A COMPREHENSIVE VULNERABILITY ASSESSMENT OF THE LAO PDR POWER SECTOR

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ACRONYMS

EDL	Électricité du Laos
EDL-GEN	EDL-Generation Public Company
MEM	Ministry of Energy and Mines
MoIC	Ministry of Industry and Commerce
MoLSW	Ministry of Labor and Social Welfare
MoNRE	Ministry of Natural Resources and Environment
MoST	Ministry of Science and Technology
MPI	Ministry of Planning and Investment
Lao PDR	Lao People's Democratic Republic
VA	Vulnerability assessment

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EXECUTIVE SUMMARY

USAID Clean Power Asia conducted an assessment of the Lao PDR power sector's vulnerability to climate and non-climate natural hazards and to human and technological hazards. The vulnerability assessment (VA) involved extensive stakeholder engagement with a VA Advisory Group of high-level power sector decision makers and a broader, more diverse Power Sector Stakeholder Group.

In August 2018, the VA team met with the VA Advisory Group to identify the most important hazards to the sector and to determine an appropriate scope for the VA. Then, in a three-day VA workshop, the VA team and the Power Sector Stakeholder Group collaborated to assess hazards to the sector, describe their impacts, and identify and assess priority vulnerabilities. Through this VA process, the Power Sector Stakeholder Group and the VA team determined that extreme precipitation, flooding, landslides, and extreme temperatures pose the greatest risks to power sector activities and expose important vulnerabilities. **Table 1** below lists the highest-risk vulnerabilities that the team identified in the VA workshop.

Table 1: List of highest-risk vulnerabilities and risk scores

Number	Vulnerability	Risk Score
29	Power system rules, regulations, and technical standards do not meet current and changing environmental conditions	High
13	Dam construction does not follow design specifications	High
21	Installation does not follow design specifications	High
12	Lack of compliance with codes in design	High
16	Corruption leads to code violations	Medium-High
20	System operations are not flexible enough to respond to changes in demand and supply	Medium-High
17	Demand forecasting is not responsive to changing load conditions	Medium-High
7	Heavy power sector reliance on hydro generation	Medium-High
31	Inadequate domestic generation capacity requires costly energy imports	Medium-High
22	Hydro generation reservoir is too small for drought conditions	Medium-High
5	Large industry (mining, cement, and economic zones) constitutes approximately 40% of demand and revenue	Medium-High
15	Poor coordination between dam operators	Medium-High
23	Transmission infrastructure located in wildfire prone areas	Medium-High
18	Transmission equipment located in zones prone to flooding	Medium-High
14	Transmission equipment located in zones prone to landslides	Medium-High
26	Transportation impacts occur with power sector impacts	Medium-High
32	Unreliable and or inadequate meteorological, hydrological, and climate change data for decision making	Medium-High

The next step of this work will focus on addressing these high-risk vulnerabilities by identifying and evaluating potential resilience strategies. The VA team will continue to collaborate with the VA Advisory Group and the Power Sector Stakeholder Group to develop a Resilience Action Plan for the Lao PDR power sector. The plan will build on the findings of the VA and will describe priority actions for reducing key power sector vulnerabilities.

1. THE VA TECHNICAL APPROACH

The VA team's approach to identifying the power sector's highest-risk vulnerabilities builds on past extensive experience with engaging stakeholders in the VA process, and it is tailored to the context of the Lao PDR power sector. This report provides a general description of the technical approach and the stakeholder engagement activities involved in each task of the VA. An appendix to the final project report will describe in more detail the process that the VA team used to engage stakeholders and to elicit the information necessary to complete the VA through multiple working group sessions and activities.

1.1 STAKEHOLDER ENGAGEMENT

The VA team engaged two groups in the VA: 1) a VA Advisory Group and 2) a Power Sector Stakeholder Group. The VA Advisory Group was a group of nine upper-level power sector directors/managers from the Ministry of Energy and Mines (MEM), Électricité du Laos (EDL), and EDL-Generation Public Company (EDL-Gen) who helped scope and frame the VA and ensure that the subsequent engagement with the Power Sector Stakeholder Group was meaningful and productive. The VA team held a half-day meeting with the VA Advisory Group prior to conducting the VA with the Power Sector Stakeholder Group during a three-day workshop. The objectives of the VA Advisory Group meeting included:

1. Determine the scope of the VA of the Lao PDR power sector.
2. Ensure buy-in from power sector decision makers, who can give permission to and encourage their staff to participate in two stakeholder workshops—the vulnerability assessment workshop and a second workshop to develop a resilience action plan.

The VA Advisory Group also reviewed a draft of this VA report and provided technical feedback that was incorporated into this final draft.

