices as well as input and output tables

present promising avenues for such research. Social Accounting matrices have been applied elsewhere with promising results in India (Pohit and Pal 2014) and in Brazil (Lenzen and Schaffer 2004). On the other hand, input-output models in climate change research have been well established and offer new possibilities in the analysis of the impacts of climate actions on poverty and inequality in South Africa.

5. Conclusions

The analysis showed a mix of favorable and disadvantaging conditions for rapid transitions towards low carbon trajectories in South Africa. The timing for a transition is favorable, as the prices for renewable energy technologies have declined significantly. The renewable energy industry established in South Africa over the past seven years is ready to build new infrastructure at least cost. The South African electricity sector needs new infrastructure, urgently. This unique opportunity to decarbonize a significant part of the economy, in the light of a disastrous climate crisis, meets major challenges that emerge from the historical inequalities that center around the income sources from the coal 'business as usual'. Existing political and economic elites favor continuity of large coal related infrastructure; trade unions protect the jobs in the fossil fuel sectors promoting anti-renewable energy discourses.

A number of relevant climate programmes, including the new electricity plan, the renewable energy program and the carbon tax are in place to lead towards less emission intensive futures. All of these policies have been fiercely opposed by the coalitions, which benefit from the established structures.

These factors challenge structural change and make low carbon energy transitions difficult to manage. Measures to limit emission intensive economic activities with the potential to create job losses are highly sensitive. The creation or loss of jobs in the economy dominates the narrative in South Africa's transition towards a low carbon economy. Regional inequalities add to the political challenges in managing 'just transitions', as the distribution of employment benefits from renewable energy generation does not correspond to the geography of traditional mining jobs. This finding presents policy challenges, which should be considered in the future of renewable energy incentives.

The research has created a unique opportunity to gather a group of South Africa's leading researchers in climate policy, poverty, inequality and labor economics to think about this problem. It became evident that the current data and the structures for data collection in the two areas of work do not correspond to the challenge of understanding poverty and inequality impacts from the decarbonisation of the economy. This finding raises pressing concerns about future measurement of the progress towards achieving the Agenda 2030; specifically SDG 1,10,7, on poverty, inequality and climate action.

6. Experts

The experts in the panel that informed the focus group discussion consisted of leading scholars at the Poverty and Inequality Initiative at the South African Labour and Development Research Unit (SALDRU), Data First, the Energy Systems Analysis Group at the Energy Research Centre (ERC) and the African Climate and Development Initiative (ACDI) at the University of Cape Town. 15 experts met at a workshop in Cape Town, on the 15th of November. Two experts were interviewed, separately.

3. Case Study 2: Social inequality, 'rapid' transitions and climate change in Brazil

Authors: Britta Rennkamp, Maria Gabriela von Bochkor Podcameni, Katrina Lehmann-Grube, Rejoice Mabhena, Annela Anger-Kraavi

1. Introduction

Climate change is no longer 'just' an environmental crisis. Global warming is increasingly surfacing geopolitical and socio-economic divisions between and within nations (Latour 2018). Societal changes related to rapid low carbon transitions have been assessed quantitatively and qualitatively (see for example Centro Clima 2015, Markannen & Anger-Kraavi 2018). There are, however, significant gaps between quantitative and qualitative assessments as well as lack of data on sector specific co-benefits to fully understand how sectorial transitions towards lower carbon pathways will impact on social inequality.

Brazil is a striking example of a social and political divide over climate policy. It is the world's most bio-diverse country and home to the world's largest tropical forests, the Amazon rainforest. Protecting the Amazon will be necessary to limit the increase in global temperature to 1.5°C. Brazil counts as one of the most unequal societies of the world, with a Gini index as high as 53 (World Bank 2017). Brazil's young democracy has witnessed dramatic climate policy change over the past 15 years. In the period between 2004-2015, social inequality and green house gas emissions have rapidly declined. These achievements resulted from a number of factors, including improved satellite technologies to monitor deforestation, an effective fining system for illegal deforestation activities, an increase in renewable energy, and one of the world's largest cash-transfer programmes, which reduced extreme poverty and hunger. This progress was gradually undone, in the aftermath of the global finance crisis and the corruption triggered by resource influx from national oil discoveries. The political crisis led to the rise of a conservative government on far right on the political spectrum. Deforestation of the Amazon forest has been rapidly increasing over the course of 2019. The environmental governance system has been weakened and left with minimal resources (Observatorio do Clima 2019).

Deforestation is the largest source of GHG emissions in Brazil, which differentiates the country from the situation of most middle-income countries. Low carbon transitions in other sectors of the economy, especially in the energy and transport sectors, remain often overshadowed by the dominance of the forestry, agriculture and land use sectors in the Brazilian climate policy debate (Viola and Franchini 2018). Brazil technically counts as a 'low carbon' economy already, because of the high share of hydro-electric power in the electricity sector. The 'lock-in' to hydro technology systems, however, is problematic because of its environmental impact and the vulnerability to changes in rainfall patterns. Drought has already constrained the electricity supply. Power outages (known as *apagão*) have led to a diversification of the electricity technologies in the mid 2006 and an increase in other renewable energy technologies.

This section assesses the bigger picture of the relationship between climate policy measures in specific sectors in the economy and the socio-economic structures of poverty and inequality in the

country. The analysis follows a mix-methods approach which combines results generated by an Intertemporal Computable Equilibrium System (ICES) as modelled in Parrado et al., (2019) with a qualitative inquiry. ICES represents a commonly used multi-sectoral economic model. The model aims to project changes in various sectors in the economy as a result of carbon constraints, so called Nationally Determined Contribution (NDC), which countries communicate to the United Nations. The model presents two scenarios, a 'current' and an 'enhanced' NDC scenario, with different levels of 'ambition' in GHG emission reduction up to 2050. These kinds of models are commonly used, but can come with flaws, especially with regards to the assumptions (Stern 2016).

Qualitative data emerged from interviews with climate policy experts in academia, the private and public sector, the existing research literature as well as policy documents. The qualitative inquiry helps to put the modeling results into the perspective of the current political situation. The results of the qualitative analysis suggest that the emissions reductions in the 'current NDC scenario' are highly unlikely to be met under the current political administration. Emissions from deforestation, oil and gas are likely to increase drastically, while some reductions can be expected from the continuation of the renewable energy and bioethanol programs. The overall outlook for climate protection, the general economic situation and social cohesion is very negative. The experts considered a presentation of an 'enhanced NDC' that will introduce more ambitious emissions reductions, highly unlikely under the current political administration.

The section is organised as follows: Section 2 presents the results of the model, section 3 contextualises the results within Brazilian climate policy and Brazil's current NDC, which was communicated to the UN in 2015 before the COP 21 in Paris. Section 4 contextualises these results with the current state of poverty and inequality in Brazil, existing data and distributional impacts of the central climate transitions.

2. Modeling gains and losses of rapid low carbon transitions in Brazil

The Intertemporal Computable Equilibrium System (ICES) is a multi-sectoral, multi-regional dynamic recursive computable general equilibrium (CGE) model of the world economy. The ICES model was developed for the analysis of decarbonisation scenarios and changes in specific sectors in the economy.

The model outputs include macro-economic variables such as GDP, consumption, savings, investment, imports and exports and sectoral outputs from 28 sectors in the economy. These include industry outputs and prices, demand and price endowments and sectoral emissions. Carbon taxes, cap and trade and border trade adjustments are included as variables to account for changes to the policy environment regarding climate action.

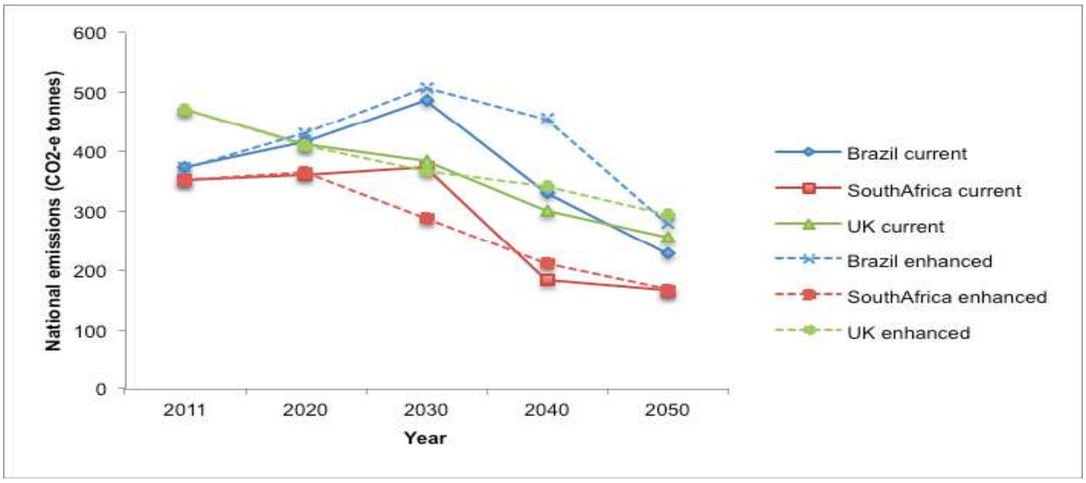
The results for the model correspond to two different scenarios: the 'current NDC' and an 'enhanced NDC' scenarios. The first scenario projects the outcome from the implementation of NDCs until 2030, with little or no increased ambition announced during the round of negotiations in 2020. This scenario requires an increased effort between 2030 and 2050 to comply with a long-term of 2°C by the end of the century. The 'enhanced NDC' scenario is allocated the same carbon budget as the 'current NDC' scenario between 2010 and 2050, however illustrates a smoother, and more gradual

emissions trajectory due to increased ambition before 2030. Importantly, the scenarios are modelled under the assumption of global cooperation and a global carbon price, which allows for an efficient global emissions trading scheme.

2.1. Brazil in the model relative to other countries

The model generated results for several countries and regions: the UK, EU, Brazil and South Africa. In order to understand the relative positioning to other countries, Brazil's population size, GDP and national emissions are compared to those of South Africa and the United Kingdom (UK). Population size across all countries shows a slowly increasing but decelerating population size, with no difference between the scenarios. In Brazil, the population size in 2050 is estimated to be approximately 233 million people, which is in line with other official estimates (IBGE, 2013). The model shows accelerated growth in Brazil's GDP, particularly from 2020, reaching an estimated 4.9 trillion USD by 2050 in both the current and enhanced scenarios. Brazil sees a much steeper increase in national emissions relative to South Africa and the UK leading to 2030, followed by a rapid drop between 2030 and 2050. This can be observed in both the current and enhanced scenarios, although overall the enhanced scenario experiences higher emissions over the entire period. Brazil's emissions remain the highest of all countries that were analysed.

Figure 1: Projected national CO2 emissions for Brazil, South Africa and the UK 2011-2050, current and enhanced NDC scenarios



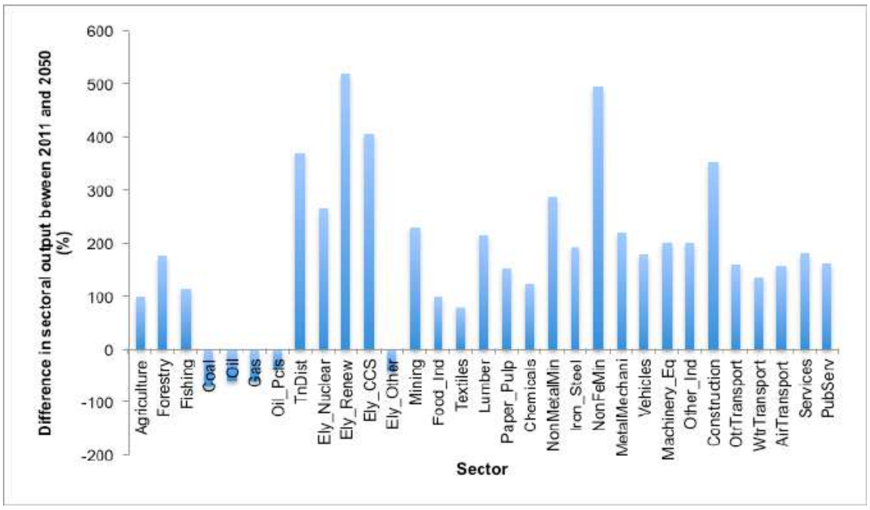
Source: ICES model, 2019

2.2. Central sectors to the NDC scenarios according to ICES

The model shows that for both current and enhanced NDC scenarios, Brazil is likely to see a substantially increased sectoral output in almost all sectors covered by the model. This increase results from high levels of GDP growth projected by the model. In absolute terms, the biggest differences are experienced in the service sector. Proportionally, however, the biggest growth is observed in renewables, carbon capture and storage (CCS), electricity transmission and distribution, construction and non-ferrous mining. The only sectors modelled to experience a decline are coal, oil, gas and oil products.

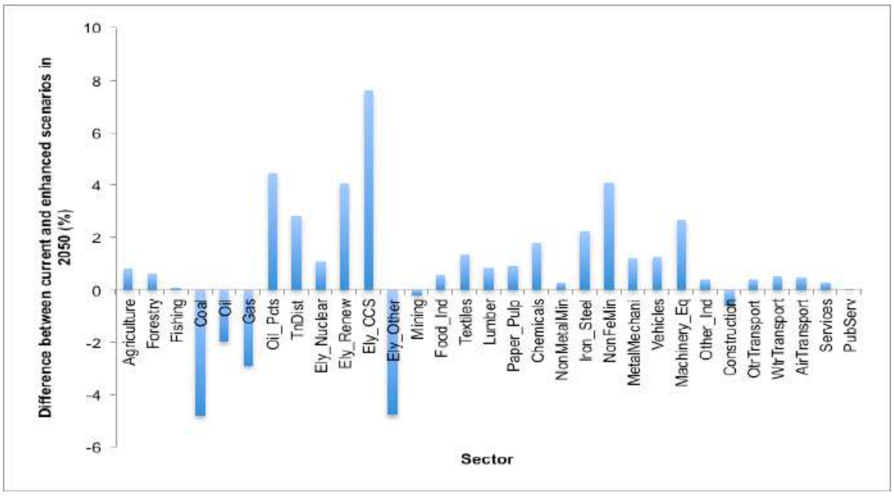
Although the differences between the current and enhanced NDC scenarios are small in 2050, there are several significant differences in 2030. In the enhanced scenario, there is proportionally less coal, oil, gas and construction. This is in line with a smoother transition to a low-carbon trajectory starting immediately. Both scenarios show an increase in labour costs in most sectors, which is most significant in electricity transmission and distribution mining, non-ferrous mining and construction between 2011 and 2050. Labour costs coal, oil, gas, oil products, as well as agriculture, fishing, food, textiles, chemicals and transport, can also be attributed to the push in economic growth predicted by the model.

Figure 2: Difference (%) in sectoral output (USD 2011 million) by sector in Brazil between 2011 and 2050 (current scenario)



Source: ICES model, 2019

Figure 3: Difference (%) in sectoral output (USD 2011 million) by sector in Brazil between the current and enhanced NDC scenarios in 2050

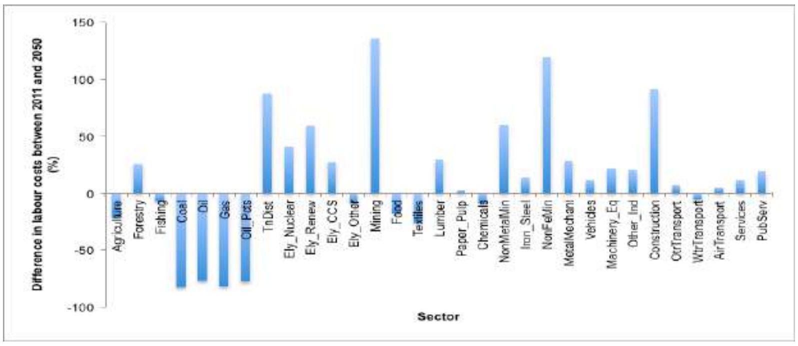


Source: ICES model

The ‘enhanced NDC scenario’ shows higher labour costs for almost all sectors in the economy, except for the fossil fuel intensive sectors. There are small differences in a number of sectors, but the most striking differences between the two scenarios are for the coal, oil and gas sectors. This is in line with

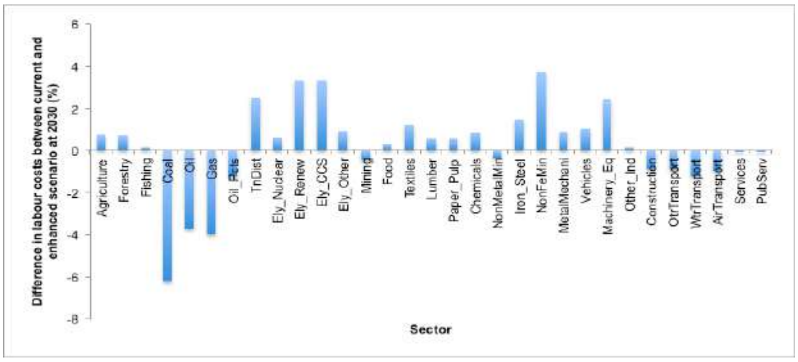
the scenario description which refers to an increased ambition before 2030. The model produces no substantive difference between the changes in labour costs of skilled and unskilled labour. The wage index is uniform between sectors and shows no substantive difference between scenarios, or between skilled and unskilled labour.

Figure 6: Difference (%) in labour costs by sector in Brazil between 2011 and 2050 (current scenario, skilled labour)



Source: ICES model, 2019

Figure 7: Difference (%) in labour costs by sector in Brazil between the current and enhanced scenarios in 2030 (skilled labour)



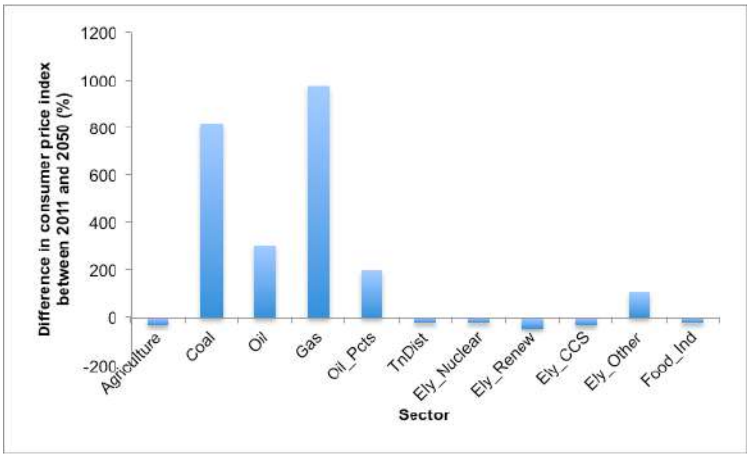
Source: ICES model, 2019

The changes in the labour cost result in an expansion of labor costs in almost all sectors of the economy, as a result from GDP growth. Growing labour costs in sectors the model considers as low emissions intensive technology, including renewable, CCS and nuclear, are in line with our anticipation. Surprisingly the labour costs in the mining sectors are projected to grow significantly. Sectors with reduced labour costs are fossil fuel intensive sectors (coal, oil, gas and oil products), agriculture, food and textiles.

The model provides consumer prices which only refer to a subset of sectors, including agriculture, coal, oil, gas, oil products, electricity generated from fossil fuel sources such as coal, gas, oil and oil products (which is the variable Ely other in Figure 8), electricity transmission and distribution activities (which is the variable Tn_Dist, in Figure 8). Consumer prices for most sectors experience a steady decline between 2011 and 2050 in both scenarios. However, large increases are experienced

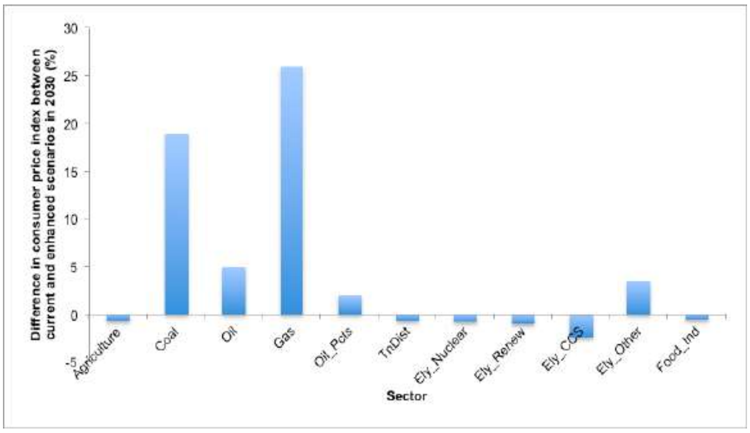
in coal, oil, gas (and oil products). The increase in price in these sectors is particularly large in the enhanced scenario, relative to the current one.

Figure 8: Difference (%) in consumer prices by sector in Brazil between 2011 and 2050 (current scenario)



Source: ICES model, 2019

Figure 9: Difference (%) in consumer prices by sector in Brazil between current and enhanced NDC scenarios in 2030



Source: ICES model, 2019

The results in projecting price changes in fossil fuel intensive sectors correspond largely to the logic of conventional transitions in the energy sectors which reduce the share of fossil fuels in the economy and increase the share of renewable energy technologies, nuclear and CCS. In the case of Brazil, conventional trade-offs between fossil fuel and renewable energy occur to some extent in the electricity and transport sectors. The large share of emissions from deforestation, the large share of hydroelectric power in the electricity sector and the large share of biofuel in the transport sector make the question about rapid transitions unique and less straightforward, as the next section will demonstrate.

3. Contextualising the results Brazil's role in climate change

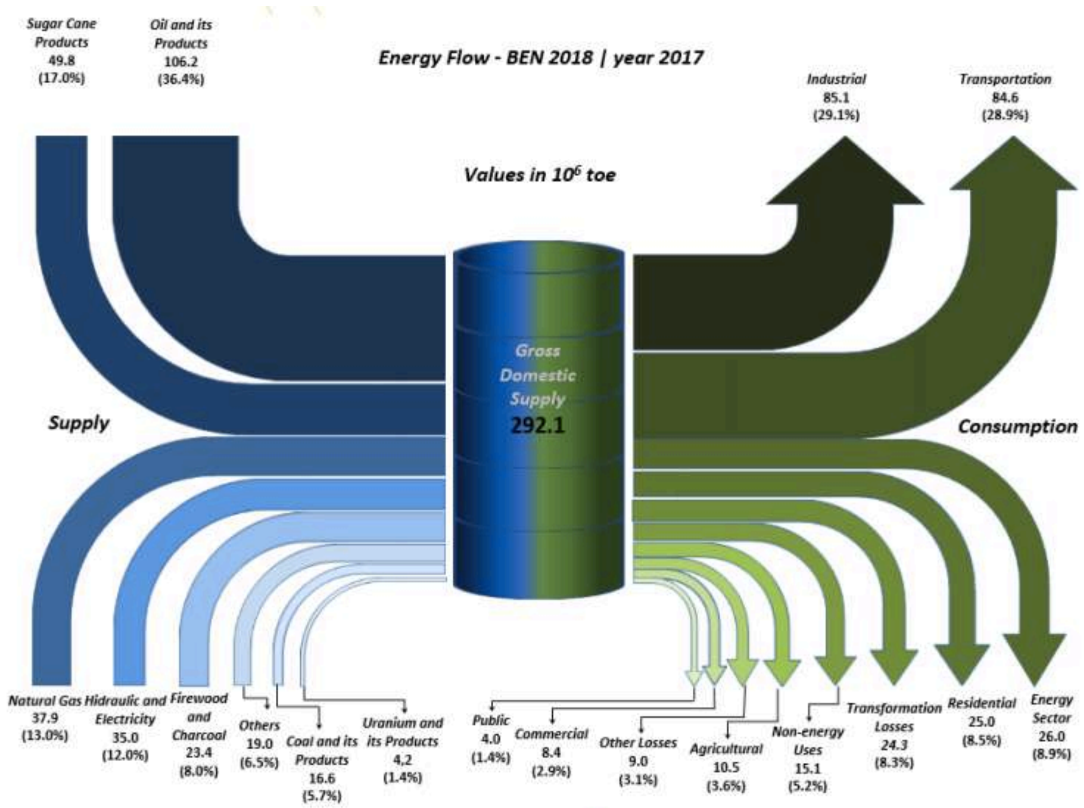
The results need to be understood in the context of Brazil's characteristics, with a colonial history based on the exploitation of forest resources, which gave the country its name. Brazil is the most biodiverse country on earth and home to the world's largest tropical rain forest. Brazil is the world's fifth largest country in the world in terms of both population size and land area (World Bank 2016). Under colonial rule, Brazil also became the home to almost 5 million slaves, who worked in the sugar cane farms, mainly from West Africa. Brazil received more slaves than any other countries in the Americas and was the last of all nations to formally abolish slavery in 1888. The colonial history lay foundations for the structure of the economy and social inequalities, which still persist in today's Brazil.

Brazil accounts for approximately 2.33% of global greenhouse gas emissions. This measure placed Brazil on rank 13 of the list of highest emitters in the world in terms of absolute emissions, and rank 18 in terms of per capita emissions. Emissions from energy account for approximately 40% of emissions, which is a relatively low share for the size of the nation and its economy. The agricultural sector contributes more than 40% (Climate Transparency, 2019). The electricity sector mainly relies on hydro-electric power. In 2017, 65.2% of the electricity come from hydro power, with an additional 17% coming from other renewable sources, mainly wind and biomass. The share of natural gas in the electricity mix is growing, with 10%. Nuclear adds 2.5%, and coal 3.6%, according to the National Energy Balance (EPE 2018). Figure 10 shows the flow of energy from supply sources and consumption by sector. The contribution of biofuels reached almost half the size of oil products (17% / 36.%). The figures show the striking role of the transport sector, which consumed almost as much energy as the industries (EPE 2018).

Brazil has an extensive and highly productive agricultural industry, with a high proportion of these emissions coming from the digestive processes of animals and the use of fertilisers (Climate Transparency, 2019). These emissions in agricultural processes are multiplied due to the impacts of deforestation and land-use change, which drastically reduce role of the Amazon as a land sink. In discussions on reducing Brazil's contribution to climate change, concern is generally with the high rate of deforestation and land use change. While deforestation dropped dramatically between 2004 and 2012 due to improved policy creation and implementation, it has since been rising again, particularly since the election of President Jaír Bolsonaro. In July 2019, an estimated 2 254km^2 was cleared in the Brazilian Amazon, almost 3 times the amount from the previous year (INPE, 2019).

The mixture of carbon intensive, economic sectors and social inequality in Brazil is unique, in scale and in the ways the various sectors intertwine. Deforestation activities interlink with the agricultural industries. The agricultural sector links with the energy and transport sector, as it produces a third of the transport fuels from sugar cane for ethanol and soy for biodiesel. Ethanol and biodiesel based fuels burn cleaner than fossil fuels, which make them an important component of Brazil's efforts for mitigation of climate change.

Figure 10 Energy Flow in Brazil's Economy, 2019



source: Energy Research Enterprise, (EPE) 2018.

The strategy to replace Brazil's dependence on imported oil through increasing the share of biofuel links the agricultural sector significantly with the energy, transport and forest sectors. The expansion of the biofuel program interferes with the protection of the Amazon rainforest (Texeira 2019). The Amazon forest is also threatened by the expansion of the hydroelectric power system. The remaining potential to develop further hydroelectric power plants in Brazil is in the center of the Amazon Rainforest. The construction of the Belo Monte dam at the Xingu River in the Amazon was environmentally and socially controversial, as it impacts on the livelihoods of the indigenous communities (Watts 2014, personal communications). At the same time, the share of natural gas and thermo-electric has been increasing in the electricity mix. Ambitions of the government to build gas pipelines to Bolivia have currently been stalled, because of lack of investments. Chinese investors are considering building further coal plants in Brazil (personal communications).

In sum, the forest, agricultural, industrial, energy, electricity and transport sectors are deeply interlinked. Just transitions towards low carbon, socio-economic pathways in Brazil reach far beyond the common challenges, elsewhere, to phase out fossil fuel for the benefit of renewable energy sources.

3.1. Brazil's Nationally Determined Contributions (NDCs)

The Brazilian government submitted an Intended Nationally Determined Contribution (INDC) under the administration of President Dilma Rousseff to the UN ahead of the COP 21 in Paris, in 2015. The

government ratified the Paris Agreement in 2016 and did not submit any update to the original INDC which then turned into Brazil's current NDC.

Brazil's NDC communicates that the country aims to commit to reducing emissions in two periods:

- Reduction of greenhouse gas emissions by 37% below 2005 levels in 2025
- Reduction of greenhouse gas emissions by 43% below 2005 levels in 2030

Further specific measures aim at achieving this goal. These include:

- increasing the share of sustainable biofuels in the energy mix to 18% by 2030
- zero illegal deforestation by 2030 and restoring and reforesting 12 million hectares of forests by 2030
- 45% of renewables in the energy mix by 2030, in particular expanding the use of non-hydro power renewables
- strengthening the Low Carbon Emission Agricultural Programme
- increasing efficiency gains in electricity, transport and industrial sectors (UNFCCC 2015)

While the NDC document claims that these contributions are both fair and ambitious, as required by Paris Agreement, international measurement systems claim that Brazil is not on track to meet their NDC by 2025 or 2030 and that the NDC is insufficient to limit global warming to 1.5°C above pre-industrial levels (Climate Action Tracker 2020).

The results of the ICES model correctly represented the emissions levels and projected an increase of emissions by 2030 in both the current and enhanced NDC scenarios. This does not align with the intentions of the NDC to reduce emissions by 2025 and 2030, but the projection does reflect the current dynamic of Brazilian climate policy which allow emissions to increase, especially from deforestation activities.

3.2. Dynamics in Brazilian climate and environmental governance towards achieving the NDC

The climate policy measures specified in the NDC ground in existing policies and plans relevant for different sectors. The implementation of these plans depends on a larger system of environmental governance. This system has been weakened, over the course of 2019, as a result of a change in direction of Brazilian climate policy. Over the course of only one year, President Bolsonaro has dismantled significant institutions of the national environmental and climate governance system. Historically, Brazil's young democracy has developed a tradition of participatory processes, which allow for substantial public consultation and inclusion of different stakeholders (FBMC 2018, Observatório do Clima 2019).

The Brazilian Forum on Climate Change (FBMC) and the National Environmental Council (CONAMA) are central components of this participatory governance system. The Forum started a process to implement the NDC through nine technical branches since March 2017. The process involved about 500 people and was predominantly consensus based (FBMC 2018). President Bolsonaro dismissed

the President of the Forum, cut the budget of the ministry of environment and left the group "paralised" (Globo 2019).

The National Environmental Council (CONAMA) was also substantially weakened in its function as a consultative organ that oversees environmental policies. President Bolsonaro's administration changed the members on this council, which used to be a mix of government, interest groups and NGOs from 96 to 23, which include ten permanently appointed staff from the central government (Agência Brasil 2019). The Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) lost 21 of 27 state superintendents and its ability to fine offenders (Wallace 2019, personal communications and Rennkamp 2020 in D.4.4.).

Numerous public administration bodies, including the National REDD+ Commission, Executive Committees for deforestation control plans in the Amazon and Cerrado biomes, the National Commission for Native Vegetation Recovery, the Steering Committee of the Amazon Fund, the Steering Committee of the National Policy for Territorial and Environmental Management of Indigenous Lands, the National Council of Traditional Peoples and Communities, the Interministerial Committee on Climate Change, whose goal was to coordinate the implementation of National Police on Climate Change and articulate government actions relating to the Climate Convention and the Executive Committee and the Support Committee of the National Contingency Plan for Oil Pollution Incidents (PNC) have been dissolved or reduced in staff members and funding (Observatório do Clima 2019).

