Archives of Environmental Protection
Vol. 45 no. 1 pp. 59–67

PL ISSN 2083-4772
DOI 10.24425/aep.2019.126422

Evaluation of environmental effects of electricity production from disposed railway sleepers

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Keywords: LCA, gasification, railway sleepers, electrical energy.

Abstract: The study focused on environmental evaluation of the disposed wooden railway sleeper gasification system used for electrical energy production. The aforementioned base technology was referred to the system producing electricity from disposed wooden railway sleepers through combustion. The evaluation was carried out using the LCA technique. The results show that in scope of impact on human health and ecosystems, the technology based on sleeper gasification is friendlier to the environment than the alternative technology. The technology of reference produces a lower environmental burden in scope of depletion of non-renewable natural resources. In comparison of the base technology (gasification) and the alternative technology (combustion), the end environmental effect shows that in scope of the analysis the base technology, i.e. the technology involving gasification of disposed railway sleepers, is more friendly to the environment.

Introduction

Over 20 thousand GWh of electrical energy is consumed globally each year. Approximately 2/3 of this energy comes from fossil fuels (Enerdata 2018). Besides creating an environmental burden, which results from emission of harmful substances to the environment, fossil fuels also have an impact on the depletion of their non-renewable deposits. Meanwhile, it is commonly believed that the potential of biomass and waste is subject to renewal (Kopczyński et al. 2017, Zuwała 2012). Thermal waste processing also protects the natural environment from the consequences of waste dumping and storage. With consideration of the above, it seems environmentally beneficial to use selected waste fractions in electrical energy production processes (Hryb et al. 2018). This study concerns electricity production from disposed wooden railway sleepers.

Railway sleepers are wooden beams saturated with creosote oil. Thanks to its biocidal properties, creosote oil extends the lifespan of the sleepers on tracks, but at the same time it is harmful to human health (Regulation EC 2008, DAW-BYTOM 2017, Kukulska-Zając et al. 2014). Due to the above, old and disposed wooden railway sleepers are classified as hazardous waste under code 17 02 04* (Regulation 2014). Their calorific value comes to around 15 MJ/kg in "as received state", which means that they hold relatively high energy potential (Cerni et al. 2015, Bałazińska 2017, KOBIZE 2017). However, the quantitative potential of disposed railway sleepers is hard to assess because most countries do not keep such records. Only selected countries have literature providing data specifying the potential of old wooden railway sleepers. Approximately 1.5 million Mg of such waste is collected from tracks in the United States and Canada (Railway Tie Association 2017, Bałazińska 2017). According to the International Union of Railways, over 300 thousand Mg of such waste was collected from roughly 60% of tracks in Europe in 2010 (International Union of Railways 2013).

On the other hand, local character of this potential "fuel" encourages their application as fuel in distributed energy systems. The dedicated process for production of electrical energy in such systems seems to be gasification. In reality, however, old railway sleepers usually do find use in electricity generation systems, but based on combustion. In the ecological aspect, there is no comprehensive description of environmental effects for disposed railway sleeper gasification systems oriented towards electrical energy production. Consequently, no comparison of the environmental effects between railway sleeper gasification and combustion for energy generation can be done. This raises the following dilemma: instead of using disposed wooden railway sleepers in combustion – as is the common practice today – perhaps it would be better for the environment to subject them to gasification? This publication gives an answer to the question presented above.

Methodology of the research

For gasification, the first step was to develop the concept of the technological system used to produce electrical energy from disposed wooden railway sleepers. The next step covered tests on the system, which produced the data required for environmental evaluation of the technology.

Simultaneously, a review of the literature concerning environmental evaluations of combustion of disposed wooden railway sleepers was conducted (Bałazińska 2017). This review was used in the selection of reference technology (Werner 2005), which gave necessary information. Collection of the data specific for given technologies was followed by environmental evaluation. The selected evaluation method was LCA (Life Cycle Assessment) analysis (Guinee 2002, Bogacka et al. 2014)

Research

The assumptions made for the purposes of the LCA analysis of railway sleeper gasification for production of electrical energy in reference to sleeper combustion ensured the necessary cohesion of the input data. Since the analysis of environmental effects of the given technology was based on disposed beech wood railway sleepers (Werner 2005), the research also involved beech wood sleepers.

