Modeling of environmental impacts of waste paper transport

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Abstract: - The article focuses on issues of energy generation from municipal waste paper in context of energy use for transport. Two base model types are presented – first for the combined production of thermal and electrical energy and the other for determination of waste paper purposeful transport distance. The theoretical background and proposed models are verified for concrete calculation on the basis of waste management in the chosen city in the Czech Republic. Software based on Petri nets was used for model construction; this allows the inclusion of the most relevant material and energy flows associated with energy production from waste paper, guaranteeing the high accuracy of the calculated results. The advantage of the model proposed in this manner is the simple and precise quantification of the environmental and economic impacts of the proposed measures; these are the main reasons for its good utilization as a tool for supporting managerial decision-making.

Keywords: Waste Management, Paper, Recycling, Combustion, Modeling, Petri Nets, Environmental Protection.

1. Introduction

The issue of waste management is a major problem in terms of environmental protection. With the gradual increase in production and consumption as well as through economic development, the problem of waste management has touched developed and also less developed countries. Environmental legislation creates constant pressure to find new solutions, which should be both economically advantageous and environmentally friendly. In the context of the EU actions to restrict the volume of emitted carbon dioxide are searched for new solutions that would meet the stated requirements. The aim was not only a partial solution, but increasingly we are finding solutions that lead to an overall decline in the growth of entropy of the reference system. The article focuses on issues of energy recovery of municipal waste, as well, however, the proposed procedure is applicable in the enterprise. Currently, there is still more waste and its disposal is becoming an increasing problem. Even though waste should be sorted, municipal communal waste still contains 22% of the paper. Communal waste represents the last and the least appropriate way of dealing with waste. Considering the fact that a single citizen of the Czech Republic generates 300 kg of communal waste, there is potential of 66 kg of usable biomass per citizen. For calculations, however, only values for separated waste paper were used.

Exploring the possibilities of utilization of waste generated is the task of environmental economics management and is applied in the area of waste management. Management in waste management should be able to find optimal solutions to current problems in compliance with the requirements at the lowest possible contribution to the overall increase in entropy of the system. [25] Management processes in waste management must focus primarily on waste with the result in the lowest possible additional increase in entropy, because this is the only way which guarantees the smallest possible impact on the environment. A very important item is represented by environment burden induced by transport. Researches claim that up to 80% of energy consumed in recycling processes is spent on transport [17,18]. In order to find the optimal process of waste handling from the viewpoint of the lowest increase of the entropy of the whole system it is necessary to include as many related material and energy flows for waste handling as possible. More types of waste usage can be also applied. To quantify such processes modeling tools for modeling dynamic quantities can be used. This paper aims to design models for evaluation of environmental and economic context of waste paper management, such as decision support tools for managers.

2. Legislative Framework

Waste management legislation in the EU countries is usually based on the EU Directive No. 75/442/ES, which contains the recommended hierarchy of waste management. The selected example will shon that strict compliance with this directive may not always lead to low environmental load and that it is crucial to make an assessment of each case separately and in the context of local environment. Waste management legislation in the Czech Republic, where chosen case study comes from the, consists of laws, regulations and decrees of the Government ministries, particularly the Ministry of Environment [23]. Currently in this area, there are two important laws, which are Act No. 185/2001 Coll., on waste and Act No. 477/2001 Coll., on packages, as amended. These laws cover management of all types of waste, which constitutes a significant portion of municipal wastes. It is interesting for further analysis that a significant proportion of household waste is paper with 22%, 18% is the biological waste, 13% plastics, glass represents 9% and 3% is hazardous waste. The quantity of paper waste generated depends on the lifestyle of the population, the method of heating and the nature of villages; the numbers represent the average for the whole country [15]. One man seems to produce 150-200 kg of waste per year, if the waste is sorted, it is possible to re-use more than one third [14].

The data [11,12] show an increasing trend in the total quantity of waste, with the only exception is 2007.

