Modular Infrastructures for Residential Areas (MIRA)

Investigating the possibility of having the MIRA system in the Urban and Rural Areas of Nepal.

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Abstract

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Abstract

With increase in global population the demand for a simple yet effective energy system is slowly growing. Especially in the case of developing countries, a good and optimal energy system could work to enhance the lives of the people as well as the environment. In case of Nepal which has regions that are economically as well as geographically very different from each other this thesis tries to find out the possibility of using the Modular Infrastructure for Residential Areas (MIRA) system in both the rural and urban areas of Nepal. For the purpose of the thesis 2 small sample areas were taken into consideration and focus was given to the energy needs and supply along with the compatibility of the MIRA system in these areas. Various factors affecting the efficiency of the system were taken into consideration. The final results show that this system would fit very well with the urban residential areas of Nepal. As for the rural residential areas, further infrastructural development needs to be done before such a system can be installed and fully utilized in the area.

Language: English Key words: Modular Infrastructures, Energy Systems, Residential Areas, Urban and Rural regions.

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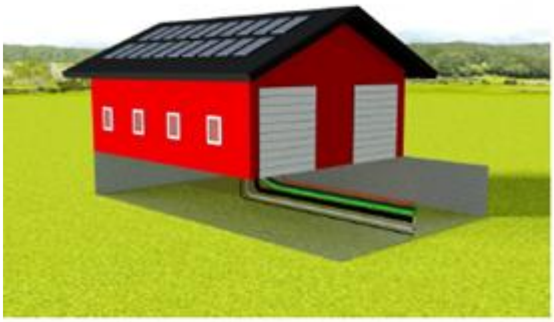
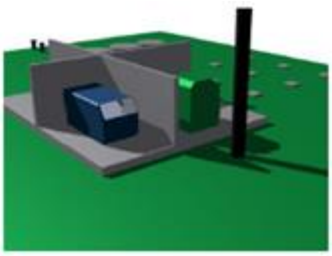
1 MIRA Project Introduction

The Modular Infrastructure for Residential Areas (MIRA) is an energy system that focuses on the energy needs of a residential area and provides an efficient infrastructure with centralized modules. As the population of the world rapidly grows, the need for living space is proportionally increasing too. This entails companies and innovators coming up with various ways to simplify the needs and wants of the people. MIRA is a system which can be modified and changed as per the needs of a residential area. It includes a way to formulate input needs such as energy sources and communication solutions as well as process outgoing solid as well as water waste. In the long term this system can prove to be one of the most economically viable as well as sustainable logical solutions.

The MIRA system would come in a package. After the data appraisal to find the needs of the selected area the system would be modified for optimal usage. For example in a small community in rural Finland consisting of around 20 houses a MIRA village hub would be created.





This system would include

- Water heating by wooden chip
- Waste water treatment
- AWCS (automatic waste collection system).
- Electrical transformer (from wind turbines and from the actual power grid).
- High speed internet connection through optical fibres.

As mentioned above the system components would change as per the needs of the area.

1.1 Aim and Scope

The main aim of this project would be to determine the need of the MIRA project in urban as well as rural parts of Nepal. As the system is a modular one the hubs created would have modifications as per the needs of the areas. To fulfil this aim and to moderate the scope of the project, two specific areas of the country (one urban area and a rural area) are the sources of the information and the basis of the results.

1.2 Employer

The MIRA consortium unites an entrepreneurial spirit with scientific methods for problem solving of complex challenges. The collection of competences in the team comprise: energy technology, chemistry, waste management, model development and simulation, and business development. The aim is to cross-link university research with business knowledge finding new models of canalizing this competence and creative energy into solutions supporting circular economy based sustainable development in rural areas.

2 Country Background

Nepal is a land locked country situated in South East Asia with a total area of 147,181 sq km. Bordered by India and China the total population as of 2016 is 29,033,914. With the capital Kathmandu, geographically Nepal is divided into 3 physiographic areas (Mountain, Hill and Terai) and 7 states. Nepal currently has 217 municipalities and 3157 village development committees (VDCs). In context municipalities in Nepal are considered as urban areas while VDCs are the rural areas. As per the data of 2011 the annual population growth rate of Nepal is 1, 3% and a population distribution of 4523820 people living in the urban areas and 21970684 people in the rural areas. [1]

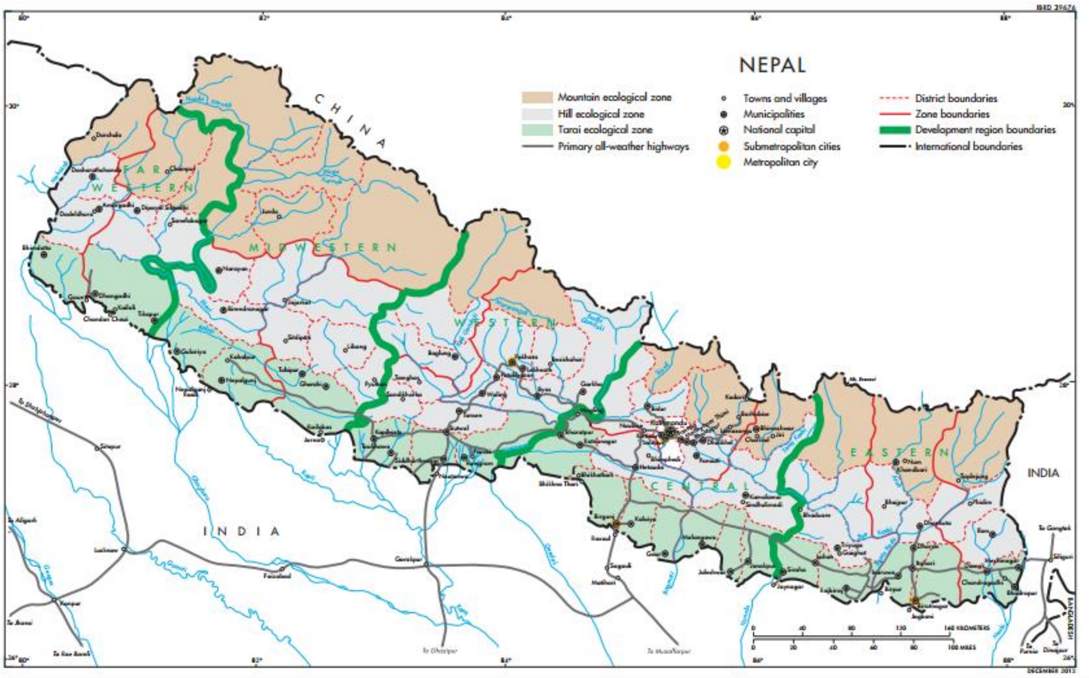


Figure 1: Map of Nepal (Muzzini and Apericio 2013)

