Universalizing Clean Energy in Nepal

A Plan for Sustainable Distributed Generation and Grid Access to All by 2022

GOVERNMENT OF NEPAL
NATIONAL PLANNING COMMISSION
KATHMANDU

NEA ENGINEERING COMPANY

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Universalizing Clean Energy in Nepal:
Sustainable Distributed Generation and Grid Access to All (SUDIGGAA) by 2022
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Preface

Despite holding a mammoth potential for generating clean hydropower, every three in ten rural Nepalese continue to live in darkness. They lack access to the national grid, and the generation of electricity is centralized which is barely keeping up with rising demand as the country urbanizes fast. The national target, aligned with the Sustainable Development Goals, is to strive for universal access to modern sources of clean energy well within 2030.

This study represents a bold policy foray, jointly undertaken by the National Planning Commission and the Nepal Electricity Authority's Engineering Company. It presents insights for policymakers and offers a practical guide for relevant stakeholders to undertake the ambitious task of supplying electricity to each municipality with their own generation. It presents a financially viable distributed generator for each of the 753 municipalities and optimal expansion of national grid to each municipality.

I take this opportunity to thank all officials, particularly at NPC and NEA for their contributions in pulling off this impressive feat in record time. I have no doubt that when the dream of near universal access to energy is realized over the next decade, this initiative by NPC would have proved presciently instrumental.

Swarnim Waglé, PhD
Vice-Chair

NATIONAL PLANNING COMMISSION

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Foreword

The topography of Nepal has always posed a challenge in ensuring access to electricity in all parts of the country. Electricity today is an essential component of daily life; it is indispensable to augmenting productivity in any vocation, from subsistence agriculture to sophisticated manufacturing and services. Realizing this, we have made solemn national and international commitments to expand the reach of modern electricity to all Nepalis within a realistic timetable.

We now need to develop plans and strategies to realize this ambitious vision. This is one such plan. This action study of Optimal Distributed Generation and Grid Access by 2022 provides a workable solution to provide access to grid electricity, with the active participation of local governments.

Arbind Kumar Mishra, PhD
Member

NEA ENGINEERING COMPANY
THAPATHALI, KATHMANDU

Foreword

We thank the collective leadership of the National Planning Commission for endorsing this novel proposal. It is a matter of honor and privilege for a new company like NEAEC to carry out this study and design work for the apex planning body of the country. We hope the Government of Nepal will consider the merits of these findings, and move swiftly towards implementation. The two-pronged strategy of constructing distributed generation at local levels of governance and extending national grid to each of these municipalities is a solution that we believed is the most viable and implementable one to remove darkness from the remote villages of Nepal in five years. We will always remain grateful to the apex planning body of Nepal to have had faith in our conceptual proposal and adopted it and even further led the whole research effort. We are confident that a faithful realization of the possibilities exhibited in this study will form a durable basis for Nepal's long term prosperity.

Hitendra Dev Shakya
Managing Director
NEA Engineering Company

Acknowledgements

This study is prepared by the National Planning Commission (NPC) under the leadership of the Vice-Chair Dr. Swarnim Waglé, with the support of all Members of the Commission. Dr. Arbind Kumar Mishra, Member of NPC, guided and coordinated the study, aided by a core team of staff at NPC including Radha Krishna Pradhan, Tulasi Prasad Gautam, Deepak Dhakal, Shiva Ranjan Poudyal, Binda Sitaula and line ministry focal points. We would also like to thank Dr. Biswo Poudel for his constructive feedback related to economic analysis. We thank all the offcials from participating ministries for their contributions to this study. From the NEA Engineering Company, Hitendra Dev Shakya took on this challenging task at the request of NPC. A list of his team and contributors to this report is included in Annex 1. To all of them, NPC expresses its gratitude.

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Chapter 1

Introduction

The National Planning Commission (NPC) commissioned the NEA Engineering Company (NEAEC) to conduct the "Study and Analysis of Optimal Distributed Generation for Access to Grid Electricity for All in Five Years with Participation from Local-level Government." The NPC, headed by the Prime Minister of Nepal, is the apex advisory body of the Government of Nepal for formulating a national vision, periodic plans and policies for development. The NPC assesses resource needs, identifies sources of funding, and allocates budget for socio-economic development, while serving as the central agency for monitoring and evaluating development plans, policies and programs.

The NEA Engineering Company Ltd. was established to provide complete engineering services and solutions to hydropower and other infrastructure industry. Nepal Electricity Authority (NEA) holds the majority ownership (51%) and the remaining 49% of shares are held by the Vidhyut Utpadan Company Limited (17%), Rastriya Prasharan Grid Company Limited (17%), and the Hydroelectricity Investment and Development Company Ltd. (15%).

1.1 The Global Context

At the global level, the problems in the energy and environment field are diverse. On the one hand, affluent nations with high energy-intensity are accelerating efforts to curb the use of fossil fuel to combat climate change; on the other hand, more than one billion people in low- or middle-income countries of South Asia and Africa have no access to modern electricity services. Access to electricity reduces human drudgery, enhances comfort and enables safer and cleaner environment. It boosts productivity and economic activity, creates jobs, and facilitates the delivery of education, health and government services. As services provided by energy are critical ingredients of socio-economic development, there is an urgent need to enable modern electricity services for everyone.

Recognizing the benefits of modern energy, the United Nations (UN) led Sustainable Energy for All (SE4ALL) initiative seeks to ensure universal access to modern energy services and the Sustainable Development Goal 7 (SDG7) aims to ensure access to affordable, reliable, sustainable and modern energy for everyone by 2030. The Government of Nepal (GoN) has adopted a Multi-Tier Framework (MTF) for household electricity access (shown in Table 1) to measure and track SE4ALL and SDG7 energy access goals and targets.

The perils of destabilizing the climate through the unabated use of fossil fuel in electricity generation have elucidated that Renewable Energy Technologies (RETs) must play the leading role to achieve "universal access to electricity" (currently de-

Access to electricity reduces human drudgery, enhances comfort and enables safer and cleaner environment. It boosts productivity and economic activity, creates jobs, and facilitates the delivery of education, health and government services.

fined as at least Tier 3 electricity access level of the MTF) by 2030. However, for countries like Nepal with limited resources, the prospect of enabling energy access through renewable technologies is saddled with challenges.

It is estimated that approximately 30% of the total population, mostly in remote villages, live in darkness.

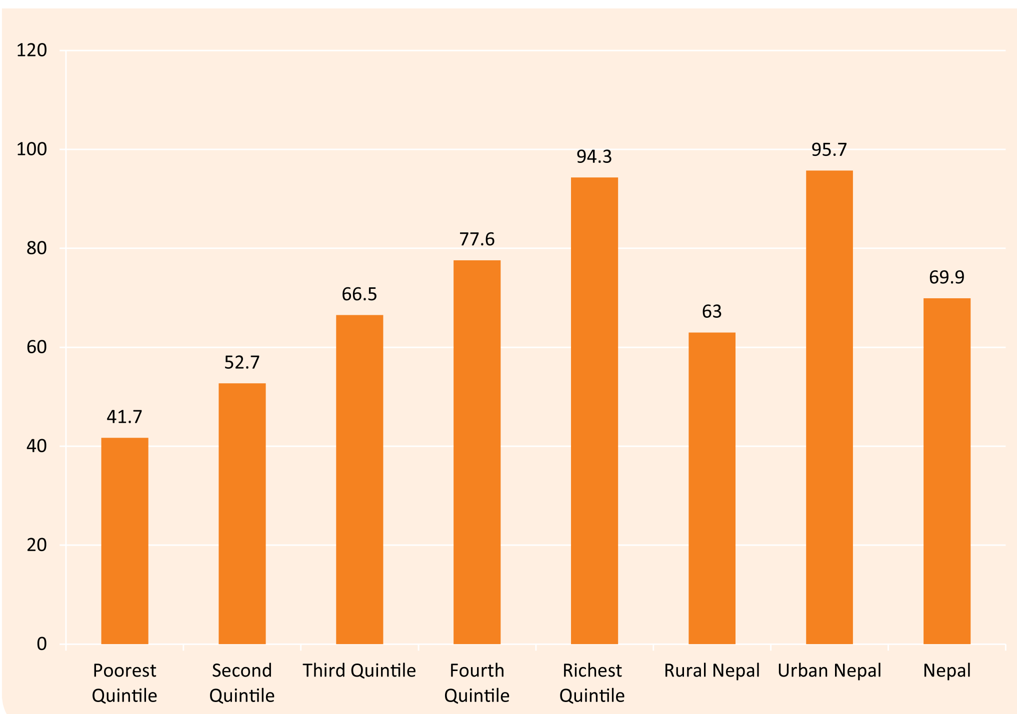
1.2 The National Context

Nepal is a mountainous country with 83% of the land lying in the hills and high mountains. The high investments required to build and extend distribution networks to remote areas have hindered government efforts in the past to provide access to electricity for communities living in remote areas.

Nepal's labor force is disproportionately employed in agriculture. In rural communities, shortage of energy negatively impacts economic development by suppressing agricultural productivity, health care, education and opportunities for entrepreneurship. The poor and rural households spend a large part of their income and time fulfilling their basic energy needs.

It is estimated that approximately 30% of the total population, mostly in remote villages, live in darkness. Based on the data of the number of customers that Nepal Electricity Authority and some small-scale distributors serve, and the average size of the household, it is estimated that only 60% of the population has access to grid electricity, and geographically, more than 60% of the country is deprived of access to the national grid. Figure 1 presents access to electricity in Nepal according to economic quintile. Only about 40 percent of the poorest 20 percent compared to 90 percent of the richest 20 percent households have access to elec-

Figure 1: Access to Electricity



Source: NLSS, 2012

Table 1a: Multi-tier Matrix for Access to Household Electricity Supply

			TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Attributes	1. Capacity	Power		Very low power min 3W	Low power Min 50W	Medium Power Min200W	High Power Min 800W	Very High Power Min 2 KW
		And Daily Capacity		Min 12Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min8.2 kWh
		OR Services		Lighting of 1,000 lmhrs per day and phone charging	Electrical lighting, air circulation, television, and phone charging are possible			
	2. Duration	Hours per Day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
		Hours per evening		Min 1 hrs	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
	3. Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration < 2 hours
	4. Quality						Voltage problems do not affect the use of desired appliances	
	5. Affordability					Cost of a standard consumption package of 365 kWh per annum is less than 5% of household income		
	6. Legality						Bill is paid to the utility, prepaid card seller, or authorized representative	
	7. Health and Safety						Absence of past accidents and perception of high risk in the future	

1. The minimum power capacity ratings in watts are indicative, particularly for Tier 1 and Tier 2, as the efficiency of end-user appliances is critical to determining the real level of capacity, and thus the type of electricity services that can be performed.

Table 1b: Multi-tier Matrix for Access to Household Electricity Services

		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
	Tier Criteria	Not applicable	Task lighting Phone charging	General lighting Television Fan (if needed)	Tier 2 AND Any medium power appliances	Tier 3 AND Any high-power appliances	Tier 4 AND Any very high-power appliances

Table 1c: Multi-tier Matrix for Electricity Consumption

		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
	Annual consumption levels, in kilowatt-hours (kWh)	<4.5	≥4.5	≥73	≥365	≥1,250	≥3,000
	Daily consumption levels, in watt-hours (Wh)	<12	≥12	≥200	≥1,000	≥3,425	≥8,219

tricity. The disparity in access to electricity has long-term implications on social equity and justice. Mid- and Far-Western Regions and rural areas of Nepal are more adversely affected by the lack of transmission lines.

Inadequate supply of electricity is one of the main constraints to expediting economic growth in Nepal. Quality electricity necessary for industrial activity is not available to the isolated networks supplied either by rooftop solar or by micro-hydro plants. A workable solution in a short time-frame to provide access to grid electricity is something the government is keen to implement.

Inadequate supply of electricity is one of the main constraints to expediting economic growth in Nepal. Quality electricity necessary for industrial activity is not available to the isolated networks supplied either by rooftop solar or by micro-hydro plants.

1.3 Identification of Challenges

The difficulties in enabling access to electricity in scattered settlements of the hilly and mountainous regions of Nepal are due to underdeveloped road and transmission links posing a major challenge in achieving SE4ALL goals. Unplanned and random extension of the grid to industries and settlements is a burden for planners at the national level and the Central Utility (NEA) as well. Moreover, demand consistently outweighs supply resulting in a disproportionate dependence on import of power from India. In the absence of such imports, scheduled power outages are likely to increase.

For off-grid population, the Alternative Energy Promotion Centre (AEPC) has been promoting and subsidizing renewable technologies for low levels of energy access for about 15% of the population. Unlike the central grid, isolated off-grid networks are unable to provide reliable and robust supply to support industrial usage of electricity, thus limiting its growth and value addition. Central grid access is essential for accelerated boost to productivity and the economy. Moreover, community-based isolated micro-hydro or solar projects demonstrate a systemic weakness of unsustainable operation. Subsidies provided to communities who help build and operate these plants have resulted in a chronic dependence upon such handouts.

More than 25% of the population has no access to either on-grid or off-grid electricity. Biomass supplies 85% of the total final energy mix and the average per capita electricity consumption annually (including domestic and commercial consumers) is only around 150 kWh.

1.4 Exploration of Solutions

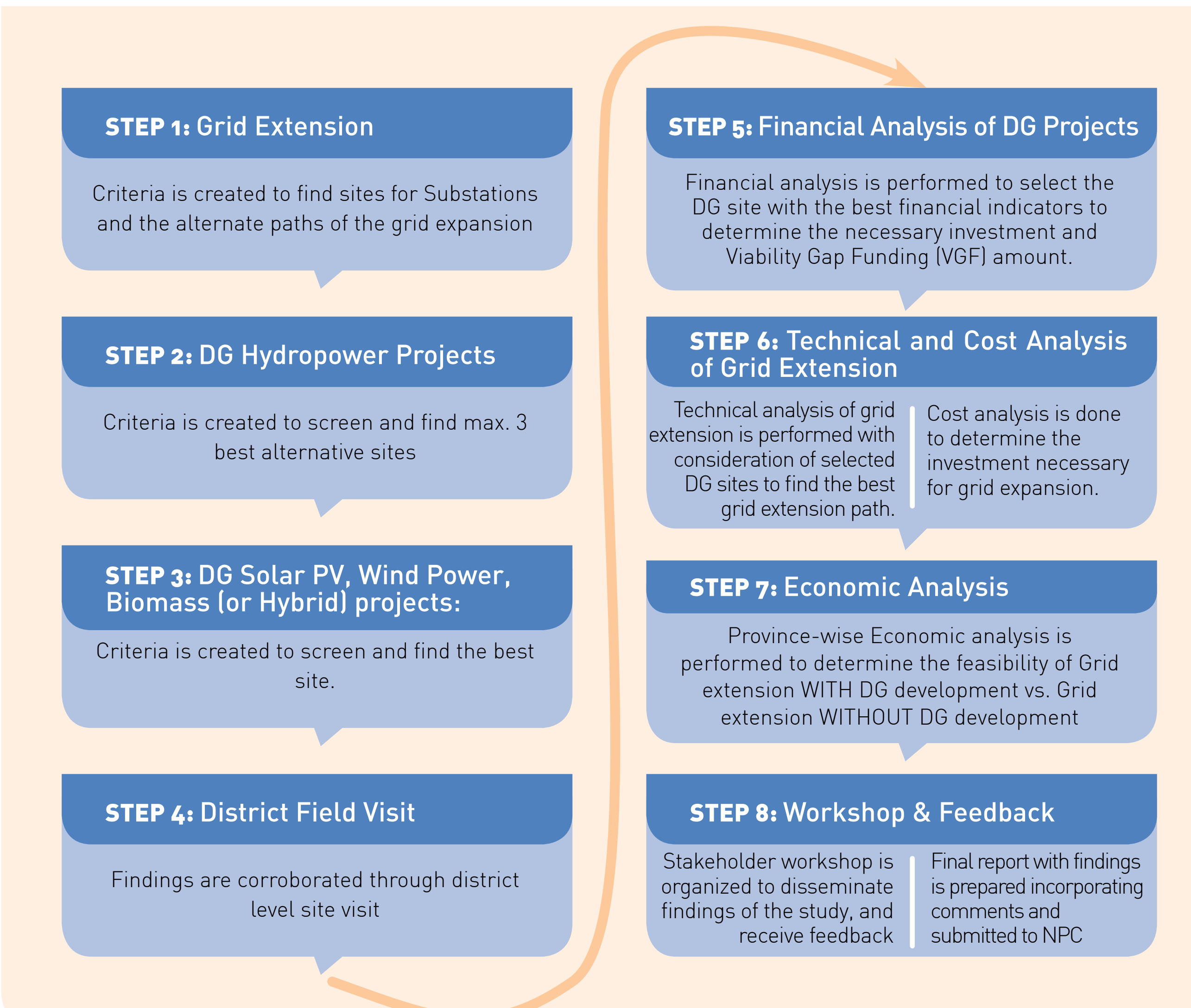
The traditional approach to electricity generation has been to generate power through large central power plants and transmit this power to different load centers through T&D network (also known as the national grid). This approach often results in low cost of electricity generation; however, by the time this electricity reaches the end users located far away, the cost increases because of the additional costs and power losses incurred by the T&D network.

