ETHIOPIAN POWER SYSTEM EXPANSION MASTERPLAN STUDY

VOL. II - GENERATION PLANNING REPORT - FINAL

East Africa Energy Program (EAEP)

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ETHIOPIAN POWER SYSTEM EXPANSION MASTERPLAN STUDY

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VOLUME II	GENERATION PLANNING
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VOLUME IV	FINANCIAL ANALYSIS AND TARIFF REVIEW
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VOLUME VI	TENDER DOCUMENT

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LIST OF ABBREVIATIONS

ABBREVIATION	DEFINITION
AEO	Annual Energy Outlook
AGC	Automatic generation control
AVR	Automatic voltage regulator
BCM	Billion cubic meters
BTU	British Thermal Unit
CCGT	Combined cycle gas turbine
COD	Commercial operation date
CoUE	Cost of unserved energy
CSP	Concentrated solar power
DSA	Dynamic security assessment
DSM	Demand-side management
DSSP	Distribution Systems Strengthening Project
EAEP	East Africa Energy Program
ECA	Economic Consulting Associates
EEA	Ethiopian Energy Authority
EEP	Ethiopian Electric Power
EEU	Ethiopian Electric Utility
EHV	Extra high voltage
EIA	Energy Information Agency
ENTGC	Ethiopia National Electricity Transmission Grid Code
EPC	Engineer, procure, construct
EPSEMPS	Ethiopian Power System Expansion Master Plan Study
ESMAP	Energy Sector Management Assistance Program
FC	Financial close

ABBREVIATION	DEFINITION
GERD	Grand Ethiopian Renaissance Dam
GHI	Global horizontal irradiation
GMSP	Grid Management Support Program
GT	Gas turbine
GTP	Growth and Transformation Plan
GW	gigawatt
GWh	gigawatt-hour
HFO	Heavy fuel oil
hm^3	Cubic hectometer
HV	High Voltage
HVDC	High Voltage Direct Current
ICS	Interconnected System
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IPP	Independent power producer
JICA	Japan International Cooperation Agency
LCoE	Levelized cost of electricity
LFO	Light fuel oil
LNG	Liquified natural gas
MoWIE	Ministry of Water, Irrigation and Energy
MSD	Medium speed diesel
MVA	mega-volt ampere
MW	megawatt
MWh	megawatt-hour
NG	Natural gas
NGCC	National Grid Control Center

ABBREVIATION	DEFINITION
NPV	Net present value
O&M	Operation and maintenance
PATRP	Power Africa Transactions and Reform Program
PPA	Power purchase agreement
PV	Photo-voltaic
SDDP	Stochastic Duel Dynamic Programming
SIS	System Integration Study
SOGA	System Operation Gap Analysis
SPS	Special protection scheme
SVC	Static var compensator
TCF	Trillion cubic feet
TTC	Total transfer capacity
UEAP	Universal Electrification Access Program
UFLS	Under-frequency load shedding scheme
USAID	United States Agency for International Development
USD	United States Dollars
USBR	United States Bureau of Reclamation
VAR	volt ampere
VRE	Variable renewable energy
WB	World Bank
WtE	Waste-to-energy

EXECUTIVE SUMMARY

INTRODUCTION

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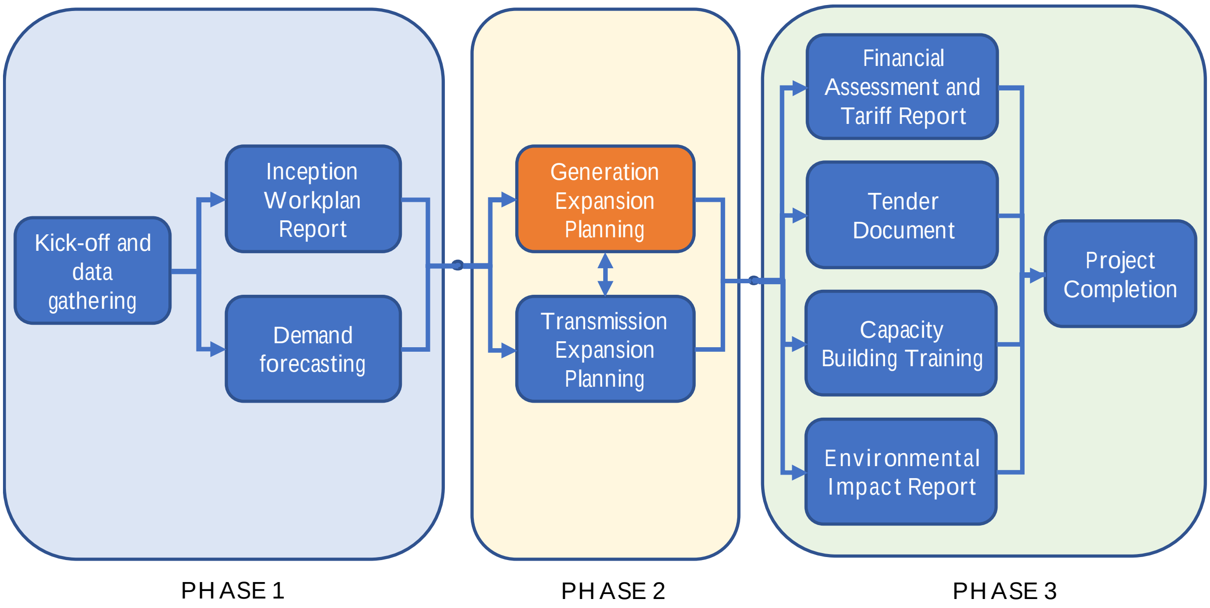
i. Data review and gap analysis, Inception Workplan Report
ii. Load Forecast
iii. Generation Expansion Plan
iv. Transmission Expansion Plan
v. Financial Assessment and Tariff Studies
vi. Tender document to implement recommendations from GMSP's SOGA exercise and Static and Dynamic Stability Studies performed by CESI.
vii. Knowledge Transfer
viii. Environmental Impact Study

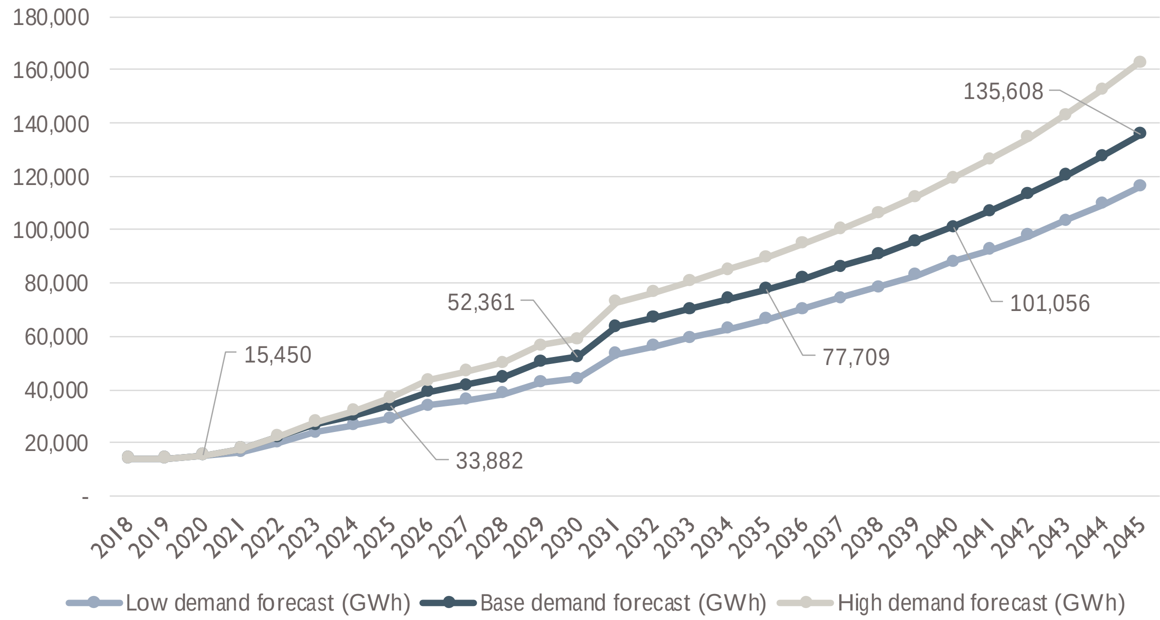
This report describes the generation planning carried out for the period up to 2045. It is based on the demand forecast, which is described in a separate report. The figure below indicates how the generation expansion plan fits into the overall study approach.



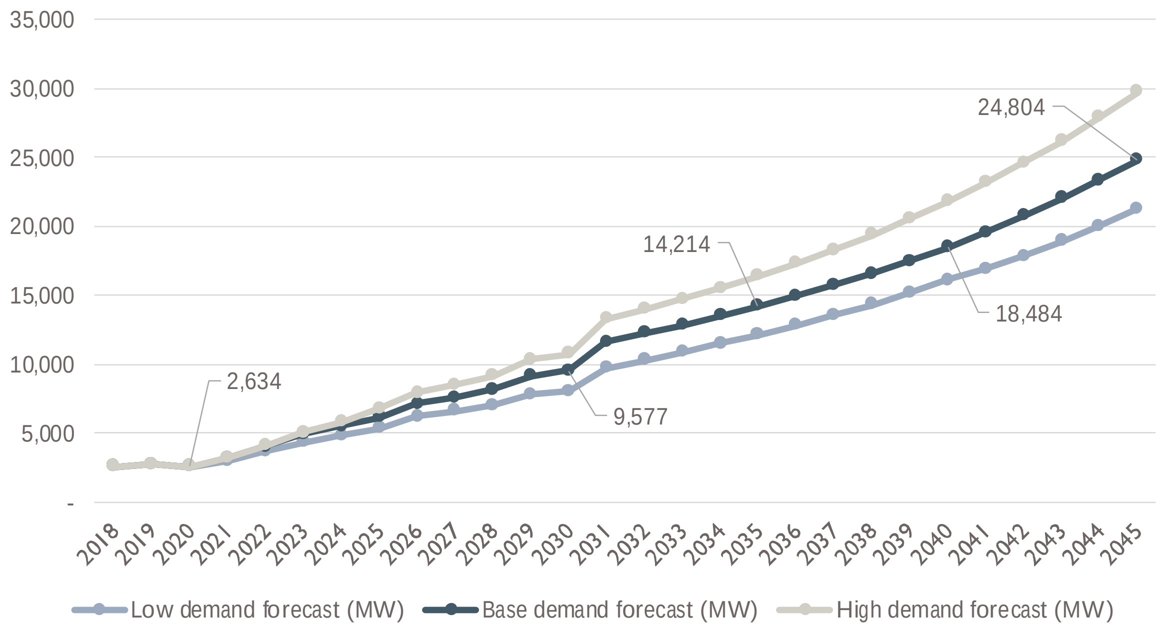
DEMAND FORECAST

The demand forecast formed the subject of a separate report. As shown below, in the Base Case, both annual energy and peak demand are forecast to increase by over three times the 2020 level by 2030 and over eight times the 2020 level by 2045. The scale of growth provides an indication of the required level of investment in generation resources.

Energy demand forecast (GWh)



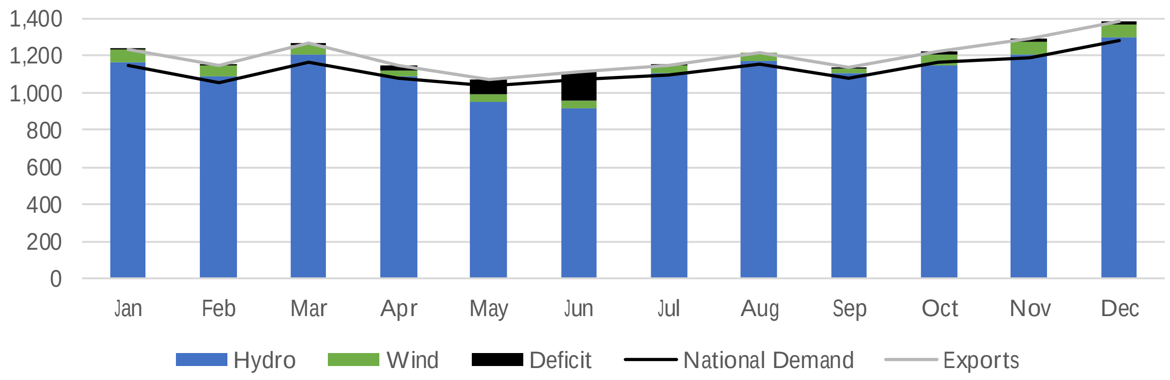
Peak demand forecast (MW)



GENERATION RESOURCES

Ethiopia is a country with high hydropower potential and aims to be a powerhouse of Africa exporting electricity to its neighbors. Approximately 95% of generated energy in Ethiopia is in the form of hydropower; however, this makes the system vulnerable to low hydrological conditions, sometimes leading to load shedding, as illustrated below.

Generation mix – 2019 (GWh)



The installed hydropower capacity by the end of 2020 was 4,077 MW from 14 plants (including Genale Dawa III, which was commissioned during 2020 and was fully operational by early 2021). However, several of the plants have significantly reduced available capacity, and the total available turbine capacity by the end of 2020 was 3690 MW. The production coefficient (MW/m3/s) of a hydropower plant is affected by reservoir level, and, therefore, the effective capacity is less than the indicated available capacity during low reservoir conditions. Hydro-dominated power systems are generally energy-constrained rather than capacity constrained and are highly dependent on hydrological conditions.[1]

The total firm (available) capacity and average energy in 2020 are compared with the demand below. It was assumed that the wind plants contribute firm capacity up to 30% of their installed capacity, (however as Ashegoda wind farm was underperforming, its capacity was neglected). It may be seen that while the system had a reserve capacity margin of 33%, the reserve energy margin (based on average hydro inflows and average wind yield) was only 1%. This minimal energy margin results in vulnerability to adverse hydrological conditions. Depending on hydrological conditions, these constraints could persist for the next few years if the Base Case forecast demand growth materializes, as detailed further in the report.

Firm capacity and energy and reserve margin (2020)

Plant type	Firm capacity (MW)	Average energy (GWh)
Hydro	3,426	14,351
Wind	60	993
WtE	25	186
Total	3,521	15,530
Demand	2,634	15,450
Reserve margin (%)	33%	1%

[1] Therefore, despite a reserve capacity margin of around 25%, due to low hydrological conditions, there was insufficient energy to meet the demand in 2019 resulting in the need for load shedding.

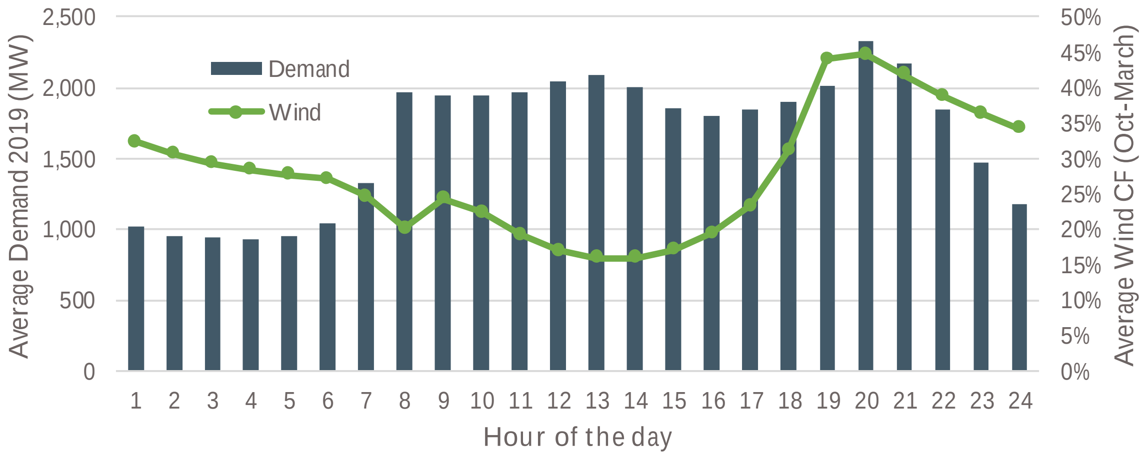
COMMITTED AND CANDIDATE CAPACITY

The installed and firm capacity of the existing, committed, and candidate generation as described in the previous section is shown below. The installed capacity includes all generation types, while the firm capacity only includes generation that can contribute to meeting the peak demand, i.e.:

- Available hydro capacity
- WtE capacity
- Geothermal capacity
- 30% of installed wind capacity

Historical wind data was used together with predicted future wind profiles to determine the possible contribution from wind at peak times. The average wind availability was taken for October to March, when demand is highest, for the hours where the average demand was above 2,000 MW in 2019. As a result of this analysis, 30% of its installed capacity has been considered firm.

Average daily demand profile and available wind capacity factor



Solar generation can't contribute to the evening peak and the sugar factory plants, while comprising thermal generation, are seasonal and therefore have not been considered firm.

While the total installed capacity of existing, committed, and candidate plants amounts to 27,718 MW, the firm capacity is just 20,974 MW. As indicated above, the Base Case peak demand reaches 24,804 MW by 2045, and including a 20% reserve margin, the firm capacity requirement would be 29,745 MW. Therefore, ignoring any plant retirements that may occur by 2045, there would be the need for a further 8,771 MW of firm capacity to fully meet the peak demand by 2045 with a 20% reserve margin.

The average annual energy production capability of the existing, committed, and candidate plants shown in the table below is based on average hydrological conditions and typical capacity factors for the non-hydro plants, i.e.

- Geothermal 85%
- Waste 85%
- Wind 35%
- Solar 25%
- Sugar factory 58%

As shown below, the total average annual energy capacity of existing, committed, and candidate plants amounts to 109,057 GWh.

As indicated above, the Base Case energy demand reaches 135,608 GWh by 2045, and, including a 20% reserve margin, the firm energy requirement would be 162,730 GWh. Therefore, ignoring any plant retirements that may occur by 2045, there would be the need for a further 53,673 GWh of energy capacity to fully meet the energy demand by 2045 with a 20% reserve margin.

Installed and firm capacity and average energy

Status	Type	Installed capacity (MW)	Firm capacity (MW)	Average energy (GWh)
Existing	Hydro	4,077	3,690	16,041
	Waste	25	25	186
	Wind	324	60	993
	Total	4,426	3,775	17,221
Committed	Geothermal	380	377	2,826
	Hydro	6,770	4,820	20,811
	Solar	250	-	548
	Sugar	317	-	1,574
	Wind	250	75	767
	Total	7,967	5,272	26,524
Candidate	Geothermal	600	600	4,468
	Hydro	10,481	10,481	49,165
	Solar	1,425	-	3,121
	Wind	2,820	846	8,559
	Total	15,326	11,927	65,312
Grand Total		27,718	20,974	109,057

SCENARIOS AND SENSITIVITIES

As discussed above, after considering all existing, committed, and candidate plants, there remains a significant capacity and energy shortfall to meet the 2045 Base Case demand forecast while also achieving a prudent 20% reserve margin. It is, therefore, necessary to consider further potential candidate generation to fill this gap.

While cost is important, other factors including resilience to climate change, diversity, and environmental impact also require due consideration and EEP provided some guidance in relation to the scenarios as follows:

- Diversification: EEP is keen to increase resilience to drought and therefore wishes to reduce its dependence on hydropower and is aiming for <=75% hydro generation by 2030
- Minimize use of fossil-fuel generation: Ethiopia does not currently produce oil or gas and relies on imported fossil fuels. While indigenous gas production is expected to commence soon in the Ogaden Basin, this is destined for export as LNG via Djibouti and is not expected to be available domestically for power generation in the short-medium term. However, the use of indigenous gas for power generation has been considered a longer-term option in the scenarios. In all scenarios, it was assumed that new thermal (fossil-fuel) generation would not be possible before 2028.
- Consideration of additional geothermal capacity
- Consideration of nuclear power
- Considering exports to be non-firm, i.e., energy-based contracts, thereby reducing the firm capacity requirement. This assumption was applied for all scenarios.

It is also necessary to take account of practical considerations in relation to plant additions, including:

- Typical construction periods for the various plant types
- Capacity additions in any particular year are limited to feasible levels

The following capacity addition limits were applied:

- Renewables: ≤300 MW/year
- Geothermal: ≤500 MW/year
- Thermal: ≤1,000 MW/year

Based on the above considerations, the following scenarios were developed:

Scenarios and sensitivities

Scenario	Demand forecast	Hydrology	Generation choices
1: Least-cost	Base Case	Average	Least-cost
2: Reference	Base Case	Average	All hydro and geothermal candidates, maximum solar and wind to reduce fossil fuel generation
3: Additional geothermal	Base Case	Average	Additional geothermal
4: Nuclear	Base Case	Average	Nuclear from 2035
5: Minimum fossil fuel	Base Case	Average	Minimum fossil fuel
6: Non-committed exports	Base Case	Average	Least-cost with non-firm exports in terms of capacity and energy

All scenarios considered the Base Case demand forecast and average hydrology. Then the following sensitivities were applied to each scenario:

- Low hydrology
- High Case demand forecast
- Low Case demand forecast

KEY RESULTS

The simulations indicate that there could be a shortage of firm capacity by 2023 if the peak demand grows in line with the Base Case demand forecast. The earliest assumed date by which new capacity can be built is 2024. Therefore, any short-term shortages need to be managed operationally (through load shedding) or contractually (in the case of exports). It was assumed that the existing hydro plants with reduced available capacity would be restored to full installed capacity by 2026 through the implementation of the required rehabilitation projects. The shortage in firm capacity is alleviated by 2024 due to a significant increase in GERD's capacity by this date.

The total installed generation capacity, firm capacity, and firm energy by 2045 for the various scenarios are summarized below.

Scenario		Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT	Total
1: Least-cost	Installed Capacity (MW)	21,683	3,694	5,050	298	25	977	-	-	6,300	38,027
	Firm Capacity (MW)	21,683	1,072	-	-	25	977	-	-	6,300	30,057
	Firm Energy (MW_{av})	9,863	1,042	1,111	155	12	880	-	-	5,670	18,733
2: Reference	Installed Capacity (MW)	22,071	6,929	5,050	298	25	977	-	-	5,180	40,530
	Firm Capacity (MW)	22,071	2,043	-	89	25	977	-	-	5,180	30,385
	Firm Energy (MW_{av})	10,053	1,785	1,111	155	12	880	-	-	4,662	18,658
3: Additional geothermal	Installed Capacity (MW)	19,683	1,894	3,850	298	25	4,977	-	-	3,780	34,507
	Firm Capacity (MW)	19,683	532	-	-	25	4,977	-	-	3,780	28,997
	Firm Energy (MW_{av})	9,223	502	847	155	12	4,480	-	-	3,402	18,621
4: Nuclear	Installed Capacity (MW)	19,458	2,464	5,025	298	25	977	2,400	-	5,320	35,967
	Firm Capacity (MW)	19,458	703	-	-	25	977	2,400	-	5,320	28,883
	Firm Energy (MW_{av})	9,035	673	1,106	155	12	880	2,040	-	4,788	18,689
5: Minimum fossil fuel	Installed Capacity (MW)	22,071	6,514	5,050	298	25	4,977	-	-	1,120	40,055
	Firm Capacity (MW)	22,071	1,918	-	-	25	4,977	-	-	1,120	30,111
	Firm Energy (MW_{av})	10,053	1,762	1,111	155	12	4,480	-	-	1,008	18,581
6: Non-committed exports	Installed Capacity (MW)	21,438	3,544	5,050	298	25	977	-	-	4,060	35,392
	Firm Capacity (MW)	21,438	1,027	-	89	25	977	-	-	4,060	27,616
	Firm Energy (MW_{av})	9,674	997	1,111	155	12	880	-	-	3,654	16,483

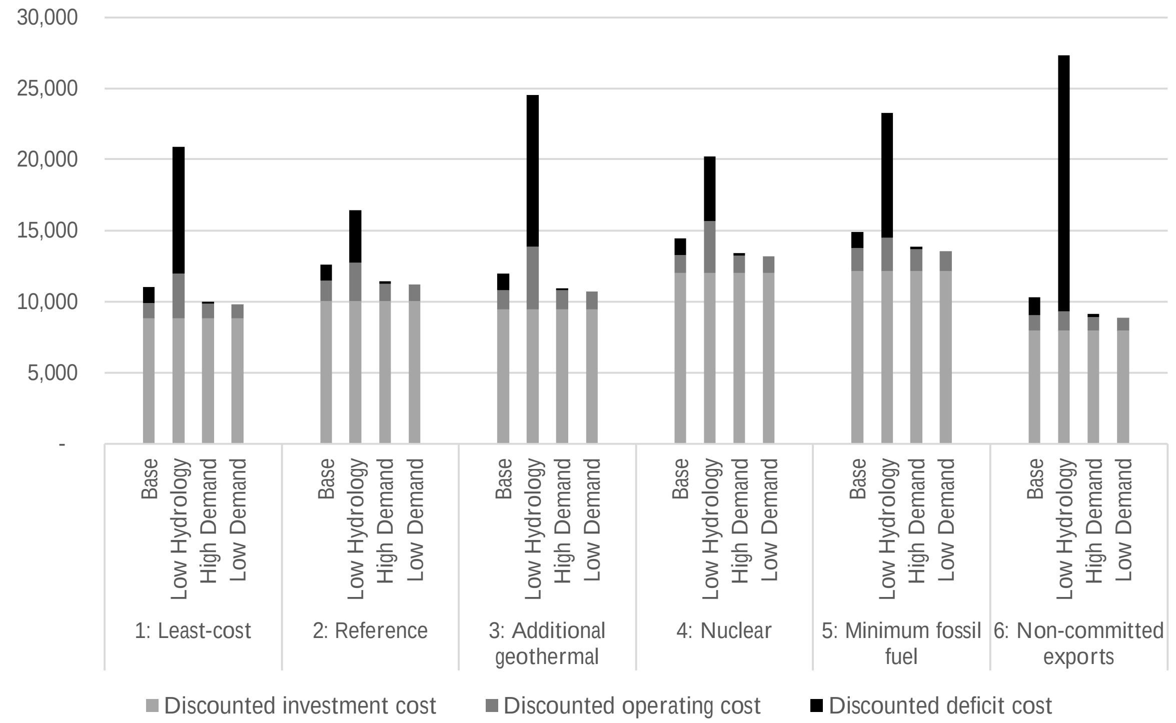
The costs of the scenarios are compared below. The costs shown are as follows:

- Investment cost of candidate projects (undiscounted)
- Investment cost of candidate project expressed as NPV in 2020 USD
- System operating costs expressed as NPV in 2020 USD (including fuel and O&M costs)
- The cost of unserved energy or deficit expressed as NPV in 2020 USD
- Total costs expressed as NPV in 2020 USD

Scenario costs (USDm)

Scenario	Sensitivity	Investment cost	Discounted investment cost	Discounted operating cost	Discounted deficit cost	Discounted total cost
1: Least-cost	Base	33,611	8,806	1,082	1,152	11,040
	Low Hydrology		8,806	3,144	8,961	20,911
	High Demand		8,806	1,034	162	10,002
	Low Demand		8,806	992	-	9,798
2: Reference	Base	40,233	10,035	1,446	1,140	12,621
	Low Hydrology		10,035	2,710	3,672	16,417
	High Demand		10,035	1,204	162	11,401
	Low Demand		10,035	1,143	-	11,178
3: Additional geothermal	Base	38,603	9,430	1,378	1,152	11,960
	Low Hydrology		9,430	4,456	10,622	24,508
	High Demand		9,430	1,344	169	10,943
	Low Demand		9,430	1,275	-	10,705
4: Nuclear	Base	44,248	12,001	1,296	1,152	14,449
	Low Hydrology		12,001	3,681	4,558	20,240
	High Demand		12,001	1,257	171	13,429
	Low Demand		12,001	1,176	-	13,177
5: Minimum fossil fuel	Base	49,773	12,180	1,585	1,152	14,917
	Low Hydrology		12,180	2,298	8,800	23,278
	High Demand		12,180	1,531	162	13,873
	Low Demand*		12,180	1,362	-	13,542
6: Non-committed exports	Base	30,642	7,970	1,056	1,252	10,278
	Low Hydrology		7,970	1,335	18,005	27,310
	High Demand		7,970	926	226	9,122
	Low Demand		7,970	888	-	8,858

Scenario costs (USDm)



*The low demand sensitivity for Scenario 5 was infeasible without curtailing capacity. It was assumed that the additional geothermal plant would not be installed in this case.

The key observations are as follows:

- There is a wide variation in costs between the various scenarios and sensitivities.
- Some deficit cost for the base sensitivity of all scenarios is unavoidable due to capacity and energy shortages in 2023 before candidate plants can be brought in.
- The deficit cost becomes significant under the low hydrology sensitivity as different capacity plans are able to compensate for drought conditions to varying degrees.
- The lowest investment cost is achieved when exports are considered to be non-committed in Scenario 6 as less firm energy is required and, therefore, less capacity. This scenario also presents the lowest total cost under all sensitivities assuming average hydrology conditions.
- Under low hydrology conditions, all the scenarios are significantly more expensive due to the additional deficit cost. Scenario 6 is the most expensive due to the 95,169 GWh of deficit across the study horizon. Under the low hydrology case for Scenario 5 there was only 35,496 GWh of deficit, however this would have increased to 69,263 GWh without the generation provided by fossil fuels. Without fossil fuels the total discounted (NPV) deficit cost would be 15.9 billion USD.
- Scenario 2 presents the most cost-effective expansion plan under the low hydrology sensitivity. The discounted investment cost is moderate, and the discounted operating and deficit costs are the lowest of all the scenarios under this sensitivity.

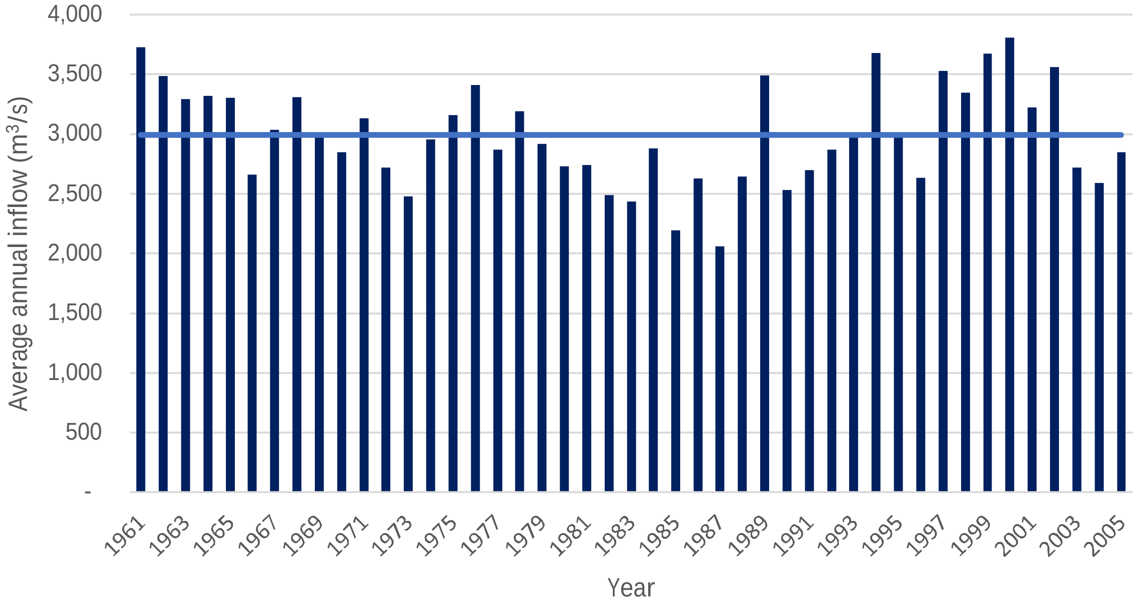
Recommended scenario

In summary:

- The least-cost scenario relies on a relatively high level of fossil fuel generation and does not achieve the desired generation diversity.
- The minimum fossil-fuel scenario has the highest cost as it relies on all hydro and geothermal candidates and maximum wind capacity in order to minimize gas turbine capacity.

- The Reference scenario is significantly more expensive than the least-cost scenario; however, it does achieve good diversity and very low levels of energy generated from fossil fuels. Under the low hydrology sensitivity, it becomes the most cost-effective scenario.

The low hydrology sensitivity models the sustained drought that occurred in the 1980s but it can be seen in the figure below that consecutive years of below average rainfall happen at least once every ten years in the historical data. It is therefore reasonable to assume that this trend will continue into the future and hydrological variation may become more difficult to predict in the future due to Climate Change.



The following factors were considered in making a recommendation for the expansion plan as follows:

- Overall cost (NPV of capital and operating costs)
- Diversity of generation and resilience under low hydrology conditions
- Minimizing the need for fossil fuel generation to minimize the system's associated emissions and total operating cost.

Based on these factors, Scenario 2 - Reference is recommended. The scenario provides generation diversity and flexible capacity that can operate cost-effectively under low hydrology conditions. The selected candidate plants are listed in Appendix B.

1 INTRODUCTION

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xiv. Tender document to implement recommendations from GMSP's SOGA exercise and Static and Dynamic Stability Studies performed by CESI.
xv. Knowledge Transfer
xvi. Environmental Impact Study

This Generation Planning Report covers several aspects as follows:

- Section 2 – Methodology: Describes the approach taken on this aspect of the assignment.
- Section 3 – Generation resources: Includes a description of each generation resource type considered in developing the expansion plan and their associated costs.
- Section 4 – Development of scenarios: Describes the development of the various scenarios considered in the analysis.
- Section 5 – Generation expansion plan: Provides details of the generation expansion plans developed for each scenario.
- Section 6 – Operational aspects: An assessment of the critical operational aspects of the generation expansion plan, including operational reserves.
- Section 7 – Conclusions

2 METHODOLOGY

2.1 GENERAL

This report describes the generation planning carried out for the period up to 2045 as part of the Ethiopian Power System Expansion Master Plan Study. It is based on the demand forecast, which is described in a separate report [Volume I Report]. Figure 2-1 shows the overall study approach and indicates how the generation expansion plan fits into this approach.

Figure 2-1 – Overall approach to the study

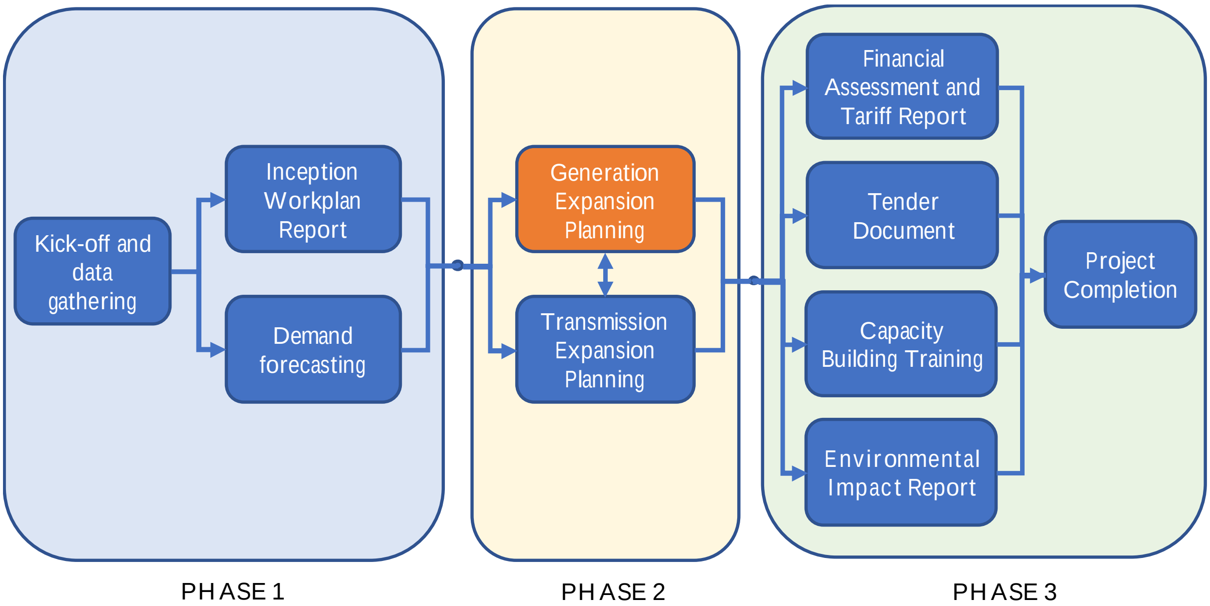


Figure 2-2 illustrates the overall planning process in developing a generation expansion plan. Each of the steps in the process is briefly described below.

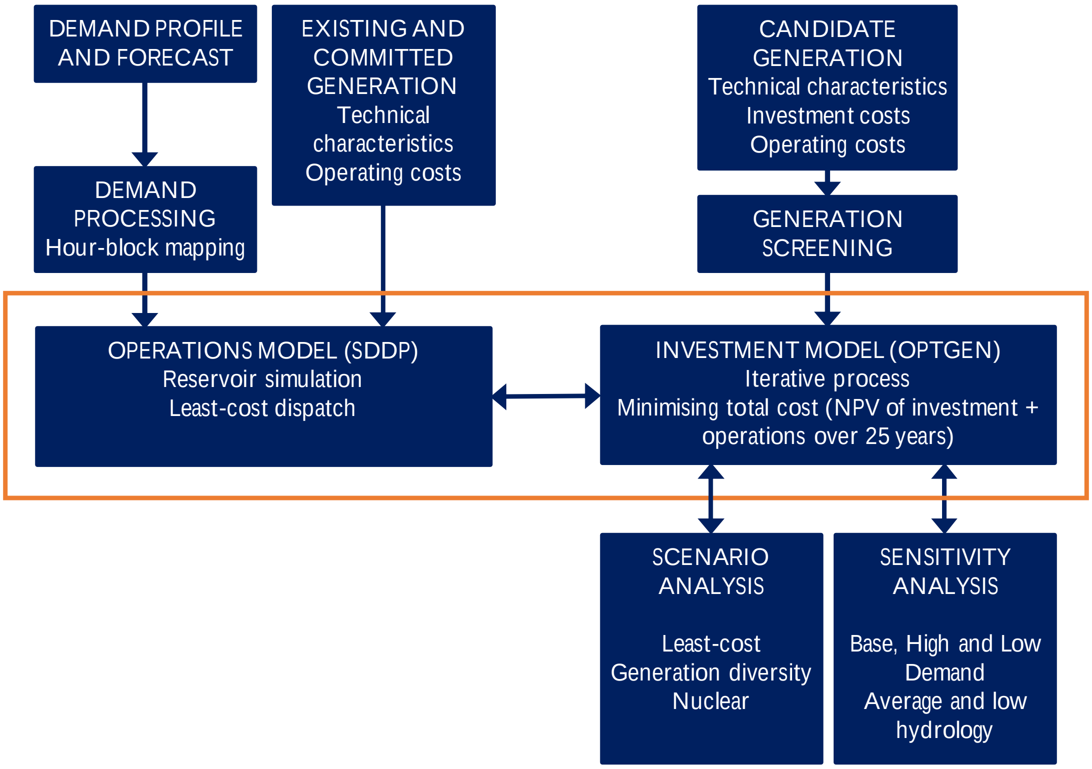
2.2 DEMAND PROFILE AND FORECAST

A key input for the generation planning process is the demand data, including both the demand profile and the demand forecast. The demand profile was derived from the hourly sent-out generation data for 2019 obtained from the National Grid Control Centre (NGCC).

The demand forecast formed the subject of a separate report [Volume I Report]. It included a Base, High and Low Case forecast for the 25-year planning period and identified the various customer categories, including exports.

Due to the complexity of the optimization problem, it is necessary to process the hourly demand profile. The demand profile and forecast were combined into an hourly 25-year profile (25 x 8,760 hours) and then processed using an hour-block mapping technique. The demand in each month was arranged as a load duration curve and then split into blocks, each with a different load level. The resultant forecast applied in SDDP and OPTGEN comprised five load blocks for each month over the 25 years. This approach results in a reasonable compromise between granularity and processing time.

Figure 2-2 – The generation planning approach



2.3 EXISTING AND COMMITTED GENERATION

The existing and committed generating plants' technical characteristics and operating costs provide direct input to the SDDP model. These characteristics and costs are described in the next section of this report. The data requirements and format depend on the type of generation:

- In the case of hydro generation, the SDDP model includes reservoir characteristics and inflow data in addition to the hydropower plant data.
- Renewable (wind, solar) plant output is based on an annual resource profile at the plant location, derived from an external geo-referenced database (Time-Series Lab) that interfaces with SDDP. Due to the seasonal operation of the sugar factory plants and their fuel source, these are also treated as renewable plants with an annual resource profile.
- Thermal plants require a fuel type and associated fuel cost in addition to the usual technical and operational characteristics and operating costs.

2.4 CANDIDATE GENERATION

Candidate generating plants are included in the OPTGEN model. Depending on requirements, these may be selected as part of the least-cost expansion plan. The key parameters, in this case, are technical (as in the case of the existing and committed plants) and costs. The costs, in this case, include both investment costs and operating costs.

2.5 GENERATION SCREENING

The results of this analysis indicate the ranking of potential generation options. Screening analysis also identifies the markedly inferior and superior alternatives and the economic range of service, whether peaking, mid-range, or baseload, that the resource option would be expected to serve over its life.

The limitation of screening analysis is that the calculations ignore the interaction between the candidate resources and the rest of the system. Due to this shortcoming, the analysis was used only to rank generation options and eliminate clearly uneconomical options, thereby informing the development of the considered scenarios.

It is also helpful to consider the required total firm generation capacity (MW) and annual generation (GWh) by the end of the planning horizon. These values indicate the type and quantity of candidate capacity required in addition to the existing and committed plants.

2.6 OPERATIONS AND INVESTMENT PLANNING MODELS

2.6.1 GENERAL

Hydro-dominated power systems, such as Ethiopia, present particular challenges in modeling and analysis, primarily due to the complexity of modeling hydro reservoirs and the relationship between water flow and power generation while also optimizing the use of reservoir storage. Two inter-related software tools that are particularly suited for modeling complex hydro-dominated systems were applied to develop the generation expansion plan: SDDP and OPTGEN.

2.6.2 OPERATIONS MODEL

SDDP allows a detailed model of hydro reservoirs and hydropower plants based on inflows, reservoir characteristics, cascade systems, turbined and non-turbined outflow, operating costs, etc. The critical operational characteristics of thermal and renewable plants, including operating costs, are also included within the SDDP model.

Generation is committed and dispatched based upon the variable operations and maintenance costs and fuel costs. Fixed costs are not included in the least-cost dispatch decision as they are incurred whether or not a plant is dispatched.

Wind, solar and geothermal generation are assumed to be must-take resources. The incremental costs per MWh of these resources are low and assumed to be zero. Power purchase agreement (PPA) based prices for these resources can be added in a post-modeling calculation to estimate total payments to generators but does not affect the dispatch decision.

Hydropower plants would similarly have effectively zero variable operating costs. They would generally be dispatched to minimize spill from reservoirs or aim to maintain reservoirs equally full. The merit order for hydro plants would typically be run-of-river plants followed by plants with storage reservoirs. Those with reservoirs would normally be dispatched based on head, i.e., those with the highest head ($MW/m^3/s$) would be dispatched first as this would minimize water usage.

2.6.3 INVESTMENT PLANNING MODEL

While SDDP is used to simulate system operation, the role of OPTGEN is to determine the least-cost expansion plan over the planning horizon. OPTGEN extracts the database of existing and committed power plants from SDDP and then determines the additional candidate generation capacity and type required to meet the demand while minimizing the combined cost of investment and operations.

Within OPTGEN, it is possible to define firm capacity and energy requirements as a proportion of the annual demand. It is also possible to define the cost of unserved energy with OPTGEN. The optimization then considers this cost within the cost minimization, i.e., the model may choose to allow some unserved energy in specific years if this results in a lower cost than installing more capacity.

The objective function involves minimizing the combined net present value (NPV) of investment costs, operating costs, and cost of unserved energy over the 25 years based on a specified discount rate (10%).

New generation addition decisions are based on economics. Production simulation and optimization programs build the least-cost plan by adding new generating resources when they are economical. New generating resources become economical when their benefits exceed their costs, including their investment and operating costs. The model evaluates many combinations of available resource additions during this process and selects the type, quantity, and schedule that produce the lowest discounted cost over the study horizon.

Load and generation in power systems must always remain in balance during real-time operations. When there is not enough available generation, load must be shed. The cost of unserved energy (CoUE) is a measure of the economic impact of not meeting electricity demand. In other words, the CoUE refers to the costs that a potential consumer incurs when electricity is not available and that he would avoid if electricity were available. This economic impact comes from interruptions to industrial output, commercial activity, residential services, and public safety. Some interruptions are incredibly costly, for example, when a product is lost due to loss of power at an industrial plant. Others are more matters of inconvenience. Some are inherently difficult to quantify but possibly large, for example, the reduction in public safety due to loss of emergency services and increased frustrations with the lack of electricity. A CoUE of USD 1/kWh is assumed.

2.7 SCENARIOS AND SENSITIVITIES

Apart from a least-cost plan, several scenarios were considered in the expansion planning process to assess the impact of certain constraints, including:

- Diversity: aiming for maximum hydro generation of 75% from 2030 onwards
- Minimizing fossil-fuel based generation
- Introduction of nuclear generation
- Increased geothermal generation

The above analysis focused on the Base Case demand forecast and the average hydrology condition; however, sensitivities were also considered as follows:

- Hydrological sensitivity: Low hydrology case
- Demand sensitivity: High and Low Case demand forecasts

3 GENERATION RESOURCES

3.1 GENERAL

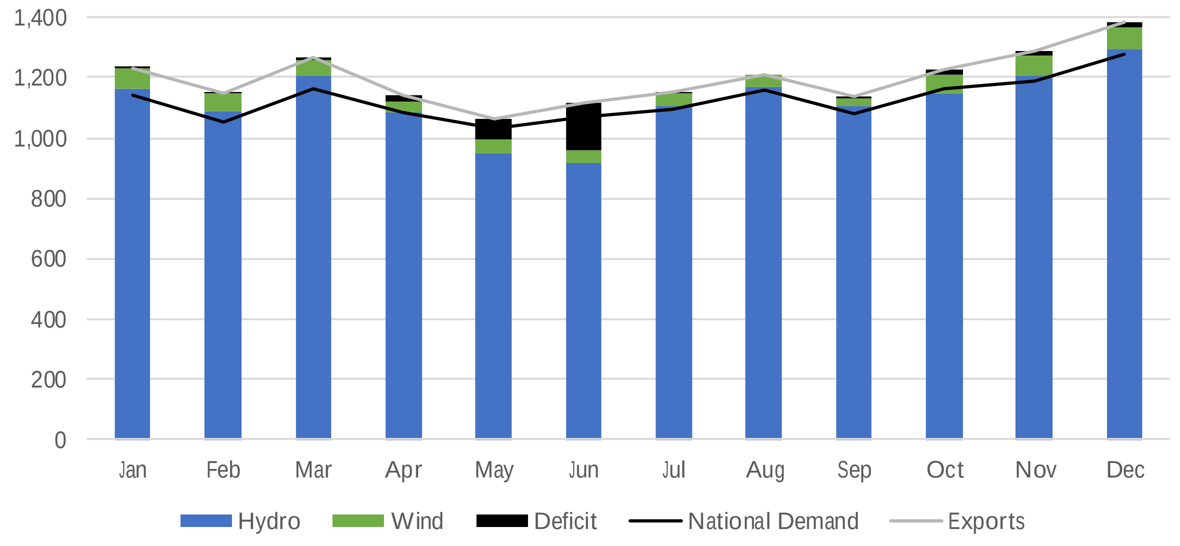
This section of the report describes the existing and planned generation plants, identifying the resources, critical technical characteristics, limitations, and costs to be applied in the development of a generation expansion plan. The details described in this section were discussed and agreed with the Technical Working Group during the study.

The information is arranged by generating plant technology and distinguishes between the various plants' statuses, i.e., existing, committed, and planned. Committed projects are those which are either under construction or for which signed contracts are in place. Committed projects are therefore assumed to enter operation on an estimated commercial operation date (COD) based on their construction schedule.

3.2 HYDRO

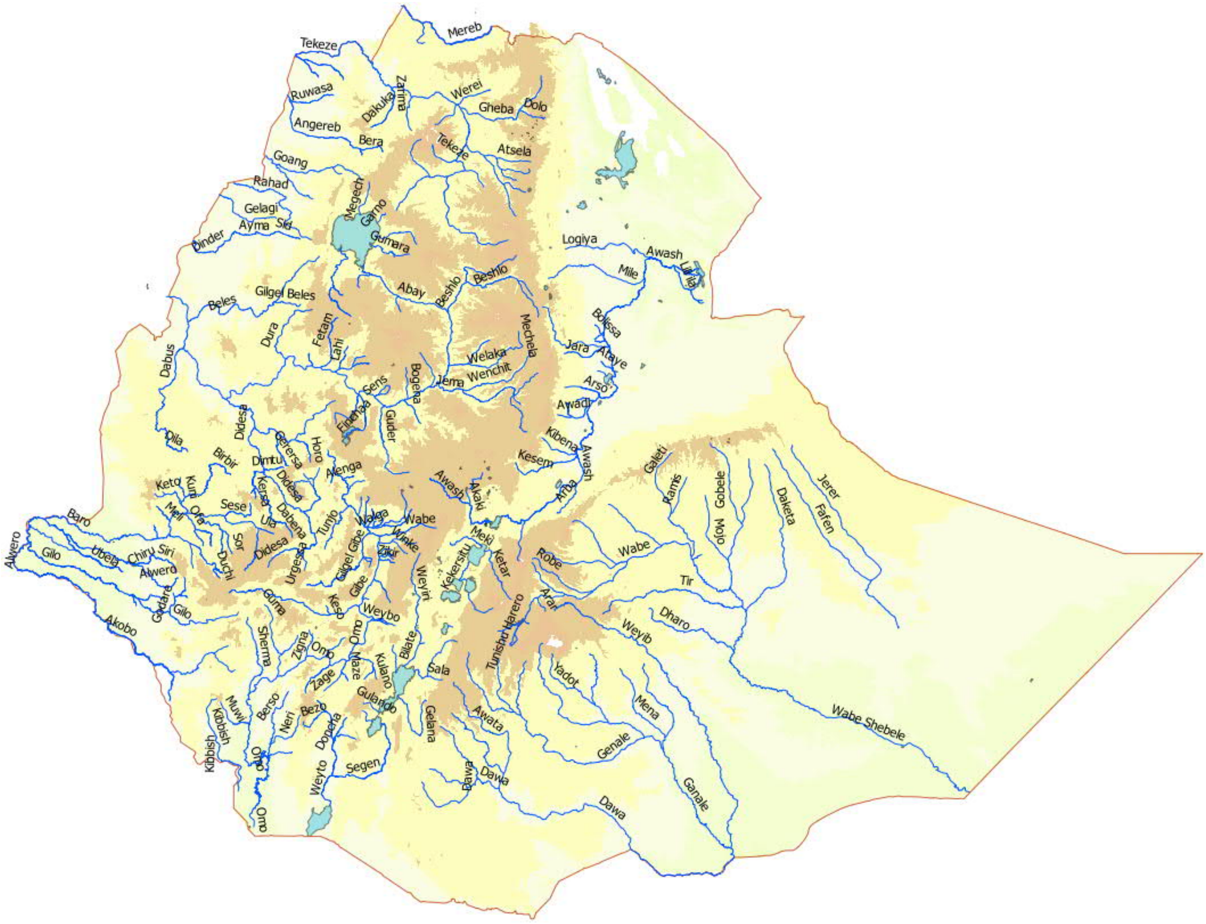
Approximately 95% of generated energy in Ethiopia is in the form of hydropower, which makes the system vulnerable to low hydrological conditions leading to load shedding. Figure 3-1 shows the load-shedding that occurred in 2019 due to low hydrological conditions.

Figure 3-1: Generation mix – 2019 (GWh)



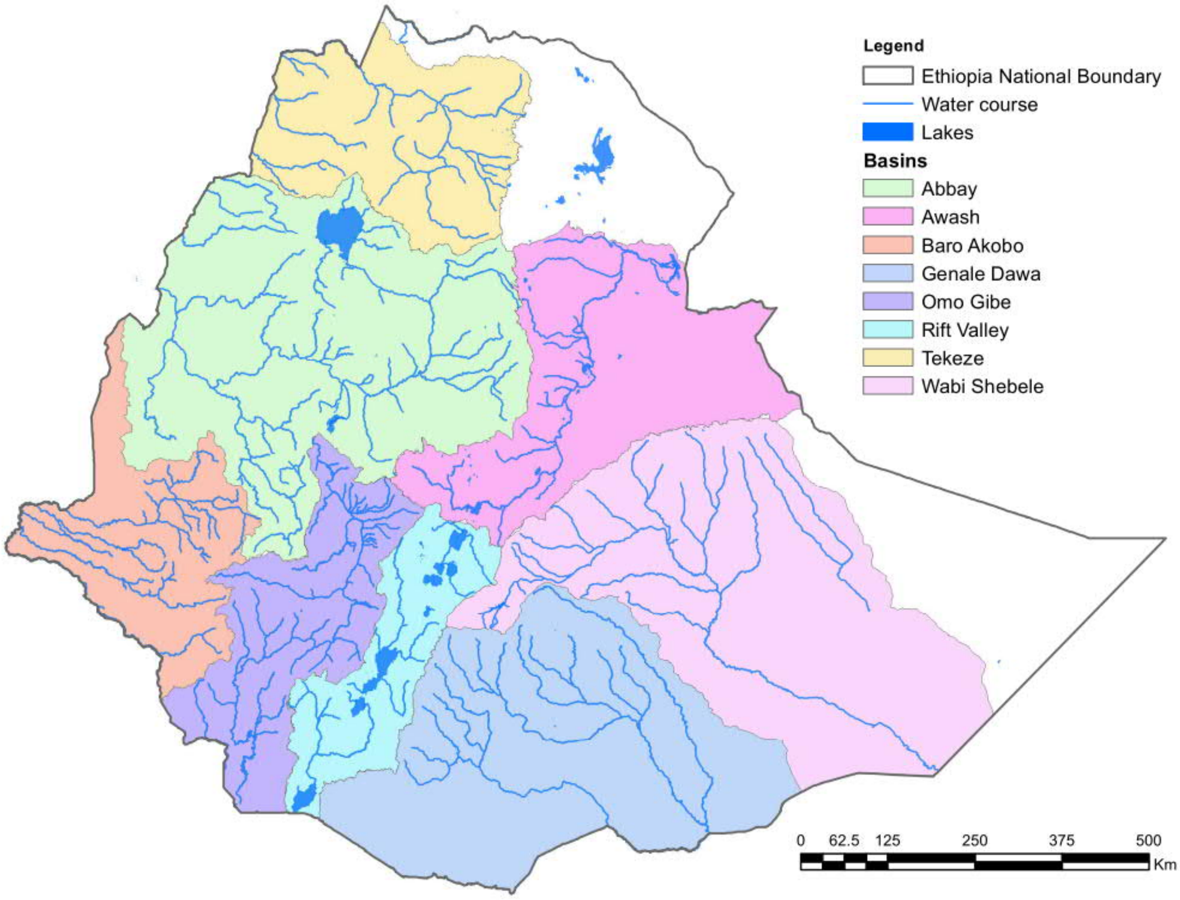
Ethiopia is a country with a very high hydropower potential and aims to be a powerhouse of Africa exporting electricity to its neighbors. Figure 3-2 traces the complex network of waterways that weave across the country.

Figure 3-2: Rivers in Ethiopia



Ethiopia can be divided into eight large river basins as depicted in Figure 3-3, seven of which are named after the main river that crosses the basin. The basins are: Abbay river (Blue Nile), Awash river, Genale river, Wabi Shebele river, Baro Akobo river, Tekeze river, Omo Gibe river and Rift Valley.

Figure 3-3: River basins in Ethiopia



3.2.1 EXISTING AND COMMITTED HYDRO PLANTS

The installed hydropower capacity by the end of 2020 was 4077 MW from 14 plants (including Genale Dawa III, which was commissioned during 2020 and was fully operational by early 2021). Several of the plants, however, have significantly reduced available capacity, and the total available turbine capacity by the end of 2020 was 3690 MW, as indicated in Table 3-1. The production coefficient (MW/m3/s) of a hydropower plant is affected by reservoir level, and, therefore, the effective capacity will be less than the indicated available capacity during low reservoir conditions. Hydro-dominated power systems are generally energy constrained rather than capacity constrained and are highly dependent on hydrological conditions.[2] The energy constraints of the hydro plants are considered later in this section.

[2] Therefore, despite a reserve capacity margin of around 25%, due to low hydrological conditions, there was insufficient energy to meet the demand in 2019 resulting in the need for load shedding.

Table 3-1: Characteristics of existing and under construction hydro plants

No.	HPP Name	Status	COD (Earliest year for candidates)	Reservoir /Run-of-River	Installed capacity (MW)	Max available capacity (MW)	Average production coefficient (MW/m3/s)	Max outflow (m^3/s)	Min storage (Hm^3)	Max storage (Hm^3)
1	Koka	Existing	1960	Reservoir	43	17	0.356	120.79	17	1185
2	Awash II	Existing	1966	Run-of-river	32	16	0.5383	59.45		
3	Awash III	Existing	1971	Run-of-river	32	16	0.5415	59.1		
4	Finchaa	Existing	1973	Reservoir	128	128	4.8225	26.54	332	1120
5	Melka Wakana	Existing	1988/2014	Reservoir	153	90	2.7109	56.44	160	760
6	Tis Abey II	Existing	2001	Reservoir	72	12	0.4224	160.98	9.5	10
7	Gibe I	Existing	2004	Reservoir	210	184	2.0158	104.18	89	807
8	Tekeze I	Existing	2009	Reservoir	300	120	1.395	215.05	4004	10958
9	Beles	Existing	2010	Reservoir	460	460	2.8971	158.78	22958	32088
10	Gibe II	Existing	2010	Run-of-river	420	420	4.2857	98		
11	Neshe	Existing	2013	Reservoir	97	97	5.0927	19.24	43	196
12	Gibe III	Existing	2015	Reservoir	1,870	1,870	1.8135	1031.16	2467	13300
13	Aba Samuel	Existing	2010	Run-of-river	6	6				
14	Genale Dawa III	Existing	2021	Reservoir	254	254	2.2618	112.3	800	2000
Total existing capacity					4,077	3,690				
15	Renaissance	Committed	2021-2026	Reservoir	5,150	5,150	1.22	4221	11750	63350
16	Koysha (Gibe IV)	Committed	2024	Reservoir	1,800	1,800	1.45	1241	4500	6500
Total under construction capacity					6,950	6,950				
Total existing and under construction capacity					11,027	10,640				

Two large hydropower plants are under construction, as shown in Table 3-1:

Grand Ethiopian Renaissance Dam (GERD): The construction of GERD hydro power project started in 2011, and for the purposes of this study is assumed to commence production in August 2021. The plant has been designed with a capacity of 6,448 MW comprising 16 units (2x375 MW + 14 x 407 MW). However, recent information provided by the project team indicates that the plant will have a maximum capacity of 5,150 MW comprising 13 units (2x375 MW+11x400 MW). Table 3-2 shows the planned filling and production schedule for the plant. Production is assumed to commence in August 2021, with two units (U9 and U10) configured to operate at a reduced head. Production is scheduled to increase progressively as the reservoir is filled over the period to 2026. A maximum of 11 units are expected to be operational by 2024 and 13 units by 2026. Annual average energy production of 15,233 GWh is expected by 2027, resulting in an average annual plant factor of around 34%.

Koysha (Gibe IV): Koysha is under construction and is scheduled to commence production in 2024, increasing to a full capacity of 6x300 MW (1,800 MW) by 2026, as shown in Table 3-3. An average annual production of 6,450 GWh is expected. The original capacity was 6x270 MW, 6460 GWh/Year, with a plant factor of 34%. Then it has been optimized to become 6x300 MW, and the energy reduced by 1.8%, resulting in an annual average plant factor of approximately 40%.

Once GERD and Koysha are fully operational, the installed hydro capacity will be 11,027 MW, with an available hydro capacity of 10,640 MW.

Table 3-2: GERD filling and production schedule

Year	Expected reservoir levels (masl)	Available units	Expected Peak Capacity (MW)	Expected Annual Energy Generation (GWh)
2021	595	2x375 MW	238	231
2022	608	2x375 MW	600	3,452
2023	617	2x 375 MW	600	4,835
2024	625	2x375 + 9x400 MW	4350	13,179
2025	632	2x375 + 9x400 MW	4350	11,315
2026	640	2x375 + 11x400 MW	5150	14,157
2027	640	2x375 + 11x400 MW	5150	15,233
2028	640	2x375 + 11x400 MW	5150	15,233

Table 3-3: Koysha filling and production schedule

Year	Expected Reservoir Level (%)	Available units	Expected Peak Capacity (MW)	Expected Annual Generation (GWh)
2024	80%	2x300 MW	300	804
2025	100%	2x300 MW	600	1,608
2026	100%	6x300 MW	1,800	6,450
2027	100%	6x300 MW	1,800	6,450

3.2.2 CANDIDATE HYDRO PLANTS

Discussions were held with EEP to agree on the candidate hydro power projects to be considered in the study. As shown in Table 3-4, 23 projects were identified with a total installed capacity of 11,213.4 MW. Based on a typical construction schedule of 6 years, 2028 was considered the earliest commissioning date for any of the projects.

Some of the hydro projects are linked and are assumed to be developed in sequence. The linked projects are as follows:

- Baro 1 and 2 and Genji
- Geba 1 and 2
- Werabesa and Halele
- Chemoga Yeda 1 and 2

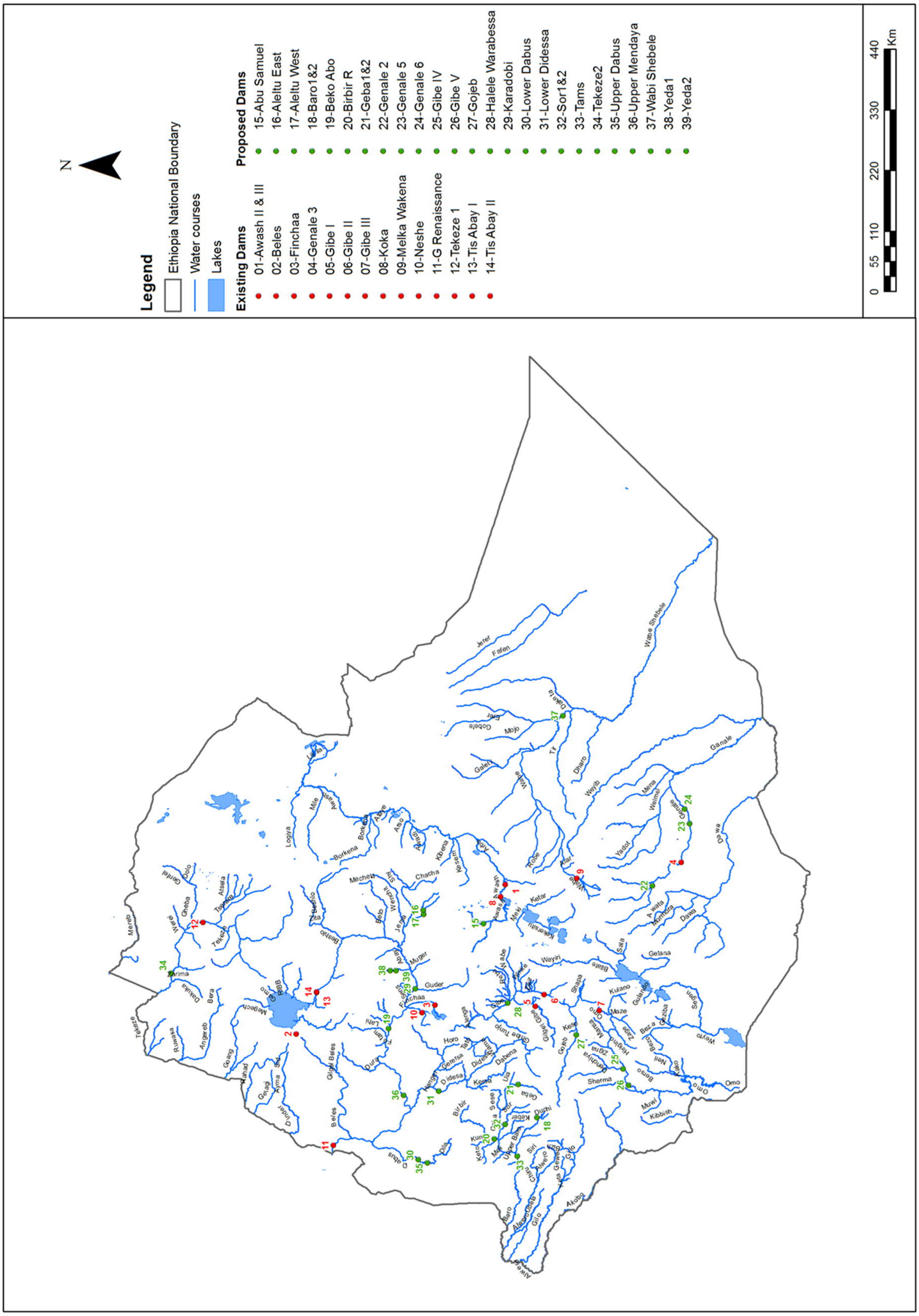
Tams hydropower project is downstream of Baro, Genji, and Birbir projects and should only be developed after the upstream projects have been developed. A development sequence has also been assumed for Karadobi, Beko Abo, and Upper Mendaya. Beko Abo has been set to commission at least one year after Karadobi and Upper Mendaya two years after Karadobi to allow filling time for the Karadobi reservoir.

Table 3-4: Candidate hydropower projects

No.	HPP Name	Status	COD (Earliest year for candidates)	Reservoir /Run-of-River	Installed capacity (MW)	Max available capacity (MW)	Average production coefficient (MW/m^3/s)	Max outflow (m^3/s)	Min storage (Hm^3)	Max storage (Hm^3)
1	Halele	Candidate	2028	Reservoir	96	96	0.7333	130.92	510	6071
2	Geba I	Candidate	2028	Reservoir	215	215	3.7094	57.69	100	1150
3	Genale VI	Candidate	2028	Reservoir	246	246	2.0242	121.53	0	210
4	Upper Dabus	Candidate	2028	Reservoir	304	304	1.292	235.29	731	2470
5	Birbir	Candidate	2028	Reservoir	467	467	3.0689	152.17	180	2670
6	Werabesa (linked with	Candidate	2028	Reservoir	340	340	2.4035	141.46	46	184
7	Geba II (linked with	Candidate	2028	Reservoir	157	157	1.8379	85.42	2535	4220
8	Genale V	Candidate	2028	Reservoir	100	100	0.5988	167	0	138
9	Yeda I	Candidate	2028	Reservoir	162	162	6.6677	24.3	120	360
10	Yeda II (linked with	Candidate	2028	Run-of-river	118	118	4.879	24.19		
11	Baro I & II	Candidate	2028	Reservoir	680	680	9.1202	97.26	344	1337
12	Lower Dabus	Candidate	2028	Reservoir	494	494	1.9955	247.55	35	53
13	Wabi Shebele	Candidate	2028	Reservoir	87	87	0.87367	99.58	348	3681
14	Genji (linked with Baro I &	Candidate	2028	Reservoir	214	214	6.79365	31.5	0	5
15	Tams	Candidate	2028	Reservoir	2,000	2,000	1.909	890.52	5543	10350
16	Tekeze II	Candidate	2028	Reservoir	450	450	1.6216	277.5	2580	9210
17	Karadobi	Candidate	2028	Reservoir	1,600	1,600	2	800	23200	41931
18	Beko Abo	Candidate	2028	Reservoir	935	935	1.02974	908	800	2035
19	Upper Mendaya	Candidate	2028	Reservoir	1,700	1,700	1.32605	1282	17340	27655
20	Dedesa	Candidate	2028	Reservoir	301	301	0.5074	593.22	0	9000
21	Gojeb	Candidate	2028	Reservoir	150	150	1.00980	148.55	169	1290
22	Birbir A	Candidate	2028	Reservoir	97.4	97.4	3.0689	152.17	69	1615
23	Wabi	Candidate	2028	Reservoir	300	300	3.2	45.23	141.2	791
Total candidate capacity					11,213.4	11,213.4				

The location of all the existing, committed, and candidate hydro plants and the river systems are shown in Figure 3-4.

Figure 3-4: Map of existing and potential hydroelectric developments



3.2.2.1 CANDIDATE HYDROPOWER PLANT CAPITAL COSTS

Candidate hydropower plants were previously identified during the 2014 Ethiopian Power System Expansion Master Plan Study, for which their costs were updated from their respective base years and currencies to 2012 USD. An EPC delivery method was assumed, considering the following fixed percentages:

- Engineering and supervision: 8%
- Contractor's overheads, development costs and margins: 20%
- Owner's administration and costs: 3%

It is recognized that the cost estimates of the various hydro projects will change further as feasibility studies are updated and some projects may not proceed due to non-financial considerations such as social and environmental impact. These updates can be incorporated when the analysis is updated in the future. However, for the purposes of the present update to the Master Plan, the derived 2012 costs from the previous study were updated to 2020 USD using the United States Bureau of Reclamation (USBR) Construction Cost Trends. As the USBR publishes the trends quarterly, it was assumed that the base costs were for the end of Q2 2012. The most recent published trend data is for the end of Q2 2020. Appendix A provides the published data. Both the indices for electromechanical equipment and the composite trend were used for the purposes of updating costs, and a 33:67 distribution of these was assumed for each project, yielding the following conversion equation:

$$Cost_{2020} = Cost_{base}\left[0.33\frac{I_{EM2020}}{I_{EMbase}} + 0.67\frac{I_{C2020}}{I_{Cbase}}\right]$$

Where,

- $Cost_{base}$ is the cost of the base year of the project, assumed to be at the end of Q2 2012.
- I_{EM2020} is the published index for electromechanical equipment at the end of Q2 2020 equal to 396.
- I_{EMbase} is the published index for electromechanical equipment at the end of Q2 2012 equal to 349.
- I_{C2020} is the published composite index at the end of Q2 2020 equal to 426.
- I_{Cbase} is the published composite index at the end of Q2 2012 equal to 367.

Table 3-5 presents the updated costs for candidate hydropower plants. These costs exclude the cost of interest during construction which is covered later in this report.

Table 3-5: Updated costs of candidate hydropower plants

Hydropower plant	Original pricing year	Original currency	Adjusted cost (2012 MUSD)	Updated cost (2020 MUSD)	Updated cost (2020 MUSD/MW)
Beko Abo	2010	MUSD	$1,261	$1,453	$1.55
Karadobi	2005	MUSD	$2,576	$2,968	$1.86
Lower Didessa	2001	MUSD	$619	$713	$2.37
Upper Dabus	2002	MUSD	$628	$422	$1.39
Lower Dabus	2002	MUSD	$866	$337.3	$0.68
Genale 6	2009	MUSD	$588	$677	$2.75
Gibe V	2008	M€	$1,037	$1,195	$1.98
Upper Mendaya	2007	MUSD	$2,436	$2,807	$1.65
Yeda 1	2006	MUSD	$366	$422	$2.60
Yeda 2	2006	MUSD	$174	$201	$1.70
Gojeb	1996	MUSD	$527	$607	$4.05
Werabesa	2005	MUSD	$375	$432	$1.27
Geba 1	2005	MUSD	$405	$467	$2.17

Hydropower plant	Original pricing year	Original currency	Adjusted cost (2012 MUSD)	Updated cost (2020 MUSD)	Updated cost (2020 MUSD/MW)
Geba 2	2005	MUSD	$167	$192	$1.22
Halele	2000	MUSD	$511	$589	$6.14
Birbir R	2001	MUSD	$1,231	$481.7	$1.03
Wabi Shebele	2004	MUSD	$888	$1,023	$11.76
Genale 5	2004	MUSD	$298	$343	$3.43
Tams	1996	MUSD	$5,815	$2,651.4	$1.33
Baro 1	2005	MUSD	$1,095	$486.9	$2.86
Baro 2	2005	MUSD	$501	$350.4	$0.68
Genji	2005	MUSD	$198	$228	$1.07
Tekeze II	2012	MUSD	$1,690	$1,948	$4.33
Wabi	N/A	N/A	N/A	$680	$2.27
Birbir A	N/A	N/A	N/A	$170	$1.74

3.2.3 HYDROLOGY

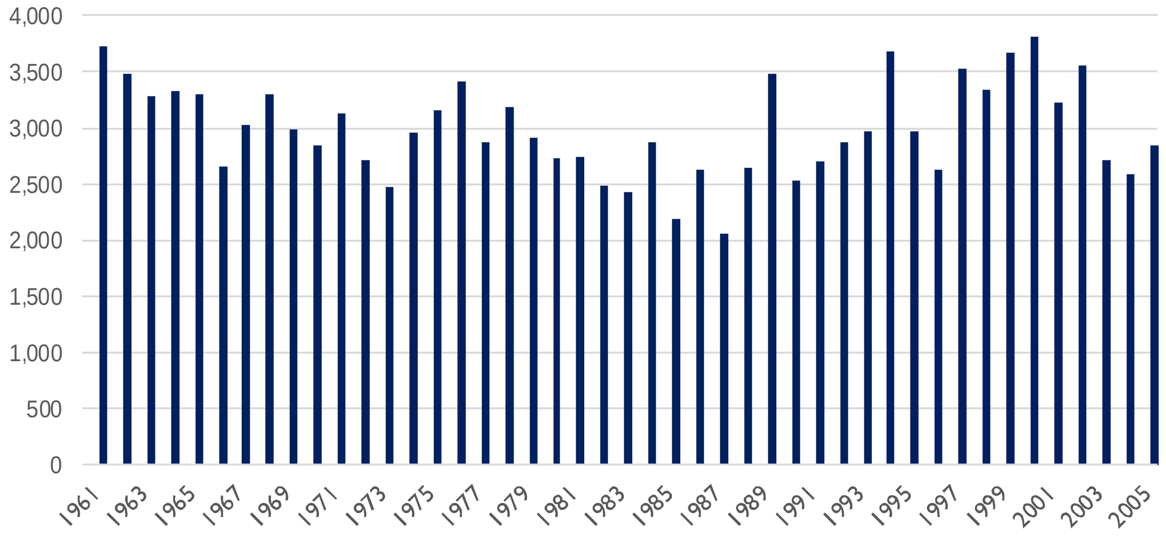
Hydrological data included:

- Flow time series for inflow to various reservoirs and hydropower plants,
- Evaporation and rainfall data at the reservoirs,
- Irrigation and other data for water abstraction from the reservoirs and
- Configuration of the hydropower plants and reservoirs.

3.2.3.1 INFLOW DATA

Inflow time series are required for the reservoirs and hydropower plants that are modeled in SDDP. These were derived from monthly inflow records from 1961 to 2005. Figure 3-5 shows the wide range of average annual inflow over this period. The variation illustrates the importance of maintaining sufficient energy margin on hydro-dominant systems to allow for periods of low hydrological conditions.

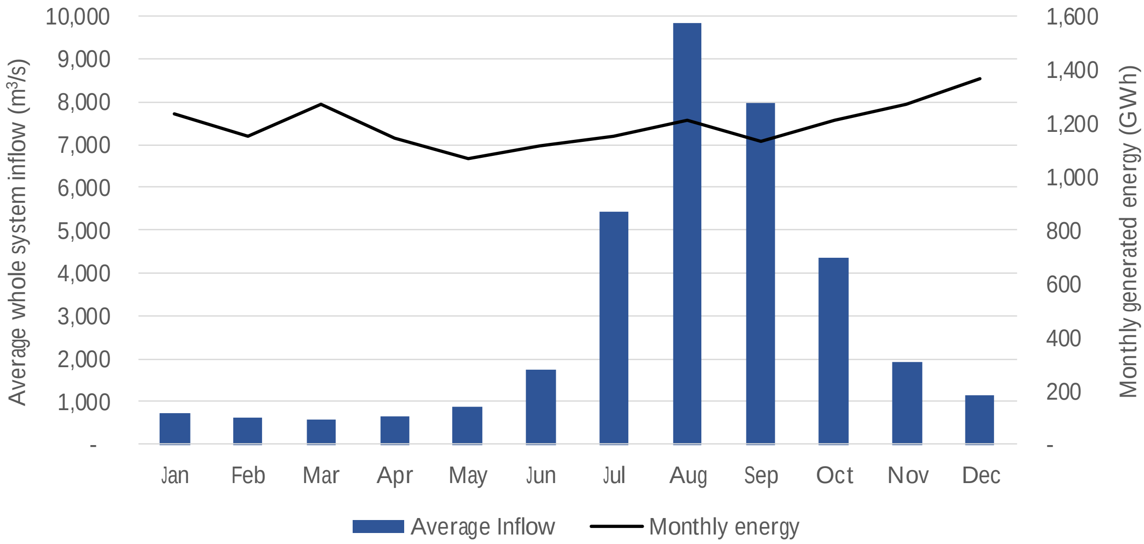
Figure 3-5: Historical average annual inflows (m^3/s)



In the case of reservoirs with upstream reservoirs or hydropower plants, the inflow data is in the form of incremental inflows, i.e., in the model, the upstream outflow is added to the incremental inflow to obtain the total inflow to the downstream reservoir in each case. This incremental time-series only accounts for the natural rainfall-runoff collected by the local catchment between the reservoirs/hydropower plant immediately upstream and the reservoir/hydropower plant to which this incremental flow applies. The monthly incremental inflow data applied in the model is included in Appendix A.

The inflow is extremely unevenly spread throughout the year, with over 85% occurring during the rainy season from June to November. The inflow distribution is illustrated in Figure 3-6, which also shows the monthly energy consumption in 2019. The relatively constant nature of the energy consumption from month to month illustrates the importance of the reservoirs to provide sufficient storage.

Figure 3-6: Average monthly inflow and monthly energy consumption in 2019



3.2.3.2 EVAPORATION DATA

Evaporation rates were applied to estimate the water loss in reservoirs due to evaporation. The Penman formula was used to estimate evaporation rates from the elevation, latitude, and daily maximum and minimum temperatures.

The calculations and evaporation rates adopted are presented in Appendix A.

3.2.3.3 IRRIGATION DATA

EEP provided irrigation data to the extent that it impacts the operation of the hydropower schemes in terms of minimum monthly water releases. The data included monthly demand from Koka Dam for downstream irrigation at Wonji and sugar factory demand downstream of Finchaa and Neshe reservoirs, as shown in Appendix A.

3.2.4 HYDRO CONFIGURATION

The hydro plants and associated reservoirs were represented in SDDP in their various cascade systems, as shown in Figure 3-7 and Figure 3-9.

Figure 3-7: Configuration of Renaissance cascade

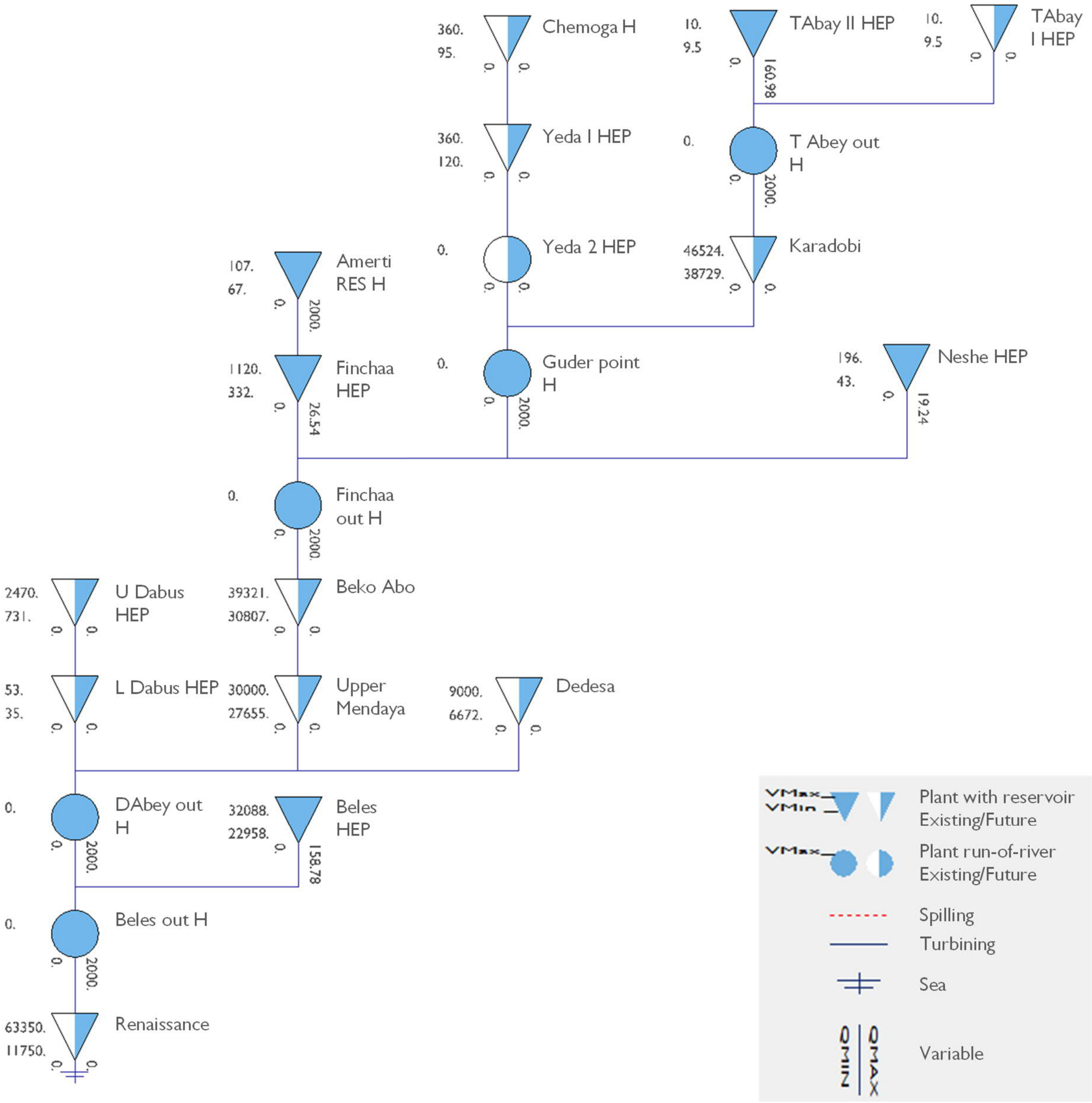


Figure 3-8: Configuration of Genale, Tams, Tekeze, Melka Wakena and Lake Koka cascades

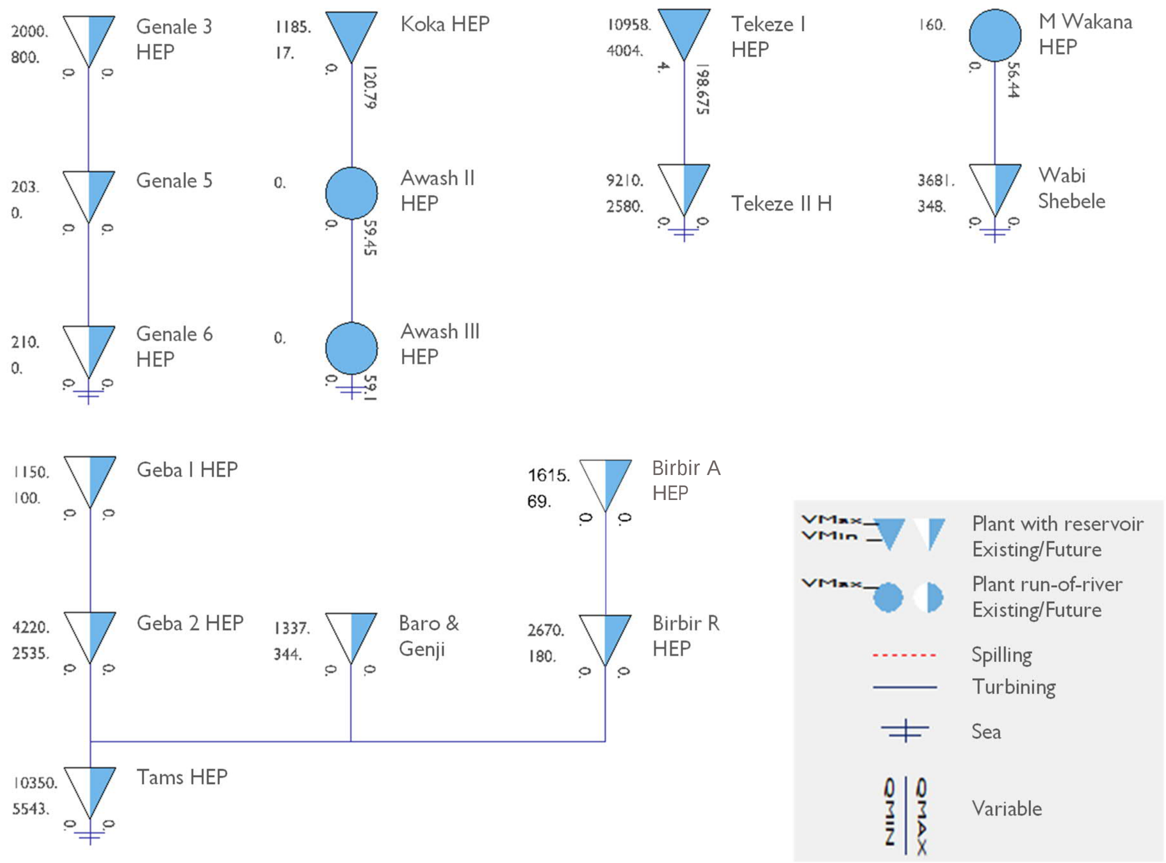
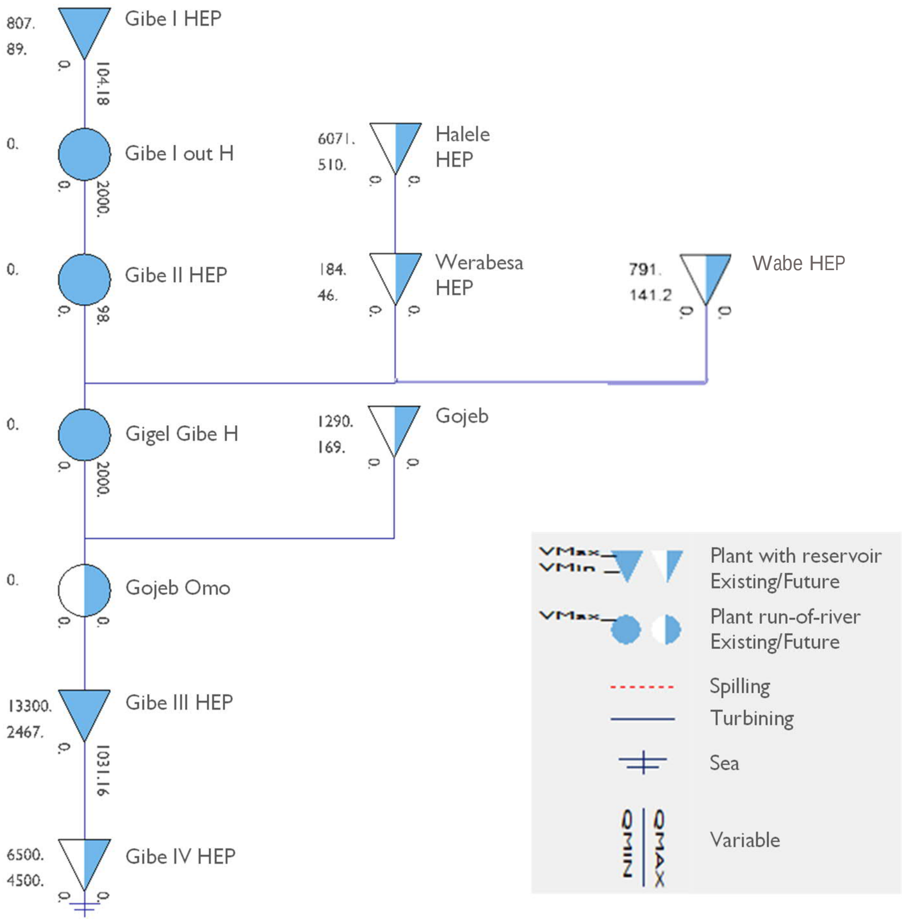


Figure 3-9: Configuration of Gibe cascade



3.3 GEOTHERMAL

3.3.1 EXISTING AND COMMITTED GEOTHERMAL PLANTS

The existing and committed geothermal plants in Ethiopia have a combined installed capacity of 380 MW, as shown in Table 3-6.

