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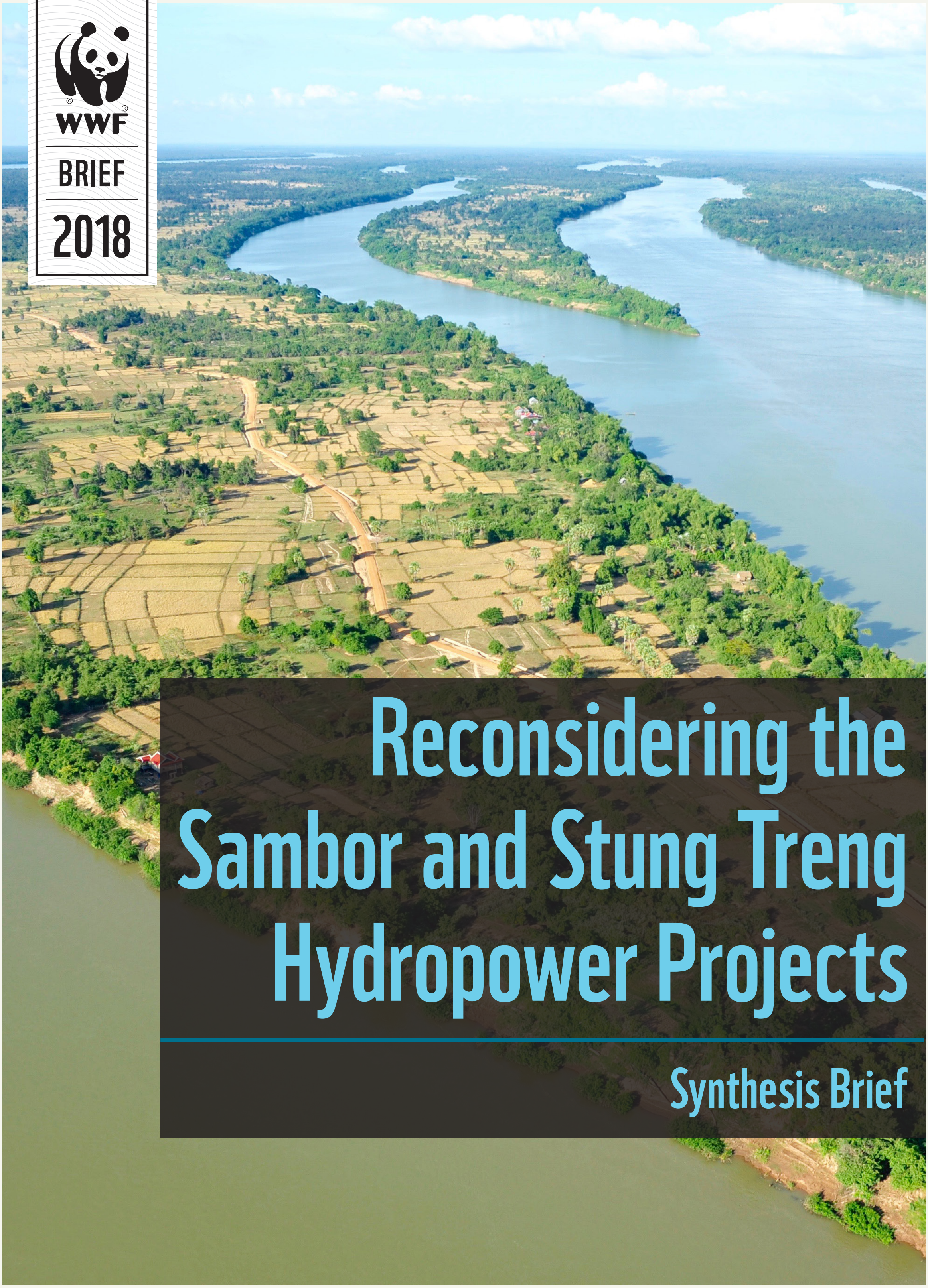

Reconsidering the Sambor and Stung Treng Hydropower Projects

Synthesis Brief

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CONTENTS

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EXECUTIVE SUMMARY

For the first time in history, Cambodia has an opportunity to achieve universal access to affordable and reliable electricity, within a short time frame, and without disrupting the lives of many of its citizens or its remarkable biodiversity.

New technologies allow the country to avoid the risks and delays associated with large-scale hydropower. This brief lays out why Cambodia would do well, under these new conditions, to reconsider whether large hydropower projects like Sambor and Stung Treng are in the best public interest.

Cambodia faces important strategic choices to continue its rapid development, and Sambor and Stung Treng would have significant implications for power supply, food security, export revenues, employment and many other policy objectives. While the projects would generate large amounts of electricity, they would also inundate large portions of the country's north-east, including protected areas that are crucial for biodiversity conservation and ecosystem services.

A review of the projects' risks shows that many of these cannot be mitigated. As for other large-scale hydropower projects, there is a high probability of cancellations, delays, and cost overruns. Because the Mekong and its floodplains are exceptionally productive, there are major risks – perhaps larger than on any other river in the world – for fisheries, agriculture, and biodiversity. Of all the possible dams in the Mekong system, it is Sambor that carries the greatest risks. There would also be major displacement of people on a scale unprecedented in Cambodia.

The direct costs of the projects would be large and uncertain, but the indirect economic costs for Cambodia and for Vietnam would also be very large. At the same time, the benefits – in terms of being able to produce power at a lower cost than from other sources – are doubtful. Cambodia has better alternatives for power generation, both for domestic demand and for export. Most importantly, these alternatives would be able to deliver power much earlier, and without risking conflicts within the country and with its neighbors.

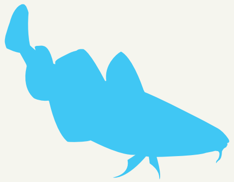
Traditionally, natural gas plants would have been the most obvious alternative. Fortunately, however, a new and even more competitive alternative has become available: Cambodia can choose to go directly to solar photovoltaics. With a concerted effort, the country can benefit from this technology to deliver a major boost to its development. Sambor and Stung Treng have become unnecessary, and continuing with their preparation has become a distraction.

Sambor and Stung Treng: Two Hydropower Projects in Their Context

Cambodia is a country with 16 million people undergoing rapid economic development. This section provides a brief description of two potential hydropower projects, located on the Mekong River in north-eastern Cambodia, as well as their economic and geographic context, which is necessary to assess the risks, costs and benefits of the projects.

CAMBODIA'S ECONOMIC DEVELOPMENT

From near-total destruction of the economy during the civil war, Cambodia has achieved a remarkable transformation. Driven by garment exports and tourism, the average economic growth rate between 1994 and 2015 was 8%, the sixth-highest rate in the world. This growth significantly reduced poverty, to 14% of the population by 2014. Nevertheless, the Human Development Index for Cambodia is still relatively low - Cambodia was ranked in 143rd place at last count[1] - and much work remains.



CAMBODIA HAS THE 5TH LARGEST INLAND FISH CAPTURE IN THE WORLD

About 90% of the poor live in the countryside,[2] and most of them belong to the 65% of Cambodians who rely on agriculture, fisheries, and forestry for their livelihoods. Fifteen percent of Cambodians are undernourished, and food security is an important social concern.[3] Fish is exceptionally important in the Cambodian diet, at 63kg per capita per year, representing 18% of all food consumed and 76% of all animal protein intake.[4] The total harvest from freshwater capture fisheries is estimated at 560,000 tons, most of which comes from rice fields and seasonally flooded lands.[5] According to FAO (2018), Cambodia has the 5th largest inland fish capture in the world, a remarkable harvest volume for a small country. It also has important rice and maize production in the Mekong floodplain.

