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Assessment of Generation Planning Process and Tools in Nepal

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Contents

Performance of the Power Generation Sector

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Evolution of Power Generation in Nepal

1911

Nepal's 1st HPP
Chandrajyoti or Pharping HEP
Estd. May 1911
Location: Kathmandu
Capacity: 500 kW

1934

2nd HPP
Sundarijal
Estd.: 1934
Location: Kathmandu
Capacity: 640 kW

1942

3rd HPP
Chisang Khola
Estd.: 1942
Location: Morang
Capacity: 1600 kW

1956

1st plan period
First five-year (1956-1961) development plan implemented by National Planning Commission (NPC).
Total installed capacity 6.28 MW

1975

5th plan period
Fifth five-year plan (1975-1980) - Water and Energy Commission established in 1975

1990

Interim period
Between 7th and 8th plan period (1990-1992)
Restoration of democracy
Formulation of Hydropower Development Policy 1992 and Electricity Act 1992.

1992

8th plan period
Encouraged private sector participation in hydro power.
Department of Electricity Development established in 1993

1997

9th plan period
A successful period in history of hydropower development.
Significant private sector participation witnessed.
Major achievement: Kaligandaki A (144 MW)

2017

Regulatory Commission
Formulation of Electricity Regulatory Commission Act 2017

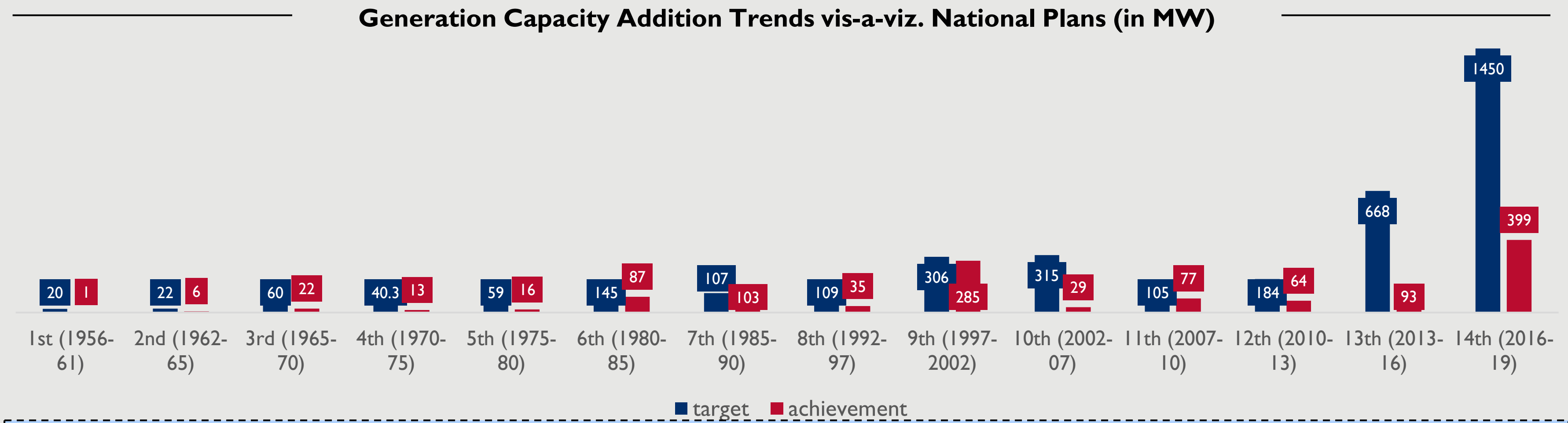
2019

15th plan period
15th five-year plan (2019-24) -High ambitious target to add 4570 MW.
NEA's Corporate Development Plan (CDP) implementation period

2021

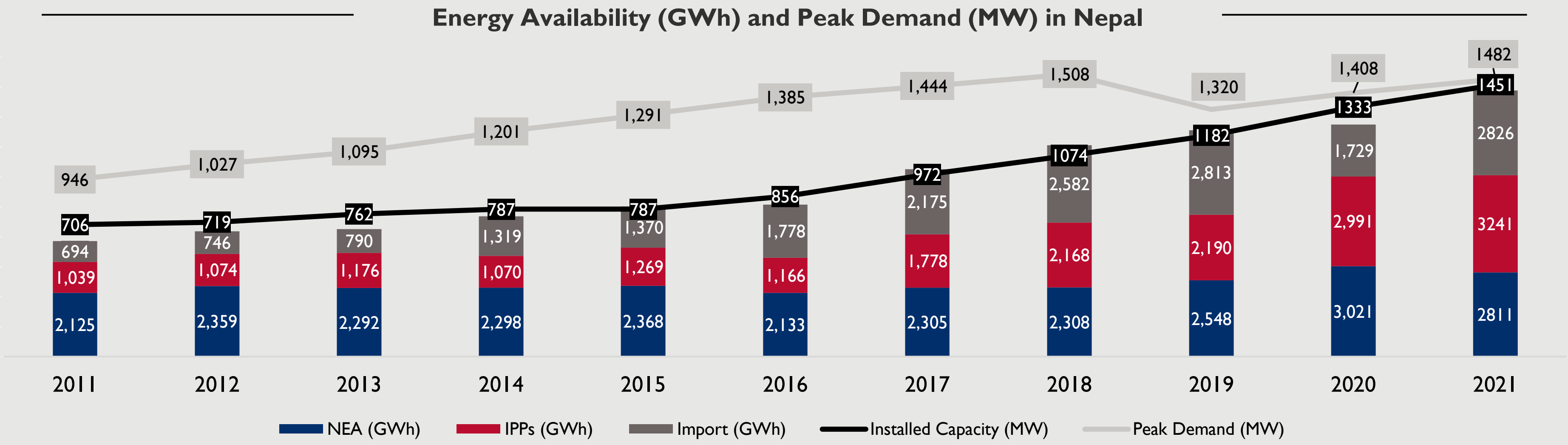
Today
Total installed capacity as of FY 2020/21 is 1450 MW.
Total hydro (NEA): 582 MW
Total hydro (IPP): 815 MW
Total thermal: 53 MW

