Negev, Dead Sea and Arava Studies
Dead-Sea & Arava Science Center
מרכז מדע ים-המלח והערבה
Under the Auspices of Ben-Gurion University of the Negev
בחסות אוניברסיטת בן-גוריון בנגב
מחקרי הנגב, ים המלח והערבה

Research article
מאמר מחקר

The potential of used cooking oil as a feedstock for biodiesel production for Eilat's public transportation

T. Abu Hamed[1, 2*], S. Chillara[2], J. Nadler[2], M. Mark[2], T. Zilbershtein[2]

[1] Dead Sea and Arava Science Center, Tamar Regional Council, Israel
[2] Arava Institute for Environmental Studies, Kibbutz Ketura, Israel

* Corresponding author: tareq@arava.org + 972 8 6356618 fax + 972 8 6356634

A B S T R A C T

This paper summarizes the biodiesel production capacities and the used cooking oil-based feedstock potential of Eilat for the first time. Israel's transportation sector is currently dependent on petroleum-based vehicles that pollute the environment and threaten public health. This study analyzes low-emission fuel alternative biodiesel for potential use in Eilat's public transportation. Calculations had been made in order to determine the current energy demand based on bus route length, determining the amount of waste oil needed to meet this requirement. Results show that the restaurants' sector can provide used cooking oil for the production of 220,000 liters of biodiesel annually. These results show that the use of used cooking oil as a feedstock can generate enough biodiesel to meet the fuel demand of the public transportation in Eilat.

Keywords:
Used cooking oil
Biodiesel
Public transportation
Eilat

1. Introduction

The transportation sector is one of the largest emitters of carbon dioxide (CO_2) and other greenhouse gases. More than 21% of CO_2 emissions in the EU (European Union) have been attributed to vehicle emissions, and transportation is the only sector whose emissions keep increasing (Laizans et al., 2016). In 2015, the transportation industry in the United States was responsible for 27% of total greenhouse emissions. Over 90% of the fuel used for transportation is petroleum-based, which includes gasoline and diesel (Ribeiro et al., 2007). In 2016, the transportation in Israel was responsible for 90% of total CO emissions, 27% of total CO_2 emissions, and 19% of total NOx emissions. This indicates a need to reduce fossil fuel dependence in response to urban population and economic growth (Central Bureau of Statistics, 2017).

Biodiesel is a nontoxic and biodegradable liquid fuel produced from vegetable oils and animal fats, a cleaner burning replacement for petroleum-based diesel fuel with a relatively high flash point. It is also safer to transport or handle than petroleum diesel (Demirbas, 2003).

Biodiesel is as a mixture of long chain fatty acid alkyl esters. It is commonly produced by the esterification of free fatty acids or the transesterification of triacylglycerol from different renewable biomass recourses, with an excess of methanol or ethanol, in or without the presence a catalyst. The predictions for the global production of biodiesel shows a growth from 30

million cubic meters in 2014 to 39 million cubic meters in 2024, a 27% increase (OECD/FAO, 2015).

Biodiesel provides 93% more net energy per gallon than is required for its production, reduces greenhouse gases by 41% compared with diesel, and has minimal impact on human and environmental health through reduced release of nitrogen, phosphorus, and pesticides (Hill et al., 2006).

Compared to diesel-fueled engines, the performance of biodiesel-fueled engines is significantly better in terms of thermal efficiency, brake-specific energy consumption, and smoke opacity, wear of vital components and exhaust emissions for an entire range of operations (Agarwal and Das 2001;Ulusoy et al., 2018). Compared to biodiesel, the combustion of conventional fossil diesel fuel produces more emissions of particulate matter (Canakci and Van Gerpen, 2003; Lapuerta et al., 2008; Tat, 2003), carbon monoxide (Mittelbach and Tritthart, 1988) and total hydrocarbon (Payrı et al., 2005).

In a 2012 presentation on the Fuel Choices Initiative, the Israeli Prime Minister's Office set a timeline for implementing current technologies and continuing research and development of future alternative fuel technologies as shown in Figure 1.

The Fuel Choices Initiative also supported electric public transportation through which the Dan bus company in 2013 pledged to upgrade 25% of its fleet to electric buses (Grossman, 2016). In 2016 the Keren Kayemeth LeIsrael – Jewish National Fund and the Ministry of Environmental Protection invested twenty million NIS to partially subsidize fifty electric buses for public bus companies (Grossman, 2016).