After significant growth of the power sector, most urban households and businesses are now connected to the power grid. Based on recent household surveys, 98% of all Cambodian households have access to at least one source of electricity, 72% on the grid, and 26% off the grid, mostly through solar home systems and rechargeable batteries. However, only 13% have quality services in terms of access to at least 23 hours of supply a

1 http://hdr.undp.org/en/countries/profiles/KHM
2 http://www.worldbank.org/en/country/cambodia/overview
3 https://www.adb.org/countries/cambodia/poverty
4 Vilain & Baran (2016). More recently, the Inland Fisheries Research and Development Institute (IFReDI) of the Cambodian Fisheries Administration reduced this estimate to 54.2kg/capita/year.
5 Chheng et al (2016)

ONLY 13% OF CAMBODIANS HAVE ACCESS TO AT LEAST 23 HOURS OF ELECTRICITY SUPPLY PER DAY WITH ADEQUATE RELIABILITY, QUALITY, AFFORDABILITY, AND HEALTH AND SAFETY.

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day with adequate reliability, quality, affordability, and health and safety. Many grid-connected customers still suffer from frequent unpredictable power shortages, experience damage to appliances due to voltage fluctuation, or cannot afford the electricity tariff.[6] Poor electricity services are a significant obstacle to development in all sectors of the economy. For example, for the garment sector (which provides 70% of all exports) they are some of the most important concerns.

Tourism is another sector that depends on modern infrastructure services such as electricity, transport, water and communications. Travel and tourism contribute approximately 14% of GDP directly, and more than 30% if indirect and induced effects are included. More than 70% of this is related to leisure travel, which relies on Cambodia's cultural and natural heritage.[7] The economy in general is highly open to trade in goods and services, which requires Cambodia's export sectors to remain competitive.[8]

Cambodia's 2014-2018 Strategic Development Plan reflected the governing party's priorities, namely Promotion of the Agriculture Sector, Development of Physical Infrastructure, Private Sector Development and Employment, Capacity Building and Human Resources Development, and Good Governance. A development plan for 2019-2023 is currently under preparation, which is expected to be aligned with the UN's Sustainable Development Goals.[9]

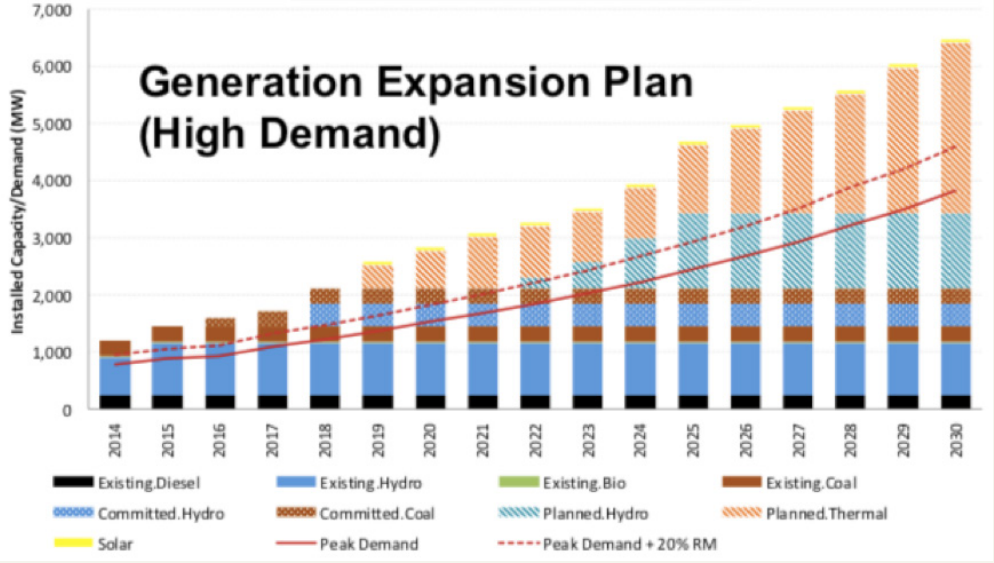
6 World Bank (2018)
7 World Travel and Tourism Council (2018)
8 https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS?locations=KH
9 http://www.cdc-crdb.gov.kh/cdc/donor_country_pro/korea/2017_12_14_Policy_dialogue/docs/NSDP.pdf

CAMBODIA'S OPTIONS FOR POWER DEVELOPMENT, EXPORT REVENUES AND PROTEIN SUPPLY

Key challenges identified above are electricity supply security and food security, as well as export revenues. Like any country, Cambodia has multiple options to address these challenges, and selecting the best option is an important government responsibility.

Electricité du Cambodge (EDC) is a state-owned and vertically integrated monopoly responsible for generation, transmission, and distribution. Supply comes from EDC's own power plants as well as purchases from independent power producers and neighboring countries. EDC is supervised by the Ministry of Industry, Mining and Energy (MIME) and the Electricity Authority of Cambodia. Between 2003 and 2017, EDC managed to expand electricity delivered from 693 GWh to 7,966 GWh, moving from a mix dominated by diesel, fuel oil and imports to hydropower (46%), coal (33%) and much reduced imports (17%). To date, renewable energy sources other than hydropower have remained largely untapped, and provide less than 1%.[10]

Figure 1 Power Sector Development Plan, High Demand Scenario (Tharakan 2018)



10 EAC (2017)

The expansion of generating capacity largely followed a plan originally formulated in the 2000's. In this plan, the Sambor project (with either 450 MW or 2,600 MW) was scheduled for a Commercial Operation Date (COD) of 2019, and the Stung Treng project (900 MW) for a COD of 2020. In the latest updates of the plan, the commissioning of Sambor has now been moved to 2025-2027.[11] Even under the "high demand" scenario shown in the graph below, constructing all possible projects would result in significant overcapacity, beyond a reasonable 20% reserve margin. The excess generation would have to be sold to neighboring countries.

Export opportunities depend on a number of factors, such as demand (Laos and Thailand have a surplus for the foreseeable future), technical issues (transmission capacity is low in the region, and the Cambodian grid is only synchronized with Vietnam), and the supply options of potential importers. The most likely destination for large-scale exports from Sambor and Stung Treng would be southern Vietnam. Vietnam's power sector is very dynamic, which contributes to some uncertainty about the future supply mix in Vietnam, and the costs at which power imports would be attractive for Vietnam.

COMPARED TO OTHER SECTORS, HYDROPOWER GENERATES LESS EMPLOYMENT AND CAN BE DETRIMENTAL TO OTHER GOODS AND SERVICES LIKE FISH EXPORTS AND TOURISM.

Best practices in generation planning (both for domestic use and for exports) include (1) updating the expansion plan regularly to take new information into account (demand growth, progress in delivering projects, changing relative costs of different technologies, results of feasibility studies, export and import opportunities etc.), and (2) using multiple criteria to prioritize projects beyond commercial and technical feasibility. For example, if food security, support to tourism, export revenues, and improved power supply to garment factories are important policy objectives for Cambodia, the implications of all generation options for these objectives should be tested.[12]

Cambodia also has several other options for export revenues. While there may be an interest in diversifying from the current focus on garments, footwear, tourism, rubber and fish, these sectors have an important advantage over power exports: they are all labor-intensive, helping to absorb the young workforce (43% of the working age population are 15-29 years old).[13] Hydropower not only generates much less employment but can also be counterproductive by reducing the export of other goods (such as fish) or services (such as tourism).

11 NHI (2018, Appendix 10.2.). The latest update does not include Stung Treng, but an 1,800 MW version of Sambor, to be commissioned in three stages of 600 MW each.
12 WWF (2016) presented an overview of these generation options.
13 http://www.oecd.org/countries/cambodia/youth-issues-in-cambodia.htm

SAMBOR DAM PROJECT SITE, MEKONG RIVER

This stretch of the river has exceptionally high values for conservation and ecosystem services (for example, dolphin and migratory fish habitat), and one section is designated as a wetland of international importance under the Ramsar convention.

Like any other country, in principle Cambodia can choose to import some of its food, or to switch between different kinds of food. For example, if the supply of its main source of animal protein (capture fisheries) went down, it could be replaced by aquaculture or marine fish, or by meat, poultry, eggs and dairy. Again, this choice can be evaluated against multiple policy objectives, such as: maintaining food sources in accordance with cultural preferences, relative costs, public health impacts, national food independence, livelihoods, land and water requirements,[14] etc. Replacing inland capture fish, rice and maize with other sources of food would lead to significant disruptions in the lives of Cambodians.

