Part II: COMPARISON OF JATROPHA SCENARIO WITH OTHER ALTERNATIVES TO ELECTRIFY REMOTE INDIAN VILLAGES

Task 2.1: GOAL AND SCOPE

1. The goal of the LCA study is to compare four alternatives to electrify remote Indian villages (Jatropha oil, fossil diesel, solar photovoltaic system, and electricity grids).
2. Functional unit: 1 kWh
3. System boundary: The processes considered in this study are to define electricity generated from the Jatropha oil, diesel-generating set (Fossil diesel genset), Chhattisgarh grid (Grid) and solar photovoltaic system (Solar PV). However, we do not consider waste materials generated from the electrification process as well as waste generated from disposed and recycled materials. Furthermore, the socio-economic implications of the electrification scenarios are not considered in this study.

Task 2.3: IMPACT ASSESSMENT

1.1 <u>Environmental performance of the different technologies assessed using the Ecoindicator99 and Recipe (endpoint) method</u>

Using Ecoindicator99 method, results shows that Jatropha oil contributed to the highest total environmental impacts estimated at 1,31 Pt, followed by diesel with total impact of 0.16Pt, electricity grid (total impacts: 0.05 Pt) and solar photovoltaic (total impacts: 0.01) (Table 1). However, results of the Recipe (endpoint) method shows that among the electrification scenarios, the diesel generating set contributes to the highest total environmental impact estimated at 0.22Pt followed by grid connection (0,133Pt), Jatropha oil (0,127Pt), and solar photovoltaic (0,013Pt) (Table 2). Table 1 and 2 also shows the impacts of each electrification scenarios on specific impact categories.

Impact category	Unit	Jatropha oil	Diesel	Grid	Photovoltaic
Total	Pt	1,30543268	0,16233709	0,05075571	0,01387325
Carcinogens	Pt	0,0153439	0,00212575	0,00603334	0,00347277
Resp. organics	Pt	2,7482E-05	4,8161E-05	3,3059E-06	2,552E-06
Resp. inorganics	Pt	0,04037205	0,01921634	0,02903381	0,00190456
Climate change	Pt	0,00108191	0,00742203	0,00541598	0,00037093
Radiation	Pt	1,3994E-05	1,8903E-05	1,2058E-06	9,2204E-06
Ozone layer	Pt	1,1923E-06	4,6261E-06	4,1385E-08	2,5611E-07

Table 1: Environmental performance of the different technologies assessed using Ecoindicator99

Impact category	Unit	Jatropha oil	Diesel	Grid	Photovoltaic
Total	Pt	0,1265568	0,2178215	0,133733	0,013147
Climate change Human Health	Pt	0,0081544	0,05652283	0,042393	0,0028505
Ozone depletion	Pt	2,955E-06	1,3351E-05	1,162E-07	7,942E-07
Human toxicity	Pt	0,0042476	0,00213562	0,0034837	0,0021477
Photochemical oxidant formation	Pt	5,671E-06	6,7745E-06	4,554E-06	3,599E-07
Particulate matter formation	Pt	0,0206644	0,01334898	0,02178	0,0014786
Ionising radiation	Pt	1,251E-05	1,6901E-05	1,078E-06	8,244E-06
Climate change Ecosystems	Pt	0,0009655	0,0066949	0,0050204	0,0003376
Terrestrial acidification	Pt	9,523E-06	1,4732E-05	3,257E-05	2,027E-06
Freshwater eutrophication	Pt	0,000612	1,8859E-06	3,625E-06	1,322E-06
Terrestrial ecotoxicity	Pt	0,0031596	9,2751E-06	1,655E-06	6,883E-06

