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Heat or power: How to increase the use of energy wood at the lowest cost?

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ABSTRACT

We compute the optimal subsidy level for fuelwood consumption that makes it possible to achieve the French biomass energy consumption target. For this purpose, we model the competition and trade-offs between the consumption of fuelwood for heat (FW-H) and the consumption of fuelwood for electricity (FW-E). To do so, we couple a forest sector model with an electricity simulation model, and we test different scenarios combining FW-H and FW-E that account for contrasting potential increases in the carbon price and the potential reduction in the number of nuclear plants. We assess the implications of these scenarios on (1) the budgetary costs for the government, (2) industrial wood producers' profits, (3) cost savings in the power sector for the different scenarios tested, and (4) the carbon balance.

We show that the scenario with the highest carbon price and the lowest number of nuclear plants is the least expensive from a budgetary perspective. Indeed, when associated with a high carbon price, co-firing may increase FW-E demand with a lower subsidy level, which makes it possible to reduce the cost of reaching the target. However, in this case, FW-E crowds out part of FW-H, which may cause political and economic issues. From a carbon balance perspective, an FW-H-only scenario performs better than any other scenario that combines FW-H and FW-E due to the relatively low emissions factors of alternative technologies for electricity generation and, in particular, nuclear energy.

1. Introduction

In 2011, renewable energy represented about 15.3% of the total production of French primary energy, i.e., about 21.2 Mtoe. European directive 2009/28/EC has set the objective of increasing the share of renewable energy in the French energy mix by 23% in 2020. In France, where forest resources are abundant—France has the fourth largest forest cover of the 25 EU countries—solid biomass energy is expected to play a major role in achieving this objective (Sergent, 2014; Caurla et al., 2013). More precisely, this objective results in an overall additional biomass consumption target of $+20$ hm^3 in 2020 compared with 2006 (Dupuis et al., 2008).

Several programs to stimulate the consumption of energy wood have been implemented to date in order to reach this biomass consumption target. They aim to increase the consumption of wood for heat production in domestic and collective installations (hereinafter referred to as FW-H) or for power production in electricity plants (hereinafter referred to as FW-E). In particular, the ability of power producers to increase FW-E consumption with no investment through the co-firing of biomass in coal plants has led to a strong interest in biomass. The technical potential for FW-E from co-firing in France has been estimated by Hansson et al. (2009) to be 1.24–2.63 TWh/yr (where the highest value assumes the use of all plants ≤40 years old and the lowest assumes the use of plants ≤30 years old). With this in mind, five generations of national public tenders have been launched to fund biomass projects for energy production. Meanwhile, France has recently made considerable progress in FW-H markets via the increased use of wood pellets following the introduction of a specific support program for wood pellet equipment (Proskurina et al., 2016).

Technically, the programs to stimulate the use of energy wood, either FW-E or FW-H, take the form of subsidies to increase harvesting, to develop commercial channels, to foster the storage of harvested products and their final consumption through investments in electricity plants, and to heat collective/domestic boilers. They result in a reduced perceived price of fuelwood for the final consumers, either domestic households that use FW-H or power generator owners that consume FW-E.

However, the impact of a subsidy on the consumption of FW-E will probably be different from those on the consumption of FW-H, in terms of both economic outcomes and carbon implications. Indeed, fuelwood is not used with the same technologies, and it does not compete with the same products in heat and power markets.

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On the one hand, FW-H demand has been estimated as being quite inelastic. Couture et al. (2012) estimate the price elasticity of fuelwood demand for French households when wood is the main source of heating energy to be −0.42. Wood can be considered a necessary good for such consumers since the choice of wood as the main source of heating energy is negatively linked to income, which seems to confirm the energy ladder theory, according to which wood is much more widely used among the lowest-income categories of society (Couture et al., 2012). In addition, using wood as a domestic, collective, or even industrial source of heating involves additional technological costs that result in a type of lock-in situation for consumers, which actually increases the inelasticity of demand in the medium and long term.

On the other hand, the use of FW-E in the electricity sector at the national scale depends on the dispatching of different technologies in the energy pool, which follows merit-order logic. This may induce stepwise variations in FW-E demand when power plants relying on wood switch places with other ones in the merit order. Accordingly, this makes the use of solid biomass for electricity very dependent on two variables: (1) the relative prices of energy sources and (2) the installed capacities of power plants that use different technologies. Two parameters are likely to play a major role with respect to these variables: carbon prices, which influence the cost of energy according to the carbon content, and the reduction of the share of nuclear energy in the electricity mix, which has to be compensated for by an increased contribution of other technologies, including wood-based power generation[1,2]

One consequence is that while a subsidy for total fuelwood consumption will probably play a rather linear role for FW-H, it is expected to play a non-linear role for FW-E, with threshold levels when power plants switch places in the merit order. For the same reasons, the budgetary costs of the subsidy are expected to rise with its level, though non-linearly. In addition, the spillover effects of the subsidy over the forest sector in both cases are ambiguous, since they depend on both electricity generation thresholds and competition between fuelwood and other wood sectors, such as that of pulp.