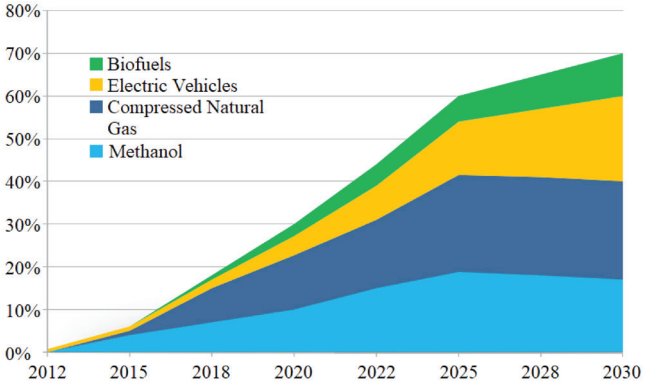

Figure 1: Expected penetration rate for transportation fuel alternatives in Israel (Rosner, 2012)

Despite global advancements in biofuels and electric vehicles research, Israel is only now shifting to fuel alternatives for energy security and developing appropriate technologies with limited natural resources as evidenced by Figure 2.

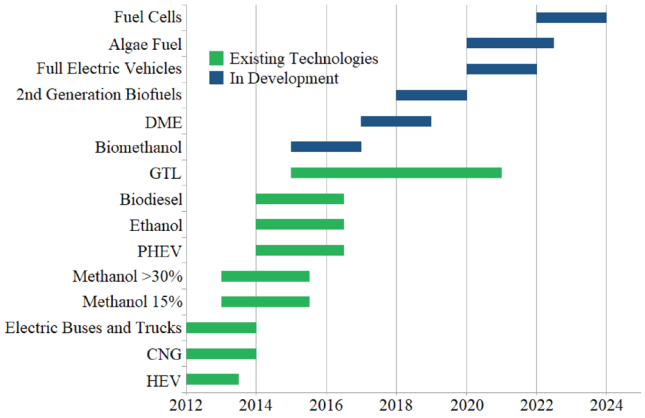

Figure 2: Forecast of economic viability of fuel technologies in Israel (Rosner, 2012)

2. Eilat as a case study

Eilat is in the southernmost tip of Israel. Minimal precipitation, minimal cloud coverage, and ample land make the Arava region suitable for solar energy production. Fifteen privately-owned solar plants of varying sizes supply 70% of the electricity demand of the whole Arava Valley including Eilat (Eilat-Eilot Renewable Energy Initiative, 2018).

For approximately the past ten years, Eilat has been involved in a process of moving towards a more sustainable way of living. According Eilat's Sustainability Report, the municipality declares to focus on solar energy generation for electricity use in households, street lights and public buildings. Additionally, the vision also emphasizes environmental education programs that run for different age groups throughout the city.

As part of this whole project the city of Eilat is encouraging people to increase their use of bikes around the city, by installing bike lanes. They provide a discount to public transportation for university students and arrange transportation for students to school and back. They do not mention at all use of biofuels or electricity for their public transportation. Not much is mentioned regarding renewable energy usage within the public transportation system in Eilat's sustainability visioning. Despite that, an OECD report recommends Eilat as a green city pilot (OECD, 2012). Shifting towards electric buses is stressed as part of the green city pilot program. Alternative fuels can be a significant change for the city of Eilat, for both environmental and public health reasons.

In collaboration with the Covenant of Mayors for Climate and Energy, Eilat set solar production goals to benefit several sectors: the public sector through increased efficiency of buildings and utilities, the private sector through subsidization of solar rooves and household monitoring with Ben Gurion

University, and the commercial sector through assistance with energy surveys or loans for carbon offsetting. Along with the Mitzpe Yam green neighborhood pilot and solar potential mapping projects, Eilat is working with the Ministry of Transportation and the Fuel Choices Initiative to assess the economic feasibility of electric taxis (Eilat-Eilot Renewable Energy Initiative, 2018).

Nearly 120,000 tourists flew to Eilat in 2016, and a 250,000 euro government grant per weekly flight in 2017 to airlines offering new direct flights to Eilat led to 50 weekly flights and an 11% increase in hotel occupancy in the first half of 2017 from the same period in 2016 (Kandel, 2017; Schindler, 2018). The new Ilan and Assaf Ramon Airport, expected to finish construction this year, will replace both Eilat and Ovdat Airport to eventually serve 4.25 million internal and external tourists (Schindler, 2018).

