ELBE

EUROPEAN LEADERS OF BLUE ENERGY

ISOLATED POWER SYSTEMS

ANALYSIS OF POTENTIAL NICHE MARKETS TO OVERCOME VALLEY OF DEATH IN WAVE ENERGY DEVELOPMENT

ELBE - European Strategic Cluster Partnership in Blue Energy

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Purpose of the project

- The world is living a transition to a cleaner and more eco-friendly energy. Different renewable energies like wind or solar, are already competing with the rest of conventional energies in the electric market. Their technology maturity allow them to have competitive prices and so, supply electricity into the main grid. However, this is not the case for other renewables energies, such as wave energy, with a lower level of maturity.

- This project aims to support wave energy development by contributing to identify potential market niches which may be a suitable target for early commercial development of wave energy converters. All these potential niches have in common that they are applications not served by the main electrical grid and therefore, prices for electricity are significantly higher, making wave energy converters to potentially become a competitive contester.

- This project has been developed as the Final Thesis of Master REM (https://www.master-rem.eu/) of Nerea Guinea in collaboration with the Basque Energy Cluster and the ELBE alliance (http://www.elbeproject.eu/), which gathers seven European clusters joining efforts for development of Blue Energy.

Two phases to identify the niches with a higher potential

The analysis carried out in the project is structured in two phases:

- **Phase 1** consisted on a first study of all possible niches with potential interest.
    - 14 niches were identified. Each niche was analysed in order to give information regarding two independent prioritization criteria:
        - Market potential, which tries to quantify the size of the potential market
        - Competitiveness, which analyses main advantages and disadvantages that wave energy presents versus other potential alternatives
    - A survey was sent to key stakeholders so that they prioritized which niches they deemed more relevant based on the information provided

- **Phase 2 (this report)** is a more in-depth analysis of the three niches that were considered more interesting based on the feedback gathered from the survey. The selected three market niches are:
    1. Isolated Power Systems
    2. Electric Supply of O&G Platforms
    3. Offshore Marine Aquaculture

  These niches has been analysed following the most suitable structure for each case depending on the available information.

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Isolated Power Systems refer to non-networked communities that depend on microgrids of usually 200kW to 5MW

Main characteristics

There are many isolated (not connected to the electrical grid) communities all over the world. These communities are located in remote areas, such as in **Arctic areas or Pacific islands**, and **need an electrical supply**. They are usually characterised by being small villages, eco resorts or military bases consuming no more than 5MW.

Today, the energy supply of these areas is mainly based on diesel and, in some cases, other renewable energies like wind and photovoltaic. However, the fact that these inhabited areas are so kept apart makes it difficult to transport diesel, raising up its price. As mentioned above, populations consuming more than 5MW will not be interesting for wave energy development because it is understood that they are better communicated and therefore, the price of the diesel would not increase, being a competitive resource. Nevertheless, diesel is a pollutant energy resource that may be replaced.

Faced with this scenario, in which the main competitor presents a high price and negative environmental aspects, wave energy has options to enter the market.

Power Requirements

Produced energy by wave energy converters (WECs) will be used for electricity generation. As the rest of possible energy sources for isolated power systems, wave energy must meet the following requirements:

- High reliability
- Easy integration in already existing diesel systems

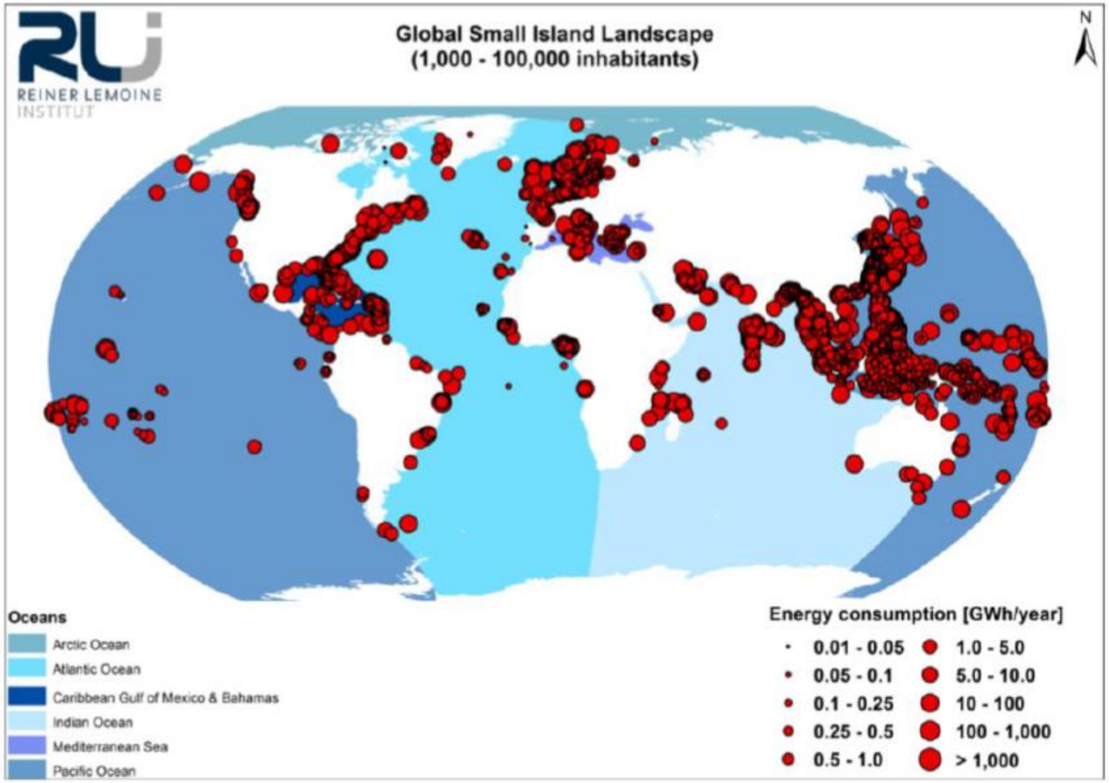
The inhabited areas with larger interest for wave energy development are those microgrids of **200kW to 5MW**. Depending on the population and the consumed power, the converter must adapt to their requirements; e.g. perhaps for a small eco resort a 100kW converter is enough even though the resource is greater.

The communities considered must be close to shore, otherwise it would be expensive to connect them with the WECs.

Isolated Power Systems are mostly found in high latitudes and in tropical areas

Location

Communities isolated from the network may be found not only in the northern or southern areas (e.g. North of Canada, Australia or Chile), but in tropical areas too. The common **characteristics** that these regions have apart from **being near the coast** are that they have **low population,** which implies a low energy demand, and that they are **difficult to access**.



Small islands worldwide

Relevant regions for the niche are mostly in high latitudes and tropical areas

High latitude regions

Some relevant markets that are located in high latitudes are:

- Canada
- United States – Alaska

These regions, due to their **large extension and low percentage of inhabitants per km²**, contain remote communities isolated from the main grid. It is not feasible to connect all of them and so, microgrids are used as energy supply.

Diesel generators are the current principal energy source. Looking for an energetic transition to make cheaper the electricity price there are several alternatives such as **wind or wave energy**. In this case, solar energy is not the best option because of the low resource that can be found in Arctic locations. Although wind energy is a mature technology with competitive prices, it is an intermittent resource while wave energy supplies a more constant power.

Tropical regions

Relevant markets that are located in the tropical areas are:

- United States – Hawaii
- Indonesia
- Pacific Islands
- Antilles
- Cameroon
- Vietnam

What almost all these regions have in common is that they are off-grid communities because they are mainly **small islands**, which suppose a difficulty in terms of connecting them to the main grid.

They main alternative to diesel is **solar energy** thanks to the high resource that is presented in these areas, but it requires batteries for a reliable supply. **Wave energy** has a more constant resource and it does not require land for its installation but, it must achieve competitive prices.

The analysis of each case has been carried out regarding **3 independent prioritization criteria**, with the **available information**

Structure

Each region/country is analysed following the same structure. The study is conditioned by the available information. For each case, there are 3 independent prioritization criteria:

- **Market analysis.** It is studied in 3 different areas.
    - Number of remote communities. An approximate value of the existing isolated communities.
    - Power demand. An average value of the power demand per community or per person.
    - Current supply source. Specification of the type of resource used by each community (diesel, solar, wind, etc.) and its cost.
- **Wave energy potential.** It is analysed in 3 different areas.
    - Wave energy density (WED). Description of the wave energy density of the site. Areas with less than 5kW/m are dismissed.
    - Bathymetry. Analysis of the depth of the water nearshore. It is not a feature to use to discard an area, but it is useful to consider it when choosing the type of converter.
    - Competitiveness. Advantages that other energy sources present.
- **Other relevant factors to be considered.** There could be several factors that can help, or not, the entry of wave energy to the market niche. These are not relevant factors when choosing the region in which implement WECs, but they are seen like an extra reason for doing it.
    - Previous facilities. It can be a positive precedent for the implementation of WECs in the niche.
    - Government targets for renewable energies. It can boost the developing of wave energy facilities.
    - Grant or subsidies for wave energy development.
    - Marine protected areas (MPAs). It can implicate that there cannot be placed WECs so, it is checked.

1. Introduction
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- Canada
- United States (Alaska)
- Indonesia
- United States (Hawaii)
- Pacific Islands
- Antilles
- Cameroon
- Vietnam

Canada has almost 70 coastal remote communities which characteristics can be interesting for wave energy development

Location of Remote Communities

Canada is a country located near the North Pole and it is divided into provinces. There are aboriginals and non-aboriginals remote communities all over the country but, only those located near the coast (up to 20km from the coastline) are interesting for wave energy. Regarding in which provinces they are, it has been done the following list:

- British Columbia (BC) with 29 remote coastal communities
- Quebec (QC) with 31 remote coastal communities, 17 in the east and 14 in the north
- Newfoundland and Labrador (NL) with 23 remote coastal communities
- Northwest Territories (NT) with 4 remote coastal communities
- Nunavut (NU) with 24 remote coastal communities

However, when considering the wave energy density (WED) atlas, as shown in following slides, some of the provinces could be neglected. The communities located in the north such as NT and NU do not have enough wave resource because their coast is in a bay, as well as the ones that are in the north side of QC.

- The **total number of isolated communities** and therefore, the ones that are going to be analysed, is **69**.

https://atlas.gc.ca/rced-bdece/en/index.html (03-08-2018)

The main power source is diesel although some communities have microgrids with access to hydropower

With the exception of some local hydropower infrastructures in QC and BC, currently, almost all remote communities rely on diesel generators for the electric supply. This means a high degree of dependence on imported fuel and on its high costs. In case of wave energy development, due to the possibility of power failure of the WECs in winter, which could be critical, the current power sources (diesel generators and hydropower plants) can be used as backup power.

West Coast: BC

- Number of remote communities: 29.
- No of the communities have year-round road or air access.
- Type: there are 16 aboriginal communities.
- Population: the mean number of inhabitants per community is 232, but there are cities like Bella Bella with 1,019 citizens and small communities with 5 – 30.
- Power source:
    - There are 3 local grids that supply 10 communities. 2 of those grids use hydropower.
    - There are in total 3 hydro plants of 5, 10 and 25MW.
    - Diesel is the main power source. 13 communities have a capacity lower than 300kW, 2 have a capacity of about 1MW and another one of 13MW. Its average price is 0.4$/l.
- The **mean annual energy demand per person is about 27MWh** although there are few data for it to be an accurate information.

East Coast: QC and NL

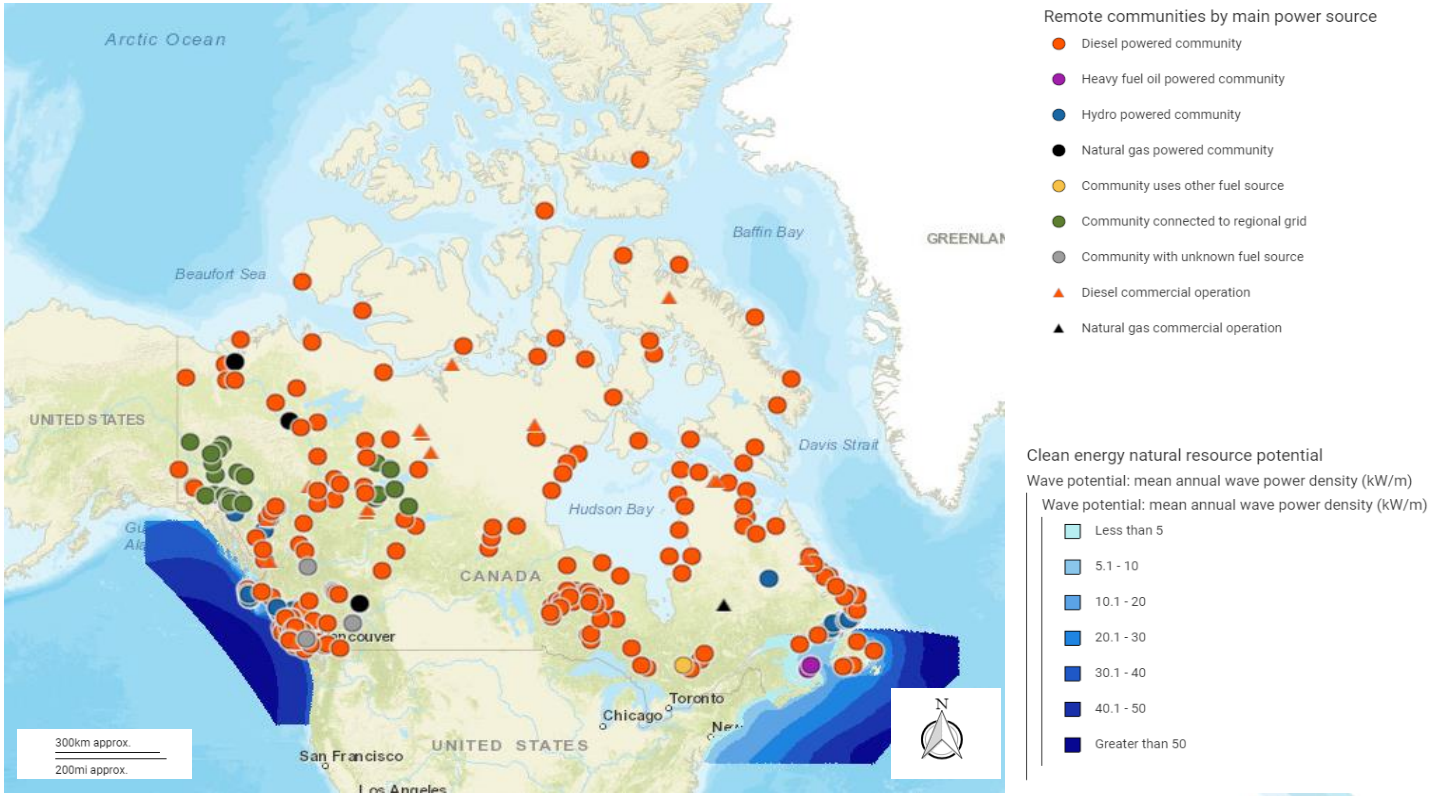
- Number of remote communities: 17 and 23 respectively.
- In QC there is only 1 community with air access while in NL 4. Other 11 communities have year-round road access.
- Type: there are 2 and 10 aboriginal communities.
- Population: while in QC the mean number of inhabitants per community is 1,276 in NL the towns are smaller, with 304 people as an average value.
- In QC[1] there are 2 local grids that supply 13 communities, one based on hydropower (75MW) and the other one on heavy fuel oil (67MW). The rest of communities (2) are supplied with diesel generators of 2 – 5MW and its mean price is of 0.56$/l.
- In NL 9 communities use 3 local grids base on diesel and one of them also on a hydropower plant of 25MW. The rest of communities are supplied with diesel that has a mean price of 0.9$/l. One of those has also a wind farm of 600kW.
- The **mean annual energy demand per person is about 12MWh** in QC and 9MWh in NL.

https://atlas.gc.ca/rced-bdece/en/index.html (03-08-2018)
[1] http://www.hydroquebec.com/data/affaires/pdf/aff-reseaux-autonomes-fevrier2017-en.pdf

The west coast of Canada has the greatest wave energy resource followed by the southeast coast

Location of Remote Communities & Wave Energy Resource

Wave energy density (WED) is greater in the west coast, 10 – 40kW/m, where 21 isolated communities still depending on the fossil fuels as main resource. Regarding the east coast, the communities of Quebec have a WED up to 10kW/m, what is a low potential. However, Newfoundland and Labrador have a WED range of 10 – 30kW/m with 17 communities depending on the fossil fuels.