Performance of the Power Generation Sector viz-a-viz. National Plan Targets



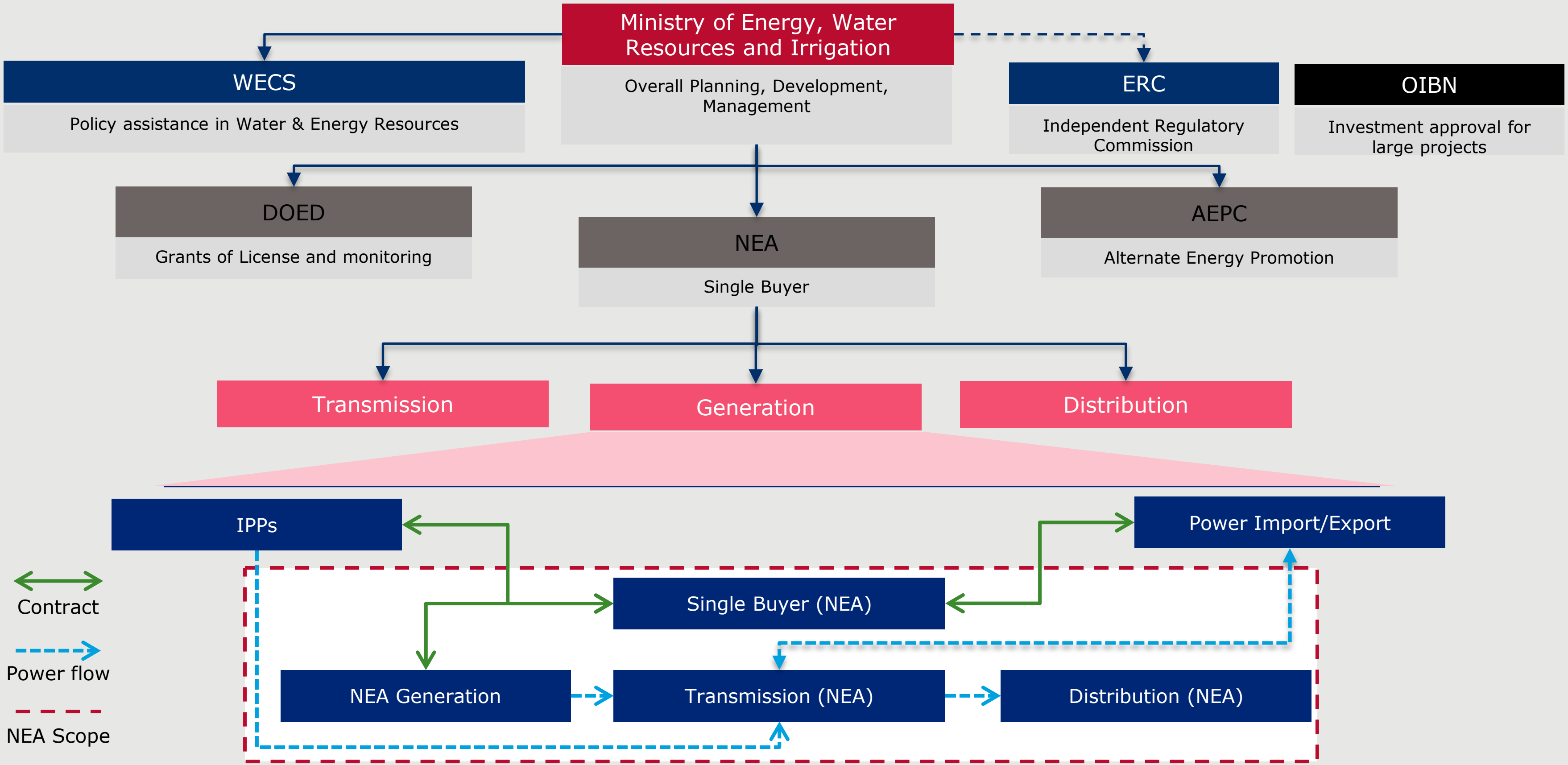
- The major factors influencing the slow progress of the installed capacity addition include: ***a lack of***
    - ***Enabling policies and frameworks***
    - ***Investment***
    - ***Supportive policies and implementation of announced measures***
    - ***Coordination between the issuance of licenses and the signing of off-take agreements***
    - ***Foreign currency PPAs and hedging mechanisms etc.***
- Political instability and 10 year long internal conflict, long transition to a federal structure have also contributed towards slow pace of development
- However, recent institutional stability has led to important policy and regulatory reforms. The future looks promising

Performance of the Power Generation Sector Since 2011



- Nepal's installed capacity of Nepal has grown from 694 MW in 2011 to 1451 MW in 2021 which amounts to a Compounded Annual Growth Rate (CAGR) of 7%
- During the same period, peak demand has increased from ~946 MW to ~1482 MW, registering an annual growth 5%. The highest peak demand during the last decade was 1508 MW in 2018
- NEA's share of total energy availability has reduced significantly due to greatly increased generation by IPPs and imports. NEA's share in total energy availability was 55% in 2011, which has dropped to 32% in 2021. In the same period, the share of IPPs have gone up from 27% to 37%

Stakeholder Map of Nepal's Generation Sector



Roles and Responsibilities of Multiple Stakeholders

Ministry of Energy, Water Resources and Irrigation
Overall vision, and policy direction; Provides the key targets for the sector and initiates key national level studies including Master Plan preparation

Nepal Electricity Authority
Vertically integrated utility which manages G-T-D planning and operations

Electricity Regulatory Commission
Independent regulator for G-T-D and power trade

Department of Electricity Development
Develops and promotes electricity sector polices/regulations and undertakes the delegated function of licensing for G-T-D projects

Vidhyut Utpadan Company Limited
Develop projects with various investors in public-private partnership to build, own and operate large scale hydropower projects

Office of the Investment Board
Central fast track agency for the promotion of infrastructure investments

Alternative Energy Promotion Centre
Promotes the integration of alternate/renewable energy in Nepal

Water and Energy Commission Secretariat (WECS)
Assists GoN to develop Water Resources strategy and formulates policies and planning for projects in the water and energy resources sector

The Legislative Framework for the Generation Sector

Nepal Electricity Authority Act 1984	Electricity Act 1992 and Electricity Rules 1993	Electricity Regulatory Commission Act 2017	Public Private Partnership and Investment Act 2019
Governs NEA's management of power supply	Governs the development and management of Nepal's hydropower sector, including the standardization and safeguarding of electricity service. Established the existing licensing regime	Established independent regulatory body, ERC, for the effective management of generation, transmission, distribution and trade of electricity	Governs projects with capacity greater than 200 MW / hydropower projects having investment cost of more than six billion Nepalese Rupees

- Licenses for the survey and generation of electricity are obtained pursuant to section 3 of the Electricity Act 1992
- One may also generate, transmit or distribute electricity upon the conclusion of an agreement with the Government of Nepal under section 35 of Electricity Act
- A company can acquire project through the competitive bidding process.

Governing Authority

DOED: Acting on behalf on MoEWRI; authorized to grant, renew, amend, and revoke HPP licenses of HPPs

OIBN: Investment approval required for hydro projects having capacity >200 MW or investment cost of more than NR 6 Bn. Investments for projects >500 MW

ERC: Regulation of the sector, including setting prices (tariffs)

