Sekong, Sesan and Srepok River Basin energy profile

Courtney Weatherby, Brian Eyler

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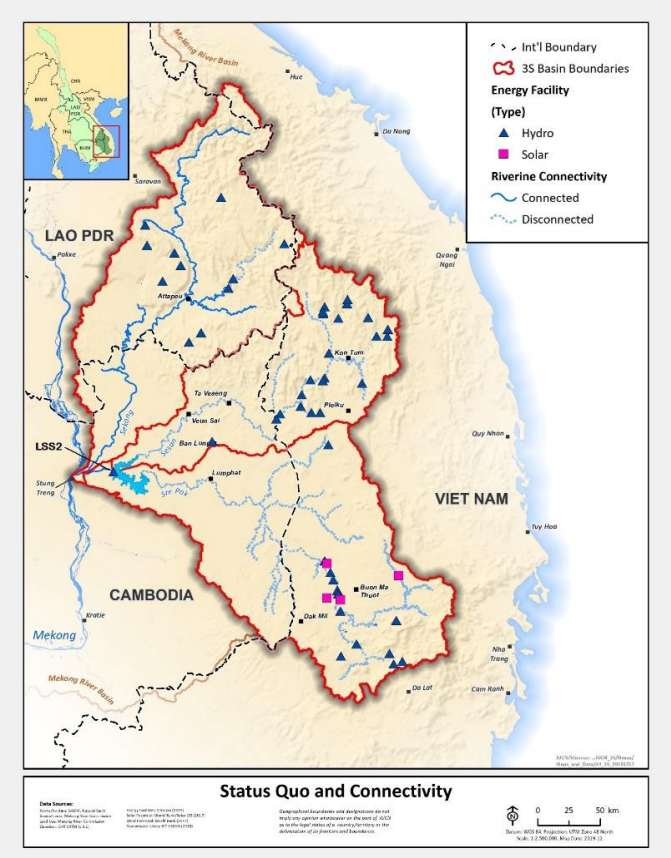
1. 3S Basin and connectivity

The 3S River Basin, an area defined by the major Mekong river tributaries of the Sekong, Sesan, and Srepok, forms a transboundary landscape of adjacent river basins all of which rise in central Viet Nam. The Sekong flows through southern Laos and into northeastern Cambodia and the Sesan and Srepok flow through northeastern Cambodia. The three rivers converge just before flowing into the Mekong at Stung Treng in Cambodia.

More than 4,300 km of rivers make up the 3S system. The Sekong mainstream and tributaries total 1,917 km, the Sesan's 706 km, and the Srepok's 1,687 km. The 3S have seen extensive hydropower construction since the 1980s, primarily in the highlands within Viet Nam. Hydropower dams have altered flow patterns, sediment load, and connectivity. A number of hydropower dams planned for the basin would further negatively impact the ecosystem, with implications for food security and sea level rise adaptation downstream. The Sekong Basin, which has remained without a dam on the mainstem, provides the best opportunity to maintain these values while providing adequate energy through an energy mix appropriate to the region.

The land and water of the 3S basin play a critical role in providing environmental flows and ecosystem services to the Tonle Sap in Cambodia and the Mekong Delta in Viet Nam. More than 20% of the Mekong's water comes from the 3S. Most of the basin receives over 2,700 mm/year of rainfall, most of which falls during the summer monsoon in June to September. Before construction of the Lower Sesan 2 (LS2) dam, the 3S contributed 15-20 million tons of sediment/year to the Mekong's sediment budget or 9.3-12.5% of the total. Sediment and nutrient flows are critical for agricultural production downstream and underpin the food web of the Mekong fish population.



***Map 1**: Status Quo and Connectivity*

Many of the Mekong's long-distance migratory fish, of which there are hundreds of species, spawn in the upstream portions of the 3S. Most of these fish spend their lives migrating to and from the Tonle Sap each year. The lake provides a nutritious habitat during the wet season and for fish eggs and larvae to mature and then return to spawning grounds upstream during the dry season. The Tonle Sap produces up to 500,000 tons/year of fish catch. Much of the Mekong's total annual catch of 2.6 million tons—the world's largest for a single river system—also spend some of their life in the Tonle Sap. These fish provide Cambodians with 50-70% of their protein intake.

A connected river system is defined as one that is unimpeded by infrastructure such as dams and levees that block or alter these environmental flows. Dams, such as the LS2 at the confluence of the Sesan and the Srepok, fragment rivers and massively reduce ecosystem productivity. A 2011 study estimated that the LS2 would reduce total Mekong fish biomass by 9.3%.[1] When the LS2 was complete in 2018, 2,388 km of the Sesan and Srepok were disconnected from Mekong, equivalent to a 55.4% loss in 3S connectivity.

The Sekong mainstream is now the only free-flowing river in the 3S and is the longest remaining free-flowing mainstream tributary (520 km) in the entire Mekong system. Preserving its connection to the Mekong is critical if fisheries and agricultural productivity are to be maintained. Six dams are planned on the Sekong mainstream, five of them in Laos. If either the mainstream Sekong dam in Cambodia (the Lower Sekong) or the most downstream dam in Laos (Sekong Downstream 4A) is built, the 3S' connectivity to the Tonle Sap will be cut to zero. Already 11 dams (787 MW) are on the tributaries of the Sekong in Laos with another 15 dams (669 MW) under construction on those tributaries. These dams have already reduced the connectivity of the Sekong tributaries by more than 500 km. Connectivity could further decrease even without any Sekong mainstream dams as an additional 38 Sekong tributary dams in Laos are in various stages of planning.

In the Sesan and Srepok, downstream connectivity was destroyed by the LS2. Cambodia has built the 1 MW O Chum II Dam on a tributary of the Srepok and has identified 19 potential dams upstream of the LS2 with a total capacity of 1,536 MW. More than half of that (865 MW) could come from two dams on the Sesan mainstream and four on its tributaries. 672 MW of that capacity could come from three dams on the Srepok mainstream and 10 dams on its tributaries. Building all these dams would have zero net change on river connectivity between the 3S and Mekong because they are located above the LS2. However, Cambodia has identified one site, the 90 MW Lower Sesan 1 dam, which is downstream of the LS2. This dam would reduce connectivity further because it is only 5 km upstream from the confluence of the Sekong and Sesan.

[1] Ziv et al (2012). Trading-off of fish biodiversity, food security, and hydropower in the Mekong Basin. Proceedings of the National Academy of Sciences of the United States (PNAS). Available at https://www.pnas.org/content/109/15/5609.

2. Why the 3S Matter for Energy Production

The vital contribution of the 3S to the productivity of the Mekong is well documented. Hydropower projects are often described by regional stakeholders in terms of their significant and irreversible transboundary impacts. But energy planning still takes place at the national rather than the regional level and the benefits that accrue are often described in terms of contribution to each country's national power goals. Although there is growing discourse on cross-border power trade, the 3S is still seen as a peripheral area of development rather than a core transboundary region with significant potential for joint planning and investment.

2.1 Viet Nam

Of the three countries, Viet Nam' s electricity sector is by far the most developed. Nearly 100% of the population has access to electricity and with an installed capacity of about 45,000 MW, Viet Nam's electricity system is about seven times larger than that of Laos and nearly 20 times that of Cambodia. Viet Nam's population of more than 95 million is also multiples of Laos' (6.85 million) and Cambodia's (16 million).

Viet Nam' s energy demand has risen by 10% annually since 2010 and the Ministry of Industry and Trade plans to expand electricity supply at this rate annually through 2030.[2] Demand has risen due to the trade war between the US and China, which has contributed to a shift of energy-intensive manufacturing from China to Southeast Asian countries including Viet Nam. Viet Nam' s economic growth is now expected to exceed projections

The headwaters of all 3S basins are in Viet Nam and the Vietnamese portion of the basin is the most developed in terms of electricity production. Viet Nam has built about 60 dams of varying sizes in the Central Highlands with a capacity of more than 4,600 MW.[3] This represents about 10% of Viet Nam' s total power supply and meets demand not only in local cities and villages but also in major demand centers closer to the coast.

2.2 Cambodia

Of the three countries, Cambodia's electricity demand will grow the fastest in coming years at about 18% annually.[4] This growth is primarily driven by urbanization and industrialization, although much of the recent growth has come from the construction sector.[5] About 70% of the country's total electricity demand comes from its capital, Phnom Penh.[6] The speed of demand growth has driven the rapid buildout of power generation.