Freshwater ecotoxicity	Pt	0,0003888	3,2193E-07	4,798E-07	1,995E-07
Marine ecotoxicity	Pt	7,411E-08	1,2736E-09	1,467E-09	6,565E-10
Agricultural land occupation	Pt	0,0719611	6,1823E-05	0,0002155	8,851E-05
Urban land occupation	Pt	0,0002104	8,336E-05	0,0001054	7,929E-05
Natural land transformation	Pt	0,0001017	0,00059213	4,474E-05	1,088E-05
Metal depletion	Pt	5,565E-05	4,1218E-05	3,832E-06	3,188E-05
Fossil depletion	Pt	0,0160049	0,1382774	0,0606423	0,0061021

Table 2: Environmental performance of the different technologies using Recipe (Endpoint) method

1.2 Comparisons between Ecoindicator99 and Recipe (Endpoint) method - per impact category

It is apparent that the environmental impact categories considered by the Ecoindicator99 and Recipe method are not similar (Figure 1 and 2). As a matter of fact, more impact categories are given in the Recipe method than in the Ecoindicator99 method. It can also be observed that the categories of the Recipe method are more specific in scope and meaning. Some of the categories are also subdivided into two. For example, we have two categories of climate change, namely climate change human health and climate change ecosystems. On the other hand, the categories of the Ecoindicator99 method are broader in scope and meaning and they do not include subdivisions.