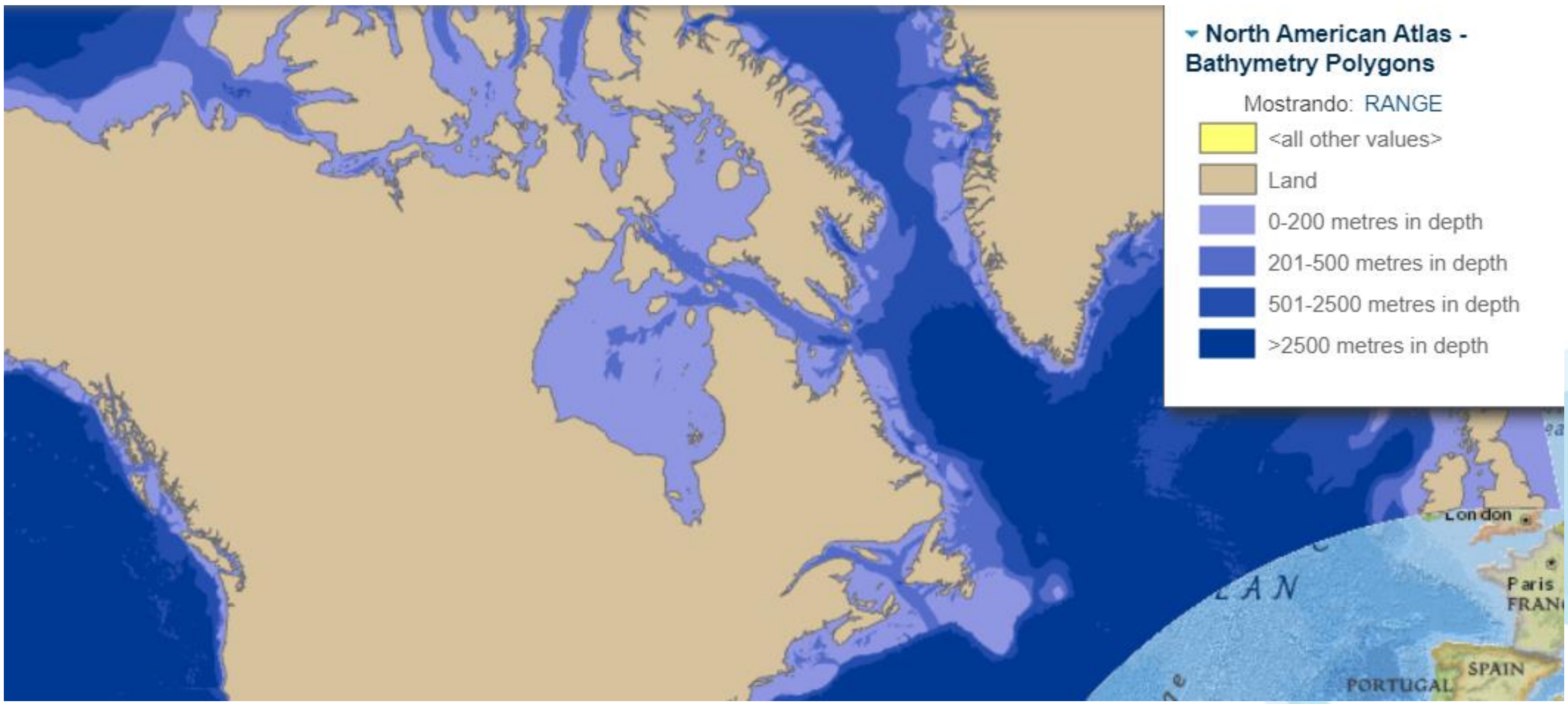


Location of Canada's remote communities and WED map

The shallow waters usually have less wave resource while the deep waters usually have greater resource

Bathymetry of the Coastline

As it is shown below, the east coast formed by NL and QC provinces has depths up to 500m, what can be considered as shallow or intermedium waters. On the other hand, BC that is in the west coast has shallow waters near shore, but the depth increases rapidly reaching 2,500m.



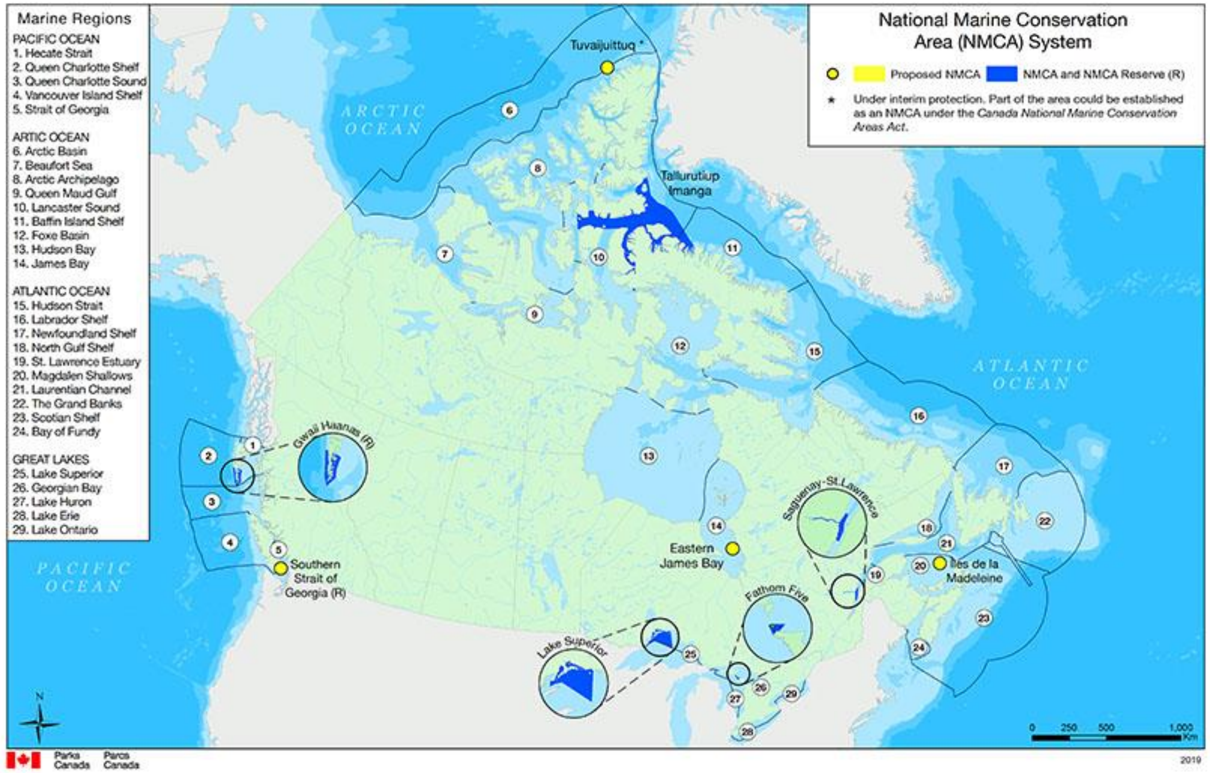
Bathymetry map of Canada

Today, the WECs implementation in any remote community is not affected by a marine conservation areas

Marine Protected Areas

As WECs cannot be installed in marine protected areas (MPAs), it is worth mentioning that although in Canada there are several marine reserves, only one could suppose a problem: Gwaii Haanas. In this case, the remote communities located in that area are in the boundaries avoiding the conservation area.

However, there are two proposed MPAs that could affect some communities in the future: Southern Strait of Georgia in the southwest coast and Iles de la Madaleine in the east coast that surrounds communities connected to Cap aux Meules local grid.



MPAs of Canada

Canada has a abundant renewable electric generation but until now, there is no wave power supply

Future Expectations

- Canada's target is to achieve 90% of the electric system supply to be clean resources by 2030.
- Today, renewable energies represent 66% of Canada's electricity generation, one of the cleanest electricity systems in the world: 59.3% is hydropower, 4.4% corresponds to wind power, biomass power is 1.9 % and solar power is 0.5%.
- Despite the fact that there are not current active project development plans related to wave energy in Canada, there is a research centre. **Wave Energy Research Centre (WERC)** is a field station used for long term research and development projects. It is located in the wharf in Lord's Cove, Newfoundland. It has 6 mooring sites within 1.5km of the centre. The activities that take places in this research centre are, among others, wave data collection, device mooring site and house different infrastructures like a Multi-Trophic pilot aquaculture farm, a lab and a workshop space.

https://www.climatescorecard.org/2017/09/canada-renewable-energy/
https://www.collegesinstitutes.ca/applied-research/wave-energy-research/
https://www.novainnovation.com/petitpassage
https://www.dpenergy.com/projects/canadauiscetapa/

Conclusions

- The selected study areas based on the wave energy density are British Columbia in the west coast with 29 isolated communities and Quebec and Newfoundland and Labrador in the east coast with 40 communities.
- The annual mean power demand is of about 27MWh/person in the west coast while in the east in a little bit lower, 12MWh/person.
- The main resource for the electric generation are diesel generators, which means a constant need of importing oil. Its costs are quite high because of the transportation to those remote sites. The average price varies depending on the province, from 0.4$/l in British Columbia to 0.9$/l in Newfoundland and Labrador. However, Canada has its own natural resources capable of powering its communities.
    - Hydropower is the second main energy source. 8 of the west coast communities and 18 of the east coast, have already hydropower facilities. Thanks to that, they do not have the problematic of the fuel dependence and the high costs.
    - Wave energy density is greater in the west coast, 10 – 40kW/m, where 21 isolated communities still depending on the fossil fuels as main resource. Regarding the east coast, the communities of Quebec have a WED up to 10kW/m, what is a low potential. However, Newfoundland and Labrador have a WED range of 10 – 30kW/m with 17 communities depending on the fossil fuels.
- After considering the wave energy potential and the electric generation type and, confirming that none of the MPAs affect the current isolated communities, there still being 38 that fulfil the requirements to develop a wave energy farm and still rely on the costly diesel.
- Today, there are supportive targets set by the government for renewable energies and some projects of marine energy close to Newfoundland and Labrador's communities but not concretely of wave energy.

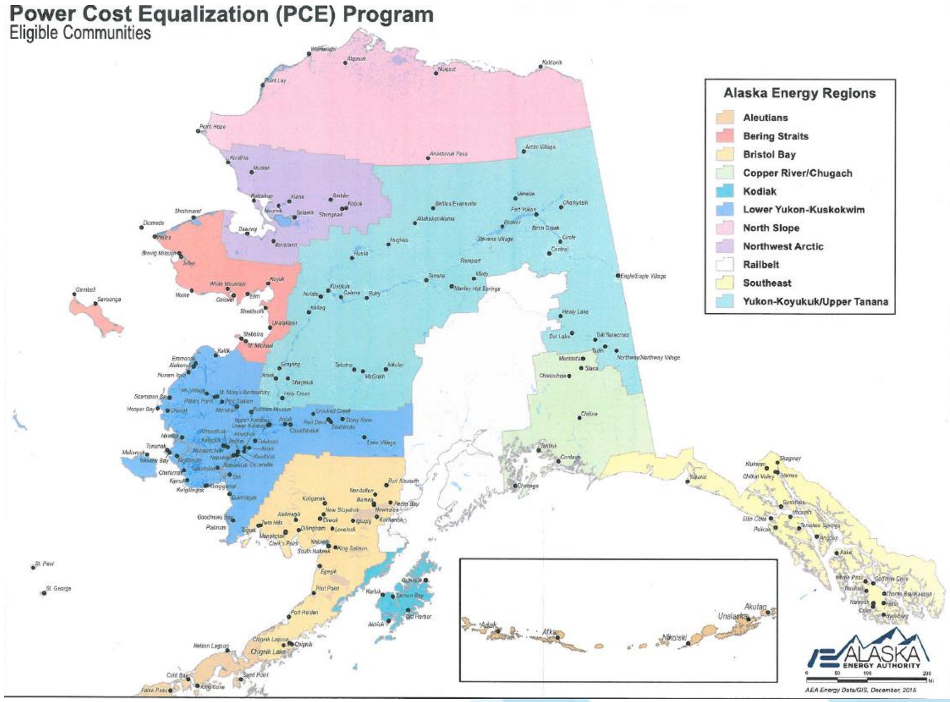
Alaska is known for its remote communities and their difficulty to access reliable electric supply

Location of Remote Communities

Alaska is the northern state of the United States. It is divided in 11 regions but, when considering the WED (shown in following slides), some of those regions have been dismissed due to the lack of interest for wave energy development, the ones with higher latitudes. The coastal communities of each considered region are listed below:

- Aleutians (AL), 10 communities
- Bristol Bay (BB), 12 communities
- Copper River/Chugach (CR), 3 communities
- Kodiak (KO), 5 communities
- Lower Yukon* (LY), 12 communities
- Southeast (SE), 19 communities

The total amount of **isolated communities** is of **61**.



Map of the remote communities of Alaska

**In this region, only communities of the half south are considered because of the low WED of the rest.*

Considering both residential and community facilities, the mean power demand per community is 0.9GWh/year

Power Demand

There are two types of electric customers in each region: residentials and community facilities. The **average annual demand per residence** is of **3MWh** and per community is 632MWh. Adding the demand of the community facilities, the **total average demand per community** is of **921MWh/year**.

The data of the communities of each region has been summarised in the next table.

Region	Avg. population	Avg. residential customers	Avg. annual energy demand per residence (MWh)	Avg. annual residential energy demand (MWh)	Avg. total energy demand (MWh)
Aleutians	719	143	2.92	412	869
Bristol Bay	450	213	2.7	668	849
Copper River/Chugach	857	346	2.9	1,158	1,819
Kodiak	113	52	2.91	154	222
Lower Yukon	443	110	4.04	445	540
Southeast	568	308	2.99	956	1,237

Summary of the residences, their demand and total power demand of each region

Communities are usually powered by fossil fuels, which transportation increases considerately the cost of the energy

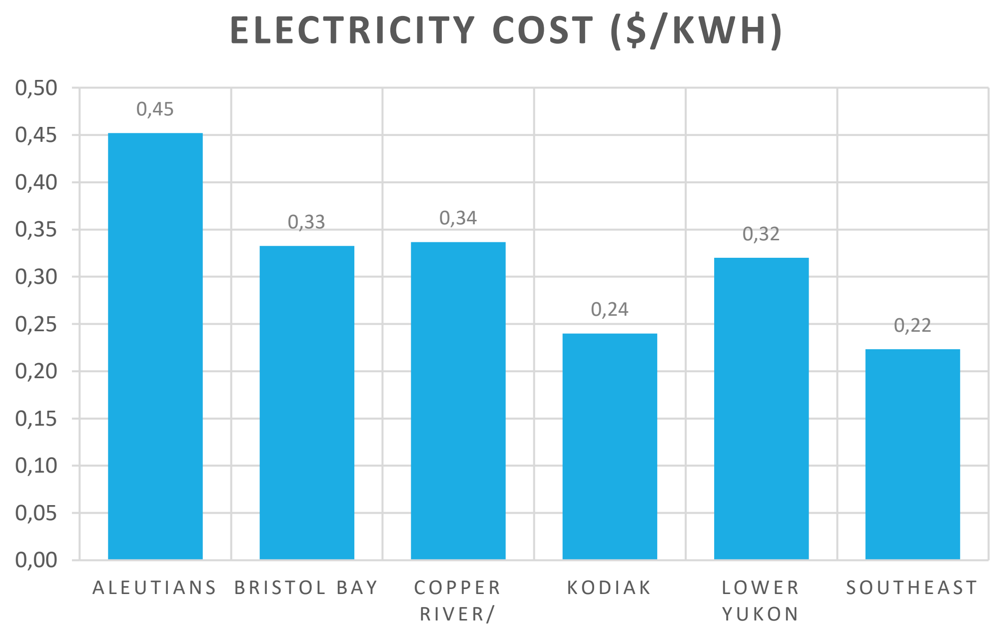
Energy Source & Electricity Costs

Electric generation power source type

Most of the remote communities of Alaska have as main source diesel generators. The **fossil fuels account for more than 70% of the resource used** for the electric generation in the whole state. Its transportation is required in most of the communities. Southeast region, however, has greater renewable generation percentage thanks to its **hydropower** facilities, which account for 26% of the electric generation of the state. It is worth highlight also the wind farm located in Kodiak island. This resource accounts for 3% of the total generation.

Electricity tariffs

Due to the necessity of transporting fossil fuels, the main source, the **average of the electricity costs** is quite high, of **0.32$/kWh**. The remote communities located in Aleutians have the highest tariffs, exceeding in several communities the 0.7$/kWh.