Ethiopia has significant geothermal potential, especially along the Ethiopian Rift system. There currently exists one 7.3 MW geothermal power plant (Aluto Langano), which is located in one of the richest geothermal areas of the country. The plant was commissioned in 1999 as a pilot project. There are eight wells drilled to a maximum depth of 2500 m (mid1980-2014), out of which four are responsible for the 7.3 MW production. The maximum reservoir temperature encountered in the productive wells is about 350ºC. It is currently under rehabilitation and is due to re-enter service in 2023 with an installed capacity of 9.5 MW and a peak output of 7.3 MW.

However, a project is currently underway to upgrade this facility to 70 MW, with the support of the World Bank and Japan International Cooperation Agency (JICA).

Aluto Langano II project, with an installed capacity of 70 MW, is under development with the support of the World Bank and Japan International Cooperation Agency, JICA. Surface exploration has been underway, and the drilling of 22 wells is also in the early stages of equipment procurement. It will be owned by EEP and is planned to be operational by 2026.

The other committed geothermal projects are Corbetti I and II and Tulu Moye I and II. Signed agreements are in place for these projects to be developed as independent power projects (IPPs) with installed capacities and commercial operation dates (CODs) from 2023 to 2026, as shown in Table 3-6.

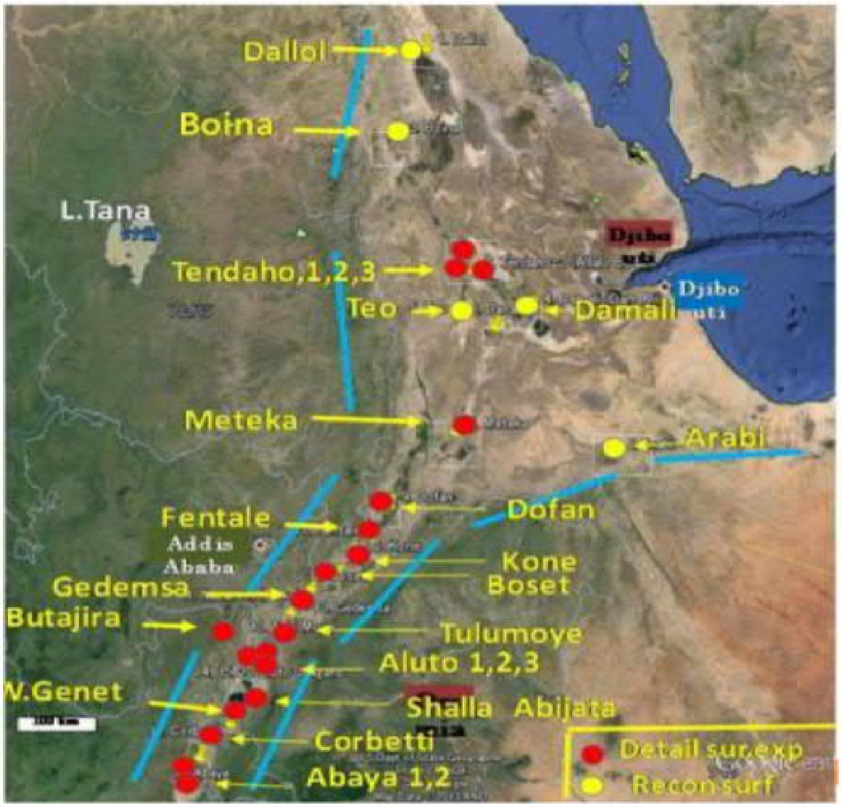
Power purchase agreements (PPAs) have been drafted for Corbetti I and II and Tulu Moye I and II. The tariff for Tulu Moye I and II tariff starts at 6.95 US cents/kWh. The tariff for Corbetti I starts at 7.53 US cents/kWh, while Corbetti II tariff starts at 6.95 US cents/kWh.

3.3.2 CANDIDATE GEOTHERMAL PROJECTS

The geothermal potential in Ethiopia has been estimated to be 10.8 GW (Ministry of Water, Irrigation and Energy, 2019); hence there is a considerable opportunity for deploying geothermal power plants in the country. Currently, 25 high-temperature areas are identified (Figure 3-10).

Five of them are at the surface study program stage, while at 20 sites, the detailed surface exploration is completed. Out of these 20, drilling has been conducted in three areas, and one area has a pilot plant. These 25 locations account for the estimated 10.8 GW geothermal potential[3]. Most sites, however, need significant further exploration to confirm the availability and quality of geothermal resources at specific locations.

Figure 3-10: Geothermal resource areas in Ethiopia



[3] Ministry of Water, Irrigation and Energy, 2019

A further six candidate geothermal plants with a combined capacity of 600 MW have been identified for development with the earliest implementation dates of 2026 and 2027, as shown in Table 3-6.

Table 3-6: Existing, committed, and candidate geothermal plants

Name	Status	Ownership (EEP/IPP)	N° units	$P_{inst.}$ (MW)	P_{max} (MW)	FOR (%)	Maintenance (%)	COD/Earliest date for candidates	Must-run
Aluto Langano I (Rehabilitation)	Committed	EEP	2	9.5	7.3	6%	4%	2023	yes
Aluto Langano II	Committed	EEP	2	70	70	6%	4%	2026	yes
Corbetti I	Committed	IPP	1	50	50	6%	4%	Q2 2024	yes
Corbetti II	Committed	IPP	2	100	100	6%	4%	Q2 2026	yes
Tulu Moye I	Committed	IPP	1	50	50	6%	4%	Q3 2023	yes
Tulu Moye II	Committed	IPP	2	100	100	6%	4%	Q3 2025	yes
Total existing and committed capacity				380	377				
Shashemene Geothermal	Candidate	IPP	2	150	150	6%	4%	2026	yes
Dugna Fango Geothermal	Candidate	IPP	2	100	100	6%	4%	2027	yes
Tendaho-Alalobad Geothermal	Candidate	IPP	2	100	100	6%	4%	2027	yes
Boku Geothermal	Candidate	IPP	2	100	100	6%	4%	2027	yes
Dofan Geothermal	Candidate	IPP	2	100	100	6%	4%	2027	yes
Fentale Geothermal	Candidate	IPP	1	50	50	6%	4%	2027	yes
Total existing, committed and candidate capacity				980	977				

Table 3-7 shows technical, operational, and cost characteristics used when modeling geothermal resources. The costs have been selected to result in levelized costs for the geothermal candidates similar to the PPA tariffs for the committed projects[4].

Table 3-7: Geothermal candidate costs

Capital cost ($/kW)	Plant life (years)	Fixed O&M ($/kW/yr)	Variable O&M ($/MWh)	Construction period (years)
3,330	25	88.4	8.4	5

3.4 ENERGY FROM WASTE AND BIOMASS

3.4.1 ENERGY FROM WASTE

Reppie waste to energy plant in Addis Ababa (Table 3-8) started operation in 2018 and exports up to 25 MW to the grid. According to operational records, in 2019, the plant produced 80 GWh, which is equivalent to an annual capacity factor of 37%.

Other Ethiopian cities have plans to conduct feasibility studies to assess the suitability of similar plants. However, none of these plants are developed to the point of being included as committed resources for the purpose of this study.

[4] The PPA tariffs are based on the levelised cost of energy which is derived from the capital and operating costs. In this case, as the PPA tariff and duration were known, it was possible to estimate corresponding capital and operating costs.

The main benefit of energy from waste plants is waste disposal, with electricity production providing a secondary benefit stream. Furthermore, energy from waste plants are generally relatively small scale compared with the other candidate generation types and not competitive purely as generation candidates. For these reasons, further energy from waste plants have not been considered in this study.

3.4.2 BIOMASS

Ethiopia's biomass resources include residues from agriculture, harvests from forests, crop residue, energy crops, animal manure, and residues from agro-industrial and food processes. Availability of resources and cost competitiveness with other types of projects need further site-specific analysis.

3.4.3 SUGAR FACTORIES

Electricity generation from bagasse is increasing and could have an important role in sugarcane-producing countries such as Ethiopia. Ethiopia has a committed schedule for developing sugar factories that burn bagasse at co-generation plants to produce steam and electricity. Bagasse is a fibrous residue remaining after sugarcane or sorghum stalks are crushed. Sugarcane has one crop per year from mid-October to June, and during this period, the co-generation plants are able to generate electricity. The electricity is used for sugar factory internal consumption, irrigation, and village use around the factory, and the surplus of electricity is exported to the grid. This supply of electricity to the grid has been included as a generation source from October to May.

The sugar factory plants which are considered committed are listed in Table 3-8. These are due to commence operation from 2022 – 2026. They will have a total installed capacity of 317 MW and export a total of 121 MW to the grid (from October to June).

Table 3-8: Existing EfW and committed biomass plants

Power Station Name	Fuel type	Status	Ownership (EEP/IPP)	Pinst. (MW)	Pmax (MW)	COD
Reppie EfW	Waste	Existing		25	25	2017
Beles 1	Sugar	Committed	IPP	20	15	2022
Beles 2	Sugar	Committed	IPP	20	10	2024
Beles 3	Sugar	Committed	IPP	20	10	2025
Wolkayit	Sugar	Committed	IPP	82	30	2023
Omo Kuraz 1	Sugar	Committed	IPP	37	15	2024
Omo Kuraz 2	Sugar	Committed	IPP	37	15	2025
Omo Kuraz 3	Sugar	Committed	IPP	37	10	2026
Kessem	Sugar	Committed	IPP	64	16	2023
Total Ethiopia				342	146	

3.5 WIND

The existing, committed, and candidate wind plants considered in the study are listed in Table 3-10.

3.5.1 EXISTING AND COMMITTED WIND PROJECTS

Ethiopia has three operational wind farms with a total installed capacity of 324 MW comprising:

- The Adama wind farm which was completed in two phases:
    - Phase 1, completed in 2012, was the first wind farm to be constructed in Ethiopia. It consists of thirty-four 1.5 MW Goldwind GW77/1500 turbines, with an installed capacity of 51 MW.

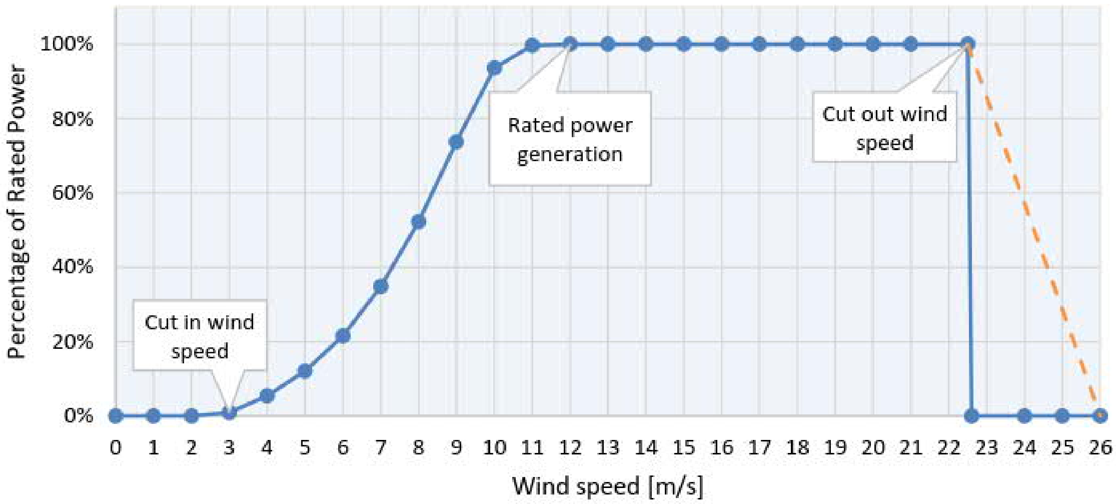
- Phase 2 was completed in 2016 and has a 153 MW capacity consisting of 102 x 1.5 MW Sany Electric SE7715 turbines.

- Ashegoda wind farm, also completed in two phases in 2011 and 2013, consists of 84 wind turbines, including 30 Vergnet GEV HP, 1 MW turbines, and 54 Alstom Eco 74, 1.67 MW turbines. The total installed capacity is 120 MW.

Operational records indicate that Adama I and II have both been operating over the past few years at capacity factors of around 30%. However, the Ashegoda plant has faced difficulties, and operational records indicate that it has achieved less than a 10% capacity factor over the past few years.

The cut-in wind speed for a wind turbine is typically 3-4 m/s. Rated power generation wind speed is 10-12 m/s. Cut-out or transition to reduced power operation occurs at wind speed around 22-25 m/s, as shown in Figure 3-11.

Figure 3-11: Typical operating range of a wind turbine



The annual energy output of a wind turbine is strongly dependent on the average wind speed at the turbine location. The average wind speed depends on the geographical location, the hub height, and the surface roughness. Hills and mountains also affect the wind flow, and therefore steep terrain requires more complicated models to predict the wind resource. In contrast, the surface roughness typically dominates the local wind conditions in flat terrain. Also, local obstacles like forests and, for small turbines, buildings and hedges reduce the wind speed, as do wakes from neighboring turbines. Furthermore, factors like the high-altitude range (with various locations being above 2,000 m) and thin air at these higher altitudes need to be accounted for in the wind turbine selection and design.

The Eastern part of Ethiopia has a good wind resource (low-to-medium-wind sites). An annual wind speed of 6-7 m/s at 100 m above ground (low-wind site) is usually considered the minimum threshold for the feasibility of a wind project (alternatively, power densities around 200 W/m2 at hub height). Some areas in the Eastern part of Ethiopia are endowed with a wind resource greater than 9 m/s at 100 m height above ground. These areas are characterized by a reasonably flat, clear terrain and little vegetation.

Table 3-9 reports wind speed data at hub height (where available) for the existing and three under development wind projects in Ethiopia.

Three wind farms with a total installed capacity of 370 MW are currently under development (committed) and are due to be operational over the next few years, as indicated in Table 3-10. These include Ayisha II (120 MW), Asela I (100 MW), and Asela II (150 MW).

Table 3-9: Wind speed data at hub height for existing and committed wind projects

Site	Capacity (MW)	Hub Height (m)	Wind speed at hub height (m/s)	Investment Cost (M$/MW)	Status
Ayisha	120	80	8.9	2.14	Committed
Adama I	51			2.29	Existing
Adama II	153	70	9.5	2.25	Existing
Ashegoda	120	70-80	8.5	2.08	Existing
Asela I	100	84	8.4	1.44	Committed
Asela II	150	84	8.7	1.77	Committed

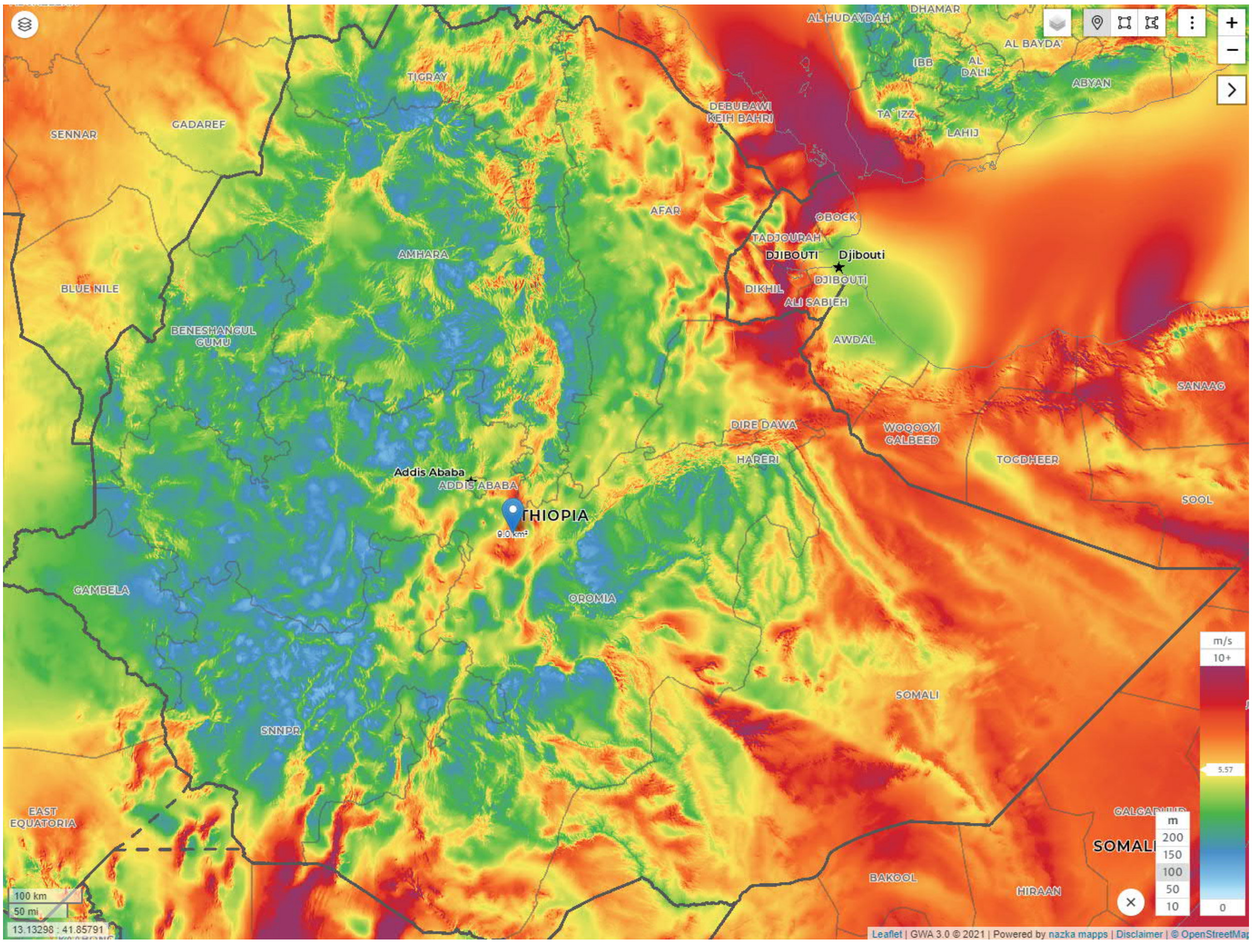
3.5.2 CANDIDATE WIND PROJECTS

The recent Energy Sector Management Assistance Program (ESMAP) resource mapping exercise shows great potential for developing wind farms in several regions. This preliminary work pointed to specific regions and locations, so a targeted and detailed site-specific resource measurement project is under way throughout the country. The ESMAP wind resource map is shown in Figure 3-12.

The development of new wind farms on additional sites will depend on the results of the ongoing wind measurement efforts. Site-specific wind speed data is required for the accurate representation of conditions due to the varying topography of sites and is typically necessary for project development and financing. In addition to the ESMAP project results, the Mesoscale wind modeling study for Ethiopia, conducted by the Department of Wind Energy at the Technical University of Denmark, provided further suggestions for measurement masts installations at locations with comparatively high wind speeds. The World Bank is providing additional support to map wind resources through the Ethiopia Resource Mapping Wind project, which derived a list of priority and validation sites for mast installation.

As shown in Figure 3-12, the highest average wind speeds are in south-eastern Ethiopia. This region is also at a lower altitude, which leads to higher wind power density than at higher altitudes. However, the southeast has a relatively low population density and limited transmission infrastructure. The central north-south axis also has relatively high wind speeds, as does the far south; however, these are also remote from the grid and in areas of lower population density.

Figure 3-12: Wind resource map



EEP provided a list of twenty potential wind projects with a combined capacity of 2,820 MW to be considered candidate plants, as listed in Table 3-10. Based on typical project development and construction schedules, the earliest feasible commercial operation dates (CODs) for the candidate wind farms is 2024/25.

The approximate locations of the wind projects are shown in Figure 3-14.

Table 3-10: Existing, committed, and candidate wind plants

No	Plant Name	P_{max} (MW)	Project Status	Ownership (EEP/IPP)	COD/Earliest date for candidates	CF (%)
1	Adama I	51	Existing	EEP	2012	29%
2	Ashegoda	120	Existing	EEP	2012	16%
3	Adama II	153	Existing	EEP	2015	29%
4	Asela-I	100	Committed	EEP	2023	19%
5	Asela-II (Iteya)	150	Committed	EEP	2024	19%
6	Ayisha-II	120	Committed	EEP	2022	39%
Total existing and committed capacity		694				
7	Ayisha-I	120	Candidate	EEP	2025	39%
8	Ayisha-IA	150	Candidate	IPP	2024	39%
9	Ayisha-IB	150	Candidate	IPP	2024	39%
10	Ayisha-III A	150	Candidate	IPP	2024	39%
11	Ayisha-IIIB	150	Candidate	IPP	2024	39%
12	Debre Birhan	125	Candidate	IPP	2025	10%
13	Deday	125	Candidate	IPP	2025	16%

No	Plant Name	P_{max} (MW)	Project Status	Ownership (EEP/IPP)	COD/Earliest date for candidates	CF (%)
14	Sure	150	Candidate	IPP	2025	22%
15	Tulu Guled	100	Candidate	IPP	2024	27%
16	Dire Dawa	150	Candidate	IPP	2024	22%
17	Gode	150	Candidate	IPP	2024	46%
18	Idabo	150	Candidate	IPP	2024	32%
19	Adigala	150	Candidate	IPP	2024	39%
20	Mekele WF	150	Candidate	IPP	2025	27%
21	Ashegoda	150	Candidate	IPP	2024	16%
22	KebriBeyah	150	Candidate	IPP	2024	38%
23	May Mekdan	150	Candidate	IPP	2024	16%
24	Mega	150	Candidate	IPP	2024	49%
25	Assosa Bambasi	150	Candidate	IPP	2024	20%
26	Sela Dingay	100	Candidate	IPP	2024	8%
Total existing, committed, and candidate capacity		3,514				

Figure 3-13: Average monthly capacity factors for wind plants

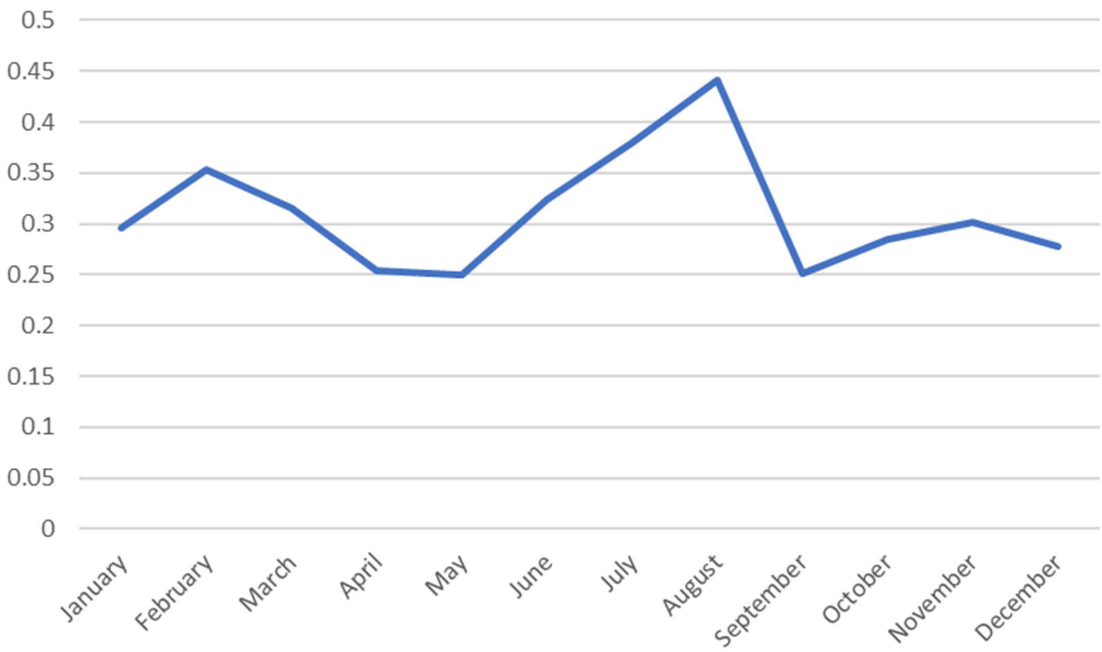


Table 3-11 shows technical, operational, and cost characteristics used when modeling wind resources. The costs are based on recent tender prices for projects in Kenya.

Table 3-11: Wind candidate costs

Capital cost ($/kW)	Plant life (years)	Fixed O&M ($/kW/yr)	Variable O&M ($/MWh)	Construction period (years)
1,770	20	28	0	2

Figure 3-14: Wind project locations

3.6 SOLAR

3.6.1 COMMITTED SOLAR PLANTS

Solar PV is currently being used for off-grid systems and rural areas. There are currently no utility-scale plants in operation; however, the development of new solar projects has been actively pursued during the last few years. Ethiopia joined the World Bank/IFC Scaling Solar initiative, and under this initiative, two plants are nearing a financial close as IPPs. The sites selected for the first two projects are near Gad and Dicheto, each with an installed capacity of 125 MW. The expected COD for both plants is Q3 2023, and it is understood that for both plants a 20-year PPA has been negotiated at a tariff of USD 0.0256/kWh.

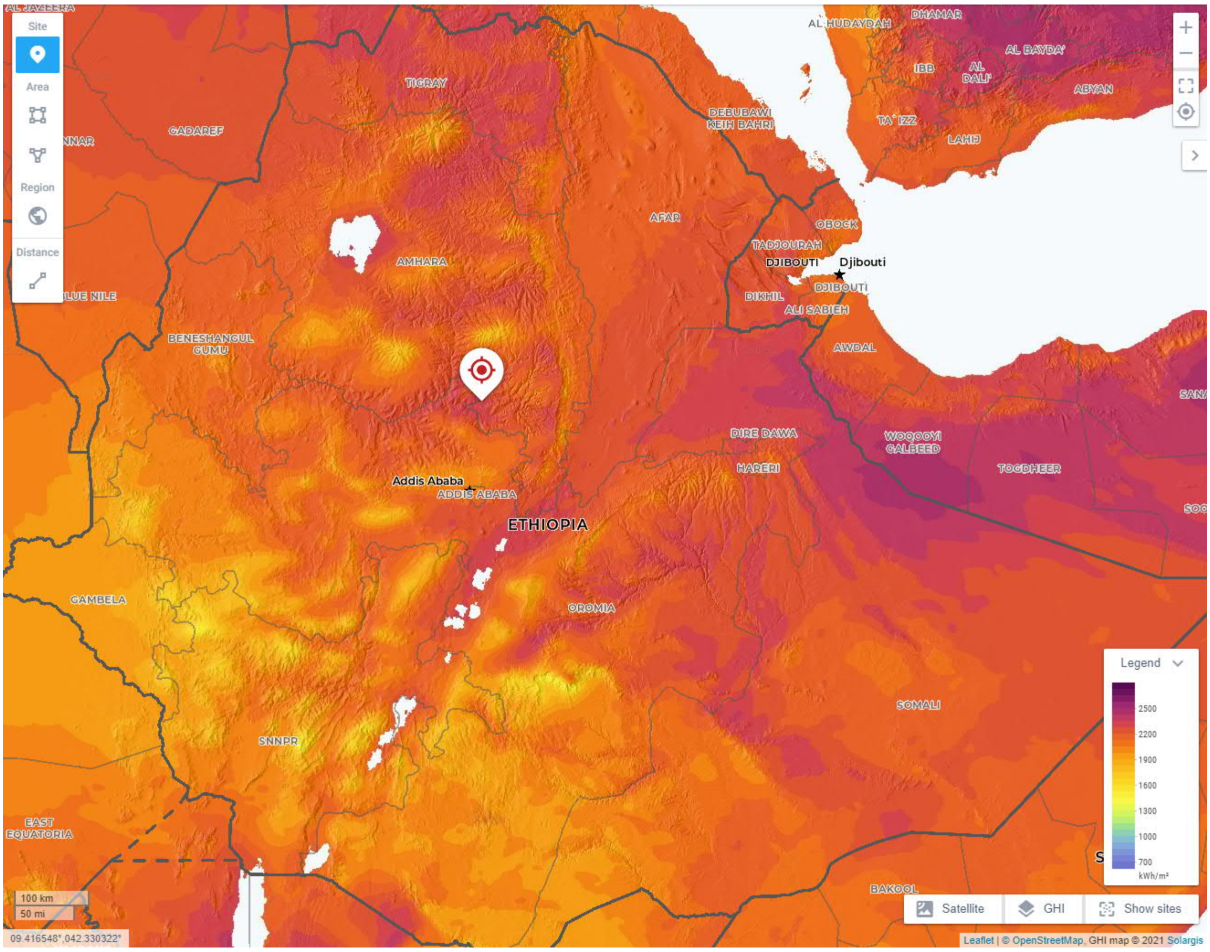
3.6.2 CANDIDATE SOLAR PROJECTS

The generation technologies available for harnessing solar energy include concentrated solar power (CSP) and solar PV technology. CSP does have some technical benefits over solar PV; however, the CSP technology is still relatively expensive global experience is limited. On the other hand, solar PV has seen a significant decrease in module prices over the last 12 years, and solar PV is the predominant technology for converting solar energy to electrical energy. For these reasons, only solar PV technology has been considered for the candidate plants.

Ethiopia has excellent solar resources all over the country, particularly in the North and in the East. The global horizontal irradiation (GHI) ranges between 1,700 and 2,500 kWh/m^2, as shown in Figure 3-15, with a photovoltaic power potential reaching 2,000 kWh/kWp in the best locations.

The World Bank/IFC has been providing support for the next phase of solar development, and resource mapping has been conducted for a number of sites across the country. Based on this work, EEP has provided a list of 12 candidate sites with a total solar PV capacity of 1,425 MW. It has been assumed that these would be developed as IPPs with the earliest CODs of 2024/25, as shown in Table 3-12.

Figure 3-15: Solar resource map



Solar generation estimates and the associated capacity factors for solar projects are based on a fixed-axis configuration and nominal output to the grid. This assumption means that the capacity of solar panels and other plant components will need to be increased to cover internal plant losses. This impact is taken into account when estimating capital costs for solar projects. Typical solar PV daily irradiance profiles and average monthly capacity factors are shown in Figure 3-17 and Figure 3-18 respectively.

Table 3-12: Committed and candidate solar PV plants

No	Power Plant Name	P_{max} (MW)	Project Status	Ownership (EEP/IPP)	COD/Earliest dates for candidates	CF (%)
1	Gad-I solar	125	Committed	IPP	Q3 2023	27%
2	Dicheto solar	125	Committed	IPP	Q3 2023	27%
Total committed capacity		250				
3	Metehara solar	100	Candidate	IPP	2024	27%
4	Humera solar	125	Candidate	IPP	2024	24%
5	Mekele solar	100	Candidate	IPP	2024	27%
6	Welenchiti solar	150	Candidate	IPP	2024	27%
7	Weranso solar	150	Candidate	IPP	2024	27%

No	Power Plant Name	P_{max} (MW)	Project Status	Ownership (EEP/IPP)	COD/Earliest dates for candidates	CF (%)
8	Metema solar	125	Candidate	IPP	2024	24%
9	Gad-II solar	125	Candidate	IPP	2024	27%
10	Yirgalem Solar	100	Candidate	IPP	2025	24%
11	Melkasedi Solar	150	Candidate	IPP	2025	28%
12	Meki Solar	100	Candidate	IPP	2025	28%
13	Wereta Solar	100	Candidate	IPP	2025	27%
14	Meshenti Solar	100	Candidate	IPP	2025	26%
Total committed and candidate capacity		1,675				

Figure 3-16: Solar project locations

Figure 3-17: Typical solar PV daily irradiance profile

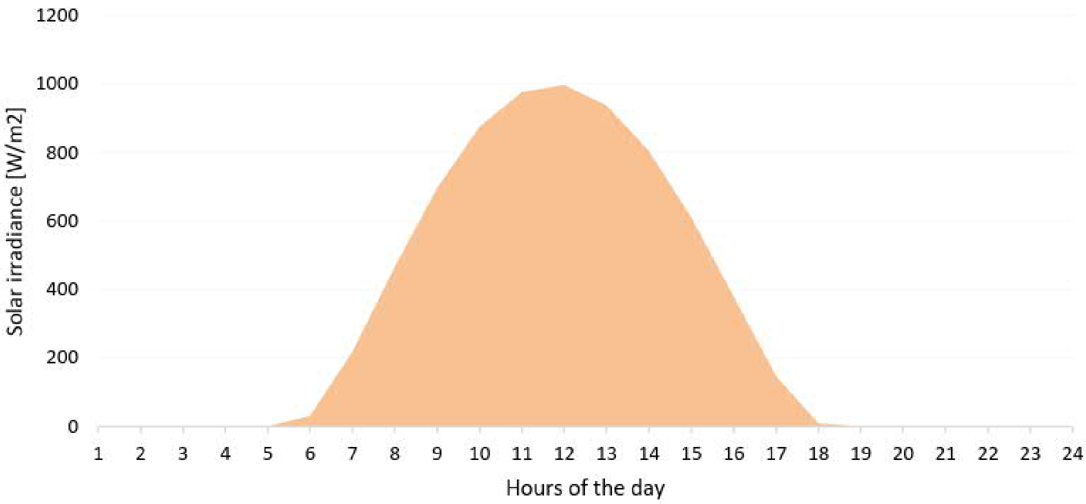


Figure 3-18: Average monthly capacity factors for solar PV plants

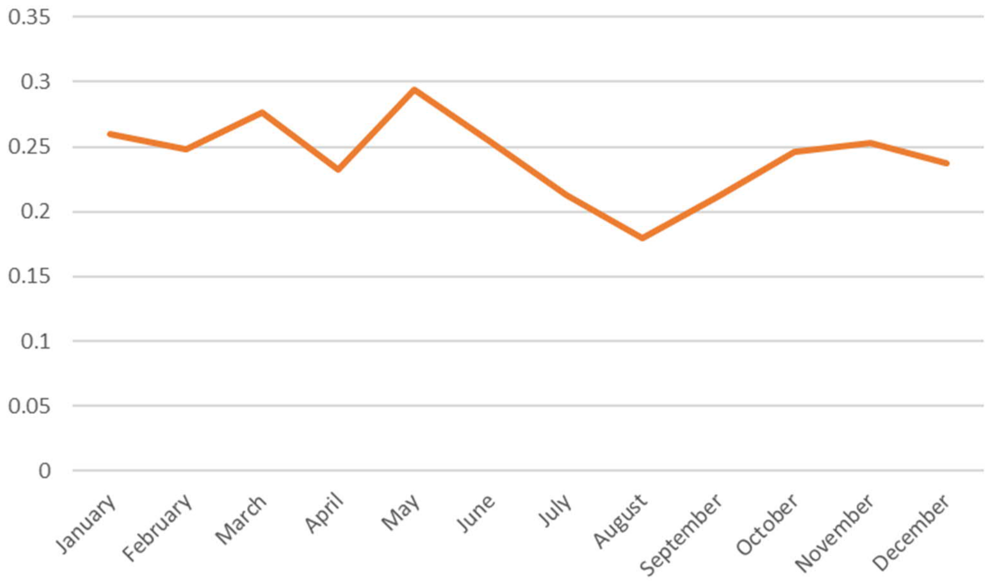


Table 3-13 shows the technical, operational, and cost characteristics used when modeling solar resources. The PPA tariffs for the committed solar projects are at the low end of the current range. Therefore, the costs of the candidate projects have been selected to result in slightly higher levelized costs than PPA tariffs for the committed projects.

Table 3-13: Solar candidate costs

Capital cost ($/kW)	Plant life (years)	Fixed O&M ($/kW/yr)	Variable O&M ($/MWh)	Construction period (years)
500	20	15	0	2

3.7 THERMAL

3.7.1 GAS

3.7.1.1 RESERVES

Ethiopia has indigenous gas reserves in the Ogaden basin, which is located in the southeastern Somali region of Ethiopia and occupies an area of 350,000 square kilometers. The basin has been divided into 21 blocks, and exploration rights have been awarded for many of them. Companies with concessions in the basin include Netherlands registered Pexco Exploration, Petronas (Malaysia), Lundin East Africa (Sweden), SouthWest Energy Ltd. (Hong Kong), and Afar Explorer (USA). The Calub and Hilala Gas Fields were discovered by Tenneco in 1973 and 1974 respectively. The Soviet Petroleum Exploration Expedition (SPEE) drilled nine development wells at Calub and three wells at Hilala during the period 1986 to 1991.

Figure 3-19: Ogaden basin gas reserves

Initial gas in place at Calub is estimated to be 2.7 TCF, and the initial recoverable condensate reserves are about 128 million barrels (SPEE, 1993). Published gas in place volumes at Hilala is 1.3 TCF. In 2018, additional estimated 3 TCF of resources were discovered in Doha area (between Calub and Hilala) by Poly-CGL.

A gas study carried out in 1998 considered various options for using the gas based on transfer by gas pipeline. The uses included electricity production, urea production (for fertilizer), synfuel, use in industry, and also mentioned export by pipeline or by ship after conversion to liquefied natural gas (LNG) – presumably at Djibouti. Dire Dawa was selected as allocation for gas turbines and Awash or Assela for urea production.

As an indication, 4 TCF is sufficient gas to run about 3,200 MW of base-loaded combined cycle plant (85% plant load factor) for twenty-five years or 11,000 MW of peaking plant (25% plant load factor) over the same period.

3.7.1.2 ETHIOPIA-DJIBOUTI PIPELINE

In February 2019, Ethiopia and Djibouti signed a memorandum of understanding for the construction of a $4 billion, 767-km natural gas pipeline from the Hilala and Calub gas fields in Ethiopia's Somali (formerly Ogaden) region to a new port at Damerjog, Arta region, east of Djibouti city. Djibouti plans to build an LNG Terminal in Damerdjog to export the gas.

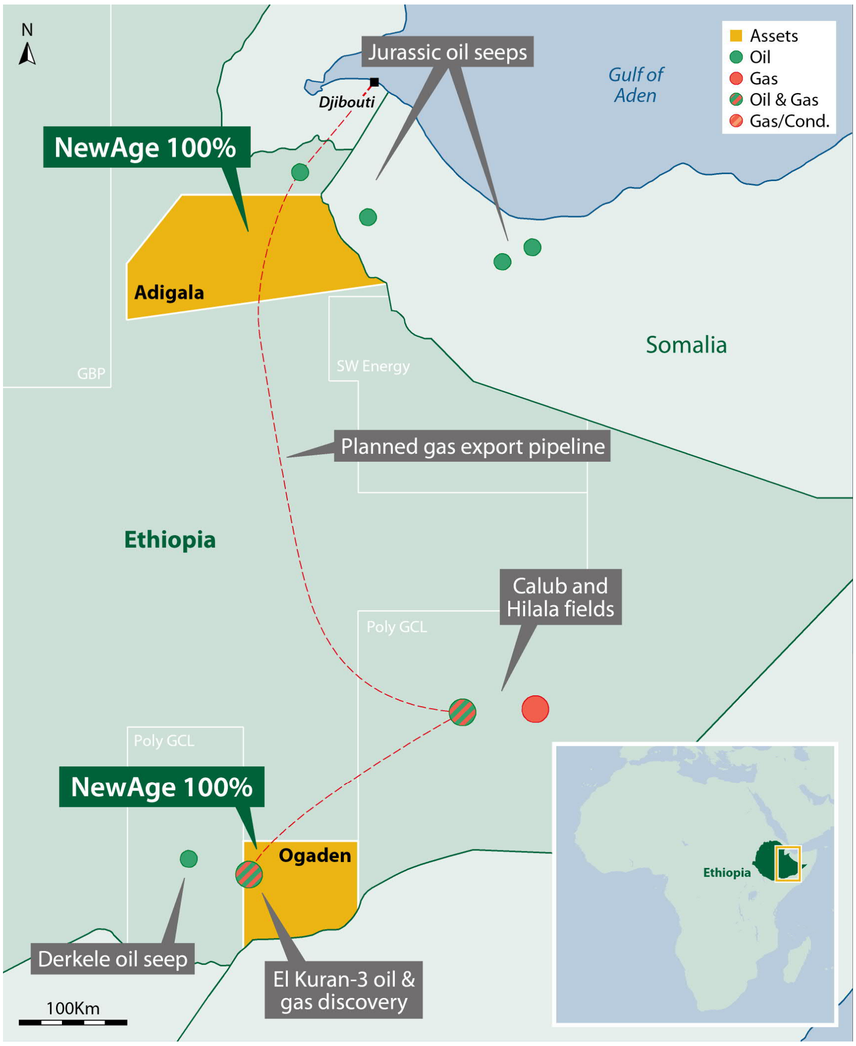
The pipeline would be built by Chinese firm GCL-Poly, which is also developing the gas fields. The pipeline would transport 12 billion cubic meters per year of gas, of which 10 billion cubic meters would be exported to China. At the time, GCL-Poly said it expected exports to begin in 2021. Ethiopia's Parliament approved the pipeline's construction in December 2019.

As indicated above, the gas produced in the short-medium term is not intended for power generation but is instead destined for export. However, it is conceivable that indigenous gas could be used for power generation in the longer term, subject to the need for thermal generation within the overall energy mix.

1.1.1 OIL

Refined oil products are currently imported via Djibouti. While there have been some oil discoveries in the Ogaden basin, for the purpose of this study, it was assumed that heavy fuel oil (HFO) and diesel for power generation would continue to be imported.

Figure 3-20: Ethiopia-Djibouti gas pipeline



3.7.2 FUEL PRICES

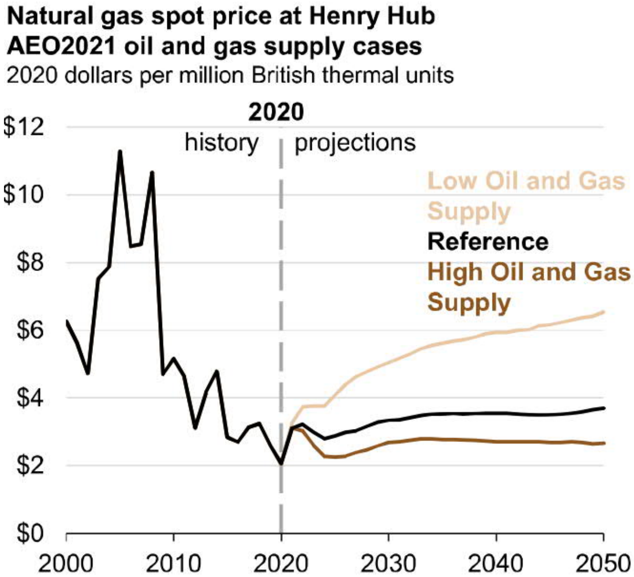
Long-term fuel price projections were obtained from the U.S. Energy Information Agency (EIA) Annual Energy Outlook 2021 (AEO2021). Figure 3-21 shows the gas price projection from the AEO2021, with the long-term Reference price of USD 3.5-4/million BTU in 2020 USD.

For the purpose of this study, it is assumed that indigenous gas from the Ogaden basin could be used for power generation in the longer term and that it could be produced at prices similar to international spot prices. However, as the production wells are far from the grid, there would be the need for significant investment in pipeline infrastructure to deliver the gas to locations closer to the load centers. For the purpose of the study, it was assumed that a pipeline to Dire Dawa or other suitable locations near major load centers would add USD4-6/million BTU to the cost of the delivered gas.

For imported gas, another USD 3-4/million BTU of cost is expected to account for LNG liquefaction, sea transport, and re-gasification.

On this basis, indigenous gas would cost USD 7.5-10/million BTU and imported gas, USD 10.5-14/million BTU.

Figure 3-21: Long-term gas price projection



EIA projects that the Brent crude oil price increases (in real dollar terms) from its 2020 average of $42/barrel (b) to $73/b by 2030 and $95/b by 2050.

In Kenya, imported HFO currently costs around USD 0.6/litre. A similar price has been assumed for Ethiopia, and based on the above projection, this would increase to USD 1.4/litre by 2030 and USD 1.36/liter by 2050.

3.7.3 EXISTING GENERATION

Existing thermal generation includes a 42 MW power plant at Dire Dawa comprising six reciprocating diesel units which can burn heavy fuel oil (HFO) or light fuel oil (LFO). The power plant is currently used only as emergency reserve and is planned to be decommissioned by the end of 2022.

3.7.4 EXPANSION CANDIDATES

The candidate generation plant types fired on gas are assumed to be gas turbines (for peaking operation) and combined cycle gas turbine plant (CCGT) for mid-merit / base load – i.e., higher load factors. Gas can also be burnt in reciprocating plants, i.e., diesel engines or gas engines. Gas could also be burnt in steam plants, but the efficiency is lower than CCGT, and the capital cost is higher than CCGT.

Thermal generation expansion candidates include reciprocating engine medium-speed diesel (MSD), open-cycle gas turbine (GT), and combined-cycle gas turbine (CCGT) plants. Table 3-14 shows plant technical parameters, and Table 3-15 shows thermal candidate plant cost assumptions.

Table 3-14: Technical parameters of thermal plant candidates

Plant type	Capacity (MW)	Fuel	Minimum stable loading (%)	Average heat rate (kJ/kWh)	Planned maintenance (%)	Forced outage (%)
MSD	80	HFO/Natural gas	40	8,200	5	10
GT	140	Natural gas	70	10,000	5	5
CCGT	420	Natural gas	70	7,500	5	5

Table 3-15 – Thermal candidate costs

Plant type	Capacity (MW)	Capital cost ($/kW)	Plant life (years)	Fixed O&M ($/kW/yr)	Variable O&M ($/MWh)	Construction period (years)
MSD	80	1,000	25	30.2	11.67	2
GT	140	750	25	13.2	7.2	2
CCGT	420	1,600	25	24	7.2	3

3.8 NUCLEAR

Nuclear reactors were considered as candidate plants in this study. Nuclear generation does not result in CO_2 and is characterized by low operating costs but very high capital costs. Unlike most electricity-generating technologies, the cost of nuclear generation has not reduced as the technology has matured. The continuing high capital cost of nuclear is due to the increasing safety standards applied by the International Atomic Energy Association and national governments, resulting in increased costs and construction periods.

Modern nuclear power plants are able to operate over wide ranges and, with increasing penetration of renewables, are required to adjust their output to match supply with demand. In Europe, it is a requirement that nuclear power plants are capable of daily cycling between 50% and 100% of nominal load, with a ramping rate of 3-5% per minute. Most modern nuclear power plants (Generation II+III) can safely lower their production to 25% of the nominal load.

However, due to the high investment cost, in order to be economical, it is necessary to run nuclear power plants as base load plants, i.e., with a capacity factor of at least 80%.

Table 3-16 – Technical parameters of nuclear plant candidates

Plant type	Capacity (MW)	Fuel	Minimum stable loading (%)	Average heat rate (kJ/kWh)	Planned maintenance (%)	Forced outage (%)
Nuclear	600	Uranium	50	9,000	5	10

Table 3-17 – Nuclear candidate costs

Plant type	Capacity (MW)	Capital cost ($/kW)	Plant life (years)	Fixed O&M ($/kW/yr)	Variable O&M ($/MWh)	Construction period (years)
Nuclear	600	7,000	60	100	-	8

3.9 COAL

Ethiopia has located coal reserves in three separate areas. About 300 million tonnes of coal reserves (lignite and high volatile bituminous coal) have been registered in the country, mainly in the western parts. The various basins include Chilga, Dilbi- Moye, Yayu, Lake Sapo, and Gojeb-Chida.

Alternatively, coal could be imported but would have to be brought by ship to Djibouti and then transported by rail into Ethiopia. Thus, coal-fired generation using imported coal would be expensive.

Coal-fired generation is not favored due to the environmental impacts, principally of carbon dioxide production, but also of waste disposal. Gas is a relatively “clean” fuel in that it produces much less carbon dioxide and other pollutants for the same amount of electricity output as coal.

Given the alternative energy sources in Ethiopia, e.g., hydro, geothermal, wind, solar, and potential gas production or imports, coal-fired plant using indigenous or imported coal has not been considered in the generation planning.

4 DEVELOPMENT OF SCENARIOS

4.1 GENERAL

This section of the report sets the scene for the expansion planning and describes the development of the scenarios considered in the study.

4.2 DEMAND FORECAST

The demand forecast provides the main driver for the generation expansion plan. As shown in Figure 4-1 and Figure 4-2 and Table 4-1 and Table 4-2, in the Base Case, the energy and peak demand are forecast to grow from 15,450 GWh and 2,634 MW in 2020 to 52,361 GWh and 9,577 MW respectively by 2030 and 135,608 GWh and 24,804 MW respectively by 2045. This provides an indication of the scale of generation and transmission infrastructure that will need to be installed over the 25-year planning period.

The corresponding High Case and Low Case figures are provided in Table 4-1 and Table 4-2.

Figure 4-1: Energy demand forecast (GWh)

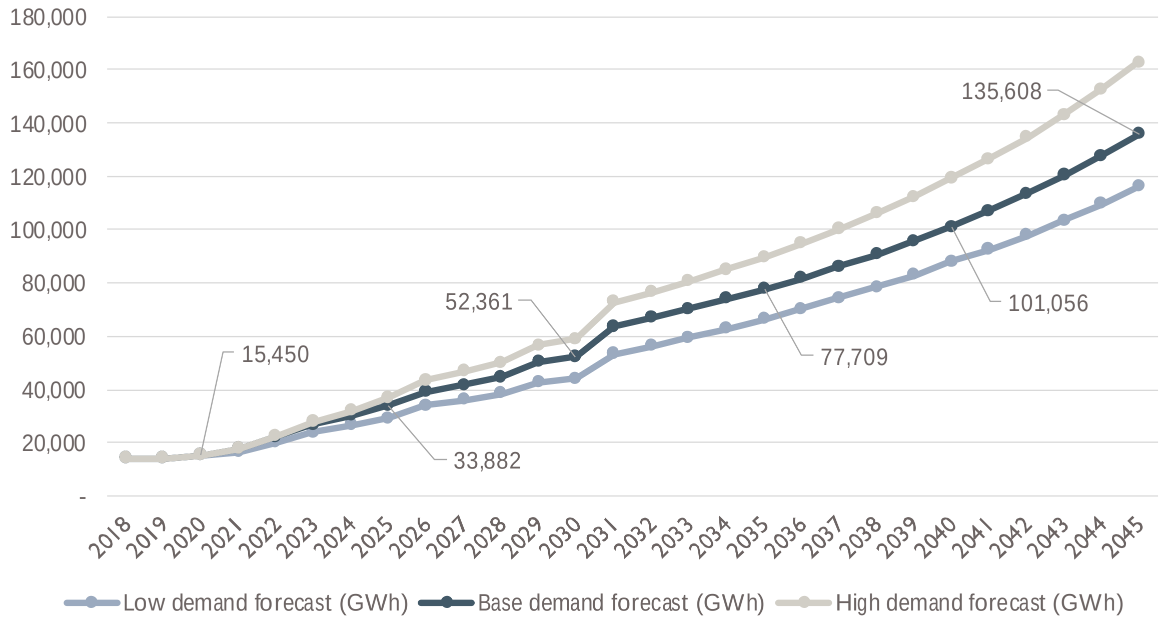


Table 4-1: Energy demand forecast (GWh)

Demand case	2020	2025	2030	2035	2040	2045
Base Case	15,450	33,882	52,361	77,709	101,056	135,608
High Case	15,450	36,732	58,994	82,583	112,015	162,599
Low Case	15,450	30,503	44,221	65,884	87,216	116,197

Figure 4-2: Peak demand forecast (MW)

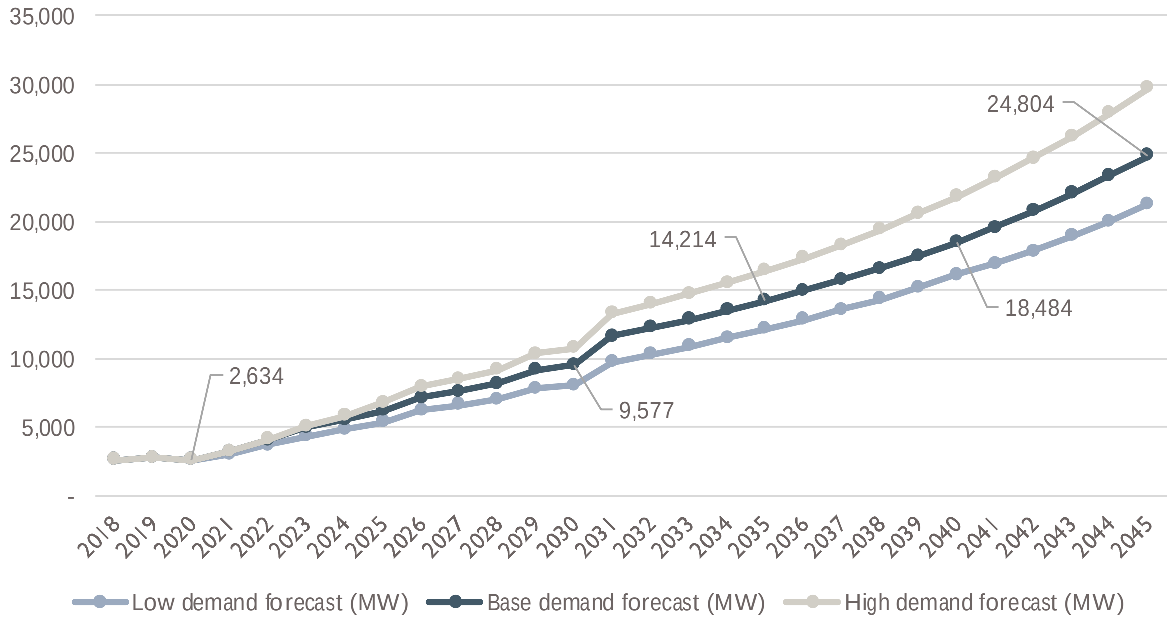


Table 4-2: Peak demand forecast (MW)

Demand case	2020	2025	2030	2035	2040	2045
Base Case	2,634	6,197	9,577	14,214	18,484	24,804
High Case	2,634	6,779	10,791	16,386	21,820	29,741
Low Case	2,634	5,374	8,088	12,153	16,093	21,254

4.3 CAPACITY AND ENERGY REQUIREMENTS

4.3.1 RESERVE MARGIN

Hydro-dominated power systems such as the Ethiopian system are usually energy rather than capacity constrained. This is due to the fact that the average capacity factor of the hydro plants is generally less than the system load factor. In Ethiopia in 2020 the hydro plants had a total available capacity of 3,461 MW (prior to commissioning of Genale III, while the average energy production potential (based on average inflows) was 14,351 GWh, i.e., an average capacity factor of around 48%. On the other hand, the peak demand in 2020 was 2,634 MW and annual energy demand 15,450 GWh, i.e., a system load factor of around 62%.

Table 4-3 compares the total firm (available) capacity and average energy in 2020 with the demand. It was assumed that the wind plants provide firm capacity equal to 30% of their installed capacity. It may be seen that while the system had a reserve capacity margin of 31%, the reserve energy margin (based on average hydro inflows and average wind yield) was only 1%.

This means that while there is currently an adequate capacity margin, the energy margin is very small, resulting in vulnerability to adverse hydrological conditions.

Figure 4-3 shows the generation dispatch profile on 8th June 2019. At this time, the reservoir storage levels would have been low and as indicated, there was a significant shortage in generation capacity and energy (despite sufficient installed capacity).

Depending on hydrological conditions, these constraints could persist for the next few years if the Base Case forecast demand growth materializes as detailed further in the next section.

Figure 4-3: Daily generation profile – 8th June 2019 (MW)

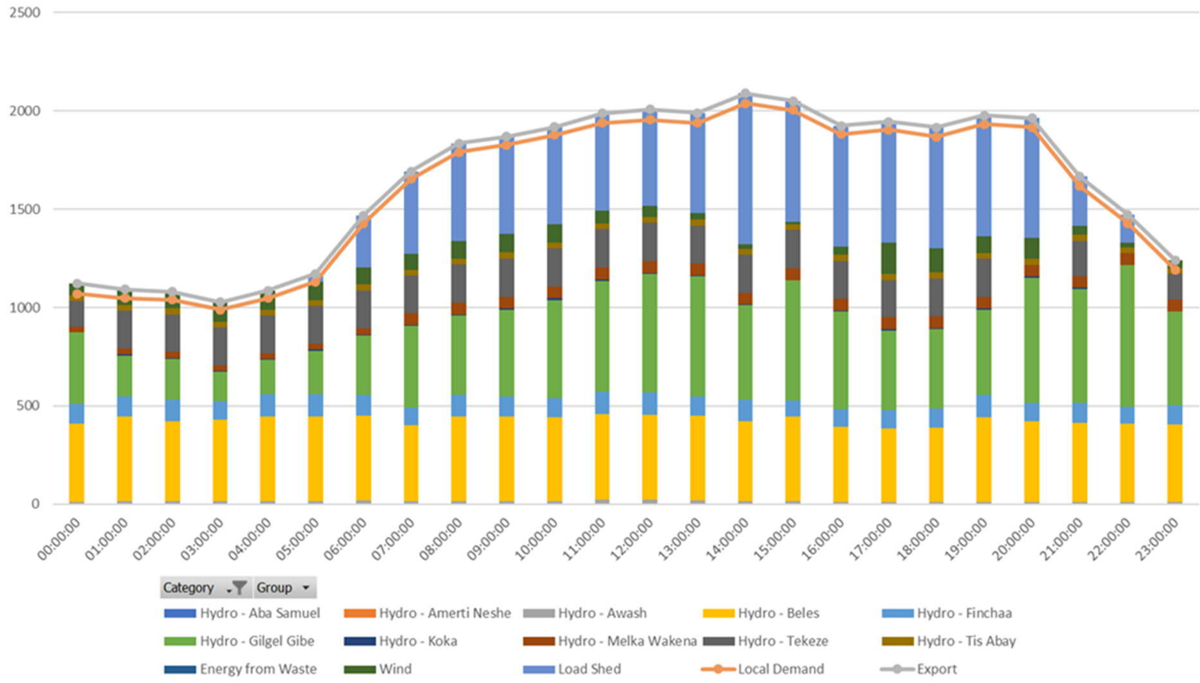


Table 4-3: Firm capacity and energy and reserve margin (2020)

Plant type	Firm capacity (MW)	Average energy (GWh)
Hydro	3,426	14,351
Wind	60	993
WtE	25	186
Total	3,521	15,530
Demand	2,634	15,450
Reserve margin (%)	33%	1%

In order to allow for planned or forced outage of plant a minimum reserve margin is generally applied when assessing future capacity requirements. In this case, a typical value of 20% has been applied in the study. Similarly, as the majority of the energy production is based on variable hydrological conditions and variable wind and solar energy, a 20% energy margin has been applied.

For the purpose of the analysis, it was assumed that the exports would be non-firm in terms of peak capacity but firm in terms of annual energy.

Table 4-4 and Table 4-5 show the capacity and energy requirements respectively by 2030 and 2045 including a 20% reserve margin.

Table 4-4: Capacity requirement (MW)

Demand/capacity	2030	2045
Base Case Demand	9,577	24,804
National demand	8,279	22,651
20% reserve margin	1,656	4,530
Capacity requirement	9,935	27,181

Table 4-5: Energy requirement (GWh)

Demand/energy	2030	2045
Base Case Demand	52,361	135,608
20% reserve margin	10,472	27,122
Energy requirement	62,833	162,730

4.4 EXISTING, COMMITTED AND CANDIDATE CAPACITY

Table 4-6 lists the installed and firm capacity of the existing, committed and candidate generation as described in the previous section. The installed capacity includes all generation types, while the firm capacity only includes generation that can contribute to meeting the peak demand, i.e.:

- Available hydro capacity
- WtE capacity
- Geothermal capacity

Solar generation can't contribute to the evening peak and wind is variable and therefore has been assumed to contribute 30% of its installed capacity as firm. The sugar factory plants, while comprising thermal generation, are seasonal and therefore have not been considered firm.

As shown in Table 4-6, while the total installed capacity of existing, committed and candidate plants amounts to 28,450.4 MW, the firm capacity is just 21,706.4 MW. As indicated in Table 4-4, the Base Case peak demand reaches 24,804 MW by 2045, and including a 20% reserve margin, the firm capacity requirement would be 27,181 MW. Therefore, ignoring any plant retirements that may occur by 2045, there would be the need for a further 5,475 MW of firm capacity to fully meet the peak demand by 2045 with a 20% reserve margin.

Table 4-6: Existing, committed and candidate installed and firm capacity by 2045

Status	Type	Installed capacity (MW)	Firm capacity (MW)
Existing	Hydro	4,077	3,690
	Waste	25	25
	Wind	324	60
	Total	4,426	3,775
Committed	Geothermal	380	377
	Hydro	6,770	4,820
	Solar	250	-
	Sugar	317	-
	Wind	250	75
	Total	7,967	5,272
Candidate	Geothermal	600	600
	Hydro	11,213.4	11,213.4
	Solar	1,425	-
	Wind	2,820	846
	Total	16,058.4	12,659.4
Grand Total		28,450.4	21,706.4

Table 4-7 lists the average annual energy production capability of the existing, committed and candidate plants based on average hydrological conditions, typical capacity factors for the non-hydro plants, i.e.

- Geothermal 85%
- Waste 85%
- Wind 35%
- Solar 25%
- Sugar factory 58%

As shown in Table 4-7, total average annual energy capacity of existing, committed and candidate plants amounts to 109,057 GWh.

As indicated in Table 4-5, the Base Case energy demand reaches 135,608 GWh by 2045, and including a 20% reserve margin, the firm energy requirement would be 162,730 GWh. Therefore, ignoring any plant retirements that may occur by 2045, there would be the need for a further 52,535 GWh of energy capacity to fully meet the energy demand by 2045 with a 20% reserve margin.

In order to meet the above shortfall in capacity and energy, additional candidate generation capacity would be required as considered further below in the development of the scenarios.

Table 4-7: Average energy

Status	Type	Average energy (GWh)
Existing	Hydro	16,041
	Waste	186
	Wind	993
	Total	17,221
Committed	Geothermal	2,826
	Hydro	20,811
	Solar	548
	Sugar	1,574
	Wind	767
	Total	26,524
Candidate	Geothermal	4,468
	Hydro	50,792
	Solar	3,121
	Wind	8,559
	Total	66,939
Grand Total		110,195

4.5 SCREENING OF CANDIDATES

Before commencing the least cost generation planning analysis, we have employed a screening curve approach to form an idea of the likely competitiveness and role for the candidate power plants. The curves have been used to screen out plants from consideration in the main generation planning that are obviously uneconomic relative to other candidates. Although screening curves by themselves cannot determine the appropriate timing of plant, nor whether the system needs baseload, mid-merit or peaking plant, they do suggest the relative competitiveness of different technologies for certain duties within the merit order. The screening curves compare the overall through-life cost, i.e. annualized capital plus fuel plus operation and maintenance costs against annual plant load factor. The costs and technical data have been based on the data discussed in the previous section and are the same as used in the SDDP and OPTGEN models. Table 4-8 shows the data used, including the calculation of the levelized capital cost, operation and maintenance cost, and the fuel costs, which were annualized assuming a 10% discount rate and their economic lifetimes.

The non-hydro power plant options that are considered in the screening analysis are:

- Geothermal;
- Wind;
- Solar;
- Diesels running on HFO;
- GT burning gas;
- CCGT burning gas;
- Nuclear;
- Waste-to-energy.

Table 4-8: Annual cost calculation – non-hydro candidates

		MSD	GT-NG	CCGT-NG	Geo	Nuclear	Solar	Wind	WtE
Installed capacity	MW	80	140	420	100	600	100	300	25
Capital Cost	$million	80	105	672	333	4,200	50	531	72
Capital Cost/kW	US$/kW	1,000	750	1,600	3,330	7,000	500	1,770	2,880
Construction period	years	2	2	3	5	8	2	2	2
Discount Rate (real)	% p.a.	10%	10%	10%	10%	10%	10%	10%	10%
Interest during construction	%	5%	5%	11%	22%	38%	5%	5%	5%
Capital + IDC	US$/kW	1,050	788	1,782	4,066	9,629	525	1,859	3,024
Life	Years	25	25	25	25	60	20	20	25
Annual capital cost	US$/kW/year	115.7	86.8	196.4	447.9	966.1	61.7	218.3	333.1
Fixed O&M cost	US$/kW/year	30.2	13.2	24.0	88.4	100.0	15.0	28.0	1282.8
Total annual fixed cost	US$/kW/year	133	91	200	488	969	70	224	1,469
Fuel		HFO	NG	NG	Geo	Uranium	Solar	Wind	Waste
Fuel cost	US$/l /(US$/mmbtu NG)	0.66	10	10					0
Fuel cost	US$/GJ	16.0	9.5	9.5		1.08			0.0
Heat rate	kJ/kWh	8,200	10,000	7,500		9,000			16,000
Efficiency		43.9%	36.0%	48.0%		40.0%			22.5%
Fuel cost per kWh	US$/kWh	0.131	0.095	0.071		0.010			0.000
Variable O&M	US$/MWh	11.67	7.20	7.20	8.40				0.24
Fuel + Var O&M	US$/kWh	0.143	0.102	0.078	0.008	0.010	-	-	0.00

Table 4-9 shows the calculation of annual and levelized costs for the hydro candidates. These are based on a discount rate of 10% and an economic life of 75 years for the hydro plants.

Table 4-9: Annual and levelized cost calculation – hydro candidates

	Installed capacity (MW)	Minimum energy (GWh/yr)	Average energy (GWh/yr)	Average plant factor	Construction cost (USDm)	IDC cost (USDm)	Total capital cost (USDm)	Specific capital cost (USD/kW)	Annualized capital cost (USDm)	Annualized Capital Cost (USD/kW/yr)	Annual Fixed Maintenance Cost (USD/kW)	Total Annualized Cost (USD/kW/yr)	Levelized cost (USD/kWh)
	MW	GWh/yr	GWh/yr	Factor	million $	million $	million $	$/kW	million $	$/kW	$/kW	$/kW	$/kWh
Beko Abo	935	4,445	6,617	0.81	1,453	381	1,834	1,962	182.2	196	18	214	0.030
Upper Mendaya	1,700	5,552	8,554	0.57	2,807	736	3,543	2,084	350.2	209	18	227	0.045
Karadobi	1,600	5,084	7,831	0.56	2,968	779	3,747	2,342	367.1	234	18	252	0.052
Geba 1 + Geba 2	372	950	1,705	0.52	659	173	832	2,239	81.8	224	18	242	0.053
Genale Dawa VI	246	1,039	1,528	0.71	677	178	855	3,474	81.8	348	18	366	0.059
Upper Dabus	304	1,142	1,455	0.55	422	111	533	1,752	53.4	175	18	193	0.040
Birbir R	467	2,459	2,702	0.66	651	171	822	1,761	82.5	176	18	194	0.034
Birbir A	97	512	544	0.64	170	45	214	2,201	21.1	220	18	238	0.043
Werabesa + Halele	436	1,025	1,966	0.51	1,021	268	1,289	2,956	124.4	296	18	314	0.070
Chemoga Yeda 1+2	280	707	1,088	0.44	623	163	786	2,809	76.1	281	18	299	0.077
Genale Dawa V	100	361	573	0.65	343	90	433	4,330	41.0	433	18	451	0.079
Baro 1+2+Genji	859	2,676	3,516	0.47	1,065	279	1,345	1,566	136.4	157	18	175	0.043
Lower Didessa	301	656	974	0.37	713	187	900	2,990	86.8	299	18	317	0.098
Tekeze II	450	1,393	2,713	0.69	1,948	511	2,459	5,465	231.1	547	18	565	0.094
Gojeb	150	379	559	0.43	607	159	766	5,108	72.2	511	18	529	0.142
Tams	2,000	3,195	5,610	0.32	2,651	696	3,347	1,673	337.2	167	18	185	0.066
Wabi Shebele	88	477	502	0.65	552	145	696	7,929	64.8	794	18	812	0.142
Wabi	300	516	1,083	0.41	680	178	859	2,862	83.0	286	18	304	0.084
Lower Dabus	494	430	2,140	0.49	337	88	426	862	46.8	86	18	104	0.024

The screening curves corresponding to the above tables are shown in Figure 4-4 and Figure 4-5. Figure 4-4 compares the overall cost per kWh (levelized cost) over a range of plant capacity factors. Figure 4-5 shows the same information but as an annual cost. Hydro, wind, and solar candidates are represented by a single point based on an average annual capacity factor. In contrast, the cost of geothermal and thermal candidates are represented by curves to show the relationship between levelized or annual cost and capacity factors. The intersection of the lines shows where the overall cost is equal for certain candidates.

Figure 4-4: Levelized costs of candidates vs. annual plant factor

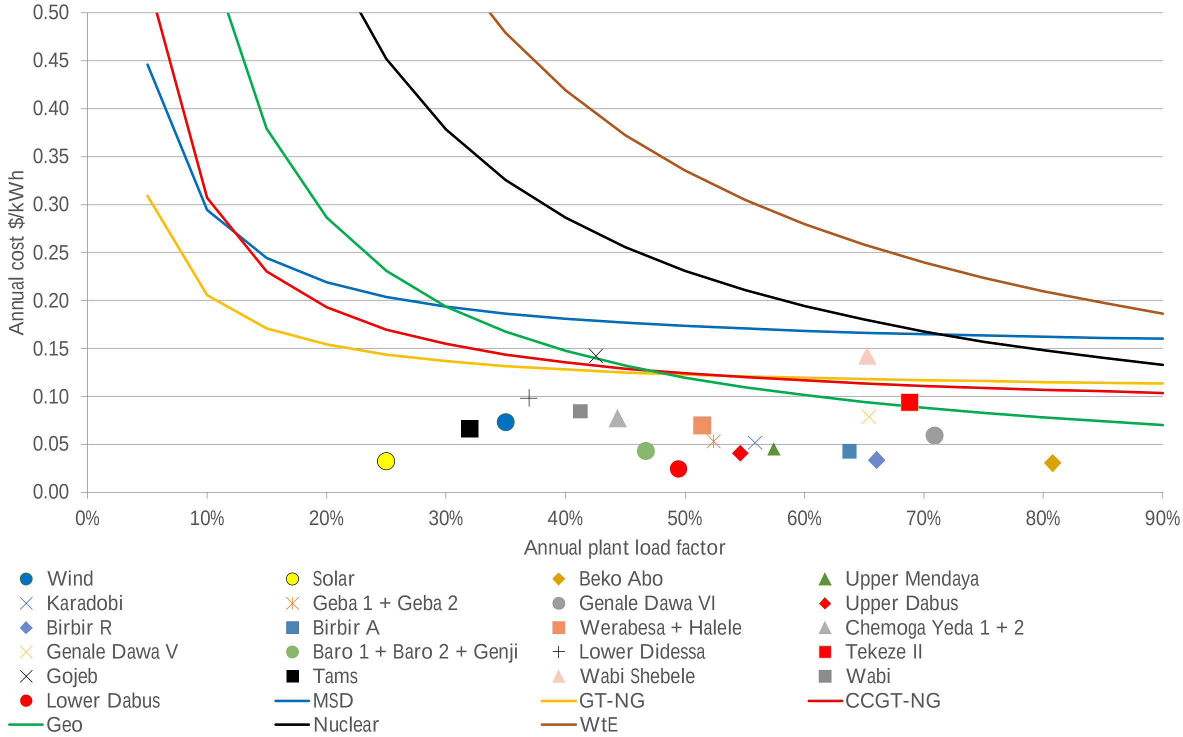


Figure 4-5: Annual costs of candidates vs. annual plant factor

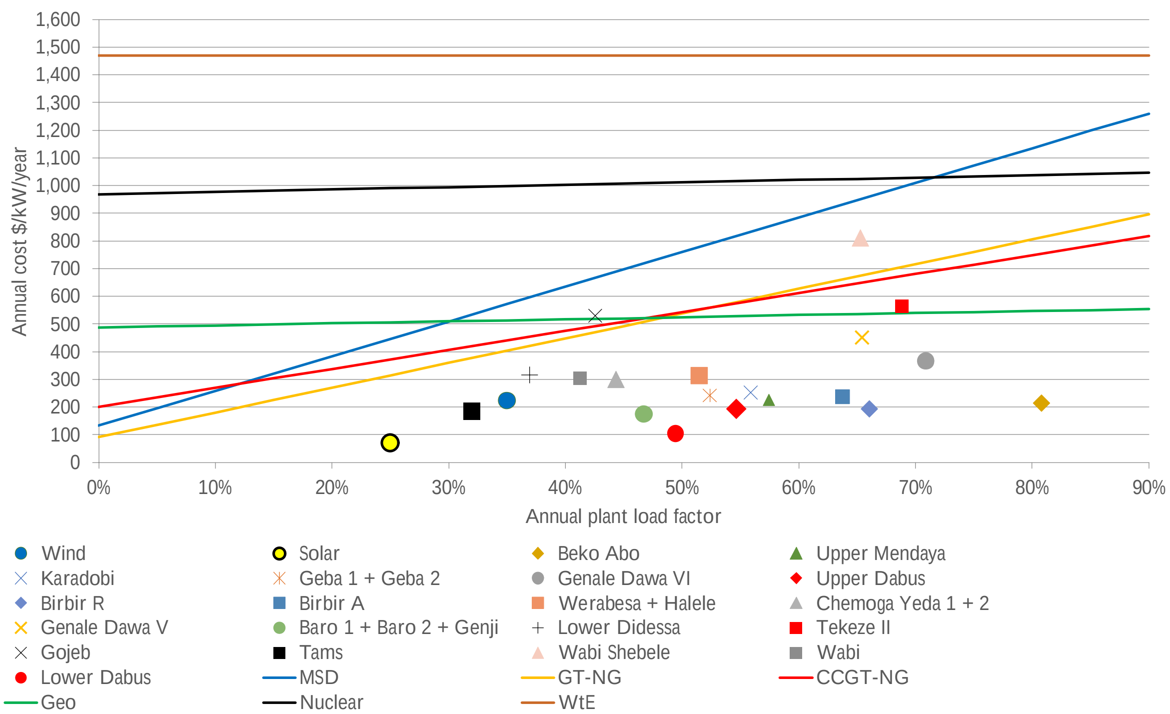


Figure 4-5 clearly shows which plants have the lowest cost at a given plant load factor. The intercept on the y-axis shows the annual fixed costs per kW. Fixed cost includes annual capital cost and the fixed component of the operation and maintenance costs. These costs are incurred whether or not the plant is operating. The slope of each line represents the expenditure on variable cost against plant utilization. Variable cost included fuel cost and the variable component of the operation and maintenance costs. The total cost (fixed and variable) depends on the capacity factor assumed for the plant.

Solar is seen to be competitive even against almost all the hydro plants; however, solar is not considered to provide firm capacity and is not economically dispatchable. Wind generation has similar limitations, albeit with the potential for some firm contribution. Therefore, a system comprising only solar and wind would be infeasible without storage. However, solar and wind can provide low-cost energy, as shown in Figure 4-4, which is highly significant for a hydro-dominated energy-constrained system.

It can be seen that most of the hydro plants have an overall cost of energy in average hydrological conditions below that of most non-hydro plants. Through-life modeling in SDDP and OPTGEN can determine the most economical planting program considering hydro plants' capabilities under different hydrological conditions and other variables such as earliest planting timings, lead times, rate of installation, and fuel price. However, it is expected that when hydro plants are available, they are mainly chosen ahead of non-hydro plants to provide peaking and base-load generation.

With their relatively small unit sizes, thermal plants are favored where a small capacity increment is required. An offline reserve can also be provided cheaply by thermal capacity, enabling a quick dispatch response to system events and increased energy provision in dry hydrological years.

Considering the thermal plant options, Figure 4-5 shows that based on the assumptions, the open-cycle gas turbines will provide the lowest cost peaking plant (at low capacity factor). This is based on the assumption that indigenous gas could be provided at prices similar to international prices. Between 35% and 50% capacity factor, combined cycle gas turbine (CCGT) plants provide the least-cost thermal capacity, while geothermal is preferred above 50% capacity factor. As shown in Figure 4-5, nuclear is relatively expensive even at high capacity factors and is unlikely to be selected as part of a least-cost plan unless other thermal resources are unavailable. WtE is seen to be the most expensive; however, the primary benefit of WtE, which is not captured in this analysis, is the disposal of waste.

4.6 SCENARIOS AND SENSITIVITIES

As discussed above, after considering all existing, committed, and candidate plants identified in the previous section, there remains a significant capacity and energy shortfall to meet the 2045 Base Case demand forecast while also achieving a prudent 20% reserve margin. It is, therefore, necessary to consider further potential candidate generation to fill this gap.

While cost is important, other factors including resilience to climate change, diversity, and environmental impact also require due consideration and EEP provided some guidance in relation to the scenarios as follows:

- Diversification: EEP is keen to increase resilience to drought and therefore wishes to reduce its dependence on hydropower and is aiming for <=75% hydro generation by 2030
- Minimize the use of fossil-fuel generation: Ethiopia does not currently produce oil or gas and is therefore reliant on imported fossil fuels. While indigenous gas production is expected to commence soon in the Ogaden Basin, this is destined for export as LNG via Djibouti and is not expected to be available domestically for power generation in the short-medium term. The use of indigenous gas for power generation has been considered a longer-term option in the scenarios. In all scenarios, it was assumed that new thermal generation would not be possible before 2028.

- Consideration of additional geothermal capacity
- Consideration of nuclear power
- Considering exports to be non-firm, i.e., energy-based contracts, thereby reducing the firm capacity requirement. This assumption was applied for all scenarios

It is also necessary to take account of practical considerations in relation to plant additions, including:

- Typical construction periods for the various plant types, as described in Section 3
- Capacity additions in any particular year are limited to feasible levels

The following capacity addition limits were applied:

Renewables: ≤300 MW/year

Geothermal: ≤500 MW/year

Thermal: ≤1,000 MW/year

Based on the above considerations, the following scenarios were developed:

Table 4-10: Scenarios and sensitivities

Scenario	Demand forecast	Hydrology	Generation choices
1: Least-cost	Base Case	Average	Least-cost
2: Reference	Base Case	Average	All hydro, geothermal, wind, and solar candidates selected
3: Additional geothermal	Base Case	Average	Additional geothermal
4: Nuclear	Base Case	Average	Nuclear from 2035
5: Minimum fossil fuel	Base Case	Average	Minimum fossil fuel
6: Non-committed exports	Base Case	Average	Least-cost

All scenarios considered the Base Case demand forecast and average hydrology. Then the following sensitivities were applied to each scenario:

- Low hydrology
- High Case demand forecast
- Low Case demand forecast

5 GENERATION EXPANSION PLAN

5.1 GENERAL

OPTGEN was used to conduct the generation expansion planning as described in Section 2. The solution for each scenario is reached by minimizing the objective function which is defined as the combined net present value (NPV) of investment costs, operating costs and cost of unserved energy over the 25-year planning period. A discount rate of 10% was applied.

For each scenario, the model found the minimum cost by evaluating many combinations of available candidate plant additions and selecting the combination and timing that produced the lowest NPV over the 25-year study horizon.

5.2 EXISTING GENERATION

The installed generation capacity (at the end of 2020) comprised; 4,077 MW of hydro, 324 MW of wind, 25 MW of WtE and 42 MW of medium speed diesel plants as described in detail in Section 3.

The maximum available capacity of several of the hydro power plants is currently significantly less than the installed capacity. These plants urgently require rehabilitation to avoid a capacity shortfall over the next few years. However, based on discussions with EEP, it seems unlikely that any of these plants will be rehabilitated in the short-term and for the purpose of this study, it was assumed that this rehabilitation would be achieved by 2026, providing up to 361 MW of additional capacity.

Table 5-1: Hydro power plants requiring rehabilitation

No.	HPP Name	Status	COD	Reservoir/ Run-of-River	Installed capacity (MW)	Max available capacity (MW)
1	Koka	Existing	1960	Reservoir	43	17
2	Awash II	Existing	1966	Run-of-river	32	16
3	Awash III	Existing	1971	Run-of-river	32	16
4	Melka Wakana	Existing	1988/2014	Reservoir	153	90
5	Tis Abey II	Existing	2001	Reservoir	72	12
6	Tekeze I	Existing	2009	Reservoir	300	120
Total					632	271

5.3 COMMITTED GENERATION PROJECTS

The under-construction and committed generation projects as described in Section 3, form part of all of the scenarios and sensitivities. These are summarized in Table 5-2.

Table 5-2: Summary of under-construction and committed projects

Type	Project	COD	Capacity (MW)	Total capacity (MW)
Hydro	GERD	2021-2026	238-5,150	6,950
	Koysha	2024-2026	300-1,800	
Biomass (Sugar factories)	Beles 1-3	2022-2025	20-60 (15-35)	342 (146)
	Wolkayit	2023	82 (30)	
	Omo Kuraz 1-3	2024-2026	37-111 (15-40)	
	Kessem	2023	64 (16)	
Geothermal	Corbetti 1	Q2 2024	50	300
	Corbetti II	Q2 2626	100	
	Tulu Moye I	Q3 2023	50	
	Tulu Moye II	Q3 2025	100	
Wind	Asela I	2023	100	370
	Asela II (Iteya)	2024	150	
	Ayisha II	2022	120	
Solar	Gad I	Q3 2023	125	250
	Dicheto	Q3 2023	125	

* Figures in brackets are exports to grid.

5.4 SCENARIO 1 - LEAST-COST EXPANSION

The key assumptions for Scenario 1 are shown in Table 5-3. Scenario 1 does not take account of diversity in generation sources and does not favor any particular type of generation. It does, however, respect the practical constraints associated with plant additions as described in the previous section.

Table 5-3: Scenario 1 – Key assumptions

Parameter	Value
Demand forecast	Base Case
Hydrology	Average
Generation choices	Least-cost

5.4.1 GENERATION ADDITIONS

The candidate generation capacity additions for Scenario 1 by 2030 and 2045 are shown in Table 5-4, with full details provided in Appendix B. These are in addition to the existing, under-construction, and committed projects.

Table 5-4: Scenario 1 – Added candidate capacity (MW)

Type	Capacity (MW)	
	2030	2045
Hydro	2,371	10,825
Solar	1,000	4,800
Wind	300	2,850
Geothermal	-	600
GT	1,400	5,320
Nuclear	-	-
Total	5,071	24,395

Table 5-5: Scenario 1 – Expansion Plan

COD	Prj	Type	Project	Capacity (MW)
01/2024	RNW	Solar	Mekele	300
01/2024	RNW	Wind	Mega	300
01/2028	TPP	GT	GT-NG	980
01/2028	HPP	Hydro	U Dabus HEP	304
01/2028	RNW	Solar	Mekele	100
01/2028	RNW	Solar	Gade 2	125
01/2029	TPP	GT	GT-NG	420
01/2029	HPP	Hydro	Birbir R HEP	467
01/2029	RNW	Solar	Metahara	100
01/2029	RNW	Solar	Gade 2	125
01/2030	HPP	Hydro	Karadobi	1,600
01/2030	RNW	Solar	Gade 2	250
01/2031	HPP	Hydro	Beko Abo	935
01/2031	RNW	Solar	Melkasedi	300
01/2032	TPP	GT	GT-NG	560
01/2032	RNW	Solar	Meki	300
01/2033	TPP	GT	GT-NG	280
01/2033	HPP	Hydro	Birbir A	97
01/2033	RNW	Solar	Weranso	300
01/2034	TPP	GT	GT-NG	420
01/2034	HPP	Hydro	L Dabus HEP	494
01/2034	RNW	Solar	Weranso	300
01/2035	HPP	Hydro	Baro & Genji	894
01/2035	RNW	Solar	Melkasedi	300
01/2036	HPP	Hydro	U Mendaya	1,700
01/2036	RNW	Wind	Mega	150
01/2036	RNW	Solar	Welenchiti	300
01/2037	RNW	Wind	Gode	300
01/2037	RNW	Solar	Welenchiti	300
01/2038	HPP	Hydro	Geba 1 HEP	215
01/2038	HPP	Hydro	Halele HEP	96
01/2038	HPP	Hydro	Werabesa HEP	340
01/2038	HPP	Hydro	Gojeb	150
01/2038	RNW	Solar	Metahara	300
01/2038	RNW	Wind	Gode	300
01/2039	TPP	GT	GT-NG	420
01/2039	HPP	Hydro	Geba 2 HEP	157
01/2039	HPP	Hydro	Yeda 1 HEP	162
01/2039	RNW	Wind	Gode	300
01/2039	RNW	Solar	Meki	100
01/2039	RNW	Solar	Yirgalem	200
01/2040	TPP	Geothermal	Dofan	100
01/2040	TPP	Geothermal	Tendaho	100
01/2040	TPP	GT	GT-NG	140
01/2040	HPP	Hydro	Yeda 2 HEP	118
01/2040	HPP	Hydro	Genale 5	100
01/2040	HPP	Hydro	Wabe	300
01/2040	RNW	Wind	Ayesha	300
01/2040	RNW	Solar	Worota	100
01/2040	RNW	Solar	Yirgalem	200
01/2041	TPP	Geothermal	Shashemene	150
01/2041	TPP	Geothermal	Fentale	50
01/2041	TPP	Geothermal	Dugna Fango	100
01/2041	TPP	Geothermal	Boku	100
01/2041	TPP	GT	GT-NG	140

COD	Prj	Type	Project	Capacity (MW)
01/2041	HPP	Hydro	Tekeze II H	450
01/2041	RNW	Wind	Adigala	300
01/2041	RNW	Solar	Worota	300
01/2042	HPP	Hydro	Tams HEP	2,000
01/2042	RNW	Wind	Adigala	150
01/2042	RNW	Solar	Meshenti	300
01/2042	RNW	Wind	KebriBeyah	150
01/2043	TPP	GT	GT-NG	980
01/2043	RNW	Wind	Ayesha	300
01/2043	RNW	Solar	Humera	100
01/2043	RNW	Solar	Meshenti	100
01/2044	TPP	GT	GT-NG	980
01/2044	HPP	Hydro	Genale 6 HEP	246
01/2044	RNW	Wind	KebriBeyah	300
01/2045	TPP	GT	GT-NG	980
01/2045	RNW	Wind	Ayesha	300
Total				25,675

Combined with the existing and committed plants, the resulting total installed capacity is shown in Table 5-6. As indicated, the firm capacity (consisting of hydro, thermal, and a 30% contribution from installed wind capacity) is short of the desired 20% margin by 2023 if the peak demand grows in line with the Base Case demand forecast. The earliest assumed date by which new capacity can be built is 2024. Therefore, any short-term shortages will need to be managed operationally (through load shedding) or contractually (in the case of exports). It was assumed that the existing hydro plants with reduced available capacity would be restored to full installed capacity by 2026 by implementing the required rehabilitation projects.

The shortage in firm capacity is alleviated by 2024 due to a significant increase in the capacity of GERD by this date. Table 5-6 shows the reserve capacity margin (MW) based on the Ethiopia peak demand, i.e., excluding exports. The 20% capacity margin target is exceeded apart from in 2023. (The system is energy-constrained rather than capacity-constrained, as described further below.)