2.1 Problems of Waste Paper Using

At the beginning of 2010, it was published by the Association of Pulp and Paper Industry reports that the Czech Republic does not have the capacity to use all recycled paper. For the year 2008 733,000 tons of waste paper was collected, but only 422,000 tons (58%) was processed by the Czech paper mills. The remaining 311,000 tons of paper (42%) was exported. The Association of Pulp and Paper Industry in this context suggests that the public and state administration at all levels supported the possible construction of a new mill, with which it could increase the participation of domestic processing of waste paper. Still, all proposed plans to build a new mill (Opatovice nad Labem, Zábřeh na Moravě), were turned down mainly due to the opposition of the population (dust, odor, traffic load) and by institutional barriers [4]. According to recent reports on the environment of the Czech Republic, year 2008 saw an increase of the amount of sorted elements of municipal waste by 29% compared to 2003, increasing the amount of the average production of municipal waste per capita to the lower limit in comparison with the EU countries. An undesirable trend can be seen that around 80% municipal waste is processed by dumping, which remains the usual method to dispose of waste (a large number of landfills, transport accessibility). Only 1.43% of waste is incinerated. In contrast, the use of waste has increased since 2002 by 4.5% mainly due to the development of technology in manufacturing and waste management.

Since 2006, the value of this ratio decreased due to the adjustments for subsequent use using sorting lines. In 2008 67.5% of waste was used, mostly used material (96%), rest energy (4%) [19]. The most known method of sorting waste paper are the recycling and cardboard recycling containers. If waste paper is not suitable for recycling, it can be incinerated. But given that paper and cardboard, along with wood and compostable waste belong among biodegradable municipal waste, also biological methods can be used, such as composting or anaerobic digestion or mechanical biological treatment [5].

2.2 Recycling Issues

In connection with recycling, there is general awareness in several views which are not based on facts. The first is the idea that recycling of material is the best possible and most ecological way of waste handling as recycling can decrease or eliminate usage of non-renewable resources, etc. In fact the best solution is the one which eliminates to the maximal extent the negative impact of waste on the environment and also induces the smallest additional material and energy flows during handling. Ideally, the rate of induced material and energy flow limit is zero. Meeting this criterion also means minimum contribution to increasing the entropy of the system.

Furthermore, there is a general belief that by recycling we protect the environment. In fact, recycling only means changing the nature and extent of pollution, usually it decreases, however, sometimes even increases the overall pollution [10]. In the context of the previous requirement, it is clear that it is necessary to carefully consider the appropriate way of dealing with waste, including each individual and specific locality where the waste arises, so that this activity instead does not cause an increase of environmental burden instead of positive effects on the environment. As an example let us see the fact that the separate waste collection, supported in many countries, induces the need of more cars on the collection of the same amount of waste. This may, if not a complete analysis of the LCA, burden the environment more than if it had been not implemented.

Another argument used for recycling is the claim that this process consumes less energy and raw materials. Neglected, however, is the fact that the market value of recycled materials used in the production process is derived from just how much they allow manufacturers to use less material and less energy. Savings in material and energy are, therefore, longer reflected in economic costs of recycling and should be compared with other methods of waste management. So in all cases a cost estimate of the degree of additional material and energy flows and the benefits of such activities should be made also in regards to the state of the environment [10].

In the case study, is suggested the possibility from produced waste, which is in this case waste paper usually used for recycling produce nenergy. This is such paper, which has minimum content of fillers and pigments, such as paper and cardboard [20], which represent in average 20% out of 22% of paper waste [27]. This approach is fully consistent with the principles of sustainability, as the paper with such characteristics has also energetic use in the form of bio-fuel. Decree of the Ministry No. 482/2005 Coll., presents this use of paper and paperboard as bio-fuel with all the advantages, such as carbon neutrality. However, it should be also added that in terms of energy consumption, paper production from waste paper requires much less energy than manufacturing paper from the same timber [21], [26].

Given that energy prices are increasing and the price of old paper decreasing, and as in the CR is not all collected paper used for recycling and is difficult to be exported due to the reasons set out in Chap. 1.2 (especially environmental burden caused by transportation of paper for further processing), incineration of paper represents a suitable solution. The law on waste incineration allows to include energy use only in case when the application does not need to waste a self ignition combustion to support the fuel and the heat generated is used for themselves or others, or waste used as fuel or as an additional fuel in power plants [8]. The advantage of burning paper is that it can be used in furnaces capable of burning solid fuel without major restrictions.

