# CLIMATE MITIGATION EFFECTS OF ECO-VILLAGE DEVELOPMENT PROJECTS






A report of the project: Next generation low carbon, climate resilient Eco-Village Development in South Asia


NOVEMBER 2023

CRT Grameen Shakti IDEA inseda INFORSE South Asia CANSA Climate Action Network South Asia dib INFORSE

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**Climate Mitigation Effects of Eco-Village Development Projects**

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Front page photos: Pictures from model villages, photos by INFORSE, INSEDA, IDEA, CRT/N

Read more on the project and download this and other publications from http://www.inforse.org/asia/EVD.htm and http://www.ecovillagedevelopment.net/

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# Background

Implementation of eco-village development (EVD) projects in South Asia contributes to low-carbon developments that improves lives and livelihoods in villages in South Asia. In addition to the improvements for the villagers, it also reduces emissions of $CO_2$ and other greenhouse gases.

This report contains an assessment of the climate effects of four demonstration eco-villages in South Asia, one in each of the countries Bangladesh, India, Nepal, and Sri Lanka. The villages are all rural, but are in different climatic zones and with different socio-economic situations. Some are electrified with connections to national grids, others are not. The assessment covers change in energy use and change in greenhouse gas emissions. There are also other benefits, including savings in purchase of fuels, less time needed to collect firewood, shorter cooking time, and reduced air pollution, including reduction in harmful indoor air pollution.

Solutions having climate mitigation effects with reduced emissions, include:

- Improved cookstoves
- Biogas
- Solar light
- Tree planting

Other solutions such as solar drying, compost, organic and other forms of environmental agriculture, also contribute to reduce climate emissions, however, their climate mitigation effects are not quantified in this report.

There are substantial differences in the selected EVD solutions in the four selected villages. Hence, the descriptions of the mitigation effects are not similar for each village. There are some similarities, however, where the most striking is probably that before EVD implementation, a majority of villagers in all villages used traditional cooking methods (traditional cookstoves, three stones, etc) with wood and other biomass for cooking of food, fodder, etc.

# Introduction

The implementation of Eco-Village Development (EVD) solutions in the four demonstration villages shows that considerable emission reductions are possible with the change from traditional to improved cooking, including cooking for animals and small-scale village industries. Also, solar electricity and tree planting contributes to net reductions of greenhouse gas emissions.

In the four villages, the majority of the families cooked primarily with traditional cookstoves and fires, such as three-stone fires. Of this, the majority of people, 59–83 percent, changed to improved cookstoves with the project. The required contributions from the villagers to get an improved cookstove ranged from just assisting in installations, to providing materials and in one case, also a financial contribution. In two of the villages, larger, institutional/village industry stoves, were also installed, for processing milk (curd production), alcohol, and cooking hard fodder for the animals. Only a small percentage of the villagers had institutional stoves, hence they used considerably more wood than other families, but with the EVD solutions, they could also achieve high reductions, saving some 66 percent of their fuelwood. The average reduction in emissions per family varied between 26 percent and 43 percent in the four villages, including the villagers that did not implement the EVD solution.

The table on the following page gives an overview of implementation rate and requirements.

| Village | Margul, Central India | Majherchar, Southern Bangladesh | Kottawatte, Southern Sri Lanka | Bhalumare, SE Nepal |
|---|---|---|---|---|
| Families | 106 | 218 | 146 | 88 |
| Families with traditional stoves as main cooking appliance at start of project | 106 (26 also used LPG regularly) | 180 | 130 | 72 |
| Number of improved stoves introduced in project as primary cookstoves, as number and share of families with traditional cookstoves (TCS) | 82 (80% of families with TCS) | 150 (83% of families with TCS) | 77 (59% of families with TCS) | 50 (69% of families with TCS) |
| Required contribution from villagers to get an improved cookstove | Local materials, assist in construction | Local materials, install stove after instruction | Local materials, assist in construction, payment of 300 Sri Lankan Rp. (1 USD) | Provide materials with a value of 500 Nepalese Rs (4 USD), assist in construction |
| Reasons for not changing to improved cookstove | Som families were not available (temporary migrated), others were rebuilding homes | Project only provided 150 stoves | Conservative, not concerned with wood demand or air pollution, happy with traditional stoves | Some families want to change between cooking indoors and outdoors. This is not facilitated by a fixed, indoor stove |
| Wood supply | Scarce | Sustainable | Sustainable | Sustainable |

In addition to improved cookstoves, the project also installed and renovated on an average one to four biogas plants in each village, mainly replacing traditional cookstoves as the main cooking appliances. In Marin Municipality, Nepal, the project also introduced 22 induction cookers with grid electricity. The greenhouse gas emission reductions with biogas is included in the table below with an overview of emissions.

With EVD, in three villages the partners installed solar electric equipment (solar lanterns, solar street lights, solar home systems, water pumping) which the villagers got for free, but contributed work and local materials. In one village the solar electricity replaced kerosene and in two villages grid power. The emissions from producing the solar PV cells and batteries introduced with the project was around 1% of the reduced emissions with the replacements of kerosene and dry cells. When replacing grid electricity with solar PV, the emissions with the productions of the solar PV cells and batteries were less than 4% of the emissions from the electricity in Bangladesh. In Nepal, where grid electricity is from hydro-power, replacing grid electricity with solar electricity does not reduce greenhouse emissions.

Tree planting was another EVD solution, where the project team could quantify net emission reductions.

Of the three types of solutions with emission reductions quantified in the project, the reduction of cooking emission was by far the most important. This is the case for all four villages, also in the three villages, where there is no current scarcity of wood and therefore no deforestation. We included non-CO2 climate effects of emissions from wood burning, including emissions of black carbon. We made the conservative assumption that there are the same black carbon emissions from all stoves per kg of wood burned, even though the particle emissions from improved cookstoves typically are smaller per kg of wood for improved cookstoves than for traditional cookstoves. We had no black carbon emission measurements from the stoves used in the project's model villages. In the below table is an overview of emission reductions in the four villages:

| **Total emission reduction, tons $CO_2$e/year** | **Margul, India** | **Majherchar, Southern Bangladesh** | **Kottawatte, Southern Sri Lanka** | **Marin Rural Municipality, Nepal** |
|---|---|---|---|---|
| Household cooking | 159 | 64 | 41 | 118 |
| Cooking of milk for sale, alcohol, fodder | n.a. | n.a. | 7 | 69 |
| Solar electricity | 9 | 2.7 | n.a. | 0 |
| Tree planting | 22 | 1.3 | n.a. | 10 |
| Total emissions | 190 | 68 | 50 | 197 |

# Margul Village, Madhya Pradesh State in India

In this village in a semi-arid area lives 629 people in 106 families of which 105 families are below the Indian poverty line. 102 of the families are farming while 98 families are (also) dependent on income from work.

The EVD project has made a radical change to how the villagers in Margul cook and get light.