Table 5-7 and Figure 5-2 show the breakdown of generated energy for Scenario 1. The share of hydro energy remains above 75% up to 2040 and then drops below 75% from 2041.

As previously mentioned, hydro-dominated systems are generally energy-constrained, and, therefore, it is necessary to consider both firm capacity (MW) and firm energy (GWh). Table 5-8 and Figure 5-3 show the firm energy by year for Scenario 1 relative to the annual energy demand. As indicated, based on average hydrological conditions, the system is expected to have an energy deficit before 2024. From 2028 the expansion plan results in an annual energy margin of approximately 20%, which provides some resilience against poor hydrological conditions.

Table 5-6: Scenario 1 – Installed capacity (MW)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Firm	Peak Demand	Exports	Reserve Margin (%)
2020	3,450	324			25	-	-	38	-	3,837	3,610	2,459	175	47%
2021	3,941	324			25	-	-	38	-	4,328	4,101	3,047	175	35%
2022	4,303	444		298	25	-	-	38	-	5,108	4,463	3,727	345	20%
2023	4,303	544	250	298	25	57	-	-	-	5,477	4,512	4,431	515	2%
2024	8,352	844	550	298	25	107	-	-	-	10,176	8,701	4,966	579	75%
2025	8,652	844	550	298	25	207	-	-	-	10,576	9,101	5,490	707	66%
2026	11,013	844	550	298	25	377	-	-	-	13,107	11,632	6,130	1,009	90%
2027	11,013	844	550	298	25	377	-	-	-	13,107	11,632	6,620	1,009	76%
2028	11,317	844	775	298	25	377	-	-	980	14,616	12,916	7,161	1,009	80%
2029	11,784	844	1,000	298	25	377	-	-	1,400	15,728	13,803	7,890	1,298	75%
2030	13,384	844	1,250	298	25	377	-	-	1,400	17,578	15,403	8,279	1,298	86%
2031	14,319	844	1,550	298	25	377	-	-	1,400	18,813	16,338	9,493	2,153	72%
2032	14,319	844	1,850	298	25	377	-	-	1,960	19,673	16,898	10,086	2,153	68%
2033	14,416	844	2,150	298	25	377	-	-	2,240	20,351	17,276	10,712	2,153	61%
2034	14,910	844	2,450	298	25	377	-	-	2,660	21,565	18,190	11,369	2,153	60%
2035	15,804	844	2,750	298	25	377	-	-	2,660	22,759	19,084	12,061	2,153	58%
2036	17,504	994	3,050	298	25	377	-	-	2,660	24,909	20,829	12,804	2,153	63%
2037	17,504	1,294	3,350	298	25	377	-	-	2,660	25,509	20,919	13,593	2,153	54%
2038	18,305	1,594	3,650	298	25	377	-	-	2,660	26,910	21,810	14,436	2,153	51%
2039	18,624	1,894	3,950	298	25	377	-	-	3,080	28,249	22,639	15,337	2,153	48%
2040	18,987	2,194	4,250	298	25	577	-	-	3,220	29,551	23,432	16,331	2,153	43%
2041	19,437	2,494	4,550	298	25	977	-	-	3,360	31,141	24,512	17,418	2,153	41%
2042	21,437	2,794	4,850	298	25	977	-	-	3,360	33,741	26,602	18,596	2,153	43%
2043	21,437	3,094	5,050	298	25	977	-	-	4,340	35,221	27,672	19,860	2,153	39%
2044	21,683	3,394	5,050	298	25	977	-	-	5,320	36,747	28,988	21,218	2,153	37%
2045	21,683	3,694	5,050	298	25	977	-	-	6,300	38,027	30,058	22,651	2,153	33%

Figure 5-1: Scenario 1 – Firm capacity and stacked national demand and exports (MW)

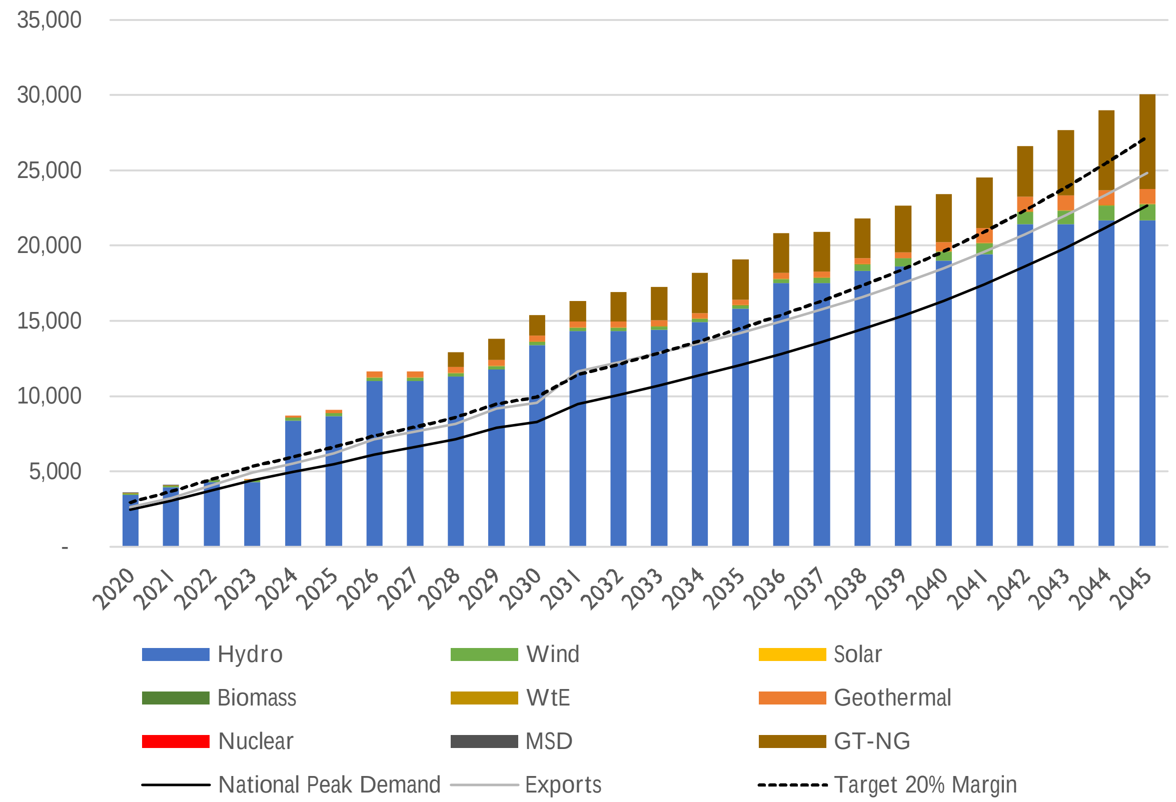


Table 5-7: Scenario 1 – Generated energy by plant type (GWh)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,795	671	-	-	103	-	-	46	-	-	17,615	95%
2022	19,633	722	-	1,516	103	-	-	277	-	14	22,251	88%
2023	22,470	1,011	291	1,516	103	256	-	-	-	1,395	25,648	88%
2024	23,874	2,278	1,341	1,516	103	749	-	-	-	57	29,860	80%
2025	27,313	2,059	1,239	1,516	103	1,243	-	-	-	86	33,474	82%
2026	31,174	2,195	1,276	1,516	103	2,780	-	-	-	-	39,044	80%
2027	33,565	2,251	1,316	1,516	103	2,975	-	-	-	1	41,726	80%
2028	36,104	2,045	1,798	1,516	103	2,975	-	-	36	-	44,577	81%
2029	41,193	2,141	2,322	1,516	103	2,975	-	-	-	-	50,249	82%
2030	42,538	2,234	3,011	1,516	103	2,975	-	-	-	-	52,376	81%
2031	53,359	2,141	3,589	1,516	103	2,975	-	-	-	-	63,684	84%
2032	55,371	2,295	4,447	1,516	103	2,975	-	-	107	-	66,814	83%
2033	58,401	2,104	4,978	1,516	103	2,975	-	-	271	-	70,348	83%
2034	61,248	2,128	5,715	1,516	103	2,975	-	-	260	-	73,944	83%
2035	64,186	2,265	6,458	1,516	103	2,975	-	-	223	-	77,725	83%
2036	66,862	3,012	7,144	1,516	103	2,975	-	-	-	-	81,611	82%
2037	69,222	4,299	7,969	1,516	103	2,975	-	-	19	-	86,103	80%
2038	71,585	5,679	8,834	1,516	103	2,975	-	-	19	-	90,711	79%
2039	74,649	6,957	9,388	1,516	103	2,975	-	-	49	-	95,636	78%
2040	77,009	7,782	9,991	1,516	103	4,359	-	-	77	-	100,837	76%
2041	78,194	8,903	10,519	1,516	103	7,705	-	-	75	-	107,015	73%
2042	82,886	10,084	11,159	1,516	103	7,705	-	-	-	-	113,453	73%
2043	88,498	10,940	11,556	1,516	103	7,705	-	-	45	-	120,364	74%
2044	94,511	12,015	11,487	1,516	103	7,705	-	-	147	-	127,484	74%
2045	100,934	12,849	11,952	1,516	103	7,705	-	-	564	-	135,623	74%

Figure 5-2: Scenario 1 – Generated energy (GWh) and percentage hydro generation

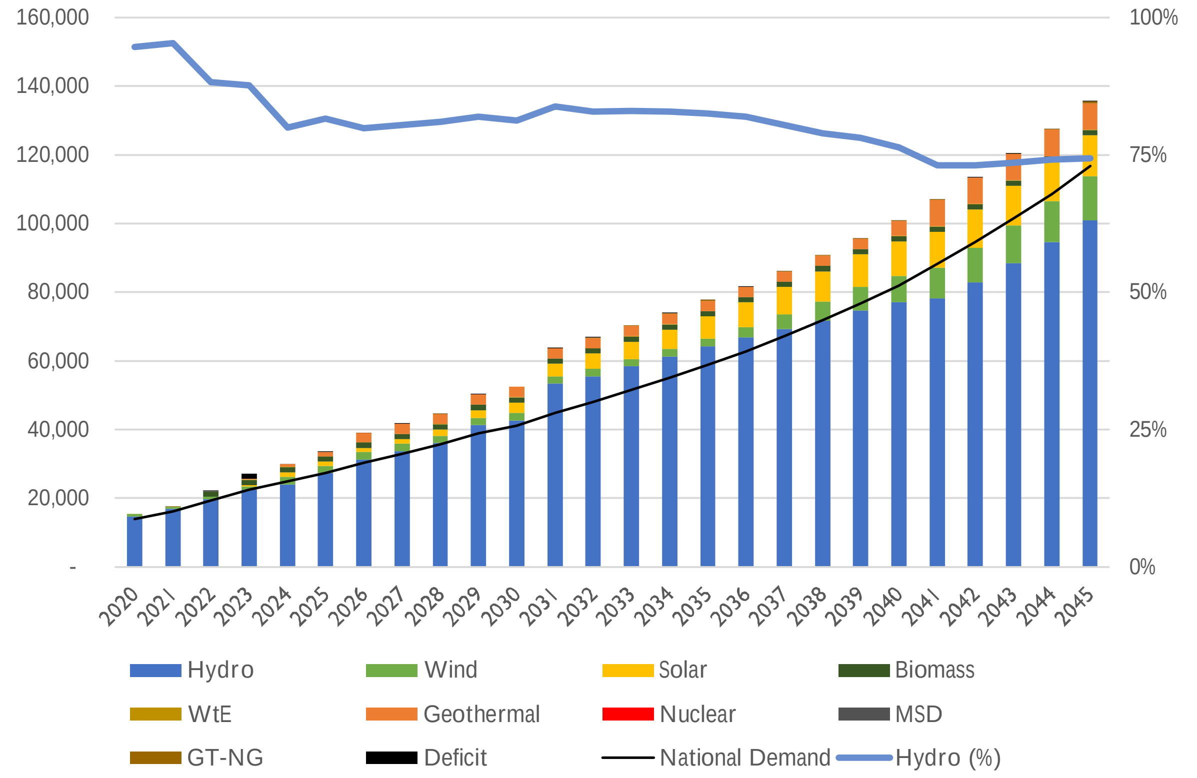
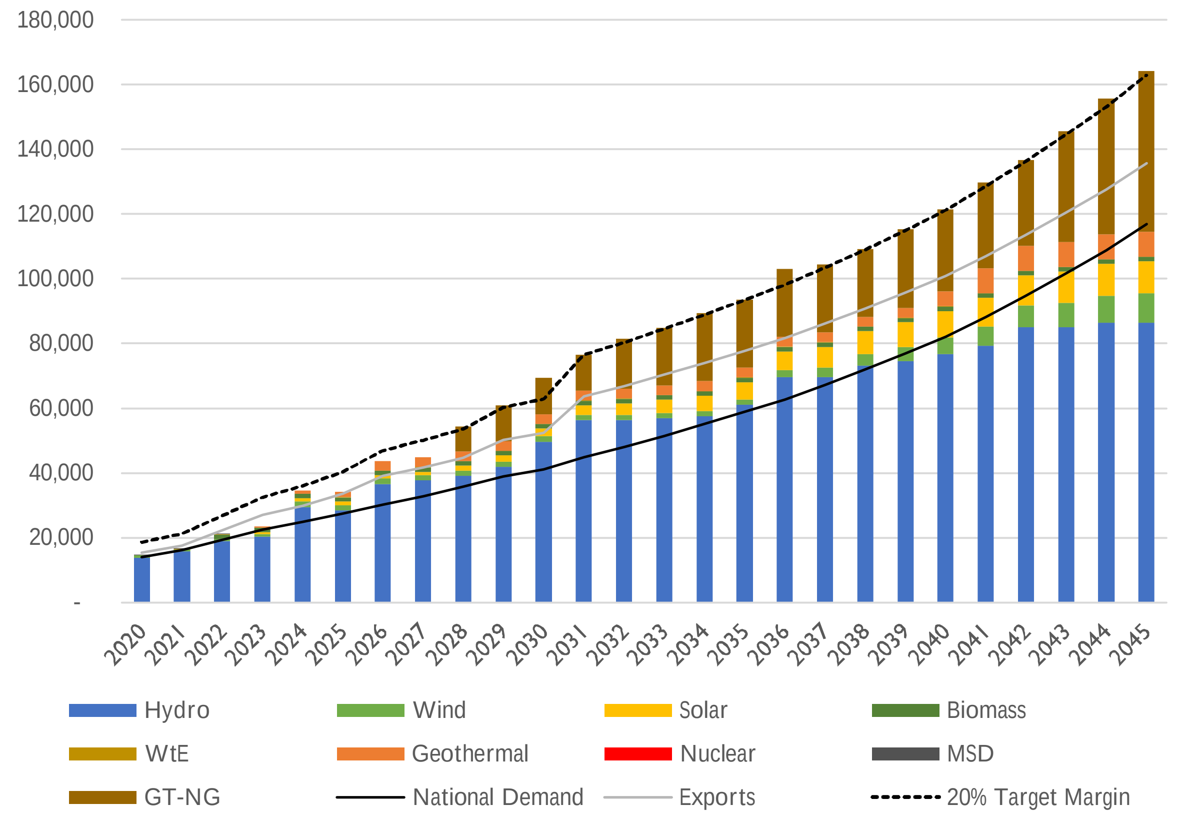


Table 5-8: Scenario 1 – Firm energy and energy margin (GWh)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Energy demand	Reserve margin
2020	13,794	686	-	-	103	-	-	277	-	14,860	15,459	-4%
2021	15,716	686	-	-	103	-	-	277	-	16,782	17,615	-5%
2022	18,937	686	-	1,360	103	-	-	277	-	21,363	22,264	-4%
2023	20,320	853	482	1,360	103	452	-	-	-	23,570	27,043	-13%
2024	29,468	1,641	1,060	1,360	103	846	-	-	-	34,479	29,917	15%
2025	28,408	1,641	1,060	1,360	103	1,634	-	-	-	34,207	33,560	2%
2026	36,633	1,641	1,060	1,360	103	2,975	-	-	-	43,772	39,044	12%
2027	37,708	1,641	1,060	1,360	103	2,975	-	-	-	44,848	41,726	7%
2028	39,163	1,641	1,494	1,360	103	2,975	-	-	7,726	54,463	44,577	22%
2029	41,880	1,641	1,927	1,360	103	2,975	-	-	11,038	60,924	50,249	21%
2030	49,711	1,641	2,409	1,360	103	2,975	-	-	11,038	69,237	52,376	32%
2031	56,327	1,641	2,987	1,360	103	2,975	-	-	11,038	76,431	63,684	20%
2032	56,327	1,641	3,565	1,360	103	2,975	-	-	15,453	81,425	66,814	22%
2033	56,871	1,641	4,143	1,360	103	2,975	-	-	17,660	84,754	70,348	20%
2034	57,506	1,641	4,722	1,360	103	2,975	-	-	20,971	89,279	73,944	21%
2035	61,022	1,641	5,300	1,360	103	2,975	-	-	20,971	93,373	77,725	20%
2036	69,576	2,035	5,878	1,360	103	2,975	-	-	20,971	102,899	81,611	26%
2037	69,576	2,824	6,456	1,360	103	2,975	-	-	20,971	104,266	86,103	21%
2038	73,054	3,612	7,034	1,360	103	2,975	-	-	20,971	109,110	90,711	20%
2039	74,434	4,401	7,612	1,360	103	2,975	-	-	24,283	115,168	95,636	20%
2040	76,551	5,189	8,191	1,360	103	4,551	-	-	25,386	121,332	100,837	20%
2041	79,264	5,977	8,769	1,360	103	7,705	-	-	26,490	129,669	107,015	21%
2042	84,874	6,766	9,347	1,360	103	7,705	-	-	26,490	136,646	113,453	20%
2043	84,874	7,554	9,732	1,360	103	7,705	-	-	34,217	145,546	120,364	21%
2044	86,403	8,343	9,732	1,360	103	7,705	-	-	41,943	155,589	127,484	22%
2045	86,403	9,131	9,732	1,360	103	7,705	-	-	49,669	164,104	135,623	21%

Figure 5-3: Scenario 1 – Firm energy (GWh)



5.4.2 COSTS

The total and discounted cost for Scenario 1 assuming a 10% discount factor are presented below.

Table 5-9: Scenario 1 – Total costs (USDm)

Year	Investment cost	Fixed O&M costs	Variable costs	Deficit cost	Discounted investment costs	Discounted fixed O&M costs	Discounted variable costs	Discounted deficit cost	Discounted total costs
2020	-	-	2	-	-	-	2	-	2
2021	-	-	11	-	-	-	10	-	10
2022	-	-	57	14	-	-	47	11	58
2023	404	-	5	1,395	303	-	4	1,048	1,355
2024	476	13	10	57	325	9	7	39	380
2025	581	13	15	86	361	8	9	53	431
2026	799	13	31	-	451	7	18	-	476
2027	1,243	13	33	-	638	7	17	-	662
2028	1,507	35	37	-	703	16	17	-	736
2029	1,260	52	33	-	534	22	14	-	571
2030	1,257	85	33	-	485	33	13	-	530
2031	1,307	106	33	-	458	37	12	-	507
2032	1,130	118	44	-	360	38	14	-	412
2033	1,409	128	61	-	408	37	18	-	463
2034	1,415	147	60	-	373	39	16	-	427
2035	1,647	167	56	-	394	40	13	-	448
2036	2,125	207	33	-	462	45	7	-	515
2037	2,465	219	35	-	488	43	7	-	538
2038	2,653	247	35	-	477	44	6	-	528
2039	2,450	271	38	-	401	44	6	-	451
2040	2,319	313	56	-	345	46	8	-	400
2041	2,021	371	91	-	273	50	12	-	336
2042	1,655	420	83	-	203	52	10	-	265
2043	1,451	444	88	-	162	50	10	-	221
2044	1,401	470	98	-	142	48	10	-	200
2045	633	491	141	-	58	45	13	-	117
Total	33,611	4,341	1,223	1,552	8,806	760	322	1,152	11,039

5.4.3 SENSITIVITIES

Given the proposed generation additions and expansion plan, the system dispatch for the 2020-2045 horizon was simulated under three sensitivities: Low Hydrology, High Demand and Low Demand. The resulting operation and associated costs are presented below.

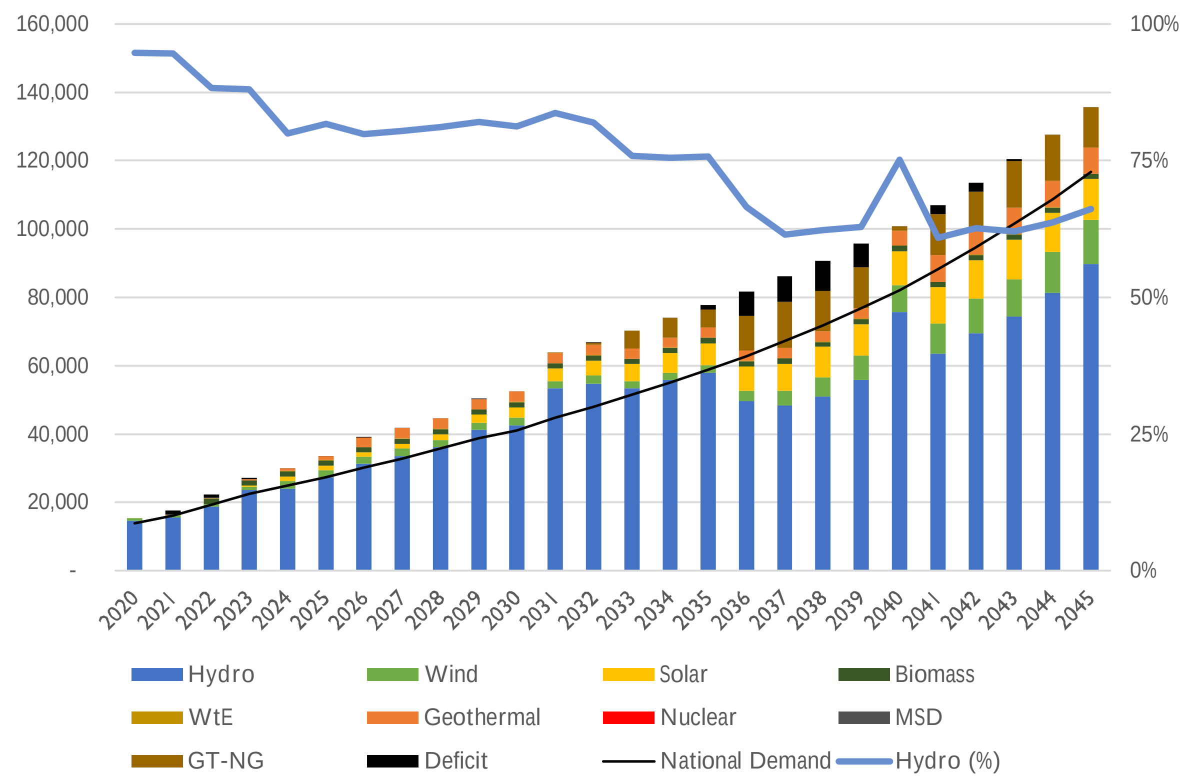
5.4.3.1 LOW HYDROLOGY

The low hydrology sensitivity simulated the dispatch of the proposed expansion plan assuming historical hydrological conditions so as to represent the worst historical drought experienced by the system. The recorded inflows for 1970 – 1995 were applied to the years 2020 – 2045 and so the historical drought in the 1980s occurs in the sensitivity in the 2030s.

Table 5-10: Scenario 1 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,460	95%
2021	15,515	671	-	-	103	-	-	117	-	1,209	16,406	95%
2022	18,800	722	-	1,516	103	-	-	142	-	982	21,283	88%
2023	23,525	1,011	291	1,516	103	256	-	-	-	340	26,702	88%
2024	23,931	2,278	1,341	1,516	103	749	-	-	-	-	29,917	80%
2025	27,399	2,059	1,239	1,516	103	1,243	-	-	-	-	33,560	82%
2026	31,174	2,195	1,276	1,516	103	2,780	-	-	-	-	39,044	80%
2027	33,565	2,251	1,316	1,516	103	2,975	-	-	-	-	41,726	80%
2028	36,140	2,045	1,798	1,516	103	2,975	-	-	-	-	44,577	81%
2029	41,193	2,141	2,322	1,516	103	2,975	-	-	-	-	50,249	82%
2030	42,538	2,234	3,011	1,516	103	2,975	-	-	-	-	52,376	81%
2031	53,357	2,141	3,589	1,516	103	2,975	-	-	3	-	63,684	84%
2032	54,721	2,295	4,447	1,516	103	2,975	-	-	758	-	66,814	82%
2033	53,329	2,104	4,978	1,516	103	2,975	-	-	5,343	-	70,348	76%
2034	55,791	2,128	5,715	1,516	103	2,975	-	-	5,717	-	73,944	75%
2035	57,903	2,265	6,458	1,516	103	2,975	-	-	5,191	1,314	76,411	76%
2036	49,580	3,012	7,144	1,516	103	2,975	-	-	10,179	7,103	74,509	67%
2037	48,292	4,299	7,969	1,516	103	2,975	-	-	13,498	7,451	78,652	61%
2038	50,939	5,679	8,834	1,516	103	2,975	-	-	11,720	8,946	81,765	62%
2039	55,858	6,957	9,388	1,516	103	2,975	-	-	12,044	6,796	88,841	63%
2040	75,741	7,782	9,991	1,516	103	4,359	-	-	1,302	42	100,795	75%
2041	63,494	8,903	10,519	1,516	103	7,705	-	-	12,066	2,709	104,306	61%
2042	69,546	10,084	11,159	1,516	103	7,705	-	-	10,854	2,486	110,967	63%
2043	74,337	10,940	11,556	1,516	103	7,705	-	-	13,670	536	119,828	62%
2044	81,212	12,015	11,487	1,516	103	7,705	-	-	13,415	31	127,453	64%
2045	89,741	12,849	11,952	1,516	103	7,705	-	-	11,757	-	135,623	66%

Figure 5-4: Scenario 1 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage



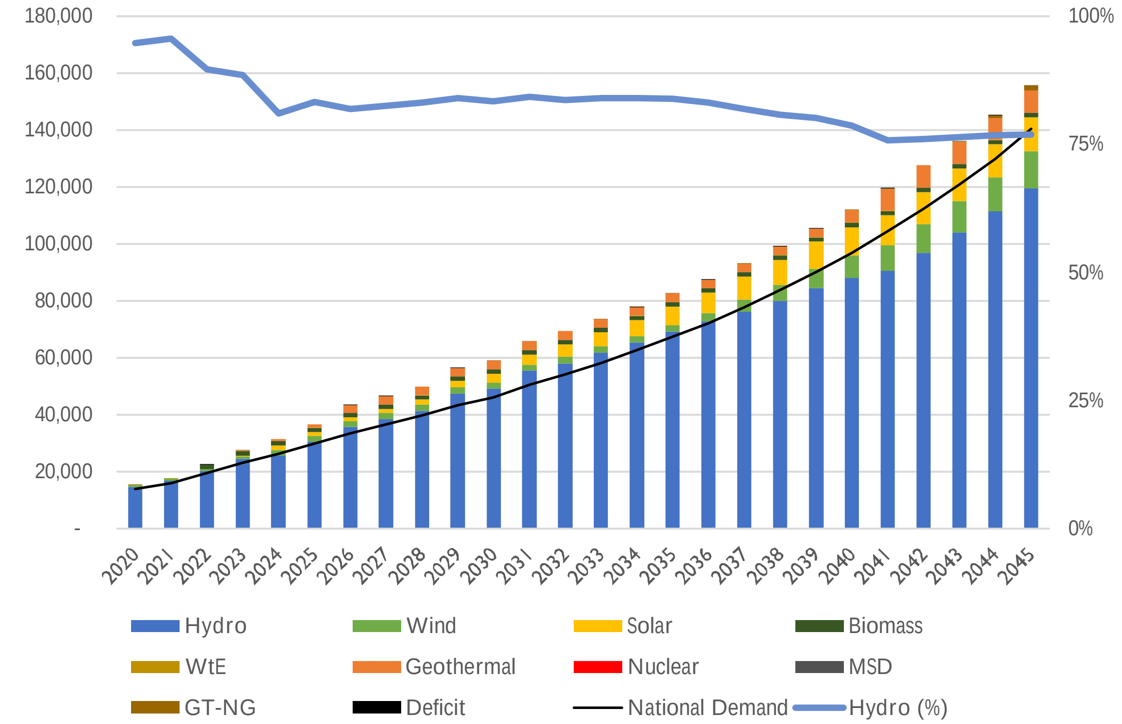
5.4.3.2 HIGH DEMAND

The high demand sensitivity simulated the dispatch of the proposed expansion plan assuming average hydrological conditions but using the high demand forecast. Stored energy within the hydro reservoirs was assumed to be available to increase hydro dispatch to meet the increased demand. The storage levels over the horizon were freely optimized given the inflows and demand. The resulting generation is shown in Table 5-11 and Figure 5-5.

Table 5-11: Scenario 1 – High Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,854	671	-	-	103	-	-	-	-	-	17,628	96%
2022	20,205	722	-	1,516	103	-	-	-	-	-	22,546	90%
2023	24,417	1,011	291	1,516	103	256	-	-	-	216	27,594	88%
2024	25,554	2,278	1,341	1,516	103	749	-	-	-	-	31,540	81%
2025	30,571	2,059	1,239	1,516	103	1,243	-	-	-	-	36,732	83%
2026	35,638	2,195	1,276	1,516	103	2,780	-	-	-	-	43,509	82%
2027	38,489	2,251	1,316	1,516	103	2,975	-	-	-	-	46,651	83%
2028	41,501	2,045	1,798	1,516	103	2,975	-	-	-	-	49,938	83%
2029	47,487	2,141	2,322	1,516	103	2,975	-	-	-	-	56,543	84%
2030	49,160	2,234	3,011	1,516	103	2,975	-	-	-	-	58,998	83%
2031	55,433	2,141	3,589	1,516	103	2,975	-	-	-	-	65,756	84%
2032	58,054	2,295	4,447	1,516	103	2,975	-	-	-	-	69,390	84%
2033	61,850	2,104	4,978	1,516	103	2,975	-	-	36	-	73,562	84%
2034	65,393	2,128	5,715	1,516	103	2,975	-	-	78	-	77,908	84%
2035	69,230	2,265	6,458	1,516	103	2,975	-	-	36	-	82,582	84%
2036	72,709	3,012	7,144	1,516	103	2,975	-	-	-	-	87,459	83%
2037	76,238	4,299	7,969	1,516	103	2,975	-	-	9	-	93,110	82%
2038	79,955	5,679	8,834	1,516	103	2,975	-	-	23	-	99,084	81%
2039	84,419	6,957	9,388	1,516	103	2,975	-	-	78	-	105,435	80%
2040	88,113	7,782	9,991	1,516	103	4,359	-	-	150	-	112,015	79%
2041	90,612	8,903	10,519	1,516	103	7,705	-	-	243	-	119,601	76%
2042	96,949	10,084	11,159	1,516	103	7,705	-	-	56	-	127,572	76%
2043	104,060	10,940	11,556	1,516	103	7,705	-	-	309	-	136,189	76%
2044	111,444	12,015	11,487	1,516	103	7,705	-	-	875	1	145,145	77%
2045	119,661	12,849	11,952	1,516	103	7,705	-	-	1,808	-	155,595	77%

Figure 5-5: Scenario 1 – High Demand Sensitivity – Generation (GWh) and Hydro percentage



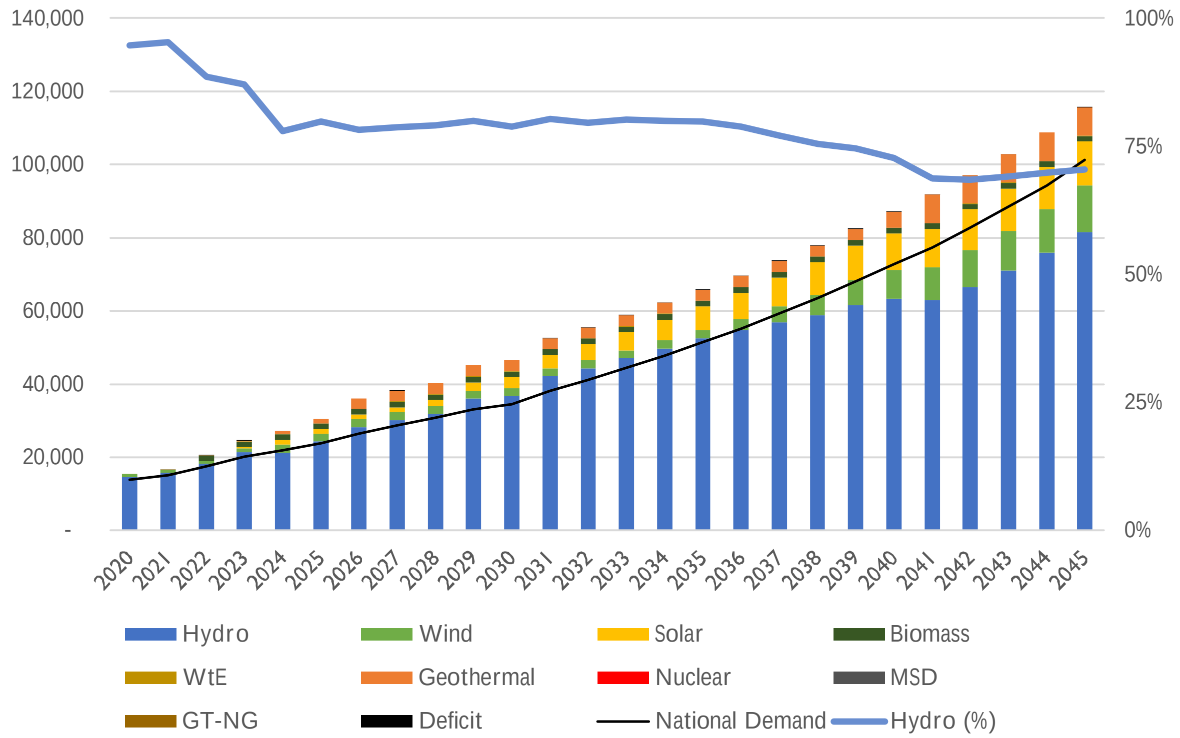
5.4.3.3 LOW DEMAND

The dispatch of the proposed expansion plan assuming the low demand forecast is presented below.

Table 5-12: Scenario 1 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	15,825	671	-	-	103	-	-	-	-	-	16,599	95%
2022	18,159	722	-	1,516	103	-	-	-	-	-	20,500	89%
2023	21,393	1,011	291	1,516	103	256	-	-	-	-	24,571	87%
2024	21,121	2,278	1,341	1,516	103	749	-	-	-	-	27,107	78%
2025	24,342	2,059	1,239	1,516	103	1,243	-	-	-	-	30,503	80%
2026	28,216	2,195	1,276	1,516	103	2,780	-	-	-	-	36,087	78%
2027	30,083	2,251	1,316	1,516	103	2,975	-	-	-	-	38,244	79%
2028	31,895	2,045	1,798	1,516	103	2,975	-	-	-	-	40,333	79%
2029	36,075	2,141	2,322	1,516	103	2,975	-	-	-	-	45,132	80%
2030	36,770	2,234	3,011	1,516	103	2,975	-	-	-	-	46,608	79%
2031	42,271	2,141	3,589	1,516	103	2,975	-	-	-	-	52,595	80%
2032	44,266	2,295	4,447	1,516	103	2,975	-	-	-	-	55,602	80%
2033	47,168	2,104	4,978	1,516	103	2,975	-	-	-	-	58,843	80%
2034	49,831	2,128	5,715	1,516	103	2,975	-	-	-	-	62,268	80%
2035	52,568	2,265	6,458	1,516	103	2,975	-	-	-	-	65,884	80%
2036	54,836	3,012	7,144	1,516	103	2,975	-	-	-	-	69,585	79%
2037	56,908	4,299	7,969	1,516	103	2,975	-	-	-	-	73,770	77%
2038	58,830	5,679	8,834	1,516	103	2,975	-	-	-	-	77,936	75%
2039	61,572	6,957	9,388	1,516	103	2,975	-	-	-	-	82,510	75%
2040	63,465	7,782	9,991	1,516	103	4,359	-	-	-	-	87,216	73%
2041	63,032	8,903	10,519	1,516	103	7,705	-	-	-	-	91,778	69%
2042	66,533	10,084	11,159	1,516	103	7,705	-	-	-	-	97,100	69%
2043	71,007	10,940	11,556	1,516	103	7,705	-	-	-	-	102,828	69%
2044	75,905	12,015	11,487	1,516	103	7,705	-	-	-	-	108,731	70%
2045	81,513	12,849	11,952	1,516	103	7,705	-	-	-	-	115,639	70%

Figure 5-6: Scenario 1 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage



5.5 SCENARIO 2 – REFERENCE CASE

The key assumptions for Scenario 2 are shown in Table 5-13. In Scenario 2, all hydro, geothermal, wind, and solar candidate projects were selected as a requirement of the scenario.

Table 5-13: Scenario 2 – Key assumptions

Parameter	Value
Demand forecast	Base Case
Hydrology	Average
Generation choices	All hydro, geothermal, wind and solar candidates selected

5.5.1 GENERATION ADDITIONS

The candidate generation additions for Scenario 2 are shown in Table 5-14 with full details provided in Appendix B. These are in addition to the existing, under-construction, and committed projects.

Table 5-14: Scenario 2 – Added candidate capacity

Type	Capacity (MW)	
	2030	2045
Hydro	1,295	11,213
Solar	725	4,800
Wind	1,885	6,385
Geothermal	-	600
GT	1,120	5,180
Nuclear	-	-
Total	5,025	28,178

The generation additions shown above combined with the existing and committed plants make up the total installed capacity shown in Table 5-15 and Figure 5-7. As indicated, there could be a shortage of firm capacity by 2023 if the peak demand grows in line with the Base Case demand forecast. The earliest assumed date by which new capacity can be built is 2024. Therefore, any short-term shortages will need to be managed operationally (through load shedding) or contractually (in the case of exports). It was assumed that the existing hydro plants with reduced available capacity would be restored to full installed capacity by 2026 by implementing the required rehabilitation projects.

The shortage in firm capacity is alleviated by 2024 due to a significant increase in the capacity of GERD by this date. Table 5-15 shows the reserve capacity margin (MW) based on the Ethiopia peak demand, i.e., excluding exports. The 20% capacity margin target is exceeded apart from in 2023. (The system is energy-constrained rather than capacity-constrained, as described further below.).

Table 5-16 and Figure 5-8 show the breakdown of generated energy for Scenario 2. The share of hydro energy does not exceed 75% from 2027 onwards.

Table 5-17 and Figure 5-9 show the firm energy by year for Scenario 2 relative to the annual energy demand. As indicated, based on average hydrological conditions, the system is expected to have an energy deficit before 2024. From 2028 the expansion plan results in an annual energy margin of approximately 20%, which provides some resilience against poor hydrological conditions.

Table 5-15: Scenario 2 – Installed and firm capacity (MW) and capacity margin

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Firm	Peak Demand	Exports	Reserve Margin
2020	3,450	324			25	-	-	38	-	3,837	3,610	2,459	175	47%
2021	3,941	324			25	-	-	38	-	4,328	4,101	3,047	175	35%
2022	4,303	444		298	25	-	-	38	-	5,108	4,553	3,727	345	22%
2023	4,303	544	250	298	25	57	-	-	-	5,477	4,602	4,431	515	4%
2024	8,352	844	550	298	25	107	-	-	-	10,176	8,791	4,966	579	77%
2025	8,652	964	550	298	25	207	-	-	-	10,696	9,227	5,490	707	68%
2026	11,013	1,229	550	298	25	377	-	-	-	13,492	11,837	6,130	1,009	93%
2027	11,013	1,529	550	298	25	377	-	-	-	13,792	11,927	6,620	1,009	80%
2028	11,317	1,829	550	298	25	377	-	-	840	15,236	13,161	7,161	1,009	84%
2029	12,211	2,129	675	298	25	377	-	-	980	16,695	14,285	7,890	1,298	81%
2030	12,308	2,429	975	298	25	377	-	-	1,120	17,533	14,613	8,279	1,298	76%
2031	13,147	2,729	1,175	298	25	377	-	-	2,100	19,852	16,522	9,493	2,153	74%
2032	13,147	3,029	1,475	298	25	377	-	-	2,380	20,732	16,892	10,086	2,153	67%
2033	13,147	3,329	1,775	298	25	377	-	-	2,660	21,612	17,262	10,712	2,153	61%
2034	13,147	3,629	2,075	298	25	377	-	-	3,080	22,632	17,772	11,369	2,153	56%
2035	14,747	3,929	2,375	298	25	377	-	-	3,080	24,832	19,462	12,061	2,153	61%
2036	14,747	4,229	2,575	298	25	377	-	-	3,080	25,332	19,552	12,804	2,153	53%
2037	15,682	4,529	2,875	298	25	377	-	-	3,080	26,867	20,577	13,593	2,153	51%
2038	15,682	4,829	3,175	298	25	377	-	-	3,080	27,467	20,667	14,436	2,153	43%
2039	15,682	5,129	3,475	298	25	377	-	-	4,060	29,047	21,737	15,337	2,153	42%
2040	16,118	5,429	3,775	298	25	377	-	-	4,060	30,083	22,263	16,331	2,153	36%
2041	17,818	5,729	4,025	298	25	377	-	-	4,060	32,333	24,053	17,418	2,153	38%
2042	20,098	6,029	4,325	298	25	377	-	-	4,200	35,353	26,563	18,596	2,153	43%
2043	20,548	6,329	4,625	298	25	377	-	-	4,620	36,823	27,523	19,860	2,153	39%
2044	21,042	6,629	4,925	298	25	977	-	-	4,760	38,657	28,847	21,218	2,153	36%
2045	22,071	6,929	5,050	298	25	977	-	-	5,180	40,530	30,385	22,651	2,153	34%

Figure 5-7: Scenario 2 – Firm capacity and stacked peak demand and exports (MW)

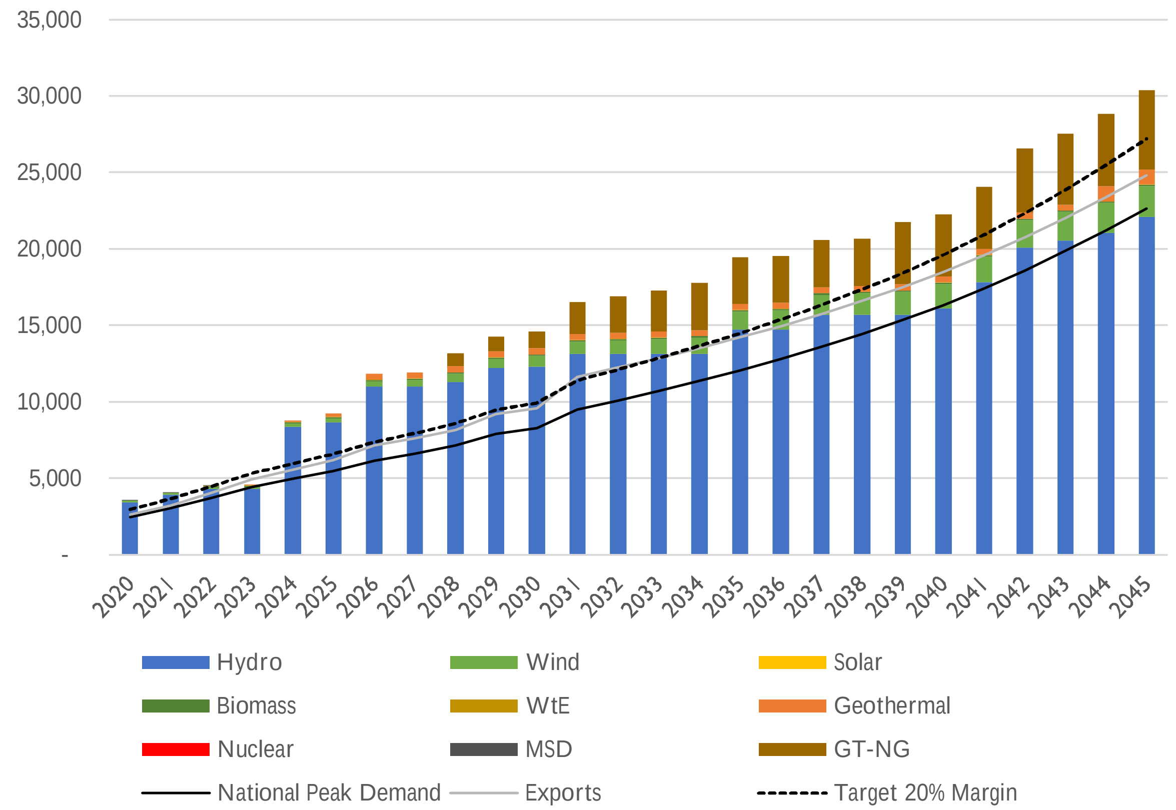


Table 5-16: Scenario 2 – Generated energy by plant type (GWh)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,795	671	-	-	103	-	-	46	-	-	17,615	95%
2022	19,633	722	-	1,516	103	-	-	277	-	14	22,251	88%
2023	22,470	1,011	291	1,516	103	256	-	-	-	1,395	25,648	88%
2024	23,874	2,278	1,341	1,516	103	749	-	-	-	57	29,860	80%
2025	26,898	2,494	1,239	1,516	103	1,243	-	-	-	66	33,494	80%
2026	29,950	3,420	1,276	1,516	103	2,780	-	-	-	-	39,044	77%
2027	31,155	4,661	1,316	1,516	103	2,975	-	-	-	-	41,726	75%
2028	33,131	5,572	1,280	1,516	103	2,975	-	-	-	-	44,577	74%
2029	37,392	6,691	1,573	1,516	103	2,975	-	-	-	-	50,249	74%
2030	37,629	7,772	2,381	1,516	103	2,975	-	-	-	-	52,376	72%
2031	47,042	9,254	2,743	1,516	103	2,975	-	-	50	-	63,684	74%
2032	48,054	10,440	3,569	1,516	103	2,975	-	-	157	-	66,814	72%
2033	49,963	10,851	4,144	1,516	103	2,975	-	-	797	-	70,348	71%
2034	51,258	11,597	4,863	1,516	103	2,975	-	-	1,632	-	73,944	69%
2035	50,894	13,359	5,614	1,516	103	2,975	-	-	3,264	-	77,725	65%
2036	56,634	14,166	6,090	1,516	103	2,975	-	-	128	-	81,611	69%
2037	58,801	15,831	6,876	1,516	103	2,975	-	-	-	-	86,103	68%
2038	61,394	16,896	7,719	1,516	103	2,975	-	-	109	-	90,711	68%
2039	64,669	17,691	8,293	1,516	103	2,975	-	-	389	-	95,636	68%
2040	68,919	17,842	8,920	1,516	103	2,975	-	-	562	-	100,837	68%
2041	72,469	19,179	9,390	1,516	103	2,975	-	-	1,384	-	107,015	68%
2042	79,063	19,735	10,061	1,516	103	2,975	-	-	-	-	113,453	70%
2043	85,136	19,943	10,660	1,516	103	2,975	-	-	32	-	120,364	71%
2044	86,505	20,623	11,201	1,516	103	7,512	-	-	23	-	127,484	68%
2045	87,882	20,674	11,901	1,516	103	7,705	-	-	5,842	-	135,624	65%

Figure 5-8: Scenario 2 – Generated energy (GWh) and percentage hydro generation

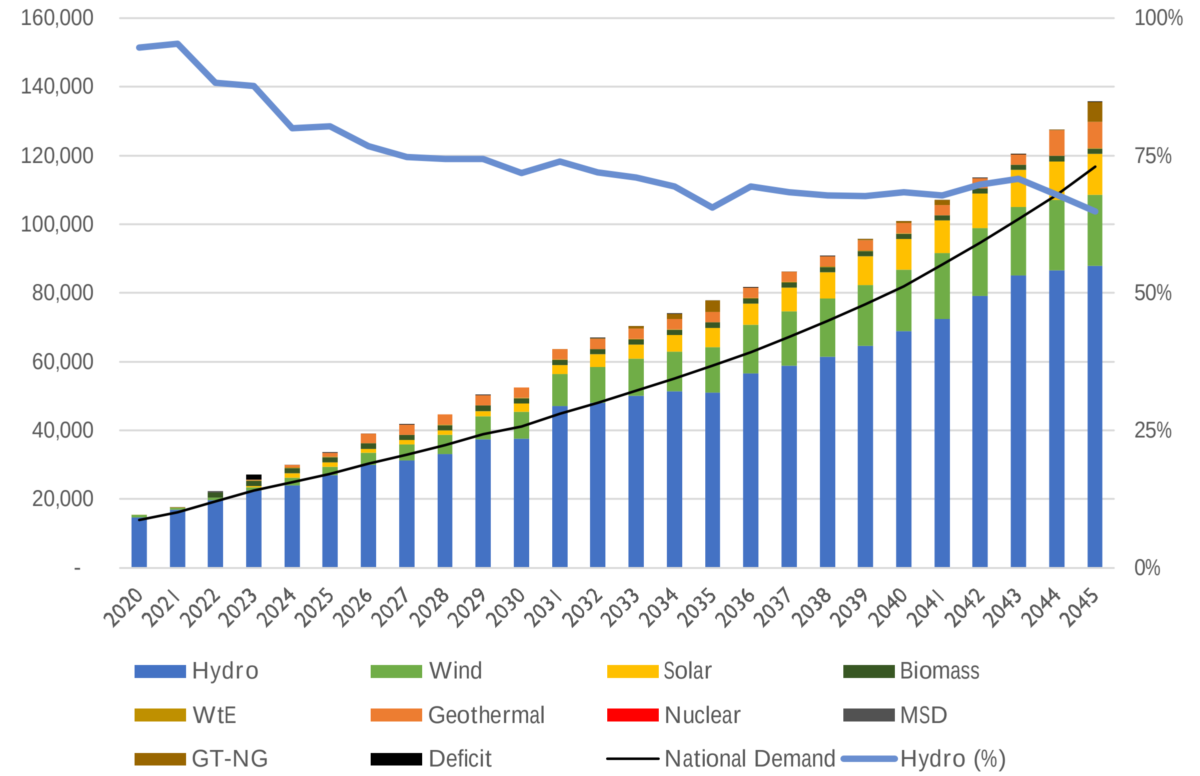
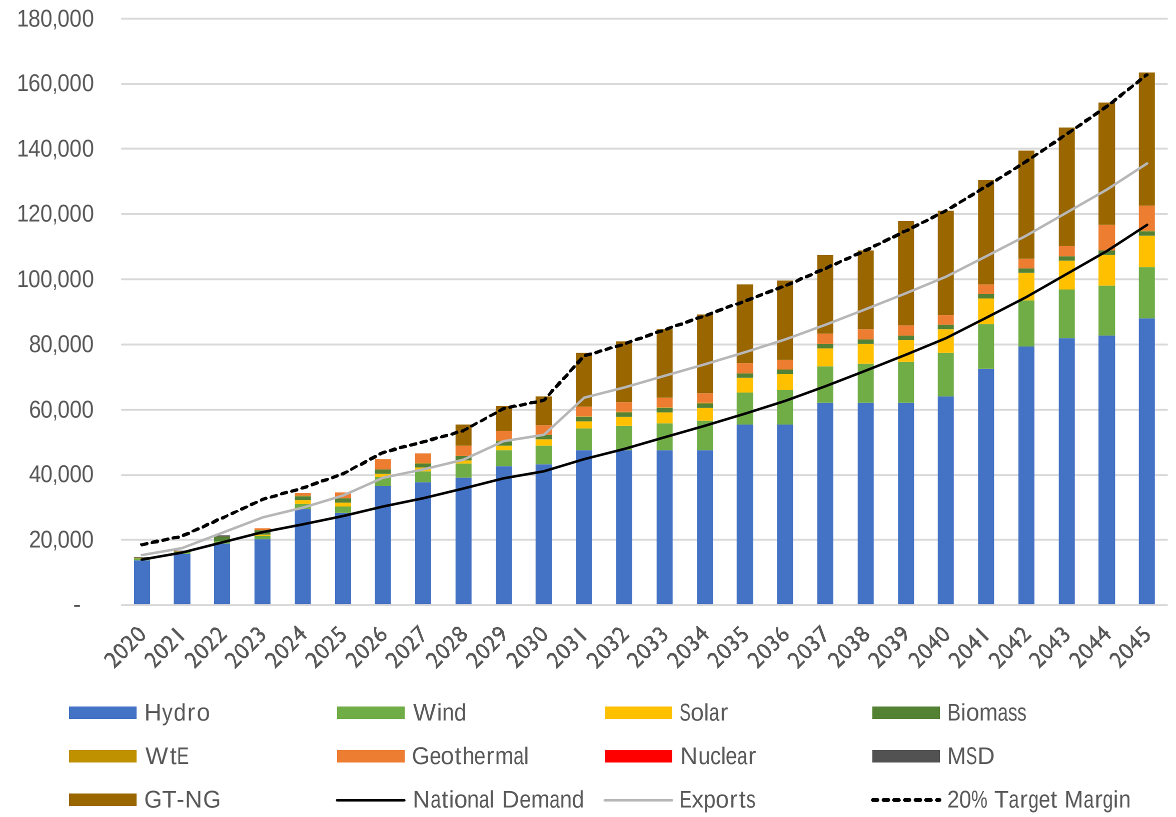


Table 5-17: Scenario 2 – Firm energy (GWh) and energy margin

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Energy demand	Reserve margin
2020	13,794	686	-	-	103	-	-	277	-	14,860	15,459	-4%
2021	15,716	686	-	-	103	-	-	277	-	16,782	17,615	-5%
2022	18,937	686	-	1,360	103	-	-	277	-	21,363	22,264	-4%
2023	20,320	853	482	1,360	103	452	-	-	-	23,570	27,043	-13%
2024	29,468	1,641	1,060	1,360	103	846	-	-	-	34,479	29,917	15%
2025	28,408	1,957	1,060	1,360	103	1,634	-	-	-	34,522	33,560	3%
2026	36,633	2,622	1,060	1,360	103	2,975	-	-	-	44,753	39,044	15%
2027	37,708	3,411	1,060	1,360	103	2,975	-	-	-	46,617	41,726	12%
2028	39,163	4,199	1,060	1,360	103	2,975	-	-	6,623	55,483	44,577	24%
2029	42,679	4,988	1,301	1,360	103	2,975	-	-	7,726	61,132	50,249	22%
2030	43,223	5,776	1,879	1,360	103	2,975	-	-	8,830	64,146	52,376	22%
2031	47,645	6,564	2,264	1,360	103	2,975	-	-	16,556	77,469	63,684	22%
2032	47,645	7,353	2,843	1,360	103	2,975	-	-	18,764	81,043	66,814	21%
2033	47,645	8,141	3,421	1,360	103	2,975	-	-	20,971	84,617	70,348	20%
2034	47,645	8,930	3,999	1,360	103	2,975	-	-	24,283	89,295	73,944	21%
2035	55,476	9,718	4,577	1,360	103	2,975	-	-	24,283	98,492	77,725	27%
2036	55,476	10,470	4,963	1,360	103	2,975	-	-	24,283	99,629	81,611	22%
2037	62,093	11,184	5,541	1,360	103	2,975	-	-	24,283	107,539	86,103	25%
2038	62,093	11,973	6,119	1,360	103	2,975	-	-	24,283	108,905	90,711	20%
2039	62,093	12,577	6,697	1,360	103	2,975	-	-	32,009	117,814	95,636	23%
2040	64,059	13,287	7,275	1,360	103	2,975	-	-	32,009	121,068	100,837	20%
2041	72,613	13,707	7,757	1,360	103	2,975	-	-	32,009	130,524	107,015	22%
2042	79,310	14,285	8,335	1,360	103	2,975	-	-	33,113	139,482	113,453	23%
2043	82,024	14,785	8,913	1,360	103	2,975	-	-	36,424	146,584	120,364	22%
2044	82,659	15,337	9,491	1,360	103	7,705	-	-	37,528	154,183	127,484	21%
2045	88,066	15,639	9,732	1,360	103	7,705	-	-	40,839	163,445	135,623	21%

Figure 5-9: Scenario 2 – Firm energy and stacked demand and exports (GWh)



5.5.2 COSTS

The total and discounted cost for Scenario 1 assuming a 10% discount factor are presented below.

Table 5-18: Scenario 2 – Total costs (USDm)

Year	Investment cost	Fixed O&M costs	Variable costs	Deficit cost	Discounted investment costs	Discounted fixed O&M costs	Discounted variable costs	Discounted deficit cost	Discounted total costs
2020	-	-	2	-	-	-	2	-	2
2021	-	-	11	-	-	-	10	-	10
2022	-	-	57	14	-	-	47	11	58
2023	404	-	5	1,395	303	-	4	1,048	1,355
2024	670	13	10	57	457	9	7	39	512
2025	589	16	15	66	366	10	9	41	427
2026	920	24	31	-	519	13	18	-	550
2027	1,287	32	33	-	660	16	17	-	694
2028	1,424	57	33	-	664	27	16	-	706
2029	1,160	85	33	-	492	36	14	-	542
2030	1,783	102	33	-	688	39	13	-	740
2031	1,802	141	39	-	632	49	14	-	695
2032	1,554	158	49	-	495	50	16	-	561
2033	1,607	174	115	-	465	51	33	-	549
2034	1,650	193	200	-	434	51	53	-	538
2035	1,621	235	367	-	388	56	88	-	532
2036	1,521	246	46	-	331	54	10	-	395
2037	2,037	276	33	-	403	55	7	-	464
2038	2,406	289	45	-	433	52	8	-	493
2039	2,508	314	73	-	410	51	12	-	473
2040	3,274	335	91	-	487	50	14	-	550
2041	3,286	378	175	-	444	51	24	-	519
2042	2,992	434	33	-	368	53	4	-	425
2043	2,354	460	37	-	263	51	4	-	318
2044	2,123	537	83	-	216	55	8	-	279
2045	1,263	574	680	-	117	53	63	-	232
Total	40,233	5,072	2,333	1,533	10,035	932	513	1,140	12,620

5.5.3 SENSITIVITIES

Given the proposed generation additions and expansion plan, the system dispatch for the 2020-2045 horizon was simulated under three sensitivities: Low Hydrology, High Demand, and Low Demand. The resulting operation and associated costs are presented below.

5.5.3.1 LOW HYDROLOGY

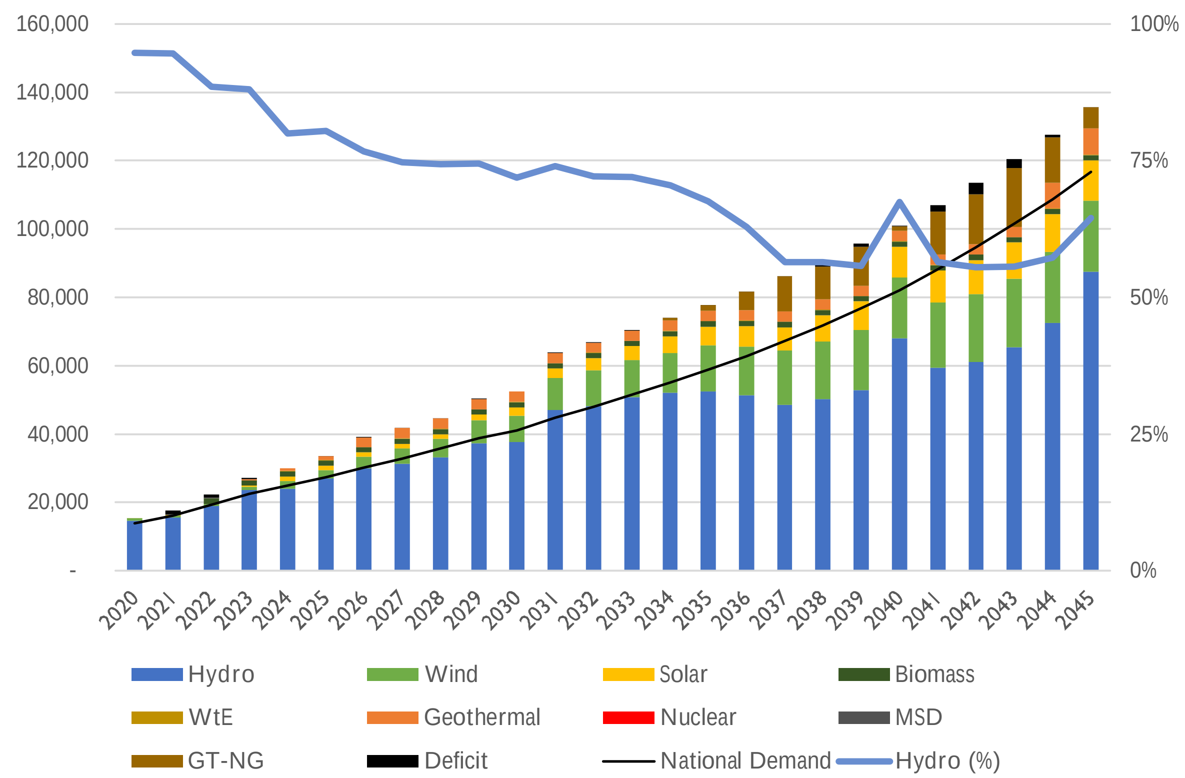
The low hydrology sensitivity simulated the dispatch of the proposed expansion plan assuming historical hydrological conditions so as to represent the worst historical drought experienced by the system. The recorded inflows for 1970 – 1995 were applied to the years 2020 – 2045, and so the historic drought in the 1980s occurs in the sensitivity in the 2030s.

The resulting generation under low hydrology conditions is presented in Table 5-19 and Figure 5-10.

Table 5-19: Scenario 2 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,460	95%
2021	15,515	671	-	-	103	-	-	117	-	1,209	16,406	95%
2022	18,827	722	-	1,516	103	-	-	114	-	982	21,282	88%
2023	23,506	1,011	291	1,516	103	256	-	-	-	360	26,683	88%
2024	23,931	2,278	1,341	1,516	103	749	-	-	-	-	29,917	80%
2025	26,964	2,494	1,239	1,516	103	1,243	-	-	-	-	33,560	80%
2026	29,950	3,420	1,276	1,516	103	2,780	-	-	-	-	39,044	77%
2027	31,155	4,661	1,316	1,516	103	2,975	-	-	-	-	41,726	75%
2028	33,131	5,572	1,280	1,516	103	2,975	-	-	-	-	44,577	74%
2029	37,392	6,691	1,573	1,516	103	2,975	-	-	-	-	50,249	74%
2030	37,629	7,772	2,381	1,516	103	2,975	-	-	-	-	52,376	72%
2031	47,092	9,254	2,743	1,516	103	2,975	-	-	-	-	63,684	74%
2032	48,211	10,440	3,569	1,516	103	2,975	-	-	-	-	66,814	72%
2033	50,685	10,851	4,144	1,516	103	2,975	-	-	74	-	70,348	72%
2034	52,141	11,597	4,863	1,516	103	2,975	-	-	750	-	73,944	71%
2035	52,512	13,359	5,614	1,516	103	2,975	-	-	1,646	-	77,725	68%
2036	51,368	14,166	6,090	1,516	103	2,975	-	-	5,394	-	81,611	63%
2037	48,583	15,831	6,876	1,516	103	2,975	-	-	10,219	-	86,103	56%
2038	50,210	16,896	7,719	1,516	103	2,975	-	-	9,542	1,751	88,960	56%
2039	52,817	17,691	8,293	1,516	103	2,975	-	-	11,325	916	94,721	56%
2040	68,008	17,842	8,920	1,516	103	2,975	-	-	1,474	-	100,837	67%
2041	59,278	19,179	9,390	1,516	103	2,975	-	-	12,663	1,912	105,103	56%
2042	61,115	19,735	10,061	1,516	103	2,975	-	-	14,730	3,218	110,234	55%
2043	65,386	19,943	10,660	1,516	103	2,975	-	-	17,149	2,632	117,732	56%
2044	72,583	20,623	11,201	1,516	103	7,512	-	-	13,165	780	126,704	57%
2045	87,538	20,674	11,901	1,516	103	7,705	-	-	6,187	-	135,623	65%

Figure 5-10: Scenario 2 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage



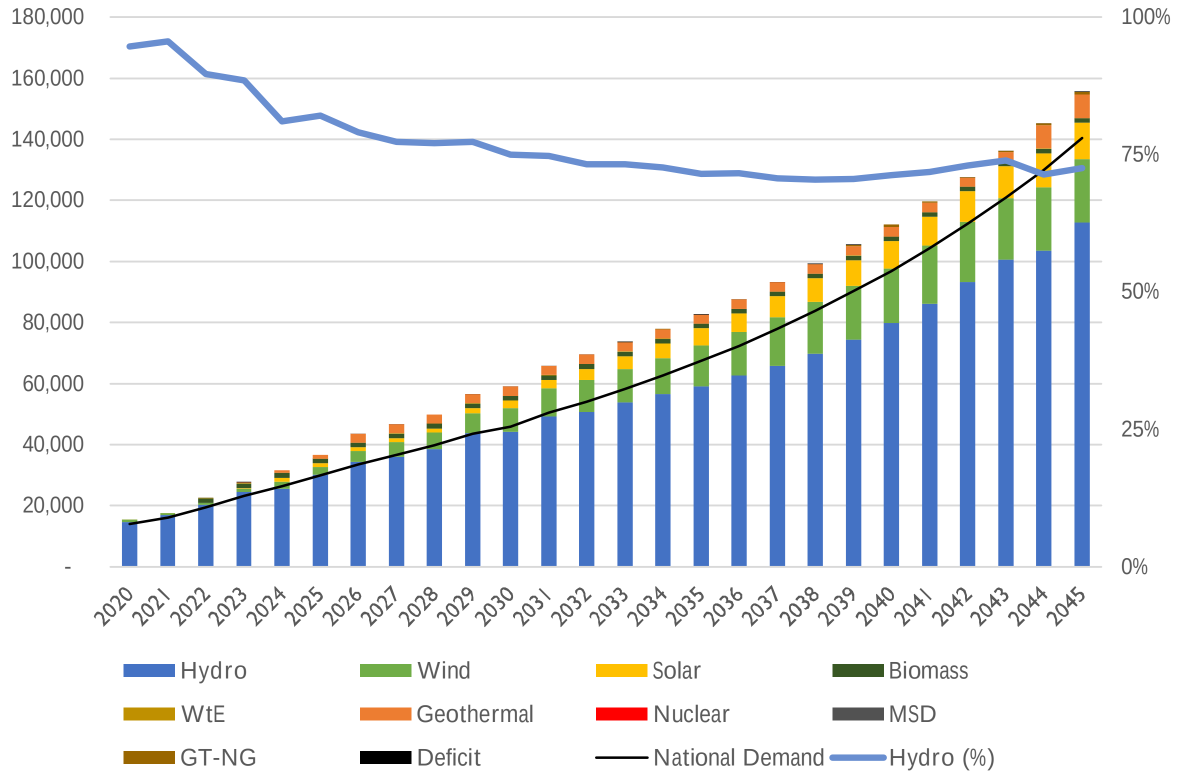
5.5.3.2 HIGH DEMAND

The high demand sensitivity simulated the dispatch of the proposed expansion plan assuming average hydrological conditions but using the high demand forecast. Stored energy within the hydro reservoirs was assumed to be available to increase hydro dispatch to meet the increased demand. The storage levels over the horizon were freely optimized given the inflows and demand. The resulting generation under high demand conditions is presented in Table 5-20 and Figure 5-11.

Table 5-20: Scenario 2 – High Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,854	671	-	-	103	-	-	-	-	-	17,628	96%
2022	20,205	722	-	1,516	103	-	-	-	-	-	22,546	90%
2023	24,417	1,011	291	1,516	103	256	-	-	-	216	27,594	88%
2024	25,554	2,278	1,341	1,516	103	749	-	-	-	-	31,540	81%
2025	30,136	2,494	1,239	1,516	103	1,243	-	-	-	-	36,732	82%
2026	34,414	3,420	1,276	1,516	103	2,780	-	-	-	-	43,509	79%
2027	36,079	4,661	1,316	1,516	103	2,975	-	-	-	-	46,651	77%
2028	38,492	5,572	1,280	1,516	103	2,975	-	-	-	-	49,938	77%
2029	43,686	6,691	1,573	1,516	103	2,975	-	-	-	-	56,543	77%
2030	44,251	7,772	2,381	1,516	103	2,975	-	-	-	-	58,998	75%
2031	49,165	9,254	2,743	1,516	103	2,975	-	-	-	-	65,756	75%
2032	50,787	10,440	3,569	1,516	103	2,975	-	-	-	-	69,390	73%
2033	53,900	10,851	4,144	1,516	103	2,975	-	-	73	-	73,562	73%
2034	56,597	11,597	4,863	1,516	103	2,975	-	-	258	-	77,908	73%
2035	59,015	13,359	5,614	1,516	103	2,975	-	-	-	-	82,582	71%
2036	62,576	14,166	6,090	1,516	103	2,975	-	-	33	-	87,459	72%
2037	65,808	15,831	6,876	1,516	103	2,975	-	-	-	-	93,110	71%
2038	69,749	16,896	7,719	1,516	103	2,975	-	-	126	-	99,084	70%
2039	74,339	17,691	8,293	1,516	103	2,975	-	-	518	-	105,435	71%
2040	79,802	17,842	8,920	1,516	103	2,975	-	-	857	-	112,015	71%
2041	85,962	19,179	9,390	1,516	103	2,975	-	-	477	-	119,601	72%
2042	93,087	19,735	10,061	1,516	103	2,975	-	-	96	-	127,572	73%
2043	100,627	19,943	10,660	1,516	103	2,975	-	-	366	-	136,189	74%
2044	103,542	20,623	11,201	1,516	103	7,512	-	-	648	-	145,146	71%
2045	112,793	20,674	11,901	1,516	103	7,705	-	-	903	-	155,595	72%

Figure 5-11: Scenario 2 – High Demand Sensitivity – Generation (GWh) and Hydro percentage



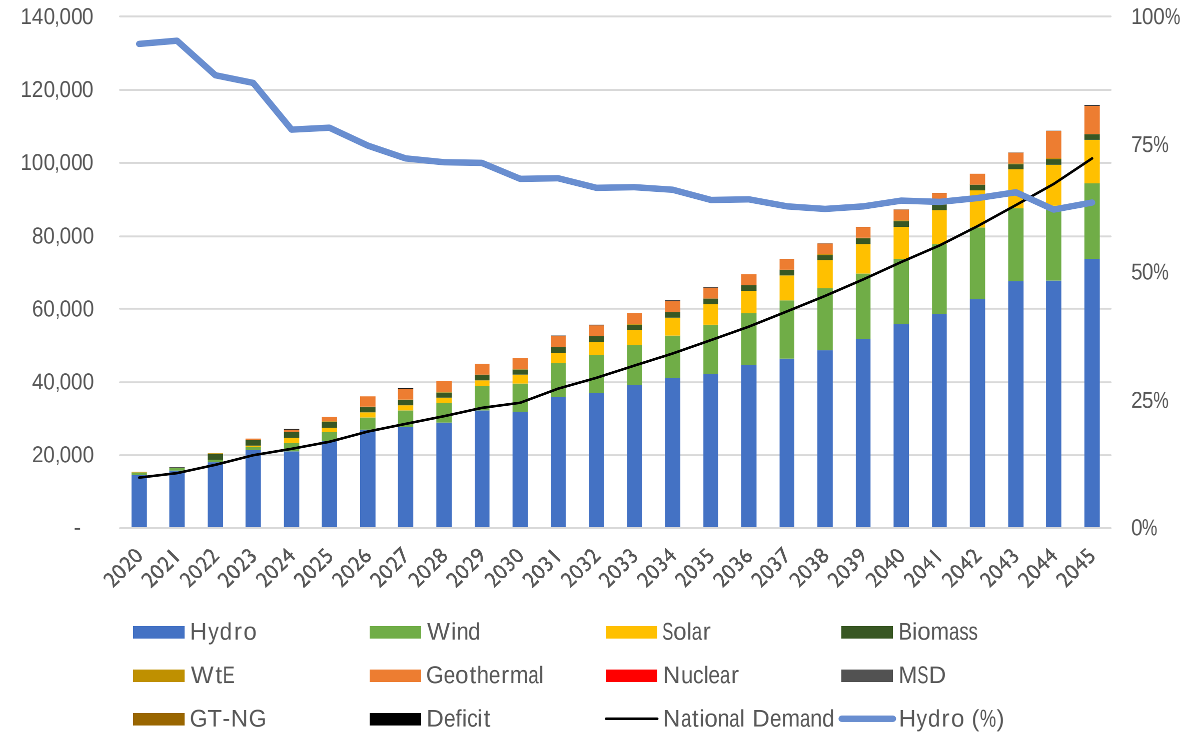
5.5.3.3 LOW DEMAND

The dispatch of the proposed expansion plan assuming the low demand forecast is presented below.

Table 5-21: Scenario 2 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	15,825	671	-	-	103	-	-	-	-	-	16,599	95%
2022	18,159	722	-	1,516	103	-	-	-	-	-	20,500	89%
2023	21,393	1,011	291	1,516	103	256	-	-	-	-	24,571	87%
2024	21,121	2,278	1,341	1,516	103	749	-	-	-	-	27,107	78%
2025	23,907	2,494	1,239	1,516	103	1,243	-	-	-	-	30,503	78%
2026	26,992	3,420	1,276	1,516	103	2,780	-	-	-	-	36,087	75%
2027	27,673	4,661	1,316	1,516	103	2,975	-	-	-	-	38,244	72%
2028	28,887	5,572	1,280	1,516	103	2,975	-	-	-	-	40,333	72%
2029	32,274	6,691	1,573	1,516	103	2,975	-	-	-	-	45,132	72%
2030	31,861	7,772	2,381	1,516	103	2,975	-	-	-	-	46,608	68%
2031	36,004	9,254	2,743	1,516	103	2,975	-	-	-	-	52,595	68%
2032	36,999	10,440	3,569	1,516	103	2,975	-	-	-	-	55,602	67%
2033	39,255	10,851	4,144	1,516	103	2,975	-	-	-	-	58,844	67%
2034	41,214	11,597	4,863	1,516	103	2,975	-	-	-	-	62,268	66%
2035	42,317	13,359	5,614	1,516	103	2,975	-	-	-	-	65,884	64%
2036	44,736	14,166	6,090	1,516	103	2,975	-	-	-	-	69,585	64%
2037	46,469	15,831	6,876	1,516	103	2,975	-	-	-	-	73,770	63%
2038	48,728	16,896	7,719	1,516	103	2,975	-	-	-	-	77,936	63%
2039	51,932	17,691	8,293	1,516	103	2,975	-	-	-	-	82,510	63%
2040	55,861	17,842	8,920	1,516	103	2,975	-	-	-	-	87,216	64%
2041	58,616	19,179	9,390	1,516	103	2,975	-	-	-	-	91,778	64%
2042	62,710	19,735	10,061	1,516	103	2,975	-	-	-	-	97,100	65%
2043	67,631	19,943	10,660	1,516	103	2,975	-	-	-	-	102,828	66%
2044	67,775	20,623	11,201	1,516	103	7,512	-	-	-	-	108,731	62%
2045	73,740	20,674	11,901	1,516	103	7,705	-	-	-	-	115,639	64%

Figure 5-12: Scenario 2 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage



5.6 SCENARIO 3 – ADDITIONAL GEOTHERMAL

The key assumptions for Scenario 3 are shown in Table 5-22. In Scenario 3, additional geothermal capacity up to a total of 5,000 MW was assumed.

Table 5-22: Scenario 3 – Key assumptions

Parameter	Value
Demand forecast	Base Case
Hydrology	Average
Generation choices	Least-cost with additional geothermal candidates

5.6.1 GENERATION ADDITIONS

The candidate generation additions for Scenario 3 are summarized in Table 5-23 with full details in Appendix B. These are in addition to the existing, under-construction, and committed projects.

Table 5-23: Scenario 3 – Added candidate capacity

Type	Capacity (MW)	
	2030	2045
Hydro	2,371	8,825
Solar	600	3,600
Wind	300	1,350
Geothermal	-	4,600
GT	1,400	3,780
Nuclear	-	-
Total	4,671	22,155

Combined with the existing and committed plants, the resulting total installed capacity is shown in Table 5-24 and Figure 5-13. The earliest assumed date by which new capacity can be built is 2024. Therefore, any short-term shortages will need to be managed operationally (through load shedding) or contractually (in the case of exports).

Table 5-25 and Figure 5-14 show the breakdown of generated energy for Scenario 3. The share of hydro energy is above 75% until 2039.

Table 5-26 and Figure 5-15 show the firm energy by year for Scenario 3 relative to the annual energy demand. As indicated, based on average hydrological conditions, the system is expected to have an energy deficit before 2024. From 2028 the expansion plan results in an annual energy margin of approximately 20%, which will provide some resilience against poor hydrological conditions.

Table 5-24: Scenario 3 – Installed capacity (MW)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Firm	Peak Demand	Exports	Reserve Margin (%)
2020	3,450	324			25	-	-	38	-	3,837	3,610	2,459	175	47%
2021	3,941	324			25	-	-	38	-	4,328	4,101	3,047	175	35%
2022	4,303	444		298	25	-	-	38	-	5,108	4,553	3,727	345	22%
2023	4,303	544	250	298	25	57	-	-	-	5,477	4,602	4,431	515	4%
2024	8,352	844	550	298	25	107	-	-	-	10,176	8,791	4,966	579	77%
2025	8,652	844	550	298	25	207	-	-	-	10,576	9,191	5,490	707	67%
2026	11,013	844	550	298	25	377	-	-	-	13,107	11,722	6,130	1,009	91%
2027	11,013	844	550	298	25	377	-	-	-	13,107	11,722	6,620	1,009	77%
2028	11,317	844	700	298	25	377	-	-	980	14,541	13,006	7,161	1,009	82%
2029	11,784	844	850	298	25	377	-	-	1,400	15,578	13,893	7,890	1,298	76%
2030	13,384	844	850	298	25	377	-	-	1,400	17,178	15,493	8,279	1,298	87%
2031	14,319	844	850	298	25	377	-	-	1,680	18,393	16,708	9,493	2,153	76%
2032	14,319	844	850	298	25	377	-	-	2,100	18,813	17,128	10,086	2,153	70%
2033	15,213	844	1,150	298	25	377	-	-	2,100	20,007	18,022	10,712	2,153	68%
2034	15,310	844	1,425	298	25	377	-	-	2,520	20,800	18,539	11,369	2,153	63%
2035	17,010	844	1,425	298	25	377	-	-	2,520	22,500	20,239	12,061	2,153	68%
2036	17,010	844	1,425	298	25	477	-	-	2,520	22,600	20,339	12,804	2,153	59%
2037	17,010	844	1,575	298	25	977	-	-	2,660	23,390	20,979	13,593	2,153	54%
2038	17,010	844	1,825	298	25	1,477	-	-	2,800	24,280	21,619	14,436	2,153	50%
2039	17,010	844	2,075	298	25	1,977	-	-	3,080	25,310	22,399	15,337	2,153	46%
2040	17,010	844	2,350	298	25	2,477	-	-	3,220	26,225	23,039	16,331	2,153	41%
2041	17,940	844	2,650	298	25	2,977	-	-	3,220	27,955	24,469	17,418	2,153	40%
2042	18,312	994	2,950	298	25	3,477	-	-	3,360	29,417	25,526	18,596	2,153	37%
2043	19,088	1,294	3,250	298	25	3,977	-	-	3,360	31,293	26,892	19,860	2,153	35%
2044	19,538	1,594	3,550	298	25	4,477	-	-	3,360	32,843	27,932	21,218	2,153	32%
2045	19,683	1,894	3,850	298	25	4,977	-	-	3,780	34,507	29,087	22,651	2,153	28%

Figure 5-13: Scenario 3 – Firm capacity and peak demand (MW)

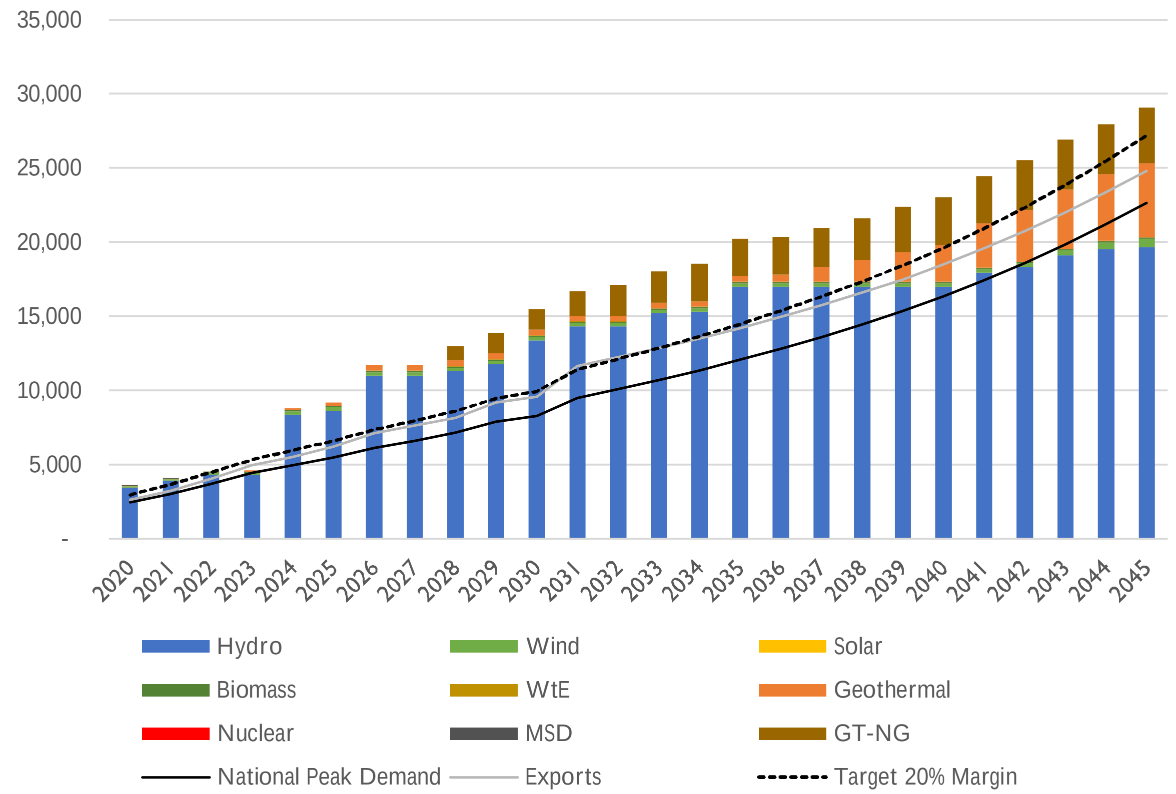


Table 5-25: Scenario 3 – Generated energy by plant type (GWh)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,795	671	-	-	103	-	-	46	-	-	17,615	95%
2022	19,633	722	-	1,516	103	-	-	277	-	14	22,251	88%
2023	22,470	1,011	291	1,516	103	256	-	-	-	1,395	25,648	88%
2024	23,874	2,278	1,341	1,516	103	749	-	-	-	57	29,860	80%
2025	27,313	2,059	1,239	1,516	103	1,243	-	-	-	86	33,474	82%
2026	31,174	2,195	1,276	1,516	103	2,780	-	-	-	-	39,044	80%
2027	33,565	2,251	1,316	1,516	103	2,975	-	-	-	1	41,726	80%
2028	36,274	2,045	1,624	1,516	103	2,975	-	-	40	-	44,577	81%
2029	41,525	2,141	1,990	1,516	103	2,975	-	-	-	-	50,249	83%
2030	43,469	2,234	2,079	1,516	103	2,975	-	-	-	-	52,376	83%
2031	54,964	2,141	1,983	1,516	103	2,975	-	-	3	-	63,684	86%
2032	57,698	2,295	2,040	1,516	103	2,975	-	-	187	-	66,814	86%
2033	60,809	2,104	2,691	1,516	103	2,975	-	-	150	-	70,348	86%
2034	63,679	2,128	3,335	1,516	103	2,975	-	-	208	-	73,944	86%
2035	67,535	2,265	3,331	1,516	103	2,975	-	-	-	-	77,725	87%
2036	70,511	2,347	3,345	1,516	103	3,763	-	-	27	-	81,611	86%
2037	70,545	2,414	3,739	1,516	103	7,705	-	-	80	-	86,103	82%
2038	70,404	2,479	4,418	1,516	103	11,647	-	-	144	-	90,711	78%
2039	70,904	2,461	4,940	1,516	103	15,460	-	-	252	-	95,636	74%
2040	71,234	2,503	5,549	1,516	103	19,531	-	-	400	-	100,837	71%
2041	73,016	2,428	6,202	1,516	103	23,473	-	-	276	-	107,015	68%
2042	74,088	3,161	6,949	1,516	103	27,351	-	-	284	-	113,453	65%
2043	75,242	4,322	7,640	1,516	103	31,357	-	-	184	-	120,364	63%
2044	76,523	5,556	8,252	1,516	103	35,299	-	-	234	-	127,484	60%
2045	78,323	6,757	9,284	1,516	103	39,241	-	-	399	-	135,623	58%

Figure 5-14: Scenario 3 – Generated energy (GWh) and percentage hydro generation

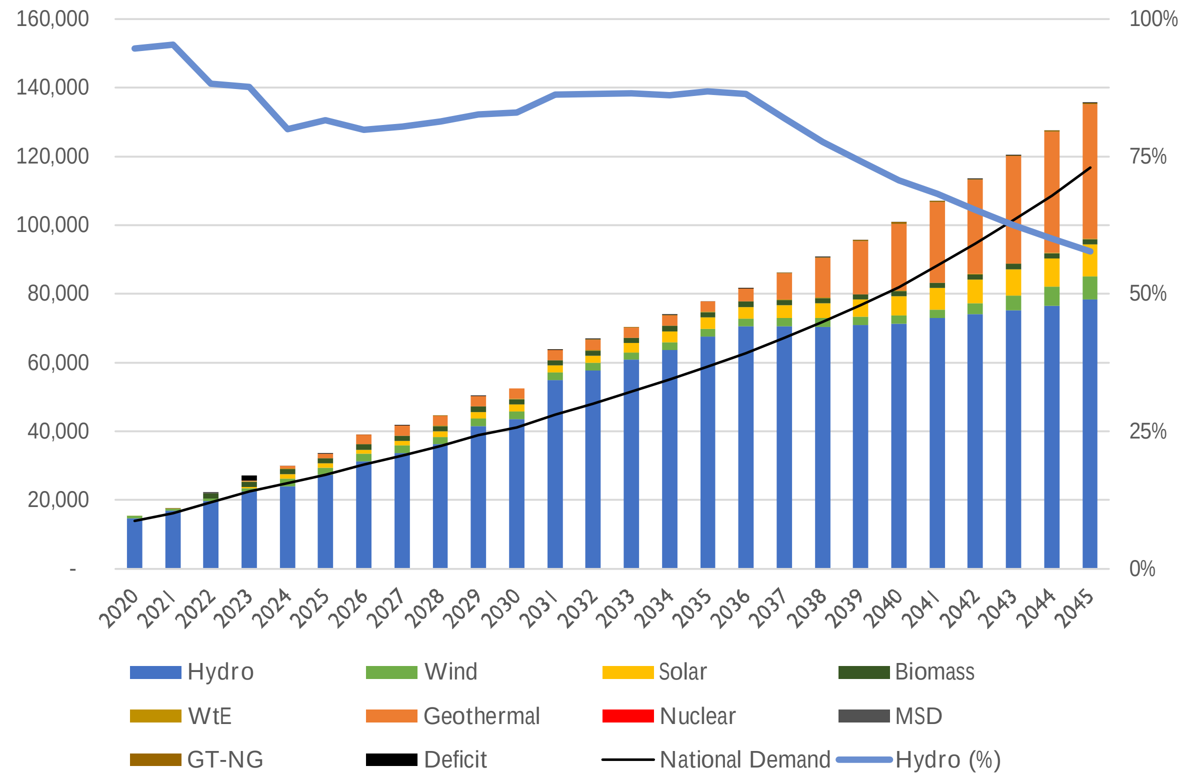
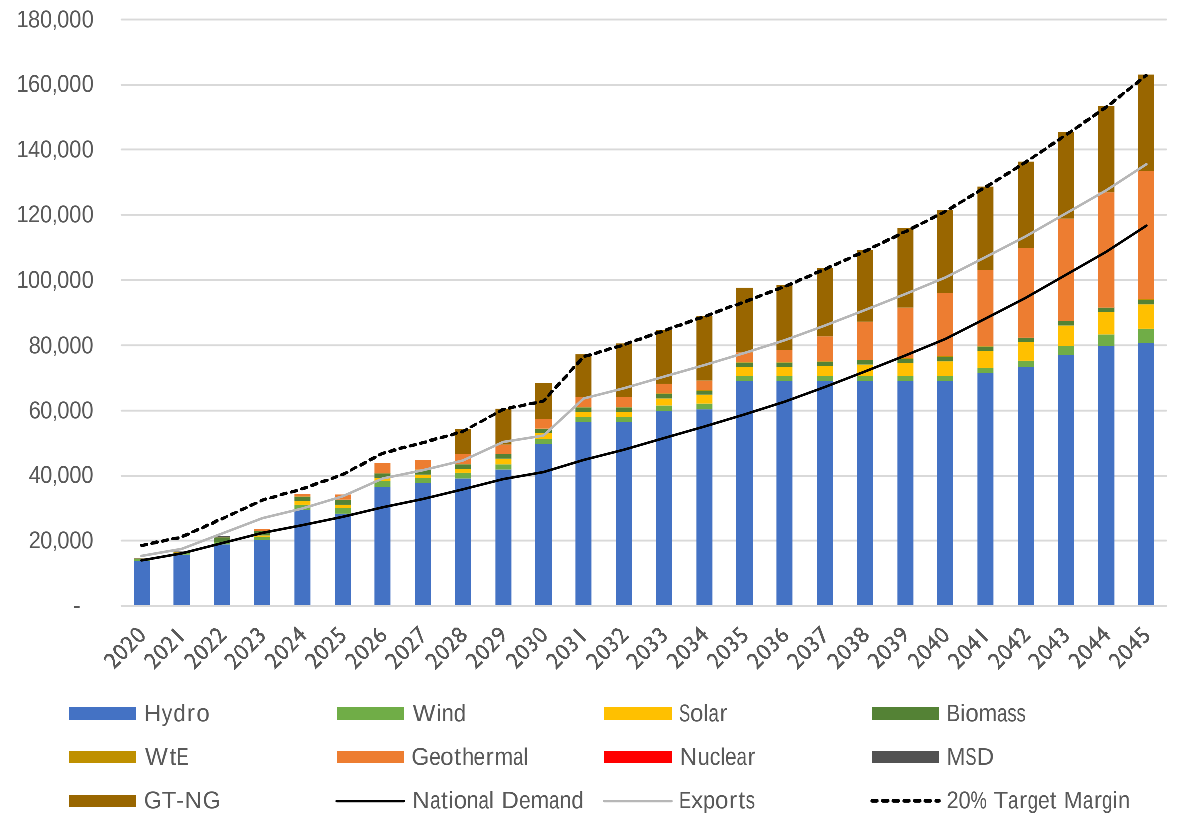


Table 5-26: Scenario 3 – Firm energy (GWh) and energy margin

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Energy demand	Reserve margin
2020	13,794	686	-	-	103	-	-	277	-	14,860	15,459	-4%
2021	15,716	686	-	-	103	-	-	277	-	16,782	17,615	-5%
2022	18,937	686	-	1,360	103	-	-	277	-	21,363	22,264	-4%
2023	20,320	853	482	1,360	103	452	-	-	-	23,570	27,043	-13%
2024	29,468	1,641	1,060	1,360	103	846	-	-	-	34,479	29,917	15%
2025	28,408	1,641	1,060	1,360	103	1,634	-	-	-	34,207	33,560	2%
2026	36,633	1,641	1,060	1,360	103	2,975	-	-	-	43,772	39,044	12%
2027	37,708	1,641	1,060	1,360	103	2,975	-	-	-	44,848	41,726	7%
2028	39,163	1,641	1,349	1,360	103	2,975	-	-	7,726	54,318	44,577	22%
2029	41,880	1,641	1,638	1,360	103	2,975	-	-	11,038	60,635	50,249	21%
2030	49,711	1,641	1,638	1,360	103	2,975	-	-	11,038	68,466	52,376	31%
2031	56,327	1,641	1,638	1,360	103	2,975	-	-	13,245	77,290	63,684	21%
2032	56,327	1,641	1,638	1,360	103	2,975	-	-	16,556	80,601	66,814	21%
2033	59,843	1,641	2,216	1,360	103	2,975	-	-	16,556	84,695	70,348	20%
2034	60,387	1,641	2,746	1,360	103	2,975	-	-	19,868	89,081	73,944	20%
2035	68,942	1,641	2,746	1,360	103	2,975	-	-	19,868	97,635	77,725	26%
2036	68,942	1,641	2,746	1,360	103	3,763	-	-	19,868	98,423	81,611	21%
2037	68,942	1,641	3,035	1,360	103	7,705	-	-	20,971	103,758	86,103	21%
2038	68,942	1,641	3,517	1,360	103	11,647	-	-	22,075	109,286	90,711	20%
2039	68,942	1,641	3,999	1,360	103	15,589	-	-	24,283	115,917	95,636	21%
2040	68,942	1,641	4,529	1,360	103	19,531	-	-	25,386	121,493	100,837	20%
2041	71,542	1,641	5,107	1,360	103	23,473	-	-	25,386	128,614	107,015	20%
2042	73,248	2,035	5,685	1,360	103	27,415	-	-	26,490	136,337	113,453	20%
2043	76,996	2,824	6,263	1,360	103	31,357	-	-	26,490	145,394	120,364	21%
2044	79,709	3,612	6,842	1,360	103	35,299	-	-	26,490	153,416	127,484	20%
2045	80,793	4,401	7,420	1,360	103	39,241	-	-	29,802	163,119	135,623	20%

Figure 5-15: Scenario 3 – Firm energy and stacked demand and exports (GWh)



5.6.2 COSTS

The total and discounted cost for Scenario 3, assuming a 10% discount factor, are presented below.