Distributed Generation (DG) is an approach that employs small-scale technologies to produce electricity close to the end users of power. DG technologies often consist of modular renewable energy generators, which have a number of benefits such as lowering the cost of electricity, and increasing the reliability and security of power supply with fewer social and environmental consequences. Moreover, DG sources can use islanding techniques to serve the local distribution network even when the central grid is offline due to outages or load shedding.

By appropriately subsidizing the development of Distributed Generation (DG) resources to make it attractive to the private sector, GoN can deliver large economic benefits to the newly constituted Municipalities as well as help kick-start the local economy.

Similarly, T&D network extension, although capital intensive, can deliver large economic benefits while enhancing the sustainability of DG plants. The central grid can enable higher level of power and energy consumption, which could qualify as the highest level of household electricity access. T&D network extension, which entails development of T&D lines, hubs, and substations to reach the Geographic and Demographic Centre (GDC) of Municipalities, alongside the development of DG projects,

Figure 2: Overall Methodology



can decrease T&D losses and increase the reliability of the power system. The GDC locates the point within a Municipality that is the best location to build a Substation to service all customers within the Municipality cost-effectively.

This concept of 'Sustainable Distributed Generation and Grid Access to All' (SUDIGGAA) can act as a guiding principle for local governments to optimally utilize subsidies and scarce resources. SUDIGGAA has the potential to be a catalyst to electrify all municipalities and economically exploit local energy resources. SUDIGGAA has many other benefits. DG plants can reduce capital and operational expenditure of Transmission and Distribution networks. Hydropower plants reduce mainly active power losses while Solar PV plants provide reactive support to the grid and help to reduce reactive losses. Additionally, they can service local loads and further reduce transmission losses of the grid. Moreover, DG development and T&D extension can have ripple economic effect through forward and backward economic linkages.

The concept of Distributed Generation (DG) in each municipality advocates the bottom-up approach for identifying the best source of energy available locally considering the population distribution and means of production. From our preliminary examination, it is evident that most of municipalities have one or more renewable sources such as mini-hydro, solar, wind, or biomass available for development within their area, if the grid is available to balance the power by exporting the surplus and importing the deficit energy. Therefore, DG development integrated with the Top-Down approach of T&D network extension will enable the expanding network to reach all the municipalities of Nepal as well as provide the local means of income through Distributed Generation while comparatively reducing the demand on the central grid to completely supply all areas.

With this in mind, the overall objectives of this study are to:

- Study all the 753 Municipalities and identify the optimum extension path of the T&D network to increase access to energy as well as integrate the proposed DG plants.
- Find small-scale renewable sources of electricity generation in these municipalities that can be developed and operated in a sustainable manner with access to the grid.
- Explore the economic and financial aspects of DG development and grid extension including Viability Gap Funding (VGF) determination.
- Prepare a workable plan for Sustainable Distributed Generation for Grid Access to All (SUDIGGAA).

The overall methodology is illustrated in Figure 2.

Therefore, DG development integrated with the Top-Down approach of T&D network extension will enable the expanding network to reach all the municipalities of Nepal as well as provide the local means of income through Distributed Generation while comparatively reducing the demand on the central grid to completely supply all areas.

Chapter 2

Findings

2.1 Hydropower

The study shows that there is potential of hydropower ranging from 500 kW to 1000 kW in 277 local government jurisdictions with a total of 456 sites (maximum three sites per Municipality considered). Total power potential is found to be 383.56 MW and Province-wise summary is presented in Table 2. The hydrological analysis shows that the discharge is relatively higher in the eastern region than western region.

The present study is based on the available data, information and analysis tools for finding the discharge. Topographical maps and digital maps are used for finding the measurement. Therefore, flow verification of the identified sites has been proposed which needs to be carried out during detailed feasibility stage before the implementation of the projects. The analysis for hydropower does not consider the cost of land, which might be significant in some areas. Moreover, the present study also needs to be verified geologically and some sites may be rejected due to geological requirements.

2.1.1 Financial Analysis of Hydropower at different Costs

Financial analysis is performed for 1 MW hydropower plant to get a better understanding of financial indicators and the Viability Gap Funding (VGF) by the federal government required for a range of capital costs with the same revenue of NPR 6/kWh (NEA PPA Rate with 8 simple escalations of 3% each). The range of costs is selected to represent the minimum and maximum cost of the hydropower projects selected through this study. The results are presented in Table 3.

The study shows that there is a potential of hydropower ranging from 500 kW to 1000 kW in 277 local government jurisdictions with a total of 456 sites.

Table 2: Province wise Summary of Identified Hydropower Sites

S.N.	Province	No. of Local Bodies	No. of Sites Identified	Power (MW)
1	Province 1	56	84	66.11
2	Province 2	-	-	-
3	Province 3	53	81	64.44
4	Province 4	29	54	45.14
5	Province 5	23	38	26.99
6	Province 6	60	102	94.75
7	Province 7	56	97	86.12
	Total	**277**	**456**	**383.56**

As can be seen in Table 3, the case of 1 MW hydropower plant with 65% PLF, the range of capital cost per kW has significant effects on the financial attractiveness of the project. For capital costs from NPR 162,528 to 235,000 per kW (Costs I, II & III), the ROE is above 15% and no VGF is required. For projects with capital costs from NPR 235,000 to 300,000 per kW (Cost IV), the VGF required is less than NPR 80,000/kW. Beyond capital costs of NPR 317,000/kW (Cost V, VI, VII), the VGF required increases beyond 100,000/kW.

2.2 Solar

2.2.1 Solar PV with Battery

For 1 MWac Solar Plant with 500 kWh battery storage, the LCOE is quite high at NPR 11.96, 12.16, 12.56, 13.25, and 14.02 per kWh for Region E (Remote West Hills), F (Very Remote West Hills), D (West Hills), C (West Terai), A (East Terai) and B (East Hills) respectively. Highest LCOE is for Region B (East Hills) due to lowest CUF of 17.00% for this region and lowest LCOE is for Region E (Remote West Hills) followed by Region F (Very Remote West Hills).

The high CUF of >20% of Regions E and F compensates for the higher capital costs of these regions (due to higher transport costs) to result in most cost effective solutions. Nonetheless, the Viability Gap Funding (VGF) required for each Region is high, at around NPR 100,000/kWac. Without VGF, the NEA PPA Rate with eight no. of 3% escalations required for 15% ROE would be around NPR 14.85/kWh. Further, if only 200 kWh of battery storage is considered for Region A, the capital costs decreases to around NPR 140,000/kWac, which will result in lower VGF of NPR 83,000/kWac.

Sensitivity analysis shows that if the capital costs of Solar PV with 500 kWh battery storage decrease to NPR 120,000/ kWac within five years, the LCOE for Region A (East Terai) will decrease from NPR 14.02 to 10.25 per kWh with ROE of 1.60%, which will require less Viability Gap Funding (VGF)

Table 3: Financial Analysis of Hydropower (1000 kW) at different Costs

COST# / OUTPUT	Cost I	Cost II	Cost III	Cost IV	Cost V	Cost VI	Cost VII
	Capital Cost* [NPR/ kW] = 162,528	Capital Cost [NPR/ kW] = 200,000	Capital Cost [NPR/ kW] = 235,000	Capital Cost [NPR/ kW] = 300,000	Capital Cost [NPR/ kW] = 400,000	Capital Cost [NPR/ kW] = 500,000	Capital Cost [NPR/ kW] = 579,475
LCOE [NPR/kWh]	3.95	4.86	5.71	7.29	9.72	12.15	14.09
LBOE [NPR/kWh]	7	7	7	7	7	7	7
ROE [%]	30.85%	20.93%	15.07%	8.33%	2.30%	-1.65%	-4.11%
NPV [NPR-Million]	136.78	93.29	52.66	-22.77	-138.84	-254.91	-347.15
Cost Benefit Ratio	3.81	2.55	1.75	0.75	-0.16	-0.70	-1.00
Pay Back Period [Years]	3.75	6.15	9.56	14.70	21.02	>25	>25
VGF required per kW [NPR/ kW]**	None	None	0	79,000	201,000	323,000	420,000
First Year PPA Rate* required [NPR/ kWh]**	4.16	5.12	6.00	7.67	10.22	12.77	14.81

* O&M Costs changes as well because Yearly O&M Costs is calculated as 3% of Capital Cost
** To achieve at least 15% ROE (criteria for financial viability)
*** With 8 simple escalations of 3% each to achieve 15% ROE in case of No VGF provided
# The Cost I to Cost VII models are based on increased costs in constructing hydropower plant due to site characteristics and distance from road head.
The Discount rate used is 10%.

Table 4: Sensitivity Analysis of Scenario A (1 MWac Solar PV With 500 kWh Battery Backup)

CASE	Base Case	Case I	Case II	Case III	Case IV	Case V
OUTPUT	Capital Cost* [NPR/ kW] = 164,661	Capital Cost [NPR/ kW] = 140,000	Capital Cost [NPR/ kW] = 120,000	Capital Cost [NPR/ kW] = 100,000	Capital Cost [NPR/ kW] = 80,000	Capital Cost [NPR/ kW] = 60,000
LCOE [NPR/kWh]	14.02	11.93	10.25	8.56	6.87	5.18
LBOE [NPR/kWh]	6.98	6.98	6.98	6.98	6.98	6.98
ROE [%]	-3.22%	-0.84%	1.60%	4.86%	9.67%	18.25%
NPV [NPR-Million]	-89.38	-63.67	-42.81	-21.95	-1.09	19.75
Cost Benefit Ratio	-0.81	-0.52	-0.19	0.27	0.95	2.10
Pay Back Period [Years]	>25 years	>25 years	22.07	17.81	13.96	6.88
VGF required** per kW [NPR/ kW]	110,000	83,000	61,000	38,000	16,000	None
First Year PPA Rate*** required [NPR/ kWh]	14.85	12.63	10.86	9.04	7.27	5.47

* O&M Costs decrease as well because Yearly O&M Costs is calculated as 1.5% of Capital Cost
** To achieve 15% ROE at the given PPA Rate
*** With 8 simple escalations of 3% each to achieve 15% ROE in case of No VGF provided

of NPR 61,000 per kW. If the capital costs further decrease to the range of NPR 60,000 per kWac within 5 to 10 years, the plant will require no VGF as the LCOE will decrease to about NPR 5.18/ kWh and the LBOE of NPR 6.98/kWh (i.e. NEA PPA Rate of NPR 6/kWh with 8 no. of 3% escalations) will be enough to generate ROE of 18%. However, such drastic decrease in costs for Solar PV with battery storage is not possible immediately. Over time, advancements in bi-directional inverter and battery technology could result in lower capital costs.

2.2.2 Solar PV without Battery

For the Base Case of alternative scenario in which 1 MWac Solar Plant without any battery storage is considered, the LCOE of Region A (East Terai) decreases substantially from NPR 14.02 to NPR 10.15 per kWh. The Viability Gap Funding (VGF) of NPR 60,000/kWac is still necessary for ensuring 15% ROE. Without VGF, the NEA PPA Rate with 8 no. of 3% escalations required for 15% ROE would be around NPR 10.79/ kWh.

It can be observed from the Sensitivity Analyses that if the capital costs of Solar PV without any battery decreases to NPR 100,000/ kWac within a few years, the LCOE for Region A will decrease from NPR 10.15 to 8.44 per kWh with ROE of 5.23%, which will require less Viability Gap Funding (VGF) of NPR 36,000 per kW. If the capital costs of Solar PV without battery storage decrease to the range of NPR 60,000 per kWac within 5 years, the plant will require no VGF as the LCOE will decrease to about NPR 5.06/kWh and the LBOE of NPR 6.98/kWh (i.e. NEA PPA Rate of NPR 6/kWh with 8 no. of 3% escalations) will be enough to generate ROE of 18%. Such a drastic decrease in costs for Solar PV seems unlikely in the immediate run. Apart from the decrease in costs in the international market, the capital cost can be decreased through substantial policy interventions such as additional exemptions on tax, customs duty and excise duty.

Within the scope of this study, it would be unfair to compare Solar PV without any battery storage to hydropower and biomass technologies, as the Solar PV would not be

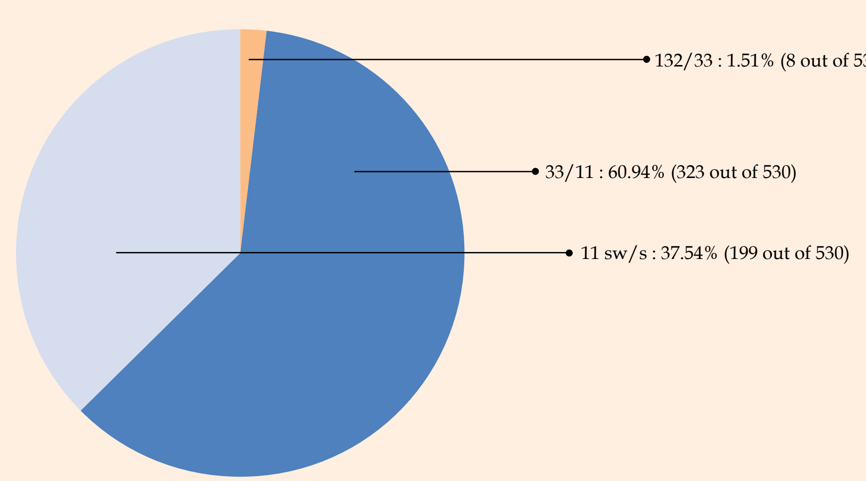
Table 5: Sensitivity Analysis of Scenario B (1 MWac Solar PV Without Battery Backup)

CASE / OUTPUT	Base Case Capital Cost* [NPR/ kW] = 120,211	Case I Capital Cost [NPR/ kW] = 100,000	Case II Capital Cost [NPR/ kW] = 80,000	Case III Capital Cost [NPR/ kW] = 60,000
LCOE [NPR/kWh]	10.15	8.44	6.75	5.06
LBOE [NPR/kWh]	6.98	6.98	6.98	6.98
ROE [%]	1.90%	5.23%	10.10%	18.70%
NPV [NPR-Million]	-41.59	-20.52	0.335	21.19
Cost Benefit Ratio	-0.15	0.32	1.01	2.18
Pay Back Period [Years]	21.53	17.26	13.44	6.88
VGF required** per kW [NPR/ kW]	60,000	36,000	15,000	None
First Year PPA Rate*** required [NPR/ kWh]	10.79	8.96	7.18	5.39

* O&M Costs decrease as well because Yearly O&M Costs is calculated as 1.5% of Capital Cost
** To achieve 15% ROE at the given PPA Rate
*** With 8 simple escalations of 3% each to achieve 15% ROE in case of No VGF provide

able to supply any electricity during nights in the event the central grid is down, thus compromising the reliability of supply. Nevertheless, Solar PV with battery can be developed in two phases, such that Solar PV Plant without battery but with adequate space for adding batteries and inverters later is developed in the first phase, and additional Inverter and battery necessary added in the subsequent phases. This will help break the total investments and VGF into multiple phases while providing the flexibility of achieving increasing reliability from the project over time.

