Carbon neutrality challenges for France in 2072

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Keywords: energy system; prospective; carbon neutrality; lifestyle; decarbonization pathways

1- Introduction

Over the last 20 years, successive COPs have highlighted the need for urgent action in reducing greenhouse gas emissions to avoid the global mean temperature exceeding a 2°C increase. To deal with climate urgency, a target of 1.5°C was written into the Paris Agreement in December 2015. To increase the likelihood of achieving this goal, emissions pathways of the scenarios in IPCC report AR5 [1] must achieve neutrality in the second half of this century. In this paper, we intend to explore the conditions under which such a stringent constraint needs to be fulfilled at a country level, France, while focusing on energy issues. The analysis horizon spans to 2072. The horizon is firstly motivated by the need to extend the commonly considered 2050 horizon: Article 4 of the Paris Agreement mentions that Parties aim to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century"[2]. Secondly, the 2072 horizon refers to the Club of Rome's Limits to Growth publication in 1972 [3], thus marking the 100th anniversary of the first attempt to assess the effect of long-term economic growth at global level using mathematical modelling.

2- Methodology

We develop a multidimensional approach, combining different levers acting on lifestyles, technologies and the economy that could help lower emissions. To this end, each of these aspects is represented through a specific model. With a lifestyle model [4][5], we obtain demand for products and services (e.g. housing, transport, manufactured goods). These demands feed into an input-output model [6] that represents the French economy and yields a volume of activity for each sector. The demand for services and the volume of activity are then incorporated into an energy system model, the TIMES-FR model, which performs an optimization of the energy system in the long term. We can then observe the impacts of lifestyles on the energy system.

Energy foresight exercises generally consider lifestyles using a "direct method"[7][8][9]. This method only proposes qualitative links between energy service demand indicators (e.g. age, employment status, size of household) and lifestyle drivers. As these indicators are subject to assumptions, their capacity to represent quantified links with future coherent societies is limited.
In order to put forward the lifestyle dimension in our prospective analysis, we use a statistical method. This method establishes quantitative relationships between indicators. Such a correlation between variables makes it possible to obtain more consistent lifestyle assumptions.
The model we use relates lifestyle scenarios to energy service demand. Lifestyle scenarios describe assumptions on several factors, such as cohabitation practices and time allocated to activities. The model then establishes a quantified relationship between these factors and several indicators (e.g. size of household, number of trips per day). The calculation results from joint statistical analyses of several French national surveys [10][11][12]. Finally, the model returns a quantified evaluation of the energy service demand (total housing surface area, total distance travelled per year, etc.).

The input-output model features a sectorial disaggregation of the French economy into 37 branches. It was built using data from the French national accounts and INSEE [13][14]. For each branch of the economy, we can express the production according to the final demand and technical coefficients found via an input-output analysis. Those coefficients represent the interdependencies between the sectors of the economy.

Energy service demand is an exogenous input of the TIMES-FR energy system model we use. The TIMES-FR model is a long-term planning bottom-up model from the MARKAL/TIMES family [15] for the French energy system. This approach is based on the optimization of a technical-economic representation of the energy system. The model minimizes the total discount cost over the whole horizon and identifies optimal investment and operation decisions from an available set of processes and commodities.

3- Results

3.1 Exploratory analysis

We explore two possible alternative lifestyles. The first, named 'digital society' represents an individualistic society, focused on self-development, where for instance people work more and undertake virtual activities. The second, named 'collective society' represents a society that puts social relationships and cooperation at the heart of its organization. This involves more people living together and less long-distance mobility.

The impacts of both lifestyles on the energy system are discussed through the results of the TIMES-FR model. In this case study, we consider a €30/tCO_2 penalty.

The choice of a particular lifestyle has a great influence on final energy consumption (Figure 1) and consequently on CO_2 emissions (Figure2). The 2072 level of CO_2 emissions in the 'collective society' scenario is significantly lower (36% decrease in 2072) than in the 'digital society' scenario, which is in line with energy consumption (28% decrease). However, if we want to maintain the target of neutral emissions, then the CO_2 emissions have not been sufficiently reduced.

