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Article

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Impact of pelleting cost on competitiveness of intentionally grown biomass for local space heating: Case example of the Czech Republic

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Abstract

Biomass plays a dominant role in the EU RES portfolio, especially in CE countries. Pellets from locally produced biomass can serve as a substitute of coal still widely used for local heating to date in the Czech Republic and other Central and Eastern European countries. Wood chips from short rotation coppice plantations (SRC) is suitable source of biomass for the production of pellets for local space heating. Cost of pellets production from biomass from SRC plantations is modeled using cash flow simulation related with all parts of pellets production chain. Article presents results of modeling of biomass cost from SRC plantations and its processing into wood pellets in the conditions of the Czech Republic. The cost of pellets, respecting the whole production cycle from biomass cultivation to pelleting, ranges from 7.85–8.55 EUR/GJ for typical yields of SRC plantations 8–10 t(DM)/ha,year. To achieve competitiveness with domestic (Czech) brown coal (6.5–7.3 EUR/GJ) for local space heating, it would be necessary either to increase the ecological tax on coal 10 x (to about 3.3 EUR/GJ) or to subsidize the establishment of the SRC plantation (1300 EUR/ha) or to double the area subsidy per year (to 390 EUR/ha,year).

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Keywords: Biomass competitiveness; Biomass fuel cycle; Pellets; SRC plantations

1. Introduction

The amount of energy produced from renewable sources increased overall by 76.7% in the EU-28 between 2006 and 2016 and currently accounts for about 17.5% of the gross final energy consumption. Biomass currently contributes predominantly to the total amount of energy from RES — in 2017 it was 60.5% (all forms of biomass including renewable waste) in EU as a whole [1]. Even though the share of solid biomass in the overall contribution of biomass is constantly decreasing, it remains the most important part of biomass (solid biomass had 81% share on total biomass contribution in 2006, while its share in 2017 decreased to 69.4%).

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Nomenclature

SRC	Short Rotation Coppice
RES	Renewable Energy Sources
NECP	National Energy and Climate Plan
YC	Yield curve

In Central and Eastern European countries, biomass and biofuels (including biodegradable waste) have an even greater share of the total RES contribution to cover gross inland energy consumption — Czech Republic 90%, Slovakia 72%, Hungary 92%, Poland 85% [1]. In the Czech Republic, energy consumption from biomass grew from 68.7 PJ in 2003 to 125.5 PJ in 2017, ie more than 1.8 x. The Czech State Energy Policy expects a further dynamic increase in biomass consumption in the 2040 horizon up to 250 PJ [2]. The increase in biomass consumption is expected both for electricity generation and centralized heat production, as well as for local heating.

The National Energy and Climate Plan (NECP) for the Czech Republic sets detailed targets and a trajectory for 2030; for solid biomass it expects growth mainly in the area of local household heating (16% increase between 2020 and 2030) and 25% for centralized heat production [3]. The consumption of solid biomass in 2030 is dominated by the household sector (92.4 PJ, 67%), with a significant share of biomass consumption for centralized production (36.7 PJ, 26.6%). By 2030, according to the NECP for the Czech Republic, it is assumed that solid biomass will have a share of about 67% of the total contribution of biomass (solid biomass, liquid biofuels, biomethane, biogas) to cover final energy consumption. The high expected share of solid biomass and in particular the high share of households in biomass consumption is due to the specificities of Central and Eastern Europe.

In the countries of Central and Eastern Europe there is still a relatively high share of coal used for local heating, for example in the Czech Republic it is still about 300th. households (app. 10%), especially in villages and small towns where natural gas is not available [4]. Biomass is thus considered as one of the possible coal substitutes for local heating.

In the last two decades, the use of biomass in the form of solid biofuels – pellets and briquettes – has been mainly developing. The advantage of transforming raw solid biomass into pellets and briquettes is the possibility of their use in a wide range of technologies — from small pellets and pellet boilers to heating family houses through local heating plants to large cogeneration plants and power plants. Worldwide production of wooden pellets rose from 1.7 Mt in 2000 to 29.7 Mt in 2015. In 2015, the European Union consumed 80% of wood pellets from all production [5]. A significant part of them was used for heat production, i.e. 61.7%, the remaining production covers electricity production. The consumption of pellets for heat production is used to the greatest extent for heating of residential houses — approx. 42.6%. Given the EU's policy goals of 2030 for renewable energy and the reduction of greenhouse gas emissions, further growth in wood pellet consumption can be expected. Given the expected trend in the growth of pellet consumption, it will be necessary to use biomass from intentionally grown stands of energy trees for the production of wood pellets [5].

