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ENERGY SOURCE REPLACEMENT IN A THERMAL POWER PLANT

ZAMENJAVA ENERGENTA V TERMOELEKTRARNI

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Abstract

In Slovenia, approximately one third of electricity is produced in thermal power plants. Electricity prices have risen sharply recently. There are several reasons for this. One of them is the large increase in the price of CO_2 coupons that thermal power plants have to buy, since they emit large amounts of greenhouse gas into the environment during the production of electricity. Emissions of the greenhouse gas CO_2 are the result of burning fossil fuels, in this case coal. We want to use renewable energy sources to replace fossil fuels and reduce greenhouse gas emissions. More than half of Slovenia is covered with forest, and as a result, wood biomass energy represents a great energy potential. One possibility is the use of wood biomass in a classic thermal power plant for the production of electricity. This contribution presents the energy potential of Slovenian forests, before evaluating the replacement of the energy source in the existing coal-based thermal power plant with wood biomass. It has been discovered that there is enough wood biomass in Slovenia, and that all the electricity that is currently produced from coal can be produced from wood biomass. The cost of wood biomass is higher than the cost of coal. By changing the energy source, we save on the purchase of CO_2 coupons. Therefore, the use of wood biomass represents an economically justified energy source for the production of electricity.

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Povzetek

V Sloveniji približno eno tretjino električne energije proizvedemo v termoelektrarnah. Električna energije se je v zadnjem času močno podražila – razlogov za to je več. Eden izmed njih je veliko povišanje cene emisijskih kuponov, ki jih morajo kupovati termoelektrarne, saj pri proizvodnji električne energije v okolje emitirajo izdatne količine toplogrednega plina. Emisije toplogrednega plina CO_2 so posledica zgorevanja fosilnih goriv, v tem primeru premoga. Z obnovljivimi viri energije želimo nadomestiti fosilna goriva in zmanjšati emisije toplogrednih plinov. Več kot polovica Slovenije je pokrita z gozdom, zato energija lesne biomase predstavlja velik energetski potencial. Ena od možnosti je uporaba lesne biomase v klasični termoelektrarni za proizvodnjo električne energije. V tem prispevku predstavimo energetski potencial slovenskih gozdov in ovrednotimo zamenjavo energenta v obstoječi termoelektrarni na premog z lesno biomaso. Ugotovitve kažejo, da je v Sloveniji dovolj lesne biomase, da lahko iz nje proizvedemo vso električno energijo, ki jo sedaj pridobivamo iz premoga. Strošek lesne biomase je višji od stroška premoga, vendar z zamenjavo energenta prihranimo pri nakupu emisijskih kuponov. Tako je uporaba lesne biomase ekonomsko upravičen energent za proizvodnjo električne energije.

1 INTRODUCTION

Renewable energy sources include all energy sources that are captured from constantly repeating natural processes. Renewable energy sources (RES) include solar radiation, wind, water flow in rivers, photosynthesis, ground heat flows and sea currents. Renewable energy sources locally reduce import dependence and increase energy security. The industry related to RES promotes greater employment and rural development. The most important renewable energy source in Slovenia is wood biomass, followed by water energy, while the use of solar energy has also been increasing recently. Slovenia had set a national goal of achieving at least a 25% share of RES in the final gross energy consumption by 2020. However, Slovenia itself did not reach this target. The achieved share of energy use from renewable sources was 24.1%. In order to fulfil the set goal, Slovenia concluded an agreement with the Czech Republic and, with the help of the mechanism of statistical transfer of renewable energy, transferred 465 GWh of energy from another EU member state and thus avoided sanctions. By 2030, Slovenia has set an overarching national goal of achieving at least a 27% share of RES in the final gross energy consumption. In accordance with the National Energy and Climate Plan (NECN), the sectoral target shares of RES in the gross final use of energy are also set for 2030. In the heating and cooling sector, the share of RES is 41.4%, in the electricity sector the share is 43.3% and in the transport sector 20.8%, with a projected share of biofuels of at least 11%. In 2020, the share of RES in the heating and cooling sector was 32.14%, in the electricity sector 35.09% and in the transport sector 10.91%. [1] It follows that we will have to significantly increase the share of RES in all sectors.