Experimental research – baseline technology

Research subject

The research focused on the gasification of disposed railway sleepers for the purpose of electrical energy production with the use of fixed bed gasification technology. The developed system concept comprised of five technological units (Fig. 1):

1. Fuel preparation unit.

The fuel preparation unit comprised of a stationery fixed band saw and a crusher. The purpose of these devices was to adapt the fuel to the requirements of the gasification reactor located in technological unit 3.

Fuel feeding and dispensing unit

The fuel feeding and dispensing unit was composed of a hopper, two knife gate valves, transitional and main fuel tank, and auger dispenser. The purpose of the respective elements composing the unit was to feed and dispense fuel to the gasification reactor.

Gasification unit

The gasification unit was composed of the gasification reactor and air ventilator, since the gasification factor in the reactor was air. The gas generator selected for research was a gasification reactor with a permanent deposit and a vertical and cylindrical structure, featuring an axial pipe with adjustable height. Thanks to this solution, the process gas could be collected directly from the gasification segment, which reduced the tar in the gas to minimum and produced a relatively high gas temperature (Billig et al. 2010).

Process gas treatment and cooling unit

The process gas treatment and cooling unit was composed of a decompressor, ceramic filter, gas cooler, flotation machine, and membrane system. The larger dust particles were separated in the decompressor due to reduction of gas velocity and returned to the gasification reactor. The next element of the system was the high-temperature candle filter, which purified the gas as it was running from the external to the internal side of the candles located inside. In order to extend the lifespan of the candles, they were coated with a thin layer of calcium carbonate. The formed filter cake was periodically removed from the candles with a stream of nitrogen. The loose material was returned to the gasification reactor. The next element after the ceramic filter was the process gas cooler, which cooled the gas down to the temperature required by the piston engine (maximum 40°C). As the gas temperature was reduced, a liquid containing tar and dust residue was produced. The mix of the listed substances was directed in the form of condensate to the flotation machine, where it was pre-treated through flotation and sedimentation. The pre-treated liquid was then directed to the membrane system. The membranes removed all of the remaining tar from the liquid through low-pressure filtration. The contamination separated during the sedimentation, flotation, and membrane filtration processes was returned to the gasification reactor. The purified liquid was collected from the system.

Electrical energy and heat production unit

The electrical energy and heat production unit included a power generator with a piston engine and an exhaust cooler. Since there was no gas engine additionally equipped with a tank allowing stabilisation of the parameters of the process gas, the engine used was the engine whose primarily fuel is diesel oil. However, it was used as a dual-fuel engine and was powered with a fuel and air mix containing both process gas and diesel fuel. The engine configured with the generator produced electrical energy, which was collected by the resistance air heater system during the tests. The produced exhaust gas was directed to the cooler, where it gave the heat into the water.

The end product of the gasification system was the electrical energy produced in the power generator as well as the heat collected in the process gas cooler and the exhaust cooler.

It should be noted that the system involved in the test is in a pilot scale and that the technological line used in the said tests was never used in this configuration before.

A series of gasification tests on disposed beech wood railway sleepers with working calorific value of 14 840 MJ/kg at absolute humidity of 26.51% was run using the system.

Fig. 1 presents the significant measuring points of the system.

Research results

22.6 kg/h of air per 10 kg/h of railway sleepers subject to gasification was used in the gasification reactor. The temperature of produced process gas was 691.6°C upon release from the inertial decompressor. This value was reduced to 30°C on intake to the engine. The exhaust gas temperature grew to 386°C on exit from the engine and dropped to 120°C after releasing heat in the cooler. 0.077 kg/h of ash and 3.562 kg/h of sewage were collected from the system. The power generator reached the electrical power of 30.4 kW.

The process gas measured on exit from the inertial decompressor had the calorific value of 4.26 MJ/Nm^3. The biggest share of combustible gas components in the process gas was measured as follows: carbon monoxide (volume of 18.40%), hydrogen (volume of 6.15%), and methane (volume of 2.48%). The content of tar and dust, which had to be removed from the process gas before releasing it to the piston engine, was respectively 9.8 g/Nm^3 and 0.664 g/Nm^3.