Figure 3: Total Proposed Substations (530)



2.3 Biomass & Wind

Biomass to electricity projects based on Municipal Waste is considered for 50 municipalities with high population density such that enough waste material can be ensured for smooth operation of the plants. But, due to the scarcity of well- established waste collection system and lack of pilot projects to demonstrate technical feasibility, the biomass to electricity projects may be an impractical choice for development.

There is a lack of wind resource data; only three wind power projects are studied with field based wind resource data available in the literature. The main challenge in developing wind power is found to be the transport of large turbines over challenging topography to reach areas with high wind power potential.

2.4 Grid Extension

The network is planned to be constructed by 2023 (taking annual domestic load consumption to be 300 kWh in electrified areas and 180 kWh in un-electrified areas) and the transmission lines are designed for 2028 considering load increases by 15% annually on both electrified and un-electrified areas which would be in Tier 3 level of electricity access according to the Multi-Tier Framework.

2.4.1 Number and Type of Substations and T&D Lines

As shown in Figure 3 , 530 Substations are proposed of which the highest share is of 33/11 kV Substations, followed by 11 kV switching stations or Substations for primary distribution. The share of 132/33 kV substations is the lowest as they are considered only when 33/11 kV Substations are insufficient.

A total of 7828 km of T&D lines are proposed of which the highest share is of 33 kV lines, followed by 11 kV lines and 132 kV lines (Figure 5). 33 kV lines have the highest share because they are found to be most suitable to service the load centers. 132 kV lines are the lowest as they are only considered when even double circuit 33 kV lines are insufficient. The proposed and existing substations and lines are shown in Annex 3.

Figure 4: Number of Proposed Substations per Province

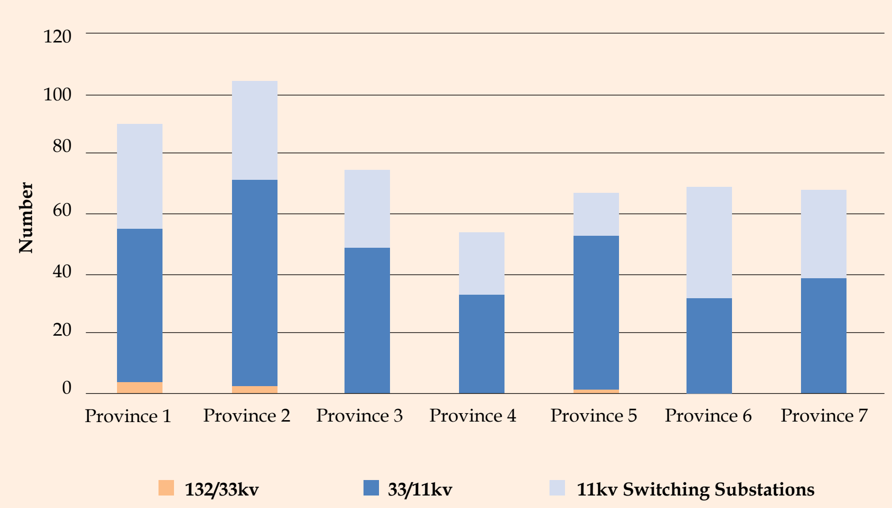
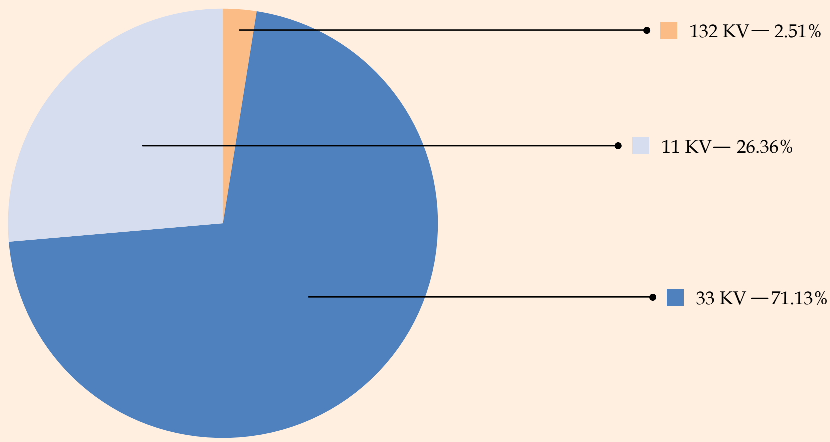


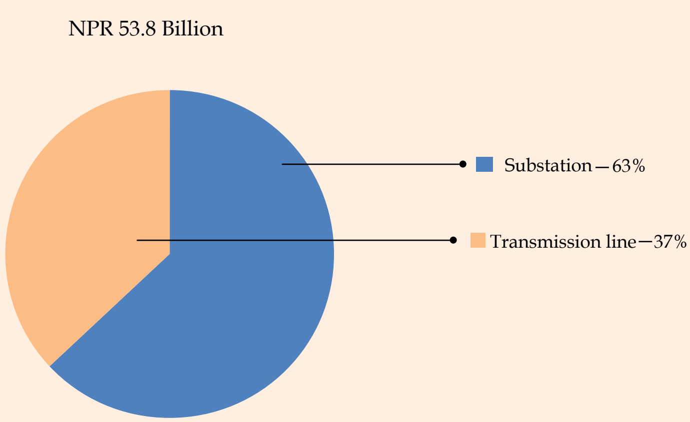
Figure 5: Total Proposed Transmission & Distribution Lines



2.4.2 Cost of Substation and T&D Lines

Figure 6 shows that the total cost of grid extension is NPR 53.8 billion, of which Substations account for almost 63% of the total cost due to high cost of transformers and associated equipment used in a Substation.

Figure 6: Total Cost of Grid Extension



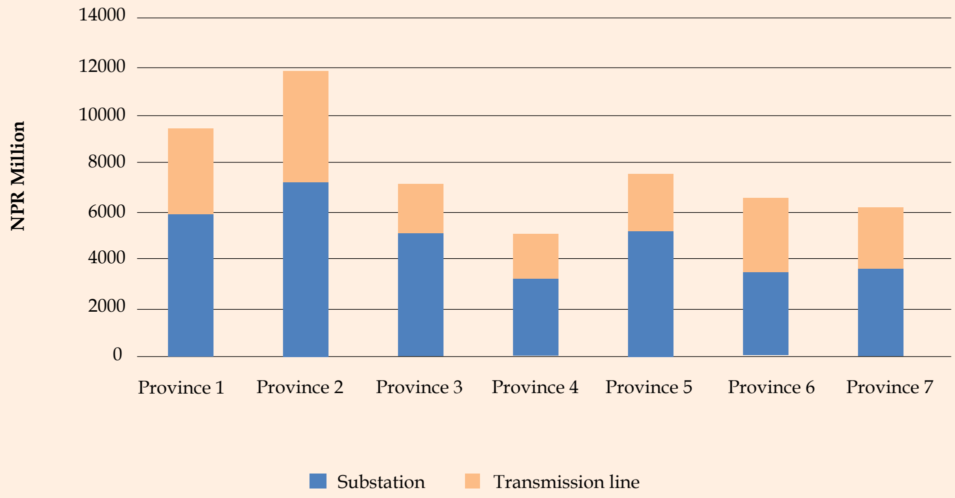
2.5 Financial Analysis of Generation Projects

Financial analysis considered unique local characteristics such as hydrology, road access, capacity utilization factor, and transport costs; therefore, each Municipality has its own unique result. Financial Discount Rate is assumed to be 10%, which is calculated by averaging the weighted average lending rate (commercial banks) over a period of 4 years (16 data points) as published by Nepal Rastra Bank (Quarterly Economic Bulletin July 2017). The generation sites chosen through Financial Analysis are shown in Figure 8.

2.5.1 Levelized Cost and Benefit of Electricity

As shown in Figure 9, biomass had a levelized cost of electricity (LCOE) of approx. NPR 9.56/ kWh and levelized benefit of electricity (LBOE) of approx. NPR 16.32/ kWh and ROE of 29%. High plant load factor, income from sale of electricity to NEA and additional income from sale of fertilizer byproduct results in an attractive ROE for biomass.

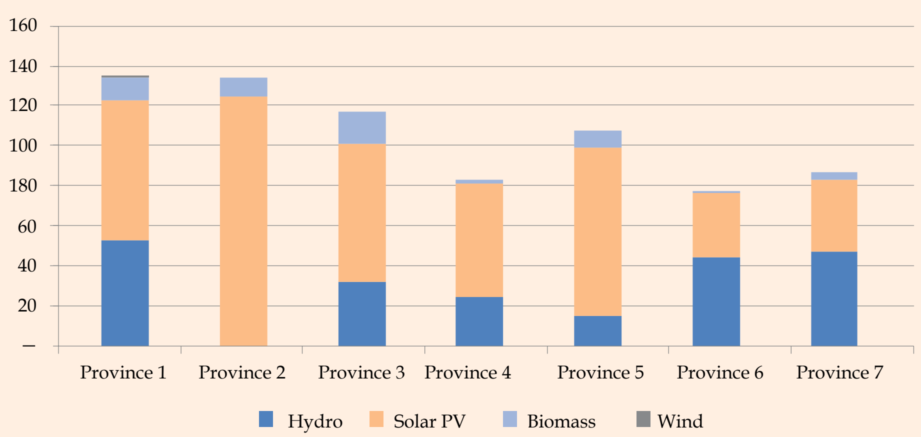
Figure 7: Province wise Division of Cost of Grid Extension



But, due to absence of well-established waste collection system, and pilot projects for testing technical feasibility; the second ranked DG project may have to be reconsidered.

For hydropower, the selected projects had LCOE in the range of NPR 4/kWh to NPR 14/kWh, and LBOE of NPR 7/kWh. For Solar PV project with 500 kWh battery, the selected projects had LCOE in the range of NPR 11.96/kWh to NPR 14.40/kWh, and LBOE of NPR 6.98/kWh. For Wind power, the LCOE was only calculated for three sites with on-site wind speed data (average annual wind speed at 10m height = 3.35m to 6.5m). It is found that the LCOE was NPR 7.95/kWh and LBOE was NPR 6.98/kWh.

Figure 8: Number of Selected Distributed Generation Projects per Province



The LBOE was around NPR 7/kWh for solar PV, wind and hydropower as it is calculated based on the NPR 6/kWh average NEA tariff and 3% escalation for 8 years. For solar, the ROE ranged from -3.6 to -0.8 % and for wind power it is around 6%. As none of the solar or wind project could deliver ROE of 15% or greater, Viability Gap Funding (VGF) was considered for all of these projects. For hydropower, the ROE ranged from -4 to 30 %. Only those hydropower projects with ROE less than 15% are considered for VGF. The high capital costs and low capacity utilization factor of Solar PV in comparison to other technologies resulted in the lowest range of ROE.

Figure 9: Levelized Cost and Benefits of Selected Distributed Generation Projects

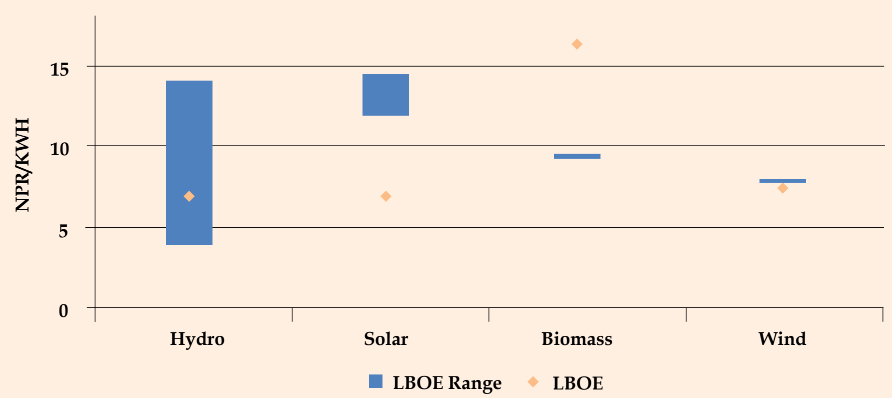


Figure-10: Installed Capacity of Selected Projects

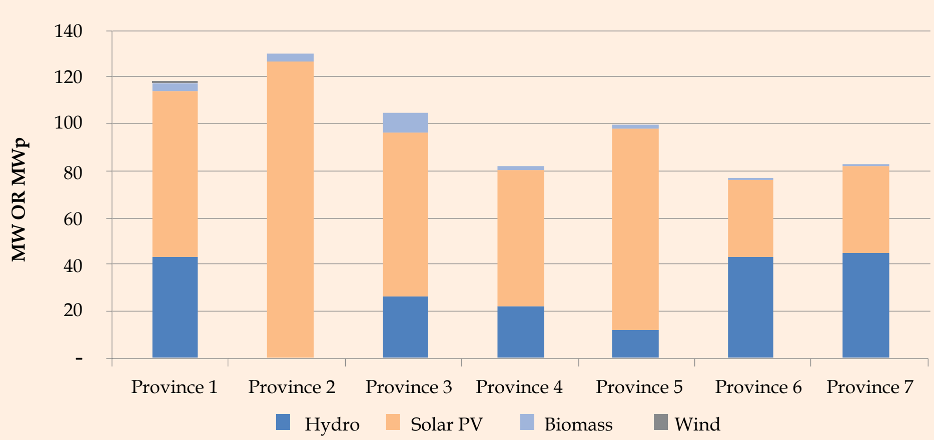


Figure 11: Investment Required for Selected Projects, per Province

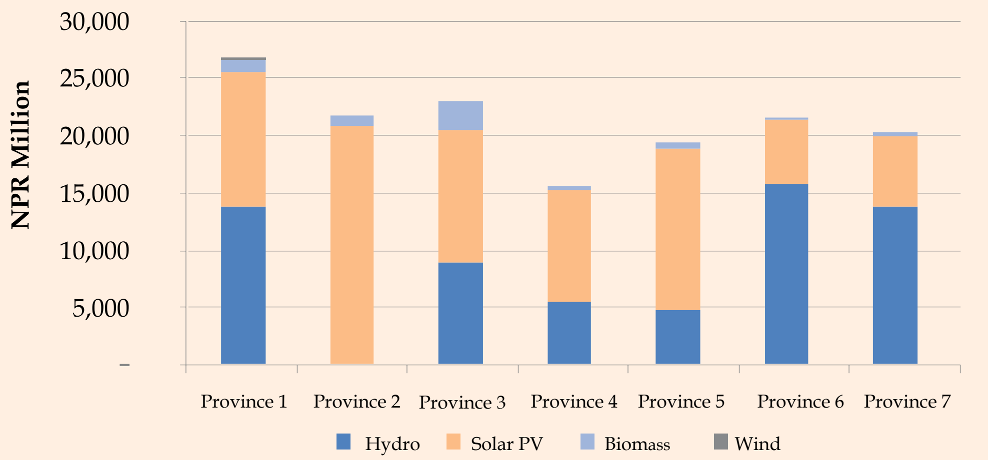
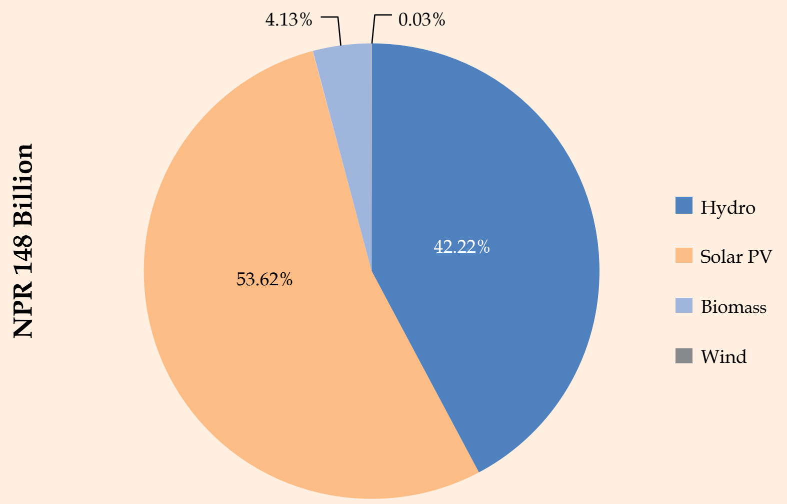


