International Journal of GEOMATE, Sept., 2018 Vol.15, Issue 49, pp. 30 - 36
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2018.49.3602
Special Issue on Science, Engineering & Environment

ENERGY EFFICIENCY AND ENVIRONMENTAL IMPACT ANALYSIS IN GROCERY STORE MARKET IN CANADA

*Jarotwan Koiwanit

Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand

*Corresponding Author, Received: 14 Jan.2018, Revised: 17 Feb. 2018, Accepted: 06 Mar. 2018

ABSTRACT: There is growing pressure to limit Global Warming Potential (GWP) as it is the most significant way to reduce serious threats to people. The increase of average temperature in the atmosphere causes adverse effects on the environment, and this is changing the way business operates. Together with undergoing changes to be more environmentally friendly, the majority of business sectors has been launching many projects to reduce environmental impacts. Similar to grocery sector in Canada, many companies have been reported to investigate the environmental performance. Loblaw Companies Limited, the largest food distributors in Canada, has put more concerns on environmental impacts and worked diligently to reduce greenhouse gas (GHG) emissions through actions such as improving energy efficiency reducing refrigerant leaks, and incorporating renewable energy sources. This study analyzed Loblaw's energy efficiency and environmental performance and provided suggestions in the applications of skylight improvement, geothermal, refrigeration systems, kinetic energy to electricity, and e-grocery shopping. The results showed that the environmental concerns were substantially decreased. However, types of lights and refrigerators, distance driven, vehicle types, fuel used in e-grocery shopping results in the different amount of emissions; consequently, the GHG emissions varied depending on these factors. By integrating more environmentally technology, Loblaw could further reduce their emissions and waste and become a more sustainable company.

Keywords: Environmental performance; Greenhouse gas emissions; Energy efficiency; TRACI; GaBi 6

1. INTRODUCTION

The Canadian's grocery store market encompasses the largest food retail channel in Canada [1]. The total grocery sales in Canada during 2016 fiscal reached $85 billion dollars. There are three largest competitors playing in Canadian's grocery sector, which include Loblaws, Metro, and Empire [1]. With a supermarket chain of over 2,000 stores operating under Loblaw and over 17 million Canadians shopping at the stores every week, Loblaw is the largest food distributor in Canada [2], [3]. For over 50 years, Loblaw has supplied the Canadian market with innovative products and services through corporate, franchised and associated stores. These supermarket chains include Loblaws®, Provigo® and Zehrs® [4]. With environmental concerns, Loblaw plays a major role in energy usage over other food distributors. They have answered with many innovations like the introduction of the reusable shopping bag, new "green" products and even installing a wind turbine to generate renewable energy. Regarding power consumption, Loblaw has worked diligently to reduce greenhouse gas (GHG) emissions through improving energy efficiency, reducing refrigerant leaks, and other renewable energy initiatives. According to Loblaw Companies Limited Corporate Social Responsibility Report in 2015, Loblaw has been tracking their operations focusing on carbon emissions since 2010 [5]. The results showed that they achieved their target of reducing energy consumption in stores by 4%, by investing in new lighting, upgrading fleet and building fuel consumption, refrigerant releases, and corporate travel, and using renewable energy technologies [5]. All of these showed that they take reducing carbon emissions and contributing to mitigating climate change as their priority.

The objective of this study is to analyze energy used by Loblaw and provide suggestions for improvement. The GHG impacts on the provided suggestion were evaluated using the Life Cycle Assessment (LCA) methodology. The GaBi software system and databases developed by PE International, Germany together with TRACI, a life cycle impact assessment methodology, were applied in this study to convert existing inventory data into GHG impacts. The broad range data sets of the GaBi cover many different industrial sectors including metals (steel, aluminum, and non-ferrous metals), plastics, mineral materials, energy supply (steam, thermal energy, power grid mixes), transport, disposal, manufacturing, and electronics.

