in association with:

DISTRIBUTION SYSTEM / RURAL ELECTRIFICATION MASTER PLAN NEPAL

CONTRACT NO. DSMP/REMP-074/75

DISTRIBUTION MASTER PLAN FOR NEPAL

Executive Summary

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Disclaimer

EXECUTIVE SUMMARY

OVERVIEW

This Executive Summary provides excerpts from the main body of the Distribution Master Plan Report for Nepal to provide a concise overview of the approach, analysis, findings and proposals, as well as the investment requirements to achieve universal access by 2023 and provide adequate network capacity for population and demand growth until 2035.

The report is structured into four parts: Introduction, Vision, Infrastructure and Implementation:

- **Part I: Introduction:** starts by presenting a brief introduction of the objective of the assignment in **Chapter 1**, followed by an overview of the Country, and the current status of the electricity sector in **Chapter 2**. The Policy Objectives, definition of access and planning approach that guide the Master Plan development are outlined in **Chapter 3**.

- **Part II: Vision:** includes forward-looking chapters such as the Load Demand Forecast in **Chapter 4**, the anticipated Transmission System development in **Chapter 5** and, finally, **Chapter 6** provides an outlook of Universal Access and the future development of the Distribution System in Nepal, by 2023 as well as in the longer term, up to 2035.

- **Part III: Infrastructure:** deals with the reinforcement and expansion of the Distribution infrastructure in order to cope with additional consumer connections and demand growth. **Chapter 7** presents the Distribution Augmentation requirements for the Metropolitan and Sub-Metropolitan Cities, while **Chapter 8** presents the network development requirements for the remainder of the Country (non-metropolitan areas), including the optimum (least-cost) rural grid expansion.

- **Part IV: Implementation:** Infrastructure requirements need to be deployed according to a plan spanning a period of time. **Chapter 9** summarizes the strategic investment requirements and assesses the economic and financial implications. **Chapter 10** assesses the potential social and environmental impacts of the proposed infrastructure. Finally, **Chapter 11** deals with various implementation considerations such as institutional framework, capacity building, funding and other cross-cutting issues.

PART I: INTRODUCTION

PROJECT OBJECTIVE

The overall objective of the Distribution System / Rural Electrification Master Plan (DS/REMP) assignment is to identify **a least-cost and economically viable means to reinforce, upgrade and expand Nepal's distribution system, including on- and off-grid options, to achieve universal access to electricity** by 2023.

PROJECT APPROACH / METHODOLOGY

The methodology - in line with the requirements of the TOR – was initially focussed mainly on least cost geospatial electrification planning, particularly with regard to grid extension in unelectrified areas and the identification of areas for off-grid / mini-grid electrification via renewable energy resources.

The diagram below illustrates the revised methodology after adjusting to certain requests from the Client during the inception phase of the project.

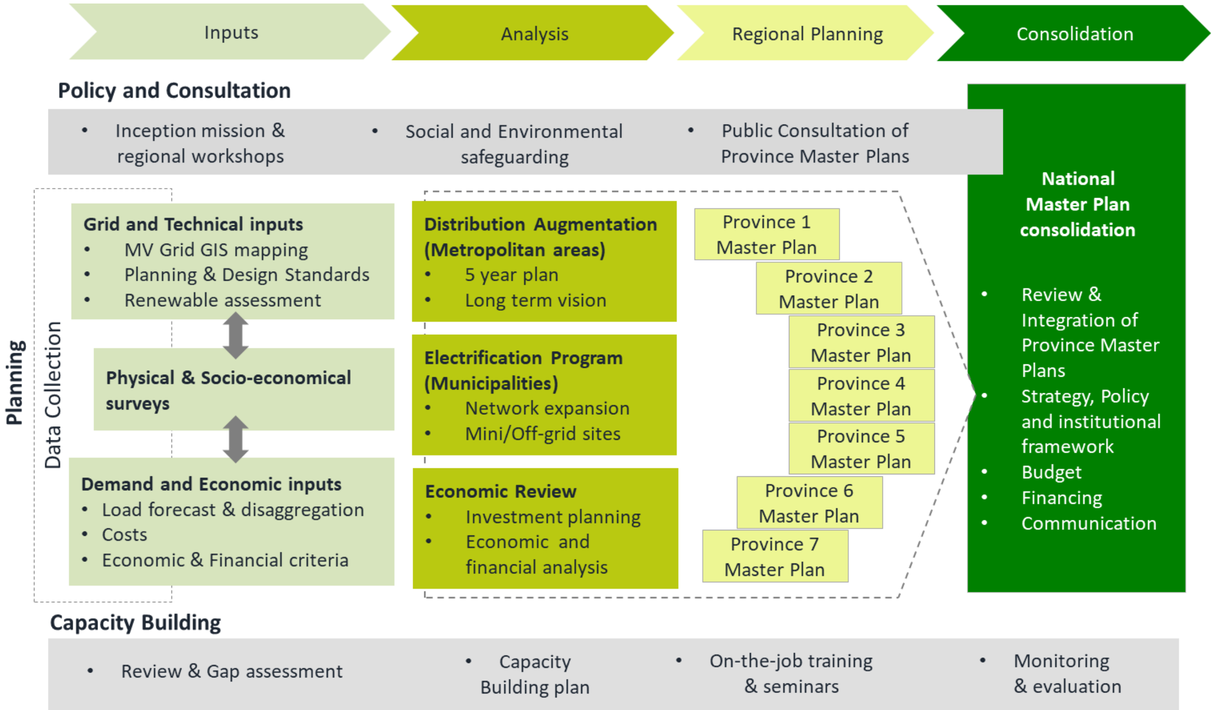


Figure 1.1 – Revised Distribution Master Plan Approach / Methodology

The main change in approach related to the delivery of seven Provincial Distribution Master Plans rather than one National Master Plan, which would be integrated into an overall National Distribution System / Rural Electrification Master Plan for Nepal – the current report.

The Client also requested that Distribution augmentation be covered in a more detailed manner in major urban areas, particularly for the short term and specifically for the Metropolitan and Sub-metropolitan cities of Nepal.

Another significant impact had to do with the total lack of geographical maps for the MV networks in Nepal - an essential requirement to do a least cost study - and therefore the need for the Consultant to capture the relevant 33kV and 11kV grid data into a Geographical Information System (GIS).

Finally, during the course of the project, the Consultant was requested to adjust the target date for Universal Access to the revised goal of 2023 as prescribed in the Government White Paper (May 2018)[1].

OVERVIEW OF THE STUDY AREA

The **Federal Democratic Republic of Nepal** is located in South Asia, neighbouring India in the east, south and west, and the Tibet Autonomous Region of the Republic of China in the north.

In accordance with Schedule 4 of the new Constitution of Nepal, adopted in September 2015, the new administrative structure of the nation is comprised of **seven (7) Provinces** and, at a second level of administrative divisions, there are **seventy-seven (77) districts**. The nation's capital is Kathmandu, located in Bagmati Pradesh (Province 3).

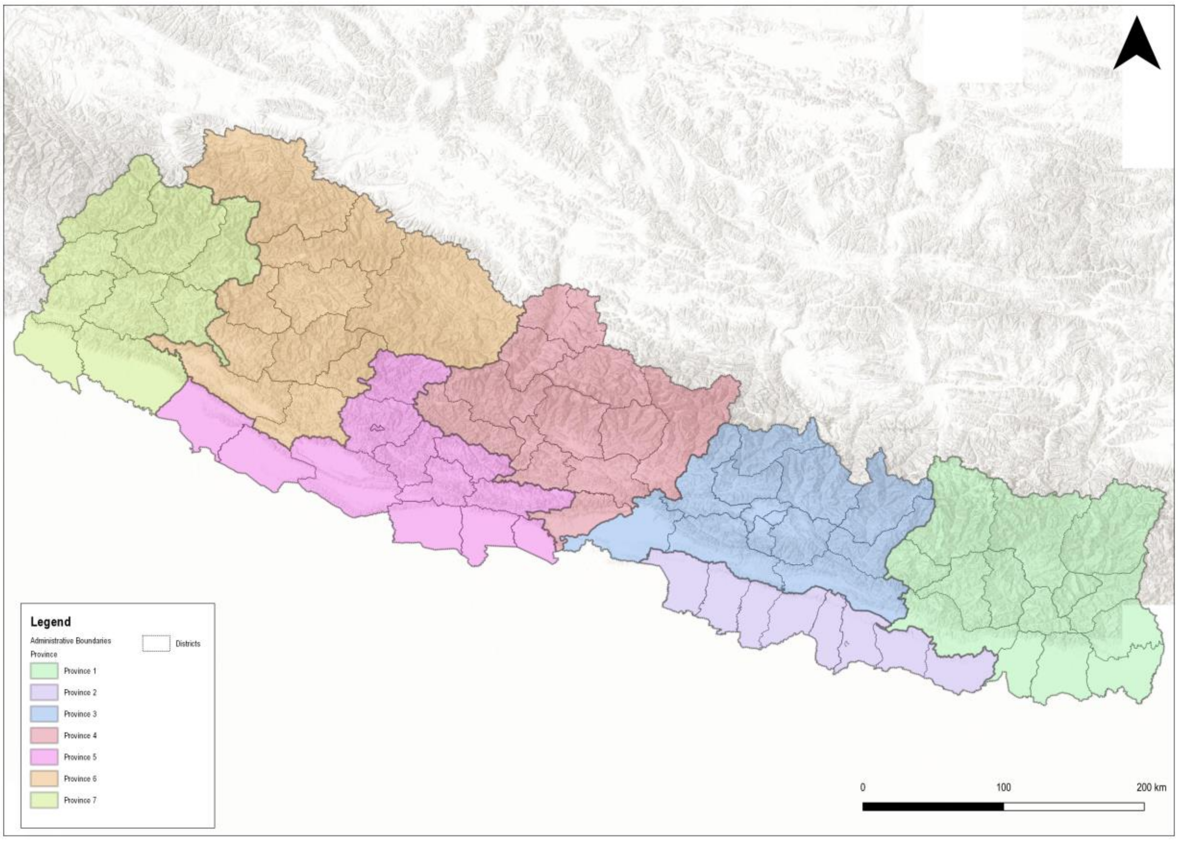


Figure 2.1 – Map of Nepal highlighting its Provinces and Districts

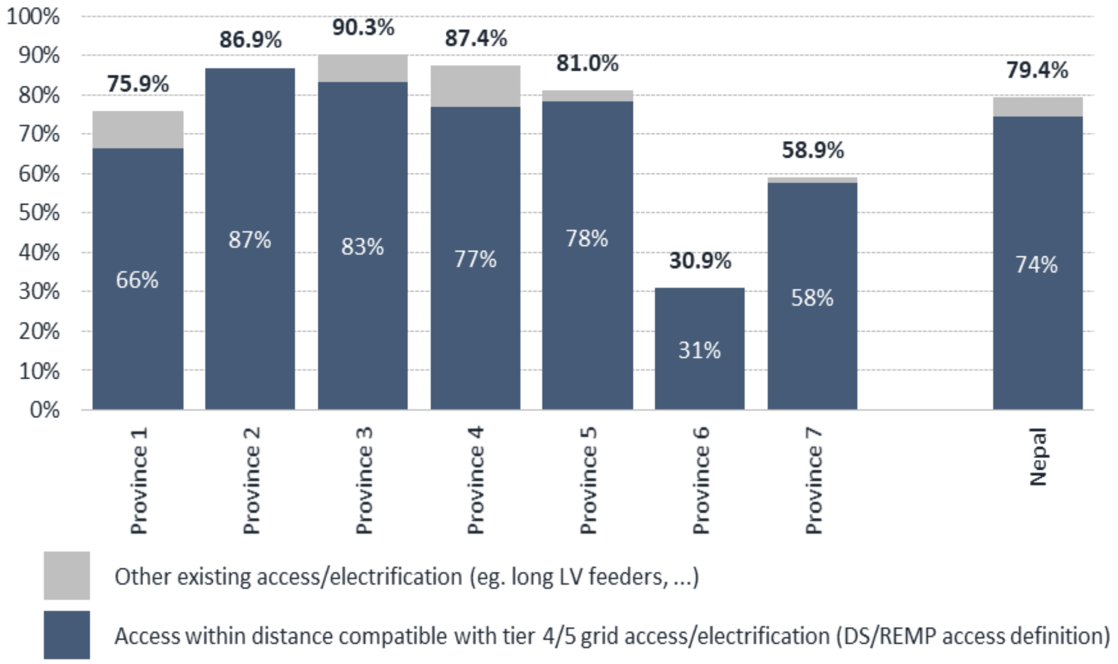
[1] Initially the Consultant was required - via the ToR - to use 2027 as the target date for universal access.

The following table summarizes some of the country's features, providing insight on some general information by Province.

Table 2.1– General overview of Nepal's Provinces

Province	No. Districts	Area (km²)	Population in 2011 (Millions)	Capital
Province No. 1	14	25 905	4.5 M	Biratnagar
Province No. 2	8	9 661	5.4 M	Janakpur
Province No. 3 (Bagmati Pradesh)	13	20 300	5.5 M	Hetauda
Province No. 4 (Gandaki Pradesh)	11	21 504	2.4 M	Pokhara
Province No. 5	12	22 288	4.9 M	Butwal
Province No. 6 (Karnali Pradesh)	10	27 984	1.2 M	Birendranagar
Province No. 7 (Sudurpashchim Pradesh)	9	19 539	2.6 M	Godawari
Nepal	**77**	**147 181**	**26.5 M**	**Kathmandu**

Figure 2.8 indicates the current grid reach in each Province of Nepal. Overall, some 80% of households currently have access to the national NEA grid.



Source: Central Bureau of Statistics, Gesto GIS mapping and analysis, NEA electrification reports

Figure 2.8 – Electrification/Access status - 2019

NEPAL ELECTRICITY AUTHORITY (NEA)

In 2019, NEA energy sales in Nepal amounted to 6 300 GWh with the majority of consumption coming from the Domestic sector (44% of total sales) and from the Industry sector (40% of total consumption), while Services and Others sectors combined sales represented 16%.

Province 3 represents about a third of total NEA sales, with significant influence from Kathmandu District, which alone represents half of the provinces total sales. Provinces 2 and 5, both highly industrialized, represent 20% of total NEA sales. Province 6, the least populated province, where grid access is still scarce, only represents 1% of total NEA electricity sales.

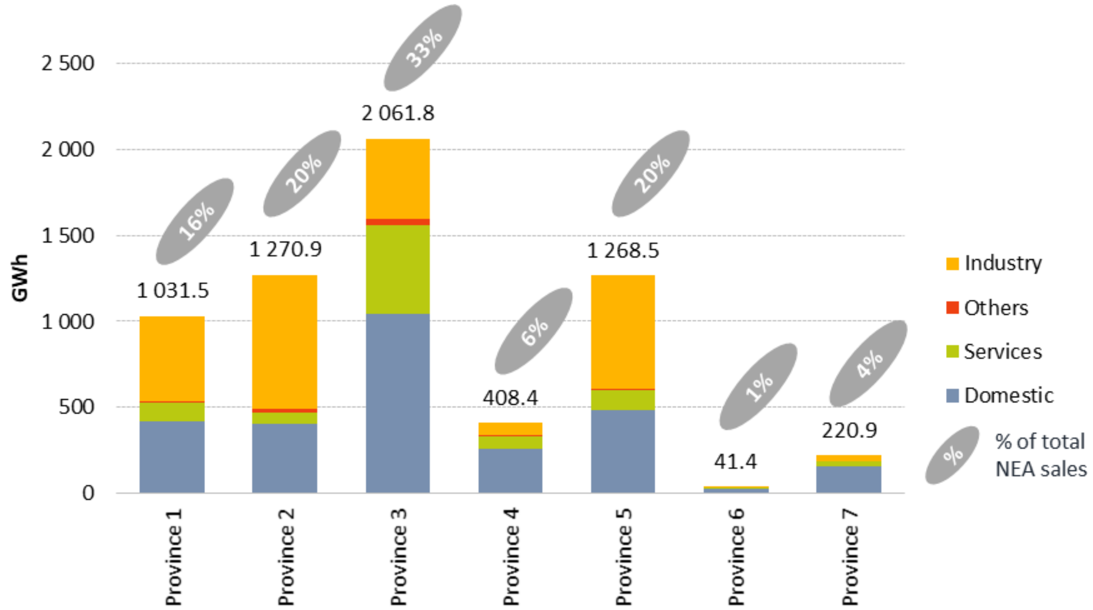


Figure 2.5 – Energy Sales by aggregated segment (constrained and with no losses)

In 2019, NEA's distribution system **served more than 4.4 million consumers.** Included in the above numbers, are the sales to 506 Community Rural Electrification Entities (CREEs) that operate in 53 districts and provide access to more than 530 000 consumers in rural areas across the country.

The existing national electricity grid of Nepal, retrieved from the GIS mapping assessment developed over the course of the study, is presented in Figure 2.4.