THE PROJECTS AND THE REGION

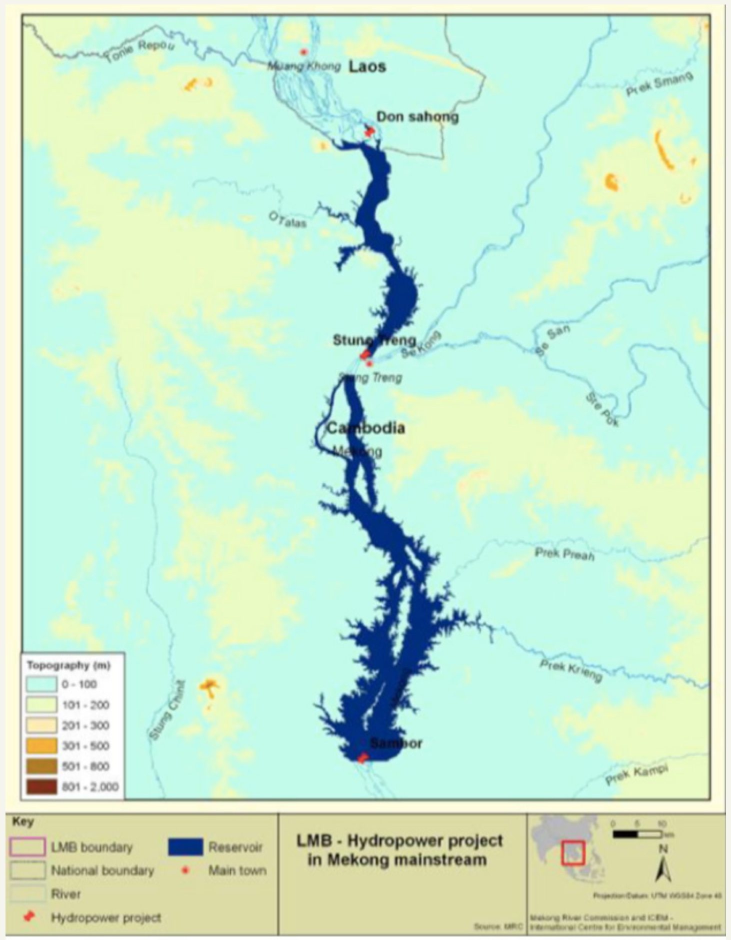
The two potential dam sites were first identified in the 1960s and included in plans by the Mekong Committee and its Secretariat. They would be located on a reach of the Mekong River, between Pakse in Lao PDR and Kratie in Cambodia, that has been categorized as a large mainstem river with a meandering channel and alluvial deposits.[15] In this section, the river is up to 1.5 km wide, has a low gradient, is braided with multiple, often temporary channels, surrounded by a floodplain, and carries large volumes of water and sediment. It has exceptionally high values for conservation and ecosystem services (for example, dolphin and migratory fish habitat), and one section is designated as a wetland of international importance under the Ramsar convention.

Because of the low gradient, both dams would be low-head with large reservoirs. The reservoirs would inundate most of the Cambodian part of this river reach, as well as adjacent villages, agricultural areas, and riparian forests. The inundated area depends on the precise location and height of the dams, which have not been finalized. The map below assumes:

- a 2,600 MW version of Sambor, based on a feasibility study by the former developer China Southern Power Grid Co., with an 18 km long dam, 16.5 m rated head, and a 620 km2, 82 km long reservoir, and
- a 978 MW version of Stung Treng, based on the MRC database, with a 10 km long dam, 15.2 m rated head, and a 211 km2, 50 km long reservoir.

14 Orr et al (2012)
15 Lehner and Ouellet Dallaire (2014)

Figure 2 Stung Treng and Sambor Reservoirs (ICEM 2009)



Stung Treng would generate an average of 4,870 GWh/yr, and Sambor 11,740 Gwh/yr. Compared to the 2017 power delivery by EDC, this would be an increase of 61% and 147%, respectively.

The area affected by the two reservoirs is the lowland part of the northeastern Plateau & Mountainous Zone of Cambodia, in the two provinces Kratie and Stung Treng. Socio-economically, the provinces are characterized by:

- low population density, as the total population of the two provinces is only about 3% of Cambodia's population (467,000 people and 384 villages),[16] which is partially a function of relatively poor soil quality, and is also reflected in below-average road density and above-average forest cover,
- a concentration of ethnic minority groups, and
- above-average poverty rates, often above 30%, except in the area around the town of Stung Treng.

16 National Institute of Statistics (2013)

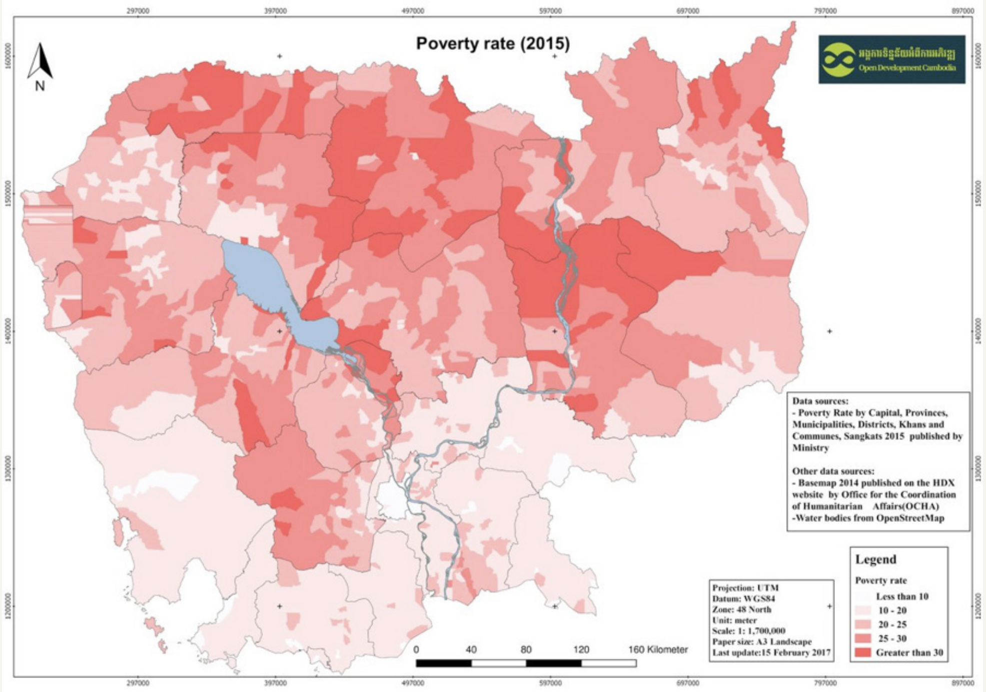


Figure 3 Poverty Rate Map, 2015 with Project Area Highlighted[17]

In October 2016, the Cambodian government authorized an MoU with The Royal Group, a Cambodian business group, to undertake studies on the Sambor (2,600 MW), Stung Treng (900 MW), and Lower Sekong (190 MW) projects. The Royal Group already holds shares in the Lower Sesan II (400 MW) project. Because of the size of the projects, they would probably be financed largely by foreign companies and banks, as build-operate-transfer (BOT) projects, which fall back to government ownership after a period of time. Over the past decade, almost all investment into Cambodian hydropower has come from China.[18]

17 https://opendevelopmentcambodia.net/dataset/?id=cambodian-population-and-poverty-rate-2015
18 https://www.hydroworld.com/articles/2016/10/china-completely-finances-nearly-all-of-cambodia-s-hydropower-projects.html

PROJECT RISKS

Investment decisions for large-scale hydropower projects should be based on a full accounting of risks (technical, commercial, social, and environmental). Risk management should be based on the 'mitigation hierarchy' (risk avoidance before risk minimization, mitigation and compensation). This section focuses on four key risk areas.