The prospects of implementation of the current NDC and of an update have been considered as unrealistic by all interviewees who were part of this study, because of the lack of deforestation control. The prospects the biofuel and renewable energy components of the NDC are comparatively more positive. Similarly, none of the interviewees could confirm the likelihood of a significant growth in GDP, which the model projected and would lead to growing labour costs in several sectors. One interviewee confirmed that the economy may recover from the current recession, as part of the common cycles of recession and economic growth, but there are no current signs of that would indicate this trend (personal communications).

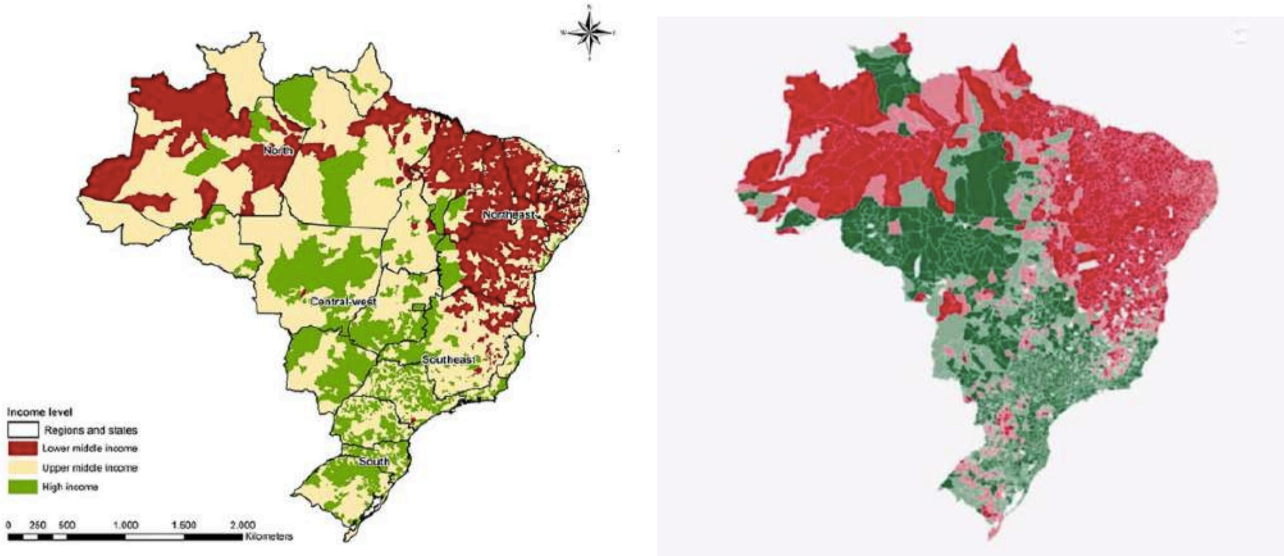
The next section will present further detail on the sectoral climate policies relevant to the NDC in the context of poverty and social inequality.

4. Relationships between 'rapid transitions', poverty and inequality in Brazil

Interestingly, the Brazil's poverty rates have been classified as higher than other countries with similar GNI at PPP over the years (Ferreira and Leitte 2008). Prior to 2003, Brazil was battling to fight poverty resulting in stagnant poverty rates during this period. Ferreira and Leitte (2008) partly attributed this to stagnation of the economy in Brazil in the 1980s. In the late 1980s and early 1990s, the country experienced a hyperinflationary environment and little GDP growth and poverty rates stagnated. This changed between 2003 and 2012 when a growth spurt kicked in resulting in significant poverty reduction. Between 2003 and 2012 under the leadership of President Lula, poverty decreased from 35.8% to 15.9% during this period and extreme poverty declined from 15.2% to 5.3%. These figures translated to 31.5 million and 16 million Brazilians, respectively, being lifted

out of poverty. Figure 11 shows the regional inequalities within Brazil, by income group of the municipalities. Figure 12 represents the regional inequalities in the vote of Brazil's nationals in the elections in 2018.

Figure 11 & 12: Income group distribution of Brazilian municipalities (Left); electoral map: Red vote for Haddad: Workers Party, Green: Jaír Bolsonaro (on the right)



Source: Vissocy et al (2019) based on scioeconomic data were extracted from Brazilian Institute of Geography and Statistic (IBGE), and used with the Brazilian gross domestic product to classify municipalities according to income groups as defined by the World Bank as high income, upper-middle income, or lower-middle income. The map of Brazil was freely obtained in shapefile format (SHP) through online access to the website of the Brazilian Institute of Geography and Statistics

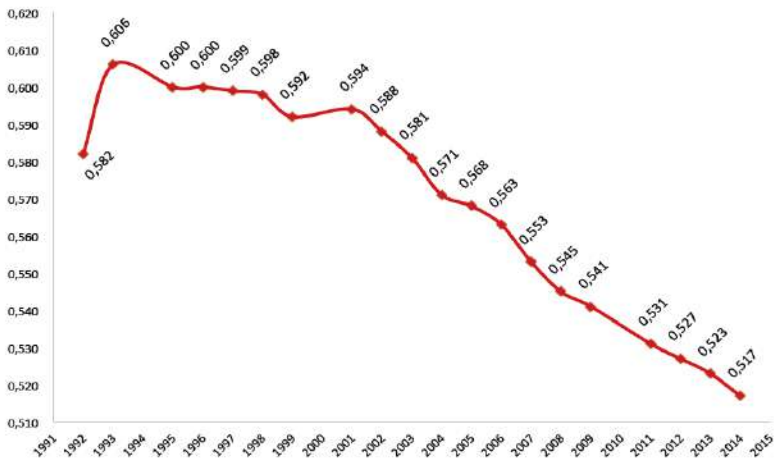
Source for the electoral map: O Globo.

The Brazilian government under the rule of the Worker's Party introduced a large-scale program for income distribution, known as *bolsa familia*, in the early 2000s. The program was designed to overcome extreme poverty and hunger. It has successfully reduced Brazil's steep income inequalities over time. The program also innovatively addresses gender inequality and explicitly makes the mothers in the families eligible to apply for the funds and spend them according to their assessment of the family needs. The funds are disbursed conditional on proof of children's school attendance and vaccination record. The successful implementation of the program has inspired an extension of a "green grant" (bolsa verde) and a "forest grant" (bolsa floresta), which aimed to transfer funds for forest protection and environmental services to families in need.

The country's Gini Coefficient has been steadily declining since 2001. Inequality on the other hand in Brazil between 2001 and 2016 reduced as a result of the increase in the number of people employed I the formal sectors of employment as well as the expansion of social protection in Brazil. At the same time in the same period even though inequality remained stubborn in the country. The reductions in poverty and inequality observed in the graphs above have been attributed to economic

growth in Brazil especially during the 'Golden decade' as well as social spending by the Lula government (Arnold 2014).

Figure 13: Brazil's Gini Coefficient (1992-2014)

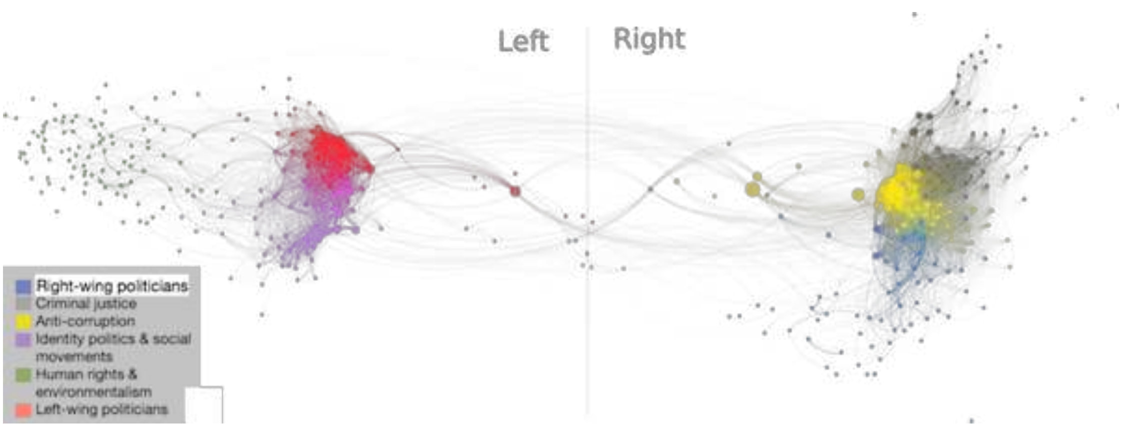


Source: Jannuzi and Souza (2016:32)

Why does *bolsa familia* matter for the question of social inequality and climate transitions? Firstly, the program is large and reaches many families.

The program supported 16.2 million people and this increased to 57.8 million in 2012, which is a quarter of the population. Secondly, it shows the regional and the political divide in the country between rich and poor, South and North. Thirdly, the program stands at the core of the political agenda of the Worker's Party, and at the core of many of the livelihoods of its supporters (Gallas 2016). Brazilian politics have severely polarized over the past few years, especially over the impeachment of President, Dilma Rousseff, Worker's Party, in 2016. The political left and the coalition of supporters of human rights and environmental issues have moved closer opposing the conservative right. (Ortellado and Moretto Ribeiro 2018).

Figure 14: Brazil's political polarization online 2016



source: Ortellado and Moretto Ribeiro, 2018

The *bolsa familia* program continues under the Bolsonaro administration to date. The environmentally linked programs, *bolsa verde* and *bolsa floresta*, have been abolished. President Bolsonaro has put environmental and climate politics at the center of his political agenda. Bolsonaro's U-turn on the past decades of climate policy hinges mainly on the devastation of the Amazon forest and the dismantling of institutions that protect the forest and the rights its vulnerable inhabitants. His approach to environmental policy found disapproval of 51% of Brazil's population, in September 2019 (DataFolha 2019). The climate related energy policies, in renewable energy and ethanol, have largely remained in tact. The following sections put the sectoral measures into perspective, acknowledging the dynamics of social, political and regional inequalities in Brazil, outlined above.

4.1. The biofuels and transport sectors

Biofuels currently make up 24% of the transport fuels (Climate Transparency, 2019). The trajectory for biofuels looks relatively positive, given the drop in global sugar prices, the historical evidence which suggests that biofuels policy and support is vulnerable both to changing oil and sugar prices, but also to political fluctuations, unbalanced power relations and election-oriented decisions (Grottera et al., 2019). In November 2019, the Bolsonaro controversially revoked a decree which erased limitations to the production of sugar cane in the Amazon. While some argue that this will allow for an increase in biofuel production, others argue that ultimately this decision will negatively impact exports in the sector, particularly to the EU, because of its new association with deforestation from which it was previously exempt (Hofmeister, 2019).

Biofuels have the potential to produce substantial employment benefits, which have already occurred in the past. Estimates of direct employment in the ethanol industry vary from 400 000 (Horta Nogueira and Silva Capaz, 2013) to more than a million (La Rovere, 2011) at different times. Ethanol is estimated to produce 32 times more jobs than oil per unity energy, because of the labour intensity in the agricultural sector (Horta Nogueira and Silva Capaz, 2013). Additionally, the vast majority of these workers is formally employed, and protected by extensive labour laws, unlike the most agricultural workers in Brazil (Moreas et al., 2010).

While the biofuel industry is likely to have positive effects on alleviating poverty for those able to get jobs, it has the potential to have much broader impacts on poverty and inequality through its effects on food prices. Following the 2007-2008 food crisis, this issue was brought to the fore of food security debates and was attributed as one of the key reasons behind the revision in biofuel policy (Timilsina, 2018). While the so-called 'fuel vs food conflict' is complex, varying according to markets, climate zones, policies, currency fluctuations and oil prices (Timilsina and Shrestha, 2011; Janda and Kristoufek, 2019), it is clear that there is a relationship between them whereby an increase in biofuel demand results in an increase in food prices, firstly through competition of the product itself (e.g. sugarcane or corn) and secondly through competition of land resources Timilsina and Shrestha, 2011. Increases in food prices are known to disproportionately affect the poor as they spend a high proportion of their incomes on food items. Therefore, increases in food prices have been shown to not only have detrimental impacts on poverty, but also have been shown to increase inequality (Ferreira et al., 2011).

The central policy to promote the production of biofuels, the RenovaBio program continues, to date. Biofuel producers have been recovering from the years of price control and achieved a new record in the production of biodiesel and ethanol in 2018 (EPE 2019). The composition of the coalitions in support and opposition to this program as well as its historical background have been analysed in more detail in Grottera et al (2019, in COP21 RIPPLES 4.4.). The expert interviews produced a consolidated view that this program is likely to continue in the future as it accommodates the central interest groups and serves the interest of the government.

Emissions reductions from ethanol and biodiesel used in light and heavy-duty vehicles, respectively, are likely to lead to emissions reductions in the transport sectors. In the long term, a strategy towards electric vehicles will be preferable because of the high share in renewable energy in the electricity production and benefits in air quality Regional inequalities are an important issue in a country as large as Brazil. (personal communications).

Transport is a central sector in Brazilian climate policy which requires significant investment in clean fuel technology, electric vehicles and road infrastructure. The sector literally connects people and is central for social cohesion. The poor communities often live either in remote areas, or in the outskirts of the cities. Social unrest often sparked over the increases for commuting prices, which have higher impacts on the lower income households.

4.2. The renewable energy sector

The renewable energy sector in Brazil also continues to grow. Wind auctions have been successful in increasing the share of onshore wind energy rapidly. As a result of the financial crisis in 2008, many actors in the wind energy industries found new opportunities in the Brazilian market. The power shortages in the Brazilian electricity sector in the early 2000s had created momentum for a program to diversify the energy mix from the dominance of hydroelectric power, known as PROINFA. PROINFA created a local champion in local wind energy technology development, but did not create a major influx of wind energy technology into the electricity mix. The program functioned on the basis of a feed-in tariff which left electricity wind energy comparatively expensive. The dynamics in the wind energy sector changed dramatically with the design of specific auctions (*leilões*). To date, Brazil has 619 installed wind turbines, which generate 15.4 GW of wind energy and produce 28 million tons of CO2, per year (Abeeólica 2020).

The National Brazilian Development Bank (BNDES) offered favorable loan conditions to the developers of wind farms if they were willing comply with sets of local content requirements. The implementation of these requirements ran not without complications, but it managed to create a local wind energy industry and significant employment benefits (See Rennkamp and Fortes Westin 2018, in D3.3.). The program also helped to ease regional inequalities, as many of the new installations are along the coastline of the North East of Brazil, which is the home to many low-income households in the need for employment. Assessments of the wind potential in Brazil show substantial area for increases in wind power which corresponds with the large suggested increase in Brazil's 10 year energy plan. The first procurement of wind energy came following the energy crisis of 2001. This 54% wind power plants, the vast majority of which are situated in the Northeastern parts

of the country (Ceará and Rio Grande do Norte). More than 85% of the wind energy produced in Brazil comes from the Northeastern region.

Wind energy projects have been widely accepted by the general public in the abstract, but frequently face local opposition (Brannstrom et al., 2017). In the case of one particular in-depth study by Janser de Azevedo Dantas et al. (2019), this opposition was due to the potential impact on other sources of livelihood, in particular artisanal fishing, environmental damage of the sand dunes and its ecosystems, reduced mobility or lack of access and consequential impacts on tourism. These negative impacts on traditional and alternative livelihoods could be found in different communities documented by Brannstrom et al. (2019). These negatives are generally counteracted by the desire for jobs and improved infrastructure. Janser de Azevedo Dantas et al. (2019) showed that while many agreed that jobs had increased, the majority occurred during the construction phase of the plants. Additionally, often it was not locals who were employed due to a lack of necessary skills. Therefore it is widely reported that affected communities are disappointed due to the lack of fulfilled promises and long-term jobs created (Araujo and Freitas, 2006; Brannstrom et al., 2016; Janser de Azevedo Dantas et al. 2019). Additionally, Gorayeb et al. (2018) report that local elites are able to manipulate processes to ensure that any benefits are concentrated amongst themselves.

More broadly, wind has been shown to create jobs. According to the International Renewable Energy Agency the wind industry is host to approximately 35 800 jobs in Brazil (Danish-Brazilian Chamber of Commerce, 2015). This has also been supported through policies such as local content requirements. Rennkamp and Westin (2008) found that an industry for low and medium technology components was created within the country, attracting a substantial amount of foreign investment, and the creation of at least 4 000 jobs (according to interview data), attributed to the local content requirements of the auction system. However, although there may be a net positive impact on jobs, it is essential to also understand the local impacts, particularly in areas such as the Northeast where poverty rates are substantially higher than the Brazilian average.

The success of the wind energy auction program has created impetus for an equivalent program for solar technologies, which has not implemented similar localisation requirements. The nature of the technology is different, the international prices have been declining and the benefits might be reduced to jobs for assembly rather than manufacturing, as experienced in other countries (see Baker and Newell, 2015 for an analysis of the case of South Africa.) The uptake of residential photovoltaic has increased significantly (EPE 2019). Controversies about the continuation of subsidies for solar photovoltaic power have eased, with a statement of President Bolsonaro in which he confirmed that the subsidies will stay. Distributed generation from solar photovoltaic technologies is still mainly affordable for the wealthy.

The characteristics of Brazil's nature and electricity system are favorable for integrating the generation of electricity from different renewable energy sources. There are examples where floating solar panels have on the hydroelectric dam are used to reduce evaporation and generate electricity. Wind technologies work well in combination with hydroelectric dams because they can provide electricity for pump storage which makes them very complementary. This technology is currently added to some of the old dams (personal communications).

Wind and solar photovoltaic technologies have diffused rapidly, from a very small base. The norm is still hydro-electric power, which has become increasingly unreliable because of the change in the rainfall patterns. The hydro-electric sector interferes with the protection of the Amazon rain forest, which is has the only significant sites left for the construction of hydro-electric power plants. The landscape is flat, which causes slow flow rates of water. As a result of the recession, public contestation and high cost of hydro-power plants several plans for the new hydro-electric plants have stalled. Building power plant infrastructure in places that are difficult to access, such as the Amazon forest, adds to the cost. Coal-fired thermal plants already had to compensate for generation losses from the Belo Monte power plant (personal communication). Coal is dominantly used in thermal plants. Currently there are 22 of these plants operating, adding less than 3 % to the overall electricity mix. However, coal consumption is growing, especially in the steel industries (EPE 2019).

Hydropower plants affect riparian biodiversity, water quality and flow for the inhabitants along the river and usually result in the displacement of communities (particularly indigenous communities) (de Souza Dias et al., 2018). Historically, an estimated 1 million people in Brazil have been displaced due to hydroelectric dam projects, with many being relocated into areas of far greater poverty (de Aruajo, 1990).

Most hydropower plants are in the Southeast and Midwest, where the potential for hydropower plants is already exhausted. The remaining potential for new hydropower plants is in the Amazon (Soito and Freitas, 2011). Whether this potential will be exploited is uncertain in the current political situation.

Hydro-electric power is highly vulnerable to the impacts of climate change. Increasing frequency and severity of droughts under climate change (de Souza Dias et al., 2018) have previously caused major electricity outages. Concerns have been raised about the efficacy and sustainability of building new hydropower stations. In 2001, when the previous droughts took place, generation had to be backed up by fossil fuel power, which resulted in an increase in tariffs. This not only affects consumers directly but also has the potential that more households disconnect from the grid and produce their own power, creating problems for the subsidization of poorer households.

4.3. Agriculture and forestry

The relationship between deforestation, poverty and inequality is complex and dynamic. While poverty is often attributed as a key cause for deforestation, satellite data suggests that the majority of deforestation in the Brazilian Amazon comes from large-scale land transformation, associated with vast agricultural expansion (Fearnside, 2005, Margulis 2004). Often this is for the sake of cattle ranching, which requires vast tracts of land but does not generate significant employment opportunities. For those conducting smaller-scale land conversion and illegal logging, deforestation can act as a key source of income and often results in poverty alleviation for those families involved (Guedes et al., 2012). This proportion of deforestation as a result of smallholders, while remaining less than that caused by large-scale conversion, has been shown to be increasing (Kalamandeen et al. 2018).

However, this also has a detrimental impact on the other long-standing communities who reside in the Amazon, including indigenous populations, riverine peasant communities and rubber tappers.

Deforestation has had a catastrophic impact on these communities, by removing their livelihoods, degrading their environment and thereby often forcing these populations into urban poverty (Carlos Diegues, 1992).

Brazil is home to large numbers of small-scale farmers who sell their produce locally. Programs in support of small-scale farming (*agricultura familiar*) have created a demand for these agricultural products. For example, schools source agricultural products from small-scale farmers in the region (FNDE 2020).

The ministry of Agriculture has introduced a plan to support "low carbon agriculture" which aims to promote the sustainable farming technologies that will help to reduce the carbon footprint. The Plan has seven quite detailed programs which include the recuperation of degraded pasture land, Crop-Livestock-Forest Integration, agroforestry systems, no-tillage systems, biological nitrogen fixation, planted forests, animal waste treatment and more generally adaptation to Climate Change. Each program performs specific action for technical assistance. The ABC Plan supports the implementation of the governments climate commitments of agriculture, signed at COP-15 (Embrapa 2020).

The ABC program runs as a credit line in support of agricultural actions in support of the implementation of the overarching plan. The Ministry of Agriculture has approved 2 billion Reais for this purpose (Embrapa 2020). Compared to the mainstream credit policy (Plano Safra), which has no environmental policy, the ABC plan is a minor initiative (personal communications). The beneficiaries of the program predominantly live in the South and the Central Regions of the country (Embrapa 2020).

In sum, many of the sectoral climate policies, especial in the biofuels and renewable energy sectors, continue under the Bolsonaro administration. The large *bolsa família* program is also continuing, but smaller programs that link environmental and social policy have been abandoned.

5. Conclusions

The Brazilian government put progressive social policies into place, which have led to a continuous reduction of income inequality, extreme poverty and hunger over the past 15 years. Social policies in different sectors have been impactful in overcoming social and regional inequalities. Many of these programs were successfully linked to environmental policy, in providing payment for environmental services and forest conservation into the pockets of the poor. These achievements rely institutions on a fragile democratic system. The damage Brazil's institutions central to participative environmental governance in only one year of the rule of the far right has been impactful on the emissions targets, the implementation of the NDC as well as social cohesion and inequality within Brazilian society.

Brazilian society has a number of historical inequalities emerging from a colonial past, the rural urban divide, regional inequalities which are hard to overcome because of the size of the country. Income inequality has been declining, but there is still a long way to go. The current political dynamics suggest that there will be a regress, rather than progress in greenhouse gas emissions. A similar dynamic has been witnessed for social inequalities and cohesion. Climate change stands at the core of the political debate.

On the positive note, the renewable energy and biofuel programs continue successfully, which also generate employment benefits in agriculture and manufacturing. Unfortunately, emissions reductions from these programs will be overshadowed by the lack of control of deforestation and the growth in the coal, gas and oil sectors. An 'enhanced' NDC scenario is unlikely, as to date, there is no process in place for an update.

The sectoral composition of emissions sources and the ways these sectors interlink create quite unique challenges for climate governance in Brazil. The current administration under Jaír Bolsonaro is in the process of putting Brazil in a similar position of a high forest emitter where it was in the early 1990s. The international community, especially the EU, will have to embrace these challenges and reconsider the ways collaboration can work with the current administration. Trade sanctions for agricultural product may be a way to reduce the support of the President. If he continues to encourage the devastation in the Amazon without facing any consequences, the global temperature goal will move further out of reach.

A further challenge emerges for research work in modeling of the distributional impacts of sectoral transitions.

6. List of Interviewees

1. Professor for Energy and Climate Policy, Federal University of Rio de Janeiro
2. Senior Researcher, Energy, Climate Change, Modelling, Federal University of Rio de Janeiro
3. Senior Researcher, Energy, Climate Change, Federal University of Rio de Janeiro
4. Professor in Economics, Federal Institute of Rio de Janeiro
5. Professor in Economics, Federal University of Rio de Janeiro
6. Professor Energy, Climate Change, Federal University of Rio de Janeiro
7. Senior Researcher, Hydro- and wind energy, Federal University of Rio de Janeiro
8. Manager, Empresa de Pesquisa Energetica, Brazil
9. Former Manager, Community development, Petrobras
10. Journalist, O Globo

The interviewees were assured to remain anonymous.

4. Case Study 3: Impacts of climate change mitigation policies on economic and gender inequality in the UK and three regions of Europe

Authors: Giacomo Piccoli, Alvaro Calzadilla Rivera, Lorenzo Lotti, Susanne Helm and Annela Anger-Kraavi

1. Introduction

The 2018 IPCC report highlights how current national determined contributions – as set out in the Paris Agreement – are not consistent with keeping global warming below 2°C higher than pre-industrial levels (IPCC 2018). Consequently, urgent action is needed to tackle the problem of global warming, thus supporting a sustainable development of countries and eradication of poverty. Policies of this type are referred to in the Paris Agreement as 'just transition'. The idea behind it is that policies tackling climate change will create benefits which should be fairly distributed among individuals in a society, so that no one is left behind (Robins *et al.* 2018). Transitioning to a less emission-intensive economy, however, also entails adverse side effects. These are likely to impact significantly those employed in the sectors most strongly hit by climate change mitigation policies (CCMPs hereafter).

In particular, there are grounds to believe that CCMP adverse side effects may pose a threat to countries' inequality. This topic has received little attention in the literature so far, as Markkanen & Anger-Kraavi (2019) highlight – especially so from a quantitative perspective. This section aims at starting to fill this gap in the literature.

This section analyses the impact of climate change mitigation policies on inequality in the UK and in three regions of Europe: Western European, Eastern European, and Former Soviet Union countries. The analysis relies on data from a Computable Generable Equilibrium (CGE) model, from Eurostat, and from existing literature on the topic. Although the data available to us make it easier to discuss economic (income) inequality, gender inequality will also be discussed. The latter type of inequality concerns the gender (im)balance in different sectors of the economy, and how this will be affected by CCMPs.

The structure of this section is as follows. Section 2 gives a brief presentation of ENGAGE, discussing some shortcomings. Section 3 describes the scenarios considered. Section 4 discusses the impact of CCMPs on the UK. Section 5 discusses the impact of CCMPs on other regions of Europe. Section 6 contains concluding remarks.

For the reader's convenience, an Annex of Tables and several Appendices of Figures are included, which contain the tables and figures referred to throughout the section.

2. A description of the model: ENGAGE

Most of the results presented in this section are derived from the Computable Generalized Equilibrium (CGE) model ENGAGE – ENvironmental Global Applied General Equilibrium. ENGAGE models 23 sectors and 16 regions. A complete list of sectors is found in **Appendix 1**. For the purposes of the present section, 4 regions were considered: the UK, Western European (WEU) countries, Eastern European (EEU) countries and Former Soviet Union (FSU) countries. A precise list of WEU, EEU and FSU countries is given below, in **Section 5.1**.

ENGAGE assumes a future of global climate cooperation and models a global carbon price aimed at reducing regional emissions per capita to match the emission trajectories determined by another model, the TISM-UCL – TIMES Integrated Assessment Model, of University College London.

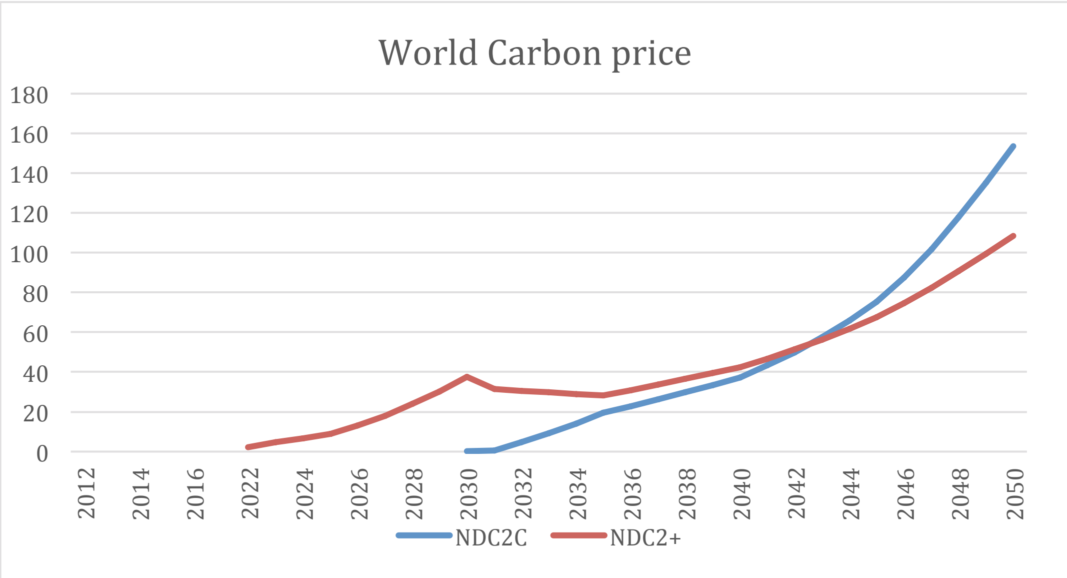


Fig. 1 World Carbon price, in million US dollars. Source: ENGAGE

The carbon price increases the cost of fossil fuel. Therefore, sectors which make a particularly heavy use of it, will seek alternative inputs to their production to minimise costs. Due to this moving away from fossil fuels, ENGAGE must also model the development of renewable energy and the electrification of the economy, which occur endogenously and are outputs of the modelling. **Fig. 1** is a graph representing the world carbon price.

The elasticity of substitution – i.e. the 'easiness' with which two production inputs can be substituted with each other – between electricity and other energy inputs, both in all 23 sectors and in households, is assumed to increase gradually. At the same time, energy efficiency is also assumed to improve gradually.

ENGAGE does not take into consideration damages deriving from climate change. So, the information this model gives us is only a part of the broader picture of CCMPs costs. For a more extensive description of ENGAGE, the reader may wish to refer to Winning *et al.* (2019).

Although insightful, ENGAGE presents a few limitations which have been tackled in different ways. These are mainly related with its assumptions of full perfect labour mobility and no unemployment. They will be briefly assessed in turn.

Full perfect labour mobility means that workers are assumed to move freely across sectors and within regions (UK, WEU, EEU and FSU). As a natural consequence, wages within the same country of region of Europe are the same across sectors. This does not allow for a heterogeneous distribution of incomes, which is necessary to understand equality in a particular region. For this reason, additional data was taken from Eurostat and combined with output from ENGAGE to obtain measures of inequality in the form of Lorenz curves and Gini coefficients

No unemployment means that ENGAGE assumes that everyone is in employment – in all years and scenarios. Again, this assumption is troublesome for two reasons. One, it is unlikely to hold in real life – there always exists some unemployment (if anything, structural unemployment). Two, it biases our considerations on inequality. If ENGAGE assumes that no person is unemployed, then no person is on a zero income. In real life, however, this is not the case: there are people on a zero (or very low) income. So, from an inequality perspective, ENGAGE risks delivering a picture of a more equal society than it would be in real life if unemployment were considered. For this reason, when discussing Lorenz curves and Gini coefficients, a distinction was made whether unemployment was counted in or not.

2. Description of the scenarios

This section will refer to three scenarios as follows: NDC (so-called Current NDC in the context of the COP21 RIPPLES project), NDC2 (so-called Enhanced NDC) and NDC2+ (so-called a P1-P2 equivalent 1.5C). NDC stands for Nationally Determined Contributions and represent the set of actions which signatory countries of the Paris Agreement communicated to the United Nations in 2015 in order to keep global warming by 2050 to 'well-below 2°C' compared to pre-industrial levels.