The medium voltage distribution system in Nepal is based on 33kV and 11kV voltage levels. NEA uses 33kV mostly as a sub-transmission voltage to supply 33/11kV medium voltage substations scattered throughout the territory and then utilises 11kV power lines to further distribute energy to the low voltage system. This is clear in Figure 2.5, where one can observe that 85% of total length in the MV system consists of 11kV and only 15% is 33kV, used mainly as a backbone to connect MV substations.

In total, there are 170 medium voltage distribution substations (33/11kV) supplying the national distribution system. Also supporting the medium voltage network are several MV generation substations that inject power directly into the MV system. These are mainly located in the northern areas of the country still with limited access to the national grid, thus being the only electrical source in several areas.

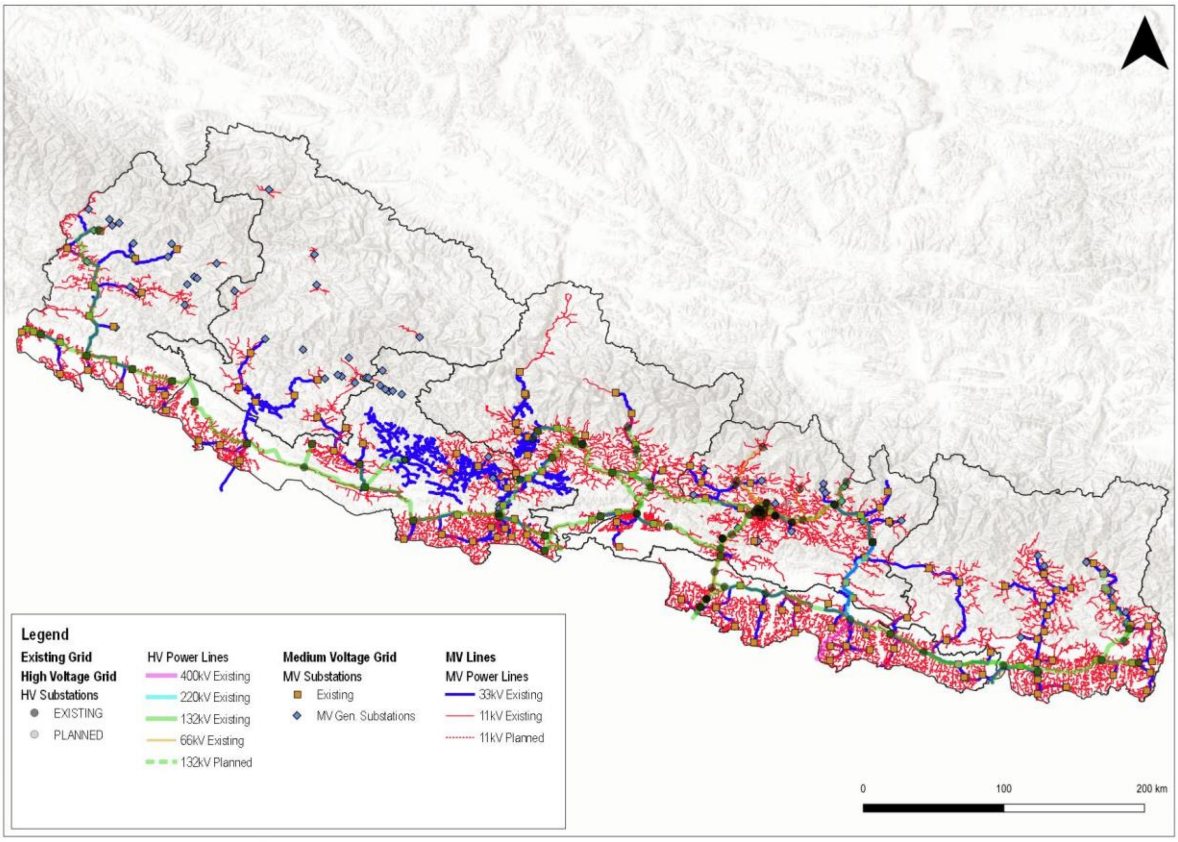


Figure 2.4 – Existing Electrical Power System of Nepal

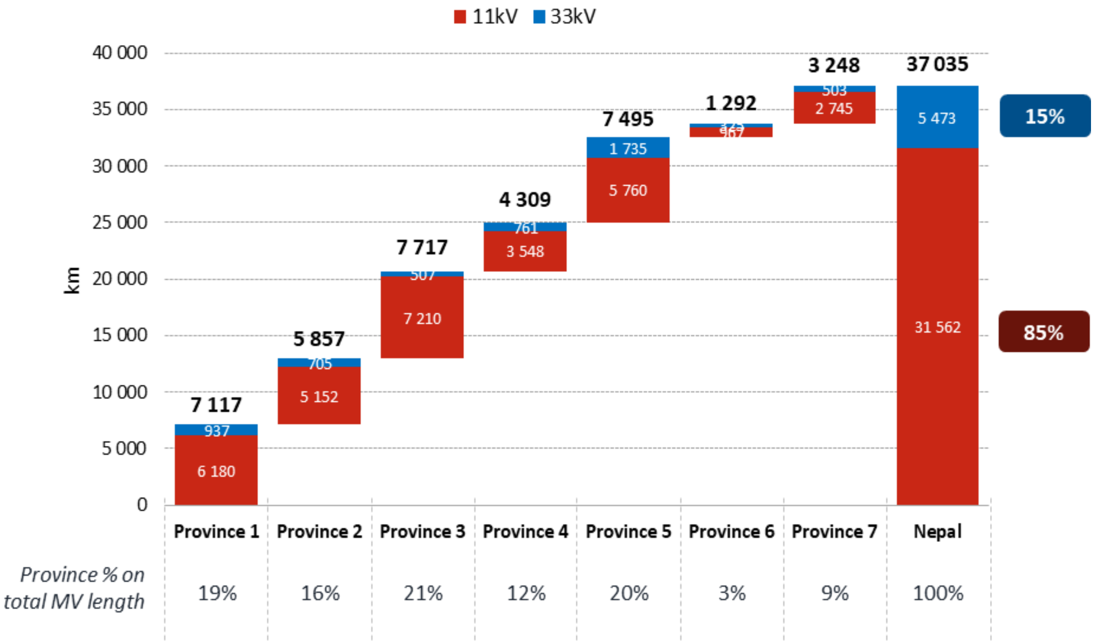
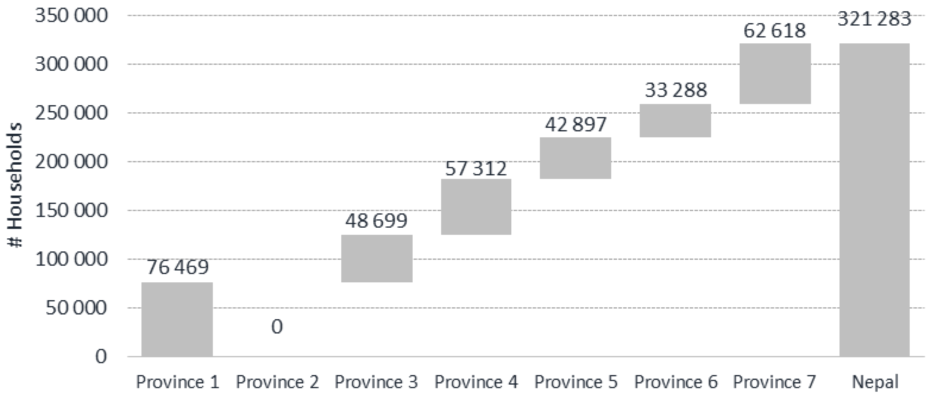


Figure 2.5 – Medium voltage system line lengths

AEPC AND OFF-GRID ELECTRIFICATION

The Alternative Energy Promotion Centre (AEPC) has supported the implementation of more than 1 700 micro-hydro schemes with combined installed capacity of ~30MW, connecting around 320 000 households.



	Province 1	Province 2	Province 3	Province 4	Province 5	Province 6	Province 7	Nepal
# of sites	497	0	417	310	155	123	209	1 711
Installed Capacity (kW)	7 918	0	4 671	6 061	2 241	3 278	5 712	29 881

Source: AEPC micro-hydro data

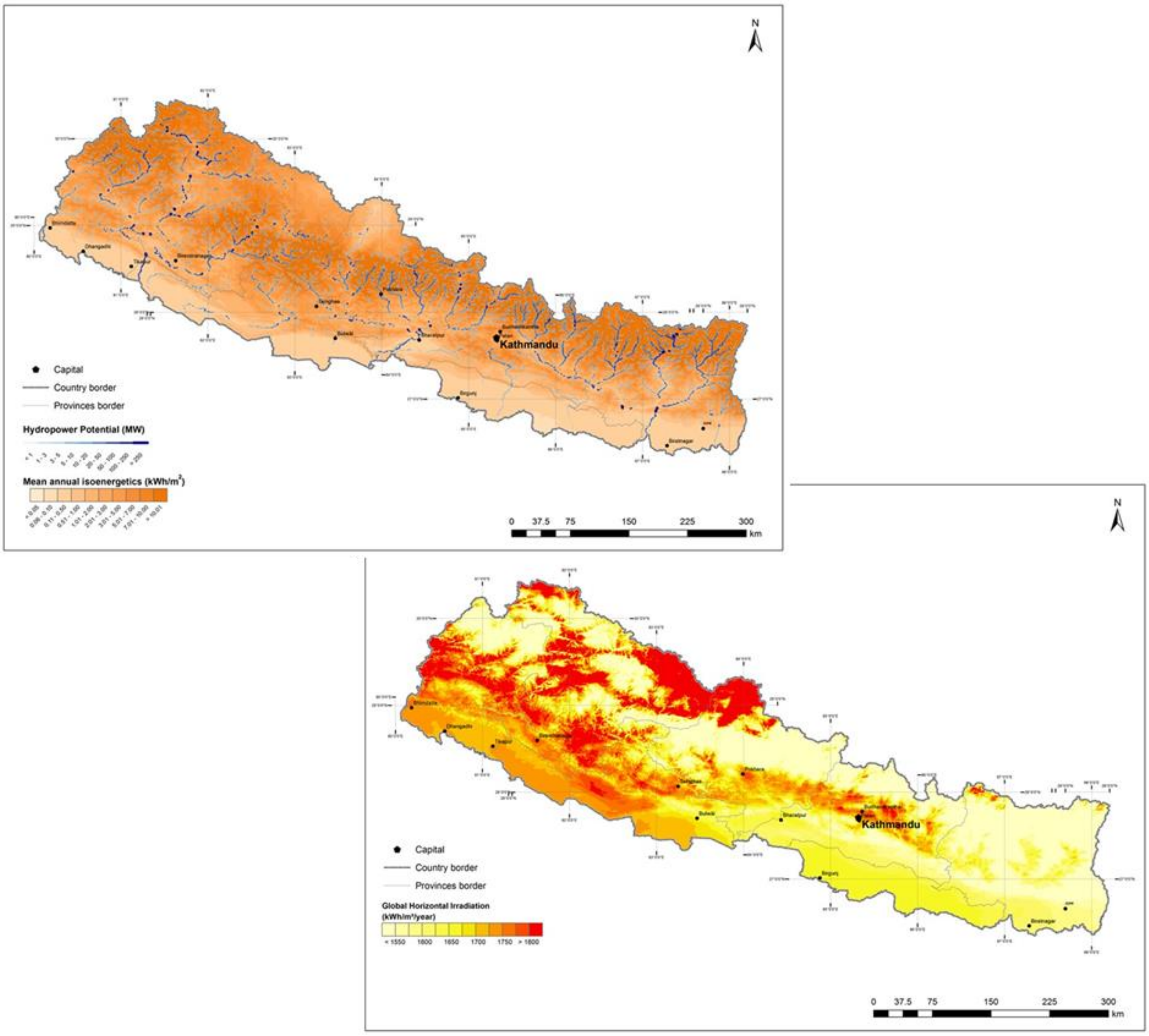
Figure 2.7 – Number of households served by existing micro-hydro systems (AEPC)

Regarding solar energy, the AEPC has also supported several initiatives to distribute solar PV systems (with and without battery storage) across the country. In addition many commercial solutions exist for the acquisition of small solar home systems (SHS's) ~10 -20W solar panels.

RENEWABLE ENERGY RESOURCE ASSESSMENT

Following the White Paper Policy, one of the premises of this Master Plan is that all off-grid systems should be 100% renewable. Taking into account Nepal's geography the most technical and economically viable renewable alternatives for decentralized and off-grid systems are hydropower and solar energy. The assessment of the hydropower and solar potential of the country supported the identification of renewable generation options and, ultimately, served as an input to the network expansion planning model and to the definition of off-grid solutions.

The overall hydro and solar assessment for the whole country resulted in the Hydropower and Solar Potential Maps, presented in the following figure.



Figures 2.9 & 2.11 – Hydropower potential and Solar Atlas for Nepal

ELECTRIFICATION POLICY AND PLANNING STRATEGY

The Master Plan takes into consideration the existing institutional and legal framework, as well as the key policy documents guiding the energy sector. Under the 2018 White Paper universal access is anticipated by 2023 under the following Policy Goal: “Make electricity accessible to each individual within 5 years”. Implementation of such goal under the Distribution System Master Plan requires a clear definition of access, including its minimum and optimal standards to guide the planning process.

Definition of Access

For the purpose of the Master Plan, access is defined by the World Bank’s 5-Tier level of access, which utilises 7 different criteria - Capacity, Duration, Reliability, Quality, Affordability, Legality, Health and Safety - to define the availability and quality of access to modern energy.

This Master Plan focuses on how to provide access at least cost to all settlements across Nepal, not only to Municipality capitals, independently of the electrification solution or technology.

The analysis of NEA's billing data at Distribution Center level shows that current demand levels in Nepal range between Tier 2 and Tier 5 standards. Many families in rural settlements of the Hill or Mountain areas having an average consumption below 321 kWh/year, which could be adequately satisfied by a 100W peak Solar Home System or equivalent.

Despite the relevant progress achieved in terms of electrification, many households – in particular in mountain areas - still have very limited access to electricity. For the purpose of the Master Plan we define two levels of access: Universal Access and Optimized Access as depicted in the image below.

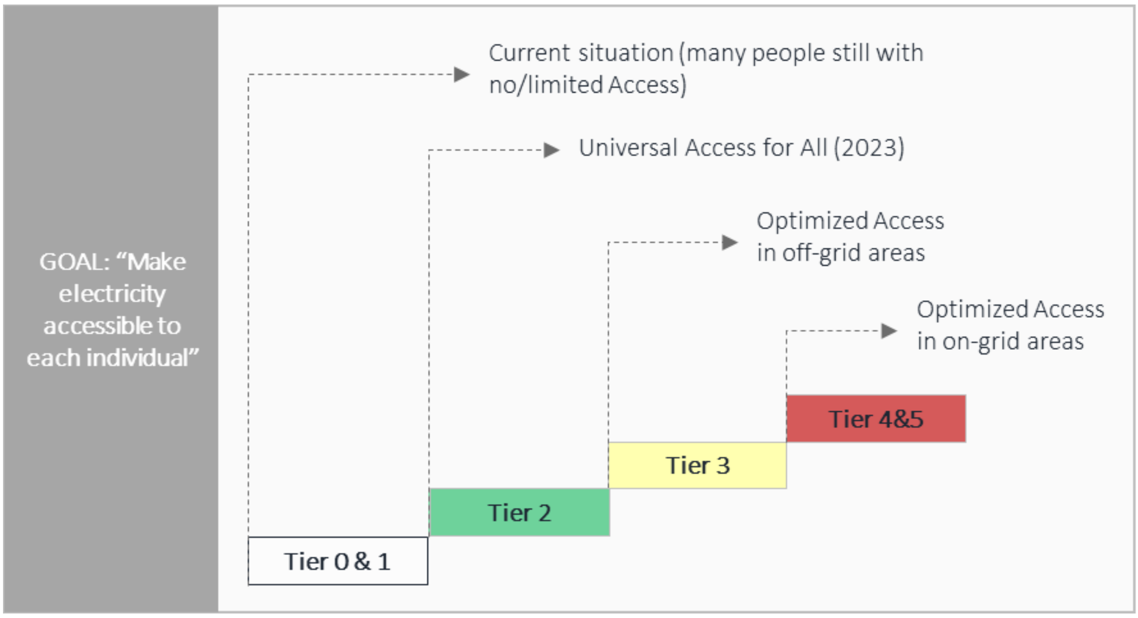


Figure 3.2 – Master Plan definition of access

Universal Access - to be achieved by 2023 - means that all households across Nepal should have at least Tier 2 level of access. Optimized Access definition depends on the electrification technology: in off-grid areas all households should have at least Tier 3 level of access and in on-grid areas households should at least have Tier 4 or higher level of access.

PLANNING STRATEGY AND GUIDELINES

Electrification policy objectives and targets for the country can only be met through deployment of distribution infrastructure. The planning strategy for the deployment of such infrastructure has been developed separately for Metropolitan and non-Metropolitan areas in each Province:

- In Metropolitan areas, where there is a higher consumption density and growth, and the grid is already established, but needs to be reinforced and upgraded in order to cope with consumption growth, and acceptable quality standards; this is referred to as "**Distribution Augmentation**".
- In Non-Metropolitan areas, where there are still some areas outside the reach of the existing grid. Those locations can either be served by the national grid, or by off-grid solutions. The Master Plan determines the least cost solution to provide electricity to all settlements across Nepal, referred to as "**Least Cost Expansion**".

