International Journal of
Science and Engineering Investigations vol. 7, issue 77, June 2018
ISSN: 2251-8843

Life Cycle Assessment of the Production of the Germinated Oil Palm Seeds and the Production of Oil Palm Seedling

Khaled Obaideen[1], Pow-Seng Yap[2], Yong Chai Tan[3],
Muhamad Bin Awang[4], Abdul Azim Bin Abd Ghani[5], Vijaya Subramaniam[6]
[1]Institute of Graduate Studies, Faculty of Engineering and the Built Environment, SEGi University
[2]Department of Civil and Construction Engineering, Faculty of Engineering and Science, Curtin University Malaysia
[3]Faculty of Engineering and Built Environment, SEGi University
[4]Faculty of Environmental Studies, Universiti Putra Malaysia
[5]Faculty of Computer Science and Information Technology, Universiti Putra Malaysia
[6]Engineering and Processing Division, Malaysian Palm Oil Board
([1]khaled.obaideen@gmail.com, [2]psyap.yps3@hotmail.com, [3]tanyongchai@segi.edu.my,
[4]muhamadrita@yahoo.com, [5]azim@upm.edu.my, [6]vijaya@mpob.gov.my)

Abstract- There is a limited number of studies on the life cycle assessment (LCA) of the germinated oil palm seeds, and oil palm seedling. In addition, over the past few years, there were major updates on the LCA. This paper aims to update environmental impact associated with the production of the germinated oil palm seeds, and the production of oil palm seedling. The life cycle inventory data was obtained from the Malaysian Palm Oil Board (MPOB) and the newest version of Ecoinvent (Version 3.4). The system boundary included activities in germinated oil palm seeds production unit and production of the seedling. ReCiPe Midpoint with Hierarchist perspective was used as an indicator of the life cycle impact assessment (LCIA). The production of 1000 germinated oil palm seeds generated 1.03 kg CO_2 eq while the production of a single oil palm seedling generated $1.42*10^{-2}$ kg CO_2 eq, therefore the environmental impact can be considered as insignificant compared with the other stages of the production of the palm oil biodiesel.

Keywords- *Open-Source Software, Life Cycle Assessment (LCA), Palm Oil Nursery, Germinated Oil Palm Seeds, Palm Oil Seedling*

I. Introduction

The decision makers need a tool to assist them in reducing the environmental impact from their products. One of those tools is life cycle assessment (LCA) [1]. LCA is a quantitative tool used to evaluate the environmental impacts associated with a product, process, or activity ISO 14044 [2].

The planted area for oil palm in Malaysia is 5.8 million ha Malaysian Palm Oil Board (MPOB) statistics, [3]. This makes Malaysia the second oil palm producer in the whole world after Indonesia. Palm oil industry in 2018 is expected to contribute RM 69 billion (USD 16 billion) to the country, which accounts for 5-6 % of Malaysia's gross domestic product (GDP) [3]. Smallholder farmers play a crucial role in the palm oil industry. For instance, in 2017, they produced around 40% of the world's palm oil Roundtable on Sustainable Palm Oil (RSPO), [4]. Employing an open-source tool will assist smallholder farmers to mitigate the environmental impact and will promote the sustainability of palm oil.

This study concentrates on the first two subsystems of the production phases of the palm oil biodiesel i.e the production of the germinated oil palm seeds and the production of the palm oil seedling in the nursery. The first subsystem of the oil palm supply chain is the production of germinated oil palm seeds. This subsystem assists to have closer supervision over the controlled area during the first 10 to 12 months of oil palm seeds [5].

Fresh fruit bunches (FFB) is first brought from the plantation to the seed production unit. After recording the weight, the stall will be separated from the spikelets, after retting the fruits in trays for around 3-5 days to allow them to detach, the isolation and separation process of normal fruits from parthenocarpics were carried out. An electrical motor driven depericarper usually will be used to separate the mesocarp from the seeds. Those seeds are soaked to ensure the optimal moisture content. After they are washed with a suitable detergent to remove the mesocarp oil from their surface before fungicide treatment start which involved vacuum infiltration, which is killing fungal spores inside the shell on the kernel surface, as well as on the outside of the seed. It is recommended that this treatment should be used permanently whenever the seed is transported from one area to another [5], [6]. To break the dormancy of oil palm seeds for germination the heat treatment is used [7]. Finally, only typical and good condition seeds are packed and transferred to the seedling production unit [5].

