Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Solar hybrid E-cargo rickshaw for urban transportation demand in India

Surender Kumar[a]*, Dr. R.S. Bharj[b]

[a*,b]*Department of Mechanical Engineering, National Institute of Technology, Jalandhar*

Abstract

The Indian transportation sector has highly depended on oil and produced more environmental pollution. Indian government wants to achieve climate goals through a sustainability approach that simultaneously addresses other environmental and developmental challenges in urban areas. Smart cities are playing a significant role in GHG emissions reduction in our nation. Economic transportation demand has grown worldwide in urban areas and supply chains. Fresh food has a short shelf life and it is spoilage with increasing temperature during transportation. Urban distribution of goods in the metropolitan market has a necessary factor for the better development of city life. Solar hybrid E-cargo rickshaw has fit for the home delivery of logistics in urban areas. SHECRs are completing the economic and green transpiration needs of supply chains in developing countries. The reduction of food losses and low carbon emissions will only possible by using SHECRs in freight mobility. Thus SHECRs is used as a feasible alternative to traditional vehicles in term of transportation cost reduction for perishable products. The purpose of this research paper is to provide a better understanding of the logistics behind SHECRs transportation and also focuses on its energy savings.

Keywords: Road transport demand; city logistics; alternative modes of transportation; solar hybrid electric vehicle; supply chain

1. Introduction

The road transport sector contributes 4.8% of overall GDP in India. Currently, India has the fourth rank in GHG emitter globally.13% of CO_2 which is only produced by the transport sector in our country (IEA and OECD, 2015). One of the world's rapidly growing economies in India. The globally third-largest vehicle market is in India. Due to increased population, annual vehicle demand has increased with a fast rate. Around 210 million vehicles in 2015

* Corresponding author. Tel.: +91-8929579100.
*E-mail address:*surender10161007@gmail.com

Nomenclature

EVs	Electric vehicles
GHG	Greenhouse gases
SHECRs	Solar hybrid E-cargo rickshaw
VCR	Vapour compression refrigeration system
GDP	Gross domestic products
TRUs	Trucks
$PM_{2.5}$	Ambient particulate matter pollution
GWP	Global warming potentials
FAI	Food agency in India

were registered in India (GOI, 2016b). India imports about 85% of oil currently and is estimated to increase by 92 % in 2020.This may pose a challenge for the balance of payment and energy security of the entire nation (IEA, 2015c). After buildings and industry, third-largest energy is consumed by the transport sector in India (IEA, 2015a). This sector will consume 22% of India's energy in 2040, as compared to 14% in 2013 according to the International Energy Agency (OECD/IEA, 2015). About 70% of diesel and 99.6% of petrol are consumed by this sector in the country (PPAC, 2013). 20 cities from India out of 40 most polluted cities are present globally according to the World Health Organization (WHO, 2016). Ambient particulate matter pollution ($PM_{2.5}$) caused about 590,000 premature deaths in India in 2013 according to the Global Burden of Disease (GBD, 2016). A major source of $PM_{2.5}$ emissions in an urban area is caused by a rapidly growing transportation demand. Today mostly products we are purchasing online. These items are delivered to the customer at a few meter distance near his home. The home delivery demands are growing in urban areas of a developing country. Food and household goods home delivery requires fast and flexible transport. It is only possible by using SHECRs for delivery. Agriculture sector contributes about 20% of GDP in the Indian economy and provides a livelihood for two-thirds of the population (ICAR, 2015). The integrated food chains are continuing grows in developing countries. Due to this reign worldwide demand for temperature controlled food distribution is increasing. It is expected that the global refrigerated vehicles market could increase from an estimated number of USD 11 million in 2016 to USD 16.5 million by 2022 (Automotive, 2016). Mostly refrigerated vehicles employ VCR system used in current time and driven by a diesel engine. These systems are used hydro fluorocarbon refrigerants (R-404A and R134a) as working fluid. Global warming potentials (GWP) for R-404A and R134a are 3922 & 1430 respectively [4]. The leakage from the VCR system estimated between 5% to 25% annual (charge per year) in diesel operated TRUs (Cowan, 2016). Global warming and environmental degradation will slow down only by using low-carbon scenario in the transportation sector (Boroojeni et al., 2016; Amini et al., 2017). The low-carbon scenario in the transportation sector is obtained only by using solar electric vehicles in urban areas. The overall problem of the cold chain can be controlled by using SHECRs.

