ENERGY TRANSITIONS TOWARDS LOW CARBON REGIONS: A METHODOLOGICAL PROPOSAL FOR SUSTAINABLE ENERGY SYSTEMS DESIGN

Juan José Gil Fernández, University of Santiago de Compostela, +34647279880, juanjose.gil@rai.usc.es

Overview

Climate change is one of the greatest environmental, social and economic threats facing humanity today. The international Paris agreement aims at pursuing efforts to limit global warming at 1,5ºC. However, to the best of my knowledge, there is currently a lack of studies that propose detailed energy transition pathways consistent with this climate target for the industry at a sub-national or small country level. These geographic and sectoral levels are though important because they allow for a detailed quantification and thorough planning of the industrial and energy transition (e.g. energy infrastructures, technology choices, pace and level of deployment of renewables…).

This research aims to contribute to filling this gap. Its objective is to propose a methodology for the design of energy transition pathways that enable industrial decarbonisation consistently with the 1,5ºC climate goal at a sub-national level in the context of sustainable human development. To achieve this goal, an inductive method is carried out through a case study, from which a methodological framework is validated and subsequently stated. The sectoral focus is made up of the major energy-intensive industries in Galicia (a sub-national region in NW Spain). These industries represented roughly 47% of fossil energy use and 13% (and growing) of GHG in the whole Galician economy in periods 2016 and 2015-2019, respectively.

Methods

This case study is carried out through a hybrid top-down-bottom-up approach. The top-down approach is applied fundamentally by taking one global mitigation pathway as a frame within which a regional pathway is designed. Instead of developing new local pathways, an already tested one at a global level is concreted sectorally and territorially, allowing for consistency with the corresponding climate target. The chosen one is the "Low Energy Demand" (LED) pathway developed in the context of the 1,5ºC IPCC report because it may be considered as the most aligned with a human sustainable development scenario. Four important features of it are taken as constraints and definitory variables of the strategy proposed in our case study. These are energy demand, material demand, energy intensity and carbon emissions; all of which experiment a significant reduction.

The bottom-up approach is used for the rest of the research, which takes place in three steps. First, a diagnosis of the productive structure of 25 industrial complexes located in Galicia is carried out for the period 2015-2019. Based on the information they provided in response to a survey, they are characterised in terms of quantity and quality of material and energy flows, carbon emissions, material energy intensity, carbon intensity and industrial processes (primarily those which emit CO_2). Second, drawing on a large literature review in engineering scientific fields, I identify a set of technological choices that would allow these EII to decarbonise and transform at the pace and level required to meet corresponding carbon and energy intensity reductions.

Finally, sectoral energy demand is estimated from a qualitative and quantitative point of view based on energy sources required, and expected energy intensity and material production projections in each industry along the projection period (until 2050). Material production levels are estimated based primarily on (1) IEA's projections, (2) historical local data and (3) material efficiency and dematerialisation multipliers from the LED pathway. These projections and multipliers are aligned with the socio-economic scenario that underlies behind LED pathway for the Global North. This scenario is mainly characterised by strong trends towards material efficiency, dematerialisation and circular economy, and a gradual shift in the way of consumption of energy services. Consequently, basic materials demand, and thus production, of the 25 industrial complexes under study declines.

Results

The results of the case study are here presented. An energy transition strategy or pathway is formulated for the major EII located in Galicia consistently with the 1,5ºC climate goal. It is comprised of 13 sub-strategies, one per industrial sub-sector. This strategy lays the foundations and establishes the guidelines for the decarbonisation of Galician EII in coordination with the global LED pathway along the first half of the century. This would be achieved through an industrial transition on three dimensions: material, energy and technological.

In the context of a specific socioeconomic scenario, a set of 40 techno-economic transformations in 13 manufacturing sub-sectors are proposed to meet the 1,5ºC climate goal. These changes drive high reductions in energy intensity, carbon intensity and energy demand. The energy transformations proposed can be categorised into two types: shifts in energy sources and energy efficiency improvements. These technological choices are based either on the best available techniques or process innovations. Some examples are magnetic heating of billets in the steel industry, hybrid-ring tunnel kiln flue-gas based combined heating system in ceramic industry and biogas or hydrogen instead of natural gas as a cross-sectoral choice.

