Presentation 10: Power production

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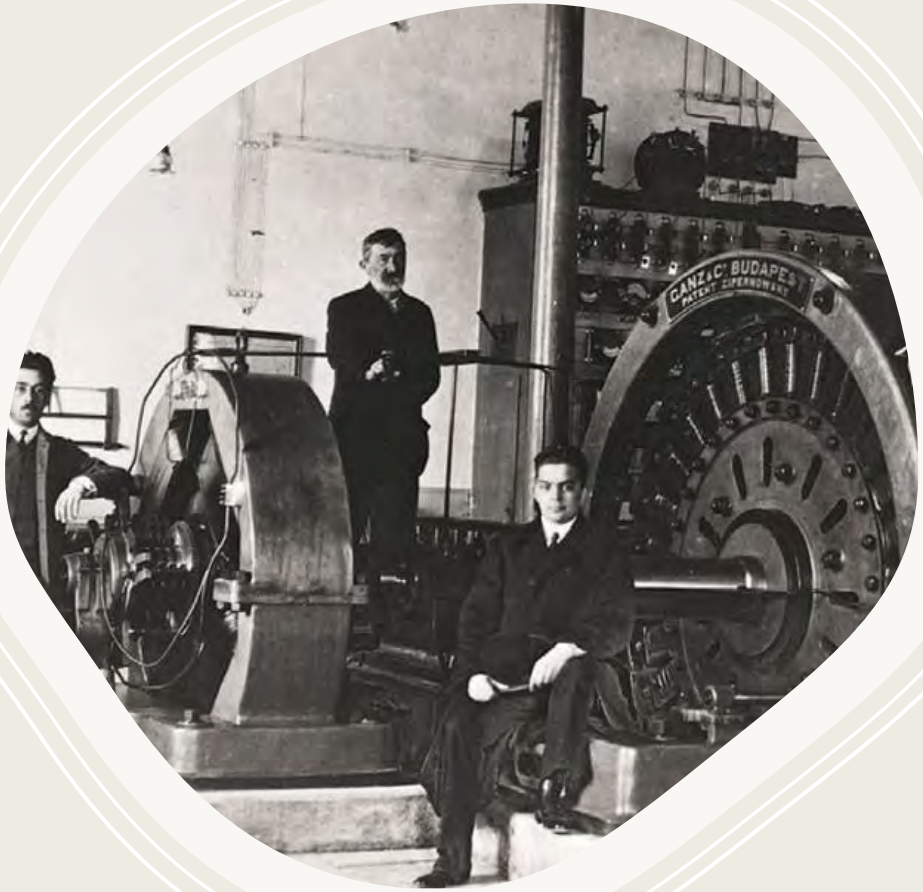
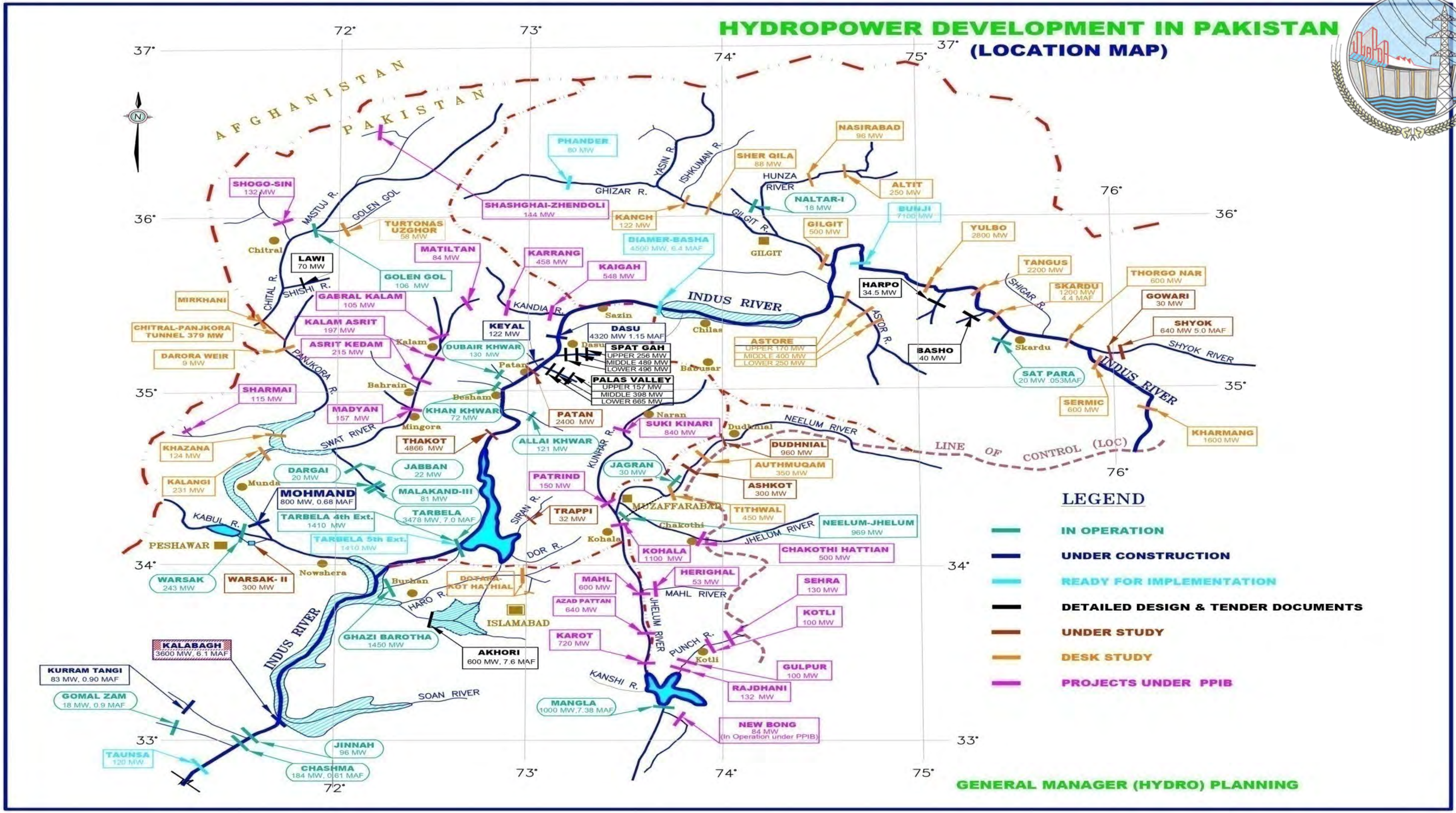


Hydropower

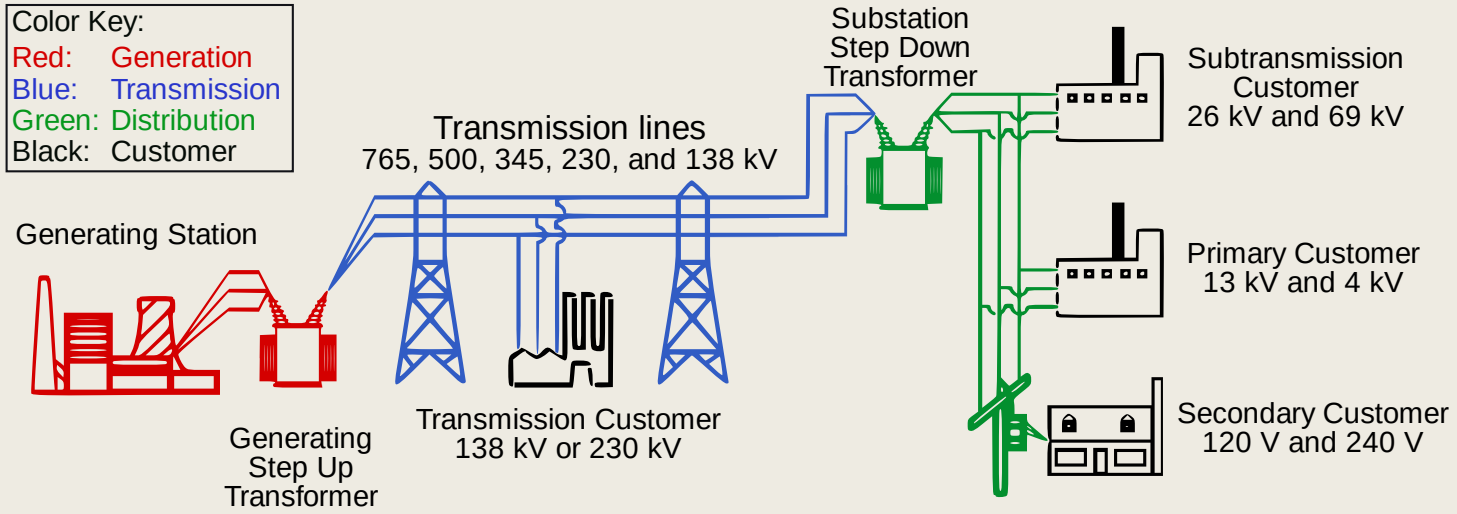
- Hydropower is power derived from the energy of falling or running water.
- As water is about 800 times denser than air, even a slow-flowing stream may deliver considerable energy.
- 1882: First HEP in the world opens on the Fox River in Wisconsin, USA.
- 1897: First HEP in Asia opens on the Teesta River in Sidrapong, West Bengal.