Cambodia's traditional power generation supplies are limited. To date, Cambodia has not commercially developed its domestic coal reserves, and Cambodia and Thailand have not settled territorial claims that

[2] Vu, K. (2019). Viet Nam 's coal, crude oil imports surge on rising energy demand. Reuters. Available at https://www.reuters.com/article/us-Viet Nam -energy-imports/Viet Nam s-coal-crude-oil-imports-surge-on-rising-energy-demand-idUSKBN1XM13O.
[3] Mekong Infrastructure Tracker (2019). Available at https://mekong-infrastructure-tracker-stimsoncenter.hub.arcgis.com/.
[4] Cambodia Ministry of Mines and Energy (2019). Cambodia Basic Energy Plan, pages XVIII and 57. Available at http://www.eria.org/publications/cambodia-basic-energy-plan/.
[5] Shaun, T. (2019). Chinese construction rush aggravates Cambodia's electricity shortage. Nikkei Asian Review. Available at https://asia.nikkei.com/Economy/Chinese-construction-rush-aggravates-Cambodia-s-electricity-shortage.
[6] Asian Development Bank (2018). Cambodia: Energy Sector Assessment, Strategy, and Road Map, page 6. Available at https://www.adb.org/documents/cambodia-energy-assessment-strategy-road-map.

impact potential oil/gas reserves in the Gulf of Thailand. With about 10,000 MW of hydropower potential, Cambodia has rapidly expanded production, which grew from one 12 MW dam in 2002 to nine dams capable of producing a total of 1,328 MW by 2019.[7] As of 2017, hydropower was the largest contributor to the electricity mix at 55%, followed by coal plants fueled by imported coal (20%), imported electricity (16%), and fuel oil (9%), with minimal contributions from solar and biomass.[8]

Most of Cambodia's operational hydropower is located along the coast but two projects, the O Chum II (1 MW) and the LS2 (400 MW), are in the 3S. If hydropower continues to be prioritized, its footprint could expand significantly. Cambodia has 21 identified potential dams in the 3S, most of which are on the Srepok and Sesan upstream of LS2.[9] If the 20 dams on the Sesan and Srepok were built, this could add 1,626 MW of capacity.[10] This power could be developed without significant impact on connectivity since the LS2 has already disconnected the Sesan and Srepok from the Mekong. Cambodia's projected energy demand in 2030 is about 7,000 MW, only a portion of which is likely to come from hydropower.[11] Given its interest in diversifying its power mix, Cambodia will probably not build all planned dams on its portion of the 3S, but it is not clear which portfolio of projects will be favored.

Box 1: 2019 drought impacts

Hydropower is only effective as an energy source when water is available and the severe drought in 2019 called into question hydropower's reliability. The 2019 monsoon season (June-October) was extremely weak, and monitoring stations throughout the Mekong river basin recorded historically low water levels.[12] The 2019 monsoon season was short and the reversal of the Tonle Sap in Cambodia came two months later than usual and lasted far shorter than normal. The Mekong River Commission predicts that the severe drought will continue at least through January 2020,[13] but the annual dry season typically transitions into the monsoon season in June of each year. With climate change projected to reduce the length of the monsoon season and alter the intensity and variability of water flow, severe droughts like those observed in 2019 and 2016 may be the new normal. This casts doubt on hydropower as a reliable power source.

Even after record-high rainfalls in the 2018 monsoon, the dry season from November 2018 to May 2019 resulted in rolling blackouts in Cambodia from March to June 2019. While unexpected rises in electricity use due to industrial development were a factor, low reservoir levels were the main reason. Cambodia's total hydropower capacity—estimated at 1,328 MW or more than half of total electricity supply—dropped by 500 MW, or 38%, due to a lack of reservoir water.[14] This trend was observed in other parts of the basin. Operators at the recently completed Xayaburi dam claim that limited discharge reduced power generation from 1,200 MW to 500 MW.[15]

[7] Mekong Infrastructure Tracker (2020). Available at https://mekong-infrastructure-tracker-stimsoncenter.hub.arcgis.com/
[8] Choumnit, G. (2017). Workshop in Strategic Water and Energy Planning in Cambodia-Laos-Viet Nam. (presentation at the Diplomatic Academy of Vietnam, Hanoi, Vietnam, December 7, 2017)
[9] Mekong Infrastructure Tracker (2019). Available at https://mekong-infrastructure-tracker-stimsoncenter.hub.arcgis.com/
[10] Mekong Infrastructure Tracker (2019). Available at https://mekong-infrastructure-tracker-stimsoncenter.hub.arcgis.com/. (Access: December 16, 2019)
[11] Cambodia Ministry of Energy and Mines (2019) Cambodia Basic Energy Plan. Pp. 18. Available at https://www.eria.org/uploads/media/CAMBODIA_BEP_Fullreport_1.pdf (Accessed 18/05/2020)
[12] Mekong River Commission (2019). Mekong water levels reach record low. Available at http://www.mrcmekong.org/news-and-events/news/mekong-water-levels-reach-low-record/.
[13] Mekong River Commission (2019). Drought continues to hit Mekong countries, risking stress on crop production, water shortages. Available at http://www.mrcmekong.org/news-and-events/news/drought-continues-to-hit-mekong-countries-risking-stress-on-crop-production-water-shortage/.
[14] Thou, V. (2019). Power shortages again in dry season, says prime minister. Phnom Penh Post. Available at https://www.phnompenhpost.com/business/power-shortages-again-dry-season-says-prime-minister.
[15] Rujivanarom, P. (2019). Xayaburi dam partly to blame for Mekong Basin crisis: activists. The Nation. Available at at https://www.nationthailand.com/news/30373621 (accessed: November 25, 2019).

The need to ensure reliability of electricity supply should push Cambodia to diversify and the government is responding. While the government has approved the 80 MW Pursat dam,16 it has also signed up for 400 MW of new oil and gas projects,17 2,400 MW of coal-generated power imports from Laos,18 and has made a significant shift towards non-hydropower renewable energy. Cambodia's utility company, Electricite du Cambodge (EDC), says that it expects solar investment to rise significantly and could meet more than 20% of supply in a few years.19 Cambodia's solar buildout is almost entirely financed by the private sector, with EDC managing the purchase of power and transmission and distribution.

2.3 Laos

Laos has long branded itself as the "Battery of Southeast Asia", welcoming foreign investment in hydropower to meet rising electricity demand in neighboring countries. Laos has more than 60 operational dams and more than 60 under construction. Laos has 28,000 MW of hydropower potential and plans to develop much of this for export to Thailand, Viet Nam, and Cambodia. Already, most of the electricity produced in Laos is exported to these countries.

Laos's power sector is highly dependent on hydropower, which accounts for 75% of total installed capacity. The remainder is primarily from the 1,878 MW Hongsa Coal Plant, which accounts for 24% of installed capacity.[20] Laos has developed a few pilot solar projects.

Thailand purchases most of Laos' hydropower with imports reaching 3,500 MW in 2018. In 2016, Thailand updated its MOU for power purchase from Laos to 9,000 MW by 2037.[21] Thai demand has been a key driver of hydropower development in Laos. But disruptive technology and energy efficiency improvements call into question the 9,000 MW target. In response, Laos is seeking new export markets such as Malaysia or Myanmar, which would likely use Thailand's power grid as an intermediary, or Viet Nam. Viet Nam currently buys 300 MW of power from Laos but this will increase after Viet Nam signed an MOU in mid-2019 to buy 5,000 MW.[22] Cambodia is also developing quickly as an export market. Cambodia currently purchases electricity from Don Sahong dam and has agreed to import 2,400 MW of coal power from two projects in Laos in the future.

[16] Joshua, L. and RFA Khmer Service (2019). Cambodia announces hydropower, solar projects amid widespread electricity shortages. Radio Free Asia. Available at https://www.rfa.org/english/news/cambodia/plants-04052019162511.html (accessed: November 25, 2019).
[17] Bangkok Post (2019). Chinese companies to build 400 MW power plants in Cambodia. Available at https://www.bangkokpost.com/world/1693880/chinese-companies-to-build-400-mw-power-plants-in-cambodia (accessed: December 17, 2019).
[18] Thou, V. (2019). Kingdom okays 2,400 MW power purchase from Laos. Phnom Penh Post. Available at https://www.phnompenhpost.com/business/kingdom-okays-2400mw-power-purchase-laos (accessed: November 25, 2019).
[19] Thou, V. (2019). Gov't to reduce reliance on hydro. Phnom Penh Post. Available at https://www.phnompenhpost.com/business/govt-reduce-reliance-hydro (accessed: December 2, 2019).
[20] Mekong Infrastructure Tracker (2019). Available at https://mekong-infrastructure-tracker-stimsoncenter.hub.arcgis.com/ (accessed: December 10, 2019).
[21] Yuthana, P. (2016). Thailand considers buying more power from Laos. Bangkok Post. Available at https://www.bangkokpost.com/business/1038989/thailand-considers-buying-more-power-from-laos (accessed: December 2, 2019). Top Stories: The visit to Thailand of Lao PDR Foreign Minister. Available at http://www.mfa.go.th/main/en/media-center/28/69097-The-visit-to-Thailand-of-Lao-PDR-Foreign-Minister.html (accessed: December 2, 2019).
[22] Taejun, K. (2019). Laos, Viet Nam agree to boost energy trade. The Laotian Times. Available at https://laotiantimes.com/2019/08/28/laos-Viet Nam -agree-to-boost-energy-trade/ (accessed: December 2, 2019).

Hydropower projects			
Status	**Laos**	**Cambodia**	**Viet Nam**
Completed	64	2	45
Under construction	63	1	0
Inventory/pipeline	301	66	0
Total	428	69	45
Of which are <15 MW	257	39	0

Table 1: Status of hydropower projects in Laos, Cambodia, and Vietnam

Although these new coal projects have attracted significant attention, Laos has nine existing and 25 proposed dams in the Sekong. If all 25 were built, they would generate 3,354 MW.[23] Much of this power would be exported to Cambodia or Viet Nam, although it is not clear which dams would be built for which market. The environmental and social impacts of these dams could be very high as the Sekong is the last remaining, major free-flowing tributary in the entire Mekong system. A 2018 study by the National Heritage Institute (NHI) concluded that none of the proposed Sekong dams could be approved under Laos' own Policy for Sustainable Hydropower Development.[24] The NHI study raised particular concern over the Sekong Downstream 4A, which is the most downstream dam planned for the Sekong and would disconnect most of the Sekong river system if built.

While power trade is a major development goal for Laos and is a regional goal in terms of creating an ASEAN Power Grid, the infrastructure to support power trade has been slow to develop. The Asian Development Bank (ADB) has included cross-border power trade in its regional plans for decades but interconnections between countries are limited.