The aim of this research is to analyse the replacement of coal as an energy source with wood biomass in a thermal power plant.

2 DATA AND METHODS

2.1 Thermal power plant

For the analysis, we will use data from 2019. During this year, the Šoštanj thermal power plant (TEŠ) operated two blocks, block 5 and block 6. Block 5 produced 775,028 MWh and block 6 produced 3,397,672 MWh of electricity. [2] A total of 4,195,305 MWh and 3,720,821 MWh of electricity were produced on both generators. They used 3,040,612 tons of lignite coal from Velenje. The calorific value of coal was 11,874 GJ/t. Depending on the technology used in the individual blocks, the specific CO_2 emissions in block 5 are 1.090 kg/MWh and 0.869 kg/MWh in block 6. In total, CO_2 emissions amounted to 3,800 tons. Companies need emission coupons for greenhouse gas emissions. For each emission coupon, the company can release 1 ton of CO_2 into the atmosphere or an equivalent amount of another greenhouse gas that is equally or similarly harmful to the environment. Companies that need emission coupons buy them on the emissions market. The basic idea behind emission coupons is to encourage companies to focus on operations that are kinder to nature and the planet. Emission coupons are issued by the European Union, and the total number of issued coupons decreases every year. In doing this, the European Union seeks to reduce the amount of greenhouse gases in the atmosphere over time. In the period between 2021 and 2030, 2.2% fewer coupons are issued each year. Figure 1 shows the evolution of emission coupon prices over time. The diagram shows that the price of coupons was low until 2018 and was around €10 per ton of CO_2. This price then rose above €20 per ton, with a subsequent sharp jump in 2021. In August 2022, the maximum price was recorded at almost €100 per coupon. The current price is around €80.

Figure 1: *Emission coupons prices on the stock exchange*

The price of coal and the cost of emission coupons have the greatest influence on the own price of the electricity produced in the thermal power plant. In 2019, the Šoštanj thermal power plant

produced 3,721 GWh of electricity and recorded €217.8 million in revenues from the sale of electricity, or a total of €225.9 million in revenues from the sale of electricity and heat. 3,040,612 tons of coal were used for the production of electricity and heat. The price of coal is €2.75/GJ. The cost of coal amounted to €99.3 million. In Slovenia, we have 45 devices that require emission coupons for their operation. In the year under review, 6,253,595 emission coupons were handed over, of which 3,817,347 went to the Šoštanj thermal power plant, which represents 61% of all the coupons handed over. The average price of emission coupons in the year in question was €24.60 per coupon. [3] Based on this data, we can calculate that the cost of coal was €26.7/MWh and the cost of emission coupons, if we consider the average price of all submitted coupons, was €25.1/MWh. On average, electricity was sold at €58.5/MWh. Mainly due to the high cost of emission coupons, the company's profit was negative. As the prices of emission coupons increase, business is getting worse. One of the possibilities for improving operations is the transition from fossil fuels to renewable energy sources, or the replacement of the energy source coal with wood biomass, thereby avoiding the cost of emission coupons.

2.2 Wood biomass

Slovenia's natural wealth is the forest, which covers 58% of Slovenia's surface. The area of commercial forests measures 1,068,484 ha, protected forests 98,762 ha and forest reserves 9,508 ha. The total area of forests is 1,176,754 ha. Taking into account the forest cultivation plans (GGN) made in 2019, the wood stock is estimated at 356,756,000 m^3 or 303 m^3/ha. The annual increase is estimated at 8,827,600 m^3 or 7.5 m^3/ha. In 2019, 5,287,863 m^3 of woody biomass were cut, of which 3,326,578 m^3 were conifers and 1,961,285 m^3 hardwoods (deciduous trees). The recorded logging in 2019 amounted to 87% of the possible logging according to GGN.