GoN Targets for the Generation Sector

Revised INDC Targets, 2020

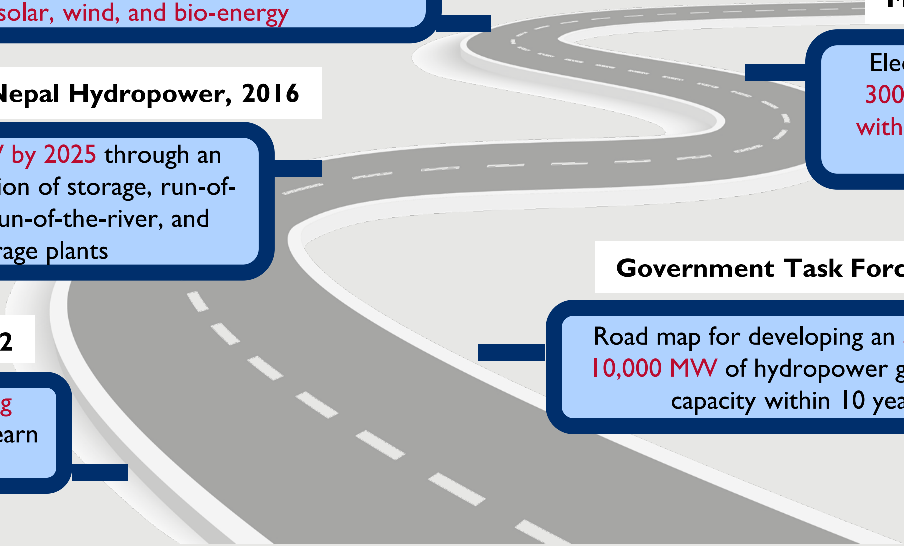
By 2030, expand clean energy generation from ~1,400 MW to 15,000 MW, of which 5-10 % will be generated from mini and micro-hydro power, solar, wind, and bio-energy

MoEWRI Whitepaper, 2018

Electricity projects with capacity of 3000 MW within 3 years, 5000 MW within 5 years, and 15000 MW within 10 years will be constructed

People Investment in Nepal Hydropower, 2016

Develop 10,000 MW by 2025 through an appropriate combination of storage, run-of-the-river, peaking run-of-the-river, and pump storage plants



Government Task Force 2008

Road map for developing an additional 10,000 MW of hydropower generation capacity within 10 years

Water Resources Strategy 2002

By 2027, Nepal should be exporting substantial amounts of electricity to earn national revenue

Over the years, the targets for the installed capacity addition in Nepal have continued to rise. In order to achieve the latest—extremely aggressive targets, extraordinary measures will be required, and planning will need to be near perfect.

Summary of Generation Sector Performance

- Until 1992, the electricity market of Nepal was fully bundled, with NEA being the single buyer and having the power to control the market. With the passage of the Electricity Act 1992, the generation segment was opened to the private sector, and Independent Power Producers (IPPs) rushed in to develop the new market

- IPPs have significantly increased their share in the public/private mix. To date, IPP's have increased their share of the generation mix by more than 37% as on date. Their share in the installed capacity mix is much higher, approaching nearly 70 percent

- Even with this improvement, the progress of the sector when compared to planned targets and potential has been dismal. The major factors for the slow progress of the installed capacity addition include: ***lack of enabling policies and frameworks, investment, supportive policies and implementation of announced measures, coordination gaps between licensing and off-take agreements, foreign currency PPAs and hedging mechanisms etc.***

- The Government has set ambitious targets for the sector. Achieving 15000 MW by 2030 looks uphill — but not impossible. Enabling processes, integrated plans, forwarding looking reforms etc. will have to be undertaken

Key Aspects of Generation Planning in Nepal

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Generation Planning in Nepal

Power system planning is a cumbersome process, which consists of **generation, transmission and distribution elements —** each which are closely tied to each other. The more robust and implementable the generation plan is, the more completely it will inform the transmission plan, which relies on it. For that reason, it is essential to fully understand all of the main elements of generation planning.

Many studies have been carried out in aid of generation planning in Nepal — some of them covered the entire country, while others focused on specific river basins. For example, the National Water Resources Development Plan Study for Koshi River Water Resources Development (1983-1985), Upper Karnali and Mahakali River Basin Study (1991-93), Gandaki Basin Power Study (1978), Medium Hydropower Study Project (1996-97), Small Hydropower Development Plan (1993), Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal (2014).

Even today, there are multiple ongoing studies being supported by MoEWRI, NEA and WECS. related to generation expansion planning.

Assessing the key aspects of generation planning

Generation Expansion Planning

Includes project planning, identification, prioritization

Licensing Process and Status

Includes an assessment of the licensing process, an assessment of the status of generation (survey and construction) licenses in Nepal

Power Procurement Planning

Identifies the coordination between the granting of licenses and power procurement planning

Source:

Generation Expansion Planning – Earlier Studies (1/4)

History of Generation Planning in Nepal

If Nepal is to achieve its goals for 2025 and 2030 set out in slide 10, the power system must be integrated—beginning with a generation planning process that optimizes the available natural resources to the forecasted demands. Because Nepal's energy mix is dominated by hydro, planning must build in the long lead times that are required to bring a plant to commercial operations. Over many years, multiple studies have been carried out to support Generation Expansion Planning, including the following:

Medium Hydropower Study Project (1997)	This study was funded by the World Bank and implemented by NEA to screen and rank hydropower sites in the 10-300 MW capacity range for further development by NEA or IPPs. A total of 138 projects were screened, and these projects were identified in various reports and studies completed from 1973 to 1996. The study considered a 20-year time horizon for project prioritization. The consultants used a screening criteria, which was a mix of economic, technical and environmental/social parameters.
Power System Master Plan for Nepal (1998)	The master plan was prepared by NEA in 1998, with the support of the Asian Development Bank. Generation expansion planning was carried out as a part of the study, and it was also complimented by a Long-Run-Marginal Cost (LRMC) report. The planning period was until 2017. Alternative generation projects were also reviewed to identify projects for early development and the most economic plan for generation expansion was determined. The earlier study conducted in 1997 (mentioned above), was a key input for preparing this expansion plan.
Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal (2014)	This study aimed to prepare a master plan for storage-type HPPs to meet domestic demand. The planning horizon was 20 years from 2013. This study was supported by JICA and made the following recommendations: • The following storage-type HPPs, should be put into commercial operations by the late 2020s: Dudh Koshi, Nalsyau Gad, and Andhi Khola • Other recommendations - Coordination between WECS and Environmental Conservation; Reasonable tariff setting and establishing a competitive electricity wholesale market; loss reduction, DSM & capacity building

Source: Medium Hydropower Study, 1997; JICA Report; TOC of Power Sector Master Plan 1998

Generation Expansion Planning – Ongoing Studies (2/4)

Ongoing Generation Planning Studies (1/2)

River Basin Master Plan	• In 2016/17, WECS hired consultants through the World Bank support to prepare River Basin Plans and HPP Master Plan • The HPP Master Plan required the Master Plans for all of Nepal's river basins to be updated/upgraded and optimized • WECS study also included recommendations on prioritization and sequencing of the development of HPPS in various basins • Based on our discussions with WECS, we understood that this study is expected to be completed soon, using the MIKE-SHE hydrological modelling tool
Power Sector Master Plan	• With the assent of MoEWRI, JICA is supporting the development of an Integrated Power System Development Plan • This work aims to develop the capacity of the policy and organizational entities necessary for smooth and sustainable export the electricity generated by domestic hydropower to neighboring countries • The project also intends to harmonize the existing Transmission Master Plan and other plans (i.e., Distribution and Generation) based on the prospective project for domestic/international market targeted to the year 2040 • It is unknown at this time which tool will be used to prepare the master plan

Source: Discussion with WECS and the World Bank team; JICA website

Generation Expansion Planning – Ongoing Studies (3/4)