Figure 12: Total Capital Investment Required for Generation Projects



2.5.2 Number of Projects and Installed Capacity

As shown in Figure 8 and Figure 10, 221 hydropower sites with total installed capacity of 192.6 MW, 481 solar PV sites with total installed capacity of 481 MWp, 50 Biomass sites with total installed capacity of 20.4 MW and 1 wind power site with installed capacity of 0.2 MW are selected in the whole country.

2.5.3 Investment and Viability Gap Funding (VGF)

From Figure 11 and Figure 12, the total country investment required for hydropower is NPR 62.54 billion, for solar is NPR 79.42 billion, for biomass, it is NPR 6.12 billion, and for wind was NPR 40 million. Thus, the total investment for generation projects necessary for whole country is NPR 148.13 billion. As shown in Figure 16 the total country VGF required for hydropower is NPR 22.9 billion, for Solar NPR 51.9 billion, and for wind NPR12 Million; thus, the total VGF necessary for whole country is NPR 74.88 billion.

For the country, the average investment required for Hydropower is NPR 324,772/kW, for Solar with 500 kWh battery is NPR 165,132/kW, and for biomass is NPR 300,000/kW, and for wind was NPR 198,250/kW as shown in Figure 15. The average VGF required for hydropower was NPR 119,110/kW, for solar was NPR 107,965/kW, and for wind was NPR 65,000/kW.

2.5.4 Alternative Cases – Investment and VGF

Table 6 and Table 7 show that changes in total investment and VGF required for alternative scenarios of solar PV with 200 kWh battery and no battery storage respectively.

Figure 13: Total Viability Gap Funding Requirement for Generation Projects

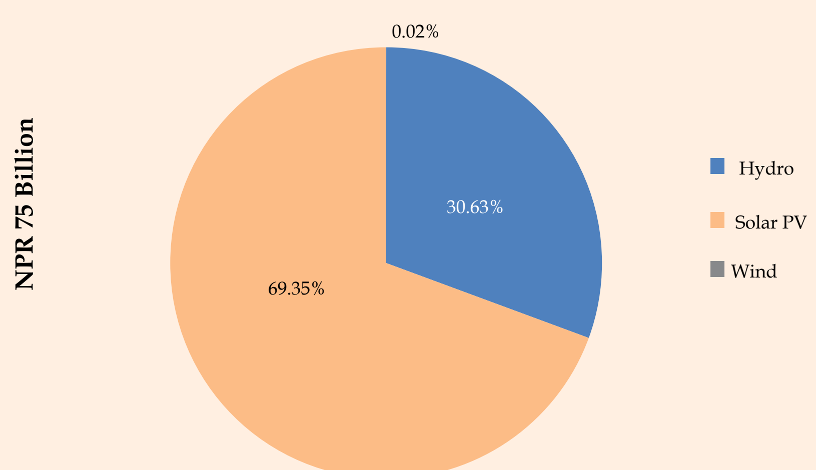
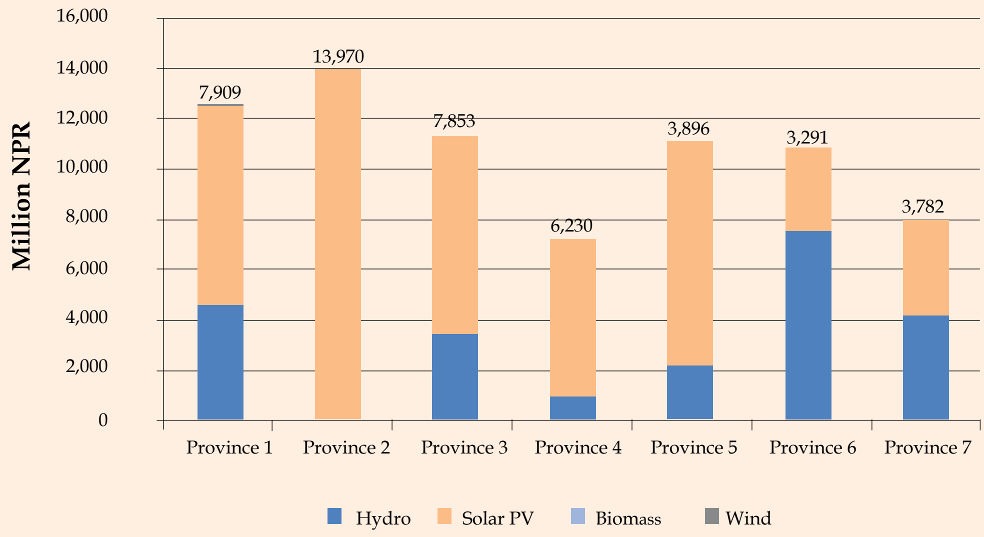


Figure 14: Province wise Division of Viability Gap Funding Required for Selected DG Projects



As can be seen from the tables, the total investment for the country decreases significantly from NPR 148 billion for Base Case of Solar PV with 500 kWh battery to NPR 138 Billion and NPR126 billion for alternative scenarios of Solar PV with 200 kWh battery and no battery storage respectively. Similarly, the total VGF decreases from NPR 74 Billion for Base Case of Solar PV with 500 kWh battery to NPR 63 Billion and NPR 51 Billion for alternative scenarios of solar PV with 200 kWh battery and no battery storage respectively.

On average, VGF required per kW for Solar PV with 200 kWh storage was approx. NPR 85,000 and for solar with no battery storage was approx. NPR 60,000. Nonetheless, these scenarios with less or no battery storage would compromise on the aspect of electricity reliability in case the central grid is down during evenings or at night.

Figure 15: Average VGF Required per kW for Different RETs

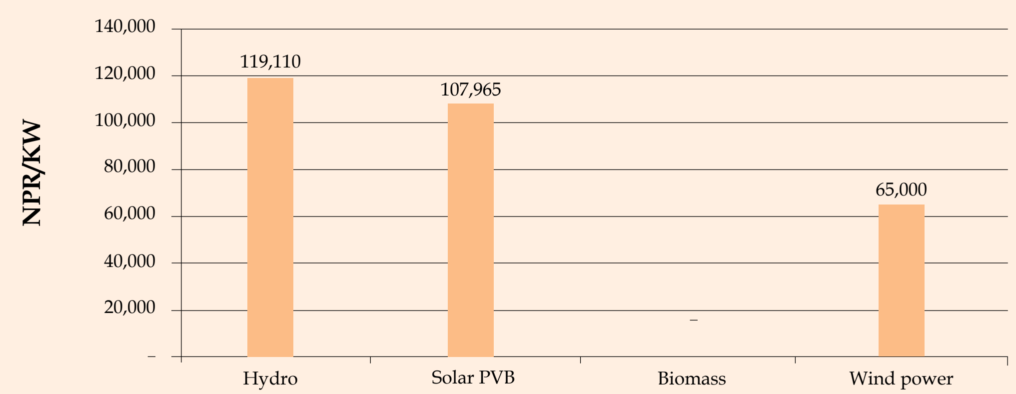


Figure 16: Average Investment Required per kW for Different RETs

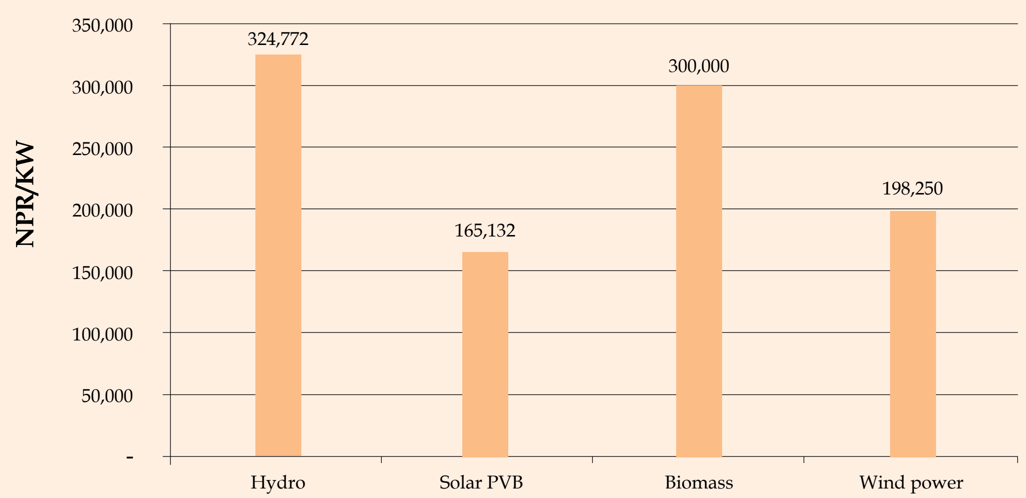


Table 6: Summary of Best DG Projects Selected for Alternative Scenario – Solar PV with 200 kWh battery storage

PROVINCE:	1	2	3	4	5	6	7	Country Total
Investment for Hydro (M-NPR)	13,746	-	8,891	5,563	4,733	15,824	13,784	62,541
Investment for Solar PV (M-NPR)	10,334	18,452	10,199	8,458	12,371	4,864	5,405	70,084
Investment for Biomass (M-NPR)	1,063	893	2,607	450	695	97	317	6,122
Investment for Wind (M-NPR)	40	-	-	-	-	-	-	40
Province Total (M-NPR)	25,183	19,345	21,697	14,471	17,799	20,785	19,507	138,787
PROVINCE:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Country Total**
VGF for Hydro (M-NPR)	4,599	-	3,465	987	2,194	7,504	4,188	22,937
VGF for Solar PV (M-NPR)	6,112	10,795	6,068	4,814	6,874	2,543	2,922	40,129
VGF for Biomass (M-NPR)	-	-	-	-	-	-	-	-
VGF for Wind (M-NPR)	13	-	-	-	-	-	-	13
Province Total (M-NPR)	10,724	10,795	9,533	5,801	9,068	10,047	7,110	63,079

Table 7: Summary of Best DG Projects Selected for Alternative Scenario – Solar PV without Battery

PROVINCE:	1	2	3	4	5	6	7	Country Total
Investment for Hydro (M-NPR)	13,746	-	8,891	5,563	4,733	15,824	13,784	62,541
Investment for Solar PV (M-NPR)	8,518	15,209	8,407	6,972	10,196	4,009	4,455	57,766
Investment for Biomass (M-NPR)	1,063	893	2,607	450	695	97	317	6,122
Investment for Wind (M-NPR)	40	-	-	-	-	-	-	40
Province Total (M-NPR)	23,367	16,102	19,905	12,985	15,624	19,930	18,557	126,469

PROVINCE:	1	2	3	4	5	6	7	Country Total
VGF for Hydro (M-NPR)	4,599	-	3,465	987	2,194	7,504	4,188	22,937
VGF for Solar PV (M-NPR)	4,314	7,620	4,283	3,398	4,852	1,795	2,063	28,326
VGF for Biomass (M-NPR)	-	-	-	-	-	-	-	-
VGF for Wind (M-NPR)	13	-	-	-	-	-	-	13
Province Total (M-NPR)	8,926	7,620	7,748	4,385	7,046	9,299	6,251	51,276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Chapter 3

Conclusion and Recommendations

3.1 Economic Analysis

Economic analysis is undertaken for two representative models, one of dispersed generation area (Province 1) and another of high load density area (Province 2) and comparison is made between the economic scenario of each province for grid extension with and without DG.

Scenario A considers grid extension with DG, which includes capital and O&M costs of selected DG plants, T&D network expansion and necessary central hydro plants to completely supply the load. For this scenario, Transmission & Distribution Network Loss is considered to be 9%. Scenario B considers grid extension without DG, which includes Capital and O&M costs of T&D Network expansion and Central Hydro plants that can supply same level of energy as the previous scenario. For this scenario, Transmission & Distribution Network Loss is considered as 18%.

Social/Economic Discount Rate (SDR) is assumed to be 2%, which is calculated by averaging the interest on Treasury-bills (364 days) over a period of 4 years (15 data points) as published by Nepal Rastra Bank (Quarterly Economic Bulletin, July 2017) and adding 0.7% for market distortion. Economic analysis is performed for a project lifetime of 25 years.

3.1.1 Province 1

In Province 1, 54 Hydropower sites with total installed capacity of 43 MW (the highest number of hydropower sites selected in a province), 71 solar PV sites with total installed capacity of 71 MWp, 11 biomass sites with total installed capacity of 3.5 MW and 1 Wind power site with total installed capacity of 0.2 MW are selected through financial analysis. As shown in Table 8 for the Base Case (SDR = 2%) of Province 1, the Net Present Value (NPV) is higher for Scenario A (grid extension with DG at NPR 736 billion) than Scenario B (grid extension without DG yields lower NPV of NPR 671 billion). As economic evaluation considers the NPV while ranking projects, i.e. the net value added to the economy, grid extension with DG is recommended for Province 1.

Sensitivity analysis at higher SDR of 5% (Case I) shows that NPV decreases to NPR 642 billion for Scenario A and to NPR 456 billion for Scenario B; nonetheless, the net economic value added is still higher for Scenario A. Similarly, Sensitivity Analysis for SDR of 8% (Case II) shows that NPV decreases to NPR 352 billion for Scenario A and to NPR 321 billion for Scenario B. The net economic value added is still higher for Scenario A. Also, preliminary analysis shows that the results of economic analysis for Provinces 3, 4, 5, 6 & 7 would be similar to that of Province 1.

Economic analysis is undertaken for two representative models, one of dispersed generation area (Province 1) and another of high load density area (Province 2) and comparison is made between the economic scenario of each province for grid extension with and without DG.