[23] Natural Heritage Institute (2018). Sustainable Hydropower Master Plan for the Xe Kong Basin in Lao PDR. Section 4-1. Available at https://data.opendevelopmentmekong.net/dataset/ad96956e-cac6-4771-bd4f-914996b37a2f/resource/293fd143-ae1f-4411-825b-2ea14c6632e5/download/lao_key-findings-of-sustainable-hydropower-master-plan_updated-8-mar-2018.pdf (Accessed 18/05/2020)

[24] Natural Heritage Institute (2018). Sustainable Hydropower Master Plan for the Xe Kong Basin in Lao PDR. Section 4-3. Available at https://data.opendevelopmentmekong.net/dataset/ad96956e-cac6-4771-bd4f-914996b37a2f/resource/293fd143-ae1f-4411-825b-2ea14c6632e5/download/lao_key-findings-of-sustainable-hydropower-master-plan_updated-8-mar-2018.pdf (Accessed 18/05/2020)

Box 2: Coal power development

Despite a global slowdown in coal investment, coal development is on the rise in Southeast Asia. Five of the 10 ASEAN countries are listed on Global Energy Monitor's 2018 list of top countries investing in new coal capacity.[25] But enthusiasm is waning due to increasing costs of modern coal technology, climate pressures, and concerns over imports. Countries are starting to remove coal plants from their pipelines. [26] Thailand has shelved the two coal plants that have triggered ongoing protests, and Viet Nam has removed about 40 projects from their revised Power Development Plan VII and will likely continue reducing the role of coal in future plans.

But there is still momentum for investment in coal. In September 2019, Cambodia agreed to buy 2,400 MW of coal power from two projects in Sekong Province in Laos.[27] While Cambodia is under pressure to address power shortages, these projects are not yet under construction and are not expected to come online until 2024. EDC has signed a power purchase agreement (PPA) to buy electricity at ¢7.7/kWh for 30 years.[28] Importing coal power from Laos has the benefit of ensuring long-term stability of supply but it also commits Cambodia to paying an above market price. Cambodia's PPA with a commercial-scale solar farm that came online in 2019 was ¢7.6/kWh.[29]

3. Renewable Energy Options?

While hydropower and fossil fuels have historically defined power mixes in the region, significant declines in the global price of solar panels and wind turbines have made these options economically and technically feasible in Southeast Asia. The 3S is no exception to this trend.

3.1 Solar in the 3S

The 3S is an ideal region for solar due to its proximity to the equator and high levels of solar irradiation. With the exception of mountainous parts of Sekong Province in Laos and Kon Tum Province in Viet Nam, the 3S receives 3.5-5 kWh/m^2/day in solar radiation. For reference, Germany, which receives 2.6-3.7 kWh/m^2/day, has installed over 40,000 MW of solar power.[30] From a technical perspective, the 3S has a wealth of untapped solar energy resources.

There is growing interest in solar in the region. In Laos, Convalt Energy has MOUs to develop two large-scale solar projects in the 3S. The first will be a 250 MW project in Attapeu Province and is a standalone solar

[25] Shearer, et al., Boom and Bust (2018). Tracking the Global Coal Pipeline, CoalSwarm. Page 12. Availabe at https://endcoal.org/wp-content/uploads/2018/03/BoomAndBust_2018_r4.pdf.
[26] Global Energy Monitor (2019). More fizz than boom: 2019 sees coal plant growth in Southeast Asia dwindling as pipeline continues to shrink. Available at https://globalenergymonitor.org/384-2/ (accessed: December 3, 2019).
[27] Thou, V. (2019). Kingdom okays 2,400 MW. (Accessed: https://www.phnompenhpost.com/business/kingdom-okays-2400mw-power-purchase-laos)
[28] Chea, V. (2019). Cambodia and Laos to sign 2,400-megawatt power deal today. The Khmer Times. Available at https://www.khmertimeskh.com/642313/cambodia-and-laos-to-sign-2400-megawatt-power-deal-today/ (accessed: December 3, 2019).
[29] Hor, K. (2019). EDC launches tender offer for solar project. The Phnom Penh Post. Available at https://www.phnompenhpost.com/business/edc-launches-tender-offer-solar-project (accessed: December 3, 2019).
[30] Wirth, H. (2020). Recent facts about Photovoltaics in Germany. Fraunhofer Institute for Solar Energy. Page 33. Available at https://www.ise.fraunhofer.de/en/publications/studies/recent-facts-about-pv-in-germany.html (accessed: February 10, 2020).

plant.[31] The second will be a floating solar project on the Xekaman 1 dam with a capacity of 280 MW.[32] The company has also signed an MOU with Electricte du Laos (EDL) to develop and invest in a 500 kV transmission line to support the sale of the electricity from these projects to Viet Nam.

Solar in the 3S in Cambodia is at an earlier stage of development, primarily at the household and village level for electrification purposes rather than commercial scale investment. However, NHI has conducted a pre-feasibility study for a floating solar project on the LS2 as part of a larger study on alternatives to the proposed Sambor dam. While this proof-of-concept study uses general data, it shows that up to 200 MW of solar could be installed on the 25,000-hectare reservoir, although this would require additional investment in transmission and battery storage to ensure power stability.[33]

Viet Nam is already a major investor in solar power. Its installed capacity jumped from 134 MW in early 2018 to 5,000 MW in December 2019 and Electricity Viet Nam (EVN) has registered more than 25,000 MW of additional solar projects.[34] A major factor behind this investment surge was a very high feed-in-tariff (FIT), which will be replaced by an auction system in 2020.

Box 3: Viet Nam' s "solar capitals"

The high solar FIT has produced three champion provinces: Binh Thuan, Ninh Thuan, and Tay Ninh.

Binh Thuan has 687 MW of solar capacity, including large-scale projects such as the 325 MW Hong Phong plant.[35] In Ninh Thuan, over 712 MW has been built, and Tay Ninh has nine solar projects producing 668 MW. [36] In all, these three provinces account for 40% (2,067 M) of Viet Nam' s total solar energy capacity. Tay Ninh, in particular, has been cited as having a great solar potential, and the head of Viet Nam' s Central Economic Commission has said that the province is now one of the "capitals" of solar power in Viet Nam. [37]

These provinces border those in the Central Highlands but are head and shoulders above their neighbors in successfully implementing solar projects and in supporting larger projects. Their success can be partially attributed to geography. Tay Ninh, Binh Thuan, and Ninh Thuan are all relatively flat, close to HCMC, and receive high levels of sunshine, making them ideal locations for future solar development.

[31] Ministry of Planning and Investment (2017). U.S. investors sign LOI with partners for development of first large-scale solar project in Lao PDR. Available at http://www.investlaos.gov.la/index.php/news-and-events/item/21-u-s-investors-sign-lois-with-partners-for-development-of-first-large-scale-solar-power-project-in-lao-pdr (accessed: December 4, 2019).

[32] Convalt Energy (2018). U.S. Firm ACO Investment Group and Vietnamese power company Viet Lao Power Joint Stock Company to partner on renewable power projects in Lao PDR. Available at http://www.convalt.com/loa-solar-hte.html (accessed: December 4, 2019).

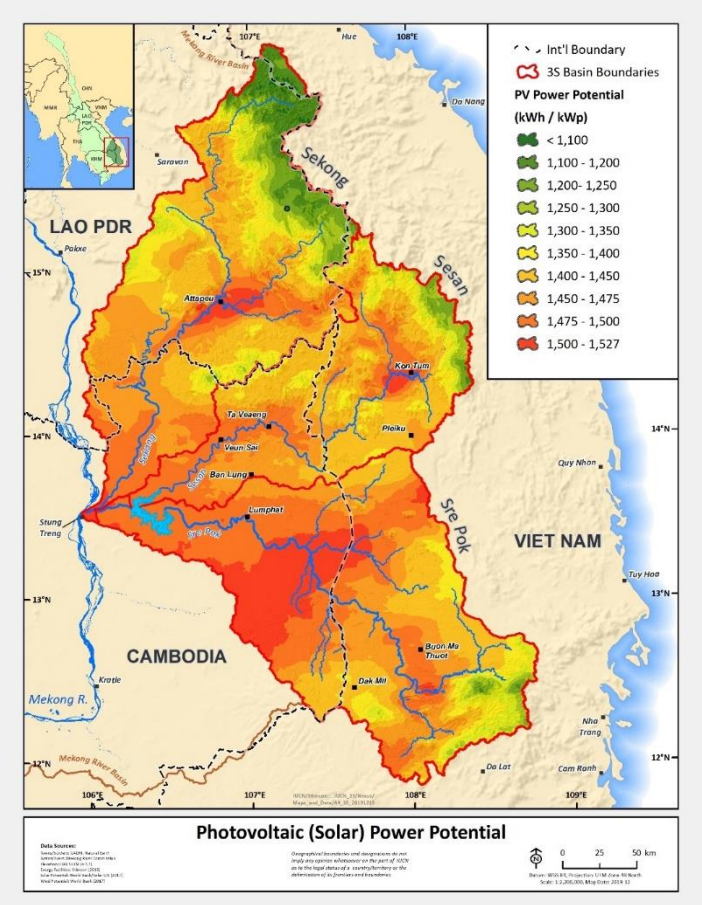
[33] Natural Heritage Institute (2017). NHI Final Report–Sambor Dam Alternatives Assessment, Volume 3. V3 -39.