Ongoing Generation Planning Studies (2/2)

Generation Expansion Plan through Optgen	• NEA has already procured the OptGen and SDDP software through the World Bank (WB) support. Owing to Covid-19, it has not yet been used to develop any analytical studies or plans. Further training on the tool is being procured by the WB • In addition, very recently, the World Bank has contracted with PSR, the developer of the planning tool, to prepare a generation expansion plan for NEA • This will be the first time the OptGen and SDDP software will have been used
Energy Options Assessment (USAID PAANI Program)	• Under one of the components of the USAID Paani program, a study was undertaken to evaluate Nepal's HPP generation options. The Paani consultants used the SWITCH model to identify optimal investment portfolios, based on existing infrastructure, future costs and demand, hydrology, and available technologies (including all possible hydropower projects). The model simulates expansion of the power system in stages (2025, 2030, 2035, and 2040). The study was conducted with support from WECS • About the SWITCH model: As a least-cost model, outputs from SWITCH can satisfy both the policy interest of keeping power costs low for consumers, and the private investor's interest in selecting competitive projects. Additional policy objectives (for example, reducing imports to regain energy independence, investing equally in the Nepal's multiple regions, or protecting certain rivers from hydropower development) can be introduced into the model. SWITCH will still select the least-cost option that meets these constraints

Multiple studies are being conducted with similar targeted outcomes. Each prior study has operated with a different planning horizon. A more coordinated approach to generation expansion planning is sorely needed. The IRRP Committee can play a pivotal role in getting the best results from these studies.

Source: Discussion with WECS and the World Bank team; JICA website

Generation Expansion Planning – Assessment of Tools (4/4)

Generation Expansion Planning Tools with NEA

Below is a summary of the expansion planning tools available with NEA. This is based on the discussions with NEA.

In recent years, **NEA has used the Wein Automatic System Planning (WASP)** tool for generation planning – but not necessarily as a planning tool. Ever since the issuance of licenses on a first-come, first-served basis, and the post-tariff regime, NEA has not used generation planning to guide the development of projects and purchase of power. WASP is only used to assist NEA, DoED, and MoEWRI when they consider developing large projects. WASP was a one-time purchase, and the subscription has not been renewed. As a result, the latest upgrades to the software are not available with NEA; yet the tool is still functional. Lastly, this tool does not permit the incorporation of cascading HPPs or hourly energy generation data.

Transition to OptGen (and SDDP) Planning Tool: The WB assisted with the procurement of two planning models (OptGen and SDDP) in aid of TA supplied for the Upper Arun HPP. These procurements included a one-year support period. Together, the two models provide a more robust substitute for WASP — in fact, they may even provide a more complex result than Nepal currently needs. There is an additional module, Net Plan—which goes along with OptGen and SDDP, was not procured. Originally, the plan was to conduct two one-week trainings with the first training focused on orienting the trainees to the software. NEA was then intended to spend approximately six months populating the software with relevant NEA data – at which point the second one-week training would be provided. Two years ago, NEA elected to have a 2-week training for 6 people in Brazil, the home of PSR. Unfortunately, without the relevant data, the training became largely theoretical; the situation was not improved by the aid of training manuals/documents, which were not detailed or well-structured enough to meet the task. Some of the challenges faced by the team in using SDDP and OptGen included:

- Incorporating Nepali Calendar in the set up
- Insufficient data/inability to collect required data (hydrological, geological data)
- One-year support period is over, and update of the software is not available
- Proper implementation of the software requires dedicated resource of about 4-6 people for a year

Licensing Process and Status – Process (1/4)

Nepal's Two-Stage Licensing Regime (>1 MW HPPs)

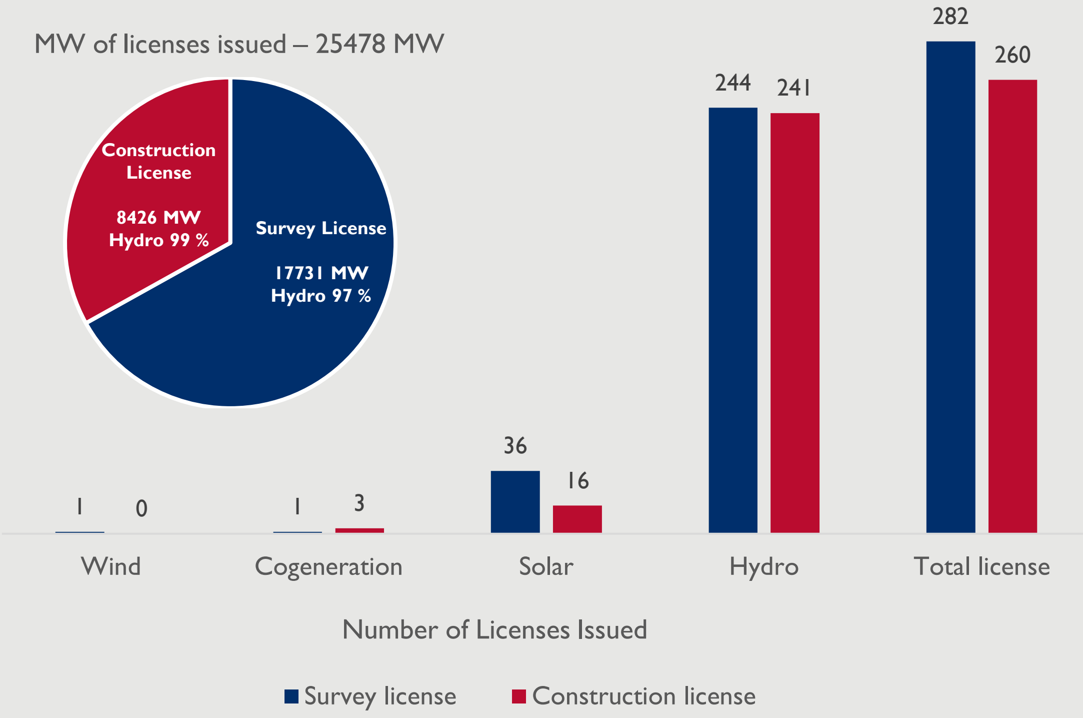
Application for Survey License	Application for Survey License is made to DOED. The application contains details on site, area to be surveyed, estimated cost and time, total capacity, and estimated annual production.
Issue of Survey License	DOED issues the Survey License on a First-Come, First-Served Basis within 30 days — subject to completeness of the application. However, the DOED issues the license for a period of 2-5 years, depending on the application/project (max. 5 years). Renewal of a survey license is possible if the original term of the license term was for less than 5 years.
Conduct feasibility and environment studies, sign PPA	The developer is required to conduct the feasibility studies along with IEE/EIA report and agreement regarding sale of power (i.e., PPA).
Application for Construction License	The developer applies to the Ministry through DOED for the construction/production license and submits the Feasibility Reports, Ownership details, mode of financing, PPA, and other statutory documents.
Issue of Construction License	DOED reviews the documents and puts a public notice for comments. At the end of the comment period, the license is issued to the developer by DOED on behalf of the Ministry. The maximum term of a Production License is 50 years (Electricity Act, 2049), However, as matter of practice, the DOED grants generation license for only 35 years.