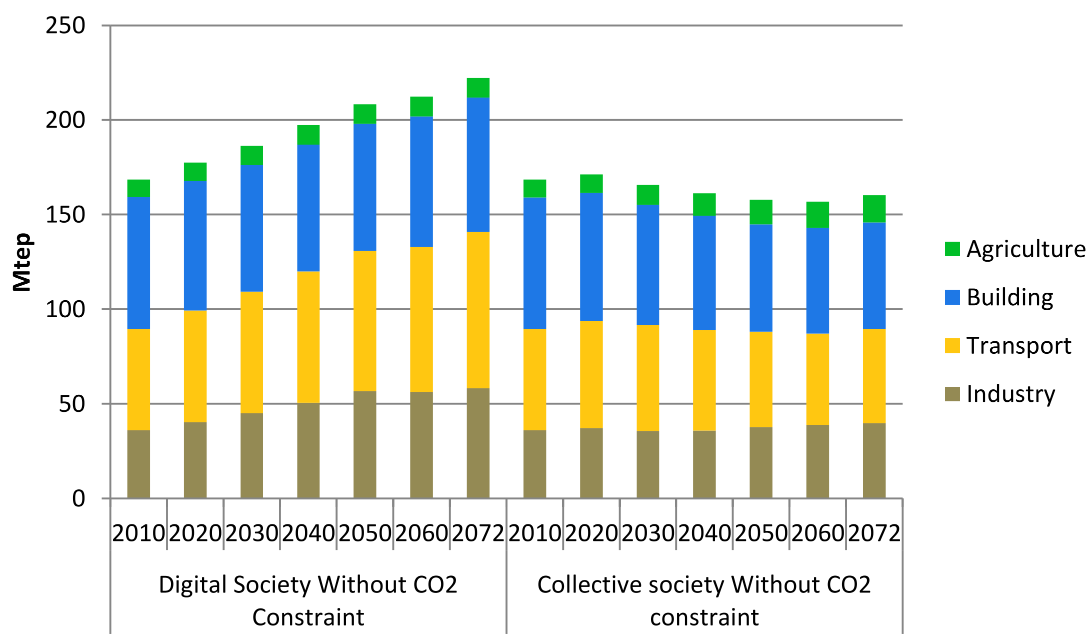

Figure 1: Final energy consumption for "Digital Society" and "Collective Society" lifestyle scenarios

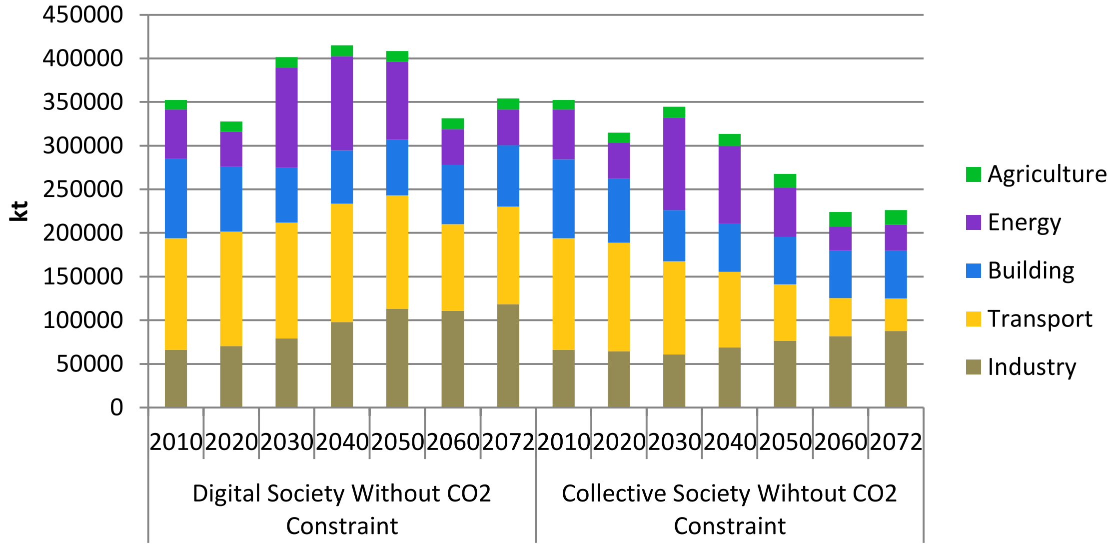

Figure 2 : CO_2 emissions for "Digital Society" and "Collective Society" lifestyle scenarios

3.1 Normative analysis

In a second phase, we put a constraint in the TIMES model on the level of emissions in order to reach neutrality by 2072. We consider a price elasticity of demand. As a result, carbon neutrality is partly achieved by lowering the demand for energy services. Figure 3 shows that the level of final energy consumption in 2072 is reduced in both lifestyle scenarios, albeit slightly less in the collective scenario than in the digital scenario. The levels of energy consumption are quite similar and no longer reflect the choice of lifestyle. Results also show that reaching neutrality is very demanding: the marginal cost of CO_2 surges from 2060 and exceeds €100000/tCO_2 (Figure 4).