2. TECHNOLOGIES TO SAVE ENERGY AND IMPROVE EFFICIENCY

Supermarkets have reduced their electricity consumption to improve energy efficiency and

reduce their carbon emissions. Lighting, refrigeration system, and heating, ventilation and air conditioning (HVAC) system are key opportunities for energy saving upgrades in typical supermarkets and these are monitored and controlled by centralized building energy management systems [6], [7]. Example of technologies for energy efficiency upgrades are shown as follows [6], [8]:

2.1 Lighting

- Occupancy sensors installed in the active storage, restroom, office zones, etc.
- Skylights usage in warm and hot climates
- Converting vertical frozen doorcases to *Light Emitting Diode* (LED) lighting
- Replacing standard lights with fluorescent technology
- Adding manual light switches and light dimmers

2.2 Refrigeration

- Using frozen food and ice cream refrigerated cases with vertical models with doors
- Using medium-temperature refrigerated display cases with doors
- Using a refrigeration system known as a transcritical refrigeration system that uses carbon dioxide (CO_2) as the sole refrigerant
- Using low GHG emitting refrigerant called hydro-fluoroolefin (HFO) blend
- Minimizing refrigerant leaks
- Adding curtains in the refrigerated areas of distribution centers to separate spaces running at different temperatures

2.3 HAVC

- Highest efficiency HVAC installed throughout corporate offices, stores, etc.
- Using an active HVAC asset performance tracking program
- implementing ground source heat pumps, packaged variable air volume systems, radiant heating, and cooling, etc.
- Solar thermal technologies usage for service water heating

3. SUGGESTIONS FOR IMPROVEMENT

Loblaw has put in much effort into improving their environmental performances in energy efficiency; however, there is also some room for improvement. After visiting the Superstore in Regina East, Saskatchewan, Canada, this study showed five suggests for Loblaw/Superstore to become more environmentally friendly. The suggestions were analyzed based on the follow:

- Reliability: the reliability of a suggested is measured by the quality of producing stable and consistent results. A high means the suggestions produce similar results under consistent conditions, medium means the suggestions produces somewhat the same results, and low means it is hard to be reproduced with similar results.

- Applicability: this indicator refers to a degree of being applied. The applicability criterion is evaluated high if Loblaws have a high potential to implement the suggestions, medium if Loblaws have potential to apply them but not immediately, and low if Loblaws are nearly unable to implement the suggestions.

- Cost: this refers to all direct and indirect costs required for the suggestion. The cost criterion is evaluated high, medium, and low if Loblaws need to spend a lot of money, not much money, and very low amount of money for the suggestions, respectively.

- Knowledge: this knowledge refers to the knowledge required for each suggestion. Advanced knowledge is required when the criteria is high, intermediate level of knowledge is required for medium, and low skills are required for low criteria.

- Time to adopt: this is the amount of time spent on implementation. For example, the time to adopt the new refrigeration systems is for six months; this means that six months are required to make changes on the refrigeration systems.

- Parties involved: this category shows the people or organizations who are involved or interested in each suggestion.

- Public perception: this refers to the conscious understanding that people have of public and official issues. A high public perception means a high level of public beliefs in the suggestions, medium means the majority of people are agree with the suggestions, low means there are not many people who support Loblaws for the implementation.

- Ease of implementation: this refers to an assessment required of the ease or difficulty of implementing the suggestions. The criteria is evaluated high if the suggestions are allowed for easy to set up, medium if the suggestions are not too difficult to set up, and low if the suggestions are not easy to set up.

- Capacity to reduce emissions: this assessment refers to an ability of suggestions to reduce emissions. The criteria is evaluated high if the suggestions have a high capacity in emission reductions, medium if the suggestions are normal in emission reductions, and low if the suggestions are low in emission reductions.

- Administrative simplicity: This is to perform the task of simplification of administrative procedures. The simplicity criteria is high when the suggestions are difficult for administration, medium when the suggestions are in general for administration, and easy when the suggestions' determination are easy to understand and manage.

The analysis of the environmental performance of the visited store and suggestions for improvement is summarized in Table 1.

Table 1 Analysis of Suggestion of Improvement

	Suggestion points	Reliability	Applicability	Cost	Knowledge	Time to adopt	Parties involved	Public perception	Ease of implementation	Capacity to reduce emissions	Administrative simplicity
1	Skylight improvement	High	High	Medium	High	Now	-Loblaw -Construction company - City of Regina	High	Medium	High	Easy
2	Geothermal (for new store)	High	High	High	High	3 – 5 years	-Loblaw -Construction company - City of Regina	High	Easy	Medium	Medium
3	Refrigeration systems	High	High	Low – Medium	High	6 months	- Loblaw - Construction company - City of Regina	High	Easy to Medium	High	Easy
4	Kinetic energy to electricity	Medium	Medium	Medium	Low	1 – 2 years	- Loblaw - Suppliers	High	Medium	low	Easy
5	E-grocery shopping system	High	Medium	Low	High	1 – 2 years	- Loblaw - Customers	High	Medium	High	High

All the above suggestions are explained in more details in Section 4.