The licensing process is two-stage one, conducted by the DOED acting on behalf of the Ministry. The **first-come, first-served process** does not place any weight on the developer's techno-economic qualification. A mechanism is needed to ensure that the applicant has adequate access to resources required to implement the project. Over years, the failure to have such a mechanism has caused financial loss to the GoN.

Source: DOED Website; Nepal Energy Forum, Electricity Rule, 2050

Licensing - Analysis of the licenses issued by DOED (2/4)

Licenses issued by DOED to Date



Survey license

- Total survey license = 282 (1 cogeneration project, 1 wind project, 36 solar projects, 244 hydro projects)
- Total capacity of the survey projects = 17731 MW (3 MW wind project, 15 MW cogeneration project, 608 MW solar projects, 17105 MW hydro projects)

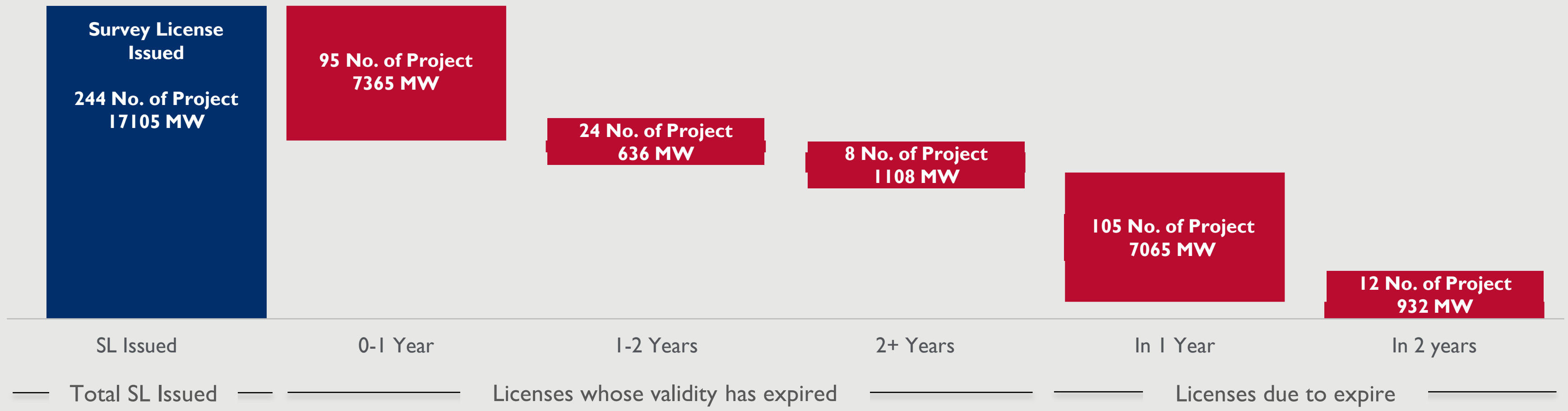
Construction license

- Total construction license = 260 projects (3 cogeneration projects, 16 solar projects, 241 hydro projects)
- Total capacity of the survey projects = 8426 MW (9 MW cogeneration projects, 100 MW solar projects, 8317 MW hydro projects)

Source: DOED Website; Data as on 30-Aug-2021

Licensing - Analysis of the Survey Licenses (SL) issued by DOED (3/4)

Status of HPP Survey Licenses

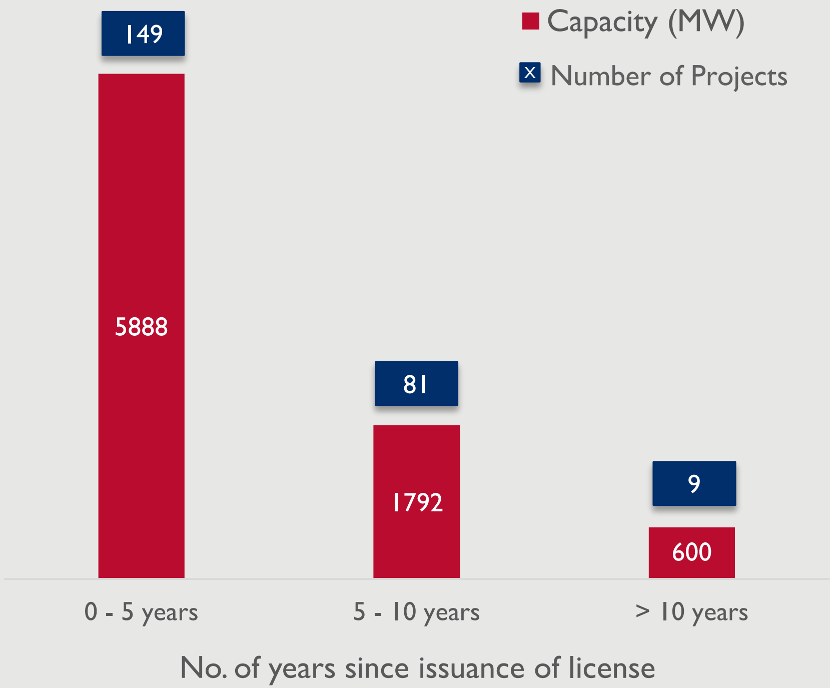


- 127 Survey Licenses for HPPs, with a cumulative capacity of 9108 MW, have already expired. Another 117 HPPs, with a capacity of ~8000 MW, will expire in the next two years
- 13 HPPs have already signed a PPA with NEA but without yet moving to the Construction License phase
- The term of a Survey License lasts from 2 to 5 years. Ideally, this period should be standardized, or depend on the size of the project
- The GoN should reconsider the licensing strategy if most of the HPPs licenses have lapsed. Checks and balances should be built into the application process to filter non-serious/speculative developers. The occurrence of 'license trading' should be severely curtailed

Source: DOED Website; Data as on 30-Aug-2021

Licensing - Analysis of the Construction Licenses (CL) issued by DOED (4/4)