Solar power potential and waste cooking oil from restaurant tourism could allow for electric and biodiesel buses to both replace conventional public transportation in Eilat and help fulfill Eilat's energy independence goal. Fuel alternatives would use renewable and recyclable resources to mitigate public transportation emissions, thereby inherently reducing cost and fossil fuel reliance.

Used cooking oil can be sourced from many a sector and source. It is typically collected from food industries, restaurants and hotels, but may also be collected from homes. In Eilat in a specific sector such as restaurants and hotels there may also be a wide variation in the quantity and quality of the produced used cooking oil, depending on the type of restaurant or the time of year.

Used cooking oil as a feedstock for biodiesel production has many benefits: reduction in the usage of fossil diesel; reduction in waste disposal; and used cooking oil is kept out from the reuse by the human food chain. This research investigates the potential of used cooking oil as feedstock for biodiesel generation which can be used as fuel for public transportation, and its feasibility to be adopted and accepted in the City of Eilat

3. Methods

3.1. Calculation of the amount of used cooking oil

There is a lack of reliable statistics on virgin, used cooking oil or collected oil in Eilat. In this study data from the literature is used to estimate the collectable potential of used cooking oil in Eilat. According to the Central Bureau of Statistics, there are 50 hotels, 173 restaurants, and 32 cafes in Eilat (Central Bureau of Statistics, 2017). The estimated total output of waste oil from a restaurant is approximately 1,200 liter per year (Miller, 2007). In this study the domestic used cooking oil was not included.

3.2. Calculation of the required amount of biodiesel to meet the public transportation sector in Eilat

There are six local bus lines in Eilat, each route ranges from 14 to 21 kilometers, and all lines together make a total of 3,255 kilometers per day (Table 1).

Table 1: Eilat Local Egged bus route and travel distance per ride and day (Egged Bus Company, 2018)

Route	Total km per ride	Total rides per day	Total km per day per route
1	18	74	1,332
2	18	74	1,332
5A	15	3	45
6A	21	2	42
15	14	18	252
16	14	18	252
		Total Traveled km per day	3,255

4. Results and Discussion

Assuming that 50 hotels and 173 restaurants in Eilat generate 1,200 liter/year of used cooking oil each, the total amount of used cooking oil in Eilat will be around 220,000 liters per year. When converting used cooking oils to biodiesel, the volume conversion factor for the used cooking oil to potential biodiesel production is assumed to be one. This is because of the negligible change in volume due to the addition of methanol, which roughly equals the volume of the side products such as glycerin and non-dissolved solids removed. Thus the total amount of biodiesel oil in Eilat will be equivalent to the amount of used cooking oil, which is around 220,000 liters per year.

The fuel economy of a standard bus is 2.6–3 km/l (Holmberg et al., 2014). Multiplying the fuel economy to the total traveled kilometers by Eilat local buses per year (300 days, Fridays are half days and Saturdays are holidays) gives us the needed volume of biodiesel for city use, which is approximately 325,000–375,000 liters per year.

Biodiesel can be used as pure fuel or as blended, B20 (20% biodiesel, 80% petro-diesel), B5 and B2. Most of the biodiesel blends in Europe and the USA are equal or less than B20. Biodiesel blends higher than B20 require engine modifications to minimize maintenance requirements and performance problems (USEPA, 2010).

In the case of B20 for Eilat public transportation, the generated amount of biodiesel (220,000 liters) will be more

than enough to meet the fuel demand (thrice more than needed). In the case of B100, the generated amount of biodiesel will meet only 58 to 68% of the fuel demand of Eilat's public transportation.

In 2015, Israel's CO_2 production was around 70 million tons, of which almost 40% generated by motor vehicles. Biodiesel is a promising option that can replace other fossil fuels. Biodiesel fuel can contribute to reducing greenhouse gas emissions and can reduce the production of many toxic pollutants in Israel. In addition, biodiesel fuel will help ensure Israel's energy independence.

The use of biodiesel will reduce the reliance on fossil fuels and oil for transportation and thus will assist our nation to reach the GHG emissions reduction target of 8.8 tCO2e by 2025 and 7.7 tCO2e by 2030, as set by the Israeli Government Decision No. 542 purposes (Ministry of Environmental Protection, 2016). This Decision included sector specific targets such as energy efficiency, renewable energy and public transport. Israel is planning to shift from private to public transportation by 20% relative to BAU scenario, including a transition from diesel to compressed natural gas for heavy vehicles. These goals can be achieved not only by switching to natural gas, but also by the use of alternative fuels such as biodiesel.