Figure 1. (Muzzini and Apericio 2013) shows the ecological zones and development regions and districts of Nepal. Around 61% of the Nepalese population depends on agriculture as a source of income and occupation. These people are mostly living in the rural areas of Nepal. Due to the varying living conditions and the drastic urbanization of bigger cities the overall social, demographical as well as economical indicators for urban and rural areas of Nepal are very distinct. As things have been progressing at a rapid speed in urban areas the internal migration in the country has increased. This can be seen in the population density data of 2011 where the average urban population density of Nepal was 1,381 people per sq. kilometre compared to the total population density of 180 people per sq. kilometre. The Kathmandu valley has become the most populated urban areas of Nepal accounting for 24% of the total urban population of the whole country. [2]

2.1 Urban Areas in Nepal

Although Nepal is a predominantly rural country, it has been experiencing rapid urbanization. According to the United Nations Department of Social and Economic Affairs, Nepal will be amongst the top 10 fastest urbanizing countries for the period of

2014 to 2050. If all the municipalities are taken into context then according to the Economic Survey of 2015-16, 42% of the total population of Nepal lives in the urban areas.

The Kathmandu valley which is the only metropolitan area in Nepal has been experiencing a population growth rate of 4% per year. Contribution of urban areas to the Gross Domestic Product (GDP) stood at 33.1 percent, while Kathmandu Valley alone is estimated at 23.4. The average population density in the urban areas of Nepal as per 2011 was 1,381 sq. kilometres. Cities like Kathmandu, Pokhara as well as medium and small scale cities along the border as well as highways have experience high growth rates. As of 2011 Nepal has 159 new municipalities from previous 58 bring it to a total of 217. The Kathmandu Valley is one of the most rapidly growing urban agglomerations in South East Asia. [3]

According to the Ministry of Urban Development of Nepal in 2015 the three major reasons for such rapid urban growth are:

- Change in the demography whereby more people are entering the labour force than leaving it.
- A spatial move due to increased rural-urban migration.
- An economic transition because of decrease in traditional subsistence economy, the declining contribution of agriculture to the GDP, and the search for new livelihood options. [4]

Table 1: Urban growth patterns in Nepal

Parameters	1961	1971	1981	1991	2001	2011	2014
Urban population ('000)	336	462	957	1,696	3,228	4,523*	5,130**
Number of urban areas	16	16	23	33	58	58*	191**
Urban population (%)	3.6	4.0	6.4	9.2	13.9	17*	18.2*
Urban growth rate (%)	4.40	3.23	7.55	5.89	6.65	3.4***	N/A
National population growth rate (%)	1.65	2.07	2.66	2.10	2.27	1.35*	N/A

Table 1 shows the steady growth of population in the urban areas of Nepal (Choe and Pradhan 2010). However this growth has not been proportional to the urbanization of the municipalities itself. There is a lack in infrastructures to manage the growing population of these areas. According to the Government of Nepal Economic Survey of 2015-16, around 67 percent of the families have access to electricity, 47 percent have water facilities and 62 percent have proper toilets.

2.2 Rural Areas in Nepal

Rural areas in Nepal account for 81, 39% of the total population in Nepal as of 2015 which is the lowest it has been for the past 55 years.

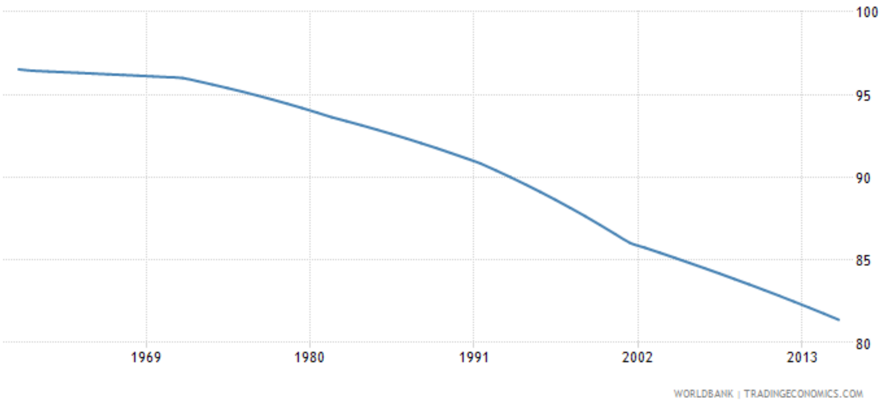


Figure 2: Rate of poulation decrease in Rural Areas of Nepal(TradingEconomics, 2015)

Figure 2 shows the decline in the % population in rural areas since 1969. Although the internal migration from rural to urban areas has increased a lot, the majority population of Nepal still lives in rural areas. Nevertheless there is a huge lack of development of infrastructure in these areas. So much so that even the central statistics bureau of Nepal does not have relevant data fully available for most of these areas. They have a high illiteracy rate with little to no access to electricity, sanitation and other basic services.

Although there are quite a few organizations that help facilitate services in rural areas they lack long term sustainability. The government has some plans but they have not been able to reach all rural areas of Nepal. Focus and economic priorities are given to urban areas so most people in rural areas are left to look after and provide for themselves, without much help from the government.

2.3 Energy Supply and Demand in Nepal

Nepal as a country does not have any known reserves of oil, coal or gas. Along with that the vast difference in topography as well as social economic standards have created different solutions that people use to cope with their energy needs via biomass, human labour, imported kerosene, and/or traditional water powered vertical axis mills. This gives Nepal one of the lowest per capita energy consumption in the world. Due to the lack of infrastructures, economy as well as vast difference in living conditions of the people in Nepal, the supply of energy has not been equivalent to the demand. But many independent researches and scientific studies have calculated that Nepal could meet all if its own energy needs if they would work on their solar and hydroelectric resources. [5] [6]

Nepal's total energy consumption in 2010 was about 428 PJ (10,220 ktoe). The primary source of energy in Nepal is biomass which accounts for 85% of the distribution, followed by petroleum products (9%), coal (3%) and hydro electricity (2%). As of 2012 81% of the total population of Nepal partially or wholly depended on traditional methods to fulfil their energy needs. Due to the larger use of renewable energy sources, Nepal's CO2 emission is very low. [5] [6]

If we look at energy consumption in households we can see significant difference based on urban and rural areas.