Status of HPP Construction Licenses

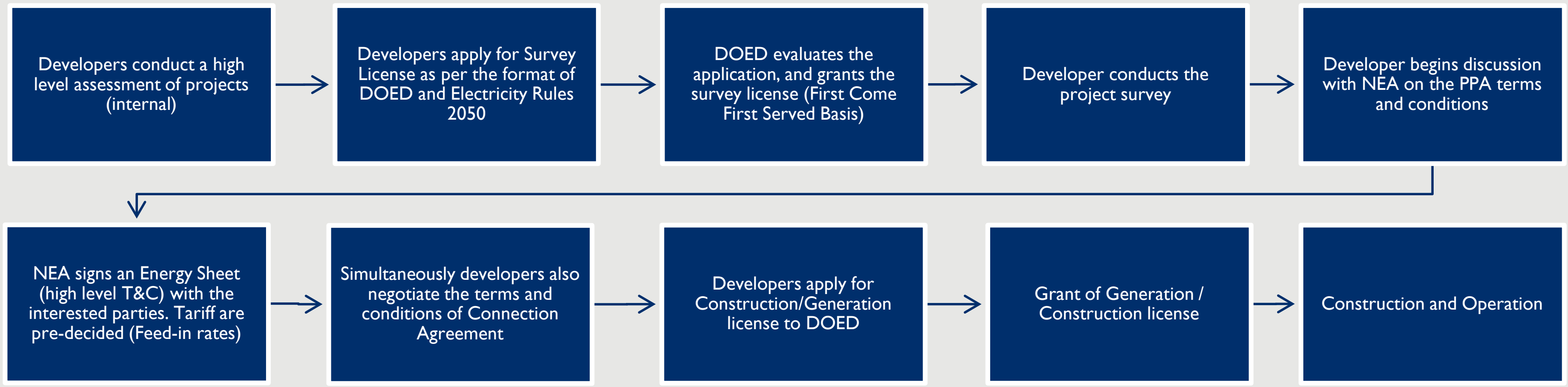


Source: DOED Website; Data as on 30-Aug-2021

- The gestation period for HPP construction is quite long; nevertheless, continuous monitoring of construction licenses will help to reduce time and cost over-runs
- Currently, over 90 projects with cumulative capacity of 2,392 MW have been delayed – and currently exceed their 5-year license term
- There are some large projects which have been extensively delayed, including Upper Tamakoshi (10.7 years), Kulekhani 3rd (13 years), Khani Khola I (10.3 years)
- These delays result in significant loss of revenue for the developer and the GoN
- Measures must be taken to monitor the status of the construction licenses post-award. This would prompt remedial action at the earliest

Generation Procurement: Planning and Tariffs – The PPA signing Process

Process of signing PPA with NEA (domestic projects)



- **Lack of Coordinated Approach -** The process of awarding the license and signing the PPA is a closely tied activity. However, if we look at the above-described process, because the survey license issuance is issued on a first-come, first-served basis, that means that multiple developers could otherwise have qualified for the same license. It also means that not all projects will move to sign a PPA with NEA at the same speed. This is because NEA's ability to sign the PPA is driven by the demand-supply scenario and is de-linked from the current license issuing process. This has led to multiple licenses being issued and even good projects getting stuck due to NEA's inability to sign the PPA

- **Feed-in Tariffs** – Historically, HPP tariffs have been fixed, irrespective of the technology or innovation being employed. This does not send the correct signal to developers, especially those developing large HPPs. Resource optimization is also constrained if projects are not analyzed based on the cost

Summary of the Assessment

Identification of key issues

1 Generation Expansion Planning Policies and Studies

- Lack of Coordinated Action
- Less focus on diversity of resources

- Generation expansion planning is currently conducted by multiple agencies. In the past, NEA and WECS have undertaken such studies with Donor support. Currently, few parallel studies are also ongoing. This calls out for a much more coordinated approach.
- The generation expansion planning studies currently being undertaken include:
  - Ministry-led National Integrated Power Sector Master Plan
  - WECS-led Water Resources Master Plan which includes Hydropower Master Plan
  - NEA-led Generation Expansion Plan using OptGen and SDDP software

2 Licensing Process and Current Status

- Too many licenses issued
- Not differentiation for technology innovation
- Improved license monitoring is required

- The first-come, first-served process does not value the techno-economic qualification of the developer. A mechanism is needed to ensure that the developer has adequate access to resources required to implement the project. This gap has Nalsya resulted in loss of revenue to the GoN.
- The survey license of 127 projects with a cumulative capacity of 9108 MW has already expired. The survey license of another 117 projects with a capacity of ~8000 MW will expire in the next two years.
- Construction of HPPs is a lengthy affair, however, continuous monitoring and mitigation may reduce the time and cost over-runs. Currently, over 90 projects with cumulative capacity of 2392 MW have been delayed and their construction period is over 5 years.

3 Power Procurement Planning and Tariffs

- Lack of Coordinated Action
- Non-optimization of resources

- DOED issues the licenses, while the PPA must be signed by NEA. During the licensing process, there is limited discussion between the licensing authority and off-taker. In the past, this has resulted in mismatch between capacity requirement and license issuance. Currently, many application are pending before NEA for approval of PPA.

Conclusion and Recommendations

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Conclusion and Recommendations – Pivotal role of IRRP Committee

1.1 Transitioning towards Integrated Planning and Improving Stakeholder Coordination

All Planning Activities should be driven by a Central Administrative Body, which coordinates with relevant stakeholders
Planning is a specialized and essential task. Globally, Today, this function is discharged by multiple central administrative bodies, The MoEWRI is the central agency in Nepal, and it should lead all planning activities. While that body can also delegate to various other state bodies, the core function should be carried by the Ministry.

Process Improvements in the Licensing and PPA formalities
There is a disconnect between the existing licensing and the off-take agreement process. License granting should be linked to actual demand scenario and its projections. This will help to identify the right set of candidate projects to most optimally meet the demand. The process can also be streamlined through better engagement with off-taker – NEA.
Further, since a very large number of licenses have already been issued, mechanisms will need to be developed to filter non-serious licensees together with those whose licenses have expired.

Having Common Timelines and Driven by the same Vision
Various plans that are being prepared have different timelines. For example, the Transmission Master Plan has been prepared in 2017 for a period of 20 years, whereas the generation expansion plans may have a different timeline. Ideally, all the national level plans should have a common period of consideration and should be closely linked to each other.

One National Level Plan involving all relevant Stakeholders
Currently multiple studies are ongoing on similar aspects. For example, the Integrated Power System Master Plan, the Hydropower Master Plan, and the Generation Expansion Plan. All of them have similar outcomes yet are being carried out separately by different bodies. It will be effective and efficient to consolidate the effort and have one national level integrated plan.

Conclusion and Recommendations – Pivotal role of IRRP Committee

1.2 Promoting Optimum use of Resources

Working towards Resource Optimization and Promoting Innovation

The existing feed-in tariff mechanism used for all domestic HPPs does not differentiate the optimal source of power generation. All the projects get the same tariff, regardless of any innovation in technology or otherwise. While FiTs are good to promote the investment during the initial years, it is time for resources to be optimized based on discovered tariffs. We may continue to have FiTs for micro/pico/mini hydro projects.

1.3 Monitoring and Evaluation

Employ Robust Monitoring and Evaluation Frameworks for all Licensees

Given the status of survey and construction licenses, we can see the number of licenses that have expired, and it is quite alarming. Proper monitoring and evaluation of the licenses are required. Modern day technology offers multiple platforms or solutions to do such monitoring through dashboards, MIS, Tools etc. This will also help in taking informed decisions.

1.4 Use of Best-in-Class Tools for Planning

Planning Tools

There are a host of power system planning tools available in the market. Each tool within each category also has its own capabilities and strengths. An illustrative list of planning tools has also been presented in Annex. These models have been reviewed based on publicly available data.