This research paper study outcomes can help understand key trends in perishable food items transport developments and provide important insights for Indian policymakers as they try to decrease carbon footprint fuel dependency improve energy efficiency in the urban area transportation sector. They more focus on SHECRs for city home delivery and reduce emissions from vehicles.

2. Cold chain perishable products transportation requirement through SHECRs

The cold chain is responsible for about 2.5% of direct and indirect GHG emissions. It is estimated that up to 31% of the world's food supplied through TRUs in worldwide and its growing with10% annual rate. Today more than 40% of food product requires refrigeration in cold chain deliveries.15% of total global energy is used in cold chains and its cooling system. The world population has increased with a faster rate in the last 50 years. It is estimated that the global population is going to reach over 9 billion people in the next three decades (Fredriksson & Liljestrand, 2015). The world near the 2050s will be faced with a new food problem challenge. Food wastage has increased globally in the past few years, because of complexity persists in-coordination among the members of the food supply chain. In order to increase efficiency and reduce the adverse impacts of urban goods distribution, a number of

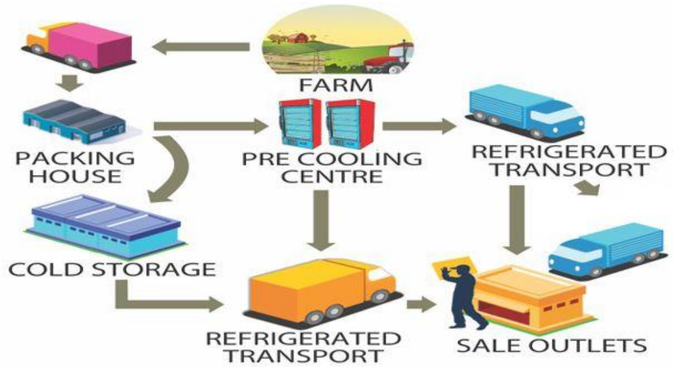

Fig. 1. Cold chain transportation.

cities have launched major initiatives to enhance cold chain transportation systems, finance organizational and technological research innovation and introduce new traffic regulations (Saskia et al., 2016). Perishable products transportation in the cold chain has become a necessary part of the food chain. It is used in all stages food chain as shown in figure 1.

3. Effect of temperature on perishable food products self-life during transportation

During cold chain transportation, perishable fresh food deterioration raises due to ambient temperature rise. The shelf life of fresh food decreases with increasing external environment temperature, as shown in figure 2. All perishable fresh food products are maintained storage temperature between 0^{o}C to 10^{o}C because most bacterial pathogens grow within temperature range 20^{o}C to 45^{o}C. For proper preservation maintains temperatures below 0^{o}C is necessary during storage, because at 0^{o}C slow progressive change in organoleptic quality. It does not objectionable for some time. Different type of vegetables and fruits (tomatoes, cucumbers, eggplants, potatoes, and lettuce) received freezing injury when these are cool at a temperature below 0^{o}C. Bacterial grow rate perishable fresh products at different temperatures is shown in figure 2. The cold chain performance is clear affected by the ambient temperature of the environment. The direct relation between climate and perishable products distribution cannot be ignored (James and James, 2010). High-temperature differences between storage and ambient temperature will raise the risk of product quality (Valli et al., 2013 and Ayyad et al., 2017). Presently, more than one-third of the food produced