The study "The combustion tests of fuel-based waste," compares the emission factors of fuels with wood briquettes, which were burned using the same equipment and under the same circumstances. It compares the quantity of fuel with solid pollutants, nitrogen oxides, sulfur dioxide and organic carbon (TOC). The result of this work is the assertion that the emission factors of alternative fuels based on paper are similar in some respects even slightly more favorable [24]. The comparison with various alternatives fuels shown in Table 2.

Table 1:Emission factors related to fuel efficiency

Fuel	Fuel efficiency [g/MJ]				
	CO	NO_x	SO_2	TOC	TZL
Paper briquettes	0,6	0,07	< 0,01	0,07	0,02
Briquettes paper - coal	0,65	0,08	< 0,01	0,06	0,01
Briquettes paper -wood	1,62	0,04	< 0,01	0,21	0,01
Paper Pellets	7,04	0,35	< 0,01	1,55	0,01
Paper Pellets -coal	9,33	0,08	< 0,01	1,73	0,02
Wood briquettes	1,98	0,04	< 0,01	0,20	0,04

Source: [24]

Another positive is the calorific value of paper in the range of 12-15 MJ / kg, which is comparable with the calorific value of coal, but when burning of coal, there is a considerable amount of sulfur dioxide as well as additional carbon dioxide emissions, which makes coal burning not climate neutral, while incinerating of paper is [13].

3. Modelling of Energy from Paper Recovery in Context of Paper Recycling and Transport Distance.

Currently there were several proposals favoring energetic use of paper to recycling (Decree of the Ministry No. 482/2005 Coll.). This offers the possibility of modeling the process of the energy value of waste paper.

But in fact, there are already several other options of utilization for this paper. It can be added to compost and use the produced compost gas for energy production, it can be added to fuel in brown-coal power plants, it can be added into the processes of anaerobic digestion, it can be gassed, pyrolyzed, burnt directly etc. An interesting option is also the alternative when it is possible, after gassing and applying appropriate methods such as Fischer-Tropsch, to use paper to produce gasoline, diesel, synthetic natural gas etc.

In order to identify a clear solution of the defined problem, it would be necessary to create models of all these alternatives so that all the related material and energy flows would be unequivocally recorded. However, even by this step a clear single solution would not be reached. It would be only possible to compare energy requirements and energy profitability of these alternatives. When comparing environmental burden created by these alternatives, there would be difficulties caused by the variety of pollutants and their complicated comparison. The next step should be evaluation of the results of modeled process with methods of multi-criteria decision making in an appropriate combination.

Such approach would, unfortunately, significantly exceed the range of the paper. The presented models should, nevertheless, be developed this was in the future. For the purpose of this article, the saving or the rate of additionally spent energy was chosen also as the indicator for the rate of environmental burden as is it closely related to energy production.

Processes to be modeled can be illustrated by the diagram in Fig. 1.

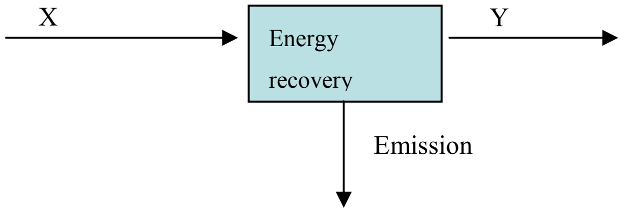

Fig. 1: The general scheme used models
Source: [own]

The first model under consideration is the ratio of processing paper cited in chap. 1.1, which is 58% recycled within the CR and the remaining 42% may be either exported or energetically used. This will be used to calculate the values in Table 3 together with the assumption that the vast majority (90%) of sorted paper is combustible. For 2009, the chosen town in the CR collected 963.440 t of waste paper in the blue paper containers, which could alternatively be used as fuel to produce electricity, thermal energy, motor fuels etc. Using 42% of waste paper which either gets exported or energetically use, we see that ((963,440 x 0.42) x 0.9) = 364.2 tons. Its modeled inputs and outputs are listed in Tab. 3.

The second model represents production of paper. Received inputs are important for mentioned comparison of energy profitability or efficiency of particular process of waste handling. 364.2 tons of waste paper represents the input for paper production by recycling in order to be able to compare alternatives. The model involves certain simplification as it presents situation when all the paper is produced only from waste paper without adding wooden pulp, which does not correspond to the real situation. This simplification is, however, necessary for comparability of results as the output which is vital for comparison relates only to the energy saved by using received amount of waste paper. This value will not change in any ratio between inputs for production of new paper as the stock of waste paper is constant. In case of adding another input of wooden pulp, it would be necessary to subtract its volume in the end, which could distort the results. Modeled inputs and outputs are listed in the second of of Tab. 3.

