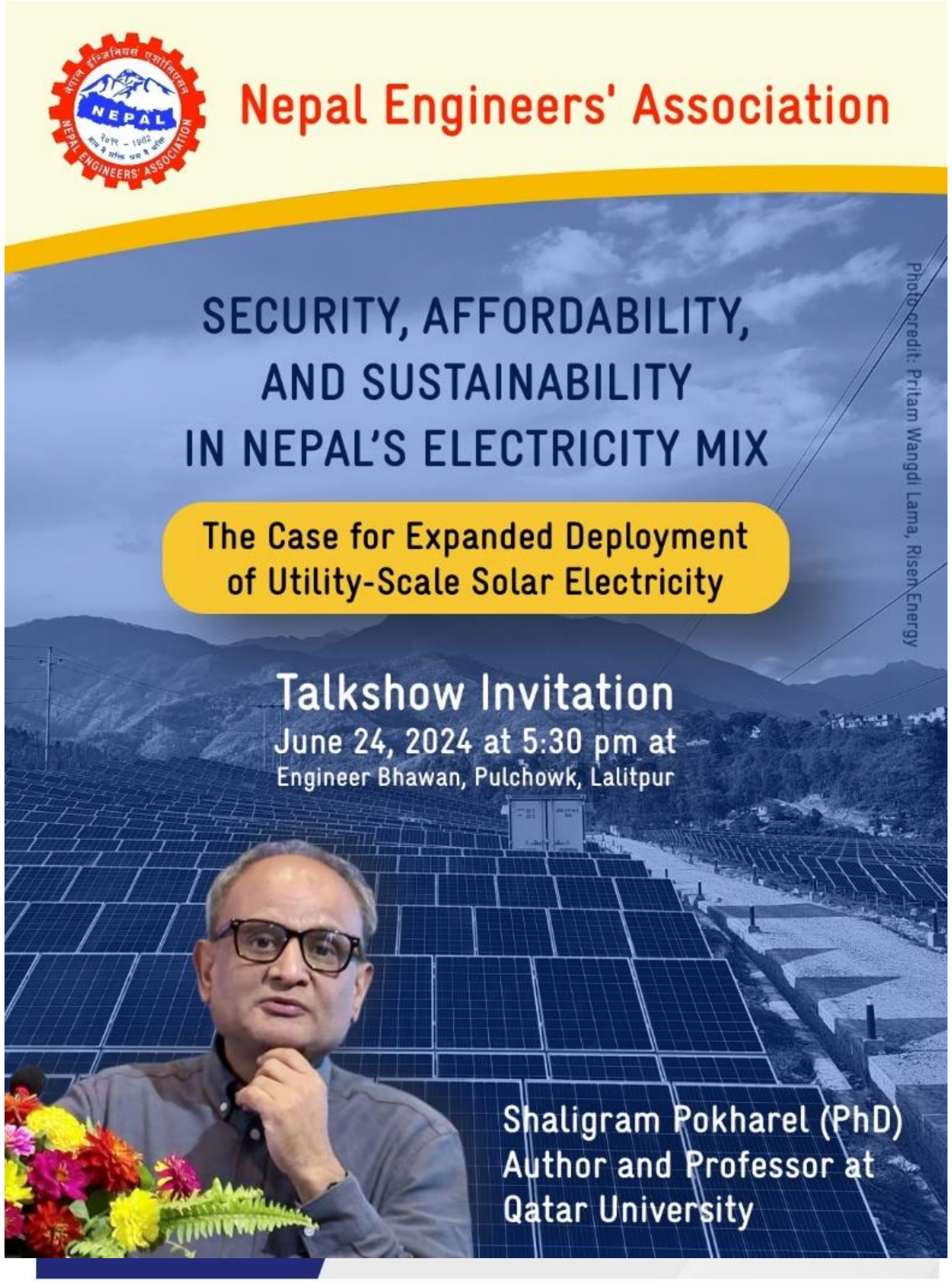
Nepal Engineers' Association
SECURITY, AFFORDABILITY, AND SUSTAINABILITY IN NEPAL'S ELECTRICITY MIX
The Case for Expanded Deployment of Utility-Scale Solar Electricity
Photo credit: Pritam Wangdi Lama, Risen Energy
Talkshow Invitation
June 24, 2024 at 5:30 pm at
Engineer Bhawan, Pulchowk, Lalitpur
Shaligram Pokharel (PhD)
Author and Professor at
Qatar University

SECURITY, AFFORDABILITY, AND SUSTAINABILITY IN NEPAL'S ELECTRICITY MIX

The Case for Complementing Hydropower with Utility-Scale Solar Electricity

June 24, 2024

Presentation at Nepal Engineering Association

INTEGRATION Project Office
231 Kandevtasthan Marg
Kupondol, Lalitpur, Nepal

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

GIZ Project Office
NTNC Complex
Khumaltar, Lalitpur, Nepal

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Sharada Shrestha, Nepal

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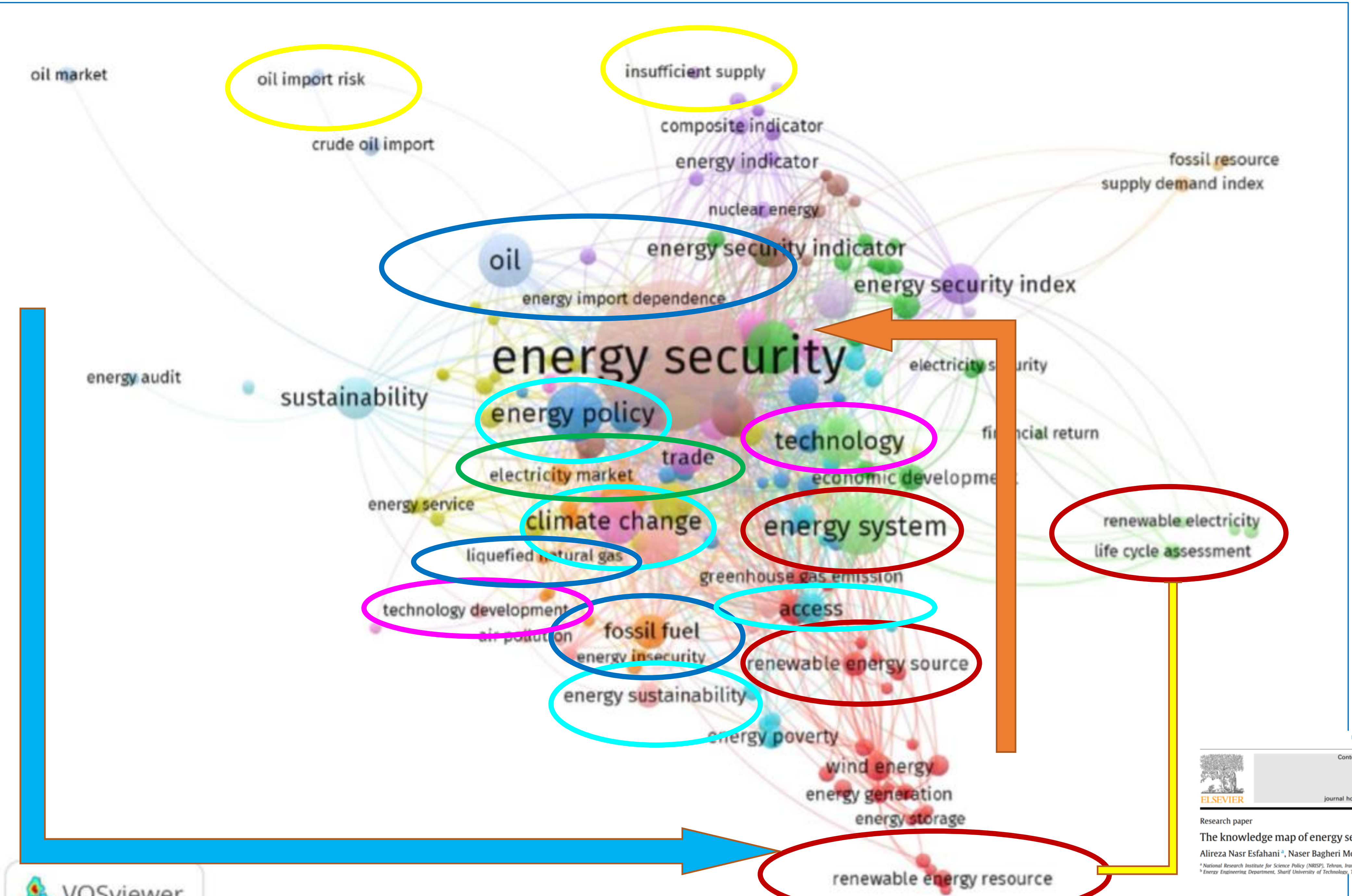