Advantages

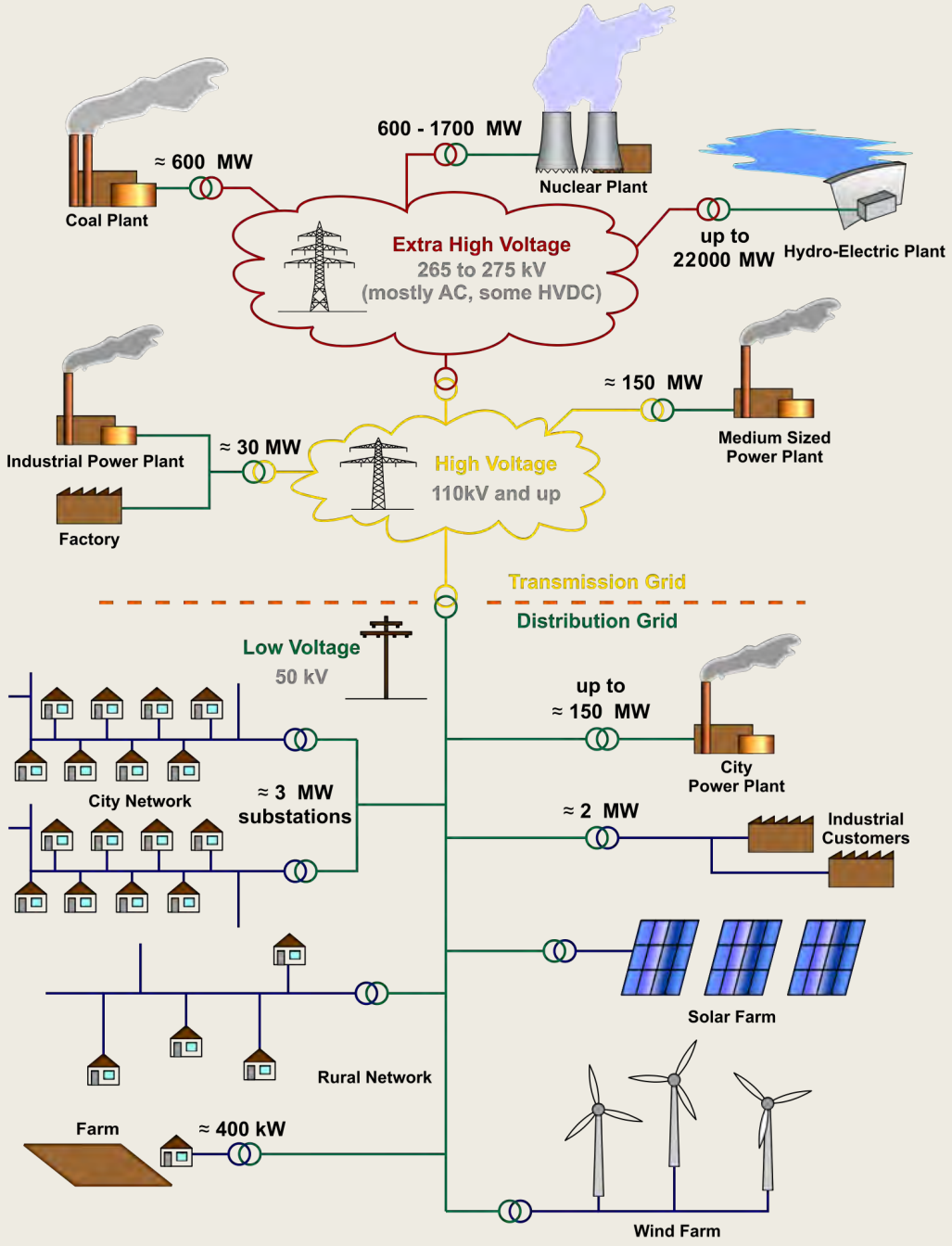
- Clean, cheap and **reliable**.
- Relatively **easy to maintain** in comparison with thermal (coal, gas) and nuclear power.
- Able to **adapt to changing load** on the power system (i.e. the grid).
- Able to **ramp up quickly** in comparison to thermal power in case of emergency, enhancing power system stability.


HYDROPOWER DEVELOPMENT IN PAKISTAN
(LOCATION MAP)
AFGHANISTAN
PAKISTAN
SHOGO-SIN 132 MW
SHASHGHAI-ZHENDOLI 144 MW
PHANDER 80 MW
TURTONAS UZGHOR 58 MW
MATILTAN 84 MW
KARRANG 458 MW
KAIGAH 548 MW
DIAMER-BASHA 4500 MW, 6.4 MAF
KANCH 122 MW
SHER QILA 88 MW
NASIRABAD 96 MW
ALTIT 250 MW
NALTAR-I 18 MW
BUNJI 7100 MW
GILGIT 500 MW
YULBO 2800 MW
TANGUS 2200 MW
THORGO NAR 600 MW
SKARDU 1200 MW 4.4 MAF
GOWARI 30 MW
SHYOK 640 MW 5.0 MAF
HARPO 34.5 MW
BASHO 40 MW
SAT PARA 20 MW 053MAF
SERMIC 600 MW
KHARMANG 1600 MW
LAWI 70 MW
GOLEN GOL 106 MW
GABRAL KALAM 105 MW
KALAM ASRIT 197 MW
ASRIT KEDAM 215 MW
MIRKHANI
CHITRAL-PANJKORA TUNNEL 379 MW
DARORA WEIR 9 MW
SHARMAI 115 MW
MADYAN 157 MW
KHAN KHWAR 72 MW
DUBAIR KHWAR 130 MW
KEYAL 122 MW
DASU 4320 MW 1.15 MAF
SPAT GAH
UPPER 256 MW
MIDDLE 489 MW
LOWER 496 MW
PALAS VALLEY
UPPER 157 MW
MIDDLE 398 MW
LOWER 665 MW
ASTORE
UPPER 170 MW
MIDDLE 400 MW
LOWER 250 MW
PATAN 2400 MW
THAKOT 4866 MW
ALLAI KHWAR 121 MW
SUKI KINARI 840 MW
DUDHNIAL 960 MW
AUTHMUQAM 350 MW
ASHKOT 300 MW
JAGRAN 30 MW
PATRIND 150 MW
TRAPPI 32 MW
TITHWAL 450 MW
NEELUM-JHELUM 969 MW
CHAKOTHI HATTIAN 500 MW
KOHALA 1100 MW
KHAZANA 124 MW
KALANGI 231 MW
DARGAI 20 MW
JABBAN 22 MW
MALAKAND-III 81 MW
MOHMAND 800 MW, 0.68 MAF
TARBELA 3478 MW, 7.0 MAF
TARBELA 4th Ext. 1410 MW
TARBELA 5th Ext. 1410 MW
WARSAK 243 MW
WARSAK- II 300 MW
DOTARA-KOT HATHIAL
GHAZI BAROTHA 1450 MW
AKHORI 600 MW, 7.6 MAF
KALABAGH 3600 MW, 6.1 MAF
KURRAM TANGI 83 MW, 0.90 MAF
GOMAL ZAM 18 MW, 0.9 MAF
TAUNSA 120 MW
JINNAH 96 MW
CHASHMA 184 MW, 0.61 MAF
MAHL 600 MW
AZAD PATTAN 640 MW
HERIGHAL 53 MW
KAROT 720 MW
SEHRA 130 MW
KOTLI 100 MW
GULPUR 100 MW
RAJDHANI 132 MW
MANGLA 1000 MW,7.38 MAF
NEW BONG 84 MW (In Operation under PPIB)
INDUS RIVER
NEELUM RIVER
JHELUM RIVER
SHYOK RIVER
SWAT RIVER
SOAN RIVER
KABUL R.
LINE OF CONTROL (LOC)
Chitral
Gilgit
Skardu
Peshawar
Islamabad
Muzaffarabad
Kotli
LEGEND
IN OPERATION
UNDER CONSTRUCTION
READY FOR IMPLEMENTATION
DETAILED DESIGN & TENDER DOCUMENTS
UNDER STUDY
DESK STUDY
PROJECTS UNDER PPIB
GENERAL MANAGER (HYDRO) PLANNING