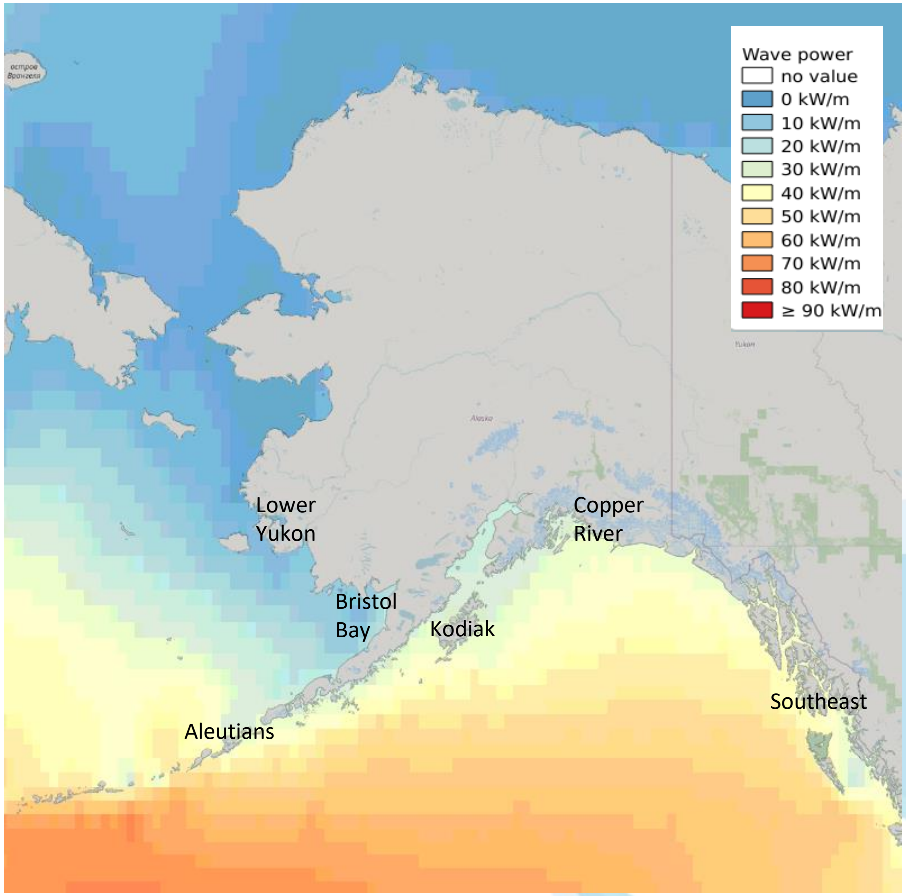
http://cnee.colostate.edu/wp-content/uploads/2018/09/State-Brief_AK_Sept-Update.pdf
http://www.akenergyauthority.org/LinkClick.aspx?fileticket=qgKDRJywe2M%3d&portalid=0

Alaska, especially in the south coast, has very high wave energy density

Wave Energy Resource

As said before, in the northern regions of Alaska there is almost no wave energy resource. Each region can be classified with respect to wave energy density (WED) as:

- Low, 10 – 20kW/m. Lower Yukon, which is the northern region, is the one with lower wave potential.
- Medium, 20 – 30kW/m. Bristol Bay.
- High, 30 – 40kW/m. Mainly in the Southeast, Copper River and Kodiak regions.
- Very high, > 40kW/m. In Aleutians the wave potential is higher than 70kW/m.



Map of the WED in Alaska

Hydropower and wind energy are the main possible competitors for renewable generation in Alaska

Competitiveness

Wind power

- There is a high potential of wind in the west coast of Alaska, including Lower Yukon, Bristol Bay and Aleutians regions.
- Installations: There are already wind farms in Alaska like in Kodiak city, but none in remote communities.

Hydropower

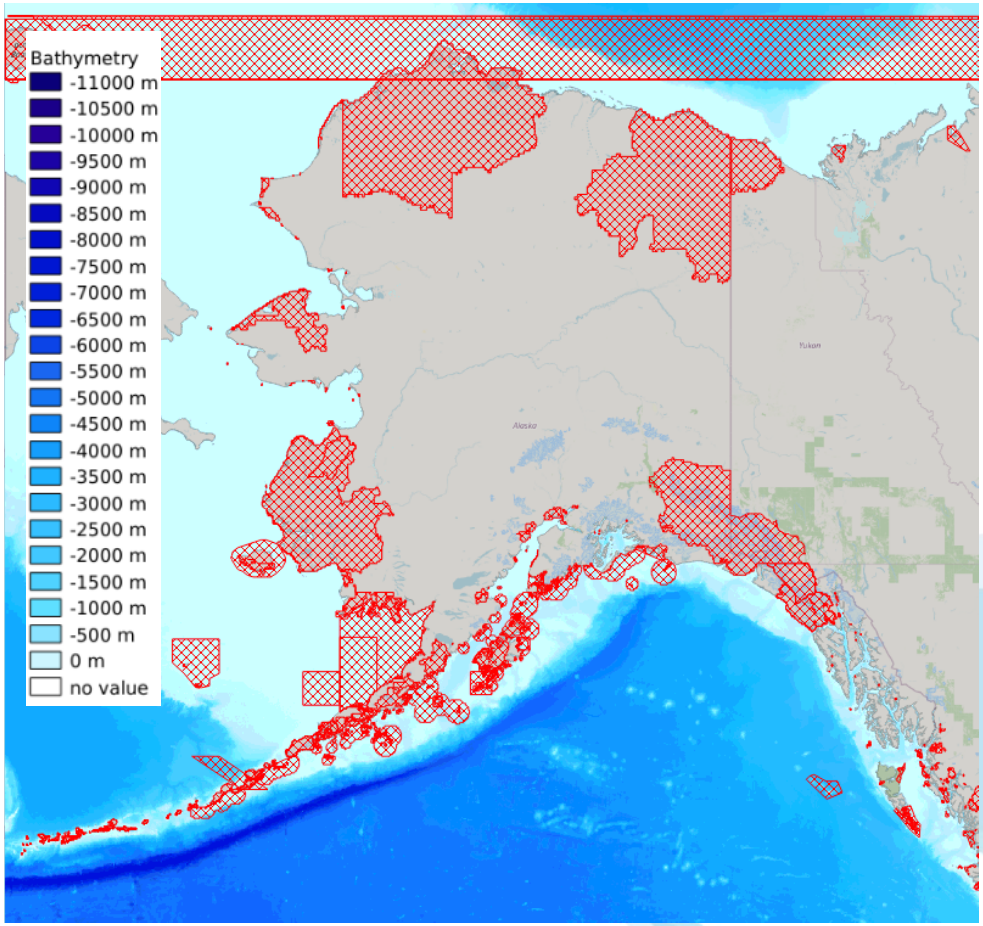
- Most of the renewable electric generation comes from this source thanks to the geographical characteristics of the state.
- Installations: Cordova, CR (6.6MW), Craig, SE (4.5MW), Klawock, SE (1.9MW) and Skagway, SE (7MW)

http://cnee.colostate.edu/wp-content/uploads/2018/09/State-Brief_AK_Sept-Update.pdf
https://www.eia.gov/state/?sid=AK#tabs-3

Generally, Alaska is surrounded by shallow waters

Bathymetry of the Coastline

As it can be seen in the bathymetry map, the Alaska's coastline is surrounded by shallow waters. Aleutians is the regions that has deepest waters.



Bathymetry map of Alaska with the MPAs in red

Alaska is mostly covered by different types of MPAs

Marine Protected Areas

As WECs cannot be installed in marine protected areas (MPAs), it is worth analysing them. Alaska is an area mostly covered by National Wildlife Refuges and by Federal Fishery Habitant Conservation Zones. These MPAs have been mapped in red in the previous slide. Some of the most affected regions are listed below:

- Kodiak. The whole island is covered by the National Wildlife Refuge.
- Bristol Bay. There are 3 communities surrounded by the National Wildlife Refuge, 2 by Critical Habitat Areas and the rest by Federal Fishery Habitant Conservation Zone. Therefore, there is no remote community that is not affected by an MPA.
- Lower Yukon. The whole region's coast is surrounded by the National Wildlife Refuge except for one community, Goodnews Bay.
- Aleutians. It is also completely surrounded by the National Wildlife Refuge.

There were two proposals of tidal energy projects in Railbelt

Future Expectations & Status of Marine Energy

Alaska wants to achieve the 50% of renewable electric generation by 2025.

There were some marine energy projects proposed in Railbelt region, where there are no isolated communities although none of them were wave energy projects:

- East Foreland Tidal Energy Project. In 2010, Ocean Renewable Power Company (ORPC) proposed a tidal energy project in Cook Inlet, Alaska. This project would be formed by several TideGen turbines of 150kW. The total capacity of the plant would be of 5MW and it would be connected to the shore station that would be in Kenai Peninsula. In 2016, 5 years after achieving a preliminary permit, the project developer surrendered that permit.
- Turnagain Arm Tidal Electric Generation Project. The project owned by Turnagain Arm Tidal Energy Corporation (TATEC) had the preliminary permit in 2014. It would be located between Fire Island and Point Possession. The capacity of the plant would be of 240MW.

http://cnee.colostate.edu/wp-content/uploads/2018/09/State-Brief_AK_Sept-Update.pdf
https://www.offshore-energy.biz/orpc-drops-cook-inlet-tidal-project-license/
https://www.hydroreform.org/projects/turnagain-arm-p-13509

Conclusions

- The coastal isolated power communities in regions with enough WED are 61. Considered regions are Lower Yukon, Bristol Bay, Aleutians, Kodiak, Copper River and Southeast.
- The mean annual power demand per residence is of 3MWh, and considering both residential and community facilities demand, the average annual power demand per community is of 921MWh.
- In Alaska there is not a problem of electrification but of oil dependence. More than 70% of the resources of the electric generation are fossil fuels, mostly imported. For this reason, they have high electric tariffs, 0.32$/kWh as an average cost, exceeding the 0.7$/kWh in some of the communities of Aleutians. This problem can be solved by using the renewable resources that the state has.
  - Hydropower is the main renewable source used, there are already several installations especially in Southeast. In the case of the wind energy, there is high potential but almost no facilities.
  - There are proposals of marine energy projects but for tidal energy.
- When regarding the wave energy density in the region, it can be confirmed the great potential that Alaska has, especially in the south coast where the WED can reach the 70kW/m. If considering this factor, all the isolated power communities are suitable for being supplied by a wave energy farm.
- The MPA is other fact that must be considered. There are 3 regions, Kodiak, Bristol Bay and Aleutians, that are completely covered by different types of MPAs. Lower Yukon it is totally surrounded by an MPA except for 1 community. This means that out of the initial 61 remote communities, there are still 23 suitable ones, mainly in the regions of Southeast and Copper River.
- There is a non-official target of achieving 50% of renewable electric generation by 2025 but, until now, there is only a 25%.

In Indonesia, which is a enormous archipelago, provinces with low electrification rate are interesting for wave energy development

Location of Remote Communities

Indonesia is an archipelago formed by more than 18,000 islands. Despite having an electrification rate of the 95%, there are several regions where that rate is quite lower, around 50 – 70%. Those are the regions are interesting for wave energy development and so, are going to be analysed.. The selected provinces are listed below with the number of settlements or communities that each has:

- West Nusa Tenggara (WNT), 49 communities
- East Nusa Tenggara (ENT), 1,569 communities
- Maluku (MA), 673 communities
- North Maluku (NMA), 537 communities
- Papua (PA), 4,665 communities
- West Papua (WPA), 1,408 communities

It is worth highlighting that not all communities have to be in the coast, but there is not enough data to give a more accurate information. The total amount of **isolated power communities** is of **8,901**.

Map of the provinces of Indonesia

The energy demand vary a lot from one province to another due to the difference in population

Power Demand

There is a big difference in the total number of households per province, e.g. in Papua there are more than 400,000 while in West Nusa Tenggara there are no more than 8,000. The **mean annual energy demand per household** is quite constant for all of them, of **303kWh**, but due to the large difference of inhabitants, the installed capacity per province is also different, from 100MW in Papua to 2MW in West Nusa Tenggara. However, the average annual energy demand per community is higher in West Nusa Tenggara, with 50MWh, than in Papua, 27MWh, or in West Papua, 14MWh.

The data of the communities for each province has been summarised in the next table.

Province	Nº communities	Avg. households per community	Avg. annual energy demand per community (MWh)	Total power capacity of the province (MW)
West Nusa Tenggara	49	167	50.7	2.1
East Nusa Tenggara	1,569	66	19.9	26.0
Maluku	673	97	29.3	6.5
North Maluku	537	112	34.1	15.2
Papua	4,665	88	26.6	102.9
West Papua	1,408	48	14.5	17.0

Summary of the communities, their population and power demand and installed capacity

It is remarkable the low electrification rate and the high percentage of fossil fuel power generation

Electrification Rate

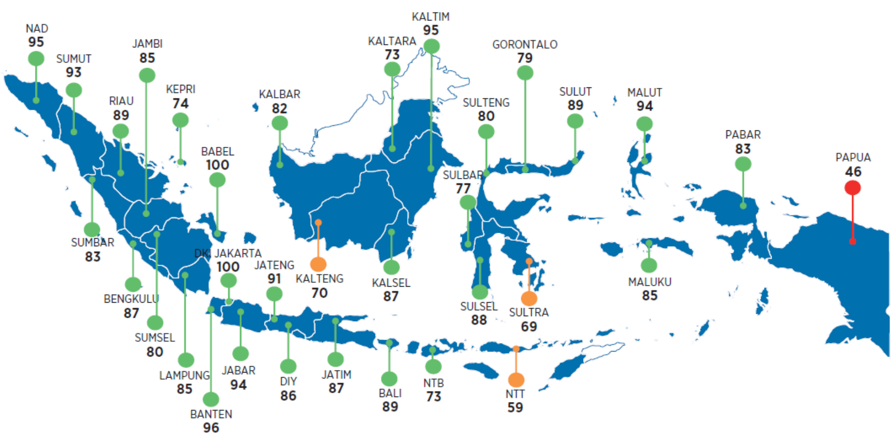
Indonesia has a high electrification rate, around 95%. However, some of its provinces have a significant lower rate. Papua is an example of this, only the 46% of the population have access to the electricity.

In the figure below it can be seen all the rates per province.

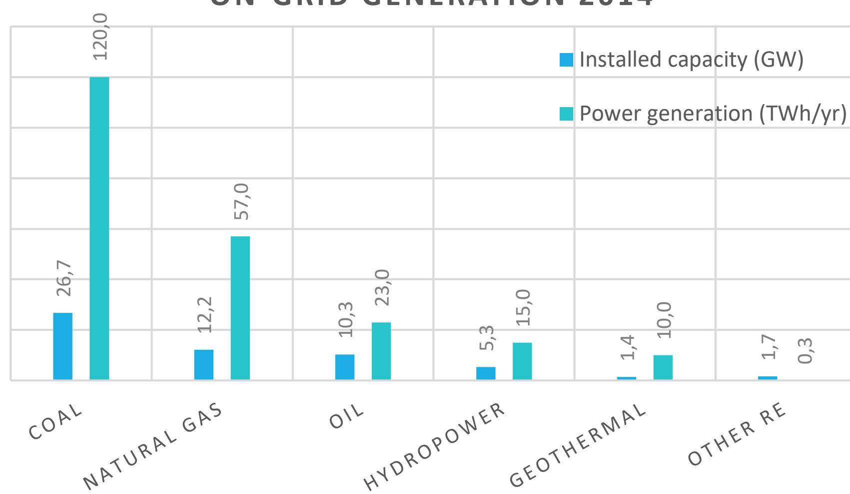
Energy Source

The energy mix of Indonesia is formed mostly by fossil fuels, which add up to 85% of the generation. The selected regions only consume 4% of the total national electricity.

Electrification rate (% of population)



ON-GRID GENERATION 2014

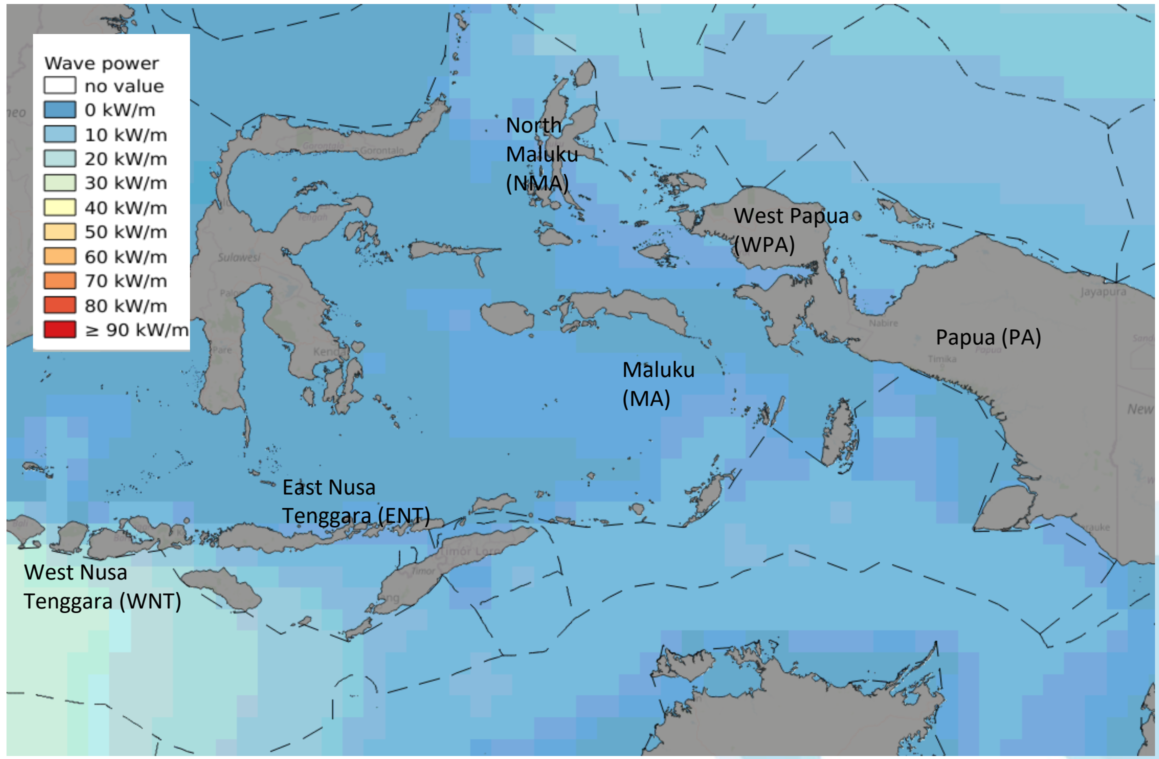


The wave energy resource varies from one island to another, being greater in both Nusa Tenggara provinces

Wave Energy Resource

The islands of the provinces are spread across 8 different seas, and therefore the potential of the waves changes from one island to another. Each province can be classified with respect to WED as:

- Very low, < 10kW/m. The south coast of PA, southwest islands of NMA, north islands of MA and the north coastline of ENT have almost no wave energy potential.
- Low, 10 – 20kW/m. WPA, north islands of NMA, the north coastline of PA, south islands of MA, southwest of ENT and the north coast of WNT have a low potential, which could be enough for low energy demand.
- Medium, 20 – 30kW/m. The southwest of ENT and the south coast of WNT have the greatest wave energy potential.