The Power Sector Stakeholder Group was a larger group of 23 stakeholders whose expertise can support power sector planning and decision-making in the Lao PDR power sector. Participants represented various departments in MEM, as well as other ministries and organizations, including the Ministry of Industry and Commerce, Ministry of Science and Technology, Ministry of Natural Resources and Environment, Lao Holding State Enterprise, EDL, and EDL-Gen. This group of stakeholders provided diverse perspectives on the power sector, from long-range planning and capital improvements to operations and maintenance. The VA team met with the Power Sector Stakeholder Group for three consecutive days to conduct a participatory vulnerability assessment. The objectives of the Power Sector Stakeholder Group workshop included the following:

1. Draw on stakeholders' expertise to identify potential vulnerabilities to climate and non-climate hazards that can affect key power sector components and activities.
2. Discuss how participants experience these climate and non-climate hazards in their work, and how these hazards affect, or could affect, their ability to meet power sector objectives.
3. Describe the severity of these potential vulnerabilities and assess their overall risk to the sector.

2. OUTCOMES OF THE VA PROCESS

2.1 TASK 1: DEVELOPING AND REVIEWING AN IMPACTS FRAMEWORK

In advance of conducting the VA stakeholder engagement activities, the project team developed an impacts framework to organize our thinking about the power sector vulnerability assessment. The impacts framework serves two primary purposes: 1) to facilitate a conversation with the VA Advisory Group about the scope of the vulnerability assessment and 2) to guide discussions about potential vulnerabilities with the Power Sector Stakeholder Group.

The impacts framework is a two-dimensional tool that cross-references the power sector's key objectives with the sector's components. Key objectives include the formal or practical objectives of the power authority. The sector components are aspects of the power system that could experience impacts from natural and non-natural hazards.

The VA team developed a generalized impacts framework based on desktop research on the Lao PDR power sector. The team discussed the draft framework with the VA Advisory Group and then revised it to more accurately reflect the context of the Lao PDR power sector. The VA Advisory Group recommended eliminating some power sector objectives that were not important or relevant, and revising some components and objectives to better describe the Lao PDR power sector.

For example, the VA Advisory Group recommended removing fuel, fuel transport, and fuel storage from the original list of power sector components because the dominant power source in the Lao PDR is hydropower, which does not require fuel, fuel transport, or fuel storage. In addition, the VA Advisory Group determined that cybersecurity, government subsidies, and air and water pollution were not important objectives to consider in the vulnerability assessment.

The final impacts framework agreed on by the VA team and the VA Advisory Group is shown in **Table 2**. Please note that the impacts framework was not used in a mechanical way. Instead, it was used as a tool to engage the Power Sector Stakeholder Group in a discussion about how natural and non-natural hazards might affect the power sector. In other words, the output of using the impacts framework is not a set of check marks, but rather the narrative descriptions of potential vulnerabilities listed in **Table 4**.

Table 2: Final Lao PDR power sector impacts framework

Objectives		Energy system components										
		Hydro Generation	Thermal generation	Generator step up transformer	Transmission lines	Substation step-down transformer	Distribution lines	Point of common coupling	Residential demand	Small commercial demand	Large Commercial and Industrial demand	Grid operations/ management
Reliability and security	Availability											
	Continuity of service											
	Good power quality											
	Skilled workforce											
Affordability	Appropriate rates											

2.2 TASK 2: IDENTIFY HAZARDS AND THEIR IMPACTS TO THE LAO PDR POWER SECTOR

The VA team presented a list of potential hazards to the VA Advisory Group to prompt discussion about the most important hazards and to determine which hazards to consider in the VA. This discussion began with a brief explanation of definitions. A "hazard" is a condition or occurrence that is outside the control of power sector planners and system operators, e.g., a typhoon. "Threat" is often used interchangeably with the term hazard. An "impact" is the interaction of a hazard with the power system, e.g., a typhoon causes wind damage to transmission lines.

Because this VA is comprehensive and intends to address all major hazards, the VA team introduced hazard categories that describe different types of hazards to the Lao PDR power sector. The VA team broadly categorized power sector hazards into "natural" hazards and "non-natural" hazards. Natural hazards include both "climate" and "non-climate" hazards. Non-natural hazards include "human-caused" and "technological" hazards.

The VA Advisory Group engaged in a small-group participatory exercise to discuss all of the potential hazards that the VA team introduced. Each group discussed the following questions for each hazard:

1. What impacts does the hazard have on the power sector?
2. How have you experienced the hazard in your work in the power sector?
3. If the hazard becomes more intense/frequent, what impacts do you expect will occur in the future?

Based on this discussion, the VA Advisory Group identified the most important hazards and impacts on the Lao PDR power sector and narrowed the range of hazards that the Power Sector Stakeholder Group would consider in the VA workshop. **Table 3** presents the final list of hazards.

Table 3: Final list of hazards selected by the VA Advisory Group

Natural Hazards
Cyclone (including extreme precipitation, landslides, and wind)
Drought
Extreme heat and cold
Lightning
Non-Natural Hazards
Technological (design, workmanship, low quality and defective materials)
Wildlife interactions
Human-caused accidents

The VA team introduced this final list of hazards to the Power Sector Stakeholder Group on the first day of the VA workshop. Working in small groups, the Power Sector Stakeholder Group discussed

how each of these hazards could impact the Lao PDR power sector, and each group developed a detailed list of the potential impacts associated with each hazard.