There are two common practices to produce the palm oil seedling i.e., the single stage and the double stage. The main benefit of the single-stage nursery is to reduce the overall time in the nursery by about 2 months, whereby the seedling is raised up directly into big polythene bags until they are ready for transplanting on the main plantation field. However, the most practiced method is the double-stage nursery system. In the double-stage, the seedlings are sown in small polybags, and this stage is usually called pre-nursery [8]. Then those seedlings are kept under protective sunlight or in shade for 3-4 months. In the second stage, which is called the main nursery, the seedlings are moved to a new larger polybag (30-38 cm) for about 12-14 months [9]. The seedlings are raised under direct sunlight. When the seedlings are ready, they are transplanted to plantation area. The number of germinated oil palm seeds in 2017 was around 50 million germinated seed [10]

An open-source software had been used, OpenLCA 1.7 [11] in this study. The OpenLCA is an open-source software that is user-friendly and it allows the user to analyze the environmental impacts from the products [12].

ReCiPe methodology is more supportive for the decision maker [13] therefore it was employed in life cycle impact assessment (LCIA). ReCiPe covered approximately 3000 substances whereas Eco-indicator covered approximately 391 substances [14]–[18]. The OpenLCA was used by Reeb et al. [19] but the old version of Ecoinvent was used and TRACI as impact assessment which included nine impact categories. This study analyzed both the production of the germinated oil palm seeds and the production of oil palm seedling using the recent version of Ecoinvent database (version 3.4).

II. Materials and Methods

A. Objectives

The main objectives of this study are:

- To quantify and update environmental impacts associated with the production of germinated oil palm seeds and the production of palm oil seedling using ReCiPe midpoint approaches.
- To obtain comprehensive results by employing ReCiPe Midpoint.
- To employ the open-source software for the implementation of the LCA of the production of the germinated oil palm seeds and production oil palm seedling.
- To evaluate the opportunities to reduce the possible impacts especially the smallholder.

B. Functional unit

The functional unit for the first subsystem, namely the production of the germinated oil palm seeds selected was 1000 germinated oil palm seeds. For the second subsystem, namely the production of seedling a single oil palm seedling was used as a functional unit.

C. Allocation of co-products

No allocation needed because of the simplicity of the production system.

D. System boundary

This study started from the transferring of the transportation of the FFB from mother oil palm to the seed production unit, seed germination process, management of germinated oil palm seeds and delivery to the nursery. Fig. 1 presents the subsystem boundary for the production of the germinated oil palm seeds.

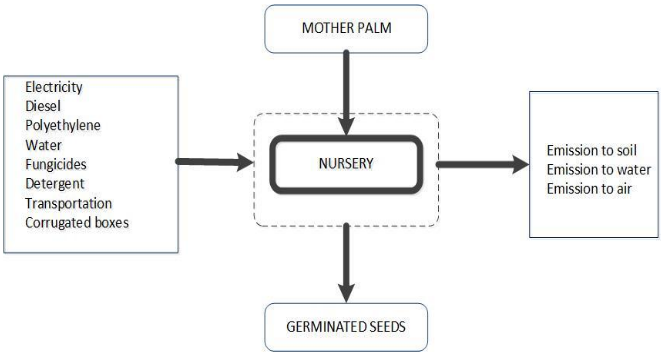

Figure 1. Boundary of LCA production of oil palm germinated seeds

The second subsystem of this study begins from the transport of the germinated oil palm seeds to the nursery and ending with the transport of 12-month-old seedlings in large polybags to the plantation area. Fig. 2 illustrates the subsystem boundary for the production of the production of oil palm seedling.

Tables I and II show the included and excluded activities of this study. All the processes are considered relevant unless excluded based on the exclusion criteria.

