ASSESSING COSTS FOR PHASING OUT FOSSIL FUELS IN BUILDINGS – AN ENERGY SYSTEM APPROACH

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(1) Overview

In the European Union (EU), energy consumption in commercial and household buildings is responsible for about 40% of total final energy use and for 36% of the total CO2 emissions (European Commission, 2008).

Buildings are acknowledged as an increasingly relevant area for CO2 mitigation and RES deployment in policy making: Schäfer (2005) stated that around half of the EU target on renewable energies can be achieved by renewable energy resources (RES) heating and cooling. According to the European Technology Platform on Renewable Heating and Cooling (2011) until 2050 renewable energies can supply 100% of the heat demand (European Technology Platform on Renewable Heating and Cooling, 2011). In the EU 2050 Energy Roadmap, the European Commission (EC) highlights the importance of RES heating and cooling and the need to analyze the cost-optimal policy choice between insulating buildings and using the waste heat in CHP plants for decarbonizing the energy system (European Commission, 2011). In support of the SET-Plan (European Commission, 2007) heating and cooling is part of the European Initiative on Smart Cities aiming amongst other at implementing 5-10 demonstration programs supplying 50 % of the heat and cooling demand from RES (European Commission). 23 of the EU Members States implemented additional policies to support the integration of RES for heating and cooling (Cansino et al., 2011), demonstrating the awareness also across Member States' policy makers; however there has been less effort into supporting RES heating and cooling than is the case for RES-electricity (Klessmann et al., 2011).

Nonetheless, this is a particularly difficult area for effective policy implementation since it involves an extremely high number of consumers and there is limited available data on buildings stock and current deployment of energy end-use technologies. Pardo et al. (2012) propose a methodology to identify the heating and cooling demand for the EU by country, fuel, economical subsector and activity. Existing literature on phasing out fossil fuels in buildings includes: Dall'O' et al., (2012); Pardo and Thiel, (2012); Meggers et al., (2012); or Balaras et al., (2007). These studies do not cover both heating and cooling for the whole of EU and/or do not emply a holistic energy system modelling approach. We believe this is relevant since the competitiveness of technologies depends on the resource potential and the costs of conventional heating and cooling (Seyboth et al., 2008); resulting in different conditions for EU Member countries. We add to the current literature by analyzing the entire energy system for the European Union including a wide range of heating and cooling technologies.

The objective of this paper is to provide insights on assessing the costs of phasing out consumption of fossil fuels in European buildings in 2050 especially for heating and cooling, including hot water for sanitary uses. We assess what alternative energy carriers and technologies are cost-effective and which implications this phase out has on heating and cooling technology deployment, as well as what is the interaction with the whole energy system (i.e. the electricity generation sector and final energy consumption in other end-use sectors).

(2) Methods

We use the JRC EU TIMES model to generate a total of 19 scenarios from 2005 to 2050 with increasingly stringent CO2 emission caps. The JRC EU TIMES is a linear optimisation bottom-up technology model developed with the TIMES model generator. The model represents the EU 27 energy system plus Norway, Switzerland and Iceland from 2005 to 2050, where each member state is one region. It considers both the supply and demand sides and includes the following seven sectors: primary energy supply; electricity generation; industry; residential; commercial; agriculture and transport.

The JRC EU TIMES is supported by a detailed database, with the following exogenous inputs: (1) end-use energy services, such as residential lighting or tonne kilometers requirements; (2) materials demand such as cement or steel; (3) characteristics of the existing and future energy related technologies, such as efficiency, stock, availability, investment costs, operation and maintenance costs (which for buildings are from Pardo-Garcia et al. 2012) and discount rates; (4) present and future sources of primary energy supply and their potentials (from the POLES model (Russ et al. 2009)); and (5) policy constraints. More information on the model's equations can be found in Loulou *et al.*(2005a and 2005b).

We model 19 scenarios differentiated by an increasing EU-wide CO2 emissions cap from 2010 until 2050. The cap increases in stringency in 2050 from less 25% emissions *vs* 1990 levels to less 90% emissions. We do not include any exogenous CO2 price, nor any other policy target (e.g. RES targets or energy efficiency targets). The costs presented in this paper are a JRC EU TIMES model output reflecting a cost-optimal solution for the whole of the EU to satisfy the demand for energy services while complying with the CO2 caps. The demand for energy services is exogenous to the model and it includes assumptions on improved energy performance of buildings. For this preliminary exercise we do not endogenously model buildings performance as such (e.g. higher insulation), but only the deployment of the more efficient end-use energy technologies supplying heating and cooling.