2.3 TASK 3: DEVELOPING A LIST OF POTENTIAL VULNERABILITIES

The VA team used the Power Sector Stakeholder Group's list of impacts to define vulnerabilities associated with each hazard and its potential impact. Each vulnerability statement should identify a problem that could lead to one or more specific solutions. For example, the Power Sector Stakeholder Group described how lightning could strike power sector infrastructure and cause damage and fires. An example of a vulnerability associated with lightning strikes that damage infrastructure could be, "Inadequate infrastructure or power system protection from lightning strikes." It is possible to define more than one vulnerability based on the potential impacts associated with each hazard.

During the workshop, the VA team modeled the process for defining several vulnerabilities associated with the hazards and impacts that the Power Sector Stakeholder Group had discussed. After the day's workshop, the VA team reconvened to develop a full list of potential vulnerabilities based on the work of the Power Sector Stakeholder Group Day 1 working groups. The Stakeholder Group validated and revised the list on workshop Day 2. **Table 4** presents this full list of potential vulnerabilities.

Table 4: The full list of potential vulnerabilities

Number	Vulnerability	Lao Translation
1	Animals nest on power system assets	ສັດທີ່ມີຜນກະທົບຕໍ່ລະບົບໄຟຟ້າ (ສັດປີກ)
2	Limited numbers of skilled workers to carry out daily activities	ບຸກຄະລາກອນທີ່ມີຄວາມຮູ້ຄວາມສາມາດໃນການປະຕິບັດວຽກງານປະຈຳວັນມີຈຳນວນຈຳກັດ
3	Transmission equipment susceptible to lightning strikes	ລະບົບສາຍສົ່ງສ່ຽງຕໍ່ການຖືກຟ້າຜ່າ
4	Theft of power (illegal connections) and power system components is common	ການລັກອຸປະກອນໄຟຟ້າ ແລະ ການລັກໃຊ້ໄຟຟ້າ
5	Large industry (mining, cement, and economic zones) constitutes approximately 40% of demand and revenue	ຄວາມຕ້ອງການໄຟໃນອຸດສະຫະກຳຂະໜາດໃຫຍ່ (ບໍ່ແຮ່, ຊີມັງ, ເຂດເສດຖະກິດພິເສດ)ກວມເອົາ 40%ຂອງຄວາມຕ້ອງການ
6	Civil work occurs near transmission infrastructure	ການກໍ່ສ້າງໃກ້ກັບລະບົບສົ່ງ ແລະ ລະບົບຈຳໜ່າຍໄຟຟ້າ
7	Heavy power sector reliance on hydro generation	ການເອື່ອຍອີງພະລັງງານໄຟຟ້ານ້ຳຕົກເປັນສ່ວນໃຫຍ່
8	Hunting and shooting in proximity to infrastructure	ການຂ້າ ແລະ ການລ່າສັດບໍລິເວນໃກ້ຄຽງກັບ T&D
9	Tree are close to distribution lines	ຕົ້ນໄມ້ ໃກ້ກັບສາຍສົ່ງ

