Setting of target values for household heating by wood

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Abstract–With the growing concern about sustainable development and sustainable energy, there exists increasing pressure on energy-efficiency technologies to reduce energy use and greenhouse gas emissions. This paper discusses and analyzes on real regional data the potential of biomass in energy-efficiency issues, how to determine the volume of changes of heating from coal or natural gas to wood and the effects of biomass combustion expansion. However, also the role of grants provided by governments to support energy-efficiency initiatives is explained.

Keywords–Biomass; Efficiency; Heating System; Renewable Energy

I. INTRODUCTION

On the one hand, the climate protection policy has been increasingly focused on possibilities of how to reduce the overall amount of greenhouse gas (GHG) emissions [5], on the other hand, there are efforts to minimize combustion processes and decrease energy consumption [7]. However, with growing world population, global energy demand is projected to more than double in this century [9,13]. The solar energy is considered as the largest source of renewable energy in terms of the volume of available renewable energy [11]. Moving towards renewable energy is not only built on solar systems, mainly due to significant fluctuations in the resources availability in summer and winter time. The shift towards sustainability in all of its basic pillars means local energy resources usage [10,12]. One of the simplest ways is to use the biomass, in particular in the form of firewood for heating, ideally in combination with appropriate heat insulation and the solar system, but this is not currently available everywhere. The energy source in the form of wood fuel has the prospect of a relatively long-term use, because even in case of almost perfectly remediated building, which has undergone redevelopment in accordance with requirements of the EnerPhit concept, the energy loss needs to be partly covered by other source in winter time.

Since 1998, certain German countries have already implemented similar measures that have been taking place in the Czech Republic since 2009 known as Green Savings. The German program had similar goals, subsidies to replace solid fuel heating system were provided, also devices using gas as a fuel, or light fuel oil (LTO) were supported by grants. Simultaneously both renewable energy use in particular combination of natural gas with Solar Domestic Hot Water systems (SDHW) and central heating were financially supported. Also grants on thermal pumps and heating biomass systems were provided [2].

When the applicant was interested for example in heating biomass system, supply of biomass (primarily wood) was ensured in the form of a contract between the customer and the respective supplier. Such a customer had a choice whether he prefers to be supplied by prepared wood for heating, or whether the customer prefers to cut and process his wood by himself within the agreed time and earmarked forest. The number of applicants for the biomass heating systems was limited to avoid demand outstripping supply in individual municipalities or regions. Otherwise, this would result into potential danger of inefficiency of such allocated grants, because the recipient would be forced to use coal due to the lack of wood.

To avoid this problem, this paper deals with the possibilities of how to determine the volume of changes of heating from coal or natural gas to wood.

As a reference agglomeration, Pardubice Region was chosen. The reason is that in this region of the Czech Republic the analysis of the energy needs for heating residential buildings was already conducted [1].

After rounding the reference value the average heating energy intensity for residential buildings in Pardubice Region is:

$$ENBHeat(t) = 161\ kWh/(m^2.a)$$

The total floor space in the region was estimated to

27,422,760 m^2 (without domestic water heating).

The value of the average energy consumption per square meter for residential buildings in Pardubice Region was determined depending on the age of the building and the construction regulations in the relevant period of construction.

The parameters of the objects that underwent various forms of remediation have been considered in the value, same as the proportion of these buildings on the total number of residential buildings.

Based on the information of the employees of the Czech Statistical Office (CSO) [3], proportion of the buildings older than 30 years that underwent any form of remediation was estimated, also data clarifying the types of remediation were identified (window replacement, window replacement and insulation and expected energy cost savings).

The total floor space is also an information from CSO, where a floor space of buildings in the region according to their purpose is used.

Due to the grant programs and legislative restrictions, decreasing trend of the total value of the heat loss in residential building can be expected over time. This will result in a higher percentage of households where wood heating will be possible. The data represents the current state.

Now it is necessary to compare this value to the wood supply capacity in the region.

For the calculation, an analysis of available spaces according to the type of the space as they are conducted in the cadaster is provided. The results consider the possibility of sustainable forestry. Therefore, a continuous annual increment of biomass was taken into account, not only one-time consumption of the wood in certain area.