[34] Kenning, T. (2019). Viet Nam ese firm completes 40 MW solar project in Binh Thuan. PV Tech. Available at https://www.pv-tech.org/news/Viet Nam ese-firm-completes-40mw-solar-project-in-binh-thuan (accessed: December 4, 2019); Le, H. (2019). Viet Nam set to become a solar power hotspot. VN Express. Available at https://e.vnexpress.net/news/business/industries/Viet Nam -set-to-become-a-solar-power-hotspot-4004965.html (accessed: on December 5, 2019).

[35] Xiaomin, Z. (2019). Chinese firms mainstay of Viet Nam solar project. China Daily. Available at http://www.chinadaily.com.cn/global/2019-07/19/content_37493358.htm (accessed: December 5, 2019).

[36] Nguyen, Q. (2019). Southeast Asia's largest solar farm begins operations in southern Viet Nam. VN Express. Available at https://e.vnexpress.net/news/news/southeast-asia-s-largest-solar-farm-begins-operations-in-southern-Viet Nam -3979068.html (accessed: December 5, 2019).

[37] Nguyen, Q. (2019). Southeast Asia's largest solar farm begins operations in southern Viet Nam. VN Express. Available at https://e.vnexpress.net/news/news/southeast-asia-s-largest-solar-farm-begins-operations-in-southern-vietnam-3979068.html (accessed: December 5, 2019).



Map 2: *Photovoltaic (Solar) Power Potential*

Solar investment in the 3S basins within Viet Nam is growing but pales in comparison to Binh Thuan, Ninh Thuan, and Tay Ninh. Gia Lai has the highest solar potential of any province in Viet Nam, and Kon Tum, Dak Lak, and Lam Dong, all of which are in the 3S basin, rank in the top 10 provinces in terms of solar potential.[38] However, only a few projects, all under 100 MW, are in development in these provinces despite having similar levels of solar irradiation to the "solar capitals."[39]

Kon Tum has one commercial-scale solar project in development: a 49 MW project that is attached to the Sesan 4 dam.[40] Dak Nong has three solar projects in its investment plan through 2020 with a total capacity of 124 MW.[41] An additional six projects are in the pipeline that could add an additional 162 MW in Dak Nong.[42]

Dak Lak and Gia Lai have set more ambitious targets. Dak Lak has set a provincial energy target of 4,000 MW of solar by 2030. [43] Development to date has been slow with only three projects operational. That said, one

[38] Vu, D. H. (2018). Final results on theoretical and technical potentials of solar PV. Presentation at MOIT/GIZ Energy Support Programme, January 24, 2018, Hanoi, slide 34. Available at http://gizenergy.org.vn/media/app/media/Presentations/Presentations%20at%20the%20solar%20workshop%20on%2024%20January%202018%20.pdf.

[39] Mekong Infrastructure Tracker database (2019). Available at https://mekong-infrastructure-tracker-stimsoncenter.hub.arcgis.com/ (accessed: December 3, 2019).

[40] Pham, L. (2019). AFD advances Viet Nam 's renewable power strategy. Hanoi Times. Available at http://hanoitimes.vn/afd-advances-Viet Nam s-renewable-power-strategy-300128.html (accessed: December 5, 2019).

[41] Viet Nam Investment Review (2019). Dak Nong calls for investment in solar power. Energy Central. Available at https://www.energycentral.com/news/dak-nong-calls-investment-solar-power-project (accessed: December 6, 2019).

[42] Hoang, Q. (2019). Solar power projects wake up potential of central highland district. Available at https://vovworld.vn/en-US/society/solar-power-projects-wake-up-potential-of-central-highland-district-794452.vov (accessed: December 6, 2019).

100 MW solar complex was the largest project in the Central Highlands when it opened in March 2019.[44] Investors have proposed more than 30 more projects[45] that could generate more than 6,000 MW if built.[46] Much of this could come from two projects: a 2,000 MW project and a 1,117 MW cluster of smaller ones.

Gia Lai has 33 projects in development with a total capacity of 4,000 MW, 1,000 MW of which would be located in Krong Pa District.[47] Krong Pa's local leaders support the idea, as they feel exhausted agricultural fields can be redeveloped as solar projects as an alternative method of economic development.[48]

Despite significant potential for solar development in Viet Nam' s portion of the 3S, high population density, especially in the most-suitable low lying and flat land, prevents a fast transition to solar.

Many projects in the Central Highlands are close to hydropower plants and have plugged into existing transmission lines rather than build new ones at a cost of $500,000-$1,000,000/km. By contrast, projects in the south-east coastal region often face curtailment due to congestion caused by limited transmission.[49]

3.2 Wind in the 3S

Although wind power is economically feasible, it is not as popular as solar because of distance from high wind areas to demand centers and limited transmission capacity. Viet Nam has led in this sector with both onshore and offshore wind projects. Viet Nam has 371 MW of wind power, most of which is offshore. Onshore wind projects are planned, but Viet Nam' s last Power Development Plan only included 2,000 MW of wind power. Solar is attracting much more attention nationally, and this holds true in the 3S as well. There are only three potential wind projects in Viet Nam' s portion of the 3S, all in Gia Lai. Two of these, a 50 MW plant and a 405 MW plant, are in the mountainous border region with Laos.[50] Most of the 3S' wind potential is in remote border areas far from transmission and inside protected areas, factors that will limit wind investment.

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[43] Viet Nam Biz (2019). Đắk Lắk: Bổ sung 3 dự án điện mặt trời vào quy hoạch phát triển điện lực Quốc gia. Available at https://Viet Nam biz.vn/dak-lak-bo-sung-3-du-an-dien-mat-troi-vao-quy-hoach-phat-trien-dien-luc-quoc-gia-30751.htm (accessed: December 6, 2019).

[44] Saigoneer (2019). Viet Nam 's largest solar power system officially opens in Dak Lak. Available at https://saigoneer.com/saigon-development/15888-Viet Nam -s-largest-solar-power-system-officially-opens-in-dak-lak (accessed: December 6, 2019). Solar power complex launched in Dak Lak," *Viet Nam News*. Available at https://Viet Nam news.vn/economy/506800/solar-power-complex-launched-in-dak-lak.html#MMPDH0m6Cdlhf5fX.97 (accessed: December 6, 2019).

[45] Nhan dan (2019). Third solar plant in Dak Lak inaugurated. Available at https://en.nhandan.org.vn/business/economy/item/7403902-third-solar-power-plant-in-dak-lak-inaugurated.html (accessed: December 6, 2019).

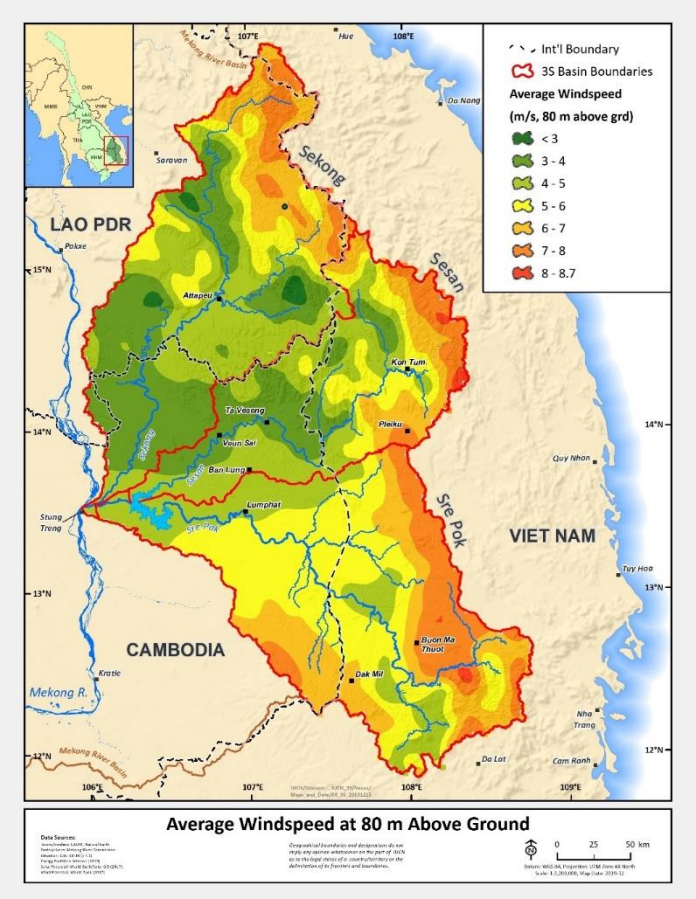
[46] Nguyen, A. T. (2018). Methodology for solar PV assessment. Presentation at MOIT/GIZ Energy Support Programme, January 24, 2018, Hanoi, slide 5, at http://gizenergy.org.vn/media/app/media/Presentations/Presentations%20at%20the%20solar%20workshop%20on%2024%20January%202018%20.pdf.

[47] Nhan dan (2019). Central highland provinces enhance development of renewable energy. Available at https://en.nhandan.org.vn/business/item/7731002-central-highland-provinces-enhance-development-of-renewable-energy.html (accessed: December 6, 2019).

[48] Nhan dan (2019). Central highland provinces enhance development of renewable energy. Available at https://en.nhandan.org.vn/business/item/7731002-central-highland-provinces-enhance-development-of-renewable-energy.html (accessed: December 6, 2019).

[49] Viet Nam Investment Review (2019). Change of direction for the solar industry. Available at https://www.vir.com.vn/change-of-direction-for-the-the-solar-industry-71390.html (accessed: December 6, 2019).

[50] DEVI Renewable Energies (2019). Wind and Solar farms in Viet Nam. Available at https://devi-renewable.com/ (accessed: December 10, 2019).