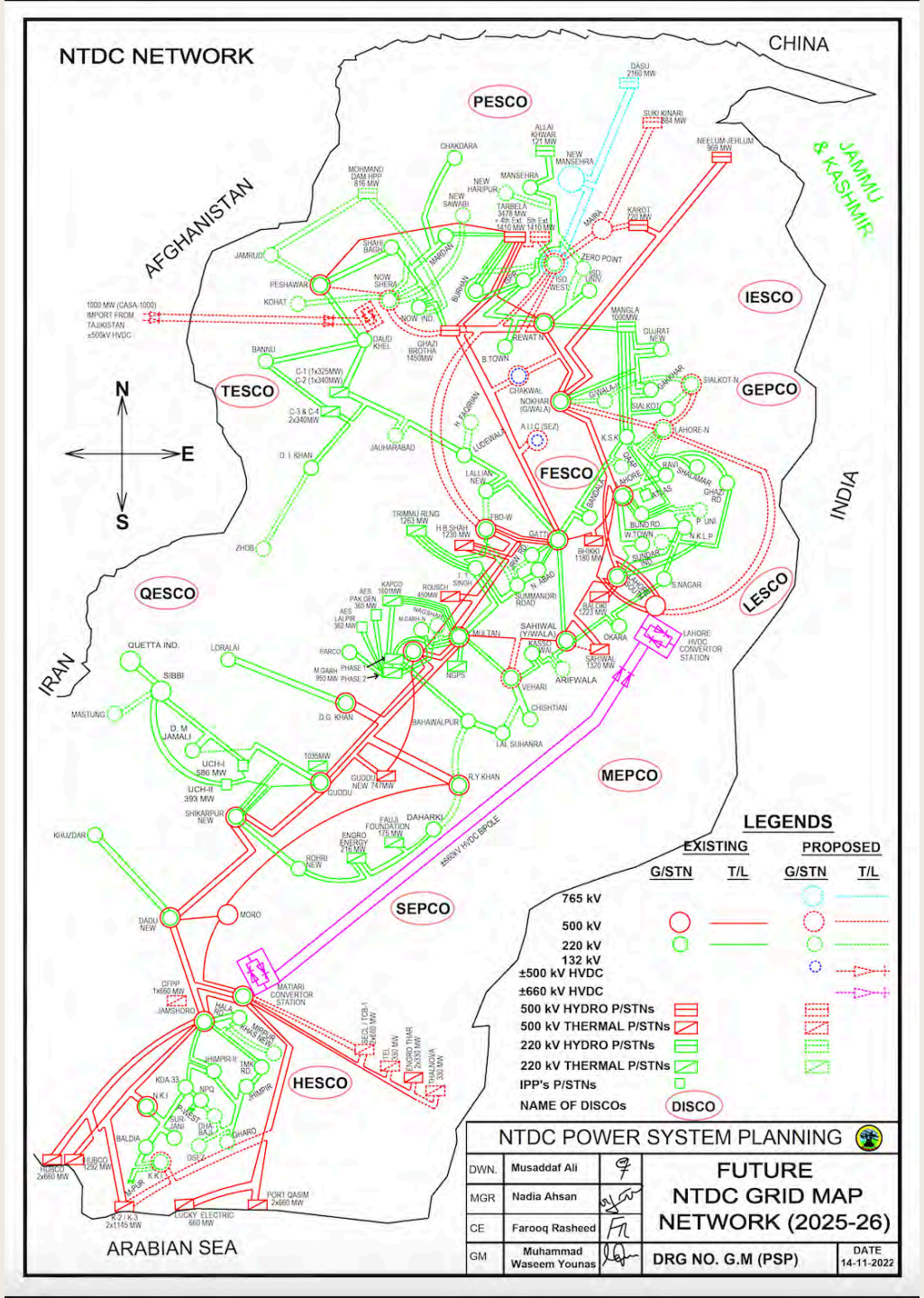
Power production and power systems



Simple power system

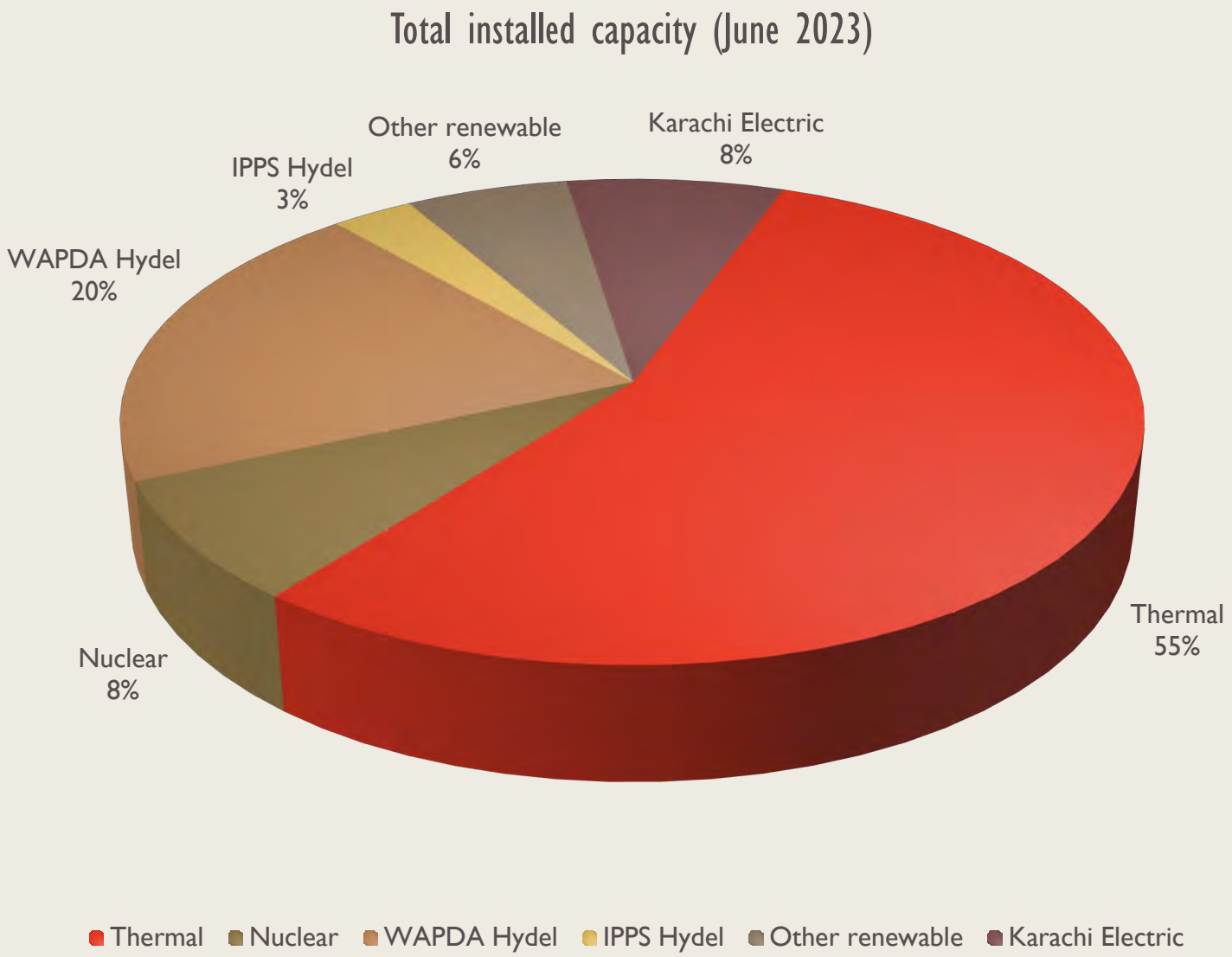


Integrated power system

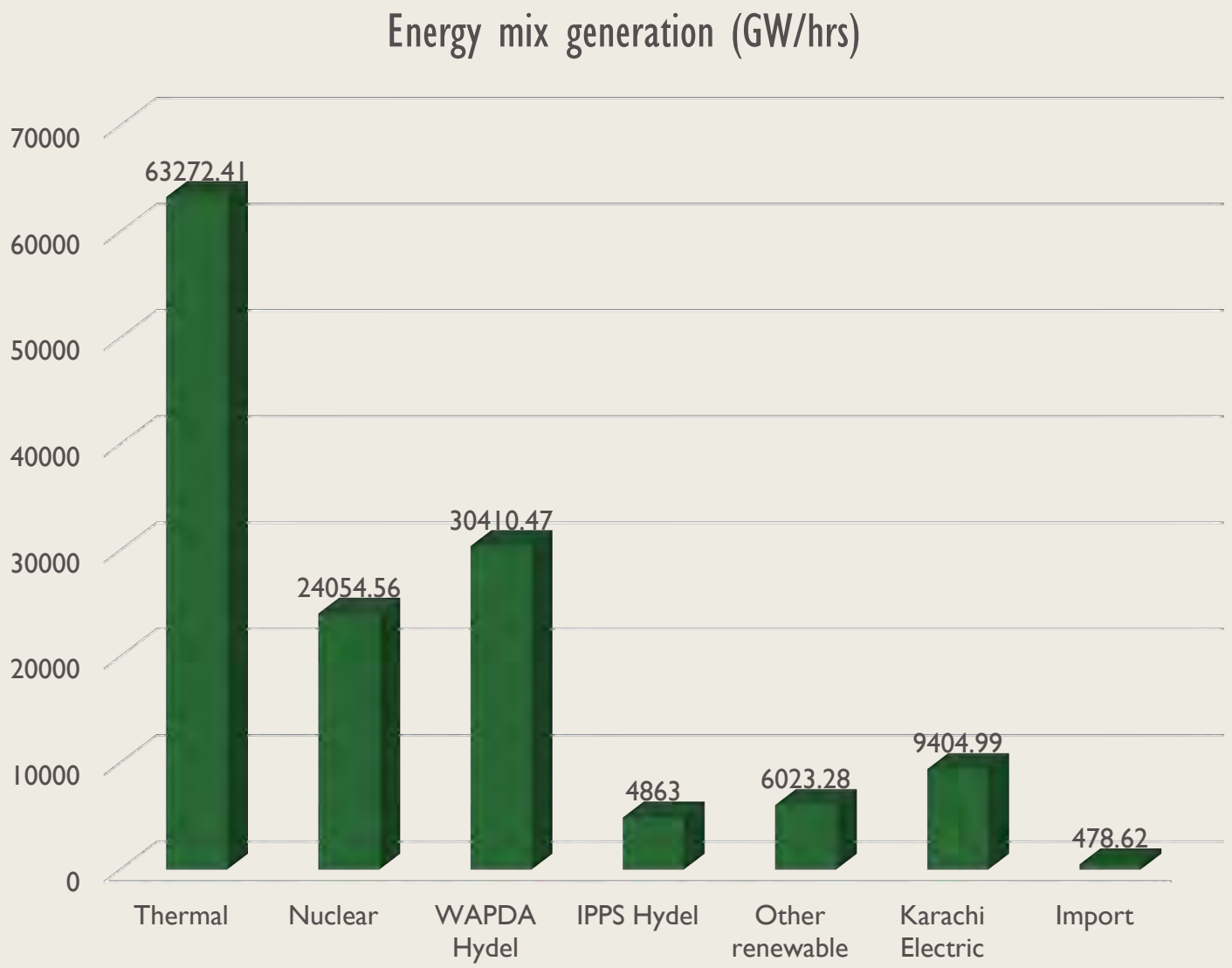


Pakistan's power system

- Developed **integrated power system** with thermal (coal, nuclear, gas) and hydroelectric (hydel) power.
- **Future grid** for 2025–2026; **Cross-border connections** and **distribution companies** (DISCOs) also shown.
- **Grid stations and transmission lines** owned and operated by the National Transmission & Despatch Company (NTDC), separated from WAPDA in 1998.



Pakistan's total installed capacity



Pakistan's energy mix generation 2022–2023

The HEP and the power system

Water	Head	Load
Run-of-river HEP without pondage	Low head HEP	Base load HEP
Run-of-river HEP with pondage	Medium head HEP	Intermediate load HEP