The unreliable supply quantity and quality of used cooking oil have been the impeding factors for used cooking oil to be considered as a commercially viable source for biodiesel production (Kumaran et al., 2011). However, there are cities and states that have developed policies, such as standards and moral benefits and economic incentives, to promote collection of used cooking oil for biodiesel production. Fryer to Fuel Collection Program in Santa Cruz County in California is a good example of free weekly service provided to restaurants (USEPA, 2017); San Francisco, another Californian city, offers used cooking oil collection program through its Water Power Sewer to produce biofuel to run San Francisco fleets (San Francisco Water Power Sewer, 2018) ; Also North Carolina has a cooking oil recycling program (The Metropolitan Sewerage District of Buncombe Count, 2018).

To maintain a low or free price for used cooking oil, the restaurants owners and households will have to develop a practice of collecting used cooking oil. In this line Eilat Municipality will have to promote a strategy to collect the used cooking oil, for example, through the municipal solid waste collection program. As mentioned above, several cities and regions have developed such programs successfully.

5. Conclusion

This study reviews current biodiesel-based transportation in Eilat and evaluates its feasibility. Biodiesel-based buses powered by waste cooking oil can replace petroleum-based fuels to help Eilat achieve 100% energy independence. If Israel implements policy to approve B100, it can also subsidize a new bus fleet, or provide passenger and tourist incentives.

Biodiesel is considered environment friendly and its' carbon dioxide emissions benefits are important. Like other renewable biomass fuels, the CO_2 released during biodiesel combustion is offset by the CO_2 captured by the plants from which fuel is produced; and considering the life cycle greenhouse gas emissions, petro-diesel has substantially higher emissions than used cooking oil biodiesel (Pleanjai et al., 2009).

The use of waste or used cooking oil for biodiesel production is an example of a good practice that if well managed can meet the criteria of a clean economic activity in the context of the promotion of low carbon energy use, while also meeting the objective of regional development, creating jobs, health benefit and increase social inclusion.

Many countries in the world have a large surface area and are blessed with natural resources, including plentiful agricultural and oily feedstock for the biodiesel production. However, there is a lack of information about the biodiesel production potential in smaller countries such as Israel, which heavily relies on imports of the majority of the liquid fuels. In order to get a more accurate numbers about the amount of used cooking oil in Eilat, surveys are planned to be conducted with restaurants, hotels and homes in Eilat.

Israel should follow the developed world to use and introduce biodiesel among other biofuels based on local resources in order to mitigate the fossil fuel dependence and to decrease negative impacts on the environment and climate.

References

Agarwal, A. K., Das, L. M., 2001. Biodiesel development and characterization for use as a fuel in compression ignition engines. Trans ASME 123 (2), 440–447.

Canakci, M., Gerpen Van, J. H., 2003. Comparison of engine performance and emissions for petroleum diesel fuel, yellow grease biodiesel and soybean oil biodiesel. Transactions of the ASAE 46 (4), 937–944.

Central Bureau of Statistics, 2017. Emissions from fuel combustion, by type of consumer. http://www.cbs.gov.il/reader/shnatonenew_site.htm

Central Bureau of Statistics, 2017. Tourist hotels, rooms, occupancy, person-nights, revenue and jobs in tourist hotels in selected localities. http://www.cbs.gov.il/reader/shnatonenew_site.htm

CMU, Carnegie Mellon University, Which Alternative Fuel Technology is Best for Transit Busses? https://www.cmu.edu/energy/education-outreach/public-outreach/17-104%20Policy%20Brief%20Buses_WEB.pdf

Demirbas, A., 2003. Biodiesel fuels from vegetable oils via catalytic and noncatalytic supercritical alcohol transesterification and other methods: A survey. Energy Conversion and Management 44, 2093–2109.

Egged Bus Company, 2018. https://mslworld.egged.co.il/?language=he&state=#/origindestination/0/0/false/2600-119/1744/2600-119/6085/1/-1

Eilat-Eilot Renewable Energy Initiative, 2018. Eilat Smart Green City. http://www.eilateilot.org/eilat-city

Fuel Efficiency: Modes of transportation ranked by MPG. https://truecostblog.com/2010/05/27/fuel-efficiency-modes-of-transportation-ranked-by-mpg

Grossman, M. M., 2016. 50 electric buses expected to hit Israel's roads by 2017. The Jerusalem Post. 24.03.2016. http://www.jpost.com

Hill, J., Nelson, E., Tilman, D., Polasky, S., Tiffany, D., 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. Proceedings of the National Academy of Sciences of the United States of America, 103.