The third model involves 3 means of transport which should transport the amount of 364.2 tons of waste paper to the designed destination. For the needs of further discussion, no concrete distance was taken into account in relation to the destination, however, maximal distance which is still efficient for the particular alternative was defined.

The sample of energy use will be implemented in software environment Umberto, which is based on colored and hierarchic Petri nets and is designed for material and energy flows modeling. At the same time to achieve better usability of the data obtained, both in public and private sector through good clarity generated models [2,7,23]. Despite the existing problems of this software, the tool is used both in private companies [1] and in the field of public administration [16], which is at least partially guaranteed by the easy portability of the model potential candidates, such as an e-mail. Furthermore, thanks to well-understood graphical presentation of models (Fig. 2), it alowes a very good possibility for graphical support by communication between managers or managers of public administrations, because they know best their needs and requirements and nature of the area concerned, therefore, they must participate in the processes of analysis and data modeling by example. Trough this graphical model interpretation would be this participation possible [9,22].

In addition to the energy requirement process also the energy consumption of exports of this paper for processing into neighboring countries will be modeled. The diagram of process presented in Fig.1 is identical to the graphical representation of models implemented in Umberto environment as presented in Fig. 2. and Fig. 3

The model shown in Fig. 4 is more complex and complicated as it involves 3 types of transport, while each of them has different energy consumption and produces different emissions.

There are inputs which consist of fuel and emissions outputs produced and of transported cargo, as shown Table 3.

Table 3: The parameters in each sub-model

Model in Fig. 2.	
X	Y
Paper for energy use	Energy produced, pollution.
Model in Fig. 3.	
Paper for recycling	Recycled paper, energy saved, pollution.
Model in Fig. 4.	
Fuel available in the place of collection, load to be transported.	Loading at the destination, pollution.

Source: [own]

The aim of this model is to search for such a distance, which is already not worth the paper export, because the energy consumed in its transport is greater than the saved energy needed to produce the same amount of new paper from this material or in the case of utilization in energy production, the amount of gained energy is lower or equal to the energy spent on transport to the premises of waste paper processing.

For the creation of the own models itself a tool based on Petri nets will be used, followed by a short description of the mathematical modeling tool.

3.1 Theoretical Background

Petri nets, which were created in 1962 by German mathematician and computer scientist Carl Adam Petri, is a graphical and mathematical modeling tool, used for theoretical study of dynamic parallel systems. Petri net is defined as: "an arrangement of five (P, T, I^-, I^+, z_0), *where* $P=\{p_1, p_2, \dots p_n\}$ is a finite nonempty set of locations, $T =\{t_1, t_2, \dots , t_m \}$ is a finite nonempty set of transitions, a set of P, T are disjoint $P \cap T = 0$, I-and I + are incidental function $P \times T \rightarrow N0$ and z0: $P \rightarrow N0$ is the initial marking. "Coloured Petri Nets (CPN) is a network of force level, the name is derived from the color, that due to the uniqueness of each brand represents a data type. CPN can be understood as a simple graphical representation of the basic Petri nets. On the positive CPN appears to be versatile, it is important CPN modeling language, thanks to its precise definition and versatility. CPN combines the advantages of Petri nets, the capabilities of the programming language [24].

3.2 Models of Paper Use for Energy and Paper Production

The input mass was defined by the calculation referred to in Chap. 3 in the value of 364,200 kg. In the case of combined heat and power and assuming a conversion efficiency of entry to 60% heat and 28% of the electricity would be produced 3083.3 GJ of heat and electricity 1438.9 GJ. Total amount of usable energy would render (3083.3 + 1438.9) = 4522.2 GJ. [3] Entering P1 in Fig. 2 is waste paper for energy production which weights 364,200 kilograms, the transition T1 is a process of transformation of electrical and thermal energy. The output energy is produced in the form of electricity and heat (P2) and emissions (P3).