TECHNICAL AND COMMERCIAL RISKS

All large infrastructure projects run substantial risks of cancellations, cost overruns and delays, but these risks are exacerbated for hydropower projects compared to other power technologies and sectors. This has been shown in recent years by a number of statistical analyses,[19] as well as notable individual cases. Myitsone in Myanmar, Diamer Bhasha in Pakistan, Budhi Gandaki in Nepal, Baram in Malaysia, Pak Beng in Laos, and Dong Nai 6/6a in Vietnam are examples of projects that have been suspended, for various reasons, and after governments and developers had spent significant funds, time and efforts on their preparation. Even in countries with strong project management experience and governance, there is a tendency for projects to become large-scale financial disasters. The three large-scale projects currently under construction in Canada (Muskrat Falls, Keeyask, Site C) will end up costing more than CAD 10 billion each and will produce energy much later than anticipated, and the developers wish they had not embarked on them.[20]

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BECAUSE OF THE MANY UNCERTAINTIES, INVESTORS ARE LIKELY TO AVOID THE SAMBOR AND STUNG TRENG PROJECTS, OR WILL EXPECT THE GOVERNMENT TO ASSUME MANY OF THE RISKS

The main reasons for cost and schedule overruns appear to be that every hydropower site is unique, with its own design and construction challenges, unexpected geological and geotechnical problems, and the inherent complexity of large scale projects. The Sambor and Stung Treng projects are good examples of this uniqueness, as few projects globally have attempted to dam wide, alluvial river valleys. The closest analogy is perhaps the Yacyretá project on the Parana River (a river of similar size as the Mekong) between Argentina and Paraguay. This 3,200 MW project with a total of 64 km of dams and a reservoir of 1,600 km2 was built in stages, starting in 1983, first entering commercial operations in 1994, and still undergoing expansion. The total cost has been

19 Ansar et al (2014), Sovacool et al (2014), EY (2016)
20 See for example: https://www.bloomberg.com/news/articles/2018-05-04/manitoba-to-probe-hydro-projects-following-tragic-cost-overrun; https://www.cbc.ca/news/canada/newfoundland-labrador/stan-marshall-muskrat-falls-nupdate-1.4174569; https://www.hydroworld.com/articles/2017/12/breaking-though-not-ideal-construction-of-site-c-will-go-on-premier-says.html

estimated at over USD 15 billion. Argentinian president Carlos Menem called Yacyretá "a monument to corruption";[21] another risk that affects large and complex construction projects.

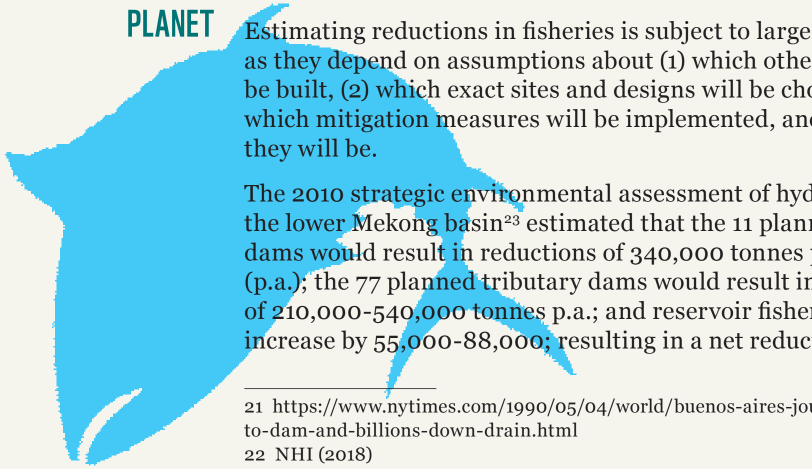
Long implementation times also pose revenue risk for investors. It is difficult to forecast the market situation in 8-10 years, a typical time span until COD, given the rapid ongoing changes in demand and costs. Potential off-takers like EDC, Electricity Generating Authority of Thailand (EGAT) or Electricity of Vietnam (EVN) are reluctant to sign long-term PPAs in order to avoid commitments that may turn out to be more costly than other options. Potential investors are also reluctant to commit to fixed delivery dates and penalties in case of delays. Other parameters such as interest and exchange rates are likely to change over the long lifetime of the projects, and estimating future generation is subject to uncertainties, because hydrology will be affected by climate change and upstream reservoirs.

The 'mitigation hierarchy' calls for avoiding risks by selecting relatively low-risk projects. As a result of the above-mentioned uncertainties, investors are likely to avoid the Sambor and Stung Treng projects, or will be expecting government to assume many of the risks, or demand a substantial risk premium on its return on investment, which will drive up the cost of capital.

THE SAMBOR REACH OF THE MEKONG RIVER EXPERIENCES THE LARGEST ANNUAL MOVEMENT OF FISH BIOMASS ON THE PLANET

CHANGES TO FISHERIES

The Sambor reach of the Mekong River is the migratory corridor that experiences the largest annual movement of fish biomass on the planet,[22] and the Sambor and Stung Treng projects are expected to substantially reduce fish stocks and fish capture.



Estimating reductions in fisheries is subject to large uncertainties, as they depend on assumptions about (1) which other dams will be built, (2) which exact sites and designs will be chosen, and (3) which mitigation measures will be implemented, and how effective they will be.

The 2010 strategic environmental assessment of hydropower in the lower Mekong basin[23] estimated that the 11 planned mainstem dams would result in reductions of 340,000 tonnes per annum (p.a.); the 77 planned tributary dams would result in reductions of 210,000-540,000 tonnes p.a.; and reservoir fisheries would increase by 55,000-88,000; resulting in a net reduction of

21 https://www.nytimes.com/1990/05/04/world/buenos-aires-journal-billions-flow-to-dam-and-billions-down-drain.html
22 NHI (2018)
23 ICEM (2010)

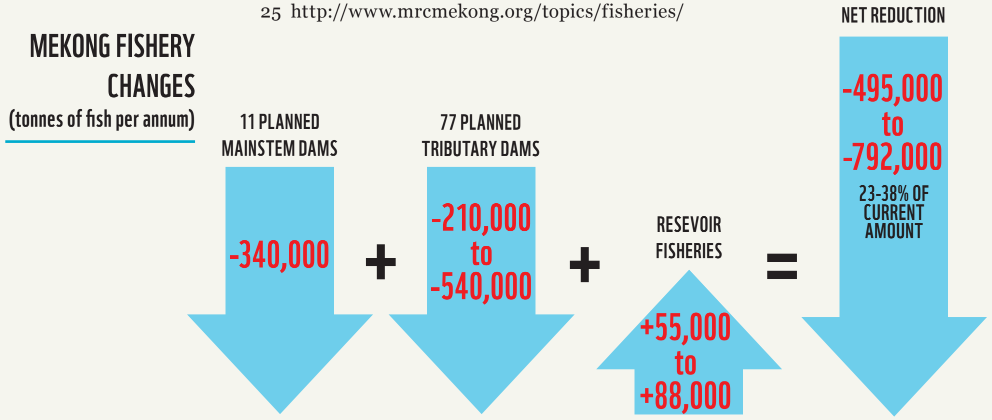
495,000-792,000 tonnes p.a. (or 23-38% of the current amount). The recent Council Study also contains quantitative estimates of cumulative impacts, for specific river reaches.

There are no specific estimates for the incremental impact of the Sambor and Stung Treng dams by themselves, but Sambor in particular has been called the "least suitable place for a physical barrier in the Mekong Basin", with "the largest impact on the Mekong fishery of any of the mainstream dams,"[24] due to its blocking access to most of the upstream spawning grounds, converting 82 km of river into a lake through which fish larvae cannot drift, and changing downstream geomorphology and flow dynamics.

REDUCTIONS IN FISHERIES WOULD AFFECT ALL CAMBODIANS

Reductions in fisheries would affect all Cambodians in varying degrees, and losses would also affect Laos and Vietnam, contributing to opposition from those countries. Most directly affected would be fishermen, traders and others for whom fishing is the primary source of livelihood, followed by people who are fishing for subsistence, and fish consumers. Since fisheries account for nearly 12% of Cambodia's GDP and contribute more to the country's economy than rice production,[25] a large proportion of the population would be affected by the losses. Cambodia's Inland Fisheries Research and Development Institute (2012) predicted that even in the absence of mainstream dams, the supply of inland aquatic resources would decline to approximately 44 kg per person by 2030 (due to an increase in demand that cannot be met by additional supply); that the construction of the Cambodian mainstream dams would decrease the supply of fish further by 6-34%; and that Sambor would have an impact equivalent to that of all mainstream dams together.