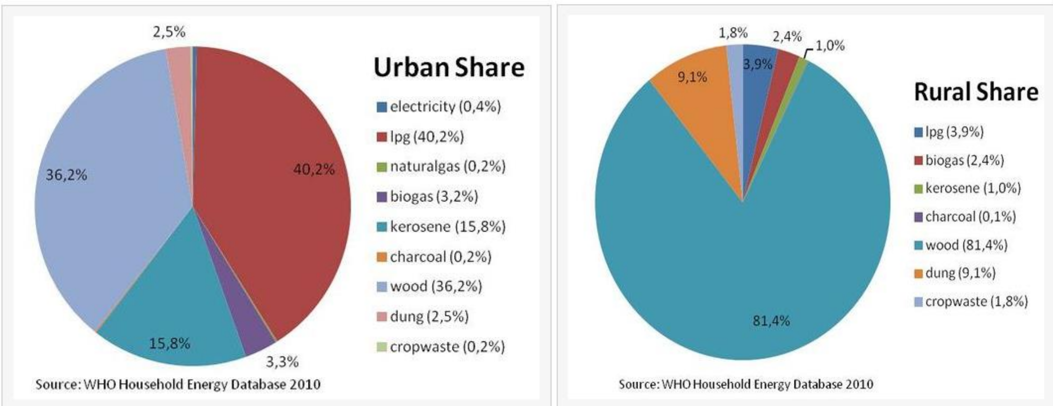


Figure 3: Enery sources in Urban and Rural Households Areas of Nepal (WHO Household Energy Database 2010)

As seen in Figure 3 above the main source of energy for residents of urban areas is LPG while people in the rural areas still use firewood as their main source of energy. Although 25, 4% of the land is covered by forests the national biomass balance for Nepal is at a deficit because of the over exploitation of wood resources in the country. [5] [6]

As most of the people in Nepal depend on agriculture for their livelihoods there is a huge dependency on livestock. Farming households not only depend on their cattle for labour and food but also use their faecal waste to produce biogas. The Nepalese government has also been promoting use of biogas by installing as well as providing subsidies for biogas plants in small villages. As of 2011, 244,827 biogas plant shave been installed in more than 2,800 village development committees in Nepal. [7]

According to the International Energy Agency Nepal's electric power consumption per capita for 2013 was 161,1kWh. As per the Ministry of Science, Technology and Environment of Nepal since 2014 the electricity demand has been increasing by 8-9% per year, but only about 70% of the population has access to electricity through grid and off grid systems. The National Electricity Authority (NEA) of Nepal which supplies electricity through the national grid only serves 15% of the population of Nepal. The rest works with diesel gensets, solar home systems, small island mini grids and other small installations. [8] [9]

Private households account for 43.4 % of national electricity consumption. The average daily household consumption is about 2 kWh which is used mainly for lighting. Nepal still suffers from lack of electricity which causes daily blackouts in all parts of the country. These load shedding last from 6-14 hours depending on the day and month. The hydropower potential for Nepal is estimated to be about 83000kW but currently only 1% of it is being harvested and used. [8] [9]

According to estimations of the NEA, the energy demand for Nepal will grow at an annual rate of 8, 34% for the next 10 years. There is an estimate that the energy demand will be approximately 8860GWh until 2018 and will exceed 17,400 GWh by 2027. Along with the growing demand it is projected that system peak load will increase with similar annual growth rates, reaching 3679 MW in 2027. [8] [9]

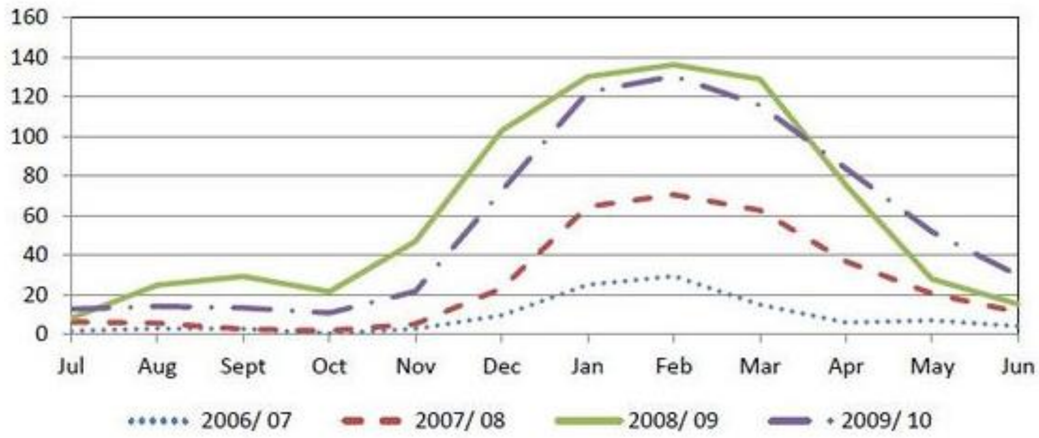


Figure 4: Electricity Supply and Demand Gap in Nepal(in GWh from 2006 to 2010)

Although the Nepalese government in the year 2008 issued a state of energy crisis in Nepal in the last 9 years nothing much has been done in order to control or mitigate this problem. Hence the margin between the supply and demand for energy has been growing bigger.

The rural areas cover more than 90% of the total land of Nepal and house more than 80% of the total population there has not been exponential improvement in their living standards. When we talk specifically about the electrification of the rural areas of Nepal, a several factors come into play. Harsh topography and low purchasing power of consumers are reasons as to why more than 56.7 % of the Nepalese population has no access to electricity.

Apart from hydropower, Nepal has also got potential in solar energy. According to the Government of Nepal’s Alternative Energy Promotion centre Nepal has 300 days of sunshine annually with an average of 3.6 to 6.2 kWh of solar radiation per square meter per day. This make for very ideal solar powered energy systems in Nepal and the number of households installing solar energy systems have increased yearly. These systems include grid-connected PV, solar water heaters, solar lanterns and solar home systems. [8] [9]

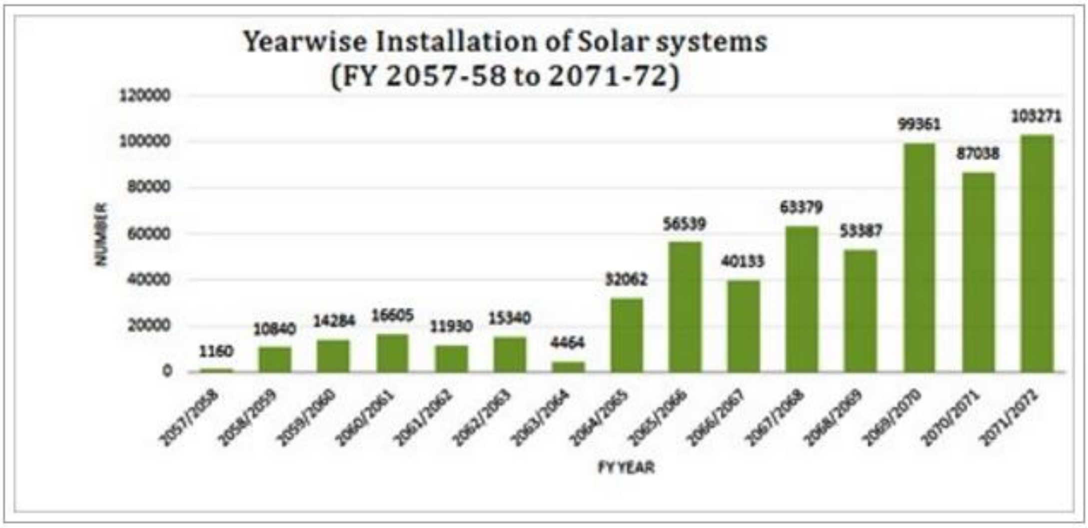


Figure 5: Installation of Solar panles in Nepal(Nepal Alternative Energy Promotion Centre2000-01 to 2014-15)