According to data from the European Centre for Renewable Energy, around 7.5 tons of wood as a waste biomass continuously growing in the forests could be obtained from one hectare per year [6]. It is a waste dry basis. This value represents a net gain for a transport distance for the raw material within 8 kilometers. We assume that grants for biomass heating reflect location and distance from the source of the biomass. In other words, all the energy costs are included for transport distance till 8 km [6].

It is assumed that only wood waste will be used for heating purposes which cannot be used otherwise. If other types of extracted wood, which in conditions of ČR are also used for heating, would be included in the calculation, the overall result would be more favorable. In the future, however, there may be greater demand for wood, as a generally renewable resource, eg as a construction material. The value considered respects the requirements for sustainable forestry because it does not foresee the intentional extraction of wood for energy purposes but only the use of wood waste generated by the maintenance of forest stands or the wood extraction for other purposes than the production of energy. This corresponds to the value of 7.5 $t.ha^{-1}.a^{-1}$ according to [6].

When considering a truck with an average transport capacity of 8-10 m3 (Tatra 815), the decreasing efficiency of the investment in the replacement of fossil fuel by renewable energy in the form of wood is caused due to the increasing consumption of fossil fuel consumed to transport this wood to its customer This relationship describing the decreasing efficiency of an investment can be expressed by the formula:

$$E_{rem} = E_{incl} - E_{trans}, \tag{1}$$

where E_{rem} represents the remaining volume of renewable energy, E_{incl} total energy content in wood and E_{trans} volume of energy needed for transport of wood.

It is clear that at the moment when the E_{rem} value reaches 0, the effect of the used biomass is fully compensated by the burned non-renewable fuel and the means expended to reduce the primary energy consumption thus have no effect. In the case of a negative value, the additional emissions are already prevailing and the overall impact on the saving of non-renewable resources is negative. For calculating, it is necessary to set additional values, especially the energy contained in the wood E_p.

Because the type of wood, its proportion, or wood moisture is unknown both in short-term and in long-term, therefore the value of E_p was determined in accordance with the average calorific value of the wood and in accordance with expected moisture content based on [15]. That is why the value of E_p is set on 14.23 MJ/kg in condition of 20 % moisture content. It is assumed that in average these values were achieved in the region.

The volume of the cargo space of the considered Tatra 815 varies usually between 8 – 10 m3 [14]. The value of the wood mass corresponding to this volume is calculated for the bulk space meters (prms) according to the relationship

$$m_w = V_w \times 0.41 \times 582, \quad (2)$$

where m_w represents the mass of wood in kg and V_w the volume of wood in m^3. The value 0.41 is the spatial volume of the wood where it is a bulk sprinkled wood, and the value 582 represents the weight per cubic meter of wood calculated as average of available trees (deciduous and coniferous wood) [15].

Substituting into (2):

$$m_w = 8 \times 0.41 \times 582$$

$$m_w = 1909\ kg$$

For the volume transported, the lower limit was chosen for caution, i.e. 8 m^3. This partly takes into account the fact that full capacity utilization of vehicles transporting cargo may not always succeed.

Therefore it would be possible to transport one-time ca. 1.9t of wood, representing the amount of energy given by:

$$E_w = 14.23 \times m_w \quad (3)$$

Where E_w is the total amount of energy included in one load.

Substituting into (3)

$$E_w = 14.23\ MJ/kg \times 1909\ kg$$

$$E_w = 27\ 165\ MJ.$$

The net calorific value of diesel is 42.61 MJ/kg [16] and the density is within the range 800 – 880 kg/l [8]. The volume of energy per liter is determined by the relationship

$$E_{dl} = m_d \times \rho_d \quad (4)$$

Substituting into (4)

$$E_{dl} = 42.61 \times 0.84$$

$$E_{dl} = 35.8\ \text{MJ/l}.$$

Expected consumption with this load is 60 l/100 km + return without load 40 l/100 km [14].

The amount of energy at which both sources equalizes is given by value E_w (27 165 MJ), where only 60% of this value should be taken into account for an overcoming the total distance, while remaining 40% falls on empty return path. The maximal transport distance could be therefore calculated according to the formula:

$$E_{w(60\%)} = E_w \times 0.6 \quad (5)$$

Substituting into (5) we get:

$$E_{w(60\%)} = 27\ 165 \times 0,6$$

$$E_{w(60\%)} = 16\ 299\ MJ.$$

The maximum transport distance is given by the point of $E_d = E_{w(60\%)}$, where E_d is the distance in km. Since the value is to be determined for the distance traveled and the estimated consumption is (60/40) l / 100 km, this value can be calculated using the formula:

$$E_d = ((E_{w(60\%)}/E_{dl})/60) \times 100 \quad (6)$$

Where the number 60 represents the fuel consumption for transport for 100 km and the 100 represents the distance that can be offended using of 60 l of diesel fuel.