3. Inequality trends in the UK

3.1 ENGAGE results on sectorial impacts of CCMPs: preamble

In this section, we will assess what sectors and regions of the UK will be most affected by CCMPs. We will also gain some insights on their impacts on inequality (of income and gender) in the country. We will use information coming from ENGAGE, in which two different policy scenarios are compared against a baseline scenario. The former two are NDC2 and NDC2+, whereby CCMPs are implemented after 2030 or before 2030, respectively. The latter, NDC, is the "business-as-usual" scenario, whereby the current policies are kept unchanged. Our considerations will be coupled with data from Eurostat to help us better understand where CCMPs effects are likely to impact more strongly.

To begin with, it may be helpful to have an understanding of the relative importance of the sectors included in ENGAGE in the UK economy. Table 1 presents the relative shares of employment in 2011 in the twelve NUTS1 regions of the UK. We focus on 2011 because it is taken as baseline year in ENGAGE, so this should help consistency of interpretations.

NUTS 1 – the acronym of *Nomenclature des Unités territoriales statistiques* 1 – is an administrative division of EU countries into regions used for statistical purposes. These regions have a population of approximately 800 thousand to 3 million individuals. For the UK, these regions are: Greater London, South West, South East, East of England, Wales, West Midlands, East Midlands, Yorkshire and the Humber, North West, North East, Scotland and Northern Ireland. These are represented in **Fig. 1**.

Fig. 1 UK NUTS1 division. Source: European Parliament (2019)

3.2. Results for effective labour supply (employment)

In terms of effective labour supply, a rapid inspection of Table 1 reveals that transport, manufacture of fabricated metal products and manufacture of food products have among the largest shares of employment in the country. These figures sum up to roughly 41% of employment in the sectors considered. Are these sectors likely to suffer significantly from the implementation of CCMPs? It shall be useful to turn out attention to ENGAGE results as well.

Table 2 shows the percentage changes in effective labour supply between 2011 and 2030, and between 2011 and 2050 under the three different scenarios – NDC, NDC2 and NDC2+. It should be stressed that ENGAGE uses a measure of effective labour supply, whereby considerations on

workers' efficiency are also accounted for. Eurostat, instead, simply gives the figures of individuals employed in certain sectors.

Table 2 suggests that the sectors mentioned above will not incur significant drops in terms of effective labour supply. In fact, the agriculture and food sector seems to experience an increase in effective labour supply in all periods and under all scenarios. The minerals sector's effective labour supply, instead, will decrease approximately by slightly more than 50% by 2030 under all three scenarios, but by approximately 90% in 2050 under all three scenarios.

However, ENGAGE is better suited to compare policies against one another. This is why we now compare alternative CCMPs against the baseline policy, i.e. NDC2 and NDC2+ outcomes (alternative policies) against NDC (baseline policy). This is done in **Table 3** for 2030 and 2050. This table shows the ratio of effective labour supply in 2030, or 2050, under NDC2 or NDC2+, to effective labour supply under NDC in the same year.

A more careful inspection of this kind of table reveals a different situation than outlined above. Take the agriculture and food sector, for instance. Under this interpretation, we can see that effective labour supply in 2030 under NDC2 and NDC2+ would basically be the same as under NDC. However, if we move our attention to 2050, we notice that under both scenarios effective labour supply is 2% or 3% smaller than under NDC.

It is interesting to compare the outcomes in 2030 under NDC2 and NDC2+. In most cases, effective labour supply differences are much more accentuated under NDC2+ than NDC2 – whether they be positive or negative compared to the baseline. This makes sense if one keeps in mind that NDC2+ assumes that policies to keep temperature increase within the 2 degrees limit will be implemented before 2030. This is not the case for NDC2, where such policies are assumed to be implemented only after 2030.

For instance, take the case of wind and solar powers. Under both scenarios, ENGAGE shows that effective labour supply in these sectors will be higher than in the BAU scenario. However, notice how this difference becomes striking when we move our focus from NDC2 to NDC2+. If in 2030 effective labour supply under the NDC2 scenario in the wind and solar power will be 9% and 10%, respectively, higher than under the NDC scenario; this will be 62% and 112%, respectively, higher under the NDC2+ scenario compared against the baseline scenario. A similar argument, although in the opposite direction, holds for sectors such as gas, coal, coal-fired or nuclear power where effective labour supply in 2050 can be up to 97% less in the NDC2+ scenario compared against the baseline scenario.

3.3. Results for output

At this point, it is interesting to keep our focus on these sectors – which are reasonable to assume to play an important role in the transition towards less carbon-intensive technologies, either by expanding or shrinking. However, it is insightful to see if there may be a similar trend in terms of output. **Table 4** shows how output changes between 2011 and 2030, and 2011 and 2050 under all three scenarios.

A quick look at the wind and solar power sectors reveals that a positive trend is also observed in output, whereas a negative one is observed in the other sectors mentioned. Notice the impressive percentage growths between 2011 and 2030, or 2011 and 2050 in the wind and solar power sectors – of up to more than 40000%. Conversely, sectors such as coal, gas, and coal-fired power experience decreases of almost 100%. This is in line with the anticipations highlighted in the case study note. However, two major points of carefulness should be stressed.

The first one, is that the solar and wind power sectors are relatively modest sectors now and if they represent a valid alternative to transition towards less carbon-intensive economies, then the massive growths shown in the table simply reflect the fact that a very modest sector will expand significantly in the future. If I have half cookie today, but six cookies tomorrow, the number of cookies will have grown by 1100%, yet I still find myself with six cookies.

The second one, is that again this is not the most appropriate way to interpret ENGAGE results. We shall draw our attention to **Table 5**, where the more environmentally stringent policies are compared against the baseline policy, in 2030 and 2050.

A closer look to this table reveals that, even by studying ENGAGE's results from this perspective, still remains the fact that the wind and solar power sectors will experience a much higher output in both 2030 and 2050 when compared against the BAU scenario. For example, in 2050 the wind power sector output will be more than 2000% bigger than the NDC scenario. On the contrary, notice that output in the coal, gas and nuclear power sectors will be much lower in 2050 under the more stringent scenarios than in the baseline scenario – again, with percentages approaching almost 100%. This is again in line with the sectors highlighted in the case study note.

3.4. Implications for employment: issues of re-skilling and relocation

We somewhat narrowed down our attention to a few, specific sectors: renewable energies on the one hand (solar and wind power), and carbon-intensive energies on the other (coal- and gas-based energies) – in line with the idea that a carbon price will affect the most carbon-intensive sectors. The former will, broadly speaking, expand, whereas the latter reduce significantly. This implies that it is the latter which may pose some issues to the policymaker in terms of understanding the impact of such change on the people employed in more carbon-intensive sectors.

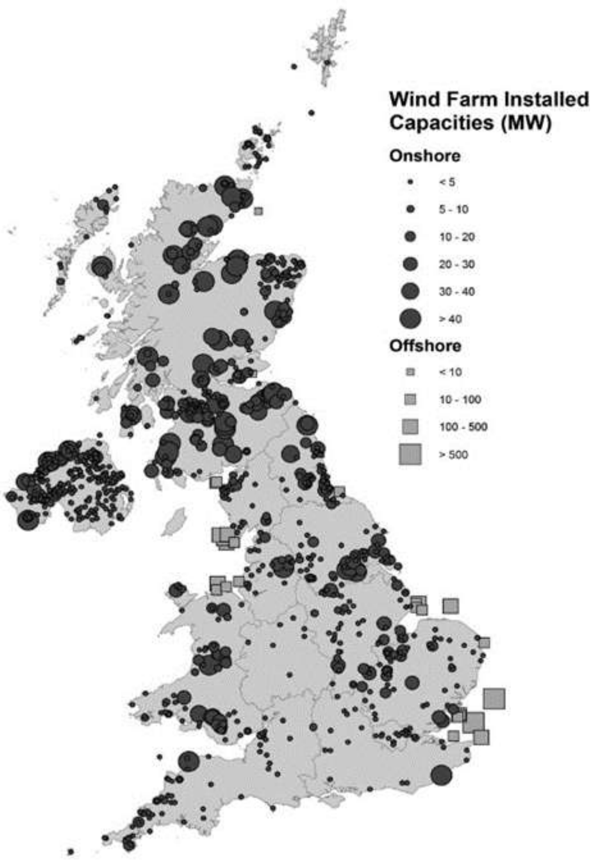
The reader should recall the data presented in **Table 1**. Notice that Yorkshire and the Humber has the highest share of people employed in the mining of coal and lignite sector, followed by Scotland. These two regions together account for slightly less than half of the total workforce employed in this sector in the UK. Moreover, Scotland also has a massive 60% of individuals employed in the extraction of petroleum and natural gas, a sector which will shrink significantly by 2050 if the more environmentally stringent policies will be enacted (see **Table 3** and **Table 5**).

Are there any possibilities for this workforce to be re-absorbed? Potentially, there might be room for their re-employment. ENGAGE suggests that the wind power and solar power sectors will experience a massive growth in employment, especially so under scenarios NDC2 and NDC2+.

Wind power in the UK accounted for 17% of total electricity produced in 2018 (Department for Business, Energy & Industrial Strategy 2019a:112), a figure anticipated to rise to 30% by 2030 (Department for Business, Energy & Industrial Strategy 2019b). **Fig. 2** shows the location of wind farms in the UK, on- and off-shore.

These are mainly located in Scotland, Northern Ireland, and, to a lesser extent, Wales, Yorkshire and the Humber and East Midlands. Perhaps surprisingly, a huge potential for creating new jobs is held by off-shore wind farms. A report commissioned to Cambridge Econometrics in 2017 gives predictions on direct, indirect and induced employment generated by the development of new off-shore wind farms (Aura 2017). The report assumes that wind power will increase from about 5.1 GW in 2016 to 20 GW by 2030 – by almost 400%.

Fig 2. Location of on- and off-shore wind farms. Source: LSE (2016).



In terms of direct employment, the report gives a range of predictions which vary between 17500 and 25000 full-time equivalent jobs by 2032, from a starting figure of 10000 in 2017. The range of estimates is because different scenarios are modelled – one in which demand for wind energy will drop in the near future, one in which it will keep steady, and one in which it will accelerate (ibid.,8). Indirect employment is estimated to increase by 10500 full-time equivalent jobs by 2032. Induced employment is anticipated to grow 5000 full-time equivalent jobs in the same time horizon. For the sake of clarity, by indirect employment the report refers to "those jobs outside of the offshore wind

energy sector but which are part of the supply chain sector" (ibid.,3). By induced employment, the report refers to all employment created due to higher wages paid to workers (ibid.,3). **Fig. 3** gives a visual representation of the distribution of full-time equivalent jobs across the UK in 2011 and 2032, by NUTS1 region.

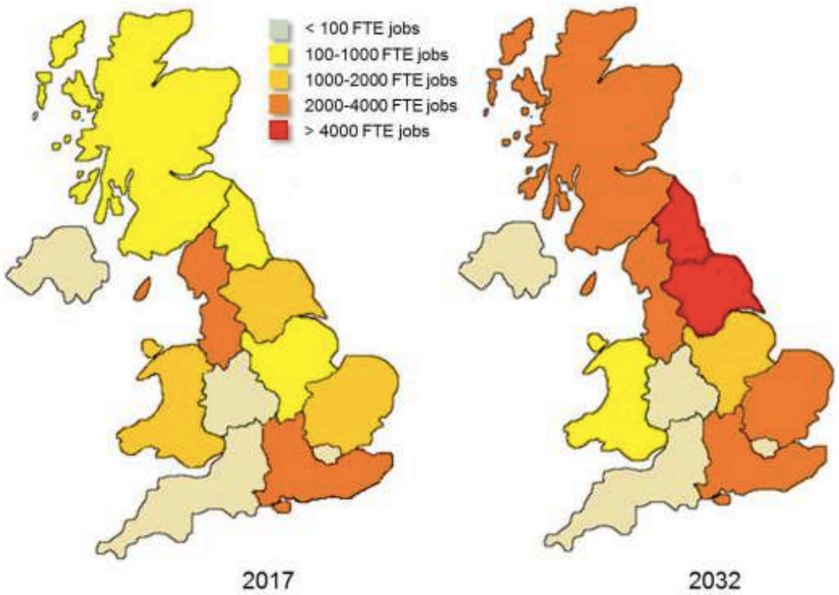


Fig. 3 Distribution of full-time equivalent jobs in the UK. Source: Aura (2017:16).

A rough estimate of the number of jobs which will be likely lost in the coal and gas sector can be obtained by coupling ENGAGE data with Eurostat statistics. More on this will follow in subsequent sections. For now, it suffices to say that this estimate is around ten thousand jobs. Of course, this figure must be taken with a (rather big) grain of salt. The reader can however see that, in theory, there exist opportunities for re-employment.

The Department for Business, Energy & Industrial Strategy (2019c) also releases data on the location of solar farms in the UK. **Table 6** summarises the location of the farms deemed as 'Operational' by said Department. It also includes the aggregate measured total power of these farms. The data was up-to-date as of December 2019.

At the aggregate level, Scotland produces the highest quantity of solar electricity – about a quarter of the total UK production, according to Department's data. Following immediately after, in terms of power, are all off-shore solar farms, which account for a fifth of the total UK production. So slightly more than half of the remaining solar electricity of the country is produced in other regions of the UK. According to the same data, some other 85 solar farms are currently under construction, the majority of which in the South West and in Scotland. Although precise data on the employment

opportunities of solar farms, or solar-energy production-related jobs could not be found, there is room to believe that the expansion of this sector will indeed generate new jobs.

If the production of wind- and solar-power energy hold the potential to create new jobs, why would it be difficult for these to be filled? Two major reasons come to mind. On the one hand, there is an issue of skill mismatching: people currently working in carbon- or oil-related sectors may not have the adequate skills to move to 'greener' sectors, unless they are re-trained. On the other hand, there is an issue of physical and geographical relocation: new jobs may be available but not necessarily in proximity.

As far as re-skilling is concerned, it is easy to see where its need comes from. Carbon- and oil-related workforce likely consists of blue-collar individuals trained for physically demanding tasks. Solar or wind farms may have a limited need of this type of personnel and are likely to need other expertise – for example people with an engineering background, or individuals in R&D for the development of new farms. Although literature on this topic is still very little, fortunately enough it does not look like so bad after all for blue-collar workers. Bowen *et al.* (2018:264) recognise that green jobs, in general, require higher skills than non-green ones, and are less routine-intensive. Nevertheless, they do not find it unfeasible for individuals currently employed in non-green jobs to obtain skills adequate to green jobs. They even find that most of the re-training 'can happen on-the-job […] if job transitions are strategically managed" (ibid.,264). Estimates from the Grantham Research Institute on Climate Change and the Environment suggest that "[…] 10% of UK jobs are likely to require reskilling' (Unsworth *et al.* 2019:6). This should be one of the policymaker's primary focuses for action (Project Heather 2019).

Of a similar stance are Malamatenios (2016) and Botta (2018). In particular, the latter highlights that many of the skills characterising 'brown' jobs can be easily transferred to greener jobs with no need for a complete re-training. A 'top-up' may often be enough. The UK Government seems to have shown awareness of this issue and created a national plan to support those employed in these sectors who lose their jobs (HM Government 2016). Some of the actions taken by Government vary from creating ad-hoc online platforms facilitating job search and skill matching (Talent Retention Solution, Skills Connect), to creating loans for vocational or training courses (Advanced Learner Loans) – similar to the student loans already available for tertiary education.

As far as relocation is concerned, the data presented above points to the direction that this may also be an issue for the re-employment of workers losing their jobs in carbon-intensive sectors. These are mostly concentrated in Scotland and Yorkshire and the Humber. Nevertheless, although many employment opportunities are potentially offered in these regions by the wind- and solar-power sectors, it is unlikely that they will be taken by workers currently employed in regions far away from the geographical location of new jobs.

Although ENGAGE assumes that workers are free to move between sectors, this assumption is pretty strong and unlikely to be met in real life. Relocation is a friction in labour market. Scotland and Yorkshire and the Humber are relatively close. Because Scotland offers anyway significant opportunities of re-employment in the renewable energy sector, it may be feasible for a Scottish or Yorkshire worker to relocate in Scotland. However, if for instance we look back at **Fig. 3**, the South

East or East of England also offer opportunities of full-time equivalent jobs in the wind-power sector. In this case, the prospect of relocation and the costs associated with it – moving to a new city, meeting new acquaintances, getting used to the new city's environment – may deter someone from accepting a new job there.

3.5. Examples from the research literature on the CCMPs impact on inequality

Because ENGAGE cannot give direct information on the impact of CCMPs on inequality, we need to turn to existing literature on the topic to understand what might happen. Markkanen & Anger-Kraavi (2019) discuss this issue already, stressing that the literature on the adverse side effects of CCMPs on inequality has only gained momentum since the second half of 2018. They also offer a review of the literature on the topic, focusing on 'outcome-based aspects of equity' (ibid.), a concept presented by Reckien *et al.* (2018:175) which refers to 'the consequences of a policy, action, or developmental trend, which is acknowledged to be important for both low- and high-income countries'.

Because Markkanen & Anger-Kraavi (2019) offer already a review of the literature, the interested reader may wish to refer to their section to have a broader view of the research on the topic. Moreover, they also stress that little attention has been devoted to quantitative analysis of the issue (ibid.,831). For these reasons, this section focuses mainly on quantitative studies, presenting a selection of case studies which are helpful in illustrating how CCMPs can adversely affect inequality.

An important point which ought to be made at this stage is that inequality can take on different forms besides economic inequality. For instance, Markkanen & Anger-Kraavi (2019) present three additional types of inequality: health, gender and ethnic inequalities. Due to time constraints and scarcity of quantitative works concerning ethnic and health inequality in the UK, following are examples of economic inequality and gender inequality.

3.5.1. CCMPs and regional economic inequality in the UK

3.5.1.1. The Welsh case

Past experience concerning the 'decarbonisation' of the UK may be insightful as to the consequences of moving the country towards less carbon-intensive technologies. During the Eighties different coalmines in the country were shut by the government – although the reason then was for the government to dismiss unprofitable businesses. Nevertheless, the effects on labour market of phasing out coal have been studied and some 'guidelines', at least, can be taken to have an idea of the consequences of turning to more environmentally friendly technologies in the UK.

The closure of coalmines in the Valleys (South Wales) accelerated a phenomenon of outmigration which had already been happening for a few years. This was particularly true of high-skill individuals, possibly aged up to 24 or between 40 and 49 (Merrill & Kitson 2017). Several attempts were made, e.g. in the form of fiscal incentives and tax relief schemes, for new businesses to be established in the Valleys. However, 'job creation could only succeed if located at the mouths of the Valleys and not in the Valleys themselves' (ibid.,15). Therefore, an unwise location choice, coupled with the general economic recession hitting the UK during the Eighties, was (partly) responsible for the failure of re-employing the labour force released from the coalmines dismissal. Several different projects,

supervised at either the local level by the National Assembly for Wales – which would only be created after the 1997 devolution referendum – or the general level by the European Union, have been put forth since the coalmines closure. Even so, some of these have devoted their attention to 'large prestige projects that did not maximize the generation of employment opportunities', having failed to directly address the needs of the Valleys (ibid.,20).

Interestingly, according to the same authors, the Valleys was suggested as a potential location for the installation of wind turbines. The residents rejected these ideas. This reluctance is apparently contrasting with other research conducted on the matter. Devine-Wright (2005), lamenting a lack of literature on the topic, conducts a qualitative, on-the-field research of residents attitudes towards projects of wind-power farms establishment in South Wales. This area is part of the same region as the Valleys, mentioned above.

Contrary to Merril & Kitson's accounts, Devine-Wright finds that the sampled local community seems to be supportive of establishing a wind farm in the region. This seems to be true, however, subject to three major conditions (ibid.63):

(i) That it be developed partnering up with local communities;
(ii) That the energy produced be destined to the local communities;
(iii) That profits generated be used at the advantage of the local communities.

Devin-Wright's preliminary study then seems to suggest that the establishment of renewable energy plants may not encounter a very strong opposition, if it is carefully embedded within the fabric of the local community. This seems to be especially true in case of South Wales (or the Valleys), as it is a relatively more economically deprived area, which has experienced a few years of economic decline. However, the author stresses an important limitation to his study. The interviewed sample likely consists of people who were, or have been, employed for a long time in the energy sector (e.g. coal mining). The particular vicissitudes of such sector, and its geographical area, may have somehow influenced their current beliefs about locally developed renewable energy projects – thus posing, in a sense, a problem of sample selection. Devin-Wright's results may thus be only limitedly generalisable to other regions of the UK characterised by a similar socio-economic pattern. Nevertheless, even if only so, investments in local projects of establishing renewable energy sources in a certain struggling region, may prove beneficial to its recovery (Houghton 2000).

3.5.1.2. The Scottish case

Another important aspect related to the dismissal of carbon-intensive energy sources is highlighted by EKOS (2014), which drafted an exploratory report on the consequences of ceasing opencast mining operations in East Ayrshire (Scotland). Besides the problems of geographical relocation and re-skilling already mentioned, EKOS stresses the importance of keeping in mind the businesses connected with the coalmining industry. In case of East Ayrshire, interviews with local businesses revealed that, in some instances, up to 55% of their turnover was due to the activity at the mine (ibid.,25). However, responses were very varied in terms of predicting the consequences of the loss of such turnover – for example, some business owners were anyway planning to retire, thus terminating their businesses.

The impact of the dismissal of opencast coalmining in East Ayrshire is likely to be borne by the broader supply chain too. According to the same exploratory report, the expenditure in businesses involved in the mines' supply chain ranged from £60 thousand to £9.7 million (ibid., 27). The closure of the mine will have negative consequences on the activities embedded within its supply chain, and a knock-on effect on their suppliers in turn.

3.5.1.3. The smart meter case

Markkanen & Anger-Kraavi state that '[t]he concept of 'just transition', which emerged to stress the need for equity and fairness to underpin the transition to a low-carbon economy, has also gained momentum over the past few years' (ibid.,829). This is particularly evident in the ILO policy brief, which stresses the importance for different actors at different levels in the economy to guarantee a 'just transition' to individuals (ILO 2018). Sovacool *et al.* (2019) consider different types of justice of decarbonization. In particular, they identify for types of justice: distributive, procedural, cosmopolitan and recognition justice. Through the lens of these types of justice, they analyse a choice of policy interventions aimed at facilitating decarbonization of the economy in different countries. For the UK, they choose to focus on water smart meters (**Fig. 4**). These devices keep track of households' water consumption, and regularly send data to the water providers. As a result, households be charged only for their actual consumption of water. Moreover, it should help households and water suppliers identify more easily potential leakages in the water pipes (Thames Water 2020).

Fig. 4 A water smart meter. Source: Thames Water (2020)

The UK Government has promoted the installation of smart meters for a few years. According to the Department for Business, Energy & Industrial Strategy (2019d), as of September 2019 there were 15.6 million smart meters across Great Britain. Does this policy facilitate a just transition towards a greener economy?

Sovacool *et al.* raise an interesting point: Assuming that smart meters lower households' bills, this is advantageous for them. However, if one keeps in mind that (part) of the utility bills is normally used to promote such activities of improvement of the national water infrastructure (or any other utility infrastructure), a lower bill means a lower contribution. In turn, this is unjust to those who, for instance, do not possess a smart meter yet. Are smart meters still just?

This example – which is rather reminiscent of a thought experiment – is not really a quantitative work. However, it was included as an *excursus* to make the case that addressing CCMPs-related inequality is troublesome, both from a policymaking point of view, but also from an ethical one. Positive and normative considerations inextricably interact with each other, conditioning the policymaker's set of feasible actions and, clearly, their impact on people.

3.5.1.4. The carbon-intensive food expenditure case

Zachmann *et al.* (2019) address the issue of food footprint. They find that in the financial year 2016/2017, high-income and low-income households' expenditure on food only differed by 19% – although the disposable income of the former group is 150% higher than the latter's. A classical way to disincentivize the consumption of carbon-intensive food is by means of a tax. However, the burden of this tax depends on each group's expenditure share on such type of food. If, proportionately, the lower-income households spend a higher share of their incomes on carbon-intensive food, clearly the impact of the tax will be heavier for them.

Nevertheless, the authors find that this should not be the case. In spite of different available budgets, low- and high-income generate the same amount of emissions per pound spent on food (ibid.,56). So, overall, taking into consideration each group's food expenditure patterns, a carbon tax on carbon-intensive food would not have worsening distributional effects. However, the authors stress that such tax would anyway be of a regressive nature in principle. That is easy to see. Food is a necessity. As such, low-income households cannot really vary the budget allocated to food. If a tax is imposed on food, this will proportionately affect them heavier than high-income households.

3.5.2. Gender inequality

Transitioning to less carbon-intensive energy sources poses potential problems of inequality which go beyond the most evident economic ones. The mining industry workforce is normally made of males mostly (Macdonald 2017). For this reason, economic shocks stemming from mine closures may impact men and women differently. Aragón *et al.* (2015) suggest that coalmines closure may lead to an increase in gender inequality.

Their claim uses the coal mine closures of the Eighties, and argues that this has a differential employment impact by gender. They implement a difference-in-difference strategy, taking advantage that relatively homogeneous geographical areas of England and Wales were characterised by the presence of an active coal mine (treatment), or an absence of it (control). The identifying assumption is hence that, absent mine closures, employment trends would have been the same in both areas with or without an active coal mine.

Their study hinges on the following central assumptions:

A1. There are two sectors: mining and manufacturing;
A2. Males are perfect substitutes in mining and manufacturing, but women can only work in the latter.

The closure of coalmines reduces the number of males working in such sector, and their wages thereof. This, in turn, creates a comparative advantage for males: their relative wages are lower than

women's. Because by A2 men can work in both sectors, they will be employed in manufacturing, thus 'pushing out' women. They find that each mine closure is associated with a 0.76 percentage points reduction in manufacturing labour share for women. As they put it, '[..] re-allocation of labour across industries […] can attenuate the negative effect on male employment, but creates a negative spill over on female workers' (ibid.,16).

3.6. The evolution of inequality: ENGAGE perspective

However interesting or insightful, experiences for the past cannot really predict how inequality will change in the UK in the future – although useful lessons can be learnt. Unfortunately, the results from ENGAGE do not allow us either to directly understand how economic inequality will change depending on the policy scenario. If anything, this is so because ENGAGE assumes full mobility of labour across the country and across sectors. This, in turn, implies a unique wage which is paid to workers. Hence, it is impossible to obtain a distribution of salaries from which conclusions on inequality can be drawn.

Nevertheless, ENGAGE gives information on the distribution of effective labour supply across different sectors and throughout time. In each year, the total sum across sectors of effective labour supply is the same under all three different policy scenarios. What changes is how the addends of this sum are distributed across different sectors.

Table 7 presents the sectorial distribution of effective labour supply under all three policy scenarios in 2011, 2030 and 2050. From this table we can see that the agriculture and food sector's share of total effective labour supply increases in 2050 under all three policy scenarios. Similarly, the wind and solar power sectors' shares increase in 2050, although only under NDC2 and NDC2+. The growth of these sectors' shares of effective labour supply seems to pick up the general trend of other sectors whose share of effective labour supply shrinks in 2050. For example, notice that the effective labour supply share of the coal sector in 2050 is basically negligible under the NDC2 and NDC2+ policy scenarios. This makes sense if one keeps in mind that in both scenarios, although at different paces, carbon-reduction policies are implemented by 2050.

Again, it may be insightful to look at this information from another perspective. Table 8 shows the (percentage) ratio of effective labour supply share in NDC2 or NDC2+ to that in NDC, in 2030 and 2050.

This table offers a slightly different perspective than the previous one. From this table, it is evident how the effective labour supply share is much greater in the wind and solar power sectors under NDC2 and NDC2+ in 2050. This is particularly evident in 2050, when effective labour supply is 936% or even 1020% greater under NDC2 or NDC2+ respectively, compared with the NDC scenario. Similarly, the coal, gas, coal-fired power and nuclear power sectors' shares of effective labour supply in 2050 are much smaller under both NDC2 and NDC2+. The gas sector is almost 100% smaller under NDC2 or NDC2+ in 2050. The coal-fired power sector is similarly smaller in 2050, although to a slightly lesser extent. The coal sector is about 89% smaller in 2050 than NDC.

3.7. The evolution of inequality: Eurostat perspective

As mentioned in the previous sector, the full mobility of labour assumption upon which ENGAGE is built implies a unique wage for all workers across the country. The most evident drawback of such assumption is that it does not allow for a distribution of wages, which in turn makes it impossible to understand the evolution of inequality. Alternative and additional statistics are necessary.

Eurostat provides them on many of the sectors covered by ENGAGE, although there is not a perfect correspondence. Moreover, it gives them at the local level, whereas ENGAGE data only refers to the whole country. The level of detail chosen to discuss inequality in the UK is NUTS1, which has been briefly introduced earlier on.

Thanks to Eurostat data it is then possible to obtain distributional data on wages and attempt to make some educated predictions about the possible outcomes of inequality in the UK under the three different policy scenarios. However, before this is discussed, it is important to explain the reasoning behind this analysis.

First of all, data was taken from Eurostat on employed individuals (absolute number) and salaries (aggregated for sectors). This made it possible to obtain a distribution of national-wide average salaries across different sectors, thus obtaining a distribution of incomes for 2011. These were then used to construct the Lorenz curve for 2011 (**Fig. 5**).

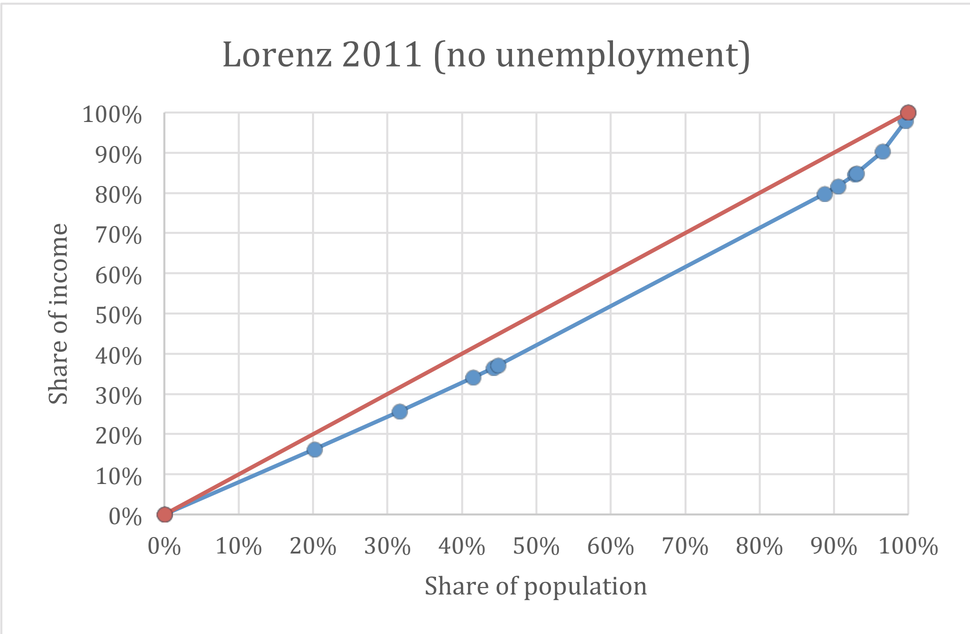


Fig. 5 Lorenz curve for the UK in 2011

The Lorenz curve is a useful tool in economics which quickly summarises the distribution of wages in a certain region. The Lorenz curve shows what percentage of the population owns what percentage of the region's total wealth – which is normally represented by the aggregation of all individuals'

incomes. So, for example, **Fig. 5** would be interpreted like so: the 20% of the population in the UK (employed in the sectors considered by ENGAGE) earns approximately 16% of the total income of the country – which is given by the sum of everyone's incomes. In **Fig. 5** the Lorenz curve is the blue line.

