Supplement File "Notes"

Guide

Methods for identifying hydropower facilities in Vietnam

Recognizing that published databases and listings of hydropower facilities (HPFs) in Vietnam are incomplete, we compiled a basic database by amalgamating a variety of existing sources and searching the web for recent and historical documents mentioning the existence of HPFs in Vietnam. The database includes the name of the facility in both English and Vietnamese, installed capacity in MW, year of completion, latitude and longitude, and estimated power output in TWh (described below). In most cases, we verified the existence of HPFs on maps such as Google Earth, MyMaps, Planet.com, and openstreet.com. However, if sufficient and reliable documentation was available, we included some HPFs that did not appear on optical image maps but were reported to be completed and connected to the grid. Although we believe the database is the most accurate available, there are substantial uncertainties, particularly for HPFs that are in some phase of construction (see uncertainties below).

It's important to note that we marked the location of the dams or the main flow disrupting structures in most cases, but in some cases, we marked the locations of the power generation unit if the location of the former was ambiguous in dated images, such as Hua Chăng (10.2 MW). Most databases and map products list the location of the electricity generation unit, but we were more interested in the locations where the most impact to streams would occur.

The following passage provides some general notes regarding issues that arose when building the database.

Issues arising when building the HPF database (Supplement File "Database")

1. Cascades of HPFs often do not appear in logical order spatially (e.g., Đắk Psi); and it is not unusual for the numbering to be imperfect, as in the case of Sông Bung 2, 4, 4A, 5, and 6. There is no #1, and both 3 and 3A have been proposed, but not constructed.

2. Older databases and lists may contain the data for HPFs that were not built in the end.

3. Locations on map may be based on pre-registered address, not the actual location of the HPF. In cases of some HPFs that were not built, the map may still list the address of the company. It is not unusual for massive delays to occur before construction following the registration of the company.

4. Spelling may be inconsistent at times because the names are often based on phonetic interpretations, which is complicated by the several vernacular languages in Vietnam: e.g., Ngòi San versus Ngòi Xan.

5. The Vietnamese name and its English version are close; however, the search engine may translate the name providing a confusing version: compare A Lưới versus A Luoi versus A Grid (or Agrid).

6. In the database we list the Vietnamese name and its English version only: e.g., A Lưới and A Luoi.

7. An HPF may be completed, but delayed in connecting to the grid, affecting the status as finished or not (e.g, Vinh Son 4).

8. In the database, HPFs that are not complete are given the year 2099, versus a year from 1927 to 2022 for completed units. HPFs we could not locate have 3099 in the completion year (these three types are listed on different pages of the excel workbook that comprises the Supplement File "Database").

9. In published works, data may be grouped when more than one units co-exist (e.g,. An Khe - Kanak). We list these two separately.

10. The current full capacities of various HPFs may not match the capacity when the facility was finished if upgraded later.

11. The completion of an HPF is sometimes tricky to glean from published English translations from Vietnamese because tense is not translated accurately. For example, the XXX HPF "is being built" may be translated simply as "is built" or possible "was built".

12. Tentative completion dates, rather than actual completion dates, may be reported in various documents describing a HPF; this applies to installed capacities and estimated power generation outputs.

13. Vietnamese Wikipedia is a good source of reference for many HPFs, but the information is not updated.

14. An earlier named HPF may now be associated with other HPF project under a new name (e.g,. Bát Đại Sơ is also known as Sông Miện 1 (6 MW). This discrepancy might happen for example if the original project failed and was then incorporated into a more recent project. Sometimes, this issue will be addressed by modifying the name by adding a letter (1 to 1a).

15. Names can be very similar: Nậm Mở (32 MW) versus Nậm Mô (18 MW) or Đa Khai (8.1 MW) versus Đa Kai (6 MW). However, each has a unique location that can be used to distinguish them.

16. Plants are occasionally built out of order, again because of delays: Song Tranh 2 (2010; 190 MW) versus Song Tranh 1 (still planning stages).

17. Old HPFs such as Duy Sơn are difficult to assess the status and timing of upgrades. We list two entries: Duy Sơn (0.8 MW) and Duy Sơn II (2.1 MW); the former originates at a pool in the river upstream from the current hydropower reservoir. When Duy Sơn was first established it had a lower capacity of 0.4 MW (https://www.bidv.com.vn/bidv/tin-tuc/bidvstories/tro-lai-duy-son-ii).

18. In general, most uncertainty relates to older plants that have evolved over time or were decommissioned without available documentation.

19. As we are interested in structures more so than installed capacity, we separated HPF units when they were composed of separate water flow blockage features: e.g, Đăk Pô Ne 1A (14 MW; small reservoir) and 1B (1.6 MW; cascaded intake).