3.1.2 Province 2

In Province 2, no hydropower sites are identified. 127 solar PV sites with total installed capacity of 127 MWp, and 9 biomass sites with total installed capacity of 3 MW are selected through financial analysis. The highest number and installed capacity of Solar PV sites in the country were selected in Province 2 due to absence of any hydropower potential. Also, the load was the highest for Province 2 due to high population density. It can be observed from Table 8 that for Base Case (SDR = 2%) of Province 2, the NPV is higher for Scenario A (NPR 940 billion) than that of Scenario B (NPR 861 billion). As Economic evaluation considers the NPV while ranking projects, i.e., the net value added to the economy, grid extension with DG is recommended for Province 2 as well.

For higher SDR of 5% (Case I) NPV decreases to NPR 643 billion for Scenario A and to NPR 589 billion for Scenario B and for further higher SDR of 8% (Case II) the NPV decreases to NPR 455 billion for Scenario A and to NPR 418 billion for Scenario B. This shows that the net economic value added is always higher for Scenario A.

The economic model captures the following elements: (i) reduction of capital and operational expenditure of Transmission and Distribution networks (grid extension) due to active and reactive power support by DG plants (ii) reduction of network losses due to DG plants servicing local loads, and (iii) economic benefits from fuel replacement and willingness to pay according to the electrification status of the Municipality.

However, due to limitation of time and scarcity of published local research, additional economic benefits of grid extension with DG such as (i) fewer social and environmental consequences over large central plants, (ii) exploitation of natural resources at the local level (iii) empowerment of local governments (iv) energy mix (v) ripple economic effect through forward and backward economic linkages that can kick-start the local economy could not be captured in the model. If they were to be considered, the NPV of Scenario A: Grid Extension with DG would increase for all provinces.

Further economic impact of GHG emissions over the project lifetime was not considered. Over the project lifetime, GHG emissions of

Table 8: Result of Economic Analysis

Scenario / Economic Indicators	Province 1		Province 2	
	Scenario A: Grid Extension with DG	**Scenario B: Grid Extension without DG**	**Scenario A: Grid Extension with DG**	**Scenario B: Grid Extension without DG**
	Network Loss = 9%	Network Loss = 18%	Network Loss = 9%	Network Loss = 18%
Base Case: SDR = 2%				
NPV (NPR- Billion)	736	671	940	861
Case I: SDR = 5%				
NPV (NPR- Billion)	642	456	643	589
Case II: SDR = 8%				
NPV (NPR- Billion)	352	321	455	418

*WITH DG includes Capital and O&M expenses of selected DG plants and T&D Network expansion

**WITHOUT DG includes Capital and O&M expenses of T&D Network expansion and Central Hydro Plant that can generate same energy as the DG plants

Final report handover by Hitendra Dev Shakya, Managing Director of NEA Engineering Company to Dr. Arbind Kumar Mishra, Member, National Planning Commission.

hydropower would be slightly higher (diesel usage over longer construction period and low-level emissions from submerged plants) than Solar PV, but both of these renewable technologies would have minimal GHG emissions when compared to fossil fuel plants such as coal or gas fired plants. Benefits of GHG mitigation are also not considered in the model; the NPV would increase for both scenarios if they were to be considered.

3.2 Implementation Modality

There are a few underlying concepts in the proposed solution, namely, investment in distributed generation projects in all municipalities as a means of increasing local economic growth on the one hand, and expansion of the national grid through sub-transmission and distribution lines to all of the municipalities on the other. The underlying concepts include improving local capabilities in institutional management and distributing VGF for equitable development. The implementation modality needs to address all these four underlying concepts.

3.2.1 The Two Technical Aspects

The fundamental concept of bi-directional planning and implementation for Sustainable Distributed Generation and Grid Access to All (SUDIGGAA) is that it has to work on both transmission and distribution sides of the power system. On distribution, at the local level, locating a substation that best serves the local distribution network plan and constructing generation projects to feed the network; and on transmission, on the part of the central grid, constructing radial network expansion targeted and homing towards the substations at the local municipalities.

Table 9: Phase-wise Implementation of Grid Extension

Phase	Duration (yrs.)	No. of 132/33 kV Substations	No. of 33/11 Substations	No. of 11 kV switching stations	Length of 132 kV line (km)	Length of 33 kV line (km)	Length of 11 kV line (km)	Estimated Cost (NPR -Million)
1	2.5	5	79	20	100	1540	270	14,156
2	1(+1.5)	3	145	79	96.2	1895	843	22,320
3	1(+2.5)	0	99	100	0	2133.4	950.9	17,326
Total	**4.5 years**	**8**	**323**	**199**	**196.2 km**	**5568.4 km**	**2063.9 km**	**53802**

3.2.1.1 Distributed Generation projects

There are 221 hydropower projects, 481 solar PV projects and 50 biomass to electricity projects, and one wind power project recommended for construction. The generation projects development cycle necessarily contains the following phases:

- Feasibility Study and Detailed Engineering Study
- Financing of the project construction and concluding operational issues such as power sale
- Formation of implementing agencies for local ownership of the generation projects, government agency for assisting the local governments to set-up the local vehicles, oversee the engineering of the projects and facilitate the equity, debt and VGF financing
- Contract management, construction management, and generation upon commissioning
- Operationalization of the plant operation agency and expansion of low voltage distribution network to consumers

Table 10: Project Implementation Activities and Timeline

Activity	Description of Work	Remarks
1	Project Verification	Within 12 Months
2	Feasibility and Detail Study	Within 18 Months
3	Financial Arrangement	Within 30 Months
4	Project Construction	Within 54 Months
5	Grid Extension	Within 54 Months
6	Project in Operation	Within 60 Months

3.2.1.2 Expansion of Grid – Sub-transmission and distribution line and substation projects

There are 196 km of 132 kV sub-transmission lines, eight 132/33 kV substations, 5568 km of 33 kV distribution lines, 323 33/11 kV substations and 2063 km of 11 kV lines with 199 11 kV switching stations for interconnection of generation projects and distribution feeders. These grid expansion projects require step-wise implementation.

Step-wise Expansion

Step-wise implementation is necessitated by the sequential nature of the expansion works as well as the need of temporally distributing the huge costs of expansion. The network expansion will start from the existing and under-construction substations of Nepal Electricity Authority. The outward expansion in first stage will consist of sub-transmission lines and 33 kV lines with substations at the end of the radial lines. The phasing here is proposed in three stages. The costs of different stages of phased expansion is given in Table 9 with details of the substation and lines.

Project Timeline

The time-duration for the phased expansion is given in Table 10. The timetable covers the different activities required in implementing the expansion work, details of which are given below.

- Feasibility survey of the lines and substations, and detail design including tender document preparation;

- Financing of the expansion project – national budget and investment planning and allocation for the expansion works;
- Facilitation with the implementing agency Nepal Electricity Authority or its Distribution agencies in the respective provinces in cooperation with the local municipality for eventual modality of operation of distribution network;
- Contract management and construction supervision by NEA and the operating agency at the level of local municipality;
- Operationalization of the entity responsible for substation and distribution and expansion of Low voltage distribution network to consumers

The sequence of programs as listed in the table will be rolled out and put in place for each phase of the expansion project. The total time-plan for the above five activities for beginning of the first phase to the end of the third phase will be five years.

Medium voltage transformer stations and low voltage distribution network expansion

The SDG7 and SE4ALL targets include the last mile connection to consumer households. This study does not cover the last mile planning, as the scope is vast and such planning and investment decisions are best left to the local governments. Nevertheless, it has to be noted here that in order to accomplish the Energy Access for All, planning for the last mile connection, and its financing must begin immediately after the launch of the first phase of the grid expansion, such that there is a seamless connection to the households and supply of electricity at the completion of the five year project.

It is understood that Nepal Electricity Authority is undertaking a Distribution Masterplan that includes the medium voltage transformer stations and aggregated nodes of low voltage lines. This Masterplan does not include detail GIS based distribution network planning. It is therefore necessary that the next phase of implementation should include GIS mapping of medium voltage transformers and planning of low voltage network that is optimized with updated GIS data of population and load demand.

Monitoring of Operation and Maintenance and support system

The operation and maintenance of 11 kV switching substation and feeder lines as well as 33/11 kV substation and distribution lines can be done by local level agencies as the technology and know-how required is easily available and the man-power can be trained. The cost of operation and monitoring increases with the location of the agency being farther from the area. The logistics and additional costs incurred for man-power migration makes such operation not viable for these agencies. Thus, a local entity is preferred.

However, for large events, such as damage to transformer or circuit breaker or substation control and protection systems, the local entity will require external support. This will be more prominent in remote areas. Hence, a regional or provincial support cell or entity need to be established to provide such operational support.

3.2.2 The Governance Aspects

The SUDIGGAA is feasible only with a meaningful participation of local governments. The Constitution of Nepal 2072 mandates three levels of governance with definite rights and duties of the local governments, which are empowered to legislate on subjects as listed in the Schedules of the Constitution. The Schedule 6 lists electricity distribution as the jurisdiction of provincial government while the Schedule 8 lists renewable generation projects falling under the jurisdiction of local governments. In recognition of the constitutional mandates, the Implementation Plan will need to enlist the support and participation of the respective governments in formulating the projects as well as forming the entities responsible for implementing and operating them.

3.2.2.1 Agency for the Distributed Generation Projects

The Distributed generation projects are proposed as joint investment projects, with federal support as grant money for funding the viability gap while the local municipalities and cooperatives and project affected people providing equity. The capital required for constructing a generation project will be ranging from NPR 16 Crores (USD 1 million) to NPR 30 Crores (USD 3 million), it is a natural proposition that a separate company shall be formed where the financing requirement after Viability Gap Fund is provided with equity injection (20%-30%) from municipality, cooperatives and project affected people, and the remaining 70% to 80% of the finance requirement is secured from low-interest development loans from multi-lateral institutions or the government or by priority sector lending from national finance institutions.

- Independent Generation Company – An independent public limited company is best suited to run the generation project and associated assets. The generation company may be wholly owned by the local municipality. It may also have alternative equity holding shared with local project-affected community or their cooperatives. This contributes towards more consolidated Sustainability of the generation project with shared and aligned interests of the localized community.
- Central Utility holding - In the cases of remote municipalities, the operation of the distribution network and providing service to the consumer from an entity based in province capital city has proven to be financially unviable and burdensome for the Central Utility. In such cases, the Central Utility is inclined to lease the operation of the network to community electrification users groups (CEUG). There are mixed experiences with CEUG networks over time. Reduction in non-technical losses have been recorded, but reliability and quality of service has not improved.
- Municipality managed utility ownership – Local ownership may reduce operational costs but a municipality owned and operated utility will be a microcosm of a government with utility at the center, which has been shown to be ineffective and consequently expensive, and hence, disowned by government at central level previously. It is therefore not recommended to keep such generation and distribution assets directly under the municipality.
- Local Utility Company with combined generation and distribution assets – Presently, the Electricity Act requires that generation, transmission and distribution companies should be separate entities with separate licenses. At the local level, such demarcation is not essential as long as the transmission network is separated. The local generation project with Viability Gap Funding to utilize locally available energy resources is expected to lower the cost of local electricity. A joint utility will be also able to compensate for the high cost of providing distribution services.

From stakeholders' workshops and discussions with experts, it has emerged that the best format for ownership of the generation project and consequent development, and operation is a separate public company (Special Purpose Vehicle, SPV). The shareholding of such an SPV is recommended to be evenly distributed amongst the municipality to provide the financial strength in case of shortfalls, and cooperatives of the project area and cooperatives of the electricity users and community user groups. Single group ownership still cannot be relied upon to function effectively. Since the generation project requires grant in terms of viability gap fund, the ownership of the SPV needs to have a broad public ownership and ensure that no private individual or business owns a disproportionate share.

3.2.2.2 Agency for the Distribution Network

The agency for distribution network could be:

- Central Utility holding – the construction of the line and substations are proposed to be completed in a condensed and intensive program within five years. Such programs can be successful only if implemented by the Central Utility having sufficient technical and organizational capability which is NEA in the present context. However, eventual ownership, transfer or leasing to local utility is possible.
- For town municipalities, the central and provincial utilities are inclined to maintain their ownership and they may also be well equipped to do so. There could still be other alternatives because the electricity supply business is undergoing rapid change. Even in South Asia, there are examples where wire and services are separated. In such a case, the wires can be owned by any of the models of a private or public company or a municipality-owned company.

From stakeholders' workshops and discussions with experts, it has emerged that the best format for Ownership of the Distribution Network is the SPV that owns the generation company itself, as the financial benefit of the generation project will balance the costs of distribution and maintenance of feeders from the grid. The generation company will be induced to maintain the connecting line to the grid as the surplus energy supplied to grid provides revenue.

Since the distribution network needs a separate license and there are issues of overlap with the Central Utility or its subsidiary, the initial phase of distribution network from the grid till the local substation needs to be with the Central Utility that constructs and completes the grid expansion. This is further so if the connecting line supplies power to more of the municipalities and hence, a SPV ownership will raise the issue of wheeling charges.

In remote areas, the cost of maintaining and operating these interconnecting lines will be uneconomically high for central and provincial utility. Thus, a phased hand-over of the interconnecting lines to the SPV is foreseen with a framework of wheeling charge or management charge in place before that.

3.2.2.3 Financing of the SUDIGGAA

A major component of the SUDIGGAA project is the Viability Gap Funding (VGF) to be provided by the federal government. Substantial VGF is required for generation projects while the wires have to be fully funded by the federal government.

It is assumed that providing a level field for economic growth to all of the municipalities in principle that will be accepted and be one of the priorities of future governments. Electricity is an essential input for industrial growth, and employment generation. Providing VGF for generation projects that enables grid expansion to remote areas is a necessary step forward in this direction. However, it is assumed that equitable VGF distribution will be called for by all municipalities. Such VGF, if provided, may not

A major component of the SUDIGGAA project is the Viability Gap Funding (VGF) to be provided by the federal government. Substantial VGF is required for generation projects while the wires have to be fully funded by the federal government.

be applicable for similar hydro-projects but may be more appropriate for alternatives that provide better electricity at lower prices. This is the principle that allows planning of solar projects in areas that are already electrified, and bio-mass projects from solid waste in towns where even solar projects are not feasible due to high land costs, customs duties, etc.

3.2.2.4 VGF for Generation- Projects and Financial Viability

The hydro-projects have been selected with design discharge of 65% probability of exceedance. Projects with such design have plant factor of approximately 65% (at the grid connection point after accounting for all losses). The economic value of the energy in an already electrified area is the 'Willingness to Pay' of the consumers. A survey done by the Millennium Challenge Corporation, which is yet to conclude the results, is known to have received a preliminary estimate of 27% more than the current price. This same price may be used for determining the economic viability of a project and a criterion for justifying the VGF. The financial viability of the project after VGF is necessary for sustainable operation of the project. Hence, a favorable debt/equity ratio is proposed for independent stock company such that the local municipality is required to put up minimum equity.

For a 1000 kW hydro-project, the median cost of construction of a hydro-project is approximately USD 3500/kW and generating approximately 6 million units in a year. A benchmark VGF of USD 1000/kW will require about USD 2.5 million capital over four to five years from the local government. A debt/equity ratio of 80/20 will ease the capital requirement from the local municipality to USD 500,000 (approximately NPR 5 Crore) in four to five years, which is an outlay of USD 100,000 (approx. NPR 1 Crore) per year.