To have a better understanding of the severity of inequality, the Lorenz curve is accompanied by the perfect equality line – which is the orange line in **Fig. 5**. The perfect equality line shows an ideal situation of full equality. This means that 1% of the population has 1% of the income, 10% of the population has 10% of the income and so forth – everyone earns the same income. The further away the Lorenz curve is from the perfect equality line, the more severe inequality is.

The proximity of the curve to the perfect equality line in **Fig. 5** is because ENGAGE assumes that there is no unemployment. Although in our analysis we drop this assumption for subsequent years, we keep it for 2011. This way, we can start from a situation of full employment and have an understanding of how many people cannot be re-employed according to ENGAGE's data. If there had been unemployed people, this would have been reflected in a Lorenz curve 'stretched' much more towards the x-axis, and in a more sever inequality too.

To be able to say something about the evolution of inequality in the future, it is necessary to understand how average salary distribution changes over time. Unfortunately, it is not possible to understand this from ENGAGE data. Again, this is due to the full mobility of labour assumption which applies for all years considered by ENGAGE. As a consequence, for all years it is impossible to derive a distribution of incomes from ENGAGE – because workers are free to move costlessly, this commands equal wages across the country and sectors. However, an alternative approach can be adopted. This will be referred to as Approach 1. This relies on the following assumptions:

- L1. Average salary grows at the same rate for all sectors. This rate is the change in the price of labour in ENGAGE.
- L2. There is a one-to-one correspondence between effective labour supply shocks and employment. In other words, this means that if there is a x% shock in effective labour supply in either direction, then output will experience a x% shock in the same direction – e.g. if effective labour supply drops by 1%, then employment will drop by 1%.

Assumption L1 allows us to have a distribution of salaries in other years too, which would be otherwise impossible. This assumption is innocuous in that it does not affect the distribution of salaries – because they all increase by the same proportion – but it still lets us model some sort of growth in wages, which is realistic to assume.

Assumption L2 allows us to act on the distribution of employed individuals in different sectors. This is done by taking the sectorial effective labour supply shocks from ENGAGE data, applying it to Eurostat data and obtaining the resulting number of employed individuals. By doing so, we can produce Lorenz curves also for other years besides 2011 (in **Appendix 2**, and **Fig. 6** and **Fig. 7**) and calculate the respective Gini coefficients (**Table 9)**.

	2011	2030			2050		
		NDC	NDC2	NDC2+	NDC	NDC2	NDC2+
No unemployment	0.126	0.186	0.186	0.184	0.314	0.304	0.303
Unemployment		0.333	0.333	0.334	0.315	0.305	0.304

Table 9 Gini coefficients for the UK. Approach 1.

The Gini coefficient is another widely used tool in economics to have some numerical quantification of the severity of inequality in a certain country. Mathematically, it is calculated like so:

$$Gini\ coefficient = \frac{A}{A+B} \tag{1}$$

Where A is the area between the perfect equality line and the Lorenz curve, and B is the area below the Lorenz (so that $A + B$ is the total area below the perfect equality line). A Gini coefficient of 0 means full equality – that's because $A = 0$, which only happens when the Lorenz curve coincides with the perfect equality line. A Gini coefficient of 1 means full inequality – that's because the area between the perfect equality line and the Lorenz curve entirely coincides with the area below the perfect equality line. Besides these two extreme values, the Gini coefficient does not have any meaning per se. The Gini coefficient allows for comparisons throughout time or across countries. In a sense, it let us 'rank' the severity of inequality.

Fig. 6 and **Fig. 7** present two Lorenz curves, for 2030 and 2050 respectively, in both cases under scenario NDC2+. In these figures, unemployment was not included. The implication is that the Lorenz curve is closer to the perfect equality line, because it does not capture the proportion of the population on zero income. This is consistent with the full employment assumption of ENGAGE, but it is not likely to hold in real life. This is why Lorenz curves, and Gini coefficients, were calculated without and with unemployment (refer to Appendix 2). Unemployment was calculated as the difference of total workers between 2011 and subsequent years, for all scenarios.

Notice how in both **Fig. 6** and **7** the Lorenz curve is more stretched towards the x-axis than in 2011. This is a sign of greater inequality (driven by differences in income distribution) in 2030 and 2050 than in 2011. This is reflected in the Gini coefficients, too. The Gini in the UK in 2011 was 0.126, whereas in 2030 will be 0.184 and in 2050 it will be 0.303.

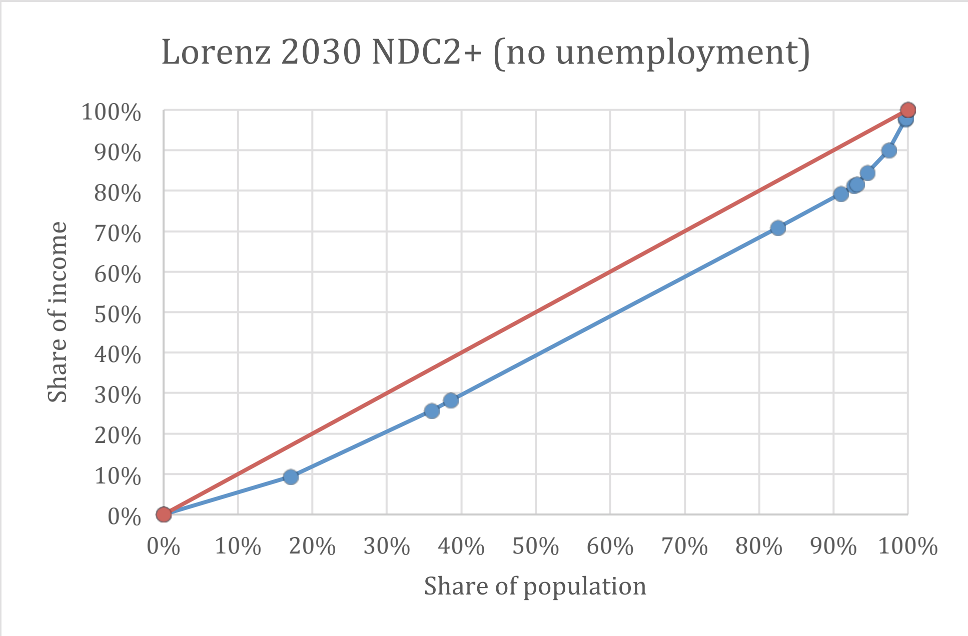


Fig. 6 Lorenz curve for the UK in 2030 under NDC2+

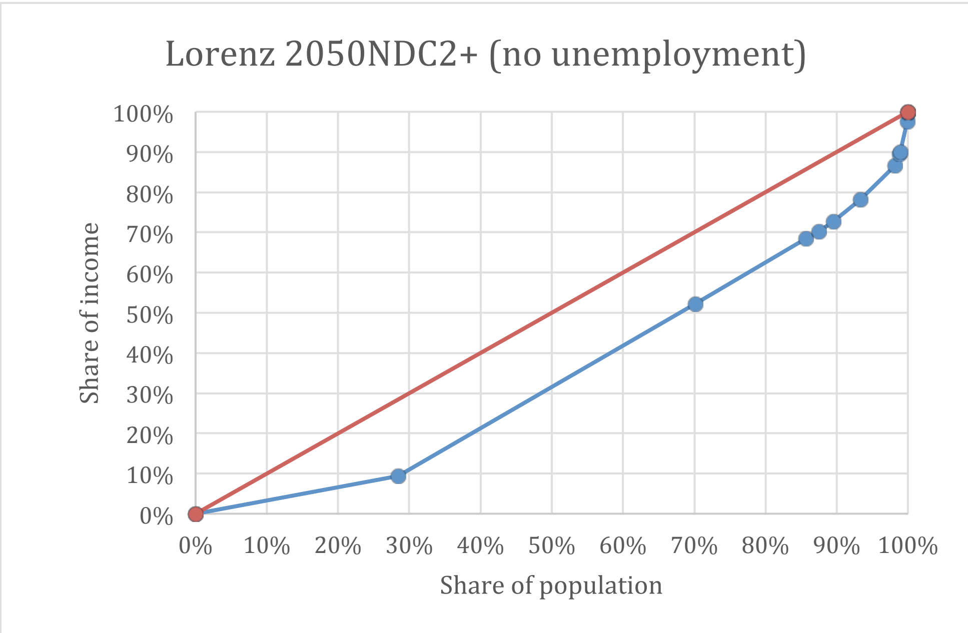


Fig. 7 Lorenz curve for the UK in 2050 under NDC2+

The exercise outlined above was repeated with a slight variation, which we denote as Approach 2. A new set of assumptions was adopted:

L3. Workers are paid their labour productivity, that is:

$$Salary \equiv Labour\ productivity = \frac{Output}{Employed\ individuals} \tag{2}$$

L4. Labour productivity grows at a constant rate throughout time. We hypothesized 1%.

Assumption L3 allows us to break free from Eurostat data on salaries and only work with data coming from ENGAGE. Assumption L4 allows us to obtain a distribution of salaries for future years. The main advantage of this approach is that it reduces mechanically the number of employed people, whilst still getting output information from ENGAGE.

Indeed, the number of employed people was obtained by simply using the reverse of (1):

$$Employed\ individuals = \frac{Output}{Labour\ productivity} \tag{3}$$

Notice that the denominator in (2) increases as a higher growth rate is chosen for labour productivity. This mechanically reduces the left-hand side, whilst keeping unaltered the distribution of salaries, just as it happens following Approach 1. **APPENDIX 3** contains Lorenz curves obtained by doing this exercise. **Table 10** is the table of Gini coefficients.

	2011	2030			2050		
		NDC	NDC2	NDC2+	NDC	NDC2	NDC2+
No unemployment	0.204	0.192	0.191	0.188	0.171	0.147	0.144
Unemployment		0.366	0.364	0.351	0.513	0.420	0.402

Table 10 Gini coefficients for the UK. Approach 2.

In general, we notice that outcomes are much more unequitable when unemployment is taken into consideration. This is understandable as when unemployment is taken into consideration, so are people earning zero, which negatively impacts inequality. Moreover, the environmentally more stringent scenarios seem to be more equitable than the less stringent ones. This is true of both Approach 1 and 2. Interestingly, in Approach 2 we notice that the Gini coefficient is much higher in 2050 for all scenarios than in Approach 1.

From the data underlying the curves we can see that individuals employed in the coal sector rank roughly at the bottom of the wage distribution, whereas individuals in the energy sector are approximately in the third quintile of the salary distribution. This may be consistent with an expansion of the energy sector, especially as far as renewable energies are concerned. Moreover, salaries in this sector have already been growing in recent years, and possible cost reductions coming from future improvements in technology efficiency – especially in the solar and wind power sectors – may help to maintain such positive trend (IRENA 2019; Open Access Government 2019).

4. Inequality trends in the rest of the regions of Europe

4.2. ENGAGE results on sectorial impacts of CCMPs

We shall now expand our focus from the UK to the other regions of Europe scrutinised by ENGAGE too. These are illustrated in **Fig. 8**.

- Western European countries (WEU): Albania, Andorra, Austria, Belgium, Denmark, Faroe Islands, Finland, France, Germany, Gibraltar, Greece, Greenland, Iceland, Ireland, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland, Vatican
- Eastern European countries (EEU): Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia, The former Yugoslav Republic of Macedonia
- Former Soviet Union countries (FSU): Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan.

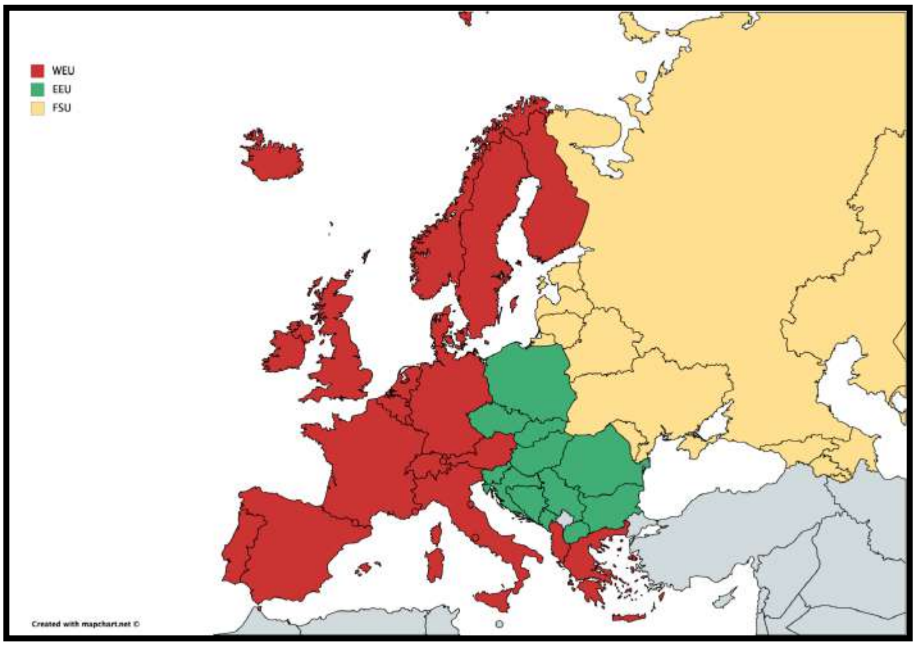


Fig. 8 ENGAGE regions of Europe. Source: here

Given the high number of countries involved, it is not feasible to go to a similar level of detail as for the UK. Nevertheless, to understand inequality trends in these countries, it may be insightful to begin with by repeating the same exercise as for the UK. **Table 11** shows the output change in 2050 compared to 2011 for the three different scenarios: baseline NDC, NDC2 and NDC2+.

A growth in output is anticipated in agriculture and food in WEU and EEU countries under all scenarios, in wind and solar powers for all countries and under all scenarios (with a couple of exceptions), and in industrial sectors for FSU countries under all scenarios. For the same reasons

outlined previously, it is best if we focus our attention on **Table 12**, which more closely relates the alternative policy scenarios to the baseline.

At a first glance, it is evident how the figures for the NDC2+ to NDC ratio are bigger (in absolute value) than those for the NDC2 to NDC ratio, thus showing a bigger difference in terms of outcomes if compared against the BAU scenario. This may be explained by keeping in mind what the NDC2 and NDC2+ scenarios model. Both scenarios aim at hitting a temperature increase of at most two degrees – compared to pre-industrial levels – by 2050. However, the former does so by assuming that climate change mitigation policies will accelerate only after 2030; whereas the latter assumes that these will accelerate already before 2030.

In particular, it is interesting to notice that, although in **Table 11** we pointed out an expansion of the agriculture and food sector, **Table 12** reveals that there is not a significant difference between policy alternatives. The output from this sector is between 0% and 1% bigger than NDC under NDC2 or NDC2+ – the only noticeable exception being FSU countries in 2050, where output in this sector will be 2% or 3% lower under the environmentally more stringent policies.

More striking differences are found in other sectors. For example, notice that the coal and gas sectors in EEU countries in 2050 will be up to 94% smaller under NDC2 or NDC2+ than under NDC. Similarly, the crude oil sector in WEU countries and the gas sector in FSU countries will be between 79% and 86% smaller if CCMPs are adopted. The same is true of the coal-fired power sector as well.

The hydroelectric, wind and solar power sectors are noteworthy in terms of comparison against the baseline policy. The nuclear power sector in 2050 in WEU countries will shrink under NDC2 or NDC2+ policies, compared against the baseline environmental policy. However, in EEU and FSU countries output from this sector will be much higher under those same scenarios – by well more than 2000%. This seems to be in line with information given by **Table 11**, where output from this sector will generally decrease in WEU countries and increase in EEU and FSU countries.

Because the aim is to move towards less carbon-intensive technologies, it is unsurprising that sectors such as wind or solar power show a much higher output under NDC2 or NDC2+ than NDC. It is a little less unsurprising, perhaps, to notice that in WEU countries, in both 2030 and 2050, output from the nuclear power sector is less than in the NDC scenario – up to 92% less. This might be due to two factors.

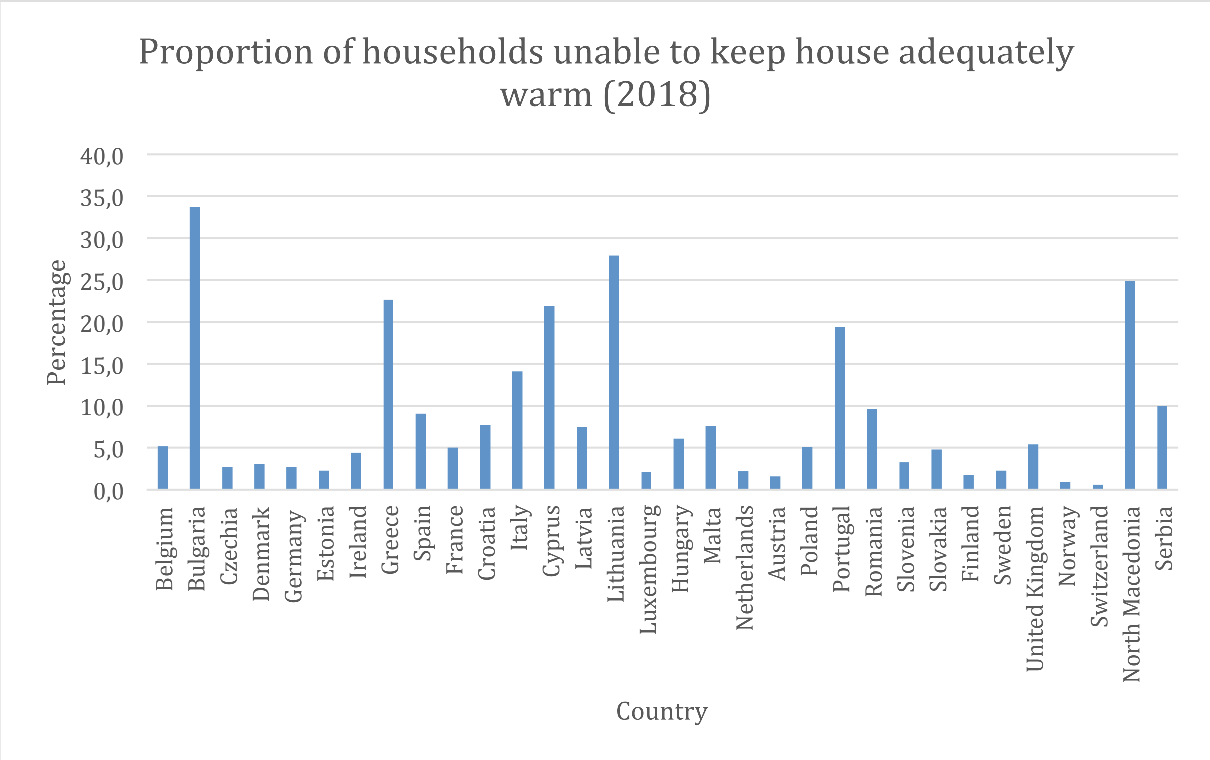


Fig. 9 Fuel poverty in EU countries. Source: Eurostat (2020)

One factor is cost reductions in solar and wind power sectors (Sovacool *et al.* 2019). Clearly, if improvements in these sectors make implementing such technologies cheaper, they are likely to be adopted instead of (relatively) more expensive nuclear power. Another factor is a general tendency to progressively abandon nuclear power in favour of other sources. Such turning away from nuclear as potential energy source gained momentum especially after the 2011 Fukushima accident. Many (Western) European countries have since decided to divert focus from nuclear to other energy sources, and committed to phasing out their nuclear plants – e.g. Germany, Belgium, Switzerland (Aune *et al.* 2015).

The decision of phasing out nuclear plants, nevertheless, comes at certain costs. Let us consider the case of Germany, which phased out nuclear power in 2011. According to Knopf *et al.* (2014), such decision led to an increase of electricity prices, of different magnitudes depending on the scenario considered. This may have particularly negative implications for those households on low incomes for whom electricity represents a big share of their budget, thus exacerbating the issue of fuel poverty. **Fig. 9** shows the proportion of households in several EU countries unable to keep their homes adequately warm at reasonable costs.

Switching to 'greener' technologies may raise (temporarily) prices. The burden of this, however, is not borne equally in the population, depending on individuals' elasticities of demand for the product affected.

Our focus has been on output mainly. It is instructive to focus on effective labour supply too, which is an input to the model. **Table 13** shows the change in effective labour supply in 2050 compared with 2011, under all three scenarios. A closer look to this table reveals interesting trends. First, notice that effective labour supply in EEU countries under all scenarios will drop in 2050 compared with 2011 in all sectors – solar and wind power being the most noticeable exception. The same is very largely true of WEU countries. The only sectors where effective labour supply increases in these countries are agriculture and food, minerals, gas (only NDC) and other power (only NDC2 and NDC2+). Second, notice the tremendous increase in effective labour supply in former FSU countries – including oil-fired power. However, the same caveat as previously presented applies here too. Effective labour supply factors in considerations about efficiency of the labour force too. Because effective labour supply starts from a rather small value in 2011, and will have increased by 2050 to reflect gains in efficiency, it is only natural that the percentage growth is so large. This is why we should focus on **Table 14** shows the ratio of effective labour supply under NDC2 and NDC2+ to NDC in 2030 and 2050 which, again, allows for a comparison of the alternative policy scenarios with the BAU scenario.

In this case the biggest differences are found in the coal, crude oil and coal-fired power sectors in 2050. In the latter sector, for instance, effective labour supply in FSU countries is almost nullified when compared against the baseline NDC scenario. A similar argument holds for the gas sector in EEU countries. A completely different trend is shown by the solar and wind power sectors again.

In 2030, there are a few examples where effective labour supply is twice as much as that under NDC, or even more than that. This happens in the solar power sector in EEU and FSU countries under NDC2+. It also happens in the nuclear power sector in EEU and FSU countries under both NDC2 and NDC2+ scenarios.

Are there going to be changes in terms of the distribution of the effective labour supply in these three macro-areas? ENGAGE can give us an insight on this question. We take a look at **Table 15**.

In general, the table shows that there are not great changes in terms of the distribution of the effective labour supply across policy scenarios, sectors and years. However, there are a few exceptions. For example, the coal-fired power sector share of effective labour supply in EEU, FSU and WEU countries shrinks almost to 0% in 2050 under the two more stringent policy scenarios.

The nuclear power sector's share of effective labour supply interestingly expands in EEU and FSU countries in 2050 under NDC2 and NDC2+ scenarios (and under NDC scenario too in the case of FSU countries). However, on the contrary, this sector's share drops in WEU countries by 2050, under all scenarios. This is consistent with the discussion above on the progressive abandonment of this sector as a source of electric power.

The wind and solar power sectors experience an increase in effective labour supply share by 2050, too, if the NDC2 or NDC2+ policies are implemented. This result is consistent with the expansion of these sectors discussed earlier on. The agriculture and food sector too expands by 2050 in effective labour supply share – except in the case of FSU countries under NDC2 and NDC2+ scenarios, in which cases it shrinks.

Fragkos & Paroussos (2018:943) highlight that the agriculture sector can likely represent a new source of employment due to the production of biofuels. This sector is then likely to be able to absorb (part of) the labour force which would be released by shrinking sectors. Not only this, but it may also contribute to impacting – in either direction – a country's inequality. **Table 16** utilises data from the World Bank to show the agriculture share of employment in the countries considered by ENGAGE, between 2017 and 2019.

WEU countries have, on average, the lowest share of labour force employed in the agriculture sector, whereas FSU countries the highest. Whereas it may be unreasonable to think that free labour force would relocate to a different macro-region (e.g. from a WEU country to a FSU country), switching to less carbon-intensive energy sources, and specifically biofuels, may have consequences on land value, due to increased demand. This is highlighted by UNCTAD (2009), which identifies in biofuel masses production and international trade a beneficial opportunity for developing countries, many of which are found among the EEU and FSU countries, according to the latest UN's World Economic Situation and Prospects report (UN 2019).

In addition, the problem of re-training may not be insurmountable. Take the case of FSU countries, for instance. Let us assume, for the sake of the example, that all FSU countries follow the NDC2 scenario – their decarbonisation policies accelerate only after 2030. Notice that sectors such as coal, or gas and petroleum extraction, will release labour force. It is unlikely that this low-skill labour force may be re-employed in, say, high-skill R&D for the renewable energy sources sector. However, as Zachmann *et al.* (2018) suggest, their skills may be easily 'recycled' in other activities related to the expansion of the renewable energy sources sector – for instance, the construction of new solar- or wind-power farms, or the upgrade of existing buildings to more stringent, low carbon impact standards (Gouldson *et al.* 2018).

4.3. Implications for economic inequality

4.3.1. A GDP-based approach

One approach to evaluating the inequality consequences of CCMPs in European countries is looking at their GDP. Data on GDP is taken from ENGAGE. **Table 17** presents the percentage growth of GDP between 2011 and 2050.

	2011-2050		
	NDC	NDC2	NDC2+
WEU	87%	84%	85%
EEU	143%	148%	150%
FSU	196%	202%	218%

Table 17 GDP percentage growth, 2011-2050. Source: ENGAGE

There does not seem to be a massive difference in terms of scenarios. Yet again, ENGAGE should be used to evaluate different policy alternatives against a baseline. So, we should now turn our attention to **Table 18**. This table shows the ratio of GDP under NDC2 and NDC2+ against the baseline NDC, for 2030 and 2050 in the three regions of Europe.

	2030		2050	
	NDC2 to NDC	NDC2+ to NDC	NDC2 to NDC	NDC2+ to NDC
WEU	0.05%	-0.30%	-1%	-1%
EEU	0.31%	0.06%	1%	2%
FSU	0.36%	-0.06%	11%	16%

Table 18 NDC2 or NDC2+ to NDC ratios in 2030 and 2050. Source: ENGAGE.

The results from this exercise are quite mixed. We can see that WEU countries in general experience a slight reduction in GDP under NDC2 or NDC2+ scenarios compared against the baseline – with a single exception: in 2030 GDP is slightly greater under NDC2 than NDC, but only by a tiny 0.05%. EEU countries show a higher GDP than the baseline scenario in all years and scenarios. FSU countries show contrasting trends for 2030: GDP under the NDC2 scenario is slightly higher than the baseline, however it is slightly lower under NDC2+ than the BAU scenario. There is a striking difference compared with the rest of the European regions in 2050. GDP of FSU countries is 11% higher under NDC2 and 16% higher under NDC2+ than the baseline scenario. Apparently, more environmentally stringent policies seem to benefit this region to a larger extent than WEU or EEU countries.

4.3.2. A Lorenz curve approach

GDP is just one angle from which we can get an insight on winners and losers from CCMPs. Just as ENGAGE, though, it does not allow us to draw any conclusion on the distribution of incomes in a specific region of Europe. To do so, we repeat the same exercise that was presented in **Section 4.5**. We restrict our attention to WEU countries only. The countries included in the exercise are Belgium, Denmark, Germany, Ireland, Greece, Spain, France, Italy, Cyprus, Austria, Portugal, Finland, Sweden and Norway. These restrictions are dictated by time constraints and a lack of data observations for some of the countries included in the WEU region as defined in ENGAGE.

Data on employment and salaries is taken from Eurostat. However, because data on salaries is very patchy, we limit our attention to data on employment. ENGAGE gives data on output. We combine data from Eurostat and ENGAGE and implement Approach 2 as outlined in **Section 2.5**. The resulting Lorenz curves are contained in **Appendix 4**. The Lorenz curve for 2011 is shown in **Fig. 10**. The table of Gini coefficients is shown too (**Table 19**).

Fig. 10 Lorenz curve for WEU countries in 2011

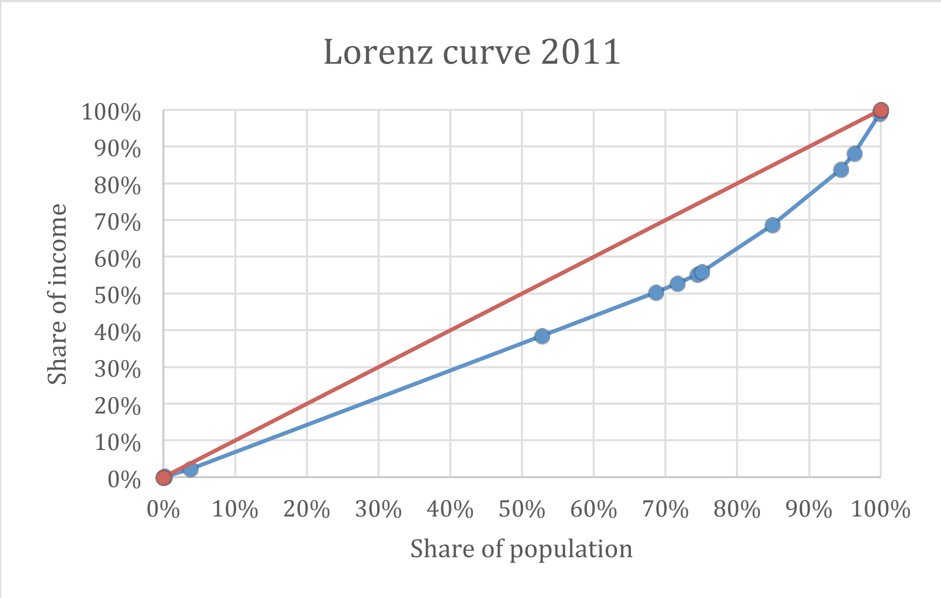


Table 19 Gini coefficients for WEU countries

	2011	2030			2050		
		NDC	NDC2	NDC2+	NDC	NDC2	NDC2+
No unemployment	0.221	0.2187	0.2185	0.2172	0.1717	0.1887	0.1874
Unemployment		0.4604	0.4588	0.4510	0.6417	0.6115	0.6048

There is a visible difference between the two variations of this exercise. When unemployment is not modelled into the Lorenz curves, notice that the Gini coefficient gently decreases over time. However, when unemployment is modelled in, not only are Gini coefficients higher overall – which intuitively makes sense, as the Lorenz curves are now capturing a portion of the population with no income; but they also increase over time, peaking at 0.64 in 2050 under scenario NDC. To see how inequality evolves from 2011, refer to **Fig. 11** and **12**, which are the Lorenz curves for WEU countries in 2030 and 2050 under NDC2+.

Notice that when unemployment is modelled in, the Lorenz curve is stretched towards the x-axis. This is reflected in a greater area between this curve and the perfect equality line, which in turn implies a higher Gini coefficient (symptom of more severe inequality). This is clearest from comparing **Fig. 11** and **Fig. 12**. Notice how the Gini coefficient, under the same scenario, increases from 0.451 to 0.605.

However, these results should be taken with a generous pinch of caution, as a few observations for 2011 were missing from Eurostat. Where possible, they were completed by using values coming from adjacent years. Otherwise, no value was inserted. This may have a significant effect on the precision of the resulting Lorenz curves.