Map 3: Average Windspeed at 80m Above Ground

Laos has an estimated potential of 2,800 MW of high-quality wind speeds above 7 m/s and has significantly higher potential at good quality wind speeds between 5-7 m/s.[51] The ADB estimates that the levelized cost of electricity (LCOE) from wind in Laos would range from ¢6.6 to ¢11.4/kWh, the lower range of which is competitive with new hydropower and coal projects.[52]

Only one wind project is under development in Laos but when built the Monsoon Wind Project will be the largest wind farm in Asia with a capacity of 600 MW. This Thai project covers 64 km^2 of Sekong and Attapeu Provinces.[53] The project is expected to begin operation in 2021. Three more projects are planned and would be located near the Lao-Viet Nam border given the high wind speeds there. [54] But these are unlikely to move ahead until the Monsoon Wind Project comes online and proves to be a commercial success.

The ADB estimates that Cambodia has 65,000 MW of theoretical wind potential.[55] A lack of site-specific studies and the high price of wind have dissuaded commercial-scale investment. But in 2019 the

[51] Intelligent Energy Systems and Mekong Economics (2016). Alternatives for Power Generation in the Greater Mekong Sub-Region. Volume 3: Power Sector Vision for the Lao People's Democratic Republic," WWF, March 20, 2016, page 22-3. Available at http://d2ouvy59p0dg6k.cloudfront.net/downloads/vol_3_ies_mke_lao_pdr_wwf_power_sector_vision_20160321_final_r4.pdf.

[52] Asian Development Bank (2015). Renewable Energy Developments and Potential in the Greater Mekong Subregion. Page 35. Available at https://www.adb.org/sites/default/files/publication/161898/renewable-energy-developments-gms.pdf.

[53] Impact Electrons Siam (2019). Monsoon Wind Power. Available at https://www.impactelectrons.com/project/monsoon-wind-power/ (accessed: December 9, 2019).

[54] Institute of Renewable Energy Promotion & Ministry of Energy and Mines (2016). Renewable Energy Data in Lao PDR. Presentation EAST and Southeast Asia Renewable Energy Statistic Training Workshop, December 12, 2016, Bangkok, slide 7. Available at https://www.irena.org/-/media/Files/IRENA/Agency/Events/2016/Dec/12/Laos-presentation.pdf?la=en&hash=C3EE41F35C533D50672C4A75B1AA0D9D10C8C66C.

[55] ADB (2015) Renewable Energy Developments and Potential in the Greater Mekong Subregion. Page 19. https://www.adb.org/sites/default/files/publication/161898/renewable-energy-developments-gms.pdf

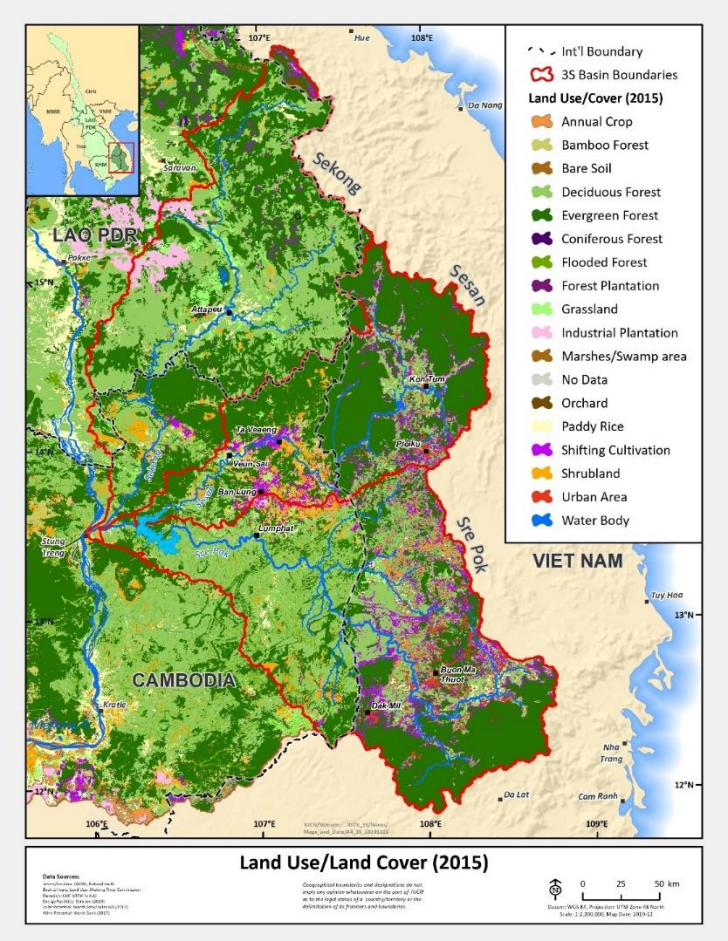
Singaporean company Blue Circle finished pre-feasibility studies in Kampot and Mondulkiri Provinces, the northeast portion of which has average wind speeds of 5-7 m/s.[56] These speeds make wind commercially viable using current technologies. While Blue Circle is prioritizing Kampot for an 80 MW pilot project, [57] success there could lead to future investment in Mondulkiri. But much of the 3S is mountainous and remote and lacks transmission to demand centers like Phnom Penh. Wind projects would be far more attractive financially if transmission lines were extended east and northeastward of the LS2.

3.3 Biomass in the 3S

Biomass is the least developed alternative energy source in the region. Thailand leads the region with an estimated 3,000 MW of capacity and has included specific targets in its most recent PDP. Viet Nam' s 2016 PDP 7 Revision set a target of 1% (about 600 MW) of the electricity mix to come from biomass by 2020.[58] Issues of economic viability have plagued the sector and as of 2018 only 325 MW of biomass were installed in Viet Nam.[59] The ADB estimates that Gia Lai and Dak Lak have high levels of agriculture waste from maize, cassava, and sugarcane.[60] But resource competition between biofuel production and electricity production will likely stunt biomass' potential to contribute significantly to the power mix.

As economies with high agricultural contributions to GDP, Laos and Cambodia both have high potential for bioenergy using crop waste and other agricultural remainders. Attapeu Province in Laos has significant rice husk, maize, and cassava residues available for biomass energy production. Other provinces have relatively low potential compared to provinces in central Laos and the floodplains of Cambodia.[61] Individual biomass pilot projects and household scale biodigesters are becoming more common, but near term biomass deployment will be limited since most land is farmed by smallholders and the region lacks a robust supply chain to support large-scale biomass power generation.

[56] NREL (2019). Renewable Energy Data Explorer (RED-E) Southeast Asia. Available at https://maps.nrel.gov/rede-southeast-asia (accessed: December 9, 2019).
[57] Chea, V. (2019). Nation's first wind energy project on the table. Khmer Times. Available at https://www.khmertimeskh.com/657768/nations-first-wind-energy-project-on-the-table/ (accessed: December 10, 2019).
[58] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (2016). Viet Nam Power Development Plan for the period 2011-2020: Highlights of the PDP 7 revised. Available at http://gizenergy.org.vn/media/app/media/legal%20documents/GIZ_PDP%207%20rev_Mar%202016_Highlights_IS.pdf.
[59] Tran, A. (2018). Viet Nam has huge biomass potential, but policy tweak needed. VN Express. Available at https://e.vnexpress.net/news/business/industries/Viet Nam -has-huge-biomass-potential-but-policy-tweak-needed-3853708.html (accessed: December 9, 2019).
[60] ADB (2015) Renewable Energy Developments and Potential in the Greater Mekong Subregion. Page 111. https://www.adb.org/sites/default/files/publication/161898/renewable-energy-developments-gms.pdf.
[61] ADB (2015) Renewable Energy Developments and Potential in the Greater Mekong Subregion. Page 21. https://www.adb.org/sites/default/files/publication/161898/renewable-energy-developments-gms.pdf



Map 4: Land Use/Land Cover (2015)

4. Energy Futures for the 3S: Development Scenarios

The 3S is well endowed with power generation potential and the renewable energy transition has expanded generation options. Yet challenges lie ahead. Will national governments favor one form of power generation over others? Could Cambodia make a commitment to full diversification of power sources in its portion of the 3S in order to reduce river connectivity losses to the Tonle Sap, only to have Laos or Viet Nam impact connectivity by developing hydropower upstream? Will Cambodia, Laos, and Viet Nam view the 3S as an opportunity for coordinated investment offering mutual benefits for all?

This section considers four potential future scenarios based on current economic, political, and technological trends. They are intended to be descriptive, not prescriptive.

4.1 Full buildout

This first scenario considers a future where most planned hydropower in the 3S is built. It assumes that electricity demand will continue to grow at current rates and that countries will prioritize investment in their current inventory of domestic assets over new technologies or power trade with neighbors. In this Full Buildout scenario, all proposed dams on the mainstream of the Sekong and its tributaries in Laos, as well as the Lower Sekong and the Lower Sesan I dams in Cambodia are built. Additionally, the two recently announced coal projects in Laos are built.

The Full Buildout scenario recognizes that the renewable energy transition is increasingly attractive and that many renewable energy projects will move ahead. But this happens on a case-by-case basis rather than through coordinated regional energy planning, or even coordinated national energy planning to eliminate the most impactful dams. As a result, there is no strategic substitution of alternatives for hydropower.