4. RESULTS AND DISCUSSION

This section presents GHG emissions result of each suggestion. GHG emissions will be calculated using GaBi 6 software tool for suggestions that show high capacity to reduce emissions**.** The GHG impact results are generated based on the TRACI methodology implemented in the GaBi 6 software**.** The users enter all the inputs and outputs of the two scenarios into the GaBi 6 software**.** GaBi 6 then generates the GHG emissions based on the TRACI methodology**.**

4.1 Skylight Improvement

Lighting makes up the second largest share of the energy use and electricity bill [9]. Based on this reason, installing skylights can help save supermarkets' energy since a well-designed building with a good spread of natural light will benefit from passive solar gain and a reduced requirement for artificial light. The combination of these factors means that including skylights can offer a dramatic reduction in a building's total energy consumption and the emissions of CO_2 associated with this energy use. A naturally-lit interior will save money, provide a more pleasant environment where people want to spend time, and contribute to the reduction of CO_2 emissions.

The Superstore in Regina (East) has skylights installed; however, the store also has lights installed beneath the skylights. During our visit to the store, there was enough natural light, but Superstore still kept their lights. An improvement Superstore can make is to combine the skylight design with an automated dimming control system will achieve substantial energy savings and improve the store environment significantly during the day. Another option would be to simply switch off the lights.

The National Association of Rooflight Manufacturers (NARM) commissioned the Institute of Energy & Sustainable Development at Leicester's De Montfort University to undertake a study to investigate the effect skylights have on the annual CO_2 emissions which result from the use of energy needed to operate a building. Savings from daylighting can cut lighting energy use by 50 percent [10]. Based on the average supermarket's electricity consumption is 5,000 MWh per year [11] and the energy consumption of lighting is

approximately 15% to 25% of the total consumption [12].

This study assumed that there was a 50% reduction of lighting energy use on a skylight improvement's scenario compared to a base case scenario. In addition, the energy consumption was assumed to be 25% of the total consumption. It can be seen from the results generated by TRACI that savings from daylighting could reduce the energy usage numbers from 1250 to 625 MWh per year. The main substances that contribute to the Global Warming Potential (GWP) are CO_2, Methane (CH_4), and Nitrous oxide (N_2O), and the highest contributor to the GWP comes from CO_2. CO_2 emissions emitted into the air could be substantially reduced by 50% from 789,026.66 to 394,513.33 kg CO_2-equiv. per year, shown in Fig. 1. This study covers electricity produced, but no accounting will be made of the GHG effects associated with construction, transportation, and operation of the Superstore.

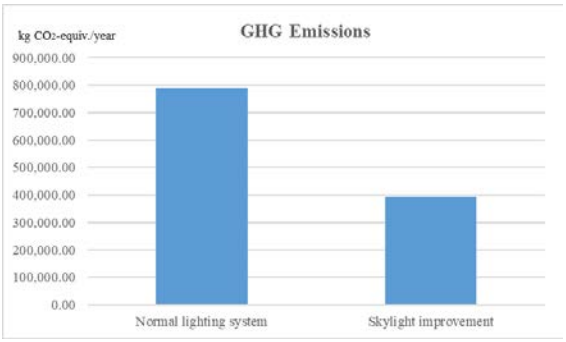

Fig. 1 GHG emissions of lighting and skylight improving systems

4.2 Use Geothermal

Geothermal energy is defined as heat from the Earth. Geothermal energy can be utilized for electricity production, for commercial, industrial, and residential direct heating purposes, and for efficient home heating and cooling through geothermal heat pumps. Heat pumps are reversible of the refrigerator and can provide either heating or cool to almost any space or location. In warm weather, the geothermal unit acts like a home refrigerator. It removes unwanted heat from the space being cooled and deposits that unwanted heat somewhere else, in this case to the earth. In cool weather, the geothermal heat pump acts as a reverse refrigerator because it withdraws heat from the earth and transfers that earth heat into the space being heated such as building, home, mall, etc. Heat pumps use a vapor compression cycle to transport heat from one location to another. In heating mode, the cycle starts as the cold liquid refrigerant within the heat pump which passes through a heat exchanger (evaporator) and then absorbs heat from the fluid circulated through the earth connection. The refrigerant evaporates into a gas as heat is absorbed from the earth connection heat exchanger (evaporator). The gaseous refrigerant then passes through a compressor where it is pressurized, raising its temperature to over 180 degrees F. The hot gas then circulates through a refrigerant-to-air heat exchanger where the heat is removed and sent through the air ducts. When the refrigerant loses the heat, it changes back to a liquid. The liquid refrigerant cools as it passes through an expansion valve and the process begins again.