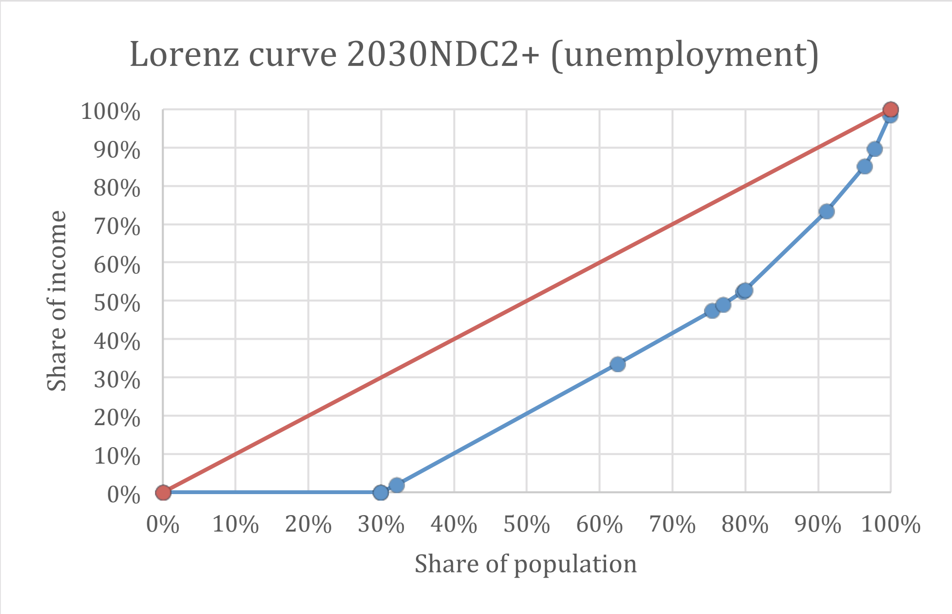
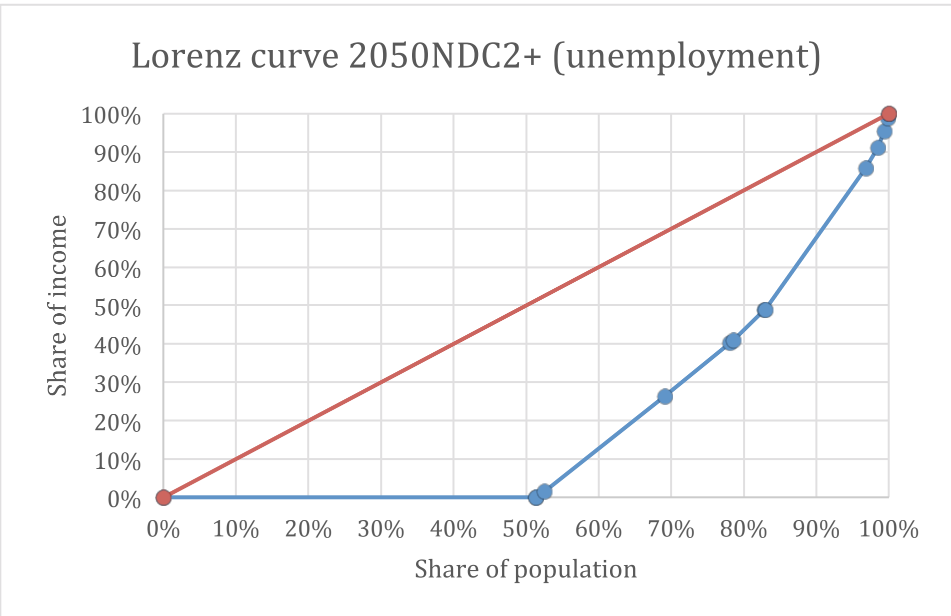


Fig. 11 Lorenz curve for WEU countries in 2030

Fig. 12 Lorenz curve for WEU countries in 2050



4.3.3. A selection of quantitative works

4.3.3.1. Problems of education

That unemployment may play an important role in increasing inequality seems to be ascertained by Alexandri *et al.* (2018). They find that transitioning to less carbon-intensive technologies in the EU will release low-skilled labour force but require the employment of high-skilled, i.e. educated at the tertiary level, labour force. They also estimate that, given the current trends in education, it will be unlikely that this demand can be met over the time horizon considered by the authors, which is 2020-2050. Similar conclusions are drawn by Behrens *et al.* (2014) too.

4.4. Inequality in renewable energy generation

Sinha (2017) offers a different approach to analysing inequality, at least as far as OECD countries are concerned in terms of renewable energy generation. The author turns to the Theil's inequality measure. Its advantage lies in enabling the author to understand between- and within-group inequality, a task otherwise unfeasible with other indexes. The author finds that in general, inequality in renewable energy generation across OCED countries has been decreasing since the Eighties. This is untrue of Central and South American countries – which are anyway not studied by ENGAGE.

An important aspect to keep in mind, however, is that of people's willingness to pay for such energies. This may depend on a wide variety of factors, including one's socio-economic background, or one's usual energy consumption pattern. For example, Bollino (2009) studies this issue focusing on Italy.

He starts from mentioning the Italian Government's goal to hit the target of producing 20% of electricity from renewable energy sources by 2010. By using two different methods to elicit participants' willingness to pay in 2006, he finds that this was not high enough to achieve the objective determined for 2010. Although this study is quite dated, a more recent one by Ma *et al.* (2015) deals with the same issue but expands its focus by performing a meta-analysis of the existing literature.

After cleaning their initial dataset of 149 papers, they are left with 29 which are directly relevant to estimating willingness to pay. They find that people's estimated willingness to pay for renewable energy seems to depend less on their socio-economic circumstances or background, and more on the design of the study. This is why the authors recommend that attention be paid when policymakers use such papers.

4.5. Relocation subsidies

The discussion so far has highlighted that the coal sector will, in general, experience a significant shrinking in terms of output and effective labour supply. Intuitively, this makes sense, as the focus is on moving away from carbon-intensive energy production methods towards greener technologies.

Potential impacts of this action on workers have already been discussed earlier on. In particular, several times in the previous section has the problem of relocation been mentioned. One solution to it is government subsidies.

At a first glance, a subsidy seems to be an innocuous but effective solution. Relocation subsidy schemes have been in place in Germany, for instance. Caliendo *et al.* (2017) study the impact of relocation subsidies paid to workers by the German government by using a sample of male workers who entered unemployment in 2005 and 2006. Interestingly, they discuss that relocation subsidies can have two opposing effects.

On the one hand, they abate relocation costs thus lowering job-seekers' reservation wage – because moving to a distant region now costs less, workers should more easily accept a new job there. This positive effect makes re-employment easier. On the other hand, relocation subsidies expand job-seekers' radius of search, which in turn increases the number of job offers they can receive. This, in turn, inflates their reservation wage, thus making it more difficult to accept a new job. The overall effect of these two opposing forces is ambiguous *a priori*.

The authors find that participants of relocation subsidy schemes end up with better labour outcomes, e.g. higher wages, more stable employment. To rule out the possibility that this result is due to some form of self-selection – i.e. only workers more strongly willing to work participate in relocation subsidy schemes, so they naturally have higher chances to find better jobs – they implement an IV strategy. Exogenous variation is given by the local employment agencies' decisions on the relocation subsidy schemes on which they want to enroll registered job-seekers. Because this choice is totally independent of job-seekers, variation in the types of schemes on which they are enrolled will create variation in their labour outcomes. The results of the IV estimation confirm that individuals who participate in relocation subsidy schemes relocate to geographically distant regions and achieve better labour outcomes.

4.6. Spanish carbon tax

In **Section 4.3.1** an example was presented of a carbon tax levied on food items with high associated emissions. A carbon tax can clearly be levied on any item of which the policymaker wants to reduce consumption. For example, it can be levied on the consumption of energy goods with a high carbon footprint.

Labandeira *et al.* (2009) study this case with regard to Spain. They use a CGE model with similar assumptions to ENGAGE's. They model a policy which "raises taxes on the consumption of energy goods (electricity, refined oil products, natural gas and coal) by 20%" (ibid.,5782). The authors justify this tax on the grounds that Spain was performing poorly in terms of emissions with respect to the goals agreed upon in the Kyoto protocol, and that its energy tax level was below the EU average. The authors assume that this tax would be revenue-neutral as they also model an endogenous decrease in VAT proportional to the revenue stemming from this new 'carbon tax'.

They find that such policy would induce changes in individuals' behaviours. Their results point towards an increase in GDP and a reduction in emissions by about 5.7% – with the oil products and

transport services contributing significantly to this end. Production of electricity would only moderately decrease, whereas coal use would remain unchanged.

Most importantly, the authors take into consideration the effects of such energy tax on other goods consumed by households. They find that the price of motor fuels would increase by almost a quarter, whereas the price of food would decrease by 1%. The distributional implications of this changes are not as negative as one may think. In fact, the authors find that households' welfare would improve by 1.5%. This is because, even though the price of fuel and, moderately, that of electricity increase, these only represent, on average, a small proportion of the households' total expenditure. Furthermore, the increase in welfare would have a slightly progressive trend. This means that, proportionately speaking, households at the lower end of the income distribution would experience a greater improvement in welfare than those at the higher end. This is a rather unusual result as 'most international empirical literature considers the effects of energy and carbon taxes to be regressive' (ibid.,5784). In this regard, Ohlendorf *et al.* (2018) present a rich review of the most relevant studies concerning the progressivity or regressivity of carbon taxes and their consequential welfare implications.

4.7. Gender inequality

It has already been mentioned how CCMPs may have adverse effects on gender inequality, thus exacerbating further a problem which policymakers are trying to tackle. This is true of WEU countries (for example, EIGE (2020)) as well as EEU and FSU countries (for example, (Khitarishvili 2016)).

The expansion of the renewable-energy sector holds great potential for the creation of new jobs. In turn, this can potentially help to re-balance the gender composition of the labour force in this sector, which seems to be among those with the lowest share of female workers employed (Cazzola 2018). IRENA (2019) estimates that about a third of the renewable energy sector workforce is female – a little higher than in the oil and gas industry, where it is 22%. Cazzola and IRENA both stress that the problem lies at a previous stage. Closing the gender gap in the renewable energy sector requires to employ women who come from an adequate background – which is usually a STEM background. There, again, a problem of gender imbalance is found. This result is confirmed, among others, by the European Parliament too (Clancy & Feenstra 2019). This study highlights the urgency of devoting more attention to this matter. So far, evidence of the CCMPs impact on gender inequality is too little and, the other way around, it is unclear how greater gender equality may benefit energy transition. To exemplify this point, the authors refer to a study conducted in the Netherlands by Van Engeland (2019, cited in Clancy & Feenstra 2019) in which women's voting preferences were scrutinized. Women give more importance to healthcare, environment, climate change, sustainability and social welfare; men to safety issues, economy and immigration (Clancy & Feenstra 2019:33).

In a report on ensuring a just transition to workers affected by mine closures, the World Bank (2018:36) makes an important point. Women – and therefore gender equality – may be negatively affected by CCMPs which will shut down mines. This is because they are likely to take on more traditionally 'female', house-related tasks while their male partners look for an alternative job. The

World Bank also states that, whereas in such situation women would be willing to accept a new job at even a lower wage, men are less likely to do so. This can only exacerbate gender inequality.

5. Conclusions

This section was a first step in discussing the adverse side effects of CCMPs which have only received attention for a short time, according to Markkanen & Anger-Kraavi (2019). The aim of this section was to take a more quantitative stance than the rest of the literature already present – which is reviewed by Markkanen & Anger-Kraavi (2019).

There are several lessons which can be learnt. The first one is more methodological. The use of CGE models to understand policy implications is certainly helpful because they lie on microeconomic foundations, but anyway allow for the interaction of different individuals among with one another, and incorporate endogenized responses to price mechanism (Labandeira *et al.* 2009). As with any other model, however, there is a cost to using it, which takes the form of assumptions. In particular, for the purposes of this section, the most restrictive assumption was the absence of involuntary unemployment coupled with perfect mobility of labour.

The first assumption 'biased' considerations on inequality because it does not allow unemployed individuals to be included in a distribution of income. The second assumption limited our analysis because it did not let us obtain a distribution of salaries directly from ENGAGE. If labour is perfectly and fully mobile across the country (or regions of Europe), then it is expected that it will be paid the same wage regardless of the geographical location. So, we had to turn to other statistics and use them alongside ENGAGE output. Moreover, this assumption is not really likely to hold in real life. We have discussed that there are limits to one's re-employment. This take the form of a mismatch of skills which need retraining – which is costly; or relocation costs – in terms of physical and psychological costs, which may deter one from moving.

The second lesson is that more work is needed on EEU and FSU countries. This work is heavily focused on the UK and WEU countries, because the large majority of the material concerns these two areas. Besides qualitative work, there did not seem to be a rich literature evaluating the effects of CCMPs on inequality in EEU and FSU countries.

The third lesson is that more work is needed, especially of a quantitative type. The literature is saturated with valuable work which discusses the implications of CCMPs for inequality. However, more systematic research is needed which points in the direction of quantifying the adverse side effects of CCMPs on inequality. One such example is CCMPs' consequences on gender equality. Will mitigation policies help women to access jobs normally taken by men (a question asked already by EIGE (2012))? Surely, the answer is not trivial. A quantitative approach would point in the direction of collecting more precise data on the gender balance of energy-related sectors. The general lack of sex-disaggregated data for energy-related sectors is an issue lamented by Cazzola (2018). However, the greater issue remains that there exist many confounding factors which impact gender equality and are not necessarily related with a specific CCMP. Even the focus of attention was narrowed down on a specific policy implemented in a specific geographical area, the generalizability of results would be troublesome, as equal policies may not necessarily have equal effects in different contexts.

Finally, the fourth lesson is that CCMPs can and do have adverse side effects, as a consequence of the expansion of the renewable energy sectors and a contraction of the carbon-based ones. Several examples have been discussed throughout this section, from unemployment consequences of transitioning towards greener energy sources, to effects on fuel poverty brought about by increases in electricity prices linked with decarbonization. The 2015 Paris Agreement stresses the importance of a 'just transition', as mentioned earlier in this section. Although it is safe to say that this difficulties should not refrain the policymaker from implementing CCMPs, this must be done by ensuring that potential losers are adequately protected, thus guaranteeing a fair distribution of climate change mitigation benefits.

5. Conclusions

This report was a first step in discussing the possible co-impacts of the transition to a low-carbon economy which have only received attention for a short time (Markkanen & Anger-Kraavi, 2019). Three case studies were conducted: the UK and Europe, Brazil and South Africa. All case studies built on the modelling results of the COP21 RIPPLES project, in particular the Paris-compatible global scenarios that represent the NDC path up to 2030 and the early action ones. Brazilian and South African cases took a qualitative approach, while the UK and Europe case took a more quantitative stance than the other two and the rest of the literature already present (which is reviewed by Markkanen & Anger-Kraavi (2019) that was published based on the Milestone 3.4).

This unique opportunity to decarbonize a significant part of the economy, in the light of a disastrous climate crisis, meets major challenges that emerge from the historical inequalities that center around the income sources from the fossil energy industries. There are several lessons which can be learnt from this research. The first one is methodological. The use of CGE models to understand policy implications is certainly helpful because they allow for the interaction of different individuals among with one another and incorporate responses to carbon pricing mechanisms. However, the models are restricted by assumptions, most restrictive being the absence of involuntary unemployment coupled with perfect mobility of labour. If labour is perfectly and fully mobile across a country, then it is expected that it will be paid the same wage regardless of the geographical location. So, we had to turn to other statistics and use them alongside models' outputs. Moreover, this assumption is not really likely to hold in real life. There are limits to one's re-employment. This take the form of a mismatch of skills which need retraining – which is costly; or relocation costs – in terms of physical and psychological costs, which may deter one from moving.

Secondly, more quantitative and qualitative work is needed on assessing distributional and inequality impacts of low-carbon transition on countries and regions. The literature is saturated with (valuable) qualitative works which discuss the implications of climate change mitigation policies for inequality – with the help of some data and do it mostly at local scales. However, more systematic research is needed which points in the direction of quantifying the co-effects on inequality at national and regional levels. One such example is consequences on gender equality. Will mitigation policies help women to access jobs normally taken by men, will there be overarching improvements in health inequalities? Surely, the answer is not trivial. A quantitative approach would point in the direction of collecting more precise data on the gender balance of energy-related sectors or regional health

indicators. The general lack of sex-disaggregated data for energy-related sectors is an issue lamented by Cazzola (2018). Even if the focus of attention was narrowed down on a specific policy implemented in a specific geographical area, the generalizability of results would be troublesome, as equal policies may not necessarily have equal effects in different contexts. It is evident that the current data and the structures for data collection do not correspond to the challenge of understanding poverty and inequality impacts from decarbonization of whole national and regional economies. This finding raises pressing concerns about future measurement of the progress towards achieving the Agenda 2030; specifically SDG 1,10,7, on poverty, inequality and climate action. A further challenge emerges for research work in modeling of the distributional impacts of sectoral transitions.

Finally, a transition to a low-carbon economy can and have adverse side effects, as a consequence of the expansion of the renewable energy sectors and a contraction of the carbon-based ones. The 2015 Paris Agreement stresses the importance of a 'just transition', as mentioned earlier in this report. Hence climate change mitigation policies must be planned and implemented ensuring that potential co-impacts are adequately identified and adequate remedies to put in place where needed, therefore guaranteeing a fair distribution of climate change mitigation benefits and just transition to all.

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7. Annex

This Annex contains all the tables referred to throughout the UK and EU case study (section 4) and its specific Appendixes.

Table 1 Regional share of employment in UK regions in 2011 (Eurostat 2019). Back to text.

ENGAGE code	Eurostat proxy	North East	North West	Yorkshire and The Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland	Northern Ireland	Total share (UK-wide)
COA	Mining of coal and lignite	12%	12%	28%	15%	0%	0%	0%	0%	0%	12%	20%	0%	0%
OIL/GAS (O_G)	Extraction of crude petroleum and natural gas	4%	4%	1%	1%	0%	1%	17%	4%	4%	4%	60%	0%	0%
MIN	Other mining and quarrying	7%	5%	9%	13%	6%	5%	2%	9%	18%	6%	10%	10%	1%
A_F	Manufacture of food products	3%	14%	12%	14%	8%	8%	6%	8%	8%	5%	10%	5%	11%
PPP	Manufacture of paper and paper products	4%	17%	11%	16%	4%	9%	3%	10%	7%	7%	9%	3%	2%
CRP	Manufacture of chemicls and chemical products	8%	28%	2%	11%	7%	10%	5%	12%	5%	5%	7%	2%	3%
NMM	Manufacture of other non-metallic mineral products	3%	14%	14%	11%	13%	11%	4%	8%	7%	4%	6%	5%	3%
I_S	Manufacture of basic metals	6%	19%	19%	7%	18%	5%	2%	1%	3%	14%	3%	1%	2%
MPR	Manufacture of fabricated metal products	5%	12%	10%	10%	19%	8%	4%	9%	8%	6%	7%	2%	10%
PAG	Electricity, gas, steam and air conditioning supply	6%	12%	9%	10%	10%	5%	6%	13%	7%	6%	15%	1%	3%
OTI	Other manufacturing (ENGAGE)	5%	12%	9%	10%	11%	10%	4%	13%	11%	5%	7%	3%	44%
TRN	Land transport and transport via pipelines	5%	11%	10%	7%	8%	9%	16%	9%	9%	5%	9%	3%	
	Water transport	1%	8%	3%	0%	1%	8%	20%	27%	7%	8%	14%	3%	
	Air transport	2%	8%	2%	3%	2%	6%	50%	17%	3%	1%	5%	1%	
TRN_CUMUL	Transport cumulative	5%	11%	9%	7%	7%	8%	18%	10%	9%	5%	9%	2%	20%

Methodological remarks (valid for whole document). OIL/GAS seems to be the aggregate equivalent of OIL and GAS in ENGAGE, so I have treated these two as a joint sector (oftentimes referred to as O_G). OTI is the aggregate of all other manufacturing categories according to NACE Rev 2 (class C) which are not explicitly reported in this table (e.g. PPP). PAG (Power AGgregate) is the Eurostat aggregate of all types of electric energy production. In general, OTI will exclude C11 – Manufacture of beverages, C15 – Manufacture of leather and related products and C21 – Manufacture of pharmaceutics due to incompleteness of observations.

Table 2 Percentage change in effective labour supply between 2011-2030 and 2011-2050. ENGAGE. Back to text.

	2011-2030			2011-2050		
ENGAGE sector	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+
Agriculture and food	23%	23%	22%	77%	73%	72%
Minerals	-53%	-53%	-52%	-91%	-90%	-90%
Paper	-16%	-16%	-16%	-31%	-33%	-33%
Chemical	-39%	-39%	-40%	-72%	-78%	-79%
Non-metallic minerals	-24%	-24%	-24%	-45%	-47%	-48%
Iron and steel	-47%	-47%	-47%	-79%	-80%	-80%
Metal products	-29%	-29%	-30%	-65%	-65%	-65%
Other industry	-18%	-18%	-18%	-35%	-34%	-34%
Coal	-44%	-44%	-66%	-55%	-95%	-95%
Crude oil	2%	2%	-1%	-3%	-29%	-28%
Gas	-4%	-5%	-43%	2%	-97%	-96%
Petroleum and coal products	-7%	-8%	-6%	-21%	-35%	-37%
Coal-fired power	-34%	-33%	-37%	-46%	-95%	-96%
Gas-fired power	-30%	-29%	-22%	-26%	-77%	-76%
Oil-fired power	-32%	-31%	-19%	-35%	-15%	-23%
Nuclear power	-38%	-40%	-44%	-72%	-97%	-98%
Hydroelectric power	-37%	-38%	-37%	-62%	-92%	-95%
Wind power	-35%	-29%	6%	-52%	397%	437%
Solar power	-21%	-13%	68%	268%	3889%	5407%
Other power	-39%	-37%	-14%	-22%	7%	-6%
Transmission and distribution	-35%	-39%	-53%	-72%	-98%	-99%
Services	-13%	-13%	-12%	-24%	-24%	-23%
Transport	-21%	-21%	-23%	-42%	-45%	-47%

Table 3 NDC2 to NDC or NDC2+ to NDC ratios, for effective labour supply, in 2030 and 2050. ENGAGE. Back to text.

	NDC2		NDC2+	
	2030	2050	2030	2050
Agriculture and food	0%	-2%	0%	-3%
Minerals	0%	8%	2%	7%
Paper	0%	-2%	0%	-3%
Chemical	0%	-20%	-3%	-26%
Non-metallic minerals	0%	-2%	0%	-4%
Iron and steel	-1%	-4%	-1%	-7%
Metal products	0%	0%	0%	-1%
Other industry	0%	1%	0%	1%
Coal	0%	-89%	-38%	-89%
Crude oil	0%	-27%	-3%	-26%
Gas	-1%	-97%	-40%	-96%
Petroleum and coal products	0%	-17%	2%	-20%
Coal-fired power	0%	-92%	-6%	-93%
Gas-fired power	2%	-69%	10%	-68%
Oil-fired power	1%	32%	18%	18%
Nuclear power	-2%	-90%	-10%	-94%
Hydroelectric power	-1%	-78%	0%	-87%
Wind power	9%	936%	62%	1020%
Solar power	10%	983%	112%	1396%
Other power	3%	37%	42%	20%
Transmission and distribution	-5%	-94%	-28%	-95%
Services	0%	1%	0%	2%
Transport	0%	-5%	-2%	-8%

Table 4 Percentage change in output between 2011-2030 and 2011-2050. ENGAGE. Back to text.

	2011-2030			2011-2050		
	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+
Agriculture and food	40%	111%	40%	112%	40%	112%
Minerals	-43%	-87%	-43%	-85%	-41%	-85%
Paper	-6%	-16%	-6%	-15%	-5%	-15%
Chemical	-33%	-70%	-33%	-74%	-32%	-75%
Non-metallic minerals	-17%	-39%	-17%	-35%	-16%	-34%
Iron and steel	-36%	-74%	-36%	-71%	-34%	-71%
Metal products	-27%	-65%	-27%	-64%	-27%	-64%
Other industry	-9%	-24%	-9%	-23%	-8%	-23%
Coal	-42%	-59%	-42%	-95%	-64%	-95%
Crude oil	15%	13%	15%	-7%	15%	-6%
Gas	10%	-6%	9%	-97%	-34%	-96%
Petroleum and coal products	7%	-7%	7%	-20%	9%	-23%
Coal-fired power	20%	38%	21%	-92%	-6%	-92%
Gas-fired power	37%	109%	39%	-43%	37%	-37%
Oil-fired power	29%	84%	31%	191%	57%	168%
Nuclear power	-6%	-43%	-8%	-94%	-15%	-96%
Hydroelectric power	8%	-1%	7%	-79%	8%	-87%
Wind power	41%	45%	118%	3534%	220%	3853%
Solar power	181%	2313%	218%	29415%	515%	40468%
Other power	67%	283%	73%	439%	137%	375%
Transmission and distribution	-30%	-69%	-33%	-98%	-49%	-98%
Services	-6%	-22%	-6%	-21%	-5%	-21%
Transport	-2%	-24%	-2%	-14%	2%	-11%
CGD	-8%	-18%	-8%	-17%	-7%	-17%

Table 5 NDC2 to NDC or NDC2+ to NDC ratios, for output, in 2030 and 2050. ENGAGE. Back to text.

	NDC2		NDC2+	
	2030	2050	2030	2050
Agriculture and food	0%	0%	0%	0%
Minerals	0%	12%	3%	14%
Paper	0%	0%	0%	0%
Chemical	0%	-13%	1%	-17%
Non-metallic minerals	0%	6%	1%	7%
Iron and steel	0%	10%	3%	12%
Metal products	0%	2%	1%	2%
Other industry	0%	1%	0%	1%
Coal	0%	-88%	-37%	-88%
Crude oil	0%	-18%	-1%	-17%
Gas	-1%	-97%	-40%	-96%
Petroleum and coal products	0%	-15%	2%	-18%
Coal-fired power	0%	-94%	-22%	-95%
Gas-fired power	2%	-73%	1%	-70%
Oil-fired power	1%	59%	21%	46%
Nuclear power	-2%	-90%	-9%	-93%
Hydroelectric power	-1%	-79%	1%	-87%
Wind power	55%	2412%	128%	2632%
Solar power	13%	1123%	119%	1581%
Other power	4%	41%	42%	24%
Transmission and distribution	-5%	-94%	-28%	-95%
Services	0%	1%	1%	1%
Transport	0%	13%	4%	17%
CGD	0%	1%	1%	2%

Table 6 Location of solar farms in the UK. Source: Department for Business, Energy & Industrial Strategy (2019c). Back to text.

Region	Number	Total power (MWelec)
Scotland	484	9900.6
South West	466	3014.6
South East	270	2549.7
East of England	270	2381.6
East Midlands	243	1709.3
Wales	219	4229.7
North West	162	1211.2
Yorkshire and The Humber	135	3960.9
Northern Ireland	115	1436.1
West Midlands	113	708.4
North East	91	1293.1
London	25	258.5
Offshore	46	8527.2
Total	**2639**	**41180.9**

Table 7 Sectorial distribution of effective labour supply. ENGAGE. Back to text.

	2011			2030			2050		
	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+
Agriculture and food	3,81%	3,81%	3,81%	5,45%	5,45%	5,43%	9,11%	8,95%	8,86%
Minerals	0,12%	0,12%	0,12%	0,06%	0,06%	0,07%	0,01%	0,02%	0,02%
Paper	2,08%	2,08%	2,08%	2,04%	2,03%	2,03%	1,94%	1,90%	1,88%
Chemical	2,64%	2,64%	2,64%	1,88%	1,88%	1,83%	1,00%	0,80%	0,74%
Non-metallic minerals	0,54%	0,54%	0,54%	0,48%	0,48%	0,48%	0,40%	0,39%	0,38%
Iron and steel	0,40%	0,40%	0,40%	0,25%	0,25%	0,25%	0,12%	0,11%	0,11%
Metal products	4,05%	4,05%	4,05%	3,33%	3,33%	3,32%	1,91%	1,91%	1,89%
Other industry	10,44%	10,44%	10,44%	9,99%	9,99%	10,00%	9,23%	9,34%	9,31%
Coal	0,03%	0,03%	0,03%	0,02%	0,02%	0,01%	0,02%	0,00%	0,00%
Crude oil	0,13%	0,13%	0,13%	0,15%	0,15%	0,15%	0,17%	0,12%	0,13%
Gas	0,18%	0,18%	0,18%	0,20%	0,20%	0,12%	0,25%	0,01%	0,01%
Petroleoum and coal products	0,26%	0,26%	0,26%	0,28%	0,28%	0,28%	0,27%	0,23%	0,22%
Coal-fired power	0,08%	0,08%	0,08%	0,06%	0,06%	0,06%	0,06%	0,01%	0,00%
Gas-fired power	0,04%	0,04%	0,04%	0,03%	0,03%	0,04%	0,04%	0,01%	0,01%
Oil-fired power	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Nuclear power	0,18%	0,18%	0,18%	0,13%	0,12%	0,11%	0,07%	0,01%	0,00%
Hydroelectic power	0,01%	0,01%	0,01%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Wind power	0,04%	0,04%	0,04%	0,03%	0,03%	0,04%	0,02%	0,24%	0,26%
Solar power	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,04%	0,05%
Other power	0,04%	0,04%	0,04%	0,03%	0,03%	0,04%	0,04%	0,05%	0,05%
Transmission and distribution	0,39%	0,39%	0,39%	0,30%	0,28%	0,21%	0,15%	0,01%	0,01%
Services	70,51%	70,51%	70,51%	71,59%	71,61%	71,90%	72,02%	72,85%	73,14%
Transport	4,04%	4,04%	4,04%	3,71%	3,71%	3,63%	3,18%	3,02%	2,92%

Table 8 Percentage ratios of effective labour supply. ENGAGE. Remarks: this table is obtained by taking ratios of effective labour supply between NDC2 or NDC2+ and NDC, in 2030 and 2050. Back to text.

	2030		2050	
	NDC2	NDC2+	NDC2	NDC2+
Agriculture and food	0%	0%	-2%	-3%
Minerals	0%	2%	8%	7%
Paper	0%	0%	-2%	-3%
Chemicals	0%	-3%	-20%	-26%
Non-metallic minerals	0%	0%	-2%	-4%
Iron and steel	-1%	-1%	-4%	-7%
Metal products	0%	0%	0%	-1%
Other industry	0%	0%	1%	1%
Coal	0%	-38%	-89%	-89%
Crude oil	0%	-3%	-27%	-26%
Gas	-1%	-40%	-97%	-96%
Petroleum and coal products	0%	2%	-17%	-20%
Coal-fired power	0%	-6%	-92%	-93%
Gas-fired power	2%	10%	-69%	-68%
Oil-fired power	1%	18%	32%	18%
Nuclear power	-2%	-10%	-90%	-94%
Hydroelectric power	-1%	0%	-78%	-87%
Wind power	9%	62%	936%	1020%
Solar power	10%	112%	983%	1396%
Other power	3%	42%	37%	20%
Transmission and distribution	-5%	-28%	-94%	-95%
Services	0%	0%	1%	2%
Transport	0%	-2%	-5%	-8%

Table 11 Percentage change of output between 2011-2050 in WEU, EEU and FSU countries. ENGAGE. Back to text.