Sources of relatively cheap and available residual and waste biomass are rapidly depleted and further development of biomass use will require intentional planting of biomass on agriculture land. E.g. [6] expects that further development of pellets production will be based among other on wet feedstock including wood chips.

At present, however, not only issues related to the development of RES and biomass, but also adaptation to climate change in the agricultural sector, combined with efforts to reduce the negative impacts of intensive agriculture on biodiversity, soil erosion, the ability of the landscape to absorb precipitation, etc., are one of the options to interconnect the objectives in the area of further development of biomass, especially for local use and requirements for the protection of soil resources. One of the solutions how combine all these targets are agroforestry systems which combine crop and tree production [7], SRC plantation are one of the options. A key issue for developing this SRC concept and plantation is the competitiveness of the biomass produced and the cost of transforming this biomass into pellets. In order to develop the use of biomass for local heating and substitution of fossil fuels (especially coal), it is necessary to transform the raw biomass (wood chips from SRC plantations) into pellets that can be burned in a stove and small pellet boilers with reasonable comfort. Thus, the competitiveness of SRC plant biomass cannot be assessed on the basis of production costs (wood chips) on the field edge, but after all costs related to storage and reprocessing of raw biomass into pellets.

The article analyzes the competitiveness of wood chip pellets from SRC plantations on the example of the Czech Republic and focuses on the identification of key factors for achieving the pellet's competitiveness against fossil fuels, especially brown coal.

2. Material and methods

For local space heating, it is not possible to use raw biomass, but only biomass transformed into solid biofuels — pellets and briquettes. Wood chips from short rotation coppices plantations are suitable for their production. A key aspect for assessing the competitiveness of solid biofuels from targeted biomass is to respect the entire production cycle of solid biofuels, not just the own costs of biomass growing. E.g. [8] presents economic analysis of pellets production from intentionally grown biomass and highlights necessity to include the whole production cycle starting with biomass growing (willow and miscanthus plantations), through its transportation, storage and finishing with its transformation into pellets. Also [6] highlights importance of distinguishing of raw biomass cost and processing cost separately and reduction of their values for pellets competitiveness. He also highlights the role of competition for raw biomass between pellets production and other wood and biomass based industries.

Presented economic analysis of raw biomass production – wood chips – from SRC plantations is based on the simulation of cash flows using the reference economic model of SRC plantation, which reflects real business conditions (agricultural subsidies, land rentals, market prices of individual agrotechnologies and seed material, mechanized harvesting costs, transport of biomass from the field, etc.). At the same time, the economic model must include all stages of the plantation life cycle from project preparation and land preparation, through the establishment of the crop, harvesting in three-year rotations to plantation disposal and soil release for further use — see e.g. [9].

SRC plantation can be seen as a classic investment project — initially the investor invests funds and subsequently, over the lifetime of the project, this investment generates (positive) cash flows that ensure return on investment and return on capital invested [10].

Investors, as rational decision makers, invest in projects to achieve a (reasonable) return on the invested capital. For each project it is possible to set the so-called minimum price of production, which will provide the investor with covering all project costs and at the same time the expected return on the invested capital (equal to discount rate r). The minimum price of production can be determined using the formula for Net Present Value calculation (NPV). NPV is set to 0 value and price of output commodity is calculated – Eq. (1):

$$c_{\min} : \sum_{t=1}^{T_{lf}} CF_t \cdot (1+r)^{-t} = \sum_{t=1}^{T_{lf}} (c_{\min,t} \cdot Q_t - E_t) \cdot (1+r)^{-t} = 0 \quad (1)$$

where t is the year of project lifetime, CF_t is the net cash flow in year t [EUR], T_{lf} is the project lifetime [years], r is the nominal discount [-], $c_{\min,t}$ is the minimum price of the production in year t [EUR/GJ], Q_t is the production quantity in year t (biomass yields) [GJ] and E_t is the expenditures of the project in year t [EUR].

Eq. (1) assumes that all operational expenditures and selling price for the biomass are escalated with the general inflation. Minimum price in the year t can be thus calculated from the minimum price of the production in the first year and its escalation with the inflation – Eq. (2).

$$c_{\min,t} = c_{\min,1} \cdot (1 + inf)^{(t-1)} \quad (2)$$

where inf is the annual average inflation.