Technical criteria have been defined to assess network capacity and determine the need for and timing of network reinforcement or reconfiguration, in order to ensure that distribution networks:

- Provide a quality, reliable and secure electricity supply
- Are optimised from an economic perspective (e.g. high utilization, low losses, etc.)
- Meet safety standards
- Meet environmental standards

Least Cost Expansion

The Master Plan applies the “Network Expansion Planner” methodology in order to define the “Least Cost Grid” (outside Metropolitan areas), based on the following steps:

1st: Definition and geo-location of existing and future Load Centres across all Provinces - considering settlement patterns and location of existing distribution transformers.

2nd: Assessment of potential future demand for each Load Centre when it is fully electrified.

3rd: Solar and Hydro resource assessment and identification of the Best Available renewable decentralized Technology (BAT) to supply the demand of each of the Load Centres not yet connected to the grid.

4th: Assess the least cost solution to serve the Load Centre – either through decentralized renewable BAT or through grid extension (“long term least cost solution”).

5th: Distribution grid design and reinforcement to meet the long term least cost solution – including location of future substations.

6th: Phasing of the proposed distribution infrastructure according to electrification policy objectives and goals – starting with the technically viable grid reinforcements which have the highest economic return.

PART II: VISION

LOAD DEMAND FORECAST

The detailed energy and load demand forecast analysis performed under the DS/REMP Project was aimed at forecasting electricity demand across Nepal in a geographically disaggregated way, so that it could be used for Distribution Planning purposes. Since Generation and Transmission planning are based on the WECS load forecast, the current load forecast uses similar fundamentals to the WECS forecast – on population growth, GDP growth, etc. – resulting in similar results and therefore some consistency at a nationally aggregated level. Although the population and economic fundamentals and the aggregated results are similar, the applied methodology is different and results from international best practices applied to the available geographically disaggregated data. The methodology is only presented in a summarized way in chapter 4 of this report; however the detailed methodology and analysis can be found in "Load Forecast Report at Province Level" (October 2018) – Annex E of DS/REMP Interim Report No. 1.

Revenue data per consumer segment was aggregated in four demand groups – Domestic, Services, Industry and Others. Demand for each group was modelled as summarized below.

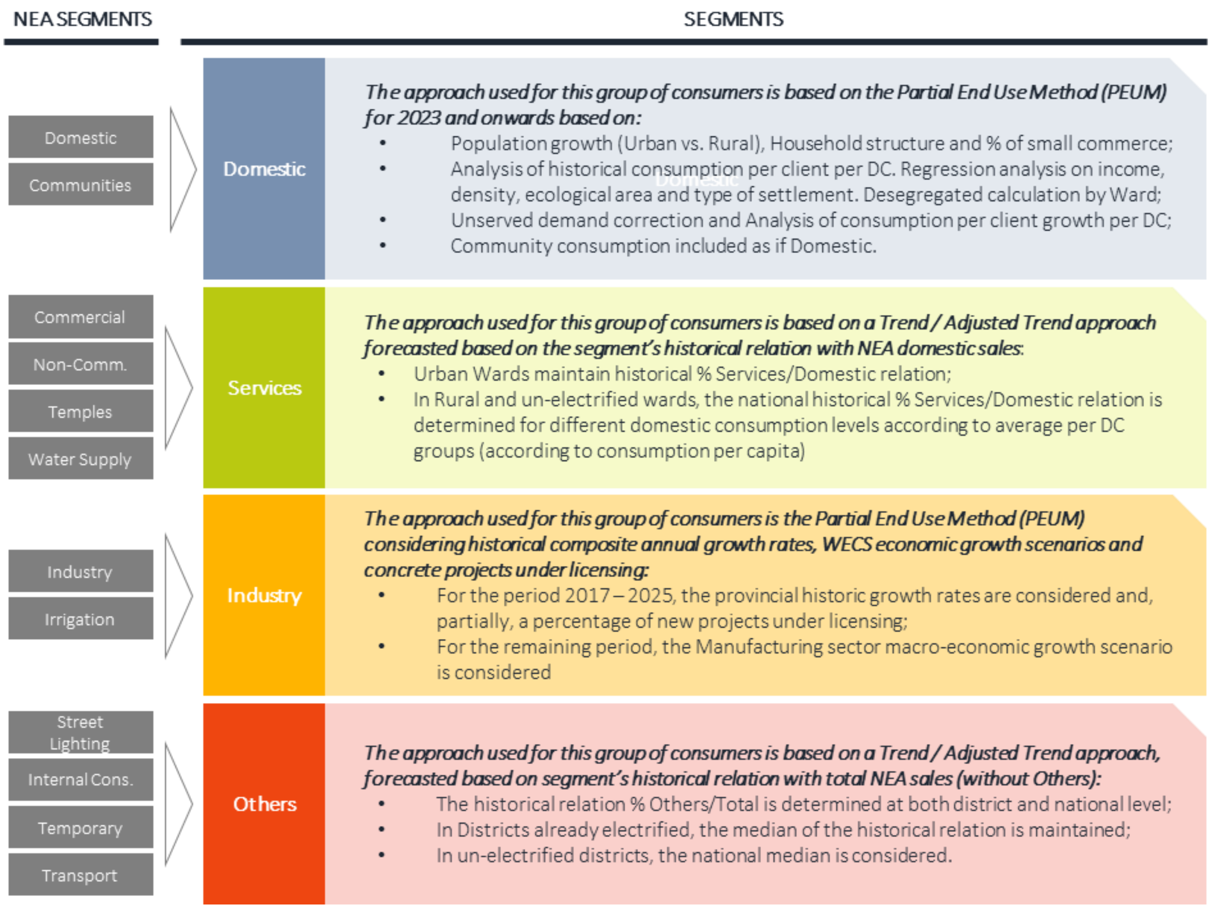
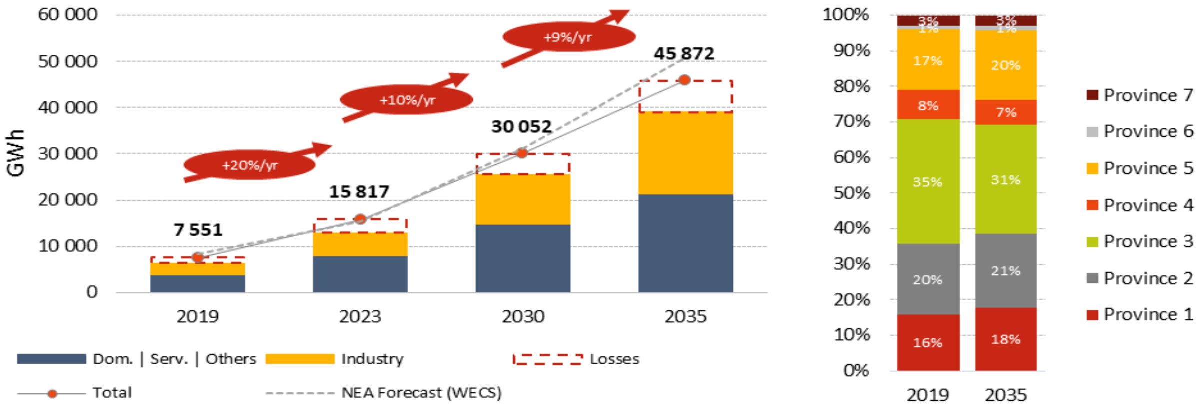


Figure 4.1 – Overall methodology followed for each demand segment

Electrical Energy Demand

The electrical energy projection for Nepal is presented below. The results separate the Domestic, Services and Others segments (which are allocated by geo-located load centers) from Industry segment, and also provides an insight on the impact of energy losses. Additionally, for comparison purposes, the WECS demand evolution curve – NEA's official demand forecast – is also represented in the graph. As the figure shows, WECS and DS/REMP projections are in the same order of values throughout the whole period, with a slight deviation towards the end of the period.

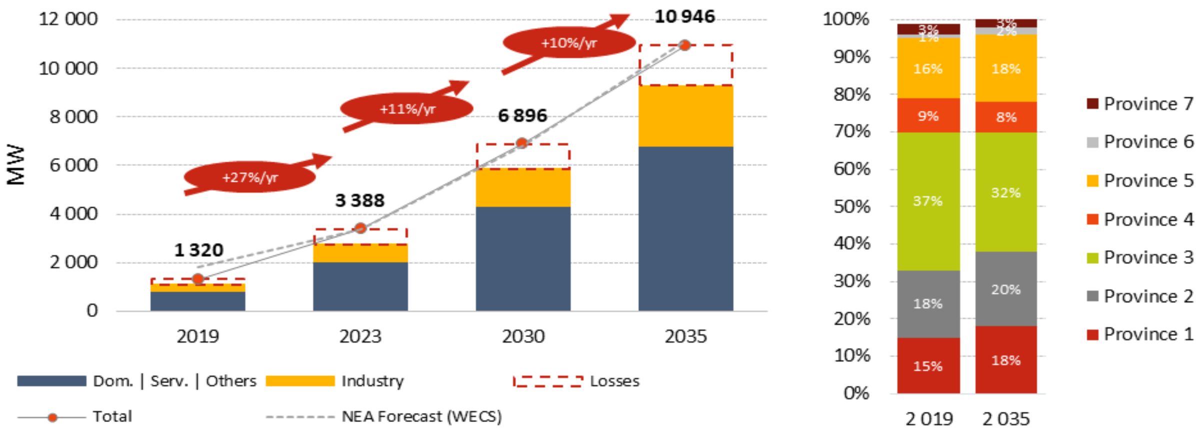


* *Considers estimated losses*

Figure 4.5 & 4.10 – Nepal electrical energy demand projection and distribution by Province (2019 – 2035)

Peak Demand

Nepal's electrical peak demand projections are provided below. Once again the WECS demand evolution curve is represented.



* Considers estimated losses

Figure 4.7 & 4.12 – Nepal electrical peak demand projection and distribution by Province (2019 – 2035)

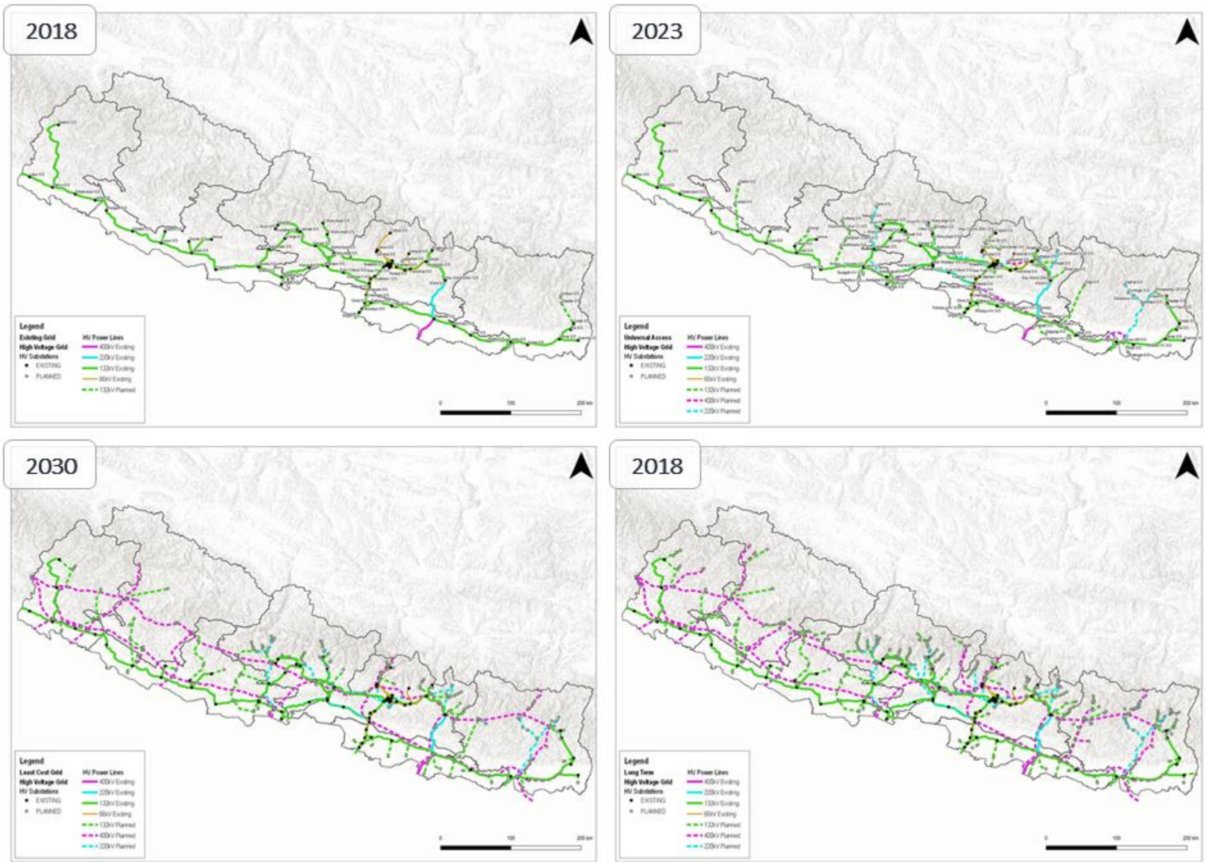
Energy demand, including losses, is expected to grow from 7 551 GWh to 45 872 GWh, while peak load demand is expected to grow from 1 320 MW to 10 946 MW.

TRANSMISSION GRID DEVELOPMENT

The transmission system development plan is a crucial input for a distribution system and rural expansion Master Plan since it defines the existing and future power sources, and regulated busbars, available to supply energy to the distribution system.

In July 2018, a new Transmission System Development Plan (TSDP) was prepared by the Rastriya Prasaran Grid Company Ltd. (RPGCL), the national transmission grid company of Nepal[2]. This document has been used as a reference for the Distribution Master Plan, along with updated information gleaned from NEA sources regarding under-construction and new proposed transmission projects.

The existing transmission system of Nepal is shown below along with the anticipated development of the transmission grid up to 2035.



Figures 5.2 - 5.5 – Nepal's existing and anticipated future transmission grid (2019 – 2035)

A number of Distribution infrastructure projects are reliant on the timely development of the associated transmission projects. It will be important to ensure proper coordination of project implementation for the Distribution System Master Plan to materialise as envisaged.

[2] A thorough review of the TSDP and the Consultants assumptions regarding the development of the transmission system between 2018 and 2035 was submitted as Annex 1 of the Interim Report No. 1 (Nov 2018).

UNIVERSAL ACCESS AND LONG TERM VISION

This chapter in the report presents a vision of the future power system and off-grid electrification in two stages i.e. by (i) the year 2023, when Nepal aims at achieving Universal Access, and (ii) in the longer term of 2030/35, the planning horizon for this study.

Under the DS/REMP study, it is envisioned that the "High Return Grid"[3] is implemented by 2023 allowing 93% of all households in Nepal to be within grid reach by that year. By 2030, it is anticipated that the Least Cost Grid will be deployed reaching 99% of all households in the country. The remaining 1% of households are to be served through permanent off-grid solutions.

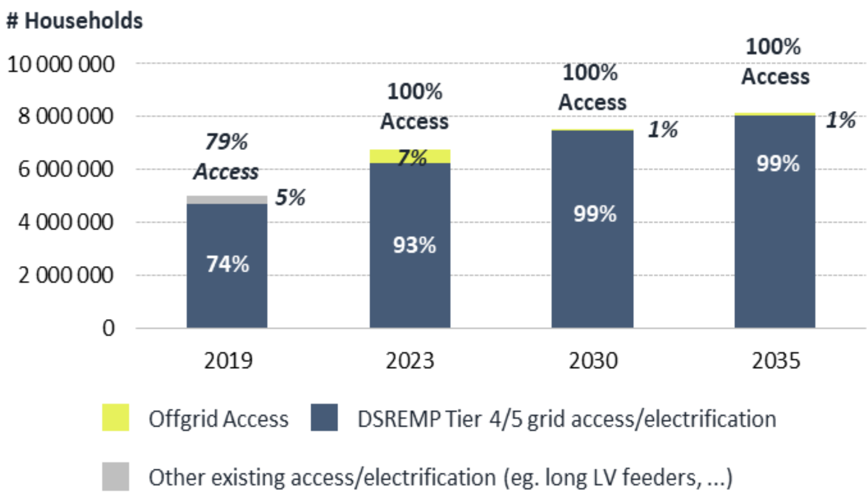


Figure 6.3 – Households grid and off-grid access evolution in Nepal

Figure 6.4 below presents the evolution of the percentage of households / potential consumers by access solution, showing that grid electrification is the predominant least-cost option across all provinces.

By 2023, the first stage of the planning period, grid reach will be above 90% in most provinces, resulting in an overall 93% grid access rate. Province 2 will be where the most households will have access to the national grid, with a 97% grid reach, while Province 6 and Province 7 have the least number of households with grid access, with 80% and 88% access respectively.