TABLE I. SYSTEM BOUNDARY (INCLUDED CRITERIA)

Production of oil palm germinated seeds	Production of oil palm seedling
Manufacturing of fungicides inputs e.g. benomyl and thiram	Manufacturing of agricultural inputs, *e.g.* polybags, fertilizers, insecticides, herbicides and fungicides
Manufacturing of small polyethylene bags	Manufacturing of polyvinylchloride for pipes
Transportation of fungicides; benomyl and thiram	Transportation of polybags, fertilizers, insecticides, herbicides, and fungicides
Water supply	Water supply
Manufacturing of chemicals e.g. sodium hypochlorite, formalin, lissapol, dettol and spirit	Agricultural activities, e.g. application of fertilizers, insecticides, herbicides, and fungicides; use of polybags
Transportation of germinated seeds to nursery	Transportation of germinated seeds to nursery
Transportation of fungicides; benomyl and thiram	Transportation of seedlings to the plantation
Electricity generation	Electricity generation
Diesel for running the water pump	Diesel for running the water pump
Emissions from the application of pesticides	Emissions from the application of pesticides

TABLE II. SYSTEM BOUNDARY (EXCLUDED CRITERIA)

Production of oil palm germinated seeds	Production of oil palm seedling
Processing Category	Processing category
Manufacturing, maintenance, and replacement of capital equipment	Manufacturing, maintenance, and replacement of capital equipment
Transportation of capital goods	Transportation of capital goods
Disposal of small polyethylene bags	Disposal of small polybags
Land occupation by seed production unit	Land occupation by nursery
Production of top soil	Production of top soil

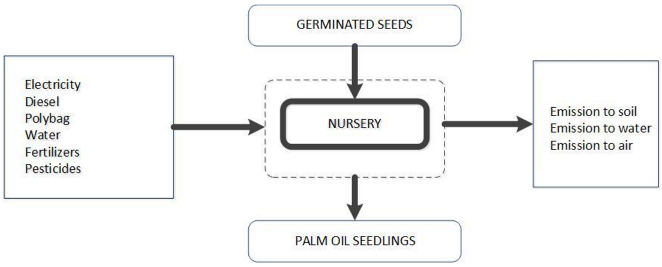

Figure 2. Boundary of LCA production of oil palm seedling

E. Life cycle impact assessment (LCIA)

The system boundary for LCIA starts from the transfer of FFB from mother palms to the seed production unit until transplanted seedling to the plantation area. OpenLCA version 1.7 was used to simulate and model the environmental impacts. Among the available LCA methodologies, the methodology used in this study was ReCiPe Midpoint with Hierarchist perspective.

III. RESULTS AND DISCUSSION

A. Life cycle inventory

The LCI data were provided by Malaysian Palm Oil Board (MPOB) and with cooperation from Standard Industrial Research Institute of Malaysia (SIRIM) and representatives of the stakeholders [20], [21]. Since the market activities reduce the uncertainty, it is used whenever it is available [22]. Table III and Table IV show the LCI for both the production units.

B. Production of the germinated oil palm seeds

Table V shows the LCIA of the production of 1000 germinated oil palm seeds. The analysis showed that the major impact category was the marine ecotoxicity which accounted around 0.0197 kg 1,4-dichlorobenzene equivalent (1,4-DB eq). The copper ion, with its impact on the long-term of the groundwater, is the major contributor in this impact category. However, electricity consumption was the primary cause of this impact whereby it accounted around 65%. The greenhouse gas (GHG) emitted was 1.03 kg CO_2 eq and the main source of this emission was electricity usage. The carbon dioxide with low population density was the most emitted GHG. In addition, electricity consumption has a considerable influence on the climate change, freshwater ecotoxicity, freshwater eutrophication, human toxicity, marine ecotoxicity, particulate matter formation, photochemical oxidant formation, urban land occupation, and water depletion. Apparently, production of germinated oil palm seeds caused a low impact on the water depletion.

TABLE III. LCI FOR PRODUCTION OF 1000 GERMINATED OIL PALM SEEDS

Input	Amount
Electricity (kWh)	0.624
Diesel (L)	0.173
Polyethylene (kg)	0.019
Water (L)	0.074
Fungicides	
Benzimidazole(kg)	0.014
Dithiocarbamate (kg)	0.011
Chemicals	
Sodium Hypochlorite 15% (kg)	0.005
Ethanol (L)	0.108
Phenol (L)	0.002
Alcohol (L)	0.003
Transportation (tkm)	3E-06
Corrugated boxes (kg)	0.017