This application can achieve very important energy savings by decreasing primary energy consumption by 28% to 32%, energy for cooling by around 25% and energy for heating by around 40%. These combined can potentially reduce CO_2 emissions by 28% to 32% [13]. However, installing geothermal energy system would be costly for the current Superstore and would be more applicable to new stores in the future.

4.3 Improve Refrigeration

Refrigeration is the largest single energy consumer in most supermarkets and has very high potential for savings. According to Loblaw Corporate Social Responsibility report from 2012, running the refrigeration system contributes to approximately 50% of a supermarket's energy consumption [2]. The most common practice is to have open freezers, which causes the following problems: (1) inefficient energy consumption, (2) cold aisles that causes discomfort to consumers, and (3) gaining temperature of food products more rapidly than the ones in freezers with doors [14]. To solve the above problems, supermarkets should consider installing doors on every refrigerated cabinet and use glass door displays instead of open displays.

In the Superstore in Regina East, there are a lot of open freezers. To reduce energy consumption and increase comfort for consumers, Loblaw could consider replacing the open freezer units with units with doors. This change would not only reduce GHG emission significantly, it will also save a large portion of Superstore's electricity bill. The closed display cabinets consumed less energy by approximately 5.46 kWh/m^2 per day compared to the opened display cabinets [15] as summarized in Table 2.

Table 2 Electrical energy consumption of the closed freezers (modified from [15])

Energy consumption	Average (kWh/m^2/day)
Opened display	12.675
Closed display	7.217

The analysis from TRACI showed that the closed cabinets will cause a reduction of 30.1% in the impact category of GWP compared to the opened cabinets. CO_2 emissions emitted into the air were reduced from 31,974.74 kg to 22,388.37 kg CO_2-equiv. per year (Fig. 2). However, the analysis covered electricity produced, but not for the GHG effects associated with construction, transportation, and operation of the Superstore.

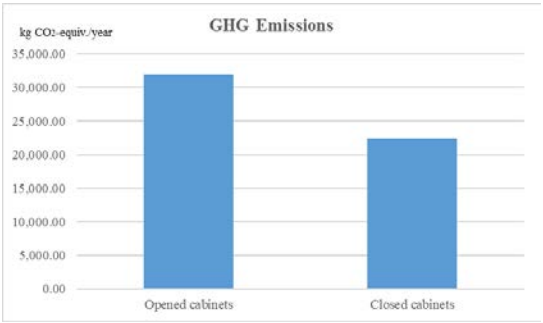

Fig. 2 GHG emissions of refrigeration systems

Another suggestion for Loblaw to reduce the energy consumption of the refrigeration system is that the store could have one enclosed area for all of the refrigerators in the store. By having all of the refrigerators in one area the cold air that escapes the refrigerator will be contained in the zone and will lower the cost of refrigerating the units in that zone. In addition, the new innovative refrigeration battery from Axiom Energy can store energy at night when it is inexpensive and this can be discharged during peak hours for electricity demands in the afternoon. The battery can retrofit to the existing refrigeration systems in which any modifications are not required. This helps the Superstore to be able to turn off their refrigeration systems' compressors and condensers and save their electricity by up to 40% [16].

4.4 Kinetic Energy to Electricity

Renewable energy options are constantly replenished and more environmentally friendly compared to coal, oil, and natural gas for generating energy [17]. These options have experienced explosive growth over the past decade [18]. For Loblaws, electricity can be generated from the footsteps of people by installing special piezoelectric floor tiles. These tiles could be installed in the supermarket to generate electricity for lights and refrigerators within the supermarket. Pavegen System is a company based in the UK and is currently only that sells energy-harvesting piezoelectric floor tiles. The new Pavegen's V3 is known to be generating over 200 times more power than the first version launched in 2009 [19]. Each footstep can generate up to 8 Watts of electricity [20].