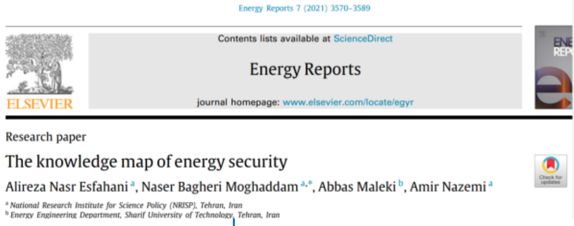
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journal homepage: www.elsevier.com/locate/egyr

Research paper

The knowledge map of energy security

Alireza Nasr Esfahani [a], Naser Bagheri Moghaddam [a,*], Abbas Maleki [b], Amir Nazemi [a]
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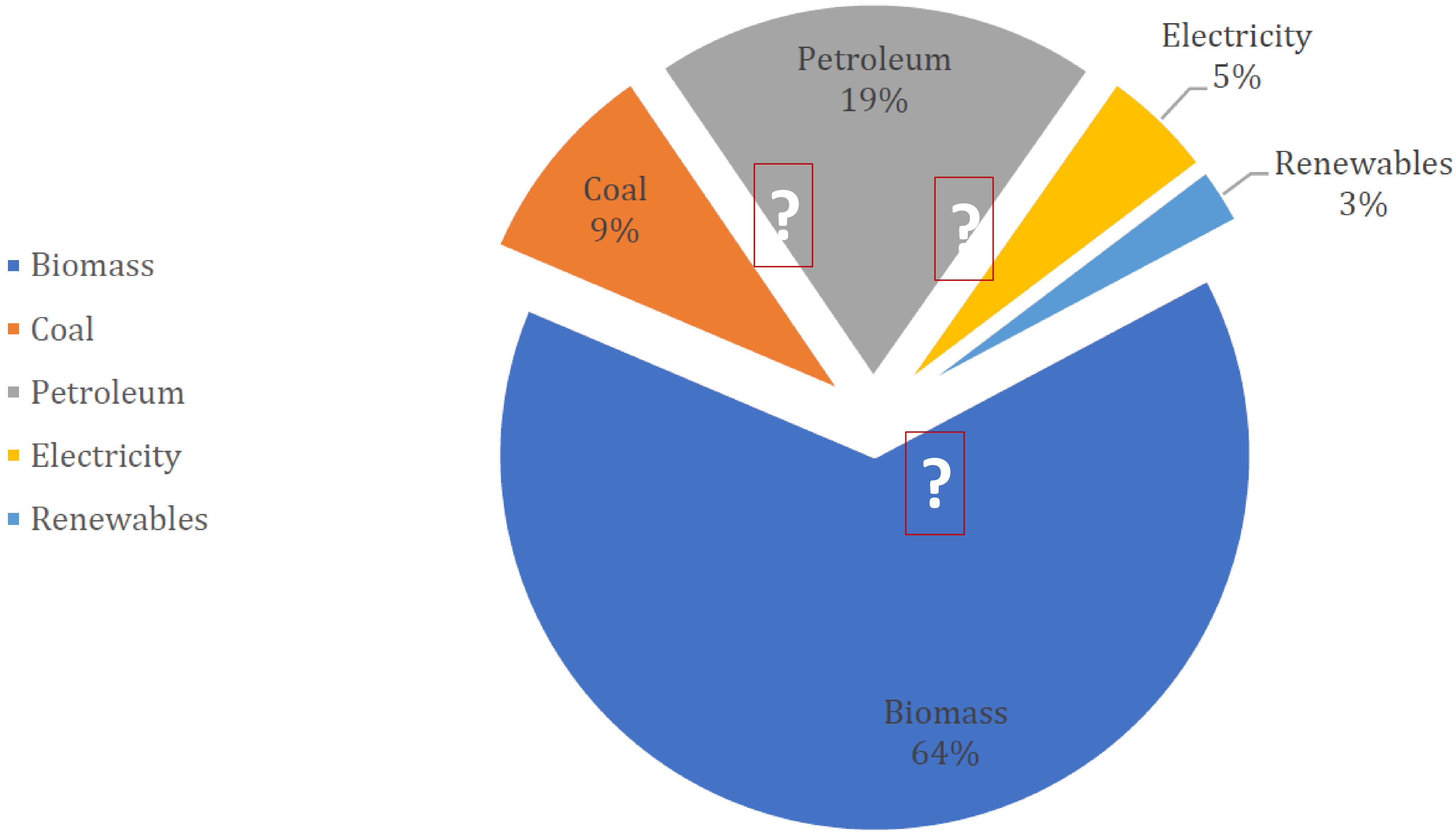
Energy Security

- Energy will be legislated, guaranteed, generated (capability/availability), and supplied for consumption as needed,
  - at the right place (accessibility)
  - by the right utility (capability)
  - in the right form (acceptability)
  - at the affordable price (affordability)
  - at the right time (availability)
  - with adequate consideration of resource utilization (sustainability)
  - with minimum loss (technical, business, environment)
  - with a provision to absorb dynamics in energy (resilience)
- Energy security is a direction, multi-dimensional, and is not focused within the nation only

The focus of presentation

- Electricity supply and demand
- Non-hydro renewables options
- Solar electricity
  - Electricity consumption and supply patterns
  - Technology/cost
  - Solar resource and complementarity with hydropower
  - Energy storage
- Recommendations


Biomass
Coal
Petroleum
Electricity
Renewables
Coal 9%
Petroleum 19%
Electricity 5%
Renewables 3%
Biomass 64%
?
?
?

Electricity supply and demand

- Dominant hydropower generation from the run-of-river hydro (except, the Kulekhani cascade 104 MW total)
  - Reduction on dry season hydropower generation
  - Increasing IPP contributions
  - Per capita electricity consumption
  - Industrial retrofitting
  - Rising temperature might increase electricity demand in the dry season.
  - Supply - Demand matching issues