24 NHI (2017)
25 http://www.mrcmekong.org/topics/fisheries/

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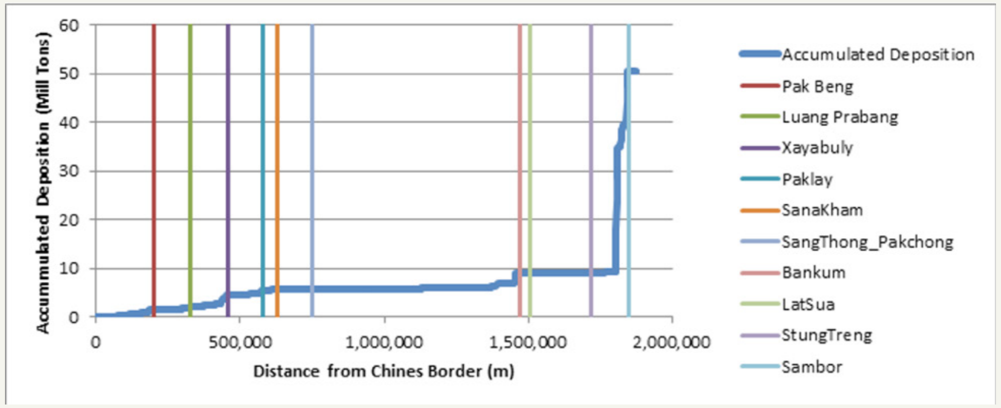
CHANGES TO RIVER LANDSCAPE

THE RESERVOIRS FROM THESE DAMS WOULD INUNDATE THE MOST BIODIVERSE STRETCH OF THE MEKONG OR ANY OTHER LARGE ASIAN RIVER.

Upstream of the dams, their reservoirs would inundate what is probably the most biodiverse stretch of the Mekong or any other large Asian river, including landscapes as such as the Mekong Flooded Forest and Stung Treng wetlands.[26] This would affect the habitat of the Irrawaddy dolphin and other endangered species, probably lead to their extirpation. These iconic species and habitats are protected by the Cambodian government and many of its development and conservation partners. In particular, 2018 was the first time in 20 years that the dolphin population increased, as a result of large conservation efforts and investments by the Government of Cambodia and NGOs like WWF. The government has nominated the Stung Treng wetlands as a Ramsar site, a wetland of international importance. The loss of these species and habitats would lead to strong international criticism.

The current sediment load passing Sambor has already been reduced to about 92 million tonnes/yr by the upper Mekong dams.[27] It has been estimated that the Sambor reservoir would accumulate about 4 times as much sediment as all other 9 lower Mekong mainstream dams combined, including Stung Treng.

Figure 4 Annual Cumulative Sediment Deposition in Mekong Cascade[28]



Sambor would trap all of the bedload (sand) and most of the suspended load (silt and clay). It has been shown that there are no effective sediment management techniques that would work at Sambor, with the possible exception of sluicing during the flood season, which has other disadvantages (loss of generation, high-

26 Bezuijen et al (2008)
27 Piman and Shresta (2017)
28 NHI (2018) webinar; HDR and DHI (2015)

turbidity pulses with further losses to fisheries downstream).[29]

Downstream of the dams, the riverbed and riverbanks would suffer from erosion, and the Mekong would dig itself a 5 m deeper channel downstream of Sambor, affecting groundwater levels and infrastructure.[30] But the most damaging changes would occur further downstream. Only about one fifth of the sediment load at Kratie is deposited in the Cambodian floodplains, but four fifths in Vietnam.[31] With reduced sediment replenishment, the delta will experience increased erosion and loss of land, compounded by subsidence and sea level rise, posing severe risks to human livelihoods and economic assets.

Nutrients are transported together with sediments, and would also be partially trapped in the reservoirs. This would affect the fertility of Tonle Sap lake, one of Cambodia's most important fisheries, of downstream fields which are seasonally flooded, requiring more mineral fertilizer to compensate, and of the productivity of the large near-shore Vietnamese marine fishery.

29 NHI (2017)
30 HDR and DHI (2015)
31 Quoted in NHI (2018)

RESETTLEMENT AND OTHER IMPACTS ON REGIONAL QUALITY OF LIFE

Large-scale infrastructure projects also bring more immediate impacts on people living directly within their 'footprint', including along access roads, transmission lines, quarries, and camps. They generate social disruption through displacement of people and through impacts such as construction noise, traffic safety, community-workforce conflicts, public health problems, water quality impacts, increases in living costs, etc. Poor populations (as in northeastern Cambodia) are more vulnerable to such impacts, and require more support.

GOING AHEAD WITH THE SAMBOR DAM CONSTRUCTION WOULD LEAD TO THE RESETTLEMENT OF OVER 20,000 PEOPLE, MORE THAN ANY OTHER PROJECT IN THE LOWER MEKONG BASIN.

Going ahead with the Sambor Dam construction would lead to the resettlement of over 20,000 people, more than any other project in the Lower Mekong Basin, with the exception of Yali Falls (Vietnam). The entire population would require new homes, fields, social services, roads, and long-term aid to restore their livelihoods. International experience (i.e. Nam Theun 2 in Laos where approximately 6,200 people were resettled) illustrates how difficult it is to provide equal or better livelihoods, standards of living, and quality of life for the displaced persons. One specific issue is finding adequate new land, and host communities that are willing to integrate the displaced persons.

Attaining these objectives is essential for local acceptance of projects and political stability. Local protests were apparently a reason behind the withdrawal of the developer from the Sambor project in 2011.[32]

32 https://www.scmp.com/print/article/977985/controversial-chinese-projects-cambodia-bow-public-pressure

ECONOMIC COSTS AND BENEFITS OF THE PROJECTS

The first section of this brief described the rationale for the projects and their context, and the second section some of the risks. The final section will now integrate that information, make costs and benefits comparable by expressing them in monetary terms, and explore whether the projects are in the best interest of Cambodia. Due to data limitations this cannot be a full cost-benefit analysis, but an overview of economic aspects from a public interest perspective, i.e. the perspective of the average Cambodian citizen.[33]

DIRECT COSTS

For reference, the global weighted average cost of hydropower projects commissioned in 2016 was USD 1,780/kW and in 2017 USD 1,535/kW.[34] Applying these averages to the two projects results in the following estimates:

- **Stung Treng (978 MW): installed cost between USD 1.50 – 1.74 billion**
- **Sambor (2,600 MW): installed cost between USD 3.99 – 4.63 billion**

THE ORIGINAL DEVELOPER OF THE SAMBOR DAM ESTIMATED A COST OF USD 5.36 BILLION PLUS USD 313 MILLION FOR THE TRANSMISSION LINE

Those estimates are likely to be too low for current conditions at the two projects, because (1) they reflect the costs of projects that were started several years ago, not taking into account that costs continue to rise (by 31% between 2010 and 2017, according to IRENA 2018), (2) both projects should cost significantly above global averages, due to their long embankment dams and high social and environmental mitigation costs, (3) in Cambodia, almost all services and goods would have to be imported, as the country does not have industries capable of constructing and equipping a project of this type, (4) due to the high complexity, the risk of delays and cost overruns should be above-average, and (5) the costs of transmission have to be added.

There are no publicly available estimates of the direct costs of the Stung Treng project, but for Sambor there is an estimate from the original developer China Southern Power Grid Co. of USD 5.36 billion plus USD 313 million for the transmission line.[35]

NHI (2017) updated the cost estimates of the Feasibility Study

33 While more estimates are available for Sambor than for Stung Treng, it is assumed that most conclusions hold for both projects. If anything, the fact that Sambor and not Stung Treng is included in the latest power development plan should show that Sambor is more feasible.
34 IRENA (2018)
35 Quoted in ICEM (2009)

and arrived at a total cost of USD 5.16 billion (or USD 1,984/kW) including transmission. This is an "overnight cost", without interest during construction. Interest during the 6-year construction period would amount to USD 1.48 billion, resulting in a total cost of USD 6.64 billion, an installed cost per kW of USD 2,558, and a levelized cost of electricity (LCOE) of USD 0.068 / kWh.