HEP attached to storage reservoir	High head HEP	Peaking load HEP
Pumped storage HEP		

HEP output

- HEP power production determined by three principal factors:
  - Availability of **water**
  - Height of available generating **head**
  - **Loading** of HEP by operator

$P = Q \times g \times h \times \rho \times \eta$

P = Power (W)

Q = Flow rate (m^3/sec)

g = Gravity (m/sec^2)

h = Generating head (m)

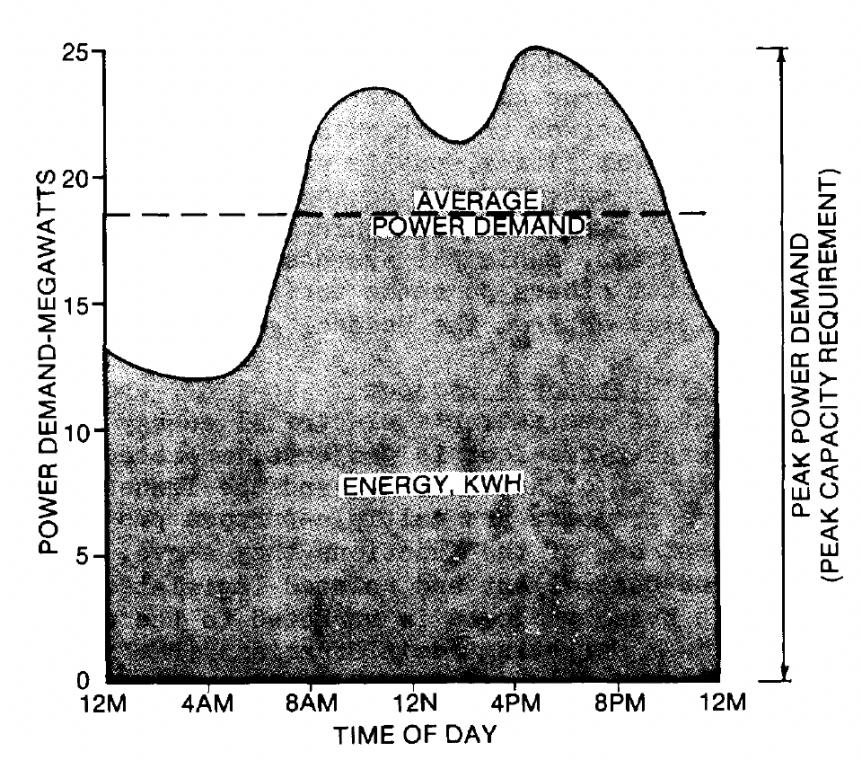
ρ = Density of water (kg/m^3)

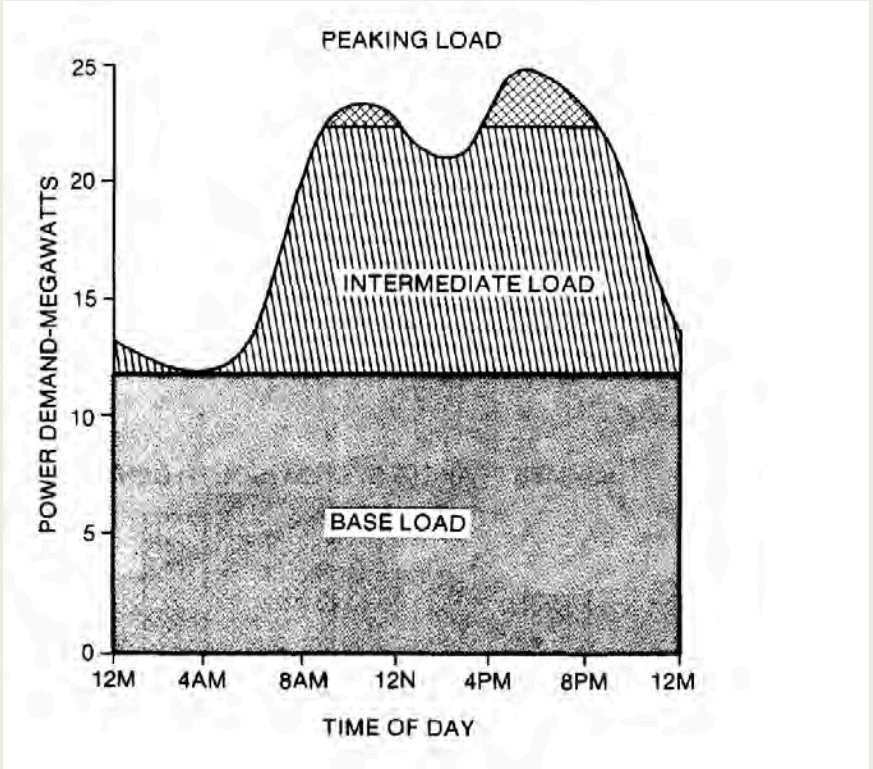
η = Turbine efficiency (%)

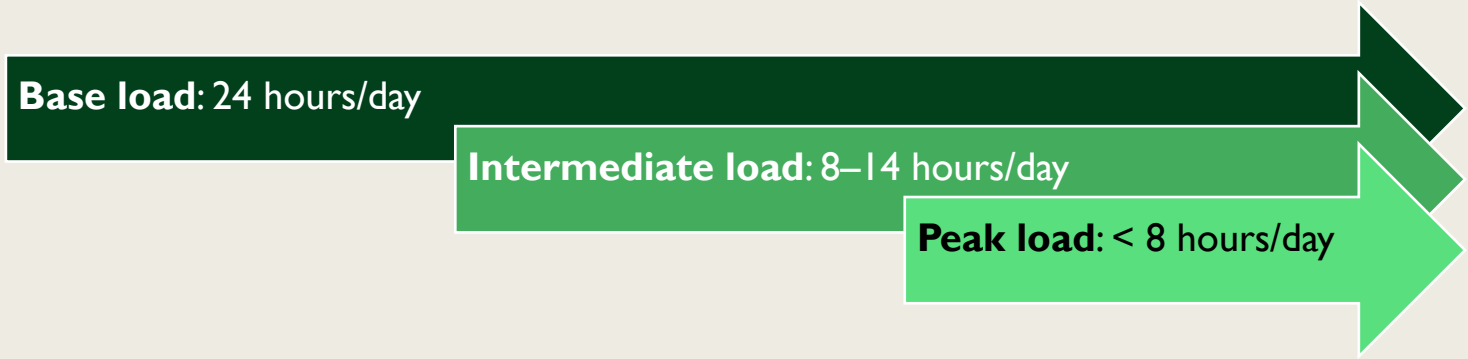
Measuring HEP output

- A HEP is a **power plant**, being a system used to generate electrical power that can be used to perform work.
- HEP output is measured in **power**, reflecting rate at which energy is produced, measured (today) in *MW*.
- **Energy** reflects the power produced over a time period, measured in *MWh*.