A view of Margul Village, India. Photo by INSEDA

The tables below show the main changes for cooking and lighting respectively.

| Change in cooking | Before (families) | After (families) |
|---|---|---|
| Traditional chulhas | 106 | 28 |
| Improved cookstoves | 0 | 82 |
| Biogas | 0 | 3 |
| LPG in regular use | 27 | 0 |
| LPG, rarely used | 26 | 53 |

The number adds up to more than the number of families, as some families have more than one form of cookstove.

The improved cookstoves (ICS) were primarily the Jwala stove (81 stoves) while one family got the more advanced Heera stove. Both stoves have an efficiency around 35%.

The changes in light are shown in the table below.

| Change in light | Before (families) | After (families) |
|---|---|---|
| Grid electricity | 3 | 3 |
| Solar lanterns | 0 | 102 |
| Kerosene lamps | 104 | 2 |
| Dry battery lamps/torches | 101 | 90 |
| Street lights (solar) | 0 lamps | 16 lamps |

**Changes in cooking energy use and climate change emissions**

The change in ways of cooking reduces the consumption of wood, cow-dung, and LPG. The following changes have been found by detailed survey of 10 families without biogas and three families with biogas:

| Families without biogas | Use before, per family | Use with ICS, per family | Change per family |
|---|---|---|---|
| Wood, average | 5.9 kg/day | 3.9 kg/day | 2 kg/day |
| Dung cake, average | 2.8 pieces/day | 1.5 pieces/day | 1.3 pieces/day |
| Families with biogas | Without biogas, traditional chulha | With biogas + ICS | |
| Wood, average | 6.3 kg/day | 2.3 kg/day | 4 kg/day |
| Dung cake, average | 2.7 pieces/day | 1.7 pieces/day | 1 piece/day |

For the families using LPG regularly before the project, the estimated change in LPG use is:

- Before EVD: 1 bottle LPG/month with 13 kg LPG, total 156 kg LPG/year
- After EVD: 1 bottle LPG/year with 13 kg LPG, total 13 kg LPG.

For the families that rarely use LPG both before and with EVD, we also expect the LPG consumption to be 1 bottle/year.

For calculation of mitigation effects, we use the energy contents and emissions from wood with 50% unsustainable use given in Annex 1. For dung cake, we will use the energy content for solar dried dung cake with 20% humidity, 3.5 kWh/kg[1]. The team have evaluated that the dung cakes in the village are typically 300 g each[2].

This gives the following reductions in biomass and LPG energy use from change to improved cookstoves (ICS) and more biogas, per family:

| **Families without biogas (average of families with and without LPG)** | **Use with traditional chulha** | **Use with ICS** | **Change** | |
|---|---|---|---|---|
| Wood, average | 8614 | 5694 | 2920 | kWh/year |
| Dung cake, average | 2862 | 1533 | 1329 | kWh/year |
| **Families with biogas** | **Use before, traditional chulha** | **Use with biogas + ICS** | **Change** | |
| Wood, average | 9198 | 3358 | 5840 | kWh/year |
| Dung cake, average | 2218 | 1737 | 480 | kWh/year |
| | **Before LPG use** | **After LPG use** | **Change** | |
| LPG, families with regular LPG use before (27 families) | 1997 | 166 | 1831 | kWh/year |

[1] Typical calorific value of dung cake, dry matter 3800 kcal/kg, according to https://www.researchgate.net/figure/Proximate-Analysis-and-Calorific-Values-of-Coal-Cattle-Dung-Blends_tbl3_263302623 Typical water content of dry dung-cake: 20%
[2] Sample with 5 dung-cakes from village had a weight of 1.5 kg

We assume that the families with rarely LPG use that did not change, have an LPG use around one bottle of LPG per year.

For the entire village, the changes in cooking energy use are then:

| Village cooking energy, village, MWh/year | Use before | Use after | Reduction |
|---|---|---|---|
| Wood, families without biogas | 1216 | 868 | 348 |
| Wood, families with biogas | 34 | 15 | 19 |
| Biogas | 0 | 6 | -6 |
| LPG, total | 58 | 9 | 49 |
| Total cooking energy | 1309 | 898 | 411 |
| Reduction | | | 31% |

For emissions, we will use the following values, from Annex 1, recalculated from kg to kWh, 50% unsustainable wood, dung cake with 20% humidity.

| Emissions, stoves/kWh fuel | $CO_2$, kg | non-$CO_2$, kg $CO_2$e | Total, kg $CO_2$e | Unsustainable share | |
|---|---|---|---|---|---|
| Wood, stove tier 0 | 0.17 | 0.21 | 0.38 | 50% | 20% humidity |
| Dung-cake, tier 0 | 0.17 | 0.42 | 0.59 | 50% | Dung-cake, 20% humidity |
| Wood, tier 2 | 0.17 | 0.21 | 0.38 | 50% | 20% humidity |
| Dung-cake, tier 2 | 0.17 | 0.42 | 0.59 | 50% | Dung-cake, 20% humidity |
| LPG | 0.23 | 0.00 | 0.23 | 100% | |

For biogas plants, we will use emissions per plant per year of 200 kg CO2e, mainly as methane emissions of 40 ltr/day (equal to 65 ltr/day of biogas with 60 % methane).

Combining, this, we get the following changes in cooking emissions for the village:

| Village- cooking emissions | Before | After | Change | |
|---|---|---|---|---|
| Families without biogas, emissions from wood | 510 | 370 | 140 | Tons CO2e/year |
| Families with biogas, all | 14 | 7 | 7 | Tons CO2e/year |
| Families with LPG, all | 14 | 2 | 12 | Tons CO2e/year |
| Total, cooking | 538 | 380 | 159 | Tons CO2e/year |
| Reduction | | | 29% | |

**Change in energy use and emissions for light**

We will include the change in emissions from the replacement of kerosene lamps and partly of dry batteries for torches with solar lanterns and solar street lamps. There are no direct emissions in solar equipment or dry battery use, but there are emissions related to the production of the batteries and equipment. We have estimated these for this analysis.

We do not include the three families with grid electricity in this analysis, assuming no change for these families. One of the three families replaced a kerosene lamp with a solar lantern, but we do not have information on the effect of this.

We estimate that:

- Production of a solar lantern with 6 W PV panel and 27 Wh battery produces 3.7 kg CO2e. With 10-year lifetime, this is equal to 0.37 kg CO2e/year[3]
- Production of a solar street light with 75 W PV and 360 Wh battery produces 48 kg CO2e. With 10-year lifetime is equal to 4.8 kg CO2e/year.[4]

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[3] The solar street light has a 75 Watt battery and a 30 Ah, 12 volt battery(360 Wh), which with the same assumptions as for solar lanterns gives emissions of 15 kg CO2e for the PV panel and 33 kg CO2e for the battery, also using a figure of 93 kg CO2e/kWh. The total is 15+33 = 48 kg CO2e, equal to 618 kg CO2e/kW solar cell.