One of the main tasks of the Forestry Institute in the field of wood for energy is to provide data on the potential of wood suitable for energy. They spatially show the potential of wood suitable for energy use (supply), its use (demand) and the balance sheet for an arbitrarily selected area. When calculating supply, in addition to other parameters, data on forests and the potential of non-forest land, industrial resources and collected wood waste in collection centres are taken into account. When determining demand, they take into account the estimated use of wood for energy by households. Table 1 shows the energy potential of wood. [4]

Table 1: *Potential of wood biomass for energy*

Source	Parameter	Net quantity in tons of dry matter
forest	available logging quantity of lower quality assortments	1,603,000
	actual logging quantity of lower quality assortments	799,000
	logging residue in the forest upon the undertaken of a possible felling	455,000
	logging residue in the forest upon the actual realisation of the felling	294,000
	the amount of log bark when a possible felling is realised	59,000
	the amount of log bark when an actual felling is undertaken	59,000
agricultural areas	estimated possible permanent felling of trees on non-forested areas	151,000
	wood and non-wood residues from agricultural land usable for energy	197,000
industry	the amount of sawmill residues during the processing of logs upon realisation of a possible felling	530,000
	the amount of sawmill residues during the processing of logs during the current realisation of the felling	500,000
collection centres	collected wood residues	350,000
consumption	consumption of lower-quality assortments in households for heating and cooking	776,000
	consumption of lower quality assortments in district heating and cogeneration systems	94,000
	wood residues used in industry	32,000
	total consumption of wood for energy in all sectors	902,000
	the amount of competitive use of lower quality wood in the industry	255,000

3 RESULTS

One of the options for the extended operation of thermal power plants is the replacement of the energy source coal with wood biomass, which is carbon neutral. In 2019, TEŠ consumed 3,040,612 tons of coal with a calorific value of 11,874 GJ/t. If the consumed amount of coal is converted into energy, we get 36 PJ of energy. Taking into account the annual increase in Slovenia and the assumed average wood density of 550 kg/m^3, as well as the average calorific value of 16.5 MJ/kg, we find that coal energy can be replaced with 45% of the annual increase. This value is also very close to the percentage of waste when processing logs into quality products with high added value. If we allocated the same amount of money for wood biomass as was spent in 2019 (before the drastic increase in the price of emission coupons) for the payment of coal and emission coupons, then the price of wood biomass delivered to the thermal power plant could be €48/m^3.

Table 1 shows a more detailed analysis of the potential of wood biomass for energy production. The possible harvest of lower-quality assortments amounts to 1,603,000 tons. If we add to this the amount of log bark at the realisation of a possible felling (59,000 tons), the amount of sawmill residues from the processing of logs at the realisation of a possible felling (530,000 tons), and the collected wood residues in collection centres (350,000 tons), we get the sum of wood biomass resources at the realisation of a possible felling in the amount of 2,542,000 tons. From this sum, we can subtract the consumption of lower-quality assortments in households for heating

and cooking (776,000 tons) and the consumption of lower-quality assortments in district heating and cogeneration systems (94,000 tons), as well as wood residues used in industry. In doing this, we obtain a quantity of lower-quality wood when the possible harvest is realised in the amount of 1,640,000 tons. This is the amount of wood biomass that could be usefully used in a thermal power plant. Taking into account the calorific value of 16.5 MJ/kg, 75% of coal consumption and consequently 75% of CO_2 emissions could be replaced with the available amount of lower-quality wood, which corresponds to 2.8 million tons of CO_2.

4 CONCLUSION

The article analyses the replacement of coal as an energy source with wood biomass in a thermal power plant. The analysis was made on the basis of data for the year 2019. This year was chosen because the Covid situation broke out a year later, and it thus represents a normal, average year. The analysis of the data showed a sharp increase in the prices of emission coupons, which have a negative impact on the operation of the thermal power plant. It was found that the entire amount of coal used can be replaced by 45% of the annual increase in wood biomass. Furthermore, it was found that if the coal was replaced only by the consumption of lower quality wood when the possible felling was realised, then 75% of the coal consumption could be replaced.

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Nomenclature

(Symbols)	(Symbol meaning)
GGN	forestry cultivation plan
TEŠ	Thermal power plant Šoštanj
RES	Renewable energy sources