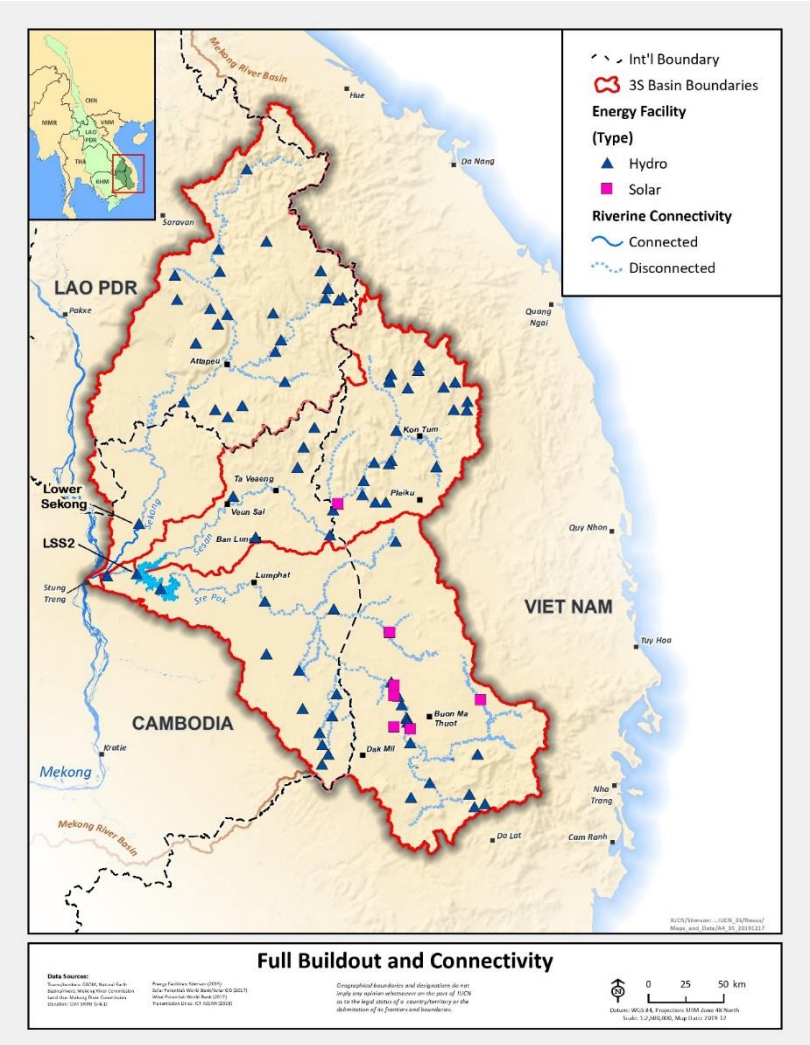
The Full Buildout scenario is unlikely to play out. Hydropower rarely reaches a full buildout of 100% of potential. Rather, the development of new projects begins to slow down over time. This slowdown occurs for many reasons, the simplest being that later projects tend to be more complex and more expensive. As a result, most river basins stop development of new hydropower projects at between 40% and 70% of potential.[62]

Full Buildout scenario	
Energy type	**Total installed capacity (MW)**
Hydropower	12,384
Coal	3,100
Solar	?
Wind	?

Table 2*: Full Buildout energy mix*

But a Full Buildout scenario is worth considering because it shows what could be lost if no strategic decision-making for hydropower development in the 3S occurs. In this scenario, even if Cambodia avoids building the controversial Sambor and Stung Treng dams, it has still lost nearly all of the Tonle Sap's connectivity to the 3S following construction of LS2.

[62] Opperman, J., Grill, G., and Hartman, J. (2015). The Power of Rivers: Finding balance between energy and conservation in hydropower development. The Nature Conservancy. Page 21. Available at https://www.nature.org/media/freshwater/power-of-rivers-report.pdf.



Map 5: Full Buildout and Connectivity

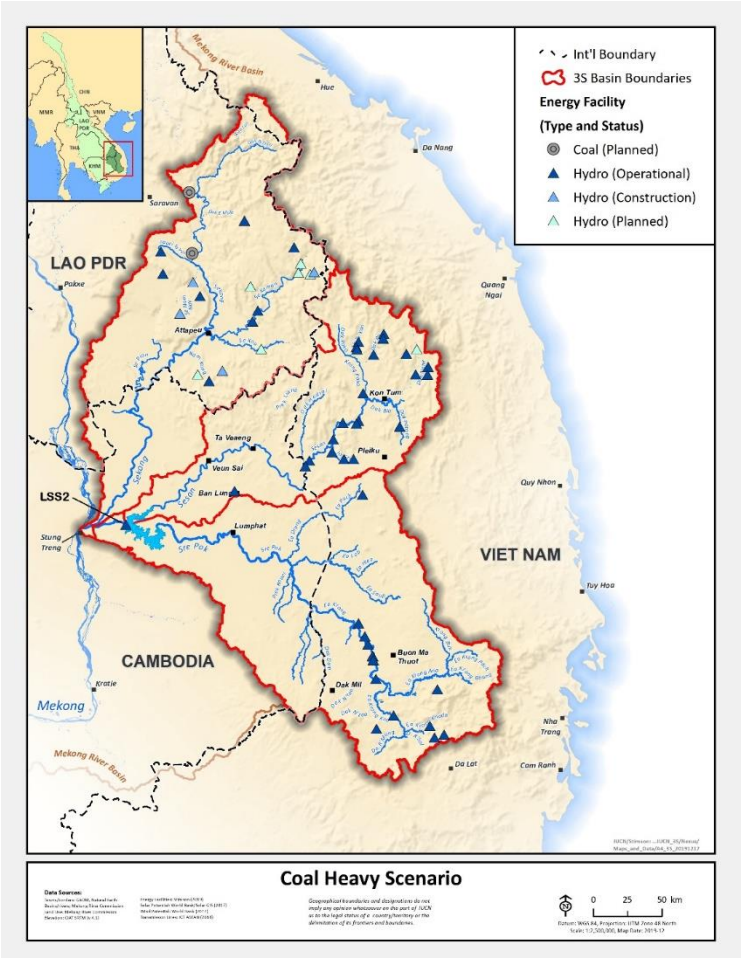
If a full buildout occurs, both power generation and connectivity losses would be notably higher than the other scenarios described below. The development of the Lower Sekong and Lower Sesan I dams would separate almost all of the 3S from the Tonle Sap and the Mekong Delta. This would disconnect an additional 1,870 km of the Sekong and a portion of the Sesan, or an additional 43% of the total 3S river system. That would raise the connectivity loss from 55% to 98%.[63] This would severely reduce migration routes available to fish and would further impact sediment flow.[64]

[63] Eyler, B. and Weatherby, C. (2019). Letters from the Mekong: Towards a Sustainable Water-Energy-Food Future in Cambodia. Stimson Center, February 27, 2019, page 29. Available at https://www.stimson.org/wp-content/files/file-attachments/WEB-FEB_Cambodia%20Report.pdf (Accessed 18/05/2020)

[64] Schmitt, R.J.P., Bizzi, S., Castelletti, A. et al. Improved trade-offs of hydropower and sand connectivity by strategic dam planning in the Mekong. Nat Sustain 1, 96–104 (2018). Pp. 98. https://doi.org/10.1038/s41893-018-0022-3

4.2 Coal-heavy buildout

This scenario assumes that all coal projects move forward but that many hydropower projects in the Full Buildout scenario are not built due to concerns about the reliability of hydropower and resettlement, as well as recognition of the need to conserve river connectivity between the Sekong and the Mekong.



Map 6: Coal Heavy Scenario

The Coal-Heavy scenario's assumptions are driven largely by energy policy and planning inside Cambodia, as well as possible coordination between Viet Nam and Laos to forego some dams in the 3S that could impact the Mekong Delta. Given the impacts of the 2019 drought on hydropower, this scenario anticipates an effort by Cambodia to diversify supply. This scenario assumes that the 2,400 MW of coal power that Cambodia will buy from Laos substitutes for much of the hydropower development that would otherwise have moved forward in Cambodia's portion of the 3S. While Cambodia might consider some additional hydropower, this scenario estimates that the remaining 3S projects are too costly given the need for additional transmission and resettlement. It therefore assumes that further hydropower development in Cambodia's portion of the 3S would be limited.

The proposed import of 2400 MW of coal power from Laos will satisfy most of Cambodia's future energy demand. Given energy security and river connectivity concerns, it is unlikely that Cambodia would be willing to purchase additional power from hydropower projects in Laos.

This leaves Viet Nam as the next likely customer for these projects. This scenario assumes that Viet Nam is an interested buyer given its commitment to purchase 5,000 MW of power from Laos. But given the many

other hydropower projects in Laos, this scenario assumes that Viet Nam will avoid buying power from mainstream dams on the Sekong due to concerns over connectivity losses and impacts on the delta. Dams on Sekong tributaries could produce about 1,150 MW. This scenario assumes that Viet Nam would negotiate to purchase power from these projects and that the remaining 3,850 MW of its power purchase commitment would be met by other projects in Laos.

Although many of the Sekong's tributaries will be dammed under this scenario, it would preserve much of the 700 km of Sekong mainstream as free flowing. At the same time, this scenario assumes that potential solar and wind development in the 3S does not materialize because of a lack of policy support and investor interest.

4.3 Strong renewable energy buildout

Given the surge in renewable energy investments in Viet Nam and the rapid expansion of solar in Cambodia's energy plans, the Strong Renewable scenario assumes that solar and wind projects will replace a significant portion of proposed hydropower in the 3S. It assumes that solar and wind power continues to increase in competitiveness, particularly in comparison to hydropower.