[4] Zinc-alkaline batteries have production emissions of 26.2 kg CO2e/kWh according to "Urban Electric Power", https://urbanelectricpower.com/wp-content/uploads/2022/02/UEP-Environmental-Impact-Report_Shareable-02-2022.pdf. A D-size battery has 1.5 Volt and 10 Ah, equal to a capacity of 15 Wh, which will give production emissions of 0.39 kg CO2e per battery.

- Production of a dry cell (D-type) we estimate to produce 0.39 kg CO2e[5]
- The families that migrated temporarily will get solar lanterns when they return, except two.

The EVD activities have made the following change in the families without grid electricity, including families that do not use dry cells any more:

| Effects of EVD per family | Before EVD | With solar lanterns | |
|---|---|---|---|
| Kerosene use/family with kerosene lamps | 2.4 | 0 | ltr/month |
| Battery (dry cell) use | 9.2 | 5 | pieces/month |

This calculation of changes is based on a survey of ten families in the village.

With emissions of 2.36 kg CO2/ltr kerosene, thus gives the following change in greenhouse gas emissions for a family without grid electricity:

| Family without grid-electricity | Before EVD | With EVD | Change | |
|---|---|---|---|---|
| Kerosene | 68 | 0 | 68 | kg $CO_2e$ |
| Dry cells | 43 | 23 | 20 | kg $CO_2e$ |
| Solar lantern | 0 | 0.2 | -0.2 | kg $CO_2e$ |
| Total | 111 | 24 | 87 | kg $CO_2e$ |

[5] The solar lantern has a 6 Watt PV panel. The emissions in production is estimated to 200 kg CO2e/kW according to average of emissions in graph in https://www.iea.org/reports/solar-pv-global-supply-chains/executive-summary, which gives 1.2 kg CO2e. The battery is 4.5 Ah, 6 volt (27 Wh, for which the manufacturing products 2.5 kg CO2e, calculated from emission values for Chinese Li-ion battery production of 93 kg CO2e/kWh of battery, taken as an average of figures in https://www.mdpi.com/2071-1050/9/4/504(103 kg CO2e/kWh) and in https://www.sciencedirect.com/science/article/pii/S0921344922004402 (82 kg CO2e/kWh). The total is 1.2+2.5)3.7 kg CO2e, equal to 646 kg CO2e/kW solar cell.

For the entire village (except for the three households with grid electricity), the total emissions from lighting are:

| Village-emissions, lighting, tons $CO_2e$/year including production of PV and batteries* | Before EVD | With EVD | Change | |
|---|---|---|---|---|
| Kerosene | 7.1 | 0.1 | 6.9 | tons $CO_2e$/year |
| Dry cells | 4.4 | 2.4 | 2.0 | tons $CO_2e$/year |
| Solar lanterns | 0 | 0.04 | -0.04 | tons $CO_2e$/year |
| Solar street lights | 0 | 0.06 | -0.1 | tons $CO_2e$/year |
| Total | 11.5 | 2.6 | 8.9 | tons $CO_2e$/year |

* For the three families with grid there is no change in emissions; they are not included in this sum

**Climate mitigation with tree planting**

The EVD project also includes tree planting, which becomes a CO2 sink as the trees grow and capture CO2 from the atmosphere. We estimate that each tree during its lifetime consumes 25 kg CO2/year. Unfortunately, not all saplings survive, so we reduce the sapling planted accordingly. The trees are many different species, including mango, jackfruit, lemon, bamboo, guava and at least seven other species. At the time of assessment (Spring 2023) they have grown to between 2 and 6 feet (0.6 – 1.5 m) in height. The resulting CO2 capture are from the 1279 saplings planted:

| | | |
|---|---|---|
| Saplings planted with EVD | 1278 | Pieces |
| Survival rate | 70% | Estimated after 20 years[6] |
| $CO_2$ collected/tree, average | 25 | kg $CO_2$/year over lifetime[7] |
| Total / year | 22 | tons/year over lifetime |

[6] According to information collected by INSEDA and partners
[7] According to estimates for average trees [in South Asia] according to https://ecotree.green/en/how-much-co2-does-a-tree-absorb

### Total emission changes in areas covered

As described above, the main changes in emissions are in cooking, light, and tree growing. The sum of emissions and changes for these three areas of emissions are

| Greenhouse emissions in areas covered by EVD in Margul Village | Before EVD | With EVD | Change | |
|---|---|---|---|---|
| Cooking, 106 families | 538 | 380 | 159 | tons $CO_2e$/year |
| Light, 104 families without grid power | 12 | 2,6 | 9 | tons $CO_2e$/year |
| Tree planting | | -22 | 22 | tons $CO_2e$/year |
| Total | 550 | 360 | 190 | tons $CO_2e$/year |
| Total/capita | 0,87 | 0,57 | 0,30 | tons $CO_2e$/year |
| Reduction | | | 35% | |

### Other emissions

There are other emissions from the village than those included in above analysis. These are primarily:

| Emissions/activities | Type | EVD activity | Reason for non-inclusion in analysis |
|---|---|---|---|
| Soil emissions, $CO_2$ | Emissions from reduction of carbon in soil | Increased biogas fertiliser, vermicompost to replace chemical fertiliser increases soil carbon | Relatively small with only 3 biogas plants & no information on vermi-compost output, difficult to estimate |
| Agricultural emissions, non-$CO_2$ | Emissions of methane and N2O from soil and animals | None | Difficult to estimate, extensive, non-standard agriculture |
| Drying | Drying of crops | Solar dryer | Solar dryer in this village replaces open air drying with no energy use, only one solar dryer installed |
| Use of electric power | Emissions from power to 3 households, irrigation, others | None | No information available on grid electricity use |
| Transport | Emissions from cars, trucks, scooters etc. | None | No EVD action in this field, no cars in the village |

The emissions not included are primarily for agricultural production and from outside actors (transport). Thus, the emissions included in the analysis are covering most of the household related emissions excluding food production, and are generally not including work-related emissions.

**Conclusion**

The EVD has given a reduction of emissions of some 190 tons CO2e/year, equal to 0.30 tons CO2e/capita or 35% of the emissions covered by the analysis. This was mainly realised with the introduction of 82 improved cookstoves and three biogas plants, covering 80% of the families. The families that did not take an improved cookstove, were not able to have it because of (temporary) migration or change of house. The calculations of reductions are based on a number of assumptions, including the climate effects of black carbon and the lack of sustainability of the biofuel (assumed 50% sustainability). If we assume that the lower biofuel consumption makes the remaining biofuel use more sustainable, the relative reductions are larger. Another assumption is that the temporarily migrated villagers will return and will continue to use traditional chulhas. If they do not return, the relative reductions will also be larger.

The solar light reduces emission of kerosene and dry batteries, while the emissions related to produce the solar equipment is two orders of magnitudes lower than the emissions of the energies they replace, in a 10-year perspective, equal to expected lifetime.