This projection is assumed to be feasible for all of the municipalities. A comparison with present Independent Power Producer (IPP) projects gives projects that have median construction costs of USD 2000/ kW for Q40 (having 5 million units a year) design discharges. Extrapolating the costs for Q65 (6 million units a year) and with a better wet-energy to dry-energy ratio, the financially viable cost of such projects lie around 2500$/kW.

However, for remote areas which are far from the road-head, the remoteness factor has to be accounted. A remoteness factor of 1.2 is considered for higher cost of transportation of construction materials and in some heavy single transport cases, heli-lifting. Thus, projects of USD 4500/kW are also selected for construction in such remote areas. Nonetheless, it is proposed that a benchmark VGF of USD 1000/kW or NPR 10 Crore per MW be considered for accomplishing SUDIGGAA. For projects that have high transport costs, alternative solar or biomass projects could be considered.

From the discussions with experts it has emerged that the benchmark subsidy or viability gap funding should be categorized to few varying VGF slabs taking into account the fact that some of the projects may not require much VGF while some of the remote areas would need a higher amount of VGF. Since the transaction analysis for a detailed work-out of VGF is complex and costs may outweigh the benefits of exact VGF determination, it is recommended that based on remoteness, three slabs of VGF be proposed, with VGF benchmark of less than USD 1000/kW for projects having road access, and USD 1000/ kW for projects that are moderately far from the road-head and USD 2000/kW for projects that involve at least one-day of travel from the nearest road.

The Levelized Cost of Energy (LCOE) from solar projects with 500 kWh battery backup is quite high (NPR 12 to 14per kWh) at present costs of battery and additional Inverter. For financial viability, VGF in the range of USD 1000 to 1100 is required out of the total capital cost of USD 1600-1700/ kW. Even for solar project without any battery backup, LCOE of 1 MWac Solar PV project is too high (NPR 9 to 10/ kWh); therefore, either NEA PPA Rate of around NPR 10/ kWh (with 8 simple escalations of 3% each) or federal VGF of around USD 600/kW is necessary.

Large part of the high cost is because of the price of land, and low capacity utilization factor (CUF) of solar. But, it would be unfair to compare solar PV without any battery storage to hydropower and biomass technologies, as the solar PV would not be able to supply any electricity during nights in the event the central grid is down, thus compromising on the aspect of reliability of supply. A middle ground could be to develop solar PV with battery in two phases, such that solar PV without Battery but with adequate space for adding batteries and inverters later is developed in the first phase, and additional Inverter and battery necessary is added in the subsequent phases. This will help break the total investments and VGF into multiple phases while providing the flexibility of achieving increasing level of reliability from the project over time. Since a benchmark VGF with three slabs is considered for hydro, same structure of VGF (i.e. USD 1000/ kW) is proposed for solar PV plant with 500 kWh battery storage.

In the case of biomass, high plant load factor, income from sale of electricity to NEA and additional income from the sale of fertilizer byproduct results in a very attractive ROE such that no VGF is required. But due to absence of well-established waste collection system, and pilot projects for testing technical aspects; the benchmark VGF of USD 1000/kW will also be appropriate for 50 selected biomass plants. For one selected 200kW Wind power plant with high wind resources available locally, the VGF required is about USD 600/ kW.

3.2.2.5 VGF vs. Benchmark VGF

Identifying the best possible generation project and then determining the VGF tends to be convoluted. A mechanism to incentivize local governments to find the best project is to set a benchmark VGF, and allow the municipalities to find the best project within the limits of the benchmark VGF. VGF helps find the equitable proportion for remote and less-endowed municipalities. The lack of sufficient experience in the determination of viability gap, and the need to undertake this exercise in all 753 units in a short period calls for a simplified VGF program. A benchmark VGF policy is therefore recommended..

3.2.2.6 Funding of the Distribution Network Expansion

The distribution network expansion shall be completely funded by federal budget as the initiation investment. The investment will ensure a medium voltage substation and access to grid for all municipalities. This will be a program that attempts to prepare a level field for all remote municipalities and those which have been far from the focus of previous development programs. Hence, federal government needs to find low-interest funds or development assistance funds from bilateral and multilateral agencies to finance the distribution grid expansion project. The outlay of funds is recommended to be distributed over three phases, to sync with the sequential construction of lines and substations to supply the power radially to outlying areas.

The outlay of funds is recommended to be distributed over three phases, to sync with the sequential construction of lines and substations to supply the power radially to outlying areas.

The stages of expansion is dispersed over three years, and each phase is assumed to take about two years to complete. Thus, all three phase will be complete within five to six years while distributing the demand on the national budget over five years. A detail of the finance required can be seen in Table 9.

Chapter 4

Selected Distributed Generation in each VM/TM

Province No.	District	Village/Town Municipality	Type of DG Selected
1	Bhojpur	Aamchowk	Hydro
1	Bhojpur	Arun	Hydro
1	Bhojpur	Bhojpur	Hydro
1	Bhojpur	Hatuwagadhi	Hydro
1	Bhojpur	Pauwa Dunma	Hydro
1	Bhojpur	Ramprasad Rai	Hydro
1	Bhojpur	Salpa Silichho	Hydro
1	Bhojpur	Shadananda	Solar
1	Bhojpur	Tyamke Maiyum	Hydro
1	Dhankuta	Chaubise	Hydro
1	Dhankuta	Chhathar Jorpati	Hydro
1	Dhankuta	Dhankuta	Solar
1	Dhankuta	Khalsa Chhintang	Solar
1	Dhankuta	Mahalaxmi	Hydro
1	Dhankuta	Pakhribas	Hydro
1	Dhankuta	Sangurigadhi	Hydro
1	Ilam	Chulachuli	Solar
1	Ilam	Deumai	Solar
1	Ilam	Fakfokathum	Hydro
1	Ilam	Illam	Hydro
1	Ilam	Mai	Solar
1	Ilam	Mai Jogmai	Hydro
1	Ilam	Mangsebung	Hydro
1	Ilam	Rong	Hydro
1	Ilam	Sandakpur	Solar
1	Ilam	Suryodaya	Hydro
1	Jhapa	Arjundhara	Solar
1	Jhapa	Barhadashi	Solar
1	Jhapa	Bhadrapur	Biomass
1	Jhapa	Birtamod	Biomass
1	Jhapa	Buddhashanti	Solar
1	Jhapa	Damak	Biomass
1	Jhapa	Gauradaha	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
1	Jhapa	Gauriganj	Solar
1	Jhapa	Haldibari	Solar
1	Jhapa	Jhapa	Solar
1	Jhapa	Kachanakawal	Solar
1	Jhapa	Kamal	Solar
1	Jhapa	Kankai	Solar
1	Jhapa	Mechinagar	Biomass
1	Jhapa	Shivasatakshi	Biomass
1	Khotang	Aiselukharka	Hydro
1	Khotang	Baraha Pokhari	Hydro
1	Khotang	Diprung	Hydro
1	Khotang	Halesi Tuwachung	Hydro
1	Khotang	Jante Dhunga	Hydro
1	Khotang	Kepilasgadhi	Hydro
1	Khotang	Khotehang	Hydro
1	Khotang	Lamidanda	Solar
1	Khotang	Rupakot Majhuwagadhi	Hydro
1	Khotang	Sakela	Hydro
1	Morang	Belbari	Biomass
1	Morang	Biratnagar	Biomass
1	Morang	Budhiganga	Solar
1	Morang	Dhanapalthan	Solar
1	Morang	Gramthan	Solar
1	Morang	Jahada	Solar
1	Morang	Kanepokhari	Solar
1	Morang	Katahari	Solar
1	Morang	Kerabari	Solar
1	Morang	Letang	Solar
1	Morang	Miklajung	Solar
1	Morang	Pathari Shanishchare	Solar
1	Morang	Rangeli	Solar
1	Morang	Ratuwamai	Solar
1	Morang	Sundarharaicha	Biomass
1	Morang	Sunwarshi	Solar
1	Morang	Urlabari	Solar
1	Okhaldhunga	Champadevi	Hydro
1	Okhaldhunga	Chishankhu Gadhi	Wind
1	Okhaldhunga	Khiji Demba	Hydro
1	Okhaldhunga	Likhu	Solar
1	Okhaldhunga	Manebhanjyang	Solar
1	Okhaldhunga	Molung	Hydro

Province No.	District	Village/Town Municipality	Type of DG Selected
1	Okhaldhunga	Siddhicharan	Solar
1	Okhaldhunga	Sunkoshi	Solar
1	Panchthar	Falelung	Solar
1	Panchthar	Falgunanda	Solar
1	Panchthar	Hilihan	Solar
1	Panchthar	Kummayak	Hydro
1	Panchthar	Miklajung	Hydro
1	Panchthar	Phidim	Solar
1	Panchthar	Tumbewa	Hydro
1	Panchthar	Yangbarak	Solar
1	Sankhuwasabha	Bhotkhola	Solar
1	Sankhuwasabha	Chainapur	Solar
1	Sankhuwasabha	Chichila	Solar
1	Sankhuwasabha	Dharmadevi	Hydro
1	Sankhuwasabha	Khandabari	Hydro
1	Sankhuwasabha	Madi	Solar
1	Sankhuwasabha	Makalu	Hydro
1	Sankhuwasabha	Panchakhapan	Hydro
1	Sankhuwasabha	Sabhapokhari	Hydro
1	Sankhuwasabha	Silichong	Hydro
1	Solukhumbu	Dhudha Koushika	Hydro
1	Solukhumbu	Dhudhakoshi	Solar
1	Solukhumbu	Khumbu Pasanglhamu	Solar
1	Solukhumbu	Likhu Pike	Hydro
1	Solukhumbu	Mahakulung	Solar
1	Solukhumbu	Necha Salyan	Solar
1	Solukhumbu	Solu Dhudhakunda	Hydro
1	Solukhumbu	Sotang	Solar
1	Sunsari	Baraha	Solar
1	Sunsari	Barju	Solar
1	Sunsari	Bhokraha	Solar
1	Sunsari	Dewangunj	Solar
1	Sunsari	Dharan	Biomass
1	Sunsari	Duhabi	Solar
1	Sunsari	Gadhi	Solar
1	Sunsari	Harinagara	Solar
1	Sunsari	Inaruwa	Biomass
1	Sunsari	Itahari	Biomass
1	Sunsari	Koshi	Solar
1	Sunsari	Ramdhuni	Solar
1	Taplejung	Aatharai Tribeni	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
1	Taplejung	Maiwakhola	Hydro
1	Taplejung	Meringden	Solar
1	Taplejung	Mikwakhola	Solar
1	Taplejung	Phaktanlung	Solar
1	Taplejung	Phungling	Hydro
1	Taplejung	Sidingba	Hydro
1	Taplejung	Sirijanga	Solar
1	Taplejung	Yangwarak	Solar
1	Terhathum	Aatharai	Hydro
1	Terhathum	Chhathar	Hydro
1	Terhathum	Laligurans	Hydro
1	Terhathum	Menchhayayem	Solar
1	Terhathum	Myanglung	Hydro
1	Terhathum	Phedap	Hydro
1	Udayapur	Belaka	Solar
1	Udayapur	Chaudandigadhi	Solar
1	Udayapur	Katari	Solar
1	Udayapur	Rautamai	Hydro
1	Udayapur	Sunkoshi	Solar
1	Udayapur	Tapli	Hydro
1	Udayapur	Triyuga	Solar
1	Udayapur	Udayapurgadhi	Hydro
2	Bara	Aadarsha Kotwal	Solar
2	Bara	Baragadhi	Solar
2	Bara	Bishrampur	Solar
2	Bara	Devtal	Solar
2	Bara	Jitpur Simara	Solar
2	Bara	Kalaiya	Biomass
2	Bara	Karaiyamai	Solar
2	Bara	Kolhabi	Solar
2	Bara	Mahagadhimai	Solar
2	Bara	Nijagadh	Solar
2	Bara	Pacharauta	Solar
2	Bara	Parawanipur	Solar
2	Bara	Pheta	Solar
2	Bara	Prasauni	Solar
2	Bara	Simroungadh	Solar
2	Bara	Subarna	Solar
2	Dhanusa	Aurahi	Solar
2	Dhanusa	Bateshwor	Solar
2	Dhanusa	Bideha	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
2	Dhanusa	Chhireshwornath	Solar
2	Dhanusa	Dhanauji	Solar
2	Dhanusa	Dhanushadham	Solar
2	Dhanusa	Ganeshman Charnath	Solar
2	Dhanusa	Hansapur	Solar
2	Dhanusa	Janak Nandini	Solar
2	Dhanusa	Janakpur	Biomass
2	Dhanusa	Kamala	Solar
2	Dhanusa	Laxminiya	Solar
2	Dhanusa	Mithila	Solar
2	Dhanusa	Mithila Bihari	Solar
2	Dhanusa	Mukhiyapatti Musaharmiya	Solar
2	Dhanusa	Nagarain	Solar
2	Dhanusa	Sabaila	Solar
2	Dhanusa	Shahidnagar	Solar
2	Mahottari	Aurahi	Solar
2	Mahottari	Balawa	Solar
2	Mahottari	Bardibas	Solar
2	Mahottari	Bhangaha	Solar
2	Mahottari	Ekadara	Solar
2	Mahottari	Gaushala	Biomass
2	Mahottari	Jaleshwor	Solar
2	Mahottari	Loharpatti	Solar
2	Mahottari	Mahottari	Solar
2	Mahottari	Manara Shisawa	Solar
2	Mahottari	Matihani	Solar
2	Mahottari	Pipara	Solar
2	Mahottari	Ram Gopalpur	Solar
2	Mahottari	Samsi	Solar
2	Mahottari	Sonama	Solar
2	Parsa	Bahudarmai	Solar
2	Parsa	Bindabasini	Solar
2	Parsa	Birgunj	Biomass
2	Parsa	Chhipaharmai	Solar
2	Parsa	Dhobini	Solar
2	Parsa	Jagarnathpur	Solar
2	Parsa	Jirabhawani	Solar
2	Parsa	Kalikamai	Solar
2	Parsa	Pakaha Mainpur	Solar
2	Parsa	Parsagadhi	Solar
2	Parsa	Paterwa Sugauli	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
2	Parsa	Pokhariya	Solar
2	Parsa	Sakhuwa Prasauni	Solar
2	Parsa	Thori	Solar
2	Rautahat	Boudhimai	Solar
2	Rautahat	Brindaban	Solar
2	Rautahat	Chandrapur	Solar
2	Rautahat	Dewahi Gonahi	Solar
2	Rautahat	Durga Bhagawati	Solar
2	Rautahat	Gadhimai	Solar
2	Rautahat	Garuda	Solar
2	Rautahat	Gaur	Biomass
2	Rautahat	Gujara	Solar
2	Rautahat	Ishanath	Solar
2	Rautahat	Katahariya	Solar
2	Rautahat	Madhav Narayan	Solar
2	Rautahat	Maulapur	Solar
2	Rautahat	Paroha	Solar
2	Rautahat	Phatuwa Bijayapur	Solar
2	Rautahat	Rajdevi	Solar
2	Rautahat	Rajpur	Solar
2	Rautahat	Yamunamai	Solar
2	Saptari	Krishna Sabaran	Solar
2	Saptari	Balan-Bihul	Solar
2	Saptari	Belhi Chapena	Solar
2	Saptari	Bishnupur	Solar
2	Saptari	Bode Barsain	Biomass
2	Saptari	Chhinnamasta	Solar
2	Saptari	Dakneshwori	Solar
2	Saptari	Hanumannagar Kankalini	Solar
2	Saptari	Kanchanrup	Solar
2	Saptari	Khadak	Solar
2	Saptari	Mahadewa	Solar
2	Saptari	Rajbiraj	Biomass
2	Saptari	Rupani	Solar
2	Saptari	Saptakoshi	Solar
2	Saptari	Shambhunath	Solar
2	Saptari	Surunga	Solar
2	Saptari	Tilathi Koiladi	Solar
2	Saptari	Tirahut	Solar
2	Sarlahi	Bagmati	Solar
2	Sarlahi	Balara	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
2	Sarlahi	Barahathawa	Solar
2	Sarlahi	Basbariya	Solar
2	Sarlahi	Bishnu	Solar
2	Sarlahi	Brahmapuri	Solar
2	Sarlahi	Chakraghatta	Solar
2	Sarlahi	Chandranagar	Solar
2	Sarlahi	Dhanakaul	Solar
2	Sarlahi	Godaita	Solar
2	Sarlahi	Haripur	Solar
2	Sarlahi	Haripurwa	Solar
2	Sarlahi	Hariwan	Solar
2	Sarlahi	Ishworpur	Solar
2	Sarlahi	Kabilashi	Solar
2	Sarlahi	Kaudena	Solar
2	Sarlahi	Lalbandi	Solar
2	Sarlahi	Malangawa	Solar
2	Sarlahi	Parsa	Solar
2	Sarlahi	Ramnagar	Solar
2	Siraha	Arnama	Solar
2	Siraha	Aurahi	Solar
2	Siraha	Bariyarpatti	Solar
2	Siraha	Bhagawanpur	Solar
2	Siraha	Bishnupur	Solar
2	Siraha	Dhangadhimai	Solar
2	Siraha	Golbazar	Solar
2	Siraha	Kalyanpur	Solar
2	Siraha	Karjanha	Solar
2	Siraha	Lahan	Biomass
2	Siraha	Laxmipur Patari	Solar
2	Siraha	Mirchaiya	Solar
2	Siraha	Naraha	Solar
2	Siraha	Nawarajpur	Solar
2	Siraha	Sakhuwa Nankarkatti	Solar
2	Siraha	Siraha	Biomass
2	Siraha	Sukhipur	Solar
3	Bhaktapur	Bhaktapur	Biomass
3	Bhaktapur	Changunarayan	Solar
3	Bhaktapur	Madhyapur Thimi	Biomass
3	Bhaktapur	Suryabinayak	Biomass
3	Chitawan	Bharatpur	Biomass
3	Chitawan	Ichchha Kamana	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
3	Chitawan	Kalika	Solar
3	Chitawan	Khairahani	Solar
3	Chitawan	Madi	Solar
3	Chitawan	Rapti	Solar
3	Chitawan	Ratnanagar	Biomass
3	Dhading	Benighat Rorang	Solar
3	Dhading	Dhunibenshi	Solar
3	Dhading	Gajuri	Hydro
3	Dhading	Galchhi	Solar
3	Dhading	Ganga Jamuna	Hydro
3	Dhading	Jwalamukhi	Hydro
3	Dhading	Khaniyabas	Hydro
3	Dhading	Netrawati	Solar
3	Dhading	Nilkhantha	Solar
3	Dhading	Rubi Valley	Hydro
3	Dhading	Siddhalek	Solar
3	Dhading	Thakre	Hydro
3	Dhading	Tripurasundari	Solar
3	Dolakha	Baitedhar	Solar
3	Dolakha	Bhimeshwor	Solar
3	Dolakha	Bigu	Solar
3	Dolakha	Gaurishankar	Solar
3	Dolakha	Jiri	Solar
3	Dolakha	Kalinchowk	Solar
3	Dolakha	Melung	Hydro
3	Dolakha	Shailung	Solar
3	Dolakha	Tamakoshi	Solar
3	Kathmandu	Budhanilkhantha	Biomass
3	Kathmandu	Chandragiri	Biomass
3	Kathmandu	Dakshinkali	Solar
3	Kathmandu	Gokarneshwor	Biomass
3	Kathmandu	Kageshwori Manahara	Solar
3	Kathmandu	Kathmandu	Biomass
3	Kathmandu	Kirtipur	Biomass
3	Kathmandu	Nagarjun	Biomass
3	Kathmandu	Shankharapur	Solar
3	Kathmandu	Tarakeshwor	Biomass
3	Kathmandu	Tokha	Biomass
3	Kavre.	Banepa	Solar
3	Kavre.	Bethanchowk	Hydro
3	Kavre.	Bhumlu	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
3	Kavre.	Chauri Deurali	Hydro
3	Kavre.	Dhulikhel	Solar
3	Kavre.	Khanikhola	Hydro
3	Kavre.	Mahabharat	Hydro
3	Kavre.	Mandan Deupur	Hydro
3	Kavre.	Namobuddha	Hydro
3	Kavre.	Panauti	Solar
3	Kavre.	Panchkhal	Hydro
3	Kavre.	Roshi	Solar
3	Kavre.	Temal	Solar
3	Lalitpur	Bagmati	Solar
3	Lalitpur	Godawari	Biomass
3	Lalitpur	Konjyosom	Solar
3	Lalitpur	Lalitpur	Biomass
3	Lalitpur	Mahalaxmi	Solar
3	Lalitpur	Mahankal	Hydro
3	Makwanpur	Bagmati	Solar
3	Makwanpur	Bakaiya	Solar
3	Makwanpur	Bhimphedi	Solar
3	Makwanpur	Hetauda	Biomass
3	Makwanpur	Indrasarowar	Solar
3	Makwanpur	Kailash	Hydro
3	Makwanpur	Makawanpurgadhi	Solar
3	Makwanpur	Manahari	Solar
3	Makwanpur	Raksirang	Solar
3	Makwanpur	Thaha	Hydro
3	Nuwakot	Belkotgadhi	Solar
3	Nuwakot	Bidur	Solar
3	Nuwakot	Dupcheshwor	Hydro
3	Nuwakot	Kakani	Solar
3	Nuwakot	Kispang	Hydro
3	Nuwakot	Likhu	Solar
3	Nuwakot	Meghang	Solar
3	Nuwakot	Panchakanya	Solar
3	Nuwakot	Shivapuri	Hydro
3	Nuwakot	Suryagadhi	Solar
3	Nuwakot	Tadi	Solar
3	Nuwakot	Tarakeshwor	Solar
3	Ramechhap	Doramba	Hydro
3	Ramechhap	Gokulganga	Solar
3	Ramechhap	Khandadevi	Hydro