Map of the WED in the Indonesian islands

There are few renewable installations in the selected provinces

Competitiveness

Solar PV power (dismissing solar water heaters)

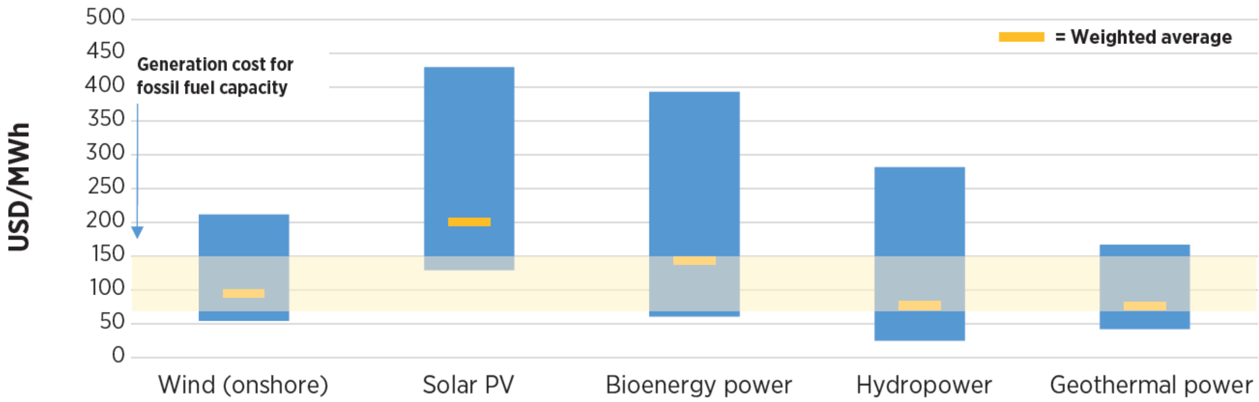
- There is great solar resource in the country and in addition, there is a support of the market through the tariff: compensations for the sold electricity from rooftop systems.
- Installations: Kupang, ENT (5MW)

Hydropower

- It is the main renewable source used for the electric generation with an installed capacity of 5.3GW. Most of the hydropower comes from large facilities.
- Installations: Nusa Tenggara

Geothermal power

- This resource, although high, is mostly located in the island of Java. In the country, it has a total installed capacity of 1.4GW.

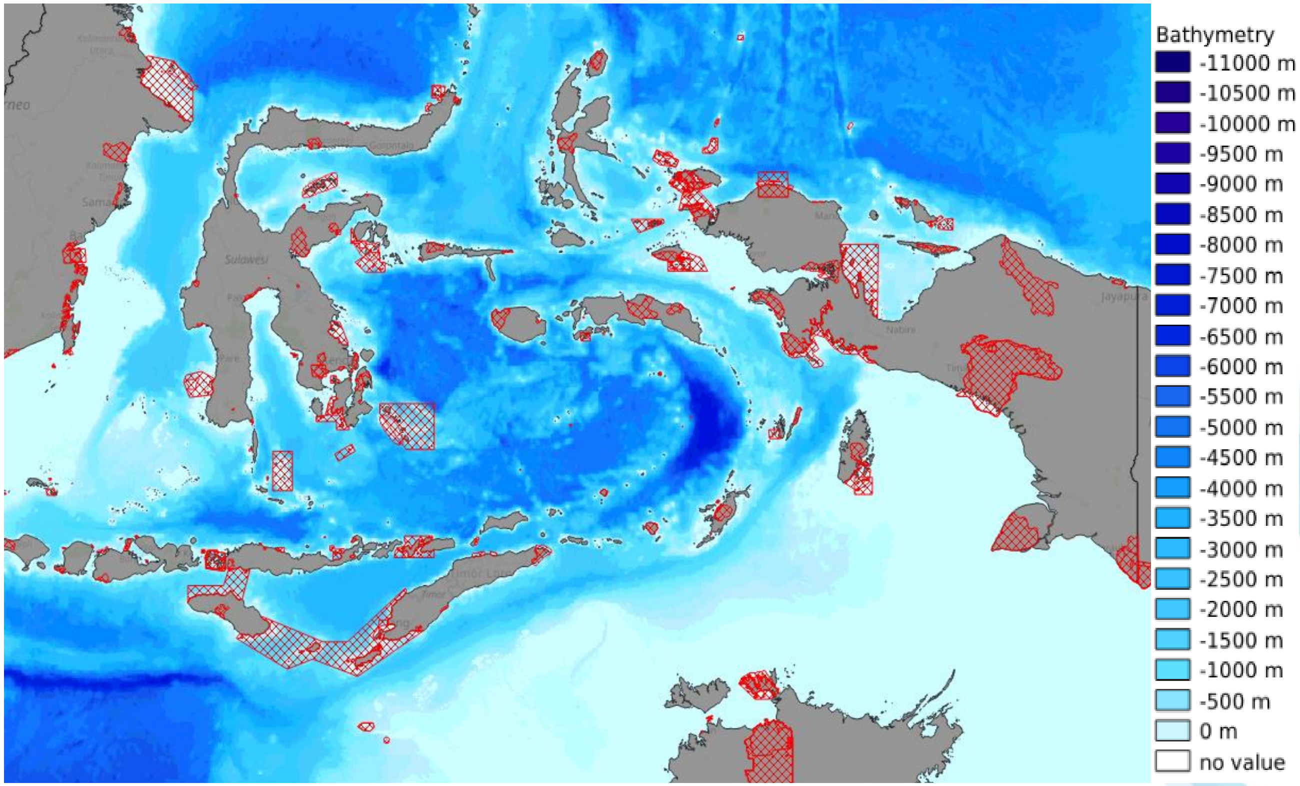


Range and average cost of electricity for various types of power generation in Indonesia

Indonesian Islands are usually surrounded by very shallow waters

Bathymetry of the Coastline

As it can be seen in the bathymetry map, the Indonesian coastline is surrounded by very shallow waters. The north coast of West Papua is the province with deepest waters.



Bathymetry map of Indonesian islands with the MPAs in red

There are several MPAs due to the touristic activity but none of them cover completely the coastline of any province

Marine Protected Areas

As WECs cannot be installed in marine protected areas (MPAs), it is worth analysing them and more specially in this case, where almost all the islands live partially from the touristic activities such as scuba diving. These MPAs have been mapped in red in the previous slide. Some of the most relevant ones are listed below:

- East Nusa Tenggara. There are several MPAs but none of them cover the whole coast of the province. The most noteworthy are Tirosa Batek and Sumba Strait National Parks.
- Maluku. The most important MPA is located in the islands of the south part of the province, named Kepulauan Aru Bagian Tenggara.
- West Papua. There are large MPAs but none of them cover completely the coast. Some examples could be Cendrawasih and Jamursba Medi National Parks and Kaimana and Selat Dampier.
- Papua. There are two main MPAs, one National Park, Gurung Lorentz, and a Wildlife Reserve, Palau Dolok Kimaam.

https://www.ocean-energy-systems.org/ocean-energy/gis-map-tool/

There are several proposed tidal energy projects, two of them in both West and East Nusa Tenggara provinces

Future Expectations & Status of Marine Energy

Indonesia has set a target for achieving the 25% renewable power generation by 2025. In addition, it has established for the same year different goals with respect the installed capacity of each renewable source, including marine energy. These targets are summarized in the following table.

Renewable power generation targets by 2025 (GW)

Enery source	Installed capacity, 2014	Installed capacity, target
Large hydropower (> 10MW)	5.1	18.3
Small hydropower (< 10MW)	0.2	3.0
Bioenergy	1.7	5.5
Geothermal power	1.4	7.1
Solar PV power	0.0	6.4
Wind power	0.0	1.8
Marine power	0.0	3.1

There are several marine energy projects in Indonesia and two of them in the studied provinces. However, none of them considers wave energy converters.

- Nautilus. It is a very ambitious project of SBS company signed in 2015 that will be located near Lombok coast (West Nusa Tenggara). The facilities will have an installed capacity of 150MW of tidal energy. The project will consist on 3 phases: an initial deployment of 12MW in December 2020, progressively increasing to 70MW and then to 150MW by 2023.
- Tidal Power Plant Larantuka. This project was proposed in 2015 by Tidal Bridge company in East Nusa Tenggara and is expected to be completed by 2020. Its installed capacity will be of 30MW for what 4 tidal bridge elements will be installed with 32 tidal turbines. This structure will also be used as a civil bridge connecting Flores and Adonara islands.

https://www.irena.org/publications/2017/Mar/Renewable-Energy-Prospects-Indonesia
http://www.sbsintl.com/nautilus-150mw-project.html
https://www.tidalbridge.com/projects/tidal-power-plant-larantuka-indonesia-3/

Conclusions

- The Indonesian provinces with lowest electrification rate have been considered, 6 in total. There are 8,901 communities and the mean annual energy demand per community is 29MWh. The population density is quite higher in provinces such as Papua, West Papua and East Nusa Tenggara.
- More than 85% of the resources for electric generation are fossil fuels. Although they are cost competitive, Indonesia wants to use its own resources.
    - Hydropower is the renewable source with higher installer capacity and in Nusa Tenggara there are plants of both hydropower and solar energy.
    - In both West and East Nusa Tenggara there are tidal energy proposed projects.
- When regarding the wave energy density in the region, there are mainly two coastlines with enough resource: the south coast of ENT, WNT and MA and the north coast of NMA, WPA and PA. But the region with greater wave energy potential is West Nusa Tenggara. As there is no information about the exact location of the communities, the ones with low potential might be dismissed but, if considering the two provinces with greater WED (East and West Nusa Tenggara) there still being 1,618 communities.
- The MPA is other fact that must be considered. In this case, although there are important National Parks and Wildlife Reserve, none of them completely affect any of the provinces.
- The government has set a target of achieving 25% of the power generation from renewable sources by 2025. In addition, it has specified the installed capacity per renewable source type that must be deployed by that year, considering marine energy as one of its goals.

Hawaii has a great dependence of fossil fuels, despite not having electrification problems

Location of Remote Communities

Hawaii (HI) is one of the United States' (U. S.) states. It is formed by several islands in the middle of the Pacific Ocean. Although not having any electrification problem, it has a great dependence of fossil fuels. Its location implies a difficulty when transporting the fossil fuels, which supply a large percentage of the electric generation.

For these reasons, even though larger in terms of population than other isolated power systems, Hawaii is a very interesting region for wave energy development.

The islands that conform Hawaii are:

- Oahu
- Hawaii
- Maui
- Kauai
- Molokai
- Lanai
- Niihau
- Kaho'olawe, uninhabited

Map of the Hawaiian Islands

Oahu has the greatest power capacity in a state where the average cost of the electricity is of 0.36$/kWh

Power Demand & Electricity Costs

Oahu, as the main island, has the greatest installed power capacity. Regarding the annual power demand per capita, all the islands have similar values, between 5.4 – 6.4MWh, with the exception of Molokai, which has lower demand.

Regarding the electricity cost, the average value is of 0.36$/kWh.

Notice that as the population of Niihau is really low, there is no data available about its power demand.

Island	Popullation	Energy demand (GWh)	Power capacity (MW)	Avg. energy demand per capita (kWh/yr)	Electricity tariffs ($/kWh)
Hawaii	186,738	1,195	292	5,652	0.37
Oahu	953,207	7,561	1,778	5,916	0.31
Kauai	66,921	452	431	6,036	0.37
Lanai	3,135	27	10	5,364	0.40
Maui	144,444	1,200	262	6,396	0.34
Molokai	7,345	34	12	3,900	0.37
Niihau	170	-	-	-	-

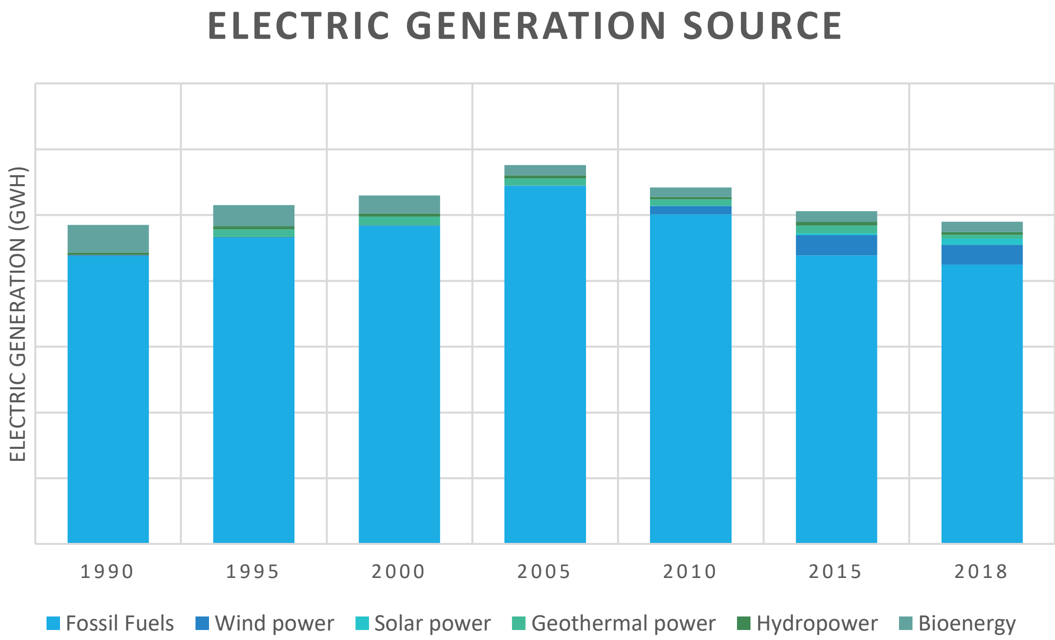
Summary of the population, power demand and electricity tariffs per island

https://energy.hawaii.gov/wp-content/uploads/2019/07/2019-FF_Final.pdf
https://energy.hawaii.gov/wp-content/uploads/2014/11/HSEO_FF_Nov2014.pdf

Oil still being the main energy source despite the necessity of importing it from the continent

Energy Source

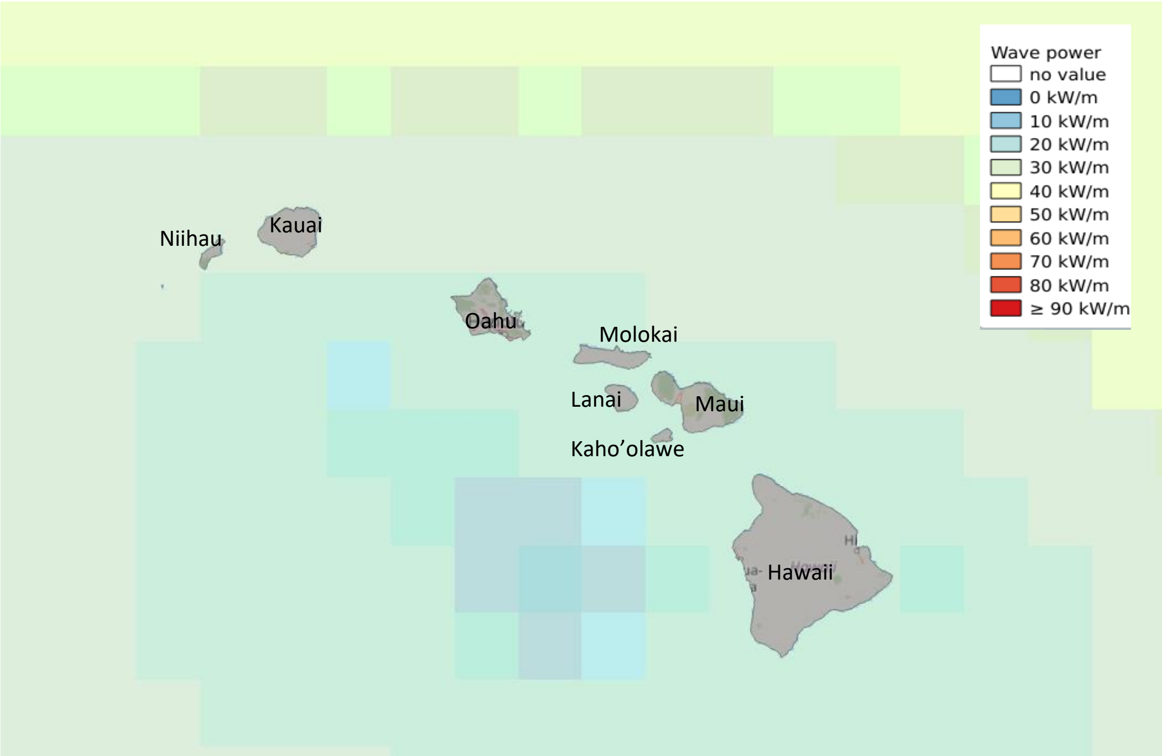
In Hawaii the main electric generation source are fossil fuels. Due to its isolated situation, the cost of importing the fuel from the continent is really high, creating a dependence of the outside because none of the islands produce this kind of resource. With the aim to face this situation, Hawaiian government has established some steps to achieve a complete transition to renewable energies. Proof of that is the greater percentage of them in the energetic mix. In 2018, their sum was 13.3% of the electric generation, underlining the presence of wind energy, solar energy, hydropower, geothermal energy and bioenergy.