This shows that EVD solutions are able to realise substantial greenhouse gas emission reductions in a poor village with some deforestation, such as the Margul Village in Madhya Pradesh in India. The reductions are mainly in the household emissions, but also include tree planting with negative emissions (CO2 uptake).

The EVD solution also improves living conditions in the village. It is one step ahead for the villagers and it reduces poverty. The solutions do not, however, fundamentally change the harsh living conditions in the area. The development over the coming years will show if the EVD with reduced cooking energy needs, move from kerosene to solar electric lamps and tree orchards as well as several other solutions are starting an upward development spiral bringing the villagers out of poverty and above the national poverty line.

# Kottawatte Village in Matara District, Southern Sri Lanka

The village with 560 inhabitants in 146 families is in the coastal district Matara in Southern Sri Lanka.

The EVD project has introduced major changes to the cooking facilities in the households and in three village industries. The project has also introduced a number of other improvements, in particular for kitchen gardening and improvements in paddy field cultivation, cash crop cultivation of which we have not quantified their effects on greenhouse emissions. In Kottawatte village, there are no EVD activities regarding light and other electricity use as the villagers are all connected to the electricity grid, which they are satisfied with. Thus, this analysis focuses on EVD solutions in efficient cooking in households and in village industries.

Top: Kottawatte Village in Southern Sri Lanka. Left: Household cookstove (Anagi) installed in the village. photo: IDEA. Right: Industrial stove installed in the village, photo: IDEA

The implementation of the stoves started with awareness activities with a community meeting, where the EVD program was introduced and the improved (Anagi) cookstoves were introduced. Immediately after the meeting follows a cooking session, where a standard meal is prepared in parallel with a traditional stove and with an Anagi stove. The fuel use and cooking time is recorded so the villagers can see the difference. After this, Anagi stoves are installed in four houses, where it is built into the kitchen with a mixture of sand, wood ash, clay and cow dung. The materials are provided by the villagers. The construction is made by a technician from IDEA and a local mason that is trained, so he can replicate it in other houses. In the following dissemination, the villagers' contributions are the materials, work to bring and mix materials and 300 Rupees (US$ 1) per stove. In this way, 77 Anagi stoves were constructed or repaired while one family got a biogas plant. 53 families remained with traditional cookstoves while three families with LPG + traditional cookstoves also did not go for improved cookstoves. The reason for the 53 families to stay with traditional cookstoves were that:

- Some are so used to using firewood conventionally and they do not see it as a major concern, they see it as a less of a priority with other issues they have - they are used to the smoke, or think they have enough firewood.
- Some find that the traditional stoves/three stones are more flexible for using bigger pots, needed occasionally for boiling larger pots of water.
- Some are not willing/lazy to commit themselves to install a stove, given the nature, the attitude, and the perspectives of the family.
- Some people are mainly cooking outside, where the clay stove will be wet and will not last, even though the Anagi stove is made from burned clay.
- Some people did not decide to install an improved stove immediately, but plan to install it later.

In the village, three institutional stoves were installed for production of curd from milk, which is sold in the local market. One stove was broken and was rebuilt while improved cookstoves were constructed to replace the two traditional stoves. The users provided some of the material and assisted with mixing of materials and the construction.

**Changes in cooking energy use and climate change emissions**

With the EVD project, the majority of families and all three village industries have moved from traditional cookstoves to improved cookstoves. The improved cookstoves are Anagi stoves for households and stoves designed by IDEA and a local partner for the village industries. The changes are shown in this table:

| | Households, before EVD | Households, EVD |
|---|---|---|
| Village total | 146 | 146 |
| Households with trad. cookstove only | 130 | 53 |
| Households with trad. cookstove + LPG | 3 | 3 |
| Households with Anagi stove | 3 | 80 |
| Household with biogas | 0 | 1 |
| Other combinations | 10 | 9 |
| Traditional stoves for industries | 3 | 0 |
| Improved Industrial stoves | 0 | 3 |

The stoves in village industries are located in three of the households in the village.

IDEA have estimated the following consumption of fuel for the different cooking options:

- Families with only traditional cookstove: 5,15 kg wood/day with an energy content of 7,500 kWh/year.
- Families with traditional cookstove + LPG: 3.3 kg wood + 0.15 kg LPG per day with an energy content of 5,500 kWh/year.
- For the families with Anagi stove: 2.8 kg wood/day with an energy content of 4,100 kWh/year.

For the family with biogas, we estimate the biogas consumption to be 4400 kWh/year equal to the energy content of 2 m3 biogas/day produced by the biogas plant.

| Institutional stoves | Traditional | Improved | |
|---|---|---|---|
| Stove 1 | 4 | 1.5 | kg/day |
| Stove 2 | 11 | 4.3 | kg/day |
| Stove 3 | 12 | 4.9 | kg/day |
| Total | 27 | 10.7 | kg/day |

For the energy content, we use the values in Annex 1 (wood: 4 kWh/kg, LPG 12.9 kWh/kg).

With these assumptions, the cooking energy consumption in the village has changed as follows with EVD:

| Energy use | Before EVD | With EVD | |
|---|---|---|---|
| Households with trad. cookstove only | 970 | 395 | MWh/year |
| Households with trad. cookstove + LPG | 17 | 17 | MWh/year |
| Households with improved cookstoves | 12 | 325 | MWh/year |
| Household with biogas | 0 | 4.8 | MWh/year |
| Other combinations | n.a. | n.a. | |
| Village industry stoves | 39 | 15 | MWh/year |
| Total cooking energy use | 1036 | 762 | MWh/year |
| Reduction | | 27% | |

We have excluded households with "other combinations" of cookstoves as we have too little information about the energy use of these households.

The results show that while the savings in each household that moves from traditional to improved cookstove (Anagi) is around 46%, the savings for the entire village is around 27%. The lower relative energy savings for the entire village is because 53 (41%) out of the 130 villagers with only traditional cookstoves at the start of the project, remained with traditional cookstoves only and because 3 families had already changed to improved cookstoves before the project started. Also 17 families remained with traditional cookstoves + LPG.

The emissions causing climate change and air pollution are reduced similarly to the reduction of energy use. The area is not a deforestation area, so generally the wood that is used for cooking is replaced with new growth. Anyhow, if trees are not cut because of lower use of trees for firewood, there will be more CO2 captured by the trees. We assume that this effect is equal to 15% of the CO2 released with combustion. This is equal to emissions of 0,2 kg CO2/kg firewood. In addition, the other climate change emissions (mainly black carbon) contribute to emissions of 0,47 kg CO2e/kg wood, as described in Annex 1. The emissions of LPG is set to 2,99 kg CO2/kg LPG as described in Annex 1.

For household biogas plants we expect a methane loss of 40 ltr/day (64 ltr biogas with 60% methane), equal to 200 kg CO2e/year, as in Annex 1.