Province No.	District	Village/Town Municipality	Type of DG Selected
3	Ramechhap	Likhu	Hydro
3	Ramechhap	Manthali	Hydro
3	Ramechhap	Ramechhap	Hydro
3	Ramechhap	Sunapati	Hydro
3	Ramechhap	Umakunda	Hydro
3	Rasuwa	Gosaikunda	Solar
3	Rasuwa	Kalika	Hydro
3	Rasuwa	Naukunda	Hydro
3	Rasuwa	Parbatikunda	Solar
3	Rasuwa	Uttargaya	Solar
3	Sindhuli	Dudhouli	Solar
3	Sindhuli	Ghyanglekha	Solar
3	Sindhuli	Golanjor	Hydro
3	Sindhuli	Hariharpurgaghi	Solar
3	Sindhuli	Kamalamai	Solar
3	Sindhuli	Marin	Solar
3	Sindhuli	Phikkal	Hydro
3	Sindhuli	Sunkoshi	Solar
3	Sindhuli	Tinpatan	Solar
3	Sindhupalchok	Bahrabise	Solar
3	Sindhupalchok	Balephi	Solar
3	Sindhupalchok	Bhotekoshi	Solar
3	Sindhupalchok	Choutara Sangachowkgadhi	Solar
3	Sindhupalchok	Helambu	Hydro
3	Sindhupalchok	Indrawoti	Solar
3	Sindhupalchok	Jugal	Solar
3	Sindhupalchok	Lisankhu Pakhar	Hydro
3	Sindhupalchok	Melanchi	Solar
3	Sindhupalchok	Panchpokhari Thangpal	Solar
3	Sindhupalchok	Sunkoshi	Solar
3	Sindhupalchok	Tripurasundari	Solar
4	Baglung	Badigad	Hydro
4	Baglung	Baglung	Solar
4	Baglung	Bareng	Solar
4	Baglung	Dhorpatan	Hydro
4	Baglung	Galkot	Hydro
4	Baglung	Jaimuni	Solar
4	Baglung	Kathekhola	Hydro
4	Baglung	Nisikhola	Hydro
4	Baglung	Tamankhola	Hydro
4	Baglung	Tarakhola	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
4	Gorkha	Aarughat	Solar
4	Gorkha	Ajirkot	Hydro
4	Gorkha	Bhimsen	Solar
4	Gorkha	Chumanubri	Solar
4	Gorkha	Dharche	Hydro
4	Gorkha	Gandaki	Solar
4	Gorkha	Gorkha	Solar
4	Gorkha	Palungtar	Solar
4	Gorkha	Shahid Lakhan	Solar
4	Gorkha	Siranchowk	Solar
4	Gorkha	Sulikot	Solar
4	Kaski	Annapurna	Solar
4	Kaski	Machhapuchchhre	Hydro
4	Kaski	Madi	Solar
4	Kaski	Pokhara Lekhnath	Biomass
4	Kaski	Rupa	Solar
4	Lamjung	Bensi Shahar	Solar
4	Lamjung	Dordi	Solar
4	Lamjung	Dudhapokhari	Hydro
4	Lamjung	Kwhola Sothar	Hydro
4	Lamjung	Madhya Nepal	Hydro
4	Lamjung	Marshyangdi	Solar
4	Lamjung	Rainas	Solar
4	Lamjung	Sundarbazar	Solar
4	Manang	Chame	Hydro
4	Manang	Naraphu	Hydro
4	Manang	Nashong	Hydro
4	Manang	Neshang	Solar
4	Mustang	Bahragaun Muktikshetra	Hydro
4	Mustang	Dalome	Hydro
4	Mustang	Gharpajhong	Hydro
4	Mustang	Lomanthang	Hydro
4	Mustang	Thasang	Solar
4	Myagdi	Annapurna	Solar
4	Myagdi	Beni	Solar
4	Myagdi	Dhawalagiri	Hydro
4	Myagdi	Malika	Hydro
4	Myagdi	Mangala	Hydro
4	Myagdi	Raghuganga	Hydro
4	Nawalparasi	Binayi Tribeni	Solar
4	Nawalparasi	Bulingtar	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
4	Nawalparasi	Bungdikali	Solar
4	Nawalparasi	Devchuli	Solar
4	Nawalparasi	Gaidakot	Solar
4	Nawalparasi	Hupsekot	Solar
4	Nawalparasi	Kawasoti	Biomass
4	Nawalparasi	Madhya Bindu	Solar
4	Parbat	Bihadi	Solar
4	Parbat	Jaljala	Solar
4	Parbat	Kushma	Hydro
4	Parbat	Mahashila	Solar
4	Parbat	Modi	Solar
4	Parbat	Paiyu	Solar
4	Parbat	Phalebas	Solar
4	Syangja	Aandhikhola	Solar
4	Syangja	Arjun Choupari	Solar
4	Syangja	Bhirkot Municipaity,6	Solar
4	Syangja	Biruwa	Solar
4	Syangja	Chapakot	Hydro
4	Syangja	Galyang	Solar
4	Syangja	Harinas	Solar
4	Syangja	Kaligandaki	Solar
4	Syangja	Phedikhola	Solar
4	Syangja	Putalibazar	Solar
4	Syangja	Walling	Solar
4	Tanahu	Aanbu Khaireni	Solar
4	Tanahu	Bandipur	Solar
4	Tanahu	Bhanu	Solar
4	Tanahu	Bhimad	Solar
4	Tanahu	Byas	Solar
4	Tanahu	Devghat	Solar
4	Tanahu	Ghiring	Solar
4	Tanahu	Myagde	Solar
4	Tanahu	Rhishing	Solar
4	Tanahu	Shuklagandaki	Solar
5	Arghakhanchi	Bhumikasthan	Solar
5	Arghakhanchi	Chhatradev	Solar
5	Arghakhanchi	Malarani	Solar
5	Arghakhanchi	Panini	Solar
5	Arghakhanchi	Sandhikharka	Solar
5	Arghakhanchi	Shitaganga	Solar
5	Banke	Baijanath	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
5	Banke	Duduwa	Solar
5	Banke	Janaki	Solar
5	Banke	Khajura	Solar
5	Banke	Kohalpur	Solar
5	Banke	Narainapur	Solar
5	Banke	Nepalganj	Biomass
5	Banke	Rapti Sonari	Solar
5	Bardiya	Badhaiyatal	Solar
5	Bardiya	Bansgadhi	Solar
5	Bardiya	Barbardiya	Solar
5	Bardiya	Geruwa	Solar
5	Bardiya	Gulariya	Biomass
5	Bardiya	Madhuwan	Solar
5	Bardiya	Rajapur	Solar
5	Bardiya	Thakurbaba	Solar
5	Dang	Babai	Solar
5	Dang	Bangalachuli	Solar
5	Dang	Dangisharan	Solar
5	Dang	Gadhawa	Solar
5	Dang	Ghorahi	Solar
5	Dang	Lamahi	Solar
5	Dang	Rajpur	Solar
5	Dang	Rapti	Solar
5	Dang	Shantinagar	Solar
5	Dang	Tulsipur	Solar
5	Gulmi	Chandrakot	Solar
5	Gulmi	Chhatrakot	Solar
5	Gulmi	Dhurkot	Solar
5	Gulmi	Isma	Solar
5	Gulmi	Kali Gandaki	Solar
5	Gulmi	Madane	Solar
5	Gulmi	Malika	Solar
5	Gulmi	Musikot	Hydro
5	Gulmi	Resunga	Solar
5	Gulmi	Ruru	Solar
5	Gulmi	Satyawoti	Solar
5	Gulmi	Gulmi Durbar	Solar
5	Kapilbastu	Banganga	Solar
5	Kapilbastu	Bijayanagar	Solar
5	Kapilbastu	Buddhabhumi	Solar
5	Kapilbastu	Kapilbastu	Biomass

Province No.	District	Village/Town Municipality	Type of DG Selected
5	Kapilbastu	Krishnanagar	Biomass
5	Kapilbastu	Maharajganj	Solar
5	Kapilbastu	Mayadevi	Solar
5	Kapilbastu	Shivaraj	Solar
5	Kapilbastu	Shuddhodhan	Solar
5	Kapilbastu	Yasodhara	Solar
5	Nawalparasi	Bardaghat	Solar
5	Nawalparasi	Palhinandan	Solar
5	Nawalparasi	Pratapapur	Solar
5	Nawalparasi	Ramgram	Solar
5	Nawalparasi	Sarawal	Solar
5	Nawalparasi	Sunawal	Solar
5	Nawalparasi	Susta	Solar
5	Palpa	Baganaskali	Hydro
5	Palpa	Mathagadhi	Hydro
5	Palpa	Nisdi	Solar
5	Palpa	Purbakhola	Hydro
5	Palpa	Rainadevi Chhahara	Solar
5	Palpa	Rambha	Solar
5	Palpa	Rampur	Solar
5	Palpa	Ribdikot	Solar
5	Palpa	Tansen	Solar
5	Palpa	Tinau	Solar
5	Pyuthan	Aairawati	Solar
5	Pyuthan	Gaumukhi	Solar
5	Pyuthan	Jhimaruk	Solar
5	Pyuthan	Mallarani	Solar
5	Pyuthan	Mandavi	Solar
5	Pyuthan	Naubahini	Hydro
5	Pyuthan	Pyuthan	Solar
5	Pyuthan	Sarumarani	Solar
5	Pyuthan	Sworgadwari	Solar
5	Rolpa	Duikholi	Hydro
5	Rolpa	Lungri	Solar
5	Rolpa	Madi	Hydro
5	Rolpa	Rolpa	Hydro
5	Rolpa	Runtigadhi	Hydro
5	Rolpa	Subarnabati	Solar
5	Rolpa	Sukidaha	Hydro
5	Rolpa	Sunchhahari	Hydro
5	Rolpa	Thawang	Hydro