Table 5-27: Scenario 3 – Total costs (USDm)

Year	Investment cost	Fixed O&M costs	Variable costs	Deficit cost	Discounted investment costs	Discounted fixed O&M costs	Discounted variable costs	Discounted deficit cost	Discounted total costs
2020	-	-	2	-	-	-	2	-	2
2021	-	-	11	-	-	-	10	-	10
2022	-	-	57	14	-	-	47	11	58
2023	404	-	5	1,395	303	-	4	1,048	1,355
2024	476	13	10	57	325	9	7	39	380
2025	581	13	15	86	361	8	9	53	431
2026	799	13	31	-	451	7	18	-	476
2027	1,225	13	33	-	628	7	17	-	652
2028	1,604	34	38	-	748	16	17	-	781
2029	1,288	50	33	-	546	21	14	-	582
2030	1,595	79	33	-	615	30	13	-	658
2031	1,159	99	34	-	406	35	12	-	453
2032	959	105	53	-	305	33	17	-	356
2033	1,369	125	49	-	397	36	14	-	447
2034	1,554	137	55	-	409	36	14	-	460
2035	1,627	167	33	-	389	40	8	-	438
2036	1,692	176	44	-	368	38	10	-	416
2037	2,173	224	91	-	430	44	18	-	492
2038	2,588	274	139	-	465	49	25	-	540
2039	2,886	326	190	-	472	53	31	-	556
2040	2,963	376	248	-	440	56	37	-	533
2041	3,135	441	277	-	424	60	37	-	521
2042	2,909	503	318	-	357	62	39	-	458
2043	2,621	574	350	-	293	64	39	-	396
2044	2,030	639	397	-	206	65	40	-	311
2045	967	707	455	-	89	65	42	-	197
Total	38,603	5,087	3,004	1,552	9,430	835	543	1,152	11,960

5.6.3 SENSITIVITIES

Given the proposed generation additions and expansion plan, the system dispatch for the 2020-2045 horizon was simulated under three sensitivities: Low Hydrology, High Demand, and Low Demand. The resulting operation and associated costs are presented below.

5.6.3.1 LOW HYDROLOGY

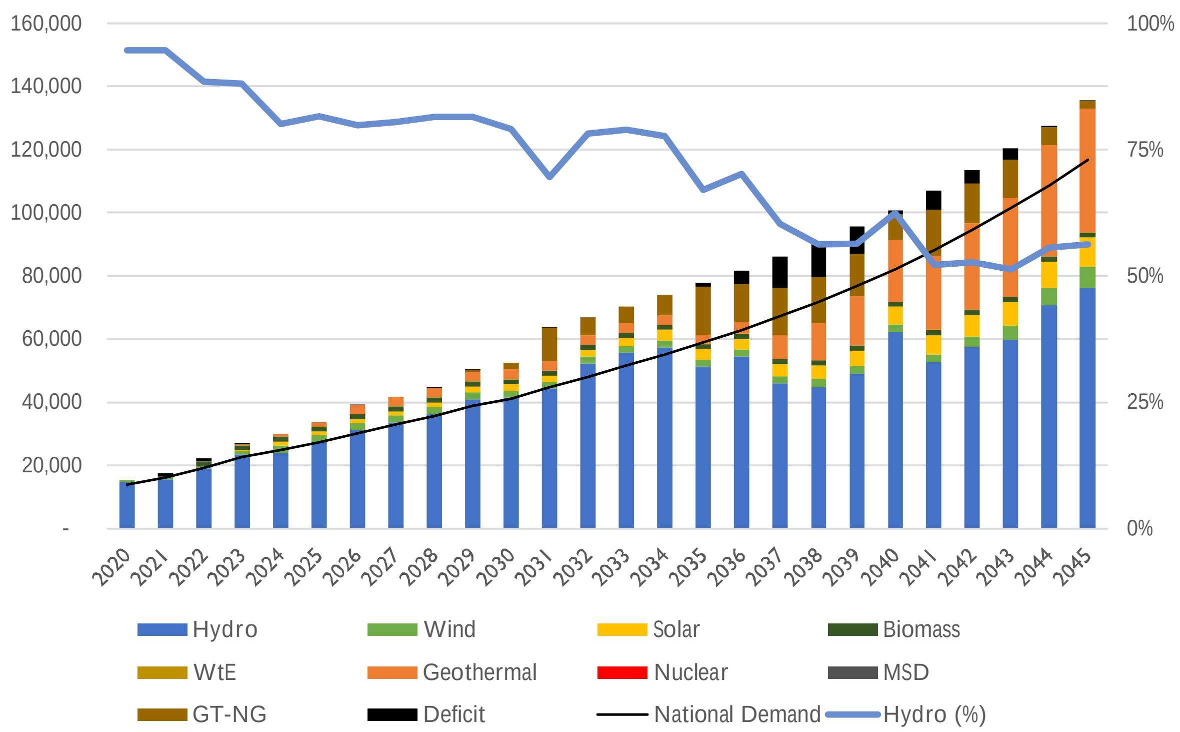
The low hydrology sensitivity simulated the dispatch of the proposed expansion plan assuming historical hydrological conditions so as to represent the worst historical drought experienced by the system. The recorded inflows for 1970 – 1995 were applied to the years 2020 – 2045, and so the historic drought in the 1980s occurs in the sensitivity in the 2030s.

The resulting generation under low hydrology conditions is presented in Table 5-28 and Figure 5-16.

Table 5-28: Scenario 3 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,460	95%
2021	15,593	671	-	-	103	-	-	117	-	1,131	16,485	95%
2022	18,881	722	-	1,516	103	-	-	114	-	928	21,336	88%
2023	23,496	1,011	291	1,516	103	256	-	-	-	369	26,673	88%
2024	23,931	2,278	1,341	1,516	103	749	-	-	-	-	29,917	80%
2025	27,399	2,059	1,239	1,516	103	1,243	-	-	-	-	33,560	82%
2026	31,174	2,195	1,276	1,516	103	2,780	-	-	-	-	39,044	80%
2027	33,565	2,251	1,316	1,516	103	2,975	-	-	-	-	41,726	80%
2028	36,314	2,045	1,624	1,516	103	2,975	-	-	-	-	44,577	81%
2029	40,907	2,141	1,990	1,516	103	2,975	-	-	618	-	50,249	81%
2030	41,388	2,234	2,079	1,516	103	2,975	-	-	2,082	-	52,376	79%
2031	44,267	2,141	1,983	1,516	103	2,975	-	-	10,699	-	63,684	70%
2032	52,244	2,295	2,040	1,516	103	2,975	-	-	5,641	-	66,814	78%
2033	55,565	2,104	2,691	1,516	103	2,975	-	-	5,395	-	70,348	79%
2034	57,412	2,128	3,335	1,516	103	2,975	-	-	6,438	37	73,907	78%
2035	51,273	2,265	3,331	1,516	103	2,975	-	-	15,134	1,129	76,595	67%
2036	54,361	2,347	3,345	1,516	103	3,763	-	-	12,036	4,141	77,471	70%
2037	45,898	2,414	3,739	1,516	103	7,705	-	-	14,774	9,953	76,150	60%
2038	44,821	2,479	4,418	1,516	103	11,647	-	-	14,656	11,071	79,640	56%
2039	49,007	2,461	4,940	1,516	103	15,460	-	-	13,445	8,704	86,932	56%
2040	62,183	2,503	5,549	1,516	103	19,531	-	-	8,173	1,278	99,559	62%
2041	52,636	2,428	6,202	1,516	103	23,473	-	-	14,503	6,153	100,862	52%
2042	57,611	3,161	6,949	1,516	103	27,351	-	-	12,622	4,139	109,314	53%
2043	59,822	4,322	7,640	1,516	103	31,357	-	-	11,998	3,606	116,758	51%
2044	70,727	5,556	8,252	1,516	103	35,299	-	-	5,693	338	127,146	56%
2045	76,136	6,757	9,284	1,516	103	39,241	-	-	2,401	185	135,439	56%

Figure 5-16: Scenario 3 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage



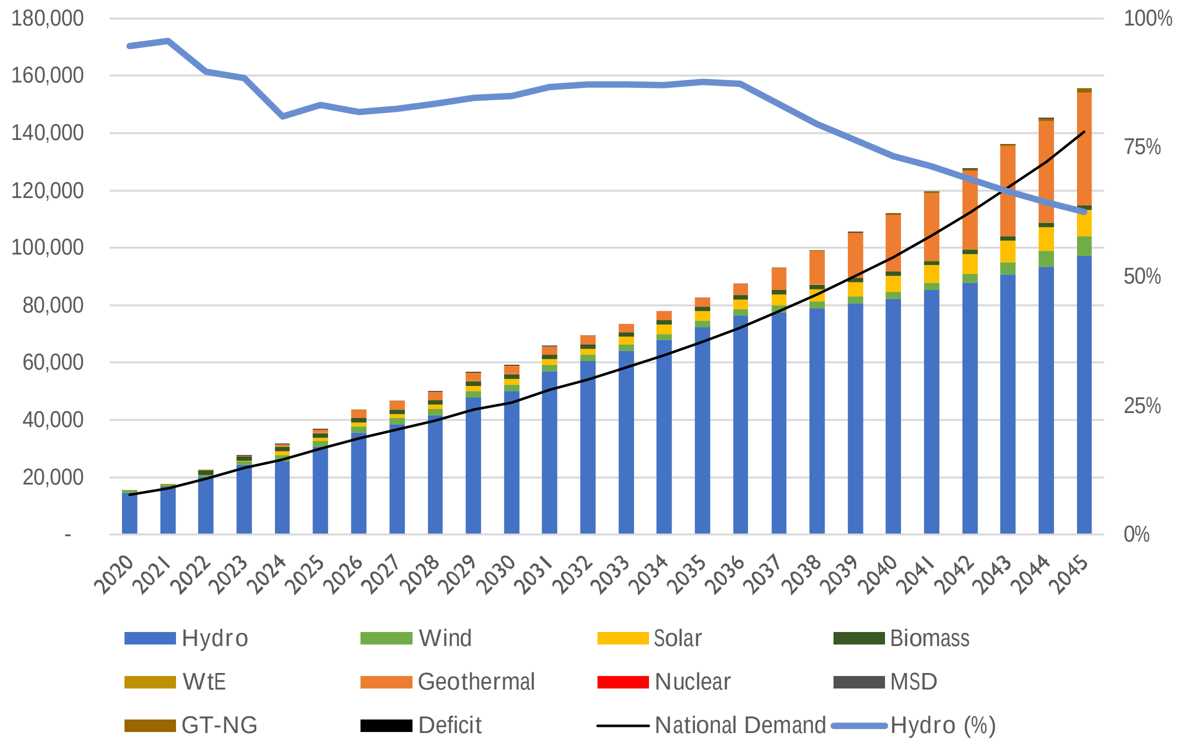
5.6.3.2 HIGH DEMAND

The high demand sensitivity simulated the dispatch of the proposed expansion plan assuming average hydrological conditions but using the high demand forecast. Stored energy within the hydro reservoirs was assumed to be available to increase hydro dispatch to meet the increased demand. The storage levels over the horizon were freely optimized given the inflows and demand. The resulting generation under high demand conditions is presented in Table 5-29 and Figure 5-17.

Table 5-29: Scenario 3 – High Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,460	95%
2021	16,854	671	-	-	103	-	-	-	-	-	17,628	96%
2022	20,205	722	-	1,516	103	-	-	-	-	-	22,546	90%
2023	24,417	1,011	291	1,516	103	256	-	-	-	216	27,594	88%
2024	25,554	2,278	1,341	1,516	103	749	-	-	-	-	31,540	81%
2025	30,571	2,059	1,239	1,516	103	1,243	-	-	-	-	36,732	83%
2026	35,638	2,195	1,276	1,516	103	2,780	-	-	-	-	43,509	82%
2027	38,490	2,251	1,316	1,516	103	2,975	-	-	-	-	46,651	83%
2028	41,675	2,045	1,624	1,516	103	2,975	-	-	-	-	49,938	83%
2029	47,818	2,141	1,990	1,516	103	2,975	-	-	-	-	56,543	85%
2030	50,091	2,234	2,079	1,516	103	2,975	-	-	-	-	58,998	85%
2031	57,039	2,141	1,983	1,516	103	2,975	-	-	-	-	65,756	87%
2032	60,461	2,295	2,040	1,516	103	2,975	-	-	-	-	69,390	87%
2033	64,173	2,104	2,691	1,516	103	2,975	-	-	-	-	73,562	87%
2034	67,815	2,128	3,335	1,516	103	2,975	-	-	36	-	77,908	87%
2035	72,393	2,265	3,331	1,516	103	2,975	-	-	-	-	82,582	88%
2036	76,385	2,347	3,345	1,516	103	3,763	-	-	-	-	87,459	87%
2037	77,576	2,414	3,739	1,516	103	7,705	-	-	55	-	93,110	83%
2038	78,749	2,479	4,418	1,516	103	11,647	-	-	172	-	99,084	79%
2039	80,590	2,461	4,940	1,516	103	15,460	-	-	364	-	105,435	76%
2040	82,173	2,503	5,549	1,516	103	19,531	-	-	640	-	112,015	73%
2041	85,312	2,428	6,202	1,516	103	23,473	-	-	566	-	119,601	71%
2042	87,778	3,161	6,949	1,516	103	27,351	-	-	713	-	127,572	69%
2043	90,572	4,322	7,640	1,516	103	31,357	-	-	679	-	136,189	67%
2044	93,432	5,556	8,252	1,516	103	35,299	-	-	987	1	145,145	64%
2045	97,223	6,757	9,284	1,516	103	39,241	-	-	1,398	73	155,522	63%

Figure 5-17: Scenario 3 – High Demand Sensitivity – Generation (GWh) and Hydro percentage



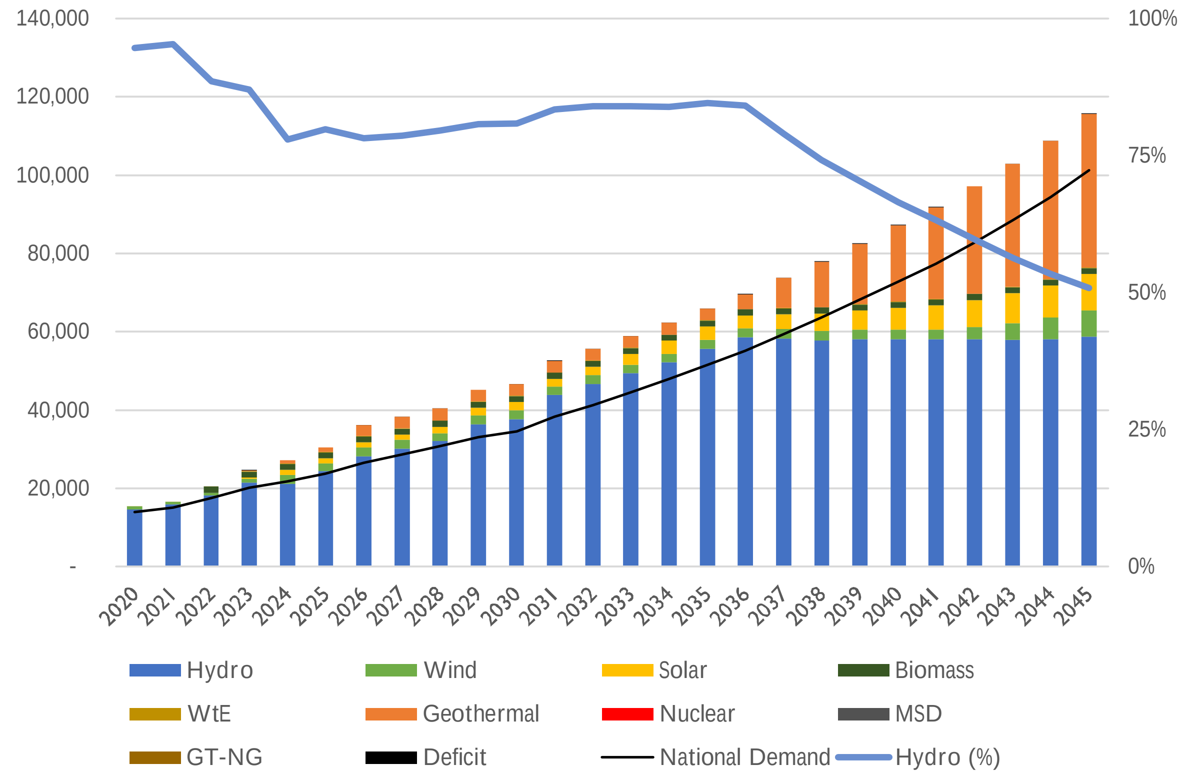
5.6.3.3 LOW DEMAND

The dispatch of the proposed expansion plan assuming the low demand forecast is presented below.

Table 5-30: Scenario 3 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	15,825	671	-	-	103	-	-	-	-	-	16,599	95%
2022	18,159	722	-	1,516	103	-	-	-	-	-	20,500	89%
2023	21,393	1,011	291	1,516	103	256	-	-	-	-	24,571	87%
2024	21,121	2,278	1,341	1,516	103	749	-	-	-	-	27,107	78%
2025	24,342	2,059	1,239	1,516	103	1,243	-	-	-	-	30,503	80%
2026	28,216	2,195	1,276	1,516	103	2,780	-	-	-	-	36,087	78%
2027	30,083	2,251	1,316	1,516	103	2,975	-	-	-	-	38,245	79%
2028	32,069	2,045	1,624	1,516	103	2,975	-	-	-	-	40,333	80%
2029	36,407	2,141	1,990	1,516	103	2,975	-	-	-	-	45,132	81%
2030	37,701	2,234	2,079	1,516	103	2,975	-	-	-	-	46,608	81%
2031	43,877	2,141	1,983	1,516	103	2,975	-	-	-	-	52,595	83%
2032	46,674	2,295	2,040	1,516	103	2,975	-	-	-	-	55,602	84%
2033	49,455	2,104	2,691	1,516	103	2,975	-	-	-	-	58,844	84%
2034	52,211	2,128	3,335	1,516	103	2,975	-	-	-	-	62,268	84%
2035	55,695	2,265	3,331	1,516	103	2,975	-	-	-	-	65,884	85%
2036	58,512	2,347	3,345	1,516	103	3,763	-	-	-	-	69,585	84%
2037	58,292	2,414	3,739	1,516	103	7,705	-	-	-	-	73,770	79%
2038	57,774	2,479	4,418	1,516	103	11,647	-	-	-	-	77,936	74%
2039	58,029	2,461	4,940	1,516	103	15,460	-	-	-	-	82,510	70%
2040	58,014	2,503	5,549	1,516	103	19,531	-	-	-	-	87,216	67%
2041	58,056	2,428	6,202	1,516	103	23,473	-	-	-	-	91,778	63%
2042	58,019	3,161	6,949	1,516	103	27,351	-	-	-	-	97,100	60%
2043	57,890	4,322	7,640	1,516	103	31,357	-	-	-	-	102,828	56%
2044	58,005	5,556	8,252	1,516	103	35,299	-	-	-	-	108,731	53%
2045	58,737	6,757	9,284	1,516	103	39,241	-	-	-	-	115,639	51%

Figure 5-18: Scenario 3 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage



5.7 SCENARIO 4 – NUCLEAR

The key assumptions for Scenario 4 are shown in Table 5-31. In Scenario 4, nuclear generation was included from 2035.

Table 5-31: Scenario 4 – Key assumptions

Parameter	Value
Demand forecast	Base Case
Hydrology	Average
Generation choices	Nuclear generation from 2035 up to a maximum of 2,400 MW by 2038

5.7.1 GENERATION ADDITIONS

The candidate generation additions for Scenario 4 are summarized in Table 5-32 with full details in Appendix B. These are in addition to the existing, under-construction, and committed projects.

Table 5-32: Scenario 4 – Added candidate capacity

Type	Capacity (MW)	
	2030	2045
Hydro	2,468	8,600
Solar	800	4,775
Wind	300	1,920
Geothermal	-	600
GT	1,400	5,320
Nuclear	-	2,400
Total	4,968	23,615

Combined with the existing and committed plants, the resulting total installed capacity is shown in Table 5-33 and Figure 5-19.

Table 5-34 and Figure 5-20 show the breakdown of generated energy for Scenario 4. The share of hydro energy remains above 75% until 2036.

Table 5-35 and Figure 5-21 show the firm energy by year for Scenario 4 relative to the annual energy demand. As indicated, based on average hydrological conditions, the system is expected to have an energy deficit in 2022 and 2023. By 2028 the required 20% energy margin is reached or exceeded for the remainder of the planning period.

Table 5-33: Scenario 4 – Installed capacity (MW)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Firm	Peak Demand	Exports	Reserve Margin (%)
2020	3,450	324			25	-	-	38	-	3,837	3,610	2,459	175	47%
2021	3,941	324			25	-	-	38	-	4,328	4,101	3,047	175	35%
2022	4,303	444		298	25	-	-	38	-	5,108	4,553	3,727	345	22%
2023	4,303	544	250	298	25	57	-	-	-	5,477	4,602	4,431	515	4%
2024	8,352	844	550	298	25	107	-	-	-	10,176	8,791	4,966	579	77%
2025	8,652	844	550	298	25	207	-	-	-	10,576	9,191	5,490	707	67%
2026	11,013	844	550	298	25	377	-	-	-	13,107	11,722	6,130	1,009	91%
2027	11,013	844	550	298	25	377	-	-	-	13,107	11,722	6,620	1,009	77%
2028	11,317	844	650	298	25	377	-	-	980	14,491	13,006	7,161	1,009	82%
2029	11,784	844	850	298	25	377	-	-	1,400	15,578	13,893	7,890	1,298	76%
2030	13,481	844	1,050	298	25	377	-	-	1,400	17,476	15,590	8,279	1,298	88%
2031	14,416	844	1,050	298	25	377	-	-	1,540	18,551	16,665	9,493	2,153	76%
2032	14,416	844	1,250	298	25	377	-	-	1,960	19,171	17,085	10,086	2,153	69%
2033	14,416	844	1,550	298	25	377	-	-	2,380	19,891	17,505	10,712	2,153	63%
2034	15,310	844	1,850	298	25	377	-	-	2,380	21,085	18,399	11,369	2,153	62%
2035	15,310	844	2,150	298	25	377	600	-	2,380	21,985	18,999	12,061	2,153	58%
2036	15,310	844	2,450	298	25	377	1,200	-	2,380	22,885	19,599	12,804	2,153	53%
2037	15,310	844	2,700	298	25	377	1,800	-	2,380	23,735	20,199	13,593	2,153	49%
2038	15,310	844	3,000	298	25	377	2,400	-	2,380	24,635	20,799	14,436	2,153	44%
2039	15,832	844	3,300	298	25	377	2,400	-	2,800	25,877	21,741	15,337	2,153	42%
2040	17,532	964	3,575	298	25	377	2,400	-	2,800	27,972	23,477	16,331	2,153	44%
2041	18,269	1,264	3,875	298	25	377	2,400	-	2,800	29,309	24,304	17,418	2,153	40%
2042	19,213	1,564	4,175	298	25	377	2,400	-	3,220	31,273	25,758	18,596	2,153	39%
2043	19,313	1,864	4,475	298	25	727	2,400	-	3,640	32,743	26,718	19,860	2,153	35%
2044	19,313	2,164	4,775	298	25	827	2,400	-	4,480	34,283	27,748	21,218	2,153	31%
2045	19,458	2,464	5,025	298	25	977	2,400	-	5,320	35,967	28,973	22,651	2,153	28%

Figure 5-19: Scenario 4 – Firm capacity (MW)

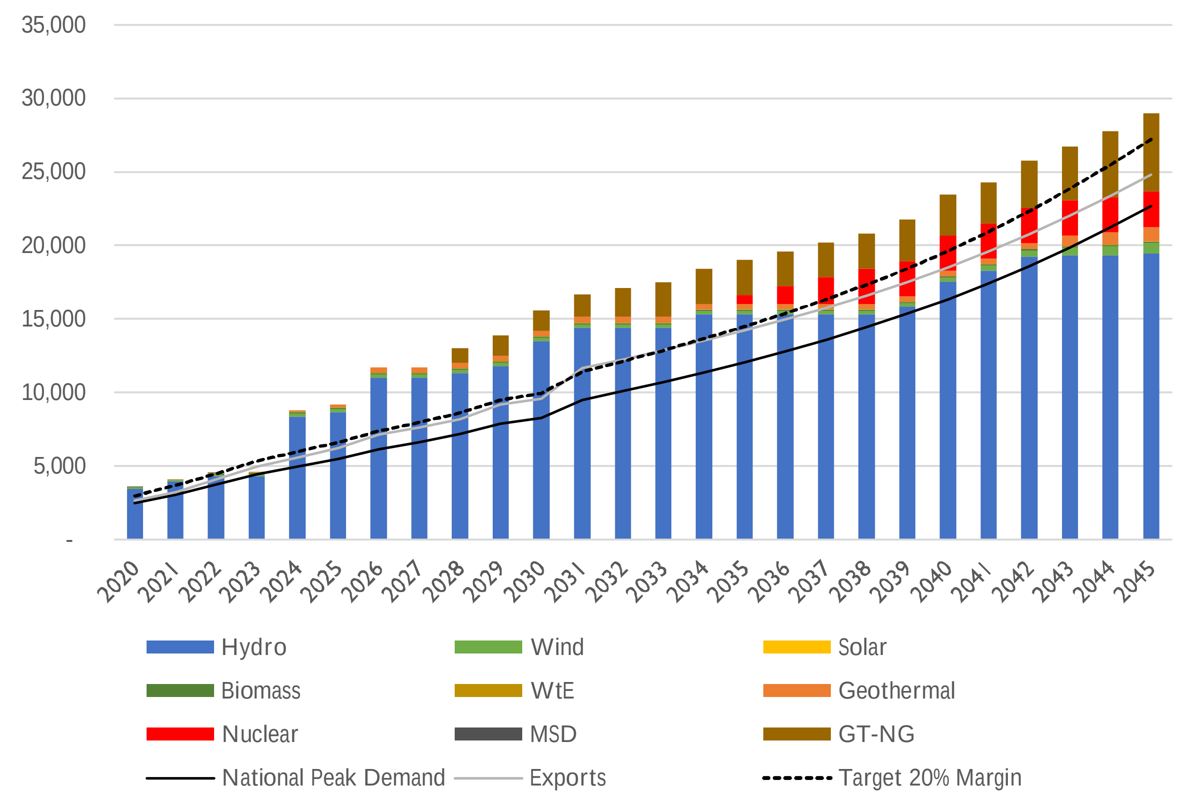


Table 5-34: Scenario 4 – Generated energy by plant type (GWh)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,795	671	-	-	103	-	-	46	-	-	17,615	95%
2022	19,633	722	-	1,516	103	-	-	277	-	14	22,251	88%
2023	22,470	1,011	291	1,516	103	256	-	-	-	1,395	25,648	88%
2024	23,874	2,278	1,341	1,516	103	749	-	-	-	57	29,860	80%
2025	27,313	2,059	1,239	1,516	103	1,243	-	-	-	85	33,474	82%
2026	31,174	2,195	1,276	1,516	103	2,780	-	-	-	-	39,044	80%
2027	33,565	2,251	1,316	1,516	103	2,975	-	-	-	1	41,726	80%
2028	36,383	2,045	1,513	1,516	103	2,975	-	-	42	-	44,577	82%
2029	41,556	2,141	1,959	1,516	103	2,975	-	-	-	-	50,249	83%
2030	43,023	2,234	2,525	1,516	103	2,975	-	-	-	-	52,376	82%
2031	54,509	2,141	2,440	1,516	103	2,975	-	-	-	-	63,684	86%
2032	56,825	2,295	2,977	1,516	103	2,975	-	-	123	-	66,814	85%
2033	59,749	2,104	3,591	1,516	103	2,975	-	-	310	-	70,348	85%
2034	62,753	2,128	4,208	1,516	103	2,975	-	-	261	-	73,944	85%
2035	61,357	2,265	4,873	1,516	103	2,975	4,468	-	169	-	77,725	79%
2036	59,954	2,347	5,645	1,516	103	2,975	8,935	-	136	-	81,611	73%
2037	59,211	2,414	6,314	1,516	103	2,975	13,403	-	166	-	86,103	69%
2038	58,339	2,479	7,197	1,516	103	2,975	17,870	-	232	-	90,711	64%
2039	62,573	2,461	7,803	1,516	103	2,975	17,870	-	335	-	95,636	65%
2040	67,014	2,915	8,362	1,516	103	2,975	17,870	-	82	-	100,837	66%
2041	71,324	4,086	8,952	1,516	103	2,975	17,870	-	188	-	107,015	67%
2042	75,807	5,443	9,641	1,516	103	2,975	17,870	-	98	-	113,453	67%
2043	78,116	6,606	10,265	1,516	103	5,670	17,870	-	218	-	120,364	65%
2044	82,270	7,773	10,832	1,516	103	6,522	17,870	-	596	-	127,484	65%
2045	87,033	8,742	11,747	1,516	103	7,576	17,870	-	1,036	-	135,623	64%

Figure 5-20: Scenario 4 – Generated energy (GWh) and percentage hydro energy

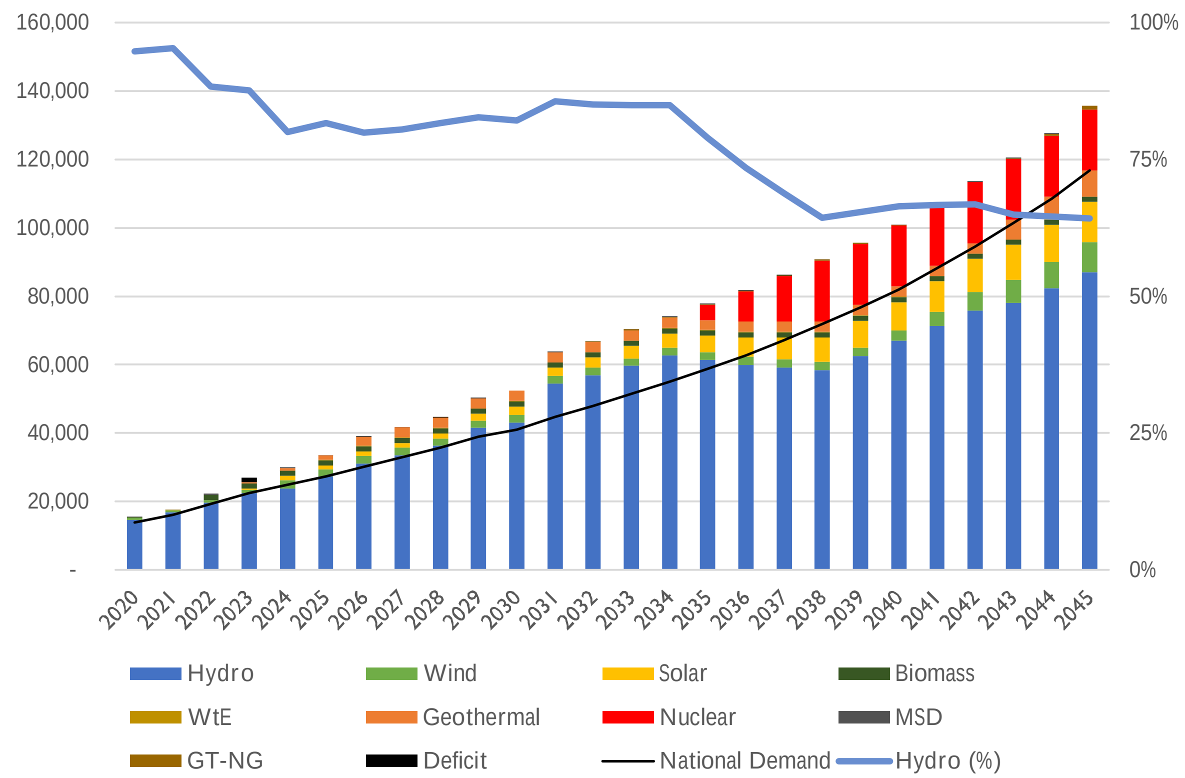
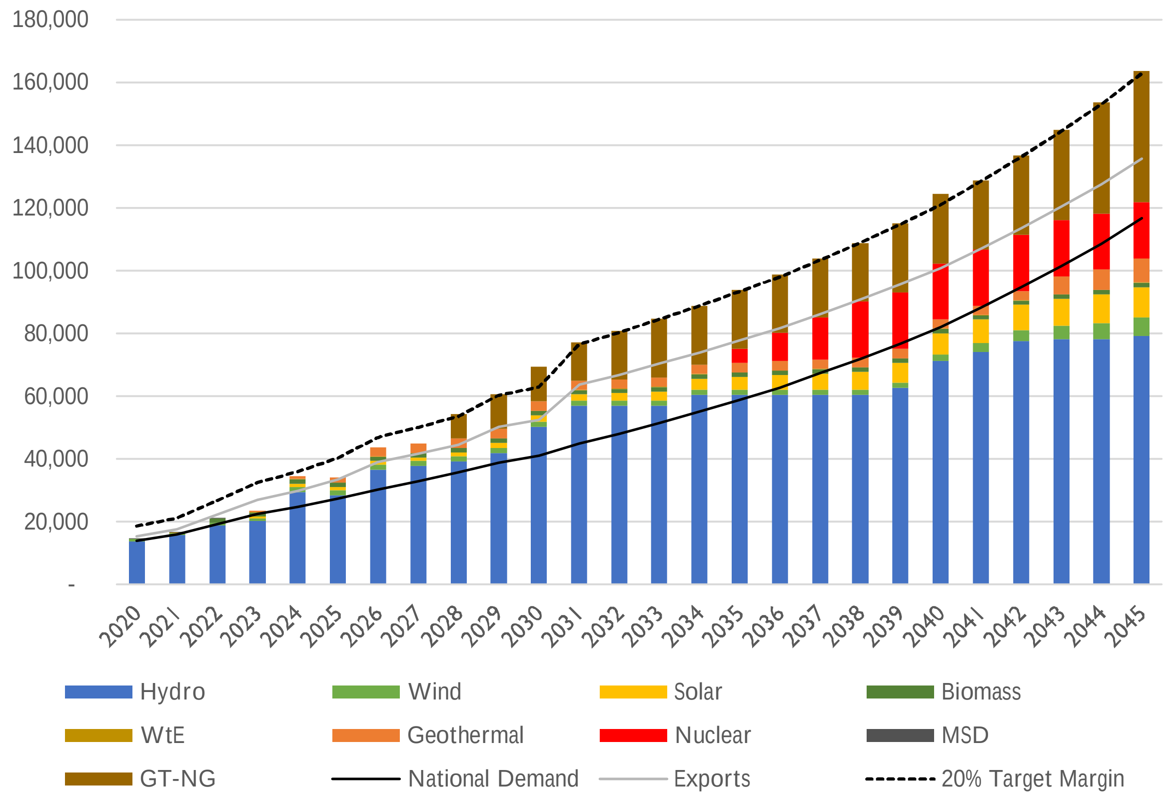


Table 5-35: Scenario 4 – Firm energy and energy margin (GWh)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Energy demand	Reserve margin
2020	13,794	686	-	-	103	-	-	277	-	14,860	15,459	-4%
2021	15,716	686	-	-	103	-	-	277	-	16,782	17,615	-5%
2022	18,937	686	-	1,360	103	-	-	277	-	21,363	22,264	-4%
2023	20,320	853	482	1,360	103	452	-	-	-	23,570	27,043	-13%
2024	29,468	1,641	1,060	1,360	103	846	-	-	-	34,479	29,917	15%
2025	28,408	1,641	1,060	1,360	103	1,634	-	-	-	34,207	33,560	2%
2026	36,633	1,641	1,060	1,360	103	2,975	-	-	-	43,772	39,044	12%
2027	37,708	1,641	1,060	1,360	103	2,975	-	-	-	44,848	41,726	7%
2028	39,163	1,641	1,253	1,360	103	2,975	-	-	7,726	54,222	44,577	22%
2029	41,880	1,641	1,638	1,360	103	2,975	-	-	11,038	60,635	50,249	21%
2030	50,255	1,641	2,024	1,360	103	2,975	-	-	11,038	69,395	52,376	32%
2031	56,871	1,641	2,024	1,360	103	2,975	-	-	12,141	77,116	63,684	21%
2032	56,871	1,641	2,409	1,360	103	2,975	-	-	15,453	80,812	66,814	21%
2033	56,871	1,641	2,987	1,360	103	2,975	-	-	18,764	84,702	70,348	20%
2034	60,387	1,641	3,565	1,360	103	2,975	-	-	18,764	88,796	73,944	20%
2035	60,387	1,641	4,143	1,360	103	2,975	4,468	-	18,764	93,842	77,725	21%
2036	60,387	1,641	4,722	1,360	103	2,975	8,935	-	18,764	98,887	81,611	21%
2037	60,387	1,641	5,203	1,360	103	2,975	13,403	-	18,764	103,837	86,103	21%
2038	60,387	1,641	5,782	1,360	103	2,975	17,870	-	18,764	108,883	90,711	20%
2039	62,652	1,641	6,360	1,360	103	2,975	17,870	-	22,075	115,037	95,636	20%
2040	71,206	1,957	6,890	1,360	103	2,975	17,870	-	22,075	124,436	100,837	23%
2041	74,146	2,745	7,468	1,360	103	2,975	17,870	-	22,075	128,742	107,015	20%
2042	77,494	3,533	8,046	1,360	103	2,975	17,870	-	25,386	136,769	113,453	21%
2043	78,067	4,322	8,624	1,360	103	5,734	17,870	-	28,698	144,779	120,364	20%
2044	78,067	5,110	9,202	1,360	103	6,522	17,870	-	35,320	153,556	127,484	20%
2045	79,151	5,899	9,684	1,360	103	7,705	17,870	-	41,943	163,715	135,623	21%

Figure 5-21: Scenario 4 – Firm energy and energy margin (GWh)



5.7.2 COSTS

The total and discounted cost for Scenario 1 assuming a 10% discount factor are presented below.

Table 5-36: Scenario 4 – Total costs (USDm)

Year	Investment cost	Fixed O&M costs	Variable costs	Deficit cost	Discounted investment costs	Discounted fixed O&M costs	Discounted variable costs	Discounted deficit cost	Discounted total costs
2020	-	-	2	-	-	-	2	-	2
2021	-	-	11	-	-	-	10	-	10
2022	-	-	57	14	-	-	47	11	58
2023	404	-	5	1,395	303	-	4	1,048	1,355
2024	476	13	10	57	325	9	7	39	380
2025	606	13	15	86	376	8	9	53	447
2026	824	13	31	-	465	7	18	-	490
2027	1,238	13	33	-	635	7	17	-	659
2028	1,889	33	38	-	881	15	18	-	914
2029	2,199	50	33	-	933	21	14	-	968
2030	2,440	83	33	-	941	32	13	-	986
2031	2,390	102	33	-	838	36	12	-	885
2032	2,490	111	46	-	793	35	15	-	843
2033	2,621	121	65	-	759	35	19	-	813
2034	2,863	141	60	-	754	37	16	-	807
2035	3,281	206	56	-	785	49	13	-	848
2036	2,899	270	57	-	631	59	12	-	702
2037	2,611	334	65	-	517	66	13	-	596
2038	2,266	398	76	-	408	72	14	-	493
2039	2,109	418	87	-	345	68	14	-	427
2040	2,220	456	61	-	330	68	9	-	407
2041	2,195	482	72	-	297	65	10	-	372
2042	2,023	518	63	-	249	64	8	-	320
2043	1,724	569	103	-	193	64	12	-	268
2044	1,601	602	151	-	163	61	15	-	239
2045	879	643	207	-	81	59	19	-	160
Total	44,248	5,587	1,472	1,552	12,001	937	359	1,152	14,449

5.7.3 SENSITIVITIES

Given the proposed generation additions and expansion plan, the system dispatch for the 2020-2045 horizon was simulated under three sensitivities: Low Hydrology, High Demand, and Low Demand. The resulting operation and associated costs are presented below.

5.7.3.1 LOW HYDROLOGY

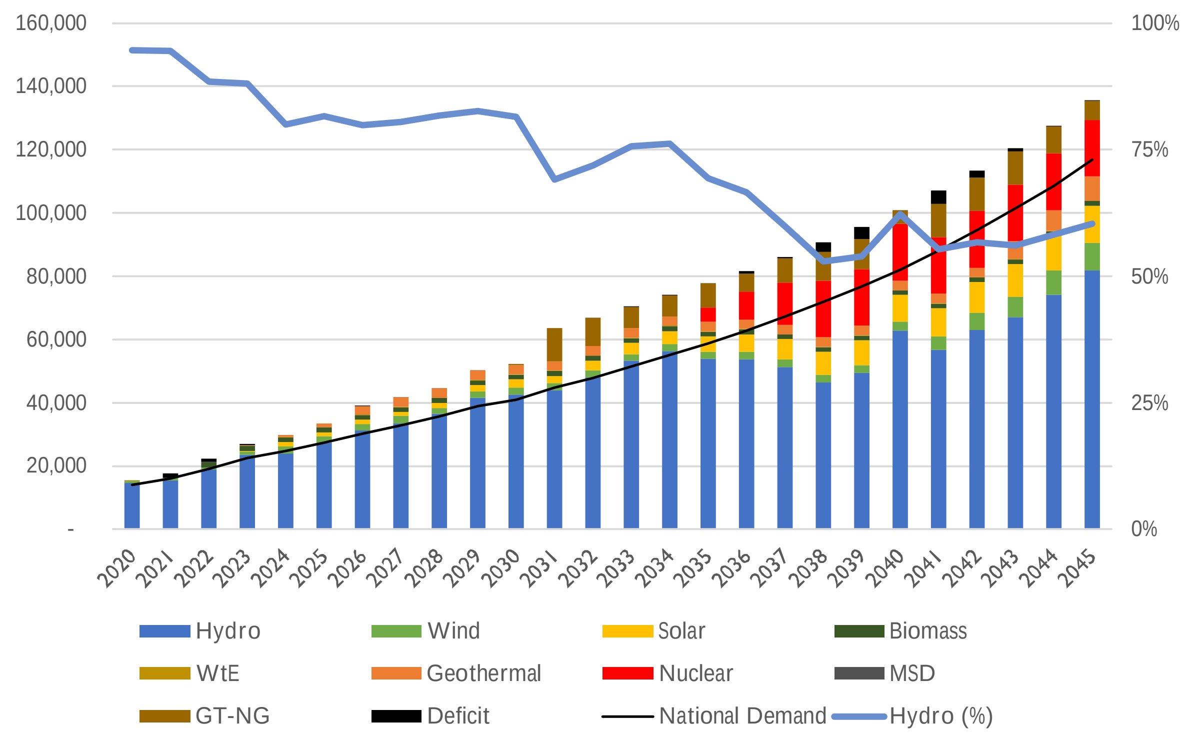
The low hydrology sensitivity simulated the dispatch of the proposed expansion plan assuming historical hydrological conditions so as to represent the worst historical drought experienced by the system. The recorded inflows for 1970 – 1995 were applied to the years 2020 – 2045, and so the historic drought in the 1980s occurs in the sensitivity in the 2030s.

The resulting generation under low hydrology conditions is presented in Table 5-37 and Figure 5-22.

Table 5-37: Scenario 4 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,460	95%
2021	15,480	671	-	-	103	-	-	117	-	1,244	16,371	95%
2022	18,886	722	-	1,516	103	-	-	112	-	926	21,339	89%
2023	23,504	1,011	291	1,516	103	256	-	-	-	361	26,682	88%
2024	23,931	2,278	1,341	1,516	103	749	-	-	-	-	29,917	80%
2025	27,399	2,059	1,239	1,516	103	1,243	-	-	-	-	33,560	82%
2026	31,174	2,195	1,276	1,516	103	2,780	-	-	-	-	39,044	80%
2027	33,565	2,251	1,316	1,516	103	2,975	-	-	-	-	41,726	80%
2028	36,425	2,045	1,513	1,516	103	2,975	-	-	-	-	44,577	82%
2029	41,556	2,141	1,959	1,516	103	2,975	-	-	-	-	50,249	83%
2030	42,651	2,234	2,525	1,516	103	2,975	-	-	373	-	52,376	81%
2031	43,971	2,141	2,440	1,516	103	2,975	-	-	10,538	-	63,684	69%
2032	48,024	2,295	2,977	1,516	103	2,975	-	-	8,924	-	66,814	72%
2033	53,236	2,104	3,591	1,516	103	2,975	-	-	6,823	-	70,348	76%
2034	56,376	2,128	4,208	1,516	103	2,975	-	-	6,638	-	73,944	76%
2035	53,871	2,265	4,873	1,516	103	2,975	4,468	-	7,655	-	77,725	69%
2036	53,749	2,347	5,645	1,516	103	2,975	8,935	-	5,505	836	80,775	67%
2037	51,343	2,414	6,314	1,516	103	2,975	13,403	-	7,646	389	85,714	60%
2038	46,394	2,479	7,197	1,516	103	2,975	17,870	-	9,156	3,020	87,691	53%
2039	49,512	2,461	7,803	1,516	103	2,975	17,870	-	9,575	3,821	91,816	54%
2040	62,775	2,915	8,362	1,516	103	2,975	17,870	-	4,244	77	100,760	62%
2041	56,864	4,086	8,952	1,516	103	2,975	17,870	-	10,543	4,105	102,910	55%
2042	63,020	5,443	9,641	1,516	103	2,975	17,870	-	10,645	2,240	111,213	57%
2043	66,997	6,606	10,265	1,516	103	5,670	17,870	-	10,430	906	119,458	56%
2044	74,163	7,773	10,832	1,516	103	6,522	17,870	-	8,643	60	127,424	58%
2045	81,830	8,742	11,747	1,516	103	7,576	17,870	-	6,072	167	135,456	60%

Figure 5-22: Scenario 4 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage



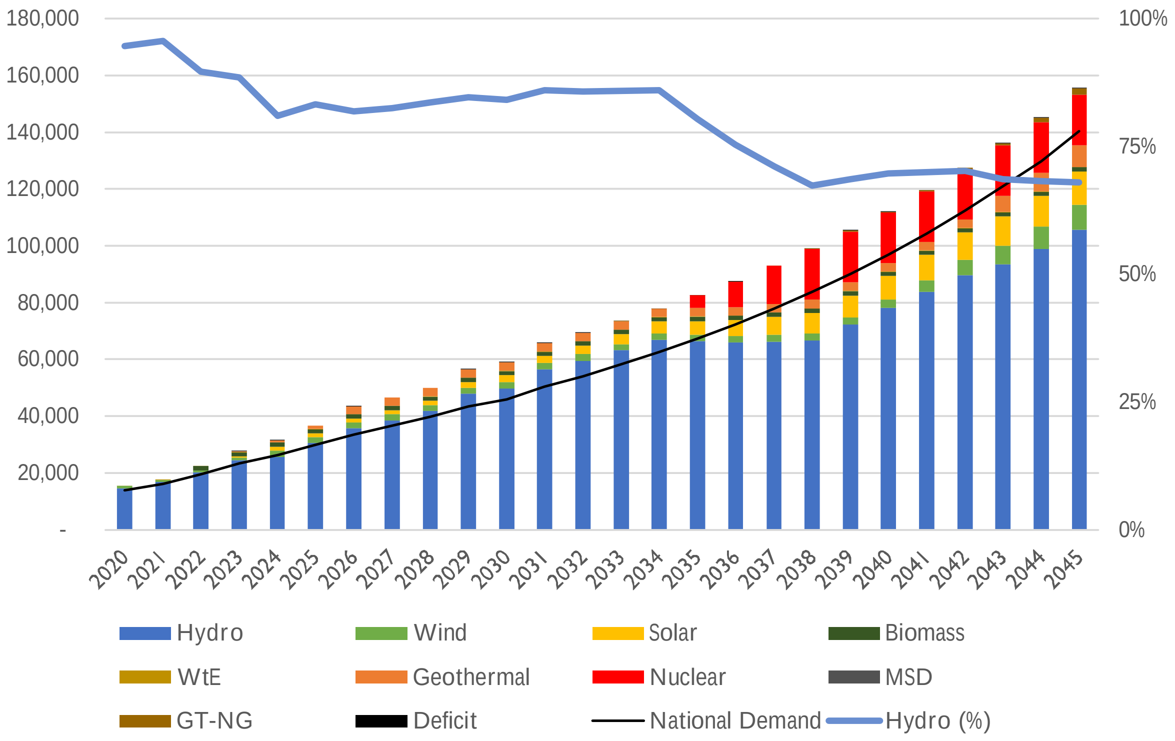
5.7.3.2 HIGH DEMAND

The high demand sensitivity simulated the dispatch of the proposed expansion plan assuming average hydrological conditions but using the high demand forecast. Stored energy within the hydro reservoirs was assumed to be available to increase hydro dispatch to meet the increased demand. The storage levels over the horizon were freely optimized given the inflows and demand. The resulting generation under high demand conditions is presented in Table 5-38 and Figure 5-23.

Table 5-38: Scenario 4 – High Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,854	671	-	-	103	-	-	-	-	-	17,628	96%
2022	20,205	722	-	1,516	103	-	-	-	-	-	22,546	90%
2023	24,417	1,011	291	1,516	103	256	-	-	-	216	27,594	88%
2024	25,554	2,278	1,341	1,516	103	749	-	-	-	-	31,540	81%
2025	30,571	2,059	1,239	1,516	103	1,243	-	-	-	-	36,732	83%
2026	35,638	2,195	1,276	1,516	103	2,780	-	-	-	-	43,509	82%
2027	38,490	2,251	1,316	1,516	103	2,975	-	-	-	-	46,651	83%
2028	41,786	2,045	1,513	1,516	103	2,975	-	-	-	-	49,938	84%
2029	47,850	2,141	1,959	1,516	103	2,975	-	-	-	-	56,543	85%
2030	49,646	2,234	2,525	1,516	103	2,975	-	-	-	-	58,998	84%
2031	56,582	2,141	2,440	1,516	103	2,975	-	-	-	-	65,756	86%
2032	59,523	2,295	2,977	1,516	103	2,975	-	-	-	-	69,390	86%
2033	63,211	2,104	3,591	1,516	103	2,975	-	-	62	-	73,562	86%
2034	66,967	2,128	4,208	1,516	103	2,975	-	-	11	-	77,908	86%
2035	66,347	2,265	4,873	1,516	103	2,975	4,468	-	37	-	82,582	80%
2036	65,879	2,347	5,645	1,516	103	2,975	8,935	-	59	-	87,459	75%
2037	66,248	2,414	6,314	1,516	103	2,975	13,403	-	136	-	93,110	71%
2038	66,684	2,479	7,197	1,516	103	2,975	17,870	-	260	-	99,084	67%
2039	72,266	2,461	7,803	1,516	103	2,975	17,870	-	441	-	105,435	69%
2040	78,040	2,915	8,362	1,516	103	2,975	17,870	-	234	-	112,015	70%
2041	83,710	4,086	8,952	1,516	103	2,975	17,870	-	389	-	119,601	70%
2042	89,597	5,443	9,641	1,516	103	2,975	17,870	-	428	-	127,572	70%
2043	93,429	6,606	10,265	1,516	103	5,670	17,870	-	730	-	136,190	69%
2044	98,907	7,773	10,832	1,516	103	6,522	17,870	-	1,611	10	145,136	68%
2045	105,642	8,742	11,747	1,516	103	7,576	17,870	-	2,320	78	155,517	68%

Figure 5-23: Scenario 4 – High Demand Sensitivity – Generation (GWh) and Hydro percentage



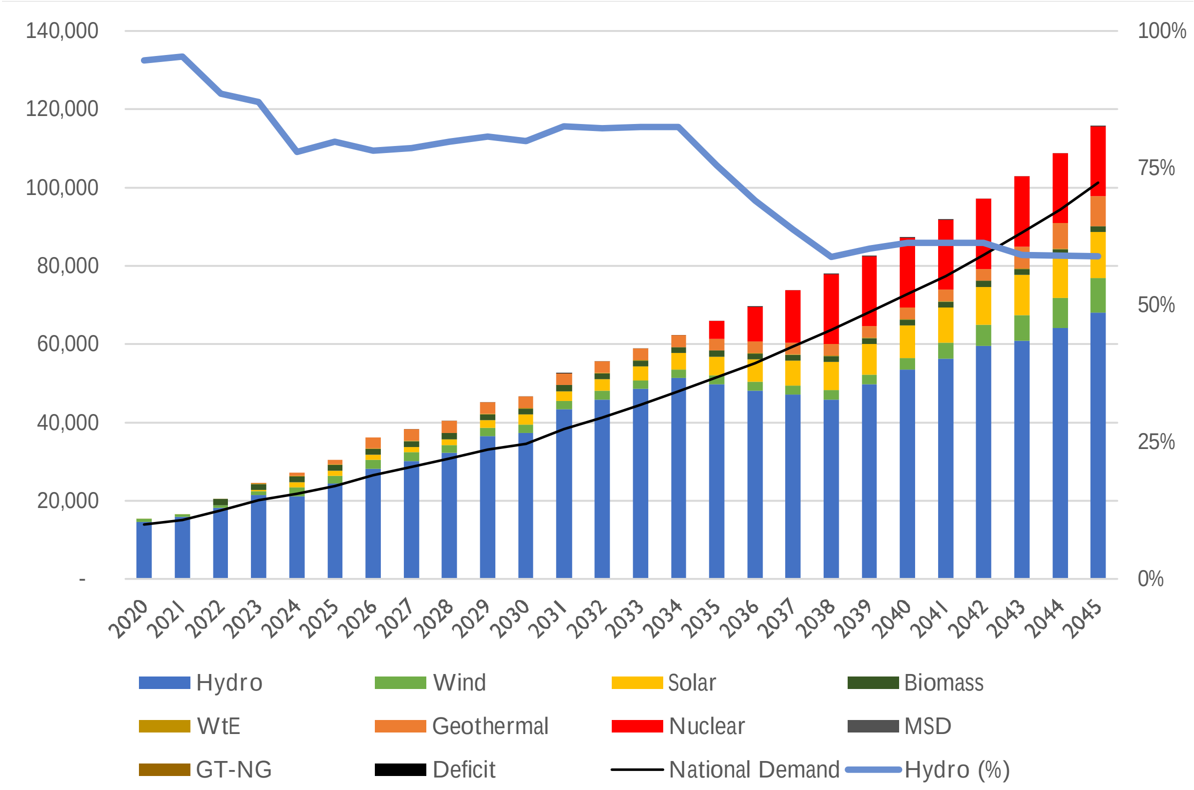
5.7.3.3 LOW DEMAND

The dispatch of the proposed expansion plan assuming the low demand forecast is presented below.

Table 5-39: Scenario 4 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	15,825	671	-	-	103	-	-	-	-	-	16,599	95%
2022	18,159	722	-	1,516	103	-	-	-	-	-	20,500	89%
2023	21,393	1,011	291	1,516	103	256	-	-	-	-	24,571	87%
2024	21,121	2,278	1,341	1,516	103	749	-	-	-	-	27,107	78%
2025	24,342	2,059	1,239	1,516	103	1,243	-	-	-	-	30,503	80%
2026	28,216	2,195	1,276	1,516	103	2,780	-	-	-	-	36,087	78%
2027	30,083	2,251	1,316	1,516	103	2,975	-	-	-	-	38,244	79%
2028	32,181	2,045	1,513	1,516	103	2,975	-	-	-	-	40,333	80%
2029	36,438	2,141	1,959	1,516	103	2,975	-	-	-	-	45,131	81%
2030	37,256	2,234	2,525	1,516	103	2,975	-	-	-	-	46,608	80%
2031	43,420	2,141	2,440	1,516	103	2,975	-	-	-	-	52,595	83%
2032	45,736	2,295	2,977	1,516	103	2,975	-	-	-	-	55,602	82%
2033	48,554	2,104	3,591	1,516	103	2,975	-	-	-	-	58,844	83%
2034	51,337	2,128	4,208	1,516	103	2,975	-	-	-	-	62,268	82%
2035	49,685	2,265	4,873	1,516	103	2,975	4,468	-	-	-	65,884	75%
2036	48,064	2,347	5,645	1,516	103	2,975	8,935	-	-	-	69,585	69%
2037	47,045	2,414	6,314	1,516	103	2,975	13,403	-	-	-	73,770	64%
2038	45,797	2,479	7,197	1,516	103	2,975	17,870	-	-	-	77,936	59%
2039	49,782	2,461	7,803	1,516	103	2,975	17,870	-	-	-	82,510	60%
2040	53,475	2,915	8,362	1,516	103	2,975	17,870	-	-	-	87,216	61%
2041	56,276	4,086	8,952	1,516	103	2,975	17,870	-	-	-	91,778	61%
2042	59,552	5,443	9,641	1,516	103	2,975	17,870	-	-	-	97,100	61%
2043	60,797	6,606	10,265	1,516	103	5,670	17,870	-	-	-	102,828	59%
2044	64,113	7,773	10,832	1,516	103	6,522	17,870	-	-	-	108,731	59%
2045	68,084	8,742	11,747	1,516	103	7,576	17,870	-	-	-	115,639	59%

Figure 5-24: Scenario 4 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage



5.8 SCENARIO 5 – MINIMUM FOSSIL FUEL

The key assumptions for Scenario 5 are shown in Table 5-40. In Scenario 5, fossil fuel (natural gas or oil) fired generation capacity is minimized by installing all possible sources of firm generation capacity (apart from nuclear), i.e., all hydro candidates, increased geothermal, maximum wind within constraints.

Table 5-40: Scenario 5 – Key assumptions

Parameter	Value
Demand forecast	Base Case
Hydrology	Average
Generation choices	All hydro, geothermal, wind, and solar candidates selected and additional geothermal capacity

5.8.1 GENERATION ADDITIONS

The candidate generation additions for Scenario 5 are summarized in Table 5-41 with full details in Appendix B. These are in addition to the existing, under-construction, and committed projects. The total installed GT capacity is significantly less than the previous scenarios, achieved by installing all of the hydro candidate capacity and a high level of geothermal capacity.

Table 5-41: Scenario 5 – Added candidate capacity

Type	Capacity (MW)	
	2030	2045
Hydro	771	11,213
Solar	1,500	4,800
Wind	1,470	5,970
Geothermal	-	4,600
GT	1,120	1,120
Nuclear	-	-
Total	4,861	27,703

Combined with the existing and committed plants, the resulting total installed capacity is shown in Table 5-42 and Figure 5-25.

Table 5-43 and Figure 5-26 show the breakdown of generated energy for Scenario 5. The share of hydro energy does not exceed 75% from 2028.

Table 5-44 and Figure 5-27 show the firm energy by year for Scenario 5 relative to the annual energy demand. By 2028 the required 20% energy margin is reached and exceeded for the remainder of the planning period.

Table 5-42: Scenario 5 – Installed capacity (MW)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Firm	Peak Demand	Exports	Reserve Margin (%)
2020	3,450	324			25	-	-	38	-	3,837	3,610	2,459	175	47%
2021	3,941	324			25	-	-	38	-	4,328	4,101	3,047	175	35%
2022	4,303	444		298	25	-	-	38	-	5,108	4,553	3,727	345	22%
2023	4,303	544	250	298	25	57	-	-	-	5,477	4,602	4,431	515	4%
2024	8,352	844	550	298	25	107	-	-	-	10,176	8,791	4,966	579	77%
2025	8,652	844	550	298	25	207	-	-	-	10,576	9,191	5,490	707	67%
2026	11,013	964	550	298	25	377	-	-	-	13,227	11,758	6,130	1,009	92%
2027	11,013	1,204	850	298	25	377	-	-	-	13,767	11,830	6,620	1,009	79%
2028	11,317	1,444	1,150	298	25	377	-	-	700	15,311	12,906	7,161	1,009	80%
2029	11,784	1,714	1,450	298	25	377	-	-	980	16,628	13,734	7,890	1,298	74%
2030	11,784	2,014	1,750	298	25	377	-	-	1,120	17,368	13,964	8,279	1,298	69%
2031	14,375	2,314	2,050	298	25	377	-	-	1,120	20,560	16,645	9,493	2,153	75%
2032	15,310	2,614	2,275	298	25	377	-	-	1,120	22,020	17,670	10,086	2,153	75%
2033	15,310	2,914	2,575	298	25	377	-	-	1,120	22,620	17,760	10,712	2,153	66%
2034	15,682	3,214	2,875	298	25	377	-	-	1,120	23,592	18,222	11,369	2,153	60%
2035	17,382	3,514	3,175	298	25	377	-	-	1,120	25,892	20,012	12,061	2,153	66%
2036	17,382	3,814	3,475	298	25	377	-	-	1,120	26,492	20,102	12,804	2,153	57%
2037	17,628	4,114	3,775	298	25	427	-	-	1,120	27,388	20,488	13,593	2,153	51%
2038	17,628	4,414	4,075	298	25	977	-	-	1,120	28,538	21,128	14,436	2,153	46%
2039	17,628	4,714	4,375	298	25	1,577	-	-	1,120	29,738	21,818	15,337	2,153	42%
2040	17,628	5,014	4,625	298	25	2,177	-	-	1,120	30,888	22,508	16,331	2,153	38%
2041	19,778	5,314	4,925	298	25	2,177	-	-	1,120	33,638	24,748	17,418	2,153	42%
2042	19,878	5,614	5,050	298	25	2,977	-	-	1,120	34,963	25,738	18,596	2,153	38%
2043	19,878	5,914	5,050	298	25	3,977	-	-	1,120	36,263	26,828	19,860	2,153	35%
2044	19,878	6,214	5,050	298	25	4,977	-	-	1,120	37,563	27,918	21,218	2,153	32%
2045	22,071	6,514	5,050	298	25	4,977	-	-	1,120	40,055	30,201	22,651	2,153	33%

Figure 5-25: Scenario 5 – Firm capacity (MW)

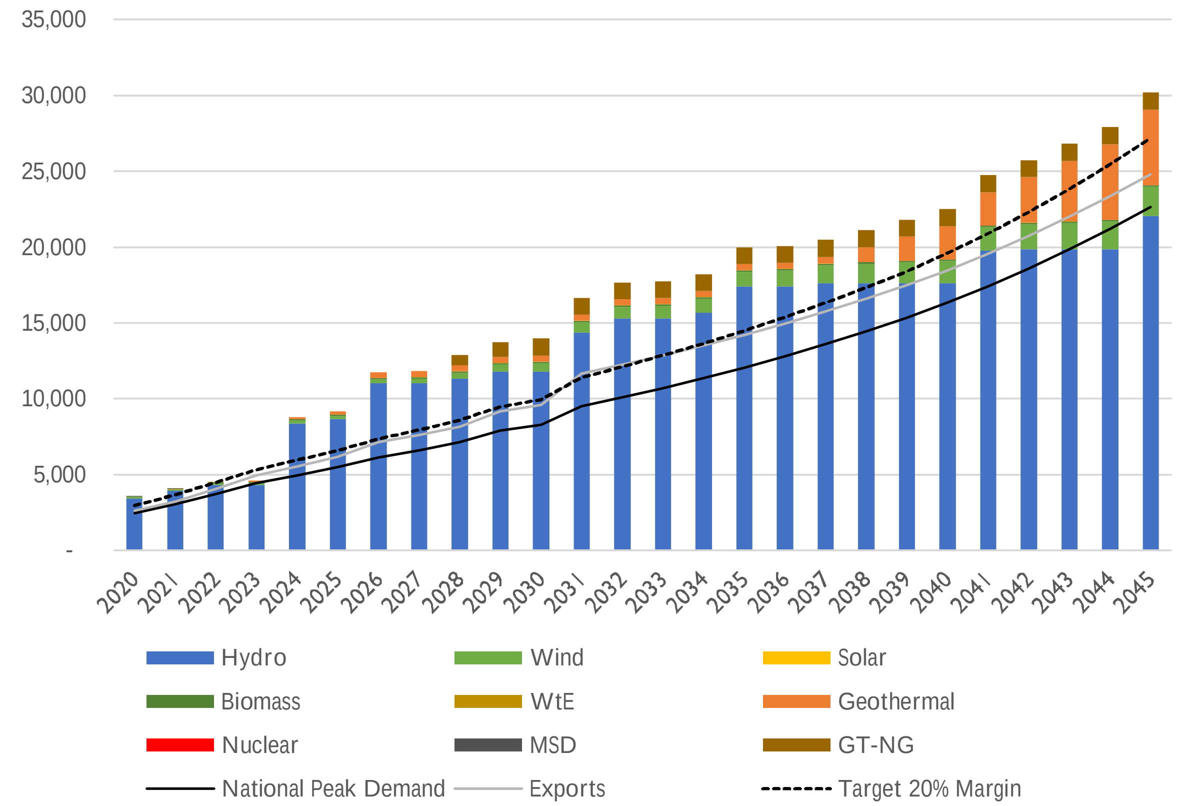


Table 5-43: Scenario 5 – Generated energy by plant type (GWh)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,795	671	-	-	103	-	-	46	-	-	17,615	95%
2022	19,633	722	-	1,516	103	-	-	277	-	14	22,251	88%
2023	22,470	1,011	291	1,516	103	256	-	-	-	1,395	25,648	88%
2024	23,874	2,278	1,341	1,516	103	749	-	-	-	57	29,860	80%
2025	27,313	2,059	1,239	1,516	103	1,243	-	-	-	86	33,474	82%
2026	30,778	2,591	1,276	1,516	103	2,780	-	-	-	-	39,044	79%
2027	31,616	3,492	2,024	1,516	103	2,975	-	-	-	-	41,726	76%
2028	33,194	4,129	2,661	1,516	103	2,975	-	-	-	-	44,577	74%
2029	37,215	5,097	3,343	1,516	103	2,975	-	-	-	-	50,249	74%
2030	37,448	6,156	4,178	1,516	103	2,975	-	-	-	-	52,376	71%
2031	46,820	7,522	4,729	1,516	103	2,975	-	-	19	-	63,684	74%
2032	48,338	8,549	5,333	1,516	103	2,975	-	-	-	-	66,814	72%
2033	50,663	9,299	5,793	1,516	103	2,975	-	-	-	-	70,348	72%
2034	52,844	10,071	6,435	1,516	103	2,975	-	-	-	-	73,944	71%
2035	54,461	11,809	6,861	1,516	103	2,975	-	-	-	-	77,725	70%
2036	56,900	12,552	7,566	1,516	103	2,975	-	-	-	-	81,611	70%
2037	58,506	14,130	8,479	1,516	103	3,369	-	-	-	-	86,103	68%
2038	56,483	15,616	9,416	1,516	103	7,576	-	-	-	-	90,711	62%
2039	55,321	16,220	10,040	1,516	103	12,435	-	-	-	-	95,636	58%
2040	54,817	16,775	10,459	1,516	103	17,166	-	-	-	-	100,837	54%
2041	59,432	17,824	10,974	1,516	103	17,166	-	-	-	-	107,015	56%
2042	58,698	18,349	11,314	1,516	103	23,473	-	-	-	-	113,453	52%
2043	57,502	18,627	11,323	1,516	103	31,293	-	-	-	-	120,364	48%
2044	56,039	19,323	11,260	1,516	103	39,241	-	-	-	-	127,484	44%
2045	63,687	19,433	11,643	1,516	103	39,241	-	-	-	-	135,623	47%

Figure 5-26: Scenario 5 – Generated energy (GWh) and percentage hydro energy

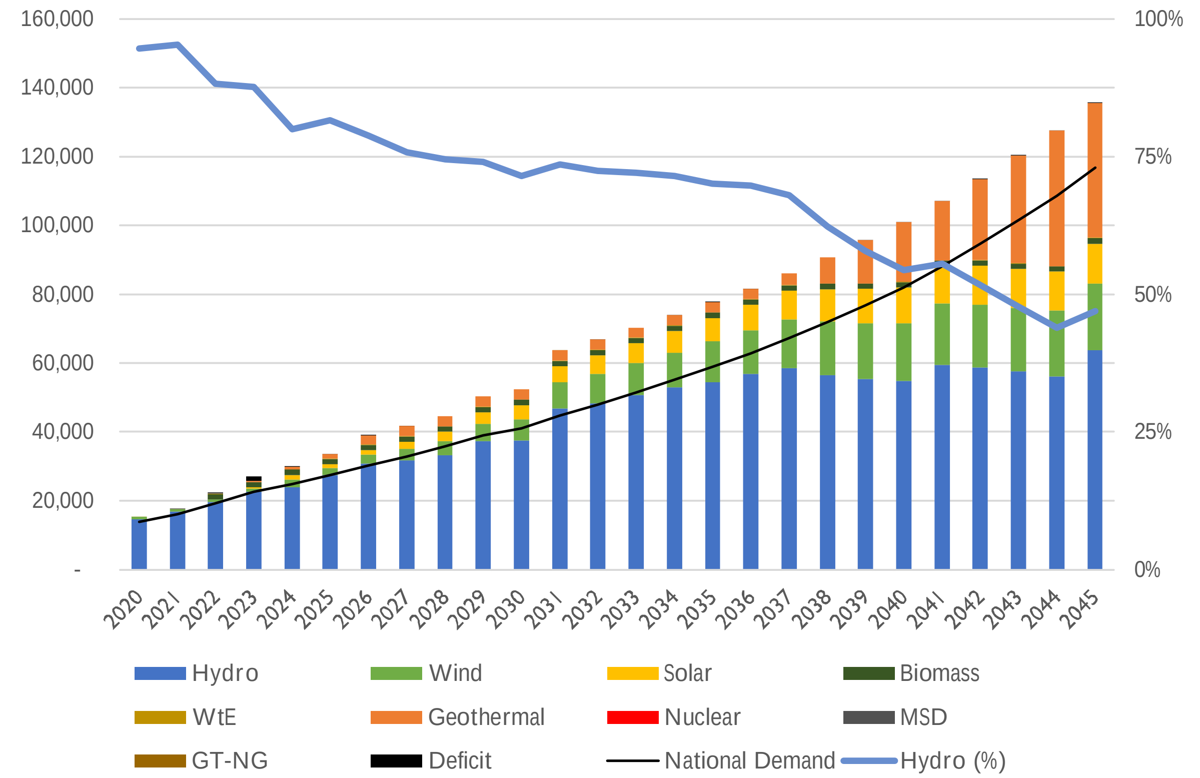
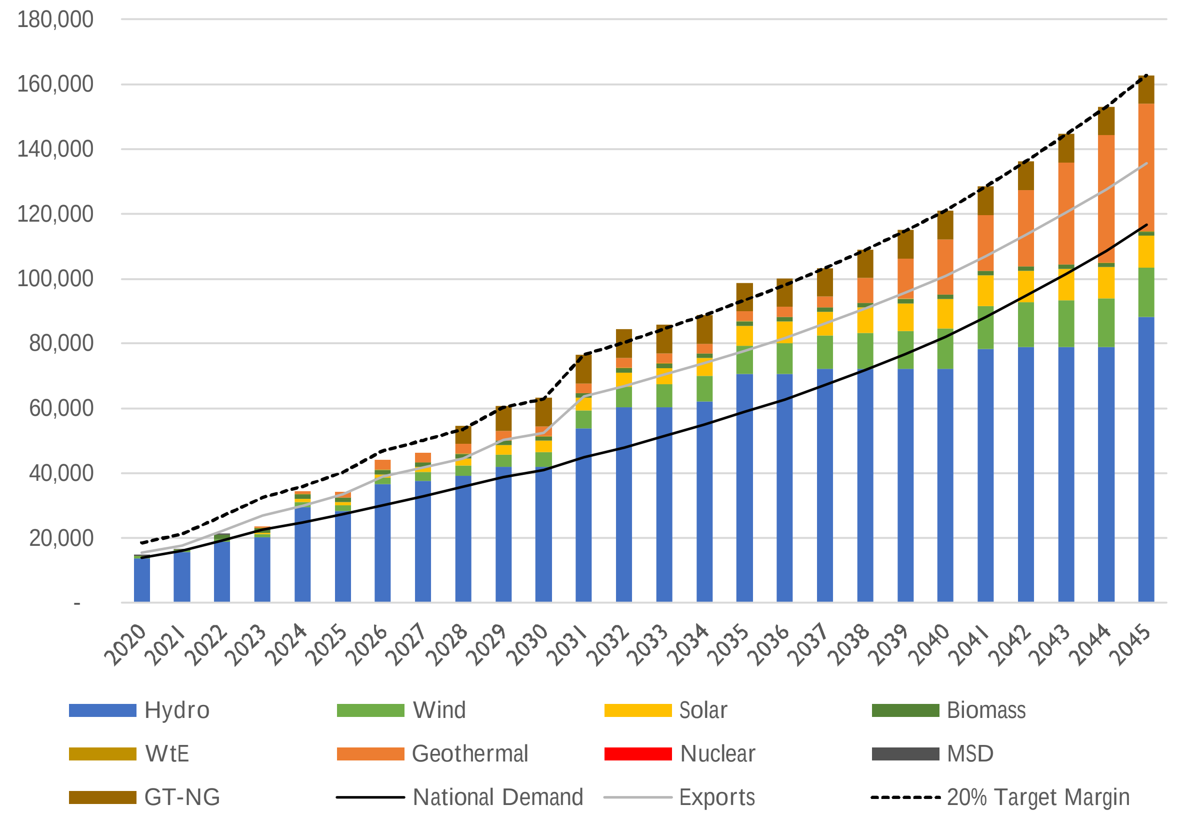


Table 5-44: Scenario 5 – Firm energy and energy margin (GWh)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Energy demand	Reserve margin
2020	13,794	686	-	-	103	-	-	277	-	14,860	15,459	-4%
2021	15,716	686	-	-	103	-	-	277	-	16,782	17,615	-5%
2022	18,937	686	-	1,360	103	-	-	277	-	21,363	22,264	-4%
2023	20,320	853	482	1,360	103	452	-	-	-	23,570	27,043	-13%
2024	29,468	1,641	1,060	1,360	103	846	-	-	-	34,479	29,917	15%
2025	28,408	1,641	1,060	1,360	103	1,634	-	-	-	34,207	33,560	2%
2026	36,633	1,957	1,060	1,360	103	2,975	-	-	-	44,087	39,044	13%
2027	37,708	2,587	1,638	1,360	103	2,975	-	-	-	46,372	41,726	11%
2028	39,163	3,218	2,216	1,360	103	2,975	-	-	5,519	54,555	44,577	22%
2029	41,880	3,928	2,794	1,360	103	2,975	-	-	7,726	60,766	50,249	21%
2030	41,880	4,716	3,373	1,360	103	2,975	-	-	8,830	63,237	52,376	21%
2031	53,771	5,504	3,951	1,360	103	2,975	-	-	8,830	76,494	63,684	20%
2032	60,387	6,293	4,384	1,360	103	2,975	-	-	8,830	84,333	66,814	26%
2033	60,387	7,081	4,963	1,360	103	2,975	-	-	8,830	85,699	70,348	22%
2034	62,093	7,870	5,541	1,360	103	2,975	-	-	8,830	88,771	73,944	20%
2035	70,647	8,658	6,119	1,360	103	2,975	-	-	8,830	98,692	77,725	27%
2036	70,647	9,446	6,697	1,360	103	2,975	-	-	8,830	100,059	81,611	23%
2037	72,175	10,235	7,275	1,360	103	3,369	-	-	8,830	103,348	86,103	20%
2038	72,175	11,023	7,853	1,360	103	7,705	-	-	8,830	109,051	90,711	20%
2039	72,175	11,733	8,432	1,360	103	12,435	-	-	8,830	115,069	95,636	20%
2040	72,175	12,521	8,913	1,360	103	17,166	-	-	8,830	121,069	100,837	20%
2041	78,345	13,204	9,491	1,360	103	17,166	-	-	8,830	128,500	107,015	20%
2042	78,918	13,783	9,732	1,360	103	23,473	-	-	8,830	136,199	113,453	20%
2043	78,918	14,361	9,732	1,360	103	31,357	-	-	8,830	144,661	120,364	20%
2044	78,918	14,913	9,732	1,360	103	39,241	-	-	8,830	153,097	127,484	20%
2045	88,066	15,438	9,732	1,360	103	39,241	-	-	8,830	162,771	135,623	20%

Figure 5-27: Scenario 5 – Firm energy and energy margin (GWh)



5.8.2 COSTS

The total and discounted cost for Scenario 1 assuming a 10% discount factor are presented below.

Table 5-45: Scenario 5 – Total costs (USDm)

Year	Investment cost	Fixed O&M costs	Variable costs	Deficit cost	Discounted investment costs	Discounted fixed O&M costs	Discounted variable costs	Discounted deficit cost	Discounted total costs
2020	-	-	2	-	-	-	2	-	2
2021	-	-	11	-	-	-	10	-	10
2022	-	-	57	14	-	-	47	11	58
2023	404	-	5	1,395	303	-	4	1,048	1,355
2024	476	13	10	57	325	9	7	39	380
2025	242	13	15	86	150	8	9	53	221
2026	1,160	16	31	-	655	9	18	-	681
2027	1,842	27	33	-	945	14	17	-	977
2028	1,998	53	33	-	932	25	16	-	973
2029	1,855	78	33	-	787	33	14	-	834
2030	2,312	92	33	-	891	36	13	-	940
2031	2,313	152	35	-	811	53	12	-	876
2032	1,574	180	33	-	502	58	11	-	570
2033	1,369	193	33	-	396	56	10	-	462
2034	1,875	213	33	-	494	56	9	-	559
2035	2,143	256	33	-	513	61	8	-	582
2036	2,504	269	33	-	545	59	7	-	611
2037	2,555	291	38	-	506	58	7	-	571
2038	2,920	353	82	-	525	63	15	-	603
2039	3,207	419	133	-	524	68	22	-	614
2040	4,588	484	182	-	682	72	27	-	781
2041	4,174	535	182	-	564	72	25	-	661
2042	3,447	618	249	-	423	76	31	-	530
2043	2,815	715	331	-	314	80	37	-	431
2044	2,466	812	414	-	250	82	42	-	375
2045	1,534	862	414	-	142	80	38	-	259
Total	49,773	6,646	2,493	1,552	12,180	1,128	457	1,152	14,917

5.8.3 SENSITIVITIES

Given the proposed generation additions and expansion plan, the system dispatch for the 2020-2045 horizon was simulated under three sensitivities: Low Hydrology, High Demand, and Low Demand. The resulting operation and associated costs are presented below.

5.8.3.1 LOW HYDROLOGY

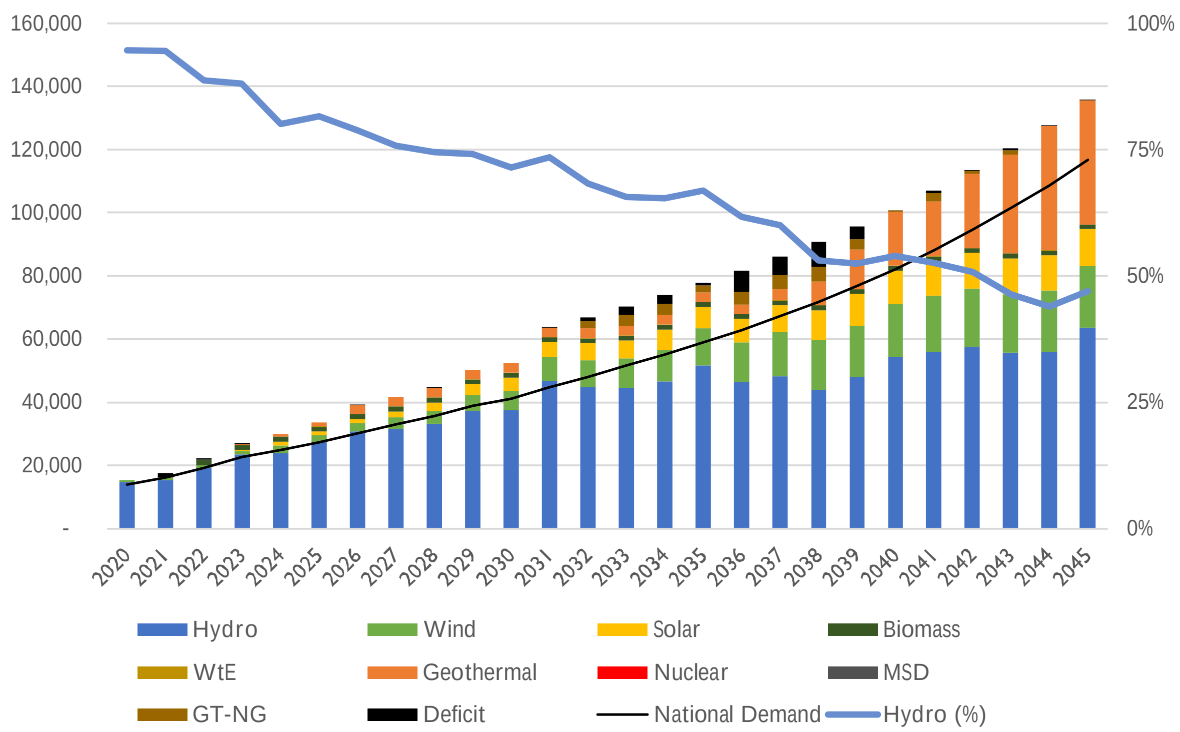
The low hydrology sensitivity simulated the dispatch of the proposed expansion plan assuming historical hydrological conditions so as to represent the worst historical drought experienced by the system. The recorded inflows for 1970 – 1995 were applied to the years 2020 – 2045, and so the historic drought in the 1980s occurs in the sensitivity in the 2030s.