This gives the following emissions from cooking and village industries in the village:

| Emissions in tons $CO_2e$/year | Before | With EVD |
|---|---|---|
| Households with trad. cookstove only | 164 | 67 |
| Households with trad. cookstove + LPG | 2.9 | 2.9 |
| Households with improved cookstove | 2.1 | 55 |
| Household with biogas | 0 | 0.2 |
| Other combinations | n.a. | n.a. |
| Traditional stoves for industries | 7 | 0 |
| Improved Industrial stoves | 0 | 3 |
| Total, cooking emissions | 176 | 127 |
| Reduction | | 27% |

The emissions do not include emissions from the 10 families with other combinations that we have not been able to quantify.

The emission reductions are very similar to the energy use reductions. We assume the same emissions per kg wood from the improved cookstoves than for the traditional cookstoves.

**Tree Planting**

86 Papaya trees were planted as a cash crop cultivation activity. Similarly to other trees, we estimate that they in average collect 25 kg CO2/year each during their lifetime, in total 2.2 tons/year for the 86 trees.

This gives a total reduction of climate emissions of:

| Greenhouse emissions in areas covered by EVD in Margul Village | Before EVD | With EVD | Change | |
|---|---|---|---|---|
| Cooking - 146 families 3 village industries | 176 | 127 | 48 | tons CO2e/year |
| Tree planting | 0 | -2 | 2 | tons CO2e/year |
| Total | 176 | 125 | 50 | tons CO2e/year |
| Reduction | 29% | | | |

### Other emissions

We have not been able to quantify emission changes from other EVD solutions in the village and in general in the village. This is mainly

| Emissions/activities | Type | EVD activity | Reason for non-inclusion in analysis |
|---|---|---|---|
| Soil emissions, $CO_2$ | Emissions from reduction of carbon in soil | Improved paddy farming<br>Increased natural fertiliser increases soil carbon | We do not have figures for the change of soil carbon of this type of improved paddy-farming.<br>Relatively small changes with improved kitchen gardening etc. |
| Agricultural emissions, non-$CO_2$ | Emissions of methane and N2O from paddy-farming and other farming | Improved paddy-farming with less chemical fertiliser | We do not have figures for the change of soil carbon of this type of improved paddy-farming. |
| Use of electric power | All houses have electricity | None | No EVD action |
| Transport | Emissions from cars, trucks, scooters etc. | None | No EVD action, no vehicles in village, all transport from outside actors |

The introduction of improved cookstoves have started to spread to other villages in the Matar District and by June 2023 at least 100 improved cookstoves have been installed in other villages, following information and replication activities from the project. Most of these are installed in a village, where the Sri Lanka Central Bank is promoting environmental solutions to develop that village into a green village.

### Conclusion

In the Sri Lankan EVD model village, 77 out of 146 households changed from traditional to improved (Anagi) cookstoves and one changed to biogas. Of the families relying on traditional cookstoves before the project, 59% changed to Anagi stoves and one family got biogas. In addition, all three village industries got improved cookstoves. This has resulted in an estimated reduction of 48 tons CO2e/year, equal to a 27% reduction of cooking greenhouse emissions of the entire village, including those that have not changed.

53 families remained with traditional cookstoves for their cooking. They were not able or willing to pay the 300 Rp for the Anagi stove and provide some local materials (such as clay) and help with the construction. They are

None of the three families that combine LPG and traditional cookstoves decided to change from traditional to improved cookstoves.
All the three institutional stoves for village industries (for milk processing) were changed to improved stoves.

The EVD cooking solutions have shown a good replication potential with over 100 improved cookstoves already installed in other villages in the district. The cooperation with a project by Sri Lanka Central Bank has helped this dissemination.

The tree planting with papaya trees was popular with 83 trees planted, collecting an estimated 2 tons $CO_2e$/year.

# Majherchar Village in Pirajpur District, Southern Bangladesh

The Majherchar village is in the southern coastal district of Pirajpur of Bangladesh (subdistrict Mathbaria). It has approx. 1000 inhabitants in 218 families. Here, the EVD project introduced improved cookstoves with chimneys, biogas plants, solar home systems, solar street lights, a solar water filtration system, solar insect traps, and three planting. All this contributes to reduce greenhouse emissions, emissions from the village as well as emissions from the power system of Bangladesh.

Visiting the Majherchar Village, photo by Grameen Shakti

Left: Two-pot improved cookstove in Majherchar, Bangladesh model. Right: Biogas plant in Majherchar Village, photos by INFORSE

**Changes in cooking energy use and climate change emissions**

With the EVD, the majority of families have moved from traditional to improved cookstoves. The improved cookstoves are tier-2 model (single burner) and tier-3 (double burner) according to the ISO 19867 standard and recommended by the national Bangladeshi agency IDCOL.

The implementation started with 50 single burner stoves. The villagers were given the ready-made concrete stoves and the chimneys, while they were providing clay to cover it and they did the installation after getting instructions. The local partner of the project installed one stove as a demonstration. After the 50 single burner stoves, 100 double stoves were installed in the same way. The cost of each concrete stove paid by the project was 500 taka for the single burner stoves and 650 Taka for the double burner stoves, in both cases including the chimney. These costs are after subtraction of government subsidy, which is partly paid by a carbon credit scheme.

In this way, the project provided 150 stoves, the remaining 40 families can get stoves later, but were not offered stoves by the project.

The changes in family cooking are shown in this table:

| Type of Stove | At project start | | At project end | |
|---|---|---|---|---|
| | Number (pieces) | % | Number (pieces) | % |
| Mud stove (Single Burner) | 130 | 63% | 30 | 14% |
| Mud stove (Double Burner) | 50 | 24% | 10 | 5% |
| Induction cooker | 5 | 2% | 5 | 2% |
| LPG | 20 | 10% | 20 | 9% |
| Improved Cook Stove (Single Burner with chimney) | 0 | 0% | 50 | 23% |
| Improved Cook Stove (Double Burner with chimney) | 0 | 0% | 100 | 46% |
| Biogas | 0 | 0% | 3 | 1% |
| Total | 205 | | 218 | |

Grameen Shakti found the savings for families with single burner stove was 2.5 kg/day and for double burner stoves 3.17 kg/day , by moving from a traditional cookstove (tier 0, efficiency 15% or. lower) to an improved cookstove (tier 3, efficiency >35%). Based on this, we assume the reduction is from 5 kg/day to 2.5 kg/day for families with one burner stoves [and from 6.67 kg/day to 3.5 kg/day for families with two-burner stoves].

For families using LPG stoves, that has an efficiency twice as high as the improved cookstove, we assume half the energy consumption of LPG than of wood fuel. 2,5 kg wood fuel has the energy content of 10 kWh (4 kWh/kg). The use of half of that, 5 kWh/day, is equal to 0,39 kg LPG/day or 141 kg/year, equal to almost one standard bottle (13 kg LPG) each month).

For families with an induction stove we assume an efficiency of 100% and therefore an energy (electricity) consumption of 3 kWh/day.