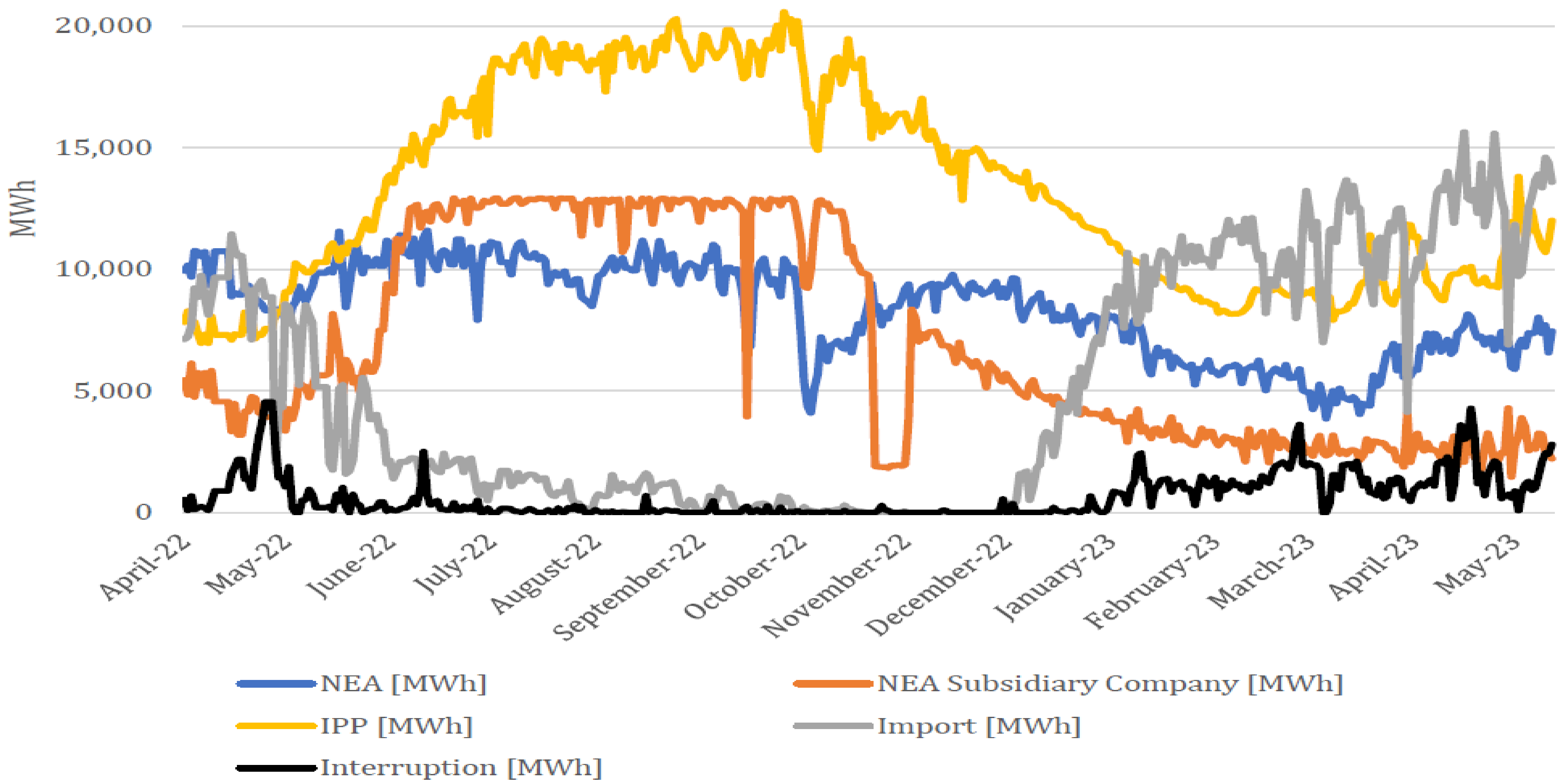


Figure 5: Generation of electricity from different sources between April 2022 and mid-May 2023

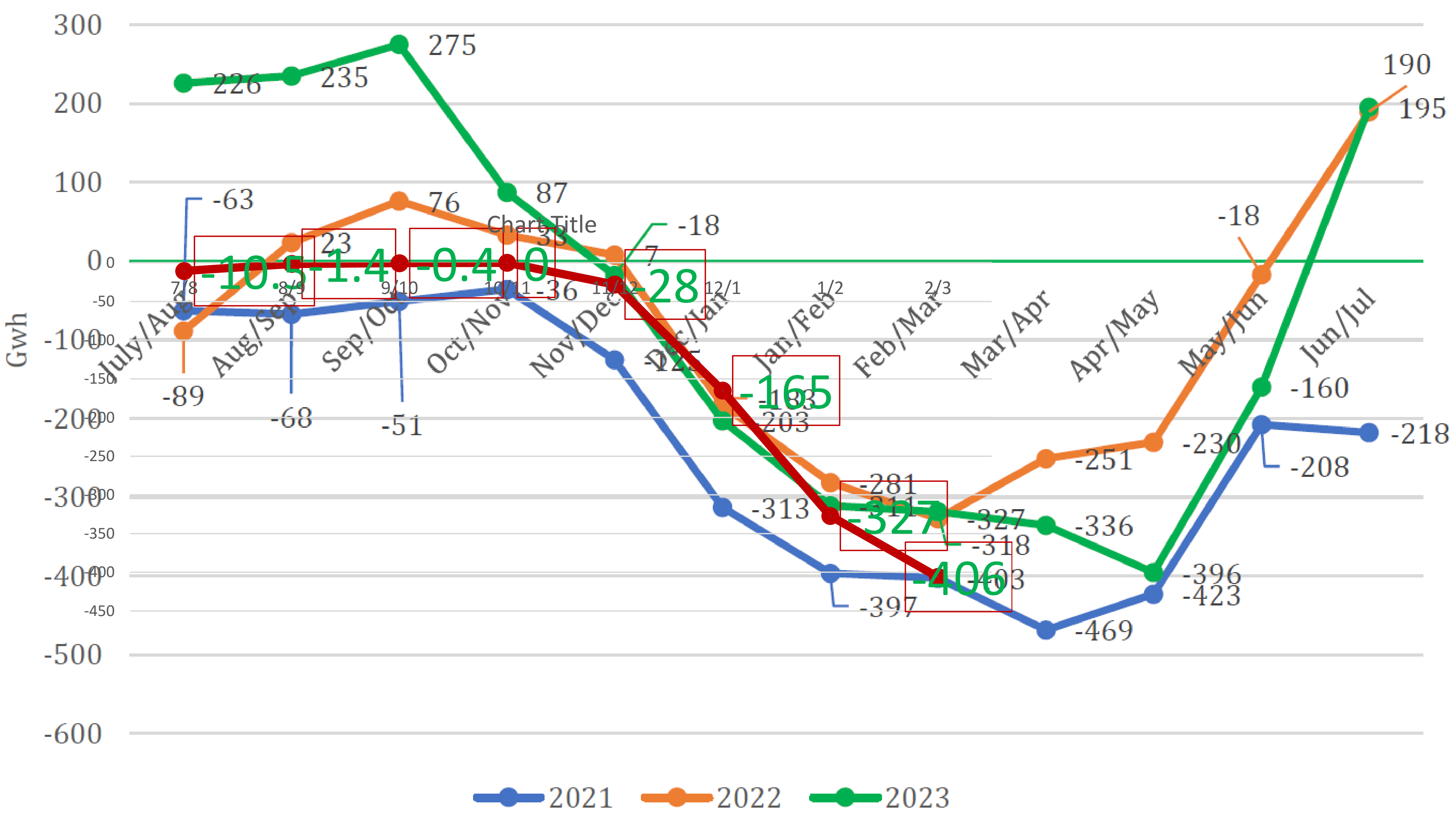


Figure 8: Net monthly electricity imports and exports of electricity from India 2021-23 – Note: Imports are shown as negative numbers, exports as positive

Electricity Demand (WECS)

- Low GDP: 8% ; High GDP: 12.8% ;
- Electrification:
  - 25% cooking by 2030 and 100% by 2050
  - 100% electrification of industrial and commercial sectors.

Year	Demand forecast (GWh)			
	BAU	High	Low	Electrification
2021	7,313		**11,547 in 2023**	
2025	15,118	15,670	14,501	14,616
2030	25,493	28,654	22,667	28,201
2035	40,994	53,459	32,868	49,122
2040	59,498	88,603	41,787	82,225
2045	86,758	147,007	53,153	133,265
2050	126,218	241,937	67,756	210,773

Table 2: Expected additions of new hydropower projects assuming 100% build-out pipeline compared to dry-season load

Year	Expected new capacity in MW					Total capacity in MW		Peak demand in MW				Reserve in MW			
	ROR	PROR	Seasonal storage	Total addition	Dry season capacity thereof	Total installed capacity	Dry season effective capacity thereof	WECS BAU scenario	WECS High scenario	WECS low scenario	WECS electrification scenario	BAU scenario	High scenario	Low scenario	Electrification scenario
2023						2,684	1,384	1,995	1,995	1,995	1,995	-611	-611	-611	-611
2024	1,626	40	0	1,716	581	4,400	1,965	2,342	2,358	2,324	2,327	-377	-393	-359	-362
2025	2,154	140	0	2,294	777	6,694	2,742	2,689	2,720	2,652	2,659	53	22	90	83
2026	247	0	0	247	84	6,941	2,826	3,058	3,171	2,951	3,154	-232	-345	-125	-328
2027	94	38	0	140	47	7,081	2,873	3,427	3,622	3,250	3,648	-554	-749	-377	-775

Note: Three large seasonal storage hydropower projects – Dudh Koshi (635 MW, estimated 3,443 GWh annually), Budhi Gandaki (1,200 MW, estimated 3,590 GWh/a) and Nalsingh Gad (417 MW, estimated 1,406 GWh/a) are not included in the table as their development has not started as of October 2023, and are not expected to contribute materially to the power situation by 2027.