The minimum price of biomass from the SRC plantation depends primarily on the average yield of biomass in t(DM)/ha,year and the cost of setting up the plantation, including seed material, harvesting costs and land rent and other overhead. In the climate conditions of the Czech Republic, the yield of biomass from SRC plantations ranges from 4 to 14 t(DM)/ha,year [11]. Biomass yields differ during the plantation life time, maximum of yields is typically obtained in 3rd and 4th rotation (assuming 3 year rotation period) – see Fig. 1.

The cost of plantation establishment (including seed — cuttings) are about 1390 EUR/ha, harvest costs depends on biomass yields (higher biomass yields results in higher consumptions of fuel for machines, higher payment for machines service paid in EUR/hour and higher cost of biomass transportation from the field). E.g. for the biomass yield curve YC4 (which has average biomass yield 10 t(DM)/ha,year) in third rotation (10th year in Fig. 1) these costs are about 360 EUR/ha [4]. The structure of the discounted expenditures of SRC plantation is demonstrated for the yield curve YC4 (10 t(DM)/ha,year) in Fig. 2.

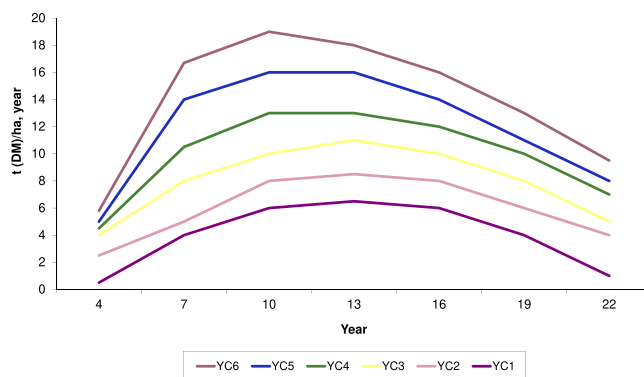


Fig. 1. Expected biomass yields from SRC plantations, climate and soil conditions of the Czech Republic, Vávrová et al. [4,11].

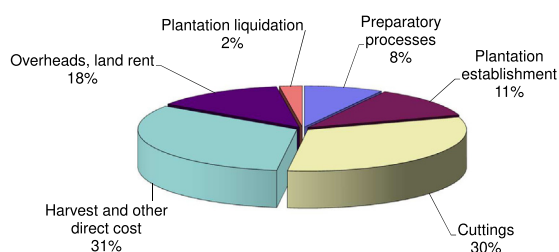


Fig. 2. Structure of discounted expenditures of SRC plantation, 10 t(DM)/ha,year yield curve.

The minimum price of biomass (chips) when considering the plantation lifetime of 22 years, 10% nominal discount, 2% price escalation per year, and the assumption of the constant amount of subsidies per area (SAPS 203 EUR/ha) is then in the range 7.2–2.0 EUR/GJ (assuming transportation distance of 5 km). For most typical SRC plantation yields of 8–10 t(DM)/ha,year is the minimum price in the range of 3.5–2.8 EUR/GJ (2018 prices). Value of discount rate for the calculation of the minimum price plays significant role. Decrease of nominal discount from 10% to 5% would lead to reduction of minimum price for biomass yields 8–10 t(DM)/ha,year to 2.9–2.4 EUR/GJ. When setting discount rate value for economic model of SRC plantation, one should consider competitive possibility for agriculture land utilization. Farmers have basically two possibilities how to use their land — for conventional crop or for energy crop including SRC plantations. Conventional crop (thanks to subsidies) has relatively high profitability [12]. Assumption of lower discount rate would lead to inadequately low minimum prices of biomass from SRC plantations not reflecting the real market conditions.

Locally produced biomass is suitable for utilization in smaller pellet and briquetting lines with a capacity of about 1000–1500 t/year. Price of pelleting can be modeled using the same methodology as for modeling minimum price of biomass from SRC plantation – i.e. modeling of cash flows related with the pelleting. Minimum price of pelleting (when considering the price of pelleting technology 210,000 EUR, an annual operating cost of 65,000 EUR) is about 4.7 EUR/GJ (for 2% growth of operating expenses, 10% nominal discount rate and 10 years of pelleting technology lifetime) [4]. After including the effect of biomass losses in storage and processing in the amount of approx. 0.35 EUR/GJ, then the minimum price of the produced pellets is 7.0–12.2 EUR/GJ. For the typical plantation yields 8–10 t (DM)/ha,year is the minimum pellet price in range 7.85–8.55 EUR/GJ. This minimum price does not include the cost of local distribution of pellets. Pelletizing lines with capacity of 1000–1500 t/year have flexible use, they can also be used for other types of products – e.g. pelletizing hay for feeding or straw for litter, etc.