For families with biogas, we assume the use of 2 m3 of biogas per day with 60% methane, equal to 13 kWh/day.

With these assumptions, the energy use for the entire village before and with EVD is estimated to:

| Energy use in village | Before | With EVD | Change | |
|---|---|---|---|---|
| Mud stove (Single Burner) | 949 | 219 | 730 | MWh/year |
| Mud stove (Double Burner) | 487 | 97 | 390 | MWh/year |
| Induction cooker | 5 | 5 | 0 | MWh/year |
| LPG | 37 | 37 | 0 | MWh/year |
| Improved Cookstove (Single Burner with chimney) | 0 | 183 | -183 | MWh/year |
| Improved Cookstove (Double Burner with chimney) | 0 | 511 | -511 | MWh/year |
| Biogas | 0 | 14 | -14 | MWh/year |
| Total | 1478 | 1066 | 412 | MWh/year |
| Reduction | | | 28% | |
| Reduction/household | | | 32% | |
| Average/household | 7.2 | 4.9 | 2.3 | MWh/year |

The reduction is 28% for the village, but because the number of households included in the surveys have increased from before the EVD project to post implementation, the reduction per average household is 32%. This is well below the savings for the households that changed and saved 50%. This difference is because some households still have the traditional cookstoves as some households (with LPG and induction) did not change, and also because many families (around 50) decided to change from single burner traditional cookstoves to double burner improved cookstoves. Using the assumptions above, based on information collected by Grameen Shakti, the change from single burner traditional cookstove to double burner improved cookstove does not give so much savings in wood as change to a single burner improved cookstove, but the change improves the comfort, by having two burners instead of one.

Emission reductions follow the reductions in energy use. The wood is from sustainable sources, from the forest on the island, where the village is. Thus, we estimate net CO2 emissions from wood combustion to 15% of total emissions, giving total emissions of 0,67 kg CO2e/kg wood, both for traditional and improved cookstoves, following Annex 1. This is somewhat below IDCOL average of 0,99 tons CO2/ton wood, probably because IDCOL includes unsustainable wood use, where net emissions are closer to gross emissions. For LPG, we use 2,99 kg CO2/kg and for biogas we estimate that the greenhouse effect of methane loss is equal to 200 kg CO2e/year for each plant. For electricity we use the emission factor for Bangladesh of 0,67 kg CO2/kWh[1]. This gives the following greenhouse gas emissions:

| **Cooking greenhouse emissions, village** | **Before** | **With EVD** | **Reduction** | |
|---|---|---|---|---|
| Mud stove (Single Burner), wood | 159 | 37 | 122 | tons $CO_2$e/year |
| Mud stove (Double Burner), wood | 82 | 16 | 65 | tons $CO_2$e/year |
| Induction cooker, electricity | 4 | 4 | 0 | tons $CO_2$e/year |
| LPG | 9 | 9 | 0 | tons $CO_2$e/year |
| Improved Cookstove (Single Burner with chimney), wood | 0 | 31 | -31 | tons $CO_2$e/year |
| Improved Cookstove (Double Burner with chimney), wood | 0 | 86 | -86 | tons CO2e/year |
| Biogas | 0 | 0,6 | -1 | tons CO2e/year |
| Total | 253 | 183 | 70 | tons CO2e/year |
| Average/household | 1,2 | 0,8 | 0,4 | tons CO2e/year |
| Reduction | | | 28% | |
| Reduction/household | | | 32% | |

[1] Information from Grameen Shakti, Bangladesh

The emission reductions for the village are closely following the reduction in energy use, driven by the change to efficient cookstoves, and limited by the lack of change for some households and the move from one pot to two pot stoves.

**Solar Electricity**

The EVD project have introduced solar PV for a number of uses:

- Solar home systems, 3 systems 200 Wp each
- Solar Street light, 10 lamps, 30 Wp solar each
- Solar water pump, 1 pump/filtration system, 2000 Wp solar modules (not in operation at the time of collecting data for this report)
- Solar insect trap, 3 pieces, 30 Wp solar module each

The solar electricity can replace fossil fuel (kerosene for lamps, diesel for the pump) and grid electricity that is available in the village, but not all are connected. Given that the village has grid electricity, we will for this calculation assume that those buying the solar equipment would otherwise have bought grid-connected electric equipment. Thus, solar electricity replaces grid electricity.

In Southern Bangladesh, the annual yield of solar panels is 1430 kWh/kWp[1]. This gives the following solar power production for each of the 4 types of solar installations:

| **Solar power production, each EVD solar equipment** | **Energy, kWh/year** |
|---|---|
| Solar home systems, 200 Wp | 286 |
| Solar Street light, 30 Wp | 43 |
| Solar pump, 1 | 2860 |
| Insect trap, 20 Wp | 29 |

[1] According to https://globalsolaratlas.info/detail?c=22.82682,88.505859,6&s=22.00811,89.802246&m=site

For the entire village, the solar power production and reduced emissions from alternative electricity use is:

| Solar power production and gross emission reductions, EVD village | Energy, MWh/year | Emission reductions tons $CO_2$/year |
|---|---|---|
| Solar home system, 3 units | 0.9 | 0.56 |
| Solar Streetlights, 11 units | 0.43 | 0.28 |
| Solar pump, 1 unit | 2.86 | 1.86 |
| Insect trap, 3 units | 0.09 | 0.06 |
| Total, solar electricity | 4.23 | 2.75 |

Some of the electricity is stored in batteries and used later. There are losses in batteries, but with modern solar batteries, it is less than 10%[1] and we have not included the battery losses in the calculations.

While the solar installations save electricity production in Bangladesh, there are emissions to produce solar cells and batteries. We have discussed that in the above chapter on the Margul village in India. We identified production emissions of 618-646 kg CO2e/kWp for solar equipment with batteries and 200 kg CO2e/kWp for solar panels alone. For solar equipment with batteries, we will use the average figure of 632 kg CO2e/kWp. With EVD is installed:

- Three Solar home systems, ten street lights, and three insect traps with batteries, total 960 Wp, all with batteries, together emitting 600 kg CO2e in production.
- One solar pump with 2000 Wp solar panels without batteries, emitting 400 kg CO2e in production.

The total greenhouse emissions are then 1000 kg CO2e, equal to 100 kg/year over a 10-year minimal useful lifetime.

This will reduce the annual net reductions for the solar installations to 2.65 tons CO2e/year.

[1] https://ww2.redearth.energy/how-efficient-are-solar-batteries/

## Tree planting

With EVD is planted 300 trees that survive according to Grameen Shakti. Using same estimate as for India and Sri Lanka, we estimate that each tree during its productive life will collect 25 kg CO2/year, in total 7.5 tons CO2e/year for the village.