The resulting generation under low hydrology conditions is presented in Table 5-46 and Figure 5-28.

Table 5-46: Scenario 5 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,460	95%
2021	15,444	671	-	-	103	-	-	117	-	1,280	16,335	95%
2022	19,263	722	-	1,516	103	-	-	124	-	536	21,728	89%
2023	23,544	1,011	291	1,516	103	256	-	-	-	321	26,722	88%
2024	23,931	2,278	1,341	1,516	103	749	-	-	-	-	29,917	80%
2025	27,399	2,059	1,239	1,516	103	1,243	-	-	-	-	33,560	82%
2026	30,778	2,591	1,276	1,516	103	2,780	-	-	-	-	39,044	79%
2027	31,616	3,492	2,024	1,516	103	2,975	-	-	-	-	41,726	76%
2028	33,194	4,129	2,661	1,516	103	2,975	-	-	-	-	44,577	74%
2029	37,215	5,097	3,343	1,516	103	2,975	-	-	-	-	50,249	74%
2030	37,448	6,156	4,178	1,516	103	2,975	-	-	-	-	52,376	71%
2031	46,790	7,522	4,729	1,516	103	2,975	-	-	49	-	63,684	73%
2032	44,807	8,549	5,333	1,516	103	2,975	-	-	2,334	1,197	65,617	68%
2033	44,462	9,299	5,793	1,516	103	2,975	-	-	3,636	2,565	67,783	66%
2034	46,445	10,071	6,435	1,516	103	2,975	-	-	3,479	2,919	71,025	65%
2035	51,485	11,809	6,861	1,516	103	2,975	-	-	2,211	765	76,960	67%
2036	46,252	12,552	7,566	1,516	103	2,975	-	-	3,973	6,675	74,936	62%
2037	48,127	14,130	8,479	1,516	103	3,369	-	-	4,463	5,916	80,187	60%
2038	44,052	15,616	9,416	1,516	103	7,576	-	-	4,634	7,797	82,914	53%
2039	48,009	16,220	10,040	1,516	103	12,435	-	-	3,234	4,078	91,558	52%
2040	54,339	16,775	10,459	1,516	103	17,166	-	-	379	100	100,737	54%
2041	55,869	17,824	10,974	1,516	103	17,166	-	-	2,806	757	106,258	53%
2042	57,578	18,349	11,314	1,516	103	23,473	-	-	1,077	42	113,411	51%
2043	55,567	18,627	11,323	1,505	103	31,293	-	-	1,415	532	119,833	46%
2044	55,955	19,323	11,260	1,516	103	39,241	-	-	71	14	127,470	44%
2045	63,681	19,433	11,643	1,516	103	39,241	-	-	5	-	135,623	47%

Figure 5-28: Scenario 5 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage



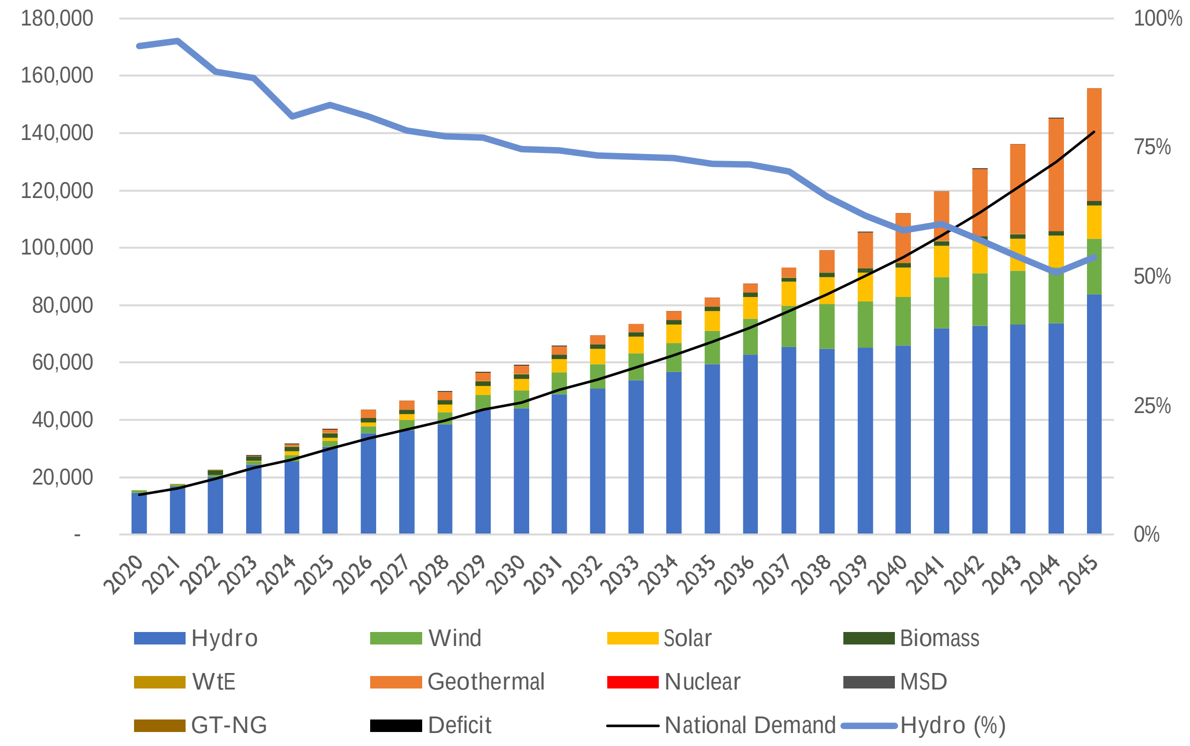
5.8.3.2 HIGH DEMAND

The high demand sensitivity simulated the dispatch of the proposed expansion plan assuming average hydrological conditions but using the high demand forecast. Stored energy within the hydro reservoirs was assumed to be available to increase hydro dispatch to meet the increased demand. The storage levels over the horizon were freely optimized given the inflows and demand. The resulting generation under high demand conditions is presented in Table 5-47 and Figure 5-29.

Table 5-47: Scenario 5 – High Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,854	671	-	-	103	-	-	-	-	-	17,628	96%
2022	20,205	722	-	1,516	103	-	-	-	-	-	22,546	90%
2023	24,417	1,011	291	1,516	103	256	-	-	-	216	27,594	88%
2024	25,554	2,278	1,341	1,516	103	749	-	-	-	-	31,540	81%
2025	30,571	2,059	1,239	1,516	103	1,243	-	-	-	-	36,732	83%
2026	35,243	2,591	1,276	1,516	103	2,780	-	-	-	-	43,509	81%
2027	36,541	3,492	2,024	1,516	103	2,975	-	-	-	-	46,651	78%
2028	38,555	4,129	2,661	1,516	103	2,975	-	-	-	-	49,938	77%
2029	43,509	5,097	3,343	1,516	103	2,975	-	-	-	-	56,543	77%
2030	44,070	6,156	4,178	1,516	103	2,975	-	-	-	-	58,999	75%
2031	48,912	7,522	4,729	1,516	103	2,975	-	-	-	-	65,757	74%
2032	50,914	8,549	5,333	1,516	103	2,975	-	-	-	-	69,390	73%
2033	53,877	9,299	5,793	1,516	103	2,975	-	-	-	-	73,562	73%
2034	56,808	10,071	6,435	1,516	103	2,975	-	-	-	-	77,908	73%
2035	59,319	11,809	6,861	1,516	103	2,975	-	-	-	-	82,582	72%
2036	62,747	12,552	7,566	1,516	103	2,975	-	-	-	-	87,459	72%
2037	65,513	14,130	8,479	1,516	103	3,369	-	-	-	-	93,110	70%
2038	64,856	15,616	9,416	1,516	103	7,576	-	-	-	-	99,084	65%
2039	65,120	16,220	10,040	1,516	103	12,435	-	-	-	-	105,435	62%
2040	65,995	16,775	10,459	1,516	103	17,166	-	-	-	-	112,015	59%
2041	72,018	17,824	10,974	1,516	103	17,166	-	-	-	-	119,601	60%
2042	72,817	18,349	11,314	1,516	103	23,473	-	-	-	-	127,572	57%
2043	73,327	18,627	11,323	1,516	103	31,293	-	-	-	-	136,189	54%
2044	73,701	19,323	11,260	1,516	103	39,241	-	-	-	1	145,145	51%
2045	83,658	19,433	11,643	1,516	103	39,241	-	-	-	-	155,595	54%

Figure 5-29: Scenario 5 – High Demand Sensitivity – Generation (GWh) and Hydro percentage



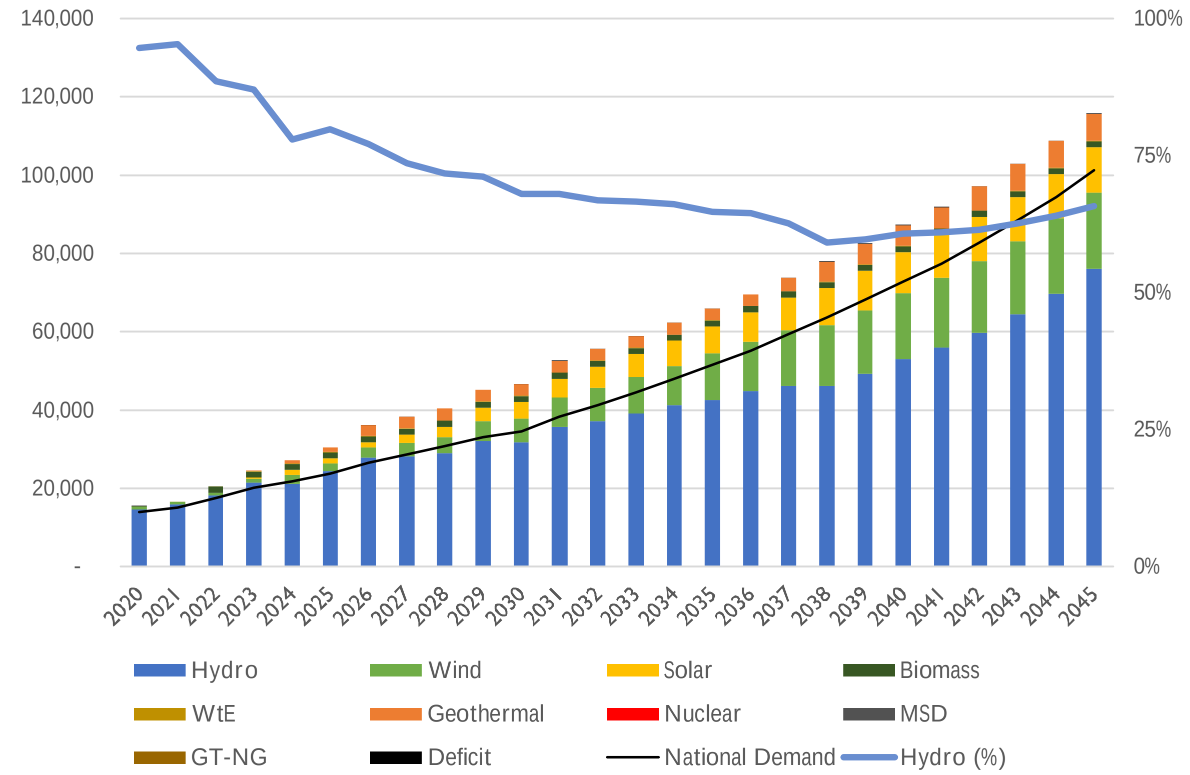
5.8.3.3 LOW DEMAND

The dispatch of the proposed expansion plan assuming the low demand forecast is presented below.

Table 5-48: Scenario 5 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	15,825	671	-	-	103	-	-	-	-	-	16,599	95%
2022	18,159	722	-	1,516	103	-	-	-	-	-	20,500	89%
2023	21,393	1,011	291	1,516	103	256	-	-	-	-	24,571	87%
2024	21,121	2,278	1,341	1,516	103	749	-	-	-	-	27,107	78%
2025	24,342	2,059	1,239	1,516	103	1,243	-	-	-	-	30,503	80%
2026	27,820	2,591	1,276	1,516	103	2,780	-	-	-	-	36,087	77%
2027	28,135	3,492	2,024	1,516	103	2,975	-	-	-	-	38,244	74%
2028	28,950	4,129	2,661	1,516	103	2,975	-	-	-	-	40,333	72%
2029	32,098	5,097	3,343	1,516	103	2,975	-	-	-	-	45,132	71%
2030	31,680	6,156	4,178	1,516	103	2,975	-	-	-	-	46,608	68%
2031	35,750	7,522	4,729	1,516	103	2,975	-	-	-	-	52,595	68%
2032	37,127	8,549	5,333	1,516	103	2,975	-	-	-	-	55,602	67%
2033	39,158	9,299	5,793	1,516	103	2,975	-	-	-	-	58,844	67%
2034	41,168	10,071	6,435	1,516	103	2,975	-	-	-	-	62,268	66%
2035	42,620	11,809	6,861	1,516	103	2,975	-	-	-	-	65,884	65%
2036	44,874	12,552	7,566	1,516	103	2,975	-	-	-	-	69,585	64%
2037	46,173	14,130	8,479	1,516	103	3,369	-	-	-	-	73,770	63%
2038	46,074	15,616	9,416	1,516	103	5,211	-	-	-	-	77,936	59%
2039	49,291	16,220	10,040	1,516	103	5,340	-	-	-	-	82,510	60%
2040	53,023	16,775	10,459	1,516	103	5,340	-	-	-	-	87,216	61%
2041	56,021	17,824	10,974	1,516	103	5,340	-	-	-	-	91,778	61%
2042	59,690	18,349	11,314	1,516	103	6,128	-	-	-	-	97,100	61%
2043	64,407	18,627	11,323	1,516	103	6,853	-	-	-	-	102,828	63%
2044	69,611	19,323	11,260	1,516	103	6,917	-	-	-	-	108,731	64%
2045	76,026	19,433	11,643	1,516	103	6,917	-	-	-	-	115,639	66%

Figure 5-30: Scenario 5 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage



It should be noted that this sensitivity is not feasible without significant curtailment of capacity. With all the proposed capacity installed, there would be 32,324 GWh of excess energy production in 2045. The excess would be larger than the total energy provided by wind and solar generation and so curtailment of those technologies would be insufficient. It was assumed that the additional proposed 4,000 MW of geothermal generation later in the horizon would not be installed if actual demand levels were substantially below the base case.

5.9 SCENARIO 6 – NON-COMMITTED EXPORTS

The key assumptions for Scenario 6 are shown in Table 5-49. In Scenario 6, the exports were treated as non-firm in terms of capacity and energy. As a result, the required reserve margin was 20% of the national peak demand excluding exports for firm capacity and 20% of the national annual energy demand excluding exports for firm energy.

Table 5-49: Scenario 6 – Key assumptions

Parameter	Value
Demand forecast	Base Case
Hydrology	Average
Generation choices	Least-cost

5.9.1 GENERATION ADDITIONS

The candidate generation additions for Scenario 6 are summarized in Table 5-50 with full details in Appendix B. These are in addition to the existing, under-construction, and committed projects.

Table 5-50: Scenario 6 – Added candidate capacity

Type	Capacity (MW)	
	2030	2045
Hydro	2,895	10,425
Solar	1,200	4,800
Wind	300	3,000
Geothermal	-	600
GT	-	4,060
Nuclear	-	-
Total	4,395	22,885

Combined with the existing and committed plants, the resulting total installed capacity is shown in Table 5-51 and Figure 5-31.

Table 5-52 and Figure 5-32 show the breakdown of generated energy for Scenario 6. The share of hydro energy does not exceed 75% after 2038.

Table 5-53 and Figure 5-33 show the firm energy by year for Scenario 6 relative to the annual energy demand. As indicated, based on average hydrological conditions, the system is expected to have an energy deficit until the end of 2023. In this scenario, exports are considered non-committed, so the deficit is less than in the other scenarios presented. By 2024, the required 20% energy margin is exceeded for the remainder of the planning period.

Table 5-51: Scenario 6 – Installed capacity (MW)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Firm	Peak Demand	Exports	Reserve Margin (%)
2020	3,450	324			25	-	-	38	-	3,837	3,610	2,459	175	47%
2021	3,941	324			25	-	-	38	-	4,328	4,101	3,047	175	35%
2022	4,303	444		298	25	-	-	38	-	5,108	4,553	3,727	345	22%
2023	4,303	544	250	298	25	57	-	-	-	5,477	4,602	4,431	515	4%
2024	8,352	844	550	298	25	107	-	-	-	10,176	8,791	4,966	579	77%
2025	8,652	844	550	298	25	207	-	-	-	10,576	9,191	5,490	707	67%
2026	11,013	844	550	298	25	377	-	-	-	13,107	11,722	6,130	1,009	91%
2027	11,013	844	700	298	25	377	-	-	-	13,257	11,722	6,620	1,009	77%
2028	11,414	844	950	298	25	377	-	-	-	13,909	12,123	7,161	1,009	69%
2029	11,414	844	1,200	298	25	377	-	-	-	14,159	12,123	7,890	1,298	54%
2030	13,908	844	1,450	298	25	377	-	-	-	16,903	14,617	8,279	1,298	77%
2031	13,908	844	1,450	298	25	377	-	-	-	16,903	14,617	9,493	2,153	54%
2032	15,310	844	1,700	298	25	377	-	-	-	18,555	16,019	10,086	2,153	59%
2033	15,804	844	2,000	298	25	377	-	-	-	19,349	16,513	10,712	2,153	54%
2034	15,804	844	2,300	298	25	377	-	-	-	19,649	16,513	11,369	2,153	45%
2035	15,804	844	2,600	298	25	377	-	-	-	19,949	16,513	12,061	2,153	37%
2036	16,176	994	2,900	298	25	377	-	-	140	20,911	17,070	12,804	2,153	33%
2037	17,876	1,144	3,200	298	25	377	-	-	140	23,061	18,815	13,593	2,153	38%
2038	18,312	1,444	3,500	298	25	377	-	-	140	24,097	19,341	14,436	2,153	34%
2039	20,462	1,744	3,750	298	25	377	-	-	140	26,797	21,581	15,337	2,153	41%
2040	20,912	2,044	4,050	298	25	377	-	-	140	27,847	22,121	16,331	2,153	35%
2041	20,912	2,344	4,350	298	25	977	-	-	140	29,047	22,811	17,418	2,153	31%
2042	20,912	2,644	4,650	298	25	977	-	-	1,120	30,627	23,881	18,596	2,153	28%
2043	20,912	2,944	4,950	298	25	977	-	-	2,100	32,207	24,951	19,860	2,153	26%
2044	20,912	3,244	5,050	298	25	977	-	-	3,080	33,587	26,021	21,218	2,153	23%
2045	21,438	3,544	5,050	298	25	977	-	-	4,060	35,393	27,617	22,651	2,153	22%

Figure 5-31: Scenario 6 – Firm capacity (MW)

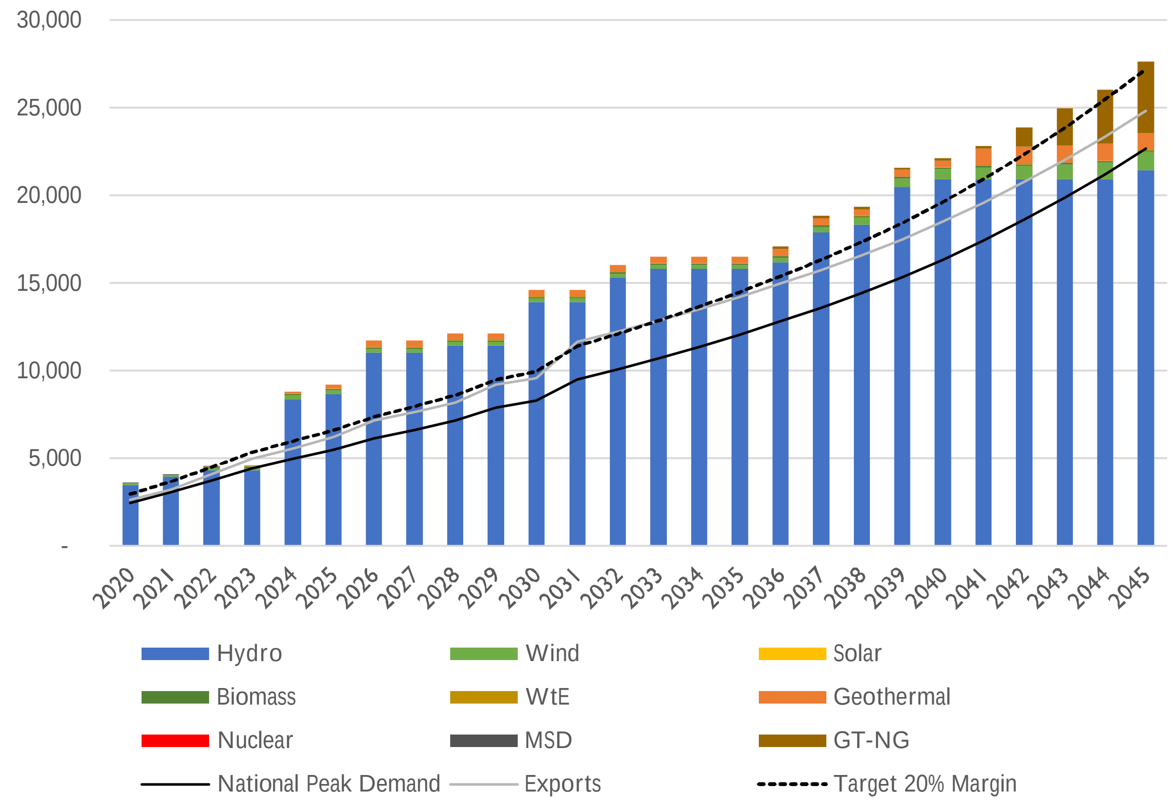


Table 5-52: Scenario 6 – Generated energy by plant type (GWh)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,795	671	-	-	103	-	-	46	-	-	17,615	95%
2022	19,633	722	-	1,516	103	-	-	277	-	14	22,251	88%
2023	22,470	1,011	291	1,516	103	256	-	-	-	1,395	25,648	88%
2024	23,874	2,278	1,341	1,516	103	749	-	-	-	57	29,860	80%
2025	27,313	2,059	1,239	1,516	103	1,243	-	-	-	85	33,474	82%
2026	31,174	2,195	1,276	1,516	103	2,780	-	-	-	-	39,044	80%
2027	33,192	2,251	1,690	1,516	103	2,975	-	-	-	-	41,726	80%
2028	35,706	2,045	2,222	1,516	103	2,975	-	-	-	10	44,568	80%
2029	40,708	2,141	2,807	1,516	103	2,975	-	-	-	-	50,249	81%
2030	42,027	2,234	3,522	1,516	103	2,975	-	-	-	-	52,376	80%
2031	53,501	2,141	3,363	1,516	103	2,975	-	-	-	84	63,600	84%
2032	55,838	2,295	4,087	1,516	103	2,975	-	-	-	-	66,814	84%
2033	59,014	2,104	4,636	1,516	103	2,975	-	-	-	-	70,348	84%
2034	61,823	2,128	5,373	1,516	103	2,975	-	-	-	27	73,918	84%
2035	64,607	2,265	6,112	1,516	103	2,975	-	-	-	146	77,578	83%
2036	67,061	3,012	6,812	1,516	103	2,975	-	-	30	103	81,509	82%
2037	70,271	3,610	7,628	1,516	103	2,975	-	-	-	-	86,103	82%
2038	72,659	4,950	8,491	1,516	103	2,975	-	-	7	9	90,702	80%
2039	75,900	6,213	8,930	1,516	103	2,975	-	-	-	-	95,636	79%
2040	79,430	7,269	9,544	1,516	103	2,975	-	-	-	-	100,837	79%
2041	79,415	8,372	10,097	1,516	103	7,512	-	-	-	-	107,015	74%
2042	83,763	9,580	10,757	1,516	103	7,705	-	-	29	-	113,453	74%
2043	89,136	10,443	11,355	1,516	103	7,705	-	-	105	-	120,364	74%
2044	94,710	11,487	11,487	1,516	103	7,705	-	-	475	-	127,484	74%
2045	90,581	12,367	11,952	1,516	103	7,705	-	-	11,399	-	135,623	67%

Figure 5-32: Scenario 6 – Generated energy (GWh) and hydro percentage

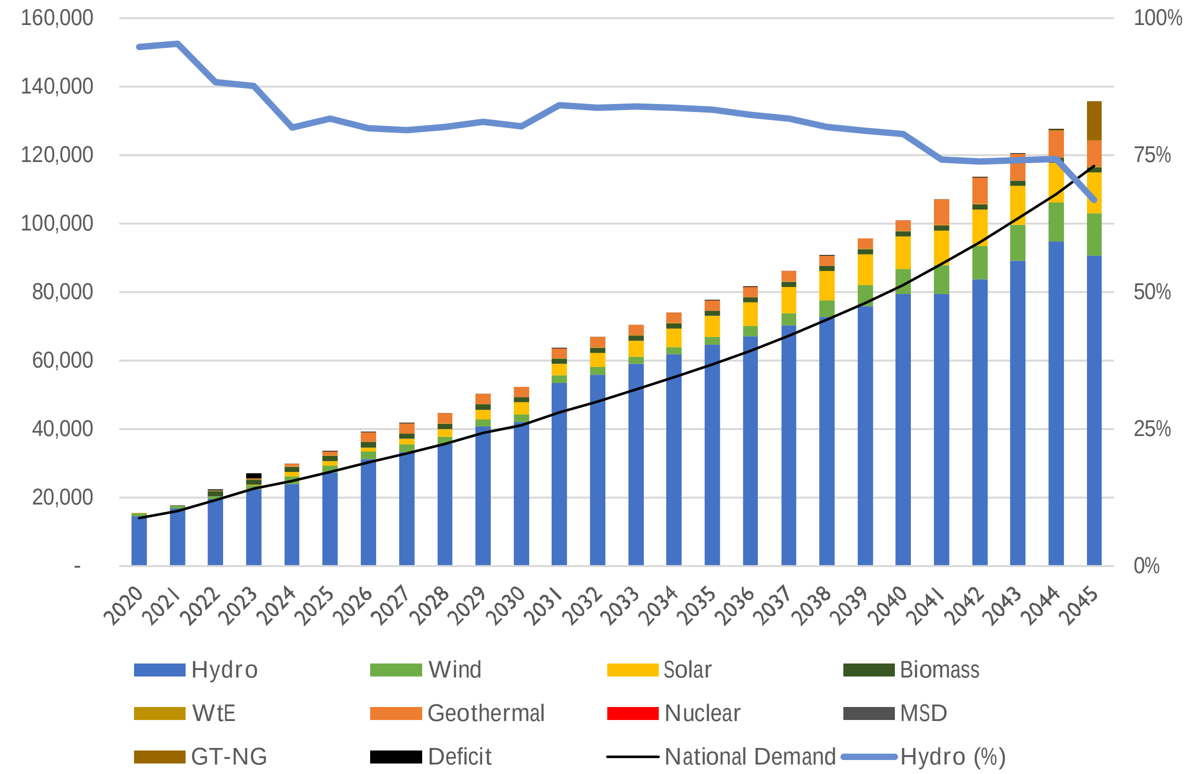
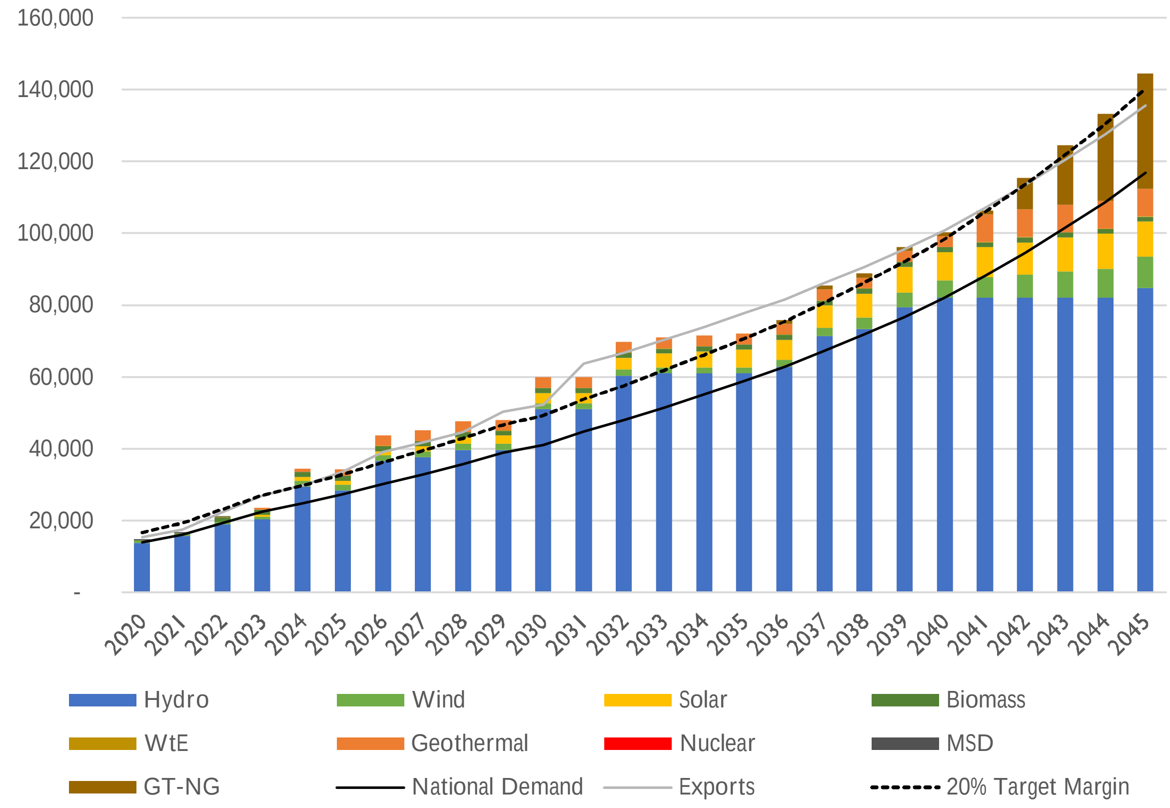


Table 5-53: Scenario 6 – Firm energy and energy margin (GWh)

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Total	Energy demand	Reserve margin
2020	13,794	686	-	-	103	-	-	277	-	14,860	13,926	7%
2021	15,716	686	-	-	103	-	-	277	-	16,782	16,082	4%
2022	18,937	686	-	1,360	103	-	-	277	-	21,363	19,242	11%
2023	20,320	853	482	1,360	103	452	-	-	-	23,570	22,531	5%
2024	29,468	1,641	1,060	1,360	103	846	-	-	-	34,479	24,845	39%
2025	28,408	1,641	1,060	1,360	103	1,634	-	-	-	34,207	27,366	25%
2026	36,633	1,641	1,060	1,360	103	2,975	-	-	-	43,772	30,205	45%
2027	37,708	1,641	1,349	1,360	103	2,975	-	-	-	45,137	32,887	37%
2028	39,707	1,641	1,831	1,360	103	2,975	-	-	-	47,617	35,738	33%
2029	39,707	1,641	2,313	1,360	103	2,975	-	-	-	48,099	38,879	24%
2030	51,054	1,641	2,794	1,360	103	2,975	-	-	-	59,928	41,006	46%
2031	51,054	1,641	2,794	1,360	103	2,975	-	-	-	59,928	44,823	34%
2032	60,387	1,641	3,276	1,360	103	2,975	-	-	-	69,743	47,954	45%
2033	61,022	1,641	3,854	1,360	103	2,975	-	-	-	70,956	51,488	38%
2034	61,022	1,641	4,433	1,360	103	2,975	-	-	-	71,534	55,084	30%
2035	61,022	1,641	5,011	1,360	103	2,975	-	-	-	72,112	58,864	23%
2036	62,728	2,035	5,589	1,360	103	2,975	-	-	1,104	75,894	62,751	21%
2037	71,282	2,430	6,167	1,360	103	2,975	-	-	1,104	85,420	67,243	27%
2038	73,248	3,218	6,745	1,360	103	2,975	-	-	1,104	88,753	71,851	24%
2039	79,417	4,006	7,227	1,360	103	2,975	-	-	1,104	96,192	76,776	25%
2040	82,130	4,795	7,805	1,360	103	2,975	-	-	1,104	100,272	81,977	22%
2041	82,130	5,583	8,383	1,360	103	7,705	-	-	1,104	106,369	88,154	21%
2042	82,130	6,372	8,961	1,360	103	7,705	-	-	8,830	115,462	94,592	22%
2043	82,130	7,160	9,540	1,360	103	7,705	-	-	16,556	124,555	101,504	23%
2044	82,130	7,948	9,732	1,360	103	7,705	-	-	24,283	133,262	108,623	23%
2045	84,746	8,737	9,732	1,360	103	7,705	-	-	32,009	144,393	116,763	24%

Figure 5-33: Scenario 6 – Firm energy (GWh)



5.9.2 COSTS

The total and discounted cost for Scenario 1 assuming a 10% discount factor are presented below.

Table 5-54: Scenario 6 – Total costs (USDm)

Year	Investment cost	Fixed O&M costs	Variable costs	Deficit cost	Discounted investment costs	Discounted fixed O&M costs	Discounted variable costs	Discounted deficit cost	Discounted total costs
2020	-	-	2	-	-	-	2	-	2
2021	-	-	11	-	-	-	10	-	10
2022	-	-	57	14	-	-	47	11	58
2023	429	-	5	1,395	323	-	4	1,048	1,375
2024	429	13	10	57	293	9	7	39	348
2025	694	13	15	86	431	8	9	53	501
2026	731	13	31	-	413	7	18	-	438
2027	1,113	15	33	-	571	8	17	-	596
2028	1,189	26	33	10	555	12	16	4	587
2029	1,272	30	33	-	540	13	14	-	566
2030	1,210	79	33	-	466	30	13	-	510
2031	599	79	33	84	210	28	12	30	279
2032	1,112	108	33	-	354	34	11	-	399
2033	890	121	33	-	258	35	10	-	303
2034	1,312	125	33	27	345	33	9	7	394
2035	1,822	130	33	147	436	31	8	35	510
2036	2,095	147	37	102	456	32	8	22	518
2037	2,494	186	33	-	493	37	7	-	537
2038	2,216	207	34	9	399	37	6	2	444
2039	2,109	258	33	-	345	42	5	-	393
2040	1,665	279	33	-	248	41	5	-	294
2041	1,643	345	81	-	222	47	11	-	280
2042	1,611	371	86	-	198	46	11	-	254
2043	1,561	397	94	-	174	44	10	-	229
2044	1,551	419	132	-	157	43	13	-	213
2045	893	450	1,248	-	82	42	115	-	239
Total	30,642	3,811	2,244	1,930	7,970	658	397	1,252	10,277

5.9.3 SENSITIVITIES

Given the proposed generation additions and expansion plan, the system dispatch for the 2020-2045 horizon was simulated under three sensitivities: Low Hydrology, High Demand, and Low Demand. The resulting operation and associated costs are presented below.

5.9.3.1 LOW HYDROLOGY

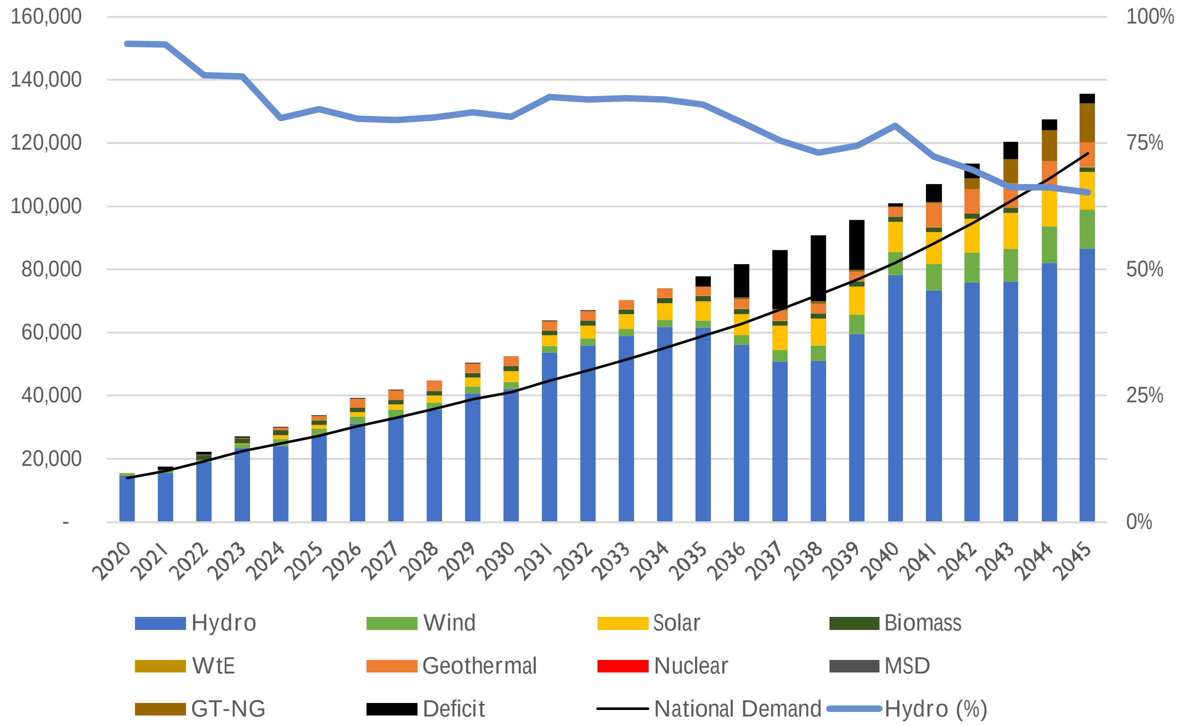
The low hydrology sensitivity simulated the dispatch of the proposed expansion plan assuming historical hydrological conditions so as to represent the worst historical drought experienced by the system. The recorded inflows for 1970 – 1995 were applied to the years 2020 – 2045, and so the historic drought in the 1980s occurs in the sensitivity in the 2030s.

The resulting generation under low hydrology conditions is presented in Table 5-55 and Figure 5-34.

Table 5-55: Scenario 6 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	23,931	2,278	1,341	1,516	103	749	-	-	-	-	29,917	80%
2021	27,399	2,059	1,239	1,516	103	1,243	-	-	-	-	33,560	82%
2022	31,174	2,195	1,276	1,516	103	2,780	-	-	-	-	39,044	80%
2023	33,192	2,251	1,690	1,516	103	2,975	-	-	-	-	41,726	80%
2024	35,716	2,045	2,222	1,516	103	2,975	-	-	-	-	44,577	80%
2025	40,708	2,141	2,807	1,516	103	2,975	-	-	-	-	50,249	81%
2026	42,027	2,234	3,522	1,516	103	2,975	-	-	-	-	52,376	80%
2027	53,586	2,141	3,363	1,516	103	2,975	-	-	-	-	63,684	84%
2028	55,823	2,295	4,087	1,516	103	2,975	-	-	-	14	66,800	84%
2029	59,014	2,104	4,636	1,516	103	2,975	-	-	-	-	70,348	84%
2030	61,826	2,128	5,373	1,516	103	2,975	-	-	-	24	73,920	84%
2031	61,561	2,265	6,112	1,516	103	2,975	-	-	-	3,193	74,532	83%
2032	56,058	3,012	6,812	1,516	103	2,975	-	-	510	10,626	70,985	79%
2033	50,871	3,610	7,628	1,516	103	2,975	-	-	685	18,715	67,388	75%
2034	50,992	4,950	8,491	1,516	103	2,975	-	-	784	20,900	69,811	73%
2035	59,457	6,213	8,930	1,516	103	2,975	-	-	566	15,876	79,760	75%
2036	78,233	7,269	9,544	1,516	103	2,975	-	-	197	1,000	99,837	78%
2037	73,244	8,372	10,097	1,516	103	7,512	-	-	436	5,734	101,281	72%
2038	75,753	9,580	10,757	1,516	103	7,705	-	-	3,403	4,635	108,817	70%
2039	76,147	10,443	11,355	1,516	103	7,705	-	-	7,678	5,417	114,948	66%
2040	82,078	11,487	11,487	1,516	103	7,705	-	-	9,626	3,481	124,003	66%
2041	86,463	12,367	11,952	1,516	103	7,705	-	-	12,445	3,072	132,551	65%
2042	23,931	2,278	1,341	1,516	103	749	-	-	-	-	29,917	80%
2043	27,399	2,059	1,239	1,516	103	1,243	-	-	-	-	33,560	82%
2044	31,174	2,195	1,276	1,516	103	2,780	-	-	-	-	39,044	80%
2045	33,192	2,251	1,690	1,516	103	2,975	-	-	-	-	41,726	80%

Figure 5-34: Scenario 6 – Low Hydrology Sensitivity – Generation (GWh) and Hydro percentage



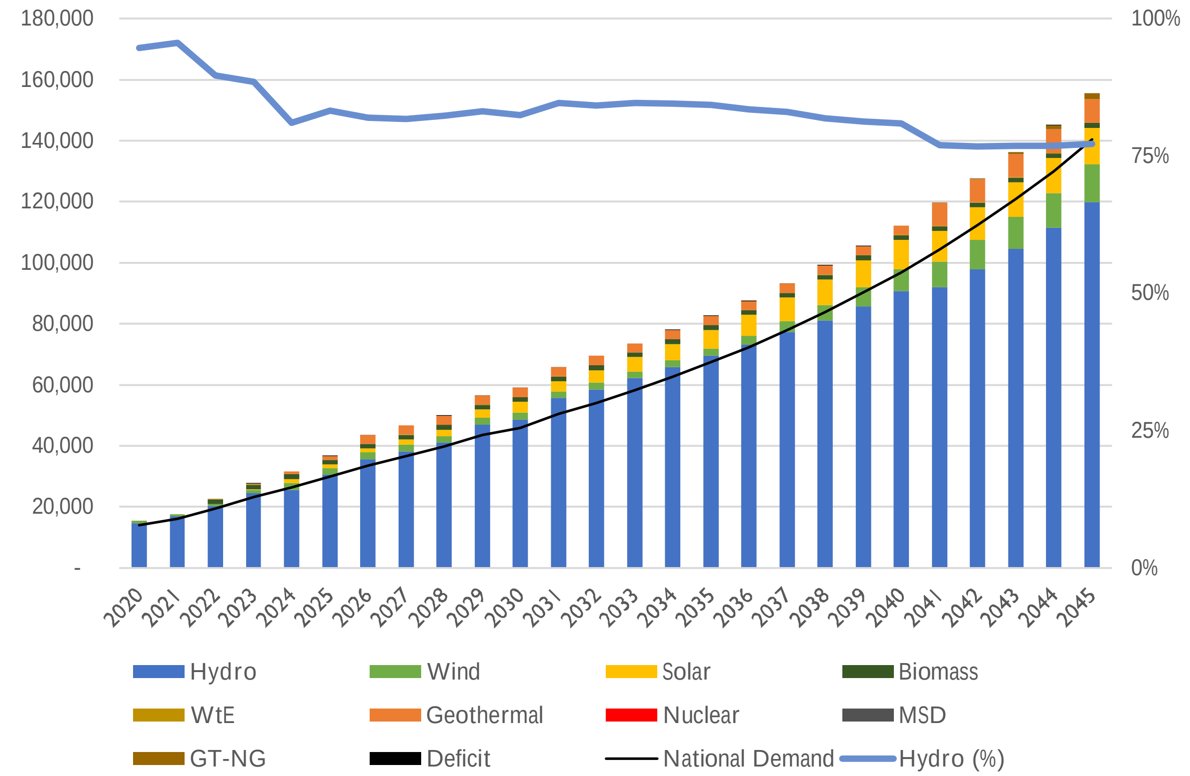
5.9.3.2 HIGH DEMAND

The high demand sensitivity simulated the dispatch of the proposed expansion plan assuming average hydrological conditions but using the high demand forecast. Stored energy within the hydro reservoirs was assumed to be available to increase hydro dispatch to meet the increased demand. The storage levels over the horizon were freely optimized given the inflows and demand. The resulting generation under high demand conditions is presented in Table 5-56 and Figure 5-35.

Table 5-56: Scenario 6 – High Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	16,854	671	-	-	103	-	-	-	-	-	17,628	96%
2022	20,205	722	-	1,516	103	-	-	-	-	-	22,546	90%
2023	24,417	1,011	291	1,516	103	256	-	-	-	216	27,594	88%
2024	25,554	2,278	1,341	1,516	103	749	-	-	-	-	31,540	81%
2025	30,571	2,059	1,239	1,516	103	1,243	-	-	-	-	36,732	83%
2026	35,638	2,195	1,276	1,516	103	2,780	-	-	-	-	43,509	82%
2027	38,116	2,251	1,690	1,516	103	2,975	-	-	-	-	46,651	82%
2028	41,077	2,045	2,222	1,516	103	2,975	-	-	-	-	49,938	82%
2029	47,001	2,141	2,807	1,516	103	2,975	-	-	-	-	56,543	83%
2030	48,649	2,234	3,522	1,516	103	2,975	-	-	-	-	58,998	82%
2031	55,658	2,141	3,363	1,516	103	2,975	-	-	-	-	65,756	85%
2032	58,413	2,295	4,087	1,516	103	2,975	-	-	-	-	69,390	84%
2033	62,228	2,104	4,636	1,516	103	2,975	-	-	-	-	73,562	85%
2034	65,813	2,128	5,373	1,516	103	2,975	-	-	-	-	77,908	84%
2035	69,573	2,265	6,112	1,516	103	2,975	-	-	-	38	82,544	84%
2036	72,984	3,012	6,812	1,516	103	2,975	-	-	10	47	87,412	83%
2037	77,278	3,610	7,628	1,516	103	2,975	-	-	-	-	93,110	83%
2038	81,029	4,950	8,491	1,516	103	2,975	-	-	7	13	99,071	82%
2039	85,699	6,213	8,930	1,516	103	2,975	-	-	-	-	105,435	81%
2040	90,602	7,269	9,544	1,516	103	2,975	-	-	6	-	112,015	81%
2041	91,962	8,372	10,097	1,516	103	7,512	-	-	7	32	119,569	77%
2042	97,791	9,580	10,757	1,516	103	7,705	-	-	85	35	127,538	77%
2043	104,535	10,443	11,355	1,516	103	7,705	-	-	467	65	136,124	77%
2044	111,382	11,487	11,487	1,516	103	7,705	-	-	1,365	101	145,045	77%
2045	119,918	12,367	11,952	1,516	103	7,705	-	-	1,863	171	155,424	77%

Figure 5-35: Scenario 6 – High Demand Sensitivity – Generation (GWh) and Hydro percentage



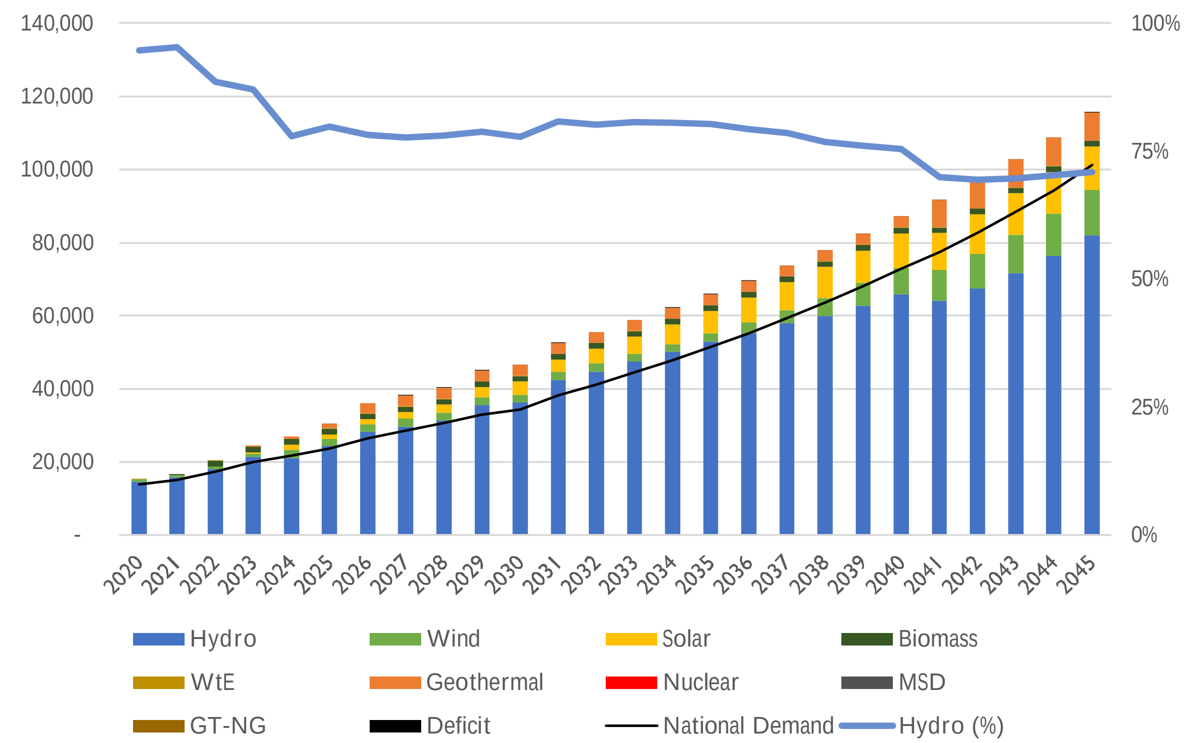
5.9.3.3 LOW DEMAND

The dispatch of the proposed expansion plan assuming the low demand forecast is presented below.

Table 5-57: Scenario 6 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage

Year	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT-NG	Deficit	Total	Hydro (%)
2020	14,635	721	-	-	103	-	-	-	-	-	15,459	95%
2021	15,825	671	-	-	103	-	-	-	-	-	16,599	95%
2022	18,159	722	-	1,516	103	-	-	-	-	-	20,500	89%
2023	21,393	1,011	291	1,516	103	256	-	-	-	-	24,571	87%
2024	21,121	2,278	1,341	1,516	103	749	-	-	-	-	27,107	78%
2025	24,342	2,059	1,239	1,516	103	1,243	-	-	-	-	30,503	80%
2026	28,216	2,195	1,276	1,516	103	2,780	-	-	-	-	36,087	78%
2027	29,710	2,251	1,690	1,516	103	2,975	-	-	-	-	38,245	78%
2028	31,471	2,045	2,222	1,516	103	2,975	-	-	-	-	40,333	78%
2029	35,590	2,141	2,807	1,516	103	2,975	-	-	-	-	45,132	79%
2030	36,259	2,234	3,522	1,516	103	2,975	-	-	-	-	46,608	78%
2031	42,497	2,141	3,363	1,516	103	2,975	-	-	-	-	52,595	81%
2032	44,626	2,295	4,087	1,516	103	2,975	-	-	-	-	55,602	80%
2033	47,510	2,104	4,636	1,516	103	2,975	-	-	-	-	58,843	81%
2034	50,173	2,128	5,373	1,516	103	2,975	-	-	-	-	62,268	81%
2035	52,913	2,265	6,112	1,516	103	2,975	-	-	-	-	65,884	80%
2036	55,168	3,012	6,812	1,516	103	2,975	-	-	-	-	69,586	79%
2037	57,938	3,610	7,628	1,516	103	2,975	-	-	-	-	73,770	79%
2038	59,901	4,950	8,491	1,516	103	2,975	-	-	-	-	77,936	77%
2039	62,774	6,213	8,930	1,516	103	2,975	-	-	-	-	82,510	76%
2040	65,809	7,269	9,544	1,516	103	2,975	-	-	-	-	87,216	75%
2041	64,178	8,372	10,097	1,516	103	7,512	-	-	-	-	91,778	70%
2042	67,439	9,580	10,757	1,516	103	7,705	-	-	-	-	97,100	69%
2043	71,706	10,443	11,355	1,516	103	7,705	-	-	-	-	102,828	70%
2044	76,432	11,487	11,487	1,516	103	7,705	-	-	-	-	108,731	70%
2045	81,996	12,367	11,952	1,516	103	7,705	-	-	-	-	115,639	71%

Figure 5-36: Scenario 6 – Low Demand Sensitivity – Generation (GWh) and Hydro percentage



5.10 COMPARISON OF SCENARIOS

5.10.1 CAPACITY

5.10.1.1 2025

In all cases, 300 MW of wind and solar are installed in 2024 to meet the immediate shortage in energy. The candidates selected are Mega Wind and Mekelle Solar plants. These sites are selected due to their favorable resource availability; however, the critical issue is the installation of additional capacity. Different projects of the same technology, capacity and energy provision could be developed in the place of these schemes. In all scenarios, it was assumed that the earliest that new capacity could be operational was the beginning of 2024 due to the required lead times. However, 2023 is forecast to have a capacity reserve margin of only 4% and a firm energy margin of 6% on the national demand. There is insufficient firm capacity and energy to commit to the forecast export levels; the system is 7% short of firm capacity and 12% short of firm energy. As such, the solar and wind projects with the greatest chance of becoming operational in 2024 or earlier should be prioritized.

In most scenarios, only Mega Wind and Mekelle Solar plants are installed by 2025; however, in Scenario 2, Assela II is installed in 2025, giving an extra 120 MW of wind capacity. Under 2 billion USD of investment is required for theses candidate schemes. It should be noted that this is in addition to the committed projects shown in Table 5-58, giving a total of 550 MW solar and 844 MW wind capacity in the period.

Table 5-58: Summary of under-construction and committed projects by end of 2025

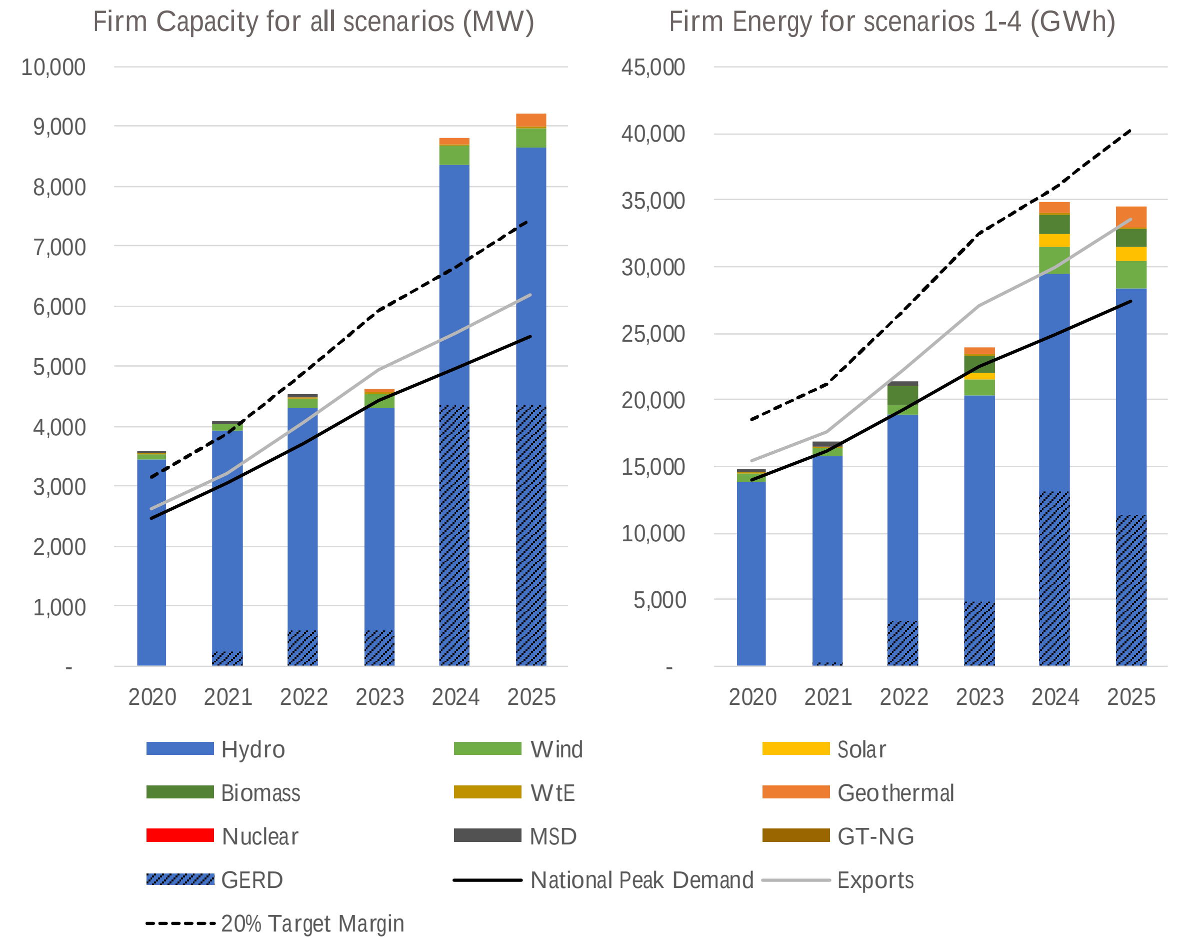
Type	Project	COD	Capacity (MW)	Total capacity at end of 2025 (MW)
Hydro	GERD	2021-2026	238-5,150	4,950
	Koysha	2024-2026	300-1,800	
Biomass (Sugar factories)	Beles 1-3	2022-2025	20-60 (15-35)	342 (146)
	Wolkayit	2023	82 (30)	
	Omo Kuraz 1-3	2024-2026	37-111 (15-40)	
	Kessem	2023	64 (16)	
Geothermal	Corbetti 1	Q2 2024	50	200
	Tulu Moye I	Q3 2023	50	
	Tulu Moye II	Q3 2025	100	
Wind	Asela I	2023	100	370
	Asela II (Iteya)	2024	150	
	Ayisha II	2022	120	
Solar	Gad I	Q3 2023	125	250
	Dicheto	Q3 2023	125	

* Figures in brackets are exports to grid.

The committed projects are most significant before 2025 as there is a sizable pipeline of projects.

The GERD's capacity increases dramatically in the period, and as a result, the contribution of hydro to the total firm capacity doubles in 2024 compared to 2023. Any changes to the commissioning schedule would significantly impact the system's adequacy. The portion of hydro contribution attributable to the GERD is hatched below.

Figure 5-37: Firm Capacity and Firm Energy margins, 2020 – 2025



It can be seen that a shortage of firm energy drives investment decisions in this period. Table 5-59 and Figure 5-38 present the resulting capacity for each scenario in detail.

Table 5-59: Comparison of capacity by 2025

Scenario		Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT	Total
1: Least-cost	Installed Capacity (MW)	8,652	844	550	298	25	207	-	-	-	10,576
	Firm Capacity (MW)	8,652	217	-	-	25	207	-	-	-	9,101
	Firm Energy (MW_{av})	3,243	187	121	155	12	187	-	-	-	3,905
2: Reference	Installed Capacity (MW)	8,652	964	550	298	25	207	-	-	-	10,696
	Firm Capacity (MW)	8,652	253	-	-	25	207	-	-	-	9,137
	Firm Energy (MW_{av})	3,243	223	121	155	12	187	-	-	-	3,941
3: Additional geothermal	Installed Capacity (MW)	8,652	844	550	298	25	207	-	-	-	10,576
	Firm Capacity (MW)	8,652	217	-	-	25	207	-	-	-	9,101
	Firm Energy (MW_{av})	3,243	187	121	155	12	187	-	-	-	3,905
4: Nuclear	Installed Capacity (MW)	8,652	844	550	298	25	207	-	-	-	10,576
	Firm Capacity (MW)	8,652	217	-	-	25	207	-	-	-	9,101
	Firm Energy (MW_{av})	3,243	187	121	155	12	187	-	-	-	3,905
5: Minimum fossil fuel	Installed Capacity (MW)	8,652	844	550	298	25	207	-	-	-	10,576
	Firm Capacity (MW)	8,652	217	-	-	25	207	-	-	-	9,101
	Firm Energy (MW_{av})	3,243	187	121	155	12	187	-	-	-	3,905
6: Non-committed exports	Installed Capacity (MW)	8,652	844	550	298	25	207	-	-	-	10,576
	Firm Capacity (MW)	8,652	217	-	-	25	207	-	-	-	9,101
	Firm Energy (MW_{av})	3,243	187	121	155	12	187	-	-	-	3,905

Figure 5-38: Comparison of capacity by 2025

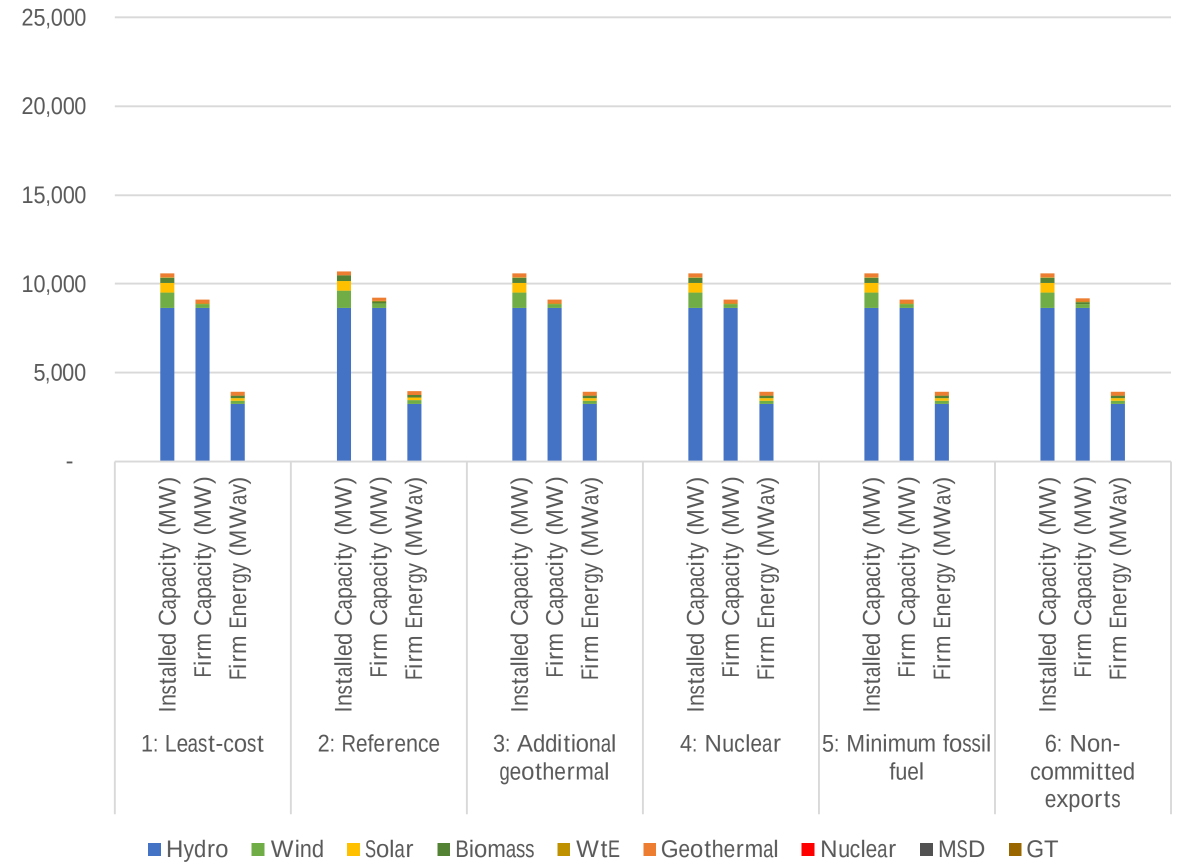
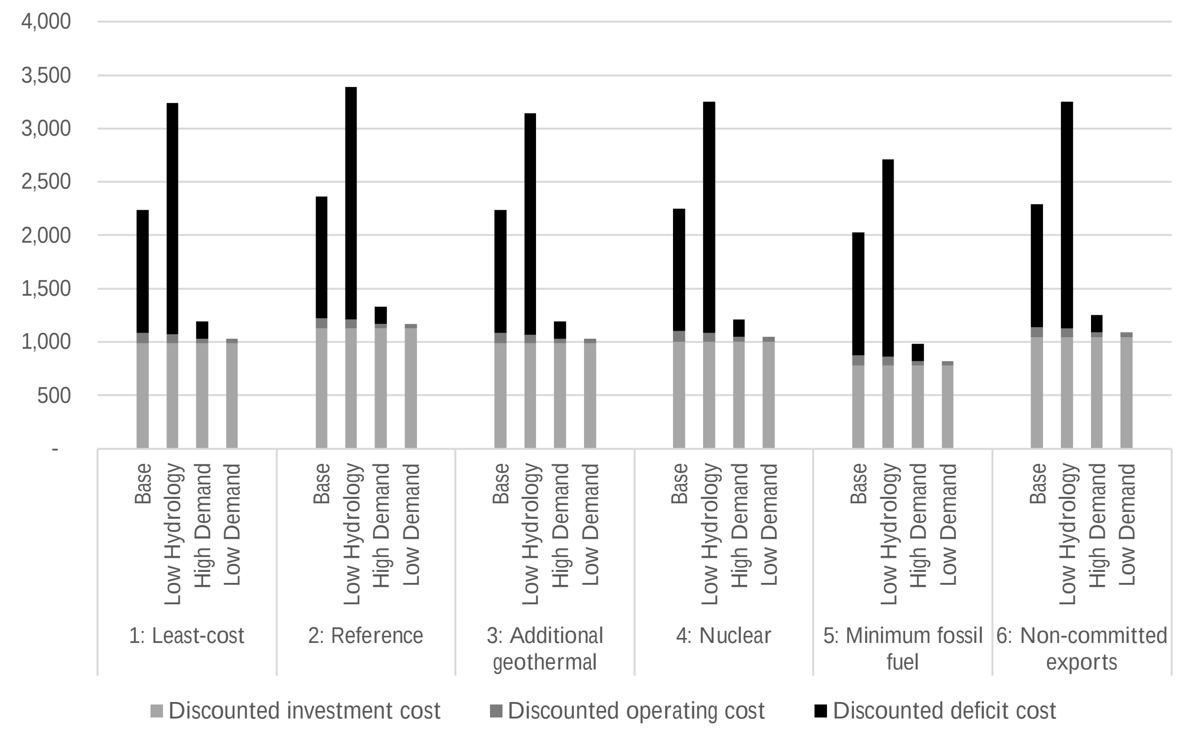


Table 5-60: Comparison of costs by 2025 (USDm)

Scenario	Sensitivity	Investment cost	Discounted investment cost	Discounted operating cost	Discounted deficit cost	Discounted total cost
1: Least-cost	Base	1,461	989	96	1,152	2,237
	Low Hydrology		989	87	2,166	3,242
	High Demand		989	43	162	1,194
	Low Demand		989	43	-	1,032
2: Reference	Base	1,663	1,127	98	1,140	2,365
	Low Hydrology		1,127	84	2,181	3,392
	High Demand		1,127	45	162	1,334
	Low Demand		1,127	45	-	1,172
3: Additional geothermal	Base	1,461	989	96	1,152	2,237
	Low Hydrology		989	82	2,073	3,144
	High Demand		989	43	162	1,194
	Low Demand		989	43	-	1,032
4: Nuclear	Base	1,486	1,005	96	1,152	2,253
	Low Hydrology		1,005	82	2,167	3,254
	High Demand		1,005	43	162	1,210
	Low Demand		1,005	43	-	1,048
5: Minimum fossil fuel	Base	1,122	779	96	1,152	2,027
	Low Hydrology		779	84	1,848	2,711
	High Demand		779	43	162	984
	Low Demand		779	43	-	822
6: Non-committed exports	Base	1,552	1,046	96	1,152	2,294
	Low Hydrology		1,046	84	2,125	3,255
	High Demand		1,046	43	162	1,251
	Low Demand		1,046	43	-	1,089

Figure 5-39: Comparison of total discounted costs by 2025 (USDm)



5.10.1.2 2030

From 2025 up to 2030, the system is also energy-constrained as there is sufficient firm capacity (capacity margin in excess of 20%). In addition to more solar and wind capacity, technology types with longer lead times are added in this period, such as hydro and thermal generation. The candidates chosen in the expansion plan for each scenario and the scheduling are chosen to produce the lowest total cost within the constraints set. In general, expansion plans that delay capacity investments further result in lower investment costs due to discounting.

The capacity expansion plan also determines the diversity of energy generation achieved. It is desired that no more than 75% of generation should be from hydropower plants by 2030. The generation mix directly impacts the system's ability to respond to drought conditions, which was further explored in the sensitivity analysis. The additional investment cost in Scenario 2 by 2030 where the desired diversity is achieved compared to the least cost case is 350 USDm NPV. Over the whole planning horizon to 2045 Scenario 1 presents 1.23 billion USD NPV less investment.

A summary of the details of each scenario in 2030 is presented below. The key points are as follows:

- Scenario 1 – Least-cost: Upper Dabus, Birbir R and Karadobi are installed by 2030 along with wind, solar, and GT candidates. The hydro capacity enables low operating costs but does not achieve the desired diversity as hydro contributes 81% of the total generation.
- Scenario 2 – Reference: Upper Dabus, Baro & Genji and Birbir A are installed by 2030 along with wind, solar, and GT candidates. Slightly less hydro capacity than the least-cost case and substantially more wind result in similar operating costs, but the desired generation diversity is achieved. Hydro contributes 72% of the total generation. Slightly less GT capacity than the least-cost case is achieved by the firm energy contribution of the increased wind capacity.
- Scenario 3 – Additional geothermal: Upper Dabus, Birbir R and Karadobi are installed by 2030 along with wind, solar, and GT candidates. By 2030, the generation capacity is similar to the least-cost scenario, but there is less solar capacity. The desired diversity is not achieved in 2030, with hydro contributing 83% of the total generation.
- Scenario 4 – Nuclear: Upper Dabus, Birbir R, Karadobi and Birbir A are installed by 2030 along with wind, solar, and GT candidates. The nuclear capacity is installed later in the horizon. By 2030, the generation capacity is similar to the least-cost scenario, but there is less solar capacity. The desired diversity is not achieved as hydro contributes 82% of the total generation.
- Scenario 5 – Minimum fossil fuel: Upper Dabus and Birbir R are installed by 2030 along with wind, solar, and GT candidates. By 2030, this case is very similar to the reference case; however, there is less hydro and wind capacity, and so more solar is installed to meet the firm energy requirements. The desired diversity is achieved as hydro contributes 71% of the total generation.
- Scenario 6 – Non-committed exports: In this case, a reduced firm energy requirement means that less capacity is required compared to the other scenarios. Upper Dabus, Birbir A, Baro & Genji and Karadobi are installed by 2030 along with wind, solar, and GT candidates. Compared to the least-cost case, there is more hydro and solar capacity, and it is the only scenario which does not install GT capacity before 2030. The desired diversity is not achieved as hydro contributes 80% of the total generation.

Table 5-61: Comparison of capacity by 2030

Scenario		Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT	Total
1: Least-cost	Installed Capacity (MW)	13,384	844	1,250	298	25	377	-	-	1,400	17,578
	Firm Capacity (MW)	13,384	217	-	-	25	377	-	-	1,400	15,403
	Firm Energy (MW_{av})	5,675	187	275	155	12	340	-	-	1,260	7,904
2: Reference	Installed Capacity (MW)	12,308	2,429	975	298	25	377	-	-	1,120	17,532
	Firm Capacity (MW)	12,308	693	-	-	25	377	-	-	1,120	14,523
	Firm Energy (MW_{av})	4,934	659	215	155	12	340	-	-	1,008	7,323
3: Additional geothermal	Installed Capacity (MW)	13,384	844	850	298	25	377	-	-	1,400	17,178
	Firm Capacity (MW)	13,384	217	-	-	25	377	-	-	1,400	15,403
	Firm Energy (MW_{av})	5,675	187	187	155	12	340	-	-	1,260	7,816
4: Nuclear	Installed Capacity (MW)	13,481	844	1,050	298	25	377	-	-	1,400	17,475
	Firm Capacity (MW)	13,481	217	-	-	25	377	-	-	1,400	15,500
	Firm Energy (MW_{av})	5,737	187	231	155	12	340	-	-	1,260	7,922
5: Minimum fossil fuel	Installed Capacity (MW)	11,784	2,014	1,750	298	25	377	-	-	1,120	17,368
	Firm Capacity (MW)	11,784	568	-	-	25	377	-	-	1,120	13,874
	Firm Energy (MW_{av})	4,781	538	385	155	12	340	-	-	1,008	7,219
6: Non-committed exports	Installed Capacity (MW)	13,908	844	1,450	298	25	377	-	-	-	16,902
	Firm Capacity (MW)	13,908	217	-	-	25	377	-	-	-	14,527
	Firm Energy (MW_{av})	5,828	187	319	155	12	340	-	-	-	6,841

Figure 5-40: Comparison of capacity by 2030

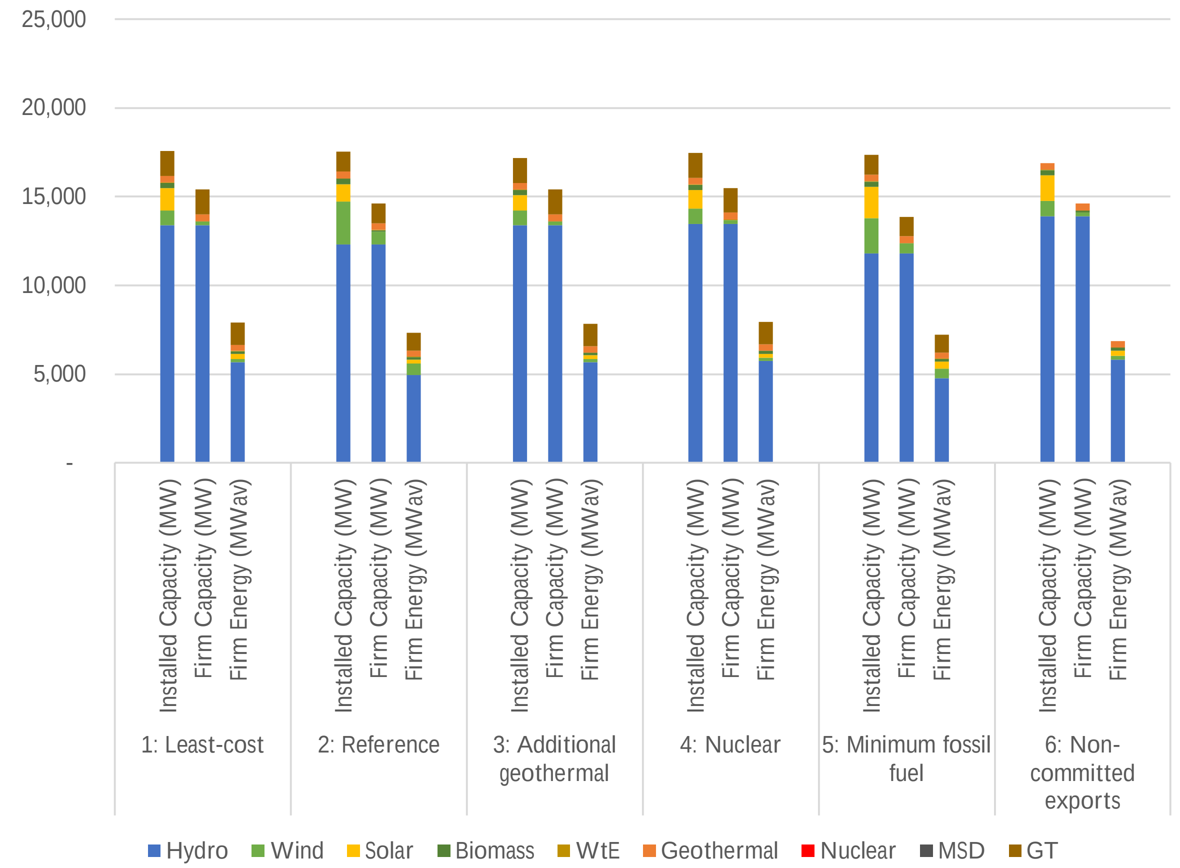
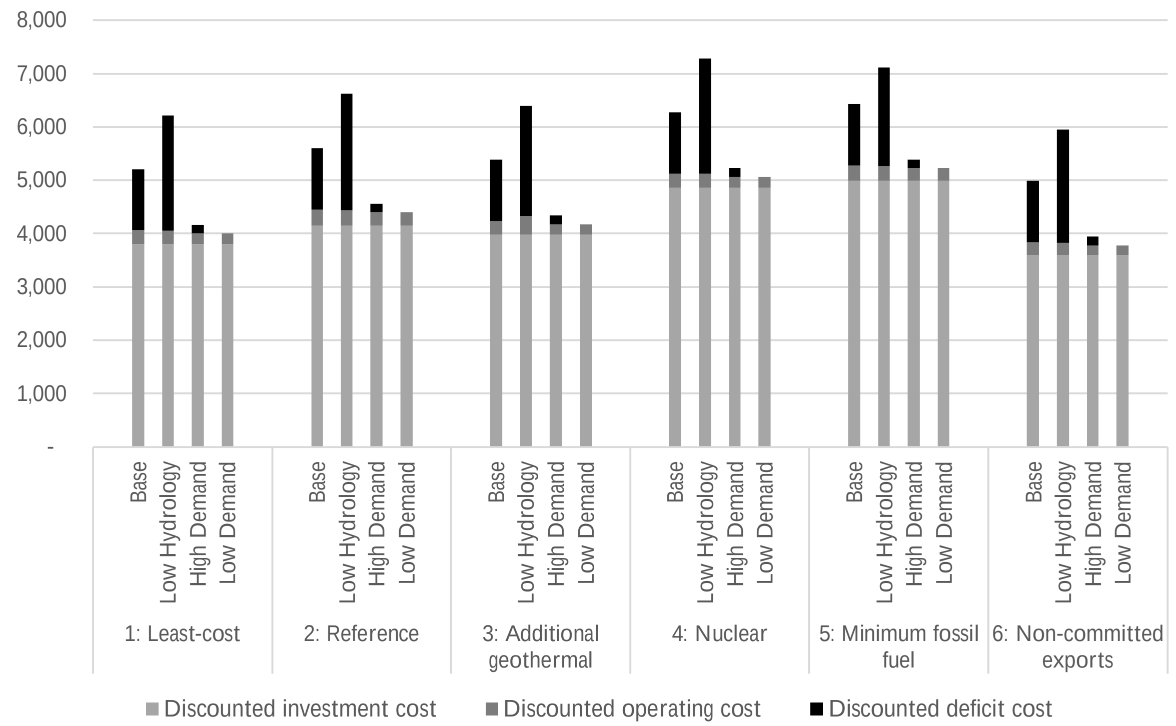


Table 5-62: Comparison of costs by 2030 (USDm)

Scenario	Sensitivity	Investment cost	Discounted investment cost	Discounted operating cost	Discounted deficit cost	Discounted total cost
1: Least-cost	Base	7,527	3,800	260	1,152	5,212
	Low Hydrology		3,800	249	2,166	6,215
	High Demand		3,800	205	162	4,167
	Low Demand		3,800	205	-	4,005
2: Reference	Base	8,237	4,150	308	1,140	5,598
	Low Hydrology		4,150	294	2,181	6,625
	High Demand		4,150	254	162	4,566
	Low Demand		4,150	254	-	4,404
3: Additional geothermal	Base	7,971	3,978	256	1,152	5,386
	Low Hydrology		3,978	350	2,073	6,401
	High Demand		3,978	201	162	4,341
	Low Demand		3,978	201	-	4,179
4: Nuclear	Base	10,077	4,860	258	1,152	6,270
	Low Hydrology		4,860	257	2,167	7,284
	High Demand		4,860	203	162	5,225
	Low Demand		4,860	203	-	5,063
5: Minimum fossil fuel	Base	10,289	4,989	290	1,152	6,431
	Low Hydrology		4,989	278	1,848	7,115
	High Demand		4,989	237	162	5,388
	Low Demand		4,989	237	-	5,226
6: Non-committed exports	Base	7,068	3,591	244	1,156	4,991
	Low Hydrology		3,591	232	2,125	5,948
	High Demand		3,591	191	162	3,944
	Low Demand		3,591	191	-	3,782

Figure 5-41: Comparison of total discounted costs by 2030 (USDm)



5.10.1.3 2045

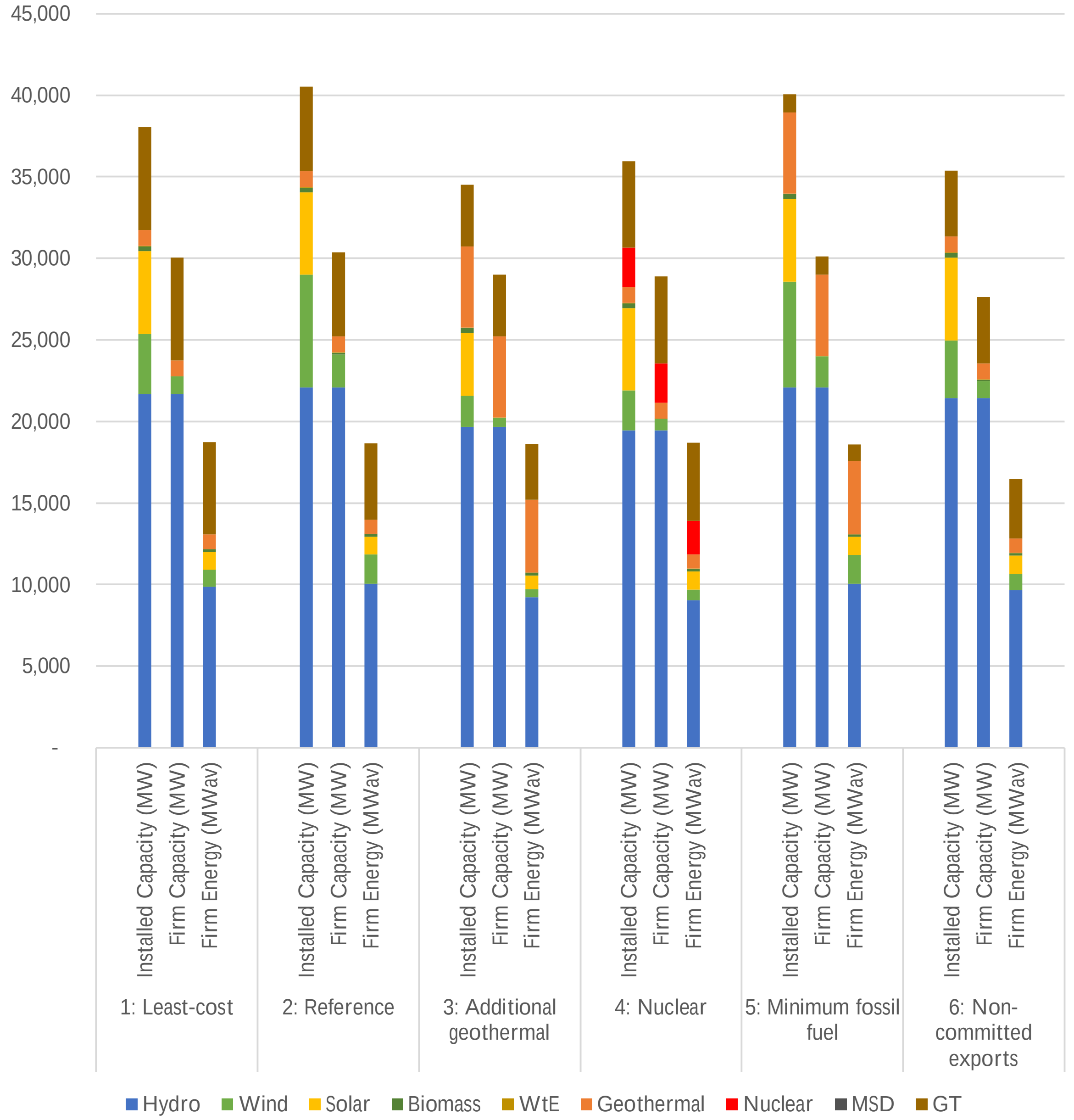
In all scenarios, between 2030 and 2045, the geothermal candidates are selected due to the high price of natural gas. Scenarios 2 & 4 then explore the effect of additional geothermal capacity up to a total of 4,977 MW. All scenarios see the installation of some GTs with the minimum capacity of 1,120 MW in Scenario 5 and the maximum capacity of 6,300 MW in Scenario 1. This GT capacity contributes considerably to the firm energy margin. In each case, 1,120 MW of the total GT capacity is not required to meet peak demand in any year and is installed only to offer offline reserve. The total installed generation capacity, firm capacity, and firm energy by 2045 for the various scenarios are summarized below. The key points are as follows:

- Scenario 1 – Least-cost: Not all of the candidate hydro generation capacity is selected. All the solar candidates are selected to provide low-cost energy, and a relatively high level of gas turbine capacity is selected to provide low-cost peaking capacity.
- Scenario 2 – Reference: All candidate hydro and geothermal generation is pre-selected along with the maximum wind and solar capacity in order to reduce the requirement for fossil fuel generation.
- Scenario 3 – Additional geothermal: 4,600 MW of geothermal capacity is pre-selected (in addition to the committed geothermal projects), resulting in a total installed capacity of around 4,977 MW of geothermal. This geothermal capacity provides a base load that reduces the need for energy generation from other sources. Fewer hydro, solar and wind candidates are installed as a result.
- Scenario 4 – Nuclear: Nuclear capacity is pre-selected, commencing in 2035 up to a total of 2,400 MW by 2038. The total installed capacity of solar is very similar to the reference case; however, the energy provision from nuclear reduces the hydro, GT and wind capacity selected.
- Scenario 5 – Minimum fossil fuel: All candidate hydro generation is pre-selected along with 4,600 MW of geothermal and high amounts of wind and solar capacity in order to minimize the requirement for fossil fuel generation. This scenario is similar to the reference scenario but with increased geothermal capacity which displaces fossil fuel.
- Scenario 6 – Non-committed exports: Less capacity is required compared to the other scenarios due to the lower firm energy requirement. There are reductions in hydro, wind, and GT capacity compared to the least-cost scenario.