Daily plant loading

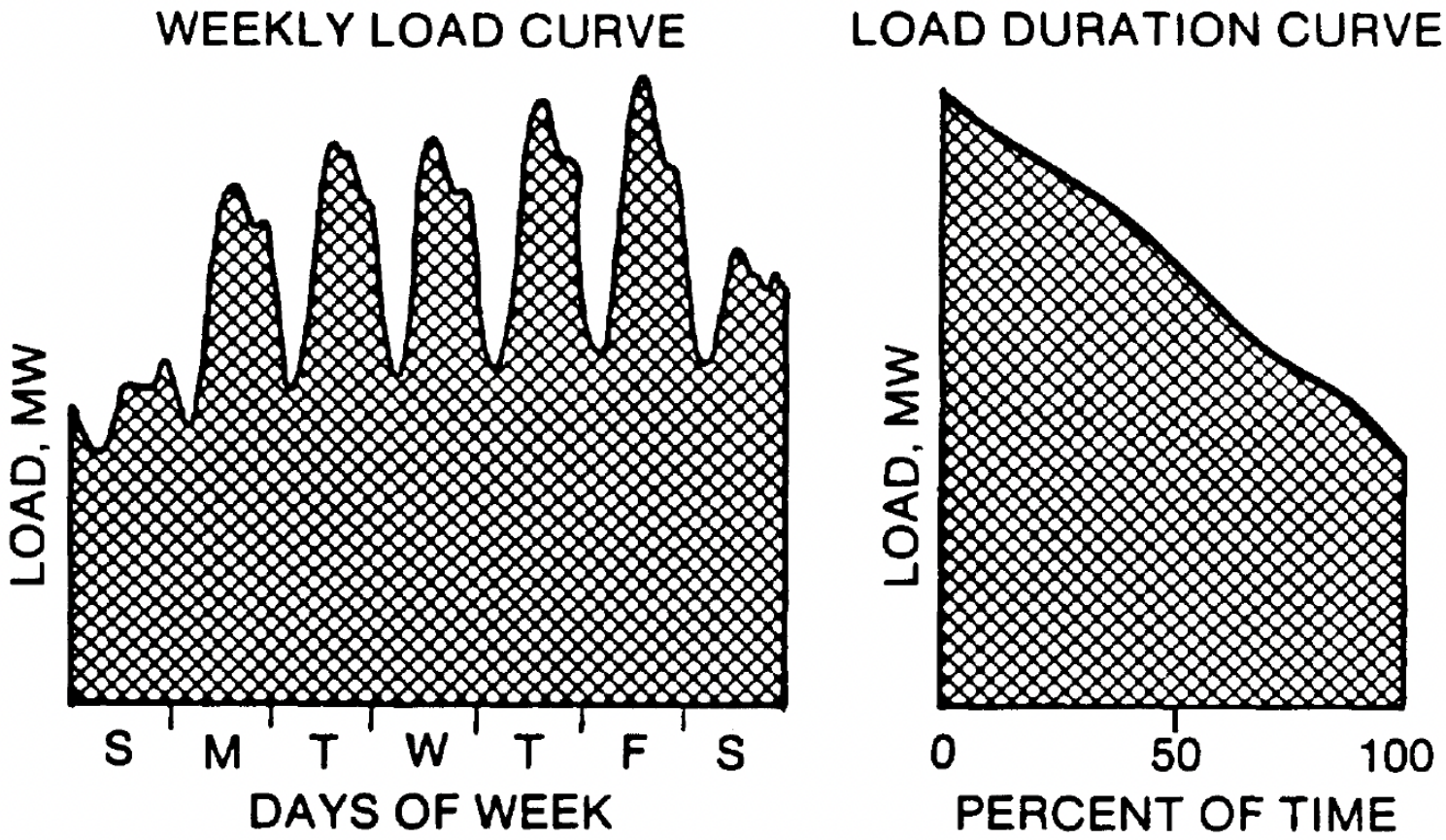






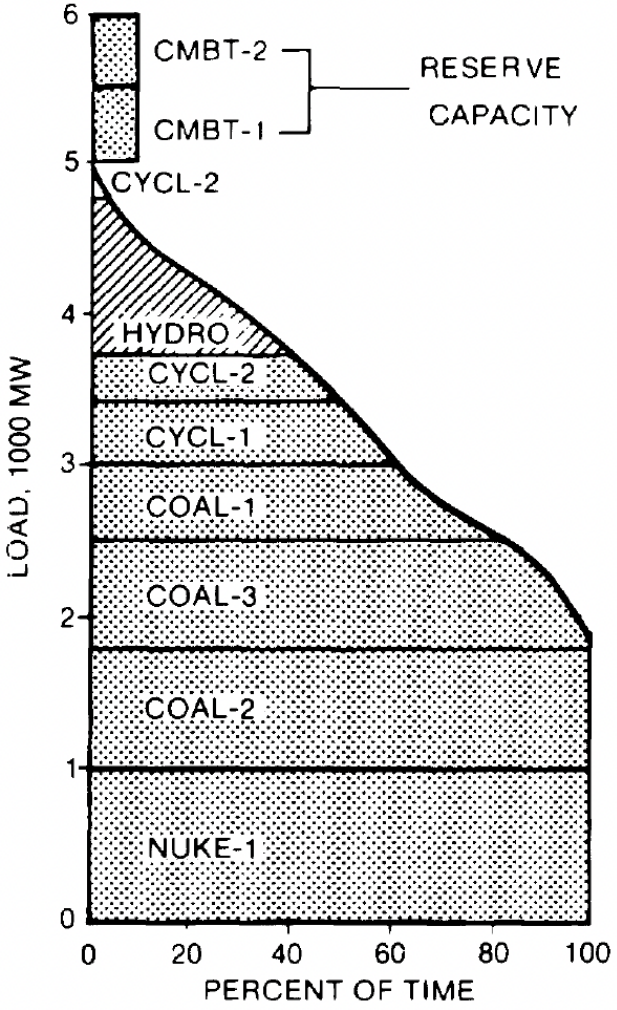
Load types

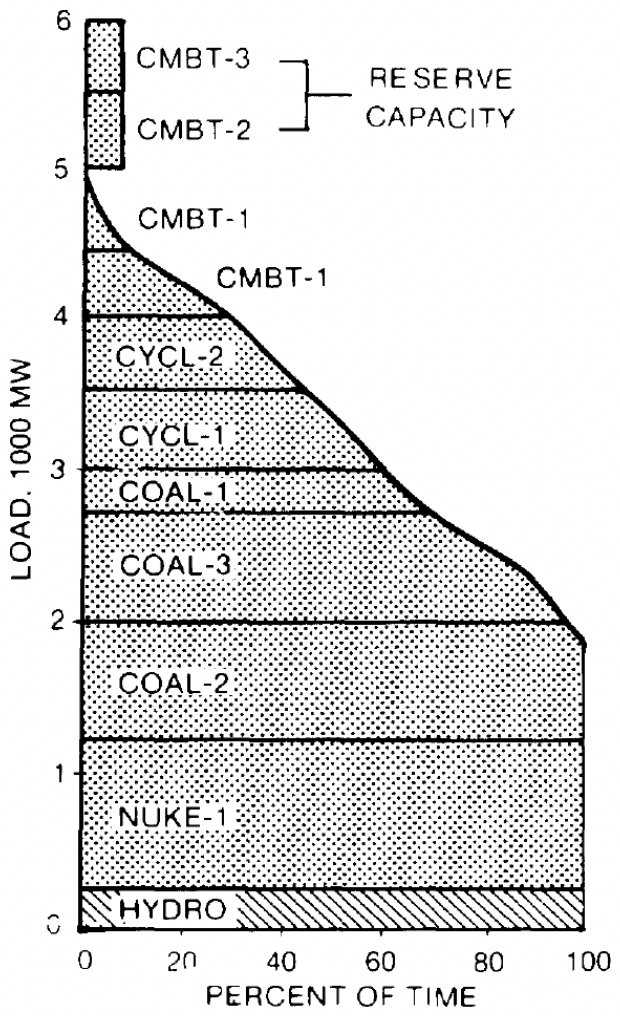
- USACE divides load types into **three categories**.
- Load categories may be **mixed** – e.g. a base load plant operating constantly may be peaked at times of high demand, provided it has the installed capacity to do so.



Weekly plant loading

- **Plant load** varies depending on the day of the week, and also on the season.
- Weekly load curve may be converted into a **load duration curve** for power planning.
- **Daily load curves** may also be converted into load duration curves.