Number	Vulnerability	Lao Translation
10	Distribution equipment susceptible to lightning strikes	ສະຖານີຈ່າຍ ແລະ ສົ່ງ ໄຟຟ້າ ສ່ຽງຕໍ່ການຖືກຟ້າຜ່າ
11	Animal access to distribution lines/substations	ສັດເຂົ້າໄປສະຖານີໄຟຟ້າ
12	Lack of compliance with codes in design	ບໍ່ປະຕິບັດຕາມມາດຕະຖານ ແລະ ຕັກນິກການອອກແບັນ
13	Dam construction does not follow design specification	ການກໍ່ສ້າງບໍ່ເປັນໄປຕາມການອອກແບບ
14	Transmission equipment located in zones prone to landslides	ອຸປະກອນສາຍສົ່ງໄປຕັ້ງຢູ່ເຂດຄວາມສ່ຽງດິນເຈື່ອນ
15	Poor coordination between dam operators	ຂາດການປະສານງານລະຫວ່າງຜູ້ປະຕິບັດການປະຈຳເຂື່ອນ
16	Corruption leads to code violations	ການສໍ້ໂກງ ຫຼື ລະເມີດລະບຽບການກໍ່ສ້າງທີ່ໄດ້ກຳນົດໄວ້
17	Demand forecasting is not responsive to changing load conditions	ການຄາດຄະເນຄວາມຕ້ອງການຊົມໃຊ້ໄຟຟ້າລາຍວັນ ແລະ ອະນາຄົດ ຍັງບໍ່ທັນແທດເໝາະກັບສະພາບການປ່ຽນແປງໃນປະຈຸບັນ
18	Transmission equipment in zones prone to flooding	ອຸປະກອນສາຍສົ່ງທີ່ຢູ່ໃນເຂດມີຄວາມສ່ຽງນ້ຳຖ້ວມ
19	Distribution equipment located in zones prone to landslides	ອຸປະກອນພາກຈຳໜ່າຍລະບົບໄຟຟ້າຕັ້ງໃນເຂດທີ່ມີຄວາມສ່ຽງທີ່ຈະເກີດດິນເຈື່ອນ
20	System operations are not flexible enough to respond to changes in demand and supply	ການບໍລິຫານລະບົບໄຟຟ້າທີ່ບໍ່ຕອບສະໜອງ ກັບ ການປ່ຽນແປງ ຂອງການຊົມໃຊ້ ແລະ ການຜະລິດໄຟ
21	Installation did not follow design specification	ການຕິດຕັ້ງອຸປະກອນທີ່ບໍ່ເປັນໄປຕາມການອອກແບບໄວ້
22	Hydro generation reservoir is too small for drought conditions[1]	ຄວາມສາມາດໃນການກັກເກັບນ້ຳໃນອ່າງເກັບນ້ຳບໍ່ພຽງພໍ ສຳລັບການຜະລິດໃນລະດູແລ້ງ
23	Transmission infrastructure located in wildfire prone areas	ໂຄງສ້າງພື້ນຖານຂອງລະບົບໄຟຟ້າຕັ້ງຢູ່ໃນເຂດທີ່ມີຄວາມສ່ຽງທີ່ຈະເກີດໄຟໄໝ້
24	Distribution equipment located in zones prone to flooding	ອຸປະກອນຂອງສາຍຈຳໜ່າຍໄຟຟ້າຕັ້ງຢູ່ໃນເຂດທີ່ນ້ຳຖ້ວມ/ມີຄວາມສ່ຽງສູງທີ່ຈະເກີດນ້ຳຖ້ວມ
25	High level of turbidity and siltation affect hydro generation	ລະດັບຄວາມຂຸ່ນຂອງນ້ຳມີຜົນຕໍ່ກັງຫັນພະລັງນ້ຳ

[1] This is based on the discussion with stakeholders during the workshop; however, representatives from EDL provided their perspective that storage volumes of all dams/reservoirs are normally available and sufficient in the dry season because these dams/reservoirs will be emptied after the end of rainy season (Nov/Dec) to prepare maximum available storing volume at the beginning of a dry season (Jan/Feb).

Number	Vulnerability	Lao Translation
26	Transportation impacts occur with power sector impacts	ຂໍ້ບົກຜ່ອງດ້ານຄົມມະນາຄົມຈະສົ່ງຜົນໃຫ້ເກີດມີຈຸດອ່ອນໃນຂະແໜງການພະລັງງານເຊື່ອມຈອກັນ
27	Population's reaction to extreme weather results in unpredictable power loads	ໃນກໍລະນີມີຜົນຫຼາຍ ຈະສົ່ງຜົນຕໍ່ການຊົມໃຊ້ໄຟຟ້າຂອງປະຊາຊົນມີການປ່ຽນແປງ
28	Critical staff may be unavailable during extreme events	ຂີດຈຳກັດທາງດ້ານແຮງງານບໍ່ພຽງພໍເພື່ອຕອບສະໜອງຕໍ່ເຫດການສຸກເສີນຮຸນແຮງ
29	Rules and regulations and technical standards do not meet current and changing environmental conditions	ລະບຽບການ, ມາດຕະຖານທາງດ້ານເຕັກນິກບໍ່ສອດຄ່ອງກັບເງື່ອນໄຂສະພາບການ ແລະ ການປ່ຽນແປງທາງດ້ານສິ່ງແວດລ້ອມໃນປະຈຸບັນ
30	Communication and SCADA systems between power system components lack certain functions	ລະບົບ SCADA ຂາດ ຟັງຊັ່ນບາງຢ່າງທີ່ເຮັດໃຫ້ບໍ່ຄົບອົງປະກອບໃນການໃຊ້ງານ
31	Inadequate domestic generation capacity requires costly energy imports	ຂີດຄວາມສາມາດໃນການສ້າງພະລັງງານພາຍໃນບໍ່ພຽງພໍ ເຊິ່ງຮຽກຮ້ອງໃຫ້ມີການນຳເຂົ້າພະລັງງານທີ່ມີຄ່າໃຊ້ຈ່າຍສູງ
32	Unreliable and or inadequate meteorological, hydrological, and climate change data for decision making	ຂໍ້ມູນກ່ຽວກັບປະລິມານຜົນຕົກ ແລະ ການປ່ຽນແປງຂອງສະພາບອາກາດ ມີບໍ່ພຽງພໍ ເພື່ອນຳໃຊ້ໃນການຕັດສິນໃຈ

The VA team developed this list from the raw output of the Power Sector Stakeholder Group Day 1. The Power Sector Stakeholder Group validated, revised, and finalized the list on workshop Day 2.