TABLE IV. LCI FOR PRODUCTION ONE OIL PALM SEEDLING

Input	Amount
Electricity (kWhr)	0.006
Diesel (litre)	0.004
Polybag (kg)	0.002
Water (litre)	1.5
Fertilizers	
Nitrogen (kg)	5E-04
Phosphorus pentoxide (kg)	3E-04
Potassium oxide (kg)	2E-04
Pesticides	
Thiocarbamate (kg)	1E-05
Pyrethroid (kg)	4E-06
Organophosphate (kg)	2E-05
Dithiocarbamate (kg)	1E-04
Unspecified pesticide (kg)	1E-06
Urea/sulfonyl urea (kg)	2E-05
Glyphosate (kg)	9E-06
Transportation (tkm)	6E-09
Polyvinylchloride (kg)	7E-04

According to the findings, the application of the alcohol has a high impact on the terrestrial ecotoxicity whereby it was equal to $1.70*10^{-4}$ kg 1,4-DB eq. Moreover, the fungicides, such as benomyl and thiram, have a considerable impact on the marine eutrophication, metal depletion, particulate matter formation, terrestrial acidification and human toxicity, especially the metal depletion. Transportation was the lowest activity in term of the environmental impact, due to the low distance.

TABLE V. LCIA RESULTS OF PRODUCTION 1000 GERMINATED SEEDS

Impact category	Result	Reference unit
Agricultural land occupation	0.05709	m^2*a
Climate change	1.03799	kg CO_2 eq
Fossil depletion	0.59524	kg oil eq
Freshwater ecotoxicity	0.02248	kg 1,4-DB eq
Freshwater eutrophication	0.00039	kg P eq
Human toxicity	0.43371	kg 1,4-DB eq
Ionising radiation	0.07355	kg U235 eq
Marine ecotoxicity	0.01973	kg 1,4-DB eq
Marine eutrophication	0.00051	kg N eq
Metal depletion	0.3499	kg Fe eq
Natural land transformation	0.00047	m^2
Ozone depletion	1.8E-07	kg CFC-11 eq
Particulate matter formation	0.00347	kg PM_{10} eq
Photochemical oxidant formation	0.00374	kg NMVOC
Terrestrial acidification	0.01022	kg SO_2 eq
Terrestrial ecotoxicity	0.00025	kg 1,4-DB eq
Urban land occupation	0.00728	m^2*a
Water depletion	1.89091	m^3

TABLE VI. LCIA RESULTS OF PRODUCTION OF A SINGLE SEEDLING

Impact category	Result	Reference unit
Agricultural land occupation	0.00066	m^2*a
Climate change	0.01415	kg CO_2 eq
Fossil depletion	0.01063	kg oil eq
Freshwater ecotoxicity	0.0002	kg 1,4-DB eq
Freshwater eutrophication	3.76E-06	kg P eq
Human toxicity	0.00314	kg 1,4-DB eq
Ionising radiation	0.00138	kg U235 eq
Marine ecotoxicity	0.00017	kg 1,4-DB eq
Marine eutrophication	2.70E-06	kg N eq
Metal depletion	0.00044	kg Fe eq
Natural land transformation	6.75E-06	m^2
Ozone depletion	3.31E-09	kg CFC-11 eq
Particulate matter formation	3.09E-05	kg PM_{10} eq
Photochemical oxidant formation	5.28E-05	kg NMVOC
Terrestrial acidification	7.10E-05	kg SO_2 eq
Terrestrial ecotoxicity	9.27E-07	kg 1,4-DB eq
Urban land occupation	0.0001	m^2*a
Water depletion	0.02124	m^3

C. Production of the oil palm seedling

Table VI shows the LCIA for the production of one oil palm seedling. The average GHG emission in the world was around 0.118 kg CO_2 eq [22]. But, in this case, it was significantly lower around at 0.0142 kg CO_2 eq. The result showed that polyethene bags (polybags) caused considerable impacts from this emission which was around 42% of the total GHG. The transportation in this subsystem cause very minimum emissions. The results revealed that marine ecotoxicity was the major impact category. However, results showed that the lowest impact category was the water depletion. Reduction in the usage of the electricity will directly result in a greater reduction of the environmental impact, especially freshwater ecotoxicity and climate change.