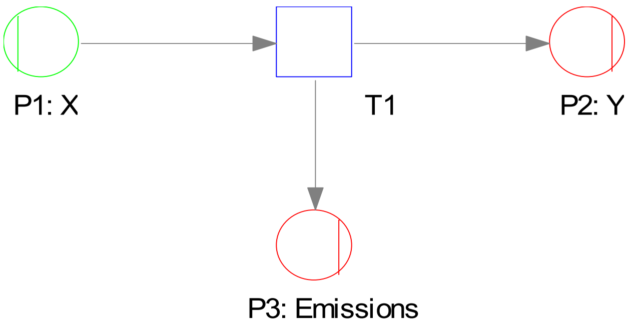

Fig. 2: Model of Energetic Waste Paper Use (combined heat and power) implemented in the Umberto Environment

Source: [own according 3]

P3 output in this case, together with emissions and waste energy, amounts to 616.7 GJ. Amount of emissions is shown in Table 4.

Table 4: Emissions from paper burning

Material	Quantity (kg)
carbon dioxide	111020.07
carbon monoxide	4042.7
methan	262.65
NO_2	150,285
SO_2	56,8
dust	131,62
ash	248535.7

Source: [own]

If the amount of paper entering the model is used to produce new paper, for the production of 364,200 kg of new paper is required (364,200 x 16.92) = 6162.264 GJ of energy (16.92 GJ/1t). In case that formed the entrance instead of wood, paper only, as a secondary raw material, it would be for the same amount of paper produced spent only (364,200 x 9.9) = 3605.58 GJ i.e. input energy (9.9 GJ/1t). Total energy savings due to recycling of 364,2 ton of waste paper therefore, would be (6162.264 - 3605.58) = 2556.684 GJ [21]. The model implemented in the Umberto environment after inserting these data is shown in Fig. 3.

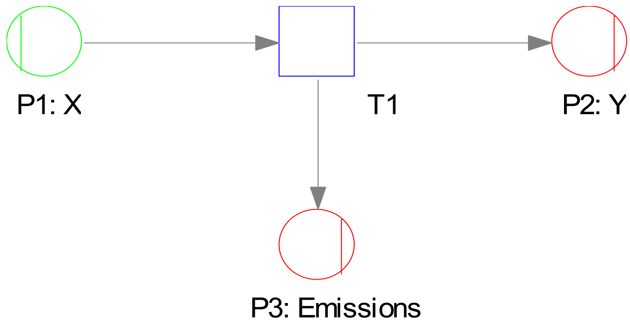

Fig. 3: Model of energy savings through waste paper recycling implemented in Umberto Environment.

Source: [own]

3.3 Model of waste paper transport

The model of transport includes 10 places and 3 transitions. Place P1, P2 and P8 represent waste paper in the original location which is necessary to be transported for processing. Places P7, P6 and P3 represent the amount of fuel for particular type of transport. In this case P7 for diesel oil for a truck, P6 kerosene for an aircraft and P3 diesel oil for a vessel. Place P4 represents all utilized means of transports, P5, P9 and P10 are emissions produced by the transport of waste paper to the final location.

For air transport, data for Boeing 737-300 was used; the truck transport was calculated based on parameters of a DAF XF 95 430 truck with trailer. In the calculations is assumed to transport a truck with a carrying capacity of 10 tons, the proportion of highway driving 85% road 10% and 5% of the village For water transport, parameters according to [6] were used.

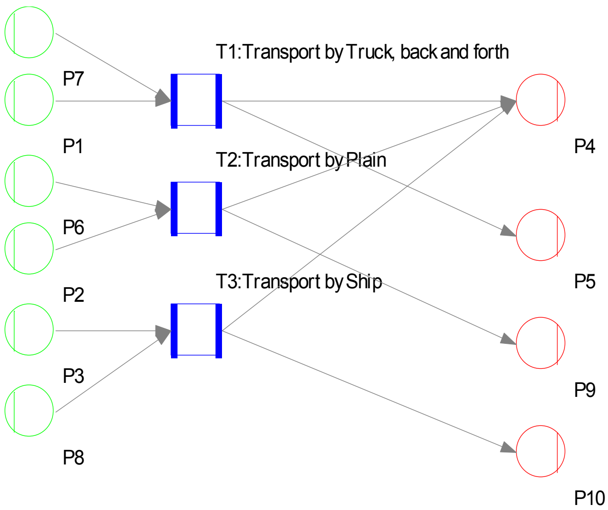

Fig. 4. Model of energy use for waste paper transport.