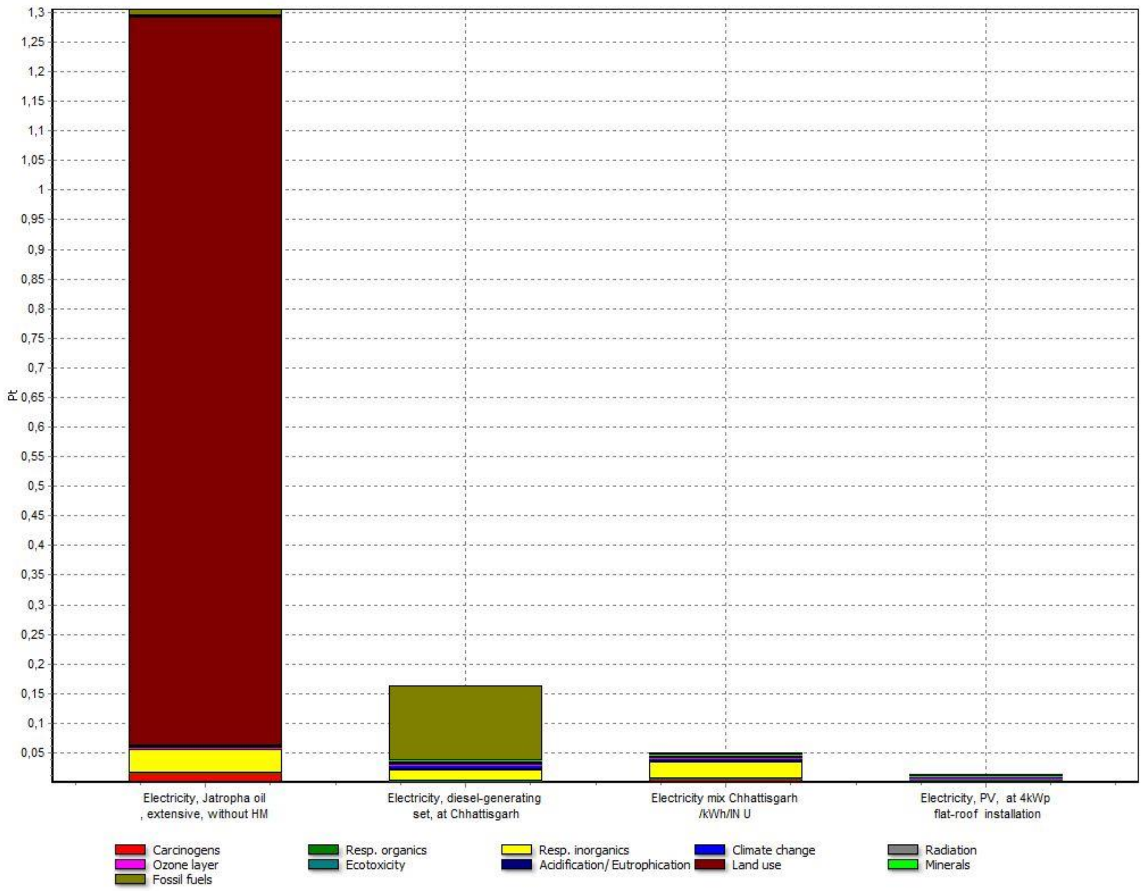


Figure 1: Environmental impact assessment of the different electricity scenarios using Ecoindicator99 method

