Scientific Journal of Riga Technical University
Environmental and Climate Technologies

2010
Volume 4

Energy Recovery from End-of-Life Tyres: Untapped Possibility to Reduce CO_2 Emissions

Ilze Dzene, *Institute of Energy Systems and Environment, Riga Technical University,* Claudio Rochas, *Institute of Energy Systems and Environment, Riga Technical University,* Dagnija Blumberga, *Institute of Energy Systems and Environment, Riga Technical University,* Marika Rosa, *Institute of Energy Systems and Environment, Riga Technical University,* Andris Erdmanis, *Institute of Energy Systems and Environment, Riga Technical University*

***Abstract* – In this paper the possibility to reduce CO_2 emissions by energy recovery from waste tyres is discussed. The objective of the study is to analyze the end-of-life tyre market in Latvia, to assess the amount of used tyres available and to calculate the potential reduction of CO_2 emissions by energy recovery from tyres in mineral products industry. Calculation results show that an improved collection and combustion of end-of-life tyres in the cement industry can save up to 17% of the present CO_2 emissions in the mineral products industry.**

***Keywords* – end-of-life tyres, biomass in tyres, waste to energy, GHG emissions.**

I. Introduction

Every year thousands of tons of greenhouse gas (GHG) emissions are released into the atmosphere contributing to global climate change. In March 2007 the European Union (EU) endorsed an integrated approach to climate and energy policy that aims to combat climate change and increase the EU's energy security while strengthening its competitiveness. To start this process, the EU Heads of State and Government set a series of demanding climate and energy targets to be met by 2020. Collectively they are known as the 20-20-20 targets:

- A reduction in EU GHG emissions of at least 20% below 1990 levels;
- 20% of EU energy consumption to come from renewable resources;
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

In 2008 the total GHG emissions in Latvia were 8 721,6 Gg CO_2-equvivalent, that is 54,7% less than in 1990. However, from 2000 to 2008 the annual GHG emissions in Latvia are increasing with an average annual growth rate of 2,6% per year. In 2008 industrial processes contributed with 2,73% to total GHG emissions and most of industrial GHG emissions (71,24%) were coming from the mineral products industry. [1]

In this paper the possibility to reduce CO_2 emissions by energy recovery from waste tyres is discussed. Certain industries, such as cement factories [2] and large combustion plants [3], use end-of-life tyres as fuel. That allows reducing the consumption of traditional fuels at the same time reducing the costs of energy. Used tyres have the advantage of presenting not only a high net calorific value that is similar to that of traditional solid fuels (coke and coal), but they also contain renewable and mineral fractions that should not be ignored [4].

The objective of this study was to analyze the end-of-life tyres market in Latvia, to evaluate amount of used tyres available and to calculate the potential reduction of CO_2 emissions by energy recovery from tyres in the cement industry.

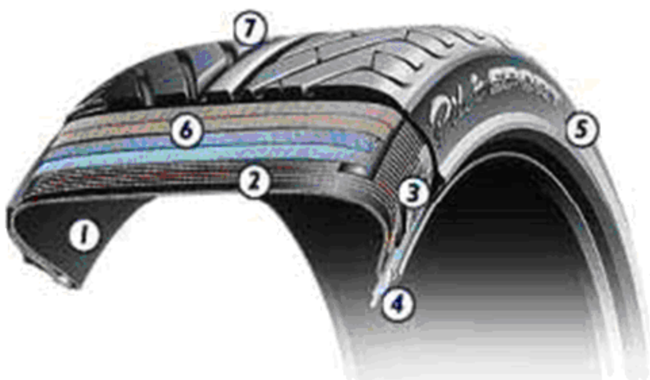
II. Biomass content in end-of-life tyres

The main component of any tyre is rubber. Usually rubber is made of a mixture of natural rubber (made from rubber tree), synthetic rubber, fillers and other chemicals which provide the needed characteristics like resistance to abrasion, oxidation, etc. Thousands of different mixtures are possible which are adapted to different types of products and different production processes. The typical content of a tyre is given in Table I [5].

There are four main rubber types used in tyre production:

- Natural rubber
- Styrene butadiene rubber (SBR)
- Polybutadiene rubber (BR)
- Butyl rubber (with halogenated butyl rubber).