The products of the processes were submitted for laboratory testing. The ordered scope of tests was dictated by their legal status and the legislative requirements applying

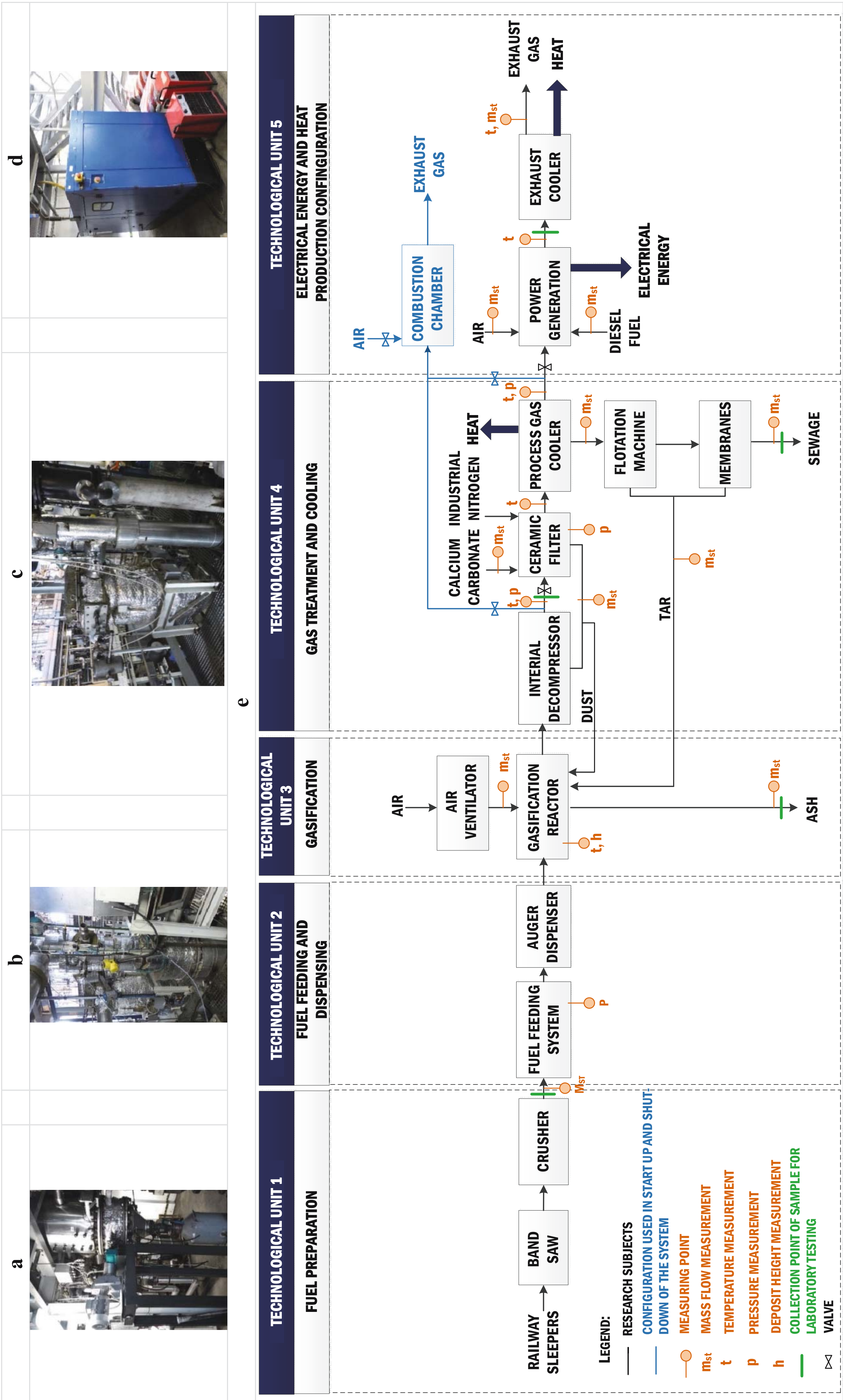

Fig. 1. Research installation configuration (Designation: a – lower segment of gasification reactor, b – upper segment of gasification reactor and inertial decompressor, c – ceramic filter and process gas cooler, d – power generator with air heater system, e – station schematic) (Białazińska 2017).

to them following their production in the target system. The legal requirements of the system itself and the potential for meeting the required exhaust gas emission levels were subject to analysis as well.