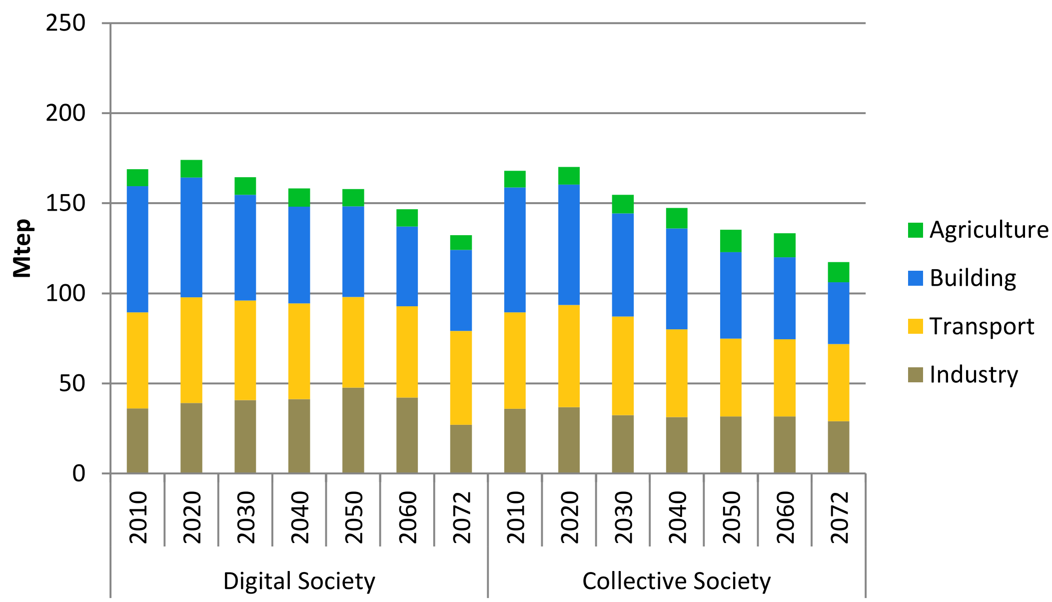

Figure 3 : Final energy consumption with a carbon neutrality constraint in 2072

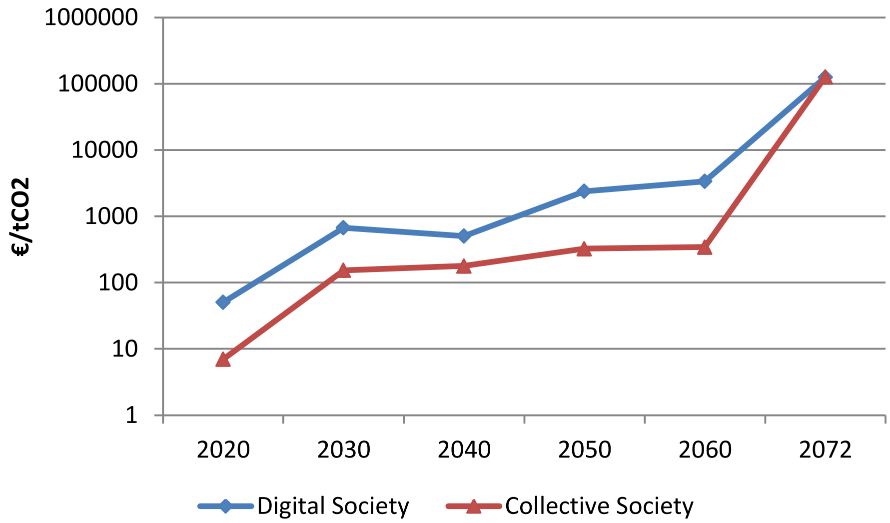

Figure 4: Marginal cost of CO_2 with a carbon neutrality constraint in 2072

According to these results, carbon neutrality in 2072 will require foreseeing more radical lifestyle and/or technological breakthroughs in order to generate downward pressure on the energy system.
Yet it also requires understanding the impacts of anticipating the target. In the 2072 carbon scenarios developed, the 75% target was considered in 2050. Sensitivity analysis allows us to evaluate whether perfect foresight of the carbon neutrality objective in 2072 would lead us to an optimal decarbonization pathway compared with an energy foresight exercise where the analysis horizon only goes as far as 2050.

4- Conclusion

This analysis has focused on the impact of lifestyle scenarios on the energy system and addressed the issue of how to anticipate achieving carbon neutrality in 2072 for France. Lifestyle choice is of great significance to achieve neutrality in France's emissions: it can either facilitate the transition or complicate it, even if green technologies are available.

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