Non-hydro Renewable Options available

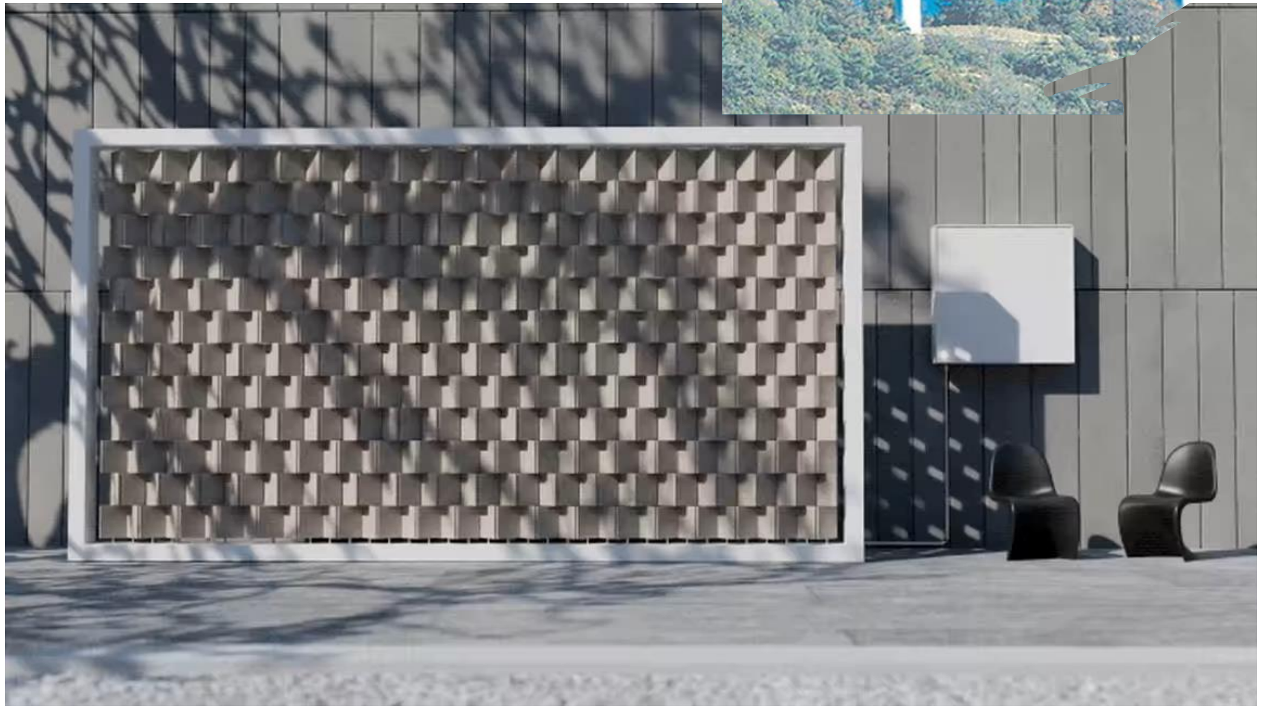
Biomass

- Potential through industrial scale biomass digestion- experimental
- Through bagasse in sugar industries –seasonal and limited capacities, 6 MW is connected; 100 MW potential from 12 mills
  - But bagasse is degradable and therefore, it can help in circular economy
    - Reusing bagasse will reduce abt 1.7 t CO_2/t of bagasse

https://nature.berkeley.edu/classes/es196/projects/2020final/ChiuJ_2020.pdf
https://www.linkedin.com/pulse/bagasse-vs-kraft-paper-comprehensive-analysis-sustainable-food-4plxc/

Wind

- LCOE/kWh from about $0.107 in 2011 to about $0.033 in 2023.
- WECS cites a wind power potential of 3 GW; another report on 100% renewable energy cites 250 MW.
- The attempts have been experimental; technology for large scale development is a constraint
  - Blade length/capacity



https://images.fastcompany.net/image/upload/w_1153,ar_16:9,c_fill,g_auto,f_webm,q_70/wp-cms/uploads/2021/10/p-1-90687369-this-ingenious-wall-could-harness-enough-wind-power-to-cover-your-annual-electricity-bill.gif

Solar

- LCOE/kWh $ 0.445 in 2010 to USD 0.049 in 2022 – down by 89%
- Efficiency and size of each module is increasing
- Solar technology absorption capacity is increasing
- About 40% of the land area can produce about 1400 kWh/kWp/year

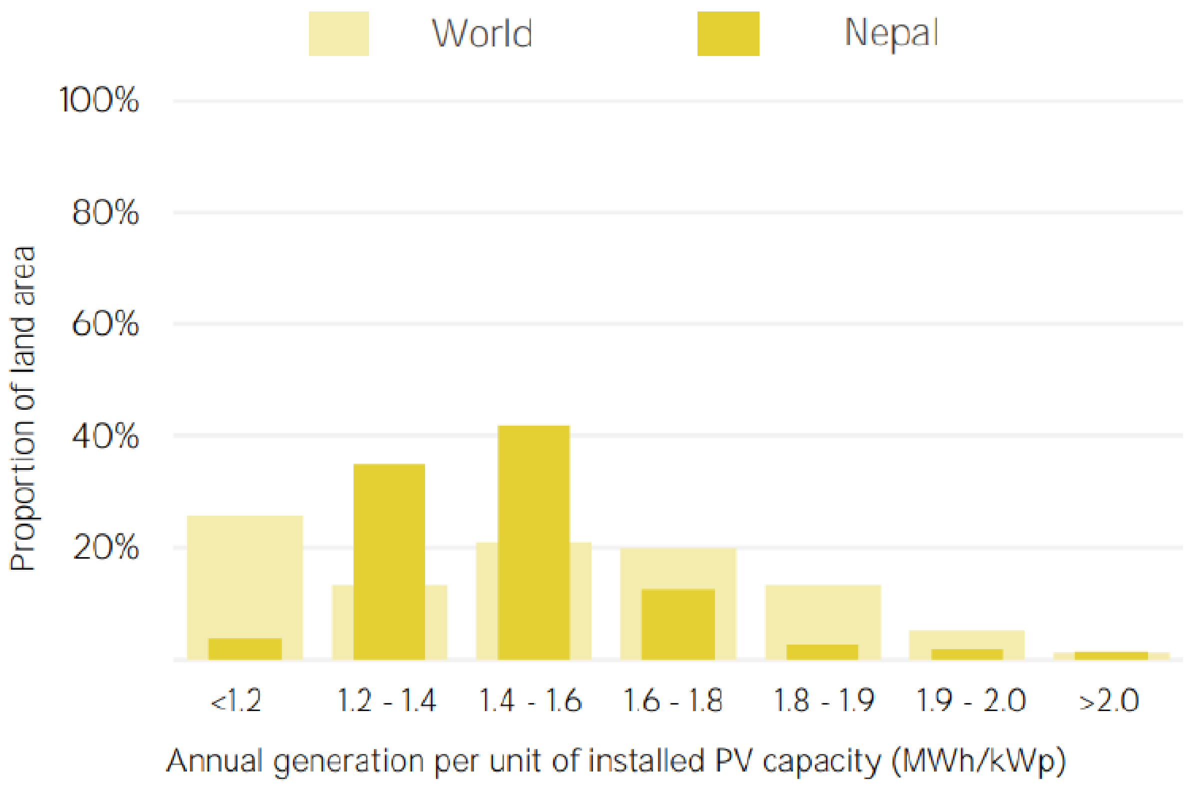


Figure 11: Comparison of Nepal's solar potential for its land mass[84]