3. Results and discussion

The minimum price of biomass from SRC plantations for typical yield curves of 8–10 t (DM)/ha, year ranges from 2.8–3.5 EUR/GJ. In addition to the yield curve, which has the greatest impact on the minimum biomass price, the SRC plantation establishment costs are the most important factor — these costs have a 49% weighting in the

total discounted SRC plantation lifetime (YC4 curve). The cost of establishing a SRC plantation is the same for all plantations realized in different soil and climatic conditions. So the weight of plantation costs is decreasing with the growing amount of biomass produced and vice versa, the dominant part of plantation establishment costs is the cost of plant material (about 30% of all discounted lifetime costs). With the development of SRC plantations, we can expect an increasing supply of seed material, improvement of SRC plantation technology and with it a decrease in total plantation costs.

The second largest item in the SRC plantation expenditure is the cost of mechanized harvesting and the removal of chips from the field. These costs are directly proportional to the amount of biomass produced and are thus, in principle, constant per GJ of heat in fuel — biomass. In the future, these costs can be expected to decrease with the development of SRC plantations and thus improve the supply of harvesting services. Land rental costs in the Czech Republic (as in other Central and Eastern European countries) have been rising relatively fast over the past two decades and are linked to agricultural land price increases. E.g. in the Czech Republic, the average price of 1 m² of agricultural land in 2018 was about 1 EUR, the average growth rate of agricultural land prices in the last 5 years was about 17%. Thus, in terms of the risk and potential impact on the minimum price of biomass from SRC plantations, land rents are the most risky item.

Conversely, minimal risk can be expected with additional cost items such as labor costs (SRC plantations have minimal labor requirements) or costs for conventional agro-technical operations (e.g. plowing, etc.). The weight of these items is minimal in total spending, and in addition, they are standard and highly competitive services where high growth in their prices cannot be expected.

No significant decrease in the minimum price of biomass produced from SRC plantations can be expected in the future. The positive effect of the expected fall in seed material prices and harvest prices will have a positive effect, while continuing increases in agricultural land rents will have a negative effect.

The costs of pelleting (considering the use of locally available/cultivated biomass and the annual production of a pellet line of 1000–1500 t/year) are mainly affected by the relatively high operating costs, which is about 65,000 EUR/year. Approximately 42% of operating costs are electricity costs, 58% of costs are maintenance and labor costs. The cost of pelleting is then about 4.7 EUR/GJ and significantly increases the minimum price of biomass (after transformation to pellets) to 2–3 times. The costs of pelleting then play a key role in assessing the feasibility of plans for high growth of solid biomass use for local heating. The calculated costs of pelleting are consistent with the results of similar works, e.g. [8] states pelleting cost for middle size pelleting plant (6–8 t/hour) at app. 6 EUR/GJ (assuming heating value of pellets at 16.5 GJ/t).

Cost of pelleting can be reduced with investment subsidy for pelleting technology purchase and with reduction of discount rate (assuming e.g. that pelleting is run by municipality on nonprofit base). Investment subsidy at 50% level and reduction of nominal discount rate to 3% leads to reduction of pelleting cost to 3.8 EUR/GJ.

Some authors (e.g. [13]) also highlights stability of price of pellets (produced from locally available biomass) compared with the conventional fuels (natural gas, heating oil, coal) as one the important factor of pellets competitiveness.

4. Conclusions

Pellets produced from locally available biomass (chips) are, even with the assumption of biomass production in favorable locations (with an average biomass yield of 8–10 t (DM)/ha,year), still uncompetitive with domestic (Czech) brown coal, whose price ranges from 6.5–7.3 EUR/GJ (2018 prices) [14]. Pellets produced from biomass from SRC plantations have, thus, only limited competitiveness with domestic brown coal at present.

There are several options (policy measures) how to increase competitiveness of pellets from intentionally grown biomass. First one is to increase coal price through significant increase in current value of carbon tax imposed to the brown coal from current value 0.33 EUR/GJ (value for the Czech Republic and year 2018) to app. 3.3 EUR/GJ. Another measure can be aimed at either reduction of cost of biomass planting (e.g. doubling the current value of area subsidy — SAPS from app. 203 EUR/ha to 390EUR/ha or financial support covering SRC plantation establishment — app. 1300 EUR/ha) or reduction of pelleting cost (e.g. through investment subsidy to technology purchase — 50% investment subsidy would reduce pelleting cost by 0.7 EUR/GJ).

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