Source: [own]

The results of modeling show energy requirements for particular types of transport as shown in Tab. 5. All values are related to transport of waste paper.

Table 5

Lorry	514,04994	MJ/Km
Plain	5041,6887	MJ/Km
Ship	219,9225	MJ/Km

3.4 Modeling Results

To express the level of achievable savings, the data are based on average values of consumption per household in a block of flats that uses electricity for lighting and for the usual appliances. This is, according to information of the CEZ Group, average consumption of 2.2 MWh of electricity per year. Energy recovery by the proposed model was constructed for the combined production of 1438.9 GJ which means 412,194 MWh of electricity. The electric energy produced would cover the annual consumption of 187 residential units.

The transport for recycling or energy use will not be efficient when the total additional energy demand exceeds the recycling process 2556.684 GJ saved energy or 4522,2 GJ in case of use in energy production of waste paper by burning. Consumed energy was chosen as an indicator of efficiency of investments, as it reflects the number of induced environmental burden in the best way..

The next step is to calculate the transport distance in order to ensure that the energetic requirement for transport for such a distance does not exceed energetic benefit as stated earlier in this paper. It is, therefore, important to find the maximum distance for which the 364,200 kg of collected paper can be transported.

The results are listed for all three modeled types of transport as well as for alternative options whether the paper was recycled or used for energy production. The first column of the table shows type of transport which the values relate to. Column two marked “energy use” shows energy which the particular type of transport consumes per 1 km. Column three shows units of measurement, in this case that consumed energy is measured in MJ. The next column called “max km 1” shows the distance of transport for waste paper recycling where the energy gain and consumption are equal. The last column marked “max km 2” shows the distance for waste paper transport for energetic use where the energy gain equals energy consumption for transport. Modeling results are shown in Table 6.

Table 6: Model outputs energy performance for different distance transport

	energy use		max km 1	max km 2
Lorry	514,04994	MJ/Km	4973,4467	8797,19974
Plain	5041,6887	MJ/Km	507,092	896,961369
Ship	219,9225	MJ/Km	11625,004	20562,6982

Source: [own]

The simulation of results shows that the transport of sorted waste paper by truck at a distance of more than ca. 5000 km for recycling and 8800 Km for energetic use is not efficient.

If the paper should be transported by air, it would be efficient to transport it for no longer distance than 500 km for recycling and 900 km for energetic use. In case of water transport the distance for efficient use is 11,500 km and for energetic use even exceeds 20,000 km. The calculation is only approximate, because the outcome will be different for different types of used trucks due to their different parameters.

Despite this, the result clearly shows that water transport is more efficient, which corresponds with the general assumptions. Although the distance for water transport looks really high and it could serve as evidence that it is efficient to transport waste material for processing for long distances, we still have to take into account that already in transport for half of the distance, which is in the case of water transport and recycling less than 6,000 km, we already lose 50% of the total savings reachable by recycling. If other type of transport was used, the distance would be significantly lower.

Also the ratio of distance for road transport and air transport was calculated in accordance with general expectation, while the worst result and shortest efficient distance was assigned to air transport.

With regards to calculation of maximum load of chosen vehicles, the model also took into account the aspect that a certain number of trips were necessary to transport the entered amount of material. This calculation was also reflected in modeling results. Therefore, descriptions do not mention transport of 364.2 kg waste paper, as the results can be understood generally, for transport of almost any quantity.

If we compare the results of the modeling based only on the efficiency of energy use, the total balance of saved and used energy clearly shows that in this context it is much more beneficial to use waste paper for energetic use (to produce energy) as 4,522.2 GJ is gained by burning 364,200 kg wasted paper while by recycling the same amount "only" 2,557 GJ is saved.

Based on these results it is easy to calculate the maximum efficient distance for transport of waste paper for both alternatives of usage.

At the same time, it is important to highlight the fact that these characteristics are often misunderstood in waste management, if waste is considered only unwanted side product. From this viewpoint is any handling which has at least minimum environmental impact, or some possibly economic benefits, understood as positive as we are used to paying high amounts of money to get rid of materials labeled as waste.