D. Uncertainty analysis

To quantify the uncertainty a Monte Carlo analysis was used together with the pedigree matrix. The pedigree matrix was introduced in Ecoinvent database by Ciroth et al. [23]. Table VII shows the results from the Monte Carlo analysis for the production 1000 germinated seeds. The uncertainty in most of impacts categories is low. Table VIII shows the results of Monte Carlo analysis from the production of a single seedling. Similar to production germinated seeds most of the impact categories have low uncertainty.

TABLE VII. RESULTS OF MONTE CARLO ANALYSIS FROM THE PRODUCTION 1000 GERMINATED SEEDS

Impact category	Coefficient of variation	Uncertainty (%)
Agricultural land occupation	7E-02	7.16
Climate Change	6E-02	6.38
Fossil depletion	7E-02	6.55
Freshwater ecotoxicity	7E-02	6.76
Freshwater eutrophication	6E-02	6.38
Human toxicity	6E-02	6.32
Ionising radiation	7E-02	6.99
Marine ecotoxicity	7E-02	6.74
Marine eutrophication	6E-02	6.04
Metal depletion	6E-02	6.35
Natural land transformation	7E-02	7.30
Ozone depletion	7E-02	7.30
Particulate matter formation	6E-02	6.27
Photochemical oxidant formation	6E-02	6.43
Terrestrial acidification	6E-02	6.22
Terrestrial ecotoxicity	6E-02	5.99
Urban land occupation	6E-02	6.11
Water depletion	6E-02	6.28

TABLE VIII. RESULTS OF MONTE CARLO ANALYSIS FROM THE PRODUCTION OF A SINGLE SEEDLING

Impact category	Coefficient of variation	Uncertainty (%)
Agricultural land occupation	7.16E-02	7.155559416
Climate Change	6.38E-02	6.383178212
Fossil depletion	6.55E-02	6.548075529
Freshwater ecotoxicity	6.76E-02	6.761966689
Freshwater eutrophication	6.38E-02	6.3837858
Human toxicity	6.32E-02	6.315214312
Ionising radiation	6.99E-02	6.991034092
Marine ecotoxicity	6.74E-02	6.741785719
Marine eutrophication	6.04E-02	6.0407428
Metal depletion	6.35E-02	6.350255996
Natural land transformation	7.30E-02	7.300560696
Ozone depletion	7.30E-02	7.295817742
Particulate matter formation	6.27E-02	6.265801951
Photochemical oxidant formation	6.43E-02	6.431515438
Terrestrial acidification	6.22E-02	6.22399384
Terrestrial ecotoxicity	5.99E-02	5.985700829
Urban land occupation	6.11E-02	6.105893586
Water depletion	6.28E-02	6.278523731

IV. CONCLUSION

This study provided a comprehensive analysis of the environmental impacts associated with the production of germinated oil palm seeds and the production of the oil palm seedling. Open-source software may provide the smallholder farmers to be able to identify the environmental impacts from their activities with a minimum cost and easier scheme to share the information. Eventually, this will improve the sustainability of palm oil biodiesel industry in Malaysia. The uncertainty analysis shows that the results have high confidence.

REFERENCES

[1] SETAC, "Guidelines for Life-Cycle Assessment: a 'Code of Practice'" 1993.

[2] I. S. O. ISO, "14044" Environ. Manag. life cycle Assess. Requir. Guidel. Manag. Environ. Anal. du cycle vie, 2006.

[3] MPOB statistics, *Sustainable Palm Oil Developments In Malaysia*. Bandar Baru Bangi, Selangor, Malaysia, 2017.

[4] RSPO, "Smallholders" 2017. [Online]. Available: http://www.rspo.org/smallholders. [Accessed: 01-Dec-2017].

[5] R. H. V. Corley and P. B. Tinker, "Seed Germination and Nurseries," in *The Oil Palm*, Chichester, UK: John Wiley & Sons, Ltd, 2015, pp. 225–239.

[6] J. Flood, R. Mepsted, and R. M. Cooper, "Population dynamics of Fusarium species on oil palm seeds following chemical and heat treatments" *Plant Pathol.*, vol. 43, no. 1, pp. 177–182, Feb. 1994.

[7] J. Flood, R. Mepsted, and R. M. Cooper, "Contamination of oil palm pollen and seeds by Fusarium spp." *Mycol. Res.*, vol. 94, no. 5, pp. 708–709, Jul. 1990.