Table 5-63: Comparison of capacity by 2045

Scenario		Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT	Total
1: Least-cost	Installed Capacity (MW)	21,683	3,694	5,050	298	25	977	-	-	6,300	38,027
	Firm Capacity (MW)	21,683	1,072	-	-	25	977	-	-	6,300	30,057
	Firm Energy (MW_{av})	9,863	1,042	1,111	155	12	880	-	-	5,670	18,733
2: Reference	Installed Capacity (MW)	22,071	6,929	5,050	298	25	977	-	-	5,180	40,530
	Firm Capacity (MW)	22,071	2,043	-	-	25	977	-	-	5,180	30,296
	Firm Energy (MW_{av})	10,053	1,785	1,111	155	12	880	-	-	4,662	18,658
3: Additional geothermal	Installed Capacity (MW)	19,683	1,894	3,850	298	25	4,977	-	-	3,780	34,507
	Firm Capacity (MW)	19,683	532	-	-	25	4,977	-	-	3,780	28,997
	Firm Energy (MW_{av})	9,223	502	847	155	12	4,480	-	-	3,402	18,621
4: Nuclear	Installed Capacity (MW)	19,458	2,464	5,025	298	25	977	2,400	-	5,320	35,967
	Firm Capacity (MW)	19,458	703	-	-	25	977	2,400	-	5,320	28,883
	Firm Energy (MW_{av})	9,035	673	1,106	155	12	880	2,040	-	4,788	18,689
5: Minimum fossil fuel	Installed Capacity (MW)	22,071	6,514	5,050	298	25	4,977	-	-	1,120	40,055
	Firm Capacity (MW)	22,071	1,918	-	-	25	4,977	-	-	1,120	30,111
	Firm Energy (MW_{av})	10,053	1,762	1,111	155	12	4,480	-	-	1,008	18,581
6: Non-committed exports	Installed Capacity (MW)	21,438	3,544	5,050	298	25	977	-	-	4,060	35,392
	Firm Capacity (MW)	21,438	1,027	-	-	25	977	-	-	4,060	27,527
	Firm Energy (MW_{av})	9,674	997	1,111	155	12	880	-	-	3,654	16,483

Figure 5-42: Comparison of capacity by 2045



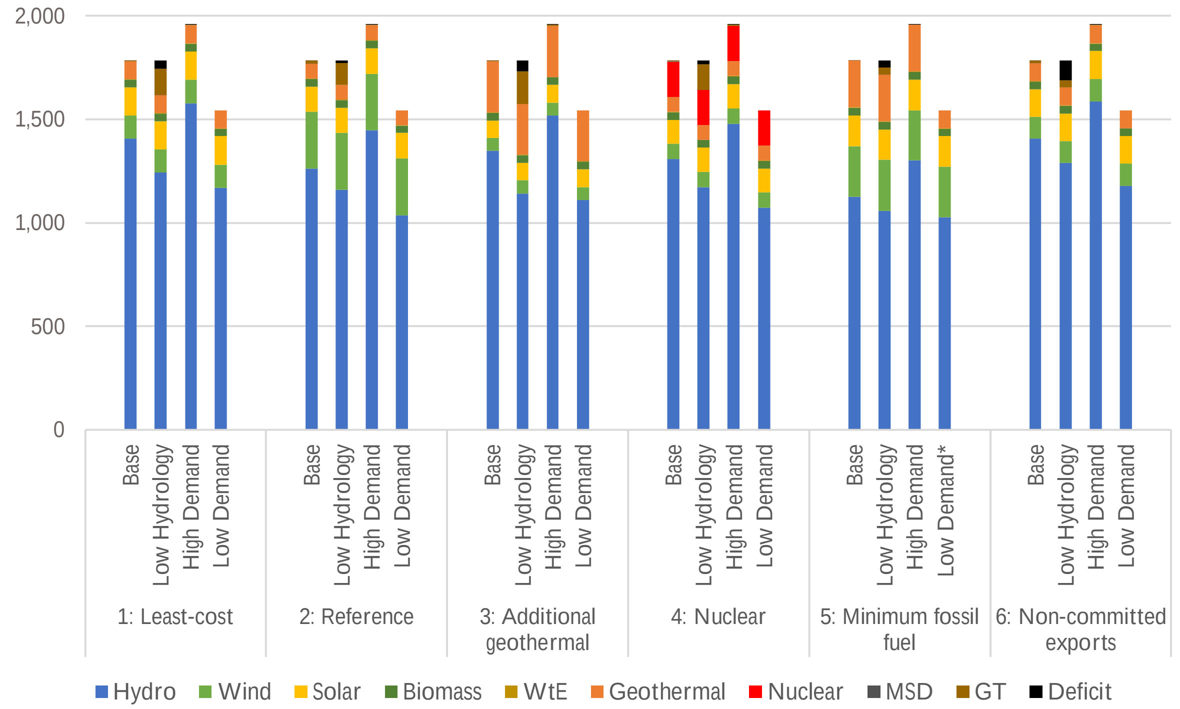
5.10.2 GENERATION

The total generation over the study horizon is presented for all the scenarios and sensitivities below.

Table 5-64: Comparison of total generation, 2020 – 2045 (GWh)

Scenario	Sensitivity	Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT	Deficit	Total
1: Least-cost	Base	1,406,207	111,780	137,778	36,389	2,678	86,583	-	323	1,892	1,554	1,783,630
	Low	1,242,255	111,780	137,778	36,389	2,678	86,583	-	259	127,518	39,944	1,745,240
	High Demand	1,578,631	111,780	137,778	36,389	2,678	86,583	-	-	3,703	219	1,957,542
	Low Demand	1,168,220	111,780	137,778	36,389	2,678	86,583	-	-	-	-	1,543,428
2: Reference	Base	1,262,244	274,093	122,740	36,389	2,678	70,815	-	323	14,369	1,535	1,783,651
	Low	1,160,160	274,093	122,740	36,389	2,678	70,815	-	232	104,317	13,761	1,771,424
	High Demand	1,446,472	274,093	122,740	36,389	2,678	70,815	-	-	4,355	218	1,957,542
	Low Demand	1,036,713	274,093	122,740	36,389	2,678	70,815	-	-	-	-	1,543,428
3: Additional geothermal	Base	1,346,200	63,691	84,852	36,389	2,678	246,628	-	323	2,870	1,555	1,783,631
	Low	1,141,245	63,691	84,852	36,389	2,678	246,628	-	232	156,306	53,164	1,732,021
	High Demand	1,517,620	63,691	84,852	36,389	2,678	246,628	-	-	5,610	292	1,957,468
	Low Demand	1,109,190	63,691	84,852	36,389	2,678	246,628	-	-	-	-	1,543,428
4: Nuclear	Base	1,307,254	74,527	116,307	36,389	2,678	72,392	169,769	323	3,993	1,554	1,785,186
	Low	1,171,330	74,527	116,307	36,389	2,678	72,392	169,769	229	123,411	18,153	1,785,185
	High Demand	1,478,676	74,527	116,307	36,389	2,678	72,392	169,769	-	6,717	307	1,957,762
	Low Demand	1,071,367	74,527	116,307	36,389	2,678	72,392	169,769	-	-	-	1,543,429
5: Minimum fossil fuel	Base	1,125,483	245,026	147,978	36,389	2,678	225,735	-	323	19	1,554	1,783,631
	Low	1,057,886	245,026	147,978	36,378	2,678	225,735	-	241	33,767	35,496	1,749,689
	High Demand	1,299,735	245,026	147,978	36,389	2,678	225,735	-	-	-	219	1,957,541
	Low Demand*	1,025,169	245,026	147,978	36,389	2,678	86,189	-	-	-	-	1,543,429
6: Non-committed exports	Base	1,405,236	106,564	135,012	36,389	2,678	85,006	-	323	12,046	1,932	1,783,254
	Low	1,287,792	106,564	135,012	36,389	2,678	85,006	-	244	36,331	95,169	1,690,016
	High Demand	1,587,582	106,564	135,012	36,389	2,678	85,006	-	-	3,811	719	1,957,042
	Low Demand	1,177,780	106,564	135,012	36,389	2,678	85,006	-	-	-	-	1,543,429

Figure 5-43: Comparison of total generation, 2020 – 2045 (TWh)



*The low demand sensitivity for Scenario 5 was infeasible without curtailing capacity. It was assumed that the additional geothermal plant would not be installed in this case.

The total generation plus the deficit is the same across the scenarios for each demand sensitivity. The variation is in the proportion of the generation provided by each technology type. The most significant hydro generation occurs in Scenario 1 and 6 as both scenarios use the available cheap hydro energy and keep the percentage hydro contribution high until near the end of the study horizon. In contrast, the lowest total hydro generation is in Scenario 5 due to high amounts of wind, solar, and geothermal coming in to displace hydro generation.

The impact of the low hydrology sensitivity is significant with 95,169 GWh of deficit in Scenario 6. Some generation mixes are more flexible than others and can respond in drought conditions. Scenario 2 displayed the smallest deficit under the low hydrology sensitivity, 13,761 GWh, over the whole study horizon. The combination of maximum hydro capacity and associated reservoir storage and backup GT capacity enabled such a relatively low level of unserved energy. The national demand was met at all times, with the shortfall being a reduction in export capacity.

Under the high demand sensitivity, the hydro capacity drew on the storage reservoirs to generate at more than average levels to reduce the deficit in all scenarios. Scenarios 1, 2 and 5 experienced the smallest deficit under the high demand sensitivity due to having a high amount of hydro capacity and associated reservoir storage.

Under the low demand sensitivity, the hydro generation was reduced in all scenarios, and no generation from GTs was required. Scenario 5 was not feasible due to the high geothermal baseload. It was assumed that the additional geothermal capacity in later years would not be installed if the demand was following the low forecast.

5.10.3 EXPANSION PLAN COSTS

The costs of the scenarios under various sensitivities are compared in Table 5-65 and Figure 5-44. The costs shown are as follows:

- Investment cost of candidate projects (undiscounted)
- Investment cost of candidate project expressed as NPV in 2020 USD
- System operating costs expressed as NPV in 2020 USD (including fuel and O&M costs)
- The cost of unserved energy or deficit expressed as NPV in 2020 USD
- Total costs expressed as NPV in 2020 USD

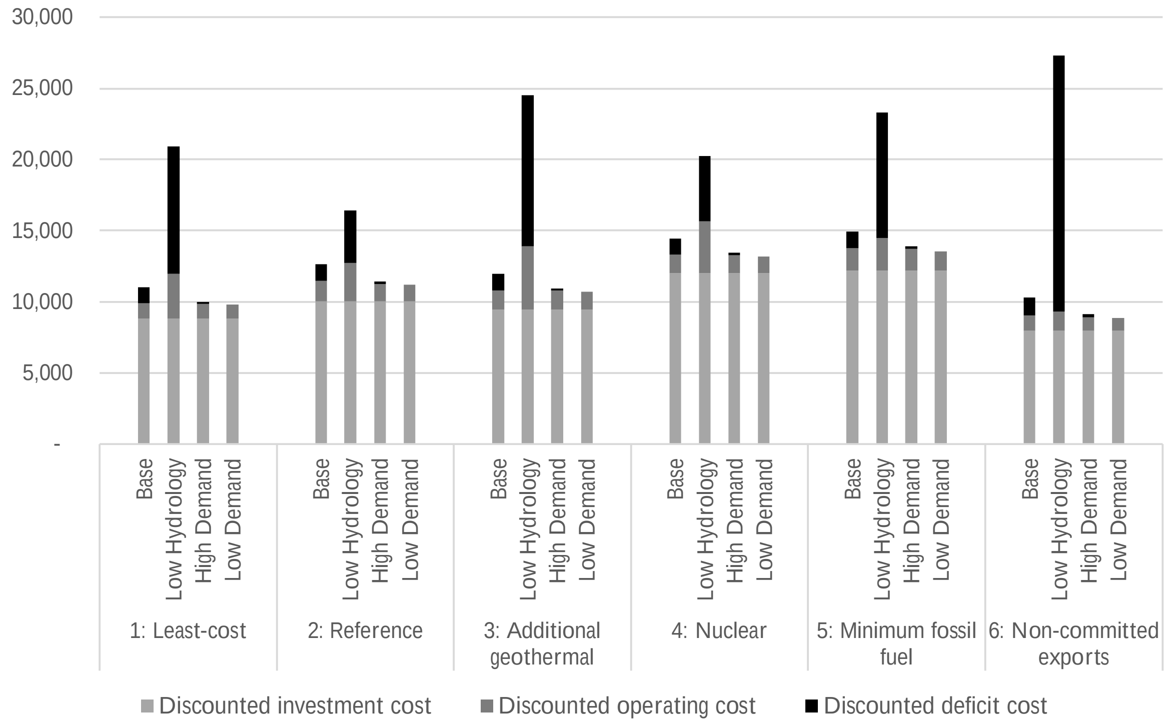
The key observations are as follows:

- There is a wide variation in costs between the various scenarios and sensitivities.
- Some deficit cost for the base sensitivity of all scenarios is unavoidable due to capacity and energy shortages in 2023 before candidate plants can be brought in.
- The deficit cost becomes significant under the low hydrology sensitivity as different capacity plans are able to compensate for drought conditions to varying degrees.
- The lowest investment cost is achieved when exports are considered to be non-committed in Scenario 6 as less firm energy is required and, therefore, less capacity. This scenario also presents the lowest total cost under all sensitivities assuming average hydrology conditions.
- Under low hydrology conditions, all the scenarios are significantly more expensive due to the additional deficit cost. Scenario 6 is the most expensive due to the 95,169 GWh of deficit across the study horizon. Under the low hydrology case for Scenario 5 there was only 35,496 GWh of deficit, however this would have increased to 69,263 GWh without the generation provided by fossil fuels. Without fossil fuels the total discounted (NPV) deficit cost would be 15.9 billion USD.
- Scenario 2 presents the most cost-effective expansion plan under the low hydrology sensitivity. The discounted investment cost is moderate, and the discounted operating and deficit costs are the lowest of all the scenarios under this sensitivity.

Table 5-65: Comparison of costs (USDm)

Scenario	Sensitivity	Investment cost	Discounted investment cost	Discounted operating cost	Discounted deficit cost	Discounted total cost
1: Least-cost	Base	33,611	8,806	1,082	1,152	11,040
	Low Hydrology		8,806	3,144	8,961	20,911
	High Demand		8,806	1,034	162	10,002
	Low Demand		8,806	992	-	9,798
2: Reference	Base	40,233	10,035	1,446	1,140	12,621
	Low Hydrology		10,035	2,710	3,672	16,417
	High Demand		10,035	1,204	162	11,401
	Low Demand		10,035	1,143	-	11,178
3: Additional geothermal	Base	38,603	9,430	1,378	1,152	11,960
	Low Hydrology		9,430	4,456	10,622	24,508
	High Demand		9,430	1,344	169	10,943
	Low Demand		9,430	1,275	-	10,705
4: Nuclear	Base	44,248	12,001	1,296	1,152	14,449
	Low Hydrology		12,001	3,681	4,558	20,240
	High Demand		12,001	1,257	171	13,429
	Low Demand		12,001	1,176	-	13,177
5: Minimum fossil fuel	Base	49,773	12,180	1,585	1,152	14,917
	Low Hydrology		12,180	2,298	8,800	23,278
	High Demand		12,180	1,531	162	13,873
	Low Demand		12,180	1,362	-	13,542
6: Non-committed exports	Base	30,642	7,970	1,056	1,252	10,278
	Low Hydrology		7,970	1,335	18,005	27,310
	High Demand		7,970	926	226	9,122
	Low Demand		7,970	888	-	8,858

Figure 5-44: Comparison of total discounted costs (USDm)



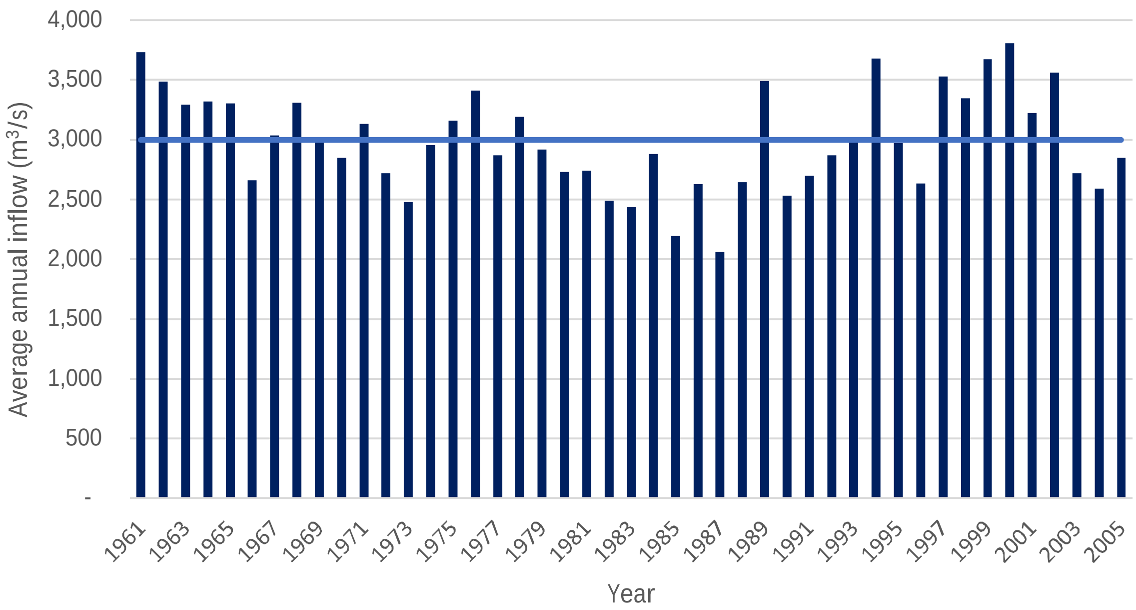
5.11 RECOMMENDED SCENARIO

In summary:

- The least-cost scenario relies on a relatively high level of fossil fuel generation and does not achieve the desired generation diversity.
- The minimum fossil-fuel scenario has the highest cost as it relies on all hydro and geothermal candidates and maximum wind capacity in order to minimize gas turbine capacity.
- The Reference scenario is significantly more expensive than the least-cost scenario; however, it does achieve good diversity and very low levels of energy generated from fossil fuels. Under the low hydrology sensitivity, it becomes the most cost-effective scenario.

The low hydrology sensitivity models the sustained drought that occurred in the 1980s but it can be seen in the figure below that consecutive years of below average rainfall happen at least once every ten years in the historical data. It is therefore reasonable to assume that this trend will continue into the future and hydrological variation may become more difficult to predict in the future due to Climate Change.

Figure 5-45: Hydrological years against average



The following factors were considered in making a recommendation for the expansion plan as follows:

- Overall cost (NPV of capital and operating costs)
- Diversity of generation and resilience under low hydrology conditions
- Minimizing the need for fossil fuel generation to minimize the system's associated emissions and total operating cost.

Based on these factors, Scenario 2 - Reference is recommended. The scenario provides generation diversity and flexible capacity that can operate cost-effectively under low hydrology conditions. The selected candidate plants are listed in Appendix B.

6 OPERATIONAL ASPECTS

6.1 GENERAL

In this section of the report, we consider generation dispatch, integration of variable renewable energy generation and the required level of operating reserves to meet grid code requirements over the planning period.

6.2 GENERATION DISPATCH

6.2.1 MERIT ORDER

The current mix of generation includes hydro, wind and WtE, with hydro providing at least 95% of generated energy. While there is a thermal power plant at Dire Dawa comprising diesel generators, these are currently maintained standby units and not generally dispatched.

Most power systems do rely to some extent on fossil-fuel based generation, and dispatch is then based on minimizing fuel costs. The mix of generation on the EEP system does not currently include fossil-fuel based plants which leads to a merit order determined by factors other than fuel cost minimization as described below.

Wind (and solar) generation is variable depending on the instantaneous availability of the energy source. While it is possible to adjust the output of these plants based on system requirements, for economic reasons, these plants are not generally dispatched or limited by the System Operator.

The primary purpose of WtE plants is waste processing, with electricity provided as a by-product. The output of these plants would, therefore, generally be determined by the waste processing requirements rather than electricity requirements.

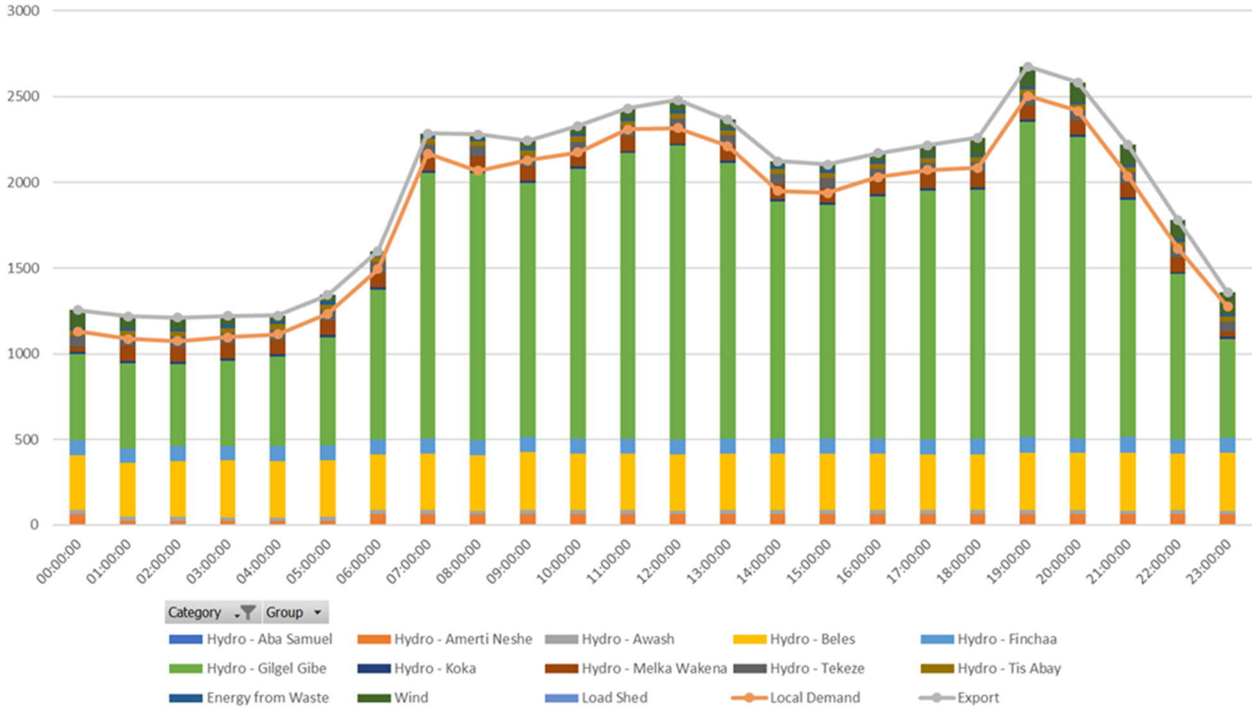
The hydro plants would, however, be dispatched by the system operator to meet the varying electricity demand while complying with the various constraints of the system. The large storage capacity of reservoirs associated with most of the hydro plants allows a high level of flexibility to provide load-following capability. In Figure 6-1, it can be seen that the output of Gibe III hydropower plant was regulated throughout the day to match the demand profile.

The hydropower plants are dispatched to minimize spill and water usage. The run-of-river plants would therefore be dispatched first as they do not include storage. The system operator will take account of daily reservoir levels to produce the dispatch schedule for the week ahead, maximizing dispatch from plants whose reservoir levels are highest in order to minimize spill. The system operator will also try to minimize water usage while meeting the demand. This is achieved by dispatching based on head or production coefficient ($MW/m^3/s$), i.e., those hydro plants with the highest production coefficient would be dispatched first as this would minimize water usage. In addition to prioritizing the hydro plants with the highest available production coefficients, those plants at reservoirs that have historically spilled due to excess water in the rainy season are dispatched as much as possible to avoid greater than necessary spilling. In particular, Koka, Beles, Tekeze, Gibe I and sometimes also Fincha are expected to spill.

In order for the hydropower plants to operate in this way, it is, however, necessary that they have both sufficient capacity and stored energy. During periods of low reservoir levels, the production coefficient of hydro plants will be reduced, which means that they will produce less output power for the same turbined flow. Once the hydro reservoirs are depleted to their minimum storage levels, the output is limited to the inflow x the minimum production coefficient.

Several of the power plants have minimum water release constraints to meet the requirements of downstream irrigation schemes or sugar plantations. Individual turbines also have minimum stable generation levels to avoid cavitation.

Figure 6-1: Daily generation profile – 24th December 2019 (MW)



As shown in Figure 6-1, Gibe III currently supplies a high proportion of the demand. Therefore, it is important to ensure that the system can handle an event such as a Gibe III generating unit outage or transmission line outage without a major impact on the output of Gibe III. Gibe III is therefore normally operated within the N-1 capacity of the transmission lines connecting it to the rest of the grid.

As other hydro plants with large storage reservoirs, including GERD and Koysha, enter service, the system will become less reliant on Gibe III. The new plants will include AGC and, therefore, allow improved load following and facilitate the integration of higher levels of variable wind and solar.

6.2.2 INTEGRATION OF WIND AND SOLAR GENERATION

Conventional generators require advance notice for commitment and dispatch to reach specified generation levels. Scheduling and load following processes need to use wind and solar power production forecasts, in addition to the short-term load forecast, to determine reserve requirements needed to achieve future system balance. Uncertainties in forecasting the output of intermittent resources and the variability of system load are not reflected in the existing analysis and tools used for generation commitment and dispatch in Ethiopia.

Generation from wind and solar plants is intermittent, depending on the variations in wind speed and solar radiation. As a result, the integration of wind and solar plants requires that other generators in the system operate differently. Additional reserve requirements will vary by year and system generation resources and will also depend on the specific generation units that operate in any given hour. The impact will vary depending on the season, day, and hour. Adding wind and solar will also require increased reserve levels and committed capacity during some periods.

The proportion of wind and solar generation is increasing rapidly on power systems in many countries around the world. This is introducing challenges for system operators due to the variable nature of wind and solar generation. In particular, system operators are finding that their fleets of conventional generation do not have the flexibility to cope with large amounts of variable generation. In many countries, these challenges are being addressed by introducing storage, including battery energy storage systems and pumped hydro storage. These measures are, however, expensive and inefficient, i.e., typically, 10-20% of the stored energy is lost. Alternatively, system operators are curtailing wind and solar generation at certain times (particularly during low load conditions) to ensure that there is sufficient conventional generation to provide stable network conditions. Curtailment results in increased operating costs as the curtailed wind and solar energy would normally be replaced with thermal generation.

The challenges associated with the integration of wind and solar PV generation increase with the level of penetration. On most systems, penetration levels of wind and solar PV above 20% of annual generation could result in the need for curtailment at certain times or the introduction of storage systems.

Hydropower reservoirs have large storage capacity, which means that hydropower-dominated systems are inherently more flexible and therefore able to adjust output on an hourly basis to accommodate the variable output of wind and solar. The Ethiopian system is therefore well placed to effectively integrate relatively high levels of wind and solar.

For Scenario 2: Reference, the combined output of wind and solar achieves a penetration level of 18% by 2030, and 24% of total generated energy by 2045. Due to the prevalence of hydro generation with large storage reservoirs and based on experience on other systems, these modest penetration levels would not be expected to result in operational issues.

6.3 OPERATING RESERVES

6.3.1 PLANNING VS. OPERATING RESERVES

The generation expansion plan developed in the previous section considered the need for planning reserve to allow for plant outages and low hydrological conditions. Planning reserve is provided through investment in additional capacity. The provision of planning reserves would generally also result in sufficient capacity to enable the system to be operated with sufficient operating reserves.

Operating reserves are the additional output from generating units or a reduction in demand, which is realizable in real-time operation to contain and correct any frequency deviation on the system. Operating reserves have three components, which are realizable in the following distinct timescales as defined in the Ethiopian National Electricity Transmission Grid Code (ENTGC).

6.3.2 PRIMARY RESERVE

Primary reserve provides automatic response by synchronized generating units to a rise or fall in the frequency of the system requiring changes in the generating unit's active power output, to restore the frequency to within operational limits. According to the ENTGC, the response to a change in system frequency shall be fully available within ten seconds of the frequency change and be sustainable for a further twenty seconds.

The ENTGC states that the amount of Primary Reserve should equal the capacity of the largest generating unit connected to the system. The largest units are currently the 187 MW Gibe III units; however, the reserve requirement will increase to 375MW in 2021 as two of the GERD units enter service on reduced head; and 400 MW by 2024 as the GERD reservoir fills and the units reach full capacity.

The demand can also participate in primary response through the self-regulating effect of frequency-sensitive loads such as induction motors or the action of under frequency relays that disconnect some demand at given frequency thresholds.

6.3.3 SECONDARY RESERVES

Secondary reserve is usually provided as a centralized automatic control that adjusts the active power production of generating units to restore the frequency and the interchanges with other control areas and with external systems to their target values following a frequency deviation. Primary reserve limits and arrests frequency deviations while secondary reserve restores the frequency to its target value.

According to the ENTGC, secondary reserve provides the automatic response to a frequency change which should be fully available by thirty (30) seconds from the time of frequency change to take over from primary reserve and sustainable for a period of at least thirty (30) minutes. Secondary reserve is provided by generating units already synchronized to the grid and is normally controlled by the system operator through automatic generation control (AGC) where available.

Regulation or secondary reserves are calculated from both load variability and the variability of intermittent resources. It is the variability in net load (load minus intermittent resources) for which regulating reserves are carried.

A recent report[5] calculated the 15-minute variability of the EEP load (1,800 MW peak in 2016) with a standard deviation of 1.7% of peak load. As load grows, the variability is expected to reduce, reflecting the characteristics of a larger, more diverse load base. Based on other larger systems, the GMSP report estimated that the standard deviation would reduce to 1% for a 5,000 MW peak load and 0.7% for a 10,000 MW peak load.

Regulation requirements are generally set to cover 3 x standard deviation (as this covers 99.7% of all changes in load). Based on this, we have estimated a load regulation requirement of 4.5% of peak demand in 2020, reducing to 3% when the peak demand reaches 5,000 MW and 2.1% for peak demand ≥10,000 MW.

In addition to load variability, it is also necessary to take account of the regulation requirements to cater for the variability of wind and solar generation. For systems with modest intermittent generation penetration levels, between 10-15%, the additional requirements tend to be modest. Typically, an additional 2-5 MW of regulation is needed for each 100 MW of added intermittent capacity. Requirements for larger systems also tend to be modest because of the geographic diversity of the intermittent generation and the fact that the combined variability of load and generation tend to offset the variability of the intermittent resources.

The following formula is used to calculate the combined variability of load, wind, and solar. This formula assumes that load variability and intermittent resource variability are not correlated so that no covariance terms are required. Regulation requirements (in MW) are calculated as:

[5] Ethiopia GMSP – System Integration Study

Regulation Requirement $= k\sqrt{\sigma^2_{load} + \sigma^2_{wind} + \sigma^2_{solar}}$

Where:

k Number of standard deviations of coverage, typically set to 3, covering 99.7% of all 10-minute changes.

σ Standard deviation (in MW) of 10-minute changes in load, wind, and solar

6.3.4 SPINNING RESERVE

Based on the ENTGC requirements described above, both primary and secondary reserve would be synchronized, i.e. spinning reserve:

Spinning Reserve = Primary Reserve + Secondary (regulating) Reserve.

Governor response of the hydropower units would provide the primary reserve, e.g. following a unit trip, while AGC of the hydropower plants would provide secondary reserve for regulation of system frequency in response to changes in load. If the machines do not have this capability, or if existing communications systems cannot ensure sufficient, timely response, the capability to provide reserve capacity in itself is not sufficient to ensure system reliability.

EEP currently aims to operate the system with sufficient spinning reserve to cover the outage of the largest unit only (187 MW). Most of this spinning reserve is currently provided by Gibe III.

Only Beles is equipped with automatic generation control (AGC); however, Gibe III is currently also being equipped with AGC. AGC allows automatic adjustment of the generation in response to changes in load, thereby regulating system frequency and managing interchanges with neighbors. The remaining plants are not equipped with AGC, so all dispatch and adjustments to aid the grid are manual.

Based on the peak demand over the planning period and the installed capacity of wind and solar generation determined in Scenario 2, the required level of regulating (secondary) reserve is indicated in Table 6-1. For full compliance with the ENTGC, the regulating reserve is required in addition to the primary reserve, where the primary reserve is intended to cover the loss of the largest generating unit. Table 6-1 shows the regulating and total spinning reserve requirements over the planning period.

6.3.5 TERTIARY RESERVE

Tertiary reserve refers to system operator instructed changes in the dispatch and commitment of generating units. Tertiary reserve is used to restore primary and secondary reserves, manage constraints on the system, and bring the frequency and the interchanges back to their target values when the secondary reserve has been depleted.

According to the ENTGC, where tertiary reserve is held on generating units not synchronized to the system, the units shall be capable of being synchronized within a specified time, generally between fifteen minutes and one hour. Non-synchronized tertiary reserve could consist of, for example, fast start hydro, gas turbine, and steam turbine generating plants on hot-standby.

Table 6-1: Spinning reserve requirements

Year	Peak demand (MW)	Wind (MW)	Solar (MW)	Load std. dev. (%)	Wind std. dev. (%)	Solar std. dev. (%)	Load regulation (MW)	Total regulation (MW)	Largest generating unit (MW)	Spinning reserve requirement (MW)
2020	2,634	324		1.5%	0.035	0.035	119	123	187	310
2021	3,222	324		1.4%	0.035	0.035	135	140	240	380
2022	4,072	444		1.3%	0.035	0.035	159	166	300	466
2023	4,946	544	250	1.0%	0.035	0.035	148	161	345	506
2024	5,545	844	550	1.0%	0.035	0.035	166	197	400	597
2025	6,197	844	550	1.0%	0.035	0.035	186	214	400	614
2026	7,139	1,109	550	0.9%	0.035	0.035	193	232	400	632
2027	7,629	1,409	550	0.9%	0.035	0.035	206	260	400	660
2028	8,170	1,709	550	0.8%	0.035	0.035	196	272	400	672
2029	9,188	2,009	800	0.8%	0.035	0.035	221	317	400	717
2030	9,577	2,309	800	0.7%	0.035	0.035	201	326	400	726
2031	11,646	2,609	1,075	0.7%	0.035	0.035	245	384	400	784
2032	12,239	2,909	1,225	0.7%	0.035	0.035	257	419	400	819
2033	12,865	3,209	1,525	0.7%	0.035	0.035	270	461	400	861
2034	13,522	3,509	1,825	0.7%	0.035	0.035	284	503	400	903
2035	14,214	3,809	2,125	0.7%	0.035	0.035	298	547	400	947
2036	14,957	4,109	2,425	0.7%	0.035	0.035	314	591	400	991
2037	15,746	4,409	2,725	0.7%	0.035	0.035	331	637	400	1,037
2038	16,589	4,709	3,025	0.7%	0.035	0.035	348	683	400	1,083
2039	17,490	5,009	3,325	0.7%	0.035	0.035	367	730	400	1,130
2040	18,484	5,309	3,625	0.7%	0.035	0.035	388	779	400	1,179
2041	19,571	5,609	3,925	0.7%	0.035	0.035	411	828	400	1,228
2042	20,749	5,909	4,225	0.7%	0.035	0.035	436	878	400	1,278
2043	22,013	6,209	4,450	0.7%	0.035	0.035	462	926	400	1,326
2044	23,371	6,509	4,750	0.7%	0.035	0.035	491	978	400	1,378
2045	24,804	6,809	5,050	0.7%	0.035	0.035	521	1,031	400	1,431

6.3.6 SYSTEM ADEQUACY

The expansion plan allows for a 20% planning margin, both in terms of capacity and energy; however, in the short term (up to 2023), this is not achievable as already described.

In terms of MW capacity, the planning margin only considers firm sources, i.e., hydro, geothermal, and thermal generation. As shown in Table 6-2, provided sufficient firm generation capacity is installed to achieve the 20% planning margin and the generating plants are well maintained, there should be sufficient spare firm capacity to provide the spinning reserve requirements over the planning period.

Table 6-2: System adequacy

Year	Peak demand (MW)	Planning margin (MW)	Spinning reserve requirement (MW)
2024	5,545	1,109	597
2030	9,577	1,915	744
2045	24,804	4,961	1,447

7 CONCLUSIONS

7.1 GENERAL

This report describes the data, assumptions, methodology and results of the generation planning aspect of the Ethiopian Power System Expansion Masterplan Study. The analysis was based on detailed modelling of the Ethiopian power system including reservoir simulation and least-cost expansion planning using SDDP-OPTGEN software.

7.2 KEY RESULTS

The simulations indicate that there could be a shortage of firm capacity by 2023 if the peak demand grows in line with the Base Case demand forecast. The earliest assumed date by which new capacity can be built is 2024. Therefore, any short-term shortages will need to be managed operationally (through load shedding) or contractually (in the case of exports). It was assumed that the existing hydro plants with reduced available capacity would be restored to full installed capacity by 2026 through the implementation of the required rehabilitation projects. The shortage in firm capacity will be alleviated by 2024 due to a major increase in the capacity of GERD by this date.

The total installed generation capacity, firm capacity, and firm energy by 2045 for the various scenarios are summarized below.

Table 7-1: Summary of generation capacity by 2045

Scenario		Hydro	Wind	Solar	Biomass	WtE	Geothermal	Nuclear	MSD	GT	Total
1: Least-cost	Installed Capacity (MW)	21,683	3,694	5,050	298	25	977	-	-	6,300	38,027
	Firm Capacity (MW)	21,683	1,072	-	-	25	977	-	-	6,300	30,057
	Firm Energy (MW_{av})	9,863	1,042	1,111	155	12	880	-	-	5,670	18,733
2: Reference	Installed Capacity (MW)	22,071	6,929	5,050	298	25	977	-	-	5,180	40,530
	Firm Capacity (MW)	22,071	2,043	-	-	25	977	-	-	5,180	30,296
	Firm Energy (MW_{av})	10,053	1,785	1,111	155	12	880	-	-	4,662	18,658
3: Additional geothermal	Installed Capacity (MW)	19,683	1,894	3,850	298	25	4,977	-	-	3,780	34,507
	Firm Capacity (MW)	19,683	532	-	-	25	4,977	-	-	3,780	28,997
	Firm Energy (MW_{av})	9,223	502	847	155	12	4,480	-	-	3,402	18,621
4: Nuclear	Installed Capacity (MW)	19,458	2,464	5,025	298	25	977	2,400	-	5,320	35,967
	Firm Capacity (MW)	19,458	703	-	-	25	977	2,400	-	5,320	28,883
	Firm Energy (MW_{av})	9,035	673	1,106	155	12	880	2,040	-	4,788	18,689
5: Minimum fossil fuel	Installed Capacity (MW)	22,071	6,514	5,050	298	25	4,977	-	-	1,120	40,055
	Firm Capacity (MW)	22,071	1,918	-	-	25	4,977	-	-	1,120	30,111
	Firm Energy (MW_{av})	10,053	1,762	1,111	155	12	4,480	-	-	1,008	18,581
6: Non-committed exports	Installed Capacity (MW)	21,438	3,544	5,050	298	25	977	-	-	4,060	35,392
	Firm Capacity (MW)	21,438	1,027	-	-	25	977	-	-	4,060	27,527
	Firm Energy (MW_{av})	9,674	997	1,111	155	12	880	-	-	3,654	16,483

The costs of the scenarios are compared below. The costs shown are as follows:

- Investment cost of candidate projects (undiscounted)
- Investment cost of candidate project expressed as NPV in 2020 USD
- System operating costs expressed as NPV in 2020 USD (including fuel and O&M costs)
- The cost of unserved energy or deficit expressed as NPV in 2020 USD
- Total costs expressed as NPV in 2020 USD

Table 7-2: Scenario costs (USDm)

Scenario	Sensitivity	Investment cost	Discounted investment cost	Discounted operating cost	Discounted deficit cost	Discounted total cost
1: Least-cost	Base	33,611	8,806	1,082	1,152	11,040
	Low Hydrology		8,806	3,144	8,961	20,911
	High Demand		8,806	1,034	162	10,002
	Low Demand		8,806	992	-	9,798
2: Reference	Base	40,233	10,035	1,446	1,140	12,621
	Low Hydrology		10,035	2,710	3,672	16,417
	High Demand		10,035	1,204	162	11,401
	Low Demand		10,035	1,143	-	11,178
3: Additional geothermal	Base	38,603	9,430	1,378	1,152	11,960
	Low Hydrology		9,430	4,456	10,622	24,508
	High Demand		9,430	1,344	169	10,943
	Low Demand		9,430	1,275	-	10,705
4: Nuclear	Base	44,248	12,001	1,296	1,152	14,449
	Low Hydrology		12,001	3,681	4,558	20,240
	High Demand		12,001	1,257	171	13,429
	Low Demand		12,001	1,176	-	13,177
5: Minimum fossil fuel	Base	49,773	12,180	1,585	1,152	14,917
	Low Hydrology		12,180	2,298	8,800	23,278
	High Demand		12,180	1,531	162	13,873
	Low Demand		12,180	1,362	-	13,542
6: Non-committed exports	Base	30,642	7,970	1,056	1,252	10,278
	Low Hydrology		7,970	1,335	18,005	27,310
	High Demand		7,970	926	226	9,122
	Low Demand		7,970	888	-	8,858

The key observations are as follows:

- There is a wide variation in costs between the various scenarios and sensitivities.
- Some deficit cost for the base sensitivity of all scenarios is unavoidable due to capacity and energy shortages in 2023 before candidate plants can be brought in.
- The deficit cost becomes significant under the low hydrology sensitivity as different capacity plans are able to compensate for drought conditions to varying degrees.
- The lowest investment cost is achieved when exports are considered to be non-committed in Scenario 6 as less firm energy is required and, therefore, less capacity. This scenario also presents the lowest total cost under all sensitivities assuming average hydrology conditions.
- Under low hydrology conditions, all the scenarios are significantly more expensive due to the additional deficit cost. Scenario 6 is the most expensive due to the 95,169 GWh of deficit across the study horizon. Under the low hydrology case for Scenario 5 there was only 35,496 GWh of deficit, however this would have increased to 69,263 GWh without the generation provided by fossil fuels. Without fossil fuels the total discounted (NPV) deficit cost would be 15.9 billion USD.
- Scenario 2 presents the most cost-effective expansion plan under the low hydrology sensitivity. The discounted investment cost is moderate, and the discounted operating and deficit costs are the lowest of all the scenarios under this sensitivity.

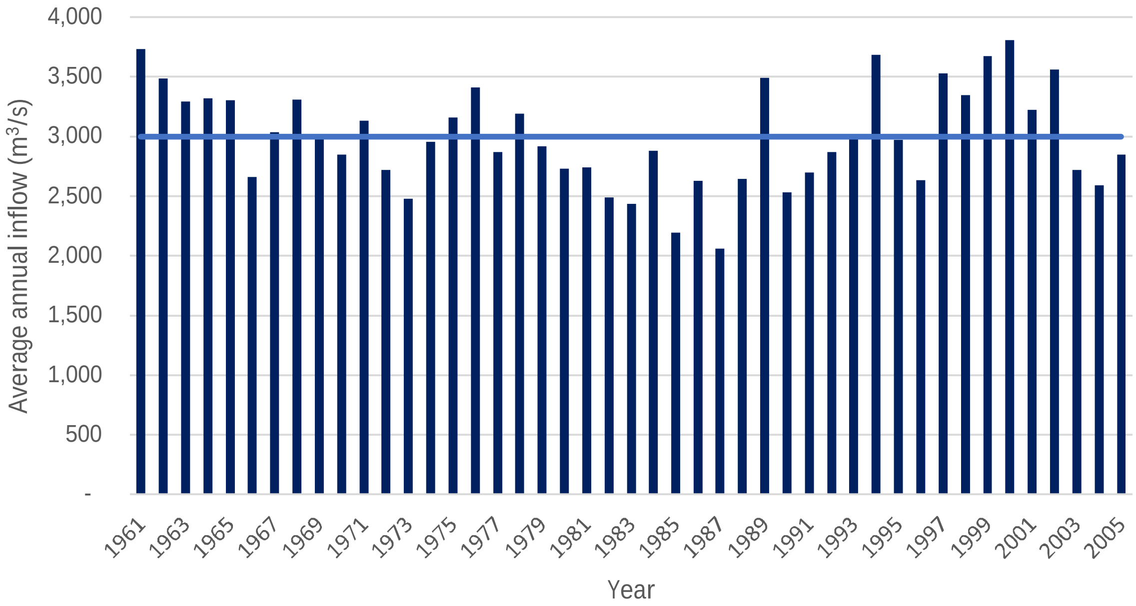
7.3 RECOMMENDED SCENARIO

In summary:

- The least-cost scenario relies on a relatively high level of fossil fuel generation and does not achieve the desired generation diversity.
- The minimum fossil-fuel scenario has the highest cost as it relies on all hydro and geothermal candidates and maximum wind capacity in order to minimize gas turbine capacity.
- The Reference scenario is significantly more expensive than the least-cost scenario; however, it does achieve good diversity and very low levels of energy generated from fossil fuels. Under the low hydrology sensitivity, it becomes the most cost-effective scenario.

The low hydrology sensitivity models the sustained drought that occurred in the 1980s but it can be seen in the figure below that consecutive years of below average rainfall happen at least once every ten years in the historical data. It is therefore reasonable to assume that this trend will continue into the future and hydrological variation may become more difficult to predict in the future due to Climate Change.

Figure 7-1: Hydrological years against average



The following factors were considered in making a recommendation for the expansion plan as follows:

- Overall cost (NPV of capital and operating costs)
- Diversity of generation and resilience under low hydrology conditions
- Minimizing the need for fossil fuel generation to minimize the system's associated emissions and total operating cost.

Based on these factors, Scenario 2 - Reference is recommended. The scenario provides generation diversity and flexible capacity that can operate cost-effectively under low hydrology conditions. The selected candidate plants are listed in Appendix B.

APPENDIX A – HYDROLOGICAL DATA

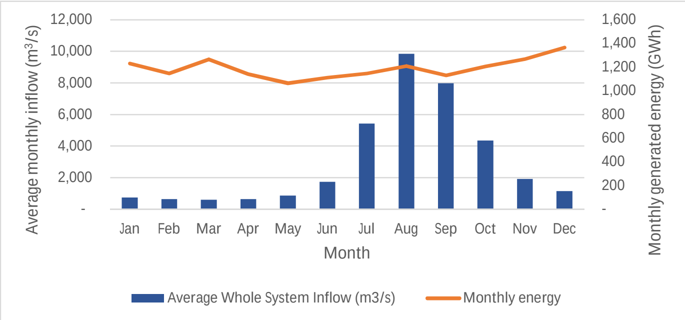
Summary

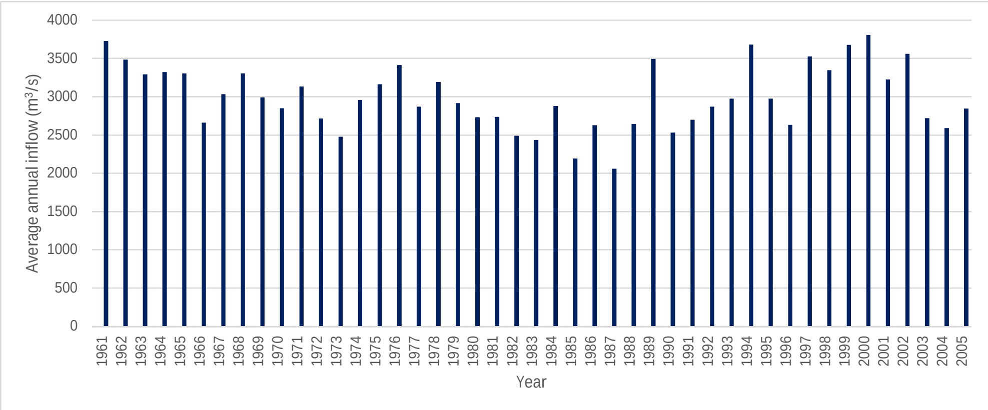
Average annual inflow for the whole system

Year	Average Whole System Inflow (m3/s)
1961	3,729
1962	3,486
1963	3,291
1964	3,322
1965	3,305
1966	2,662
1967	3,035
1968	3,307
1969	2,991
1970	2,848
1971	3,135
1972	2,718
1973	2,477
1974	2,958
1975	3,161
1976	3,413
1977	2,871
1978	3,193
1979	2,918
1980	2,732
1981	2,738
1982	2,491
1983	2,433
1984	2,879
1985	2,193
1986	2,627
1987	2,059
1988	2,643
1989	3,492
1990	2,530
1991	2,697
1992	2,871
1993	2,974
1994	3,680
1995	2,973
1996	2,633
1997	3,528
1998	3,345
1999	3,675
2000	3,806
2001	3,224
2002	3,560
2003	2,719
2004	2,591
2005	2,847

Average monthly inflow for the whole system

Month	Month Name	Average Whole System Inflow (m3/s)	Monthly energy	Column1
1	Jan	745	1,231	1231118
2	Feb	638	1,149	1149113
3	Mar	598	1,267	1266511
4	Apr	649	1,144	1143876
5	May	869	1,065	1064885
6	Jun	1,734	1,113	1113234
7	Jul	5,432	1,149	1149405
8	Aug	9,851	1,211	1211480
9	Sep	7,988	1,131	1131281
10	Oct	4,354	1,207	1207468
11	Nov	1,923	1,270	1270258
12	Dec	1,156	1,367	1367049





m^3/s

Finchaa RES	1											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	4.032	2.852	2.24	2.199	1.904	2.16	14.561	28.674	46.451	45.027	25.926	9.185
1962	4.032	2.852	2.24	2.199	1.904	2.16	14.561	28.674	46.451	45.027	25.926	9.185
1963	4.219	2.646	2.315	1.852	1.643	1.929	14.225	30.018	41.551	44.131	21.026	6.608
1964	3.659	2.935	2.203	2.199	2.165	2.739	9.371	32.818	40.702	28.487	10.108	5.19
1965	3.547	2.594	1.979	1.235	1.792	2.508	9.259	34.536	46.296	41.517	22.531	7.579
1966	3.584	2.48	1.979	1.659	1.605	1.698	7.915	37.896	41.242	30.914	18.441	8.886
1967	5.04	3.679	3.099	2.816	1.979	2.083	5.974	21.879	38.349	30.279	17.438	9.035
1968	3.734	2.439	1.867	1.736	1.568	2.045	10.379	25.015	44.637	42.077	26.505	15.121
1969	5.638	3.712	2.165	1.62	1.419	1.968	7.878	17.324	27.469	22.551	13.04	6.198
1970	5.414	4.423	2.726	2.276	2.128	3.279	11.387	42.824	53.742	36.253	20.139	6.459
1971	3.696	2.77	2.24	1.929	1.568	1.813	7.094	28.338	40.316	31.213	15.818	6.123
1972	3.472	2.48	1.904	1.543	1.456	2.315	12.47	35.469	40.895	33.005	17.323	7.467
1973	4.219	2.874	2.053	1.62	1.605	1.929	8.102	27.852	35.224	27.554	14.352	5.824
1974	3.472	0.744	1.269	3.164	3.958	5.517	19.676	44.952	44.213	28.711	18.133	7.616
1975	3.248	2.687	2.016	3.202	4.368	5.131	23.522	51.859	56.867	24.194	13.58	7.542
1976	2.277	0.455	0.896	0.965	3.136	1.157	11.014	36.216	45.91	37.56	25.309	12.209
1977	1.568	2.115	1.792	2.662	3.248	6.289	12.806	33.714	35.88	21.617	17.477	12.918
1978	6.608	2.604	2.24	2.16	4.144	15.355	24.119	30.765	33.951	30.989	15.239	6.795
1979	3.398	2.025	1.12	2.546	2.763	9.954	27.852	33.639	35.147	24.716	13.233	10.417
1980	3.92	0.537	0.709	0.617	0.859	4.437	18.108	36.104	31.443	18.257	13.194	8.177
1981	4.182	2.235	0.672	3.434	6.422	7.677	24.866	42.376	31.366	25.239	16.088	8.363
1982	0.821	1.736	1.904	1.389	0.747	2.16	15.27	39.352	37.269	12.843	12.616	7.43
1983	1.904	1.653	0.672	2.238	1.755	4.861	16.913	32.146	34.877	20.049	13.889	4.928
1984	6.422	4.712	0.411	0.733	0.971	3.125	9.595	34.2	35.802	14.897	8.179	4.331
1985	2.987	1.836	1.755	3.318	3.696	5.363	17.212	40.099	57.677	14.449	12.654	7.766
1986	2.464	0.703	0.523	2.045	2.576	5.247	13.852	47.23	47.029	29.943	23.302	8.998
1987	2.427	1.405	2.352	2.778	1.979	3.279	18.929	43.085	38.194	20.609	9.375	5.675
1988	3.547	1.529	2.203	2.122	3.584	13.773	28.973	40.621	41.127	23.858	14.39	5.451
1989	2.464	1.237	0.933	1.35	1.68	5.401	7.953	55.854	51.427	32.183	10.069	5.152
1990	3.547	1.405	1.269	0.81	0.635	2.701	13.292	52.681	50.502	36.626	18.21	12.097
1991	2.501	1.777	1.307	0.772	1.083	10.764	21.393	48.798	26.89	18.182	14.043	6.235
1992	3.51	2.191	1.643	1.929	2.24	4.514	14.412	35.917	40.008	27.554	15.972	7.654
1993	3.622	2.195	1.68	1.968	2.277	4.63	14.822	36.962	41.165	28.3	16.435	7.878
1994	4.48	2.811	2.128	2.469	2.838	5.748	18.444	45.96	51.235	35.245	20.448	9.782
1995	3.696	2.315	1.755	2.006	2.352	4.745	15.233	37.933	42.245	29.085	16.86	8.102
1996	3.024	1.901	1.419	1.659	1.904	3.897	12.433	30.989	34.529	23.746	13.773	6.608
1997	3.584	2.195	1.68	1.968	2.277	4.591	14.748	36.738	40.934	28.151	16.319	7.841
1998	3.435	2.149	1.605	1.89	2.165	4.437	14.15	35.245	39.275	27.031	15.664	7.504
1999	6.465	6.817	6.096	6.192	6.45	7.52	18.706	34.219	31.759	29.723	11.599	7.053
2000	6.66	6.84	6.001	6.176	6.761	11.205	30.478	58.011	63.07	55.589	9.735	7.073
2001	6.568	6.678	6.101	6.45	6.518	7.362	14.9	24.31	31.343	23.496	10.964	8.572
2002	6.605	6.894	6.153	6.382	6.288	8.21	19.593	50.86	33.286	13.788	7.604	6.52
2003	6.372	6.789	6.093	6.621	5.998	7.596	21.707	44.689	26.426	9.345	6.864	6.378
2004	6.166	6.62	6.056	6.1	5.763	7.435	14.655	49.925	60.932	24.412	7.061	6.363
2005	6.07	6.338	5.816	6.076	5.8	9.084	32.1	40.121	32.987	20.422	8.214	6.506

m^3/s

Amerti RES 2

	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	0.377	0.314	0.265	0.274	0.314	1.308	12.321	22.745	19.691	10.2	2.87	0.945
1962	0.377	0.314	0.265	0.274	0.314	1.308	12.321	22.745	19.691	10.2	2.87	0.945
1963	0.426	0.314	0.261	0.201	0.317	1.181	9.472	20.236	16.806	8.412	1.906	0.68
1964	0.373	0.331	0.239	0.471	0.732	1.103	6.302	14.352	13.931	4.48	1.327	0.859
1965	0.463	0.323	0.231	0.243	0.396	2.176	12.515	21.576	13.858	9.308	2.164	0.907
1966	0.564	0.537	0.362	0.544	0.34	0.583	6.239	27.964	15.98	7.635	2.801	1.497
1967	0.601	0.467	0.467	0.351	0.205	0.887	7.478	19.321	16.15	4.48	1.47	0.564
1968	0.37	0.306	0.358	0.309	0.418	0.702	7.773	17.238	23.059	12.15	2.442	1.303
1969	0.526	0.603	0.377	0.208	0.168	0.802	4.996	10.842	9.637	5.152	1.057	0.556
1970	0.504	0.703	0.672	0.455	0.485	0.671	9.532	26.93	14.275	3.11	0.891	0.463
1971	0.37	0.368	0.366	0.278	0.134	0.201	4.383	24.94	14.799	3.678	1.022	0.459
1972	0.306	0.219	0.175	0.131	0.202	2.627	16.943	22.133	8.843	5.115	1.435	0.732
1973	0.515	0.307	0.146	0.112	0.381	0.459	6.709	20.46	7.01	3.17	1.022	0.504
1974	0.325	0.194	0.142	0.096	0.661	1.825	7.863	21.894	20.166	6.56	1.79	0.818
1975	0.631	0.413	0.299	0.189	0.448	2.35	15.016	22.323	19.56	11.69	1.879	0.93
1976	0.332	0.434	0.302	0.154	0.134	0.968	9.517	24.933	23.63	5.813	1.624	0.526
1977	0.314	0.291	0.254	0.17	0.246	0.895	9.05	21.688	14.174	5.346	1.539	0.978
1978	0.444	0.248	0.149	0.081	0.161	1.898	12.425	14.02	14.078	11.23	5.54	1.128
1979	0.511	0.459	0.377	0.262	0.224	0.556	7.273	12.171	11.574	7.844	1.327	0.601
1980	0.441	0.302	0.149	0.069	0.209	1.146	6.127	11.246	9.313	4.813	1.335	0.422
1981	0.179	0.116	0.09	0.116	0.355	0.965	9.39	16.726	11.806	3.782	0.795	0.37
1982	0.22	0.136	0.108	0.139	0.22	0.374	4.174	10.644	15.563	6.683	1.454	0.5
1983	0.314	0.157	0.119	0.085	0.06	0.108	4.346	11.163	11.559	5.977	2.006	0.605
1984	0.224	0.128	0.142	0.077	0.093	0.282	4.394	11.223	11.532	6.687	1.84	0.582
1985	0.287	0.172	0.097	0.035	0.015	0.802	13.329	17.328	11.034	4.286	0.648	0.396
1986	0.239	0.095	0.063	0.108	0.444	1.485	9.472	26.564	18.947	8.946	3.669	0.96
1987	0.362	0.203	0.347	0.212	0.377	1.694	8.531	13.508	9.9	3.487	0.656	0.403
1988	0.321	0.31	0.179	0.077	0.437	2.77	10.443	19.497	8.279	3.222	1.169	1.269
1989	0.403	0.279	0.306	0.208	0.112	1.181	10.723	20.18	17.022	9.319	2.211	0.661
1990	0.351	0.285	0.209	0.305	0.399	0.93	11.764	24.115	19.078	8.359	1.169	0.855
1991	0.508	0.389	0.239	0.177	0.205	0.367	5.264	14.535	12.041	5.35	1.188	0.508
1992	0.467	0.376	0.295	0.243	0.351	1.319	10.439	22.263	17.149	7.77	2.068	0.87
1993	0.332	0.259	0.213	0.174	0.25	0.941	7.467	15.927	12.269	5.556	1.478	0.624
1994	0.478	0.384	0.302	0.247	0.362	1.35	10.693	22.801	17.566	7.956	2.118	0.892
1995	0.47	0.376	0.299	0.243	0.355	1.327	10.525	22.443	17.288	7.833	2.083	0.877
1996	0.314	0.252	0.198	0.162	0.235	0.883	6.986	14.893	11.474	5.197	1.385	0.582
1997	0.321	0.247	0.205	0.166	0.243	0.907	7.172	15.293	11.779	5.335	1.42	0.597
1998	0.377	0.306	0.239	0.197	0.284	1.069	8.457	18.033	13.893	6.291	1.674	0.706
1999	1.013	0.953	0.83	0.805	1.005	1.463	7.079	14.765	13.473	12.54	3.484	1.304
2000	1.109	0.964	0.783	0.797	1.16	3.289	12.911	26.554	28.988	25.35	2.56	1.314
2001	1.064	0.967	0.832	0.933	1.039	1.384	5.192	9.855	13.267	9.452	3.169	1.843
2002	1.082	0.991	0.858	0.899	0.925	1.804	7.518	23.011	14.23	4.642	1.504	1.04
2003	0.967	0.939	0.829	1.017	0.782	1.5	8.565	19.953	10.831	2.44	1.137	0.97
2004	0.865	0.855	0.81	0.759	0.665	1.42	5.071	22.547	27.928	9.906	1.235	0.963
2005	0.817	0.799	0.691	0.747	0.683	2.238	13.715	17.689	14.082	7.928	1.806	1.033

m^3/s

Maleka Wakana R	4											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	6.16	9.714	15.457	30.826	21.132	17.4	53.129	101.37	69.213	45.811	16.358	6.272
1962	6.16	9.714	15.457	30.826	21.132	17.4	53.129	101.37	69.213	45.811	16.358	6.272
1963	5.899	7.482	10.529	15.818	12.321	8.719	31.922	73.253	67.168	62.948	14.892	7.206
1964	8.027	9.549	10.678	23.92	29.906	9.568	34.088	75.754	47.106	17.734	8.642	4.331
1965	3.547	6.106	10.417	17.593	15.868	9.838	33.527	76.762	66.435	38.642	10.108	4.928
1966	3.547	4.01	8.214	11.883	8.961	7.562	28.3	69.743	49.421	24.306	13.889	6.795
1967	6.31	9.011	8.737	14.468	9.073	9.568	35.058	89.83	58.449	23.932	8.102	4.144
1968	3.622	3.968	3.734	8.912	11.537	7.716	37.634	84.752	72.801	65.412	43.017	8.774
1969	4.219	15.605	21.095	68.519	32.818	20.293	43.907	74.298	43.017	23.185	9.645	5.899
1970	9.483	17.692	40.509	19.29	22.289	9.375	43.197	89.307	50.193	14.001	6.636	4.966
1971	8.513	5.167	29.309	31.019	16.39	6.636	28.711	99.798	74.19	34.498	10.802	4.63
1972	4.667	4.051	4.555	12.886	22.7	25.887	57.497	90.203	52.315	47.304	12.384	7.28
1973	5.488	13.29	14.785	43.711	18.892	8.989	39.203	53.651	42.901	9.259	7.755	4.779
1974	3.92	3.596	3.323	3.318	6.384	6.096	31.399	80.944	50.887	16.017	4.514	4.443
1975	4.592	3.803	9.707	8.912	5.974	7.33	31.063	49.432	33.333	9.035	6.404	5.003
1976	3.995	4.258	3.696	8.758	6.534	13.927	45.96	108.05	76.427	24.866	6.752	3.435
1977	4.406	3.752	4.406	6.366	17.66	7.677	34.797	75.866	42.13	10.454	21.181	6.459
1978	14.337	13.476	7.915	18.326	17.249	20.409	74.261	143.71	84.182	104.5	29.552	5.526
1979	5.152	8.061	24.082	13.233	6.87	7.948	51.337	92.331	52.238	32.146	7.677	6.608
1980	15.345	27.612	17.025	20.023	18.78	16.628	26.322	46.296	36.535	21.804	7.87	4.667
1981	3.92	4.51	4.331	5.363	9.185	7.755	56.116	98.828	38.426	19.191	5.787	4.331
1982	4.032	3.844	10.603	39.12	9.521	4.938	14.188	62.836	79.745	22.663	6.597	4.48
1983	6.011	10.169	14.225	14.313	15.308	8.951	23.671	81.205	43.441	37.149	11.883	11.985
1984	5.675	7.358	7.206	37.847	58.58	21.875	24.791	119.77	97.068	41.107	19.985	6.683
1985	4.406	3.672	3.808	3.897	6.31	18.866	38.941	49.022	42.091	9.931	7.176	5.264
1986	4.406	4.175	4.182	12.23	20.124	17.361	45.55	90.576	62.269	24.492	8.449	4.854
1987	3.771	7.523	7.803	18.171	16.278	17.631	38.904	73.999	54.977	26.844	8.256	4.854
1988	4.555	7.068	20.759	33.488	36.925	25.116	34.648	72.954	40.432	32.295	14.005	5.227
1989	5.787	9.579	7.542	11.651	9.035	15.702	30.317	86.694	48.187	26.023	11.767	7.168
1990	4.928	5.084	4.294	44.637	11.686	9.684	49.246	55.668	48.611	25.09	18.48	7.392
1991	13.292	24.802	43.048	42.593	17.66	16.165	27.33	69.071	52.894	40.92	17.245	13.74
1992	6.422	10.541	1.269	1.427	13.142	30.903	18.444	62.836	71.605	33.49	0	3.435
1993	6.086	8.701	0	1.852	7.542	8.063	28.711	88.448	25.116	13.702	4.552	0
1994	0.075	13.269	1.232	9.066	23.671	29.36	39.576	66.084	31.404	21.543	0.347	2.987
1995	0	0	0	0.694	17.025	0	36.44	88.262	79.591	0	0	0
1996	0	0	0.448	21.952	7.056	0	24.044	62.575	49.151	7.878	4.36	2.763
1997	2.614	0	0.933	14.892	37.037	39.969	54.174	97.446	52.739	6.31	0	0.261
1998	1.941	0	1.493	4.823	3.099	0	44.318	49.694	15.432	34.125	52.431	17.137
1999	8.517	7.672	23.851	40.336	81.936	24.703	34.106	52.843	50.93	40.966	10.075	1.373
2000	2.951	0.453	22.653	26.069	14.362	7.885	26.944	52.583	33.965	54.412	4.225	0.278
2001	1.323	0.11	5.361	30.459	21.641	6.812	24.557	57.969	29.135	32.575	25.712	5.863
2002	16.771	18.181	16.353	16.919	16.478	18.613	28.806	57.779	41.849	23.427	18.052	16.692
2003	16.556	18.083	16.297	17.141	16.209	18.045	30.765	52.061	35.493	19.31	17.366	16.561
2004	16.364	17.927	16.262	16.658	15.991	17.895	24.23	56.912	67.466	33.272	17.549	16.547
2005	16.275	17.259	16.04	16.636	16.025	19.424	40.395	47.828	41.573	29.574	18.617	16.679

m^3/s

Lake Tana	5											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	170.25	88.87	102.3	5.79	0	0	152.7	888.59	1224.2	448.4	141.98	114.62
1962	170.25	88.87	102.3	5.79	0	0	152.7	888.59	1224.2	448.4	141.98	114.62
1963	44.8	85.15	61.98	0	0	0	0	1123.1	1083.7	386.8	62.5	112.38
1964	73.92	97.14	72.06	0	27.63	0	22.03	822.13	717.21	196.39	114.97	140.38
1965	84.75	91	29.5	0	0	0	173.24	1322.8	1277.4	437.95	150.08	82.89
1966	24.27	119.46	1.87	41.28	0	0	0	580.57	590.28	377.46	194.44	126.19
1967	73.55	100.86	86.99	1.16	0	0	0	625.75	819.06	212.81	115.74	104.91
1968	75.04	36.38	87.74	43.98	0	0	66.46	1067.1	905.86	443.92	108.02	99.69
1969	52.27	71.44	73.18	0	0	0	245.67	797.12	637.35	229.99	94.14	104.54
1970	95.21	63.24	85.5	37.42	0	0	0	846.03	870.76	116.86	28.94	60.48
1971	69.82	95.9	73.18	0	0	0	0	719.09	851.85	275.54	122.69	51.52
1972	59.36	69.44	63.1	0	0	0	61.98	762.4	833.33	187.43	94.91	40.7
1973	53.76	82.22	57.12	0	0	0	84.01	351.33	471.84	177.34	86.42	53.02
1974	46.3	89.29	50.03	0	0	0	21.65	637.32	741.13	371.49	193.67	25.76
1975	63.84	71.51	52.27	0	0	22.76	225.88	830.72	1026.6	300.93	0	47.04
1976	50.03	126.07	76.54	0	0	0	83.26	979.32	1478.4	447.66	55.56	52.27
1977	45.18	4.39	105.29	0	0	0	67.2	938.62	852.62	176.22	136.19	78.78
1978	61.23	69.86	48.91	0	0	0	160.17	952.81	801.7	357.3	191.74	80.27
1979	58.24	83.91	66.46	11.19	0	0	132.17	747.09	665.51	264.34	50.54	49.66
1980	74.67	40.92	92.97	0	0	0	0	619.03	645.45	250.9	121.53	55.26
1981	50.78	56.27	62.35	16.2	0	0	65.71	774.72	652.39	242.68	36.65	72.06
1982	53.39	57.87	61.6	0	0	0	26.88	625.75	774.69	343.86	47.07	38.46
1983	65.34	60.76	182.57	0	0	0	0	515.98	573.3	385.3	113.04	50.4
1984	73.18	62.83	46.67	0	0	0	0	558.92	741.51	192.65	112.27	57.5
1985	45.18	74.63	58.99	0	0	0	29.5	440.56	482.64	198.63	62.11	58.62
1986	50.4	58.28	60.86	0	0	0	34.72	563.02	1000.8	252.02	69.44	51.15
1987	41.82	74.82	67.2	0	0	0	127.31	589.16	664.35	358.42	125	35.84
1988	61.23	95.9	62.72	0	0	63.66	0	398.75	523.15	260.98	133.1	39.2
1989	51.9	49.89	60.48	0	0	0	162.78	1362.4	1114.6	485.36	164.35	17.55
1990	29.5	55.39	60.11	0.39	0	0	80.65	701.54	754.24	248.66	91.82	51.9
1991	55.26	71.1	63.47	0	0	0	0	635.08	782.02	303.17	46.68	36.22
1992	55.26	63.66	57.87	0	0	0	432.72	989.02	1057.9	294.58	42.44	44.8
1993	48.16	83.41	41.82	7.72	0	0	0	758.29	861.11	382.69	253.86	73.55
1994	19.79	60.35	77.66	10.03	0	0	86.25	639.56	695.99	793.01	179.4	43.68
1995	40.7	64.48	41.07	0	0	0	463.71	1162.6	984.57	72.06	41.28	34.72
1996	118.35	137.24	48.16	12.35	0	0	41.44	746.71	679.78	130.3	33.56	12.32
1997	80.65	37.52	204.97	0	17.17	118.44	109.77	891.58	1081.4	319.97	52.08	87.74
1998	24.64	83.5	66.46	0	0	34.34	95.95	623.13	484.18	324.45	457.18	103.05
1999	73.11	59.28	74.86	69.69	77.27	130.42	517.87	673.32	205.26	221.39	183.2	91.97
2000	87.94	83.29	51.6	48.51	31.39	54.86	950.85	1589.5	613.8	431	216.07	126.44
2001	93.23	79.66	40.39	77.73	49.29	50.09	435.19	1052.3	446.37	320.16	220.25	121.27
2002	64.5	70.81	112.01	118.6	101.05	143.95	833.29	1134.1	418.27	194.46	138.46	110.49
2003	123.5	125.58	105.4	111.53	90.68	118.65	331.34	734.4	312.95	121.43	98.82	89.97
2004	82.32	87.96	87.17	87.68	69.33	89.15	535.3	895.68	389.9	136.86	98.23	92.03
2005	90.66	87.25	80.79	85.64	72.27	98.37	388.22	819.59	250.85	148.36	91.72	80.4

m^3/s

Tis Abey	6											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	0.179	0.198	0.342	0.501	0.279	0.936	21.204	42.787	9.053	1.033	0.354	0.237
1962	0.179	0.198	0.342	0.501	0.279	0.936	21.204	42.787	9.053	1.033	0.354	0.237
1963	0.232	0.717	0.279	0.223	0.163	3.985	69.591	33.542	16.396	1.138	0.191	0.074
1964	0.095	0.111	0.042	0.468	0.342	0.033	16.215	42.824	6.777	0.068	0.098	0.116
1965	0.174	0.259	0.306	0.376	0.263	0.212	30.618	30.718	8.563	0.453	0.218	0.2
1966	0.163	0.14	0.142	0.147	0.142	0.136	0.632	21.567	10.278	0.269	0.784	0.148
1967	0.227	0.204	0.216	0.267	0.242	0.196	12.506	44.104	11.111	0.184	0.142	0.153
1968	0.142	0.122	0.105	0.098	0.216	0.098	6.295	24.881	8.04	3.603	0.664	0.2
1969	0.047	0.056	0.037	0.12	0.095	0.484	31.045	29.427	6.62	0.374	0.076	0.047
1970	0.142	0.157	1.438	0.539	0.448	2.809	16.236	55.115	3.228	0.126	0.103	0.1
1971	0.063	0.052	0.068	0.054	0.047	0.049	1.702	36.724	3.435	0.126	0.065	0.058
1972	0.074	0.064	0.058	0.065	0.105	0.114	5.242	52.022	2.999	0.105	0.093	0.079
1973	0.263	0.214	0.158	0.142	0.195	0.147	2.681	14.84	3.947	0.311	0.207	0.216
1974	0.221	0.192	0.148	0.147	0.179	0.191	6.401	35.18	15.803	0.427	0.348	0.353
1975	0.174	0.169	0.2	0.321	0.153	0.185	28.99	33.874	4.948	0.358	0.163	0.148
1976	0.211	0.245	0.195	0.229	0.174	0.408	24.086	27.916	12.918	0.485	0.207	0.169
1977	0.142	0.175	0.295	0.207	0.263	0.191	5.263	40.98	9.962	0.385	0.256	0.169
1978	0.227	0.181	0.169	0.136	0.158	11.21	30.46	34.227	2.134	0.669	0.768	0.284
1979	0.184	0.181	0.184	0.131	0.105	0.125	12.533	22.347	9.744	1.191	0.25	0.211
1980	0.248	0.245	0.232	0.082	0.105	0.098	29.549	38.931	2.107	0.79	0.544	0.227
1981	0.19	0.079	0.105	0.076	0.026	0.082	14.745	11.874	1.083	0.416	0.131	0.184
1982	0.269	0.245	0.363	0.773	0.242	0.332	13.544	19.966	5.89	3.019	0.31	0.316
1983	0.205	0.227	0.153	0.011	0.132	0.125	0.759	23.801	4.965	3.25	0.528	0.374
1984	0.132	0.157	0.153	0.37	0.242	0.582	3.477	25.492	3.713	0.395	0.278	0.148
1985	0.163	0.124	0.121	0.098	0.095	0.631	4.33	6.474	4.594	0.827	0.327	0.237
1986	0.047	0.035	0.032	0.234	0.579	0.338	9.735	51.638	8.498	0.543	0.321	0.295
1987	0.248	0.175	0.358	0.648	0.095	1.04	19.181	30.265	8.394	0.385	0.305	0.263
1988	0.227	0.198	0.406	0.544	1.328	1.421	0.369	3.93	0.925	1.069	0.599	0.4
1989	0.211	0.231	0.184	0.207	0.932	0.272	9.24	38.225	22.063	1.306	0.523	0.169
1990	0.2	0.181	0.184	0.762	0.19	0.125	5.927	28.964	9.935	0.248	0.098	0.095
1991	0.021	0.099	2.265	2.852	0.105	0.005	20.187	59.419	6.728	0.674	0.065	0.005
1992	0.126	0.14	0.453	0.169	0.058	0.093	5.784	27.457	5.852	0.258	0.12	0.021
1993	0.111	0.135	0.269	0.24	0.19	0.147	3.63	26.767	9.08	0.532	0.267	0.242
1994	0.1	0.017	0.237	0.201	1.897	0.397	18.444	39.848	11.862	1.538	0.452	0.216
1995	0.179	0.163	0.179	0.158	0.163	0.207	24.886	32.646	17.964	0.437	0.18	0.174
1996	0.121	0.163	0.242	0.234	0.174	0.191	7.944	31.108	6.69	0.274	0.223	0.158
1997	4.099	0.124	0.432	0.452	0.917	2.308	27.573	35.196	4.246	0.274	0.185	0.132
1998	0.216	0.198	0.232	0.392	0.2	0.425	14.561	26.182	1.682	6.337	2.831	0.622
1999	1.093	1.208	1.094	1.14	1.261	1.143	5.826	14.178	4.861	1.61	1.221	1.094
2000	1.082	1.193	1.092	1.115	1.078	1.152	3.912	18.581	2.815	1.59	1.182	1.124
2001	1.064	1.135	1.06	1.108	1.077	1.146	6.539	11.219	3.333	1.645	1.496	1.104
2002	1.075	1.195	1.531	1.338	1.189	1.157	17.863	28.161	2.953	1.165	1.153	1.084
2003	1.073	1.187	1.115	1.139	1.2	1.124	2.149	23.087	5.935	1.104	1.112	1.088
2004	1.088	1.215	1.654	1.955	1.355	1.468	9.038	8.015	3.066	1.441	1.488	1.44
2005	1.381	1.355	1.179	1.321	1.222	1.205	4.47	18.842	2.684	1.309	1.325	1.265

m^3/s

Tekeze I RES	7											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	5.227	3.307	4.854	14.66	14.934	17.361	543.23	577.21	273.92	59.737	16.975	8.214
1962	5.227	3.307	4.854	14.66	14.934	17.361	543.23	577.21	273.92	59.737	16.975	8.214
1963	5.974	4.134	5.974	8.488	15.308	42.824	273.67	930.03	364.58	64.217	21.991	12.694
1964	4.48	2.894	4.48	6.173	11.201	31.636	299.06	593.26	266.2	47.416	16.204	9.334
1965	6.72	4.39	7.094	9.645	17.548	49.383	464.83	889.34	457.56	73.925	25.463	14.561
1966	2.24	1.653	2.24	3.086	5.974	16.59	69.44	507.77	22.38	24.642	8.488	4.854
1967	2.987	2.067	3.36	4.63	8.214	23.148	154.94	485.74	206.79	34.722	11.96	6.72
1968	6.72	4.547	7.094	10.031	17.921	37.809	1017	1428.8	421.3	109.4	20.448	17.921
1969	11.201	6.386	4.854	7.33	5.6	98.765	429.73	516.35	167.44	30.615	9.259	6.72
1970	5.227	4.134	25.388	27.392	58.99	35.494	249.03	577.58	193.29	66.458	24.306	7.094
1971	3.734	2.894	2.987	6.173	1.867	77.932	737.01	466.7	263.12	65.338	16.975	9.334
1972	6.72	3.72	4.107	5.015	22.028	39.352	237.46	344.98	149.69	23.895	9.259	5.974
1973	3.36	1.996	2.614	12.731	7.841	48.225	276.66	309.89	74.46	10.454	8.488	2.987
1974	1.867	1.653	1.867	4.63	13.441	2.701	428.61	1015.5	233.02	60.857	15.818	7.467
1975	4.854	2.894	4.107	4.244	23.522	56.327	391.28	821.39	221.84	35.469	15.818	10.454
1976	5.974	5.787	3.36	9.259	2.614	45.91	380.08	1091.3	748.07	131	47.068	31.362
1977	17.921	11.175	14.188	11.188	23.522	55.17	295.33	713.11	240.74	51.897	33.179	15.308
1978	4.48	2.894	4.48	6.559	11.574	32.793	300.93	687.35	207.18	48.91	16.59	9.707
1979	4.107	2.894	4.107	5.787	10.454	29.707	476.03	404.72	208.33	44.43	15.432	8.587
1980	2.987	2.067	3.36	4.63	8.214	22.762	292.34	427.87	116.13	34.349	11.574	6.72
1981	4.107	2.794	4.107	5.787	10.827	30.093	327.06	617.53	160.88	45.176	15.432	8.961
1982	4.48	2.894	4.48	6.173	11.201	31.636	376.72	485.74	305.94	47.79	16.204	9.334
1983	2.614	1.653	2.987	3.858	7.094	20.062	161.66	512.99	55.17	29.869	10.417	5.974
1984	3.734	2.48	3.734	5.015	9.334	26.235	257.99	526.06	181.71	39.576	13.503	7.841
1985	3.36	2.395	3.734	5.015	8.961	25.463	285.62	431.97	212.58	38.082	13.117	7.467
1986	3.734	2.48	3.734	5.401	9.707	27.392	247.91	454.38	310.57	41.443	14.275	8.214
1987	4.48	2.894	4.48	6.559	11.574	32.793	445.42	419.65	346.84	49.283	16.975	9.707
1988	2.24	1.653	2.24	3.086	5.6	15.818	80.65	358.42	144.68	23.895	8.102	4.854
1989	7.094	4.39	7.094	10.031	18.295	51.312	705.27	877.76	289.74	76.912	26.235	14.934
1990	4.107	2.894	4.107	5.787	10.454	29.321	240.82	505.15	327.16	43.683	15.046	8.587
1991	2.987	2.067	2.987	4.244	7.467	21.219	168.38	434.21	179.01	32.109	10.802	6.347
1992	6.347	4.134	6.347	8.873	16.428	45.91	614.17	576.84	503.86	69.071	23.534	13.441
1993	4.48	2.794	4.48	6.559	11.947	33.179	362.16	670.55	180.17	49.657	16.975	9.707
1994	5.227	3.307	5.227	7.33	13.441	37.809	263.59	585.8	544.37	56.75	19.29	11.201
1995	6.347	4.547	6.72	9.259	16.801	47.454	684.74	840.8	209.88	71.311	24.306	13.814
1996	3.36	2.48	3.734	5.015	8.961	25.463	381.2	452.14	91.44	38.082	13.117	7.467
1997	17.174	17.96	80.272	67.515	58.99	172.1	434.59	889.71	316.36	104.9	59.028	47.416
1998	8.961	31.415	162	62.114	137.77	157	283.75	684.74	244.98	66.458	67.13	26.135
1999	36.138	23.803	37.449	32.963	39.252	78.393	368.87	485.16	134.38	147.07	117.88	50.247
2000	47.231	41.766	20.047	17.121	4.926	21.867	692.78	1170.6	440	303.87	142.47	76.033
2001	51.194	39.758	11.664	38.976	18.319	18.302	307.01	768.68	314.76	220.96	145.59	72.167
2002	29.696	32.433	65.243	69.554	57.044	88.515	604.83	829.86	293.74	126.92	84.412	64.107
2003	73.837	73.406	60.292	64.262	49.282	69.587	229.32	530.85	214.94	72.288	54.756	48.751
2004	43.026	45.261	46.656	46.421	33.314	47.518	381.91	651.51	272.54	83.828	54.313	50.297
2005	49.27	45.441	41.882	44.896	35.508	54.42	271.88	594.59	168.49	92.431	49.44	41.595

m^3/s

Tekeze II RES	8											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	3.71	2.347	3.445	10.405	10.6	12.322	385.56	409.67	194.41	42.398	12.048	5.83
1962	3.71	2.347	3.445	10.405	10.6	12.322	385.56	409.67	194.41	42.398	12.048	5.83
1963	4.24	2.934	4.24	6.024	10.865	30.394	194.24	660.09	258.76	45.578	15.608	9.01
1964	3.18	2.054	3.18	4.381	7.95	22.454	212.26	421.07	188.94	33.654	11.501	6.625
1965	4.77	3.116	5.035	6.846	12.455	35.049	329.91	631.21	324.75	52.468	18.072	10.335
1966	1.59	1.174	1.59	2.191	4.24	11.774	49.29	360.39	15.88	17.489	6.024	3.445
1967	2.12	1.467	2.385	3.286	5.83	16.429	109.97	344.75	146.77	24.644	8.489	4.77
1968	4.77	3.227	5.035	7.119	12.72	26.835	721.83	1014.1	299.02	77.642	14.513	12.72
1969	7.95	4.532	3.445	5.203	3.975	70.099	305	366.48	118.84	21.729	6.572	4.77
1970	3.71	2.934	18.019	19.441	41.868	25.192	176.75	409.94	137.19	47.168	17.251	5.035
1971	2.65	2.054	2.12	4.381	1.325	55.312	523.09	331.24	186.75	46.373	12.048	6.625
1972	4.77	2.64	2.915	3.56	15.634	27.93	168.53	244.85	106.24	16.959	6.572	4.24
1973	2.385	1.416	1.855	9.036	5.565	34.228	196.36	219.94	52.85	7.42	6.024	2.12
1974	1.325	1.174	1.325	3.286	9.54	1.917	304.21	720.77	165.39	43.193	11.227	5.3
1975	3.445	2.054	2.915	3.012	16.694	39.978	277.71	582.98	157.45	25.174	11.227	7.42
1976	4.24	4.107	2.385	6.572	1.855	32.585	269.76	774.57	530.94	93.012	33.406	22.259
1977	12.72	7.931	10.07	7.941	16.694	39.157	209.61	506.13	170.87	36.834	23.549	10.865
1978	3.18	2.054	3.18	4.655	8.215	23.275	213.58	487.85	147.04	34.714	11.774	6.89
1979	2.915	2.054	2.915	4.107	7.42	21.084	337.86	287.25	147.86	31.534	10.953	6.095
1980	2.12	1.467	2.385	3.286	5.83	16.156	207.49	303.68	82.42	24.379	8.215	4.77
1981	2.915	1.983	2.915	4.107	7.685	21.358	232.13	438.29	114.18	32.064	10.953	6.36
1982	3.18	2.054	3.18	4.381	7.95	22.454	267.38	344.75	217.14	33.919	11.501	6.625
1983	1.855	1.174	2.12	2.738	5.035	14.239	114.74	364.1	39.16	21.199	7.393	4.24
1984	2.65	1.76	2.65	3.56	6.625	18.62	183.11	373.37	128.97	28.089	9.584	5.565
1985	2.385	1.7	2.65	3.56	6.36	18.072	202.72	306.59	150.88	27.029	9.31	5.3
1986	2.65	1.76	2.65	3.834	6.89	19.441	175.95	322.49	220.43	29.414	10.131	5.83
1987	3.18	2.054	3.18	4.655	8.215	23.275	316.13	297.85	246.17	34.979	12.048	6.89
1988	1.59	1.174	1.59	2.191	3.975	11.227	57.24	254.39	102.68	16.959	5.75	3.445
1989	5.035	3.116	5.035	7.119	12.985	36.418	500.57	622.99	205.64	54.588	18.62	10.6
1990	2.915	2.054	2.915	4.107	7.42	20.811	170.92	358.53	232.2	31.004	10.679	6.095
1991	2.12	1.467	2.12	3.012	5.3	15.06	119.51	308.18	127.05	22.789	7.667	4.505
1992	4.505	2.934	4.505	6.298	11.66	32.585	435.91	409.41	357.61	49.023	16.703	9.54
1993	3.18	1.983	3.18	4.655	8.48	23.549	257.04	475.92	127.88	35.244	12.048	6.89
1994	3.71	2.347	3.71	5.203	9.54	26.835	187.08	415.77	386.36	40.279	13.691	7.95
1995	4.505	3.227	4.77	6.572	11.925	33.68	485.99	596.76	148.96	50.613	17.251	9.805
1996	2.385	1.76	2.65	3.56	6.36	18.072	270.56	320.9	64.9	27.029	9.31	5.3
1997	12.19	12.747	56.973	47.919	41.868	122.13	308.45	631.47	224.54	74.462	41.895	33.654
1998	6.36	22.297	115.01	44.086	97.781	111.45	201.39	485.99	173.88	47.168	47.645	18.549
1999	25.649	16.894	26.579	23.395	27.859	55.64	261.8	344.34	95.38	104.38	83.665	35.663
2000	33.522	29.643	14.229	12.151	3.496	15.52	491.7	830.8	312.29	215.67	101.12	53.964
2001	36.335	28.218	8.278	27.663	13.002	12.99	217.9	545.57	223.4	156.83	103.33	51.22
2002	21.077	23.02	46.306	49.366	40.487	62.823	429.28	589	208.48	90.083	59.912	45.5
2003	52.406	52.1	42.792	45.61	34.978	49.389	162.76	376.77	152.56	51.306	38.863	34.601
2004	30.538	32.124	33.114	32.948	23.645	33.726	271.06	462.41	193.44	59.497	38.548	35.698
2005	34.97	32.252	29.726	31.865	25.201	38.625	192.96	422.01	119.58	65.603	35.09	29.522