By 2035, according to the results of the costing analysis, an off-grid solution is the least-cost option for around 1% of the population i.e. it will be financially viable to provide grid access to approximately 99% of households. Provinces 6 and 7 will remain the ones with the highest rate of off-grid systems, while all the other provinces will have a grid access rate of 99% or higher.

[3] The "High Return Grid" represents an intermediate step in the development of the "Least Cost Grid", where approximately 50% of the more profitable grid extension investments are deployed.

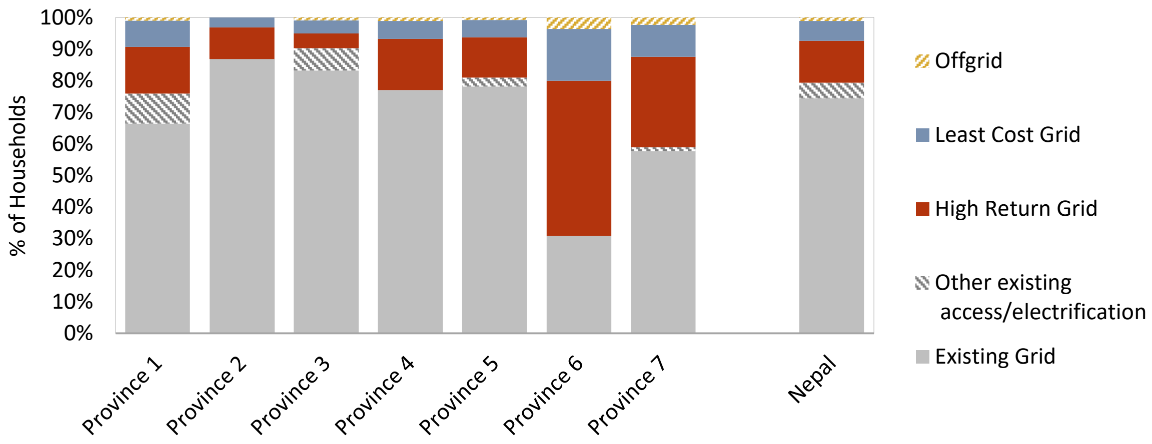


Figure 6.4 – Evolution of Access by Province and technology type

UNIVERSAL ACCESS BY 2023

Grid Access by 2023

Taking into consideration the load growth, as well as other planning criteria, the evolution of network up to the year 2023 – the target for Universal Access – is presented in this sub-section. The power system by the end of this phase is presented in Figure 6.5. More detail is provided in the respective Provincial Master plans.

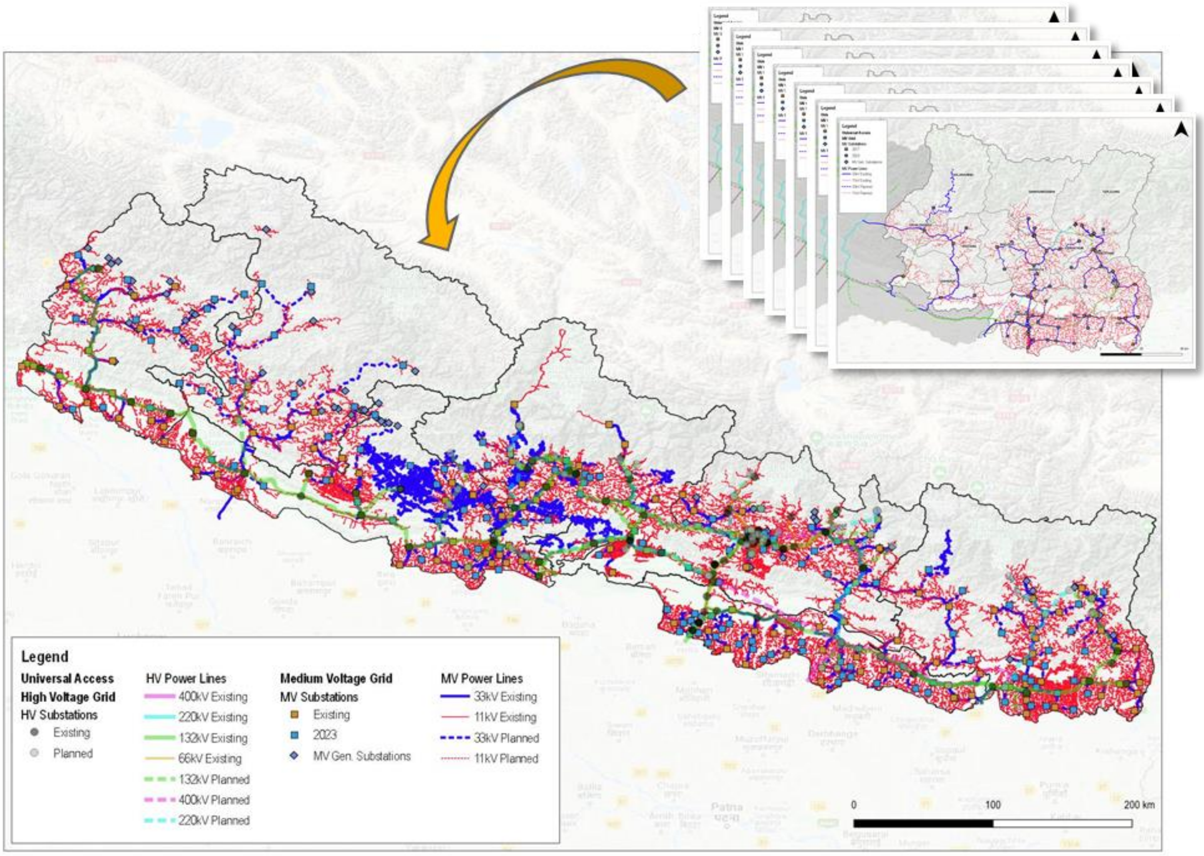


Figure 6.5 – Map of Nepal power system – Universal Access Phase (up to 2023).

By 2023, the 'High-Return Grid" is planned to be implemented, at which point 93% of households, will be within reach of a grid transformer (see Table 6.1 below).

Table 6.1 – Households reached by the grid (%) with Tier 4/5 standards

	2019	2023
Province 1	66%	91%
Province 2	87%	97%
Province 3	83%	95%
Province 4	77%	93%
Province 5	78%	94%
Province 6	31%	80%
Province 7	58%	88%
NEPAL	74%	93%

The remaining households will be provided access through an off-grid solution, some of these on a transitional basis until the least cost grid can be implemented.

In total more than 18 000 km of new MV grid will be required to be installed and some 143 new 33/11kV substations, of which 57 are already under construction, will be required to be constructed during the Universal Access phase.

Figure 6.7 shows the number of new consumers that will be provided with grid access by 2023. New grid connections continue to be made during the remainder of the planning period due to population growth, as well as households converting from existing or transitional off-grid systems to grid connections.

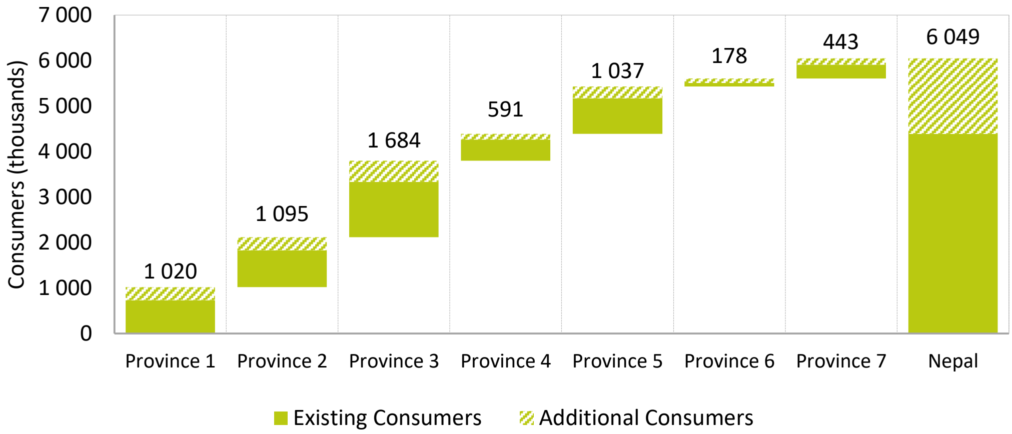


Figure 6.7– Number of consumers connected to the national grid in Nepal by 2023

Off-Grid Access by 2023

Once again, following the goals of the 2018 White Paper, decentralized off-grid systems are implemented to "make electricity accessible to each individual" by the year 2023. Figure 6.9 presents an overall view of the proposed off-grid systems by 2023, as determined by the Network Expansion Planner methodology.

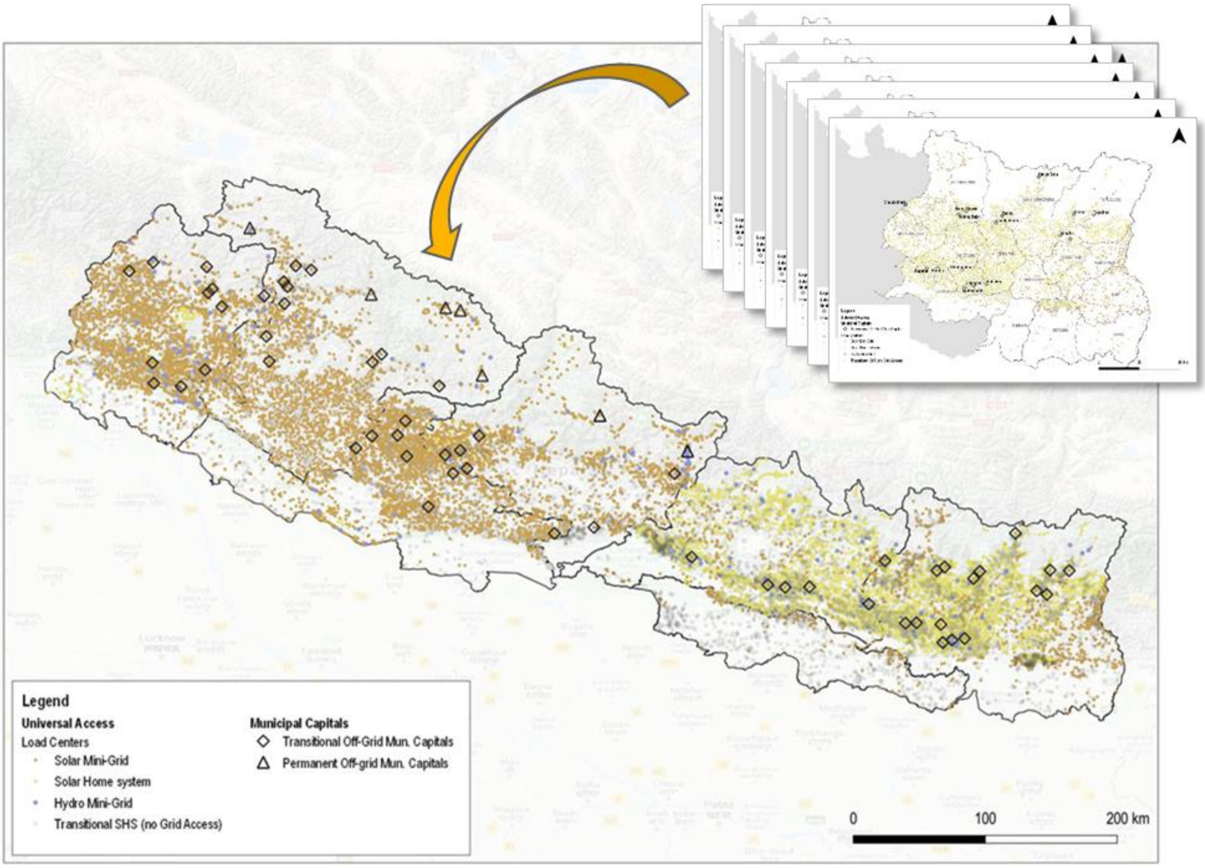


Figure 6.9 – Load centers served by off-grid systems (permanent and transitional) as at 2023

It is clear that solar systems are the most widely used alternative energy source. In the following table, the number of off-grid clusters (settlements) and households per Province is given.

Table 6.3 – Off-grid systems distribution per Province

	Solar Mini-grid Systems	Solar Home Systems	Hydro Mini-grid Systems
Prov. 1	561 (4 523)	2 180 (12 362)	30 (863)
Prov. 2	117 (1 098)	0	0
Prov. 3	205 (1 446)	1 996 (15 831)	86 (2 646)
Prov. 4	1 140 (9 511)	92 (454)	25 (1 025)
Prov. 5	1 675 (11 249)	56 (56)	23 (614)
Prov. 6	1 993 (16 810)	5 (5)	24 (727)
Prov. 7	2 041 (16 948)	39 (39)	57 (1 437)

XXX – # of load clusters/projects
(xxx) - # of households

It should also be noted that the solar transitional systems presented in Figure 6.9 correspond to load centres that are intended to be grid connected in the longer term, but where the grid has not yet been extended by the year 2023.

LONG TERM VISION FOR THE DISTRIBUTION SYSTEM

Long Term Grid Electrification

By 2035, the national grid will be extended to reach approximately 99% of all households in Nepal. These households will benefit from at least Tier 4 level of access i.e. 24 hour supply and at least 1 kVA of available capacity to connect several appliances in each house.

Although grid expansion occurs up to 2030 - the year when the **Least Cost Grid** is planned to be fully deployed – grid adoption and demand will continue to grow until 2035 requiring further grid upgrades and improvements.

The power system at the end of this phase is presented in Figure 6.10.

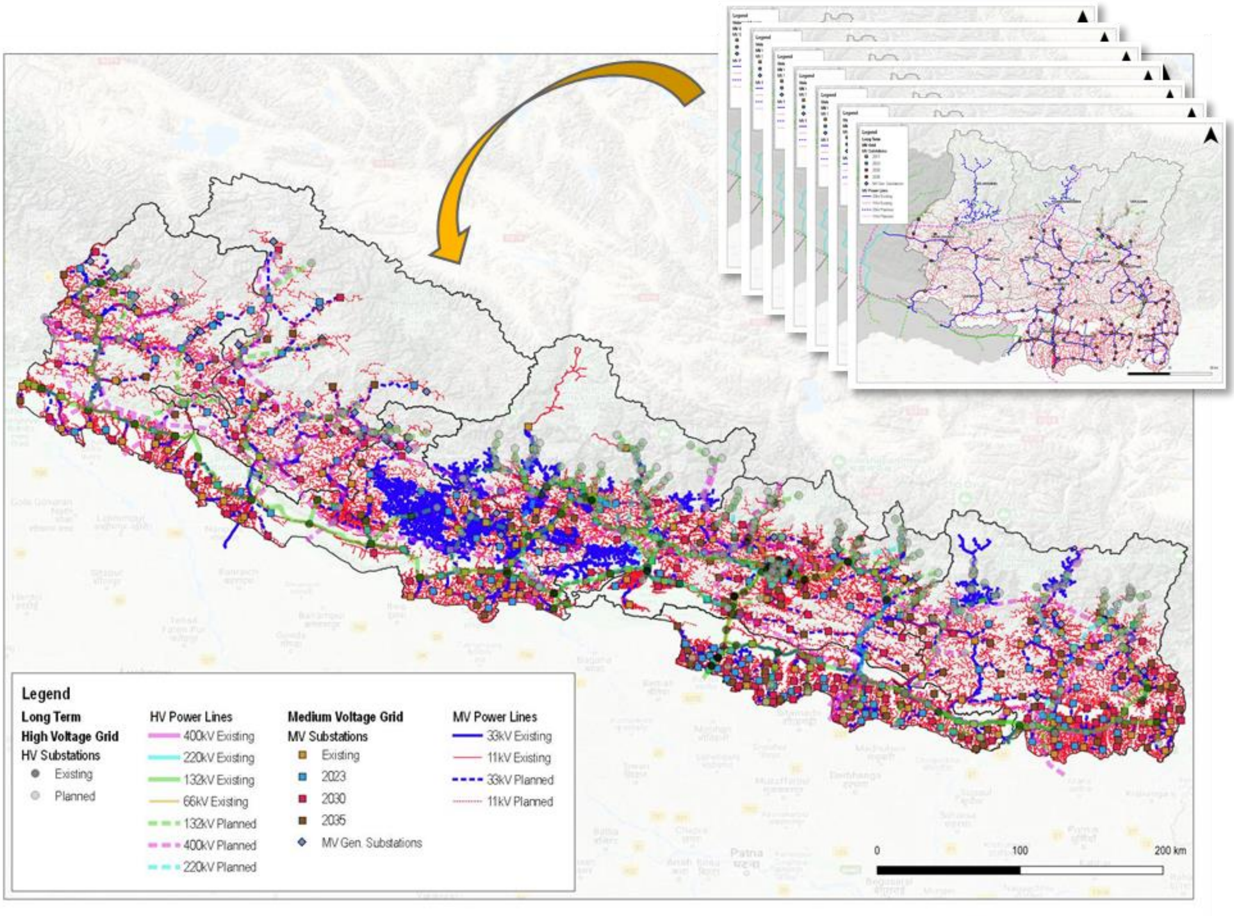


Figure 6.10 – Map of Nepal power system – Least Cost Grid phase (2035).

