EXTREME HEAT IMPACTS ON ELECTRICITY DEMAND IN EFATE

INFRASTRUCTURE

This case study examines the impact of temperature on electricity demand in Efate. Guidance around conducting this type of step-by-step assessment is provided in more detail on the Van-KIRAP web portal, along with other case studies (called infobytes), factsheets, visualisation tools and technical resources. This case study can be used as an example for undertaking similar climate hazard-based impact assessments.

STEP 1 Understand the context and scope

Electricity for about half of Efate (including Port Vila) is supplied by UNELCO, a private company operating since 1939, with electricity generation of 60 GWh in 2021 [1]. In 2022, total generation was almost 63 GWh, of which 92 % was from diesel, 4 % from wind, 3 % from solar and 1 % from an independent power producer (UNELCO, personal communication), though this mix varies month-by-month depending on local and prevailing weather factors e.g. wind or solar input [2]. This energy mix is currently provided by two diesel power stations, two solar farms and one wind farm (UNELCO, personal communication). UNELCO had around 16,000 electricity customers in 2021 [1].

The National Energy Roadmap 2016–2030 (NERM, 2016) for Vanuatu lists five priorities for action and investment: (1) access to secure, reliable, and affordable electricity for all citizens by 2030, (2) reliable, secure and affordable petroleum supply, (3) a more affordable and low-cost energy service, (4) an energy secure Vanuatu, and (5) mitigating climate change through renewable energy and energy efficiency. While around two-thirds of Vanuatu's population can access the electricity grid [3], energy security can be disrupted by extreme weather events such as tropical cyclones.

An analysis of UNELCO electricity demand data for Efate during 2019–2022 showed that highest demand is required in the warmest and wettest months of the year, mainly for both public and private use of air conditioning (Figure 1). Climate change will increase the frequency, intensity, and duration of extreme heat, leading to greater use of air-conditioning and greater electricity demand. This infobyte assesses **the impact of extreme heat on electricity demand** in Efate, using data provided by UNELCO and Vanuatu Meteorology and Geo-hazards Department (VMGD), along with future climate change scenarios from CSIRO. For information on how this climate hazard-based impact study fits into a broader risk framework, see the Climate risk factsheet.

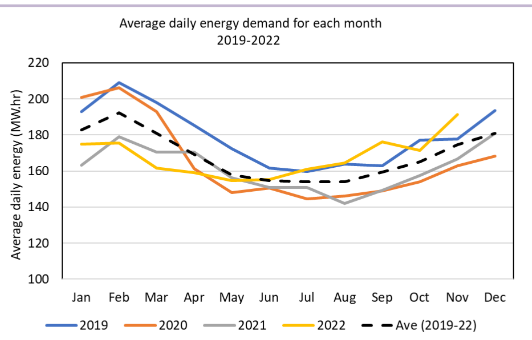


Figure 1: Average daily electricity demand for each month during 2019-2022 for Vanuatu.

STEP 2 Engage and meet with stakeholders

Van-KIRAP infrastructure sector experts, VMGD and CSIRO scientists liaised with UNELCO energy company in 2023 to discuss electricity production and demand and to review available data. Relevant literature was also drawn upon, including energy policy and planning reports.

STEP 3 Explore background information and historic climate data

For the 1986–2005 period, the hottest day of the year was, on average, 32–33 °C at all seven VMGD weather stations, with the hottest day being 33–34 °C. Over the past decades the number of cold nights in Port Vila has been decreasing, while the number of hot days has been increasing [4]. Over the period 1950–2020, there has been a clear warming of the hottest day of the year (Figure 2) [5, 6].

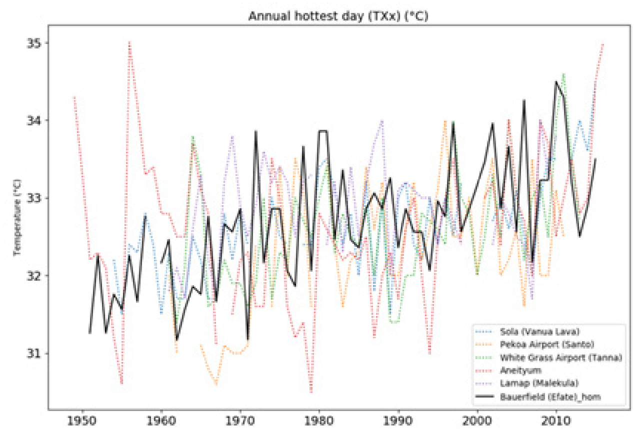


Figure 2 Temperature (°C) time series (1950–2020) of the annual hottest day for selected VMGD weather stations across Vanuatu. The station with homogenised data (Bauerfield, Efate) is shown with a solid line. Data source: [7]

Around 30 % of the variation in electricity demand is explained by daily maximum temperature variability (Figure 3, top), with the correlation being statistically significant. Unsurprisingly, higher maximum temperatures are related to higher electricity demand, mainly due to meeting increasing demand for air conditioning on hotter days. This correlation is strengthened through heatwave periods, with 40 % of the variability in electricity demand explained by variation in daily maximum temperature (Figure 3, bottom).