Solar radiation in Nepal complements water availability

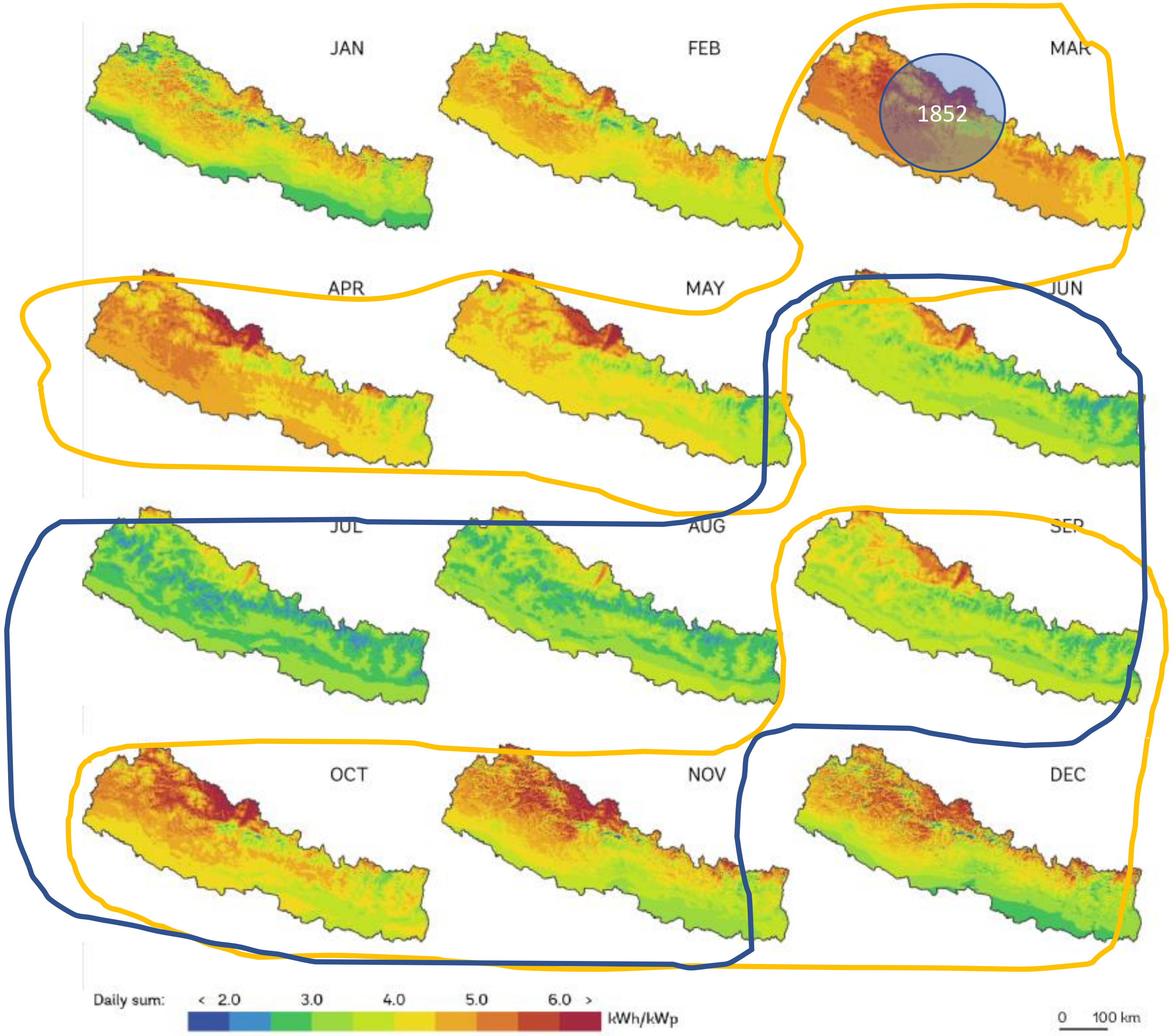
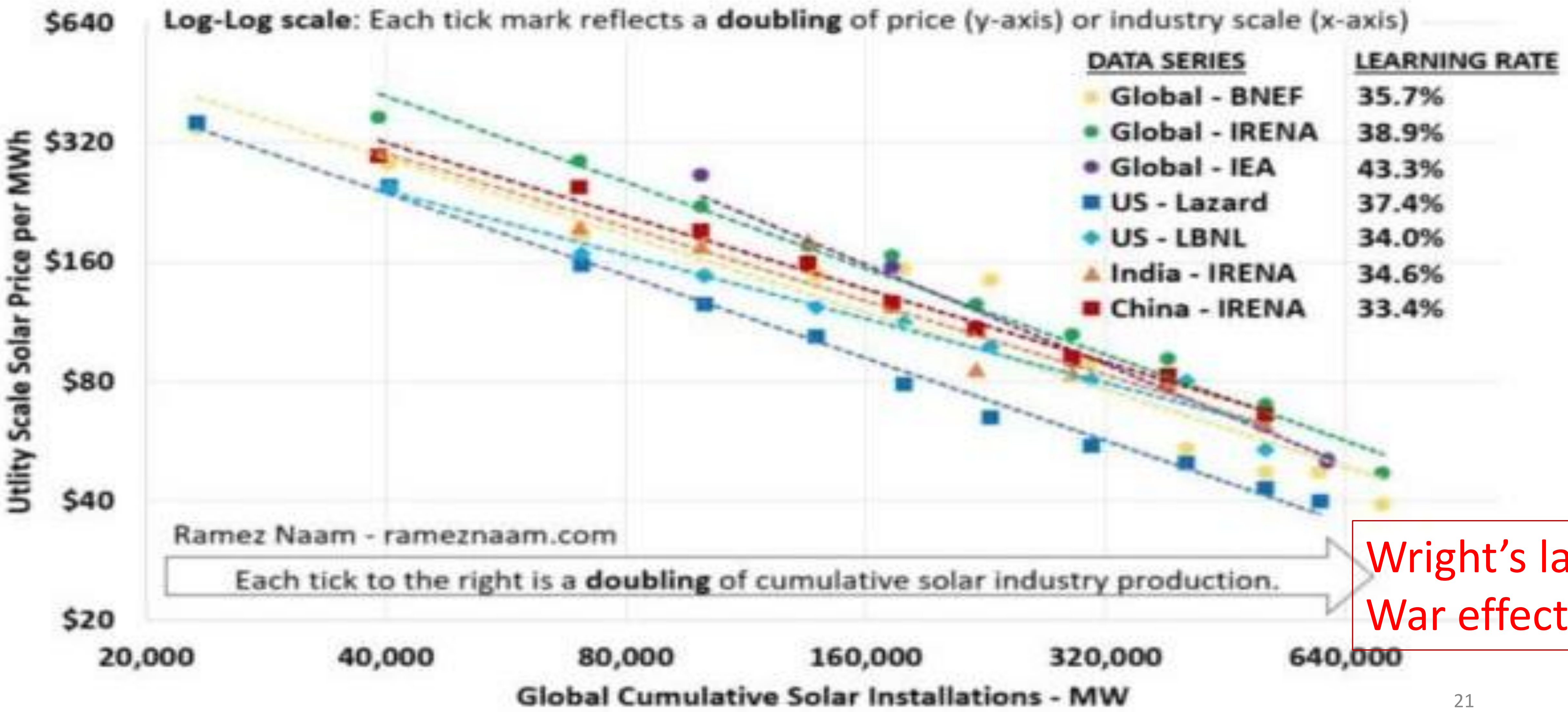


Table 3: Global comparison of average installation costs and LCOE[79]

	Total installed costs (2022 USD/kW)			Capacity factor (%)			Levelised cost of electricity (2022 USD/kWh)		
	2010	2022	Percent change	2010	2022	Percent change	2010	2022	Percent change
Bioenergy	2 904	2 162	-26%	72	72	1%	0.082	0.061	-25%
Geothermal	2 904	3 478	20%	87	85	-2%	0.053	0.056	6%
Hydropower	1 407	2 881	105%	44	46	4%	0.042	0.061	47%
Solar PV	5 124	876	-83%	14	17	23%	0.445	0.049	-89%
CSP	10 082	4 274	-58%	30	36	19%	0.380	0.118	-69%
Onshore wind	2 179	1 274	-42%	27	37	35%	0.107	0.033	-69%
Offshore wind	5 217	3 461	-34%	38	42	10%	0.197	0.081	-59%

Cost of solar with increased installation



Wright's law
War effect

Solar PV can complement hydropower in Nepal

- Inexpensive electricity
- Reduces expensive dry season imports
- Reduces dry-season blackouts (especially when combined with storage)
- Rapid deployment (6 to 12 months)
- Reliable – no moving parts