m^3/s

Gibe I RES	9											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	7.47	6.61	6.72	9.26	13.44	39.74	127.69	199.37	167.82	98.94	37.81	15.68
1962	7.47	6.61	6.72	9.26	13.44	39.74	127.69	199.37	167.82	98.94	37.81	15.68
1963	8.21	7.03	6.35	8.1	12.69	38.58	115.74	197.13	165.9	96.33	33.56	13.07
1964	6.72	6.61	3.36	4.24	21.65	26.62	106.78	208.71	232.25	106	23.15	10.45
1965	7.09	6.78	1.87	7.72	12.32	62.89	147.85	211.32	184.41	128.1	21.6	10.45
1966	7.84	6.2	3.73	7.72	5.97	35.11	203.11	164.65	133.87	75.42	26.23	11.95
1967	6.35	7.03	6.72	22.38	8.21	44.37	136.65	144.12	148.15	48.54	37.42	12.32
1968	7.09	5.79	4.11	9.26	17.17	21.99	137.77	216.17	210.65	178.8	65.2	25.39
1969	8.96	8.78	5.23	8.49	12.69	50.54	98.94	232.97	162.81	70.56	20.06	10.83
1970	9.33	11.16	21.65	12.73	20.53	64.04	113.5	187.8	143.13	39.95	17.36	8.96
1971	6.35	8.27	13.07	13.5	14.56	46.3	156.44	359.17	216.05	103.8	32.02	11.95
1972	7.47	3.72	0.75	7.72	15.31	49	122.09	203.48	213.35	112.8	43.21	18.67
1973	10.45	8.78	8.96	11.96	21.65	31.64	143.37	209.08	145.06	46.67	35.49	18.29
1974	8.96	4.96	1.12	5.02	13.81	28.16	66.08	237.46	204.48	101.9	15.43	7.84
1975	6.72	7.03	6.72	8.49	7.09	25.08	132.54	130.3	99.92	42.94	21.99	12.32
1976	4.48	5.37	4.11	10.8	7.47	33.18	110.89	162.04	150.08	89.61	15.82	7.47
1977	4.48	3.59	4.11	3.47	12.32	39.35	156.06	190.41	158.56	38.46	41.67	11.57
1978	10.83	10.33	8.96	4.63	5.23	34.34	137.02	189.29	182.48	94.83	97.61	16.8
1979	7.47	7.03	7.47	6.17	29.5	47.07	143	259.48	173.23	116.5	22.76	14.56
1980	10.83	19.01	10.45	13.12	21.65	34.72	96.7	134.04	76.77	48.16	10.42	8.59
1981	5.23	3.19	4.48	8.49	11.57	54.01	94.46	154.57	91.05	34.72	11.19	5.6
1982	2.99	3.72	15.68	9.26	9.71	22.76	104.17	150.84	135.03	75.42	18.52	7.47
1983	6.72	3.31	3.36	3.47	9.71	20.06	48.16	110.14	172.84	90.35	45.91	36.96
1984	14.19	8.68	4.85	10.03	11.95	43.21	54.88	130.68	246.14	233.7	89.89	28.75
1985	14.19	5.59	3.36	5.02	11.57	57.48	129.18	151.21	124.61	32.48	13.12	9.33
1986	3.73	2.89	1.87	7.72	18.29	44.75	109.02	190.79	145.06	61.23	18.9	8.96
1987	3.36	3.72	5.97	4.63	5.23	41.67	110.14	115.37	138.5	54.88	15.43	7.47
1988	5.97	3.72	11.95	5.4	7.47	63.66	134.04	147.85	125.77	29.87	31.25	14.93
1989	5.97	5.99	2.24	1.93	4.48	13.12	83.26	256.12	147.76	204.6	40.9	8.21
1990	5.23	2.07	4.85	8.49	20.53	33.95	112.38	256.87	75.23	21.28	33.95	11.95
1991	7.09	6.2	5.97	7.72	12.32	35.88	110.14	179.21	150.85	77.28	27.01	11.2
1992	11.2	9.92	13.07	8.87	18.29	64.04	134.78	243.43	174	35.84	6.94	5.6
1993	3.36	4.79	5.23	9.26	18.67	79.86	176.97	435.33	255.79	152	35.11	13.81
1994	12.69	15.29	17.17	20.83	34.35	118.1	201.61	320.71	233.41	152.7	96.06	33.98
1995	10.83	7.03	8.21	9.26	38.08	141.2	278.15	384.18	270.83	49.28	19.68	10.45
1996	6.72	7.03	5.97	14.27	20.16	26.23	86.25	129.55	159.72	32.86	13.89	11.2
1997	8.96	9.98	14.56	22.38	43.31	183.3	181.08	269.56	186.73	87.74	30.09	25.39
1998	11.57	7.03	5.6	29.71	47.04	141.2	141.13	222.89	144.68	2.99	273.9	104.2
1999	36.27	22.22	20.28	14.66	26.51	41.46	131.78	297.94	163	131.3	47.81	18.44
2000	12	7.68	8.62	7.39	20.52	49.73	120.84	172.97	89.54	108.7	34.96	13.19
2001	7.51	4.84	3.16	8.87	25.09	40.74	92.29	126.43	139.82	113.7	51.26	18.88
2002	29.4	33.56	31.91	31.91	49.66	103.6	189.34	169.03	121.11	70.71	40.71	71.22
2003	11.64	7.7	8.53	11.97	8.42	40.57	83.68	115.31	92.44	27.92	15.25	15.25
2004	12.71	6.94	10.68	12.33	6.79	32.4	123.26	130.59	152.31	40.89	15.93	11.79
2005	7.63	6.09	4.98	8.17	16.33	45.08	96.09	155.49	154.25	117.6	26.73	16.02

m^3/s

Gibe II RES fic	11											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0

m^3/s

Neshe RES	12											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	0.747	0.827	0.747	0.772	0.747	2.315	12.321	27.255	19.29	8.214	2.701	1.12
1962	0.747	0.827	0.747	0.772	0.747	2.315	12.321	27.255	19.29	8.214	2.701	1.12
1963	0.747	0.827	0.747	0.386	0.747	2.315	11.947	26.135	18.904	7.841	2.315	1.12
1964	0.747	0.827	0.448	0.656	0.859	2.045	7.579	17.286	16.242	8.027	1.89	1.232
1965	0.896	0.798	0.448	0.656	1.008	5.478	15.084	25.202	17.708	11.014	2.932	1.829
1966	1.008	0.909	0.597	0.965	0.56	1.042	8.102	28.524	17.052	8.55	3.974	2.539
1967	1.643	0.827	0.672	0.617	0.373	1.466	9.185	20.871	18.017	6.011	1.89	0.971
1968	0.672	0.62	0.672	0.694	1.008	1.389	9.969	18.967	25.849	14.3	3.549	2.165
1969	0.896	0.878	0.672	0.502	0.56	1.736	7.878	16.054	11.034	6.272	1.389	0.859
1970	0.784	0.909	0.896	0.656	0.709	1.466	10.454	29.085	15.085	2.763	1.003	0.672
1971	0.597	0.455	0.448	0.386	0.299	0.579	6.72	26.994	16.435	5.488	1.466	0.747
1972	0.635	0.413	0.336	0.27	0.597	2.778	13.366	21.505	15.471	6.646	1.968	0.971
1973	0.821	0.439	0.299	0.27	0.597	0.694	6.235	20.012	8.218	4.294	1.235	0.635
1974	0.373	0.248	0.187	0.154	0.747	2.894	10.603	25.911	17.593	6.907	1.775	0.747
1975	0.672	0.372	0.336	0.193	0.709	2.353	17.921	21.953	16.975	6.086	1.042	0.56
1976	0.373	0.703	0.336	0.154	0.299	1.466	8.251	19.751	17.747	6.534	2.971	0.933
1977	0.597	0.319	0.224	0.193	0.523	1.505	10.305	21.207	14.583	2.838	2.508	0.859
1978	0.485	0.331	0.261	0.231	0.336	2.122	10.342	16.502	14.39	4.443	2.894	1.941
1979	0.747	0.372	0.336	0.27	0.485	0.926	10.193	16.913	17.245	9.409	1.235	0.747
1980	0.821	0.537	0.261	0.193	0.56	1.466	4.928	11.985	14.545	7.504	1.235	0.56
1981	0.373	0.279	0.224	0.309	0.56	1.273	16.54	26.396	15.895	4.294	1.003	0.485
1982	0.112	0.248	0.373	0.231	0.336	0.463	5.339	12.731	17.323	7.467	1.543	0.485
1983	0.411	0.331	0.224	0.231	0.373	0.926	4.144	16.614	16.551	11.462	3.125	1.008
1984	0.411	0.289	0.261	0.154	0.187	0.309	4.219	12.433	20.448	9.371	2.623	0.821
1985	0.373	0.239	0.187	0.116	0.112	2.006	23.335	18.182	13.156	5.526	0.965	0.56
1986	0.299	0.124	0.149	0.309	0.971	3.048	12.358	33.229	19.367	10.753	5.671	1.792
1987	0.448	0.248	0.709	0.309	0.896	4.012	8.998	15.27	12.23	3.958	0.965	0.523
1988	0.597	0.579	0.261	0.077	0.971	6.25	11.35	23.858	8.603	3.808	1.813	0.448
1989	0.485	0.359	0.56	0.386	0.187	2.585	11.238	18.481	17.978	10.006	1.929	0.635
1990	0.523	0.455	0.336	0.656	0.784	1.62	19.34	29.271	21.258	9.259	0.424	2.091
1991	1.045	0.537	0.336	0.309	0.411	0.733	36.701	29.831	20.37	8.027	1.698	0.709
1992	0.485	0.413	0.299	0.039	0.56	0.733	13.142	22.028	24.614	2.539	0.887	0.672
1993	0.56	0.399	0.299	0.424	0.709	2.315	4.256	13.068	23.418	23.409	5.363	1.829
1994	0.971	0.579	0.373	0.617	0.784	3.935	18.145	51.971	42.708	17.286	2.816	0.933
1995	0.709	0.496	0.411	0.27	1.12	2.315	5.526	20.311	20.602	4.032	1.119	0.635
1996	0.411	0.331	0.336	0.27	0.859	0.772	5.227	19.975	8.989	4.107	0.887	0.523
1997	0.523	0.319	0.187	0.27	0.523	5.015	23.148	23.223	14.66	6.571	1.543	0.784
1998	0.448	0.331	0.187	0.27	0.523	5.015	23.297	36.216	20.448	7.318	3.086	1.008
1999	0.889	0.751	0.636	0.584	0.879	1.494	9.273	19.896	18.094	16.818	4.288	1.292
2000	1.022	0.767	0.571	0.573	1.092	4.018	17.335	36.191	39.537	34.532	3.011	1.306
2001	0.96	0.791	0.64	0.761	0.926	1.386	6.666	13.11	17.809	12.553	3.852	2.565
2002	0.985	0.804	0.676	0.714	0.768	1.966	9.88	31.293	19.14	5.904	1.551	0.927
2003	0.826	0.732	0.635	0.878	0.57	1.546	11.328	27.067	14.442	2.862	1.044	0.83
2004	0.684	0.616	0.609	0.521	0.409	1.435	6.498	30.653	38.073	13.18	1.179	0.82
2005	0.618	0.558	0.445	0.504	0.433	2.565	18.445	23.939	18.935	10.447	1.969	0.917

m^3/s

Lake Koka	15											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	17.17	11.99	5.97	7.33	5.97	15.05	68.32	217.67	87.19	43.31	24.69	14.56
1962	17.17	11.99	5.97	7.33	5.97	15.05	68.32	217.67	87.19	43.31	24.69	14.56
1963	9.33	9.51	9.71	10.8	8.59	11.19	81.77	144.86	159.34	59.36	12.73	13.07
1964	12.32	11.16	5.23	20.45	31.36	16.59	89.98	220.65	132.33	28	12.35	8.21
1965	8.96	9.58	13.44	11.19	14.19	17.75	73.55	166.52	212.19	50.78	14.66	8.96
1966	5.97	4.13	7.47	8.49	4.48	6.56	52.64	165.02	117.67	27.26	9.65	7.09
1967	9.33	14.47	10.08	8.87	6.35	11.19	64.22	261.35	186.34	27.63	13.89	5.6
1968	4.11	5.79	7.84	11.57	15.68	20.83	85.87	163.53	126.93	46.67	21.99	7.09
1969	6.35	11.97	10.08	37.42	14.93	13.12	104.91	196.01	118.83	37.71	14.27	11.2
1970	11.95	15.71	25.01	17.75	17.55	31.64	168.38	352.45	153.94	19.04	14.27	9.33
1971	19.79	11.99	26.14	15.43	4.85	8.49	184.07	333.78	170.14	39.95	12.73	10.83
1972	11.2	6.61	4.85	7.72	11.2	42.44	175.85	403.23	314.04	54.14	11.96	6.72
1973	13.07	17.96	24.64	27.78	13.81	14.27	97.07	172.86	72.92	22.03	10.42	9.71
1974	8.21	5.37	2.61	3.47	5.6	8.49	61.98	232.6	182.1	41.07	6.17	5.97
1975	6.72	8.27	11.2	8.87	12.32	17.36	122.46	232.97	143.52	32.48	14.27	12.32
1976	8.96	2.89	4.11	3.86	5.6	15.05	162.41	226.63	192.13	65.34	13.89	11.2
1977	10.83	12.77	8.21	10.03	10.83	18.9	82.14	201.61	106.48	20.53	8.87	7.47
1978	6.72	8.68	8.21	9.65	9.71	27.01	154.57	245.3	105.71	43.31	89.89	34.72
1979	9.33	9.92	13.07	14.27	17.55	31.64	97.07	225.51	148.92	39.95	15.05	11.2
1980	16.8	11.16	14.93	6.94	13.81	18.13	84.38	227	100.31	29.12	11.57	10.45
1981	9.71	9.58	8.96	3.47	7.09	15.05	105.29	250.15	98.77	22.03	6.94	5.97
1982	6.72	11.57	32.11	27.78	9.71	13.5	112.01	231.85	221.45	37.34	15.43	6.35
1983	9.33	15.71	10.83	8.49	11.57	7.72	57.5	207.21	91.44	32.48	10.8	5.97
1984	7.09	19.84	29.5	20.45	46.3	24.31	81.77	288.61	180.94	51.15	11.57	6.72
1985	7.09	7.98	7.84	3.09	7.09	28.16	138.89	172.86	133.1	29.12	13.12	7.47
1986	4.85	4.55	4.48	6.94	12.69	19.29	116.11	344.98	174.38	42.94	12.73	6.72
1987	7.09	19.01	11.2	12.35	11.2	29.71	79.15	183.32	125	22.03	13.89	10.08
1988	4.48	7.03	16.05	26.62	24.27	30.09	60.86	88.86	46.3	10.83	7.33	4.48
1989	4.85	4.79	3.73	5.79	5.23	9.65	57.12	309.51	241.13	38.83	17.36	10.08
1990	10.45	11.57	17.17	21.22	8.96	19.29	97.07	250.52	204.86	38.08	14.66	10.83
1991	13.44	34.31	27.63	15.43	7.09	9.26	106.03	225.13	148.92	45.92	21.6	10.08
1992	2.99	10.75	16.05	24.31	4.11	9.26	80.27	231.48	108.02	14.19	3.47	2.61
1993	2.61	3.99	7.47	2.7	2.24	8.49	85.87	260.23	148.92	7.84	3.09	2.99
1994	3.73	6.61	3.36	4.63	4.11	10.42	75.04	234.84	162.42	15.68	4.24	3.36
1995	2.61	4.55	2.61	8.87	11.57	24.31	126.57	285.99	200.23	28.75	6.94	3.73
1996	2.61	2.07	2.24	3.86	3.73	8.1	68.7	144.86	136.19	13.44	4.24	4.11
1997	4.11	3.99	2.99	13.5	4.85	9.65	69.44	200.49	73.3	7.09	3.09	2.99
1998	4.85	4.13	2.61	10.8	19.41	77.93	209.45	403.97	132.33	11.57	5.4	1.49
1999	22.6	19.57	23.04	21.88	23.64	37.15	134.43	173.51	55.97	59.9	50.42	27.34
2000	26.33	25.61	17.19	16.56	12.11	18.15	243.3	403.88	158.69	112.6	58.69	36.01
2001	27.66	24.54	14.37	23.9	16.61	16.95	113.64	268.81	116.59	84.7	59.73	34.71
2002	20.43	22.47	32.38	34.18	29.62	40.55	213.74	289.37	109.53	53.11	39.17	32
2003	35.27	36.24	30.72	32.4	27.02	34.19	87.53	188.87	83.04	34.75	29.2	26.84
2004	24.91	26.78	26.13	26.4	21.65	26.77	138.81	229.42	102.4	38.6	29.06	27.36
2005	27.01	26.45	24.53	25.89	22.39	29.09	101.83	210.29	67.43	41.52	27.42	24.43

m^3/s

Gibe III RES	19											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	69.87	59.74	63.92	59.63	80.71	189.37	559.24	695.33	362.39	326.78	57.32	54.18
1962	69.87	59.74	63.92	59.63	80.71	189.37	559.24	695.33	362.39	326.78	57.32	54.18
1963	48.67	51.57	59.06	59.75	49.71	3.5	217.14	656.69	457.19	380.32	159.64	76.06
1964	64.03	60.6	55.06	35.7	68.26	0	312.64	807.62	993.14	557.93	112.9	74.7
1965	62.39	62.18	29.15	55.25	89.36	154.33	632.36	1149.5	623.92	335.91	95.75	249.56
1966	36.92	35.08	23.92	47.83	49.77	138.8	537.25	933.99	576.89	351.88	117.52	92.84
1967	33.83	34.93	31.43	60.6	54.98	148.31	540.26	900.09	590.94	227.25	83	42.54
1968	26.68	26.55	27.15	44.32	67.43	209.4	516.34	793.6	570.35	364.42	135.75	64.37
1969	34.09	39.62	27.93	54.79	52.83	146.16	609.06	933.59	507.22	227.97	70.76	42.25
1970	31.81	41.82	66.96	54.57	72.85	193.84	630.88	975.08	555.51	267.07	74.85	38.44
1971	5.42	5.05	24.93	51.4	60.33	155.42	644.14	1171.4	683.51	322.13	89.98	47.47
1972	23.38	18.79	16.36	28.43	46.15	147.43	600.7	1032.6	703.03	305.31	98.08	39.21
1973	19.61	18.9	14.66	34.99	49.73	117.78	537.97	772	435.67	137.6	58.06	25.25
1974	20.39	15.74	11.8	26.43	56.17	82.42	603.17	985.17	660.71	274.05	64.28	27.96
1975	20.84	20.44	23.82	30.84	29.49	135.18	454.24	820.43	386.47	219.17	71.61	32.77
1976	26.4	28.66	24.36	44.14	52.1	161.95	659.21	1113.2	762.58	292.33	76.52	44.49
1977	25.76	26.67	23.03	31.61	71.04	165.8	518.15	776.87	410.81	144.2	73.27	30.53
1978	34.86	106.26	31.34	42.61	54.54	164.81	692.15	1176.9	699.11	411.44	113.08	57.68
1979	33.36	33.96	32.57	48.22	89.7	213.75	706.42	1161.2	602.04	350.48	98.46	72.03
1980	58.16	66.03	51.1	59.06	75.27	158.64	477.94	725.09	444.36	205.41	73.54	185.52
1981	188.92	51.29	41.62	52.53	69.63	142.44	461.61	752.27	440.25	194.88	76.01	43.08
1982	31.73	32.37	42.67	52.43	69.48	102.04	436.26	773.23	344.15	143.67	0	23.78
1983	26.67	230.66	22.34	34.52	47.87	117.82	375.27	740.1	457.97	260.13	81.43	50.86
1984	34.1	67.02	28.51	43.37	68.37	137.91	462.27	947.27	635.88	388.74	131.46	59.84
1985	265.63	27.04	22.29	32.84	48.58	167.2	526.95	734.82	478.58	134.14	48.17	33.16
1986	21.84	20.47	19.35	30.61	60.67	148.58	487.32	970.42	556.31	180.25	59	41.24
1987	28.06	31.64	39.1	56.1	62.85	173.26	500.24	640.04	464.68	172.98	50.6	32.32
1988	19.06	17.79	34.28	73.03	63.95	141.39	332.5	545.62	340.85	141.27	53.63	23.05
1989	27.27	36.19	29.57	46.64	60.15	137.19	1249.6	1627.7	992.41	723.94	352.82	176.21
1990	42.23	28.2	24.42	65.91	48.15	118.2	479.88	755.41	503.17	217.61	66.3	52.08
1991	4.16	30.4	32.61	39.44	47.74	136.92	487.12	917	622.85	332.72	99.31	92.85
1992	54.47	52.35	53.4	84.23	196.87	276.05	759.7	936.98	232.11	140.61	91.7	71.96
1993	28.49	37.37	29.18	51.19	56.35	127.41	430.97	802.29	1053.4	540.72	360.31	94.67
1994	61.03	73.41	27.87	80.73	103.66	0	716.08	1276	903.45	288.5	145.95	91.06
1995	45.35	42.05	38.47	64.3	100.9	312.6	760.04	1307.1	741.74	112.59	81.1	65.11
1996	34.83	31.41	34.02	58.89	109.32	224.16	470.54	886.17	286.02	240.7	82.48	91.56
1997	38.38	59.33	110.33	91.36	148.26	450.54	877.95	1447.1	653.79	300.19	100.69	63.26
1998	42.03	40.71	32.36	76.33	87.95	406.25	585.58	944.27	494.1	371.78	509.65	179.23
1999	96.2	53.02	95.6	62.21	139.37	152.95	778.09	1396.8	753.88	625.72	150.5	71.64
2000	14.05	6.53	7.55	18.66	89.33	201.59	685.2	1135	462.49	468.08	100	25.5
2001	10.97	8.41	4.53	53.41	150.17	224.88	794.73	1207.3	699.86	479.28	180.81	50.36
2002	0	0	10.67	56.67	125.84	511.82	990.9	1454.5	1098.8	506.81	287.25	39.22
2003	71.52	72.31	40.65	58.63	46.72	159.56	401.58	498.9	433.24	109.57	55.36	62.98
2004	41.35	29.42	36.78	41.67	31.05	67.8	325.75	645.9	595.1	264.35	87.19	58.14
2005	79.91	97.79	109.92	127.35	137.78	204.64	392.14	511.67	500.03	490.61	191.74	102.37

m^3/s

Genale 3 RES	20											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	36.14	47.62	20.91	105.56	36.74	22.53	94.09	87.22	130.25	172.04	103.7	97.37
1962	36.14	47.62	20.91	105.56	36.74	22.53	94.09	87.22	130.25	172.04	103.7	97.37
1963	41.82	48.94	70.79	105.86	150.24	49.07	103.94	141.28	83.02	125.15	0	69.89
1964	37.34	22.16	58.84	84.57	63.62	45.99	71.09	100.66	122.22	113.8	83.33	93.19
1965	31.66	42.46	31.06	66.05	146.95	144.44	92.59	107.83	203.09	196.54	130.86	31.36
1966	0	0	0	20.68	0	34.26	82.74	94.09	94.75	91.7	29.94	83.33
1967	38.53	36.38	26.28	34.26	76.16	143.52	125.75	161.29	112.35	93.49	90.12	71.39
1968	25.39	3.64	14.34	32.41	70.79	52.78	81.84	120.37	180.86	119.77	32.72	32.26
1969	14.64	19.8	24.49	73.15	0	66.98	79.15	85.13	100.31	110.51	46.91	45.1
1970	27.18	13.89	0	38.89	83.03	18.21	108.12	132.32	120.68	92.89	7.72	24.19
1971	11.65	20.5	14.34	54.32	89.01	112.04	126.34	186.68	129.32	157.11	208.64	89.61
1972	17.92	0	22.4	36.42	94.09	93.83	79.15	155.02	141.98	99.16	46.6	21.8
1973	18.52	41.51	56.75	98.15	100.06	93.52	92.89	118.28	169.14	258.06	80.56	17.62
1974	27.78	44.97	53.46	76.23	95.58	12.35	60.63	135.6	131.17	20.01	0	0
1975	9.86	23.15	19.71	35.19	15.53	27.47	63.92	110.81	129.94	114.1	0.93	0
1976	0	4.63	36.74	62.04	140.08	175.31	109.32	118.28	105.86	37.04	79.32	25.39
1977	40.32	24.27	58.24	98.15	109.02	87.96	86.92	151.73	138.27	179.81	116.67	36.14
1978	0	10.58	15.83	50.62	37.04	86.42	119.47	173.84	116.98	119.77	43.21	0
1979	1.79	8.93	0	25.31	10.45	6.48	61.83	72.28	166.05	268.82	72.53	10.75
1980	16.43	8.27	14.04	63.27	144.27	140.74	122.46	167.26	152.78	59.14	0	0
1981	43.31	37.04	34.35	65.12	163.98	106.48	90.8	126.34	250.93	265.83	105.86	40.02
1982	12.25	37.7	28.67	78.7	108.12	122.53	92.59	146.65	85.8	56.45	29.32	35.84
1983	27.18	15.21	23.3	32.1	132.32	82.41	94.98	138.89	150.93	209.38	212.04	56.75
1984	5.38	0	26.28	22.22	128.43	68.83	88.71	113.2	87.65	139.78	125.31	67.2
1985	14.04	5.43	3.58	6.79	24.49	56.48	68.4	114.4	170.06	98.27	39.81	15.83
1986	5.38	3.31	3.29	45.06	141.28	90.74	107.83	129.33	103.7	109.32	47.84	15.83
1987	5.68	4.63	3.58	26.85	78.26	104.94	83.63	81.24	164.51	107.83	35.19	18.82
1988	6.27	5.29	14.04	59.88	159.2	151.54	98.86	83.93	81.17	145.16	81.17	21.21
1989	10.75	6.07	5.08	18.21	43.01	46.91	122.46	175.03	116.98	227.6	48.15	13.44
1990	6.87	5.29	5.68	76.23	51.67	67.28	102.75	102.45	207.72	240.74	92.59	106.33
1991	47.19	35.05	66.01	116.98	78.26	84.88	75.27	143.67	108.95	90.5	41.05	17.62
1992	3.88	1.65	12.54	38.27	42.11	33.95	72.58	135.3	113.89	61.53	44.14	39.43
1993	34.35	30.97	25.39	18.83	13.14	38.89	84.23	120.07	139.51	292.71	107.1	57.05
1994	51.37	71.1	65.41	65.12	184.89	69.14	84.83	102.15	89.2	163.38	95.37	34.65
1995	40.92	3.64	7.17	34.26	127.24	117.28	142.17	181.3	132.41	135.01	93.21	43.91
1996	25.99	23.15	34.95	111.42	77.06	45.99	68.7	129.63	173.77	153.52	63.27	32.56
1997	15.53	11.81	8.06	40.74	102.75	215.12	116.79	152.93	182.1	94.38	29.32	14.64
1998	9.86	5.62	2.09	34.88	34.65	31.48	91.7	75.57	48.15	198.33	314.2	114.4
1999	137.42	87.06	37.3	42.75	108.09	52.93	101.89	145.75	138.77	266.97	82.74	21.49
2000	11.62	5.72	11.54	13.57	28.4	29.16	76.58	98.4	86.12	186.91	64.34	16.58
2001	5.65	2.16	0.92	5.8	92.84	23.03	49.13	109.07	110.45	202.98	145.68	30.02
2002	12.07	9.48	13.72	35.76	87.92	116.65	97.54	135.69	134.49	128.29	84.06	31.41
2003	14.66	5.8	13.65	29.72	43.99	33.89	56.64	86.05	74.56	84.69	33.29	37.15
2004	24.8	6.33	4.63	40.2	70.8	59.53	64.6	87.32	91.68	89.01	34.3	41.59
2005	24.27	17.7	6.59	32.05	49.73	40.12	54.09	112.3	140.01	127.47	68.89	28.1

m^3/s

Genale 5 RES	21											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	2.71	3.54	1.6	7.74	2.75	1.72	6.91	6.41	9.54	12.57	7.61	7.15
1962	2.71	3.54	1.6	7.74	2.75	1.72	6.91	6.41	9.54	12.57	7.61	7.15
1963	3.12	3.64	5.22	7.77	10.99	3.65	7.63	10.34	6.11	9.17	0.04	5.16
1964	2.8	1.7	4.36	6.22	4.7	3.42	5.24	7.39	8.95	8.34	6.13	6.85
1965	2.38	3.17	2.34	4.88	10.75	10.57	6.8	7.91	14.82	14.34	9.58	2.36
1966	0	0	0	1.59	0	2.57	6.09	6.91	6.96	6.74	2.26	6.13
1967	2.88	2.73	1.99	2.57	5.61	10.5	9.21	11.79	8.24	6.87	6.63	5.27
1968	1.93	0.35	1.13	2.44	5.22	3.92	6.02	8.82	13.21	8.78	2.46	2.43
1969	1.15	1.52	1.86	5.39	0	4.95	5.83	6.26	7.36	8.1	3.49	3.36
1970	2.06	1.1	0	2.91	6.11	1.41	7.93	9.69	8.84	6.83	0.65	1.84
1971	0.93	1.58	1.13	4.03	6.54	8.22	9.25	13.63	9.47	11.48	15.22	6.59
1972	1.39	0	1.71	2.73	6.91	6.89	5.83	11.33	10.39	7.28	3.47	1.67
1973	1.43	3.1	4.2	7.21	7.35	6.87	6.83	8.67	12.36	18.81	5.93	1.37
1974	2.1	3.35	3.97	5.62	7.02	0.98	4.49	9.92	9.6	1.54	0	0
1975	0.8	1.77	1.52	2.64	1.21	2.08	4.72	8.13	9.51	8.36	0.16	0
1976	0	0.42	2.75	4.59	10.25	12.8	8.02	8.67	7.77	2.77	5.84	1.93
1977	3.01	1.85	4.31	7.21	8	6.47	6.39	11.09	10.12	13.13	8.55	2.71
1978	0	0.86	1.24	3.76	2.77	6.36	8.75	12.7	8.57	8.78	3.22	0
1979	0.22	0.74	0	1.92	0.85	0.56	4.57	5.33	12.13	19.59	5.35	0.87
1980	1.28	0.69	1.11	4.68	10.55	10.3	8.97	12.22	11.17	4.38	0	0.02
1981	3.23	2.77	2.58	4.81	11.98	7.81	6.67	9.25	18.29	19.37	7.77	2.99
1982	0.98	2.82	2.17	5.8	7.93	8.98	6.8	10.73	6.31	4.18	2.21	2.69
1983	2.06	1.19	1.78	2.42	9.69	6.07	6.98	10.16	11.04	15.28	15.47	4.2
1984	0.48	0	1.99	1.7	9.4	5.08	6.52	8.3	6.45	10.23	9.18	4.96
1985	1.01	0.5	0.34	0.59	1.93	4.27	5.11	8.29	12.06	7.2	3.02	1.17
1986	0.5	0.34	0.34	3.35	10.14	6.7	7.87	9.38	7.62	7.96	3.69	1.26
1987	0.5	0.5	0.42	2.01	5.78	7.62	6.28	6.11	11.81	7.87	2.68	1.42
1988	0.59	0.42	1.09	4.52	11.48	10.89	7.29	6.11	6.11	10.39	5.95	1.59
1989	0.84	0.59	0.5	1.42	3.35	3.69	8.88	12.65	8.46	16.17	3.6	1.09
1990	0.59	0.5	0.5	5.61	3.94	5.03	7.54	7.54	14.66	17.09	6.87	7.79
1991	3.6	2.68	5.03	8.54	5.95	6.37	5.78	10.3	7.96	6.78	3.1	1.34
1992	0.42	0.25	1.01	2.93	3.27	2.6	5.61	9.72	8.29	4.69	3.43	3.02
1993	2.6	2.26	1.93	1.42	1.01	2.51	6.28	8.21	9.97	20.77	7.79	4.44
1994	4.02	7.29	5.03	5.03	13.4	5.28	4.27	7.46	6.62	11.73	7.04	2.43
1995	1.68	1.26	1.42	2.68	8.21	8.04	11.14	13.74	9.55	9.72	6.87	3.35
1996	1.93	1.68	2.68	8.04	5.86	3.52	5.44	9.38	12.4	10.97	4.69	1.42
1997	1.17	0.92	0.67	3.18	7.87	15.16	8.54	10.89	12.9	7.04	2.26	1.09
1998	0.84	0.5	0.34	2.68	2.6	2.35	6.78	5.7	3.69	14.91	26.47	8.54
1999	10.14	6.37	2.76	3.18	7.87	3.94	7.46	10.64	10.14	19.52	6.11	1.68
2000	0.92	0.5	0.92	1.09	2.18	2.18	5.61	7.2	6.28	13.65	4.77	1.26
2001	0.5	0.25	0.17	0.5	6.87	1.76	3.69	8.04	8.13	14.83	10.64	2.26
2002	0.92	0.84	1.09	2.68	6.45	8.54	7.12	9.97	9.8	9.38	6.2	2.35
2003	1.17	0.5	1.09	2.26	3.27	2.51	4.19	6.28	5.44	6.28	2.51	2.76
2004	1.84	0.5	0.42	3.02	5.28	4.44	4.86	6.45	6.78	6.53	2.6	3.1
2005	1.84	1.42	0.59	2.43	3.69	3.02	4.02	8.21	10.22	9.38	5.03	2.18

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Renaissance RES 22

	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	42.06	0	0	0	0	75.78	564.69	1037.1	2515.7	2393.1	429.46	307.64
1962	42.06	0	0	0	0	75.78	564.69	1037.1	2515.7	2393.1	429.46	307.64
1963	155.59	68.29	46.46	15.67	71.58	281.01	822.58	2174.7	2145.6	1118.9	389.69	199.48
1964	90.93	28.08	0	0.55	114.57	169.2	486.61	1260.1	1876.6	581.37	293.81	344.54
1965	66.77	33.09	47.58	29.16	30.96	199.51	335.36	1333.2	1541	1230.8	527.01	250.14
1966	91.58	69.7	39.93	0	0	138.83	334.1	1007.9	1438.2	785.7	324.68	208.13
1967	79.08	22.1	21.14	3.75	48.94	370.97	783.07	1125.6	1493	401.94	157.18	108.5
1968	0	23.95	0	0	0	209.4	242.64	1093.9	1670.1	840.21	382.97	218.53
1969	75.71	42.68	10.93	0	0	90.25	846.04	1173.7	1228.2	1022.5	243.38	112.22
1970	67.14	21	0	33.45	24.77	163.85	450.69	1385.7	738.3	472.04	218.3	87.98
1971	23.45	0	0	0	0	45.78	123.23	1445.3	1056.7	888.46	375.55	142.3
1972	74.32	16.32	6.3	0	0.94	165.65	454.56	1027.4	1588.9	652.54	416.83	171.85
1973	88.41	23	7.97	0	37.44	162.45	325.73	337.7	1138.4	403.44	198.38	79.06
1974	65.72	57.27	0	0	48.97	215.09	249.68	834.7	1263.6	698.49	260.44	150.19
1975	104.94	73.63	63.4	14.21	57.62	279.79	418.88	1473.4	1647.2	912.46	309.2	189.36
1976	68.92	0	0	0	21.02	1072.9	3944.4	1335.8	0	0	143.06	0
1977	62.51	0	8.58	0	49.04	342.49	1124.1	1109	2007.5	322.93	60.37	102.84
1978	0	0	0	0	36.54	311.1	652.7	759.9	1020	1021.5	602.54	198.48
1979	313.97	295.96	46.5	234.46	182.42	348.46	751.15	717.6	1086.4	889.41	156.4	24.51
1980	0	16	12.93	42.3	210.91	325.69	726.25	765.8	1332	735.6	223.1	55.07
1981	73.79	0	0	0	0	0	939.21	1050.2	0	271	0	0
1982	0	0	0	0	23.82	182.52	0	791.5	1248.2	447.82	116.03	38.6
1983	16.43	0	0	0	29.03	113.38	384.25	0	740.5	906.45	65.33	22.76
1984	0	0	0	0	0	59.2	135.48	0	3982.4	1746.7	1813.3	28.98
1985	18.38	19.1	0	0	0	168.78	371.45	81.9	962.4	276.26	0	0
1986	0	0	0	0	64.9	124.62	559.75	1352.1	1437.8	460.39	149.56	71.23
1987	13.77	0	0	0	253.46	173.18	85.69	63.4	313.6	210.21	0	0
1988	0	0	0	0	27.28	401.84	549.99	404.1	705.3	395.21	141.23	55.45
1989	7.24	15.4	44.48	0	0	288.07	1621	979.9	1650.4	1442.8	168.64	0
1990	0	2	0	0	30.47	97.52	860.06	881.2	886.5	424.55	29.7	0
1991	56.49	2.41	0	0	0	11.58	270.98	674.4	885.3	703.96	78.2	5.89
1992	0	0	0	0	40.2	145.37	567.85	572.9	1268.8	140.39	205.6	111.75
1993	45.34	0	0	0	0	170.92	272.57	279.9	1117.2	947.61	476.42	220.53
1994	154.81	74.51	44.64	0	106.98	630.25	940.01	1922.9	1773	1255.8	500.25	198.52
1995	123.78	71	34.44	25.52	112.37	314.81	204.72	798.3	1519.7	177.1	0	109.96
1996	7.49	4.86	0	0	46.54	218.79	247.05	894.1	804.5	281.36	31.69	0
1997	16.57	23.31	0	0	127.31	621.03	573.35	1104.1	1489	668.98	156.32	104.45
1998	44.33	18.85	0	0	0	63.14	541.39	698	871.7	26.3	0	0
1999	0	0	0	3.02	0	108.99	0	0	2610.7	2139	749.01	331.35
2000	0	0	0	3.29	118.33	435.22	2842.6	0	2777.1	1470.8	833.21	153.33
2001	0	0	0	69.56	5.19	415.96	72.71	429.2	742.5	1179.1	116.98	254.18
2002	161.88	97.06	84.43	100.86	205.55	962.61	840.5	0	2688.9	1424.2	826.26	295.7
2003	0	240.28	0	28.39	4.71	176.47	1154.6	1593	1382.7	666.4	378.1	0
2004	73.39	19.65	34.54	65.97	0	405.32	365.6	1218.3	1202.6	685.4	161.4	36.4
2005	73.39	19.65	34.54	65.97	0	405.32	365.6	1218.3	1202.6	685.4	161.4	36.4

m^3/s

Geba 1 RES	24											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	0	3.17	4.97	5.2	16.22	43.22	60.09	105.54	101.72	52.44	10.6	11.05
1962	0	3.17	4.97	5.2	16.22	43.22	60.09	105.54	101.72	52.44	10.6	11.05
1963	7.45	0.7	4.07	7	16.45	59.87	62.57	102.62	108.69	78.77	27.02	7.22
1964	4.3	4.97	2.95	0.47	11.27	30.17	33.99	67.97	120.84	49.07	13.75	10.6
1965	9.47	4.07	3.4	4.97	15.32	28.14	12.85	53.12	54.92	47.27	20.95	9.92
1966	6.1	6.1	3.85	4.97	13.75	33.99	61.44	83.94	66.62	35.12	18.25	9.7
1967	1.82	3.85	4.07	1.6	2.72	27.69	81.92	112.74	35.79	26.57	13.75	2.5
1968	11.05	10.82	3.4	6.32	5.87	16.45	54.92	90.69	204.54	150.54	38.27	20.05
1969	7.45	5.42	1.82	1.15	4.07	8.35	22.07	77.87	129.17	39.39	5.65	10.37
1970	7.67	4.97	7.22	4.3	9.02	29.27	29.04	56.94	72.69	45.47	7.22	4.07
1971	3.62	5.2	2.95	1.82	8.8	40.52	71.34	91.82	113.64	76.52	27.47	18.02
1972	20.95	4.97	6.1	12.62	31.97	20.95	75.84	77.64	113.19	80.12	38.94	15.77
1973	8.12	2.95	1.37	3.85	9.92	27.02	63.47	96.09	85.07	24.32	22.07	9.47
1974	5.42	3.4	2.95	3.17	14.2	33.77	71.57	106.89	108.24	63.92	14.42	6.32
1975	3.8	2.2	2.4	6.8	16.7	89.3	149.8	190.1	191.6	83.8	9.5	4.2
1976	1.1	2.2	1.4	4	8.5	30.6	55.9	56.6	91.3	58.4	23.3	8.6
1977	3.5	3.4	4	3.6	8.9	31.2	53.9	92.6	74.6	30.9	24.5	9.1
1978	4.8	3.4	2.8	2.1	3.1	18.6	38.8	80	136.3	56.4	22	10.3
1979	6.5	2.5	2.4	5	14.1	36.7	84.5	91.5	90.2	70.9	14.9	8.5
1980	8.9	4.2	2.3	1.8	5.1	15.7	41.7	61.8	69.7	36.7	11.7	5.3
1981	2.4	1.8	1.6	4.1	16.1	36.7	81.3	95.5	88.3	39.4	12.5	5.9
1982	3	1.3	2.4	1.2	5.8	20.1	36.4	89.6	125.4	68.9	17	6
1983	5.6	3.9	3.7	2.1	6.5	27.7	44.4	67.2	65.9	58.3	12.9	5
1984	2.1	2.2	2.6	2.3	3.3	11.2	47.4	62.7	88.8	63.3	19.5	6.6
1985	1.2	0.6	0.9	1.3	4	20.5	73.3	57.4	59.9	18.2	7.6	5.6
1986	2.3	1.1	0.9	2.1	9.8	26	53.3	71.2	88.1	40.9	12.7	7.4
1987	3.1	1.8	1.9	1.5	1.9	13.4	39	61.1	83	31.4	11.6	9.1
1988	9	3.1	2	2.2	4.5	23.7	52.1	88.6	76.5	69.7	17.8	9.2
1989	6.3	5.6	4	1.1	5.2	36	80.1	103	111.3	94	19.8	5.8
1990	2.1	3.7	2.3	3.6	5.2	19	54.5	91.5	79.6	38.7	10.7	14.3
1991	5.5	4.6	2.5	2.9	5.1	41.8	67.6	94.2	104.1	53.1	12.3	5.5
1992	4.3	1.8	2	3.6	4.1	15.9	44.3	91.1	78	36.3	13.7	6.8
1993	4.1	3.4	2.3	7.1	14.5	26	48	88.1	95.5	42.8	25	13.7
1994	5.3	3.9	2.6	11.9	13.5	58.9	97.7	118.3	95.7	52.3	20.7	8.5
1995	4.7	3	2.4	2.6	8.5	24.6	68.7	67.5	116.4	47.1	8.5	5.3
1996	1.8	1.5	2.4	3.8	5.8	20.5	47.7	80.2	107	51.7	17.5	10.9
1997	6.8	6.3	3.1	2.3	14.9	46.4	77.1	105.3	103.8	56.5	10.2	5.1
1998	3.1	1.9	1.3	4.8	9.8	37.1	53	98.9	73.6	53.5	50.4	11.7
1999	3.1	1.4	2.4	1.4	6	30.6	65.4	104.6	100.8	80.5	22.6	4.3
2000	2.3	0.8	0.2	0.6	24.7	47.8	60.6	74.9	60.2	91.6	15.1	4.3
2001	2.3	0.7	0.3	1.4	9.1	37.1	77.1	85.7	94.4	74.4	28.9	7
2002	3.6	2	1.5	1.6	7.4	32.4	76.6	79.8	88.9	53.9	18.1	6.3
2003	5.1	2.4	2.1	3.1	2.1	22.6	61.3	69.7	65.6	23.8	11.3	5.9
2004	2.5	1.8	4	6.1	2.8	18.6	56.1	54.5	75.7	28.3	5.5	3.3
2005	3.54	3.09	2.2	2.22	5.62	19.94	61.08	69.72	87.4	49.32	13.04	8

m^3/s

Geba 2 RES	25											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	0	1.85	2.9	3.03	9.43	25.12	34.92	61.33	59.11	30.48	6.16	6.43
1962	0	1.85	2.9	3.03	9.43	25.12	34.92	61.33	59.11	30.48	6.16	6.43
1963	4.33	0.41	2.37	4.07	9.56	34.79	36.36	59.63	63.16	45.77	15.71	4.2
1964	2.5	2.9	1.72	0.28	6.56	17.54	19.76	39.5	70.22	28.52	7.99	6.16
1965	5.51	2.37	1.98	2.9	8.91	16.36	7.47	30.87	31.92	27.47	12.18	5.77
1966	3.55	3.55	2.24	2.9	7.99	19.76	35.71	48.78	38.71	20.41	10.61	5.64
1967	1.07	2.24	2.37	0.94	1.59	16.1	47.6	65.51	20.8	15.45	7.99	1.46
1968	6.43	6.29	1.98	3.68	3.42	9.56	31.92	52.7	118.85	87.47	22.24	11.65
1969	4.33	3.16	1.07	0.67	2.37	4.86	12.83	45.25	75.05	22.9	3.29	6.03
1970	4.46	2.9	4.2	2.5	5.25	17.01	16.88	33.09	42.24	26.43	4.2	2.37
1971	2.11	3.03	1.72	1.07	5.12	23.55	41.46	53.35	66.03	44.47	15.97	10.48
1972	12.18	2.9	3.55	7.34	18.58	12.18	44.07	45.12	65.77	46.56	22.63	9.17
1973	4.73	1.72	0.8	2.24	5.77	15.71	36.88	55.84	49.43	14.14	12.83	5.51
1974	3.16	1.98	1.72	1.85	8.26	19.63	41.59	62.11	62.9	37.14	8.39	3.68
1975	2.2	1.3	1.4	3.9	9.7	51.9	87.1	110.4	111.3	48.7	5.6	2.4
1976	0.7	1.3	0.9	2.4	5	17.7	32.5	32.9	53.1	34	13.6	5
1977	2.1	2	2.4	2.1	5.1	18.1	31.2	53.9	43.3	17.9	14.3	5.3
1978	2.7	2	1.7	1.3	1.9	10.9	22.5	46.4	79.3	32.8	12.8	6
1979	3.7	1.5	1.4	2.8	8.2	21.3	49.2	53.2	52.4	41.1	8.7	4.9
1980	5.2	2.4	1.3	1	2.9	9.1	24.3	35.9	40.6	21.3	6.9	3
1981	1.4	1.1	0.9	2.4	9.4	21.3	47.3	55.4	51.2	22.9	7.2	3.4
1982	1.7	0.7	1.5	0.7	3.3	11.7	21.2	52	72.9	40	9.9	3.4
1983	3.2	2.3	2.2	1.2	3.7	16.2	25.9	39	38.3	33.9	7.5	2.8
1984	1.2	1.3	1.5	1.3	2	6.6	27.5	36.4	51.6	36.7	11.4	3.8
1985	0.7	0.3	0.5	0.7	2.4	12	42.5	33.4	34.9	10.6	4.4	3.3
1986	1.3	0.7	0.6	1.3	5.7	15.2	31	41.4	51.1	23.8	7.4	4.3
1987	1.8	1	1.1	0.9	1.1	7.7	22.6	35.5	48.2	18.3	6.8	5.3
1988	5.3	1.9	1.2	1.3	2.6	13.7	30.3	51.4	44.5	40.5	10.3	5.4
1989	3.6	3.2	2.4	0.6	3	20.9	46.5	59.9	64.7	54.7	11.5	3.3
1990	1.2	2.2	1.3	2.2	3	11	31.7	53.1	46.2	22.4	6.2	8.3
1991	3.1	2.6	1.5	1.7	3	24.3	39.3	54.7	60.4	30.9	7.2	3.1
1992	2.4	1	1.2	2.2	2.4	9.3	25.8	53	45.4	21.2	8	4
1993	2.4	2	1.3	4.1	8.4	15.1	27.9	51.2	55.5	24.9	14.5	8
1994	3.1	2.3	1.6	7	7.8	34.3	56.7	68.8	55.5	30.4	12	4.9
1995	2.7	1.7	1.5	1.5	4.9	14.3	40	39.3	67.6	27.4	5	3
1996	1	0.9	1.5	2.3	3.3	11.9	27.7	46.6	62.2	30	10.2	6.4
1997	3.9	3.6	1.9	1.4	8.7	27	44.9	61.2	60.2	32.8	5.9	3
1998	1.8	1.2	0.8	2.8	5.7	21.6	30.8	57.5	42.7	31.2	29.3	6.8
1999	1.9	0.9	1.4	0.8	3.5	17.7	38	60.8	58.6	46.8	13.1	2.5
2000	1.4	0.5	0.1	0.4	14.3	27.7	35.2	43.6	35	53.3	8.7	2.5
2001	1.4	0.4	0.2	0.8	5.3	21.6	44.9	49.9	54.9	43.2	16.9	4
2002	2.2	1.2	0.9	1	4.3	18.8	44.5	46.4	51.6	31.2	10.6	3.7
2003	2.9	1.4	1.2	1.9	1.3	13.1	35.6	40.6	38.1	13.8	6.6	3.4
2004	1.5	1	2.3	3.5	1.7	10.8	32.6	31.6	44	16.5	3.1	2
2005	2.02	1.77	1.26	1.27	3.21	11.4	34.91	39.84	49.94	28.19	7.45	4.57

m^3/s

Genale 6 RES	26											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	0.53	0.69	0.31	1.5	0.53	0.33	1.34	1.24	1.85	2.44	1.48	1.39
1962	0.53	0.69	0.31	1.5	0.53	0.33	1.34	1.24	1.85	2.44	1.48	1.39
1963	0.6	0.71	1.01	1.51	2.13	0.71	1.48	2	1.18	1.78	0.01	1
1964	0.54	0.33	0.84	1.21	0.91	0.66	1.02	1.43	1.74	1.62	1.19	1.33
1965	0.46	0.61	0.45	0.95	2.08	2.05	1.32	1.53	2.87	2.78	1.86	0.46
1966	0	0	0	0.31	0	0.5	1.18	1.34	1.35	1.31	0.44	1.19
1967	0.56	0.53	0.39	0.5	1.09	2.03	1.79	2.28	1.6	1.33	1.28	1.02
1968	0.37	0.07	0.22	0.47	1.01	0.76	1.17	1.71	2.56	1.7	0.48	0.47
1969	0.22	0.3	0.36	1.05	0	0.96	1.13	1.21	1.43	1.57	0.68	0.65
1970	0.4	0.21	0	0.56	1.18	0.27	1.54	1.88	1.71	1.32	0.13	0.36
1971	0.18	0.31	0.22	0.78	1.27	1.59	1.79	2.64	1.84	2.23	2.95	1.28
1972	0.27	0	0.33	0.53	1.34	1.34	1.13	2.2	2.01	1.41	0.67	0.32
1973	0.28	0.6	0.81	1.4	1.42	1.33	1.32	1.68	2.4	3.65	1.15	0.26
1974	0.41	0.65	0.77	1.09	1.36	0.19	0.87	1.92	1.86	0.3	0	0
1975	0.16	0.34	0.29	0.51	0.24	0.4	0.92	1.58	1.84	1.62	0.03	0
1976	0	0.08	0.53	0.89	1.99	2.48	1.55	1.68	1.51	0.54	1.13	0.37
1977	0.58	0.36	0.84	1.4	1.55	1.25	1.24	2.15	1.96	2.55	1.66	0.53
1978	0	0.17	0.24	0.73	0.54	1.23	1.7	2.46	1.66	1.7	0.62	0
1979	0.04	0.14	0	0.37	0.16	0.11	0.89	1.03	2.35	3.8	1.04	0.17
1980	0.25	0.13	0.21	0.91	2.05	2	1.74	2.37	2.17	0.85	0	0
1981	0.63	0.54	0.5	0.93	2.32	1.51	1.29	1.79	3.55	3.75	1.51	0.58
1982	0.19	0.55	0.42	1.12	1.54	1.74	1.32	2.08	1.22	0.81	0.43	0.52
1983	0.4	0.23	0.34	0.47	1.88	1.18	1.35	1.97	2.14	2.96	3	0.81
1984	0.09	0	0.39	0.33	1.82	0.98	1.26	1.61	1.25	1.98	1.78	0.96
1985	0.19	0.1	0.06	0.11	0.37	0.83	0.99	1.61	2.34	1.4	0.58	0.23
1986	0.1	0.06	0.06	0.65	1.96	1.3	1.53	1.82	1.48	1.54	0.71	0.24
1987	0.1	0.1	0.08	0.39	1.12	1.48	1.22	1.19	2.29	1.53	0.52	0.28
1988	0.11	0.08	0.21	0.88	2.22	2.11	1.41	1.19	1.19	2.01	1.15	0.31
1989	0.16	0.11	0.1	0.28	0.65	0.71	1.72	2.45	1.64	3.13	0.7	0.21
1990	0.11	0.1	0.1	1.09	0.76	0.97	1.46	1.46	2.84	3.31	1.33	1.51
1991	0.7	0.52	0.97	1.66	1.15	1.23	1.12	2	1.54	1.32	0.6	0.26
1992	0.08	0.05	0.19	0.57	0.63	0.5	1.09	1.88	1.61	0.91	0.67	0.58
1993	0.5	0.44	0.37	0.28	0.19	0.49	1.22	1.59	1.93	4.03	1.51	0.86
1994	0.78	1.41	0.97	0.97	2.6	1.02	0.83	1.44	1.28	2.27	1.36	0.47
1995	0.32	0.24	0.28	0.52	1.59	1.56	2.16	2.66	1.85	1.88	1.33	0.65
1996	0.37	0.32	0.52	1.56	1.14	0.68	1.06	1.82	2.4	2.13	0.91	0.28
1997	0.23	0.18	0.13	0.62	1.53	2.94	1.66	2.11	2.5	1.36	0.44	0.21
1998	0.16	0.1	0.06	0.52	0.5	0.45	1.32	1.1	0.71	2.89	5.13	1.66
1999	1.96	1.23	0.54	0.62	1.53	0.76	1.44	2.06	1.96	3.78	1.19	0.32
2000	0.18	0.1	0.18	0.21	0.42	0.42	1.09	1.4	1.22	2.65	0.93	0.24
2001	0.1	0.05	0.03	0.1	1.33	0.34	0.71	1.56	1.57	2.87	2.06	0.44
2002	0.18	0.16	0.21	0.52	1.25	1.66	1.38	1.93	1.9	1.82	1.2	0.45
2003	0.23	0.1	0.21	0.44	0.63	0.49	0.81	1.22	1.06	1.22	0.49	0.54
2004	0.36	0.1	0.08	0.58	1.02	0.86	0.94	1.25	1.32	1.27	0.5	0.6
2005	0.36	0.28	0.11	0.47	0.71	0.58	0.78	1.59	1.98	1.82	0.97	0.42

m^3/s

U Dabus RES	28											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	46.85	35.9	31.09	47.08	51.61	82.8	265.04	488.19	642.45	560.8	238.99	166.62
1962	46.85	35.9	31.09	47.08	51.61	82.8	265.04	488.19	642.45	560.8	238.99	166.62
1963	63.38	34.24	27.41	27.11	32.17	90.29	184.97	349.88	401.49	471.51	132.77	51.29
1964	33.43	26.79	25.2	25.84	59.82	87.96	226.35	423.79	496.12	374.66	185.23	97.56
1965	58.49	34.65	28.34	27.13	33.94	94.71	216.21	485.57	464.48	527.69	292.31	72.52
1966	58.1	36.63	24	21.07	14.56	47.2	189.06	312.54	473.48	463.52	259.5	112.26
1967	57.65	38.41	24.22	15.22	39.41	115.61	236.76	359.96	538.65	382.18	245.53	134.91
1968	42.94	39.78	27.55	17.64	21.56	59.67	132.18	187.14	567.93	570.93	265.59	121.92
1969	64.36	41.04	23.84	14.37	28.53	75.27	152.55	413.28	494.43	404.42	179.37	91.13
1970	55.64	34.37	27.47	18.99	21.44	79.76	248.62	443.07	542.73	374.52	179.64	96.16
1971	51.87	31.08	21.62	14.34	15.08	57.76	139.42	259.7	477.85	426.29	221.67	103.42
1972	60.22	33.43	19.11	21.49	18.55	47.43	142.57	320.57	457.79	374.42	201.96	105.46
1973	56.93	32.51	17.04	17.04	19.31	69.46	165.8	278.51	422.6	355.11	165.15	72.9
1974	40.89	21.11	18.57	19.54	35.74	114.31	183.98	272.57	466.61	406.04	201.62	83.76
1975	45.96	25.4	16.76	20.85	27.19	100.18	177.31	312.98	475.27	413.24	192.06	80.27
1976	43.67	30.62	24.35	24.48	29.1	59.81	158.72	236.33	318.68	452.5	204.49	82.7
1977	41.98	33.22	26.16	13.57	22.45	60.93	157.56	271.28	406.99	328.08	156.85	86.62
1978	40.9	27.74	25.94	23.82	19.9	72.62	125.93	205.12	342.64	341.09	241.43	131.78
1979	40.72	21.09	14.1	13.17	25.19	88.37	194.77	324.84	395.78	471.41	293.87	117.63
1980	59.05	30.6	17.61	12.06	28.92	74.26	173.45	280.63	329.11	218.97	117.61	40.88
1981	27.4	23.84	21.84	27.23	93.43	162.69	301.77	431.95	512.98	385.49	87.35	59.01
1982	60.17	41.55	33.01	33.55	33.13	42.21	99.01	268.04	426.65	381.62	152.5	49.11
1983	38.65	35.19	29.64	25.43	28.51	64.99	212.74	356.8	369.83	301.07	212.57	86.4
1984	42.15	31.41	27.05	29.88	27.66	63.43	158.29	365.68	444.83	490.02	265.1	135.92
1985	49.64	26.71	22.43	21.07	22.21	56.41	193.27	311.56	259.53	172.23	48.41	37.38
1986	26.05	21	19.36	20.53	29.91	62.65	169.86	272.56	402.48	266.79	85.1	41.23
1987	27.13	21.83	22.23	23.54	22.47	31.79	169.16	218.01	251.07	235.69	69.45	33.25
1988	24.27	21.22	21.09	22.1	24.51	70.88	190.06	255.84	304.18	227.24	170.23	61.8
1989	35.09	29.87	27.12	21.82	21.76	100.95	206.04	357.7	424.37	345.82	214.44	71.05
1990	42.83	29.82	24.4	28.34	25.96	39.93	135.18	200.21	304.96	384.86	141.6	60.73
1991	64.37	30.17	29.36	39.58	33.71	59.99	159.09	248.29	477.58	289.2	75.56	34.13
1992	24.7	20.97	21.27	22.19	21.43	27.66	157.39	327.62	408.82	223.9	93.65	35.43
1993	27.35	27.19	23.58	23.01	31.98	77.48	146.18	243.75	327.99	281.28	206.63	64.54
1994	38.09	29.46	27.68	29.09	50.97	108.68	211.74	348.16	402.86	228.94	161.31	57.98
1995	34.94	27.95	23.78	23.15	30.19	64.56	199.6	332.71	468.03	214.67	60.82	37.39
1996	26.69	23.18	21.91	23.37	29.91	33.59	109.99	184.66	238.94	182.92	62.34	43.92
1997	82.37	27.87	23.68	31.07	42.63	149.19	233.35	364.12	249.36	253.28	144.99	76.89
1998	43.19	28.74	22.76	26.76	55.48	160.74	219.91	311.16	331.25	223.76	301.93	209.43
1999	121.54	64.16	52.67	50.56	53	101.07	190.31	365.21	437.37	356.71	321.88	131.49
2000	26.53	21.95	19.19	18.63	22.67	139.49	193.28	270.27	286.38	318.79	245.17	62.07
2001	32.63	24.45	31.44	31.65	51.91	130.3	196.44	219.45	307.04	260.56	214.26	123.39
2002	69.93	47.49	40.32	47.81	45.9	150.2	227.06	388.91	430.31	280.81	228.61	99.22
2003	67.21	51.52	39.83	43.17	36.47	63.63	173.86	220.29	256.08	204.32	100.41	59.29
2004	48.29	35.18	33.79	40.55	49.87	42.01	165.9	227.15	290.96	255.92	99.77	58.22
2005	39.79	37.35	29.03	27.93	32.98	80.91	175.45	224.47	299.45	250.72	158.93	75.9

m^3/s

Birbir R RES 32

	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	55.16	59.99	53.37	63.15	57.11	95.33	266.88	374.04	357.26	126.17	107.08	60.44
1962	55.16	59.99	53.37	63.15	57.11	95.33	266.88	374.04	357.26	126.17	107.08	60.44
1963	59.21	59.93	53.86	54.67	57.34	84.18	149.06	203.68	261.92	206.88	68.91	58.8
1964	55.69	57.66	51.75	58.27	72.36	102.33	158.04	295.61	235.77	107.17	80.21	75.97
1965	63.8	59.53	53.14	57.42	58.38	87.05	231.03	278.67	264.52	297.18	83.57	61.76
1966	58.68	58.98	51.46	59.19	53.64	78.12	187.21	228.71	165.97	218.44	101.18	74.08
1967	61.35	66.36	59.1	63.67	59.69	74.12	191.5	236.24	277.71	115.11	93.37	72.46
1968	49.03	40.06	33.55	30.38	46.7	90.11	167.44	256.71	299	178.16	93.23	62.89
1969	40.43	31.89	27.67	25.05	38.51	74.3	138.07	211.67	246.55	146.9	76.87	51.86
1970	30.43	24.86	20.83	18.86	28.99	55.93	103.93	159.34	185.59	110.58	57.87	39.04
1971	48.3	39.46	33.05	29.93	46	88.76	164.93	252.86	294.52	175.49	91.83	61.95
1972	44.57	36.41	30.5	27.62	42.45	81.91	152.21	233.34	271.79	161.95	84.74	57.17
1973	42.08	33.2	28.8	26.08	40.09	77.34	143.72	220.34	256.64	152.92	80.02	53.98
1974	53.21	43.47	36.41	32.97	50.68	97.79	181.71	278.57	324.48	193.34	101.17	68.25
1975	50.63	41.37	34.65	31.37	48.23	93.06	172.92	265.09	308.77	183.98	96.27	64.95
1976	51.67	42.22	35.36	32.01	49.22	94.96	176.45	270.52	315.09	187.75	98.24	66.28
1977	43.64	34.43	29.86	27.04	41.57	80.2	149.04	228.49	266.13	158.58	82.98	55.98
1978	50.07	40.91	34.26	31.03	47.69	92.02	171	262.16	305.35	181.94	95.2	64.23
1979	50.62	41.36	34.64	31.37	48.22	93.03	172.87	265.03	308.7	183.94	96.25	64.93
1980	52.1	42.57	35.65	32.28	49.63	95.75	177.93	272.78	317.72	189.32	99.06	66.83
1981	53.07	41.87	36.32	32.89	50.55	97.53	181.24	277.86	323.64	192.84	100.91	68.08
1982	51.72	42.26	35.39	32.05	49.27	95.06	176.64	270.81	315.43	187.95	98.35	66.35
1983	44.16	36.08	30.22	27.36	42.07	81.17	150.83	231.22	269.32	160.48	83.97	56.65
1984	38.37	31.35	26.26	23.78	36.55	70.52	131.04	200.9	234	139.43	72.96	49.22
1985	35.76	28.2	24.47	22.16	34.06	65.71	122.11	187.2	218.04	129.92	67.98	45.86
1986	43.04	35.16	29.45	26.67	40.99	79.09	146.97	225.31	262.43	156.37	81.82	55.2
1987	33.12	27.05	22.66	20.52	31.54	60.86	113.09	173.37	201.94	120.33	62.96	42.48
1988	41.83	34.18	28.62	25.92	39.84	76.88	142.85	219	255.08	151.99	79.53	53.66
1989	47.83	37.73	32.73	29.64	45.56	87.91	163.35	250.42	291.68	173.8	90.95	61.35
1990	45.7	37.34	31.27	28.32	43.53	83.99	156.07	239.27	278.69	166.06	86.89	58.62
1991	40.29	32.92	27.57	24.96	38.37	74.04	137.58	210.92	245.67	146.38	76.6	51.68
1992	51.65	42.2	35.34	32	49.19	94.91	176.37	270.39	314.93	187.65	98.19	66.24
1993	55.91	44.1	38.25	34.64	53.25	102.74	190.92	292.69	340.91	203.14	106.29	71.71
1994	55.69	45.49	38.1	34.5	53.04	102.34	190.17	291.54	339.58	202.34	105.88	71.43
1995	46.43	37.93	31.77	28.77	44.22	85.32	158.55	243.07	283.12	168.7	88.27	59.55
1996	40.25	32.89	27.54	24.94	38.34	73.98	137.47	210.75	245.47	146.26	76.54	51.63
1997	44.13	34.81	30.2	27.35	42.04	81.11	150.72	231.07	269.14	160.37	83.92	56.61
1998	39.51	32.28	27.03	24.48	37.63	72.6	134.92	206.84	240.92	143.55	75.12	50.68
1999	48.1	39.3	32.92	29.81	45.82	88.4	164.28	251.85	293.34	174.79	91.46	61.7
2000	49.8	40.69	34.08	30.86	47.44	91.52	170.07	260.73	303.69	180.96	94.69	63.88
2001	54.28	54.48	49.33	52.86	61.94	125.4	160.71	164.56	159.49	173.5	92.6	63.36
2002	55.51	57.64	50.62	52.21	56.05	89.19	133.79	215.7	214.56	109.87	78.87	59.85
2003	55.06	56.99	50.44	51.29	50.8	70.76	107.46	170.14	175.64	92.03	57.56	53.31
2004	51.44	55.73	51.43	49.76	50.34	61.68	104.68	133.99	182.6	113.13	68.46	56.1
2005	52.28	53.63	49.01	51.46	50.78	70.29	129.06	138.16	186.5	129.89	71.68	58.79

m^3/s

Halele RES	33											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	20.16	18.03	16.97	19.1	23.36	46.77	200.7	336.2	289.02	163.1	50.67	32.22
1962	20.16	18.03	16.97	19.1	23.36	46.77	200.7	336.2	289.02	163.1	50.67	32.22
1963	19.1	16.97	15.91	18.03	21.58	42.86	181.55	303.92	261.36	147.9	46.41	29.74
1964	11.31	9.16	7.26	9.62	12.95	3.34	88.62	192.5	162.3	41.7	8.53	9.29
1965	5.96	4.21	4.09	9	12.46	39.66	211.8	195.7	308.6	234.7	55.66	55.2
1966	15.49	8.06	3.52	16.52	2.61	27.84	129.1	290.6	192.6	208.7	87.07	36.13
1967	13.81	18.59	14.71	32.19	6.46	29.84	181.1	269.9	311	75.27	32.11	12.25
1968	5.2	3.12	5.95	9.93	15.42	29.17	142.9	258.1	210.7	221.5	91.27	42.6
1969	20.52	20.67	10.84	13.08	12.31	49.34	190.4	248.8	181.7	133.5	42.89	26.23
1970	12.87	20.11	35.51	16.36	26.9	74.76	199	311.5	253.7	183.1	32.9	18.26
1971	12.53	8.88	9.46	6.87	6.15	21.01	164.4	351.6	245.7	123.3	29.57	14.33
1972	9.99	6.77	6.3	4.53	11.33	33.84	152.1	275.5	215.7	147.8	42.82	18.54
1973	13.36	8.7	6.41	10.18	13.55	21.1	162.1	221.9	165	49.09	15.58	6.03
1974	2.28	2.34	1.66	11.01	9.54	8.1	112.4	284.6	293.8	145.3	27.9	9.31
1975	4.12	4.28	5.01	8.91	15.05	9.37	54.97	159.4	136.2	161.7	56	12.21
1976	7.41	6.99	2.97	2.57	5.66	44.92	171.3	420.5	424.9	180.9	49.8	24.84
1977	15.52	10.07	9.11	7.46	25.53	46.56	166.1	196.2	144.8	62.23	21.36	9.28
1978	6.61	5.35	2.68	6.04	5.51	33.94	240.6	236.3	412.8	317.6	18.94	34.83
1979	15.23	8.6	8.17	4.57	15.71	52.37	275.6	347.3	266.8	203.3	51.75	28.77
1980	26.92	22.83	16	14.72	19.69	42.84	147.4	219.2	173.6	74.17	59.98	22.63
1981	69.14	49.31	32.25	19.67	28.82	18.78	146.9	197.2	100	40.69	39.2	20.4
1982	16	16.24	6.87	7.02	6.7	9.71	68.24	239.4	237	113.7	17.9	8.91
1983	7.46	5.1	5.43	7.63	8.89	22.91	67.92	198	146.2	141.5	46.09	26.03
1984	6.01	5.59	7.51	5.64	24.66	30.75	57.76	321.8	213	183.8	45.02	21.44
1985	10.28	7.9	6.34	3.96	5.04	20.34	113.8	213	175.1	27.1	6.57	4.29
1986	3.27	1.94	0.97	2.94	3.57	1.91	82.95	216.3	230.8	62.87	14.42	5.46
1987	3.73	2.43	2.49	2.4	1.16	33.66	171.2	155.1	192.8	73.72	12.29	4.48
1988	2.39	2.08	2.02	2.42	1.08	20.96	72.24	123.1	112.8	44.93	10.33	7.17
1989	9.61	4.97	5.15	1.51	1.07	21.07	119.3	335	249.6	170.3	17.8	12.42
1990	12.62	8.02	5.93	9.58	6.75	22.08	97.01	217.6	224.8	83.98	18.09	12.8
1991	34.91	10.84	9.19	17.49	15.28	50.66	214.3	321.4	248.1	94.88	38.31	1.85
1992	9.62	6.41	6.31	1	1.81	127.1	189.5	249.4	314.7	102.7	6.62	1.22
1993	7.47	8.37	5.54	2.97	9.83	23.84	123.9	439.8	260.1	145.1	18.35	10.65
1994	14.92	8.49	8.99	13.16	60.18	411.3	227.6	266.5	207.9	161.5	47.41	27.5
1995	19.18	16.01	11.62	9.79	38.44	17.23	215	540	338	129	39.2	18.47
1996	19	15.26	10.09	12.41	14.55	29.03	97.59	439.3	301	69.14	23.18	11.34
1997	7.99	5.29	3.48	29.97	81.46	217.2	310.5	590.6	220.8	150.9	55.24	33.11
1998	26.16	23.92	14.59	26.48	29.82	100.6	190.6	218.2	168.4	154.7	173.1	47.01
1999	41.72	22.43	24.59	14.24	27.07	51.14	238.6	486.6	390	307.7	134.9	24.57
2000	28.77	15.95	13.27	10.42	24	63.91	156.2	288.7	188.2	250.5	94.04	25.77
2001	21.06	11.82	7.99	11.25	26.82	50.88	153.4	472.6	368.1	281.8	97.14	40.31
2002	21.24	17.15	13.56	13.74	28.59	39.57	252.2	321.5	245.2	152	44.82	20.11
2003	10.77	9.49	8.64	12.63	11.04	28.57	112.3	231.9	192.3	65.4	21.01	2.08
2004	8.74	5.66	7.14	9.21	5.13	18.5	107.81	218.07	202.77	85.79	25.04	14.51
2005	21.95	29.17	32.25	38.89	41.96	66.11	130.37	172.15	169.81	164.5	61.43	28.18

m^3/s

Werabesa RES	34											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	1.517	1.357	1.277	1.437	1.757	3.519	15.101	25.296	21.747	12.272	3.812	2.424
1962	1.517	1.357	1.277	1.437	1.757	3.519	15.101	25.296	21.747	12.272	3.812	2.424
1963	1.437	1.277	1.197	1.357	1.624	3.225	13.66	22.868	19.665	11.125	3.492	2.238
1964	0.851	0.689	0.546	0.724	0.975	0.251	6.668	14.49	12.21	3.137	0.642	0.699
1965	0.448	0.316	0.308	0.677	0.938	2.984	15.93	14.72	23.22	17.66	4.188	4.153
1966	1.166	0.606	0.265	1.243	0.196	2.095	9.716	21.87	14.49	15.7	6.552	2.719
1967	1.039	1.399	1.106	2.422	0.486	2.245	13.63	20.31	23.4	5.663	2.416	0.922
1968	0.391	0.235	0.447	0.747	1.16	2.195	10.75	19.42	15.85	16.67	6.867	3.205
1969	1.544	1.555	0.815	0.984	0.926	3.712	14.33	18.72	13.67	10.04	3.227	1.973
1970	0.969	1.513	2.672	1.231	2.024	5.625	14.98	23.44	19.09	13.77	2.475	1.374
1971	0.943	0.668	0.711	0.517	0.463	1.581	12.37	26.45	18.49	9.274	2.225	1.078
1972	0.752	0.51	0.474	0.341	0.853	2.546	11.44	20.73	16.23	11.12	3.222	1.395
1973	1.005	0.654	0.482	0.766	1.02	1.588	12.2	16.7	12.41	3.694	1.172	0.454
1974	0.172	0.176	0.125	0.828	0.718	0.61	8.459	21.41	22.11	10.93	2.099	0.7
1975	0.31	0.322	0.377	0.67	1.133	0.705	4.136	12	10.24	12.17	4.213	0.919
1976	0.558	0.526	0.224	0.194	0.426	3.38	12.89	31.64	31.97	13.61	3.747	1.869
1977	1.168	0.758	0.686	0.562	1.921	3.503	12.5	14.76	10.89	4.682	1.607	0.698
1978	0.497	0.402	0.202	0.454	0.414	2.554	18.1	17.78	31.06	23.9	1.425	2.621
1979	1.146	0.647	0.615	0.344	1.182	3.941	20.74	26.13	20.08	15.3	3.894	2.165
1980	2.026	1.717	1.204	1.107	1.481	3.223	11.09	16.5	13.06	5.581	4.513	1.702
1981	5.202	3.71	2.427	1.48	2.168	1.413	11.06	14.84	7.527	3.062	2.95	1.535
1982	1.204	1.222	0.517	0.528	0.504	0.731	5.134	18.01	17.83	8.556	1.347	0.67
1983	0.561	0.384	0.409	0.574	0.669	1.724	5.11	14.89	11	10.65	3.467	1.958
1984	0.452	0.42	0.565	0.425	1.855	2.313	4.346	24.21	16.03	13.83	3.387	1.613
1985	0.774	0.595	0.477	0.298	0.38	1.531	8.566	16.03	13.18	2.039	0.494	0.323
1986	0.246	0.146	0.073	0.221	0.268	0.144	6.241	16.27	17.36	4.73	1.085	0.411
1987	0.281	0.183	0.187	0.181	0.087	2.533	12.88	11.67	14.51	5.547	0.925	0.337
1988	0.18	0.157	0.152	0.182	0.081	1.577	5.435	9.26	8.488	3.381	0.777	0.54
1989	0.723	0.374	0.387	0.114	0.081	1.585	8.978	25.21	18.78	12.81	1.339	0.935
1990	0.95	0.604	0.447	0.721	0.508	1.662	7.299	16.37	16.91	6.319	1.361	0.963
1991	2.627	0.816	0.692	1.316	1.15	3.812	16.13	24.18	18.67	7.139	2.883	0.139
1992	0.724	0.482	0.475	0.076	0.136	9.565	14.26	18.76	23.68	7.731	0.498	0.092
1993	0.562	0.63	0.417	0.224	0.74	1.794	9.323	33.09	19.57	10.92	1.381	0.801
1994	1.122	0.639	0.677	0.99	4.528	30.95	17.12	20.05	15.65	12.15	3.567	2.069
1995	1.443	1.205	0.874	0.737	2.892	1.296	16.18	40.63	25.43	9.706	2.949	1.39
1996	1.429	1.148	0.76	0.934	1.095	2.184	7.343	33.05	22.64	5.202	1.744	0.853
1997	0.601	0.398	0.262	2.255	6.129	16.34	23.36	44.43	16.61	11.35	4.156	2.492
1998	1.968	1.799	1.098	1.992	2.244	7.566	14.34	16.42	12.67	11.64	13.02	3.537
1999	3.139	1.688	1.85	1.072	2.037	3.847	17.96	36.61	29.34	23.15	10.15	1.849
2000	2.164	1.2	0.999	0.784	1.806	4.809	11.75	21.72	14.16	18.84	7.076	1.939
2001	1.585	0.889	0.601	0.846	2.018	3.829	11.55	35.56	27.7	21.2	7.309	3.033
2002	1.598	1.29	1.02	1.034	2.151	2.977	18.98	24.19	18.45	11.44	3.372	1.513
2003	0.811	0.714	0.65	0.95	0.83	2.15	8.449	17.45	14.47	4.921	1.581	0.157
2004	0.658	0.426	0.538	0.693	0.386	1.392	8.112	16.407	15.256	6.455	1.884	1.092
2005	1.652	2.195	2.427	2.926	3.157	4.974	9.809	12.952	12.777	12.376	4.622	2.12

m^3/s

Chemoga RES	35											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	0.224	0.248	0.224	1.235	0.896	1.35	25.426	34.76	19.29	12.17	1.698	1.008
1962	0.224	0.248	0.224	1.235	0.896	1.35	25.426	34.76	19.29	12.17	1.698	1.008
1963	0.523	0.372	0.597	0.502	0.523	0.579	8.438	24.007	18.248	6.272	0.772	0.485
1964	0.448	0.372	0.261	0.502	0.784	0.772	11.798	27.33	22.569	2.016	0.926	3.398
1965	1.12	0.918	0.597	0.502	0.597	1.968	22.289	27.143	22.415	9.782	0.965	1.083
1966	0.56	0.496	0.299	0.579	0.261	0.309	7.654	25.015	7.176	3.547	0.887	2.053
1967	0.672	0.661	0.411	0.386	0.299	0.617	7.131	22.887	18.943	1.195	0.694	0.411
1968	0.261	0.248	0.299	0.231	0.56	0.309	13.926	28.599	16.86	9.409	1.89	0.784
1969	0.448	0.439	0.299	0.386	0.336	2.816	14.412	24.156	16.898	4.63	0.849	0.485
1970	0.56	1.364	4.928	1.312	1.792	1.312	14.673	29.645	15.702	1.456	0.617	0.373
1971	0.299	0.289	0.336	0.347	0.187	0.347	11.462	33.079	11.381	3.323	0.694	0.373
1972	0.336	0.248	0.224	0.193	0.373	2.238	16.502	29.533	9.877	3.099	1.505	0.56
1973	0.448	0.319	0.299	0.347	0.523	0.386	6.832	17.884	6.674	1.232	0.617	0.336
1974	0.187	0.124	0.112	0.116	0.411	0.656	11.238	22.065	10.918	2.912	0.733	0.336
1975	0.261	0.165	0.336	0.193	0.411	1.042	10.902	24.94	7.292	1.68	0.694	0.336
1976	0.224	0.496	0.187	0.116	0.149	2.508	14.598	35.282	21.566	3.174	0.772	0.523
1977	0.597	0.519	0.635	0.502	0.933	2.546	21.767	26.583	7.832	1.829	3.125	0.821
1978	0.411	0.413	0.672	0.27	0.523	5.864	1.68	28.898	18.094	7.467	4.128	0.672
1979	0.336	0.165	0.299	0.193	0.299	0.617	9.745	20.199	19.946	11.91	1.042	0.597
1980	0.149	0.455	0.299	0.347	1.083	5.864	18.332	25.276	16.744	2.203	0.54	0.261
1981	0.149	0.279	0.187	0.463	0.336	1.775	20.572	22.999	14.043	2.389	0.656	0.261
1982	0.149	0.041	0.411	0.386	0.336	0.193	9.782	17.286	11.767	2.651	0.733	0.336
1983	1.493	0.496	0.411	0.772	0.56	0.424	6.048	19.863	6.79	5.451	1.659	0.933
1984	0.336	0.372	0.112	0.116	0.411	0.579	3.323	31.063	20.602	5.899	3.241	0.747
1985	0.411	0.2	0.149	0.039	0.373	5.478	21.169	19.9	13.194	1.307	0.502	0.336
1986	0.149	0.083	0.037	0.309	0.149	0.926	14.337	26.135	12.731	2.016	0.502	0.261
1987	0.075	0.041	0.149	0.193	0	1.582	12.731	19.303	13.503	1.232	0.193	0.112
1988	0.224	0.083	1.12	0.617	2.726	4.398	11.201	27.18	7.215	2.427	0.656	4.667
1989	0.261	0.359	0.112	0.039	0.075	0.463	7.355	40.397	19.869	6.646	0.424	0.299
1990	0.187	0.331	0.187	1.08	0.299	0.463	17.361	23.522	9.529	1.867	0.231	0.597
1991	0.373	0.207	0.037	0.54	0.635	0.617	15.494	23.634	12.809	3.696	0.579	0.448
1992	0.149	0.248	0.299	1.427	1.12	5.941	32.855	41.592	33.102	0.56	0.579	0.747
1993	0.299	0.718	0.709	0.502	0.373	0.54	8.027	20.833	21.103	3.622	1.89	0.299
1994	0.485	0.496	0.597	1.89	4.256	9.375	20.236	33.714	28.395	6.048	0.424	0.747
1995	0.224	0.124	0.037	0.116	0.336	0.463	7.43	41.891	9.221	6.384	3.318	0.261
1996	0.075	0.041	0.037	0.733	0.859	0.386	10.865	20.497	10.88	1.269	0.309	0.672
1997	0.933	0.399	0.224	2.122	3.846	5.17	17.025	19.975	13.349	1.792	0.772	0.411
1998	0.224	0.041	0.037	0.154	0.187	1.389	11.947	20.647	7.446	3.883	2.816	0.896
1999	0.922	0.703	0.632	0.502	1.25	1.745	13.445	15.962	12.743	12.24	1.611	0.712
2000	0.642	0.563	0.466	0.48	0.498	1.412	13.954	26.39	11.889	12.32	1.39	0.776
2001	0.606	0.538	0.473	0.559	1.314	1.731	6.308	11.916	16.022	10.25	4.167	1.053
2002	0.673	0.685	0.656	0.615	0.817	2.724	19.615	30.676	6.204	1.927	0.905	0.706
2003	0.985	0.617	0.875	0.883	0.519	1.322	10.365	24.061	13.092	2.998	1.434	1.23
2004	0.528	0.715	1.038	0.979	0.864	1.774	10.136	19.907	14.804	2.462	0.775	0.627
2005	0.541	0.539	0.55	0.793	0.884	1.334	12.458	20.667	8.653	4.336	0.915	0.764

m^3/s

Yeda RES	36											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	0.187	0.289	0.373	1.62	0.896	1.505	25.164	32.034	18.673	11.238	1.62	0.859
1962	0.187	0.289	0.373	1.62	0.896	1.505	25.164	32.034	18.673	11.238	1.62	0.859
1963	0.448	0.289	0.747	0.463	0.821	0.849	8.849	23.746	16.975	5.75	0.694	0.411
1964	0.411	0.413	0.261	0.81	0.896	1.042	11.425	26.06	21.373	1.755	1.119	2.95
1965	1.008	0.878	0.523	0.733	0.896	2.199	21.393	25.724	21.489	8.998	0.81	1.045
1966	0.485	0.413	0.261	0.617	0.224	0.617	9.222	23.297	6.79	3.398	0.965	1.829
1967	0.56	0.661	0.448	0.54	0.336	1.08	7.766	22.327	17.477	1.045	0.579	0.336
1968	0.224	0.165	0.485	0.193	0.709	0.579	14.486	26.508	16.319	8.774	1.813	0.635
1969	0.373	0.439	0.299	0.463	0.485	3.086	14.188	23.223	16.204	4.294	0.733	0.411
1970	0.635	1.24	4.63	1.273	1.829	1.543	14.262	28.076	14.699	1.157	0.502	0.299
1971	0.299	0.289	0.411	0.347	0.224	0.54	12.059	31.586	11.806	3.51	0.54	0.299
1972	0.336	0.207	0.224	0.193	0.485	2.508	16.204	28.3	9.838	3.323	1.466	0.523
1973	0.411	0.279	0.261	0.54	0.709	0.617	7.43	17.436	7.33	1.008	0.54	0.261
1974	0.149	0.124	0.075	0.309	0.709	0.926	11.462	21.057	10.725	3.024	0.617	0.336
1975	0.224	0.165	0.485	0.193	0.672	1.312	11.35	23.559	8.372	1.605	0.579	0.299
1976	0.224	0.579	0.261	0.154	0.299	2.585	14.972	32.706	20.756	2.726	0.656	0.448
1977	0.523	0.439	0.672	0.54	1.232	2.469	20.945	25.202	8.14	1.456	2.894	0.709
1978	0.373	0.413	0.709	0.231	0.896	5.401	3.211	26.508	16.975	7.318	3.511	0.56
1979	0.261	0.124	0.299	0.231	0.299	0.849	9.894	19.191	18.866	10.902	0.887	0.597
1980	0.187	0.455	0.299	0.309	1.195	5.324	18.332	23.671	16.397	1.941	0.424	0.224
1981	0.149	0.279	0.224	0.463	2.875	1.698	20.161	21.841	12.693	2.726	0.656	0.261
1982	0.187	0.083	0.373	0.386	0.411	0.231	10.305	17.622	12.269	2.651	0.694	0.336
1983	1.232	0.413	0.448	0.694	0.635	0.424	4.966	19.228	6.944	5.824	1.505	0.859
1984	0.299	0.331	0.149	0.116	0.373	0.617	5.563	29.906	18.48	5.115	2.778	0.672
1985	0.373	0.16	0.149	0.077	0.411	5.71	20.796	18.295	12.847	1.195	0.502	0.336
1986	0.149	0.083	0.037	0.309	0.299	0.849	13.329	24.306	12.423	1.941	0.502	0.261
1987	0.075	0.083	0.149	0.231	0.037	2.276	12.769	19.34	13.233	1.381	0.231	0.149
1988	0.224	0.083	1.083	0.656	2.875	4.398	10.043	25.239	6.25	2.165	0.579	3.846
1989	0.261	0.359	0.112	0.039	0.224	0.463	9.745	40.173	18.75	6.944	0.502	0.261
1990	0.187	0.331	0.448	1.157	0.336	0.694	16.614	22.588	9.221	1.68	0.193	1.12
1991	0.411	0.331	0.149	0.54	0.597	0.502	13.814	21.879	11.998	3.248	0.502	0.411
1992	0.149	0.207	0.261	1.157	0.933	4.861	30.13	38.68	28.318	0.597	0.54	0.672
1993	0.261	0.639	0.597	0.54	0.485	0.502	7.504	20.46	19.059	3.734	1.659	0.299
1994	0.448	0.455	0.485	1.929	3.995	8.063	20.721	29.757	25.231	5.824	0.502	0.747
1995	0.224	0.165	0.075	0.116	0.373	0.656	11.761	41.629	10.108	5.414	2.816	0.299
1996	0.112	0.083	0.075	0.772	0.821	0.424	10.715	20.423	10.224	1.12	0.309	0.597
1997	1.008	0.399	0.261	2.431	3.958	5.208	16.502	19.863	12.577	1.68	0.887	0.411
1998	0.224	0.041	0.037	0.116	0.187	1.35	11.574	19.975	7.176	3.734	2.739	0.859
1999	2.072	1.683	2.121	1.976	2.189	3.687	14.602	18.981	5.795	6.249	5.174	2.603
2000	2.489	2.36	1.466	1.379	0.896	1.558	26.799	44.792	17.304	12.154	6.1	3.574
2001	2.639	2.257	1.15	2.202	1.401	1.424	12.272	29.658	12.588	9.032	6.217	3.429
2002	1.829	2.008	3.168	3.354	2.859	4.068	23.487	31.962	11.796	5.49	3.913	3.125
2003	3.491	3.551	2.981	3.155	2.567	3.355	9.347	20.702	8.829	3.433	2.797	2.547
2004	2.331	2.491	2.468	2.483	1.965	2.524	15.093	25.245	10.998	3.868	2.78	2.605
2005	2.566	2.471	2.288	2.425	2.048	2.784	10.949	23.102	7.079	4.192	2.596	2.277