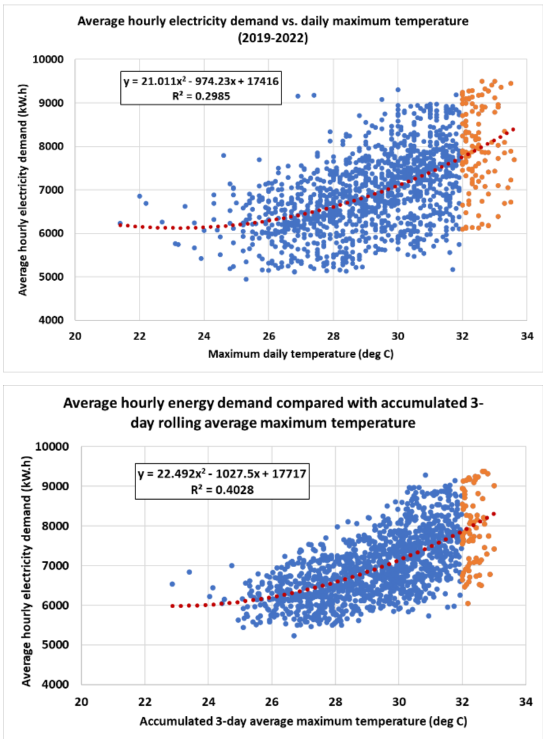


Figure 3 Average hourly energy demand (kW/hr) compared to daily maximum temperature (top) and average 3-day electricity demand compared to accumulated 3-day average maximum temperature (bottom). Non-linear regression lines (dashed) are statistically significant. Days with maximum temperature 32 °C and above are coloured orange. Electricity demand data courtesy of UNELCO. Temperature data procured from VMGD for Bauerfield, Port Vila.

The influence of other climate variables on electricity demand were explored in this assessment (e.g. relative humidity and minimum temperature) however maximum temperature was found to have the most influence.

STEP 4 Collect information about future climate scenarios

Extreme temperatures are projected to rise, consistent with the observed trends and projected warming in average temperatures. The projections are influenced by uncertainty in greenhouse gas emissions scenarios [8], regional climate responses simulated by climate models for each emissions scenario, and natural climate variability (see also Step 5). Under a high emissions scenario (RCP8.5), extreme temperatures are projected to be approximately 0.6–1.8 °C hotter by 2050 and 1.0–3.5 °C hotter by the end of the century (Figure 4).

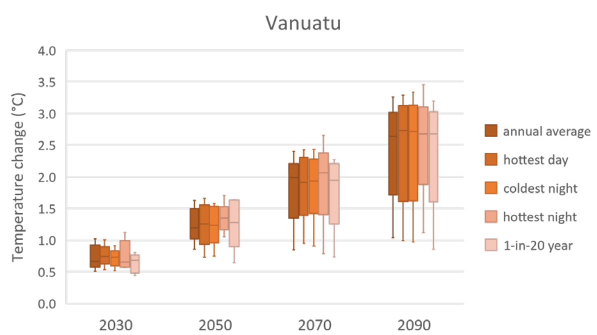


Figure 4 Projected changes in various temperature metrics: annual average, annual hottest day, annual coldest night, annual hottest night and 1-in-20 year hottest day, for the Vanuatu region over four future time periods (2030, 2050, 2070, 2090), relative to 20-years centred on 1995. The box plots show the multi-model minimum and maximum; 25th and 75th percentile; and median (50th percentile) based on the five CCAM climate model simulations under a high emissions scenario (RCP8.5).

STEP 5 Analyse climate-related impacts

When undertaking climate hazard-based impact assessments to inform climate change risk, it is important that a range of future climate change scenarios is considered. 'What would be the impact and what would we do (how would we adapt or otherwise manage or reduce risks) under a 'best-case' or 'worst-case' future climate scenario?' This is known as the 'storyline approach' [9].

Future daily maximum temperature timeseries for four years centred on 2050 and 2070 were created by adjusting four years of observed (2019–2022) maximum temperature data with the changes in temperature projected from climate models. The analysis considered low and high emissions scenarios, as well as a climate model projecting 'less warming' and a climate model projecting 'more warming' [10]. (See Climate projections for use in impact assessments factsheet for explanation of methods). Future electricity demand was estimated using these projected daily maximum temperature data in the electricity-temperature relationship derived in Step 3.

For low emissions (Figure 5 dashed lines), there was almost no change in electricity demand for the 'less warming' model, and around 4.0 % increase in electricity demand for the 'more warming' model by 2050. Under high emissions (Figure 5 solid lines), there was around 1.6 % increase in electricity demand for a 'less warming' model, and around 6.6 % increase for a 'more warming' model by 2050. Larger changes were estimated by 2070 e.g. high emissions and a 'high warming' model caused up to 11 % increase in electricity demand by 2070 (not shown).