Province No.	District	Village/Town Municipality	Type of DG Selected
5	Rolpa	Tribeni	Hydro
5	Rukum	Bhoome	Hydro
5	Rukum	Putha Uttanganga	Hydro
5	Rukum	Sisne	Hydro
5	Rupandehi	Butwal	Biomass
5	Rupandehi	Devdaha	Solar
5	Rupandehi	Gaidahawa	Solar
5	Rupandehi	Kanchan	Solar
5	Rupandehi	Kotahimai	Solar
5	Rupandehi	Lumbini Sanskritik	Biomass
5	Rupandehi	Marchawari	Solar
5	Rupandehi	Mayadevi	Solar
5	Rupandehi	Om Satiya	Solar
5	Rupandehi	Rohini	Solar
5	Rupandehi	Sainamaina	Solar
5	Rupandehi	Sammarimai	Solar
5	Rupandehi	Siddharthanagar	Biomass
5	Rupandehi	Siyari	Solar
5	Rupandehi	Suddhodhan	Solar
5	Rupandehi	Tilottama	Biomass
6	Dailekh	Aathbis	Solar
6	Dailekh	Bhagawatimai	Hydro
6	Dailekh	Bhairabi	Solar
6	Dailekh	Chamunda Bindrasaini	Hydro
6	Dailekh	Dullu	Solar
6	Dailekh	Dungeshwor	Solar
6	Dailekh	Gurans	Solar
6	Dailekh	Mahabu	Hydro
6	Dailekh	Narayan	Solar
6	Dailekh	Naumule	Solar
6	Dailekh	Thantikandh	Solar
6	Dolpa	Chharka Tangsong	Solar
6	Dolpa	Dolpo Buddha	Solar
6	Dolpa	Jagadulla	Hydro
6	Dolpa	Kaike	Solar
6	Dolpa	Mudkechula	Hydro
6	Dolpa	Shey Phoksundo	Hydro
6	Dolpa	Thulibheri	Hydro
6	Dolpa	Tripurasundari	Hydro
6	Humla	Adanchuli	Hydro
6	Humla	Chankheli	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
6	Humla	Kharpunath	Solar
6	Humla	Namkha	Solar
6	Humla	Sarkegad	Hydro
6	Humla	Simkot	Hydro
6	Humla	Tanjakot	Hydro
6	Jajarkot	Barekot	Hydro
6	Jajarkot	Bheri Malika	Solar
6	Jajarkot	Chhedagad	Hydro
6	Jajarkot	Junichande	Hydro
6	Jajarkot	Kuse	Hydro
6	Jajarkot	Shivalaya	Hydro
6	Jajarkot	Tribeni Nalagad	Hydro
6	Jumla	Chandannath	Solar
6	Jumla	Guthichaur	Hydro
6	Jumla	Hima	Hydro
6	Jumla	Kanaka Sundari	Solar
6	Jumla	Patarasi	Hydro
6	Jumla	Sinja	Hydro
6	Jumla	Tatopani	Hydro
6	Jumla	Tila	Hydro
6	Kalikot	Kalika	Hydro
6	Kalikot	Khandachakra	Hydro
6	Kalikot	Mahawai	Hydro
6	Kalikot	Naraharinath	Hydro
6	Kalikot	Pachal Jharana	Hydro
6	Kalikot	Palata	Hydro
6	Kalikot	Raskot	Hydro
6	Kalikot	Sanni Tribeni	Hydro
6	Kalikot	Tilagupha	Hydro
6	Mugu	Chhayanath Rara	Hydro
6	Mugu	Khatyad	Hydro
6	Mugu	Muguma karmarog	Hydro
6	Mugu	Soru	Hydro
6	Rukum	Aathabisakot	Hydro
6	Rukum	Banphikot	Hydro
6	Rukum	Chaurjahari	Solar
6	Rukum	Musikot	Hydro
6	Rukum	Sanibheri	Hydro
6	Rukum	Tribeni	Solar
6	Salyan	Bagachour	Solar
6	Salyan	Banagad Kupinde	Hydro

Province No.	District	Village/Town Municipality	Type of DG Selected
6	Salyan	Chhatreshwori	Solar
6	Salyan	Darma	Solar
6	Salyan	Dhorchaur	Solar
6	Salyan	Kalimati	Hydro
6	Salyan	Kapurkot	Solar
6	Salyan	Kumakh Malika	Solar
6	Salyan	Sharada	Hydro
6	Salyan	Tribeni	Solar
6	Surkhet	Barahatal	Solar
6	Surkhet	Bheriganga	Solar
6	Surkhet	Birendranagar	Biomass
6	Surkhet	Chaukune	Solar
6	Surkhet	Chingad	Hydro
6	Surkhet	Gurbhakot	Solar
6	Surkhet	Lekabeshi	Solar
6	Surkhet	Panchapuri	Solar
6	Surkhet	Simta	Solar
7	Achham	Bannigadhi Jayagadh	Hydro
7	Achham	Chaurpati	Solar
7	Achham	Dhakari	Hydro
7	Achham	Kamal bazar	Solar
7	Achham	Mangalsen	Solar
7	Achham	Mellekh	Hydro
7	Achham	Panchdebal Binayak	Solar
7	Achham	Ramaroshan	Hydro
7	Achham	Sanphebagar	Hydro
7	Achham	Turmakhand	Solar
7	Baitadi	Dasharathchand	Hydro
7	Baitadi	Dilasaini	Solar
7	Baitadi	Dogada Kedar	Hydro
7	Baitadi	Melauli	Hydro
7	Baitadi	Pancheshwor	Hydro
7	Baitadi	Patam	Hydro
7	Baitadi	Puchaundi	Hydro
7	Baitadi	Shivanath	Solar
7	Baitadi	Sigas	Hydro
7	Baitadi	Surnaya	Solar
7	Bajhang	Bitthadchir	Solar
7	Bajhang	Bungal	Hydro
7	Bajhang	Chhabis Pathibhara	Hydro
7	Bajhang	Durgathali	Solar

Province No.	District	Village/Town Municipality	Type of DG Selected
7	Bajhang	Jayaprithbi	Hydro
7	Bajhang	Kanda	Hydro
7	Bajhang	Kedarsyun	Hydro
7	Bajhang	Khaptad Chhanna	Hydro
7	Bajhang	Masta	Hydro
7	Bajhang	Surma	Hydro
7	Bajhang	Talkot	Hydro
7	Bajhang	Thalara	Solar
7	Bajura	Badimalika	Hydro
7	Bajura	Budhiganga	Hydro
7	Bajura	Budhinanda	Hydro
7	Bajura	Chhededaha	Hydro
7	Bajura	Gaumul	Hydro
7	Bajura	Himali	Hydro
7	Bajura	Pandab Gufa	Hydro
7	Bajura	Swami Kartik	Hydro
7	Bajura	Tribeni	Hydro
7	Dadeldhura	Ajayameru	Hydro
7	Dadeldhura	Amargadhi	Hydro
7	Dadeldhura	Bhageshwor	Hydro
7	Dadeldhura	Ganyapdhura	Hydro
7	Dadeldhura	Nawadurga	Hydro
7	Dadeldhura	Parashuram	Solar
7	Dadeldhura	Shuklaphanta	Solar
7	Darchula	Apihimal	Hydro
7	Darchula	Byas	Hydro
7	Darchula	Duhun	Hydro
7	Darchula	Lekam	Solar
7	Darchula	Mahakali	Hydro
7	Darchula	Malikarjun	Solar
7	Darchula	Marma	Hydro
7	Darchula	Naugad	Hydro
7	Darchula	Shailyashikhar	Solar
7	Doti	Aadarsha	Hydro
7	Doti	Badi Kedar	Solar
7	Doti	Bogatan	Solar
7	Doti	Dipayal Silgadhi	Solar
7	Doti	Jorayal	Hydro
7	Doti	K.I. Singh	Solar
7	Doti	Purbichouki	Hydro
7	Doti	Sayal	Hydro

Province No.	District	Village/Town Municipality	Type of DG Selected
7	Doti	Shikhar	Hydro
7	Kailali	Bardagoriya	Solar
7	Kailali	Bhajani	Solar
7	Kailali	Chure	Hydro
7	Kailali	Dhangadhi	Biomass
7	Kailali	Gauriganga	Solar
7	Kailali	Ghodaghodi	Solar
7	Kailali	Godawari	Hydro
7	Kailali	Janaki	Solar
7	Kailali	Joshipur	Solar
7	Kailali	Kailari	Solar
7	Kailali	Lamki Chuha	Solar
7	Kailali	Mohanyal	Solar
7	Kailali	Tikapur	Biomass
7	Kanchanpur	Bedkot	Solar
7	Kanchanpur	Beldandi	Solar
7	Kanchanpur	Belouri	Solar
7	Kanchanpur	Bhimdatta	Biomass
7	Kanchanpur	Krishnapur	Solar
7	Kanchanpur	Laljhadi	Solar
7	Kanchanpur	Mahakali	Solar
7	Kanchanpur	Punarbas	Solar
7	Kanchanpur	Shuklaphanta	Solar

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Annex 1: Contributors to SUDIGGAA

Name	Particulars
Hitendra Dev Shakya	Team Coordinator
Deepak Das Tamrakar	Team Leader of Assignment
Om Krishna Shrestha	Group Leader (Electrical)
Gopal Basnet	Sub-group Province Leader
Kalidas Neupane	Biomass Group Leader
Bhaskar Kafle	Sub-group P-3 Leader
Sitaram Neupane	Sub-group P-4 Leader
Khimananda Kandel	Group Leader - Hydropower
Netra Timilasina	Sub-group P-5 Leader
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Prajwal Khadka	Group Leader (Electrical)
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Saurav Suman	Engineer –Hydropower
Yuba Raj Acharya	Engineer –Hydropower
Raju Mandal	Engineer –Hydropower
Binod Karki	Engineer –Hydropower
Neeraj Kumar Sah	Engineer –Hydropower
Nabin Panta	Engineer –Hydropower
Binay Paudyal	Engineer - Power System
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Bishnu Dawadi	Engineer – Electrical
Tika Ram Regmi	Engineer – Electrical
Ravi Raj Shrestha	Engineer – Electrical
Prasan Lama	Engineer-Geomatics
Suraj Upadhyay	Engineer-Geomatics
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Sujan Nepali	Engineer-Geomatics
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Ramesh Kandel	Engineer - Civil
Ashish Regmi	Engineer - Electrical

Annex 2: Glimpses of the Event

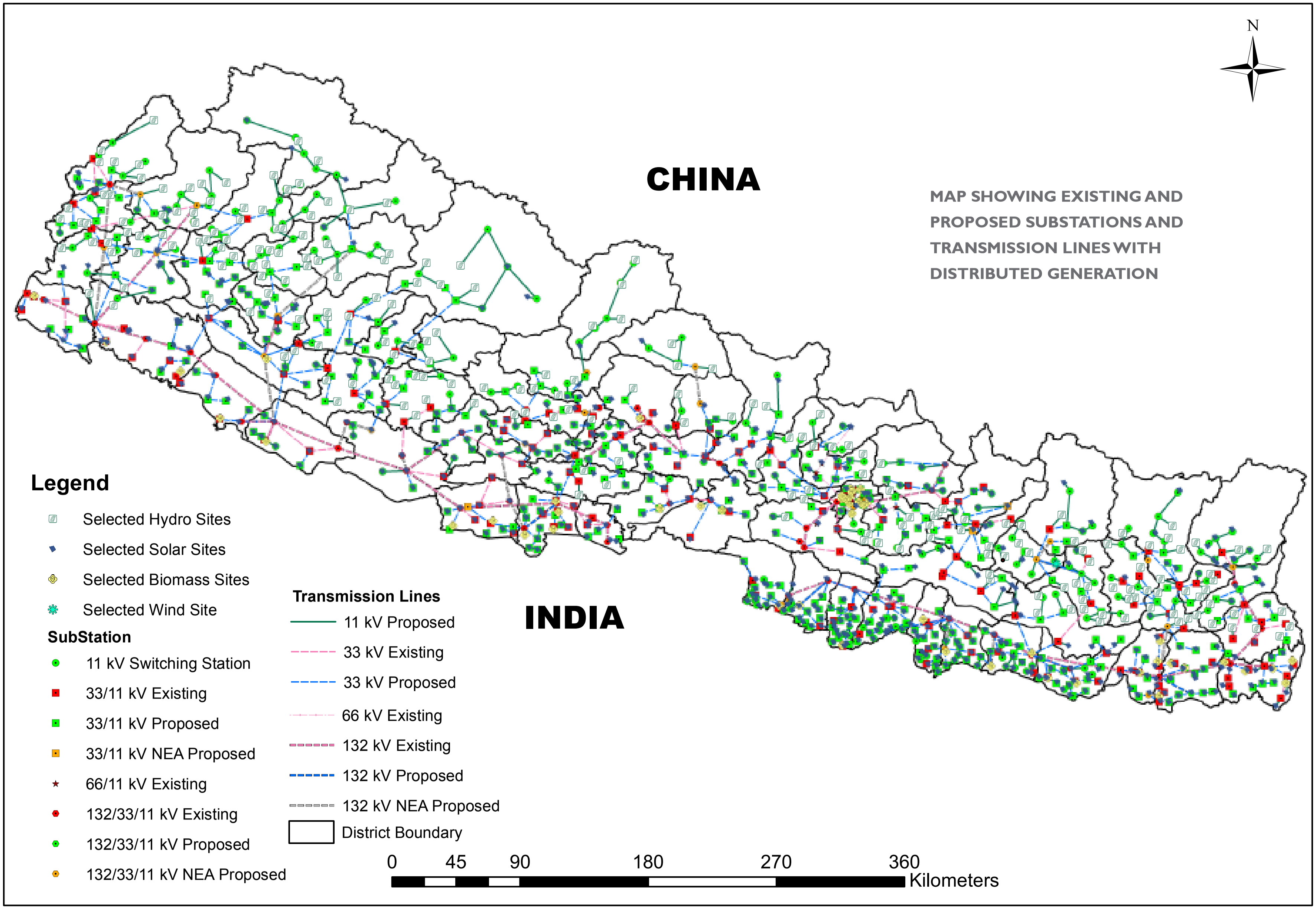
Members of SUDIGGAA team of NEA Engineering Company, with honorable Dr. Arbind Kumar Mishra, Member, National Planning Commission

Honorable delegates sharing their views on the workshop organized by National Planning Commission and NEA Engineering Company on 27th Jan 2018

Attendees on meeting on Initiation of SUDDIGGAA, organized by NEA Engineering Company on 11th Oct 2017

Kulman Ghising, Managing Director, Nepal Electrical Authority, addressing the Workshop on SUDIGGAA, organized by National Planning Commission and NEA Engineering Company on 4th Jan 2018.

Annex 3: Selected Distributed Generation in each VM/TM with Existing and Proposed Substations and Lines



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