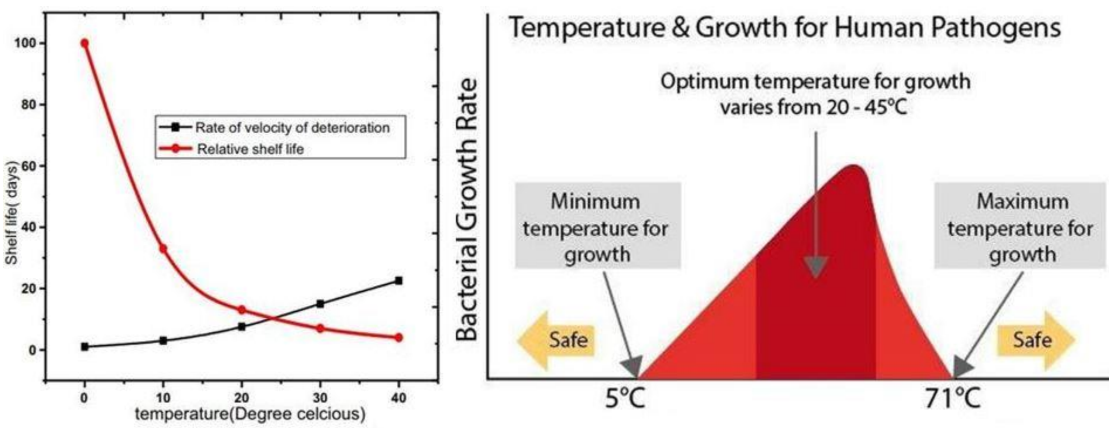

Fig. 2. Self-life and bacterial growth in perishable fresh products after increasing environment temperature.

Table 1. Light commercial vehicle use in market with source of energy.

Author name	Energy source	Barriers	Economics & environmental benefits
Tozzi et al.	D & M	NA	NA
Lebeau et al.	E	Acquisition costs, Capacity (weight and dim.)	Reduction of CO_2 emissions and atmospheric pollutants
Roumboutsos et al.	E	Operational cost, Recharge infrastructure	Reduction of CO_2 emissions, atmospheric pollutants, and noise
Montwill	E	NA	NA
Thompson& Hassall	E	NA	NA
Alessandrini et al.	E	Recharge infrastructure	Reduction of CO_2 emissions and atmospheric pollutants
Faccio & Gamberi	E	NA	Operational cost, Reduction of CO_2 emissions and atmospheric pollutants
Lebeau et al.	E	Fleet acquisition costs	Reduction of CO_2 emissions and atmospheric pollutants
Andaloro et al.	E	Acquisition costs, Capacity (weight and dim.)	Reduction of CO_2 emissions and atmospheric pollutants
Schau et al.	E	Infrastructure, vehicles charging time	Reduction of CO_2 emissions and atmospheric pollutants
Margaritis et al.	E	Cargo consolidation	NA
Rizet et al.	E	Recharge infrastructure	Traffic congestion, Reduction of CO_2 emissions and atmospheric pollutants
Taniguchi et al.	D	Cargo consolidation centre	centre - Reduction of CO_2 emissions, atmospheric pollutants and noise

*E- Electric, D- Diesel, M- Methane

universally is lost to waste/spoilage. Therefore, in food preservation cold chain transportation plays an important role in addressing world hunger. Light commercial vehicle use in the market with a source of energy as shown in table 1.

4. SHECRs operating principle

The operating principle of SHECRs is explained in figure 3. Four PV modules were installs on the top roof of the vehicle. These panels convert solar energy directly into DC electric power. SHECRs use four lead-acid automotive batteries which are connected in series and produced 48 volts. The maximum power point tracking (MPPT) controller was used to get the maximum power output from solar panels for charging batteries. The brushless direct current (BLDC) electric motor (1000W) was set up to convert battery bank power into mechanical impel energy for SHECRs. This type of motor consumed less power and is operating with minimum noise. Brushless direct current (BLDC) electric motor is safe to use in any session. The motor controller of the motor senses the position of the form stator and supplies the energy to the rotor by using Hall Effect sensor.

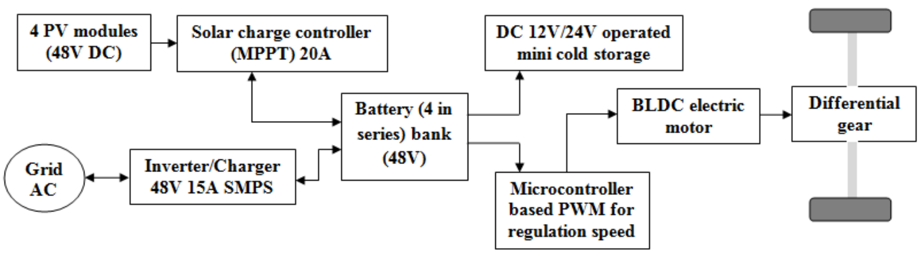

Fig. 3. Block diagram of SHECRs.

Fig. 4. SHECRs photographic and software view (solid works).