2.4 TASK 4: ASSOCIATE HAZARDS WITH POTENTIAL VULNERABILITIES

The VA team presented the full list of potential vulnerabilities to the Power Sector Stakeholder Group for review and validation on workshop Day 2. To validate the list of vulnerabilities that the VA team developed, the Power Sector Stakeholder Group worked in small groups to discuss the specific intersection of each vulnerability with the entire suite of potential hazards. The stakeholders suggested some revisions to finalize the list. (**Table 4** above presents this final list.) The groups recorded the key points of their discussions about the correlation between vulnerabilities and hazards to inform the risk analysis in the next step of the VA process. **Table 5** shows an example of a subset of the vulnerabilities and hazards that the working groups discussed.

Table 5: Subset of potential vulnerabilities associated with a subset of hazards

Hazards	Power system rules, regulations, and technical standards do not meet current and changing environmental conditions	Corruption leads to code violations	Dam construction does not follow design specifications	Installation does not follow design specifications	Lack of compliance with codes in design	System operations are not flexible enough to respond to changes in demand and supply
Extreme Precipitation	Yes	No	Yes	Yes	Yes	Yes
Extreme Temperatures	Yes	No	No	No	No	Yes
Flooding	Yes	No	Yes	Yes	Yes	Yes
Landslides	Yes	No	Yes	Yes	Yes	No
Wildlife interactions	No	No	No	No	No	No
Wind	Yes	No	No	No	No	Yes
Human Actions: Bad Actors	No	Yes	Yes	Yes	No	No
Human Actions: Accidents	No	No	Yes	Yes	No	No
Technological Design	Yes	No	Yes	Yes	Yes	Yes

2.5 TASK 5: SCORE SEVERITY OF POTENTIAL VULNERABILITIES

Severity scores of each vulnerability reflect the magnitude of the consequence of realizing each vulnerability, or the extent to which each vulnerability could negatively impact the power sector. The VA approach involves ranking the severity from low to high. **Table 6** shows the qualitative scores used to assign the vulnerability scores. A threshold description of each score provides a guideline for assigning an appropriate score. The score for each vulnerability takes into account the following considerations:

- **Effect on delivery of power**: the percentage of service disrupted, effects on power quality, etc.
- **Effect on capital and operating costs**: additional costs for the reliable operation of the power system
- **Extent of health and safety impacts to the population**: metrics of health and safety for the population
- **Extent of environmental effects**: metrics of the release of toxic materials, effects on biodiversity, changes to area's ecosystem, impacts on historic sites, and others

Table 6: Qualitative Vulnerability Consequence Scores and Threshold Descriptions

Vulnerability Consequence Score		Threshold Descriptions
Qualitative	Quantitative	
High	9	Highest magnitude of consequence. Entire power system would be impacted. Extreme financial impacts would exist.
Medium-High	7	Significant consequences to the organization. Majority of population served would be impacted. Staff tasks would be switched to emergency/critical operations. Significant financial impacts would exist
Medium	5	Medium magnitude of consequence. The organization would be somewhat affected. Specific systems or functions would be substantially interrupted, but not all. Financial impacts would be expected to change budgeting plans or require reallocation of funds.
Low-Medium	3	Slightly elevated consequence to the organization. The power sector may need to temporarily transition operations to backup systems to resolve failure. Limited financial impacts may become apparent.
Low	1	Lowest magnitude (or severity) of consequence to the organization. The power sector would experience little to no affect or an in-place backup system would resolve the failure.

Source: Power Sector Resilience Planning: Handbook for Practitioners (NREL 2018)

After the VA team introduced this scoring methodology on Day 2 of the workshop, the Power Sector Stakeholder Group worked in small groups to assign a severity score to a subset of the vulnerabilities. The small work groups then reviewed one another's scores to ensure that the severity scores reflect the consensus of the full group. **Table 7** presents the final consequence scores.

Table 7: Vulnerability consequence scores

Number	Vulnerability	Consequence Score
29	Power system rules, regulations, and technical standards do not meet current and changing environmental conditions	High
16	Corruption leads to code violations	High
13	Dam construction does not follow design specifications	High
21	Installation does not follow design specifications	High
12	Lack of compliance with codes in design	High
20	System operations are not flexible enough to respond to changes in demand and supply	Medium-High
17	Demand forecasting is not responsive to changing load conditions	Medium-High
7	Heavy power sector reliance on hydro generation	Medium-High
31	Inadequate domestic generation capacity requires costly energy imports	Medium-High
22	Hydro generation reservoir is too small for drought conditions	Medium-High
5	Large industry (mining, cement, and economic zones) constitutes approximately 40% of demand and revenue	Medium-High
15	Poor coordination between dam operators	Medium-High
23	Transmission infrastructure located in wildfire prone areas	Medium-High
18	Transmission equipment located in zones prone to flooding	Medium-High
14	Transmission equipment located in zones prone to landslides	Medium-High
3	Transmission equipment susceptible to lightning strikes	Medium-High