Along with solar power, according to the 2012 Renewable Energy and Energy Efficiency Partnership, Nepal also has potential for wind energy harvesting. One independent study showed that in some areas of Nepal (Mustang district) where the recorded wind speeds was 46 meters/sec Nepal has capacity of getting approximately 200 to 300MW worth of energy. A study done by the Department of Geology at Tribhuvan University and the Ministry of Physical Planning and Works found at least, 3,000 MW of technical wind potential existed in various areas of Nepal. This source of energy however has not been able to develop because of the absence of roads and transmission networks district in and around the area.

Petroleum which is the second largest energy source in Nepal is imported 100% via India. The Nepal Oil Corporation buys petroleum exclusively through the Indian Oil Corporation. But the dependence on petroleum products has increased significantly throughout the years. This has led to not only a huge shortage in the market but also seen an in fluctuation in the price which has made it next to impossible for people of lower economic levels to buy it. More than 62 % of the petroleum products are used in the transportation sector and the rest is used by urban households for cooking purposes.

According to the UNDP in 2012, the potential of renewable energy for Nepal was as follows:

Total Installed Capacity: 710 MW (mostly hydropower)
Technical Renewable Energy Potential: 77,949 MW
Annual Total Electricity Generation 3,851: GWh
Annual Renewable Energy Potential: 226,460 GW

When we talk about communication infrastructure in Nepal despite the large investments put in this sector, there is still a significant disparity between the high coverage levels in the cities and the coverage available in the underdeveloped rural regions. The number of internet service subscribers in the country has crossed the 10-million mark. The latest Management Information System (MIS) report of Nepal Telecommunications Authority (NTA) says that the number of data customers in the country stood at 10.09 million by mid-December, 2014. With this, the internet penetration rate has reached 38.09 per cent. Of the total internet users, more than 9.5 million are using mobile internet being provided by Nepal Telecom (NT), Ncell and Smart Telecom. [9]

2.4 Waste Management in Nepal

For the context of this project we will only be looking at household waste management and solid waste management in the residential areas of Nepal. As with the energy needs, dud to the difference in altitude, temperature, rainfall, and humidity, as well as socio-economic factors, such as population, economic status, and consumption patterns and general life style, the amount of household waste produced by residents in urban areas are significantly higher than the rural areas. Because of this the waste management techniques used are also different. While most of the urban area household waste is collected by the government, for majority of rural areas the waste is managed locally. The average household waste produced per capita per day is around 170g.

According to the UN Statistics Division data for 2012 in Nepal:

- Biomass and waste, production was 21.402Terajoules.
- Biomass and waste consumption by households was 21.028 terajoules.
- Vegetal waste consumption by households was 13.061 thousand metric tons.

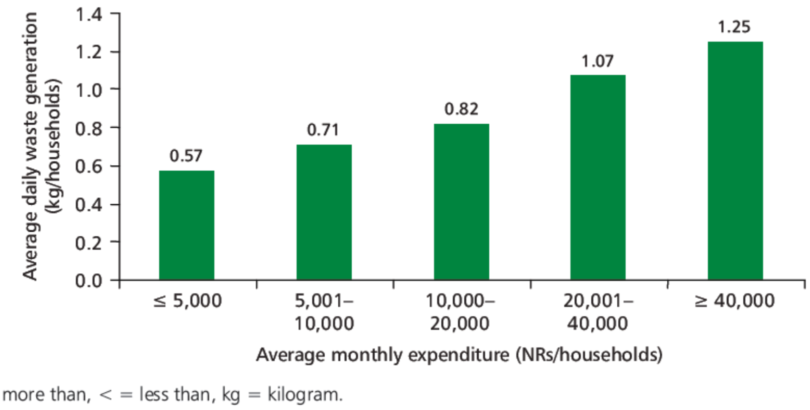


Figure 6: Average Household Waste Generated by Monthly Expenditure Level(Asian Development Bank 2013)

As shown in Figure 6 economic status place a huge role in the average household waste generated. An obvious observation is that people living in the rural areas have less monthly expenditure than those living in the urban areas.

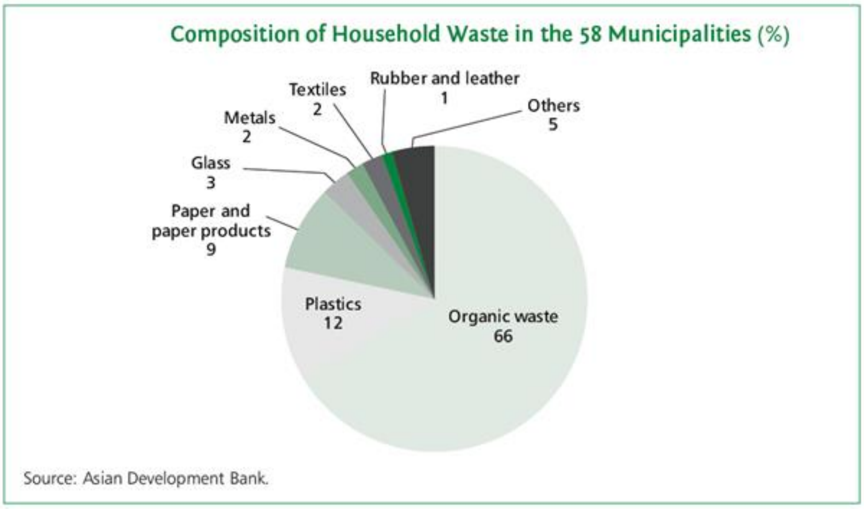


Figure 7: Household Compositon of Urban Household Waste(Asian Development Bank 2013)

Along with the waste amount the waste composition also varies according to area. As shown in Figure 7, in urban areas organic waste sums to 66% of the total waste produced, followed by plastic (12%), glass, metals and others.