The first three kinds of rubbers are used for producing treads and side edges but butyl rubber and halogenated butyl rubber are used inside the tyre. The typical structure of a tyre is given in Figure 1.



1-inner layer (butyl rubber), 2-frame fibre (fabric), 3-steel cord belt layer (steel), 4-circle core (steel wire covered with rubber), 5-side edges (natural rubber), 6-bandage (nylon covered with rubber), 7-protector (synthetic and natural rubber)

Fig.1. Composition of a tyre [6].

Initially the natural rubber has been used to ensure resistance from abrasion, but later, because of its characteristics of durability, the SBR co-polymer has been added. Nowadays most tyres are made of different types of natural rubber materials that have been extracted from the juice of the natural rubber tree.

Natural rubber is elastomer (elastic hydrocarbon polymer) which is made from milk suspension or latex which can be found in some plants. Natural rubber is one of most important unsaturated hydrocarbons. Natural rubber is made from the *Hevea brasiliensis* tree juice (90-96% of the total natural rubber production). A cut in the trunk of a rubber tree is made to collect the natural rubber (caoutchouc). The milky juice which comes out from the cuts is collected. The juice is coagulated with electrolysis or by heating and an elastic mass - caoutchouc - is produced.

TABLE I

AVERAGE COMPOSITION OF END-OF-LIFE EUROPEAN TYRE WITH CARBON BLACK TREAD RESPECTIVELY SILICA BASED TREAD AFTER 10% AND 20% WEAR LOSS OF THE TREAD [5]

Components	**Carbon black tread tyre**		**Silica based tread tyre**	
	10% wear loss	**20% wear loss**	**10% wear loss**	**20% wear loss**
	%			
Synthetic rubber	22,7	20,0	22,4	20,0
Natural rubber	18,7	21,0	19,1	21,1
Carbon Black	26,1	25,0	19,8	21,1
Synthetic silica	0,6	0,7	7,8	5,3
Sulphur	1,4	1,5	1,4	1,5
ZnO	1,6	1,7	1,6	1,7
Aromatic Oils	6,9	5,8	5,7	5,1
Stearic Acid	0,8	0,8	1,0	1,0
Accelerators	0,9	0,9	1,0	1,0
Antidegradants	1,5	1,5	1,6	1,6
Recycled rubber	0,5	0,5	0,5	0,5
Coated wires	13,0	14,7	12,8	14,4
Textile fabric	5,3	6,0	5,2	5,8
Total %	100	100	100	100

TABLE II

CHEMICAL COMPOSITION OF USED TYRES [6]

Content of elements, %	**Passenger car tyres**	**Truck tyres**
Carbon (C)	68-70	60-63
Iron (Fe)	11-12	25-27
Hydrogen (H)	6-6,3	5,3-5,6
Oxygen (O)	3,3-3,8	1,5-2,2
Silica (Si)	1,5-1,9	0,3-0,5
Zinc (Zn)	1,3-1,5	1,3-1,8
Sulphur (S)	1-1,5	1,2-1,6
Nitrogen (N)	0,4-0,6	0,3-0,4
Calcium (Ca)	0,2-0,3	0,06-0,08
Manganese (Mn)	0,06-0,07	0,1-0,2

Carbon is the main element which makes up the mass of a tyre. The carbon content in used tyres is about 60-70%. Another important element in used tyres is iron which can be up to 27% of the total content of truck tyres. Iron content is important to ensure the quality of the end product when tyres are used for energy production in cement kilns. The typical chemical content of tyres is given in Table II [4].

There is more synthetic rubber than natural rubber in the content of tyres of passenger cars. There is more natural rubber than synthetic in trucks tyres. There is almost no synthetic rubber in the content of tyres for cross-country vehicles, including cargo transport, agricultural and industrial transport. The exact composition of a tyre is typically not known due to a commercial secret of the producer. According to a study of Anne & Russ Evans [7], the typical content and weight of passenger car and truck tyres is provided in Table III.