The grid presented above will enable the further increase of grid access in the country to around 99% of the population, as presented in the following table.

Table 6.4 – Households reached by the grid (%) with Tier 4/5 standards

	2019	2023	2035
Province 1	66%	91%	99%
Province 2	87%	97%	100%
Province 3	83%	95%	99%
Province 4	77%	93%	99%
Province 5	78%	94%	99%
Province 6	31%	80%	96%
Province 7	58%	88%	98%
NEPAL	73%	93%	99%

In total, more than 37 000 km of new MV line will be installed during the entire planning period, as illustrated in the figure below, which disaggregates the additional MV lengths by Province and voltage level, in the Universal Access and Long Term periods.

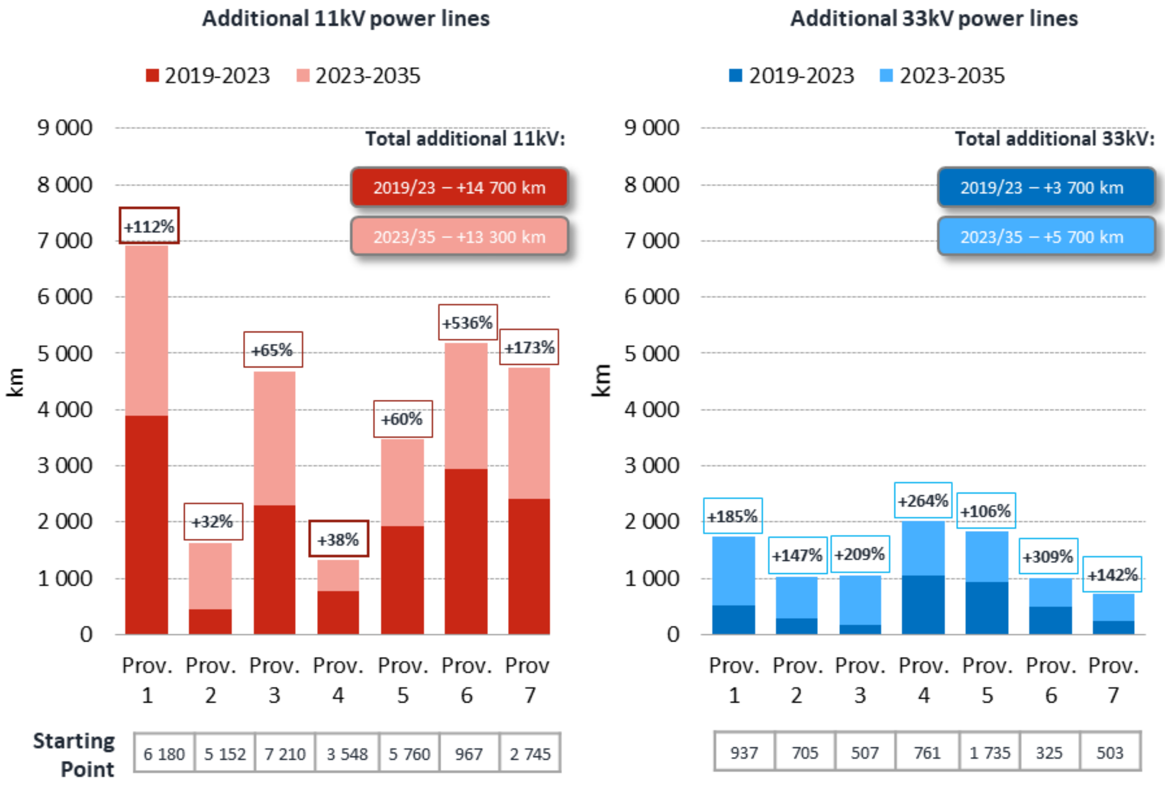
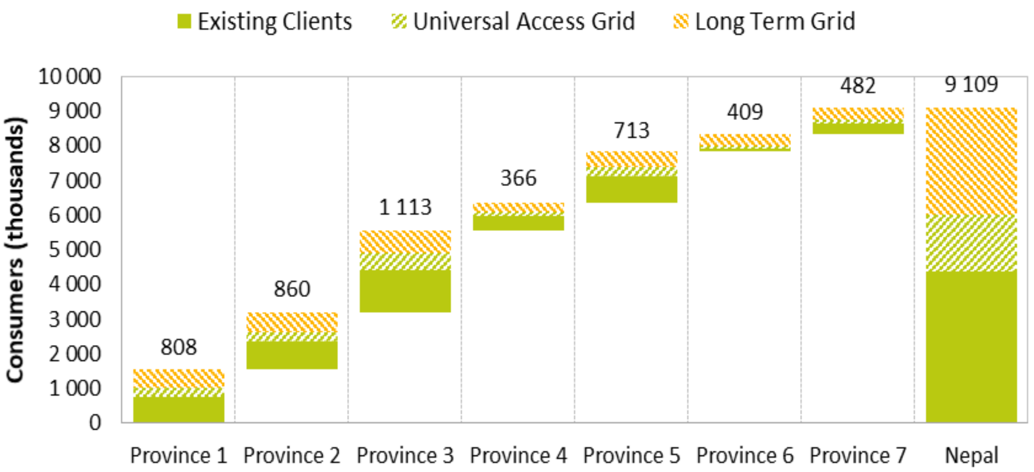


Figure 6.12 – Existing and additional MV line length for the Long Term Period, disaggregated by Province and voltage level.

Province 1 has the highest amount of additional MV line length installed (11kV and 33kV combined) during the whole period, more than doubling the current MV grid length, mostly due to its large occupied area. On the other hand, Province 2, the smallest province of the country by area and the one with the highest current grid access rates, has lowest additional MV extension requirement.

A total of 268 new 33/11kV substations will be installed during the 12 year period since 2023 (~22 substations per year, countrywide). At a provincial level, Provinces 1, 2 and 3 are where more distribution substations need to be installed during this period, with an average of ~5 substations per year in each province. The remaining provinces have an average of ~2-3 new substations installed per year.

By the year 2035, Nepal is estimated to have increased grid access to more than 9 000 000 consumers (households, small commerce and services, big services and industries). Province 3 stands out from the other provinces, representing more than 25% of total potential consumers; Provinces 1, 2 and 5 altogether represent 50% and Province 6 remains with the lowest number of consumers. At a national scale, these numbers represent an average of 297 000 additional potential consumers per year over the 16 year planning period.



	Province 1	Province 2	Province 3	Province 4	Province 5	Province 6	Province 7	Nepal
Average additional consumers per year (thousands)	50	54	70	23	45	26	30	297

Figure 6.18 – Number of consumers connected to the national grid by 2035.

The total grid peak demand, presented in Figure 6.14, is expected to reach 10 275 MVA by 2035, where Province 3 represents almost a third of total demand, while Provinces 6 and 7 have significantly lower demand requirements.

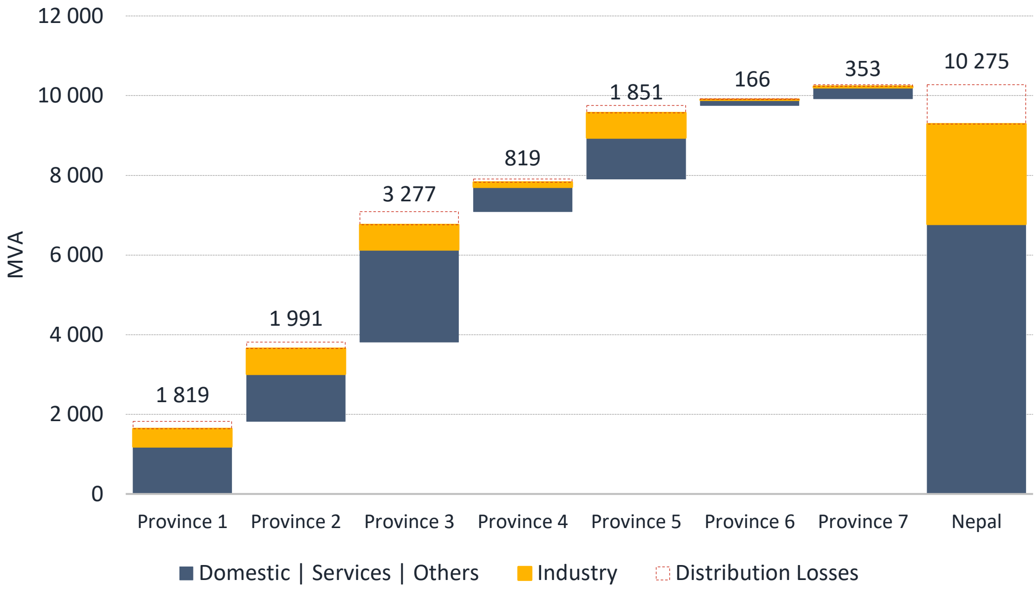


Figure 6.14 – Estimated distribution grid demand by 2035

Long Term Off-Grid Access

Although the results of the "Network Expansion Planner" shows that it is financially viable to connect around 99% of the population to the national grid, the model still recommends that the most viable electrification alternative for around 12 300 load centres (settlements) is a permanent off-grid system, corresponding to 98 000 households. These are mainly in areas with low aggregated population density and low energy consumptions. Seven Municipal Capitals (5 in Province 6 and 2 in Province 4) are proposed to be supplied via a permanent off-grid system based on the least-cost financial analysis.

PART III: INFRASTRUCTURE

DISTRIBUTION AUGMENTATION IN THE METROPOLITAN AREAS

An assessment of the power systems in the Metropolitan and Sub-Metropolitan areas of Nepal was undertaken, and the proposed Distribution Augmentation requirements determined under each one of the seven developed Provincial Distribution System Master Plans.

The objective of the Distribution Augmentation In Metropolitan Areas assessment is to 1) identify existing and potential future capacity constraints on MV feeders and substation transformers in the study areas, 2) identify immediate short-term relief measures for existing overloaded feeders and substation transformers, 3) identify longer term mitigation measures to cater for the load growth over the planning period of 2018 to 2035 and, 4) estimate the investment requirements covering all aspects of the Metropolitan and Sub-Metropolitan electrical networks. The studied Metropolitan and Sub-Metropolitan areas are represented in the following figure and detailed in Table 7.1.

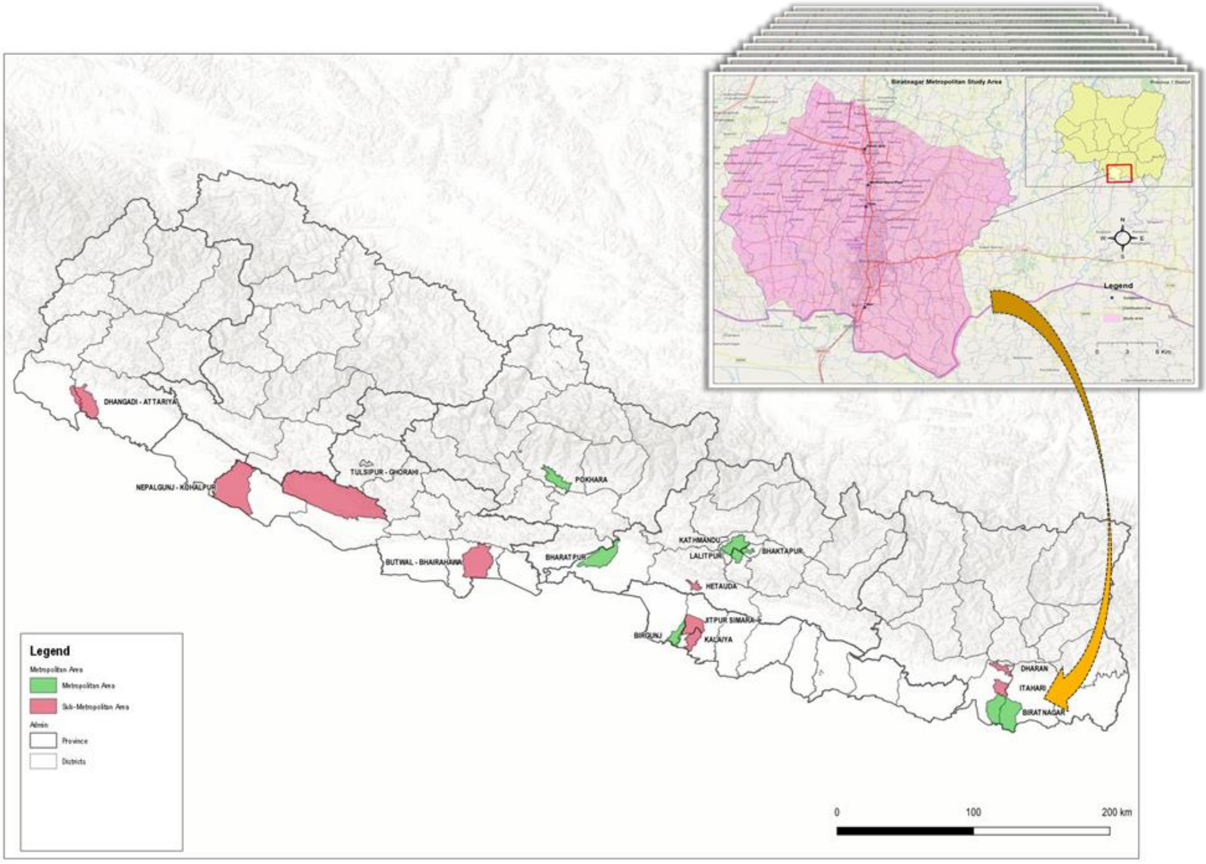


Figure 7.1 – Location of Metropolitan Study Areas

In total, the distribution augmentation assessment was undertaken for seven Metropolitan and nine Sub-Metropolitan areas across all provinces, except for Province 6, which does not have any designated metropolitan/sub metropolitan area.

Table 7.1 – List of the Metropolitan study areas

Province	Study Area	Type
1	Biratnagar	Metropolitan Area
	Dharan	Sub-Metropolitan Area
	Itahari	Sub-Metropolitan Area
2	Birgunj	Metropolitan Area
	Jitpur-Simara	Sub-Metropolitan Area
	Kalaiya	Sub-Metropolitan Area
3	Bhaktapur	Metropolitan Area
	Bharatpur	Metropolitan Area
	Kathmandu	Metropolitan Area
	Lalitpur	Metropolitan Area
	Hetauda	Sub-Metropolitan Area
4	Pokhara	Metropolitan Area
5	Butwal-Bhairahawa	Sub-Metropolitan Area
	Nepalgunj-Kohalpur	Sub-Metropolitan Area
	Tulsipur-Ghorahi	Sub-Metropolitan Area
7	Dhangadi-Attariya	Sub-Metropolitan Area

The analysis of the existing networks and future loads identified the following key issues which are prevalent in each of the metropolitan study areas to a greater or lesser degree:

- Overloaded feeders
- Long feeder length
- Universal access
- Increasing demand
- High system losses
- Poor plant condition and network performance

The Master Plan study examined the distribution networks for each metropolitan study area separately, and proposes mitigation measures to address the above issues. These are presented in more detail in the respective Provincial Master Plans.

In order to address the increase in electricity demand, mitigation measures are proposed for the three planning periods defined under the DS/REMP. These were developed and customized for each of the study areas, depending on their specific requirements. A compilation of the typical mitigation measures used to augment the distribution systems in the (Sub) Metropolitan areas by phase is shown below:

Phase 1: up to 2023

- Redistributing loads between existing feeders
- Conductor upgrades to address immediate feeder overloading issues
- Additional conductor and transformer upgrades to cater for growing load and universal access

Phase 2: from 2024 to 2030

- Redistributing loads between existing and new feeders and substations
- Providing additional HV and MV substation and feeder capacity for growing loads
- Rehabilitation of MV assets to improve performance / Quality of Service

Phase 3: 2031 – 2035

- Optimization of the grid
- Further rehabilitation of the distribution MV and LV assets
- General improvements and reinforcements

For each study area, a set of mitigation measures has been developed, containing the area of influence of the measure, the assets, the description and time schedule of the interventions, amongst other relevant information.