The research system in question is legally classified as experimental, for the purposes of testing consuming less than 50 Mg of waste per year. Consequentially, pursuant to art. 163 point 2 of the Waste Law (Law of 2013), this system is exempt from numerous requirements, which would be applicable if it used waste in the gasification process commercially. The selected target system had the power of approximately 1 MW of railway sleeper chemical energy. This system would be classified as a "thermal waste processing system" and would be subject to the legal requirements specified in art. 155–163 of the Waste Law (Law of 2013). However, pursuant to art. 163 point 2a of the said Law, the system can be exempt from the said guidelines as long as the "gases produced in gasification or pyrolysis processes are purified to a degree no longer classifying them waste prior to combustion and cannot produce emissions greater than those produced in combustion of natural gas". The study examined the potential to fulfil the aforementioned condition. For the analysed instance, the said condition referred to the maximum value of NO_x emission, which was 1502 mg/Nm^3 (converted to 15% of oxygen content in exhaust gas). Meanwhile, the emission level for the reference conditions during the research on the system reached 1039 mg/Nm^3. The lower level of NO_x emission in tests than the permitted value evidences that the legal requirements allowing for exemption of the target device from the guidelines specified in art. 155–163 of the Waste Law (Law of 2013) are fulfilled.

The remaining legal requirements associated with thermal utilisation of disposed railway sleepers in the target gasification system referred to the appropriate treatment of the produced waste, i.e. the ash from the gasification reactor and the sewage collected from the membrane system.

The ash from the gasification reactor was classified under waste code 19 01 12 (Regulation 2014). Based on the waste code and the obtained results of the laboratory tests on the said material (so-called washability test), it was suggested that the ash can be referred to a non-hazardous and non-inert waste landfill (Regulation 2015a, Regulation 2015b).

For sewage, pursuant to the provisions (Regulation 2006), the level of permitted chemical oxygen demand in industrial waste released to sewerage systems is to be established on an individual basis for specific treatment plants. The treated sewage collected from the membrane system held the chemical oxygen demand value of 2000 mgO_2/Nm^3. Due to the above, one of the Silesian waste treatment plants was consulted in order to establish the potential for sewage collection to reach the final conclusion that the sewage stream will not present a hazard to the biological life in the treatment plant and that it can be collected for treatment.

Reference technology

Combustion is the reference technology for the gasification system producing electrical energy from old railway sleepers . The review of literature in range of this subject showed that only (Werner 2005) presented an extensive LCA analysis for combustion of disposed wooden railway sleepers for electrical energy production. The author collected the data characterising railway sleepers and the values characterising the production of electrical energy and heat in the German electricity system and used them to create the calculation model recognising utility consumption and emissions associated with energy production in cogeneration. This model produced the data which was used in the next step for the purposes of LCA analysis.

LCA analysis

General principles

The LCA analysis covered two systems, i.e. the base technology (gasification) and the reference technology (combustion). The comparative LCA analysis of both technologies required establishment of the corresponding principles:

- The selected functional unit was 1 MWh of net produced electrical energy – in accordance with the objective of the study.