TABLE III

COMPOSITION OF TYRES AND WEIGHT OF PASSENGER CAR TYRES AND TRUCK TYRES [7]

Component	**Tyre for passenger car, %**	**Tyre for truck, %**
Natural rubber	22	30
Synthetic rubber	23	15
Soot	21,5	22
Metal	16,5	25
Fibre	5,5	-
Zinc oxide	1	2
Sulphur	1	1
Fillers	7,5	5
Joint carbon materials	74	67
Average weight of tyre	New 8,5 kg Old 7 kg	New 65 kg Old 56 kg

TABLE IV

COMPARISON OF TYRES WITH COAL [4]

	Passenger car end-of-life tyre	Truck end-of-life tyre	Coal
Net calorific value, MJ/kg	30,2	26,4	26
Carbon (C)	69%	61%	64-68%
Biomass fraction (% mass)	18,3%	29,1%	0%
Sulphur	1,3%	1,4%	1,3%
Emission factor: tCO_2/TJ	59*	43*	90-95
Emission factor: tCO_2/t	1,8*	1,1*	2,5

* Net emission factors, taking the biomass carbon into account

An analysis carried out on tyre samples in France showed little variability in terms of net calorific value, carbon, biomass carbon and sulphur parameters. According to this research [4], the truck used tyres have net calorific values and carbon contents that are lower than those of passenger cars because of the higher proportion of metal in the tyres. Conversely, the content in the carbon of biomass origin is greater in the case of used truck tyres. Used tyres used as fuel have a high heating value, and it is comparable with that of coal. A comparison of tyres with coal is given in Table IV.

III. MANAGEMENT OF END-OF-LIFE TYRES

Most products, including tyres, comprise an entire chain of players rather than a single economic operator managing the process, therefore the responsibility for waste management must be shared equally amongst all economic operators and other stakeholders. In Europe, three systems exist [8]:

- countries with a free market (e.g. Austria, Germany, UK);
- countries with a national tax system (e.g. Croatia, Denmark, Slovakia);
- countries with a statutory ‘take back’ system through a producer responsibility approach (e.g. France, Netherlands, Sweden, Poland).

Within those countries operating under a statutory regime, tyre manufacturers have set-up companies to deal with the management of end-of-life tyres. These companies, backed with a proper statutory regime, aim at organising the collection and ecologically sound recovery treatment of end of life tyres through the most economical solutions. For the end user, this system guarantees transparency of costs through a visible contribution, clearly indicated on the invoices.

In Latvia all companies who are producing or importing products in packaging or products potentially hazardous to the environment are obliged to avoid or neutralize the impact of waste on environment. According to the legislative framework in Latvia this is done by paying the tax for natural resources from where the income is used for funding the environmental protection projects or by organizing the waste management system – separate collection, reuse, recycling or disposal in landfill by using best available technologies.

There are three different types of actors involved in the end-of-life tyres management in Latvia (see Figure 2):

- Producers (creators) of the end-of-life tyres
- Waste collectors and management companies
- Processing and recycling organizations

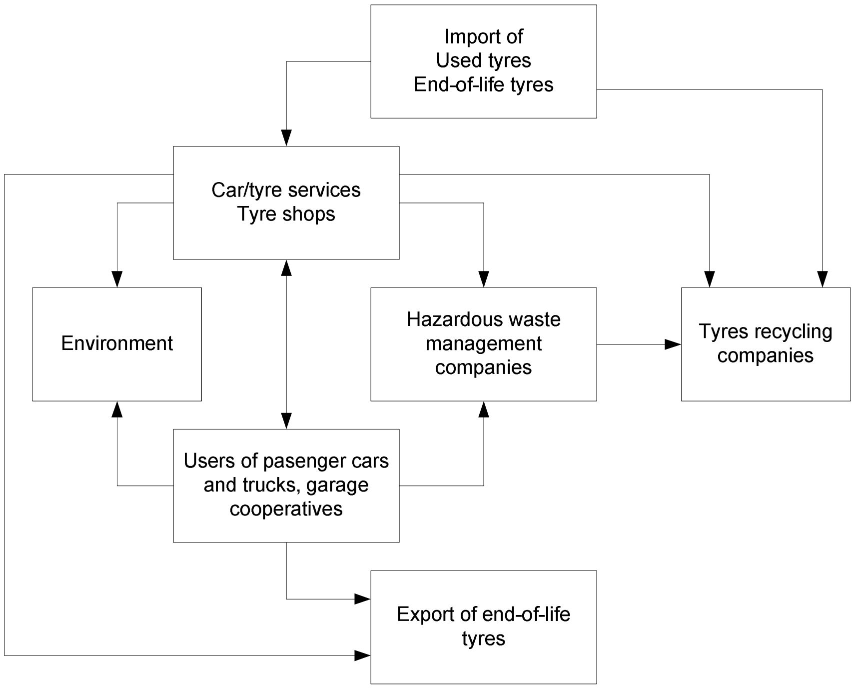


Fig.2. Actors of the used tyres management system in Latvia.