The most common method to treat the household waste produced in urban areas is open dumping. Household waste is collected 1-2 times per week depending on the area and is taken to a dumping site. The government is responsible for the collection of the waste and he residents need to pay a monthly sum for the services. No sorting or recycling initiative takes place either by the people or the government.

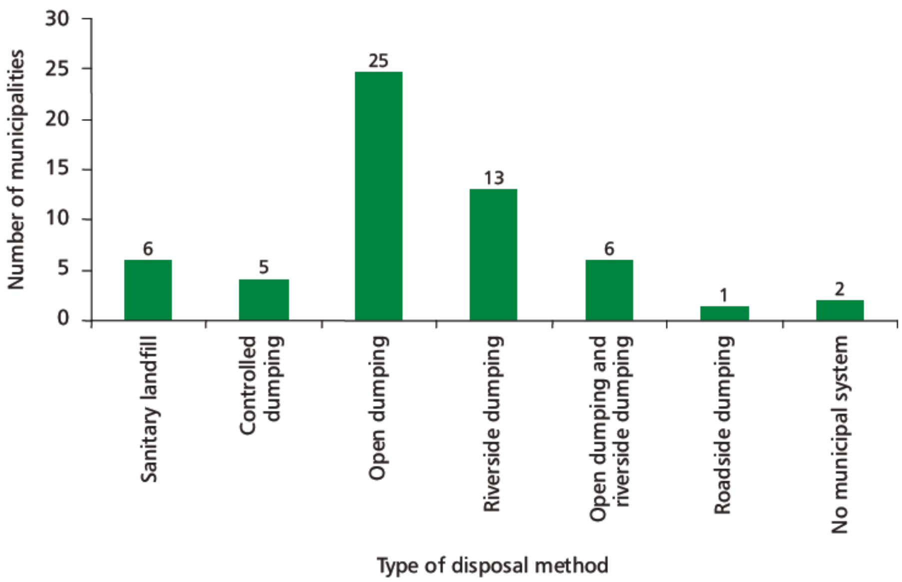


Figure 8: Solid Waste Disposal Methods in Municipalities of Nepal (Asian Development Bank 2013)

In rural areas around 85% of the household waste produced is organic matter followed by paper (9%), plastic (3%) and wood (2%). In most cases each individual family is responsible for their own waste management. People living in rural areas use the organic waste either as fertilizers or for biogas. Waste that cannot be reused is either incinerated in an open fire or dumped in an open riverside dumping area. There is a huge lack of proper waste management in both urban and rural areas of Nepal.

In the urban areas there is practically no recycling or sorting of the waste and everything either ends up in a landfill or in the banks of rivers. This has caused quite a bit of pollution issues in bigger cities where waste can be seen along the roads and smaller streets. It is not just the lack of infrastructures to blame but people who would not want to or cannot afford to pay money to get their waste picked chose to dump it near the streets or any remote place around their place of residence.

Rural areas are in a better condition as people use and recycle most of their waste themselves. As they do not have any waste collection services people in the villages take care of their waste themselves. Due to the increase in knowledge on biogas and the initiation from the government as well as non profit organizations many VDCs have biogas plants installed. This has not only increased the use of animal manure for biogas but also reduced waste quantity as well as firewood usage. In many rural areas of Nepal biogas is now used for cooking purposes.

No reliable data is available on the total volume of wastewater production in the urban and rural areas of Nepal. Due to the absence of these dates the waste water is estimated by the average daily water consumption per capita. This gives 75 litres per capita per day in the urban areas and 40 litres per capita per day in the rural areas.

3 MIRA System in Nepal

In today’s world one of the major factors to help push a country towards development and progress is the easy accessibility of energy sources in day to day life as well as for commercial and industrial uses. For this study we will be focusing on the energy needs for residential use in the rural and urban areas of Nepal and the effectiveness of having a modular infrastructural energy system in these areas.

The urban and rural areas of Nepal have vast differences between them. From the energy needs to the energy sources used. These contrasting factors make it such that there has to be different energy plans which correlate specifically to the focused area. As Nepal is not an economically strong nation, there are not enough facilities to cater to needs of all these different areas. Maybe this is one of the reasons why the difference between the urban and the rural areas are quite wide and seem to be getting more uneven as time passes.

Under these conditions the availability of modular energy systems is a viable option as they are composed of standardized units which are easy to build as well as flexible according to the need and environment of the particular area. The MIRA system does not just include energy also facilitates with the waste management problems in both the urban and rural areas.

For the purpose of this thesis data has been taken from a residential area in urban Nepal and a residential area in Rural Nepal. The sample areas include 10 houses each. Date with regards to energy input and waste output was collected from each house so as to see the feasibility of the MIRA system in these areas.

3.1 Urban Areas

The urban area from where the data is taken is Battisputali, Kathmandu, Nepal. Being in the capital city, this area has the typical needs of residents living in the urban areas of Nepal. They have all modern infrastructures provide including electricity, water pipes connected to the house as well as garbage pickup services. People living in the urban areas of Nepal use AC's and fans for cooling and heaters(gasoline or electric) for warming rooms.

In Kathmandu the average temperature is 23°C (73°F) and the coldest temperature is in the month of January which is around 9°C. Because of the year long temperate weather much focus is not given to the heating or cooling of residential houses. Thus this list does not contain energy needs for the same. The table below shows the needs, infrastructures availability as well as waste produced in the area.

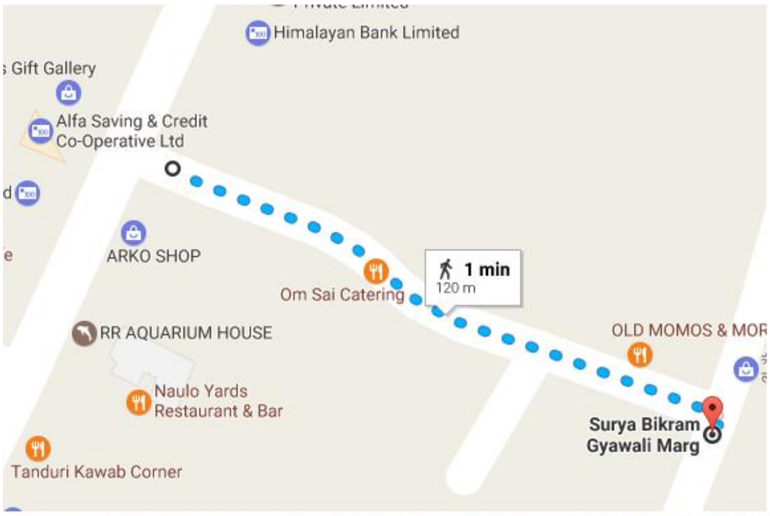
Table 2: Energy Input and Output datas collected from Urban Households of Nepal