20. Some HPS are inconsistently referred to among sources. A good example is Đăk Lồ, which according to 1609/QĐ-BTNM has four structures Đăk Lồ (dams A, B, B1) and Đăk Lồ 2; but the facility is referred by the Kontum Department of Industry and Trade as a single 22W unit at Đăk Lồ, which corresponds in capacity with what Wikipedia and others report: Đăk Lồ 1 (6MW), Đăk Lồ 2 (6MW), and Đăk Lồ 3 (10MW). Reference is made only do Đăklồ 1 and Đăk Lồ 2 on open-source maps. Another example is Đăk Pô Cô (1609/QĐ-BTNM) versus Đăk Pô Kô (us and Google Earth).

21. Spelling on maps occasionally does match that in reports: (e.g. Đăk Mi 4C versus Dak My 4C)

22. As we are viewing the HPFs from space we cannot have full knowledge on those that have been built in the last few years (because images tend to be 1-2 years old. Therefore, the 1609/QĐ-BTNM document has better information regarding multiple dams, for example in the case of Nậm Pạc 1, 1A, and 2, each with two dams or six total; we, however, only report three structures.

23. Occasionally inconsistent spellings occur for HPFs that are in the same geographical area: e.g,. Đa Chomo (9 MW) vs Đa Cho Mo 2 (4.6 MW).

24. The name of the HPF may not match the name of the reservoir where it is situated, or the name of the HP company for which it belongs.

25. Maps may contain originally identified locations of HPFs, not the location where they were actually built. For example, a search for Thuỷ điện Nậm Xây Luông places the plant within the cluster of Minh Lương Thượng (two HPFs), rather than in the cluster of the five Nậm Xây Luông HPFs (Nậm Xây Luông, #3, #4-5), which we assume is accurate.

26. Identical names may exist: e.g, Nậm Mu is both Bắc Quang and Lào Cai.

Uncertainties in the HPF database (Supplement File "Database")

As we collected information from various sources, mostly unofficial, we acknowledge that there may be some level of uncertainty in the hydropower plant database for Vietnam, especially for older plants and those currently under construction. To indicate our level of confidence in the information, we use yellow shading in the database (an Excel file) for each of the three groups: operational, not completed, and not located. For example, for Séo Chong Hô, we are uncertain about the year of completion. For Môngˆ Ân HPF, although we know it became operational in 2020, we are unsure of its exact location. Another example is Ngàn Trươi, for which we believe we have reliable information that it supplies electricity to the grid, but we lack data on its power output and completion date. It's possible that some of the other information in the database that we haven't marked with yellow shading may also be incorrect. Our estimate of 5-10% accuracy for the information in the database is not based on a rigorous analysis, but we consider it reasonable.

Power output data and calculations

Regarding power output, only 340 of 532 HPFs had information available on the annual electricity generated. Of these, few reported statistical data based on more than one year of data. Thus, we view this information with moderate skepticism, as the reported values are often inflated to promote performance, or they may be estimated based on assumptions from other plants but presented as observations. From the data reported ("Reported Output") in Supplement file "Database", we developed a relationship between output (TWh) and installed capacity (GW), which we use to estimate the outputs from the plants with no data: Output = 0.0039 * PIC^1.0073 (appears in Figure 2b of the main text). In a second column in the database, we reported the observed and "simulated" outputs ("Estimated Output"), from which we calculate plausible power output ranges that are listed in the text and tables (e.g., Table 1).

To estimate the range of outputs for a plant, we first determine the mean, then values 20% lower and 5% higher. While this approach lacks mathematical foundation, we consider three issues: (a) the reported output data are likely elevated; (b) we have probably included more HPFs in the database than are currently operational, rather than missing ones that are (again we find more installed capacity than most people report); and (c) deviation in expected annual outputs typically relate to lack of rainfall and/or down time for maintenance; these two issues occur often but the supporting information is not available to make adjustments to the values.

Supplement Table S1
The number of hydropower facilities and their total installed capacities (MW) built on the S3 rivers and their tributaries in Vietnam, Laos and Cambodia. Numbers in parentheses are facilities that are under construction or planned (for Cambodia and Laos only). This table pertains to Figure 3 in the paper.

River	Vietnam	Laos	Cambodia
Sekong	4: 217 MW	3 (20): 273 MW	NA
Sê San	51: 2259 MW	NA	1 (4): 1 MW
Srêpôk	26: 1182 MW	NA	0 (2)

Data for Vietnam are from this study; Data for Cambodia and Laos are downloaded

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