Modelling energy demand in support of China's 2060 neutrality targets

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Overview

China has recently announced its intention to become climate neutral by 2060 and official scenarios have been released presenting high level trajectories for meeting overall emission reduction targets.[1] While these scenarios provide an overview of the changes to be implemented, they still lack of transparency in terms of assumptions for technical indicators, penetration and deployment rates for energy usage processes, and incorporation of efficiency measures. Understanding the burdens for technology incorporation within final energy uses and their potential for decarbonisation is crucial, considering that direct demand related greenhouse gas emissions account for 54% of China's total emissions.[2] The aim of this research is to develop a cluster of scenarios to analyse the decarbonisation potential associated with key measures for different final energy uses across five different climatic macro-regions in China. Results of this work are expected to provide further detailed insights of the needed transformation for fulfilling climate change mitigation goals in the world largest emitting economy.

Methods

A bottom up approach for energy demand modelling has been followed in this work, distinguishing among several final energy uses and different subcategories – residential and commercial buildings (heating, cooling, and appliances); road transport (passenger cars and motorbikes, light duty vehicles, trucks, and buses); light industries; heavy industries (steel, cement, and chemicals); rail; navigation; and aviation. Service demand has been quantified using projections for socio-economic indicators and other demand drivers in 2060 from the official Chinese scenarios[1] – supplemented with inhouse developed correlations for household area, value added for industries, and income-based electrification fleet functions. These input data in addition to different trajectories accounted for: pathways suggested for different European nations;[3] the evolution for fuel economy standards in the road transport sector;[4] techno-economic and environmental indicators for CO_2 capture processes;[5] assumptions on building envelope efficiency; and previous scenarios carried out for China.[6,7] The scenario runs were conducted using a tailored version of the DESSTINEE (Demand for Energy Services, Supply and Transmission of Electricity) model, which is a free and open source full energy system modelling tool that enables to forecast yearly and hourly energy and power consumption.[8,9]

Results

Final energy consumption in China accounted for 14 EJ in 2015[1] and our estimates indicate that the implementation of the aforementioned decarbonisation measures could enable reductions of up to 20% by 2060 – translating into a decrease of 78% of the energy intensity of the Chinese economy by 2060. The changes in overall fuel basket, for final energy uses, will cause electricity to be the most used energy vector followed by biomass – including bioliquid and biomethane employed for transportation – and H_2. Consequently, final power consumption is modelled to increase by 62% in 2060, when considering 2015 as a reference year.

Direct fossil CO_2 emissions from the different final energy uses are foreseen to go down by 92% between 2015 and 2060, when considering the measures analysed in this work, reaching 500 Mt. According to official scenarios, these residual emissions will be compensated by carbon sinks and negative emission power generation technologies in view of reaching net zero.[1] Emission reductions are mostly derived from electrification whilst carbon capture, storage and utilisation (CCUS) also plays a significant role in the case of heavy industries, Within the latter, different decarbonisation pathways were explore– having modelled in detail the impact of technology incorporation within the steel, cement, methanol and ammonia production, Measures included: a significant spread of electric arc based production methods for steel manufacturing, the use of calcium looping CO_2 capture technologies for cement plants, and the incorporation of pre-combustion CO_2 capture in coal gasification based H_2 production for methanol and ammonia synthesis.

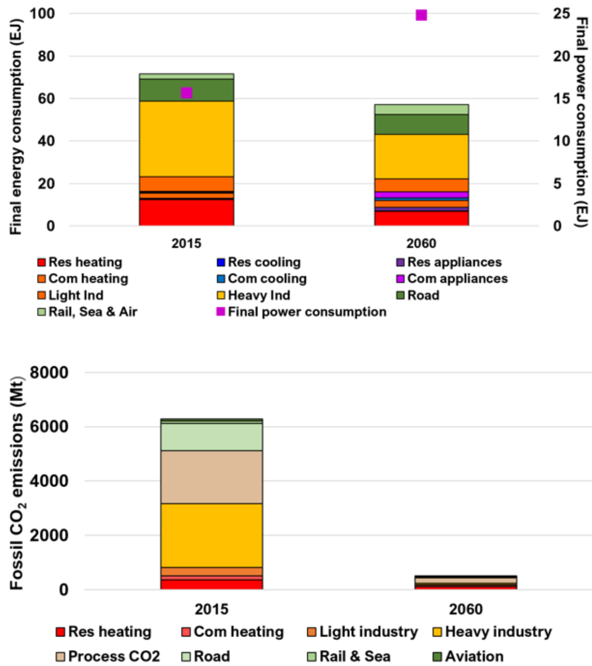

Figure I Final energy (primary vertical axix, panel a), power (secondary vertical, panel a) and direct (on-site) fossil CO_2 emissions. Res heating accounts for residetial heating, Res Cooling for residential cooling, Res appliances for electricity consumed in appliances. Com referes to service related activities and agriculture . Heavy Ind and Light Industry refer to heavy and light industries respectively. Sea and Aviation denote domestic navigation and aviation.

Different options were considered to meet sectorial emission reduction targets, within buildings, namely: the widespread of electric shares for heating (up to the figures expected for the EU27); 100% penetration for heat pumps within electric heating; and high rate scenarios for building renovation and building envelope efficiency improvements.

Road transport contributed to 14% of total energy demand in 2015 and 18% of total CO_2 emissions.[2] Heavy duties were the responsible for most of these emissions, followed by passenger cars, light duties, and buses. Emissions from transport are required to reach around 20-30 Mt CO_2 in 2060 to fulfil with China's claims for carbon neutrality.[2] This must be accomplished despite a substantoial increase of transport demand. Electriicate ratest in he range of 90% for passenger cars and 60% for freight, and assuming a high proportion of H_2 and biofuel blending would enable the fulfilment of emission caps.

Conclusions

This is one of the first works aimed at modelling energy demand and technology incorporation within final energy uses, compatible with the 2060 neutrality targets for China. Results of this modelling exercise evidence the role that electrification amd CCS will have in the future Chinese energy matrix. The combination of measures proposed in this article are quite extreme, in some cases going beyond what expected for the same final uses in the context of the 2050 targets for the EU. These measures enable to reduce fossil CO_2 energy demand related emissions from c.a. 6.5 Gt to 0.5 Gt, cut significantly down final energy consumption at the expense of a 62% of increase in power usage. Making this possible will require significant investments in terms of renewable sourced power and CO_2 removal processes, which are foreseen to be speeded up to unprecedented rates in the coming years. The granularity of the results in this study allow to better understand the required changes providing well informed and highly disaggregated scenarios for relevant policy makers and stakeholders.

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