House No.	Electricity useage (kWh/month)	Household waste(gm/day)	Water useage(L/month)	Internet	Communications	no. of occupents	Liquefied petroleum gas (kg/ month)	Aletmate Energy Sources
1	125	1250	13000	Cable Internet Access	Landline: 1 Mobile Phone : 6	10	14	-
2	100	549	10000	Assymmetric digital subscriber line(ADSL)	Landline: 1 Mobile Phone : 3	4	7,2	Solar Panel : 20Watts
3	200	7500	25000	Assymmetric digital subscriber line(ADSL)	Landline: 1 Mobile Phone : 13	18	18,5	Solar Panel : 100Watts
4	137	1000	12500	Assymmetric digital subscriber line(ADSL)	Landline: 1 Mobile Phone : 2	6	7,5	Solar Panel : 80Watts
5	110	2000	11500	Cable Internet Access	Landline: 1 Mobile Phone : 10	4	7	-
6	130	2650	16000	Cable Internet Access	Landline: 1 Mobile Phone : 9	9	20	Solar Panel : 180Watts
7	105	1150	14000	Cable Internet Access	Landline: 1 Mobile Phone : 3	6	14	-
8	134	1250	13200	Assymmetric digital subscriber line(ADSL)	Landline: 2 Mobile Phone : 4	6	16	-
9	87	475	7000	Assymmetric digital subscriber line(ADSL)	Landline: 0 Mobile Phone : 2	2	4,7	-
10	250	8000	27500	Cable Internet Access	Landline: 1 Mobile Phone : 18	22	19,2	Solar Panel : 120Watts

As seen in the table above, people living in this area have all the basic infrastructures available to them. Water is supplied via government pipelines, waste is collected every third day, there is 24/7 access to internet and communication lines. The only major concern for them is the interupted supply of electricity due to load shedding. To cope with this problem many people have taken the initiative to install solar panels to use during times of blackouts. Solar panels are also used to heat water in many houeholds. Those households without solar panels use gyesers to heat water as per their needs. Landline phones are only available via the natioanl telecom association while people have their own preferences for mobile and internet providers. Liquified pertoleum gas is used for cooking purposes in the all the above households.

When we see this area in the context of MIRA project we have certain points. They are:

- Starting with the area, the 10 households are all on the same street.



The figures above show the location of the area via Google maps and Street view. The first 2 buildings at the beginning of the street are commercial office building, thus they are excluded from the sample area as we only focus on residential areas. Even if the system were to be placed at the end of the street the maximum distance between the system and the households at the furthest end would be less than 200m. This would be the case for most urban areas in Nepal as the population density per square meter is quite high. Houses are more compact allowing for easy access to the system. People would not have to travel far to access any component of the complex and in case of a malfunction someone would always be close to check immediately what the problem could be.

- When it comes to electricity the term "load shedding" has become quite prominent in Nepal. Government allocated blackouts are common especially in urban areas to cope with the growing demand for electricity. This has led to a boom in solar panel installations for residential areas. Many houses in Kathmandu are fitted with solar panels, Inverters and batteries so that people can live normally during blackouts. Out of the 10 houses in our sample area, 5 are fitted with solar panels. But one major drawback of this is the Nepalese government does not allow people to feed excess electricity back to the grid which leads to wasted energy.

  In context with the MIRA system, the inclusion of electricity transfer wires could be used to shift the excess electricity produced to the other houses within the system. This provides the opportunity for the people living in the area to suffice with alternate sources of electricity during power cut offs. This in turn would also lower the consumption of kerosene and batteries.

- Household Waste is a major concern for people living in the urban areas of Nepal. What the MIRA system would entail is the use of an automatic waste collection system. This system would not only help eliminate the problem of waste management but also encourage people to separate and recycle their waste. Currently waste is not separated in the area. People do not have any incentive or reason for doing so. If an easy to follow system would be put in place then people could start sorting their waste. This could lead to a huge change in the way waste is handled in the urban areas of Nepal. If we think about the sample area although the government is supposed to pick up the garbage from houses every 3rd day sometimes they fail to do so. Their reasons vary from shortage of fuel pick up the garbage to the protest of city employees with regards to employment matters. Because of this there have been cases whereby some households have thrown their garbage out on the street so as to not mess their own homes.

  If a system is in place that allows for garbage disposal as per their own convenience, it allows people to not only sort their waste but also eliminates any changes of pollution caused by unclaimed waste bags. The automatic waste collection system can start out simple with various big bins for various wastes and then later can be changed to a pneumatic waste collection system whereby underground tubes can be used to directly transport of waste materials. This would be one of the most important features of the MIRA project in this area as it is not an uncommon sight to see garbage bags being discarded in the streets. Also this would reduce the amount of waste that goes into landfills as well as the overall pollution it causes to the environment.

- In case of waste water produced by the area, Kathmandu valley has currently only one operating activated sludge system. The rest of the four are either not opened or are only partially working. So for this sample residential area the only option currently available is use of sewage system which leads directly to the banks of the Bagmati River. This has caused massive degradation of this river as well as increased chances of air or water contaminations.

  With MIRA we could add a small scale waste water treatment plant in the system so that the water is treated before it joins the river. A sewage treatment which uses Membrane Bioreactor technology can be beneficial for the residence as well as the surrounding environment. These types of domestic treatment plants can be installed within a couple of hours, are ready for use as soon as installed and do not require much ground moving work during installation.

Taking all the above points into consideration the only con of having the MIRA system in this area seems to be the initial investment costs. But due to the higher economic standards of people living in the urban areas of Nepal as well as the constant government initiatives to better plan and facilitate the needs of the people living in these area, the initial financial aspects of the system are not a huge concern.

With that in mind, I also conducted a survey whereby I asked questions to members of the households to know more about their interests in such a modular energy system. For the survey 2 members from each household were chose. The questions were yes/maybe/no based. Here are the results:

Question 1. Do you as a resident of this area see the need for a centralized modular energy system?
16 out of the 20 people asked responded with a “yes”. The remaining 4 answered “maybe”. They said they required further information on the system.

Question 2. Do you think having an easy sorting centre would motivate you to sort your household waste?
14 out of the 20 responded with a “yes”. 2 people were not sure if they would have the time and the remaining 4 people replied “no”.

Question 3. Do you feel the need for a domestic waste water treatment system for your neighbourhood?
20 out of 20 residents responded with a “yes”. (It should be noted that this residential area is around 2km away from the Baghmati River. Because of the close proximity to the now polluted water all residents agreed that a waste water treatment would be a must.)

Question 4. Would you be willing to chip in for the initial investment costs of building such a system in your neighbourhood?
13 out of the 20 people responded with a “yes”. 4 people said “maybe” but they would only want to invest if everyone else is doing so. 3 people said “no” stating that it should be the responsibility of the government to provide them with this system.