INDIRECT COSTS

COSTS THAT SHOULD ALSO BE TAKEN INTO ACCOUNT: LOST TOURISM REVENUE, INCREASES IN FISH PRICES, AND LOST FARMLAND DUE TO EROSION

Indirect costs, sometimes also called 'negative externalities', are costs not borne by the developer but by the general public. Examples for indirect costs would be: a farmer losing land and future income to riverbank erosion, a household having to pay more for fish as it gets scarcer, or a tourism business losing revenue, as visitors interested in dolphins stay away. While these costs are real, they are difficult to quantify, and no cost estimates are available for most of them.

Some attempts at valuation have been made for Sambor. The most up-to-date, methodologically conservative and specific estimates of indirect costs are in the NHI study (2017):

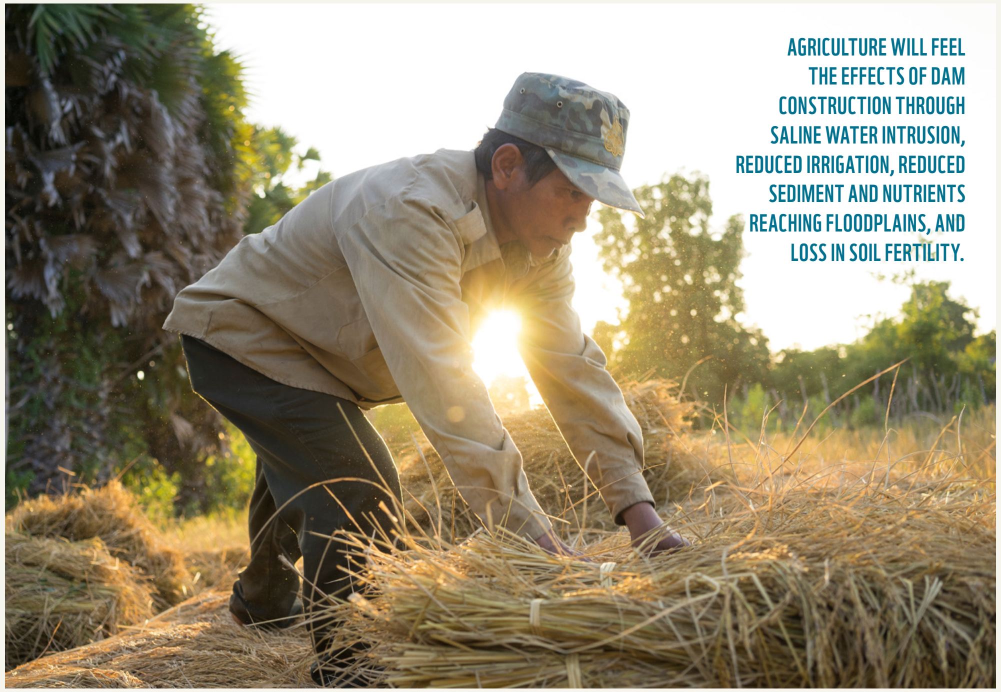
- Out of a total sustainable fisheries yield in Vietnam and Cambodia of 1.2 million tonnes/year, 38% of all fish are migratory -- 70% of these would be affected because they have their spawning grounds above Sambor, and these will suffer a 100% reduction (because mitigation is not feasible). At a net value to fishermen of USD 1.50/kg, this represents a loss of USD 479 million/year.
- On the basis of productivity differences of paddy fields in An Giang province, between fields that receive 2.5cm/year sediment deposition or none, a total value of the sediment load at Sambor of USD 120 million/year is estimated. At a trapping efficiency of 62%, the Sambor reservoir would reduce this value by USD 74 million/year.

The study does not include estimates for other indirect costs (such as a decrease in income from tourism, greenhouse gas emissions from the reservoirs, and loss of biodiversity).

A notable omission are the costs of downstream erosion, which should include the cost of lost assets (land, homes, roads, bridges), of additional dikes to prevent erosion, of river incision that will lead to lowering of the water table and reduced inundation of the Tonle Sap, and of reduced sand and gravel availability to the construction sector. Chapman and Darby (2018) note that the situation in the delta is more complex than assumed in NHI (2017) and other studies that focus only on soil fertility. For agriculture, there will be multiple additional changes such as intrusion of saline water into the delta, loss of infrastructure, additional expenses for fertilizer, and reductions in gravity irrigation. Chapman and Darby (2018) state that even a damage of USD 220 million/year (for the cumulative impact of all dams) is likely an underestimate. Further disruptions of livelihoods and economic activities are likely. For example, Vietnam's USD 7.3 billion annual fish and shrimp exports (FAO 2018) will be affected by damages to aquaculture in the delta, and reduced productivity in the near-shore marine fishery.

Impacts and costs will increase over time, as less sediments and nutrients reach the downstream floodplains. For example, if all 11 mainstream dams are built, rice production in Vietnam and Cambodia would decline by an estimated 552,500 tonnes and 203,300 tonnes per year after 10 years and by 2.4 million tonnes and 430,100 tonnes after 50 years.[36] Maize production would also decline significantly.

36 The research on sediment impacts is summarized in Piman and Shresta (2017).



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BENEFITS

Traditionally, the financial benefits of a power generation project are simply estimated as the revenues, while its economic benefits are estimated as the avoided costs from the next-best available project. For example, if hydropower project A is the cheapest source of power and gas project B is the next-cheapest, then the benefits of project A equal the costs saved by not generating from project B.

Following this approach, NHI (2017) choose gas-fired combined cycle projects in Vietnam as the 'counterfactual' (the next-best source of power in the absence of Sambor).[37] Compared to this alternative, Sambor:

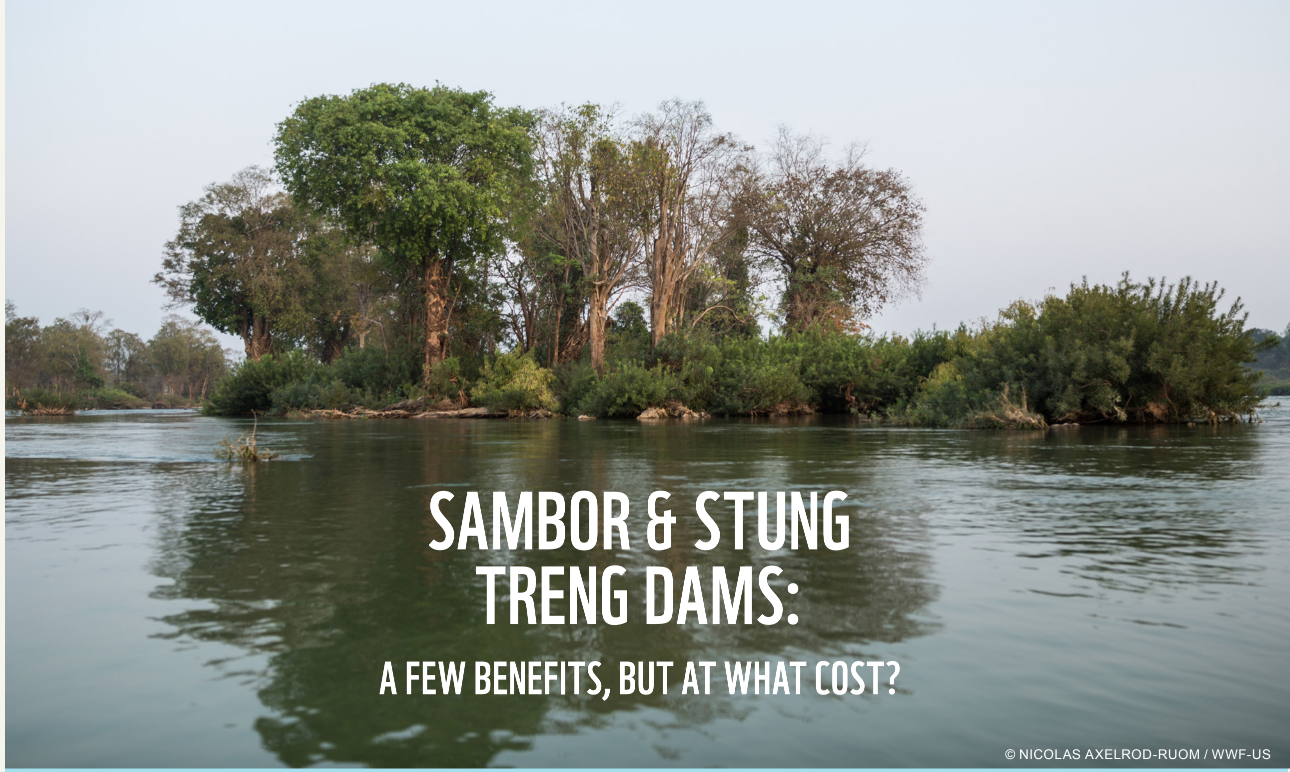
- has almost twice the capital costs but no fuel costs, resulting in an economic rate of return (ERR) of 12.1% and a net present value (NPV) of USD 1.88 billion, if only direct costs are taken into account;
- has indirect costs for fisheries with an NPV of USD 3.2 billion and for sediments of USD 458 million; when these are added the ERR becomes negative and the total NPV becomes a negative USD 1.74 billion;
- has indirect benefits in terms of less GHG emissions than a combined cycle plant, with an NPV of USD 1.00 billion; when this is added the ERR remains negative and the overall NPV becomes a negative USD 742 million.