Annex

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Assessment of OptGen (with SDDP) Planning Tool (1/3)

Planning Element	OptGen (with SDDP)
Load Demand Modelling	• The load in each stage is represented in SDDP by blocks. Each block is, in turn, defined by a pair {duration (hours); load (GWh or MW)}. It is possible to represent up to 21 load blocks per stage. Each block is represented through conventional hourly load curve or load duration curve • The duration of the load block, fixed by the load input data, can be selected to be variable through all the stages of the study • The model allows the representation of different types of demand for each system. Each system can have more than one demand associated to it, which can be composed of a combination of elastics and inelastic components • Each demand in SDDP can be defined as a curve that indicates its willingness to purchase energy for different price levels of the system in 3 categories: Elastic, Inelastic, and Mixed • From version 12 of SDDP it is allowed to represent the uncertainty in the demand data, with variability following a normal distribution
Long Term Generation Planning Features	SDDP calculates economic indices, such as load marginal costs in each region in case of a simplified energy interchanges model or in each bus in case of a transmission network wheeling rates, transmission congestion costs, water values in each hydroelectric plant, marginal cost of fuel constraints, etc.
Hydro Modelling	• Operating details of hydroelectric plants: hydraulic balance, storage and flow rate limits through turbines, spillways, head effect and others • Hydrological uncertainty: stochastic inflow model representing hydrological system characteristics such as seasonality, time and spatial inflow correlations and droughts • Hydro inflows, allow handling macroclimatic events (El Niño and La Niña), snowmelt and others

Source: Assessment of OptGen Tool and Software, USAID SEP Project, Pakistan, 2019

Assessment of OptGen (with SDDP) Planning Tool (2/3)

Planning Element	OptGen (with SDDP)
Renewable Energy Planning and Integration	Renewable sources (wind, solar, biomass etc.), allow capturing correlation between hydrology and climatic conditions
Storage	It does not offer the feature to model energy storage technology

Transmission Planning and Analysis	• Detailed transmission network: Kirchhoff laws, power flow limits in each circuit, losses, security constraints, limits on export and import among electric areas, sum of flow constraints and others
	• There are two mutually exclusive alternatives for representing transmission aspects
	    • Linearized power flow model;
	    • Interconnection model
	• 5000 buses and lines including DC

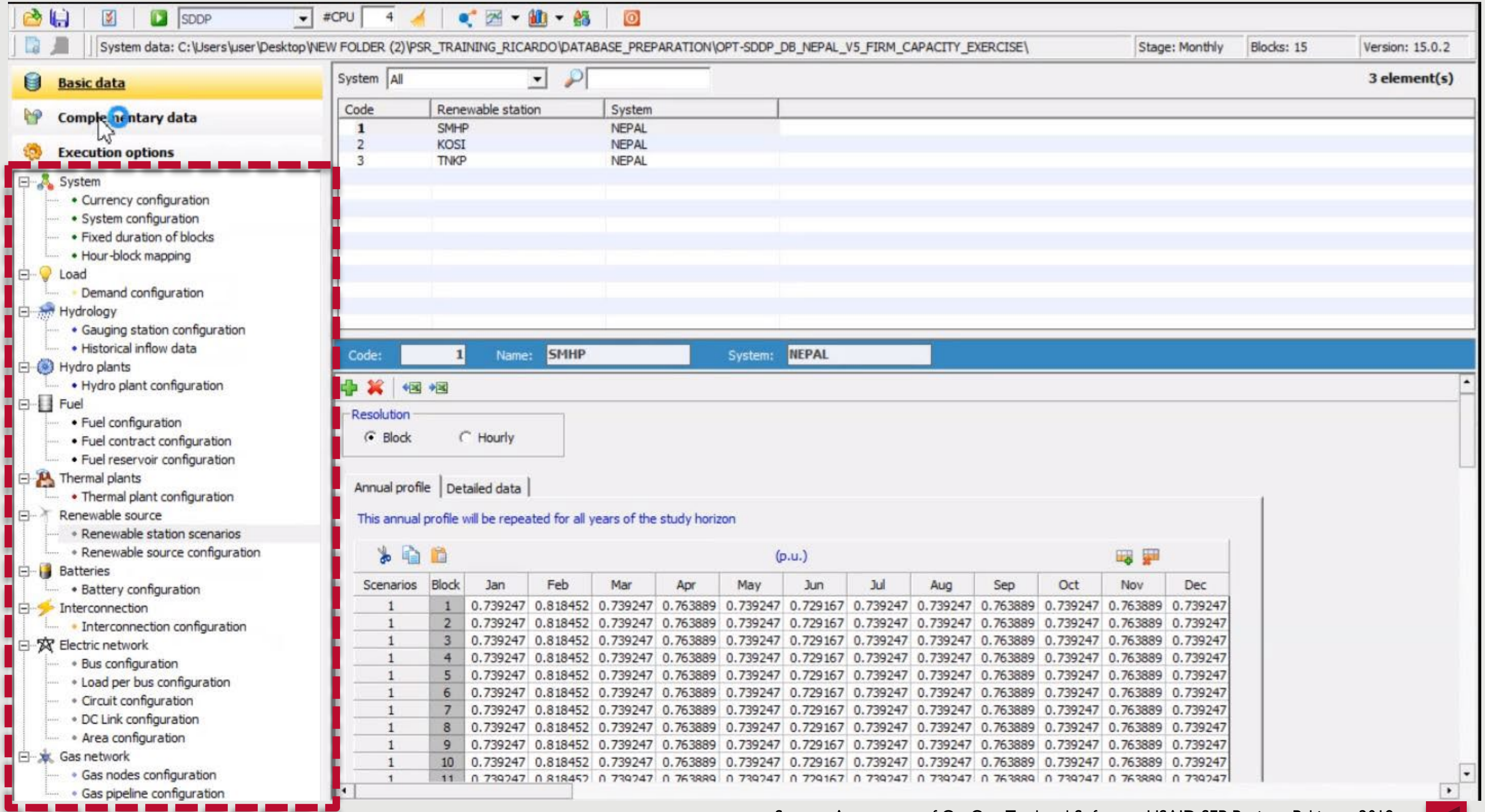
Source: Assessment of OptGen Tool and Software, USAID SEP Project, Pakistan, 2019

- While the OptGen (with SDDP) model offers a robust generation expansion planning tool, there are a few complexities around load modelling and factoring the storage solutions

- **While the first set of data inputs are being prepared for modelling with OptGen, it should be seen how this integrates or informs the transmission and distribution planning elements in Nepal. The reason for mentioning this is that another PSR software "NetPlan" which is used for transmission network planning and analysis, is not part of the package procured by NEA**

Assessment of OptGen (with SDDP) Planning Tool (3/3)

Key features and Dashboard of OptGen/ SDDP



Source: Assessment of OptGen Tool and Software, USAID SEP Project, Pakistan, 2019

Summary of Various Planning Tools available for Expansion Planning (1/4)