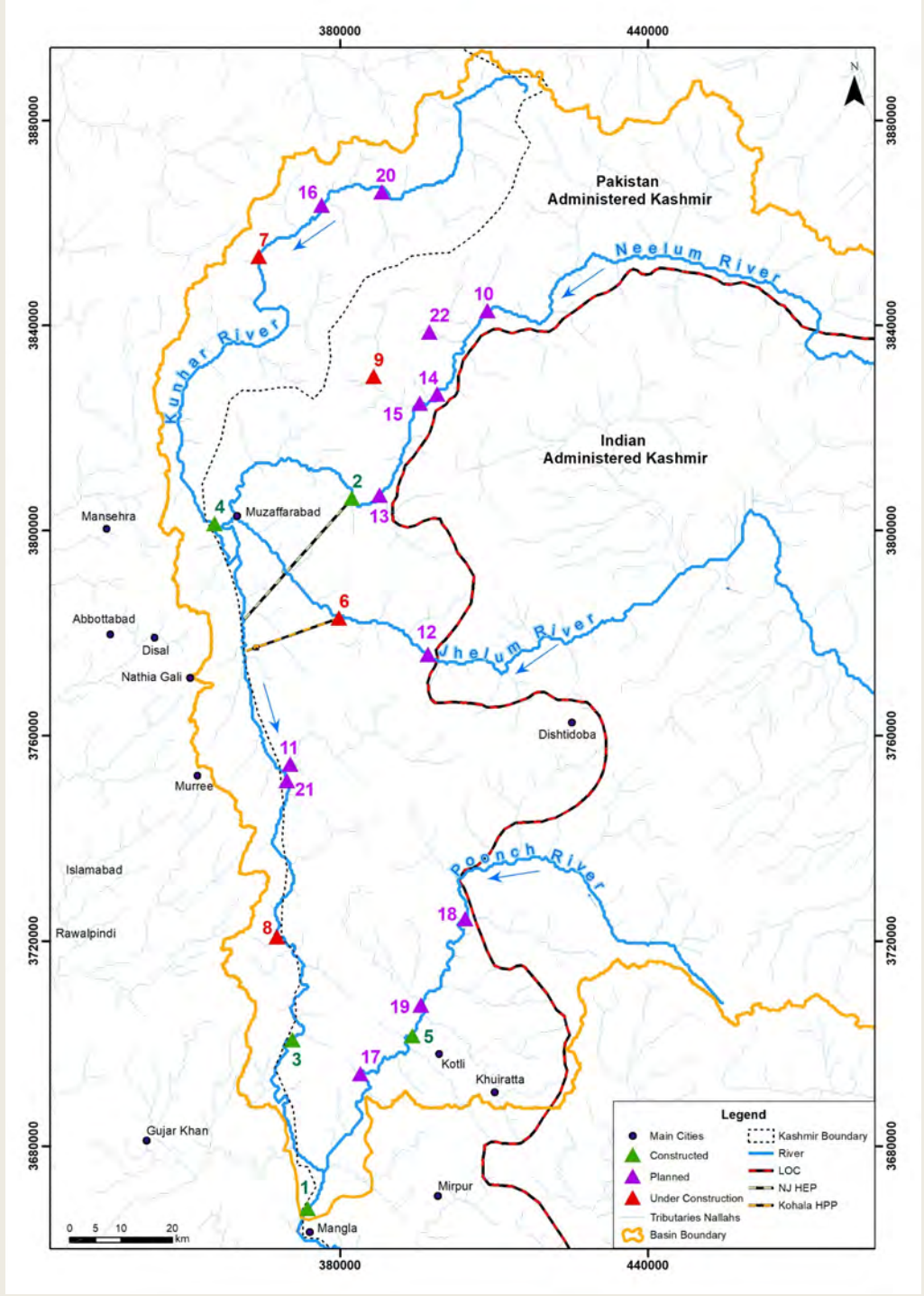
HEPs in a power system

- Run-of-river HEPs with pondage can play varying roles in a power system.
- Can be run as a **peaking plant** (left) providing more power for shorter periods.
- Can be run as a **base load plant** (right) providing less power constantly.
- Use may vary depending on **wet or dry** season.

The NJHEP in Pakistan's power system

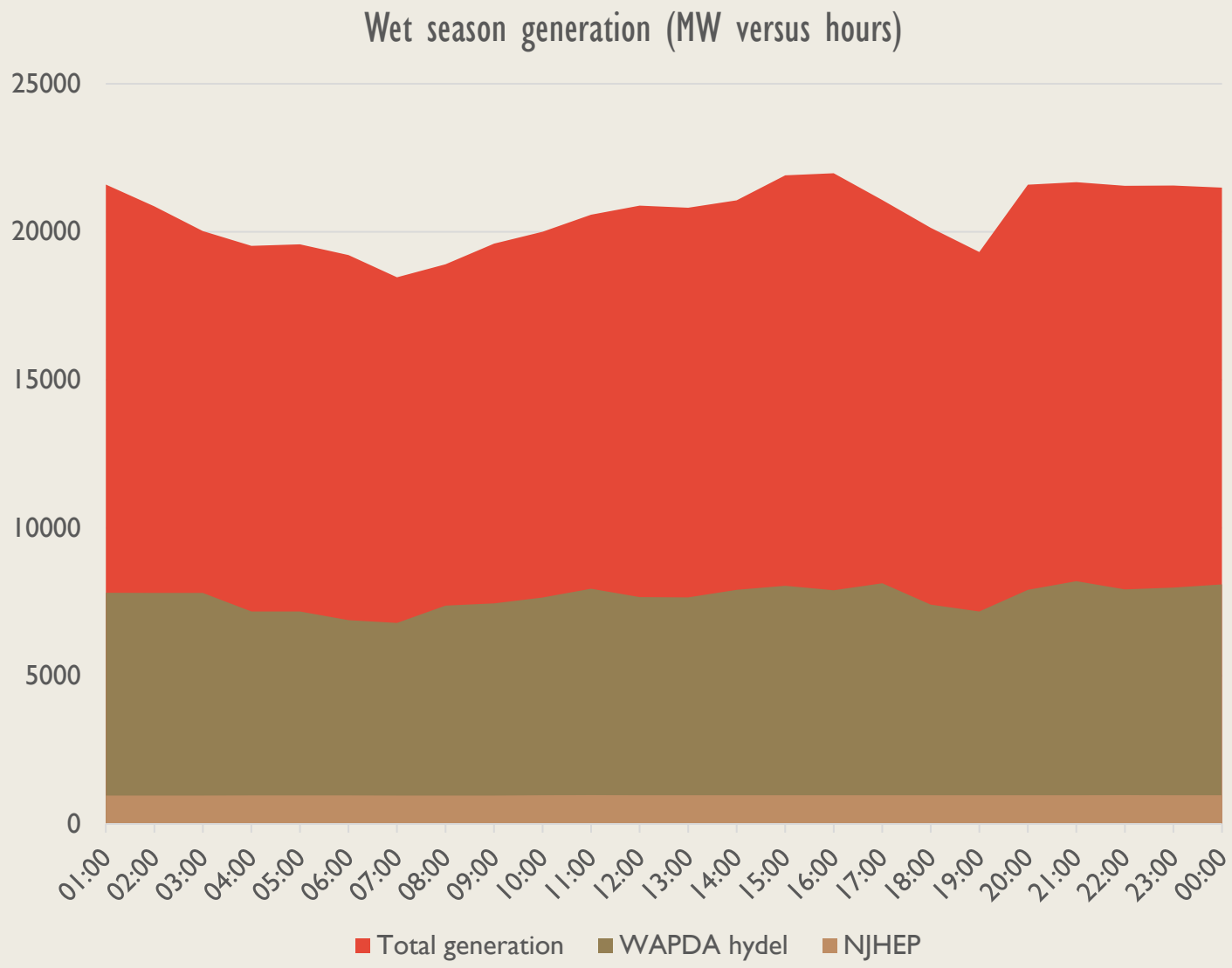
NJHEP operations

- The **NJHEP** (969MW run-of-river HEP) operates in conjunction with three other major HEPs in its immediate region: **Patrind** HEP (150MW run-of-river HEP); **Karot** HEP (720MW run-of-river HEP); and **Mangla** HEP (1000MW storage HEP).
- During the dry season, it is usually operated as a **combination baseload and peaking plant**. In the wet season, it is a baseload plant.