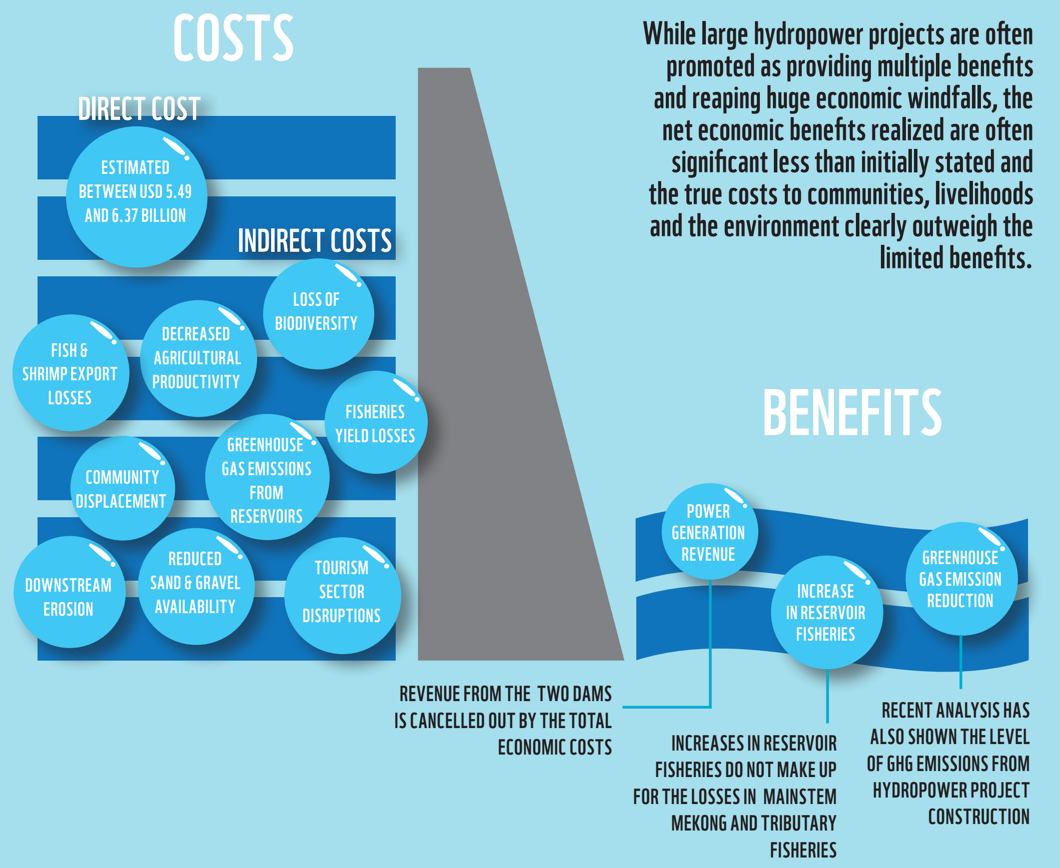
In other words, choosing the Sambor project instead of a combined-cycle plant with the same generation capacity would result in economic losses. Even if Cambodia took a narrow perspective and ignored some of the externalities outside its own borders (such as fisheries and fertility losses in Vietnam, and global climate mitigation benefits), NHI (2017) conclude that the project still makes no economic sense.

In fact, the economic benefits of Sambor look even less convincing if additional factors are taken into account:

- Firstly, Sambor has a certain fixed size (here assumed to be 2,600 MW). This size is too large for the domestic market and requires complex export and financing arrangements. Most power technologies can be scaled to smaller sizes without

37 This is based on the assumption that most of Sambor's generation will be delivered to Vietnam, as dispatchable non-baseload power. A 2,600 MW version of Sambor would be expected to produce at baseload power at full capacity for three months of the year, and less than full capacity for 9 months of the year.





significant increases in costs, to more closely reflect power demand in the medium term. Smaller alternatives at the Sambor site to a 2,600 MW plant have been investigated by NHI (2017). These have some advantages in terms of their social and environmental impacts, but are all significantly more expensive, hence even less competitive than the full-sized Sambor.

- Secondly, because of rapid changes in the costs of different technologies, the assumption that a combined-cycle plant is the next-cheapest alternative may no longer be correct. As new renewable technologies are rapidly becoming more competitive, even cheaper alternatives are becoming available, making Sambor even less attractive (see section on Alternative Solutions).
- Thirdly, the assumption that all alternative options deliver additional power at the same time is not correct. In reality, if an investment decision was taken today, Sambor would deliver power years later than other alternatives. In the meantime, Cambodia would continue to suffer from inadequate electricity services.

Achieving 100% electrification of Cambodia a few years earlier would deliver a significant economic boost. While this boost could only be quantified with macro-economic modeling, it is widely agreed that the cost of unserved power is much higher than the cost of delivered power, from almost any source. In developed countries, power is generally only unavailable for a few hours per year, but supply interruptions can generate significant losses to production, as few consumers have backup power. In developing countries, permanently unreliable power supply leads to lack of competitiveness, underinvestment, damage to machinery, and significant spending on inefficient self-generation, as well as multiple other social and environmental problems.

IN SUMMARY, THE BENEFITS OF UNIVERSAL ACCESS TO RELIABLE ELECTRICITY COULD BE ACHIEVED EARLIER, AT LOWER COST, AND WITH FEWER UNCERTAINTIES, FROM OTHER SOURCES OF POWER THAN THE SAMBOR AND STUNG TRENG PROJECTS.