There are clear limits of this viewpoint when we look at the example used in this paper with energetic use of waste paper and related transport distances. Importing paper for energetic use for distance where the energy consumption equals or even exceeds the energy gained by the energetic utilization of the paper is as mistaken as cultivating a field with oil-plant for energetic use where the tractor consumption equals the energetic profit of the field. Then we do work which consumes all its outputs into inputs and brings no added value. Seeing it from the point of energy balance, and provided there are no forms of incentive policy, such activity has no positive effect and only generates environmental burden.

The goal of waste management should be finding such a solution which will not bring only some utility or will not be somewhat better than already applied solution, however, which will lead to the lowest increase of the overall entropy of the system. Based on published results it is possible to find such a solution.

4. Conclusion

The test case is analyzed by incineration of paper and related energy and transport loadings including consideration of potential environmental-political context. After the analysis is made the evidence shows that recycling paper is not universally the best possible solution in terms of economic, environmental and socio-political; we propose the possibility of its energetic use. Its benefits are modeled using Petri nets models which are implemented in the Umberto environment. The model of combined heat and power shows that the modeled case could supply electricity all-year-round to 187 housings. It was also shown that it is necessary to consider at what distance the paper for recycling is shipped, since the efficiency of transport for recycling by truck ends at a distance of more than 4973 km after which it would cost more energy to transport the waste paper than what would be saved by recycling.

The advantage of this proposed model is easy possibility to quantify the environmental and economic impacts of the proposed measures, because the model includes, through the use of CPN, the most relevant material and energy flows. The model allows easy change of process parameters in response to the change of technology which will change the output. Combined heat and power from the assumptions of the model shows the best economic and environmental benefits of proposed solutions. This work can be further developed by both verification and refinement parameters of the modeled process according to the results of further emission measurements, first, adding other possible processes and their variants possible inputs and associated outputs.

In order to keep the results of modeling up to date, the transport distance efficiency model should be updated as it can be expected that the development of new technologies will decrease the consumption and therefore the maximal efficient distance should increase. Generally, the analysis can be further developed by adding new models for alternative methods of waste paper utilization and also for other types of transport.

References:

[1] ANTLOVÁ, K., Motivation and barriers of ict adoption in small and medium-sized enterprises. E+M Ekonomie a management, 2009, XII, No. 2, p. 140-153.

[2] BAŤA, R., OBRŠÁLOVÁ, I., VOLEK, J., Using Petri nets for handling variants biodegradable municipal waste [online] 2008 [cit. 2010-08-03]. University of Pardubice: Scientific Papers. http://www.upce.cz/fes/veda-vyzkum/scipap/e-verze-sborniku/2008/scipap-c-13.pdf

[3] BAŤA, R., KADLECOVÁ. P. Modelling of Economic and Environmental Impacts of Energy Generation Using Waste Paper. E+M Ekonomie a management. Liberec 2/2011. ISSN 1212-3609

[4] BIOM.CZ, Biomass, biofuels, biogas, pellets, composting and recovery [online]. 27. 1. 2010 [cit. 2010-02-03]. Biom: ACPP: Czech Republic lacks the capacity to use waste paper. <http://biom.cz/cz/zpravy-z-tisku/acppcesku-chybi-kapacity-na-vyuziti-sberoveho-papiru>.

[5] BIOM.CZ, Biomass, biofuels, biogas, pellets, composting and recovery [online]. 31. 3. 2004 [cit. 2010-02-02]. Implementation Program for the biologically degradable waste. <http://biom.cz/rp-bro/rp-bro.pdf>.

[6] Borken et.al. Basisdaten für ekologische Bilanzierungen: Einsatz mobiler maschinen im Transport. Braunschweig 1999. Vieveg Verlag. ISBN 3-528-03118-2.

[7] BUDIŠ. P., ŠTŘEDROŇ, B., Electronic Communications. Iss. 1. Bratislava: Magnet press, 2008. 110 p. ISBN 978-80-89169-11-5.

[8] CENIA, Czech Environmental Information Agency [online]. 15. May 2001 [cit. 2010-02-20]. Act No. 185/2001 Coll., on waste and amending certain other laws. <http://www.cenia.cz/web/www/web-pub2.nsf/$pid/CENMSFSO6QS1/$FILE/Zakon_185_2001_o_odpadech.pdf>

[9] BUDIŠ, P., GRAMLICH, L., ŠTĚDROŇ, B., Secure electronic communication. 1.print. Chemnitz: GUC 2009. 226 p. ISBN 978-3-934235-77-9.