Substituting into (6):

$$E_d = ((16\ 299/35.8)/60) \times 100)$$

$$Ed = 758,8\ km$$

From the result may be seen, that the transport distance could be relatively large, but it is also worth noting that the investing in reducing the use of the reducing of primary energy consumption is devalued with each unnecessary mileage. The decrease of the remaining additional energy depending on the transport distance is shown in the graph in Fig.

1.

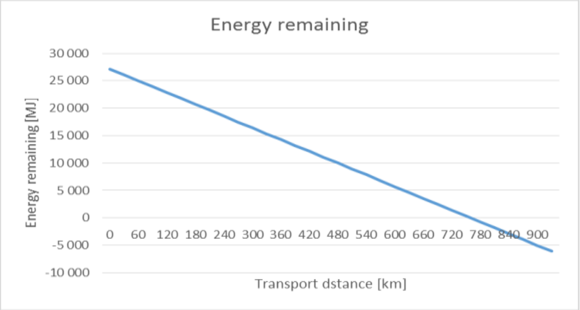

Fig. 1 Energy decrease according transport distance

This implies additional requirement for optimal use of funding under the assumption that the selected indicator of primary energy consumption and optimization criterion is maximization of the savings spent on the crown of the grant funds.

Poor funding allocation would lead to the extension of transport routes and the growth of primary energy consumption. Therefore, in practice, the best way how to optimize process of allocating funds is to conclude contracts with the forest owners about cooperation in the funding programs in terms of willingness to provide a certain amount of firewood to the subsidies recipients. However, it is necessary to take sustainability of such cooperation into consideration.

Waste biomass utilization potential is calculated according to the formula:

$$E = A \times E_p \times H \quad (7)$$

Where
E represents available biomass energy potential,
A represents available area for biomass harvesting in hectars (forest area),
E_p represents the annual energy potential obtained from 1 hectare of forest biomass and
H represents average calorific value of 1 kilogram of considered biomass.

According to CSO data, the available area of forests in the Pardubice region is 130.353 hectares [4]0

Substituting into (7):0

$$E = 130{,}353\ ha \times 7,\ 500\ kg.a^{-1} \times 14.23\ MJ.kg^{-1}$$
$$E = 1{,}961.64819\ GJ.a^{-1}$$

From the forest of 130 353 ha can be obtained due to the continuously emerging biomass 1,961.64819 $GJ.a^{-1}$ of primary energy (boiler input power).

Under grant schemes, there are specific conditions regulating the type of the boilers that can be supported by the grant. For the calculation, only boilers with the efficiency higher than 80 % are considered. This condition is met by a number of biomass boilers commercially available, such as

Heat output was determined according to the formula:

$$E_v = E \times \eta \quad (8)$$

Where η represents combustion efficiency,

E_v represents heat output.

Substituting into (8)0 for minimum value of 80 % of efficiency:

$$E_v = 1{,}961.64819\ GJ.a^{-1} \times 0.8$$

$$E_v = 1{,}569{,}318.552\ GJ.a^{-1}$$

Comparing with the values given in the study [1] about energy efficiency in buildings, following results were obtained:

The overall energy performance of residential buildings for energy for heating can be determined according to the formula:

$$C_{Heat} = ENB_{Heat} \times TFs \quad (9)$$

Where C_{Heat} represents the total heat consumption,
ENB_{Heat} represents the average energy performance of these building for heating and
TFs represents the total floor space of all buildings in the Pardubice region.

Substituting into (9)0

$$C_{Heat} = 161 \times 27{,}422{,}760 = 4{,}415{,}064{,}360\ kWh/a$$

The study works with values in kWh, which needs to be converted to MJ.