(3) Results

Our preliminary results for our 2050 scenarios indicate that reducing the consumption of natural gas in European buildings only starts to be cost-effective for CO2 costs above 38 euros/t CO2. This corresponds to a CO2 cap of 25% less emissions than in 1990 (Fig. 1). With this carbon cost natural gas represents 62% of final energy consumption (FEC) for heating and cooling in buildings. With higher CO2 costs the share of natural gas in FEC can be reduced up to 25% with a cost of roughly 490 euros/tCO2 (corresponding to an emission reduction of 70% below 1990 levels). Oil starts to loose cost-effectiveness also for CO2 costs above 38 euros/t CO2 but unlike gas it is almost completely phased out with a a cost of 380 euros/tCO2 (emission cap -65% of 1990 levels). With that cap oil represents less than 1% of buildings FEC, whereas gas still represents 37% of FEC.

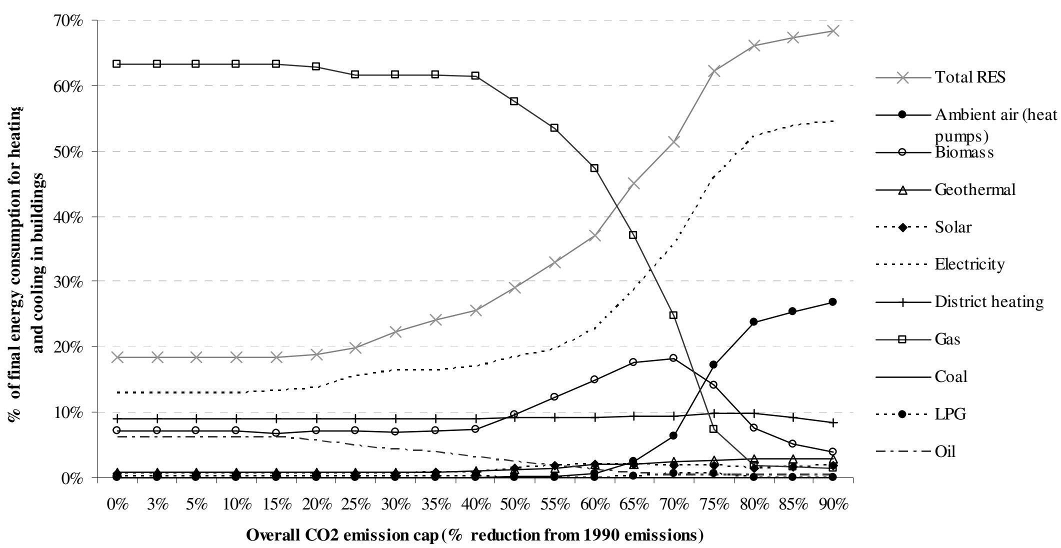

Fig. 1: % of final energy consumption of different energy carriers in heating and cooling in buildings in EU27+ in 2050 for increasing CO_2 emission caps. Note: the input of ambient air into heat pumps is included merely to illustrate their contribution although strictly speaking ambient air is not usually included in FEC.

The phase out of fossil fuels is accompanied by increased RES deployment. Total RES share in final energy consumption for heating and cooling in 2050 increases from 18% (without any CO2 cap) up to a maximum of 68% for the -90% emission cap. This is mostly due to the increase of renewable electricity followed closely by biomass, but this latter only for caps up to -70% emissions from 1990 levels. For more aggressive emission caps, biomass consumption is more cost-effective in the transport sector. For these higher caps the reduced biomass in buildings is replaced with more electricity, ambient air as an input into heat pumps and geothermal devices. Finally, the caps can only be met in association to an endogenous reduction in the demand for heating and cooling in buildings. This is due to the consideration in the JRC EU TIMES model of long term price elasticities of demand for the different materials and energy end-uses.

(4) Conclusions

With our preliminary analysis we conclude that phasing out fossil fuels in European buildings, although technically possible with the current and future expected technology portfolio, will be extremely challenging. Substantially high marginal costs have to be dealt with, representing a policy challenge. Our analysis is limited to the nature of the used model which, as any partial equilibrium model, tends to underestimate the effort associated to technology substitution. Nonetheless, we believe these results can provide insights on the dynamics between the different energy carriers and technologies for low carbon buildings in Europe and the rest of the energy system.

Further work will include an assessment of the effects of technology learning for the RES heating and cooling technologies, with a particular emphasis on solar, heat pumps and geothermal heating and cooling technologies, coupled with heat storage. We will also perform a sensitivity analysis on exogenous assumptions on fossil fuel and bioenergy prices and availability and on the demand elasticity exogenous parameters.

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