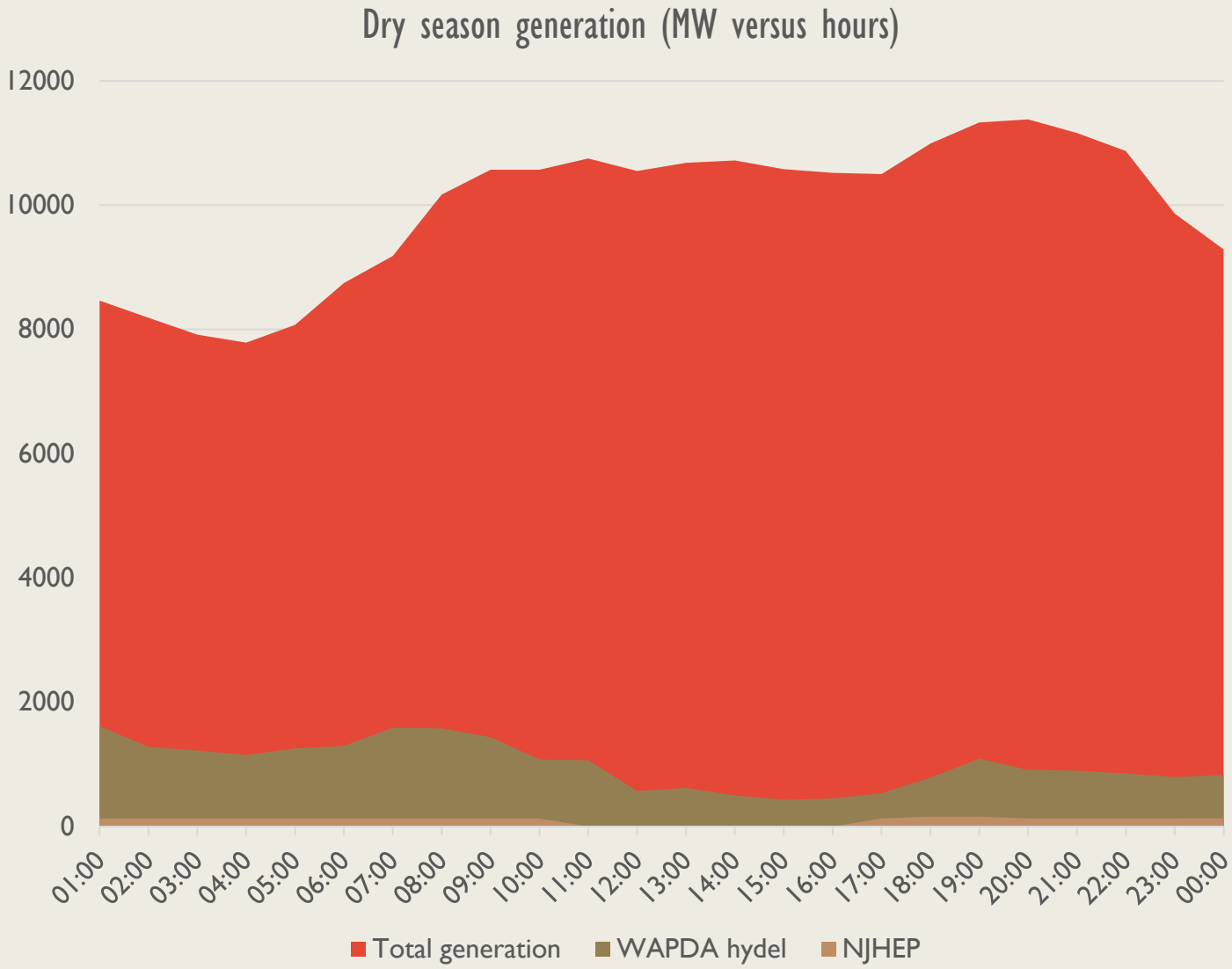
Power system expansion

- A HEP rarely operates alone. In particular, if it is intended have a peaking function it must feed into a wider power system.
- As such, the HEP is designed in view of future power system requirements, and the role the HEP may play within it.
- In illustration of this, the NJHEP is part of Pakistan's wider power grid and power planning strategy.



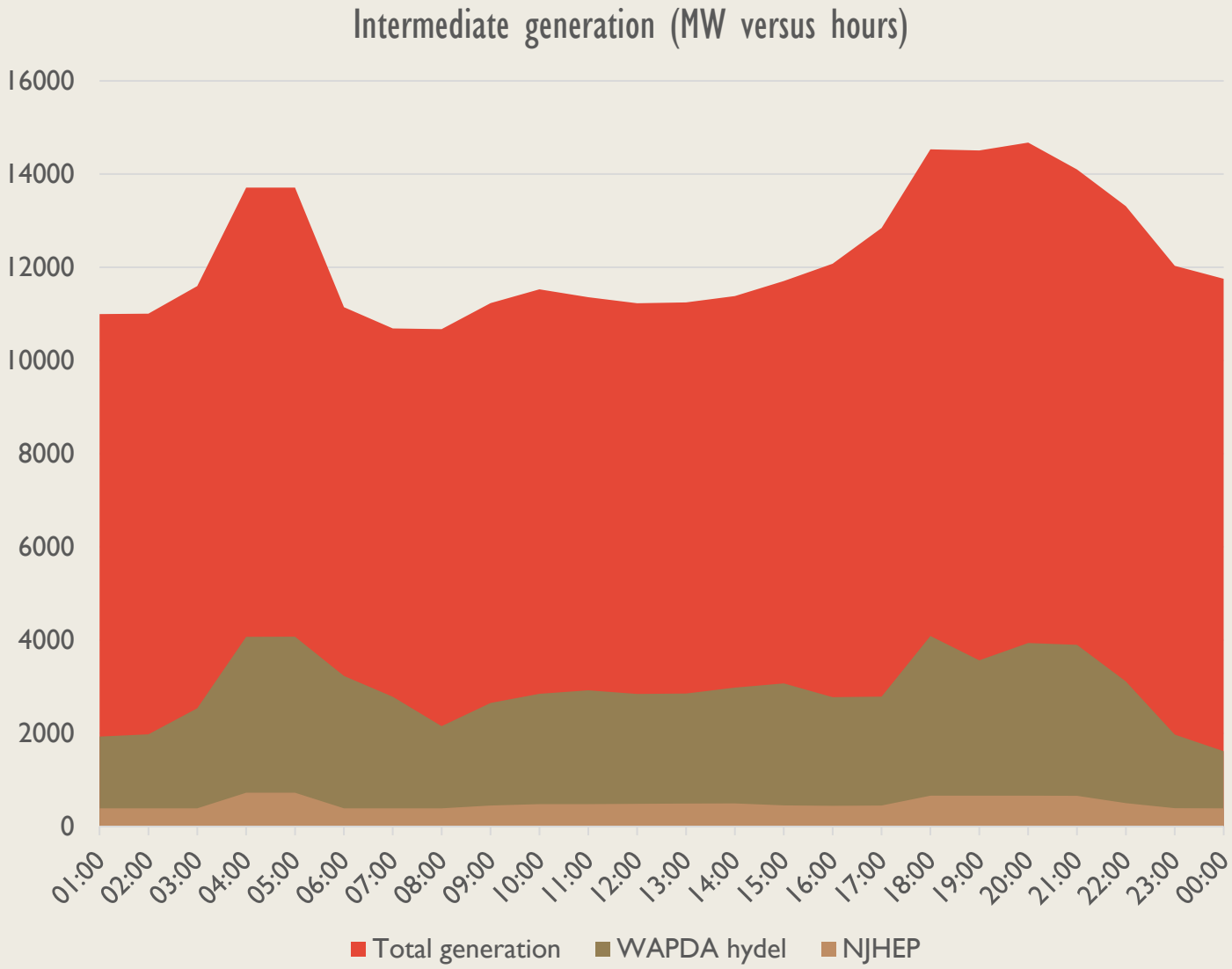
Wet season generation

- A snapshot of Pakistan's power system in the wet season on **31 July 2023**.
- Shows the use of the NJHEP as baseload power at around its **installed capacity** (969MW).