The Hawaiian islands are a optimum location in terms of wave energy density

Wave Energy Resource

Thanks to being in the middle of the Pacific Ocean, all Hawaiian Islands have great wave energy potential, with an average density of 20 – 30kW/m. It is worth mentioning that almost all the islands follow the same pattern: greater WED in the north coast than in the south although being a small variation.



Map of the WED in the Hawaiian Islands

https://www.ocean-energy-systems.org/ocean-energy/gis-map-tool/

Solar energy is the most used renewable energy resource for electric generation followed by wind energy

Competitiveness

Solar PV power (only considering large ground mounted solar farms)

- In the recent years, it has been experienced an unprecedented growth in solar generation thanks to the abundant solar resource and the high prices of the electricity.
- Installations: Oahu (284MW), Maui (75MW), Hawaii (47MW), Kauai (14MW) and Molokai (6MW). Proposed installations: 426MW
- Average price: 0.161$/kWh

Wind power

- It is the second most used renewable source although in Kauai, there cannot be any wind farm due to the seabird protected area.
- Installations: Oahu (99MW), Maui (72MW) and Hawaii (35MW). Proposed installations: Oahu (71MW)
- Average price: 0.175$/kWh

Hydropower

- It was the first renewable energy used for electric generation in the state. It is fully reliable, but it can be limited by the fluctuations of the water level. Thanks to Hawaii's geographical characteristics, it does not need dams.
- Installations: Hawaii (17MW), Kauai (9.5MW) and Maui (500kW). Proposed installations: Kauai (31MW) and Maui (40MW)
- Average price: 0.132$/kWh

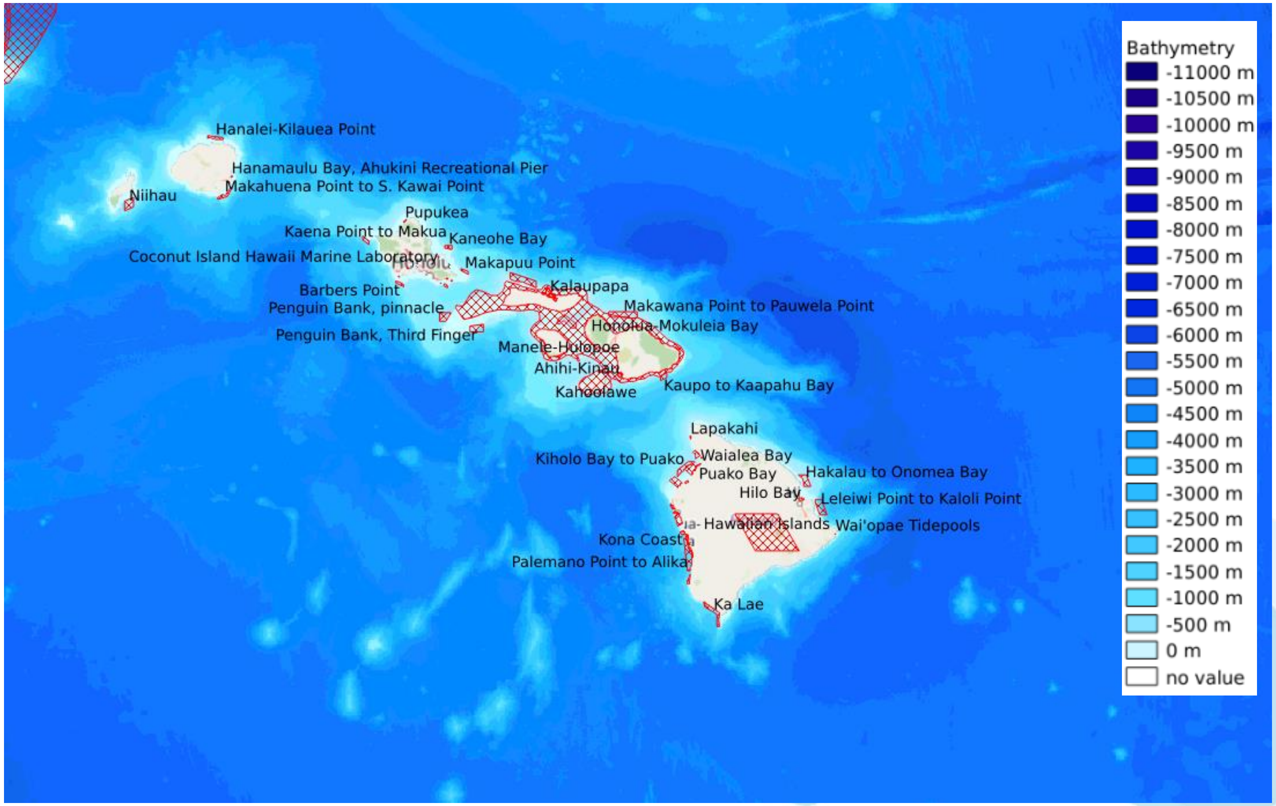
Geothermal power

- Hawaii and Maui islands have volcanic activity and that means a great geothermal potential. There was a 38MW plant in Hawaii that closed after the Kilauea eruption in 2018.
- Proposed installations: Hawaii (40MW) and Maui (40MW)
- Average price: 0.104$/kWh

Hawaii islands are surrounded by deep waters

Bathymetry of the Coastline

The Hawaiian Islands are characteristic for their topography. The mountains altitude increases rapidly from the sea level as well as the depth of the water, which rises quickly near the coast of the islands.



Bathymetry map of Hawaii with the MPAs in red

There are 2 MPAs that cover 100% of the coastline of 4 Hawaiian islands

Marine Protected Areas

The MPAs can suppose a real challenge to develop wave energy farms. For this reason, it is necessary to check the MPAs that can be found in the surroundings of the study area, in this case, Hawaii. This regions, as many other in the equator, it is known for being a touristic place where practise diving and also, for being a sanctuary for many marine species. The existing MPAs have been mapped in red in the previous slide. Some of the most relevant ones are listed below:

- The Hawaiian Islands Humpback Whale National Marine Sanctuary. This MPA covers completely the coastline of Molokai, Lanai and Maui islands with the aim of protecting humpback whales.
- Kaho’olawe Island Reserve, which covers the whole island.

https://hawaiihumpbackwhale.noaa.gov/
http://www.kahoolawe.hawaii.gov/biosecurity.shtml

Hawaii has a clear goal of achieving a carbon neutral economy by 2045

Future Expectations

Hawaii's government is very concerned about oil dependence and its high prices.

The Hawaiian Islands want to become a carbon neutral economy by 2045. To achieve it, they set targets for increasing the renewable electric generation percentage in the mix. These targets have been set since 2010.

Although the renewable generation percentages are not reaching the targets set, they show the efforts of the country for the transition to the green energies.

	Renewable Electric Targets	
Renewable Electric Generation (%)	% of the Total Generation	Year
7.54	10	2010
13.24	15	2015
-	30	2020
-	40	2030
-	70	2040
-	100	2045

Summary of the renewable generation targets and achievements

https://energy.hawaii.gov/wp-content/uploads/2019/07/2019-FF_Final.pdf
https://www.eia.gov/electricity/data/state/

There are two testing centres in Hawaii, one for WECs and the other for OTECs

Status of Marine Energy

In Hawaii there are 2 research centres, which are described below, but there is no electric generation from marine resources.

- Wave Energy Test Site (WETS). It is located in the Kaneohe Bay, Oahu, 1.9 – 2.5km away from the coast. The aim of the centre is to analyse wave buoy equipment performance. The installations can test as many as 3 WECs with a power range of 10 – 1,000kW.

WETS research centre

- National Energy Laboratory of Hawaii Authority (NELHA). Located in Keahole Point, Hawaii, it is one of the most important research centres in the world in this field. It was used for achieving a 1MW floating OTEC pilot plan, Mini-OTEC.

http://hinmrec.hnei.hawaii.edu/nmrec-test-sites/wave-energy-test-site/
http://nelha.hawaii.gov/about/

Conclusions

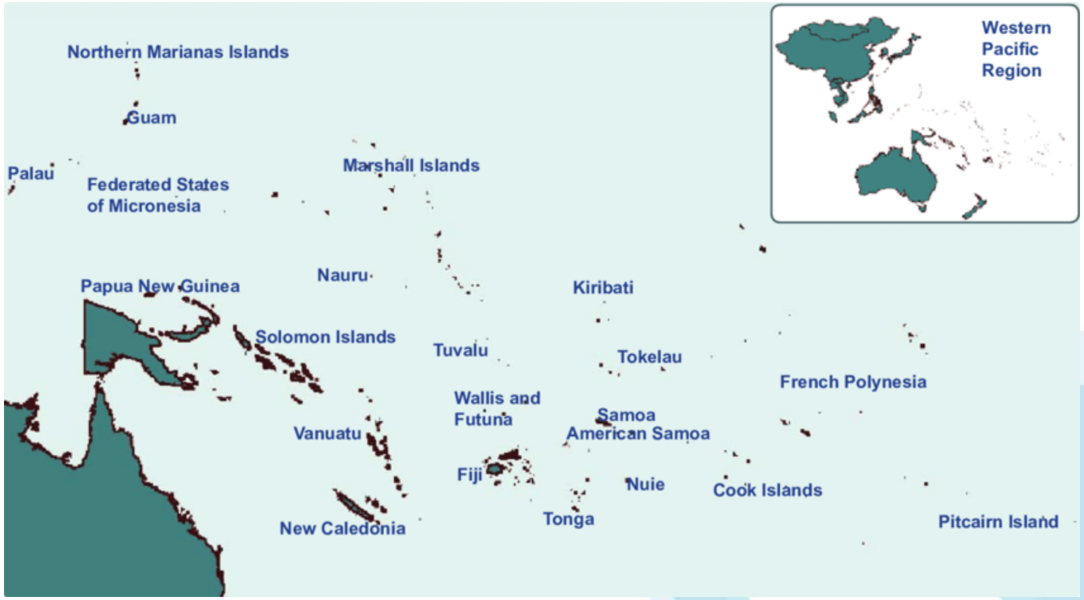
- Hawaii has been considered interesting as study case for wave energy development due to its remote location, which means high fossil fuel costs and high dependence of the continent.
- The annual electric demand in 2018 was of 10,000 GWh, 87% coming from imported fossil fuels. For this reason, the electricity has high prices varying in a range of 0.31 – 0.4$/kWh. In recent years, the islands have started to take advantages of their renewable resources for the electric generation. These energy sources have lower electric costs, 0.1 – 0.18$/kWh.
  - Solar energy has the highest installed capacity due to its abundant potential. There are already 143MW installed and other 426MW proposed. Oahu has most of this capacity. Regarding wind energy, there are already 205MW installed, mainly in Oahu, and other 71MW proposed. With respect the hydropower and geothermal energy, there are several proposed plants.
  - Marine energy is not supplying power to the main grid, but there are two research centres for WECs and OTECs.
- All the coasts have a WED between 20 – 30kW/m, resulting in an ideal place to develop wave energy farms.
- The MPA is other fact that must be considered and more in Hawaii, known for its marine mammal sanctuaries. Four of the islands, Molokai, Lanai, Maui and Kaho'olawe, are surrounded by two different MPAs.
- The Hawaiian government has set targets to transit to a carbon neutral economy and, although they are not achieving their goals, the percentage of renewable generation is growing considerately.
- There are many proposed plants of other renewable energies but if the state wants to meet the set targets, more projects must be developed. Wave energy resource is optimum in this region and there are still 4 islands where it can be implemented.

The Pacific Islands region accounts for more than 3,000 islands

Location of Remote Communities

The region of the Pacific Islands is formed by several countries, the ones selected for this study are listed below together with the number of islands that conform them:

- Cook Islands, 15 islands
- F. S. Micronesia, 607 islands
- Fiji, 332 islands
- Kiribati, 33 islands
- Marshall Islands, 34 islands
- Nauru, 1 island
- Niue, 1 island
- Palau, 300 islands
- Papua New Guinea (PNG), 600 islands
- Samoa, 9 islands
- Solomon Islands, 998 islands
- Tokelau, 3 islands
- Tonga, 171 islands
- Tuvalu, 9 islands
- Vanuatu, 84 islands



Map of the Pacific Islands

The total amount of islands, and therefore of **isolated communities**, is of **3,197**.

The average per capita demand is of 1MWh/year although there is a great variation from country to country

Power Demand

The **population** of each country and each island varies a lot, from some thousands to millions in the case of PNG.

The **mean annual power demand per capita** is of 1MWh, although there are certain countries such as Solomon Islands, Vanuatu and Kiribati with low demand while others double the average value like Nauru, Niue and Palau.

There is no data about the number of inhabitants per community/island and therefore, it cannot be known the power demand per community.

Country	Popullation	Annual demand per capita (kWh)	Annual total power demand (GWh)
Cook Islands	15,472	1899	29.38
F. S. Micronesia	102,198	591	60.40
Fiji	879,057	941	827.19
Kiribati	120,640	201	24.25
Marshall Islands	55,591	1398	77.72
Nauru	11,369	2103	23.91
Niue	1,382	2000	2.76
Palau	18,185	4326	78.67
Papua New Guinea	8,275,154	121	1001.29
Samoa	186,737	582	108.68
Solomon Islands	690,600	151	104.28
Tokelau	-	-	-
Tonga	103,052	507	52.25
Tuvalu	11,861	603	7.15
Vanuatu	296,690	229	67.94

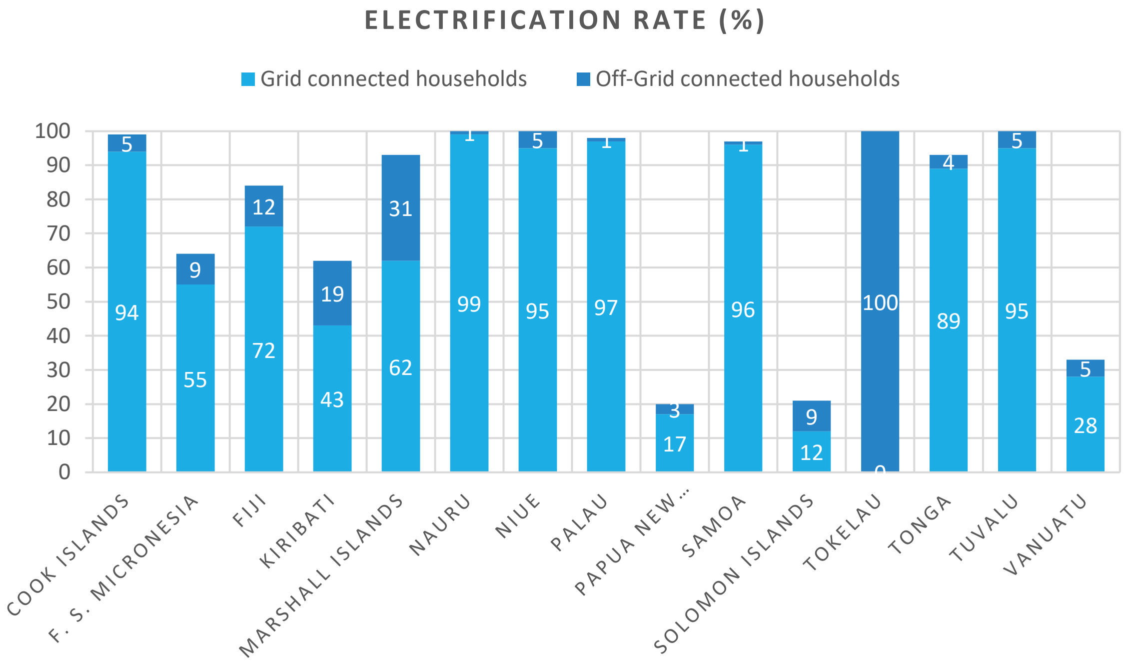
Summary of the population and power demand of each country of the Pacific Islands

Despite the full electrification of some countries, there are 3 cases with a rate lower than 40%

Electrification Rate

The **average electrification rate is of 77.4%** but it changes quite a lot from one country to another. Countries like Cook Islands, Nauru, Niue, Palau, Samoa, Tokelau or Tuvalu supply almost at 100% the electric demand of their inhabitants. However, Papua New Guinea, Solomon Islands and Vanuatu have the lowest **electrification rate**, which must be improved.