Following relation is applicable:

$$1 \quad kWh = 3.6\ MJ \quad (10)$$

Therefore

$$C_{Heat}\ (MJ) = C_{Heat}\ (kWh) \times 3.6 \quad (11)$$

Substituting into (11)0:

$$C_{Heat}\ (MJ) = 4{,}415{,}064{,}360 \times 3.6$$

$$C_{Heat}\ (MJ) = 15{,}894{,}231.696\ GJ.$$

Following formula express compares the energy potential of biomass in the form of technically available wood in the region and heating energy demand:

$$S_v = E_v\ /C_{Heat} \tag{12}$$

Where
Sv represents a percentage expressed as a proportion, which can be covered by biomass combustion in the Pardubice region,
Ev is a total energy consumption for heating in the Pardubice region and
C_{Heat} represents firewood potential availability in the Pardubice region.

Substituting into (12):0

$$S_v = 1{,}569{,}318.552/15{,}894{,}231.696$$
$$S_v = 9.87\%$$

II. CONCLUSION AND DISCUSSION

Provided calculated value is called ´technically available potential´ and it does not include economic aspects such as price requirements of forest owners, also their willingness to keep clear the wood from the forest away, unclear ownership of some woods, accessibility of certain locations etc. It is therefore an optimal value on condition accessibility is ensured and all the administrative issues are resolved.

The results show that under such conditions the direct combustion of biomass could possibly cover maximum
of 9.87 % of the current energy consumption for heating residential buildings in the region. Under the abovementioned conditions, wood boilers grants would only make sense, if they were provided in order to exchange already operated biomass boilers for better ones.

Biomass combustion expansion would lead to a decline in the environmental benefits of provided subsidies in terms of decreasing effect of grants on decrease in primary energy consumption.

REFERENCES

[1] R. Baťa, “Determination of the Potential of Energy Savings for Heating in the Czech Republic,” unpublished.

[2] R. Baťa, Grenzüberschreitende Umweltprojekte. E+M: Ekonomika a management, březen 2002, roč. V., mimořádné číslo, str. 7-8. ISSN 1212-3609.

[3] CSO, Additional information obtained under direct examination by experts from Czech Statistical Office in Jan – March 2015 and in Oct. 2016.

[4] CSO: Forestry: Public database [online]. Pardubice: CSO, 2016 [cit. 2016-02-15]. Retrieved from: https://vdb.czso.cz/vdbvo2/faces/index.jsf?page=statistiky#katalog=30841

[5] E. Worrell, et al., Industrial energy efficiency and climate change mitigation. Energy efficiency, 2009, 2.2: 109.

[6] European Centre for Renewable Energy: Sustainable forestry [online]. 2016 [cit. 2016-06-23]. Retrieved from: http://www.eee-info.net/index.php/en/energieberatung

[7] C. Fischer, Feedback on household electricity consumption: a tool for saving energy?. Energy efficiency, 2008, 1.1: 79-104.

[8] Fyzikální tabulky objemové hmotnosti. Density of liquids. [online]. 2017 [cit. 2017-03-18]. Retrieved from: http://www.converter.cz/tabulky/hustota-kapalin.htm

[9] J. Fuka, L. Gresova, K. Satera, Differences in Municipal Structure in Czech and Slovak Republic with Emphasis on Delegated Powers, Proceedings of The 27th International Business Information Management Association Conference, 2016, 25-261, 978-0-9860419-6-9.

[10] L. A. Greening, Greene, D. L., Difiglio, C., Energy efficiency and consumption—the rebound effect—a survey. Energy policy, 2000, 28.6: 389-401.

[11] J. Twidell; Weir, T.. Renewable energy resources. Routledge, 2015.

[12] K. Šatera, I. Obršálová. The possibilities of determining environmental impacts of economic activities in a region. Scientific

Papers of the University of Pardubice, Series D, 2015, vol. 22, iss. 33: 131-141

[13] R. Foster, Ghassemi, M.; Cota, A., Solar energy: renewable energy and the environment. CRC Press, 2009.

[14] Tatra. Technical data of individual versions. [online]. 2017 [cit. 2017-03-15]. Retrieved from: http://tatratech.wz.cz/prospekty/t815-2/260s43.html

[15] TZB info: Calorific value and measurement units of firewood [online]. 2016 [cit. 2016-02-15]. Retrieved from: http://www.tzb-info.cz/tabulky-a-vypocty/12-vyhrevnosti-a-merne-jednotky-palivoveho-dreva 12

[16] TZB info. Caloric value of fuels. [online]. 2017 [cit. 2017-03-18]. Retrieved from: http://vytapeni.tzb-info.cz/tabulky-a-vypocty/11-vyhrevnosti-paliv