This study did an observation on people visiting the Superstore in Regina and the results showed that during the busiest time on a Sunday, there are approximately 200 people entering the store hourly. Based on this, we can make an assumption that on hourly average of 200 people would enter the store from 9 am to 9 pm and 100 people would enter the store another period of times (store hours is 6 am to 11 pm), giving a total of 2,300 people entering the store daily. Assuming that Superstore has 8 tiles at the entrance and each person entering the store would step on 6 of them; that would give a total of 0.139 MWh per day. This gives a total of 50.808 MWh per year, saving 1% of the electricity (based on the previous assumption that an average supermarket consumes 5000 MWh of electricity per year). Based on 2.17 pound of CO_2 eq/kWh electricity generated by lignite [21], the GHG reduction per year would be approximately 29,312.03 kg CO_2 equiv.

Fig. 3 GHG reduction from kinetic energy

Although the amount of electricity saved by the tiles is not as high as the wind turbine, the capital required is also much lower, which makes the feasibility much higher. Wind turbine generating 10 kW costs approximately $48,000 – 65,000 to install [22]. Pavegen's V3 is easy to install with no maintenance costs. Even though the cost of this technology is currently not released to the media, cost of a standard square meter of used in a building would cost approximately $1,170 [23]. Since there are no regulations and community restrictions on this project, it is mostly up to the company to execute this project. From planning to installing and running, this project should be able to execute within a year. This product should be popular among the public. The tile itself has a LED lighting, which lights up with it is being stepped on (uses 5% of the electricity it generates), this is not only visually attractive but can also be a good source of education to the public about sustainable and clean energy.

4.5 E-Grocery Shopping System

An online ordering and delivering service is becoming increasingly popular in many companies because of continued increases in mobile adoption and broadband penetration which result in its service convenience with time-saving [24]. The idea of the E-Grocery shopping system is that Loblaw/Superstore provides an online grocery shopping system to consumers. However, instead of delivering individually to the customers, Superstore delivers to companies in which the consumers are. In

other words, Superstore would have some arrangement with big companies and customers are "grouped" by the companies they are in. The groceries are delivered by the Loblaw truck to the company at a certain time once or twice a week (depending on the demand). The coordinators from the company are responsible for distributing the groceries to employees in need. As employees can take their groceries from the workplace directly home, the individual trips to grocery stores can be avoided and the vehicles' emissions can be greatly reduced. The applicability of this system should be high in Regina, since majority of the people are grouped in limited places for work and the system has high potential to reduce GHG emission reduction.

This study assumed that 100 employees from the University of Regina (U of R) join this program and their average traveling distance is 6 km one way (i.e. 12 km return). A typical car is assumed to have a luggage space with around 424 liters [25], whereas a cargo van is assumed to have a luggage space with 6,787 liters [26]. In addition, this study assumed that customers will buy goods with their full of luggage space. As a result, Superstore will need to deliver their products to 100 customers for 7 rounds in total.

By delivering to the 100 employees to the U of R, the results from the TRACI method showed a 92.9 % reduction of the impact in the GWP category in the "E-grocery shopping" scenario compared to the "conventional shopping" scenario. GHG emissions were emitted into the air were reduced from 245.93 kg CO_2 eq. to 17.22 kg CO_2 eq. per year, shown in Fig. 4. However, this study covers transportation and gas produced, but no accounting will be made of the GHG effects associated with construction, the operation of the Superstore. It may also need an extra staff to run this system, for taking the order, collecting goods, packing, delivering etc.; however, Superstore can rearrange their manpower to manage the system at the less busy time of the day and that would not require too many extra staff. The administrative procedures could be complicated at the start but once it is running, it should be much easier. With a little price from the consumer, this system with not only reduce GHG emission but will also save time for consumers.

Another suggestion to reduce environmental impacts should be on road transportation. Since different types of vehicles consume a different amount of fossil-fueled usage which leads to different GHG emissions and other environmental impacts. Electric vehicles (EVs) are one of the attractive options to reduce noise and eliminate the downsides of using conventional fossil fueled vehicles [27]. This also help boost Superstore by building their green image. Overall, the suggestions' results show a significant reduction in energy and environmental effects compared with the traditional energy systems.

Fig. 4 GHG emissions of conventional and online shopping systems

5. CONCLUSION

Over the years, supermarkets have been undergoing changes to be more environmentally friendly. Loblaw committed to creating a positive impact in the community being socially responsible by respecting the environment. They have taken big measures to reduce their emissions, such as cutting discharges from refrigeration units and implementing a new low-temperature system, which reduces greenhouse gas emissions. In addition, this makes supermarkets substantially cost savings and consequently high returns on investment. In this study, the energy efficiency and environmental performance of Loblaw have been analyzed. It can be shown that Loblaw has put in a lot of effort to enhance their environmental performance.