Number	Vulnerability	Consequence Score
26	Transportation impacts occur with power sector impacts	Medium-High
32	Unreliable and or inadequate meteorological, hydrological, and climate change data for decision making	Medium-High
6	Civil works occur near transmission infrastructure	Medium
19	Distribution equipment located in zones prone to landslides	Medium
24	Distribution equipment located in zone prone to flooding	Medium
10	Distribution equipment susceptible to lightning strikes	Medium
25	High levels of turbidity and siltation affect hydro generation	Medium
30	Communication and SCADA systems between power system components lack certain functions	Medium
2	Limited number of skilled workers to carry out daily activities	Medium
28	Critical staff may be unavailable during extreme events	Medium
4	Theft of power and power system equipment is common	Low-Medium
27	Population's reaction to extreme weather results in power unpredictable loads	Low-Medium
9	Trees are close to distribution lines	Low-Medium
11	Animals access to distribution lines	Low
1	Animals nest on power system assets	Low
8	Hunting and shooting in proximity to infrastructure	Low

2.6 TASK 6: SCORE LIKELIHOOD OF HAZARDS

In addition to scoring the severity of each vulnerability, the VA approach also involves scoring the likelihood that each hazard will occur. Like the severity scores, likelihood scores range from low to high. **Table 8** shows the qualitative and quantitative likelihood scores and threshold descriptions to guide scoring.

Table 8: Scores and Descriptions for Likelihood Scoring

Hazard Likelihood Scores		Threshold Descriptions
Qualitative	Quantitative	
High	9	Almost certain to occur. Historic and frequent occurrences.
Medium-High	7	More likely to occur than not.
Medium	5	May occur.
Low-Medium	3	Slightly elevated level of occurrence. Possible, but more likely not to occur.
Low	1	Very low probability of occurrence. An event has the potential to occur but is still very rare.

It is important to note that these likelihood scores did not represent simply the likelihood of the hazard occurring, but rather the likelihood of the hazard affecting the power sector. For example, “lightning” is almost certain to occur, but this information is not useful to our analysis. What we care about is the likelihood of lightning interacting with the power sector to cause an impact. After the workshop activities on Day 2, the VA team assigned tentative likelihood scores to each hazard based

on our understanding of each hazard in the Lao PDR context. When the VA team was uncertain about the appropriate likelihood score, we used the "medium" likelihood score as a placeholder.

On workshop Day 3, the VA team asked the Power Sector Stakeholder Group to review and revise the tentative likelihood scores in small working groups and then report back to the full group. Participants discussed each score and reached consensus on the final scores to include in the VA. **Table 9** shows the final hazard likelihood scores across natural and non-natural hazards.

Table 9: Natural and non-natural hazard likelihood scores

Hazard	Likelihood score
Natural Hazards	
Extreme precipitation	Medium-High
Flooding	Medium-High
Extreme temperatures	Medium-High
Landslides	Medium-High
Wind	Medium
Drought	Low-Medium
Lightning	Low-Medium
Non-Natural Hazards	
Human bad actors	Medium
Technological poor design	Medium
Technological poor materials	Medium
Human accidents	Low-Medium
Technological poor workmanship	Low-Medium
Wildlife interaction	Low-Medium

2.7 TASK 7: SCORE RISK AND CREATE FINAL RISK MATRIX

The final step of the VA involves entering the vulnerability consequence scores and hazard likelihood scores into a spreadsheet tool to generate a risk matrix. The VA team presented the risk matrix to the stakeholder group on workshop Day 3 to explain this scoring method and the final step of the VA process. Table 10 presents the final matrix.

Table 10: Final risk matrix

Vulnerability	Consequence score	Extreme Precipitation	Extreme Temperatures	Flooding	Landslides	Wind	Human Actions: Bad Actors	Technological Design	Technological Materials	Wildlife interactions	Human Actions: Accidents	Technological Workmanship	Drought	Lightning
likelihood score		7	7	7	7	5	5	5	5	3	3	3	3	3
Power system rules, regulations, and technical standards do not meet current and changing environmental conditions	9	63	63	63	63	45		45	45				27	27
Corruption leads to code violations	9						45							
Dam construction does not follow design specifications	9	63		63	63		45	45	45		27	27		
Installation does not follow design specifications	9	63		63	63		45	45			27	27		
Lack of compliance with codes in design	9	63		63	63			45	45			27		27
System operations are not flexible enough to respond to changes in demand and supply	7	49	49	49		35		35					21	21
Demand forecasting is not responsive to changing load conditions	7	49	49					35					21	
Heavy power sector reliance on hydro generation	7	49	49	49				35					21	
Inadequate domestic generation capacity requires costly energy imports	7	49	49	49									21	
Hydro generation reservoir is too small for drought conditions	7		49					35					21	
Large industry (mining, cement, and economic zones) constitutes approx 40perc of demand and revenue	7	49	49	49				35					21	
Poor coordination between dam operators	7	49	49	49									21	
Transmission infrastructure located in wildfire prone areas	7		49										21	21
Transmission equipment located in zones prone to flooding	7	49		49	49			35						
Transmission equipment located in zones prone to landslides	7				49			35						
Transmission equipment susceptible to lightning strikes	7							35						21
Transportation impacts occur with power sector impacts	7	49		49	49	35								
Unrealiable and or inadequate meteorological, hydrological, and climate change data for decision making	7	49	49	49	49	35		35					21	21
Civil works occur near transmission infrastructure	5										15			
Distribution equipment locationed in zones prone to landslides	5	35		35	35			25						
Distribution equipment locationed in zoneze prone to flooding	5	35		35				25						
Distribution equipment susceptible to lightning strikes	5							25						15
High levels of turbidity and siltation affect hydro generation	5	35		35	35			25					15	
Communication and scada systems between power system components lack certain functions	5						25	25	25					
Limited number of skilled workers to carry out daily activities	5								25			15		
Critical staff may be unavailable during extreme events	5	35	35	35	35	25	25	25		15				
Theft of power and power system equipment is common	3						15				9			
Population's reaction to extreme weather results in power unpredictable loads	3	21		21		15	15	15			9			
Trees are close to distribution lines	3					15		15		9	9			9
Animals access to distribution lines	1							5	5	3				
Animals nest on power system assets	1									3	3			
Hunting and shooting in proximity to infrastructure	1					5		5			3	3		3