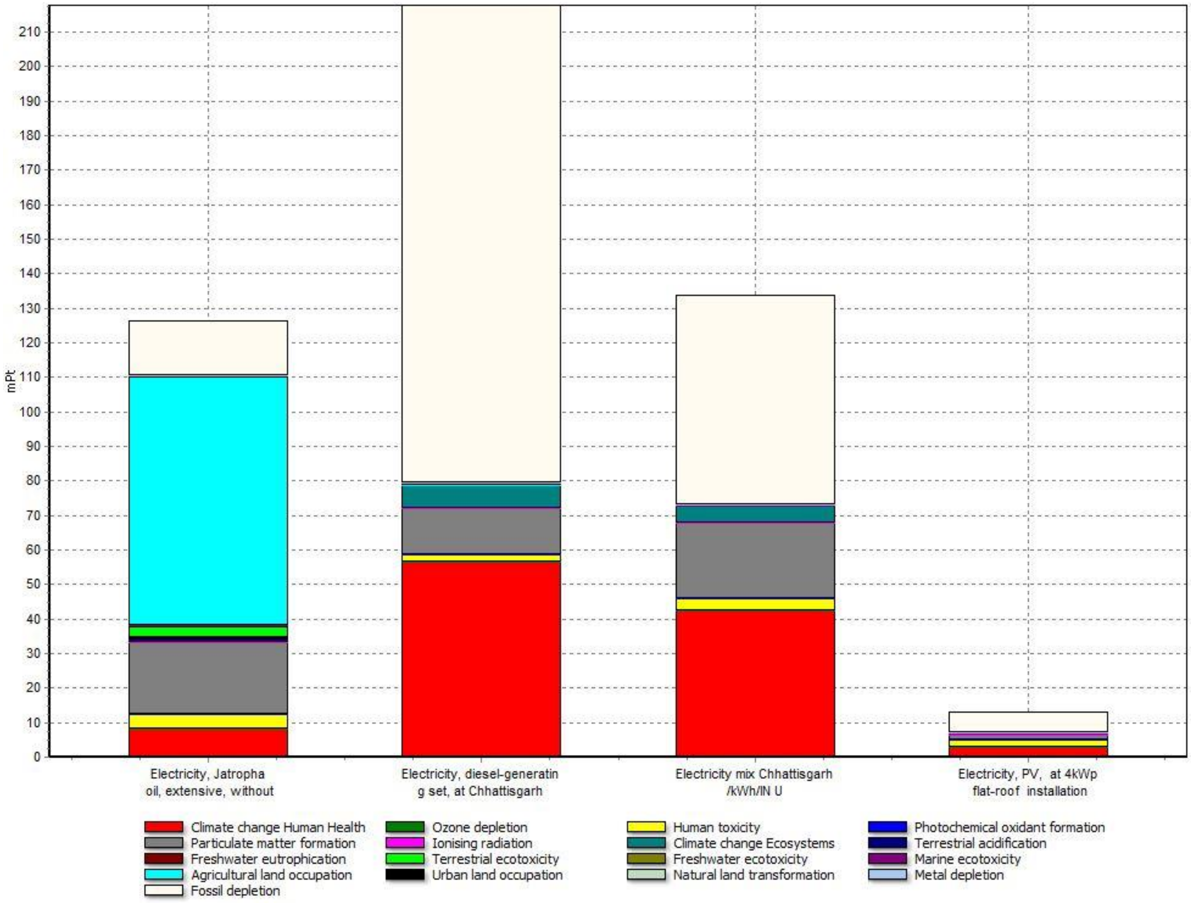
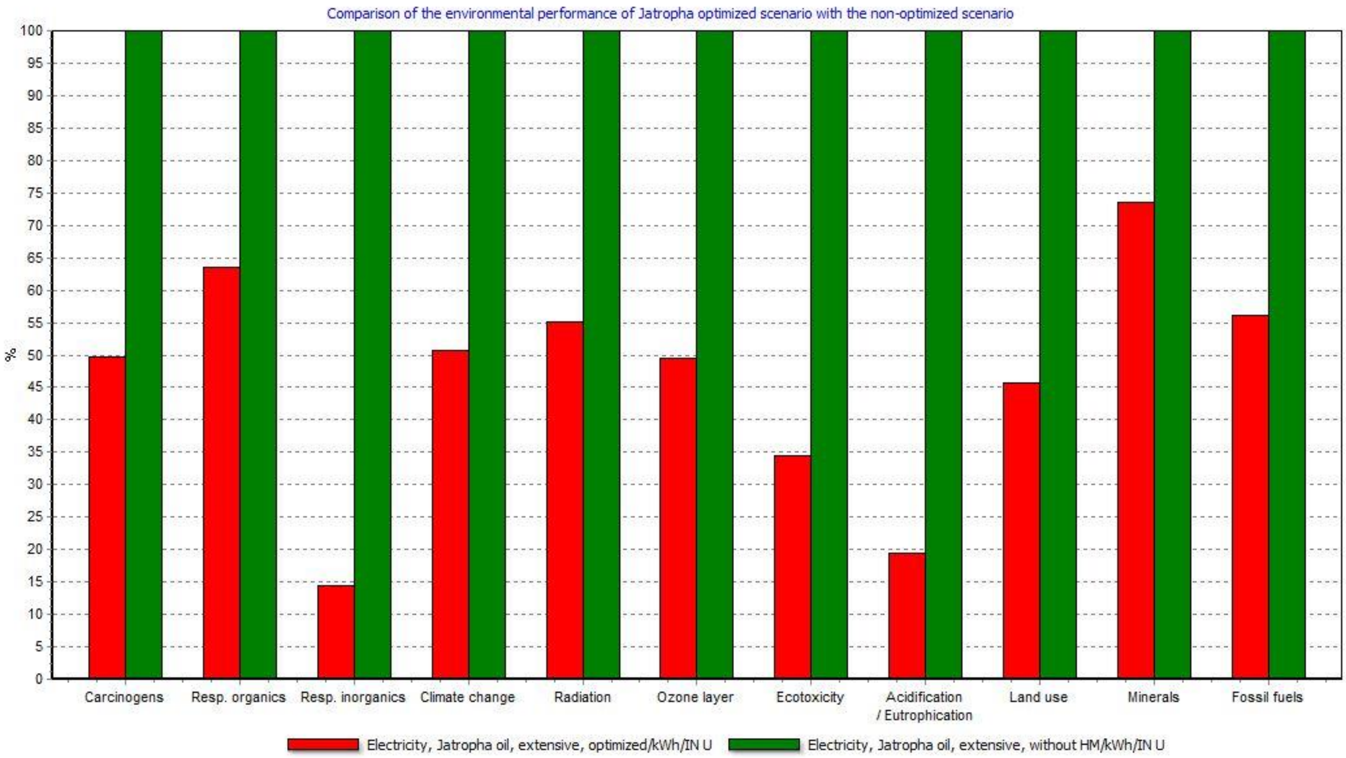


Figure 2: Environmental impact assessment of the different electricity scenarios using the Recipe (Endpoint) method

2. <u>Comparison between the optimized Jatropha scenario and the non-optimized scenario</u>



The optimized scenario produces lesser environmental impacts than the non-optimized scenario mainly due to the contributions of the pre-heating to air pollution (Gmünder et al. 2010). Electricity production with Jatropha oil can be improved in the optimized scenario if the engine is powered using vegetable oil rather than being powered by diesel. This will also reduce impacts on the environment.