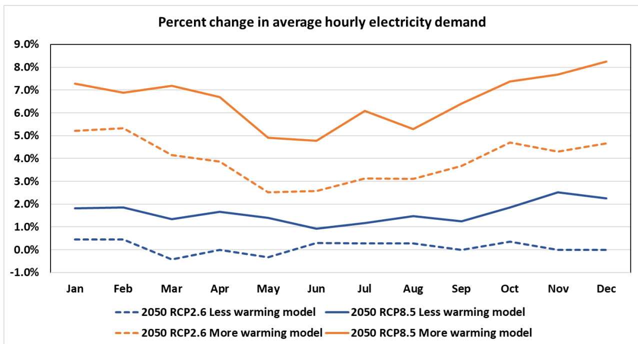


Figure 5 Per cent change in average hourly energy demand for Port Vila for 20-year periods centred on 2050 for a low emissions scenario (RCP2.6), a high emissions scenario (RCP8.5), a climate model with less warming (GISS-E2-R) and a climate model with more warming (IPSL-CM5A-MR).

This analysis assumes no other change in demand based on possible new connections to the grid over the reporting period driven for instance by population growth, industry development and/or productivity gains, and/or improved socio-economic circumstances of the population more generally (see also Step 6). International studies indicate that an increase in energy demand is likely with future climate change, e.g. 25 % increase in the tropics by 2050 [11-13], a 4 % increase in Brisbane (Australia) for a 2–3 °C warming [14, 15], and while not as tropical, a 9.2 % increase for a 1.0 °C warming in the Yangtze River Delta, China [16].

STEP 6 Evaluate other climate and non-climate factors

It is important to note that only temperature conditions are assessed in Step 5. Other climate and non-climate factors are listed below that may also influence energy demand. Further analysis around these may be prudent.

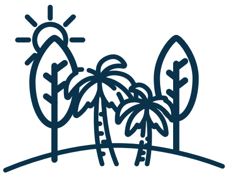
Climate factors affecting electricity demand	
Extreme rainfall	Flooding associated with extreme rainfall may damage electricity sub-stations and other critical infrastructure, disrupting electricity distribution.
Tropical cyclones	Extreme wind associated with cyclones may damage critical infrastructure, disrupting electricity generation, transmission and distribution. Extreme wind can also require shutdown of wind turbines and cause damage to solar panels, limiting renewable energy generation.
Solar radiation	High solar radiation (low rainfall and cloud cover) can enhance solar electricity generation, while low solar radiation (high rainfall and cloud cover) can limit solar electricity generation.
El Niño Southern Oscillation (ENSO)	ENSO is a large-scale driver of climate variability in the Pacific, affecting rainfall, temperature and drought [17]. In El Niño years, the South Pacific Convergence Zone (SPCZ) moves north-east, leading to drier conditions. In La Niña years, the SPCZ moves south-west, leading to wetter conditions. ENSO also affects tropical cyclone frequency [18]. Extreme La Niña and El Niño events are projected to increase in future [19, 20].
Non-climate factors	
Socio-economic	Population growth and/or industry productivity growth and socio-economic wellbeing may increase uptake of electrical and cooling appliances, thereby increasing electricity demand. On the other hand, improved climate resilience and energy efficiency within industry and local communities may compensate.
Tourism	Increased tourism may increase electricity demand for hotel air conditioning and other electrical appliances.
Transport	Electrification of private cars and public transport would increase electricity demand unless improved energy efficiency can compensate.
Other industry development and/or socio-economic drivers	New forms of industry manufacturing driven by diversification imperatives and/or enhanced technologies driven by increased uptake of more sustainable renewable energies may occur as a result of initiatives by government, development partners and the private sector.

STEP 7 Plan future adaptation

Adaptation can be incremental or transformative, with enablers and barriers, synergies and trade-offs, pathways and limits, costs and benefits. The process usually starts with consideration of adaptation options. A list of adaptation options and planning considerations for Vanuatu to reduce electricity demand increasing in a warmer climate that could be reviewed, tested, and verified as appropriate with local sectoral and community stakeholders include:

Installing ceiling insulation and building more energy efficient houses is more effective for reducing energy demand for residential cooling than increasing the energy efficiency of cooling systems or decreasing the uptake of cooling systems [21].

Passive cooling includes solar shading, window orientation, increased insulation, reflective materials and greater natural ventilation [22].



Changes to the design and built form of cities can contribute to reduction of the urban heat island effect and the impacts of heatwaves. Urban 'greening' includes parks, open spaces, forests, wetlands, and green roofs [21].

Increased energy demand may be sustainably managed by way of increased generation of and access to lower cost renewable energy supplies (e.g. mix of wind, solar and battery supply).

The National Energy Road Map (NERM) emphasises affordability, accessibility, sustainability, reliability, and the importance of transitioning to renewable energy generation [23].

STEP 8 Communicate findings

Communicating the assessment findings to key sector stakeholders is the final step of the climate hazard-based impact assessment. Multiple communication formats, co-designed and co-produced with target users in mind are more likely to support action and decision-making. The contents of this infobyte, together with other related resources shown below, can be disseminated and shared with key stakeholders to help them plan for and adapt to the changing climate.

Van-KIRAP Web Portal

Case Studies

Fact Sheets

Guidance Material

Videos

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INFRASTRUCTURE

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