Software	Key Features	Paid/Free	Remarks (if any)
AURORA	• Normal, log-normal, uniform and binomial distributions • Internal Monte Carlo and Latin Hypercube simulations • Positive and negative correlation of variables • Flexible selection of assumptions, drivers and stochastic variables • Histogram results • Lifecycle analysis and resource capacity expansion optimization studies. • Open or closed system modeling • Multiple portfolio comparisons	Paid	Aurora find its use cases in Power Market Price Forecasting, Energy Portfolio Analysis, Optimized Resource Expansion and Power Market Risk Analysis
BALMOREL	• Balmorel project supports modelling and analyses of the energy sector with emphasis on the electricity and combined heat and power sectors • The model is data-driven and has a high degree of flexibility with respect to temporal and spatial options • Balmorel supports different running modes which can be applied depending on the desired level of foresight for optimization between time segments	Free (but payment required for GAMS license)	The Balmorel model is coded in General Algebraic Modeling System (GAMS). This ensures complete transparency of modeling details and supports modifications of the model code by any user. GAMS software and a solver is required to run the model.
CAPCAITY EXPANSION (ABB)	• Request for proposal (RFP) evaluations – for resource acquisition to determine the best combination of resources that minimize cost and meet renewable and emissions regulations • Environmental compliance planning to include complex emissions compliance rules as well as renewable energy requirements • Produce resource investment plans to meet long-term reliability requirements, incorporating factors like technology type, fuel, size, location, and timing of capital projects	Paid	Capacity Expansion is built upon ABB's latest technology platform, e7 which utilizes a common interface that is shared by ABB's other market and portfolio solutions.

Summary of Various Planning Tools available for Expansion Planning (2/4)

Software	Key Features	Paid/Open Source	Remarks (if any)
EGEAS	• Dynamic programming algorithm to develop portfolios from identified alternatives meeting a reliability constraint • Conducts minimum present value revenue requirements (PVRR) or lowest electric rate economic ranking of candidate portfolios dispatched, with an existing and future set of assets • Support multiple scenarios to test different generation plans	Paid	• EGEAS – Electric Generation Expansion Analysis System • The tool also has modules to specifically accommodate demand-side management options and to facilitate the development of environmental compliance plans
LEAP	• An integrated, scenario-based modeling tool that can be used to track energy consumption, production and resource extraction • LEAP provides a range of accounting, simulation and optimization methodologies that are powerful enough for modeling electric sector generation and capacity expansion planning • Capable of performing multiple types of analysis, including Demand Analysis, Transformation Analysis, Resource Analysis and Environmental Analysis	Paid	• The latest versions of LEAP support optimization modeling: allowing for the construction of least cost models • LEAP is highly flexible in terms of the types of data and degree of customization it can support • LEAP is free only to students and nonprofit, governmental or academic operations in developing countries. All other users must pay a licensing fee
MESSAGE	• Systems engineering optimization model used for planning medium to long-term energy systems with the analysis of climate change policies • All thermal generation, renewable, storage and conversion, and transport technologies can be simulated by MESSAGE. • MESSAGE includes endogenous technology learning (ETL) for various technologies using a Mixed Integer Programming (MIP) approach	Free	• MESSAGE - Model for Energy Supply Strategy Alternatives and their General Environmental Impact • Python package that ties together all components of the framework. MESSAGE _ix and ixmp are free and open source, licensed under the APACHE 2.0 open-source license

Summary of Various Planning Tools available for Expansion Planning (3/4)

Software	Key Features	Paid/Open Source	Remarks (if any)
PLEXOS	• Mathematical Optimization - PLEXOS uses optimization to convert the properties and behaviors of a physical power system into mathematical problems • A Unified Platform - Consolidates power system analyses in one tool. PLEXOS and uses the short-term simulations ensuring outcomes are completely consistent across • Flexibility and Customization – PLEXOS can be customized with many scenarios, customized constraints, conditional variables, physical elements, simulation horizon, duration of the simulation period, phases in the integration and model resolution	Paid	• PLEXOS drives high performance through cloud computing and instant access to the best hardware for simulation • High level of granularity is supported with resolution of models to years, hours or seconds
REEDS	• Comes with high-spatial resolution and advanced algorithms to represent cost, value, and technical characteristics of integrating renewable energy technologies • REEDS has been linked to a variety of models such as Distributed generation adoption models, Natural gas supply models, Water and climate models and Economy-wide market equilibrium models	Free	• The ReEDS model is implemented using GAMS (General Algebraic Modeling System), Python and R. A GAMS license and appropriate solver will be required to run the model.. The model is built to be executed in Windows, but it can be configured to run on Unix as well
SDDP & OPTGEN	• SDDP is a hydrothermal dispatch model with transmission network and used for short-, medium-, and long-term operation studies • Results of the model SDDP are written to . csv format files which are further managed by a graphic interface (the GRAF program) • OptGen is a model for generation expansion planning and regional interconnections to determine the least-cost expansion (generation and interconnections) of a multi-regional hydrothermal system	Paid	• The SDDP model uses a new solution methodology called stochastic dual dynamic programming, developed by PSR • **Integration with SDDP -** OPTGEN also has a built-in feature for joint use with SDDP

Summary of Various Planning Tools available for Expansion Planning (4/4)

Software	Key Features	Paid/Open Source	Remarks (if any)
UPLAN	• Budgeting • Emissions Monitoring • Energy Price Analysis • Load Management • Risk Management • Cost / Use Reporting • Various UPLAN Components are • Volatility Model, Maintenance Scheduling Model (MSM), UPLAN Application Programming Interface, UPLAN PowerStack Cluster, UPLAN Configuration Tools, Transmission Model and UPLAN Advance Clearing Engine	Paid	• UPLAN-NPM stands for UPLAN Network Power Model • UPLAN has no inherent restriction on size, speed, transmission contingencies, number of generators, and load buses

Source:

1. AURORA – Energy Exemplar Website: energyexemplar.com/solutions/aurora/, energyexemplar.com/software/optimized-resource-expansion/
2. BALMOREL – Balmorel Website: balmorel.com/index.php/downloadmodel/
3. CAPACITY EXPANSION (ABB) – HitachiABB –Powergrids Website: hitachiabb-powergrids.com/offering/product-and-system/energy-planning-trading/market-analysis/capacity-expansion
4. EGEAS – University of HongKong Website: eee.hku.hk/~cees/software/egeas.htm, The Electric Generation Expansion Analysis (EGEAS) Report: esca.epri.com/pdf/Diamant_EPRI__EGEAS_UsersGroup_091715_Final.pdf
5. LEAP – Open EI Website: openei.org/wiki/Long_range_Energy_Alternatives_Planning_(LEAP)_System, Leap Website: leap.sei.org/default.asp
6. MESSAGE – Messageix Framework: docs.messageix.org/en/stable/, GitHub: github.com/iiasa/message_ix, Energy Modelling Framework: webarchive.iiasa.ac.at/Research/ENE/model/message
7. PLEXOS – Energy Exemplar Website: energyexemplar.com/solutions/plexos/, energyexemplar.com/plx-features/
8. REEDS – National Renewable Energy Laboratory (NREL) Website: nrel.gov/analysis/reeds/about-reeds, nrel.gov/analysis/reeds/
9. SDDP & OPTGEN – PSR Website: psr-inc.com/softwares-en/?current=p4040
10. UPLAN – LCG Consulting Website: energyonline.com/Products/Uplane, Capterra: capterra.com/p/2197/UPLAN/#about