3. Cumulative energy demand (CED) of the different technologies including the two Jatropha scenarios

To arrive at the total amount of energy and non-renewable energy that will be required to produce 1 kWh of electricity for each of the electrification scenarios, the given energy values in megajoules (MJ) were divided by 3.6 for conversion to kWh (Table 2).
The non-optimized Jatropha scenario demands the highest amount of total energy but demands a relatively low amount of non-renewable energy, therefore it is not considered a cost-effective option for electricity production. Meanwhile, the diesel-generating system has mid-values for total cumulative energy demand but has the highest figure for total non-renewable energy demand, therefore it is not a good option too. The grid system demands the least amount of total energy and a relatively high amount of non-renewable energy, but overall can be considered a good option for electrifying these remote Indian villages.

Impact category	**Jatropha oil, opt**	**Jatropha oil, non-opt**	**Diesel-generating set**	**Grid**	**PV**
Total energy (MJ)	15,3678746	51,0598394	27,0654432	11,8728155	39,6194234
Total non-renewable energy (MJ)	1,91143743	3,40133343	26,9168253	11,6101451	1,40122729
Total CED (kWh)	4,268	14,183	7,518	3.298	11,005
Toal non-renewable CED (kWh)	0,530	0.945	7,477	3,225	0,389

Table 3: Cumulative energy demand (kWh) of the different technologies. The amount of energy needed to produce 1kWh of electricity for the scenarios in consideration. CED values were calculated by dividing total energy values by 3.6 MJ.

4. Sensitivity analysis

Environmental performance results will look different if Jatropha is planted on natural forests rather than marginal lands as there will be more adverse environmental impacts. The processes of cultivation and harvesting of Jatropha seeds causes emissions of metals and fertilizers to air, water and soil which are harmful to natural ecosystems. More importantly, the most significant environmental impact of Jatropha production is land use change which will have negative impacts on the rich biodiversity of the natural forest. Furthermore, a reduction of the forest's flora and fauna may also cause spillover effects on climate change because the forest's capacity to sequester and store carbon from the atmosphere would reduce.

2.4 Interpretation

Recommendation to the Indian Government

Based on the results of task 2.3, I would recommend the solar photovoltaic system to the Indian Ministry because it has the lowest environmental impacts and the lowest non-renewable energy demand among all other electrification options. The optimized Jatropha scenario would also be a suitable option if its environmental impacts can be further reduced.
The environmental impacts of electricity production with Jatropha can be further reduced by switching to the optimized scenario. By analyzing the environmental performance of both the optimized and non-optimized scenario of Jatropha, we observe a high impact on land use from these two scenarios. Therefore, the environmental impacts of Jatropha production can be reduced if necessary actions are taken towards reducing the environmental footprints of

Jatropha production. Furthermore, Jatropha planting can be restricted to marginal lands and waste lands with strict actions to avoid infringements into natural areas.
We also see that among the processes that contribute mostly to environmental impacts is burning Jatropha in a diesel generating system. However, this can be avoided by using more environmentally friendly substances such as vegetable oil.

Certainty of results: Our results are not very certain because most of the methods used here (such as the Ecoindicator99 and Recipe method) were designed for European regions and applying these for Indian villages may be ambiguous. In addition, some parameters have also not been taken into consideration in the model which may have affected the accuracy of our results.

REFERENCES

Gmünder et al. 2010. Life cycle assessment of village electrification based on straight Jatropha oil in Chhattisgarh, India. Biomass Bioenerg 34 (3) 347-355.