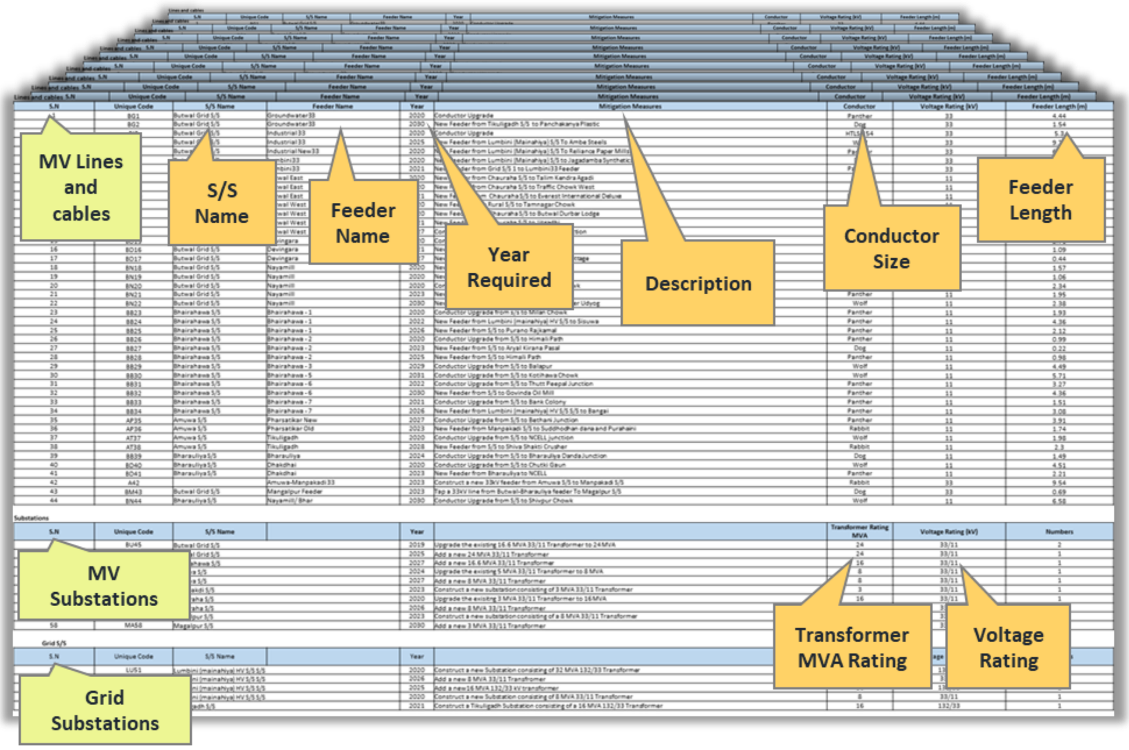


Figure 7.4 – Example of summary table of proposed mitigation measures for each Metropolitan area

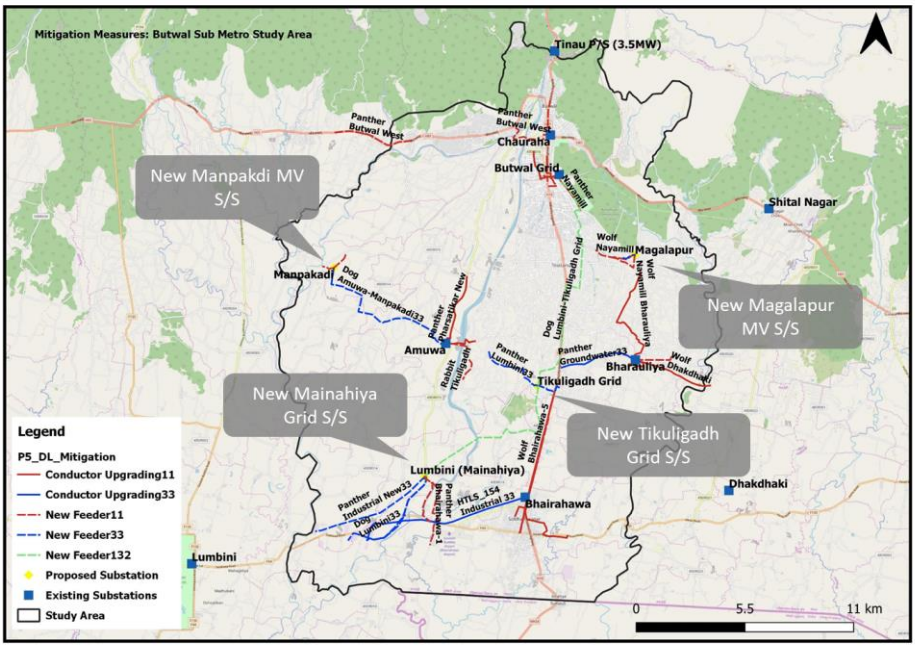


Figure 7.5 – Geographical view of the proposed mitigation measures by substation supply area (e.g. Butwal-Bhairahawa Sub-Metropolitan Area)

There is a need for strong integration between the Distribution Master Plan and the development of the Transmission System, and vice versa. The transmission system serves to interconnect with the generation stations, but also to reinforce and inject power into the distribution system where it is consumed. The implications on the transmission system have also been evaluated when necessary. Furthermore, in order to cope with growing loads, prevent network overload and assure quality of service, already ongoing T&D projects to address key short term issues have been integrated into the DSREMP proposals, and new HV bulk points were recommended when needed.

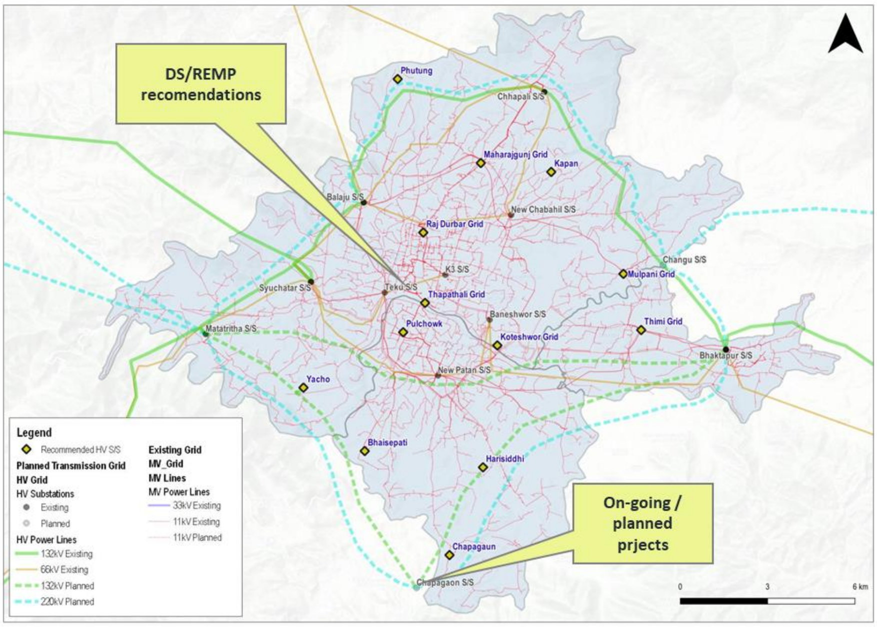


Figure 7.6 – Geographical View of transmission grid requirements (e.g. Kathmandu Valley)

DISTRIBUTION NETWORK DEVELOPMENT OUTSIDE METROPOLITAN AREAS

The diagnosis of the current status of the existing network of each Province is a crucial step for the development of the grid extension planning.

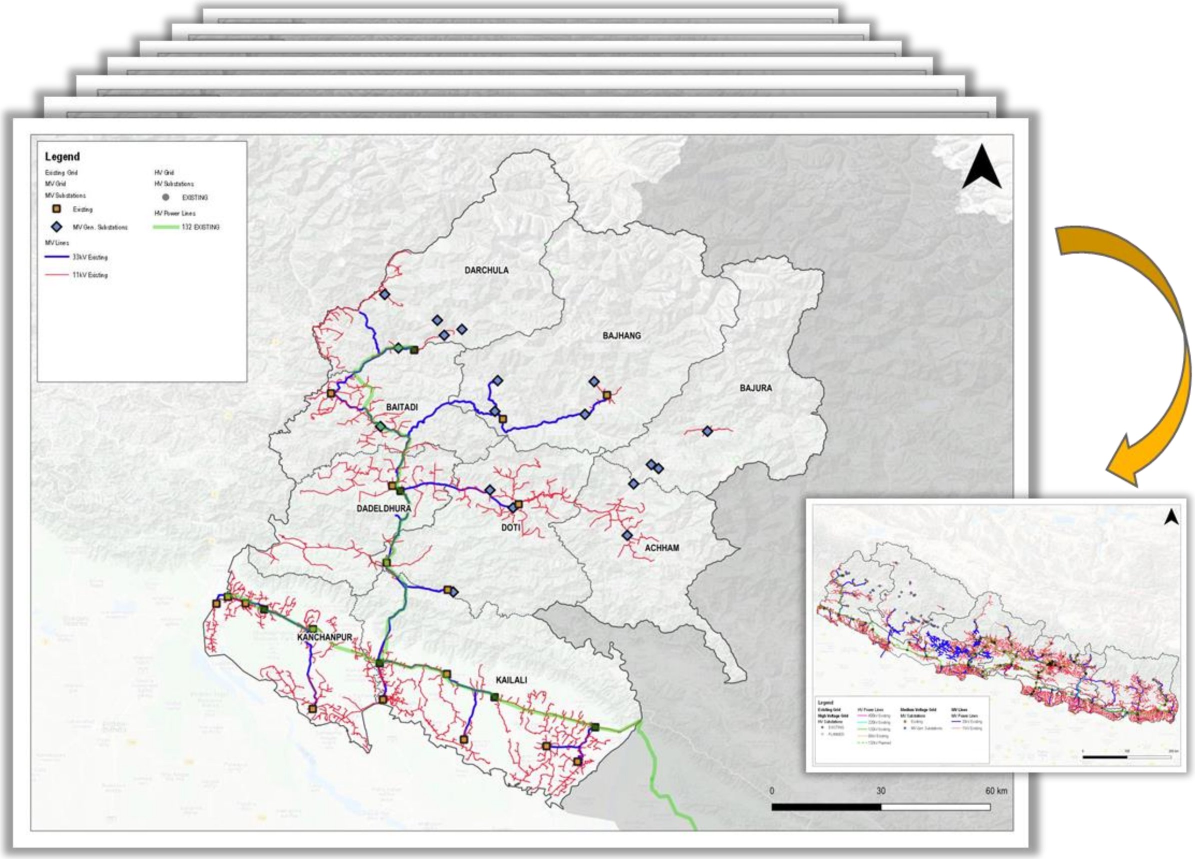


Figure 8.1 – Current power system of Nepal (derived from the Provincial grids)

ISSUES

The analysis of the existing network and future loads identified 3 key issues that need to be addressed:

- Excessive reliance on 11kV voltage level for distribution in rural areas
- Long and overloaded feeders
- Grid extension and densification

As example, the following figure shows the Kalyanpur feeder in Province 2 which is only and exclusively connected to Rupeni substation and extends throughout most of the western region Saptari district, with an aggregate length of around 180 km and a total MV/LV installed capacity of 12 000 kVA.

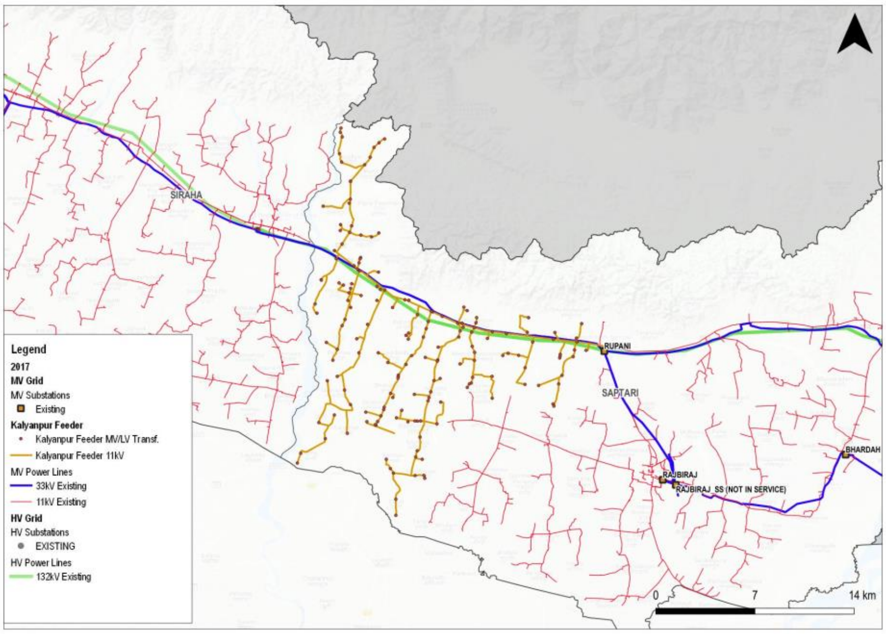


Figure 8.5 – Example of long feeder - Kalyanpur feeder at 11kV

As new consumers are added to the networks, combined with average household consumption increasing, these long feeders will become even more overloaded and problems such as low voltages and increased energy losses will occur.

PROPOSED SOLUTIONS

Phase 1 (up to 2023)

In Phase 1, the Universal Access Phase, existing grid extends to the proposed "High Return Grid", providing access to many new communities previously outside the grids reach, thereby significantly increasing the overall access rate in every Province. Due to the distances to the existing national grid of some of these locations, new MV substations are required in strategic locations to support these additional loads.

The legacy 11kV infrastructure cannot easily be replaced and the most cost-effective solution in already electrified areas is therefore to construct new 33/11kV substations to split / reinforce the existing 11kV feeders to improve the load distribution, voltage profiles and reduce losses. Countrywide, 130 new substations (55 already under construction) are implemented in non-metropolitan areas during this phase and 3 100 km of new 33kV grid are required to be constructed to connect the new substations as well as some load centers.

Next, a compilation of the additional infrastructure by province is presented.

In each Provincial Master Plan, the additional MV substations can be identified in detail, along with the proposed capacities and location.

Table 8.1 – Additional infrastructure in non-metropolitan areas in Phase 1

	Under Construction HV S/S (w/ impact on Distribution system)	Under Construction MV S/S	Additional MV S/S	Additional 33kV km
Province 1	6	13	9 (~2 S/S per year)	280 (~70 km/year)
Province 2	6	7	22 (~5 S/S per year)	165 (~40 km/year)
Province 3	8	8	15 (~3 S/S per year)	150 (~40 km/year)
Province 4	4	2	8 (~2 S/S per year)	970 (~240 km/year)
Province 5	8	13	7 (~1 S/S per year)	850 (~210 km/year)
Province 6	2	4	9 (~2 S/S per year)	490 (~120 km/year)
Province 7	0	8	5 (~1 S/S per year)	226 (~60 km/year)
Nepal	32	55	70 (~17 S/S per year)	3 131 (~780 km/year)

Phase 2 (up to 2030)

By 2030, the Least Cost Grid should be fully deployed i.e. the financially viable MV infrastructure is intended to be fully extended. Additional 33/11kV substations are required to support the existing 11kV networks as demand continues to increase and as the proposed rural grid extends to more remote areas. In some cases, namely in remote green-field areas with long distances to the existing grid, 33kV is proposed to feed the low voltage distribution system directly.

A total of 160 new 33/11kV substations are proposed to be installed in the non-metropolitan areas of the country, and 3 800 km of new 33kV grid are to be constructed.

The following table provides a compilation of the additional infrastructure in each province.

Table 8.2 – Additional infrastructure in non-metropolitan areas in Phase 2

	Additional HV S/S (w/ impact on Distribution system)	Additional MV S/S	Additional 33kV km
Province 1	2	27 (~3 S/S per year)	780 (~110 km/year)
Province 2	4	36 (~5 S/S per year)	385 (~55 km/year)
Province 3	2	36 (~5 S/S per year)	515 (~75 km/year)
Province 4	0	22 (~3 S/S per year)	840 (~120 km/year)
Province 5	2	16 (~2 S/S per year)	620 (~90 km/year)
Province 6	2	13 (~1 S/S per year)	360 (~50 km/year)
Province 7	2	10 (~1 S/S per year)	340 (~50 km/year)
Nepal	14	160 (~22 S/S per year)	3 840 (~550 km/year)

In each Provincial Master Plan, the additional MV substations can be identified in detail, along with the proposed capacities and location.

Phase 3 (up to 2035)

The final 5 year phase of this master planning study focuses on "Optimising Access" i.e. ensuring the best (least cost) supply option, with adequate quality of supply, is provided to all households in Nepal. Since the Least Cost Grid is already implemented, only minor extensions will be required to connect new financially viable households as a result of population growth. The balance of households still utilising "transitional" SHS's will be connected to the grid.

During this period, a total of 107 new 33/11kV substations are required to be commissioned throughout the country and approximately 1 900 km of 33kV power lines are to be constructed.

The following table provides a compilation of the additional infrastructure in each province.

Table 8.3 – Additional infrastructure in non-metropolitan areas in Phase 3

	Additional HV S/S (w/ impact on Distribution system)	Additional MV S/S	Additional 33kV km
Province 1	2	28 (~5 S/S per year)	425 (~85 km/year)
Province 2	0	22 (~4 S/S per year)	360 (~70 km/year)
Province 3	2	25 (~5 S/S per year)	360 (~70 km/year)
Province 4	0	3 (~0 S/S per year)	130 (~25 km/year)
Province 5	0	12 (~2 S/S per year)	295 (~60 km/year)
Province 6	0	8 (~1 S/S per year)	175 (~35 km/year)
Province 7	0	9 (~1 S/S per year)	145 (~30 km/year)
Nepal	4	107 (~21 S/S per year)	1 890 (~380 km/year)

In each Provincial Master Plan, the additional MV substations can be identified in detail, along with the proposed capacities and location.