Only about 5,600 MW of potential hydropower projects exist in the 3S, and the solar, wind, and biomass endowments in Cambodia, Laos, and Viet Nam are more than enough to replace this. Cambodia's solar endowment alone is 8,000 MW.[65] Laos' solar potential is also about 8,000 MW, and it has significant wind potential as well. Viet Nam has built more than 5,000 MW of solar power since 2017 and could build multiples of this in the future.

Solar and wind cannot wholly substitute for hydropower given the need to ensure diversity and reliability of electricity supplies. Moreover, preparing national electricity grids to handle high levels of intermittent power is a technical challenge. However, from a price standpoint, the table below shows how solar and wind are already on par with new hydropower and coal projects. These alternatives are likely to become increasingly competitive while hydropower is likely to become less reliable due to climate change. Renewables will become more competitive with coal due to the need to add expensive scrubbing and carbon capture technologies as countries become more committed to climate change mitigation and air pollution reduction.

Like Coal-Heavy, the Strong Renewable scenario assumes that Cambodia's demand for further hydropower imports from Laos is limited and that much of the proposed hydropower in Cambodia's northeast would be foregone for overdependency reasons. Both cost considerations and river connectivity concerns drive Cambodia's decision to favor alternative power. The Strong Renewable scenario assumes that any future hydropower in Cambodia would come from projects above the LS2 which are not located on the Sekong. Cambodia has a large portfolio of projects above the LS2 from which to choose.

[65] De Ferranti, R., Fullbrook, D., McGinley, J. and Higgins, S. (2016). Switching On: Cambodia's Path to Sustainable Energy Security. Mekong Strategic Partners, 2016. Page 16. Available at http://www.mekongstrategic.com/switching-on--cambodia-s-path-to-sustainable-energy-security.html (accessed: November 15, 2018); for a higher estimate, see Intelligent Energy Systems, "Alternatives for Power Generation in the Greater Mekong Subregion, Volume 2: Power Sector Vision for the Kingdom of Cambodia," WWF, March 2016, page 30.

Energy source	LCOE (kWh)[66]	Examples
Solar	$0.032-0.042	SchneiTec solar plant in Kampong Speu, Cambodia: $0.076[67]
Wind (onshore)	$0.028-0.054	Viet Nam FIT for wind projects: $0.085[68]
Coal	$0.066-0.152	Sekong coal projects in Laos: US $0.077[69]
Hydropower	$0.030-0.110	LS2: $0.0695[70]

Table 3: Comparative energy costs

In the Strong Renewable scenario, the renewable energy transition unlocks domestic power generation in Cambodia and Viet Nam so that power trade with Laos becomes a marginal conversation. This scenario assumes that Viet Nam will move forward with its committed purchase of 5,000 MW from Laos.

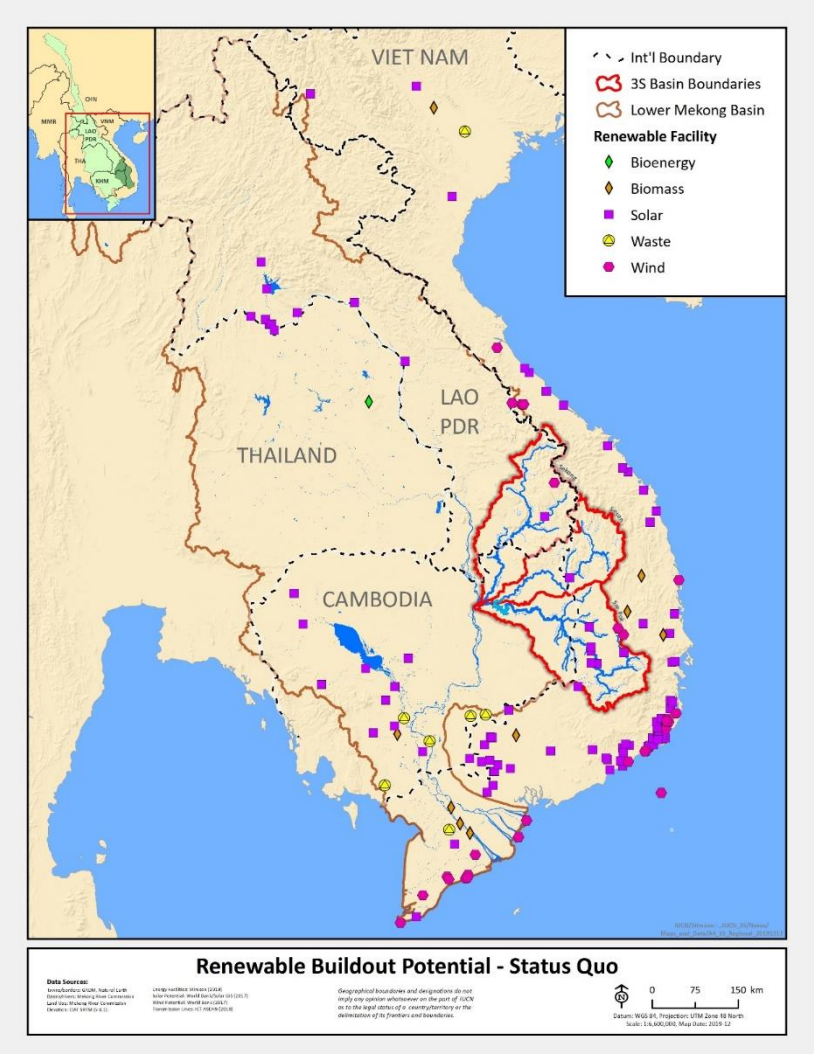
[66] LCOE (2019). Levelized Cost of Energy and Levelized Cost of Storage 2019,"Lazard. Available at https://www.lazard.com/perspective/lcoe2019 (accessed: December 9, 2019). Lazard does not calculate LCOE for hydropower, so figures for hydropower are drawn from "Hydropower," IRENA, at https://www.irena.org/costs/Power-Generation-Costs/Hydropower.

[67] Kimsay, H. (2019). EDC launches tender offer for solar project. The Phnom Penh Post. Available at https://www.phnompenhpost.com/business/edc-launches-tender-offer-solar-project (accessed :December 10, 2019).

[68] Pham, L. (2019). Why is wind energy more cost-competitive in Viet Nam ?. Hanoi Times. Available at http://hanoitimes.vn/why-is-wind-energy-more-cost-competitive-in-Viet Nam -41903.html (accessed: December 10, 2019).

[69] The Phnom Penh Post (2019). Asia News Network: Cambodian-Lao coal power deal an environmental worry. Available at https://www.phnompenhpost.com/business/cambodian-lao-coal-power-deal-environmental-worry (accessed: December 11, 2019).

[70] Koemsoeun, S. (2018). Lower Sesan II dam opens. The Phnom Penh Post. Available at https://www.phnompenhpost.com/national/lower-sesan-ii-dam-opens (accessed: December 10, 2019).



Map 7*: Renewable Buildout Potential – Status Quo*

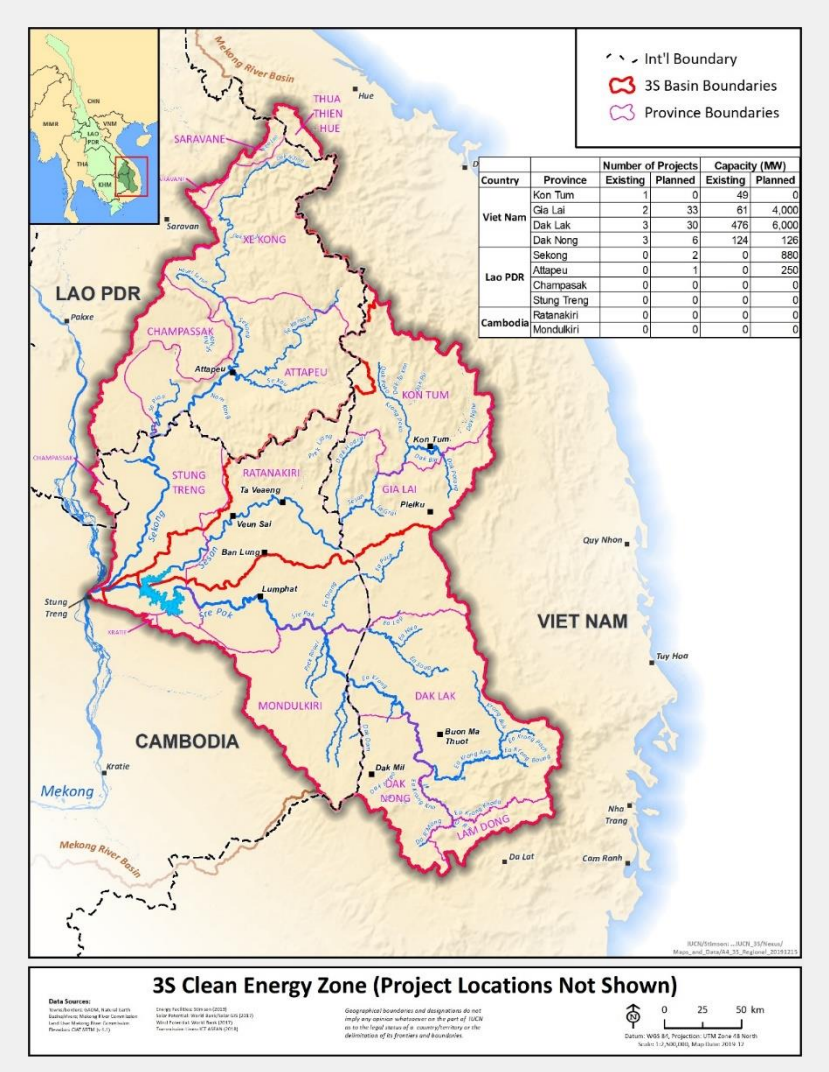
Similarly, this scenario assumes that only a portion of the 3,400 MW of planned hydropower in Laos' portion of the 3S would move ahead due to a preference for non-hydropower renewables to meet future demand. This scenario is agnostic about which dams in Laos are built. Its assumption that regional power trade is not effectively coordinated means that neither Cambodia nor Viet Nam engages with Laos on strategic planning, and as a result some of the dams on the Sekong mainstream would move ahead. This scenario therefore has a range of potential impacts on connectivity depending on which 3S dams are built.