	WEU			EEU			FSU		
Sector	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+
Agriculture and food	105%	107%	108%	54%	54%	55%	-15%	-17%	-17%
Minerals	-88%	-87%	-87%	-84%	-84%	-84%	66%	102%	107%
Paper	-30%	-29%	-28%	-3%	-2%	-2%	127%	175%	186%
Chemical	-71%	-76%	-78%	-51%	-60%	-62%	709%	1857%	2192%
Non-metallic minerals	-56%	-54%	-54%	-41%	-40%	-39%	10%	24%	27%
Iron and steel	-81%	-81%	-80%	-57%	-53%	-51%	99%	168%	175%
Metal products	-75%	-75%	-75%	-54%	-53%	-53%	9%	6%	3%
Other industry	-52%	-50%	-50%	-15%	-13%	-12%	-15%	-23%	-24%
Coal	-86%	-97%	-97%	-62%	-97%	-97%	-8%	-78%	-78%
Crude oil	39%	13%	13%	-43%	-88%	-87%	17%	8%	11%
Gas	-34%	-71%	-62%	-71%	-98%	-98%	91%	-74%	-73%
Petroleum and coal products	-29%	-27%	-26%	-17%	-41%	-45%	26%	-5%	-5%
Coal-fired power	-28%	-96%	-95%	0%	-96%	-97%	107%	-97%	-97%
Gas-fired power	99%	-2%	33%	174%	13%	26%	269%	-92%	-89%

Oil-fired power	63%	271%	331%	82%	131%	123%	237%	388%	596%
Nuclear power	-64%	-96%	-97%	-67%	614%	676%	294%	9421%	10227%
Hydroelectric power	-28%	-20%	-36%	-27%	98%	73%	256%	7044%	7079%
Wind power	-6%	981%	1046%	-7%	2018%	2302%	820%	32529%	36710%
Solar power	331%	925%	961%	1351%	7027%	8116%	73313%	661568%	803398%
Other power	67%	110%	94%	189%	187%	141%	997%	1954%	2113%
Transmission and distribution	-81%	-98%	-98%	-76%	-99%	-99%	9%	-90%	-92%
Services	-36%	-35%	-35%	-8%	-5%	-3%	85%	98%	105%
Transport	-28%	-20%	-17%	-40%	-38%	-36%	95%	140%	150%
CGD	-35%	-34%	-33%	-3%	1%	3%	14%	12%	16%

Table 12 NDC2 to NDC, or NDC2+ to NDC ratios, for WEU, EEU and FSU countries, in 2030 and 2050. ENGAGE. Back to text.

	2030						2050					
	WEU		EEU		FSU		WEU		EEU		FSU	
Sector	NDC2	NDC2+	NDC2	NDC2+	NDC2	NDC2+	NDC2	NDC2+	NDC2	NDC2+	NDC2	NDC2+
Agriculture and food	0%	1%	0%	1%	0%	0%	1%	1%	0%	1%	-2%	-3%
Minerals	0%	1%	1%	0%	1%	2%	9%	9%	-1%	-1%	22%	25%
Paper	0%	1%	0%	1%	0%	2%	2%	3%	0%	1%	21%	26%
Chemical	0%	0%	1%	0%	2%	18%	-18%	-23%	-20%	-23%	142%	183%
Non-metallic minerals	0%	1%	0%	1%	0%	0%	4%	5%	3%	4%	13%	15%
Iron and steel	0%	3%	1%	3%	2%	2%	3%	5%	11%	15%	35%	38%
Metal products	0%	1%	0%	1%	0%	1%	3%	3%	2%	3%	-3%	-6%
Other industry	0%	1%	0%	1%	0%	0%	3%	3%	3%	4%	-9%	-11%
Coal	-1%	-36%	0%	-33%	0%	-39%	-80%	-79%	-93%	-93%	-76%	-76%
Crude oil	0%	0%	0%	29%	0%	1%	-19%	-19%	-79%	-78%	-7%	-5%
Gas	0%	-9%	0%	-25%	0%	-17%	-56%	-42%	-94%	-92%	-86%	-86%
Petroleum and coal products	0%	2%	0%	6%	0%	2%	3%	3%	-28%	-34%	-25%	-25%
Coal-fired power	-1%	-31%	1%	-24%	0%	-49%	-94%	-94%	-96%	-97%	-99%	-99%

Gas-fired power	2%	2%	3%	10%	1%	-16%	-51%	-33%	-59%	-54%	-98%	-97%
Oil-fired power	1%	16%	1%	22%	1%	21%	128%	165%	27%	23%	45%	107%
Nuclear power	-5%	-17%	63%	82%	52%	144%	-89%	-92%	2081%	2269%	2318%	2523%
Hydroelectric power	11%	18%	30%	49%	54%	113%	12%	-11%	170%	137%	1904%	1914%
Wind power	43%	88%	43%	102%	57%	182%	1052%	1122%	2190%	2496%	3445%	3899%
Solar power	8%	56%	12%	105%	16%	186%	138%	146%	391%	466%	801%	994%
Other power	2%	24%	3%	38%	3%	52%	26%	16%	-1%	-17%	87%	102%
Transmission and distribution	-5%	-31%	-5%	-30%	-1%	12%	-92%	-92%	-96%	-96%	-91%	-93%
Services	0%	1%	0%	2%	0%	1%	1%	2%	4%	5%	7%	11%
Transport	0%	4%	0%	2%	0%	0%	12%	16%	5%	7%	23%	28%
CGD	0%	1%	0%	2%	0%	1%	2%	3%	4%	6%	-2%	2%

Table 13 Percentage change in effective labour supply between 2011-2050, in WEU, EEU and FSU countries. ENGAGE. Back to text.

% change 2011-2050

	WEU			EEU			FSU		
Sector	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+
Agriculture and food	77%	73%	72%	-49%	-51%	-51%	100%	84%	79%
Minerals	20%	18%	17%	-94%	-94%	-94%	20%	22%	19%
Paper	-94%	-94%	-94%	-70%	-71%	-71%	85%	91%	87%
Chemical	-64%	-64%	-65%	-83%	-88%	-89%	532%	749%	756%
Non-metallic minerals	-83%	-88%	-89%	-75%	-76%	-76%	55%	47%	42%
Iron and steel	-74%	-74%	-75%	-89%	-90%	-90%	88%	77%	66%
Metal products	-91%	-91%	-92%	-83%	-83%	-83%	136%	120%	110%
Other industry	-83%	-83%	-83%	-70%	-70%	-69%	139%	119%	112%
Coal	-66%	-66%	-66%	-56%	-97%	-97%	11%	-77%	-77%
Crude oil	-85%	-97%	-97%	-58%	-92%	-91%	28%	-3%	-2%
Gas	9%	-22%	-21%	-72%	-98%	-98%	105%	-74%	-74%
Petroleum and coal products	-33%	-73%	-64%	-51%	-66%	-69%	2%	-28%	-30%
Coal-fired power	-56%	-56%	-56%	-75%	-99%	-99%	82%	-95%	-96%

Gas-fired power	-77%	-98%	-98%	-47%	-76%	-75%	170%	-92%	-91%
Oil-fired power	-50%	-72%	-65%	-64%	-61%	-64%	155%	151%	218%
Nuclear power	-58%	-18%	-8%	-85%	-42%	-40%	121%	805%	819%
Hydroelectric power	-86%	-98%	-99%	-81%	-69%	-73%	108%	1477%	1428%
Wind power	-80%	-82%	-86%	-78%	97%	119%	275%	4558%	4915%
Solar power	-75%	17%	23%	15%	413%	488%	13804%	118020%	142662%
Other power	-39%	33%	37%	-67%	-68%	-74%	341%	521%	526%
Transmission and distribution	-72%	-67%	-70%	-81%	-99%	-99%	78%	-87%	-91%
Services	-85%	-99%	-99%	-60%	-59%	-58%	70%	82%	87%
Transport	-58%	-58%	-58%	-65%	-67%	-67%	63%	64%	59%

Table 14 NDC2 to NDC, or NDC2+ to NDC ratios of effective labour supply for WEU, EEU and FSU countries, in 2030 and 2050. ENGAGE. Back to text.

	2030						2050					
	WEU		EEU		FSU		WEU		EEU		FSU	
Sector	NDC2	NDC2+	NDC2	NDC2+	NDC2	NDC2+	NDC2	NDC2+	NDC2	NDC2+	NDC2	NDC2+
Agriculture and food	0%	0%	0%	0%	0%	0%	-2%	-2%	-3%	-4%	-8%	-10%
Minerals	0%	0%	0%	-2%	0%	0%	5%	3%	-7%	-9%	2%	-1%
Paper	0%	0%	0%	0%	0%	1%	-2%	-3%	-3%	-3%	3%	1%
Chemical	0%	-4%	0%	-4%	1%	7%	-26%	-32%	-29%	-35%	34%	36%
Non-metallic minerals	0%	-1%	0%	-1%	0%	0%	-3%	-4%	-3%	-5%	-5%	-9%
Iron and steel	-1%	-1%	0%	-1%	0%	-1%	-7%	-9%	-9%	-11%	-6%	-12%
Metal products	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	-7%	-11%
Other industry	0%	0%	0%	0%	0%	0%	2%	2%	2%	3%	-9%	-11%
Coal	-1%	-37%	0%	-35%	0%	-40%	-81%	-80%	-93%	-93%	-79%	-80%
Crude oil	0%	-2%	0%	23%	0%	-1%	-28%	-27%	-80%	-79%	-24%	-23%
Gas	0%	-10%	0%	-25%	0%	-18%	-60%	-46%	-94%	-92%	-87%	-88%

Petroleum and coal products	0%	2%	-1%	5%	-1%	2%	0%	0%	-31%	-36%	-29%	-31%
Coal-fired power	-1%	-14%	0%	-6%	-1%	-24%	-91%	-91%	-94%	-95%	-97%	-98%
Gas-fired power	2%	11%	2%	17%	1%	1%	-44%	-30%	-54%	-52%	-97%	-97%
Oil-fired power	1%	15%	1%	20%	1%	22%	97%	120%	8%	0%	-2%	24%
Nuclear power	-5%	-18%	0%	9%	-5%	50%	-89%	-93%	276%	293%	309%	315%
Hydroelectric power	0%	6%	5%	20%	9%	52%	-12%	-30%	61%	38%	657%	633%
Wind power	1%	33%	1%	42%	10%	98%	372%	394%	803%	902%	1142%	1237%
Solar power	5%	54%	8%	101%	13%	184%	117%	123%	346%	412%	750%	927%
Other power	2%	23%	3%	38%	3%	50%	19%	9%	-3%	-20%	41%	42%
Transmission and distribution	-5%	-31%	-6%	-31%	-1%	7%	-92%	-92%	-96%	-97%	-93%	-95%
Services	0%	0%	0%	1%	0%	0%	1%	2%	4%	4%	7%	9%
Transport	0%	-2%	0%	-2%	0%	-1%	-5%	-8%	-4%	-6%	1%	-3%

Table 15 Effective labour supply distribution in WEU, EEU and FSU countries in 2011, 2030 and 2050. ENGAGE. Back to text.

	EEU							FSU							WEU						
	2011	2030			2050			2011	2030			2050			2011	2030			2050		
	NDC	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+	NDC	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+	NDC	NDC	NDC2	NDC2+	NDC	NDC2	NDC2+
Agriculture and food	10,71%	11,64%	11,61%	11,61%	15,57%	15,10%	14,92%	9,69%	10,09%	10,06%	10,05%	10,25%	9,42%	9,17%	5,05%	7,93%	7,93%	7,91%	14,68%	14,44%	14,33%
Minerals	0,40%	0,23%	0,23%	0,23%	0,07%	0,07%	0,07%	0,79%	0,78%	0,78%	0,78%	0,50%	0,51%	0,50%	0,20%	0,11%	0,11%	0,11%	0,03%	0,03%	0,03%
Paper	1,78%	1,72%	1,71%	1,72%	1,52%	1,48%	1,46%	0,49%	0,51%	0,51%	0,51%	0,48%	0,49%	0,49%	1,79%	1,73%	1,73%	1,72%	1,57%	1,54%	1,53%
Chemical	3,53%	2,92%	2,92%	2,80%	1,71%	1,22%	1,12%	0,96%	1,80%	1,81%	1,93%	3,19%	4,29%	4,33%	3,24%	2,56%	2,56%	2,47%	1,30%	0,96%	0,88%
Non-metallic minerals	1,66%	1,48%	1,48%	1,47%	1,20%	1,16%	1,14%	1,11%	1,05%	1,05%	1,05%	0,91%	0,86%	0,83%	0,89%	0,76%	0,76%	0,75%	0,57%	0,55%	0,54%
Iron and steel	1,30%	0,86%	0,86%	0,85%	0,42%	0,39%	0,38%	1,05%	1,15%	1,14%	1,14%	1,05%	0,99%	0,92%	0,72%	0,44%	0,43%	0,43%	0,16%	0,15%	0,15%
Metal products	6,02%	5,06%	5,06%	5,05%	2,94%	2,94%	2,94%	2,89%	3,89%	3,89%	3,90%	3,61%	3,36%	3,21%	5,43%	4,51%	4,51%	4,52%	2,23%	2,25%	2,24%
Other industry	20,42%	19,18%	19,18%	19,25%	17,30%	17,73%	17,80%	15,92%	18,85%	18,85%	18,87%	20,10%	18,36%	17,81%	15,94%	15,30%	15,31%	15,34%	12,99%	13,27%	13,28%
Coal	0,63%	0,63%	0,63%	0,41%	0,79%	0,06%	0,05%	0,80%	0,43%	0,43%	0,26%	0,47%	0,10%	0,10%	0,09%	0,05%	0,05%	0,03%	0,03%	0,01%	0,01%
Crude oil	0,12%	0,11%	0,11%	0,14%	0,14%	0,03%	0,03%	2,91%	2,07%	2,06%	2,04%	1,96%	1,48%	1,51%	0,07%	0,13%	0,13%	0,13%	0,19%	0,14%	0,14%
Gas	0,30%	0,28%	0,28%	0,21%	0,24%	0,02%	0,02%	3,02%	2,41%	2,40%	1,97%	3,27%	0,41%	0,41%	0,09%	0,12%	0,12%	0,11%	0,14%	0,06%	0,08%
Petroleoum and coal products	0,22%	0,21%	0,21%	0,22%	0,30%	0,21%	0,19%	0,40%	0,28%	0,28%	0,29%	0,22%	0,15%	0,15%	0,11%	0,12%	0,12%	0,12%	0,12%	0,12%	0,12%
Coal-fired power	0,66%	0,51%	0,51%	0,48%	0,47%	0,03%	0,02%	0,30%	0,26%	0,26%	0,20%	0,29%	0,01%	0,01%	0,08%	0,06%	0,06%	0,05%	0,04%	0,00%	0,00%
Gas-fired power	0,04%	0,03%	0,03%	0,04%	0,06%	0,03%	0,03%	0,08%	0,07%	0,07%	0,07%	0,11%	0,00%	0,00%	0,03%	0,03%	0,03%	0,03%	0,04%	0,02%	0,03%
Other-fired power	0,02%	0,02%	0,02%	0,02%	0,02%	0,03%	0,02%	0,01%	0,01%	0,01%	0,01%	0,02%	0,02%	0,02%	0,02%	0,01%	0,01%	0,01%	0,02%	0,03%	0,03%
Nuclear power	0,63%	0,51%	0,51%	0,56%	0,28%	1,05%	1,09%	0,74%	0,62%	0,59%	0,94%	0,86%	3,53%	3,59%	0,20%	0,14%	0,14%	0,12%	0,07%	0,01%	0,01%
Hydroelectic power	0,15%	0,12%	0,12%	0,14%	0,08%	0,13%	0,11%	0,13%	0,11%	0,12%	0,17%	0,15%	1,12%	1,08%	0,07%	0,05%	0,05%	0,05%	0,03%	0,03%	0,02%
Wind power	0,05%	0,04%	0,04%	0,05%	0,03%	0,26%	0,29%	0,00%	0,00%	0,00%	0,01%	0,01%	0,10%	0,11%	0,07%	0,05%	0,05%	0,07%	0,04%	0,19%	0,20%
Solar power	0,01%	0,01%	0,01%	0,02%	0,04%	0,17%	0,19%	0,00%	0,00%	0,00%	0,00%	0,02%	0,16%	0,19%	0,02%	0,02%	0,02%	0,03%	0,03%	0,07%	0,08%
Other power	0,08%	0,06%	0,06%	0,08%	0,08%	0,07%	0,06%	0,01%	0,00%	0,00%	0,01%	0,01%	0,02%	0,02%	0,06%	0,04%	0,04%	0,05%	0,04%	0,05%	0,04%
Transmission and distribution	1,17%	0,98%	0,93%	0,68%	0,63%	0,02%	0,02%	1,10%	1,20%	1,18%	1,28%	1,04%	0,07%	0,05%	0,44%	0,34%	0,32%	0,23%	0,16%	0,01%	0,01%
Services	45,31%	48,43%	48,51%	49,09%	51,39%	53,28%	53,60%	49,18%	46,55%	46,62%	46,78%	44,26%	47,26%	48,45%	62,17%	62,40%	62,43%	62,68%	62,75%	63,43%	63,71%
Transport	4,78%	4,99%	4,99%	4,89%	4,75%	4,56%	4,44%	8,41%	7,86%	7,87%	7,74%	7,23%	7,27%	7,05%	3,23%	3,11%	3,11%	3,04%	2,77%	2,63%	2,55%

Table 16 Agriculture share of employment. Source: World Bank (2019). Back to text.

	Country	2017	2018	2019
WEU	Albania	38.20	38.00	37.79
	Austria	3.93	3.90	3.86
	Belgium	1.16	1.15	1.14
	Denmark	2.21	2.19	2.17
	Finland	3.76	3.73	3.69
	France	2.63	2.60	2.58
	Germany	1.28	1.27	1.25
	Greece	12.08	11.97	11.85
	Iceland	3.76	3.72	3.68
	Ireland	5.06	5.02	4.98
	Italy	3.78	3.75	3.72
	Luxembourg	1.39	1.38	1.36
	Malta	1.01	1.00	1.00
	Netherlands	2.27	2.25	2.22
	Norway	2.06	2.04	2.02
	Portugal	6.40	6.34	6.28
	Spain	4.35	4.31	4.27
	Sweden	1.83	1.81	1.79
	Switzerland	3.11	3.08	3.05
EEU	Belarus	10.70	10.59	10.48
	Bosnia and Herzegovina	16.64	16.50	16.36
	Bulgaria	7.01	6.94	6.87
	Croatia	6.98	6.91	6.85

	Czech Republic	2.80	2.78	2.75
	Hungary	5.04	4.99	4.94
	Montenegro	7.93	7.85	7.76
	North Macedonia	16.24	16.11	15.98
	Poland	10.22	10.13	10.05
	Romania	22.78	22.61	22.45
	Serbia	17.22	17.08	16.95
	Slovak Republic	2.71	2.68	2.66
	Slovenia	5.56	5.51	5.46
FSU	Armenia	33.44	33.29	33.15
	Azerbaijan	36.35	36.13	35.90
	Estonia	3.53	3.49	3.45
	Georgia	43.12	42.90	42.67
	Kazakhstan	15.13	15.01	14.89
	Kyrgyz Republic	26.65	26.52	26.38
	Latvia	6.87	6.80	6.73
	Lithuania	7.78	7.71	7.64
	Moldova	32.34	32.18	32.03
	Russian Federation	5.90	5.84	5.77
	Tajikistan	51.28	51.06	50.83
	Turkmenistan	22.94	22.78	22.61
	Ukraine	15.41	15.33	15.25
	Uzbekistan	33.52	33.36	33.20

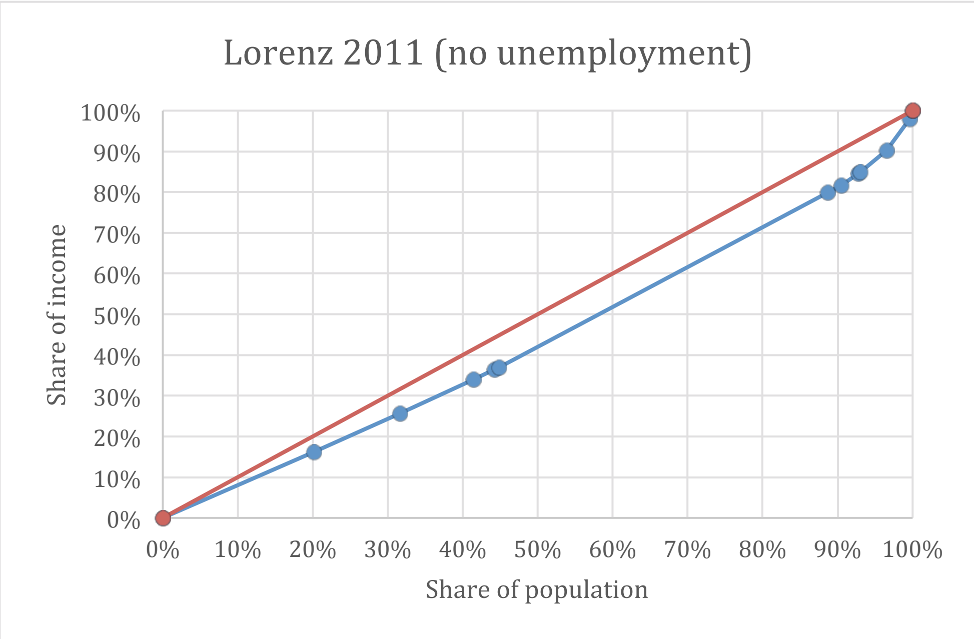
6. Appendix 1

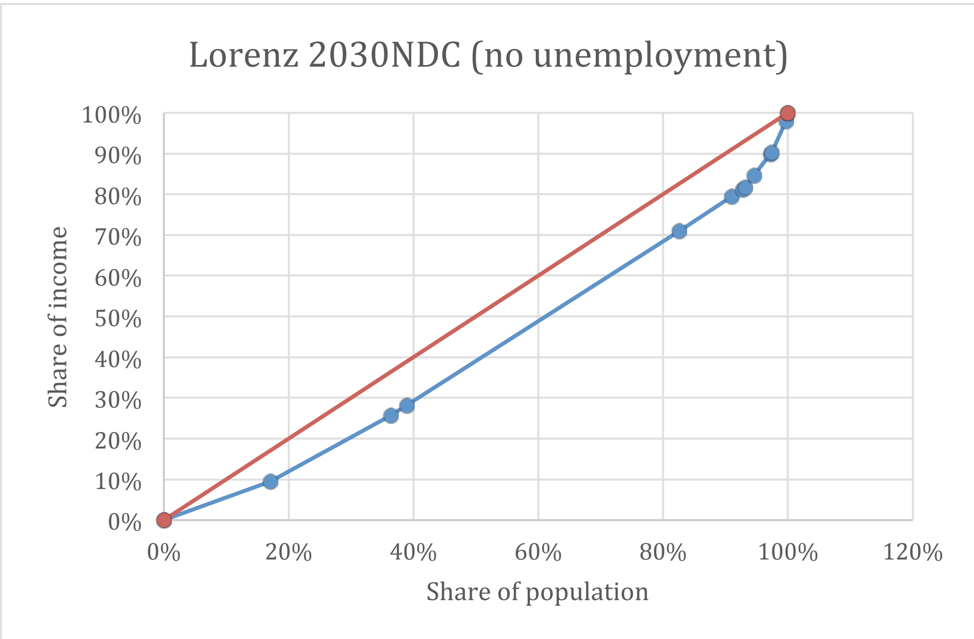
Following is the list of sectors included in ENGAGE:

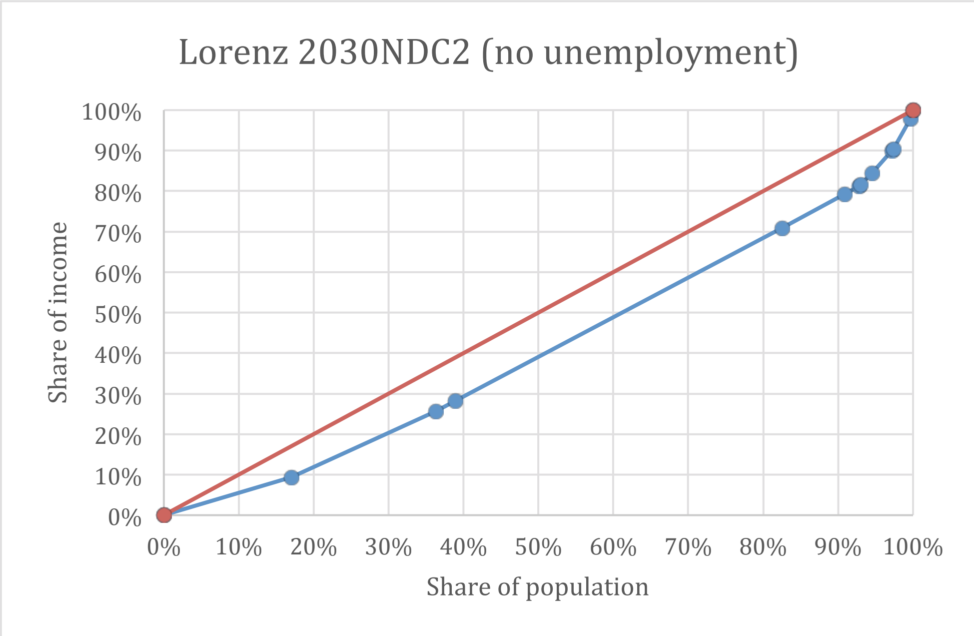
(a) Agriculture and food
(b) Minerals
(c) Paper
(d) Chemical
(e) Non-metallic minerals
(f) Iron and steel
(g) Metal products
(h) Other industry
(i) Coal
(j) Crude oil
(k) Gas
(l) Petroleum and coal products
(m) Coal-fired power
(n) Gas-fired power
(o) Oil-fired power
(p) Nuclear power
(q) Hydroelectric power
(r) Wind power
(s) Solar power
(t) Other power
(u) Transmission and distribution
(v) Services
(w) Transport

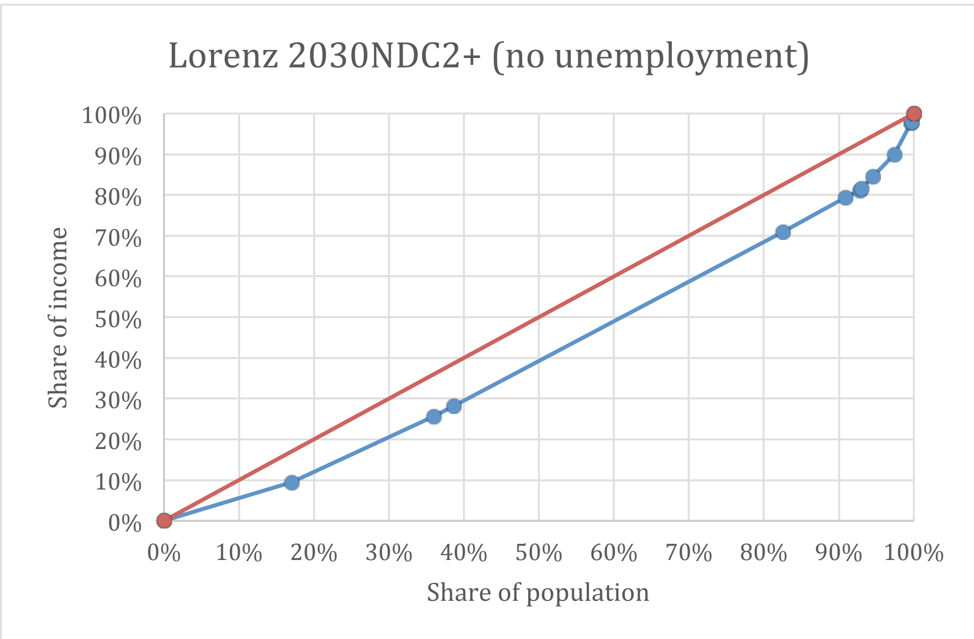
7. Appendix 2

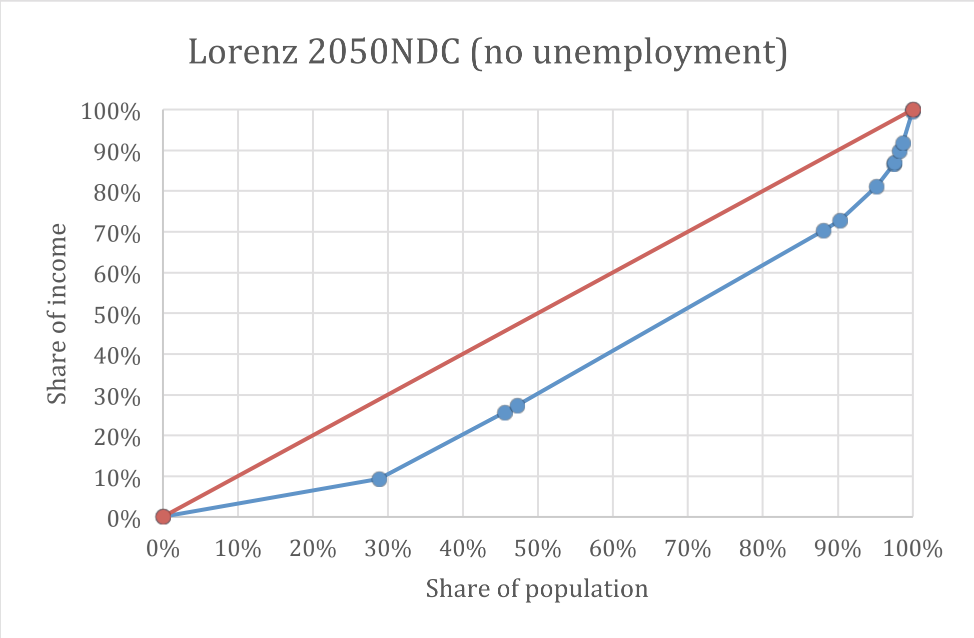
This Appendix contains Lorenz curves for the UK for all years and scenarios, with and without unemployment, as obtained by following Approach 1. It also contains the table of relative Gini coefficients. Back to text.