A. Producers of used tyres

Producers of the used tyres in Latvia are basically users of cars that are individuals, companies and organizations like cargo and public transportation companies, public utilities etc. Imported tyres are also included in this category. As can be seen in Figure 2, a part of the end-of-life tyres are delivered directly to the waste management companies by car users, partly used tyres are left in the automobile service shops and some part are exported – mainly by big companies with a significant annual amount of waste tyres.

Car services and tyre shops are intermediate bodies among car users, waste management companies and recycling organizations. When changing their old tyres to new ones car users can leave the old tyres at the auto service shops free of charge. Later tyres are collected by waste management companies or delivered directly to recyclers or exported.

B. Waste collectors and management companies

There is a two-level tyre collection system in Latvia. The first collection level is represented by companies which are collecting tyres from waste producers and delivering them to hazardous waste management companies – i.e. the second level of collection.

Hazardous waste management companies are contracted by producer responsibility organizations and therefore are obliged to collect used tyres free of charge, except the transportation costs that has to be paid by producers of used tyres. Producer responsibility is a policy concept designed to extend manufacturer’s responsibility beyond the sale and use of their products to include disposal at end of life as well.

C. Processing and recycling organizations

During the processing and recycling stage, the end-of-life tyres are transformed into a new product or into energy. Almost all collected tyres except the exported amounts are now processed in a cement factory where the tyres are used as fuel.

There are also a few tyre processing companies which mechanically treat used tyres (chipping or pressing) thus producing material that can be used for road construction or landfill covering works.

D. Assessment of the amount of used tyres in Latvia

According to the information from the organization *Latvijas Zaļais Punkts* (first producer responsibility organization in Latvia) 15 000 tons of tyres are imported into Latvia each year. Respectively, the same amount of tyres is ending their life every year. The exact numbers of used tyres are not available because only bigger companies have to declare and report their waste amounts.

In order to assess the amount of used tyres in Latvia, an indicative calculation based on transport fuel consumption and the number of cars that has been actively used in this study was performed. The following data and assumptions were applied in the calculation:

- Number of cars with valid roadworthiness test: 544399
- Average fuel consumption per car (l/100 km): 8,5
- Total fuel consumption per country (l): 1135294117
- Number of km to go before the change of tyres: 45 000
- Weight of a used passenger car tyre (kg): 8,5
- Weight of a used truck car tyre (kg): 65

The calculation shows that the annual amount of end-of-life tyres is 1197678 which corresponds to 10 180 t/year.

According to waste collection statistics [9], the amount of collected and recycled tyres in Latvia in 2006 was around

8000 t meaning that at least 20% of used tyres are not collected and are ending their life in the environment.

E. Environmental impacts of tyres

Each stage of the tyre life cycle is associated with certain environmental impacts. Impacts on the environment occurs during the acquisition of raw materials for tyre production, during the production stage, transportation, use and finally during the end-of-life tyres processing, recycling or disposal. In this study only the last stage of tyre life cycle was analyzed and detailed research on environmental impacts from end-of-life tyres recycling was performed.

In a study implemented by the Swedish Environmental Research Institute Ltd, six scenarios for the utilization of used tyres were analyzed. The study [10] compares the environmental impacts of each of the following six scenarios using the life cycle assessment approach:

- Incineration of tyres in a cement kiln;
- Material recycling producing granulates used as filling material in artificial football fields;
- Reuse of the tyres as drainage material in final covering of landfills;
- Incineration of tyres in a district heating plant;
- Material recycling producing granulates used in asphalt;
- Reuse of the tyres as filling material in noise abatement installations.