Power transmutation was possible BLDC motor to wheels by using differential gears. These type vehicles have the ability to power supply V2H or V2G. The software (solid works) view of fabricated SHECRs with PV panels is shown in figure 4.

5. Temperature effect on storage life of perishable products in cold chain

Perishable fresh food items must be stored at low temperature for maintaining quality prolong the shelf life in transported food chain items. Transporting fresh food items have been widely accepted as a serious aspect for the cold food chain. Refrigerated products temperature during transportation must be kept within close limits to ensure optimum food safety levels. Satisfaction level of the customer depends on the freshness of the delivered food items. The freshness of each delivered products depends on its traveling time and ambient temperature. The freshness of delivered products is higher when it's delivered by refrigerated vehicle. Table 3 shows temperature effects on the storage life of perishable products.

6. Challenges for SHECRs implementation

- The SHECRs technology since its inception sets the main problem of enlarged cost as a result of which it finds lower acceptance in the majority of middle-class income group of the Indian population. But today the government gives subsidies on all type of electric vehicles.
- Battery bank charging times for all SHECRs are few hours, thus this leads to a lower acceptance as compared to the conventionally fueled vehicles.
- Electricity demands in all power consuming sector is already quite high; the use of SHECRs will give extra load on the Indian power grid.
- Considering the Indian population the amount of a load of the power system will be extremely high during the peak load periods.
- For SHECRs requires efficient solar panels at a lower cost, it is only possible by government subsidies.
- Short battery life is also one kind of problem in SHECRs because battery bank gives efficient voltages for a few years.
- SHECRs is suitable for the medium load (100-300 kg) and medium distance (20-85 km).
- SHECRs only uses in-plane area delivery process.

Table 2. Emission produced via different type vehicles used in cold chain [Lujano et al. & Sasaki et al.].

Parameters name	Gasoline vehicle	Electric vehicle	SHECRs
Emission type	CO, NOx, HC & CO_2	No emission	No emission
Max. speed range	50 to 60 km/h	25–30 km/h	24–29 km/h
Mileage	18 to 20 km/L (City) 25 km/L (Highway)	Battery capacity: 70–85 km	96 km per complete charging

Table 3.Temperature effects on storage life of perishable products [Bharj et al., 2015].

Product	Optimum Temperature [ºC]	RH [%]	Storage Life
Fresh products			
Apple	-1 to 4.5	90-95	1–12 m
Asparagus	2	95-100	2–3 w
Avocado	3-13	85-90	2–8 w
Banana	13-15	90-95	1–4 w
Blueberries	0.5-1	90-95	2–3 w
Broccoli	0	90-100	2 w
Cabbage	0	95	2–3 m
Cucumber	7-10	95	2 w
Eggplant	8-12	90-95	1 w
Ginger	13	65	25 w
Guava	5-10	90	2–3 w
Green beans and field peas	3-7	95	5–10 d
Leafy vegetables	0	95	1–2 w
Lime	9-10	85-90	6–8 w
Mango	13	90-95	2–3 w
Onion	0	70	2–3 m
Papaya	7-13	85-90	1–3 w
Peach	0	95-98	2–4 w
Peppers	7-10	90-95	2–3 w
Potato	3-4.5	90-95	5–8 m
Strawberry	0	90-95	5–7 d
Sweet corn	0	90-95	5–7 d
Sweet potato	13	90	6–12 m
Tomato, pink	9-10	85-95	7–14 d
Turnip	0	95	4–5 m
Watermelon	10-15.5	90	2–3 w
Fish	0-3	90	1–3 d
Milk	4	-	3–5 d
Cooked food			
Vegetables	0-4	-	2–4 d
Fish	0-4	-	2–3 d
Meat	0-4	-	3–5 d
Soup	0-4	-	2–3 d

*d-Days, w- Weeks, m- Months

7. Conclusions

Globalization increases the import and export all over the world at longer distances. Low cost and energy efficient temperature control transportation require for perishable products transportation. Temperature control TRUs are transporting goods from production level to retailer (customer final sale). These TRUs are playing an important role in urban transportation especially in cold chain supply. But current IC engine based refrigerated TRUs is producing a huge amount of pollution and using carbon footprint fossil fuels. Thus, an alternative method of cold chain transportation is required. The major conclusions coms from this study are listed below:

- Metro-city food retail sector is growing faster rate in our country, worth around 15 billion USD 40%.
- VCR system with IC engine based refrigerated TRUs consumed higher energy as compare to SHECRs.
- SHECRs use in cold chain supply is more useful as environmental and economic point of view.
- Solar PV panels can successfully be used for SHECRs to reduce dependence on fossil fuel and grid electricity.
- It reduced transportation cost of products means reduced selling cost of the product and provides direct benefit to the customer.
- It can be supplied with electricity V2H (vehicle to home) in remote areas.
- SHECRs offer fewer burdens on the power grid at peak hours.
- SHECRs fit for transportation of perishable products in urban areas up to 10-85 km with products load 150-360 kg.

India has the adequate potential of solar energy but a combination of the right technology and correct human behaviour is desired because every technology has its own limitation.

References

Amini, M.H., Moghaddam, M.P., Karabasoglu, O., 2017. Simultaneous allocation of electric vehicles' parking lots and distributed renewable resources in smart power distribution networks. Sustain.

Automotive Fleet. Environmental Danger of Global Refrigerated Transport Studied 2016; 2015. Accessed on 08.3.2018.

Ayyad, Z., Valli, E., Bendini, A., Accorsi, R., Manzini, R., Bortolini, M., Gamberi, M., GallinaToschi, T., 2017. Simulating international shipments of vegetable oils: focus on quality changes. Italian J. Food Sci. 29, 38-49.

Bharj, R.S., Kumar, S., Kumar, R., 2015. Study on solar hybrid system for cold storage. International Journal of Research in Management, Science & Technology 3.2, 71-74.

Boroojeni, K.G., Amini, M.H., Nejadpak, A., Iyengar, S., Hoseinzadeh, B., Bak, C.L., 2016. A theoretical bilevel control scheme for power networks with large-scale penetration of distributed renewable resources. In: Electro.

Boyette, M.D., Wilson, L.G., Estes, E.A., 2010. Postharvest handling and cooling of fresh fruits, vegetables, and flowers for small farms.

Barbieri, J., Colombo, E., Mungwe, J.N., Riva, F., Berizzi, A., Bovo, C., Ellipsis, Adhikari, R., 2015. Guidelines on sustainable energy technologies for food utilization in humanitarian contexts and informal settlements.

Coulomb, D., 2008. Refrigeration and cold chain serving the global food industry and creating a better future: two key IIR challenges for improved health and environment. Trends Food Sci. Technol. 19, 413-417.

CPCB, 2015. National Air Quality Index. National Air Quality Index for 85 cities at 225 locations. Bulletin of Ambient Air Quality National Ambient Air Quality Monitoring Programme (NAMP) - Manual monitoring system. State Pollution Control Board, New Delhi.

Del -Pero, C., Butera, F.M., Piegari, L., Faife,r M., Buffoli, M., Monzani, P., 2016. Characterization and monitoring of a self-constructible photovoltaic-based refrigerator. Energies 9.9, 749.

Evans, A., Hammond, E.C., Gigiel, A.J., Reinholdt, L., Fikiin, K., Zilio, C., 2014. Assessment of methods to reduce the energy consumption of food cold stores. Appl. Therm. Eng. 62, 697–705.

Food and Agriculture Organization of the United Nations (FAO-2017a). State of Food Insecurity in the World 2015. Accessed on 18.3.2018.

Food and Agriculture Organization of the United Nations (FAO) (2017b). FAOSTAT. Accessed on 20.3.2018.

Food and Agriculture Organization of the United Nations (FAO) (2017c). The future of food and agriculture, trends and challenges. Accessed on 22.3.2018.

Food and Agriculture Organization of the United Nations (FAO) (2017d). Key facts on food loss and waste you should know. Accessed on 23.3.2018.

Fredriksson, A., & Liljestrand, K., 2015. Capturing food logistics: A literature review and research agenda. International Journal of Logistics Research and Applications 18, 16–34.

Garden & Robinson, 2009. J. Food Storage Guide. Answers the Question. Accessed on 24.3.2018.

GBD, 2016. The Global Burden of Disease Study 2013. Institute for Health Metrics and Evaluation, Seattle. Accessed on 25.3.2018.