Lower Kaleköy, Turkey

510 MW hydro, 80 MW PV

Photo: Kalehan Energy Group

Options available: Floating solar

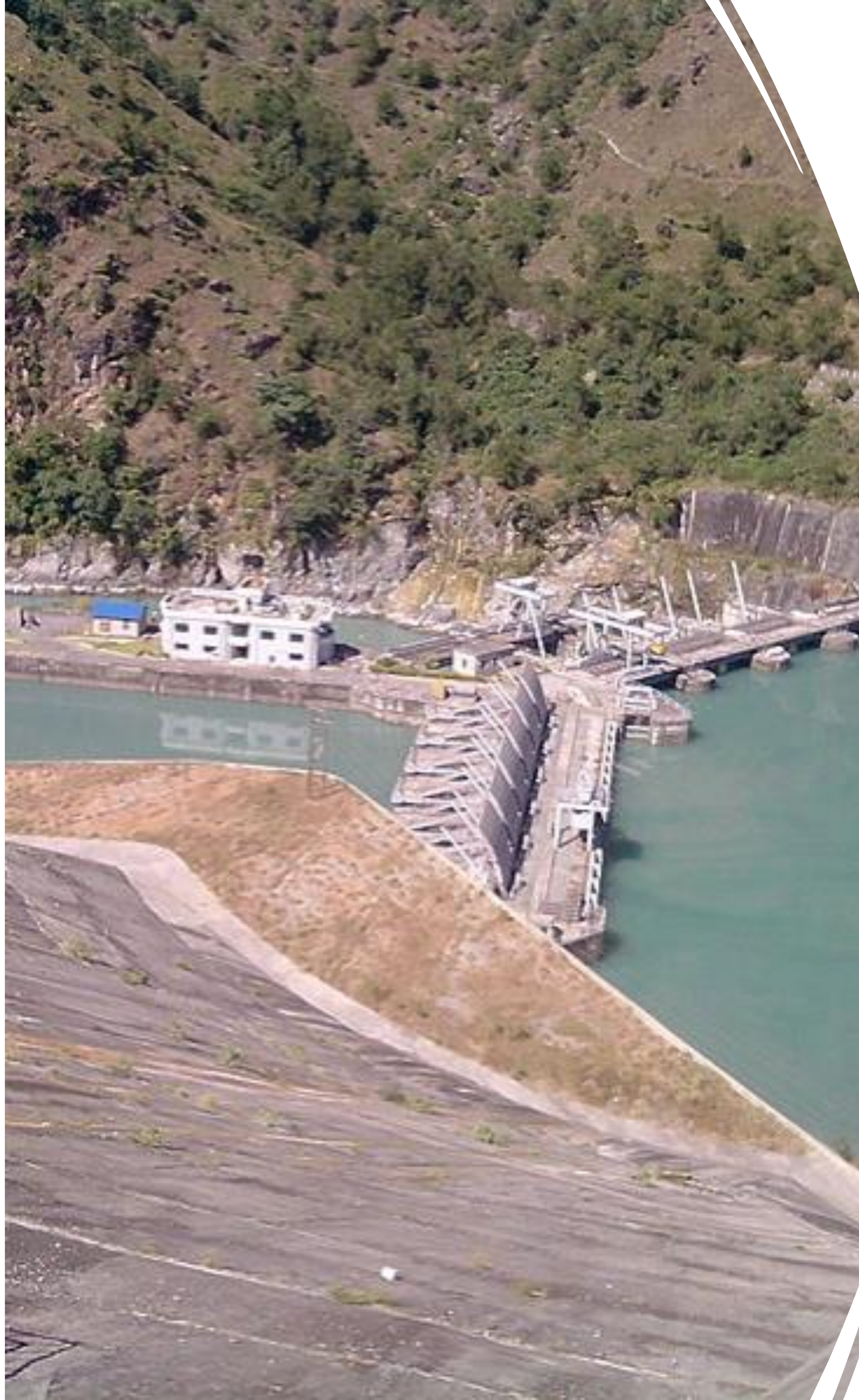
58.5 MW
Total floating 2.7 GW

Figure 16: 45 MW floating solar at Sirindhorn Dam, Thailand[114]

Cooling effect/reduction in reservoir temperature/evaporation/No negative impact-Singapore study

Daily pondage

- Daily pondage storage behind the weir of a run-of-river hydropower project provides storage for hours of electricity
- Even pondage of several hours can provide a crucial function in peak hours.
- Complement with solar PV for generation



Electricity Storage

- Pumped storage
  - Pumping water using daylight electricity in pumped storage, for peak generation.
  - Cost ranging from $1.8 to 50/MWh of energy stored
- Battery storage is a possibility but costly
  - Battery storage costs dropped by about 80% in about a decade reaching around $ 137/kWh
    - US is expected to deploy equivalent 30 GW/111 GWh by 2025

Combining solar with other power sources is smart way of using technical infrastructure. In Germany two hydro power stations will get additional solar power

Vattenfall to install solar plant at pumped hydro project. (Credit: Vattenfall AB.)

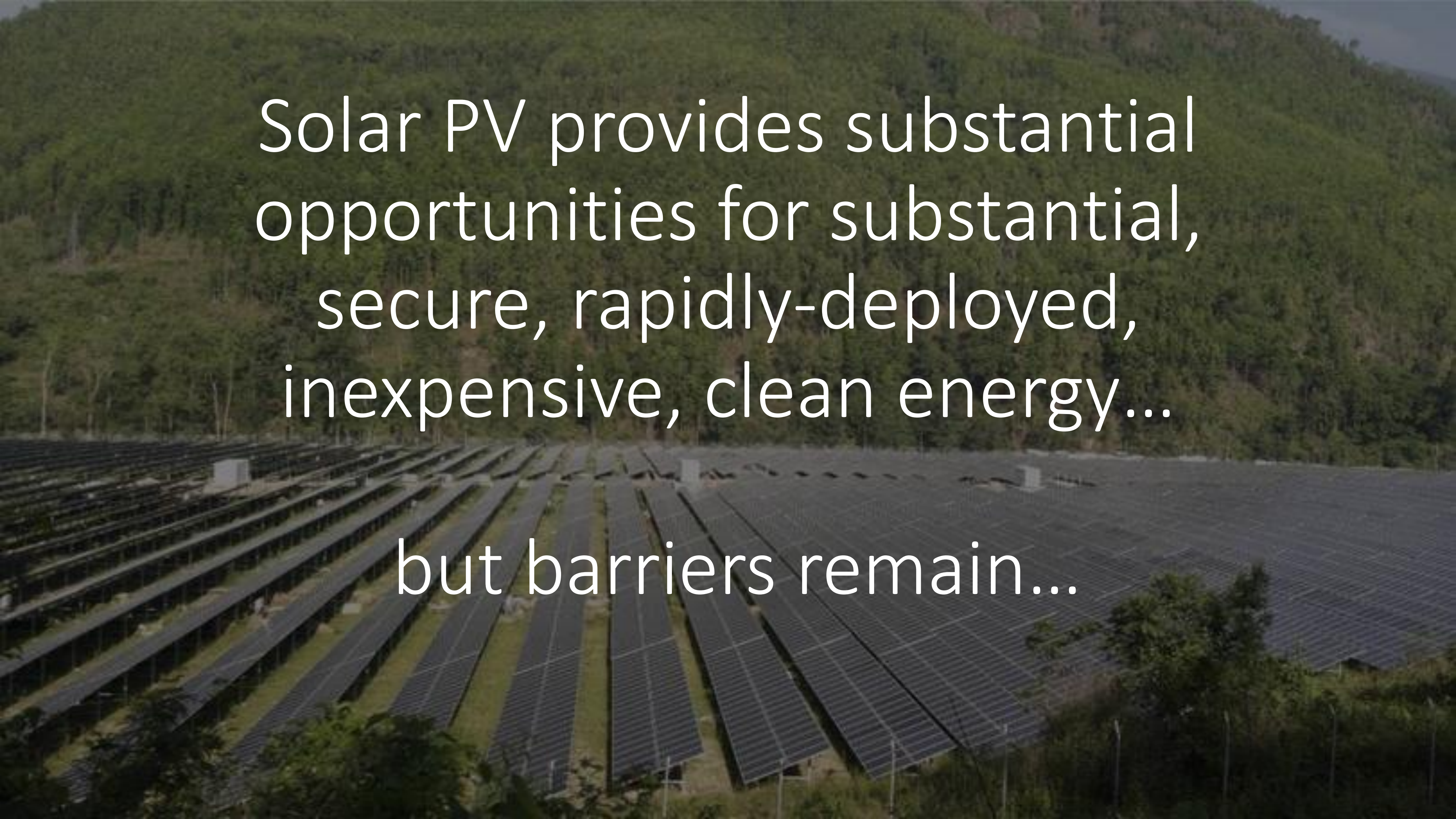
Pumped hydro

- “Gravity battery”
- Accounts for 96% of global power storage (MW) and 99% of energy volume (MWh)
- USD 1.8 to USD 50 per MWh of energy stored
- NPC 15th plan: 1,538 MW Tamor Multipurpose project will include pumped hydropower functionality