The Strong Renewable scenario assumes that together with several thousands of MW of solar and wind, the Downstream Sekong 4A dam in Laos is built. This would only preserve connectivity along the lowest 110 km of the Sekong, the distance between the Downstream Sekong 4A dam and the confluence of the Sekong with the Mekong. Thus, despite a major shift toward renewables, connectivity to the Mekong would be lost. This scenario therefore results in losses in capture fisheries and equal to those of the Full Buildout scenario.

4.4 3S clean energy zone

A fourth scenario, the 3S Clean Energy Zone (CEZ), assumes that the desire for regional energy trade and a diverse energy mix push Cambodia, Laos, and Viet Nam to explore coordinated, transboundary investments.

In this case, Cambodia and Viet Nam engage Laos to adopt a planning approach that minimizes downstream impacts while producing a similar amount of electricity for export to Cambodia and Viet Nam.



Country	Province	Number of Projects: Existing	Number of Projects: Planned	Capacity (MW): Existing	Capacity (MW): Planned
Viet Nam	Kon Tum	1	0	49	0
	Gia Lai	2	33	61	4,000
	Dak Lak	3	30	476	6,000
	Dak Nong	3	6	124	126
Lao PDR	Sekong	0	2	0	880
	Attapeu	0	1	0	250
	Champasak	0	0	0	0
	Stung Treng	0	0	0	0
Cambodia	Ratanakiri	0	0	0	0
	Mondulkiri	0	0	0	0

Map 8*: 3S Clean Energy Zone (Project Location Not Shown)*

As river connectivity is prioritized, the countries agree to keep much of the Sekong free-flowing and to develop new dams only above existing ones on 3S tributaries. In this scenario, the countries would likely build a small number of new hydropower projects in Laos and Cambodia. It does not prescribe which dams would be built but assumes that dams would be sited to facilitate the integration of solar and wind generation and avoid significant connectivity losses. The hydropower buildout includes about 1,500 MW of tributary dams in Laos and 1,536 MW of dams upstream of the LS2 in Cambodia.

To replace the foregone hydropower projects in the 3S and to delay a decision on the Stung Treng and Sambor dams, Cambodia, Laos, and Viet Nam incentivize investments in solar, wind, biomass, and transmission capacity in the 3S. The 600 MW Monsoon Wind project in Laos would be fully utilized. A preference for floating solar on existing reservoirs in the 3S replaces some generation capacity. Finally, existing and new dams in the 3S are operated in ways that complement intermittent solar and wind power, allowing for their full integration into the grid.

Cambodia, Laos, and Viet Nam promote the CEZ as an investment framework that complements other regional frameworks. The CEZ would seek designation from Thailand's Ayeyarwady-Chao Phraya-Mekong Economic Cooperation Fund (ACMECS), a financing mechanism that supports high-quality investment in the Mekong countries with a focus on Laos, Cambodia, and Myanmar. With an ACMECS designation, Japan and other development partners also contribute financially and technically to the CEZ. Power from the CEZ would feed into cross-border power trade agreements but could also travel farther afield through Thailand's grid.

The CEZ scenario assumes that such coordinated efforts maximize non-hydropower renewable generation in the 3S and sites hydropower in ways that maximize water and sediment flows from the 3S.

Box 4: Floating solar on the LS2

Of the many potential renewable energy projects proposed for the 3S, one is a floating solar project on the LS2 reservoir in Cambodia. This was explored by the NHI as part of an alternative to the Sambor dam on the Mekong mainstream. Floating solar is more technically complex than ground-mount solar farms but comes with no inherent land costs since it is built on a reservoir and operated in conjunction with the host hydropower project. Additionally, floating solar panels have operational and maintenance benefits. Natural heat transfer from panels into the reservoir improves efficiency, and water access makes floating solar installations easy to clean.

NHI concludes that up to 200 MW can be easily integrated into Cambodia's grid without further transmission line investment.[71] With increased investment in transmission and battery storage, the project could reliably supply Cambodia's grid with up to 400 MW.

Floating solar farms have already proven successful globally. Viet Nam' s first large-scale (48 MW) floating solar project came online in Binh Thuan in May 2019.[72] Thailand plans to deploy 2,700 MW of floating solar by 2037 and has laid out a clear timeframe for implementation.[73] Cambodia has a 2.8 MW pilot built by Cleantech, a Singaporean company, as part of an industrial complex.[74]

Investment in floating solar on the LS2 would only require an increase of $0.006/kWh over the original purchase price of power from the LS2 (just under $0.07). [75] This increased cost of power from the LS2 is on par with Cambodia's recently signed purchase price for imported coal power from Laos, making LS2 floating solar economically competitive.

[71] Thomas, G. and et al (2019). Sambor Hydropower Alternatives Assessment, Natural Heritage Institute. Page 39. Available at: https://data.opendevelopmentmekong.net/dataset/4f1bb5fd-a564-4d37-878b-c288af460143/resource/fed94672-dc65-4571-a953-15fa544be213/download/cambodia_key-findings-of-sambor-assessment_updated-11-mar-2018.pdf (Accessed: 18/05/2020)

[72] Viet Nam Electricity (2019). DHD completed the project of floating solar power plant on Da Mi reservoir. Available at https://en.evn.com.vn/d6/news/DHD-completed-the-project-of-floating-solar-power-plant-on-Da-Mi-reservoir-66-163-1485.aspx (accessed: December 10, 2019).

[73] Bangkok Post (2019). Thailand to build world's biggest floating solar farms. Available at https://www.bangkokpost.com/business/1639562/thailand-to-build-worlds-biggest-floating-solar-farms (accessed: December 9, 2019).

[74] Ciel & Terre (2019). Ciel and Terre Partners Cleantech Solar for Flagship Floating Solar Plant in Cambodia. Available at https://www.ciel-et-terre.net/ciel-terre-partners-cleantech-solar-for-flagship-floating-solar-plant-in-cambodia/ (accessed: December 9, 2019).

[75] Kaufmann, A. (2018). Renewable Energy: The price of power. Southeast Asia Globe. Available at https://southeastasiaglobe.com/an-alternative-to-catastrophic-hydropower-in-cambodia/ (accessed December 9, 2019).

5. Conclusions

These four scenarios outline different futures for energy development in the 3S. They are suggestive and would benefit from more detailed data and modeling to understand their specific costs, benefits, and tradeoffs. Tools already exist to do so and to optimize water-energy-food tradeoffs at the river basin scale.

A few general conclusions can be drawn from these scenarios. Most importantly, to preserve river connectivity between the 3S, the Tonle Sap, and the Mekong Delta, transboundary cooperation between Cambodia, Laos, and Viet Nam is essential. The Strong Renewable scenario sees both Cambodia and Viet Nam transition toward domestic renewable generation, but without transboundary cooperation this scenario could still result in dams on the Sekong mainstream that would reduce connectivity almost to the same extent as the Full Buildout scenario.

While the Coal-Heavy and CEZ scenarios both assume that mainstream Sekong dams would be foregone, some river connectivity loss is incurred from dam construction on the Sekong's tributaries. How much loss would depend on whether the three countries coordinate investments, for example, by collectively selecting only certain tributaries to dam in cascades. The CEZ scenario would preserve the Sekong mainstream and maintain current water and sediment flows to the Mekong.

Further analysis would be needed to accurately determine the costs for each scenario but in terms of investment cost, the Full Buildout scenario would be the most expensive since it includes at least 53 projects, most of them dams. The Coal-Heavy scenario only includes 15 dams. The number of dams under the Strong Renewable and CEZ scenarios is unknown as both include as-yet unspecified renewable energy projects.

A 2017 University of California-Berkeley study comparing different energy mixes for Laos provides a useful window into the investment costs of the different scenarios. Even using conservative price drop projections for solar and wind, the study concluded that a solar and wind-heavy energy mix in Laos would result in a total capital investment cost $2.6 billion lower than Laos' business-as-usual trajectory, while generating the same amount of reliable power.

These findings demonstrate the potential cost savings that accrue from non-hydropower renewables.[76] And solar and wind costs are projected to continue to fall, whereas those for hydropower and coal projects are projected to rise as mitigation or offset costs and carbon scrubbers and/or carbon capture and storage technology are increasingly required by law or international financiers. With this in mind, it is likely that the electricity cost for the Strong Renewable and the CEZ scenarios is cheaper than for the other two scenarios.

To receive the spreadsheet for list of projects included in each scenario, contact: ThuyAnh.NGUYEN@iucn.org.

[76] Avila, N., Kittner, N., Shirley, R., Dwyer, B.M., Roberts D., Sagerand, J., and Kammen, M. D. (2019). Distributed Renewables Offer Flexibility and Sustainability for Development in Lao PDR. Lower Mekong Public Policy Initiative. Page 17. Available at http://www.lmppi.edu.vn/en/research/policy-brief/distributed-renewables-offer-flexibility-and-sustainability-for-development-in-lao-pdr/.

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