[10] ČAMROVÁ, L., (ed.). Economy and environment: Enemies or Allies?. 1. print. Praha: Alfa Publishing, s.r.o., 2007. 399 p. ISBN 978-80-86851-69-3, ISBN 978-80-86389-47-9.

[11] CZECH STATISTICAL OFFICE: ČSÚ [online]. 2009 [cit. 2010-04-08]. Municipal waste production. <http://www.czso.cz/csu/2009edicniplan.nsf/t/41002FD7ED/$File/20010906.pdf>.

[12] CZECH STATISTICAL OFFICE: ČSÚ [online]. c2010 [cit. 2010-03-25]. <http://www.czso.cz/csu/redakce.nsf/i/home>.

[13] TEAM SYSTEM [online]. 2010 [cit. 2010-03-05]. Comparison of the calorific value of solid fuels. <http://soustav.mypage.cz/menu/vlastnosti-a-vyhrevnost-briket/zkousky-paliv-na-bazi-papiru>.

[14] EKO-KOM [on-line]. C2009 [cit 2010-03-15]. For public: What is the sorting of waste: Eko-kom. <http>//www.ekokom.cy/scripts/detail.php?id=146>

[15] HLAVATÁ, M., Waste management. reprint 1. Iss. Ostrava: VŠB - Technická univerzita Ostrava, 2006. 174 s. ISBN 80-248-0737-8.

[16] IFU HAMBURG GmbH. [online] 1.6.2010 [cit.1.6.2010]. References. http://www.umberto.de/en/references/index.htm

[17] Ligia T. Silva, Jose F. G. Mendes, Rui A. R. Ramos. Urban Air Dispersion Model of a Mid-Sized City. Validation Methodology. WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT. Issue 1, Volume 6, January 2010. ISSN: 1790-5079.

[18] Ligia T. Silva, Jose F. G. Mendes. Industrial Contribution to the Air Quality of One Mid-Sized Portuguese City. WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT. Issue 1, Volume 6, January 2010. ISSN: 1790-5079.

[19] MINISTERY OF ENVIRONMENT [online]. 2009 [cit. 2010-02-02]. Report on the Environment of the Czech Republic 2008. <http://www.mzp.cz/C1257458002F0DC7/cz/zprava_zp_2008/$FILE/OPZP-Zprava_o_ZP_shrnuti-20100304.pdf>.

[20] ODPADY.IHNED.CZ, Waste management, environmental economics [online]. 15. 4. 2009, [cit. 2010-02-02]. Briquettes from waste paper for energy use. <http://odpady.ihned.cz/2-36734690-E00000_d-52>. ISSN 1213-7693.

[21] OFFICIAL WEBSITE OF JIHLAVA CITY. [on line] 2010 [cit. 7.9.2010]. PAPER. http://www.jihlava.cz/vismo/dokumenty2.asp?id=365521&n=historie-a-soucasnost-papir&grafika=0

[22] ŠIMONOVÁ, S. Modeling Approach of Management. In Podniková ekonomika a

manažment, 2009. p. 498-503, ISSN1336-5878.
[23] ŠTĚDROŇ, B., Protection and licensing of computer program. Praha: Wolters Kluwer , 2010. 220 s. ISBN 978-80-7357-555-7
[24] TENKRÁT, D., et al. Team System [online]. Brno: 2005 [cit. 2010-03-05]. The combustion test of waste paper based fuel. <http://media1.soustav.mypage.cz/ files/media1:4b8235ab1169e.pdf.upl/zkou%C5%A1ky%20paliv%20na%20b%C3%A1zi%20pap%C3%ADru.pdf>.
[25] Teodorescu G. Climate Change Impact on Urban Ecosystems and Sustainable Development of Cities in Romania. WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT. Issue 2, Volume 6, February 2010 ISSN: 1790-5079.
[26] VERONICA [online]. 7.9.2010 [cit. 2010-09-15]. Recovery and recycling of waste. <http://www.veronica.cz/?id=87>.
[27] VORÁČKOVÁ, Š., PĚNIČKA, M.; VESELÝ, J., Introduction to process modeling by Petri nets. Iss. 1. Praha: Česká technika-nakladatelství ČVUT, 2008. 126 p. ISBN 978-80-01-03979-3