The colored cells in the matrix represent all risk combinations that the stakeholder group believed could be linked; blank cells represent vulnerabilities that are not associated with the hazard in that column, and therefore present no risk. Brightly colored cells represent threat/vulnerability combinations that met the criteria to be considered high or medium-high risk; gray cells represent lower-risk vulnerabilities. Table 11 highlights just the highest-risk vulnerabilities to the power sector.

Table 11: Highest-risk vulnerabilities risk matrix

Vulnerability	Consequence score	Extreme Precipitation	Extreme Temperatures	Flooding	Landslides	Wind	Human Actions: Bad Actors	Technological Design	Technological Materials
likelihood score		7	7	7	7	5	5	5	5
Power system rules, regulations, and technical standards do not meet current and changing environmental conditions	9	63	63	63	63	45		45	45
Corruption leads to code violations	9						45		
Dam construction does not follow design specifications	9	63		63	63		45	45	45
Installation does not follow design specifications	9	63		63	63		45	45	
Lack of compliance with codes in design	9	63		63	63			45	45
System operations are not flexible enough to respond to changes in demand and supply	7	49	49	49		35		35	
Demand forecasting is not responsive to changing load conditions	7	49	49					35	
Heavy power sector reliance on hydro generation	7	49	49	49				35	
Inadequate domestic generation capacity requires costly energy imports	7	49	49	49					
Hydro generation reservoir is too small for drought conditions	7		49					35	
Large industry (mining, cement, and economic zones) constitutes approx 40perc of demand and revenue	7	49	49	49				35	
Poor coordination between dam operators	7	49	49	49					
Transmission infrastructure located in wildfire prone areas	7		49						
Transmission equipment located in zones prone to flooding	7	49		49	49			35	
Transmission equipment located in zones prone to landslides	7				49			35	
Transmission equipment susceptible to lightning strikes	7							35	
Transportation impacts occur with power sector impacts	7	49		49	49	35			
Unrealiable and or inadequate meteorological, hydrological, and climate change data for decision making	7	49	49	49	49	35		35	

Finally, the VA team assigned a qualitative risk score to each highest-risk vulnerability for ease of discussion. These are shown in **Table 12** below and were assigned based on the numerical scores in **Table 11**. A vulnerability that scored over 50 for any hazard was considered high risk, and a

vulnerability that scored between 40 and 50 for any hazard was considered medium-high. Vulnerabilities scoring below 40 were excluded from the highest-risk vulnerabilities.

Table 122: List of highest-risk vulnerabilities and risk scores

Number	Vulnerability	Risk Score
29	Power system rules, regulations, and technical standards do not meet current and changing environmental conditions	High
13	Dam construction does not follow design specifications	High
21	Installation does not follow design specifications	High
12	Lack of compliance with codes in design	High
16	Corruption leads to code violations	Medium-High
20	System operations are not flexible enough to respond to changes in demand and supply	Medium-High
17	Demand forecasting is not responsive to changing load conditions	Medium-High
7	Heavy power sector reliance on hydro generation	Medium-High
31	Inadequate domestic generation capacity requires costly energy imports	Medium-High
22	Hydro generation reservoir is too small for drought conditions	Medium-High
5	Large industry (mining, cement, and economic zones) constitutes approximately 40% of demand and revenue	Medium-High
15	Poor coordination between dam operators	Medium-High
23	Transmission infrastructure located in wildfire prone areas	Medium-High
18	Transmission equipment located in zones prone to flooding	Medium-High
14	Transmission equipment located in zones prone to landslides	Medium-High
26	Transportation impacts occur with power sector impacts	Medium-High
32	Unreliable and or inadequate meteorological, hydrological, and climate change data for decision making	Medium-High

3. VULNERABILITY ASSESSMENT OUTCOMES AND NEXT STEPS

Reducing the matrix view to focus on the highest-risk vulnerabilities (see **Table 11** above) reveals that extreme precipitation, flooding, and landslides (which are often correlated) are the threats that most expose vulnerabilities. The top four vulnerabilities have severe exposure to these hazard and earn the highest risk scores within the assessment. Extreme temperatures also contribute to one of the high risk vulnerabilities and many of the medium-high risk vulnerabilities. These final risk scores suggest that vulnerabilities associated with extreme precipitation, flooding, landslides, and extreme temperatures will be a focus of the resilience action plan.