The study [10] was based on a functional unit of 1 ton of tyres collected from the tyre dealers. The results show that the "Material recycling of tyre granulate in football fields (scenario 2)" is the best scenario, the "Incineration of tyres in a cement kiln (scenario 1)" is the second best scenario and that the "Material recycling in asphalt (scenario 5)" is definitely the worst scenario from the environmental impact point of view.

IV. POTENTIAL FOR REDUCTION OF CO_2 EMISSIONS BY ENERGY RECOVERY FROM TYRES IN CEMENT INDUSTRY

As can be seen from study [10] results, one of the best ways to utilize end-of-life tyres is energy recovery by incineration in cement kilns.

Already now in Latvia tyres are being used by the cement industry and due to the construction of a new cement factory the tyre recycling capacity has recently increased. The cement industry is able to use all tyres available in Latvia. Since cement factories are part of the European Emission Trading Scheme, it is possible to save CO_2 emissions that are generated from renewable and mineral fractions existing in tyres.

In this study three scenarios for CO_2 emission savings in the cement industry in Latvia have been developed:

- Base scenario;
- Complete recycling scenario;
- Extended recycling scenario.

A. Base scenario

The base scenario reflects business as usual assuming that energy recovery from tyres in the cement industry stays at the present level of recycling capacity. In 2009 the recycling capacity of the cement industry in Latvia was 4 785 t of end-of-life tyres per year.

B. Complete recycling scenario

In the complete recycling scenario it is assumed that all end-of-life tyres available in Latvia are used as fuel in the cement industry. The annual amount of tyres in Latvia is assumed equal to 15 000 t according to the information from *Latvijas Zaļais Punkts* [11].

In case of this scenario, the current end-of-life tyres management system needs to be improved in order to be able to collect all tyres and to avoid them ending their life without being used in recycling or re-used.

C. Extended recycling scenario

In extended recycling scenario the maximum tyre recycling capacity of the Latvian cement industry is considered. After construction of the new cement factory owned by the company *Cemex*, the total recycling capacity is increased up to 25 000 t per year.

In case of this scenario an additional amount of end-of-life tyres need to be imported from other countries.

V. CALCULATION OF CO_2 SAVINGS

CO_2 emission from fuel combustion was calculated for each scenario using formula (1).

$$CO_2 = B \cdot Q \cdot EF_{CO_2} \cdot 10^{-3} \qquad (1)$$

CO_2 – annual CO_2 emission, tCO_2/year;
B – fuel consumption, t/year;
Q – net calorific value, MJ/kg;
EF_{CO2} – CO_2 emission factor, tCO_2/TJ

CO_2 emission factors and net calorific values for tyres were assumed as given in Table IV. CO_2 emission savings were calculated compared to coal, i.e. if 100% coal was used as fuel instead of tyres and the corresponding emission factor were assumed according to the reference value given in national CO_2 emission calculation methodology (92,2 tCO_2/TJ) [12].

A share between passenger car and truck tyres was calculated based on the information from the Road Traffic Safety Department of Latvia indicating the number of passenger cars and trucks with a valid roadworthiness test and normalized by taking into account the difference in weight of each type of tyres. According to the calculations, the share of passenger car tyres is 50,24% and the share of truck tyres is 49,76%.

The calculation results for each scenario are summarized in Table V.

TABLE V
CALCULATION RESULTS OF CO_2 EMISSION SAVINGS FOR EACH SCENARIO

	Fuel consumption	**Fuel input**	**CO_2 (tyres)**	**CO_2 (coal)**	**CO_2 savings**	**Potential savings from national total CO_2 emissions**	**Potential savings from mineral products industry CO_2 emissions**
	t/year	TJ	tCO_2/year	tCO_2/year	tCO_2/year	%	%
Scenario 1	4 785	135	6 986	12 489	5 503	0,1	3,2
Scenario 2	15 000	425	21 901	39 152	17 251	0,2	10,2
Scenario 3	25 000	708	36 501	65 253	28 751	0,3	17,0

VI. CONCLUSIONS

Passenger car and truck tyres contain a significant amount of biomass in the form of natural rubber. The use of End-of-life tyres as fuel instead of traditional fossil fuels (like coal) can lead to considerable CO_2 emission savings.