GOI, 2015b. First Biennial Update Report to the United Nations Framework Convention on Climate Change. Ministry of Environment, Forest and Climate Change, New Delhi. Accessed on 27.3.2018.

GOI, 2016b. Road Transport Year Book (2013–2014 & 2014–2015). Government of India. Ministry of Road Transport & Highways, New Delhi.
WA. Accessed on 28.3.2018.

Gustavsson, J., Cederberg, C., Sonesson, U., Otterdijk v, R., Meybeck, A., 2011. Global food losses and food waste – Extent, causes, and prevention. Paper presented at the inter pack 2011.

Gustavsson J, Cederberg C, Sonesson U, Van Otterdijk R, Meybeck A., 2011. Global food losses and food waste. Rome: Food and Agriculture Organization of the United Nations-2011.

ICAR, 2015. VISION 2020—Indian Council of Agricultural Research.ICAR, New Delhi, India. Accessed on 10.4.2018.

IEA, 2015a. Energy Balances of Non-OECD Countries. International Energy Agency, Paris. Accessed on 12.4.2018.

IEA, 2015b. Energy Statistics of Non-OECD Countries. International Energy Agency, Paris. Accessed on 13.4.2018.

IEA, 2015c. India Energy Outlook. World Energy Outlook Special Report. International Energy Agency, Paris. Accessed on 15.4.2018.

Lujano-rojas, J.M., Dufo-lópez, R.; Atencio-guerra, J.L., Rodrigues, E.M.G., Bernal-agustín, J.L., Catalão, J.P.S., 2016. Operating conditions of lead-acid batteries in the optimization of hybrid energy systems and micro-grids. Appl. Energy 179, 590–600.

MNRE, 2015. National Policy on Biofuels. Government of India. Ministry of New & Renewable Energy, New Delhi. accessed on 18.4.2018.

Morana, J., Gonzalez-Feliu, J., Semet, F., 2014. Urban consolidation and logistics pooling. Planning management and scenario assessment issues. Sustainable Urban Logistics: Concepts, Methods and Information Systems. Springer, Heidelberg, pp. 187–210.

OECD/IEA, 2015. World Energy Outlook Special Report: India. Energy Outlook. International Energy Agency, Paris. Accessed on 15.4.2018.

Osvald, A., Stirn, L.Z., 2008. A vehicle routing algorithm for the distribution of fresh vegetables and similar perishable food. J. Food Eng. 85.2, 285-295.

Paull, R., 1999. Effect of temperature and relative humidity on fresh commodity quality. Postharvest Biol Technol. 15.3, 263–77.

Rahman, S., 2007. Handbook of food preservation. CRC Press-2007.

Regattieri, A., Gamberi, M., Manzini, R., 2007. Traceability of food products: general framework and experimental evidence. J. Food Eng. 81.2, 347-356.

Saskia, S., Mareï, N., Blanquart, C., 2016. Innovations in e-grocery and logistics solutions for cities. Transportation Research Procedia 12, 825–835.

Sasaki, K., Yokota, M., Nagayoshi, H., Kamisako, K., 1997. Evaluation of electric motor and gasoline engine hybrid car using solar cells. Sol. Energy Mater. Sol. Cells 47, 259–263.

Storoy, J., Thakur, M., Olsen, P., 2012. The Trace Food Frame work Principles and guidelines for implementing traceability in food value chains. J. Food Eng. 115.1, 41-48.

Thakur, M., Wang, L., Hurburgh, C.R., 2010. A multi-objective optimization approach to balancing cost and traceability in bulk grain handling. J. Food Eng. 101.2, 193-200.

Taefi, T.T., Kreutzfeldt, J., Held, T., Fink, A., 2016. Supporting the adoption of electric vehicles in urban road freight transport – a multi-criteria analysis of policy measures in Germany transport. Res. Part A: Policy Pract. 91, 61–79.

Wang, C.Y., Wallace, H.A., 2004. Chilling and freezing injury. The commercial storage of fruits, vegetables, and florist and nursery stocks. USA.

WHO, 2016. Global Urban Ambient Air Pollution Database. World Health Organization. Accessed on 23.4.2018.

Xue, M., Kojima, N., Zhou, L., Machimura, T., Tokai, A., 2017. Dynamic analysis of global warming impact of the household refrigerator sector in Japan from 1952 to 2030. J. Clean. Prod.