2,800 good pumped storage sites in Nepal

Export to India

- Increased solar PV deployment in Nepal can lead to periods of excess electricity generation during peak sunlight hours.
- Increasing number of cross boarder connections will allow export from nearest generation point
- The need for daytime electricity (mainly in industry in the boarder areas) can be met
  - Caution: competing with subsidized Indian solar PV


Solar PV provides substantial opportunities for substantial, secure, rapidly-deployed, inexpensive, clean energy…
but barriers remain…

Barriers

- Developer's perspectives
  - Low FiT and competitive bidding
    - Inconsistent and without much consultation
    - Solar PV are not considered as electricity generators but as technology
  - Financial (high loan interest rate)
    - Difficult to get loan for large scale investment
  - Limited capacity of NEA substations to absorb power
  - Current IPP hydro sites not allowed for PV based generation
    - The land and infrastructure is available

Barriers

- NEA's perspectives
  - Focus on Terai
    - Land use problems as agriculatural/forest land are considered.
    - Should focus more on remote areas like in Karnali zone.
  - Grid capacity and spillage:
    - Hydropower expansion plan is already in place
    - Commitment to hydro may need NEA to spill electricity and pay for it.
    - NEA may not have enough capacity to tap the IPP generated solar PV.
  - PV supply pattern mismatches demand:
    - Current system peak is in the morning and evening and does not match solar peak generation.
    - Combining solar PV with existing hydro will create administrative problems for execution as there is no policy on it.
  - Policy uncertainty:
    - NEA implements government policy and when there are changes in the policies it becomes difficult for NEA to develop a consistent policy solar PV promotion.

Barriers

- Government perspectives
  - Land use conflict
    - Once Solar PV is installed in agricultural land, food production is impacted and similarly conservation of the forest is important. Therefore, government cannot issue licenses for utilizing such lands.
  - Land speculation concerns:
    - Once solar PV is installed in a land purchased at a lower price, there may be an intention to close (prematurely) the solar PV and sell the land for purposes rather than returning them to the original use conditions.
  - Land clearance, and waste management:
    - There are no provision in place for site clearance and the management of PV at the end of their operating life
      - Although it contains a lot of silver, aluminum and copper, there are yet no programs for its recycle,

Solar based future is a distinct electricity generation possibility

Recommendations for action (1)

- Stable and fair tariff
  - Raise current tariff
    - Compensate at par with the current hydropower tariff policy
    - Provide an average tariff based on current hydro tariff
  - Incentivize day time consumption through TOD tariff
    - This can be mainly for industry and for other purposes like EV charging

Recommendation for action (2)

- Revise electricity generation cap for non-hydro
    - Current 10% assumption does not promote economy of scale
    - Leave the market to develop itself
        - NEA tender will enhance this development
    - More PV also means more job in this area
        - More capacity building for development and customization
            - Transformer development Nepal/Inverter
        - More internal employment
        - More reduction in price

Electricity mix examples

- India:
  - 211 GW, coal; 24 GW, gas; 0.6 GW diesel
  - 132 GW renewable
  - Coal based generation growth reduced to 0.6% and renewables 16% from 2021.
  - Ratio of renewables to 35% in 2030 from 19% current.
- Germany:
  - Electricity feed-in Act 1991; Renewable Energy Sources Act 2001
  - 70 GW of wind and 80 GW of solar; 50% of electricity mix
- Indonesia:
  - Plans to replace 1.8 GW of coal with renewables, retire 8 GW of coal by 2030
  - Phase out coal by 2056

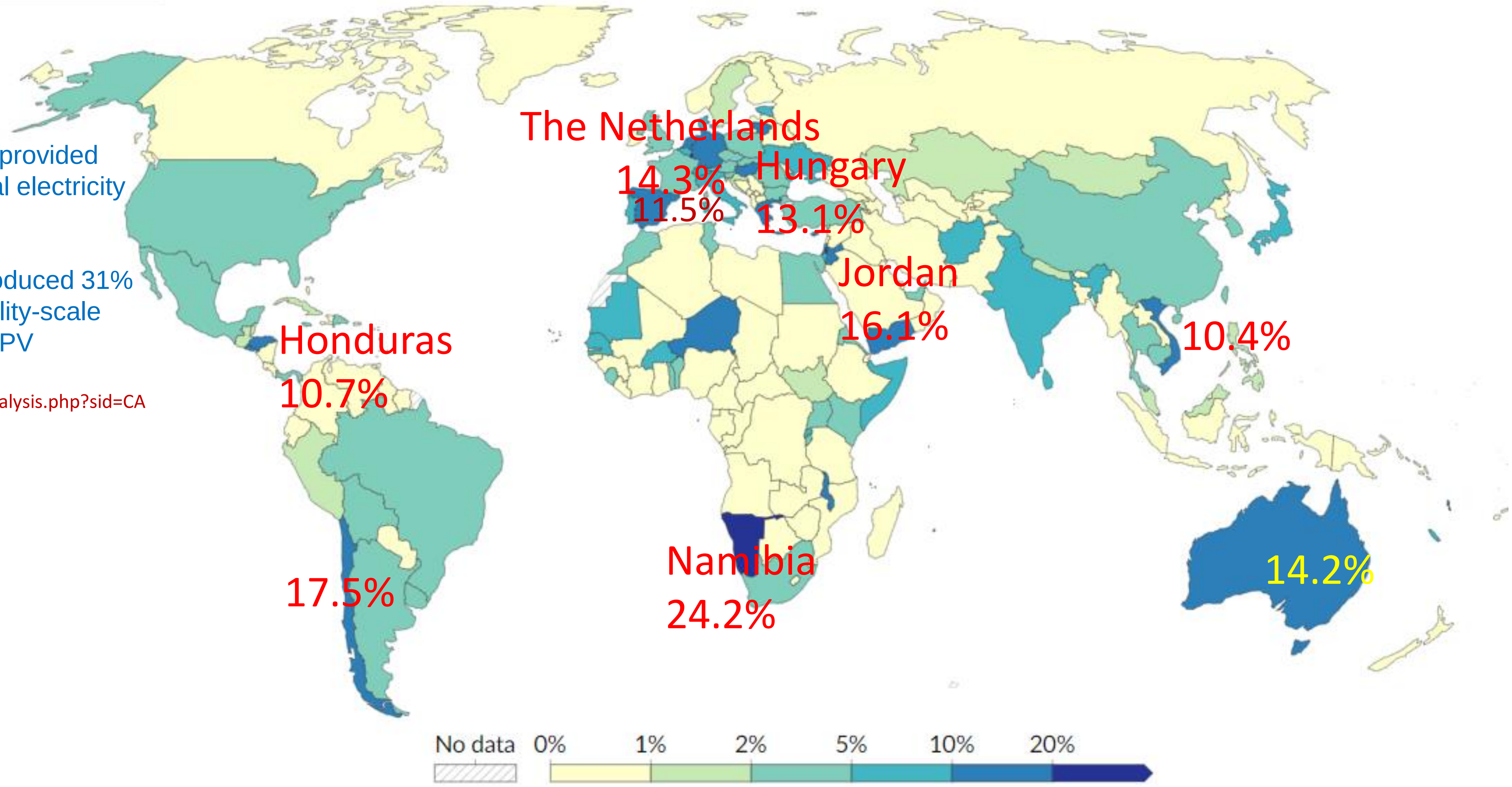
Share of electricity production from solar, 2022

Measured as a percentage of total electricity.

Table Map Chart

In 2022, solar energy provided 27% of the state's total electricity net generation.

In 2022, California produced 31% of the nation's total utility-scale and small-scale solar PV electricity generation.
https://www.eia.gov/state/analysis.php?sid=CA



Recommendation for action (3)

- Promote solar electricity integration
  - Promote the development of pumped hydropower storage by complementing it with solar PV
  - Leveraging NEA's commitment to PROR capacity
    - NEA integration of solar PV in the projected reservoir based IPPs.
  - Addressing market dynamics and stability:
    - When electricity is being traded and there is a severe penalty for not being able to supply, solar will help to stabilize the supply to a greater extent by supporting supply during the day time and utilizing hydro capacity during the other times.