It is worth mentioning also that Kiribati, Marshall Islands and Tokelau have high percentage of **off-grid connections**, which means that the main grid does not supply a large number of households.



The Pacific Islands, with fossil fuels as main energy resource, have the highest cost of diesel due to their location

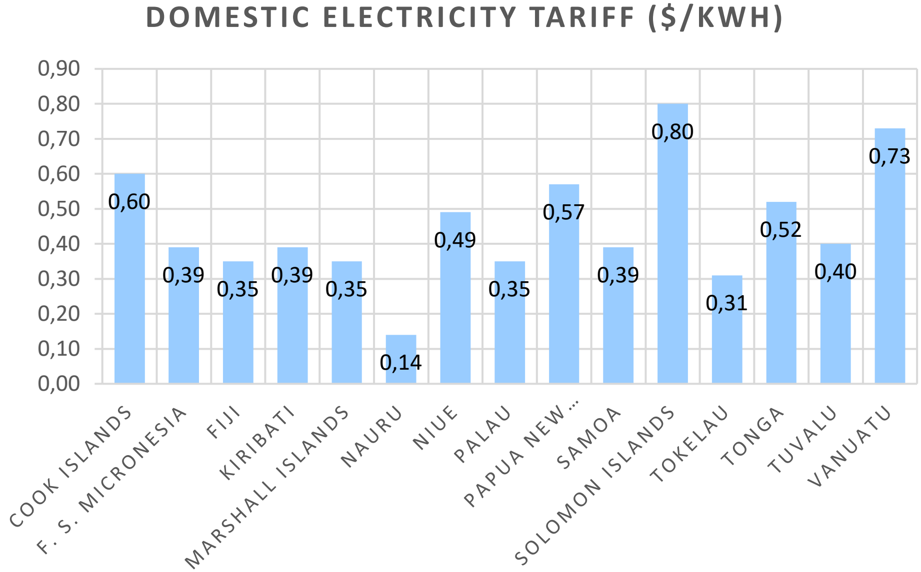
Electricity Costs

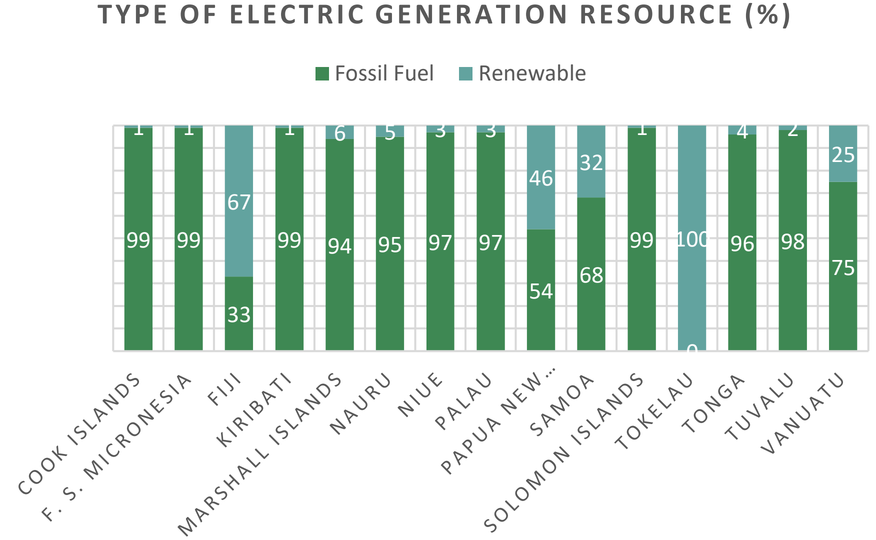
The **average cost** of the power supply is of **0.45$/kWh**. The Pacific Islands have the highest cost of diesel due to their geographical characteristics. Some countries like Solomon Islands or Vanuatu pay more than 0.7$/kWh.

Energy Source

With respect to the type of source used for the generation of the electricity, in most of the cases **fossil fuel** are used, which create a huge dependency with high costs.

Fiji, PNG, Samoa, Tokelau or Vanuatu are example of the transition to **renewable energies** as a solution to the challenges that oil presents.





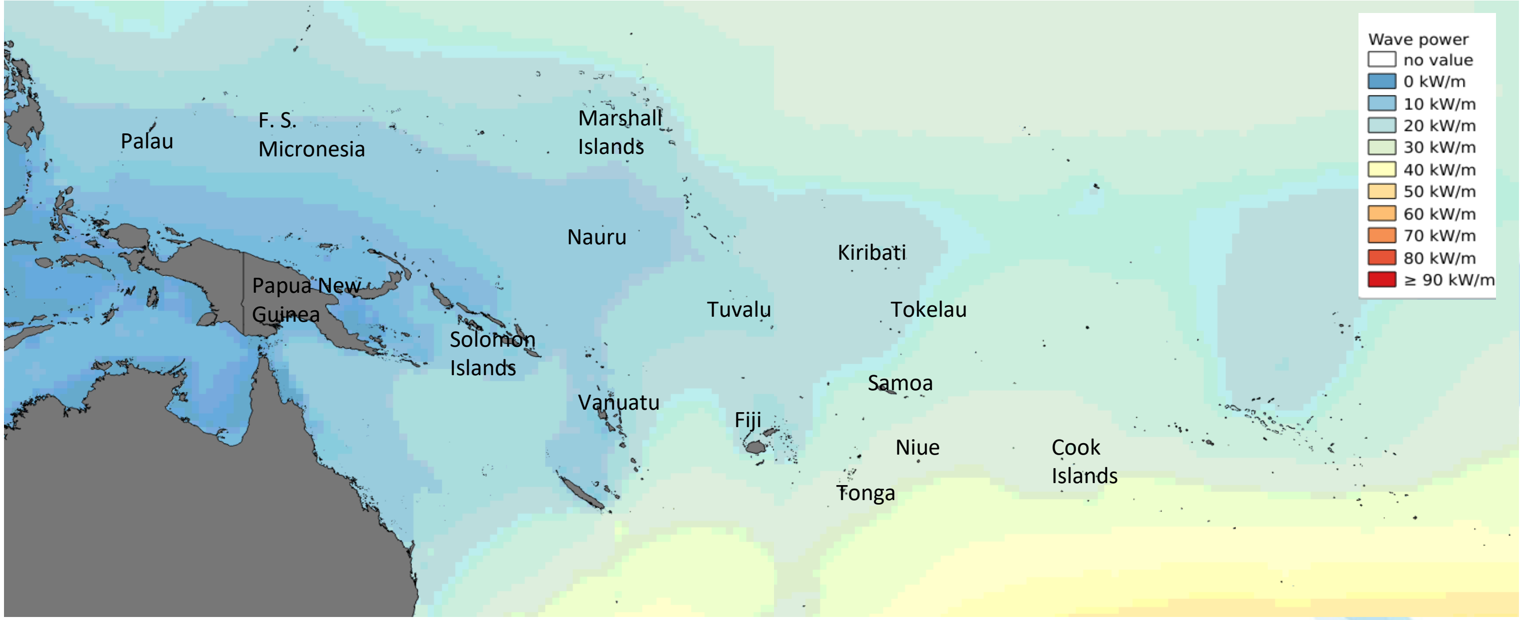
https://www.irena.org/documentdownloads/publications/pacific-lighthouse-roadmapping.pdf
https://www.theprif.org/documents/regional/infrastructure-planning-and-management/2016-pacific-infrastructure-performance

The farthest countries from the continent have greater wave energy potential

Wave Energy Resource

The islands are spread across the Pacific Ocean, and therefore the energy potential of waves changes from one point to another. Each country can be classified with respect to WED as:

- Low, 10 – 20kWh/m. Countries located in the west (Vanuatu, Papua New Guinea, Palau and Solomon Islands) have this potential, which although not being great could be enough.
- Medium, 20 – 30kWh/m. Countries of the northeast (Kiribati, Nauru, Marshall Islands, F. S. Micronesia and Tuvalu) have higher potential.
- Large, 30 – 40kWh/m. Thanks to being further from the main continent, these countries (Fiji, Tonga, Niue, Cook Islands, Samoa and Tokelau) have the greatest potential of the region.



Map of the WED in the Pacific Islands

Solar power is the principal renewable source mostly used as long as there is no option to install hydropower or geothermal power

Competitiveness

Hydropower

- Mountainous islands with high rainfall and large areas to collect the water have great potential for this energy source, also to develop small hydropower stations to use them as pumping storage for solar.
- Current installations: Papua New Guinea (221.5MW), Fiji (127MW), Solomon Islands (15MW), Samoa (10MW), F. S. Micronesia (1.8MW) and Vanuatu (1.2MW)

Geothermal power

- It is available in those islands located where the tectonic plates overlap, more exactly between Vanuatu and Tonga.
- Current installations: Papua New Guinea (52.8MW) and Vanuatu (4 – 8MW)

Solar PV power (dismissing solar water heaters)

- It is the most common renewable source used in the region thanks to its easy maintenance and the high solar resource.
- Current installations: Tonga (5.5MW), Cook Islands (4.2MW), Solomon Islands (3MW), Tuvalu (2MW) and F. S. Micronesia (1.5MW)

Wind power

- There are a limited reliable data and assessments, and in addition, wind resource is seasonal and wind turbines must resist strong tropical storms.
- Current installations: Fiji (10MW), Vanuatu (3MW), F. S. Micronesia (1.5MW), Palau (0.6MW) and Tuvalu (0.5MW)

Biomass/Biofuel

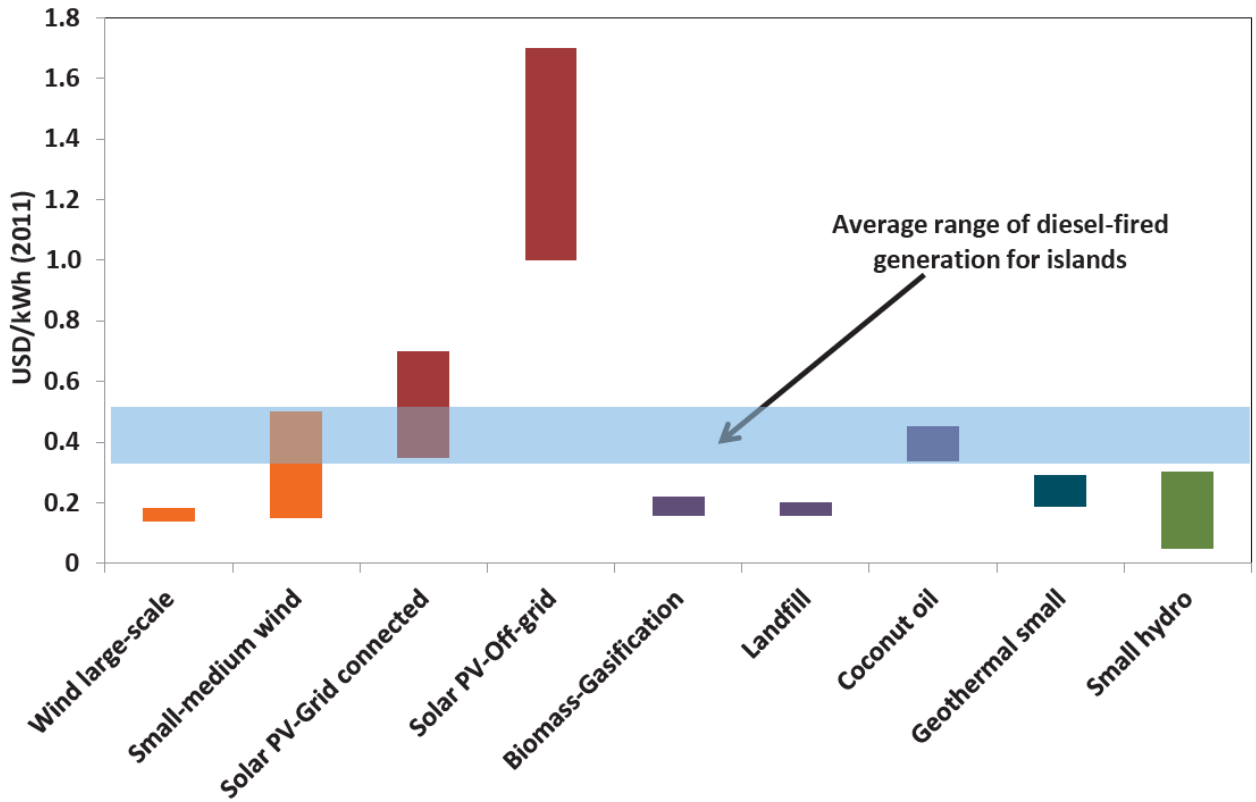
- Despite having dense vegetation, it is commonly used as biomass for heating than for electric supply.
- Current installations: Fiji (15MW)

https://www.adb.org/sites/default/files/institutional-document/425871/pacific-energy-update-2018.pdf
https://www.irena.org/documentdownloads/publications/pacific-lighthouse-roadmapping.pdf

In the Pacific Islands, almost all the renewable technologies have a more competitive price than diesel

Competitiveness

The Pacific Islands are not commonly producers of fossil fuels, and in addition, their location implies the necessity of transporting them from far away. This leads in a scenario where almost all the renewable energies have more competitive prices.

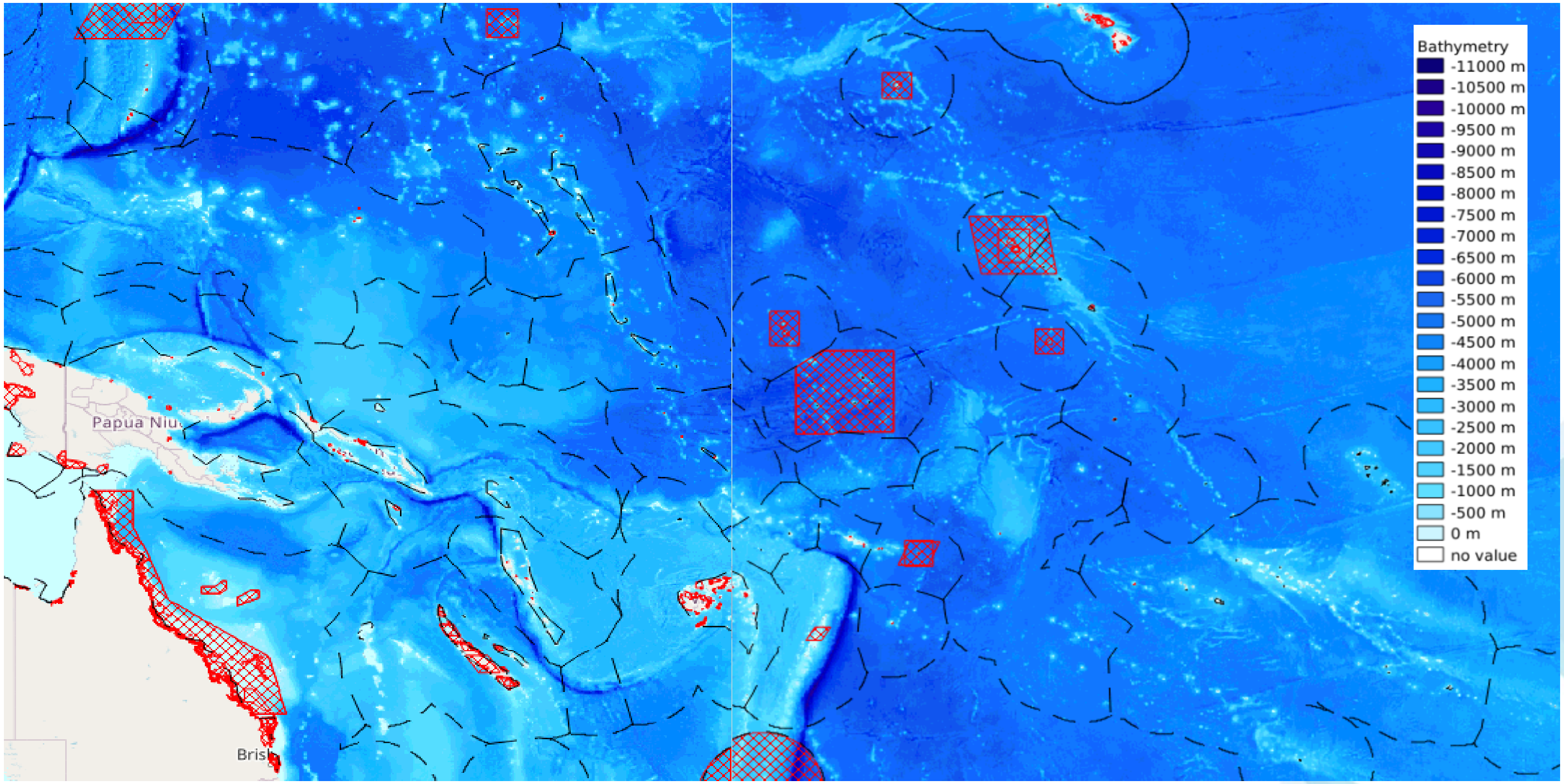


Comparative of the energy cost depending on the source in the Pacific Islands

Generally, the Pacific Islands are surrounded by deep waters

Bathymetry of the Coastline

With the exception of some countries such as Papua New Guinea, Solomon Islands and Fiji, the Pacific Islands are surrounded by deep waters.