Within this context, our paper simulates a subsidy to total fuelwood (FW-E + FW-H) consumption that represents that stipulated in the current national programs implemented to increase fuelwood consumption by +20 hm^3 in 2020 compared with 2006.

Our first objective is to compute the optimal level of this accounting for (1) the relative prices of biomass and fuel substitutes in the electricity sector; (2) the carbon price, which affects the costs of other energy sources, and (3) the reduction of nuclear power generation.

The second objective of our study is to compute the impact of this subsidy on the economy of the entire forest sector. Caurla et al. (2013) have already conducted such an analysis but without considering the trade-offs between FW-H and FW-E production. Nevertheless, the impact of such programs on the forest sector remains unclear. First, by competing for the same raw products, these projects could increase competition with the pulp, panel and paper sectors and thus increase the price of these products for the consumer. Second, the costs of this additional consumption and the distribution of these costs among forest sector agents and the French government are unknown.

A third objective is to provide a carbon balance outcome for the different scenarios in order to compare them both in terms of their ability to contribute to climate change mitigation.

To do so, we coupled two models that represent the consumption of FW-H and the forest sector economy on the one hand (French Forest Sector Model: Lecocq et al., 2011; Caurla et al., 2013), and the consumption of FW-E on the other (Green Electricity Simulate Model: Bertrand and Le Cadre, 2015).

In the first section, we review previous studies to situate our contribution in the literature. In the second section, we present our modeling framework and the coupling procedure. In the third section, we present the scenarios tested, and we present the results of our simulations in the fourth section. We then provide conclusions in the fifth section.

2. Position of our work in the literature

Several studies have previously question the optimal policies to reach exogenous wood biomass targets.

A first group of studies, stemming from the forest sector modeling literature, addresses the impact of fuelwood subsidies on the forest sector.

In this group of studies, Sjølie et al. (2010) show that subsidizing fuelwood by implementing a tax of €60/CO_2eq on competing fossil fuels could increase bioenergy use in district heating installations by almost 4000 GWh/year. The same amount of bioenergy could be used in domestic pellet stoves and central heating systems, but a higher tax is then necessary. A 50% investment grant to district heating installations may also have a large effect on bioenergy use, but the effect of subsidies rapidly decreases if they are applied together with a tax.

Kallio et al. (2011) show that to increase fuelwood availability, industries using sawlogs would need to expand because logging residues and stumps are primarily collected from final fellings driven by sawlog demand. Consequently, policies leading to the increased use of wood in construction could also possibly support renewable energy goals. Moreover, subsidies for combined heat and power production at sawmills could be beneficial in this respect.

Caurla et al. (2013) show that the optimal level and therefore costs of subsidies—either the budgetary costs for the government or the costs for society—greatly depend on which part of the forest sector is subsidized. They show that subsidizing fuelwood production is costlier for the government than subsidizing fuelwood consumption. However, an upstream subsidy also reduces competition with other sectors, such as that of pulp, and increases export levels.

A second group of studies focuses on the consequences of climate policies for the use of wood biomass in co-firing.

In this vein, Johnston and van Kooten (2015) couple a mathematical programming model of the electricity grid with a transportation model of wood pellets for Canada in order to compare the impact of a carbon tax with those of feed-in tariffs on the rate of conversion of coal plants to co-fire. They show that there is an upper threshold on a carbon tax after which retrofitting of coal plants is less efficient than increasing natural gas-generating capacity.

Kangas et al. (2009) explore the consequences of feed-in laws (either feed-in premiums or feed-in tariffs) and emission trading on biomass utilization in co-firing. They study two different power plants that are located in two different European electricity market areas and show that feed-in tariffs can lead to an unexpected situation where the wood share in co-firing decreases when the emission credit price increases.

Neither of these two groups of studies above explicitly addresses both FW-E and FW-H.

This gap is filled by Kangas et al. (2011), who compare three policies (namely, an investment subsidy, an input subsidy, and a production subsidy) to support biofuel production in the pulp and paper sector.

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[1] Other drivers can play a role in the use of biomass for electricity. Among them, the GES model considers variables, parameters, and constraints such as the constraint regarding the share of renewables in power generation, the availability of different power technologies, cross-border trade in electricity, and differences in cost and technical parameters for different technologies (see Section 3.2). Beyond this, there are other drivers that are not in the scope of this paper. In particular, the existing infrastructure capacity for fossil fuel use and the preferences of society for renewables and biomass are likely to play a role in the use of biomass for electricity. We discuss their implications in Section 6.

[2] In France, the electricity mix is largely dominated by nuclear energy, which represents more than 50% of the installed capacity and about 75% of the power generation (76% in 2015, according to RTE, Statistiques Production Consommation Echanges 2015). Hence, any reduction in nuclear-based power generation in France may induce very substantial effects on the contribution of wood-based power generation and the demand for fuelwood. In particular, the recently passed “Law on energy transition” aims to reduce the proportion of nuclear power by 2025, while obtaining 27% of the total power produced using renewables. This is likely to affect the fuelwood sector.