m^3/s

Baro-Genji RES	37											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	29.62	44.79	49.46	50.04	78.63	148.64	192.41	310.27	300.35	172.57	64.04	65.22
1962	39.17	42.46	48.61	51.73	78.85	164.34	194.74	307.52	306.93	197.4	79.52	61.61
1963	52.9	42.41	46.05	48.56	74.34	163.82	171.89	270.01	329.9	212.83	94.13	58.47
1964	52.59	48.61	44.63	42.03	69.62	112.9	104.78	198.83	287.78	162.12	79	63.41
1965	57.95	49.03	45.8	49.46	74.82	115.08	115.71	203.39	190.02	147.69	88.34	62.08
1966	48.35	50.26	46.75	46.27	61.81	118.79	215.21	281.41	180.26	119.58	79.65	54.92
1967	33.39	33.03	35.9	44.02	51.88	128.69	235.68	308.55	234.26	222.04	60.97	41.41
1968	21.5	13.1	19.4	40.3	66.9	167.4	231.2	353.7	321	272.8	68.2	35.9
1969	22	15.6	24.5	55.9	105.4	148.5	245	434.3	216.9	117.9	89.6	25
1970	14.2	11.7	21.5	61.8	132.3	145.1	241.3	329.7	262	181	60.5	45.6
1971	22.3	17.6	47.6	87.2	151.1	161.5	240.1	282.5	258.9	209.8	127.2	79.9
1972	35.8	28.3	73.2	118	196.7	174	243.4	263.7	256.4	175.3	178.3	48.7
1973	24	17.1	27.7	39.2	90	159	231.3	292.2	238.8	130	82.8	29.2
1974	18.7	12	19.5	36	111.8	147.4	248.8	470.3	277.6	207.1	37.4	22.3
1975	14.9	9.4	14.7	36.4	105.2	123.2	268.5	594.3	286.6	218.5	60.5	26.8
1976	16.5	11.1	28.1	47.6	91.1	151.1	225	231.4	254.1	157.8	114.4	34.4
1977	21.4	15.2	40.6	58.4	86.4	144.7	213.8	293.9	261.4	152.5	108.5	40.1
1978	23.1	15	22.9	38.7	79	140.7	218.3	285.7	275.3	204.8	59.6	50.4
1979	25.9	17	23.9	38.5	110.6	167.6	240	287.7	243.5	174.5	40.3	40.8
1980	22.5	15.8	21.5	38.2	84.2	160.3	222.3	232.8	244.7	132.3	44.8	25.5
1981	19	11.2	16.4	36.7	100.9	165	233.3	277.2	276.8	168.8	39.2	23.3
1982	17.1	10.2	19.7	31.8	60.2	160.3	197.7	247	310	208.1	39.6	19
1983	14	10.1	20.8	40.4	67.2	155.1	211.7	230.1	267.8	191.6	55	23.1
1984	15.8	9.3	14.2	22.1	38.3	150.1	227.2	199.2	239.8	140.1	58	29.3
1985	17.6	8.4	10.5	17.5	48.4	149.2	240.2	206.9	218	92	37.1	33.6
1986	22.3	12.9	16.2	22.3	55.9	149	214.6	226.6	238	125.1	47.1	39.6
1987	28.9	20	25.3	29	38.6	131.8	205.9	229.6	244	148.5	46.3	47.1
1988	28.7	22.1	42	38.8	56	128.9	230.9	309	234	207.5	53.5	37.1
1989	20.1	16.3	64.6	70.4	70.5	122.2	241.9	325.7	236.4	217.3	58.7	54.2
1990	21.1	18.5	49	71.1	77.3	167.2	223.5	268.4	219.2	146.9	48.6	70.1
1991	35.5	30.7	23.7	33.3	112.2	208.3	199.4	271.4	199.8	86.2	39	38.9
1992	38	76.1	88.3	108.3	191	227.4	215.1	254.1	187.2	104.2	74	45.6
1993	28.8	88.7	113.8	142.7	125.9	201	267.2	263.9	223.8	143.9	102.2	38.6
1994	32.2	17.4	17.8	58.4	87.5	161	241.3	261.8	256.4	165.5	68.3	31.3
1995	29	16.2	16.4	53.8	113.6	171.5	286.7	284.8	243.8	144.3	46.4	48.2
1996	21.7	17.6	22.4	64.2	129.6	167.1	334.1	369	271.2	183.3	46.1	50.2
1997	19.3	11.5	16.7	40.3	84.4	169.9	217.8	284.7	326.1	211.4	111.8	20.2
1998	12.6	6.7	15.1	45	86.8	181.6	191.1	410.3	267.8	193.2	160.3	19.4
1999	10.5	6	18.1	22.8	74.5	162.1	239.8	550.3	233.1	253.2	47	14.2
2000	7.8	6.1	3.8	12.4	97.3	154.5	242.5	293.2	185.5	214.5	65	18.6
2001	8	3.1	3.6	11.9	49.9	136.8	260.8	248.5	236.8	247.3	86.7	25
2002	18.5	7.4	10.2	18.4	44.9	152.7	246.3	260.4	260.8	214.9	78.4	30.1
2003	26.5	10.7	13.5	17.4	17	104.8	186.9	207.7	237.1	123.3	66.4	36.2
2004	29.92	23.59	23.56	21.98	31.06	81.28	209.1	185.59	256.85	131.29	51.02	44.49
2005	46.67	44.26	43.68	43.65	51.54	83.82	168.26	225.13	278.12	170.8	77.83	56.83

m^3/s

L Dabus RES	43											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	1.83	1.4	1.21	1.84	2.02	3.23	10.36	19.07	25.09	21.91	9.33	166.62
1962	1.83	1.4	1.21	1.84	2.02	3.23	10.36	19.07	25.09	21.91	9.33	166.62
1963	2.48	1.34	1.07	1.06	1.26	3.52	7.22	13.67	15.69	18.42	5.19	51.29
1964	1.3	1.05	0.99	1.01	2.34	3.44	8.84	16.56	19.38	14.63	7.23	97.56
1965	2.29	1.35	1.1	1.06	1.33	3.7	8.44	18.96	18.14	20.62	11.42	72.52
1966	2.27	1.43	0.94	0.82	0.56	1.84	7.39	12.21	18.49	18.11	10.13	112.26
1967	2.25	1.5	0.95	0.6	1.54	4.52	9.25	14.07	21.04	14.92	9.59	134.91
1968	1.68	1.55	1.08	0.69	0.84	2.34	5.17	7.31	22.19	22.3	10.38	121.92
1969	2.51	1.61	0.93	0.56	1.12	2.94	5.96	16.14	19.32	15.79	7.01	91.13
1970	2.17	1.34	1.07	0.74	0.83	3.11	9.71	17.31	21.2	14.63	7.02	96.16
1971	2.03	1.21	0.85	0.56	0.59	2.25	5.45	10.14	18.67	16.65	8.65	103.42
1972	2.35	1.3	0.75	0.83	0.73	1.85	5.57	12.53	17.88	14.63	7.89	105.46
1973	2.22	1.27	0.67	0.67	0.75	2.71	6.48	10.88	16.51	13.87	6.45	72.9
1974	1.6	0.82	0.73	0.76	1.4	4.46	7.19	10.65	18.22	15.86	7.88	83.76
1975	1.8	1	0.66	0.81	1.06	3.91	6.93	12.22	18.56	16.14	7.5	80.27
1976	1.7	1.2	0.95	0.95	1.14	2.34	6.2	9.23	12.45	17.67	7.98	82.7
1977	1.64	1.3	1.02	0.53	0.88	2.38	6.15	10.6	15.9	12.82	6.13	86.62
1978	1.6	1.08	1.01	0.93	0.78	2.84	4.92	8.01	13.39	13.33	9.43	131.78
1979	1.59	0.82	0.55	0.52	0.99	3.45	7.61	12.69	15.46	18.41	11.48	117.63
1980	2.3	1.2	0.69	0.47	1.13	2.9	6.78	10.97	12.86	8.56	4.59	40.88
1981	1.07	0.93	0.86	1.07	3.65	6.35	11.79	16.87	20.04	15.06	3.42	59.01
1982	2.35	1.62	1.29	1.31	1.29	1.64	3.86	10.47	16.66	14.91	5.95	49.11
1983	1.51	1.37	1.16	1	1.12	2.54	8.31	13.94	14.44	11.76	8.3	86.4
1984	1.64	1.22	1.06	1.16	1.08	2.48	6.19	14.29	17.38	19.14	10.36	135.92
1985	1.94	1.04	0.88	0.82	0.87	2.21	7.55	12.18	10.13	6.73	1.89	37.38
1986	1.02	0.82	0.75	0.8	1.16	2.44	6.63	10.65	15.72	10.43	3.32	41.23
1987	1.06	0.86	0.87	0.92	0.88	1.24	6.61	8.51	9.8	9.21	2.71	33.25
1988	0.95	0.83	0.82	0.87	0.96	2.77	7.42	9.99	11.88	8.88	6.65	61.8
1989	1.37	1.16	1.06	0.86	0.85	3.95	8.04	13.97	16.58	13.51	8.37	71.05
1990	1.68	1.16	0.95	1.1	1.01	1.56	5.28	7.82	11.92	15.03	5.53	60.73
1991	2.51	1.17	1.15	1.55	1.32	2.35	6.21	9.7	18.66	11.3	2.95	34.13
1992	0.96	0.82	0.83	0.87	0.83	1.08	6.15	12.8	15.97	8.75	3.66	35.43
1993	1.07	1.06	0.92	0.9	1.25	3.03	5.71	9.52	12.81	10.99	8.07	64.54
1994	1.49	1.15	1.08	1.14	2	4.25	8.27	13.6	15.73	8.95	6.3	57.98
1995	1.36	1.09	0.93	0.9	1.17	2.52	7.8	13	18.28	8.38	2.37	37.39
1996	1.04	0.9	0.86	0.92	1.16	1.31	4.3	7.21	9.33	7.15	2.43	43.92
1997	3.22	1.09	0.93	1.21	1.67	5.82	9.11	14.22	9.74	9.9	5.66	76.89
1998	1.69	1.13	0.89	1.05	2.17	6.28	8.59	12.15	12.94	8.74	11.8	209.43
1999	4.66	2.5	2.06	1.97	2.07	3.95	7.43	14.27	17.08	13.94	12.58	131.49
2000	1.03	0.86	0.75	0.73	0.88	5.45	7.55	10.56	11.19	12.46	9.58	62.07
2001	1.28	0.95	1.23	1.23	2.03	5.1	7.68	8.57	12	10.18	8.37	123.39
2002	2.74	1.86	1.57	1.87	1.8	5.87	8.87	15.19	16.81	10.97	8.93	99.22
2003	2.63	2.01	1.56	1.69	1.42	2.49	6.79	8.61	10	7.98	3.92	59.29
2004	1.89	1.37	1.32	1.58	1.95	1.64	6.48	8.88	11.37	9.99	3.9	58.22
2005	1.55	1.46	1.14	1.09	1.29	3.16	6.86	8.77	11.7	9.79	6.21	75.9

m^3/s

Wabi Shebele 56

	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	48.607	57.7914	72.6326	112.35	87.298	77.6538	169.986	294.652	211.55	151.074	74.961	48.8965
1962	48.607	57.7914	72.6326	112.35	87.298	77.6538	169.986	294.652	211.55	151.074	74.961	48.8965
1963	47.9325	52.0234	59.8975	73.5655	64.5285	55.2201	115.182	221.991	206.266	195.36	71.1725	51.3101
1964	53.4318	57.365	60.2826	94.503	109.972	57.4141	120.779	228.454	154.421	78.5169	55.0211	43.8805
1965	41.8544	48.4675	59.6081	78.1525	73.6947	58.1118	119.33	231.059	204.371	132.548	58.8096	45.4233
1966	41.8544	43.0509	53.915	63.3966	55.8455	52.2301	105.822	212.92	160.403	95.5	68.5805	50.248
1967	48.9947	55.9747	55.2666	70.0768	56.1349	57.4141	123.286	264.829	183.734	94.534	53.6256	43.3972
1968	42.0483	42.9424	42.3377	55.7188	62.5024	52.6281	129.943	251.707	220.823	201.728	143.854	55.3622
1969	43.591	73.0151	87.202	209.757	117.497	85.13	146.154	224.691	143.854	92.604	57.6131	47.9325
1970	57.1944	78.4084	137.373	82.538	90.288	56.9153	144.319	263.478	162.398	68.87	49.8371	45.5215
1971	54.6877	46.0409	108.429	112.848	75.0437	49.8371	106.884	290.589	224.412	121.839	60.603	44.6532
1972	44.7488	43.1569	44.4593	65.9886	91.35	99.586	181.274	265.793	167.882	154.933	64.6913	51.5014
1973	46.8704	67.0326	70.896	145.647	81.509	55.9178	133.998	171.335	143.554	56.6156	52.7289	45.0382
1974	42.8184	41.9811	41.2756	41.2626	49.1859	48.4416	113.83	241.866	164.192	74.0798	44.3534	44.1699
1975	44.555	42.516	57.7733	55.7188	48.1264	51.6306	112.962	160.432	118.828	56.0367	49.2376	45.6171
1976	43.0122	43.6918	42.2395	55.3209	49.5735	68.6787	151.459	311.914	230.193	96.948	50.1369	41.565
1977	44.0743	42.3842	44.0743	49.1394	78.3257	52.5273	122.612	228.743	141.562	59.7037	87.425	49.3797
1978	69.7383	67.5132	53.1423	80.0468	77.2635	85.43	224.596	404.068	250.234	302.74	109.057	46.9686
1979	46.0021	53.5196	94.922	66.8853	50.4418	53.2276	165.355	271.293	167.683	115.761	52.5273	49.7648
1980	72.3432	104.044	76.6847	84.432	81.22	75.6587	100.71	152.328	127.103	89.035	53.0261	44.7488
1981	42.8184	44.343	43.8805	46.5474	56.4243	52.7289	177.705	288.082	131.99	82.282	47.6431	43.8805
1982	43.1078	42.6219	60.0888	133.783	57.2926	45.4491	69.3532	195.071	238.768	91.255	49.7363	44.2655
1983	48.222	58.9672	69.4488	69.6762	72.2476	55.8196	93.859	242.541	144.95	128.69	63.3966	63.6602
1984	47.3537	51.7029	51.3101	130.494	184.072	89.218	96.754	342.201	283.534	138.918	84.334	49.9586
1985	44.0743	42.1775	42.5289	42.7589	48.9947	81.442	133.321	159.372	141.461	58.3522	51.2326	46.2916
1986	44.0743	43.4773	43.4954	64.2933	84.693	77.553	150.4	266.757	193.606	95.981	54.5223	45.232
1987	42.4333	52.1293	52.8529	79.6462	74.7543	78.2507	133.225	223.919	174.761	102.059	54.0236	45.232
1988	44.4593	50.9535	86.334	119.229	128.111	97.594	122.227	221.218	137.174	116.146	68.8803	46.1959
1989	47.6431	57.4425	52.1784	62.797	56.0367	73.2657	111.034	256.725	157.214	99.938	63.0968	51.2119
1990	45.4233	45.8264	43.7849	148.04	62.8875	57.7138	159.951	176.547	158.31	97.526	80.4447	51.7908
1991	67.0377	96.782	143.934	142.758	78.3257	74.4622	103.315	211.183	169.378	138.435	77.2532	68.1955
1992	49.2841	59.9285	35.9676	36.3759	66.6501	112.549	80.3517	195.071	217.732	119.234	32.6882	41.565
1993	48.4158	55.1736	32.6882	37.4742	52.1784	53.5248	106.884	261.258	97.594	68.0973	44.4516	32.6882
1994	32.882	66.9783	35.8719	56.1168	93.859	108.561	134.962	203.464	113.843	88.36	33.5849	40.4073
1995	32.6882	32.6882	32.6882	34.4816	76.6847	32.6882	126.857	260.777	238.37	32.6882	32.6882	32.6882
1996	32.6882	32.6882	33.8459	89.417	50.9225	32.6882	94.823	194.396	159.706	53.0467	43.9554	39.8284
1997	39.4433	32.6882	35.0993	71.1725	128.4	135.977	172.686	284.511	168.978	48.9947	32.6882	33.3627
1998	37.7042	32.6882	36.5464	45.1519	40.6967	32.6882	147.216	161.109	72.568	120.875	168.182	76.9741
1999	54.6981	52.5144	94.325	136.926	244.43	96.526	120.826	169.247	164.303	138.554	58.7243	36.2363
2000	40.3142	33.8588	91.229	100.056	69.8029	53.0648	102.318	168.575	120.462	173.301	43.6065	33.4066
2001	36.1071	32.9724	46.5422	111.401	88.613	50.2919	96.149	182.493	107.98	116.869	99.134	47.8395
2002	76.0283	79.672	74.9481	76.4107	75.2711	80.7884	107.129	182.002	140.836	93.229	79.3387	75.8241
2003	75.4727	79.4188	74.8034	76.9844	74.5759	79.3206	112.192	167.226	124.41	82.59	77.5659	75.4856
2004	74.9765	79.0157	74.7129	75.7363	74.0126	78.933	95.304	179.762	207.036	118.671	78.0388	75.4494
2005	74.7465	77.2894	74.1392	75.6794	74.1004	82.884	137.078	156.287	140.122	109.114	80.7988	75.7905

m^3/s

Beko Abo	57											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	19.03	12.55	8.61	11.68	4.23	0	51.4	53.3	121.8	86.3	56.5	48.3
1962	25.72	13.24	10.78	5.6	3.66	0	0	135.3	84.2	53.4	29.61	27.36
1963	20.64	14.58	11.9	4.83	16.19	6.2	24.8	162.2	84.2	38.1	44.39	34.98
1964	22.2	13.7	5.71	7.15	0.57	2.78	93	253.1	170.6	83.3	55.66	47.51
1965	31.26	19.11	12.23	13.53	3.14	0	28.4	34.4	0	30.4	21.1	20.82
1966	14.36	13.1	6.23	3.04	0.36	1.03	0	7.3	42	17.6	20.74	17.67
1967	13.31	7.72	8.11	12.57	15.62	1.9	106.6	172.6	69	35.3	34.35	25.94
1968	18.88	13.16	8.8	9.09	5.3	14.21	12.2	89.9	42.3	48.9	29.54	22.25
1969	15.86	12.23	18.3	3.65	3.9	0	54.8	102.6	186.1	48.1	22.89	20.59
1970	16.91	14.59	12.23	7.59	6.48	4.11	85.9	57.1	111.7	57	28.82	22.67
1971	15.01	10.66	5.99	5.31	3.8	7.9	72.7	104.8	112	36.5	25.8	20.44
1972	11.22	8.21	4.29	7.21	0.59	5.7	50.2	9.3	0	3.9	10.15	8.36
1973	6.17	3.45	1.33	0	0	0	47.8	140.4	0	33.7	18.4	14.55
1974	12.68	7.37	4.23	1.11	3.76	3.44	27.2	98.8	82.9	52.2	33.56	22.41
1975	18.5	15.16	8.86	5.29	0.43	13.76	10.8	246.5	241.8	105.9	45.97	38.02
1976	33.67	18.71	13.36	9.57	6.12	0	41.8	149.4	131.1	36.5	29.45	19.92
1977	14.67	14.27	10.15	4.3	0	0	0	125.4	200.2	46.7	59.19	29.36
1978	23.66	17.11	9.58	4.77	2.1	0	51.5	148.4	56.2	43	31.28	17.58
1979	17.03	14.08	6.4	4.4	3.54	0	0	16.2	58.2	30.2	20.16	13.98
1980	10.16	8.43	6.49	3.76	0	0	0	179.8	235.5	72	36.5	22.97
1981	19.23	21.78	38.8	10.18	10.08	2.8	134.2	182.8	110.4	33.5	27.74	18.69
1982	15.84	11.73	9.65	7.02	4.91	0.7	21.8	45.5	39.3	10.8	15.41	13.63
1983	8.53	5.85	8.54	10.19	13.22	10	4.4	78.9	40.3	34.3	21.74	16.4
1984	10.66	6.07	2.54	0.42	2.28	4.28	0	112.3	0	14	11	6.72
1985	6.85	3.08	3.16	7.95	2	0	0	0	102.8	39.1	14.12	17.55
1986	17.32	14.68	8.68	10.1	22.76	0	100.3	152.3	97.2	64	35.33	21.16
1987	13.29	10.61	13.44	9.91	6.04	0	0	98.8	24.6	23	21.3	7.06
1988	10.16	8.32	3.86	3.22	0	0	148.3	273.1	175.1	122.6	80.96	57.78
1989	26.51	17.07	13.92	14.55	5.73	4.25	14.3	71.4	38	23.3	24.04	14.12
1990	13.21	9.85	4.43	2.8	1.43	0	0	61.8	96.3	37.1	19.77	13.46
1991	8.18	5.45	3.73	5.45	4.8	0	139.4	83.7	112.8	73.4	34.03	21.77
1992	14.67	10.35	6.2	3.1	2.62	0	36.2	204.5	71.3	57	46.8	31.77
1993	16.95	11.03	4.38	26.67	14.59	2.2	64.7	0	54.8	66.6	44.8	26.75
1994	17.03	10.66	6.36	2.23	4.78	14.9	208.2	365.4	216.3	91	46.26	19.68
1995	7.75	5.32	6.24	11.53	7.3	8.7	132	213.9	141.3	33	19.89	12.03
1996	2.53	3.98	11.88	12.63	25.09	54	171.5	324.3	166.6	85.8	45.08	38.13
1997	32.25	19.59	35.7	28.06	35.19	51.8	95.4	141.6	31.3	45.1	60.9	36.01
1998	23.57	5.2	0	0	0.61	0	211.8	612.9	203.5	67.3	38.1	25.03
1999	16.32	10.08	4.88	2.63	0	0	184.4	219.4	51.1	0	51.2	30.65
2000	17.06	9.39	0	8.8	0	0	133.1	369.7	88.4	38.5	49.8	25.14
2001	4.55	4.97	27.34	26.33	19.71	25	267.7	244.4	121.1	50	26.49	18.3
2002	42.69	10.09	23.31	21.75	16.74	20.7	60.4	147.5	36	21.7	14.41	7.46
2003	11.94	8.31	12.56	10.3	5.11	6.53	160.2	221.8	1.2	0.7	17.79	10.94
2004	35.39	31.01	31.62	30.97	26.34	27.79	60.1	189.2	9.8	14.3	28.43	28.95
2005	28.36	29.63	34.75	31.4	43.86	24.06	139.2	275.1	75.4	37.9	40.71	31.69

m^3/s

Karadobi	58											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	129.831	92.067	72.509	102.093	52.24	46.693	1276.4	2173.13	1468.83	842.726	444.164	319.079
1962	168.321	106.567	84.329	47.663	41.03	51.813	461.952	1968.93	1336.13	641.756	286.794	185.619
1963	134.305	100.125	77.028	58.389	117.45	62.522	623.051	2411.66	1118.39	408.742	304.422	249.016
1964	153.641	105.903	58.634	64.462	33.116	92.27	1886.65	2893.56	1726.1	845.593	437.729	305.3
1965	194.594	125.266	84.278	95.233	35.071	22.249	265.142	1700.2	596.67	421.334	275.679	194.792
1966	121.239	103.281	62.806	45.07	23.961	40.462	421.82	1727.15	1044.48	306.037	218.56	147.322
1967	97.904	61.4	62.659	81.86	108.311	36.711	1024.39	2263.78	1236.76	752.572	381.873	239.947
1968	136.821	98.843	64.106	65.3	43.049	138.866	1211.3	1708.83	779.141	452.581	234.369	156.431
1969	124.215	110.07	204.208	63.261	67.499	79.3	965.51	2756.37	1633.16	473.728	237.826	149.45
1970	113.661	94.552	71.626	53.467	20.453	22.547	774.293	2416.35	1393.64	581.365	248.555	157.888
1971	103.666	72.878	45.507	39.478	36.835	106.005	845.375	2481.99	1040.74	469.725	249.086	156.432
1972	105.21	75.897	46.706	59.694	33.202	54.986	557.24	1338.62	431.077	224.038	151.703	93.789
1973	59.645	29.884	19.544	14.869	28.878	50.123	730.756	2435.5	984.602	431.088	219.429	133.891
1974	94.252	61.698	44.757	34.911	59.702	80.786	1401.5	2177.92	1073.75	496.24	264.354	166.742
1975	116.737	97.712	59.959	40.882	25.711	116.406	973.468	2708.05	2259.24	821.099	399.381	272.939
1976	192.32	116.515	92.152	73.392	68.624	57.881	641.648	2290.38	1248.44	353.53	295.638	186.981
1977	122.756	97.542	75.663	39.734	24.559	44.073	988.262	2137.26	1543.5	562.345	482.969	211.732
1978	152.452	108.262	65.911	46.097	33.015	19.055	972.489	1951.84	1116.06	571.457	246.735	161.01
1979	122.135	90.969	47.944	32.024	42.242	65.594	643.765	1838.72	756.2	332.256	203.191	125.884
1980	85.748	61.89	43.598	46.3	20.452	36.616	525.258	2010.79	1654.35	572.556	286.568	173.931
1981	113.552	130.124	225.009	89.902	54.277	28.823	1265.08	2034.01	1210.3	433.133	236.666	151.43
1982	117.126	85.966	64.41	54.412	47.679	42.862	287.095	1821.86	795.784	444.42	213.653	127.746
1983	80.925	59.747	50.085	61.642	91.781	86.772	333.468	1997.21	943.036	379.865	207.68	119.53
1984	77.301	43.573	24.743	19.868	35.762	136.96	646.35	1285.15	474.172	205.286	130.455	82.345
1985	50.72	20.552	19.97	57.298	56.076	46.07	578.115	2030.26	1437.57	477.634	244.492	153.064
1986	106.848	86.404	69.282	88.004	129.574	53.869	1151.46	1895.98	1235.35	490.997	243.434	145.108
1987	94.964	69.756	102.006	85.58	106.133	147.852	230.028	1541.23	503.526	303.147	207.856	118.093
1988	72.828	58.018	29.615	27.649	9.393	23.932	1366.22	3344.22	1891.19	967.27	492.787	325.537
1989	161.226	101.74	84.528	101.058	40.797	53.69	599.6	1690.08	977.455	406.438	226.028	160.202
1990	92.796	69.206	45.537	41.569	23.135	17.393	519.601	1686.96	1027.28	389.137	193.45	109.403
1991	67.344	49.144	34.264	49.126	50.048	61.941	1233.02	2326.35	1432.84	570.568	278.059	166.491
1992	102.8	79.415	51.274	34.338	34.441	18.962	416.107	2082.11	1219.88	628.947	379.621	219.949
1993	123.808	81.113	42.816	180.338	156.772	161.084	1234.31	1793.77	1601.58	726.44	363.707	203.888
1994	115.557	72.575	45.894	23.439	42.725	108.058	1710.66	3463.13	1882.05	733.402	371.24	151.524
1995	60.954	40.725	44.52	83.522	63.335	78.137	998.637	2268.69	1205.94	346.658	184.246	109.582
1996	69.471	40.63	80.364	103.887	207.652	416.958	1917.03	3093.06	1520.52	671.373	341.996	248.715
1997	181.891	116.544	194.421	154.583	205.662	332.206	1249.83	1920.77	611.322	506.82	465.531	244.084
1998	192.55	86.432	46.582	35.236	89.146	115.291	1717.16	4075.51	1697.31	963.509	370.073	206.921
1999	153.16	115.378	69.029	57.492	22.349	71.142	1906.6	2963.6	1398.14	916.491	428.043	249.167
2000	157.515	108.841	32.004	106.161	48.19	50.136	1093.82	2746.86	1260.58	731.596	501.626	240.212
2001	83.827	85.345	217.997	213.263	185.761	283.173	2373.64	2958.89	1211.32	465.568	232.674	171.91
2002	237.118	209.017	193.534	192.945	151.556	209.134	795.072	2024.34	845.894	278.623	168.796	122.811
2003	223.058	215.328	236.804	230.264	188.844	233.525	1438.89	2353.06	999.109	369.561	257.915	250.187
2004	247.365	222.164	218.696	223.838	196.771	257.516	1019.2	2175.72	634.566	400.288	240.679	218.358
2005	209.761	218.17	258.424	234.75	307.644	285.372	1796.75	2296.35	1132	421.854	308.399	231.199

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UMendaya	59											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	0.745	7.024	5.857	30.718	23.455	159.09	632.199	931.458	883.899	115.485	121.477	0
1962	9.155	6.034	5.587	5.198	24.825	117.49	243.999	213.658	565.699	449.585	5.867	0
1963	0.233	0	0	22.62	69.333	174.777	192.787	569.674	464.324	107.018	41.715	58.968
1964	29.972	10.8	8.994	15.476	31.01	128.153	510.195	403.306	502.029	800.699	54.474	0
1965	0.158	0	0	17.149	11.745	90.647	348.324	443.383	294.408	523.175	140.462	62.637
1966	27.913	29.985	30.388	43.802	38.966	84.949	494.104	508.37	699.504	177.318	112.924	55.53
1967	70.62	0	2.561	0	45.904	110.675	261.054	470.207	618.042	819.222	228.695	86.937
1968	38.775	22.618	3.009	50.651	68.805	160.77	254.677	522.211	318.596	57.184	21.133	1.342
1969	12.465	18.287	23.814	22.131	42.042	198.324	437.258	708.647	339.718	78.353	20.29	4.007
1970	0	51.157	47.142	52.96	16.481	157.901	408.62	684.61	674.241	393.609	60.122	12.064
1971	6.503	0	0	0.395	29.394	134.922	399.778	445.715	405.993	382.836	137.33	39.643
1972	20.747	11.595	7.131	16.03	35.587	57.806	365.231	565.816	389.878	74.902	39.767	12.729
1973	2.19	0	0	0.727	62.695	156.821	311.13	904.076	886.65	309.02	58.02	16.458
1974	4.072	1.412	2.189	0.357	46.896	153.46	311.756	538.361	537.479	48.832	17.896	0
1975	0	0	0	0	0	5.482	0	57.118	134.538	128.929	31.63	6.317
1976	0	2.233	0	51.129	54.015	111.6	55.376	295.68	328.855	179.923	112.804	85.503
1977	21.647	0	0	0	28.292	129.814	234.501	252.346	139.367	157.244	123.955	32.817
1978	1.165	0	41.251	0	33.424	27.94	126.703	413.053	802.844	519.715	158.572	118.156
1979	98.349	71.213	51.301	8.236	22.48	75.548	265.277	385.193	239.534	67.737	21.216	0
1980	0	0	0	37.041	114.284	314.867	470.775	480.356	519.144	142.602	10.584	23.032
1981	23.758	3.574	0	6.683	11.52	16.648	0	427.414	484.231	331.138	98.7	45.002
1982	18.033	5.436	3.455	0.703	19.956	156.015	363.442	435.633	317.029	444.867	79.83	34.051
1983	11.606	11.546	9.58	0.068	14.733	80.707	321.165	522.784	629.949	734.337	126.22	48.619
1984	20.684	8.484	11.179	10.744	25.301	160.244	575.352	294.591	353.01	62.041	107.683	65.831
1985	3.593	3.365	0	3.769	53.103	136.079	294.499	686.048	533.004	161.683	47.055	17.582
1986	0	0	9.647	3.752	0	99.369	210.482	14.26	429.707	77.915	0	0
1987	0	0	0	5.671	27.581	113.877	342.28	359.864	474.152	282.863	115.27	50.252
1988	25.473	20.3	14.282	3.443	24.251	219.869	260.852	623.345	524.476	291.882	73.135	10.539
1989	20.494	7.875	6.689	19.114	19.128	98.413	160.206	111.565	766.828	263.19	61.379	90.834
1990	33.895	21.581	27.753	59.468	38.037	139.342	210.075	646.695	489.142	142.213	74.207	33.89
1991	39.84	29.511	18.572	23.008	51.159	145.007	199.46	649.785	336.536	371.349	27.13	8.809
1992	7.118	13.535	6.997	15.567	46.96	131.346	172.654	294.506	280.205	588.164	84.914	27.173
1993	0	0	0	0	5.136	70.678	35.764	130.916	0	0	0	0
1994	0	0	0	0	0	12.935	0	0	0	0	0	0
1995	0	0	0	0	0	1.38	0	0	0	0	0	2.748
1996	20.392	9.586	2.271	0	3.384	37.856	0	0	0	126.713	27.211	0
1997	0	0	0	52.679	88.129	316.593	150.559	247.016	269.709	642.623	705.689	241.882
1998	114.59	80.536	78.731	54.289	101.744	148.79	153.353	154.72	266.698	334.069	116.359	36.453
1999	16.533	2.297	13.717	10.031	67.905	174.805	170.243	238.121	187.014	309.91	58.802	5.798
2000	0	0	0	11.565	87.937	136.414	95.199	0	235.782	225.075	0	0
2001	0.585	0	0	0	0	65.521	0	0	51.205	50.627	0	0
2002	0	0	0	0	0	3.014	0	0	27.538	0	0	0
2003	0	0	0	0	0	5.903	211.19	0	442.41	136.514	29.81	20.329
2004	0	0	0	0	0	6.886	1.571	0	2.933	63.19	0	0
2005	0	0	0	0	0	14.625	0	0	103.996	10.157	0	0

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Dedesa	60											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	120.3013	130.8353	116.3974	137.7271	124.5542	207.9102	582.0526	815.7634	779.167	275.1708	233.5364	131.8168
1962	120.3013	130.8353	116.3974	137.7271	124.5542	207.9102	582.0526	815.7634	779.167	275.1708	233.5364	131.8168
1963	129.1342	130.7045	117.4661	119.2327	125.0558	183.5926	325.0928	444.2164	571.235	451.1954	150.2894	128.24
1964	121.4572	125.7537	112.8643	127.0841	157.8137	223.1769	344.6777	644.7113	514.2031	233.7327	174.9342	165.687
1965	139.1448	129.8321	115.8958	125.2303	127.324	189.8519	503.8654	607.766	576.9055	648.1354	182.2622	134.6956
1966	127.9783	128.6326	112.2318	129.0906	116.9863	170.376	408.2961	498.8056	361.9727	476.4072	220.6688	161.565
1967	133.8014	144.728	128.8943	138.8612	130.181	161.6522	417.6524	515.2282	605.6723	251.0494	203.6355	158.0318
1968	106.9321	87.36895	73.17095	66.25733	101.8505	196.5256	365.1787	559.8723	652.1048	388.5585	203.3302	137.1601
1969	88.1759	69.55057	60.34695	54.63286	83.98848	162.0448	301.1241	461.6422	537.7138	320.3819	167.6498	113.1042
1970	66.36638	54.21848	45.42924	41.13276	63.22581	121.9807	226.6664	347.513	404.763	241.1697	126.2117	85.14438
1971	105.34	86.06038	72.08048	65.2759	100.3238	193.5813	359.7045	551.4756	642.3341	382.7353	200.2769	135.11
1972	97.20505	79.40848	66.51905	60.2379	92.58143	178.6418	331.9628	508.9034	592.761	353.2052	184.8139	124.685
1973	91.77448	72.40762	62.81143	56.87924	87.43438	168.6749	313.4465	480.551	559.7196	333.5112	174.5198	117.7278
1974	116.0485	94.806	79.40848	71.906	110.5307	213.2753	396.3009	607.5479	707.6754	421.6653	220.647	148.85
1975	110.4216	90.226	75.57	68.41648	105.1873	202.9594	377.1303	578.1487	673.4127	401.2516	209.9603	141.6529
1976	112.6898	92.07981	77.11848	69.81229	107.3465	207.1032	384.829	589.9912	687.1963	409.4738	214.2568	144.5535
1977	95.17676	75.09019	65.12324	58.97295	90.66219	174.9124	325.0491	498.3258	580.4169	345.8554	180.9754	122.0897
1978	109.2003	89.22276	74.71943	67.67495	104.0096	200.6912	372.9429	571.7585	665.9538	396.8025	207.6267	140.0826
1979	110.3998	90.20419	75.54819	68.41648	105.1655	202.894	377.0212	578.0178	673.26	401.1644	209.9167	141.6092
1980	113.6276	92.84314	77.75095	70.40114	108.2407	208.8262	388.0569	594.9202	692.9322	412.8979	216.0451	145.753
1981	115.7431	91.31648	79.21219	71.73152	110.2471	212.7083	395.2758	605.9994	705.8434	420.5749	220.0799	148.4792
1982	112.7989	92.16705	77.1839	69.89952	107.4555	207.3213	385.2434	590.6237	687.9378	409.91	214.4967	144.7062
1983	96.31086	78.68876	65.90838	59.67086	91.75267	177.0279	328.953	504.2798	587.3741	349.9992	183.1346	123.551
1984	83.68314	68.37286	57.27181	51.86305	79.71381	153.8008	285.792	438.1533	510.3429	304.0902	159.1223	107.3465
1985	77.99086	61.50286	53.3679	48.3299	74.28324	143.3104	266.3161	408.2743	475.5349	283.3493	148.2611	100.0185
1986	93.86819	76.68229	64.22905	58.166	89.39724	172.4915	320.5346	491.3904	572.3473	341.0355	178.4455	120.3886
1987	72.23314	58.99476	49.42038	44.75314	68.78724	132.7328	246.6439	378.1117	440.4215	262.434	137.3128	92.64686
1988	91.22924	74.54495	62.41886	56.53029	86.88914	167.6716	311.549	477.6286	556.3173	331.483	173.4511	117.0299
1989	104.315	82.28733	71.38257	64.64343	99.36419	191.7275	356.2586	546.1541	636.1402	379.0495	198.3576	133.8014
1990	99.66952	81.43676	68.19838	61.76457	94.93686	183.1782	340.3812	521.8365	607.8096	362.169	189.503	127.8474
1991	87.87057	71.79695	60.12886	54.43657	83.68314	161.4777	300.0554	460.0065	535.7946	319.2478	167.061	112.7116
1992	112.6462	92.03619	77.07486	69.79048	107.281	206.9942	384.6546	589.7077	686.8473	409.2557	214.1477	144.4663
1993	121.937	96.18	83.42143	75.54819	116.1357	224.071	416.3874	638.343	743.5085	443.0387	231.8134	156.3961
1994	121.4572	99.21152	83.09429	75.24286	115.6777	223.1987	414.7517	635.8349	740.6078	441.2939	230.9192	155.7854
1995	101.2616	82.72352	69.28886	62.746	96.44171	186.0789	345.79	530.1241	617.4712	367.9267	192.5127	129.8757
1996	87.78333	71.73152	60.06343	54.39295	83.61771	161.3469	299.8155	459.6357	535.3584	318.9861	166.9301	112.6026
1997	96.24543	75.91895	65.86476	59.64905	91.68724	176.897	328.7131	503.9527	586.9815	349.7593	183.0255	123.4637
1998	86.16943	70.40114	58.95114	53.38971	82.06924	158.3371	294.2541	451.1082	525.435	313.0757	163.8331	110.5307
1999	104.9038	85.71143	71.79695	65.01419	99.93124	192.7962	358.2869	549.2729	639.7606	381.2087	199.4699	134.5648
2000	108.6114	88.74295	74.32686	67.30419	103.4644	199.6008	370.9146	568.6397	662.3334	394.6651	206.5144	139.3192
2001	118.3821	118.8183	107.5864	115.2851	135.0882	273.4914	350.5009	358.8975	347.8401	378.3952	201.9562	138.1851
2002	121.0647	125.7101	110.3998	113.8675	122.2424	194.5191	291.7896	470.4314	467.9451	239.6212	172.0117	130.53
2003	120.0832	124.2925	110.0072	111.861	110.7924	154.3242	234.3651	371.0672	383.0625	200.713	125.5356	116.2666
2004	112.1882	121.5445	112.1664	108.5242	109.7891	134.5211	228.3021	292.2258	398.2419	246.7311	149.308	122.3514
2005	114.0202	116.9645	106.8885	112.2318	110.7488	153.2991	281.4737	301.3204	406.7476	283.2839	156.3307	128.2182

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Gojeb	61											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	23.7503	20.3069	21.7278	20.2695	27.435	64.3708	190.097	236.357	123.184	111.079	19.4843	18.4169
1962	23.7503	20.3069	21.7278	20.2695	27.435	64.3708	190.097	236.357	123.184	111.079	19.4843	18.4169
1963	16.544	17.5297	20.0757	20.3103	16.8975	1.18972	73.8104	223.223	155.408	129.279	54.265	25.8544
1964	21.7651	20.5992	18.7161	12.1352	23.203	0	106.273	274.527	337.589	189.652	38.3771	25.3921
1965	21.2077	21.1363	9.9087	18.7806	30.3753	52.46	214.952	390.739	212.084	114.183	32.5474	84.8307
1966	12.5499	11.9244	8.13091	16.2584	16.9179	47.181	182.623	317.483	196.097	119.611	39.9475	31.5583
1967	11.4995	11.8734	10.6837	20.5992	18.6889	50.4137	183.646	305.959	200.873	77.247	28.2134	14.4602
1968	9.06909	9.0249	9.22886	15.0653	22.9209	71.1795	175.515	269.761	193.874	123.874	46.1443	21.8807
1969	11.5879	13.4677	9.49399	18.6243	17.958	49.6829	207.032	317.347	172.415	77.4918	24.0528	14.3617
1970	10.8129	14.2155	22.7611	18.5495	24.7632	65.8903	214.449	331.45	188.83	90.7827	25.4431	13.0666
1971	1.84237	1.7166	8.47423	17.4719	20.5074	52.8305	218.957	398.183	232.339	109.499	30.5861	16.136
1972	7.94735	6.38712	5.56111	9.66395	15.6874	50.1146	204.191	351.002	238.975	103.781	33.3395	13.3283
1973	6.66585	6.42451	4.98324	11.8938	16.9043	40.0359	182.867	262.419	148.093	46.7731	19.7358	8.58301
1974	6.93099	5.35036	4.01107	8.98411	19.0934	28.0163	205.03	334.88	224.589	93.1554	21.8501	9.50419
1975	7.08395	6.94799	8.09692	10.4832	10.0243	45.9505	154.406	278.881	131.369	74.5005	24.3417	11.1392
1976	8.97391	9.74214	8.28048	15.0041	17.7099	55.0502	224.079	378.4	259.217	99.3691	26.0108	15.1231
1977	8.75636	9.06569	7.82838	10.7449	24.148	56.3589	176.13	264.074	139.643	49.0166	24.906	10.3778
1978	11.8496	36.12	10.6531	14.484	18.5393	56.0224	235.276	400.053	237.642	139.857	38.4383	19.6066
1979	11.3398	11.5437	11.0712	16.391	30.4909	72.6581	240.127	394.716	204.646	119.136	33.4686	24.4845
1980	19.7698	22.445	17.37	20.0757	25.5859	53.9251	162.462	246.473	151.047	69.8232	24.9978	63.0621
1981	64.2179	17.4345	14.1475	17.8561	23.6687	48.4183	156.911	255.712	149.65	66.2438	25.8374	14.6438
1982	10.7857	11.0032	14.5044	17.8221	23.6177	34.6855	148.294	262.837	116.984	48.8365	0	8.08332
1983	9.06569	78.4062	7.59384	11.7341	16.272	40.0495	127.562	251.576	155.674	88.4236	27.6798	17.2884
1984	11.5913	22.7815	9.69115	14.7424	23.2404	46.8785	157.135	321.997	216.149	132.141	44.686	20.3409
1985	90.2932	9.19146	7.57684	11.163	16.5134	56.8348	179.121	249.781	162.679	45.597	16.374	11.2718
1986	7.42387	6.95818	6.57747	10.405	20.623	50.5055	165.65	329.866	189.101	61.2708	20.0553	14.0183
1987	9.53818	10.7551	13.2909	19.0696	21.364	58.8947	170.042	217.563	157.954	58.7995	17.2	10.9862
1988	6.47889	6.04719	11.6525	24.8244	21.7379	48.0614	113.024	185.468	115.862	48.0206	18.23	7.83518
1989	9.26965	12.3017	10.0515	15.8539	20.4462	46.6338	424.765	553.289	337.341	246.082	119.931	59.8975
1990	14.3549	9.58577	8.30087	22.4042	16.3672	40.1787	163.121	256.78	171.038	73.9702	22.5368	17.7031
1991	1.41407	10.3336	11.0848	13.4065	16.2278	46.542	165.582	311.708	211.72	113.099	33.7576	31.5617
1992	18.5155	17.7949	18.1518	28.6315	66.9202	93.8352	258.238	318.499	78.8991	47.7963	31.1708	24.4607
1993	9.68435	12.7028	9.91889	17.4006	19.1545	43.3093	146.496	272.715	358.073	183.802	122.477	32.1803
1994	20.7454	24.9536	9.4736	27.4418	35.2362	0	243.411	433.739	307.102	98.0672	49.6115	30.9532
1995	15.4154	14.2937	13.0768	21.8569	34.298	106.259	258.354	444.311	252.133	38.2717	27.5676	22.1323
1996	11.8394	10.6769	11.5641	20.0179	37.1602	76.1967	159.946	301.228	97.2242	81.819	28.0367	31.1232
1997	13.0462	20.1675	37.5035	31.0552	50.3967	153.148	298.434	491.9	222.237	102.041	34.2266	21.5034
1998	14.2869	13.8382	10.9998	25.9462	29.8961	138.093	199.051	320.977	167.955	126.376	173.241	60.924
1999	32.7004	18.0226	32.4964	21.1465	47.3748	51.9909	264.489	474.802	256.26	212.695	51.1581	24.3519
2000	4.77589	2.21968	2.5664	6.34293	30.3651	68.5247	232.914	385.81	157.21	159.11	33.9921	8.66799
2001	3.72893	2.85874	1.53984	18.1552	51.0459	76.4414	270.145	410.387	237.897	162.917	61.4611	17.1184
2002	0	0	3.62696	19.2633	42.7757	173.978	336.828	494.415	373.505	172.275	97.6423	13.3317
2003	24.3111	24.5797	13.8178	19.9296	15.8811	54.2378	136.505	169.587	147.267	37.2451	18.818	21.4082
2004	14.0557	10.0005	12.5023	14.1645	10.5545	23.0466	110.729	219.555	202.287	89.8581	29.6377	19.763
2005	27.1631	33.2409	37.3641	43.2889	46.8343	69.5614	133.297	173.927	169.971	166.769	65.1765	34.7977

m^3/s

Tams	63											
	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	15.2346	16.5686	14.7403	17.4414	15.7732	26.3292	73.7096	103.306	98.6716	34.8469	29.5744	16.6929
1962	15.2346	16.5686	14.7403	17.4414	15.7732	26.3292	73.7096	103.306	98.6716	34.8469	29.5744	16.6929
1963	16.3532	16.5521	14.8756	15.0993	15.8367	23.2497	41.1689	56.2544	72.3397	57.1382	19.0323	16.24
1964	15.381	15.9251	14.2928	16.0936	19.9851	28.2625	43.6491	81.6445	65.1173	29.5993	22.1532	20.9822
1965	17.6209	16.4416	14.6767	15.8588	16.124	24.0423	63.8082	76.9659	73.0578	82.0781	23.0812	17.0575
1966	16.2068	16.2897	14.2127	16.3477	14.8148	21.576	51.7055	63.1674	45.8393	60.3309	27.9449	20.4602
1967	16.9443	18.328	16.3228	17.585	16.4858	20.4712	52.8904	65.2471	76.7007	31.7922	25.7879	20.0127
1968	13.5416	11.0642	9.26617	8.39065	12.8981	24.8875	46.2453	70.9007	82.5808	49.206	25.7492	17.3696
1969	11.1664	8.8077	7.64218	6.91856	10.6361	20.5209	38.1336	58.4611	68.0946	40.5723	21.2307	14.3232
1970	8.40446	6.86608	5.75304	5.20894	8.00675	15.4473	28.7044	44.0081	51.2581	30.5411	15.9831	10.7825
1971	13.34	10.8985	9.12808	8.26637	12.7047	24.5146	45.552	69.8374	81.3435	48.4686	25.3625	17.11
1972	12.3098	10.0561	8.4238	7.62837	11.7243	22.6227	42.0389	64.4462	75.0657	44.729	23.4043	15.7898
1973	11.6221	9.16951	7.95427	7.20304	11.0725	21.3605	39.694	60.8557	70.8814	42.235	22.1007	14.9087
1974	14.6961	12.006	10.0561	9.10598	13.9973	27.0086	50.1865	76.9382	89.6181	53.3986	27.9421	18.85
1975	13.9835	11.426	9.56998	8.66408	13.3206	25.7022	47.7588	73.2152	85.2792	50.8134	26.5888	17.9385
1976	14.2707	11.6607	9.76608	8.84084	13.5941	26.227	48.7337	74.7149	87.0247	51.8547	27.1329	18.3059
1977	12.0529	9.50922	8.24703	7.46818	11.4812	22.1504	41.1634	63.1067	73.5024	43.7982	22.9182	15.4611
1978	13.8288	11.2989	9.46227	8.57018	13.1715	25.415	47.2285	72.406	84.3346	50.25	26.2933	17.7397
1979	13.9807	11.4232	9.56722	8.66408	13.3179	25.694	47.745	73.1986	85.2599	50.8024	26.5833	17.933
1980	14.3895	11.7574	9.84617	8.91541	13.7073	26.4452	49.1425	75.3391	87.7511	52.2883	27.3594	18.4578
1981	14.6574	11.5641	10.0312	9.08389	13.9614	26.9368	50.0567	76.7422	89.3861	53.2605	27.8703	18.803
1982	14.2845	11.6718	9.77436	8.85189	13.6079	26.2546	48.7862	74.795	87.1186	51.9099	27.1633	18.3252
1983	12.1966	9.96494	8.34646	7.55656	11.6193	22.4183	41.6577	63.8607	74.3835	44.323	23.1917	15.6462
1984	10.5974	8.65856	7.25275	6.5678	10.0947	19.4769	36.1919	55.4866	64.6285	38.5092	20.1508	13.5941
1985	9.87655	7.78856	6.75837	6.12037	9.40703	18.1484	33.7256	51.7028	60.2205	35.8826	18.7754	12.6661
1986	11.8872	9.71084	8.1338	7.36599	11.321	21.8439	40.5916	62.2284	72.4805	43.1878	22.5979	15.2457
1987	9.14741	7.47094	6.25847	5.66742	8.71103	16.8089	31.2343	47.8831	55.7738	33.2339	17.3889	11.7326
1988	11.553	9.44017	7.90456	7.15884	11.0034	21.2335	39.4537	60.4856	70.4505	41.9781	21.9654	14.8204
1989	13.2102	10.4206	9.0397	8.18627	12.5832	24.2799	45.1156	69.1635	80.5591	48.0018	25.1195	16.9443
1990	12.6219	10.3129	8.63646	7.8217	12.0226	23.1972	43.105	66.084	76.9714	45.8641	23.9981	16.1903
1991	11.1277	9.09217	7.61456	6.8937	10.5974	20.4491	37.9982	58.254	67.8516	40.4287	21.1562	14.2735
1992	14.2652	11.6552	9.76055	8.83808	13.5858	26.2132	48.7116	74.679	86.9805	51.8271	27.1191	18.2948
1993	15.4418	12.18	10.5643	9.56722	14.7071	28.3758	52.7302	80.8381	94.1559	56.1052	29.3562	19.8056
1994	15.381	12.5639	10.5228	9.52856	14.6491	28.2653	52.5231	80.5204	93.7886	55.8843	29.243	19.7283
1995	12.8235	10.4759	8.77456	7.94599	12.2131	23.5645	43.7899	67.1335	78.1949	46.5933	24.3793	16.4471
1996	11.1166	9.08389	7.60627	6.88818	10.5891	20.4325	37.9678	58.207	67.7964	40.3955	21.1396	14.2597
1997	12.1883	9.61417	8.34094	7.5538	11.611	22.4018	41.6274	63.8192	74.3338	44.2926	23.1779	15.6351
1998	10.9123	8.91541	7.46542	6.76113	10.393	20.0514	37.2636	57.1271	66.5397	39.6471	20.7474	13.9973
1999	13.2847	10.8543	9.09217	8.23322	12.655	24.4152	45.3725	69.5585	81.0176	48.2753	25.2603	17.0409
2000	13.7543	11.2382	9.41256	8.52322	13.1025	25.2769	46.9716	72.011	83.8761	49.9793	26.1524	17.643
2001	14.9916	15.0468	13.6245	14.5994	17.1072	34.6342	44.3865	45.4498	44.0495	47.919	25.5752	17.4994
2002	15.3313	15.9196	13.9807	14.4199	15.4804	24.6334	36.9515	59.5742	59.2593	30.345	21.7831	16.53
2003	15.207	15.7401	13.931	14.1658	14.0305	19.5432	29.6794	46.991	48.51	25.4178	15.8975	14.7237
2004	14.2072	15.3921	14.2045	13.7432	13.9034	17.0354	28.9116	37.0067	50.4323	31.2454	18.908	15.4943
2005	14.4392	14.8121	13.5361	14.2127	14.0249	19.4134	35.6451	38.1584	51.5094	35.8743	19.7973	16.2372

$$E_0 = \frac{700\ T_m/(100-A)+15(T-T_d)}{(80-T)}(\text{ mm day}^{-1})$$

where $T_m = T + 0.006h$,
h is the elevation (metres),
T is the mean temperature,
A is the latitude (degrees)
and T_d is the mean dew-point.

Edward T. Linacre,
A simple formula for estimating evaporation rates in various climates, using temperature data alone,
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(https://www.sciencedirect.com/science/article/pii/0002157177900073)

Abstract: The Penman formula for the evaporation rate from a lake is simplified to the following: E0=700Tm/(100−A)+15(T−Td)(80−T)(mmday−1) where Tm = T + 0.006h, h is the elevation (metres), T is the mean temperature, A is the latitude (degrees) and Td is the mean dew-point. Values given by this formula typically differ from measured values by about 0.3 mm day−1 for annual means, 0.5 mm day−1 for monthly means, 0.9 mm day−1 for a week and 1.7 mm day−1 for a day. The formula applies over a wide range of climates. Monthly mean values of the term (T − Td) can be obtained either from an empirical table or from the following empirical relationship, provided precipitation is at least 5 mm month−1 and (T − Td) is at least 4°C:(T−Td)=0.0023h+0.37T+0.53R+0.35Rann−10.9°C where R is the mean daily range of temperature and Rann is the difference between the mean temperatures of the hottest and coldest months. Thus the evaporation rate can be estimated simply from values for the elevation, latitude and daily maximum and minimum temperatures.

T_m	32.67233	E_0	51.22016	mm/month
h	2219			
T	19.35833			
A	9.561			
$T-T_d$	8.697117			

$$(T - T_d) = 0.0023h + 0.37\ T + 0.53\ R + 0.35\ R_{ann} - 10.9^\circ\ \mathrm{C}$$

where R is the mean daily range of temperature
and R_{ann} is the difference between the mean temperatures of the hottest and coldest months.

				13.6	13.8	13	12.1	11.5	10.7	9.4	9.6	10.6	12.2	13.2	13.3	R
				2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	R_{ann}
				4.131	4.644	4.59	4.187	3.869	3.26	2.201	2.233	2.837	3.574	3.845	3.75	
				26	27.1	27.8	27.4	27.2	26	24	23.8	24.8	25.8	25.6	25.3	High
				12.4	13.3	14.8	15.3	15.7	15.3	14.6	14.2	14.2	13.6	12.4	12	Low
				18.4	19.5	20.5	20.7	20.7	20.2	19.2	19	19.2	18.9	18.2	17.8	
		h	A	.Ev1	.Ev2	.Ev3	.Ev4	.Ev5	.Ev6	.Ev7	.Ev8	.Ev9	Ev10	Ev11	Ev12	
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Finchaa HEP	31.714	2219	9.561	48.79456	43.41471	49.04198	48.87272	51.57231	51.58549	56.5922	56.2716	52.27332	51.05699	47.96647	49.56094776	1
M Wakana HEP	33.529	2521.5	7.1761	48.85152	43.54047	49.17536	48.93926	51.58475	51.48051	56.2267	55.91624	52.07855	51.01414	47.97389	49.55153958	1
Beles HEP	29.134	1789	11.8196	48.44155	42.98786	48.57279	48.50485	51.27146	51.46357	56.84664	56.51196	52.2859	50.84298	47.69293	49.30423559	1
Gibe II HEP	18.406	1	7.7571	0	0	0	0	0	0	0	0	0	0	0	0	0
Tekeze I HEP	25.3	1150	13.3492	47.3337	41.82121	47.27563	47.37212	50.21772	50.70381	56.66954	56.3141	51.74352	49.93689	46.7231	48.34445382	1
Gibe I HEP	28.444	1674	7.8349	47.29044	41.96646	47.41868	47.35225	50.05302	50.24037	55.49509	55.16838	51.04302	49.63463	46.55953	48.13251452	1
Neshe HEP	31.72294	2220.49	9.789	48.84599	43.45938	49.09257	48.9241	51.62737	51.64227	56.65818	56.33709	52.33216	51.11229	48.01773	49.61416544	1
TAbay I HEP	28.1374	1622.9	11.4887	48.00801	42.56411	48.09848	48.06578	50.83772	51.09078	56.57203	56.23449	51.95499	50.4421	47.29165	48.89842143	1
TAbay II HEP	28.1374	1622.9	11.4887	48.00801	42.56411	48.09848	48.06578	50.83772	51.09078	56.57203	56.23449	51.95499	50.4421	47.29165	48.89842143	1
Koka HEP	27.946	1591	8.468	47.24209	41.89891	47.34519	47.3007	50.01771	50.24441	55.58595	55.25589	51.07726	49.61806	46.52806	48.10567602	1
Awash II HEP	18.406	1	8.3932	0	0	0	0	0	0	0	0	0	0	0	0	0
AwashIII HEP	18.406	1	8.3932	0	0	0	0	0	0	0	0	0	0	0	0	0

Gibe III HEP	23.758	893	6.8482	45.01429	39.75206	44.9389	45.04829	47.76995	48.26505	54.01753	53.67629	49.28009	47.51799	44.44679	45.99383443	1
Genale 3 HEP	25.05406	1109.01	5.51	45.32688	40.10006	45.32403	45.37033	48.05483	48.43494	53.94351	53.61141	49.36253	47.74655	44.70777	46.24701605	1
Renaissance	22.36	660	11.21528	45.39437	39.97413	45.20294	45.41405	48.24778	48.93701	55.20147	54.8384	50.11382	48.08095	44.89789	46.48758342	1
Geba 1 HEP	31.48	2180	8.211	48.43358	43.09356	48.6792	48.51117	51.19077	51.2038	56.17337	55.85515	51.88651	50.67923	47.61159	49.19427342	1
Geba 2 HEP	25.12	1120	8.211	45.99463	40.67215	45.97279	46.03633	48.77489	49.19118	54.85381	54.51387	50.15675	48.47617	45.37874	46.9454513	1
Genale 6 HEP	21.91024	585.04	5.68	43.73791	38.54281	43.58126	43.7604	46.4692	47.0872	53.00974	52.66458	48.18372	46.28733	43.24123	44.76575392	1
Gibe IV HEP	18.406	1	6.58	0	0	0	0	0	0	0	0	0	0	0	0	0
U Dabus HEP	26.6422	1373.7	11.5948	47.45745	42.00955	47.47945	47.50608	50.29766	50.65547	56.32753	55.98367	51.59478	49.95634	46.793	48.39828576	1
Birbir R HEP	25.36	1160	11.21501	46.82936	41.39673	46.79336	46.87008	49.66889	50.115	55.93366	55.58539	51.11585	49.37502	46.21126	47.80989675	1
Halele HEP	28	1600	9.010793	47.3862	42.02505	47.48792	47.44477	50.17136	50.40143	55.76555	55.43423	51.23894	49.77174	46.67108	48.25393712	1
Werabesa HEP	27.16	1460	9.010793	47.05651	41.69735	47.12168	47.11018	49.84508	50.13052	55.5909	55.25653	51.00705	49.4746	46.36955	47.95036753	1
Yeda 1 HEP	32.152	2292	9.010793	48.81421	43.45088	49.08068	48.89477	51.58117	51.56499	56.50681	56.18874	52.23039	51.05198	47.97367	49.56412507	1
Yeda 2 HEP	18.406	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baro & Genji	27.52	1520	11.21501	47.71173	42.27693	47.77678	47.76602	50.53978	50.83085	56.37113	56.03195	51.72088	50.16491	47.01587	48.61896233	1
Tams HEP	22.936	756	11.21501	45.69155	40.26785	45.53141	45.71548	48.54257	49.18237	55.35522	54.99522	50.32317	48.3499	45.17038	46.76208912	1
Tekeze II H	24.22	970	13.3492	46.85857	41.34605	46.74484	46.88951	49.74981	50.32282	56.45049	56.08959	51.4257	49.51404	46.29091	47.91032482	1
L Dabus HEP	25.78	1230	11.5948	47.10242	41.65516	47.08352	47.14556	49.94741	50.36813	56.15376	55.80617	51.3525	49.63892	46.46943	48.07299926	1
Amerti RES H	31.804	2234	9.010793	48.7059	43.34237	48.95951	48.78475	51.47444	51.4773	56.45144	56.13236	52.15592	50.95526	47.87507	49.46501969	1
Chemoga H	32.98	2430	9.010793	49.06454	43.70192	49.36099	49.14908	51.82774	51.76733	56.63427	56.31852	52.40206	51.27528	48.20144	49.79302716	1
				31	28	31	30	31	30	31	31	30	31	30	31	

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	Company Name: **Finchaa Sugar Factory** ፊንጫአ ስኳር ፋብሪካ	Document No. FSF/OF/093	
Title		Issue No. 1	Page 1 of 1
		Effective Date: June 16, 2010	

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ቁጥር 01/3738/51
Ref. No.

ቀን 18 መጋቢት 2010
Date

ለኢትዮጵያ ኤሌክትሪክ ኃይል
ዋና ሥራ አስፈፃሚ ጽሕፈት ቤት
አዲስ አበባ

ጉዳዩ:- በምዕራብና ምስራቅ ባንክ የውሃ አቅርቦት መዋዠቅ፤

ፊንጫአ ስኳር ፋብሪካ የሃገሪቱን የስኳር ፍላጎት ለማሟላት ብሎም በዓለም አቀፍ ደረጃ ተወዳዳሪ ለመሆን የበኩሉን አስተዋፅዖ እያደረገ ይገኛል፡፡ ይህንን ከባድ ኃላፊነት ለመወጣት ከኢትዮጵያ ኤሌክትሪክ ኃይል ያለውንና ሊኖር የሚገባው ድጋፍ ከባለ ድርሻ አካላት ሁሉ ከፍተኛውን ስፍራ የያዘ ነው፡ ይኸውም ለእርሻም ሆነ ለፋብሪካ ምርታማነት ውጤታማ እንዲሆን የውሃና የኃይል አቅርቦት ሳይቆራረጥ ማግኘት ወሳኝነት አለው፡፡

ነገር ግን ከላይ በርዕሱ የተጠቀሱት የፋብሪካው የአገዳ እርሻ ማሳዎች ውሃ የሚያገኙት ከፊንጫአ Hydro-powr station ሲሆን አብዛኛውን ጊዜ በቋሚነት እያገኙ ቢሆንም ከህዳር 15 ጀምሮ ግን ሰዓቶቹ የተለያዩ ቢሆኑም ለሊት ላይ ከምሽቱ 5:00 እስከ ንጋቱ 1:00 ሰዓት ባለው ጊዜ ውስጥ በተከታታይ የውሃ መዋዠቅ ስለሚከሰት በአገዳው ምርታማነት ላይ ከፍተኛ አሉታዊ ተፅዕኖ እያሳደረብን ይገኛል፡፡

ይህንን ጉዳይ አስመልክቶ በተለያዩ ጊዜ (በየዓመቱ) አስፈላጊ የውሃ ፍጆታችንን በሠንጠረዥ አስደግፈን መግለፃችን ይታወሳል (በቀን 03 ታህሳስ 2010 በቁጥር 01/1758/51 የላክንላችሁን በዚህ ዓመት የተሠራውን ሠንጠረዥ ብቻ ለምሳሌነት ከዚህ ደብዳቤ ጋር አያይዘናል) ፡፡

በመሆኑም ከዚህ ጋር በተያያዘው ሠንጠረዥ ላይ የሰፈረው የውሃ ፍጆታ መጠን የመጨረሻ ዝቅተኛው ፍላጎታችን መሆኑን እየገለጽን ከፊንጫአ ኃይል ማመንጫ ጣቢያ የሚለቀቅ የውሃ መጠን በሠንጠረዡ በሰባተኛው አምድ (Column) ላይ በየሰከንዱ ከተጠቀሰው መጠን ያላነሰ እንዲሆን በአክብሮት እንጠይቃለን፡፡

ከሠላምታ ጋር

ስለሺ ዲጋ ድርባባ
ዋና ሥራ አስኪያጅ

እንዲያውቁት
- በኢፌድሪ ስኳር ኮርፖሬሽን ለክቡር ዋና ሥራ አስፈፃሚ
  አዲስ አበባ

ግልባጭ፡-
- ለጀነሬሽን ኦፕሬሽን ሥራ አስፈፃሚ ቢሮ
- ለትራንስሚሽን ሰብስቴሽን ኦፕሬሽን ሥራ አስፈፃሚ ቢሮ
- ለስኳር ኮርፖሬሽን የእርሻ ኦፕሬሽን ምክትል ዋና ሥራ አስፈፃሚ
  አዲስ አበባ
- ለፊንጫአ ኃይል ማመንጫ ጣቢያ
  ፊንጫአ
- ለሲቪል፣ መስኖና መሠረተ ልማት ዘርፍ
- ለእርሻ ኦፕሬሽን ዘርፍ
  አግሞሣ

20/7/2010

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Water Demand of West and East Banks Cane Agricultural Plots, factory & drinking water for the year 2010 E.C.

Total Cane Planted Area		**15,678.31** ha (WB &EB)	**19,559.88**	**ha (FSF)**
Crop Water Demand		**1** Lit/sec/ha		
Village Demand (for East/West bank)	560 m^{3}/day	6.5 Lit/sec		
Factory	8000 m^3/hr	2222.2 Lit/sec		
Main town raw water demand	360 m^3/hr	100.0 Lit/sec		

Ser No	Month	Plant Area (ha)		Days per month	Water Demand				
		Dry-off	Irrigable		lit/Sec	m^3 per/sec	m^3 Per/hr	m^3 Per day	m^3 per month
1	November	2,079.98	13,598.33	30	15,927.03	15.93	57,337.32	1,376,095.71	**41,282,871.36**
2	December	1,461.86	14,216.45	31	16,545.15	16.55	59,562.55	1,429,501.28	**44,314,539.68**
3	January	932.64	14,745.67	31	17,074.37	17.07	61,467.75	1,475,225.89	**45,732,002.53**
4	February	939.82	14,738.49	28	17,067.19	17.07	61,441.90	1,474,605.54	**41,288,955.01**
5	March	1,873.30	13,805.01	31	16,133.71	16.13	58,081.37	1,393,952.86	**43,212,538.78**
6	April	1,635.37	14,042.94	30	16,371.64	16.37	58,937.92	1,414,510.02	**42,435,300.48**
7	May	2,883.27	12,795.04	31	15,123.74	15.12	54,445.48	1,306,691.46	**40,507,435.14**
	Total Per Year	**11,806.24**							298,773,642.98

Water Demand of Neshie Cane Agricultural Plots & drinking water for the year 2010 E.C.

Total Cane Planted Area		**3,881.57**	ha
Crop Water Demand		**1**	Lit/sec/ha
Village raw water Demand (N-B & N-C)	**112** m^{3}/day	1.3	Lit/sec

Ser No	Month	Plant Area (ha)		Days per month	Water Demand				
		Dry-off	Irrigable		lit/Sec	m^3			
						per/sec	Per/hr	Per day	per month
1	November	-	3,881.57	30	3,882.87	3.88	13,978.32	335,479.65	**10,064,389.44**
2	December	1,479.72	2,401.85	31	2,403.15	2.40	8,651.33	207,631.84	**6,436,587.04**
3	January	563.27	3,323.30	31	3,324.60	3.32	11,968.55	287,245.12	**8,904,598.72**
4	February	271.70	3,614.87	28	3,616.17	3.62	13,018.20	312,436.77	**8,748,229.50**
5	March	198.81	3,687.76	31	3,689.06	3.69	13,280.60	318,734.46	**9,880,768.38**
6	April	277.61	3,603.96	30	3,605.26	3.61	12,978.92	311,494.14	**9,344,824.32**
7	May	449.54	3,432.03	31	3,433.33	3.43	12,359.97	296,639.39	**9,195,821.15**
	Total Per Year	**3,240.65**							**62,575,218.56**

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APPENDIX B – DETAILED RESULTS OF SCENARIOS

SCENARIO 2: REFERENCE

Scenario 2 – Expansion Plan

COD	Prj	Type	Project	Capacity (MW)
01/2024	RNW	Solar	Mekele	300
01/2024	RNW	Wind	Mega	300
01/2025	RNW	Wind	Aysha II	120
01/2026	RNW	Wind	Aysha II	240
01/2026	RNW	Wind	Ashegoda 1	25
01/2027	RNW	Wind	Adigala	150
01/2027	RNW	Wind	Mega	150
01/2028	TPP	GT	GT-NG	840
01/2028	HPP	Hydro	U Dabus HEP	304
01/2028	RNW	Wind	Gode	300
01/2029	TPP	GT	GT-NG	140
01/2029	HPP	Hydro	Baro & Genji	894
01/2029	RNW	Wind	Adigala	300
01/2029	RNW	Solar	Gade 2	125
01/2030	TPP	GT	GT-NG	140
01/2030	HPP	Hydro	Birbir A	97
01/2030	RNW	Wind	Gode	300
01/2030	RNW	Solar	Melkasedi	300
01/2031	TPP	GT	GT-NG	980
01/2031	HPP	Hydro	Geba 1 HEP	215
01/2031	HPP	Hydro	Geba 2 HEP	157
01/2031	HPP	Hydro	Birbir R HEP	467
01/2031	RNW	Solar	Mekele	100
01/2031	RNW	Wind	Gode	300
01/2031	RNW	Solar	Meki	100
01/2032	TPP	GT	GT-NG	280
01/2032	RNW	Solar	Meki	300
01/2032	RNW	Wind	KebriBeyah	300
01/2033	TPP	GT	GT-NG	280
01/2033	RNW	Wind	Ayesha	300
01/2033	RNW	Solar	Weranso	300
01/2034	TPP	GT	GT-NG	420
01/2034	RNW	Wind	Ayesha	300
01/2034	RNW	Solar	Weranso	300
01/2035	HPP	Hydro	Karadobi	1,600
01/2035	RNW	Wind	Ayesha	300
01/2035	RNW	Solar	Melkasedi	300
01/2036	RNW	Solar	Metahara	200
01/2036	RNW	Wind	Ayesha I	120
01/2036	RNW	Wind	Ashegoda 1	30
01/2036	RNW	Wind	KebriBeyah	150
01/2037	HPP	Hydro	Beko Abo	935
01/2037	RNW	Solar	Welenchiti	300
01/2037	RNW	Wind	Ayesha I	240
01/2037	RNW	Wind	Ashegoda 1	60

01/2038	RNW	Wind	Idabo	300
01/2038	RNW	Solar	Welenchiti	300
01/2039	TPP	GT	GT-NG	980
01/2039	RNW	Solar	Metahara	200
01/2039	RNW	Wind	Idabo	150
01/2039	RNW	Wind	Deday	125
01/2039	RNW	Solar	Yirgalem	100
01/2039	RNW	Wind	Ashegoda 1	25
01/2040	HPP	Hydro	Halele HEP	96
01/2040	HPP	Hydro	Werabesa HEP	340
01/2040	RNW	Wind	Tuloguled	300
01/2040	RNW	Solar	Yirgalem	300
01/2041	HPP	Hydro	U Mendaya	1,700
01/2041	RNW	Solar	Gade 2	250
01/2041	RNW	Wind	Deday	250
01/2041	RNW	Wind	Ashegoda 1	50
01/2042	TPP	GT	GT-NG	140
01/2042	HPP	Hydro	Yeda 1 HEP	162
01/2042	HPP	Hydro	Yeda 2 HEP	118
01/2042	HPP	Hydro	Tams HEP	2,000
01/2042	RNW	Wind	Dire Dawa	300
01/2042	RNW	Solar	Worota	300
01/2043	TPP	GT	GT-NG	420
01/2043	HPP	Hydro	Tekeze II H	450
01/2043	RNW	Wind	Dire Dawa	150
01/2043	RNW	Solar	Worota	100
01/2043	RNW	Solar	Meshenti	200
01/2043	RNW	Wind	May Mekdan	150
01/2044	TPP	Geothermal	Shashemene	150
01/2044	TPP	Geothermal	Dofan	100
01/2044	TPP	Geothermal	Fentale	50
01/2044	TPP	Geothermal	Tendaho	100
01/2044	TPP	Geothermal	Dugna Fango	100
01/2044	TPP	Geothermal	Boku	100
01/2044	TPP	GT	GT-NG	140
01/2044	HPP	Hydro	L Dabus HEP	494
01/2044	RNW	Solar	Humera	100
01/2044	RNW	Solar	Meshenti	200
01/2044	RNW	Wind	Sure	150
01/2044	RNW	Wind	Assosa Bamba	150
01/2045	TPP	GT	GT-NG	420
01/2045	HPP	Hydro	Genale 6 HEP	246
01/2045	HPP	Hydro	Wabi Shebele	87
01/2045	HPP	Hydro	Dedesa	301
01/2045	HPP	Hydro	Gojeb	150
01/2045	HPP	Hydro	Genale 5	100
01/2045	HPP	Hydro	Wabe	300
01/2045	RNW	Solar	Metema	125
01/2045	RNW	Wind	Debre Birham	125
01/2045	RNW	Wind	Ashegoda 1	75
01/2045	RNW	Wind	Sela Dingay	100
Total				28,178

SCENARIO 3: ADDITIONAL GEOTHERMAL

Scenario 3 – Expansion Plan

COD	Prj	Type	Project	Capacity (MW)
01/2024	RNW	Solar	Mekele	300
01/2024	RNW	Wind	Mega	300
01/2028	TPP	GT	GT-NG	980
01/2028	HPP	Hydro	U Dabus HEP	304
01/2028	RNW	Solar	Weranso	150
01/2029	TPP	GT	GT-NG	420
01/2029	HPP	Hydro	Birbir R HEP	467
01/2029	RNW	Solar	Melkasedi	150
01/2030	HPP	Hydro	Karadobi	1,600
01/2031	TPP	GT	GT-NG	280
01/2031	HPP	Hydro	Beko Abo	935
01/2032	TPP	GT	GT-NG	420
01/2033	HPP	Hydro	Baro & Genji	894
01/2033	RNW	Solar	Meki	300
01/2034	TPP	GT	GT-NG	420
01/2034	HPP	Hydro	Birbir A	97
01/2034	RNW	Solar	Weranso	150
01/2034	RNW	Solar	Gade 2	125
01/2035	HPP	Hydro	U Mendaya	1,700
01/2036	TPP	Geothermal	Boku	100
01/2037	TPP	Geothermal	Boku	500
01/2037	TPP	GT	GT-NG	140
01/2037	RNW	Solar	Welenchiti	150
01/2038	TPP	Geothermal	Boku	500
01/2038	TPP	GT	GT-NG	140
01/2038	RNW	Solar	Welenchiti	150
01/2038	RNW	Solar	Meki	100
01/2039	TPP	Geothermal	Shashemene	150
01/2039	TPP	Geothermal	Fentale	50
01/2039	TPP	Geothermal	Tendaho	100
01/2039	TPP	Geothermal	Boku	200
01/2039	TPP	GT	GT-NG	280
01/2039	RNW	Solar	Gade 2	250
01/2040	TPP	Geothermal	Dugna Fango	100
01/2040	TPP	Geothermal	Boku	400
01/2040	TPP	GT	GT-NG	140
01/2040	RNW	Solar	Gade 2	125
01/2040	RNW	Solar	Melkasedi	150
01/2041	TPP	Geothermal	Boku	500
01/2041	HPP	Hydro	Halele HEP	96
01/2041	HPP	Hydro	Werabesa HEP	340
01/2041	HPP	Hydro	L Dabus HEP	494
01/2041	RNW	Solar	Welenchiti	300
01/2042	TPP	Geothermal	Dofan	100
01/2042	TPP	Geothermal	Boku	400
01/2042	TPP	GT	GT-NG	140
01/2042	HPP	Hydro	Geba 1 HEP	215
01/2042	HPP	Hydro	Geba 2 HEP	157
01/2042	RNW	Wind	Mega	150

01/2042	RNW	Solar	Melkasedi	300
01/2043	TPP	Geothermal	Boku	500
01/2043	HPP	Hydro	Genale 6 HEP	246
01/2043	HPP	Hydro	Yeda 1 HEP	162
01/2043	HPP	Hydro	Yeda 2 HEP	118
01/2043	HPP	Hydro	Gojeb	150
01/2043	HPP	Hydro	Genale 5	100
01/2043	RNW	Wind	Gode	300
01/2043	RNW	Solar	Weranso	300
01/2044	TPP	Geothermal	Boku	500
01/2044	HPP	Hydro	Tekeze II H	450
01/2044	RNW	Wind	Gode	300
01/2044	RNW	Solar	Yirgalem	300
01/2045	TPP	Geothermal	Boku	500
01/2045	TPP	GT	GT-NG	420
01/2045	HPP	Hydro	Wabe	300
01/2045	RNW	Wind	Gode	300
01/2045	RNW	Solar	Worota	300
Total				22,155

SCENARIO 4: NUCLEAR

Scenario 4 – Expansion Plan

COD	Prj	Type	Project	Capacity (MW)
01/2024	RNW	Solar	Mekele	300
01/2024	RNW	Wind	Mega	300
01/2028	TPP	GT	GT-NG	980
01/2028	HPP	Hydro	U Dabus HEP	304
01/2028	RNW	Solar	Meki	100
01/2029	TPP	GT	GT-NG	420
01/2029	HPP	Hydro	Birbir R HEP	467
01/2029	RNW	Solar	Humera	100
01/2029	RNW	Solar	Worota	100
01/2030	HPP	Hydro	Karadobi	1,600
01/2030	HPP	Hydro	Birbir A	97
01/2030	RNW	Solar	Mekele	100
01/2030	RNW	Solar	Meki	100
01/2031	TPP	GT	GT-NG	140
01/2031	HPP	Hydro	Beko Abo	935
01/2032	TPP	GT	GT-NG	420
01/2032	RNW	Solar	Meki	200
01/2033	TPP	GT	GT-NG	420
01/2033	RNW	Solar	Welenchiti	150
01/2033	RNW	Solar	Weranso	150
01/2034	HPP	Hydro	Baro & Genji	894
01/2034	RNW	Solar	Humera	200
01/2034	RNW	Solar	Yirgalem	100
01/2035	TPP	Nuclear	Nuclear	600
01/2035	RNW	Solar	Melkasedi	300
01/2036	TPP	Nuclear	Nuclear	600
01/2036	RNW	Solar	Melkasedi	300
01/2037	TPP	Nuclear	Nuclear	600
01/2037	RNW	Solar	Gade 2	250
01/2038	TPP	Nuclear	Nuclear	600

01/2038	RNW	Solar	Weranso	300
01/2039	TPP	GT	GT-NG	420
01/2039	HPP	Hydro	Geba 1 HEP	215
01/2039	HPP	Hydro	Geba 2 HEP	157
01/2039	HPP	Hydro	Gojeb	150
01/2039	RNW	Solar	Welenchiti	150
01/2039	RNW	Solar	Weranso	150
01/2040	HPP	Hydro	U Mendaya	1,700
01/2040	RNW	Solar	Welenchiti	150
01/2040	RNW	Solar	Gade 2	125
01/2040	RNW	Wind	Ayesha I	120
01/2041	HPP	Hydro	Halele HEP	96
01/2041	HPP	Hydro	Werabesa HEP	340
01/2041	HPP	Hydro	Dedesa	301
01/2041	RNW	Solar	Metahara	200
01/2041	RNW	Wind	Gode	300
01/2041	RNW	Solar	Yirgalem	100
01/2042	TPP	GT	GT-NG	420
01/2042	HPP	Hydro	Tekeze II H	450
01/2042	HPP	Hydro	L Dabus HEP	494
01/2042	RNW	Solar	Metahara	100
01/2042	RNW	Solar	Humera	100
01/2042	RNW	Wind	Gode	300
01/2042	RNW	Solar	Yirgalem	100
01/2043	TPP	Geothermal	Shashemene	150
01/2043	TPP	Geothermal	Dofan	100
01/2043	TPP	Geothermal	Boku	100
01/2043	TPP	GT	GT-NG	420
01/2043	HPP	Hydro	Genale 5	100
01/2043	RNW	Wind	Gode	300
01/2043	RNW	Solar	Worota	200
01/2043	RNW	Solar	Yirgalem	100
01/2044	TPP	Geothermal	Dugna Fango	100
01/2044	TPP	GT	GT-NG	840
01/2044	RNW	Wind	Adigala	150
01/2044	RNW	Wind	Mega	150
01/2044	RNW	Solar	Worota	100
01/2044	RNW	Solar	Meshenti	200
01/2045	TPP	Geothermal	Fentale	50
01/2045	TPP	Geothermal	Tendaho	100
01/2045	TPP	GT	GT-NG	840
01/2045	HPP	Hydro	Wabe	300
01/2045	RNW	Wind	Adigala	300
01/2045	RNW	Solar	Metema	250
Total				23,615

SCENARIO 5: MINIMUM FOSSIL FUEL

Scenario 5 – Expansion Plan

COD	Prj	Type	Project	Capacity (MW)
01/2024	RNW	Solar	Mekele	300
01/2024	RNW	Wind	Mega	300
01/2026	RNW	Wind	Ayesha I	120
01/2027	RNW	Wind	Aysha II	240

01/2027	RNW	Solar	Welenchiti	300
01/2028	TPP	GT	GT-NG	700
01/2028	HPP	Hydro	U Dabus HEP	304
01/2028	RNW	Solar	Meki	300
01/2028	RNW	Wind	Ayesha I	240
01/2029	TPP	GT	GT-NG	280
01/2029	HPP	Hydro	Birbir R HEP	467
01/2029	RNW	Solar	Metahara	300
01/2029	RNW	Wind	Aysha II	120
01/2029	RNW	Wind	Adigala	150
01/2030	TPP	GT	GT-NG	140
01/2030	RNW	Wind	Gode	300
01/2030	RNW	Solar	Worota	100
01/2030	RNW	Solar	Meshenti	200
01/2031	HPP	Hydro	Baro & Genji	894
01/2031	HPP	Hydro	Karadobi	1,600
01/2031	HPP	Hydro	Birbir A	97
01/2031	RNW	Wind	Gode	300
01/2031	RNW	Solar	Worota	300
01/2032	HPP	Hydro	Beko Abo	935
01/2032	RNW	Wind	Ayesha	300
01/2032	RNW	Solar	Metema	125
01/2032	RNW	Solar	Yirgalem	100
01/2033	RNW	Solar	Humera	300
01/2033	RNW	Wind	Mega	150
01/2033	RNW	Wind	KebriBeyah	150
01/2034	HPP	Hydro	Geba 1 HEP	215
01/2034	HPP	Hydro	Geba 2 HEP	157
01/2034	RNW	Wind	Ayesha	300
01/2034	RNW	Solar	Meki	100
01/2034	RNW	Solar	Meshenti	200
01/2035	HPP	Hydro	U Mendaya	1,700
01/2035	RNW	Wind	Ayesha	300
01/2035	RNW	Solar	Yirgalem	300
01/2036	RNW	Solar	Metahara	100
01/2036	RNW	Solar	Humera	100
01/2036	RNW	Solar	Mekele	100
01/2036	RNW	Wind	Idabo	300
01/2037	TPP	Geothermal	Fentale	50
01/2037	HPP	Hydro	Genale 6 HEP	246
01/2037	RNW	Solar	Melkasedi	300
01/2037	RNW	Wind	KebriBeyah	300
01/2038	TPP	Geothermal	Shashemene	150
01/2038	TPP	Geothermal	Tendaho	100
01/2038	TPP	Geothermal	Boku	300
01/2038	RNW	Wind	Gode	300
01/2038	RNW	Solar	Weranso	300
01/2039	TPP	Geothermal	Boku	600
01/2039	RNW	Wind	Tuloguled	300
01/2039	RNW	Solar	Melkasedi	300
01/2040	TPP	Geothermal	Boku	600
01/2040	RNW	Wind	Adigala	300
01/2040	RNW	Solar	Metema	250
01/2041	HPP	Hydro	Tams HEP	2,000
01/2041	HPP	Hydro	Gojeb	150
01/2041	RNW	Wind	Idabo	150
01/2041	RNW	Solar	Weranso	300
01/2041	RNW	Wind	Sure	150

01/2042	TPP	Geothermal	Dugna Fango	100
01/2042	TPP	Geothermal	Boku	700
01/2042	HPP	Hydro	Genale 5	100
01/2042	RNW	Wind	Dire Dawa	150
01/2042	RNW	Solar	Metema	125
01/2042	RNW	Wind	Sure	150
01/2043	TPP	Geothermal	Dofan	100
01/2043	TPP	Geothermal	Boku	900
01/2043	RNW	Wind	Dire Dawa	300
01/2044	TPP	Geothermal	Boku	1,000
01/2044	RNW	Wind	Sure	150
01/2044	RNW	Wind	Assosa Bamba	150
01/2045	HPP	Hydro	Halele HEP	96
01/2045	HPP	Hydro	Werabesa HEP	340
01/2045	HPP	Hydro	Yeda 1 HEP	162
01/2045	HPP	Hydro	Yeda 2 HEP	118
01/2045	HPP	Hydro	Tekeze II H	450
01/2045	HPP	Hydro	L Dabus HEP	494
01/2045	HPP	Hydro	Wabi Shebele	87
01/2045	HPP	Hydro	Dedesa	301
01/2045	HPP	Hydro	Wabe	300
01/2045	RNW	Wind	Assosa Bamba	300
Total				27,703

SCENARIO 6: NON-COMMITTED EXPORTS

Scenario 6 – Expansion Plan

COD	Prj	Type	Project	Capacity (MW)
01/2024	RNW	Solar	Mekele	300
01/2024	RNW	Wind	Mega	300
01/2027	RNW	Solar	Melkasedi	150
01/2028	HPP	Hydro	U Dabus HEP	304
01/2028	HPP	Hydro	Birbir A	97
01/2028	RNW	Solar	Mekele	100
01/2028	RNW	Solar	Melkasedi	150
01/2029	RNW	Solar	Gade 2	250
01/2030	HPP	Hydro	Baro & Genji	894
01/2030	HPP	Hydro	Karadobi	1,600
01/2030	RNW	Solar	Gade 2	250
01/2032	HPP	Hydro	Birbir R HEP	467
01/2032	HPP	Hydro	Beko Abo	935
01/2032	RNW	Solar	Meki	100
01/2032	RNW	Solar	Melkasedi	150
01/2033	HPP	Hydro	L Dabus HEP	494
01/2033	RNW	Solar	Weranso	300
01/2034	RNW	Solar	Weranso	300
01/2035	RNW	Solar	Welenchiti	150
01/2035	RNW	Solar	Melkasedi	150
01/2036	TPP	GT	GT-NG	140
01/2036	HPP	Hydro	Geba 1 HEP	215
01/2036	HPP	Hydro	Geba 2 HEP	157

01/2036	RNW	Wind	Mega	150
01/2036	RNW	Solar	Meki	300
01/2037	HPP	Hydro	U Mendaya	1,700
01/2037	RNW	Wind	Adigala	150
01/2037	RNW	Solar	Welenchiti	300
01/2038	HPP	Hydro	Halele HEP	96
01/2038	HPP	Hydro	Werabesa HEP	340
01/2038	RNW	Solar	Metahara	300
01/2038	RNW	Wind	Gode	300
01/2039	HPP	Hydro	Tams HEP	2,000
01/2039	HPP	Hydro	Gojeb	150
01/2039	RNW	Wind	Gode	300
01/2039	RNW	Solar	Welenchiti	150
01/2039	RNW	Solar	Yirgalem	100
01/2040	HPP	Hydro	Tekeze II H	450
01/2040	RNW	Wind	Gode	300
01/2040	RNW	Solar	Yirgalem	300
01/2041	TPP	Geothermal	Shashemene	150
01/2041	TPP	Geothermal	Dofan	100
01/2041	TPP	Geothermal	Fentale	50
01/2041	TPP	Geothermal	Tendaho	100
01/2041	TPP	Geothermal	Dugna Fango	100
01/2041	TPP	Geothermal	Boku	100
01/2041	RNW	Wind	Ayesha	300
01/2041	RNW	Solar	Metahara	100
01/2041	RNW	Solar	Worota	200
01/2042	TPP	GT	GT-NG	980
01/2042	RNW	Wind	Adigala	300
01/2042	RNW	Solar	Worota	200
01/2042	RNW	Solar	Meshenti	100
01/2043	TPP	GT	GT-NG	980
01/2043	RNW	Wind	Ayesha	300
01/2043	RNW	Solar	Meshenti	300
01/2044	TPP	GT	GT-NG	980
01/2044	RNW	Solar	Humera	100
01/2044	RNW	Wind	KebriBeyah	300
01/2045	TPP	GT	GT-NG	980
01/2045	HPP	Hydro	Genale 6 HEP	246
01/2045	HPP	Hydro	Yeda 1 HEP	162
01/2045	HPP	Hydro	Yeda 2 HEP	118
01/2045	RNW	Wind	Ayesha	300
Total				**22,885**