[8] I. R. Rankine and T. . Fairhurst, *Field handbook – Oil palm series, Vol. 1, Nursery*. Singapore: Potash and Phosphate Inst, 1994.

[9] G. Singh, L. KimHuan, T. Leng, and D. L. Kow, Eds., *Oil palm and the environment: a Malaysian perspective.* Kuala Lumpur, Malaysia: Malaysian Oil Palm Growers' Council, 1999.

[10] MPOB statistics, *Demand of Germinated Seed*. Bandar Baru Bangi, Selangor, Malaysia, 2017.

[11] GreenDeltaTC, "The OpenLCA Project and Software." 2015.

[12] M. Ormazabal, C. Jaca, and R. Puga-Leal, "Analysis and Comparison of Life Cycle Assessment and Carbon Footprint Software," in Proceedings of the Eighth International Conference on Management Science and Engineering Management: Focused on Computing and Engineering Management, J. Xu, A. V. Cruz-Machado, B. Lev, and S. Nickel, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2014, pp. 1521–1530.

[13] M. Goedkoop, R. Heijungs, M. Huijbregts, A. De Schryver, J. Struijs, and R. van Zelm, "ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level," 2013.

[14] Y. H. Dong and S. T. Ng, "Comparing the midpoint and endpoint approaches based on ReCiPe---a study of commercial buildings in Hong Kong," *Int. J. Life Cycle Assess.*, vol. 19, no. 7, pp. 1409–1423, 2014.

[15] D. Burchart-Korol, "Life cycle assessment of steel production in Poland: A case study," *J. Clean. Prod.*, vol. 54, pp. 235–243, 2013.

[16] M. Owsianiak, A. Laurent, A. Bjørn, and M. Z. Hauschild, "IMPACT 2002+, ReCiPe 2008 and ILCD's recommended practice for characterization modelling in life cycle impact assessment: a case study-based comparison," *Int. J. Life Cycle Assess.*, vol. 19, no. 5, pp. 1007–1021, 2014.

[17] T. Kägi, F. Dinkel, R. Frischknecht, S. Humbert, J. Lindberg, S. De Mester, T. Ponsioen, S. Sala, and U. W. Schenker, "Session ``Midpoint, endpoint or single score for decision-making?''---SETAC Europe 25th Annual Meeting, May 5th, 2015," *Int. J. Life Cycle Assess.*, vol. 21, no. 1, pp. 129–132, 2016.

[18] B. Steubing, G. Wernet, J. Reinhard, C. Bauer, and E. Moreno-Ruiz, "The ecoinvent database version 3 (part II): analyzing LCA results and comparison to version 2," *Int. J. Life Cycle Assess.*, vol. 21, no. 9, pp. 1269–1281, 2016.

[19] C. W. Reeb, T. Hays, R. A. Venditti, R. Gonzalez, and S. Kelley, "Supply Chain Analysis, Delivered Cost, and Life Cycle Assessment of Oil Palm Empty Fruit Bunch Biomass for Green Chemical Production in Malaysia," *Bioresources*, vol. 9, no. 3, pp. 5385–5416, 2014.

[20] H. Muhamad, Y. A. Tan, N. S. K. Khairuddin, M. D. Amiruddin, and Y. C. May, "Life Cycle Assessment for the Production of Oil Palm Seeds," *Trop. Life Sci. Res.*, vol. 25, no. 2, p. 41–51., 2014.

[21] H. Muhamad, Z. Hashim, V. Subramaniam, Y. A. Tan, C. W. Puah, C. C. Let, and C. Y. May, "Life Cycle Assessment of Oil Palm Seedling Production (Part 1)," *J. Oil Palm Res.*, vol. 22, pp. 878–886, 2010.

[22] B. P. Weidema, C. Bauer, R. Hischier, C. Mutel, T. Nemecek, J. Reinhard, C. O. Vadenbo, and G. Wernet, "The ecoinvent database: Overview and methodology, Data quality guideline for the ecoinvent database version 3," 2013.

[23] A. Ciroth, S. Muller, B. Weidema, and P. Lesage, "Empirically based uncertainty factors for the pedigree matrix in ecoinvent," *Int. J. Life Cycle Assess.*, vol. 21, no. 9, pp. 1338–1348, Sep. 2016.