## Total Climate Mitigation with EVD

Adding the emission reductions in cooking, the reduction in grid electricity use from the solar installations compared with expected business as usual, and tree planting, the total emission reductions from the EVD project in the village are:

| Total emission reductions with EVD | Tons $CO_2e$/year |
|---|---|
| Cooking emissions, 253-183 tons $CO_2e$/year | 70 |
| Electricity use | 2.7 |
| Tree planting | 7.5 |
| Total | 80 |

## Other EVD Solutions

The other EVD solutions in the village do not influence greenhouse gas emissions.

## Conclusion

In the Bangladeshi EVD model village, 150 out of 205 households changed from traditional to improved cookstoves and three changed to biogas, in total a change for 68% of the families. In parallel, there was an expansion of the village with 13 families that, according to available information, started to use improved cookstoves. The effects of EVD combined with the increase of families have resulted in 28% reduction of energy use and of greenhouse emissions. The estimated emission reductions is 70 tons CO2e/year. The emissions per family reduced on average 32%, higher than the village reduction of 28% because of the increase in the number of families.

40 families, equal to 20% has not changed to improved cookstoves and remain with traditional cookstoves only. Mainly because the project only had plans for installation of 150 stoves None of the families that used LPG (20 families) or induction cooking (5 families) changed cooking energy.

Three families introduced solar homes systems and in the village were introduced three electric insect killers and 10 solar street lights as well as a larger solar water pump/filtration system. The villagers assisted in the installations. In a business-as-usual situation, the villagers could instead have used grid electricity for these functions. By going for solar instead for grid electricity, greenhouse emissions are 2,7 tons $CO_2e$/year lower, including the emissions to produce the solar energy equipment, which is just 3% of emission reductions. If more than 3 families will change to solar home systems instead of grid electricity, the emission reductions can be much higher.

With the EVD is also planted 300 surviving trees that over their productive lifetime will capture around 7,5 tons $CO_2$/year.

This brings the total climate mitigation effect of EVD in Majher Chor Village in Southern Bangladesh to 80 tons $CO_2e$/year.

## Bhalumare village, Marin Rural Municipality, South East Nepal

The Bhalumare village in the lower, southern part of Eastern Nepal has 516 inhabitants in 103 families. In this village, the EVD project introduced improved cookstoves, tree planting, a solar driven irrigation pump and other water supply. Among the EVD solutions, cooking and tree planting contribute to climate mitigation.

Bhalumare Village, Marin Rural Municipality, Nepal, photo by CRT/N.

Introducing improved cookstoves (one pot model) in the project village, photo by CRT/N

The implementation was made in the following way:

For the improved cookstoves, the villagers paid for the bricks as well as sugar and salt that was mixed into the clay to make it better insulating and enhancing the binding capacity, a total of 500 NPR (4 USD) while the project paid other costs, around 3000 NPR (23 USD). The villagers also helped with the work to install the stoves that were all fixed stoves.

Of the 72 families that used simple cookstoves before the project, 52 moved to the improved cookstove as the main cooking appliance, two turned to (repaired) biogas plants and 20 (23%) stayed with the traditional cookstove as primary cooking appliance.

The main reason for the 20 families that stayed with traditional cooking was that they cooked both inside and outside and wanted to continue that practice, so they did not want to allocate space in the house for a larger, fixed cookstove. The project did not offer portable cookstoves that could overcome this problem.

The 15 users of LPG as main cooking fuel were primarily people living in the bazaar of the village, where they did not want to increase local air pollution, which will increase when moving to firewood, even if the cookstoves have chimneys. Two of these families moved to induction cooking as their primary mode of cooking with the help of the project.

**Improved Cooking Solutions**

The EVD project has introduced 49 household improved cookstoves (ICS, two-pot), 15 institutional improved cookstoves (one pot, larger), 22 electric induction cookers, and renovated 4 household biogas plants. Based on this implementation and a survey after the installation, the following change of cooking (change of primary cookstove) is found for 88 families covered by the survey by CRT/Nepal:

| Households according to primary cookstove | Before EVD | Before EVD | EVD | EVD | |
|---|---|---|---|---|---|
| | Households | Persons | Households | Persons | HH size |
| Traditional cookstove as primary | 72 | 453 | 20 | 113 | 5.7 |
| Improved cookstove as primary | 1 | 7 | 51 | 333 | 6.5 |
| LPG as primary | 15 | 63 | 13 | 50 | 3.8 |
| Biogas as primary | 0 | 0 | 2 | 11 | 5.5 |
| El-Induction as primary | 0 | 0 | 2 | 9 | 4.5 |
| Total | 88 | 522 | 88 | 516 | 5.9 |

The survey also showed that many families have two or three types of cookstoves, for instance for the 52 households with improved cookstoves as primary cookstove, 21 indicate LPG stove as secondary cookstove and 14 indicate traditional cookstove (TCS) as secondary cookstove.

We use the same energy contents as above for wood (4 kWh/kg) and LPG (12,8 kWh/kg). For households with biogas as primary fuel, we assume the same energy consumption of gas as for households with LPG. For households using induction stoves as primary cookstoves, we assume an electricity consumption of 1/7th of the energy consumption of TCS.

Based on findings from CRT, surveying 5 families in the village moving from TCS to ICS , we have identified the following cooking energy use for food per person in the village:

| Fuel use per person | TCS primary | ICS primary | LPG + TCS | LPG + Induction | Biogas + ICS | |
|---|---|---|---|---|---|---|
| Wood use per day | 2.7 | 1.4 | 0.9 | 0.25 | 0.47 | kg/day |
| Wood use/year | 986 | 511 | 329 | 91 | 170 | kg/year |
| LPG use/year | 0 | 0 | 22 | 15 | 0 | kg |
| Energy use/year | 3942 | 2044 | 1603 | 693 | 971 | kWh/year |

For the above table, we estimate that when a wood-fired cookstove is secondary to LPG or biogas, the wood consumption will only be 1/3 and when a household only use a wood-fired cookstove as tertiary option, the wood consumption will be less than 1/10th of a household with traditional cookstove as primary option. For households with LPG, we assume that with EVD, half use TCS as secondary cooking and half use induction. Before EVD, there was no induction cooking.

In the village are also 15 institutional/village industry stoves, where CRT/N have identified a wood use reduction from 4 kg/day to 1.3 kg/day, when moving from traditional to improved stoves.

The 15 institutional stoves are used for cooking, and also used to cook fodder for cows and buffaloes as well as for alcohol production. The 15 families with single-pot institutional stoves produce alcohol while 16 families have cows or buffaloes (12 and 4 respectively). The 15 families that produce alcohol each used 675 kg/month for this according to the baseline study (in 2019). With the improved cookstoves, the reduction is 67%, reducing wood demand for alcohol from 23 kg/day to 7.3 kg/day. The 16 families with cows and buffaloes each used 265 kg/month according to the baseline study. Not all of them got institutional stoves, so we assume that they on average save 40%, reducing daily wood demand from 8.8 kg/day to 5.3 kg/day.