  However, as the author of the publication covering LCA analysis for the alternative technology selected one railway sleeper as the functional unit for the said analysis, it would have been impossible to compare the results of the LCA analysis for the base technology (gasification) and for the reference technology (combustion) (ISO 14040:2009, ISO 14044:2009, Guinee 2002, Curran 1996). Therefore, the LCA analysis for the combustion technology had to be repeated with the application of the input data of the publication's author (Werner 2005), this time with 1 MWh of net produced electrical energy serving as the functional unit. Unfortunately, (Werner 2005) did not include the direct input data for the purposes of the analysis. Therefore, the author of the publication was contacted and asked to provide the necessary data. Thanks to the kindness of Dr Frank Werner of Werner Umwelt & Entwicklung, the previously unpublished data characterising railway sleeper combustion were available for further work.
- System boundaries:
  - ➢ The gasification technology system covered the stages from fuel preparation, through fuel feeding and dispensing to the gasification reactor, gasification, purification and cooling of the produced process gas, to the production of electrical energy and heat.
  - ➢ The combustion technology system included the stages from fuel preparation, through fuel feeding and dispensing, fuel combustion, to the production of electrical energy and heat.
- The environmental burdens were allocated proportionally to the volume of the produced electrical energy and heat (ISO 14044:2009, Sonnemann et al. 2011, Śliwińska et al. 2017, Śliwińska 2016). The results of the LCA analyses refer to electrical energy in accordance with the title of the study.
- The demand for electrical energy to cover the system's internal demands was covered internally (for the established state of the system).
- The ash collected in the lower part of the gasification reactor was referred to as non-hazardous and non-inert waste landfill.
- Following tar removal, the liquid generated in the process gas cooler was referred to the waste treatment plant.

Data inventory

When the data required for comparative LCA analysis of the gasification technology used to produce electrical energy from disposed railway sleepers in reference to combustion technology was in place, it was subject to validation based on the mass and energy balance. Tab. 1 presents the inventoried input and output data of the compared technologies.

For the gasification technology, per 10 kg/h of railway sleepers there were used 372.303 kg/h of air (22.600 kg/h in the gasification reactor and 349.703 kg/h in the engine), 0.005 kg/h of calcium carbonate, 0.001 kg/h of industrial nitrogen, and 7.015 kg/h of diesel fuel. It produced 28.9 kW of net electrical energy, 38.8 kW of heat, 0.077 kg/h of reactor ash, 3.562 kg/h of sewage and385.685 kg/h of exhaust gas.

For the combustion technology, per 10 kg/h of railway sleepers 121.730 kg/h of air was used. It produced 4.4 kW of electrical energy, 11.5 kW of heat, 0.115 kg/h of ash and 131.615 kg/h of exhaust gas.

LCA analysis results

The LCA analyses of the gasification technology used to produce electrical energy from railway sleepers and of the railway sleeper combustion technology for the purposes of electricity generation were conducted with SimaPro 8 software equipped with the Ecoinvent 3 database. The method selected to evaluate the impact of the life cycle on the environment was ReCiPe, including ReCiPe Midpoint and ReCiPe Endpoint 2008 H/A (Goedkoop et al. 2013).

The data collected and assessed during the inventory stage was used in LCA analyses of the base technology of railway sleeper gasification for the purposes of electrical energy production and of the alternative system – sleeper combustion. It should be noted that the results of every LCA analysis stage always refer to the established functional unit (FU), which, for the purposes of this study, corresponds to 1 MWh of net produced electrical energy. The analysis conducted in the first stage of evaluation of the life cycle's impact on the environment was performed in ReCiPe Midpoint. The results of this stage are presented in Tab. 2.

A noteworthy aspect in the results of the analysis obtained through the ReCiPe Midpoint method used for the compared technologies is the environmental burden produced by climate change. The burden value obtained for the sleeper combustion technology (1.43E+03 kg CO_{2eq}) is much greater than the corresponding environmental impact of the base technology (5.55E+02 kg CO_{2eq}). With exception of freshwater eutrophication, the environmental burden values in the remaining impact categories were lower for the combustion technology than for the base technology. However, these values are very low in the scope of successive impact categories. In order to standardize the environmental effects in the scope of successive areas of impact, the ReCiPe Midpoint results were converted to ReCiPe Endpoint. Tab. 3 presents the category indicators for the base railway sleeper gasification technology and the combustion technology according to ReCiPe Endpoint.