From the survey it could be seen that majority of the people are interested in having a modular system in their area as they are able to chose what they feel is of importance in their neighbourhood. The priorities to all of them were electricity and waste water treatment system. Also it was known that most of them are willing to invest in such a system that customizes to their needs.

3.2 Rural Areas

The rural area from where the data has been gathered is Nalang 6 Balumdada, Bumesthan, Nepal. This rural area in Nepal is quite remote with limited transport, communicational or infrastructural access. The Nepal Doorsanchar Company Ltd which is the state owned telecommunication service provider in Nepal has not been able to reach this area leaving the people with no fixed line, ISDN and leased-line services. Instead the people use mobile services here.

The one thing that this area does have is the use of fixed-dome biogas generator in almost every household. People living in this area all have small domestic biogas plants in their backyard which they use to turn faecal matter into gas for cooking purposes. There is also use of dried faecal and firewood for heating of the houses. The table below shows the needs, infrastructures availability as well as waste produced in the area.

Table 3: Energy Input and Output datas collected from Rural Households of Nepal

House No.	Electricity useage (kWh/month)	Household waste(gm/day)	Water useage(L/month)	Internet	Communications	no. of occupents	Firewood (kg/ day)	Aletrnate Energy Sources
1	65	285	4250	Mobile Data Useage	Landline: 0 Mobile Phone : 2	2	1	BioGas
2	45	370	7000	-	Landline: 0 Mobile Phone : 3	3	1,5	BioGas
3	80	570	9250	Mobile Data Useage	Landline: 0 Mobile Phone : 4	5	3,5	BioGas
4	125	1100	11000	Mobile Data Useage	Landline: 0 Mobile Phone : 7	7	4,5	BioGas
5	72	650	8650	-	Landline: 0 Mobile Phone : 3	4	1,5	BioGas
6	100	1075	12500	-	Landline: 0 Mobile Phone : 9	10	6	BioGas
7	55	430	7850	Mobile Data Useage	Landline: 0 Mobile Phone : 3	3	2	BioGas
8	100	865	9850	-	Landline: 0 Mobile Phone : 6	8	5,5	BioGas
9	75	500	7640	Mobile Data Useage	Landline: 0 Mobile Phone : 4	4	2	BioGas
10	95	690	9000	-	Landline: 0 Mobile Phone : 6	6	4	BioGas

When we take these dates with regards to the MIRA system we have the following points to take into consideration:

- Unlike the residential area in the urban region, houses in Bumesthan are very far away from each other. This is very true for most rural areas of Nepal. In case of the 10 houses that have been taken in the sample area the closest houses are 700m apart while the farthest one is around 400 square meters from its closet neighbour. This is because people live next to their farm lands and they require a lot of space not only for farming but also for cattle rearing. This could create a problem with the MIRA system. As the system would be far from reach for certain residents, the system becomes inconvenient as it lacks accessibility.

- Electricity wires have reached this part of Nepal, but the people do not rely much on electricity. The primary use of electricity is for lighting. They do not have a lot of electrical appliances at home. The only exception is one house which has a small rice mill which is used by everyone in the neighbourhood. The people in this area do not have any alternative electricity sources and the blackout hours are also lower for this area. Electricity is more of a convenience to people than a need. Because of this electrical transformers or transfer wires are of no use in this area. Thus the electrical components of the MIRA system would not be required in this area.
- People in this area produce little to no waste. Most of the organic household waste produced is reused as either food for cattle or fertilizer for the soil. All families in this area sort their waste and burn or put into landfill the paper and plastic waste. The government does not have a garbage disposal plan for this area. Instead all the residents work to reduce the waste they produce and have allocated an area outside their community to dispose of the remaining waste.

  As all residents take care of the waste, building of another system in its place would not be a priority for them. Of course having an automatic waste collection system would be beneficial but like mentioned above as the houses are not really close to each other it would take the same time for some households to dispose of their waste where the MIRA system as would it to directly take it to the disposal site themselves. Also as they reuse most of their organic household waste as well as paper waste, the system would only be used for plastic and metal waste. The % of these components in the waste configuration for this area is less than 2%.
- In the case of waste water in this area the bathroom facilities are still quite primitive. Instead of sewage drains they collect their waste water in septic tanks which is then later emptied out in a deep hole and is buried. T his is a very archaic method to treat waste water but currently the government does not have any plans in place for this area with regards to sewage treatment.

  Simultaneously although having a small scale sewage treatment plant as part of the MIRA system would be beneficial for the area, there are certain factors which affect this. Due to the long distances between the houses large amount of piping needs to be dug out for this process. This would not be possible as most of the land around the area is all farm lands that cannot be disturbed. Also as the government does not really have any existing pipe lines in this area, there needs to be installation of pipes as well as allocation from the government on where the treated waste can be drained. All this would require allot of infrastructures and time.

- Biogas is one of the major energy sources in this area. All 10 houses have individual biogas domes in their backyard. This provided the residents with cooking gas which is connected via normal pipes to the kitchen. Depending on the amount of biogas produced sometimes households do use firewood for cooking and heating of the house. Firewood is brought from the forest that is part of their community. People here do not have to pay for the firewood they take. Instead they all take care of the forest so as to not let it degrade. Because these sources of energy are individualized as per the houses, it is not quite possible to integrate it into the MIRA system.
- When we talk about daily water usage in this area, the situation is such that there are no pipelines that provide water to every household. Water is taken from a spring which has a groundwater source. This has been the only source of drinking water for the people living in this area. The residents fill their buckets as per their household needs every day. For irrigation river water is used. A MIRA system which helps get drinking water to all the households would be well received but there are a few obstructions. Firstly as with the pipes for the sewage water, drinking water would also require the installation of pipes. The people of this area do not have the means to pay for the installations themselves.

  Another thing is currently no one in this area pays for the use of this water. As it is a natural water source and thy fetch the water themselves they do not have to pay the government anything. If the government does funds the installation of drinking water pipes then there is a possibility that they would start charging the people living in the area for the water they use. This would not work for the residents economically. Without the pipelines the MIRA system would not be able to add any value to this point.

As with the sample size in the urban area I also asked 2 members of each household in the rural areas about their interest and needs with regards to the MIRA project. The questions were yes/maybe/no answer based. Here are the results of that survey:

Question 1. Do you as a resident of this area see the need for a modular energy system?
18 out of the 20 people responded with a “no”. They said that as most of their energy needs are met via themselves they do not feel the need to have a centralized system. The remaining 2 said “maybe” as they do not think that have such a system installed would bring about any major difference in their lifestyle.