In summary, the development of the 33kV distribution network is illustrated in the images below.

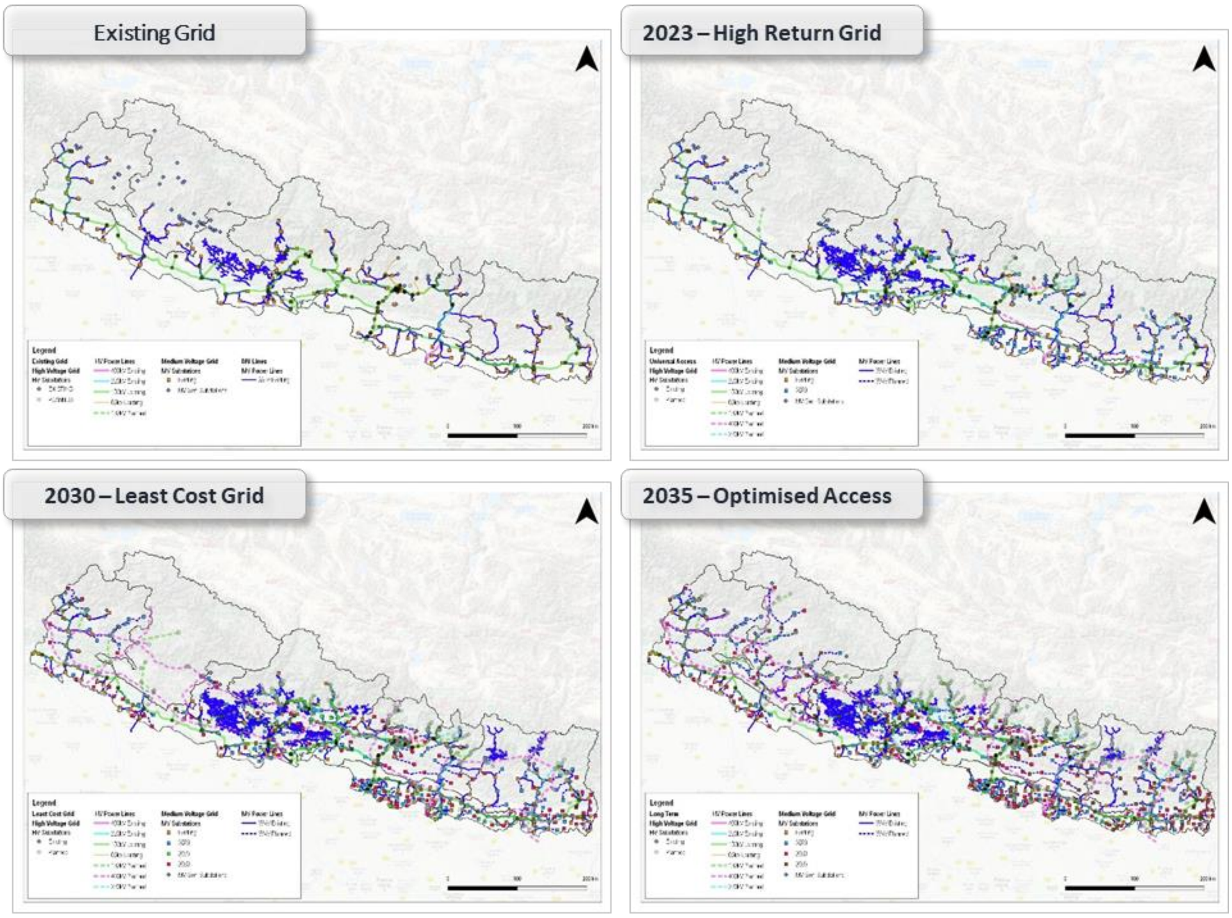


Figure 9.2 – Evolution of Nepal's power system and off-grid systems over the planning period

PART IV: IMPLEMENTATION

INVESTMENT PLAN

Program Structure

The investment requirements determined under the Distribution System / Rural Expansion Master Plan study, separately for each one of the seven Province of Nepal, have been organized into 5 main programs (categories) and further disaggregated into 22 sub-programs (sub-categories) as shown in Figure 9.1.

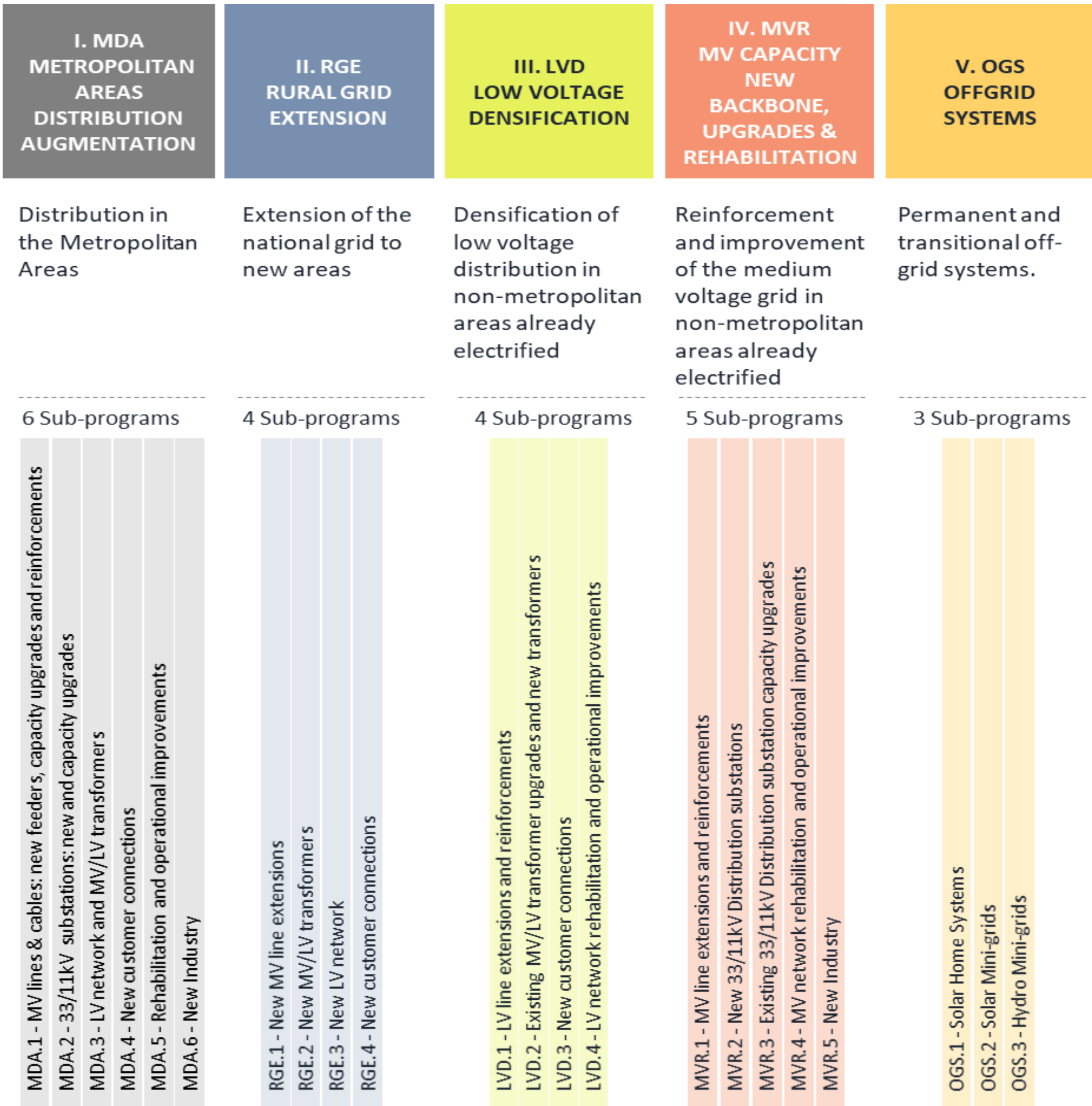


Figure 9.1 – Investment Plan structure – Program and Sub-Program Categories

The investment requirements cover the aspects necessary for a strategic plan of this nature, including:

- MV lines & cables: new feeders, capacity upgrades and reinforcements
- 33/11kV distribution substations: new and capacity upgrades

- LV networks and MV/LV transformers: new and capacity upgrades
- New customer connections: meters and service connections
- Rehabilitation and operational improvements
- New Industry: extensions, reinforcements and upgrades

Investment Plan Summary

Universal Access Phase – 2020 to 2023

Public Sector investments in Phase 1 are around 987 MUSD representing 70% of total required funds. Disaggregating these public investments, one can see that to achieve the Universal Access target, the **total NEA/CRED funding requirement for the expansion of the grid amounts to 690 MUSD (173 MUSD/year)**, while **AEPC total funding requirement for permanent Off-Grid systems is 103 MUSD (26 MUSD/year).** The remaining Public Sector investment requirements (194 MSUD) are related to the rehabilitation and operational improvement of the distribution grid.

Private Sector funds, related to the connection of new consumers, acquisition of solar transitional systems and the connection of additional industrial loads, constitute 30% of total investment requirements, which amounts to 412 MUSD.

Rural Grid Extension, which combines MV and LV development in unelectrified areas, requires a total investment of 350 MUSD, representing an annual average budget of 87.4 MUSD countrywide.

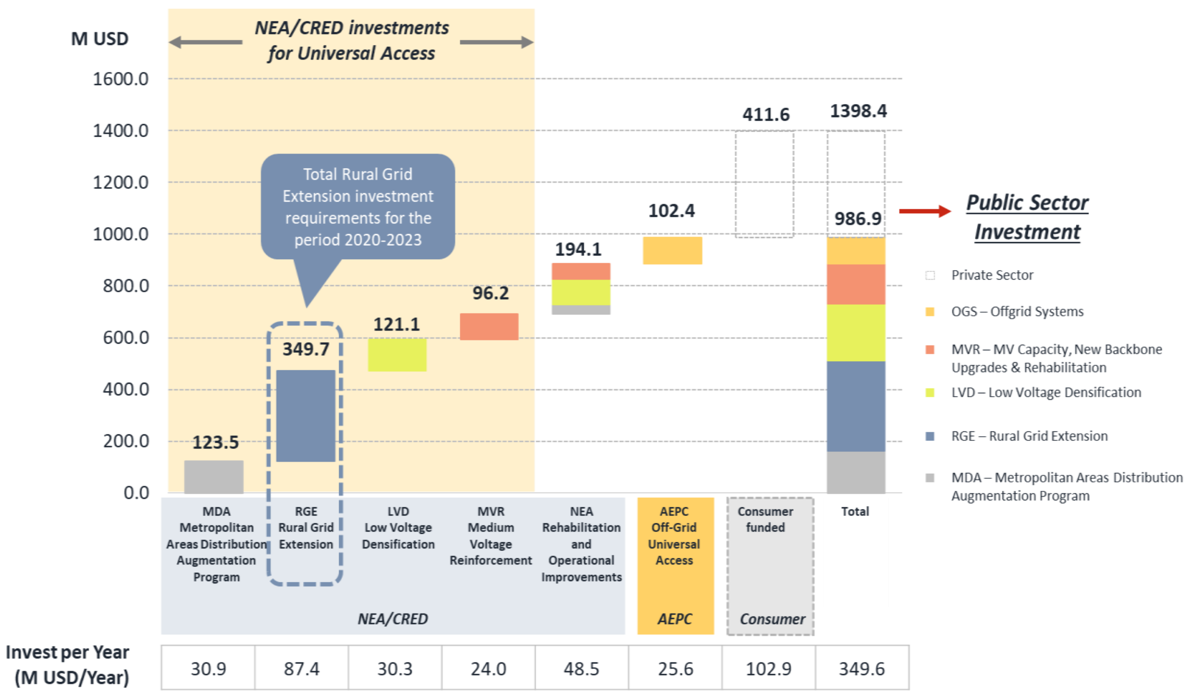


Figure 9.3 – Investment Plan in 2020-2023 period for all Provinces, separating Public and Private Sector funding

Further disaggregation of the investments by Province is presented below.

Figure 9.4 – Investment Plan in 2020-2023 period by Province, separating Public and Private Sector funding

Province 3 has the highest investment requirements of 75 MUSD per annum, mainly due to the Metropolitan Areas Distribution Augmentation and Low Voltage Densification programs. Nonetheless, the RGE program also presents significant requirements in this province.

Province 1 requires 70 MUSD on average every year during this phase, where the highest portion of the investments go to the Rural Grid Extension program. Observing the above numbers, one can see that the Rural Grid Extension category is the most demanding requirement in all provinces but Provinces 2, while Provinces 2, 3 and 5, the most urbanized ones, have a bigger LV densification component.

<u>*Complete planning period – 2020 to 2035*</u>

Regarding the whole period, Figure 9.5 presents the estimated annual investment requirements per phase and project category, segregating what is expected to be Public Sector budget and what is considered to be funded by the Private Sector.

Phase 1 – *Universal Access Phase* – is the most financially demanding period. The Rural Grid Extension program requires annual investments of around 87 MUSD/year. However, during this phase, Private Sector funding is the highest, due to (i) installation of transitional off-grid systems in areas without grid access and (ii) the connection of many new consumers, for which the consumer pays the service connection and meter.

In Phase 2, annual investment requirements are somewhat reduced since rural grid extension is less intensive and because the installation of new transitional systems is no longer required. On the other hand, during this period LV densification is increased, since more locations are now within the reach of the national grid.

In Phase 3, the annual investment requirements continue to decrease compared with the previous periods. Since rural grid extension is complete, no investment is required for this program.

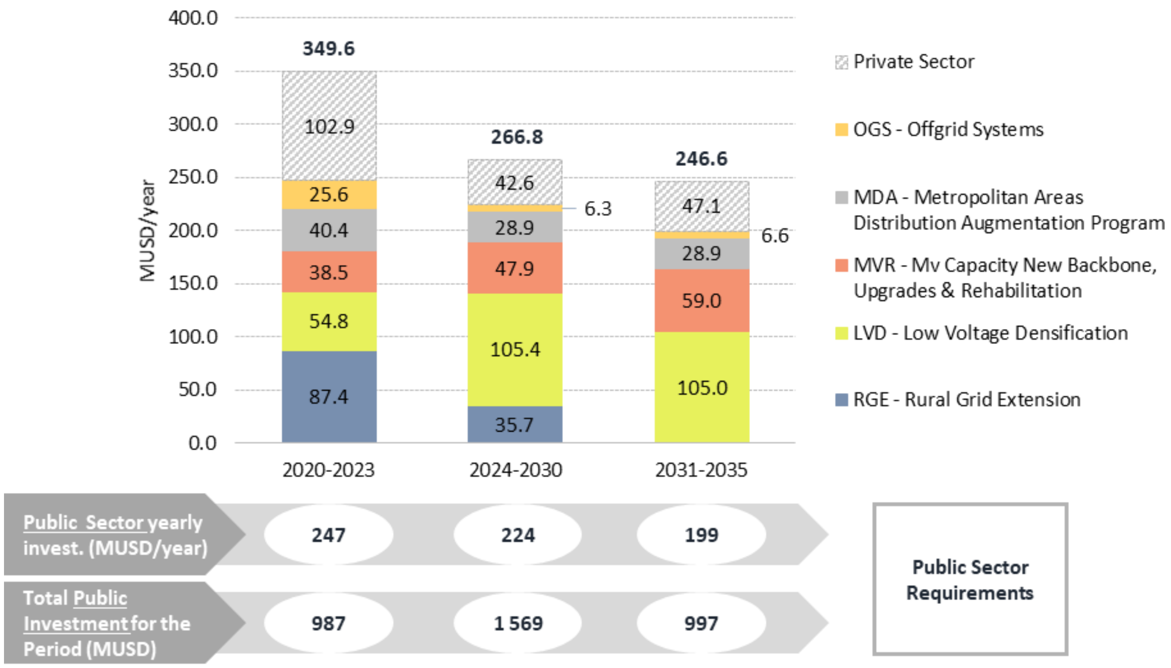


Figure 9.5 – Total Public and Private Sector annual investment requirements per Phase and Project

Analysing the Public Sector requirements alone, one can observe that the early investments consistently decrease over time, from 247 MUSD/year (from 2020-2023 period) to 224 MUSD/year (from 2024-2030 period) to 199 MUSD/year (from 2031-2035 period).

New connections and the extension/upgrading of the LV networks is a significant component of the investment requirements. Additional potential NEA/CRED consumer connections per year is presented the figure below.