In order to be able to use the end-of-life tyres for energy recovery, it is necessary to organize an efficient and well-functioning tyre collection system where the responsibility for waste management is shared equally amongst all economic operators and other stakeholders. In Latvia the collection of tyres is based on the producer responsibility principle. However, in practice, the collection system is not functioning well – about 20% of tyres are not collected and end their life in the environment.

From the life cycle assessment point of view energy recovery by incineration in cement kilns is one of the best ways for the utilization of end-of-life tyres. Therefore three scenarios for using tyres as fuel in the cement industry were developed. CO_2 emission savings and the potential savings related to total emissions and GHG emissions from mineral products industry were calculated for each scenario.

Results show that in the base scenario 0,1% of the total GHG emissions and 3,2% of the mineral products industry emissions can be saved.

In the complete recycling scenario when all tyres are collected and used for energy recovery, 0,2% of the total GHG emissions and 10,2% of the mineral products industry emissions can be saved.

In the extended recycling scenario when the maximum capacity of cement industry is used and an additional amount of tyres is imported, 0,3% of the total GHG emissions and 17,0% of the mineral products industry emissions can be saved.

REFERENCES

1. *Summary of GHG Emissions for Latvia*. Framework Convention on Climate Change, Secretariat, 2009, 4 p.
2. Junginger M., Van Dam J. *Biomass Use in the Dutch Cement Industry*, ENCI, Maastricht, The Netherlands, EUBIONET project report, 2009, 6 p.
3. Singh S., Nimmo W., Gibbs B.M., Williams P.T. Waste Tyre Rubber as a Secondary Fuel for Power Plants. *Fuel*, 2009, Nr.88 p. 2473–2480.
4. Clauzade C.. *Using used tyres as sources of fuel. Reference values and characterisation protocols*. Aliapur, R&D, July 2009, 15 p.
5. Edeskär T. *Technical and Environmental properties of tyre shreds focusing on ground engineering applications*, SE-971 87, Luleå, 2004, 111 p.
6. *Positioning used tyres as a major fuel source*. Aliapur, 2009, 15 p.
7. Evans A., Evans R. *Creating markets for recycled resources. The Composition of a Tyre: Typical Components*, 2006., 5 p.
8. *Country specific implementation and end-of-life tyres (ELT) management companies* [Online]. European Tyre and Rubber Manufacturers' Association (ETRMA), June 2009- [Accessed 11.08.2010]. Available: http://www.etrma.org/
9. National waste database - Atkritumi-3 [Online]. Latvian Environmental, Geological and Meteorological Agency, 2000-2008- [Accessed 11.08.2010]. Available: http://vdc2.vdc.lv:8998/atkritum.html
10. Hallberg L. *LCA of the utilization of used tyres*, Swedish Environmental Research Institute Ltd. on behalf of the Swedish Tyre Recycling Association, 2007, 4 p.
11. *Annual Report*, Latvijas Zaļais punkts, 2008, 37 p.
12. *Methodology for CO_2 emission calculation from stationary combustion and industrial processes*, Latvian Environmental, Geological and Metheorological Agency, 2009, 8 p.

Ilze Dzene, M.Sc.ing, Researcher
Institute of Energy Systems and Environment, Riga Technical University
Address: Kronvalda boulevard 1, LV1010, Riga, Latvia
Phone: +371 67089908, Fax: +371 67089908
e-mail: ilze.dzene@rtu.lv

Claudio Rochas, Dr.sc.ing.
Institute of Environment and Energy Systems, Riga Technical University
Address: Kronvalda blvd. 1, Riga, LV 1010, Latvia
Phone: 371 67089923, 371 67089908,
Fax: 371 67089908
e-mail: claudio.rochas@rtu.lv

Dagnija Blumberga, Dr.habil.sc.ing., Professor
Institute of Environment and Energy Systems, Faculty of Energy and Electrical Engineering, Riga Technical University
Address: Kronvalda blvd. 1, Riga, LV 1010, Latvia
Phone: 371 67089923, 371 67089908,
Fax: 371 67089908
e-mail: dagnija.blumberga@rtu.lv