The energy cooking energy consumption for the village is estimated to be as follows, covering the 88 families in the survey, including cooking for animals and alcohol production.

| Energy use for village, cooking, MWh/year | Before EVD | EVD | Reduction |
|---|---|---|---|
| Traditional cookstove as primary | 1784 | 445 | 1338 |
| Improved cookstove as primary | 13 | 681 | -667 |
| LPG as primary | 101 | 80 | 21 |
| Biogas as primary | 0 | 8 | -8 |
| El-Induction as primary | 0 | 9 | -9 |
| Institutional Improved cookstoves | 692 | 282 | 411 |
| Total | 2591 | 1504 | 1086 |
| Reduction | | | 42% |

Emission reductions follow the reductions in energy use. The wood is from a sustainable source, a community forest near the village. Thus, we estimate net CO2 emissions from wood combustion to 15% of total emissions, giving total emissions of 0.67 kg CO2e/kg wood, both for traditional and improved cookstoves. For LPG, we use 2.99 kg CO2/kg and for biogas we estimate that the greenhouse effect of methane loss is equal to 200 kg CO2e/year for each plant. For electricity we use zero emissions as the power supply in Nepal is from hydropower. This gives the following greenhouse emissions from cooking in the village:

| **Greenhouse emissions in village, cooking** | **Before EVD** | **EVD** | **Reduction** | |
|---|---|---|---|---|
| ***per year for village*** | ***tons CO2e/year*** | ***tons CO2e*** | | ***tons CO2e*** |
| Traditional cookstove as primary | 299 | 75 | 225 | tons CO2e/year |
| Improved cookstove as primary | 2 | 114 | -112 | tons CO2e/year |
| LPG as primary | 18 | 10 | 8 | tons CO2e/year |
| Biogas as primary | 0 | 1,9 | -2 | tons CO2e/year |
| El-Induction as primary | 0 | 1,0 | -1 | tons CO2e/year |
| Institutional stoves | 116 | 47 | 69 | tons CO2e/year |
| Total | 436 | 249 | 187 | tons CO2e/year |
| Reduction | | | 43% | |

The emission reductions for the village are closely following the reduction in energy use, driven by the change to efficient cookstoves including induction cookers, and limited by the lack of change for some households.

**Tree planting**

With EVD is planted 250 tree saplings along roads, of which 190 are surviving, as well as 200 mango tree saplings that are all surviving. This is in total 390 trees. Using the same estimate as for India and Sri Lanka, we estimate that each tree during its productive life will collect 25 kg CO2/year, in total 9,75 tons CO2/year for the village.

**Total climate mitigation with EVD**

Adding the emission reductions in cooking and tree planting, the total emission reductions from the EVD project in the village are:

| **Total emission reduction with EVD** | **tons $CO_2$e/year** |
|---|---|
| Household cooking | 118 |
| Institutional stoves | 69 |
| Tree planting | 10 |
| Total | 197 |

**Other EVD Solutions**

The other EVD solutions including the solar water pump are not contributing to climate mitigation. The solar electricity for the pump could alternatively be provided by Nepalese grid power that has no emissions as it is from hydro-power.

**Conclusion**

In the Nepalese EVD model village, 52 out of 88 households changed from traditional to improved cookstoves as primary cookstove, two changed to biogas and two to electric induction stoves, in total a change for 61% of the families included in the survey of the village. In addition, all the home producers of alcohol changed to improved cookstoves The effects of EVD includes 42% reduction in cooking energy and a total reduction of greenhouse gases of 43%, estimated with a reduction of 187 tons CO2e/year.
21 households, equal to 24% of the families in the survey, decided not to change to improved cookstoves and remain with traditional cookstoves as primary cookstove. Two households out of 15 that used LPG changed to an improved cookstove as the primary cooking device. Now, 100% of the households have access to clean cooking technology, even though not all use it as their primary cooking device.

With the EVD is also planted 390 surviving trees that over their productive lifetime will capture around 9.75 tons CO2/year.

This brings the total climate mitigation effect of EVD in Bhalumare village in Southeast Nepal to 197 tons CO2e/year.

## Annex 1: Energy contents and emissions of fuels for cooking and lighting

We used the following energy contents and emission factors and reductions for all four countries:

| | Energy | | $CO_{2-total}$ | Other GHG | | Unsust. Part | Total net GHG | |
|---|---|---|---|---|---|---|---|---|
| Wood | 4.0 | kWh/kg | 1.3 | 0.47 | kg $CO_2$e/kg | 50% | 1,14 | kg $CO_2$e/kg |
| Wood | 4.0 | kWh/kg | 1.3 | 0.47 | kg $CO_2$e/kg | 15% | 0,67 | kg $CO_2$e/kg |
| Straw | 4.2 | kWh/kg | 1.4 | 0.49 | kg $CO_2$e/kg | 15% | 0,71 | kg $CO_2$e/kg |
| Dung, dry | 4.4 | kWh/kg | 1.5 | 1.05 | kg $CO_2$e/kg | 100% | 2,56 | kg $CO_2$e/kg |
| LPG | 12.8 | kWh/kg | 3.0 | 0 | kg $CO_2$e/kg | 100% | 2,99 | kg $CO_2$e/kg |
| Kerosene | 9.84 | kWh/ltr | 2.36 | 0 | kg $CO_2$e/kg | 100% | 2,36 | kg $CO_2$e/kg |

Wood and straw have natural water content in fuels (20% for wood, 10% for straw). Dung has dry matter.

Wood and straw are only included in part of the emissions that would not be released if the biomass is not used for energy. The reduction compared to total emissions is from natural decay of wood and straw and for wood the net additional growth that the trees will have if they are not cut (fully or partly) for fuel. The time frame is 20 years. In areas without deforestation, the part of emissions not released if the material is not used for energy is set to 15%, assuming 15% of material not burned will contribute to soil carbon and additional tree growth. For the project area in India, where there is some unsustainable wood use, with deforestation and land degradation, the part is set to 50%, assuming that part of the tree cutting for fuel is reducing the tree growth substantially.

A conservative assumption was made that there are the same black carbon emissions from all stoves per kg of wood burned, even though particle emissions from improved cookstoves typically are smaller per kg of wood for improved cookstoves than for traditional cookstoves. We have no black carbon emission measurements from the stoves used in the project's model villages.

For biogas plants, the emissions per plant per year is assumed to be 200 kg CO2e, mainly as methane emissions of 40 ltr/day (equal to 65 ltr/day of biogas with 60% methane). The CO2 produced in the biogas plant and in the combustion of biogas is expected to be equal to the CO2 emitted from composting or other use of the manure.

The source of the information on emissions is the report: "White Paper: Mitigation and Adaptation with Eco-Village Development (EVD) Solutions", INFORSE, October 2018, link: http://www.inforse.org/doc/Pub_EVD_White_Paper_Climate_Mitigation_Adaptation_2018.pdf

CLIMATE MITIGATION EFFECTS OF ECO-VILLAGE DEVELOPMENT PROJECTS

A report of the project: Next generation low carbon, climate resilient Eco-Village Development in South Asia