Question 2. Do you think having an easy sorting and garbage disposal centre would help them with their waste management?
19 out of the 20 responded saying “no”. As mentioned above they said that they recycle and sort their own waste in their own premises. They also use most of the reusable waste they produce so they do not see the point in having such a system. 1 person however did mention that it would be nice to have a place where he could dispose of his metal and plastic waste.

Question 3. Do you feel the need for a domestic waste water treatment system for your neighbourhood?
15 out of 20 residents responded with a “yes”. They said that it would be nice to have a system in place whereby they could treat their waste water so that it can be later disposed near the river banks. The rest of the 5 people mentioned that although it would be good, they do not have any inconvenience with the current system they are using now.

Question 4. Would you be willing to chip in for the initial investment costs of building such a system in your neighbourhood?
20 out of the 20 people responded with a “no”. People in this area are not financial secure enough to invest in infrastructural development. Most mentioned that they do not even have any savings as such to help with the system installation even if they wanted to. Even if the government would be willing to fund the project, they mention that for them the system would not be on their priority list. They would rather the

government provide them with basic landline communications and proper road for transport in the area.

It can be seen that maybe a system like MRA would be too advanced to work in the rural areas of Nepal. As these areas are still lacking basic infrastructural facilities, the system would not be able to fit and be efficient in such situations.

4 Results and Conclusions

The main point of this thesis was to see the possibility of efficiency of the MIRA system in residential areas of Nepal. When we look at the use of such a modular energy systems in the urban areas the results seem to be quite fruitful. A system as such would be able to solve various infrastructural problems for the urban area and elevate the living standard of the people. Along with that depending on the needs, modification features of the system give it a marketable approach. As most of the technologies in the system are already available and fit well with the residential areas' needs, no extra cost goes into new technology research. This would make the system purchase and installation more viable which could make the MIRA System a commercially successful business also.

However for the rural area of Nepal, the MIRA system does not seem to fit well. At least not right now. The rural areas in Nepal still lack a lot of basic infrastructures. Fitting of a MIRA system before the basic needs of people are met would not yield efficient results. If building of the infrastructures is taken as part of the system installation then the overall cost would not be feasible. Nepal as a country needs to better facilitate and develop its rural areas before such a system can be placed to ease the daily lives of the people. The rural areas of Nepal cannot be considered as a commercial marketplace for the MIRA system. As most people living there are below the poverty line, various government subsidies as well as national and international findings are the only available way to make this system available in the rural areas. One way the system could be integrated in the rural areas could be as part of a rural infrastructural development project whereby the project deals with the infrastructural development required in the area as well as the installation of the energy system. But currently no such projects are in works, either via the government or other non profit organizations.

5 Discussion and Evaluation

For the last part of the thesis, I will be presenting my views on the MIRA concept, a critical analysis of my thesis work as well as my opinions on the future steps of this project in Nepal.

The overall process for the thesis was quite uninterrupted. Most of the data regarding the general urban areas of Nepal were available online and even the people living in the sample areas were forthcoming during the data collection and survey process. There were however two things that could have been done differently. First the data collection procedure, took longer than required because some residents were unable to provide accurate numbers. It would have been more efficient to be more hands on with regards to the data collection. The other thing that I wish were different was that during the initial research phase I realized the lack of information and data with regards to the rural areas of Nepal. Except for a few individual reports I could not find anything substantial when it came to the energy needs, demands and supplies of residences in the rural areas. Even the Nepal Statistics Board did not have much information. My emails to the Statistics Board with regards to the data in the rural areas of Nepal were unanswered. Thankfully because of the cooperation of the residents of the sample area I was able to get most of the information I required, but if someone would want to see the potential of the MIRA system in another rural area of Nepal, this entire process would have to be repeated.

When we talk about the MIRA concept in general, I think it is very ingenious idea. When a system is made modular it is able to mould itself as per the needs of the surrounding. This concept in general works very well with Nepal as the environment and surroundings in the various places of Nepal are drastically different. Also the MIRA system consists of technologies that are available and have been working in Finland. This provides a reference point to people who are trying to implement these technologies as part of the MIRA system in their residential area. Factors such as optional choices in the system as well as already existing technologies would make the MIRA system affordable however is not without bumps. If you would picture having such a system in the commercial market of Nepal, cost would be the major factor. If the components of the system are shipped from Finland to Nepal that would add tariff + taxes which would make the cost per piece of the product very high. Along with that there is also the installation and maintenance of the system that needs to be though about. Who would be responsible for the installation of the entire energy system and if something goes wrong how much time would it take for the system to be fixed? Also how would be responsible for the maintenance of the system?

From the overall information I have gathered, I think focusing the MIRA system on the urban areas for now would be the most practical approach. The flaws with the rural areas are such that they would require at least another 3 to 7 years to be fixed. During that time if the MIRA system can be opened to the urban area, it would provide a much stronger base for when opportunities arise in the rural areas later. As per my observation, there are certain pointers I would like to mention:

- As the MIRA energy system takes a lot of infrastructures into its aspects, the first thing to do would be to contact the Nepal Government's Ministry of Population and Environment. Several components of the MIRA system (electricity, garbage, and wastewater) are co-related to the governmental services so it is very important that the government knows what the system is about.
- Instead of diving straight into the Nepalese market place maybe the most favourable approach would be to collect funds and install the system in one residential area first. This provides an opportunity to see the kinks in the sample system as well as retune the system to reach full potential.
- Affordability of the system is probable the most important factor. Even though people living in the urban areas have better financial means than people in the rural areas, if the parts are to be imported from Finland this would make the system too expensive for the Nepalese market.
- If this system is going to be a commercial business in Nepal, it would be very important to have a team present in Nepal. This team can be taught and trained

about the installation as well as maintenance factors with regards to the MIRA System. This would eliminate problems and time constraints if there would ever be a system failure.

These are just some of my opinions on what could be done with the MIRA system in Nepal. As I mentioned before, this system could really help Nepal deal with its core waste management and electricity supply/demand problems. I think there are quite good prospects for the MIRA system in Nepal.

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Table 2 Data Table of energy needs and inputs for sample households in urban area of Kathmandu, Nepal.

Table 3 Data Table of energy needs and inputs for sample households in rural area of Bumesthan, Nepal.

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Figure 7 Solid waste management in Nepal: Current status and policy recommendations, Asian Development Bank, Philippines, 2013, https://www.adb.org/sites/default/files/publication/30366/solid-waste-management-nepal.pdf

Figure 8 Solid waste management in Nepal: Current status and policy recommendations, Asian Development Bank, Philippines, 2013, https://www.adb.org/sites/default/files/publication/30366/solid-waste-management-nepal.pdf

Figure 9 Data Table of energy needs and inputs for sample households in Kathmandu, Nepal.