Marika Rosa, Dr.sc.ing., Assistant Profesor
Institute of Environment and Energy Systems, Faculty of Energy and Electrical Engineering, Riga Technical University
Address: Kronvalda blvd. 1, Riga, LV 1010, Latvia
Phone: 371 67089923, 371 67089908,
Fax: 371 67089908
e-mail: marika.rosa@rtu.lv

Andris Erdmanis, M.Sc.
Institute of Energy Systems and Environment, Riga Technical University
Kronvalda boulv.1, LV-1010, Riga, Latvia
Phone: +37126465373
e-mail: andris.erdmanis@rtu.lv

Ilze Dzene, Claudio Rochas, Dagnija Blumberga, Marika Rošā, Andris Erdmanis. Enerģijas atguve no lietotām riepām: neizmantota CO_2 emisiju samazināšanas iespēja

Šajā rakstā tiek pētīta iespēja samazināt CO_2 emisijas, atgūstot enerģiju no lietotām automašīnu riepām. Pētījuma mērķis ir veikt nolietoto riepu tirgus analīzi Latvijā, novērtēt pieejamo nolietoto riepu daudzumu un aprēķināt potenciālo CO_2 emisiju samazinājumu, izmantojot riepas kā kurināmo minerālu produktu ražošanā. Vieglo automašīnu un kravas mašīnu riepas satur nozīmīgu biomasas daudzumu, kas riepu sastāvā ir dabīgās gumijas veidā. Izmantojot nolietotās riepas kā enerģijas avotu tradicionāli lietoto fosilo kurināmo, piemēram, ogļu vietā, ir iespējams sasniegt nozīmīgu CO_2 emisiju ietaupījumu. Šajā pētījumā tiek piedāvāti trīs scenāriji riepu kā kurināmā izmantošanai cementa rūpniecībā un katram no tiem tiek aprēķināts sasniedzamais CO_2 emisiju ietaupījums. Potenciālais CO_2 emisiju ietaupījums tiek attiecināts uz valsts kopējām emisijām un uz minerālu produktu ražošanas siltumnīcefekta gāzu emisijām, iegūstot potenciālo emisiju samazinājumu valsts līmenī. Aprēķina rezultāti rāda, ka, uzlabojot nolietoto riepu savākšanas sistēmas organizāciju un dedzinot tās cementa rūpniecībā, ir iespējams ietaupīt no 3,2% līdz pat 17% no pašreizējām CO_2 emisijām minerālu produktu ražošanā. Lai varētu savākt lielāko daļu nolietoto riepu, ir nepieciešams uzlabot esošo riepu apsaimniekošanas sistēmu, jo šobrīd aptuveni 20% riepu Latvijā netiek savāktas un beidz savu dzīvi apkārtējā vidē.

Илзе Дзене, Клаудио Роша, Дагния Блумберга, Марика Роша, Андрис Эрдманис. Получение энергии из использованных покрышек: неиспользуемая возможность сокращения выбросов CO_2

В этой статье исследована возможность сокращения выбросов CO_2 путём получения энергии из использованных автомобильных покрышек. Цель исследования – провести анализ рынка использованных автомобильных покрышек в Латвии, оценить доступное количество покрышек и рассчитать потенциальное снижения объёма CO_2 в ходе использования покрышек в качестве топлива для производства минеральных продуктов. Покрышки для легковых и грузовых автомобилей содержат значительное количество биомассы, которая в составе находится в виде натуральной резины. Используя покрышки как источник энергии и заменяя традиционные ископаемые источники энергии, например, уголь, возможно достичь значительных сокращений выбросов CO_2. В данном исследовании представлены три сценария для использования покрышек в качестве топлива в производстве цемента и рассчитано достигаемое снижение выбросов CO_2 для каждого из них. Потенциальное сокращение выбросов CO_2 соотносится с общими выбросами в государстве и с выбросами в результате производства минеральных продуктов, и таким образом проводится оценка потенциального снижения выбросов на государственном уровне. Результаты расчётов показали, что, улучшая организацию системы сбора использованных покрышек и организуя сжигание покрышек в качестве топлива для производства цемента, возможно снизить существующий выброс CO_2 от 3,2% до почти 17%. Для того, чтобы собрать большое количество использованных покрышек, необходимо улучшить существующую систему управления отходами, т.к. на данный момент около 20% использованных покрышек не сдаются переработчикам и остаются в окружающей среде.