Table 1. Inventoried input and output data for gasification and combustion technologies

<table>
<tr><th></th><th colspan="2">MASS/ENERGY STREAM</th><th colspan="2">Base technology – gasification</th><th colspan="2">Reference technology – combustion</th></tr>
<tr><td rowspan="5">INPUT</td><td colspan="2">railway sleepers</td><td colspan="2">10.0 kg/h</td><td colspan="2">10.0 kg/h</td></tr>
<tr><td colspan="2">air</td><td colspan="2">372.303 kg/h</td><td colspan="2">121.730 kg/h</td></tr>
<tr><td colspan="2">calcium carbonate</td><td colspan="2">0.005 kg/h</td><td colspan="2">–</td></tr>
<tr><td colspan="2">industrial nitrogen</td><td colspan="2">0.001 kg/h</td><td colspan="2">–</td></tr>
<tr><td colspan="2">diesel fuel</td><td colspan="2">7.015 kg/h</td><td colspan="2">–</td></tr>
<tr><td rowspan="13">OUTPUT</td><td colspan="2">reactor ash</td><td colspan="2">0.077 kg/h</td><td colspan="2">0.115 kg/h</td></tr>
<tr><td colspan="2">sewage</td><td colspan="2">3.562 kg/h</td><td colspan="2">–</td></tr>
<tr><td rowspan="9">exhaust gas</td><td>O_2</td><td rowspan="9">385.685 kg/h</td><td>48.856 kg/h</td><td rowspan="9">~ 131.615 kg/h</td><td>16.066 kg/h</td></tr>
<tr><td>CO_2</td><td>36.444 kg/h</td><td>15.777 kg/h</td></tr>
<tr><td>H_2O</td><td>15.005 kg/h</td><td>6.377 kg/h</td></tr>
<tr><td>N_2</td><td>284.542 kg/h</td><td>93.366 kg/h</td></tr>
<tr><td>dust (PM 2.5)</td><td>0.124 kg/h</td><td>0.008 kg/h</td></tr>
<tr><td>organic substances in form of gases and vapour expressed as total organic carbon</td><td>0.001 kg/h</td><td>0 kg/h</td></tr>
<tr><td>SO_2</td><td>0.019 kg/h</td><td>0.000323 kg/h</td></tr>
<tr><td>CO</td><td>0.196 kg/h</td><td>0.005 kg/h</td></tr>
<tr><td>NO_x</td><td>0.498 kg/h</td><td>0.016 kg/h</td></tr>
<tr><td colspan="2">electrical energy (net)</td><td colspan="2">28.9 kW</td><td colspan="2">4.4 kW</td></tr>
<tr><td colspan="2">usable heat</td><td colspan="2">38.8 kW</td><td colspan="2">11.5 kW</td></tr>
</table>

Table 2. Indicators of impact categories for the analysed technologies converted to functional units (FU) – characterisation stage according to ReCiPe Midpoint

Impact categories	Unit	Base technology – gasification	Reference technology – combustion
Climate change	kg CO_{2eq}	5.55E+02	1.43E+03
Ozone depletion	kg CFC-11_{eq}	4.51E-05	3.63E-08
Terrestrial acidification	kg SO_{2eq}	4.65E+00	8.43E-01
Freshwater eutrophication	kg P_{eq}	4.48E-02	3.45E-01
Marine eutrophication	kg N_{eq}	2.87E-01	1.23E-01
Human toxicity	kg 1.4-DB_{eq}	1.02E+01	1.99E+00
Photochemical oxidant formation	kg NMVOC	7.39E+00	1.48E+00
Particulate matter formation	kg $PM10_{eq}$	3.43E+00	1.05E+00
Terrestrial ecotoxicity	kg 1.4-DB_{eq}	5.46E-03	4.79E-06
Freshwater ecotoxicity	kg 1.4-DB_{eq}	3.01E-01	5.45E-02
Marine ecotoxicity	kg 1.4-DB_{eq}	3.62E-01	4.99E-02
Ionising radiation	kBq $U235_{eq}$	6.86E+00	1.09E-02
Agricultural land occupation	$m^2 \cdot yr$	2.12E-01	3.67E-03
Urban land occupation	$m^2 \cdot yr$	6.17E-01	5.35E-02
Natural land transformation	m^2	I.81E-01	-5.91E-04
Water depletion	m^3	1.15E+00	3.81E-03
Metal depletion	kg Fe_{eq}	1.31E+00	3.65E-03
Fossil depletion	kg oil_{eq}	1.19E+02	7.17E-02

Table 3. Indicators of categories for the base railway sleeper gasification technology and for the combustion technology converted to the functional unit (FU) – characterisation stage according to ReCiPe Endpoint H/A