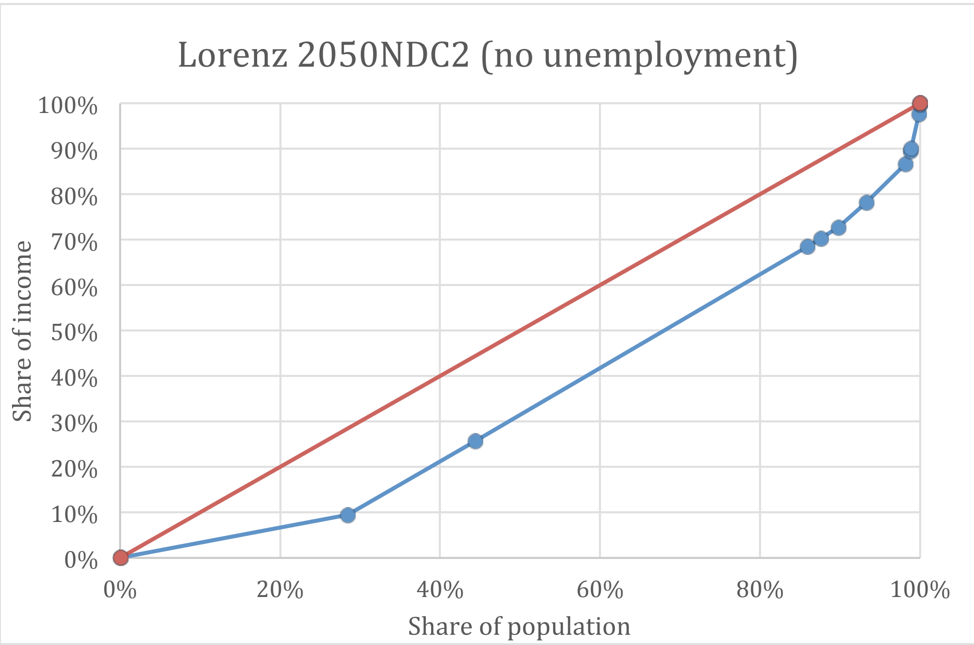


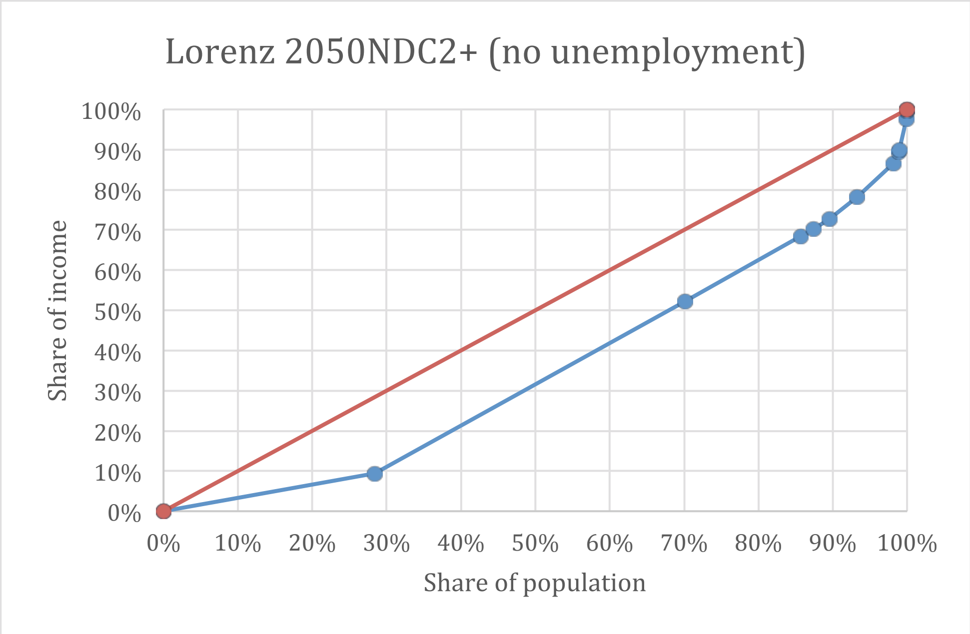



Lorenz 2030NDC2 (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Share of population

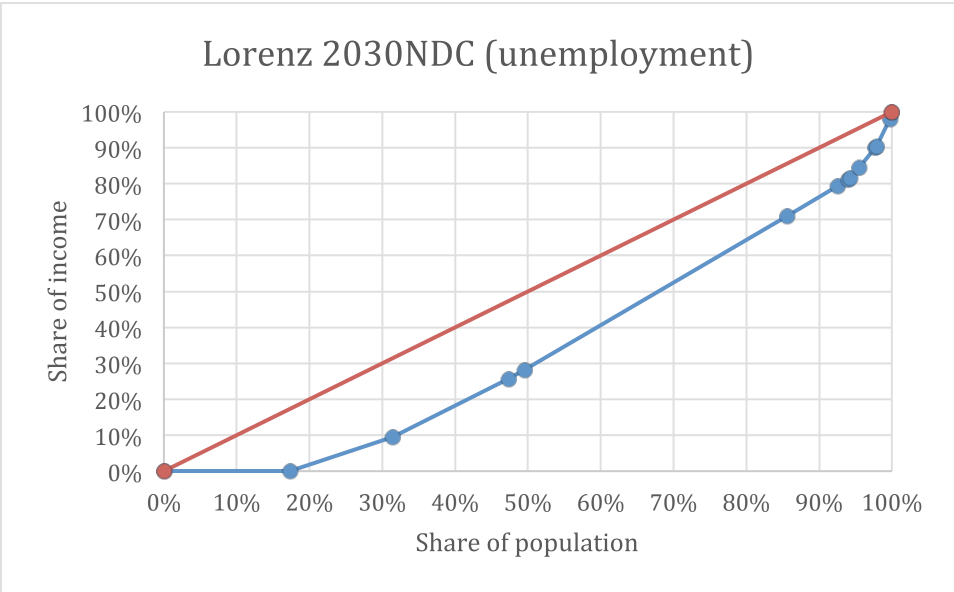

Lorenz 2030NDC2+ (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Share of population


Lorenz 2050NDC (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Share of population

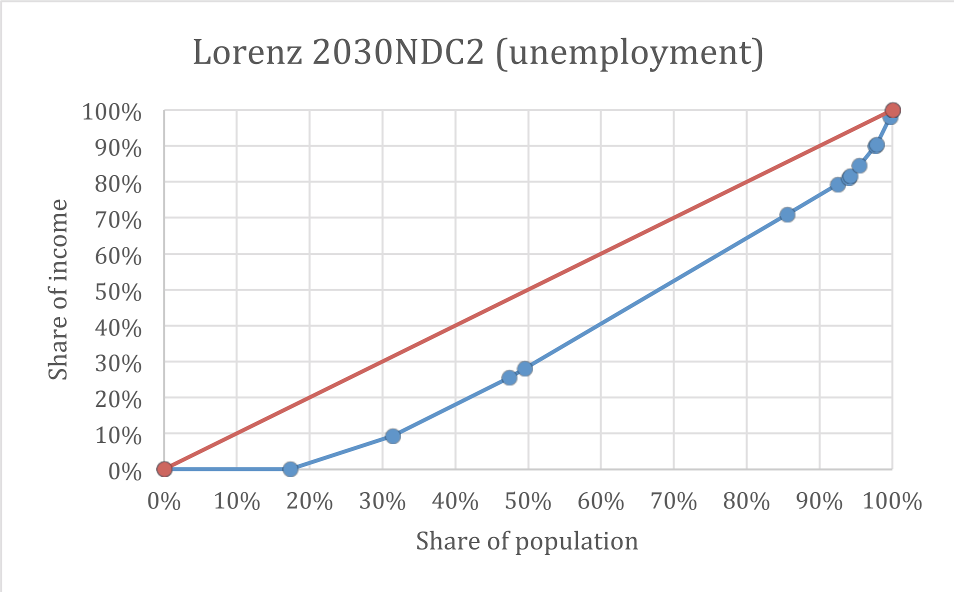

Lorenz 2050NDC2 (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0% 20% 40% 60% 80% 100%
Share of population

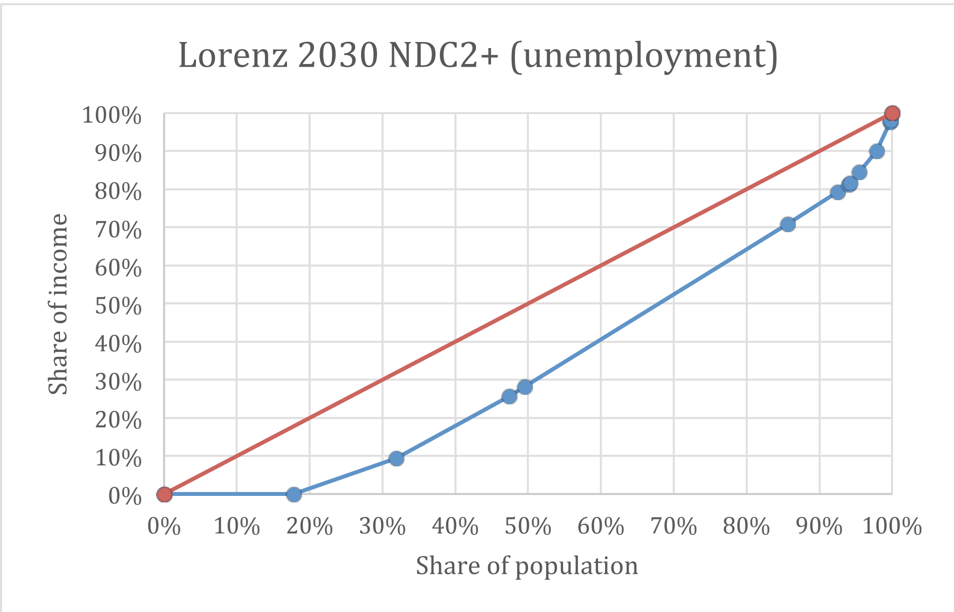


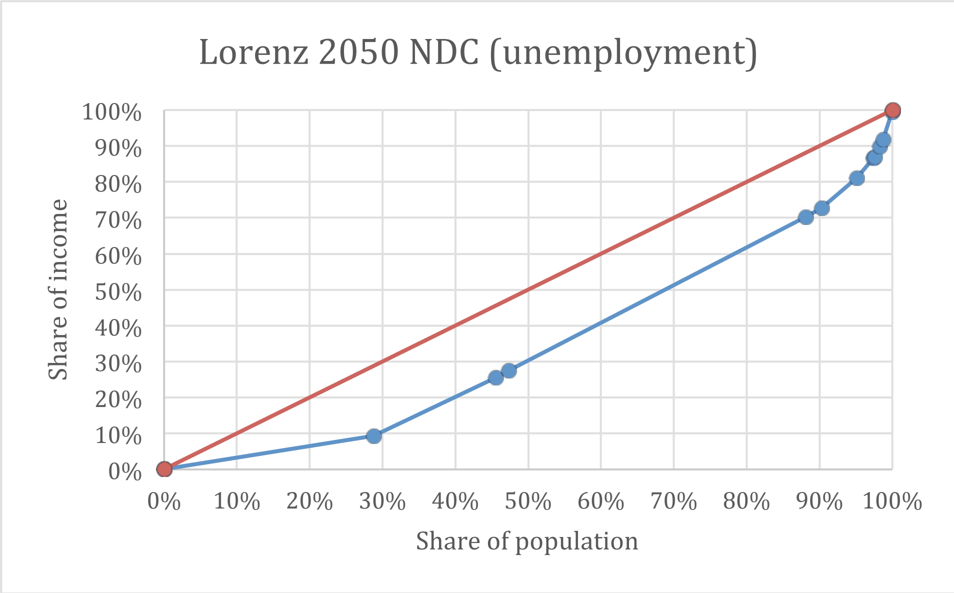
Lorenz 2050NDC2+ (no unemployment)
Share of income
Share of population
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%



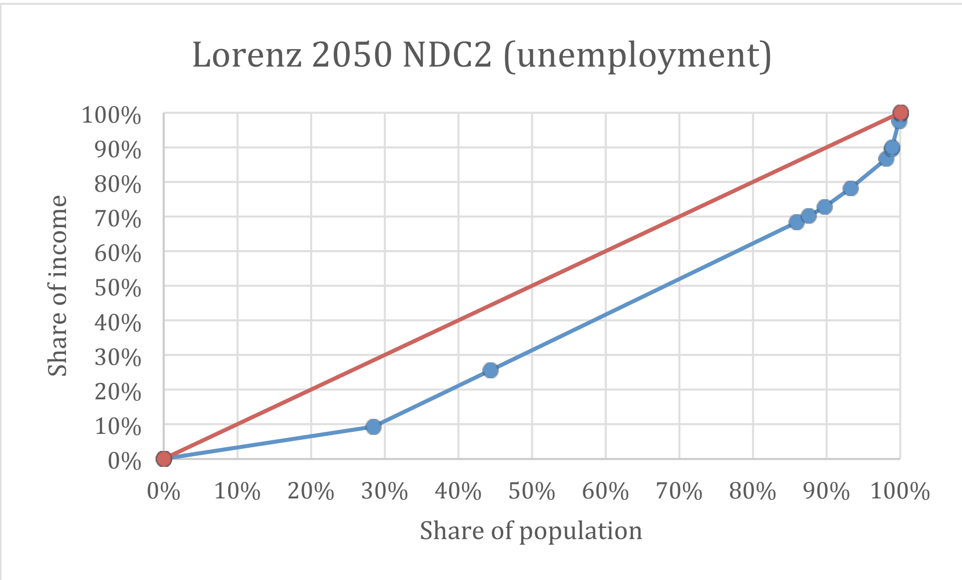
Lorenz 2030NDC (unemployment)
Share of income
Share of population
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Lorenz 2030NDC2 (unemployment)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Share of income
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population

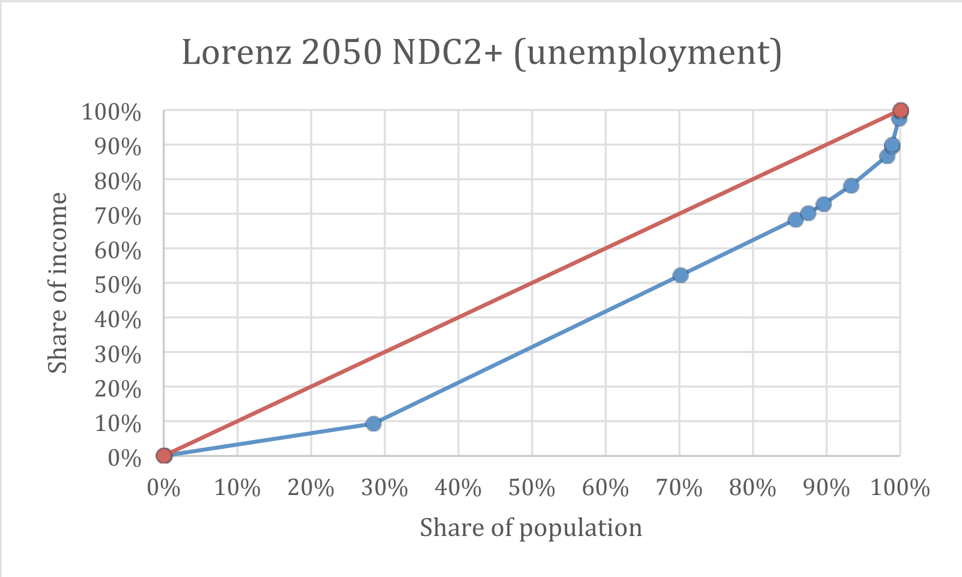

Lorenz 2030 NDC2+ (unemployment)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Share of income
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population



Lorenz 2050 NDC (unemployment)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of income
Share of population

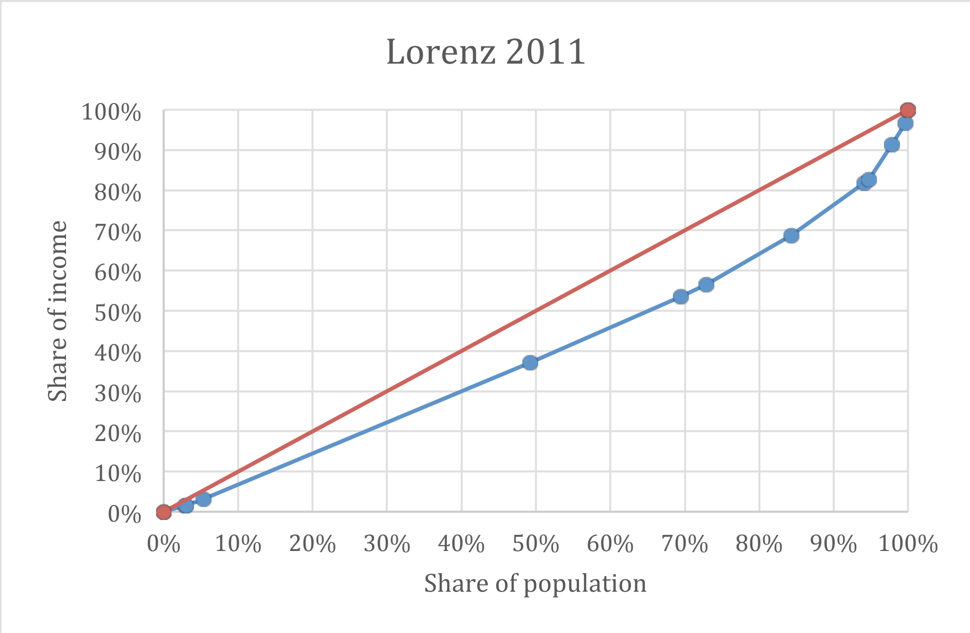


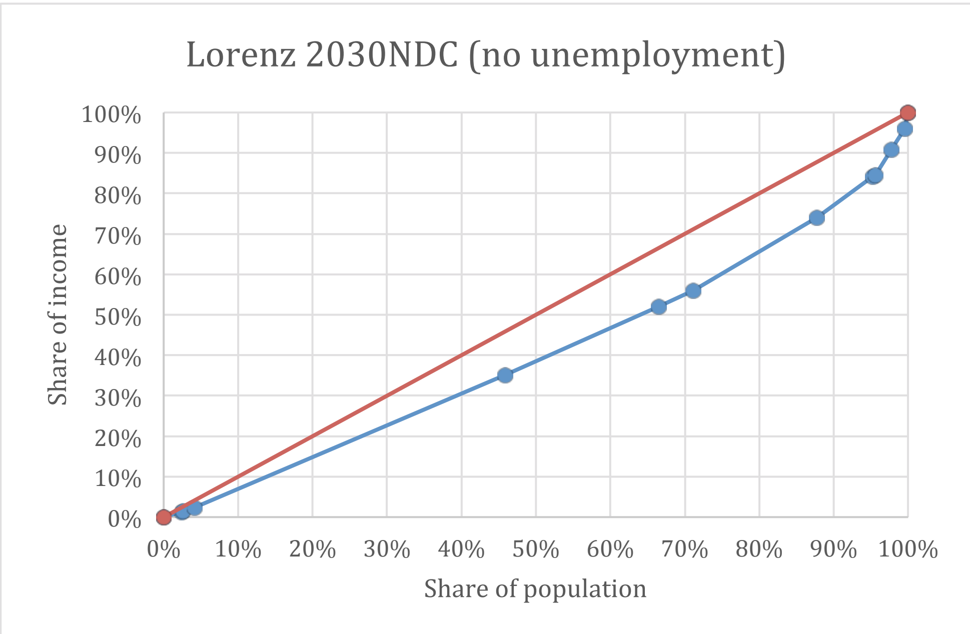
Lorenz 2050 NDC2 (unemployment)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of income
Share of population

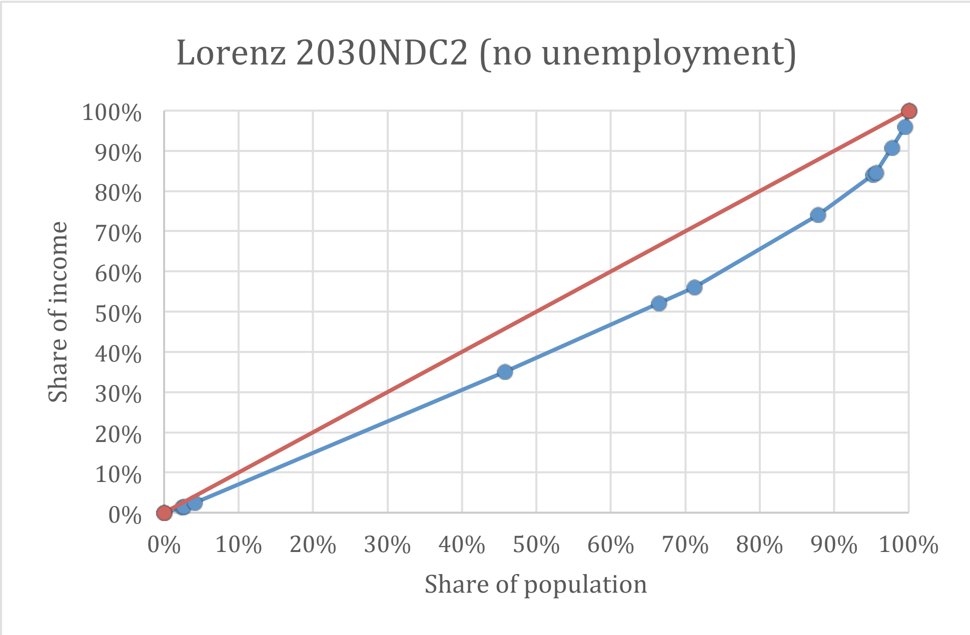

Lorenz 2050 NDC2+ (unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population

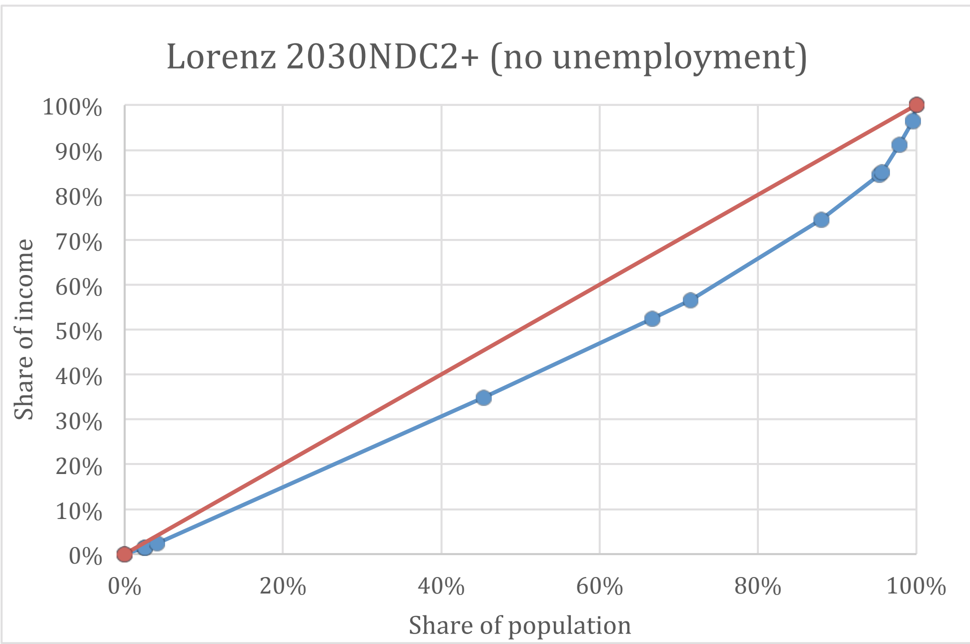
8. Appendix 3

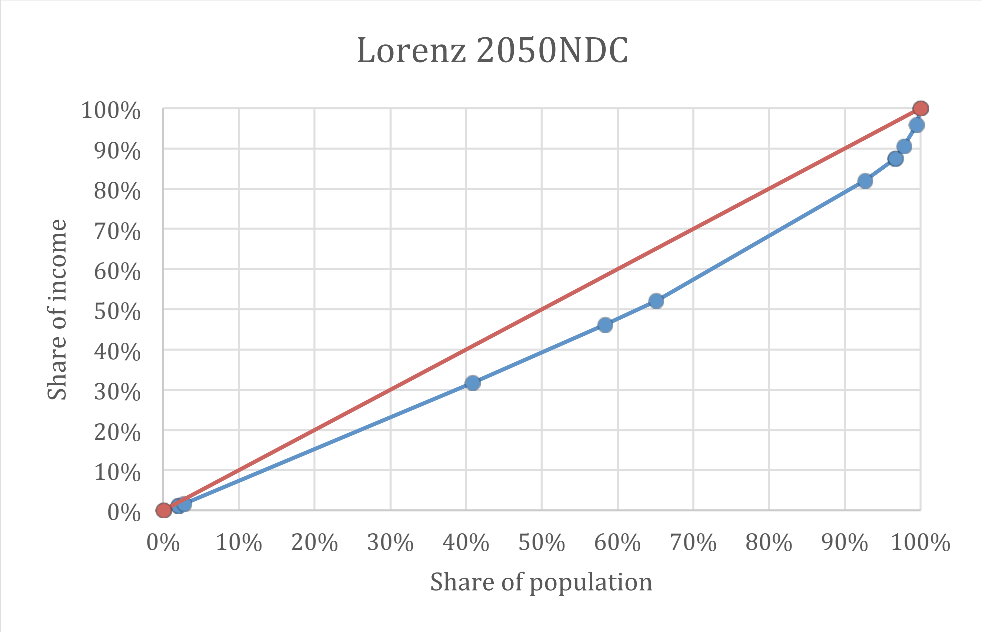
This Appendix contains Lorenz curves for the UK for all years and scenarios, with and without unemployment, as obtained by following Approach 2. It also contains the table of relative Gini coefficients. Back to text.

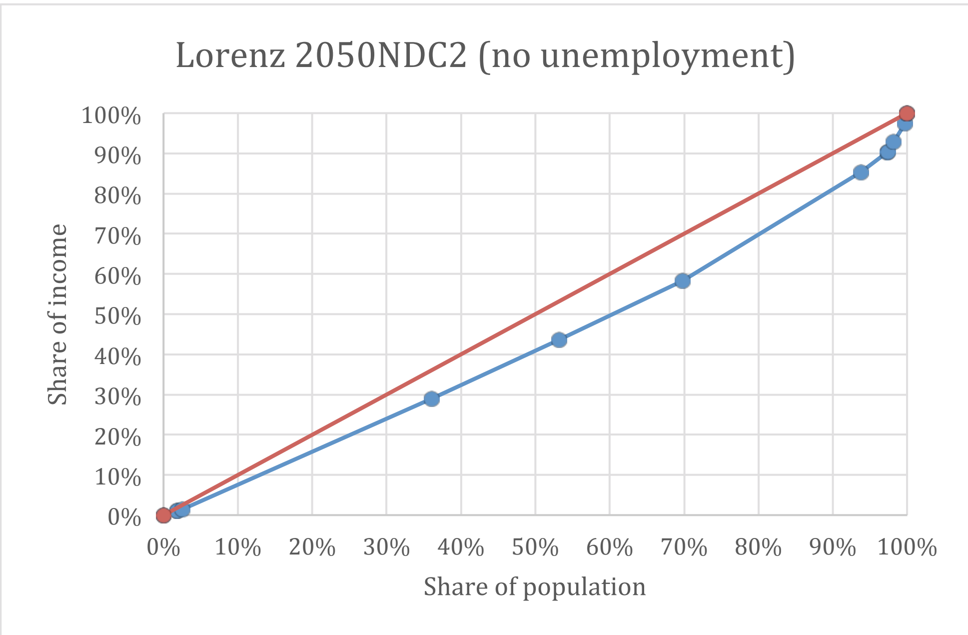


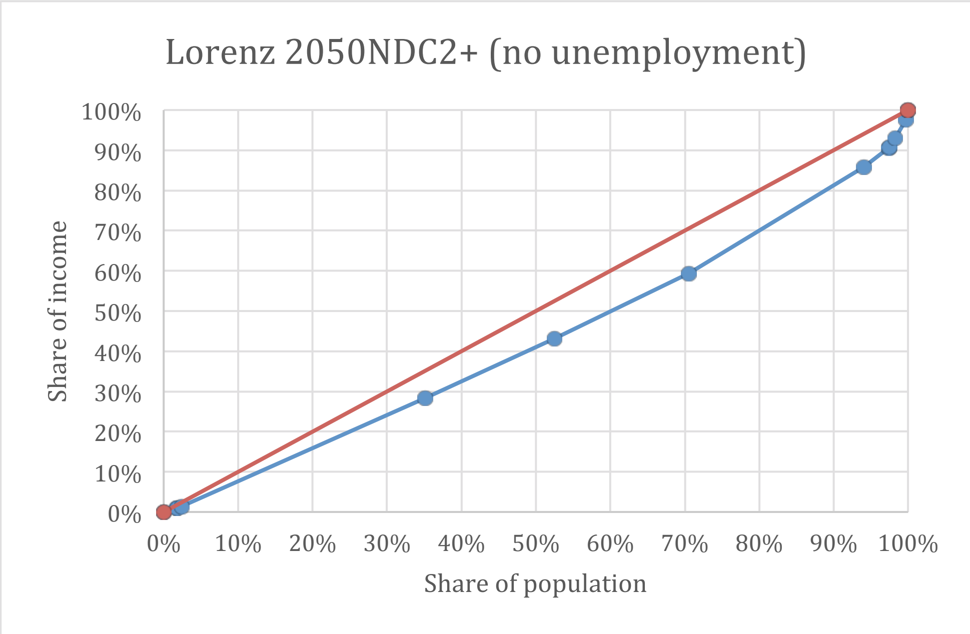


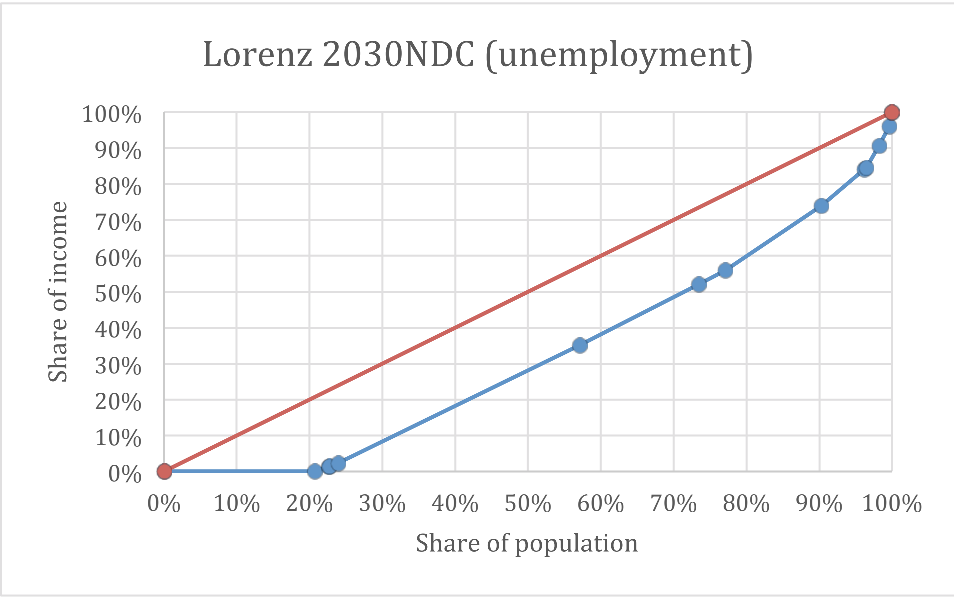

Lorenz 2030NDC2 (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population

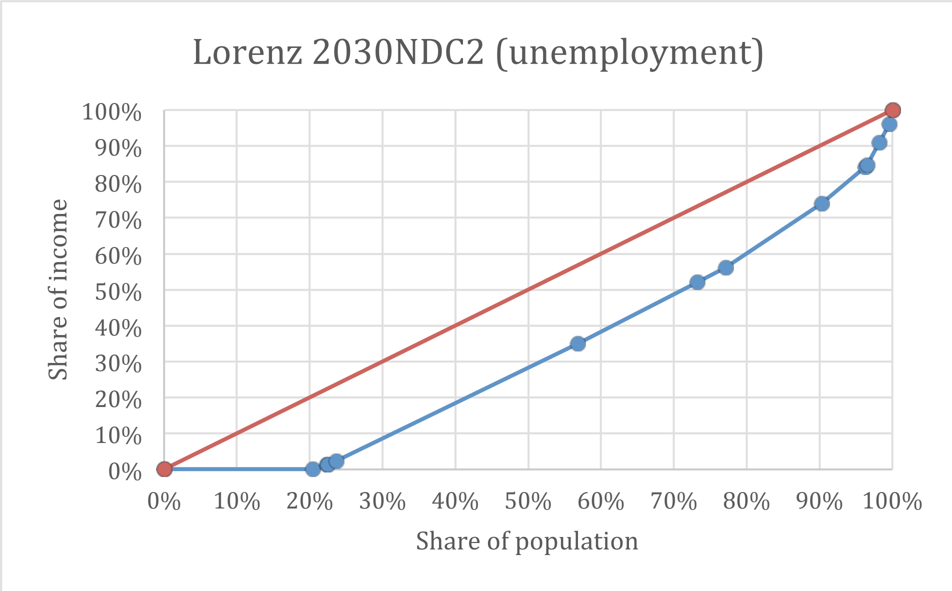

Lorenz 2030NDC2+ (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
20%
40%
60%
80%
100%
Share of population