Holmberg, K., Andersson, P., Nylund, N. O., Mäkelä, K., Erdemir, A., 2014. Global energy consumption due to friction in trucks and buses. Tribology International 78, 94–114.

Kandel, R. R., 2017. Eilat airport slated to open in 2018 after years of delay over post-gaza war security requirements. Haaretz. 20.11.2017 https://www.haaretz.com

Kumaran, P., Mazlini, N., Hussein, I., Nazrain, M., Khairul, M., 2011. Technical feasibility studies for Langkawi WCO (waste cooking oil) derived-biodiesel. Energy 36 (3), 1386–1393.

Laizans, A., Graurs, I., Rubenis, A., Utehin, G., 2016. Economic viability of electric public busses: Regional perspective. Procedia Engineering 134, 316–321.

Lapuerta, M., Agudelo, J. R., Rodriguez-Fernandez, J., 2008. Diesel particulate emissions from used cooking oil biodiesel. Bioresource Technology 99 (4), 731–740.

Metropolitan Sewerage District of Buncombe County, 2018. http://www.cookingoilrecycling.org

Miller, J., 2007. Determining the rate of used cooking oil output by the restaurant industry in the Salt Lake Valley, UT. Waste oil resources 1–14.

Ministry of Environmental protection, 2016. National Plan for the Reduction of GHG Emissions, http://www.sviva.gov.il/English/env_topics/climatechange/NatlEmissionsReductionPlan/Pages/default.aspx

Mittelbach, M., Tritthart, P., 1988. Diesel fuel derived from vegetable oils, III. Emission tests using methyl esters of used frying oil. Journal of the American Oil Chemists' Society 65 (7), 1185–1187.

OECD, 2012. Eilat green smart city presentation of clean-tech clustering as an engine for local development: The Negev region, Israel. http://www.oecd.org/israel/presentation-clean-tech-clustering-as-an-engine-for-local-development-israel.htm

OECD, 2015. Food and agriculture organization of the United Nations. OECD-FAO Agricultural Outlook 2015. OECD Publishing, Paris. pp. 126–142.

Pleanjai, S., Gheewala, S. H., Garivait, S., 2009. Greenhouse gas emissions from production and use of used cooking oil methyl ester as transport fuel in Thailand. Journal of Cleaner Production 17 (9), 873–876.

Payri, F., Macián, V., Arregle, J., Tormos, B., Martínez, J. L., 2005. Heavy duty diesel engine performance and emission measurements for biodiesel (from cooking oil) blends used in the ECOBUS project. SAE technical papers. doi: 10.4271/2005-01-2205

Ribeiro, K., Kobayashi, S. S., Beuthe, M., Gasca, J., Greene, D., Lee, D. S., Muromachi, Y., Newton, P. J., Plotkin, S., Sperling, D., Wit, R., Zhou, P. J., 2007. Transport and its infrastructure, climate change 2007: Mitigation of climate change. In: Metz, B., Davidson, O. R., Bosch, P. R., Dave, R., Meyer, L. A., (Eds.), Working group III contribution to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Rosner, E., 2012. Strategic plan. http://fuelchoicessummit.com/portals/37/Docs/2014Presentations/Eyal_Rozner.pdf

San Francisco Water Power Sewer, 2018. http://sfwater.org/index.aspx?page=154

Schindler, M., 2018. More tourists visit Israel in 2017 than ever before. The Jerusalem Post. 2.1.2018. http://www.jpost.com

Tat, M. E., 2003. Investigation of oxides of nitrogen emissions from biodiesel fueled engines. PhD thesis, Iowa State University.

Ulusoy, Y., Arslan, R., Tekin, Y., Surmen, A., Bolat, A., Sahin, R., 2018. Investigation of performance and emission characteristics of waste cooking oil as biodiesel in a diesel engine. Petroleum Science 5, 396–404.

USEPA, 2010. Biodiesel, technical highlights, EPA-420-F-10-009. https://nepis.epa.gov/Exe/ZyPDF.cgi/P1006V0I.PDF?Dockey=P1006V0I.PDF

USEPA, 2017. Fryer to Fuel Collection Program. https://19january2017snapshot.epa.gov/www3/region9/waste/biodiesel/docs/fryer-to-fuel-report.pdf