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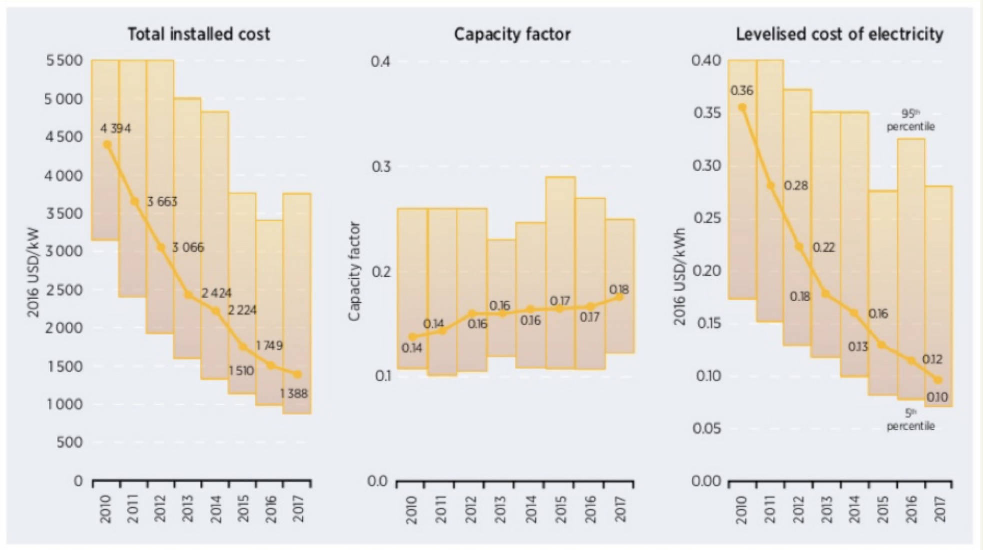
NEW OPTIONS FOR CAMBODIA

As already described, the traditional assumption was that fossil fuels are the best alternative to hydropower. In the case of a large dispatchable hydropower plant with a storage reservoir, like Sambor or Stung Treng, a gas plant would have been the direct comparison. However, gas plants are not without disadvantages, as they contribute to climate change and are subject to future changes in fuel prices.

Fortunately, within the last few years, new alternatives have become a viable reality. China alone installed 53 GW of solar and 20 GW of wind capacity in 2017, and India installed 6 GW of solar and 4 GW of wind. This is a result of rapidly dropping costs, as documented by IRENA (2018) specifically for solar PV, the technology most relevant to Cambodia.

Figure 5 Global Average Cost and Capacity Factor of New Solar Plants (IRENA 2018)



Source: IRENA Renewable Cost Database.

Solar PV plants commissioned in 2017 still had an average LCOE of USD 0.10/kWh, compared to an average of USD 0.05/kWh for hydropower (and USD 0.068 for Sambor). However, looking forward, the costs of solar PV continue to fall. This is demonstrated by results of recent auctions in a number of countries, where developers have offered prices as low as USD 0.02/kWh, for delivery in a few years. In some countries with particularly low solar costs, such as India, power prices are coming down so rapidly that governments are starting to consider whether they need to subsidize hydropower, to keep it competitive.[38]

The costs of solar PV in a specific country also depend on other factors, such as:

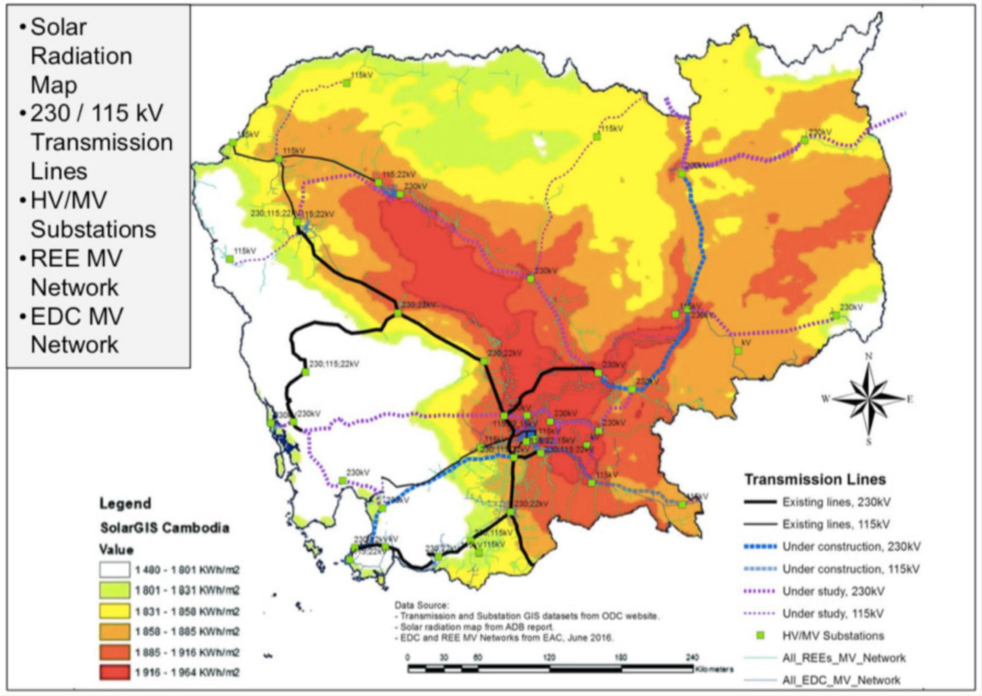
- the solar resource potential (typically expressed as kWh/m2),
- the distance to transmission lines and load centers,
- the availability of dispatchable sources in the power grid that can help integrate variable sources of power, particularly during evening peak demand hours, if possible without additional storage costs, and

38 Bloomberg (2018)

- the institutional framework (such as, creditworthiness of the offtaker, market mechanisms like capacity auctions and reliable PPAs, government incentives such as feed-in tariffs, availability of concessional finance, etc).

The map below illustrates that the solar resource potential in Cambodia is high, and the areas with the highest potential are conveniently located, close to load centers and the transmission network.

Figure 6 Solar Radiation and Power System in Cambodia (Tharakan 2018)



Cambodia's first utility-scale solar PV plant (Bavet, 10 MW) is operational, solar has already reached grid parity in Cambodia, and solar and existing reservoir hydropower plants complement each other very well in Cambodia.[39] Solar is no longer a niche technology, but an opportunity for an ambitious, country-wide push for universal access to power. New solar farms can be built within less than one year, substantially accelerating energy access and economic development.

39 Tharakan (2018)

The table below summarizes the advantages and disadvantages of Cambodia's choices for future power supply:

	Sambor and Stung Treng Hydropower Plants	Alternative 1: CCGT Plant	Alternative 2: Solar PV, with Hydropower or Battery Back-Up
Direct Costs	High capital costs, plus transmission costs	Lower capital costs, but high operational costs (fuel supply); transmission costs depend on fuel supply location	High capital costs except for transmission (can be co-located with existing grid infrastructure such as sub-stations)
Indirect Costs	High costs in terms of impacts on fisheries, agriculture, tourism, social disruption etc.	High costs in terms of climate change impacts	Very low costs
Benefits	Depends on avoided cost from lowest-cost alternative (all three alternatives are fairly close currently, but trends are shifting toward solar PV)		
Scalability	Not easily scalable, as specific costs per kW and kWh rapidly increase if scaled down	Available at medium- to large-scale	Available at any scale, can be utility-scale or distributed; at large scales requires adjustments to operations of existing power plants
Uncertainty	High probability of cost overruns and delays, hydrological risks	High uncertainty over future fuel costs	Low uncertainty if well integrated into power system
Deployment	Long lead time before delivering power	Deployment depends on fuel supply infrastructure	Deployment within approximately one year

If Cambodia chooses to move toward solar, it needs to:

- Make regulatory reforms, to allow rapid upscaling of solar to a point where it can significantly reduce power prices, and make unsustainable power plants unnecessary,[40] and
- Once solar reaches a certain proportion of supply, make adjustments to the power system to ensure grid stability, for instance by expanding interconnections with neighboring countries and by re-operating existing hydropower reservoirs.

Compared to the financial, social and environmental risks posed by the Sambor and Stung Treng projects, these challenges appear manageable. They are not any bigger than in other countries that are already rapidly expanding their solar capacity. Furthermore, by going solar, instead of damaging relations with its neighboring countries, Cambodia would be able to enjoy the full support of the international community, financially, technically and politically.

40 Watson Farley & Williams (2018) suggest introducing a single regulatory framework and agency for solar, a standard PPA, and clarifying land acquisition issues.

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DAM IMPACTS IN NUMBERS

92

Number of Irrawaddy dolphins remaining in the Mekong

13.7 MILLION

13.7 million people in Cambodia live without safe and reliable access to electricity.

65%

65% of Cambodians rely on agriculture, fisheries, and forestry for their livelihoods

$17 BILLION

Estimated worth of Lower Mekong fisheries per year, in USD

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To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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