Bathymetry map of the Pacific Islands with the MPAs in red

As the Pacific Islands' economy is based principally in touristic activities like diving, there are a lot of marine protected areas

Marine Protected Areas

As WECs cannot be installed in marine protected areas (MPAs), it is worth analysing them and specially in this case, where almost all the islands live partially from the touristic activities such as scuba diving and where there are thousands of sanctuaries for the sea life. These MPAs have been mapped in red in the previous slide. Some of the most relevant ones are listed below:

- F. S. Micronesia. There are two islands almost completely covered by different MPAs, which are Pohnpei Island and Kosrae.
- Papua New Guinea. There are several MPAs spread through the country, but the two main ones are located in the south coast of the main island. Their names are Maza and Tonda.
- Solomon Islands. Kia, he main MPA, can be found in the north coast.
- Fiji. This country is one of the most touristic one and therefore, its coasts are completely protected.
- Tonga. There is a large MPA that cover a whole island, Ha'apai, and some more distributed in other islands.
- Samoa. Although they are not relevant due to their small size, there are several MPAs through the whole country.

There is a clear need and intention to transit from fossil fuels to renewable electric generation

Future Expectations

All the Pacific Islands have suffered the volatility of the fuel price and the economy difficulties linked to it. Not only that, but they are especially vulnerable to climate change impacts like the rising ocean levels and the more frequent storms.

For these reasons, governments prioritized the increase of renewable electric generation. Almost all the countries stablished policies and goals related with the use of renewable energy to generate power and reduce fuel dependence.

Country	Renewable Electric Generation (%)	Renewable Electric Targets	
		% of the total	Year
Cook Islands	<1	50/100	2015/2020
F. S. Micronesia	<1	30	2020
Fiji	67	90/99	2015/2030
Kiribati	<1	Official targets in process to be approved	
Marshall Islands	6	20	2020
Nauru	<5	50	2020
Niue	3	100	2020
Palau	3	20	2020
Papua New Guinea	46	No tagets set to date	
Samoa	32	+20	2030
Solomon Islands	<1	50/79	2015/2030
Tokelau	100	100	2012
Tonga	4	50/70	2020/2030
Tuvalu	2	100	2020
Vanuatu	25	40/65	2015/2020

Summary of the renewable generation targets and achievements

Today, there are several marine energy projects in the Pacific Islands although none of them are of wave energy

Status of Marine Energy

- MAKO Energy, an Australian company, developed a **tidal energy** project in Buka passage, **Papua New Guinea**. Thanks to the huge tidal potential that the passage located between two cities of Papua New Guinea has, in 2017 it was signed a cooperation agreement to implement a tidal demonstration project. Through this demonstration they wanted to show the possibility of supplying tidal generated electricity to the city grid.

MAKO's tidal turbine installed in Papua New Guinea

- Korea Research Institute of Ships and Ocean Engineering (KRISO) designed an **Ocean Thermal Energy** Converter (OTEC) of 1MW, which was established in the coast of South Tarawa, **Kiribati,** in 2014. This converter is the first practical level of the company's path to construct 100MW commercial system. It consists of a four deck floating platform moored 6km offshore in a water depth of 1,300m. Pipes of 1km are used to pump cool water from the depths.

https://www.mako.energy/buka
https://www.marinelink.com/news/converter-thermal-energy404268

Conclusions

- The Pacific countries are characterised, generally, for being divided in small islands. For this reason, each island has been considered as an isolated power community giving back 3,197 communities of 15 different countries.
- It has been estimated that the mean annual energy demand is of 1MWh per capita.
- There are 9 countries with a greater electrification rate than 90% while other 3 do not achieve even 40%. This shows the differences between them. These differences appear also in the electricity tariffs. Although the mean cost of the electricity is 0.45$/kWh, there are 4 countries that pay more than 0.6$/kWh. The high costs are a result of an electric system based almost completely in imported fossil fuels. However, the islands have a great green resource that can and want to use.
    - Hydropower and solar energy have the greatest potential and because of that, there are already several installations of hundreds of megawatts.
    - Marine energy is developing but with OTECs and tidal energy.
- Regarding the WED in the region, countries where there is low potential such as Vanuatu, Papua New Guinea, Palau and Solomon Islands can be dismissed due to the lack of interest for wave energy development. This gives back a total of 1,215 isolated communities.
- The MPA is other fact that must be considered. Out of those communities with the optimum conditions for developing a wave energy farm, 335 are completely surrounded by MPAs. This is the case of the 332 islands of Fiji, which is one of the most touristic countries. After regarding this aspect, there are only 880 isolated power communities with suitable characteristics.
- All the countries have ambitious renewable electric targets and a several are investing to achieve them. In 6 of the Pacific countries there is already a great percentage of renewable generation.

The Antilles considers 10 Caribbean countries, which are formed by a total of 113 parishes

Location of Remote Communities

The countries located in the Caribbean Sea that form Antilles are going to be considered interesting isolated power communities for wave energy development. Cuba and Dominican Republic are also part of the Antilles. However, there is no specific data of coastal isolated communities. The given data corresponds to the whole country, what is not enough to hold the analysis since there are many mountainous communities. Similarly, Haiti is also ruled out because, aside the above reason, it is a really poor country that would not be able to afford wave energy technology. So, the selected countries are listed below, all of them with a small radius from any point to the coast:

- Antigua & Barbuda, 2 inhabited islands with 6 parishes
- The Bahamas, 16 inhabited islands
- Barbados, a single island with 11 parishes
- Dominica, a single island with 10 parishes
- Grenada, 2 inhabited islands with 7 parishes
- Jamaica, a single island with 14 parishes
- St Kitts and Nevis, 2 inhabited islands with 14 parishes
- St Lucia, a single island with 10 parishes
- St Vincent and the Grenadines, 6 islands with 10 parishes
- Trinidad and Tobago, 2 inhabited islands with 15 parishes

Map of the Antilles' countries

As some of the islands are quite large, in some cases instead of considering the whole island as an isolated power community, their parishes are going to be taken into account. Therefore, the total amount of **isolated communities** is of **113**.

https://www.irena.org/publications/2012/Sep/Renewable-Energy-Country-Profiles-for-the-Caribbean
Figure: https://mltoday.com/caribbean-peace-movement-hands-off-venezuela/

There are 55 communities with a power demand lower than 5MW

Power Demand

From the total 113 isolated communities, 64 have been neglected due to their high power demand, exceeding 5MW. As a result, Jamaica and Trinidad & Tobago are no longer going to be considered.

The data of the communities for each country has been summarised in the following table.

Country	Nº communities	Avg. inhabitants per community	Avg. annual energy demand per community (MWh)	Avg. installed capacity per community (MW)
Antigua & Barbuda	1	3,125.0	3,950.0	4.4
The Bahamas	9	992.8	3,235.6	2.5
Barbados	1	5,139.0	3,438.8	2.0
Dominica	9	5,561.3	5,309.1	2.2
Grenada	3	4,495.3	4,631.8	1.9
St Kitts and Nevis	13	2,530.1	5,776.4	1.5
St Lucia	5	5,912.4	6,275.2	1.6
St Vincent and the Grenadines	8	3,746.4	7,178.3	1.9
	49	**3,937.8**	**4,974.4**	**2.3**

Summary of the communities, their population and power demand of each country

Despite the high electrification rate, the use of fossil fuels as main electric generation resource increases the electricity costs

Electrification Rate, Electricity Costs & Energy Source

Electrification rate

Generally, the countries located in the Caribbean Sea have a high electrification rate. All the analysed countries have a percentage greater than 90%, being the **average of 97.5%**. Antigua & Barbuda, the Bahamas, Barbados and Grenada have achieved (or almost) the total electrification of the country.

Electric generation power source type

In most of the countries, the **fossil fuels account for more than 90% of the resource used** for the electric generation. It must be pointed out that none of this countries are big producers of this kind of source and so, the importations are necessary. Countries like Dominica or St Vincent and the Grenadines have greater renewable generation percentage thanks to their **hydropower** facilities. Barbados, in less grade, use **solar energy** to minimise the negative impacts, both environmental and economic, of using fossil fuels.

Electricity tariffs

Despite the high electrification rate, almost all generation sources are fossil fuels, which must be imported from the outside. This means high and volatile costs. The **mean value of in the electric tariff** is **0.38$/kWh**, although Antigua & Barbuda, Dominica and Grenada exceed the 0.4$/kWh.

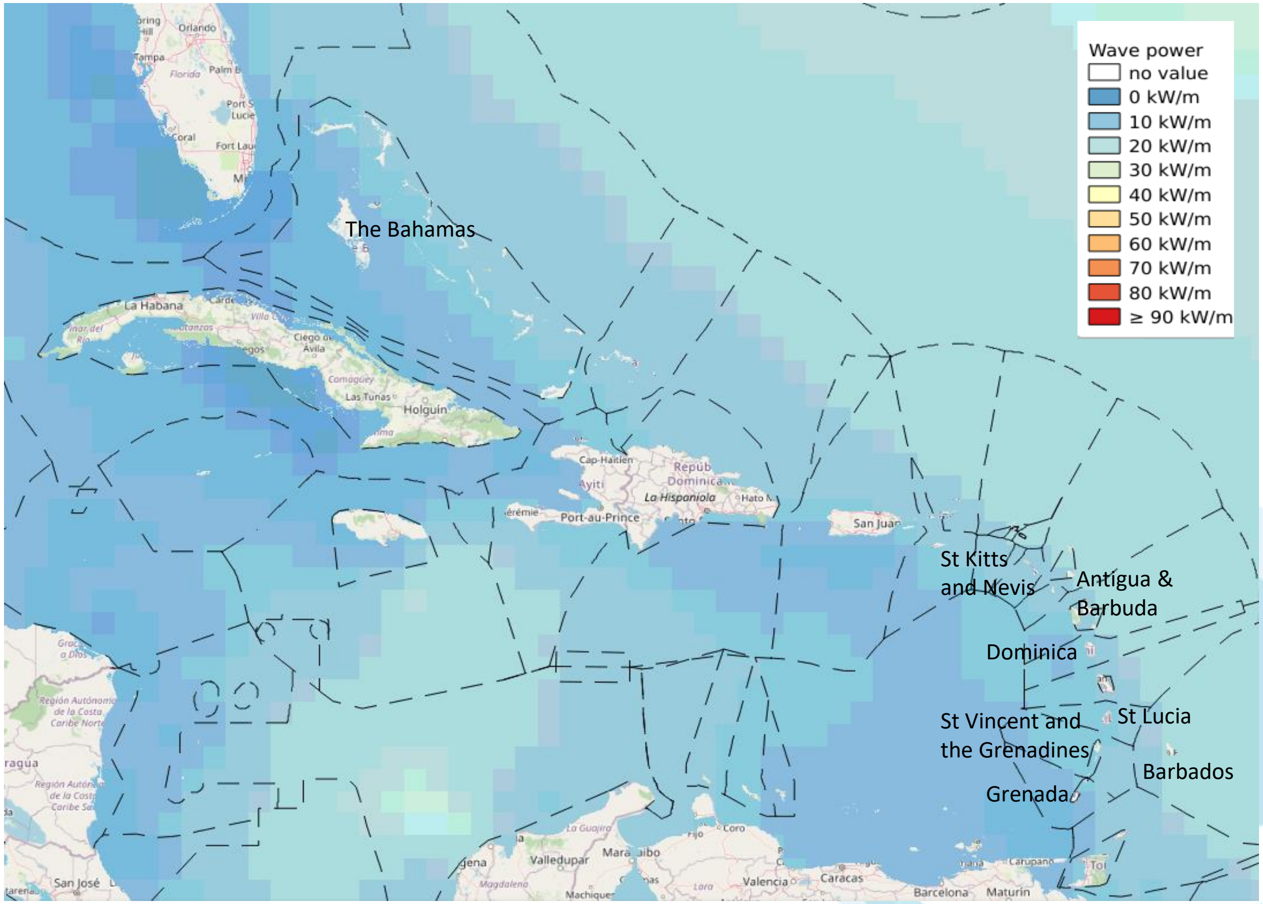
https://www.irena.org/publications/2012/Sep/Renewable-Energy-Country-Profiles-for-the-Caribbean
https://www.researchgate.net/publication/303811380_Caribbean_Sustainable_Energy_Roadmap_and_Strategy_C-SERMS_Baseline_Report_and_Assessment
https://www.imf.org/external/pubs/ft/wp/2016/wp1653.pdf

Wave energy density is generally low in the Antilles

Wave Energy Resource

The islands are spread across the Caribbean Sea, and therefore the potential of the waves changes from one island to another. Each country can be classified with respect to WED as:

- Very low, < 10kW/m. Grenada that is in the southeast, has almost no wave energy potential.
- Low, around 10kW/m. Countries in the east side of the Caribbean Sea like Dominica, St Kitts and Nevis, St Lucia and St Vincent and the Grenadines have a low potential, which could be enough for low energy demand.
- Medium, 10 – 20kW/m. The Bahamas, Barbados and Antigua & Barbuda have the greatest wave energy potential.



Map of the WED in the Antilles

Solar energy has great opportunities to dominate the electric generation thanks to the abundant resource in the Caribbean Sea

Competitiveness

Hydropower

- For countries high hilly topography and high rainfall, it represents an ideal option. Although large hydropower by damming rivers can harms naturals ecosystems and population, small hydropower can operate diverting water avoiding the negative impacts.
- Installations: Dominica (6.6MW) and St Vincent and the Grenadines (5.6MW)
- Estimated average price: 0.07$/kWh

Solar PV power (dismissing solar water heaters)

- It is the best option for these countries since the solar potential is strong in all of them. Thanks to its mature technology, it is presented as an opportunity to develop these kind of facilities.
- Installations: Barbados (5.5MW), St Kitts and Nevis (1MW), Antigua & Barbuda (0.8MW), St Vincent and the Grenadines (0.8MW), Dominica (0.8MW), Grenada (0.6MW), and St Lucia (0.2MW)
- Estimated average price: 0.16$/kWh PV utility-scale and 0.3$/kWh PV small-scale

Wind power

- There is a high potential of wind in the Caribbean and small-scale wind-diesel hybrid systems are becoming popular in these countries.
- Installations: St Kitts and Nevis (2.2MW) and Dominica (0.2MW)
- Estimated average price: 0.08$/kWh