The energy transition proposed draws a new energy model in the sub-national region under study. It is important to note, however, that its whole energy model is not derived from this study, as other economic sectors (including energy exports) remain to be covered. Nevertheless, approximately 50% of fossil fuel use is covered, so relevant results can be obtained from this study. Two facts must be highlighted which take place in the scenario developed: a strong phase-out of fossil fuels and wide deployment of renewable energy sources (hydrogen, bioenergy and electricity). The share of each energy source is not defined in this strategy because it depends on the specific technologies adopted by the firms, several options are available.

This study constitutes a starting point for the design of the regional energy model of the next three decades that enables decarbonisation of Galician EII in a frame of human sustainable development. Some research yet needs to be done to make an accurate energy planning. Particularly, the development of similar studies for the rest of the regional economy and a quantitative assessment of the renewable energy potential of Galicia by source would allow knowing how feasible and sustainable is the energy transition proposed.

The quantitative estimations of energy demand made should be regarded as approximated values. Several limitations have been present in the research that condition the accuracy of the results, particularly concerning material demand projections. Furthermore, the lack of transparency in some industries has posed a high obstacle for energy demand quantification. This emerges as a barrier that needs to be addressed: I argue that the public sector should promote regional economic stakeholders to work in coordination with academia towards this common societal and environmental goal.

Economic implications stem from the industrial transition proposed. First, an array of economic activities must be developed so that the energy and material inputs needed by industrial firms are properly and timely provided. Second, economic development opportunities emerge with the energy transition proposed, as well as threats to existing energy industries. Future pertinent researches may contribute to taking advantage of these opportunities, while propose interventions to mitigate economic damage; capital requirements should be assessed as well. The results of this research provide valuable information on which these investigations and interventions may be based and, eventually, contribute to the sustainable economic development of this region.

Conclusions

A novel methodological approach for the design of energy transitions in the industry has been developed and applied to the EII in Galicia. A global mitigation pathway, an extensive literature review on techno-economic mitigation options and a comprehensive diagnosis of the productive structure of major CO_2-emitting industries in a sub-national region are combined to bring about a clear decarbonisation strategy to meet ambitious international environmental targets. The corresponding section of the energy model structure of this region can be derived from this pathway, provided the fact that local renewable energy resources may form the basis of the energy supply to these industries. Economic development strategies may also be designed based on the energy transition designed.

The backcasting normative scenario making carried out in this case study can inform public policy and, particularly, energy policy drawing on a rigorous and robust top-down-bottom-up analysis from an interdisciplinary perspective, including energy economics, industrial ecology and industrial engineering approaches. Consequently, future policy interventions in the region under study may aim at planning and catalysing the development of the energy supply (e.g. energy infrastructures, technology choices, pace and level of deployment of renewables…). according to the results of this research. Importantly, this would have to be done by taking into account the local ecological implications of it, so that the deployment of the needed infrastructure does not bring about environmental damage[1]. The results of this research provide valuable information on which these public policies may be based and, eventually, contribute to a gradual sustainable energy transition to take place in the region under study.

The designed methodological framework may be applied in other regions and industries and comparable results can be obtained. This is necessary to facilitate the implementation of the global LED pathway and, particularly, the deployment of a low carbon energy system able to fulfil the Paris Agreement. It is important to note though that an interdependence exists between (1) the energy transition proposed and (2) the decarbonisation pathway and its underlying socio-economic scenario: the former is valid provided the latter takes place in the following decades and vice-versa. To this end, regional energy policies must be accompanied by a range of public policies from sub-national to international governments (industrial, R&D, fiscal…) aiming at catalysing both regional energy and industrial transition and the overarching decarbonisation scenario at a supra-regional level.

[1] The expansion of certain modes of energy production could bring about negative ecological impacts, e.g. depletion of valuable forests (to produce bioenergy) or biodiversity (both marine and terrestrial e.g. to produce electricity from wind resources) loss.