Through this VA process, the VA team and power sector stakeholders collaborated to systematically identify and describe the highest-risk vulnerabilities of the Lao PDR power sector. The next steps of this work will focus on identifying the most appropriate resilience actions to address high-risk vulnerabilities. The VA team will reconvene the VA Advisory Group and the Power Sector Stakeholder Group for a Resilience Action Planning Workshop in November 2018 to discuss the concept of resilience and resilience goals for the Lao PDR power sector, and to identify and evaluate the most effective and feasible strategies to build resilience in the power sector. The VA team and power sector stakeholders will use the outcomes of the Resilience Action Planning Workshop to develop a Resilience Action Plan for the power sector. The plan will build on the findings of the VA and will detail resilience goals and priority actions to address the power sector's most pressing vulnerabilities.

ANNEX A: MEMBERS OF VA ADVISORY GROUP

Name		Organization	Position
Sanhya	Somvichit	Department of Energy Policy and Planning, MEM	Deputy Director General
Litthanoulok	Laspho	Power Generation Division, Department of Energy Policy and Planning, MEM	Chief of Division
Davanhny	Xaneth	Energy Policy and Planning Division, Department of Energy Policy and Planning, MEM	Chief of Division
Soukvilai	Phimmasene	System Planning Division, Department of Energy Policy and Planning, MEM	Technical Officer
Chitpanya	Phamisith	Power Development Plan Office, EDL	Deputy Chief of Office
Hongsakoun	Kongsup	Department of Transmission System Planning, EDL	Technical Officer
Phetsamone	Bounnouvong	National Control Center, EDL	Deputy Chief of Unit
Vinalong	Phonekeo	Project Study Division, Department of Business Development, EDL-Gen	Technical Officer

ANNEX B: LIST OF STAKEHOLDERS WHO PARTICIPATED IN THE WORKSHOP ON ASSESSING VULNERABILITIES IN THE LAO PDR POWER SECTOR, AUGUST 21-23, 2018[2]

Name		Organization	Position
Dr. Daovong	Phonekeo	MEM	Permanent Secretary, Cabinet Office
Sanhya	Somvichit	Department of Energy Policy and Planning, MEM	Deputy Director-General
Davanhny	Xaneth	Energy Policy and Planning Division, MEM	Chief of Division
Chansamone	Xaiyalath	Energy Policy and Planning Division, MEM	Deputy Chief of Division
Phaysone	Phouthonesy	Energy Policy and Planning Division, MEM	Technical Officer
Yevang	Nhiavue	Energy Policy and Planning Division, MEM	Technical Officer
Khamphan	Lasachak	Energy Policy and Planning Division, MEM	Technical Officer
Soukvilay	Phimmasen	Power System Planning Division, MEM	Deputy Chief of Division
Anousith	Bounsou	Information Division, , MEM	Technical Officer

[2] Missing stakeholders are representatives from Department of Social work (Disaster Emergency Response and Preparedness) under Ministry of Labor and Social Welfare, Climate Change Department, Department of Meteorology, and Department of Mines. VA team will work closely with MEM on inviting them to revise and provide feedback on VA results in the Resilience action planning workshop in November 2018.

Name		Organization	Position
Chitpanya	Phamisith	Power System Planning Office, EDL	Deputy Chief
Phetsamone	Bounnouvong	National Control Centre, EDL	Deputy Chief of Planning Team
Vinalong	Phonekeo	Department of Business Development, EDL-Gen	Technical Officer
Thippavanh	Mamphousay	EDL-Gen	Technical Officer
Noumay	Souvannaphoum	Project Division Lao Holding State Enterprise	Deputy Chief
Mona	Sychanthongthip	Department of Planning and Cooperation, Ministry of Industry and Commerce	Technical Officer
Kongsin	Saiyalin	Alternative Energy Division, Ministry of Science and Technology	Deputy Chief of Division
Boupha	Phiathep	Department of Natural Resource and Environmental Policy, Ministry of Natural Resource and Environment	Technical Officer
Vimala	Bulyaphol	Department of Planning and Cooperation, MEM	Technical Officer
Phayvanh	Phasiboriboun	Ministry of Labor and Social Welfare	
Phonesamay	Phaxay	Central Bank of Lao PDR	Deputy of Division
Lay	Phommalin	Department of Energy Management, MEM	
Alounzay	Inthilath	MEM	Technical Officer
Vilakone	Maniphousay		Officer
Mixaykone	Phongsavath		Officer