Damage category	Impact category	Unit	Base technology – gasification		Reference technology – combustion	
Human health	Climate change	DALY (reduced life years or disability-adjusted life years)	1.68E-03	7.77E-04	2.28E-03	2.00E-03
	Ozone depletion			1.19E-07		0.56E-11
	Human toxity			7.15E-06		1.39E-06
	Photochemical oxidant formation			2.28E-07		5.75E-08
	Particulate matter formation			8.92E-04		2.73E-04
	Ionising radiation			1.13E-07		1.78E-10
Ecosystems	Climate change	species times year (loss of species over a year)	4.72E-06	4.40E-06	1.14E-05	1.13E-05
	Terrestial acidification			2.70E-08		4.89E-09
	Freshwater eutrophication			2.00E-09		1.54E-08
	Terrestial ecotoxity			8.22E-10		7.22E-13
	Freshwater ecotoxicity			2.59E-10		4.68E-11
	Marine ecotoxicity			6.39E-11		8.79E-12
	Agricultural land occupation			2.58E-09		5.55E-11
	Urban land occupartion			1.28E-08		1.11E-09
	Natural land transformation			2.73E-07		-1.15E-09
Resources	Metal depletion	$ (increased costs of procuring resources from increasingly difficult to access deposits)	1.97E+01	9.39E-02	1.21E-02	2.61E-04
	Fossil depletion			1.96E+01		1.19E-02

After conversion of the environmental burden to ReCiPe Endpoint and grouping of the obtained results into damage categories such as human health, ecosystems, and resources, the obtained indicator values show that the base technology is more environmentally favourable than the reference technology in the scope of human health and ecosystems. Meanwhile, in the context of resources, the base technology produces a much greater burden on the environment than the alternative technology, which is the result of co-firing of the gas obtained from railway sleeper gasification and the diesel fuel in the piston engine.

For comprehensive comparison of the analysed technologies, the obtained results were converted into so-called ecopoints (Fig. 2). One ecopoint (1 Pt) expresses a thousandth part of the annual damage to the environment caused by one resident of Europe.

The total environmental burden produced by the base technology of gasification reached 56.43 Pt/FU in comparison to 70.27 Pt/FU produced by the alternative technology (combustion). This is the direct result of the much greater environmental burden produced by the alternative technology in the categories of human health and ecosystems.

Furthermore, the result of the analysis of the researched technology of gasification was subject to an uncertainty analysis, which showed that the value of the LCA indicator of the examined technology falls between 54.44 and 58.72 Pt/FU with a probability rate of 95%. The presented narrow value range confirms credibility of the environmental evaluation result.

Conclusions

The developed concept of the technological system for gasification of disposed wooden railway sleepers to produce electrical energy was technologically verified in the results of the pilot tests performed on the system. It was also verified for compliance with legal requirements towards the target system in the scale of 1 MW of chemical energy in railway sleepers. The system concept passed both the technological and the legal verification.

The experiments produced results which were subsequently used to establish the mass and energy balances for the system to produce data subsequently used as input LCA analysis data for the railway sleeper gasification system. As an alternative technology to the analysed gasification technology the disposed railway sleeper combustion for the purposes of electrical energy production was selected. In order to obtain the data required to perform the LCA comparative analysis, the data characterising the reference technology was expanded over previously unpublished information.

The LCA analysis of the base technology of disposed railway sleeper gasification for purposes of electrical energy production demonstrated that the technology produces an environmental burden of 56.43 Pt/FU. This value is the sum of the environmental burden on human health (33.21 Pt/FU), ecosystems (10.44 Pt/FU), and resources (12.78 Pt/FU). According to the uncertainty analysis, the value of the LCA indicator (56.43 Pt/FU) falls between 54.44 and 58.72 Pt/FU with probability of 95%. The presented narrow value range confirms credibility of the environmental evaluation result.