However, there are some areas of improvement and this study has presented 5 suggestions for Loblaw's further improvement. This study paid a visit to the Superstore in Regina East to inspect the applicability of our suggestions. The results showed that the option that is the most reliable, cheap, and easy for an implementation is the skylight improvement. However, as online shopping is becoming more popular these days, e-grocery shopping becomes an important option for Loblaw to be considered. The sensitivity analysis can be obtained as a future work to identify important parameters that affect the most of the results in each suggestion.

6. ACKNOWLEDGEMENTS

I am grateful for the conception, required information, and suggestions from Dr. Veronica Chan, Dr. Lakkana Piewkhow, and Naveen for this project.

7. REFERENCES

[1] Vincent J., Allion J., Florescu A., and Steckly C., Canadian grocery market report: A fresh look at some appetizing investments, Canada: QUIC Research Report, 2017.
[2] 2012 Loblaw Corporate Social Responsibility Report, 2012 Loblaw Corporate Social Responsibility Report? Respect the Environment, 2012.
[3] Glen B., Loblaw responds to a customer survey, 2017.
[4] Smartcanucks, Loblaws to close 52 stores across Canada, 2015.
[5] Loblaw Companies Limited, The way we do business: 2015 corporate social responsibility report, Ontario: Loblaw Companies Limited, 2015.
[6] Retail Industry Leaders Association, Energy saving opportunities and tactics for retail, 2014.
[7] Arias J., Energy usage in supermarkets-modeling and field Measurements, Ph.D. thesis, KTH, School of Industrial Engineering and Management (ITM), Energy Technology, 2005.
[8] Leach M., Hale E., Hirsch A., and Torcellini P., Grocery store 50% energy savings technical support document, Colorado, National Renewable Energy Laboratory, 2009.
[9] The Fraunhofer Gesellschaft (FhG), Supermarkets: Energy-optimized, 2013.
[10] Research for Energy Optimized Building (EnOB), Energy-efficient supermarket uses daylight and ground cooling, 2017.
[11] Natural Resources Canada, RETScreen Interna tional RETScreen - Energy Efficient Arenas & Supermarkets, 2017.
[12] Ge Y., Tassou S., Foster A., Evans J., and Maidment G., Modelling and evaluation of supermarket energy use and emissions, 2016.
[13] Garcia J., Coelho L., Cerdeira R., Sanner B., Lentz P., and Frechin N., Application of ground source heat pump to a supermarket in Portugal, J. of Civil Engineering and Architecture, Vol. 5, No. 3, 2011.
[14] Tyrewala A. S., Nelson D., and Almanza B., The effects of the door opening and food placement on food temperature within the refrigerator when power is lost during a disaster, 2011.
[15] Ligthart F., Closed supermarket refrigerator, and freezer cabinets: A feasibility study, No. ECN-E-07-098, Petten: Energy research Centre of the Netherlands (ECN), 2017.
[16] Maloney P., Walmart, axiom exergy partner for refrigeration energy storage project, 2016.
[17] Renewable Energy World, Types of renewable energy, 2016.
[18] Myers T., The experts: What renewable energy source has the most promise? The Wall Street Journal, 2013.
[19] Ellis E. G., The best new green energy tech could be right underfoot, 2016.
[20] Fujimoto A., Energy harvesting flooring, 2014.
[21] The U.S. Energy Information Administration (EIA), How much carbon dioxide is produced per kilowatt-hour when generating electricity with fossil fuels? 2017.
[22] Energy Wind Power, Small wind turbines for homes & businesses, 2017.
[23] Freddie D., Pavegen wants to become the tesla of walking, 2016.
[24] The Nielson Company, The Future of Grocery. Ontario: The Nielson Company, 2015.
[25] Popular science, Wrong-way wings: Give new agility to supersonic planes, 1980.
[26] General Motor Fleet, 2016 GMC savana cargo dimensions, 2017.
[27] Del Duce A., Egede P., Ohlschlager G., Dettmer T., Althaus H., Thomas Butler T. and Szczechowicz E., Guidelines for the LCA of electric vehicles, European Union Seventh Framework Programme, 2013.