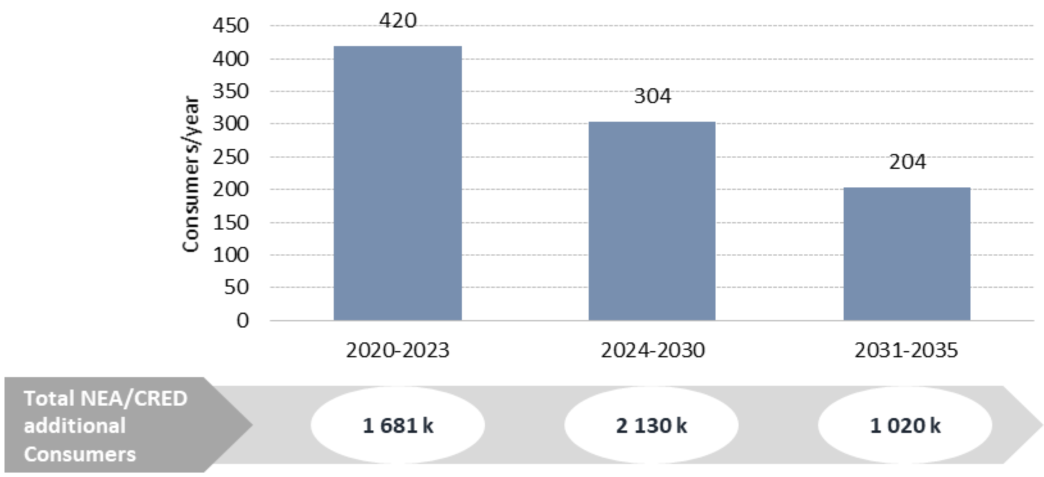


Figure 9.6 – Additional consumers per year and per phase

ECONOMIC ANALYSIS AND FINANCIAL IMPLICATIONS

Significant funding is required to be sourced from Government of Nepal and multilateral lenders and therefore the current section analyses the financial and economic implications of the Master Plan, in particular in what concerns key requirements of lenders such as ADB:

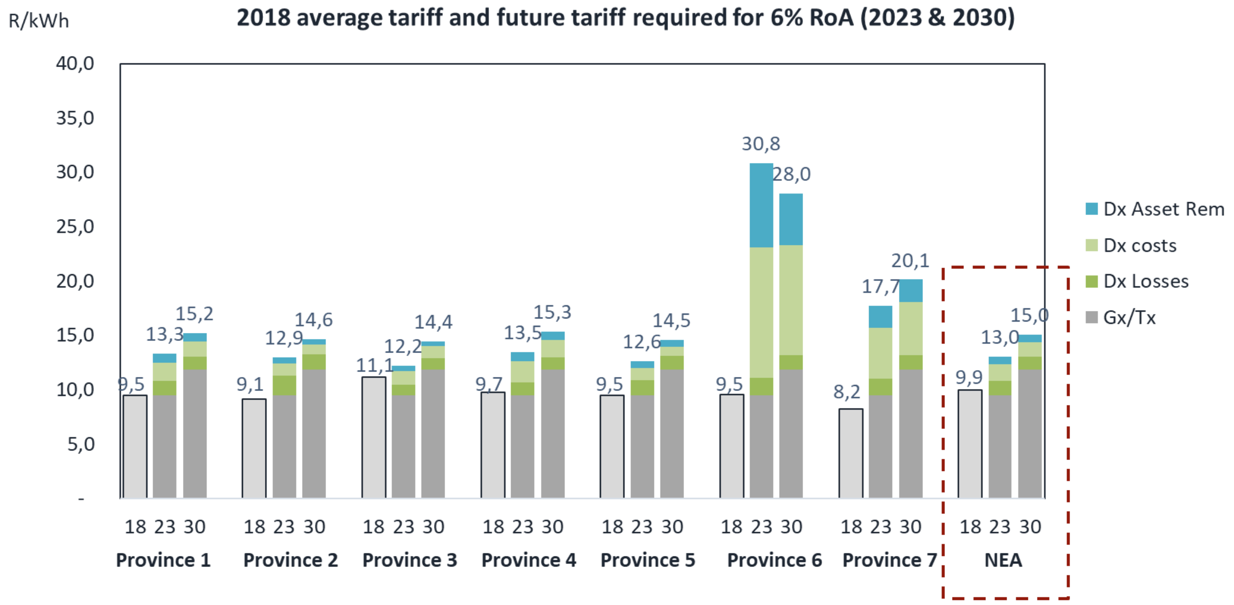
- Alternative analysis: tries to ensure that the proposed project represents the most efficient option among available feasible alternatives for addressing the objective. The Master Plan planning methodology ensures that the selected investments correspond to the least cost option to achieve universal and optimized access in Nepal within the defined timeframe. Alternative analysis is embedded in the network planner methodology and is not addressed in this section.
- Sustainability analysis: addresses not only the ability of the project to generate sufficient incremental cash flows to cover its financial costs ("financial evaluation of the project"), but also if the key implementing entity (NEA DCS or Regional DCS units) is financially robust enough to undertake the project and operate and maintain the project assets ("financial analysis of the project-executing entity"). The section will analyse the key financial and tariff setting implications of the proposed investment plan.
- Cost-Benefit analysis: funding allocation needs to take into consideration the opportunity cost of not investing in other sectors or projects also relevant for the country. For example, ADB uses a discount rate of 9% as the minimum required Economic Internal Rate of Return (eIRR) to accept or reject a project.

The analysis in this chapter will focus on MDA, RGE, MVD and MVR programs - which represent more than 90% of the public investment - where historical financial data on revenues and costs are available from NEA's accounting data.

Sustainability Analysis

Sustainability analysis was performed per Province as if each had an autonomous "Distribution Company" – corresponding to the aggregation of all Distribution Centers operating within that province. The Provincial Master Plans include the detailed calculations for each of the respective provinces.

The following graph shows a summary of the results regarding future required average tariff in each Province to cover estimated Generation, Transmission and Distribution costs, including adequate remuneration on proposed investments under the Master Plan (considering 6% return on assets required by lenders):



	Province 1	Province 2	Province 3	Province 4	Province 5	Province 6	Province 7	NEA
Yearly % Δ 23/18	7,0%	7,2%	1,8%	6,8%	5,9%	26,4%	16,6%	5,6%
Yearly % Δ 30/18	4,0%	4,0%	2,2%	3,9%	3,6%	9,4%	7,7%	3,5%

Figure 9.6 – Tariff requirements for 6% RoA per Province

The tariff analysis shows that it is not advisable to differentiate tariffs across Provinces and that, if unbundling or tariff setting per Province occurs, adequate cross-subsidization mechanisms need to be implemented. Another key conclusion of the analysis is that the proposed investment plan although substantial can be funded and implemented with annual tariff increases until 2023 in line with inflation and lower thereafter. In summary, the proposed investment plan can be implemented in a sustainable way.

Cost Benefit Analysis

An economic Cost-Benefit Analysis according to ADB guidelines was performed for the investment plan of each province considering a 50-year time horizon.

To identify project benefits and costs the estimates per province were compared with a scenario without the project i.e. where existing sales and some growth was considered viable with existing infrastructure.

The following figure summarizes the economic internal rate of return calculated for each Province:

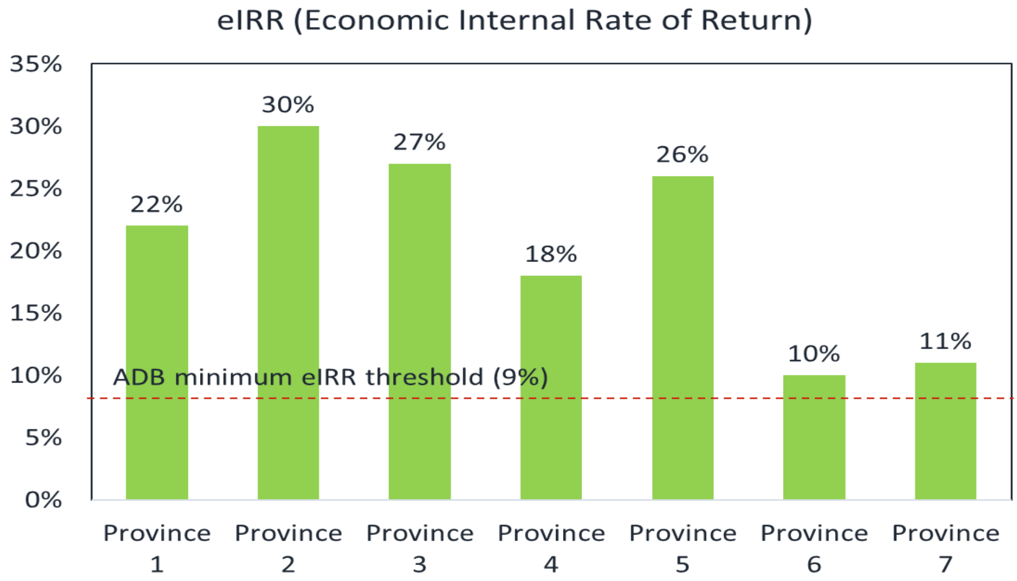


Figure 0.1 – Economic internal rate of return of the Master Plan investments per Province

All Provincial investment plans yield an economic internal rate of return above ADB's minimum 9% threshold, thus demonstrating that the proposed investment plans are economically justifiable from Nepal's perspective.

RECOMMENDATIONS FOR IMPLEMENTATION

The challenge of achieving universal access by 2023 requires a clear strategy for implementation of the Distribution Master Plan. The present chapter outlines several key aspects for a successful implementation.

Responsibilities

The investments for the Distribution Master Plan are organized under 5 main implementation programs based on the category of projects. While it will be essential to have a global coordinator for the overall program, it is also important that the different programs are each coordinated by an appropriate entity, with clear tasks and responsibilities. Each coordinator should develop a detailed implementation plan for their program in coordination with the global coordinator and the other program coordinators.

I. MDA METROPOLITAN AREAS DISTRIBUTION AUGMENTATION	**II. RGE RURAL GRID EXTENSION**	**III. LVD LOW VOLTAGE DENSIFICATION**	**IV. MVR MV CAPACITY NEW BACKBONE, UPGRADES & REHABILITATION**	**V. OGS OFFGRID SYSTEMS**

Overall Program Management

Overall program management should be assigned to a unit established under the Project Management Directorate, which is responsible for target setting, standardisation of designs and materials and ensuring that funds are efficiently disbursed for the implementation of the various programs.

Program I. MDA (Metropolitan Areas Distribution Augmentation)

Significant growth and the need for grid reinforcement is expected under the Metropolitan Distribution Augmentation program. Implementation of the MDA program should be done directly by the respective NEA Regional Office.

Program II. RGE (Rural Grid Extension)

Rural Grid Extension is about launching new projects to electrify new areas. In order to guarantee good coordination with the existing Community Rural Electrification program the Community Rural Electrification Department (CRED) should be the Coordinator of the RGE Program.

Program III. LVD (Low Voltage Densification)

Low Voltage Densification should be one of the key focus of the NEA Distribution Centers across Nepal. Each DC should be responsible for its local LVD program together with support at Regional Office level to coordinate and structure all the Low Voltage Densification programs.

Program IV. MVR (MV Capacity new backbone upgrades & rehabilitation)

This program is focused on the development of Medium Voltage backbone infrastructure and its reinforcement. Each NEA Regional Office has a 33 kV Line and Substation Section which should be responsible for the MVR program.

Program V. OGS (Off Grid Systems)

Off-Grid Systems should remain a priority of AEPC, which should be the responsible coordinator of the OGS Program.

The proposed Implementation Structure and Responsibilities are illustrated in Figure 11.2 below.

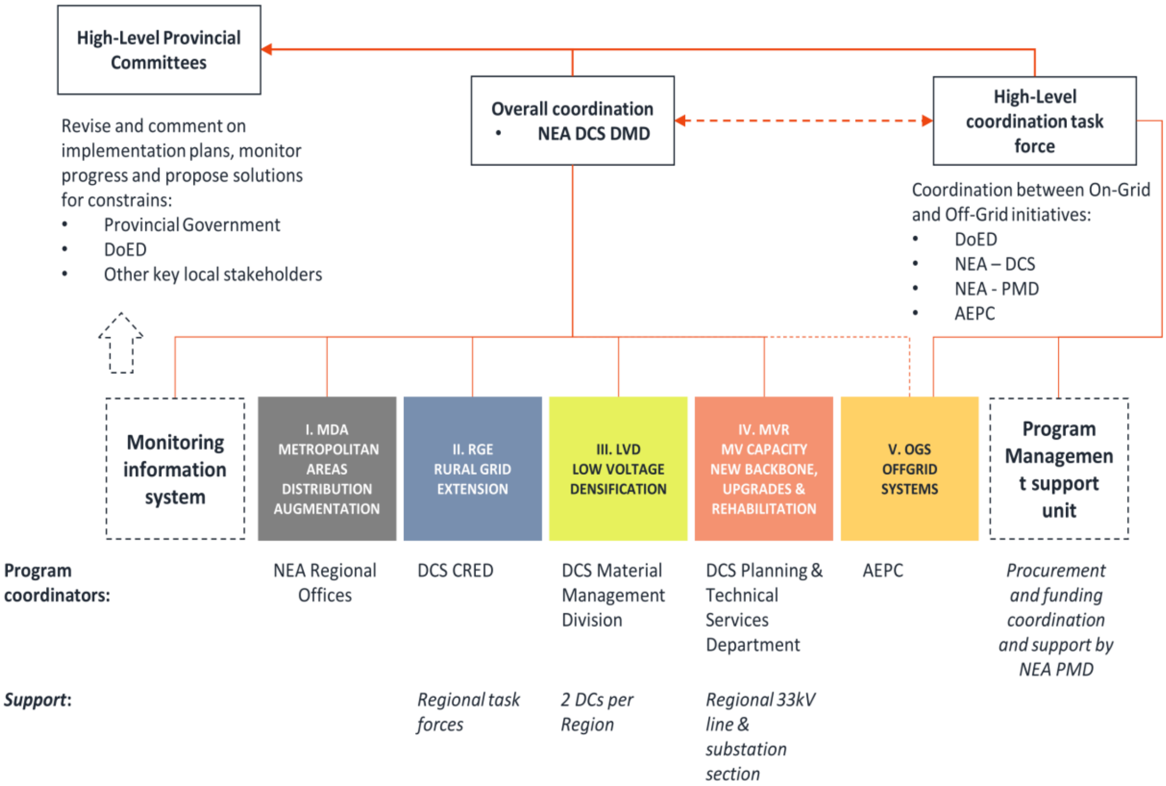


Figure 11.2 – Proposed Implementation Structure and Responsibilities

Implementation Strategy

The Distribution Master Plan implementation strategy should be differentiated according to the type of investment. New distribution substations or the electrification of new areas should be structured as integrated projects with joint procurement of equipment and works. Reinforcements or densification initiatives should be based on a differentiated procurement of equipment and works:

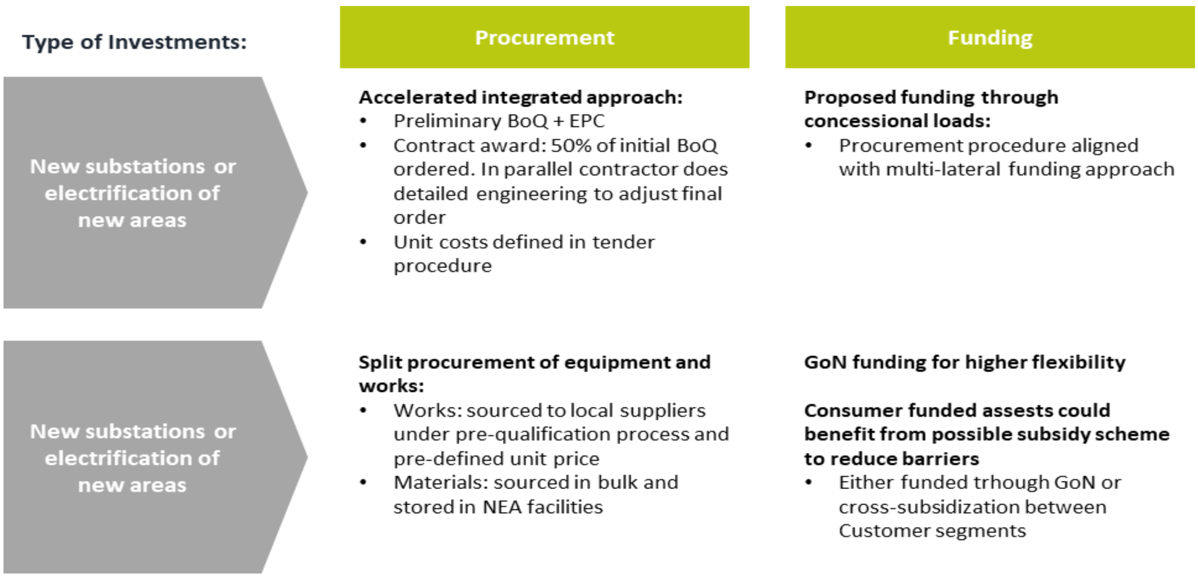


Figure 11.3 – Proposed Implementation Strategy

Miraflores Office Center

Avenida das Túlipas, n.º 6, Piso 5

1495-158 Algés

Portugal

T. +351 211 579 899

F. +351 211 540 900

Kamal Pokhari, Lalupate Marg - 1

Kathmandu

G.P.O. Box: 888

Nepal

T. +977 01 443 1367