The comparative LCA analysis of disposed railway sleeper gasification for the purposes of electrical energy production in reference to the alternative technology of railway sleeper combustion for the purposes of electrical energy production allowed for the evaluation of the environmental effects produced by the studied gasification technology. Concerning the category of human health, the gasification technology demonstrated a lower environmental impact than the reference technology (33.21 Pt/FU < 45.11 Pt/FU). A similar correlation was observed in the category of ecosystems (10.44 Pt/FU < 25.15 Pt/FU). However, the sleeper gasification technology produced a higher environmental burden than the sleeper

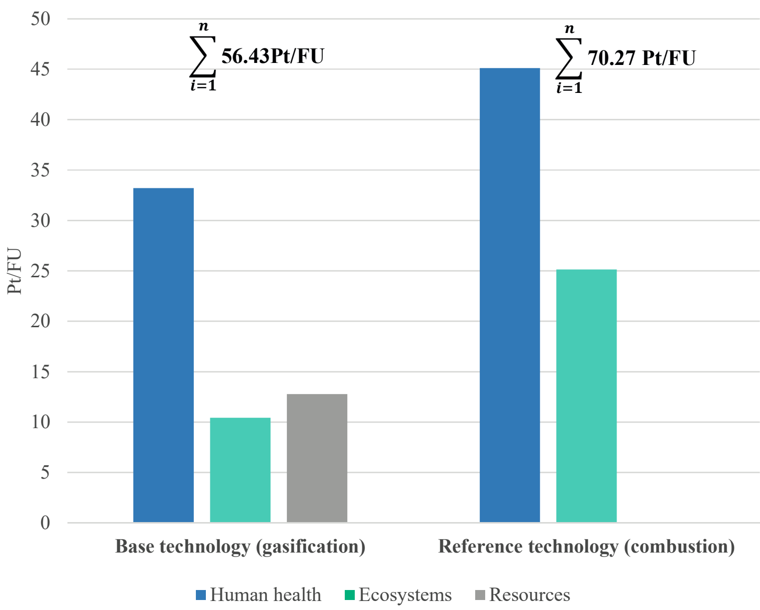

Fig. 2. List of results of LCA analyses of electrical energy production from railway sleepers with the base technology (gasification) in comparison to the reference technology (combustion), Pt/FU

combustion technology in the category of resources (12.78 Pt/FU > 0.01 Pt/FU). The total environmental impact of the base sleeper gasification technology assumed a value lower than that of the alternative technology (56.43 Pt/FU < 70.27 Pt/FU). Consequentially, it was proven that in the scope of the analysis the researched disposed railway sleeper gasification technology produces a lower burden on the environment than the compared disposed sleeper combustion technology.

Acknowledgments

The authors would like to thank Dr Frank Werner for providing access to the previously unpublished information on disposed wooden railway sleeper combustion. Thanks to this information, it was possible to refer the environmental effects of the sleeper gasification technology to the use of sleepers in the combustion process.

The research work presented in this study was financed by the Ministry of Science and Higher Education via the dedicated subsidy granted to the Institute for Chemical Processing of Coal for scientific research or development work and associated activity serving the development of young scientists and doctoral students in the years 2016–2017, known as the “subsidy for young scientists” (Information no. 6799/E-134/M/2016, Information no. 6799/E-134/M/2017).

The authors would like to express their gratitude for the above mentioned financial support.

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Ocena efektów środowiskowych zgazowania zużytych podkładów kolejowych dla produkcji energii elektrycznej

Streszczenie: Przedstawiona analiza obejmuje ocenę efektów środowiskowych wykorzystania zużytych podkładów kolejowych do produkcji elektryczności poprzez zastosowanie technologii zgazowania. Technologię tę odniesiono do alternatywnej technologii wytwarzania elektryczności ze zużytych podkładów kolejowych, wykorzystującej ich spalanie. Analizy dokonano z wykorzystaniem techniki LCA. Uzyskane wyniki prac wskazują, że korzystniejszym pod względem środowiskowym jest zagospodarowanie zużytych, drewnianych podkładów kolejowych w oparciu o technologię wykorzystującą proces zgazowania, a nie spalania jak powszechnie ma to dziś miejsce. Zaleca się zatem by mając na celu minimalizację obciążeń środowiskowych w cyklu życia podczas produkcji energii elektrycznej z podkładów kolejowych wybrać technologię opartą na procesie zgazowania.