Recommendation for action (4)

- Allow existing IPPs to add solar PV
  - NEA has collocated 25 MW solar PV in Devighat hydropower station area
  - Present IPP licenses are limited to hydropower
    - Allowing the addition of solar power would enhance land utilization at these sites and bolster overall electricity output. Given that the necessary transmission infrastructure is already established, this integration is not only feasible but also beneficial in aiding IPPs in consistently meeting NEA requirements towards a balanced electricity production
      - NEA mandates IPPs to maintain their rated generation capacity for at least 40% of the year, equivalent to about 4.8 months.
        - Integration will also avoid concern about reduced wet season generation, cited by NEA

Recommendation for action (5)

- Pursue floating solar at hydropower sites with suitable reservoirs
  - Co-location of solar and hydropower is the use of floating solar on existing and planned reservoirs.
  - Floating solar provides efficient land use, reduces water evaporation, and cools the solar panels, leading to higher efficiency and synergistic benefits when combined with hydropower
  - Floating plants are also being studied by NEA as it quickly pays off the relatively higher cost of it as compared to that of terrestrial project.

Recommendations for action (6)

- Enhance land utilization through agrivoltaics and canal top solar
  - Utilization of non-cultivated agricultural land can be promoted instead of cultivated land.
    - Condition should be to complement with agricultural activities
  - There is an extended length of irrigation canals, they should be leased for PV with a condition to maintain those canals.
    - Street Furniture concept

10,300 sq.km of uncultivated agricultural land

Recommendation for action (7)

- Enhancing concessionary financing for grid connected PV
  - Banks should be encouraged for such loans by providing opportunities to access international financing where possible
  - Establishing central funds for solar parks development can eliminate problems for land requirements by the developers
  - Non-banking institutes can be promoted to develop utility scale solar PV. There are models like that in India and Bangladesh as well.

Recommendation for action (8)

- Open up opportunities for cross-border electricity trade by the private sector
  - Efficient in finding matching demand companies in India to link their supply.
    - Helps in removing some of the coal capacity in India’s generation system.
  - Support infrastructure development for the transfer of electricity
  - May, in the long term, support the development of an independent national transmission authority electricity wheeling

Recommendation for action (9)

- Identify areas where grid connected solar is most beneficial to NEA
  - Given the voltage reliability, quality and supply constraints, NEA can conduct geospatial mapping for power evacuation and strengthen the power evacuation capabilities.
  - This will help to conduct long term solar planning and will give a clear indication to the developers on the market potential of solar in Nepal.

Process used

- Discussion on upscaling started in August 2022
- Work started in October 2022 with study of evidences in different countries and Nepal
  - On policies, case studies, provisions, and programs
  - 18 meetings (including the final workshop) held in November 21-25, 2022.
    - Including meetings at MOEWRI, NPC, WECS, AEPC, DOED
  - 25 April 2023 Stakeholder consultative meeting
  - 27 April 2023 Consultative meeting with Secretary at MOEWRI
- Findings and Report shared at a meeting with the Secretary of Ministry of Energy, Water Resources and Irrigation and officials from NPC, NEA, ERC, MOEWRI (April 12, 2024).

Aggregated theme (dimensions)-Gioia Method

Future state towards promotion of solar

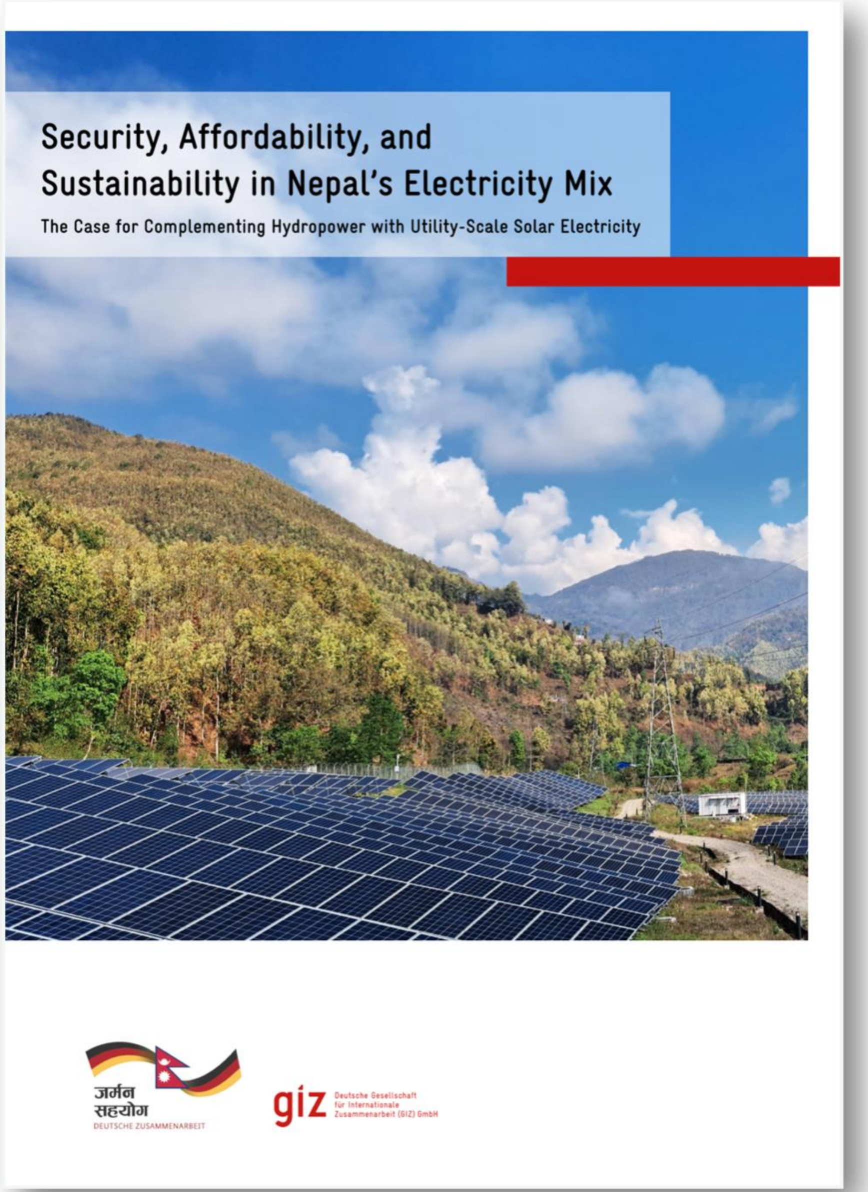
- Market and Economy
  - Economics
    - Utilization Cost/Paid Price (-) → (+)
    - Technology cost (+)
  - Technology
    - Technology for combining with hydro (-)→ (+)
    - Grid infrastructure and power evacuation (-) → (+)
  - Market
    - Current focus, market, and renewable energy cap (-) → (+)
    - Solar potential (+)
    - Electricity Demand (+/-) → (+)
    - Utilization
      - Irrigation (+)
    - mini grids(-) → (+)
    - Agro-voltaics (+/-) → (+)
    - Reactive power generation (-) → (?)

- Policy and Program Development
  - Promotion Policy
    - Regulations/Policy (-) → (+)
    - Waste Management (-) → (+)
    - Standardization (-) → (+)
    - Climatic situation (+)
    - Promotion policy in India (-)→ (?)
    - Net metering (-) → (+)
    - Wheeling (-) → (+)
  - Education/Capacity building
    - Education of planners (-) → (+)
    - Awareness among the planners (-) → (+)
    - Awareness among the engineers (-) → (+)
    - Manpower training (-) → (+)

+/- means neutral or undecided based on the discussion, + positive influence
→ (+) shows the need to focus on developing recommendations

Conclusions

- Solar is a potential and complementary source for electricity
- Technology capacity of independent solar producers is increasing
- Global and local cost of technology is decreasing
- The demand for electricity may change substantially,
  - If private sector electricity export to India is allowed, the situation would change
  - If the export is required (due to commitment), then it will change electricity supply dynamics in the country
  - Swiftness of solar PV can help
- Not all action to be taken are financial
  - Policy initiatives would help a lot
    - Relieving the generation cap
    - Policy changes on land/canal top,
    - Promotion of agri-voltaics
    - Allowing opportunity on cross-border trade by IPPs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Thank You