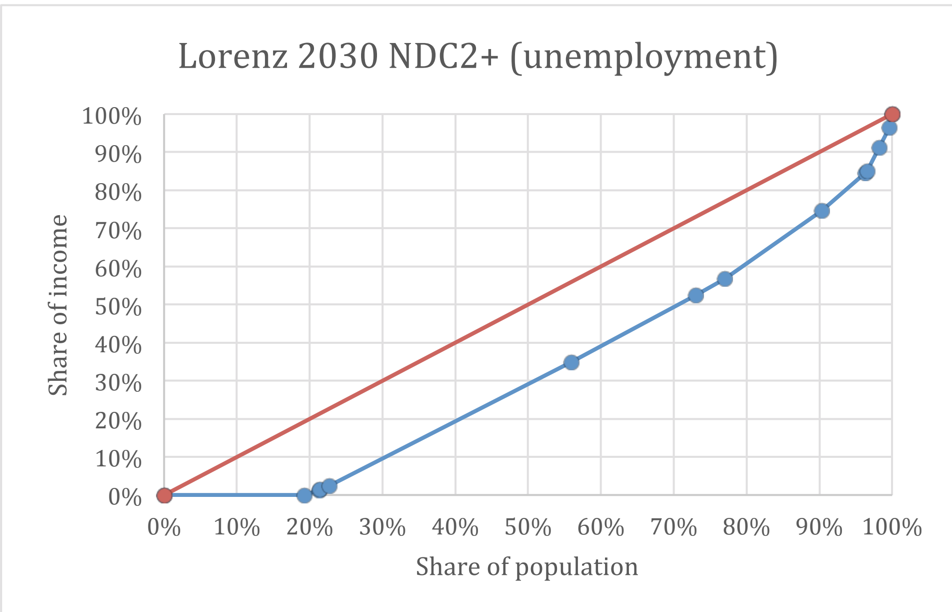

Lorenz 2050NDC
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population

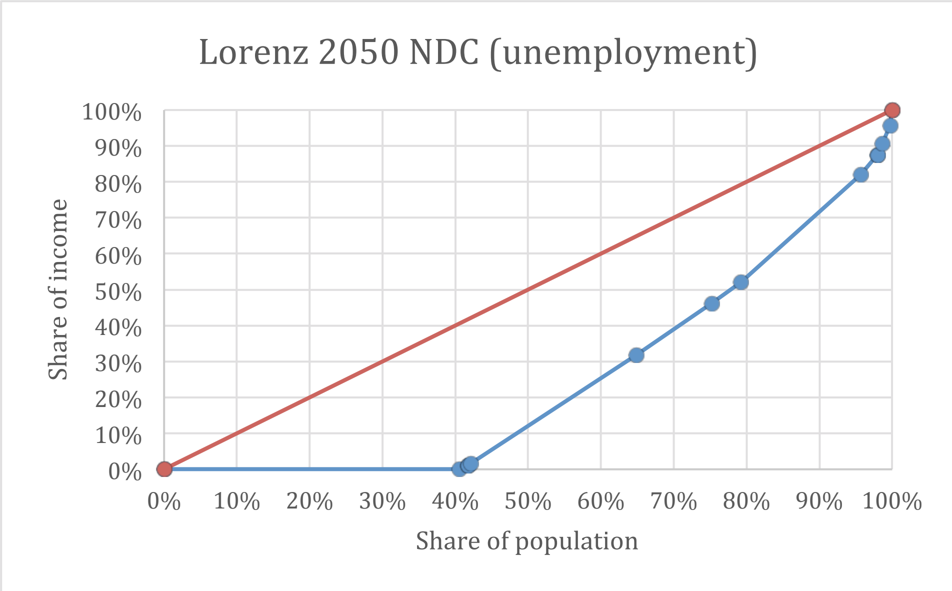

Lorenz 2050NDC2 (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population

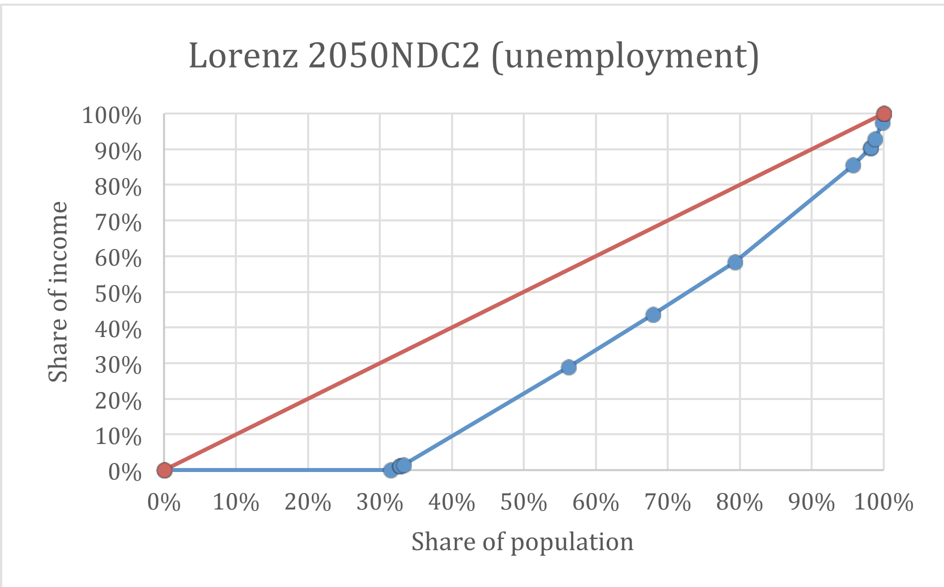

Lorenz 2050NDC2+ (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population

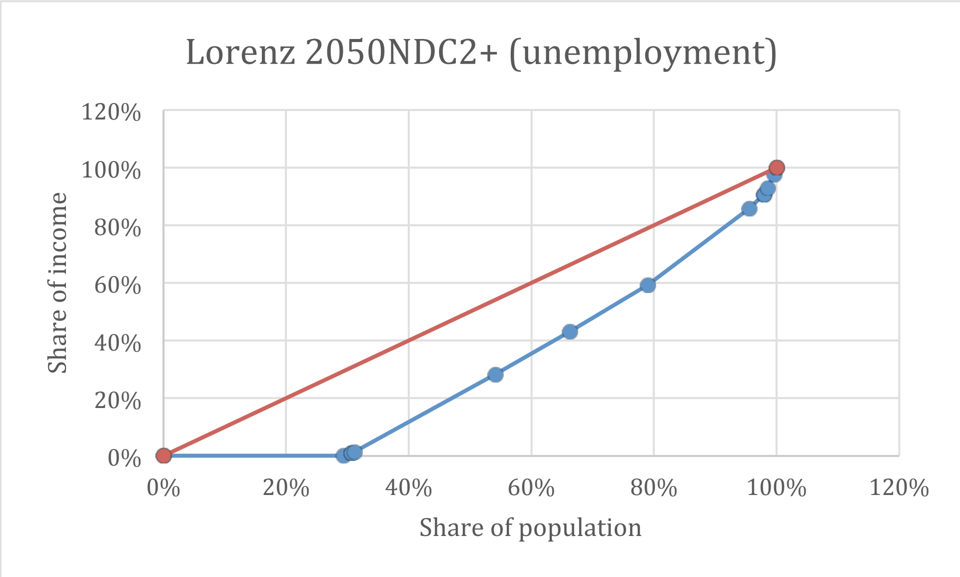

Lorenz 2030NDC (unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population


Lorenz 2030NDC2 (unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Share of population


Lorenz 2030 NDC2+ (unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Share of population

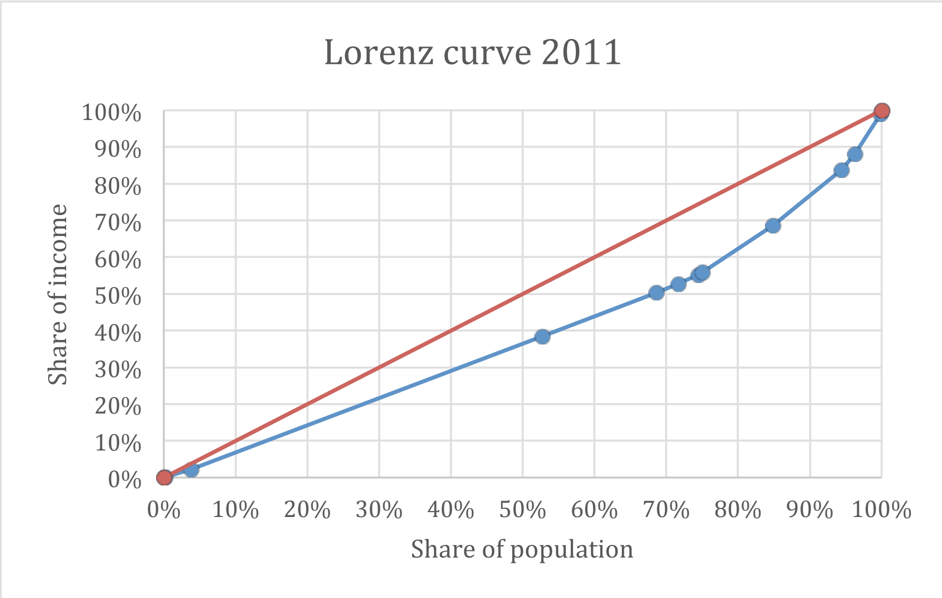

Lorenz 2050 NDC (unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population

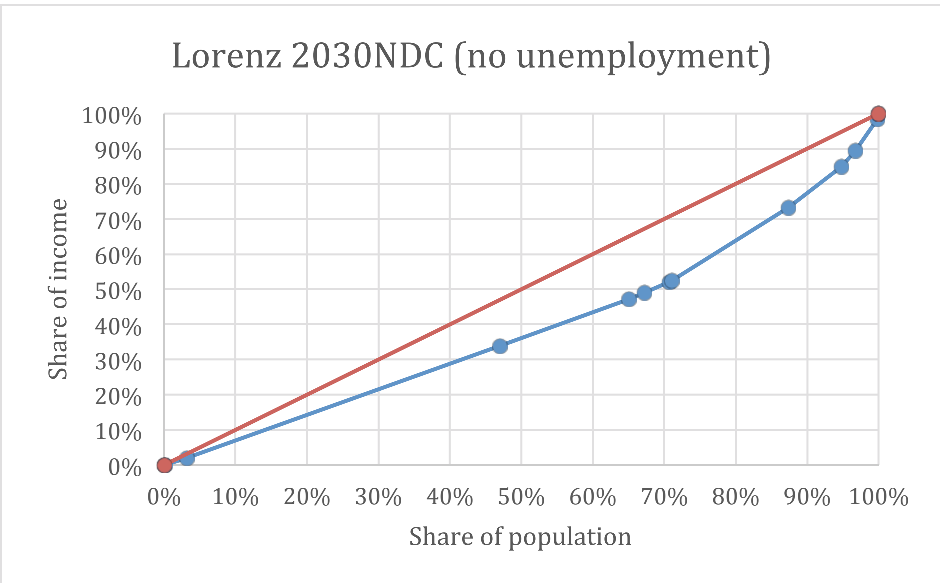

Lorenz 2050NDC2 (unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population

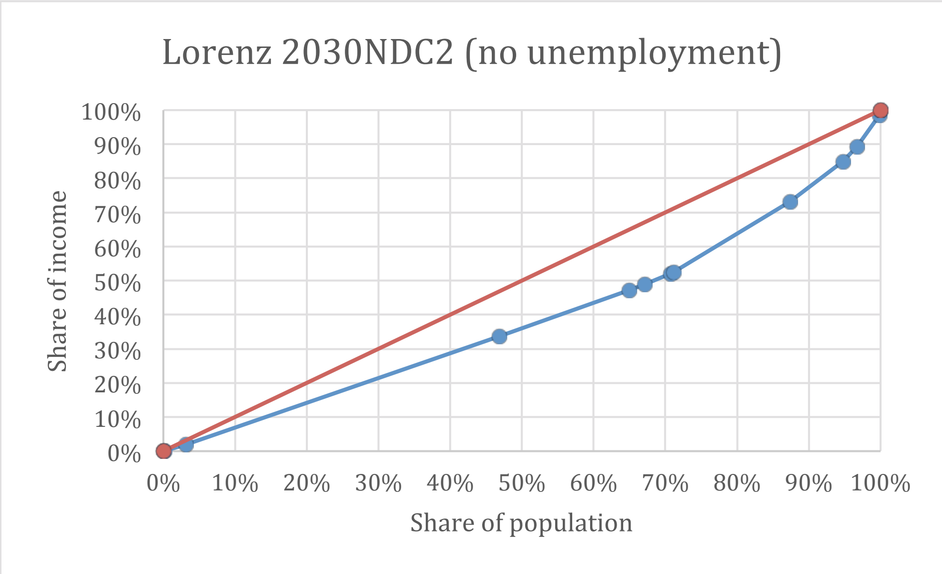

Lorenz 2050NDC2+ (unemployment)
120%
100%
80%
60%
40%
20%
0%
Share of income
0%
20%
40%
60%
80%
100%
120%
Share of population

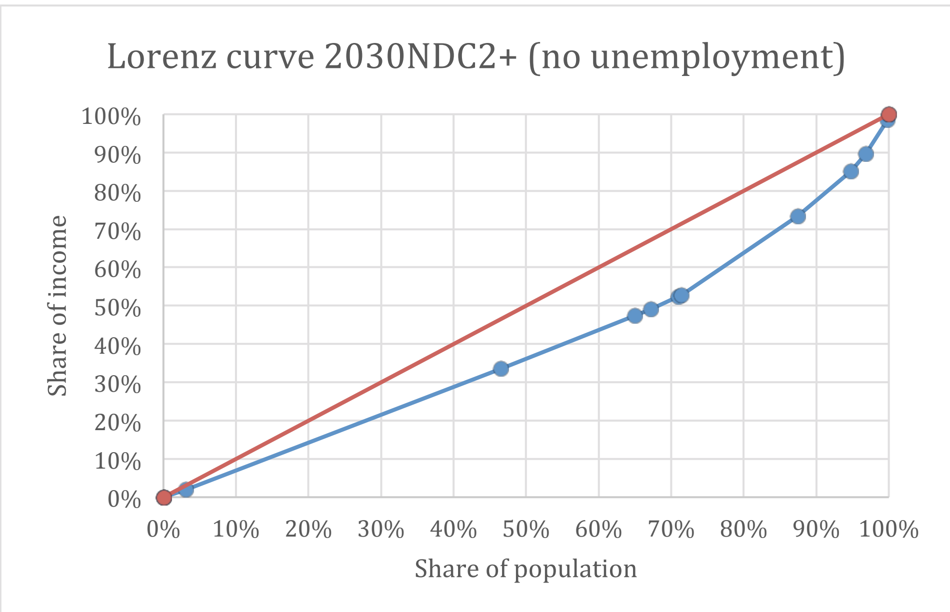
9. Appendix 4

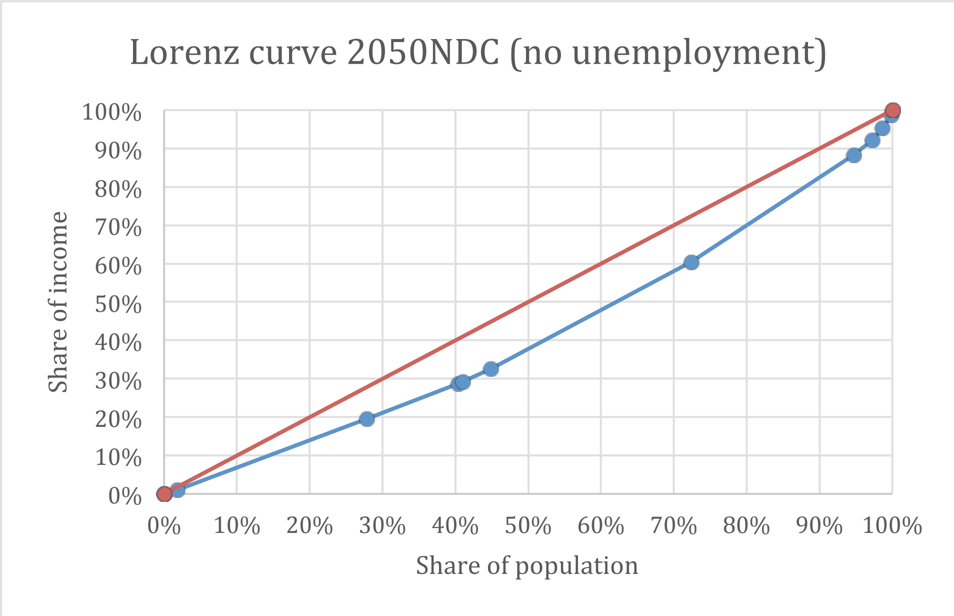
This Appendix contains Lorenz curves for WEU countries for all years and scenarios, with and without unemployment, as obtained by following Approach 2. It also contains the table of relative Gini coefficients. Back to text.



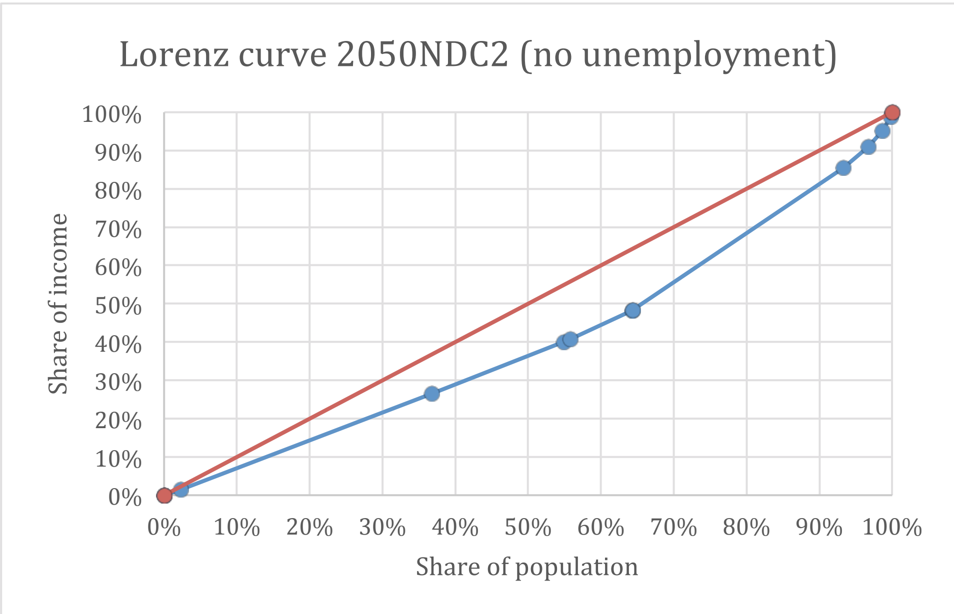



Lorenz 2030NDC2 (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population

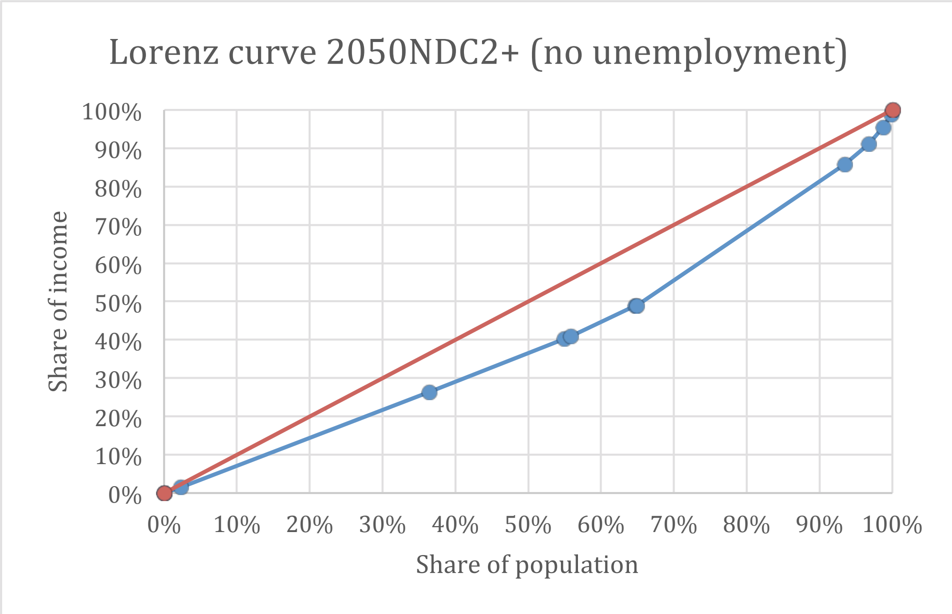

Lorenz curve 2030NDC2+ (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population

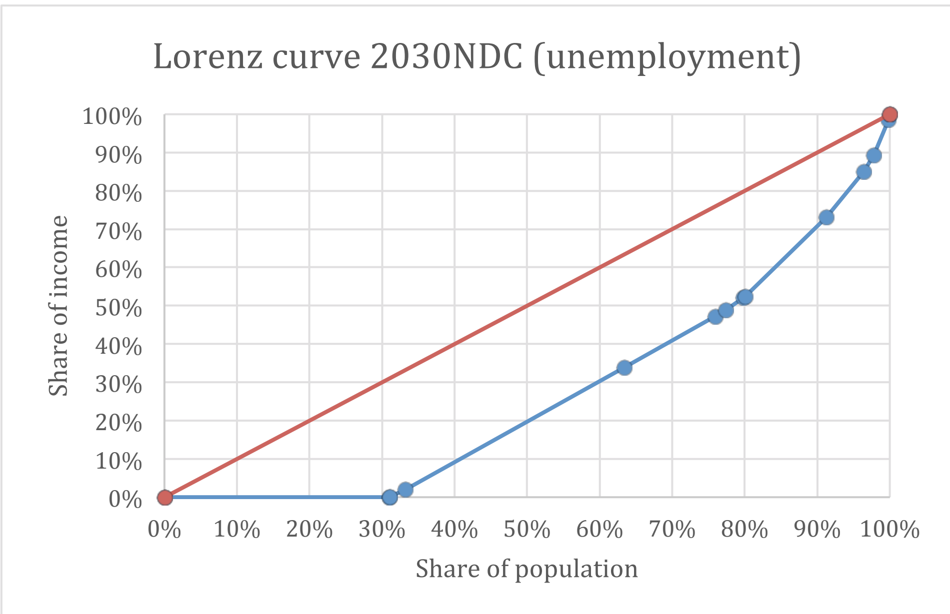


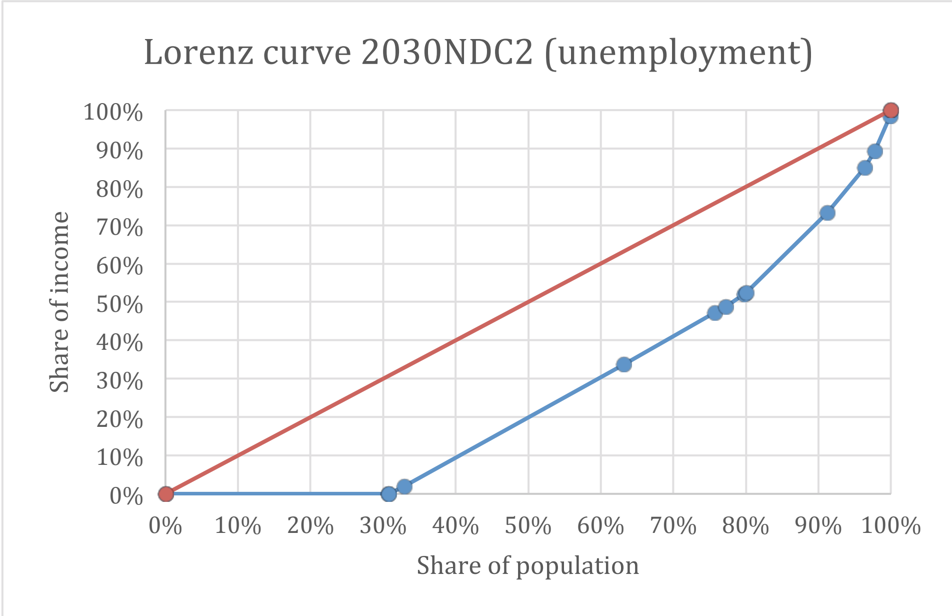
Lorenz curve 2050NDC (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Share of population

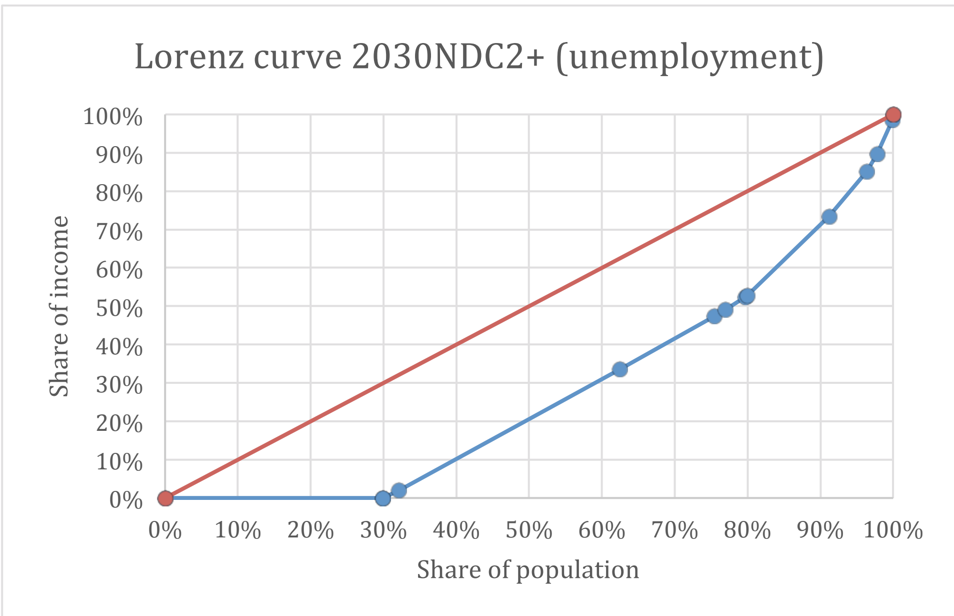


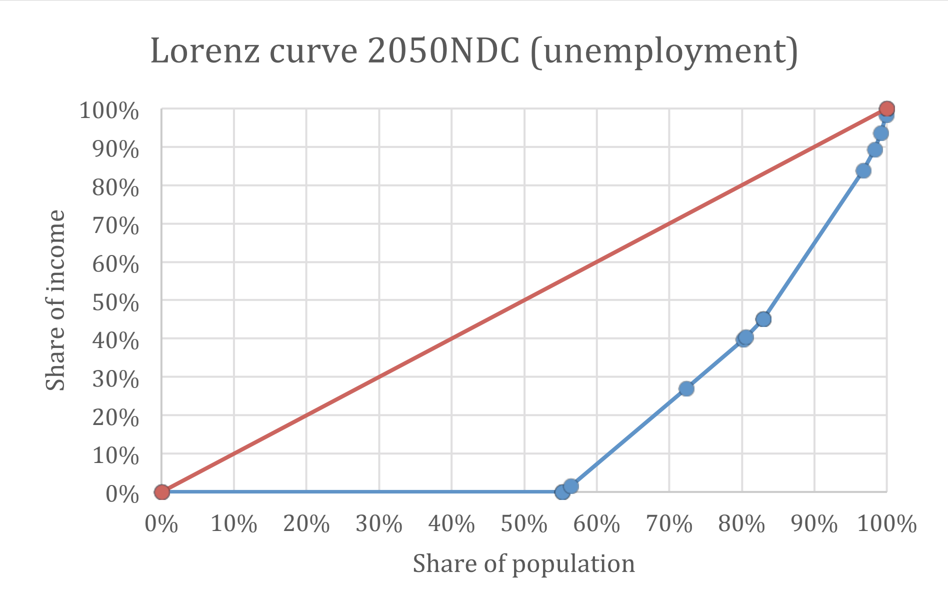
Lorenz curve 2050NDC2 (no unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Share of population

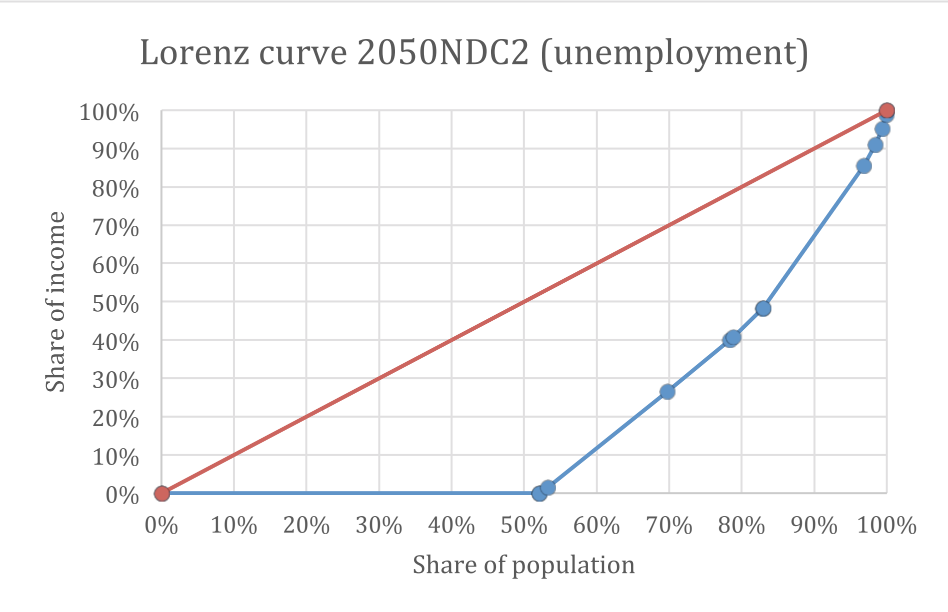

Lorenz curve 2050NDC2+ (no unemployment)
Share of income
Share of population
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

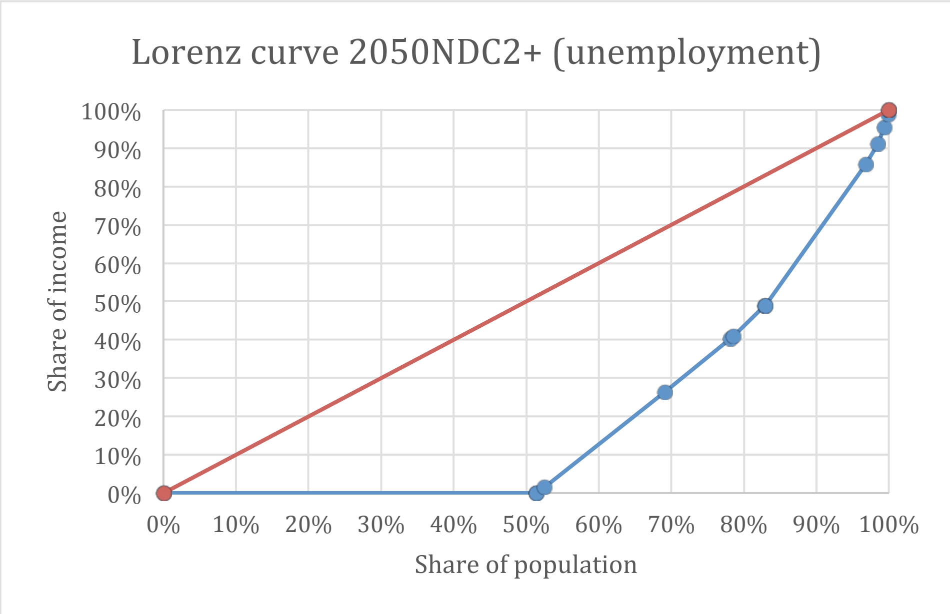

Lorenz curve 2030NDC (unemployment)
Share of income
Share of population
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Lorenz curve 2030NDC2 (unemployment)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Share of income
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Share of population


Lorenz curve 2030NDC2+ (unemployment)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Share of income
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Share of population


Lorenz curve 2050NDC (unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population


Lorenz curve 2050NDC2 (unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population



Lorenz curve 2050NDC2+ (unemployment)
Share of income
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Share of population