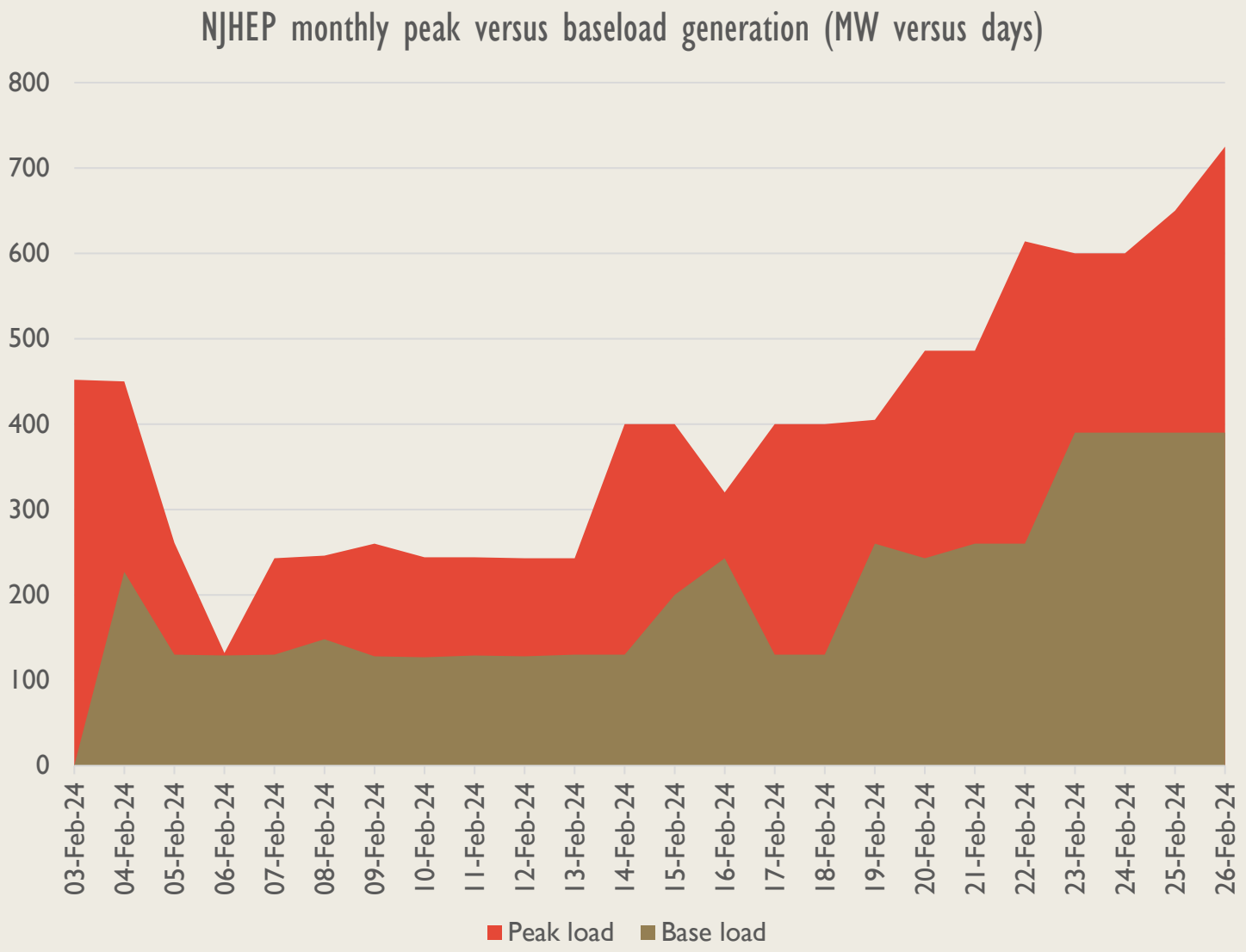
Dry season generation

- A snapshot of Pakistan's power system in the dry season on **23 December 2023**.
- Shows the use of the NJHEP as **intermediate power**.



Intermediate generation

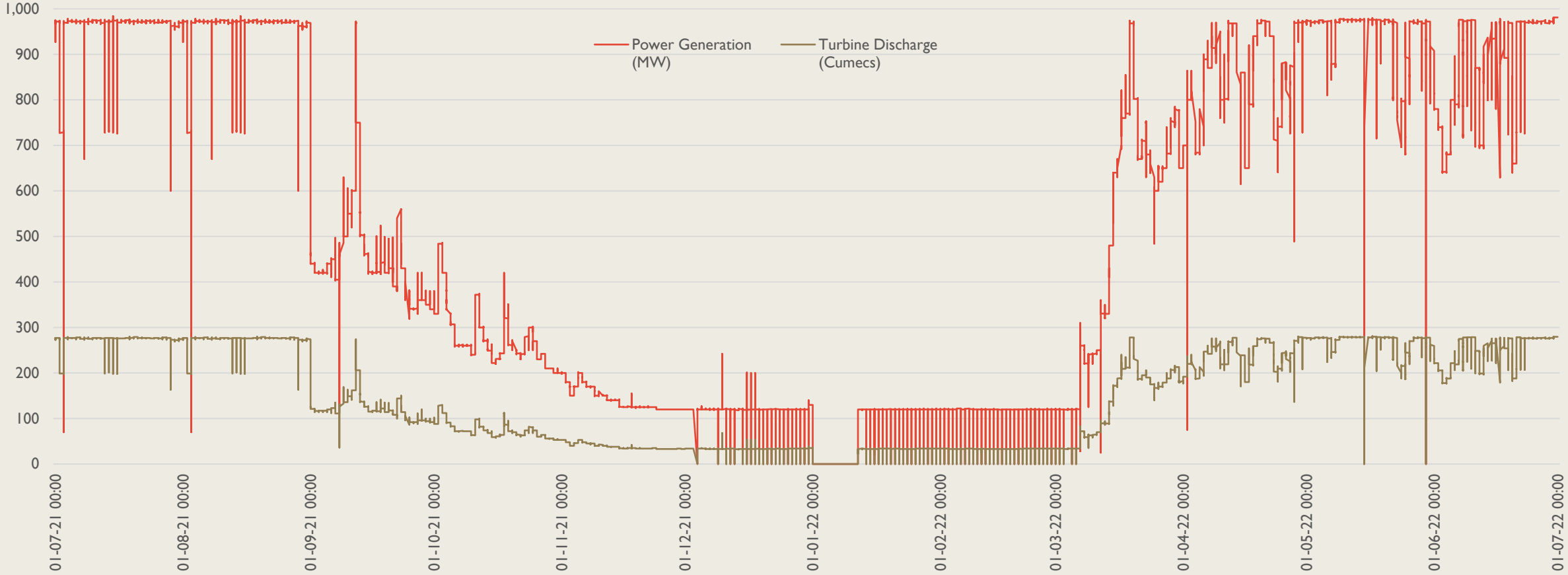
- A snapshot of Pakistan's power system in the intermediate season on **25 March 2024**.
- Shows the use of hydel and the NJHEP as **mixed baseload and peaking power**.



Monthly generation

- A snapshot of NJHEP production in **February 2024**.
- As the supply of water slowly increases as the dry season ends, the power production of the NJHEP **increases**.

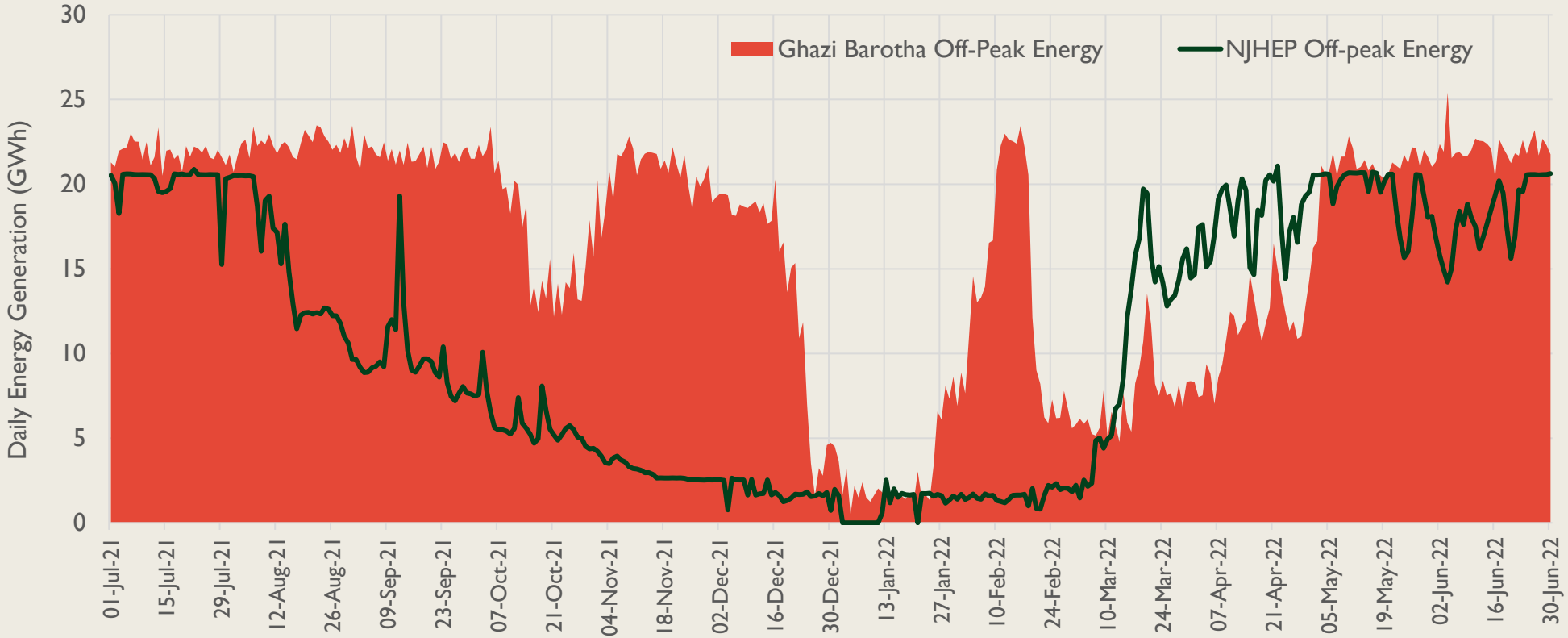
Yearly generation: 2021–2022



Production plans

- The HEP operator may set plans for a HEP's power production based on the requirements of the power system and each HEP's individual capacity.
- This may mean that an unconstrained HEPs operate differently despite having the same fundamental design.
- One example of this is the **NJHEP**, which is not peaked aggressively in the dry season owing to its distance from demand centres and the need to avoid transmission losses – it may be compared with **Ghazi Barotha HEP** ('GBHEP') (1,450MW), which is peaked more aggressively in the dry season.

GBHEP versus NJHEP off-peak production



GBHEP versus NJHEP peak production