Geothermal power

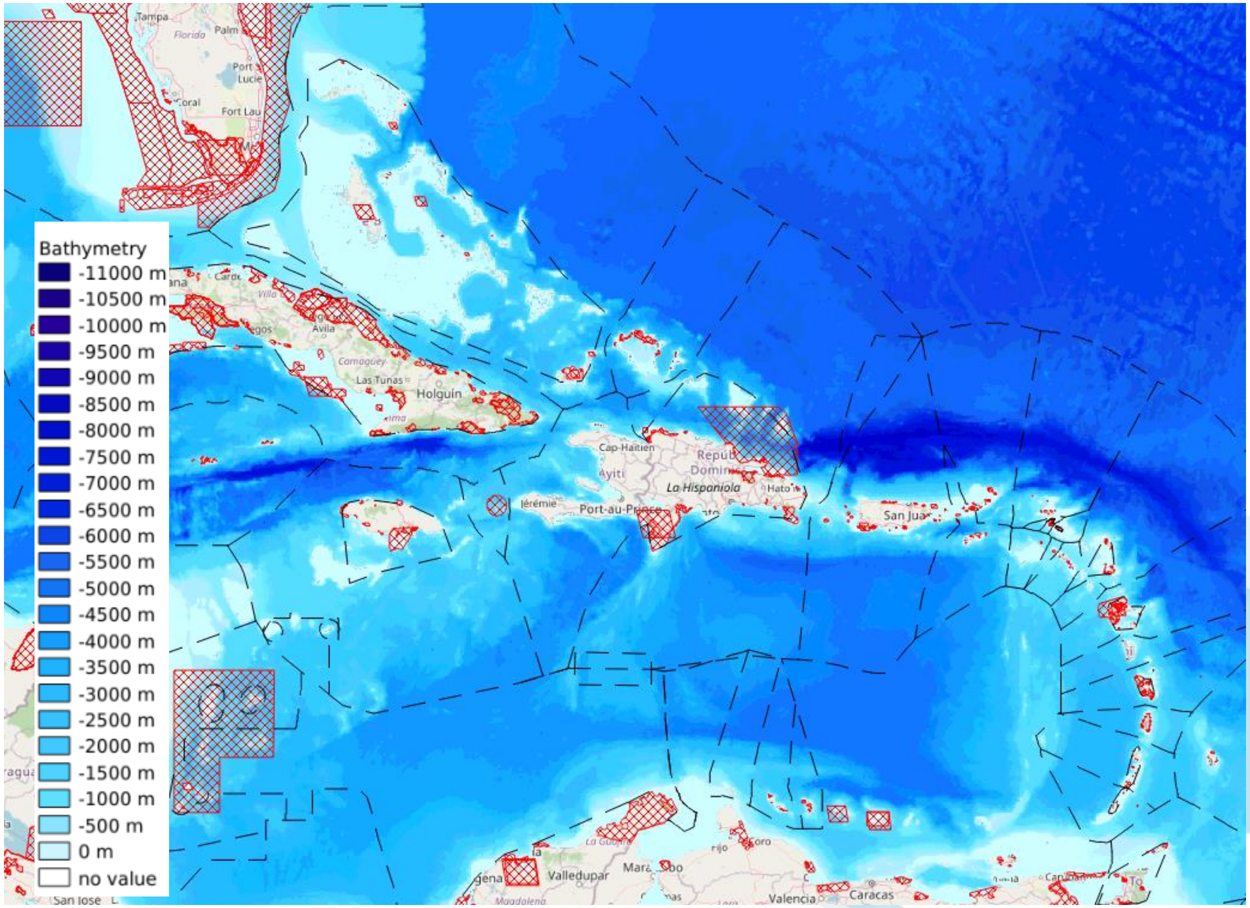
- Countries close to the volcanic arch of the Lesser Antilles possess huge geothermal potential, e.g. Dominica, Grenada, St Lucia, St Kitts and Nevis and St Vincent and the Grenadines.
- Estimated average price: 0.1$/kWh a 10MW installation and 0.06$/kWh a 100MW installation

https://www.researchgate.net/publication/303811380_Caribbean_Sustainable_Energy_Roadmap_and_Strategy_C-SERMS_Baseline_Report_and_Assessment
https://www.imf.org/external/pubs/ft/wp/2016/wp1653.pdf

Generally, the Antilles are surrounded by shallow waters

Bathymetry of the Coastline

As it can be seen in the bathymetry map, all the countries are surrounded by shallow waters although in the north side of Puerto Rico there is a huge depression known as Puerto Rico Trench.



Bathymetry map of the Antilles with the MPAs in red

As the Caribbean economy is based principally in touristic activities like diving, there are a lot of marine protected areas

Marine Protected Areas

As WECs cannot be installed in marine protected areas (MPAs), it is worth analysing them and specially in this case, where almost all the islands live from the touristic activities such as scuba diving. These MPAs have been mapped in red in the previous slide. Some of the most relevant ones are listed below:

- Antigua & Barbuda. There are several MPAs but none of them cover the whole coast of any community. The communities with the biggest MPAs are St Paul, St Peter and St Mary.
- The Bahamas. There are two islands almost completely covered by different MPAs, which are Harbour and Inagua.
- Barbados. The only considered community, St Andrew, is surrounded by an MPA.
- St Kitts and Nevis. There is a huge MPA in each island, but they do not cover the whole coast of the respective communities, which are St George and St James.
- St Lucia. It has several MPAs around the country but there are two main areas, one covering the whole community of Soufriere and another one over a partial area of Anse la Raye.

Despite having set targets for the renewable electric generation, countries have not taken significant measures to meet them

Future Expectations

Due to the high costs of the fossil fuels because of their importation to the Antilles, all of them have set targets regarding the penetration of the renewable energies in the electric generation mix.

However, only Dominica achieved its target. The rest of the countries are far away of meeting their goals.

		Renewable Electric Targets	
Country	**Renewable Generation in 2015 (%)**	**% of the total**	**Year**
Antigua & Barbuda	0.7	20	2020
The Bahamas	0.0	15/30	2020/2030
Barbados	2.3	29	2029
Dominica	28.6	25	2010
Grenada	1.4	100	2030
St Kitts and Nevis	5.7	20	2015
St Lucia	0.2	35	2020
St Vincent and the Grenadines	12.2	30/60	2015/2020

Summary of the renewable generation targets and achievements

https://www.researchgate.net/publication/303811380_Caribbean_Sustainable_Energy_Roadmap_and_Strategy_C-SERMS_Baseline_Report_and_Assessment

There are two OTEC projects in development stage in the Caribbean Sea

Status of Marine Energy

There are some marine energy projects in the Caribbean Sea. None of them are located in the studied countries but they still being in the same sea. However, there are no wave energy projects.

- NEMO. The project, which is in development, is located in Martinique, a Caribbean island of France. It is an Ocean Thermal Energy Converter (OTEC) with a power capacity of 10.7MW, enough to power around 35,000 households in a year. It will begin operating in 2020.

Design of NEMO project

- OTE. This company has a project of developing a pilot OTEC EcoVillage in Virgin Islands, U. S. They want to promote the sustainability by supplying fossil fuel free energy and water for communities. In 2018, the first draft of the plan was complete.

https://www.akuoenergy.com/en/nemo
https://otecorporation.com/projects/

Conclusions

- If considering isolated power communities like parishes with no more than 5MW of power demand, in the Antilles there are 49. Taking into account this first requirement for being considered suitable for wave energy development, Jamaica and Trinidad & Tobago have been neglected.
- The average number of inhabitants of these communities is approximately 4,000, and their mean power demand is of 2.3MW.
- In the Antilles there is not a problem of electrification, the mean rate is 97.5%, but of oil dependence. More than the 90% of the resources of the electric generation are imported fossil fuels. For this reason, they have high electric tariffs, 0.38$/kWh as an average cost. This problem can be solved by using the renewable resources that the islands have.
    - Solar energy has the greatest potential and because of that, there are already several installations. In the case of hydropower, there are facilities in some countries, but this is a limited resource.
    - Marine energy is developing but with OTECs thanks to the characteristics that the Caribbean Sea presents: warm water in the surface with cold water in the depths.
- When regarding the WED in the region, only the Bahamas, Antigua & Barbuda and Barbados have great or enough potential with a value of 10 – 20kW/m. The sum of the isolated communities of these countries is 11.
- The MPA is other fact that must be considered. Out of those 11 communities with the optimum conditions for developing a wave energy farm, 3 are completely surrounded by MPAs, 2 in the Bahamas and the Barbados' community, giving back a total number of 8 suitable isolated power communities.
- Despite the governments have set targets to transit to a more green and stable energy system, they have not taken actions to achieve them.

The number of non-electrified households in Cameroon is very high although the coastal areas are in a better situation

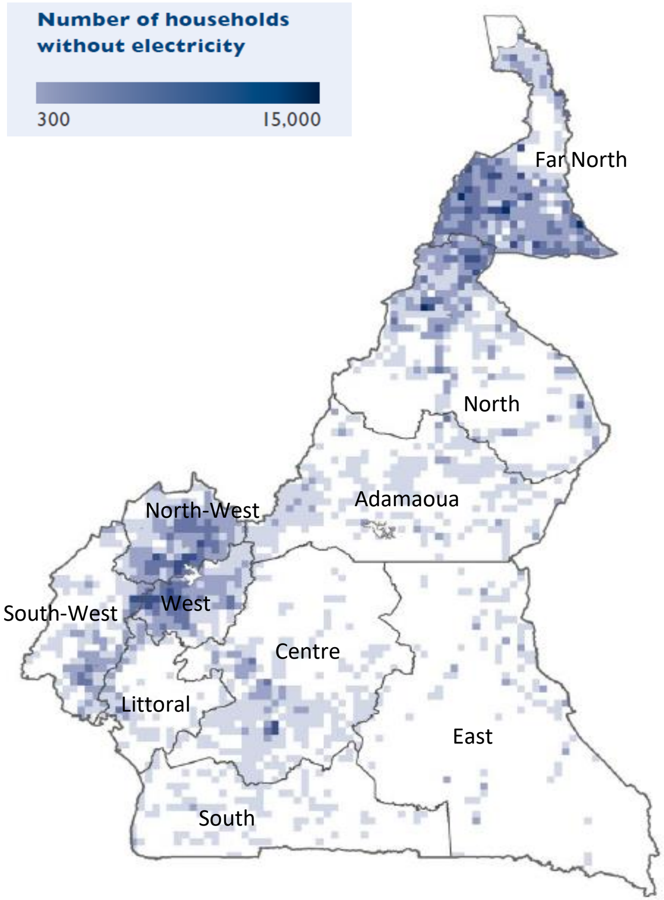
Location of Remote Communities

Cameroon has a coastline in the Gulf of Guinea of approximately 420km. It is divided in regions, being 3 of them coastal regions and therefore, the ones that are interesting for the wave energy development.

The country has electrification problems; despite in urban areas the rate reaches 90%, in **rural areas** the **electrification rate is of 23%.** Most of the non-electrified households are in rural areas. Below it is listed each region with the number of non-electrified households:

- South-West regions with 152,735 households without electricity. Muyuka, Ekona, Buea, Tiko and Limbre are the most remarkable towns of this region if considering non-electrified households.
- South region with 88,252 households without electricity.
- Littoral region with 65,923 households without electricity. There is more density of non-electrified households in Douala.

The **total off-grid market** potential is approximately **307,000 households**.



Map of the provinces of Cameroon with non-electrified households' density

The energy mix of he country is based on fossil fuels and hydropower

Power Demand, Energy Source &Electricity Costs

Power demand

The energy required by each household varies depending on the region. For example, a household located in the South-West region consumes **648kWh/year**. This value can be used for the rest of the coastal regions.

Electric generation source type

In 2017, Cameroon had an installed capacity of 1,558MW. The 52% of that capacity corresponded to fossil fuels plants, the 47% was hydropower capacity and the other 1% were other renewable energies such as bioenergy and solar energy.

Electricity tariffs

The electricity cost depends on the demand of the consumer. In the following table it is summarized these tariffs.

Annual energy demand (kWh)	Tariffs ($/kWh)
< 1,320	0.100
1,320 - 4,800	0.158
4,800 - 9,600	0.188
> 9,600	0.198

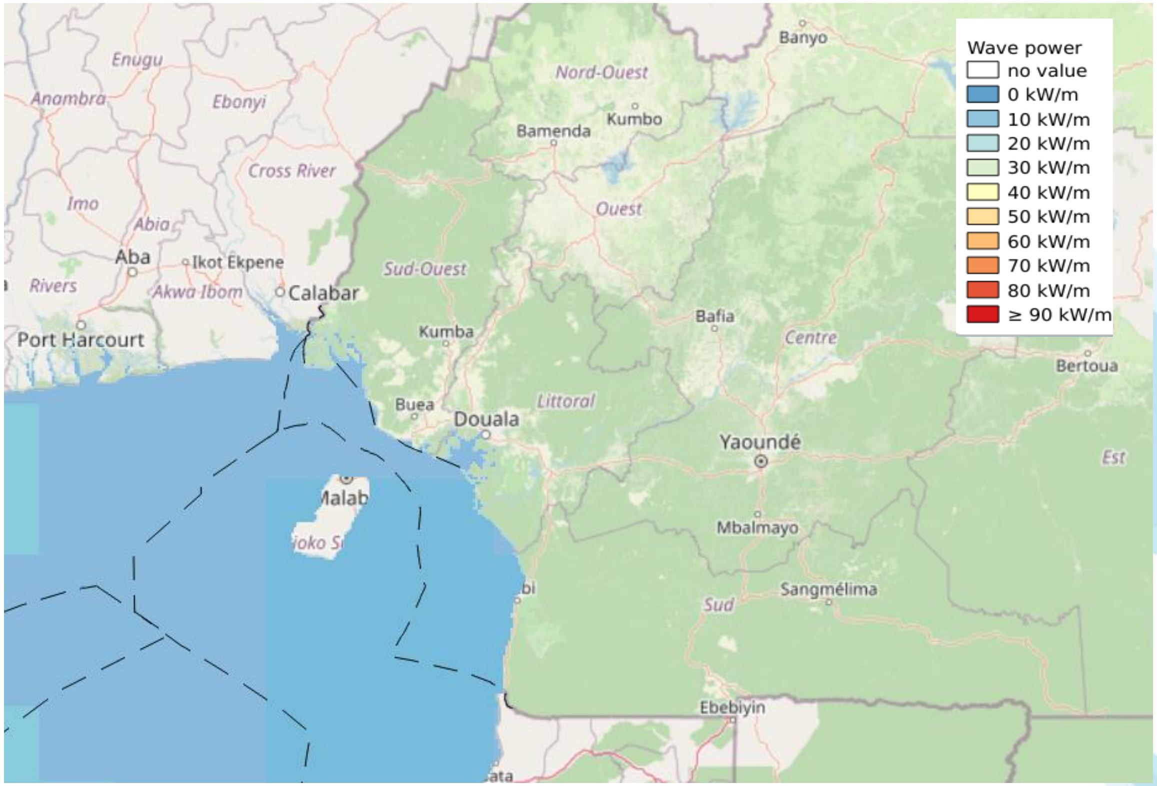
Electricity tariffs

http://documentos.bancomundial.org/curated/es/260941545015657290/pdf/Cameroon-Rural-Electricity-Access-Project-for-Underserved-Regions-Project.pdf
https://www.get-invest.eu/market-information/cameroon/governmental-framework/#
https://www.usaid.gov/powerafrica/beyondthegrid/off-grid-solar-assessment/cameroon

Due to being in the Gulf of Guinea, Cameroon coast has very low WED, lower than 10kW/m

Wave Energy Resource

Cameroon's coast is located in the middle of the Gulf of Guinea and therefore, the WED that the region have is limited, being lower than 10kW/m. This means that this country is not suitable for wave energy development.



Map of the WED in Cameroon

Cameroon has a huge renewable electric potential thanks to biomass, solar and hydro resources

Competitiveness

Small Hydropower

- The total potential is of 1,115TWh. The small hydropower plants can have a capacity of a range from 5kW – 10MW.

Bioenergy

- By using biomass residues, it could be generated around 1,050GWh, almost a quarter of the country's demand. It has the potential to replace fossil fuels. However, there are certain technical, social and economic barriers that should be overcome.

Solar PV power (dismissing solar water heaters)

- Cameroon has an abundant solar potential, with a mean daily radiation of 4kWh/m^2. Despite the daily potential of 780TWh/m^2, the exploitation of this resource is almost non-existent.

Wind energy

- There is low wind resource in Cameroon, with no more than 5m/s, which is too low to for the commercial production of electricity.

Cameroon coastline does not reach to a depth greater than 500m in the first 50km

Bathymetry of the Coastline

Cameroon's coast has shallow waters. In the first 50km the depths do not exceed 500m of deep, which increases slowly.

Bathymetry map of the coastline of Cameroon with the MPAs in red

There are two MPAs that cover partially two of the Cameroon's regions

Marine Protected Areas

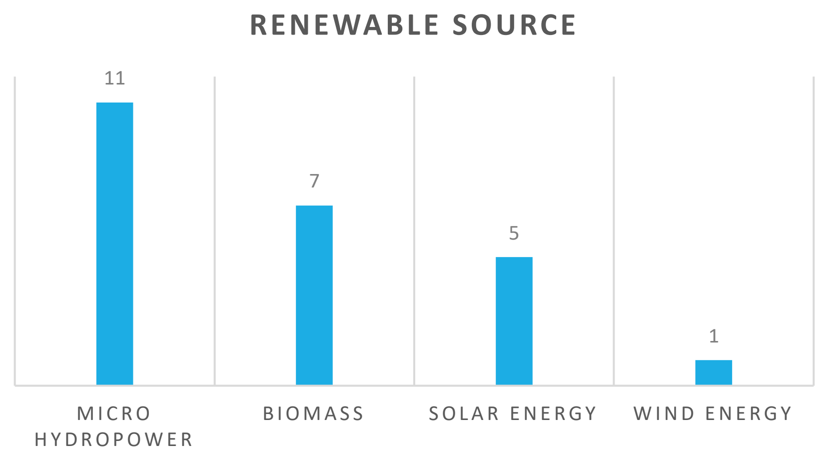
As WECs cannot be installed in marine protected areas (MPAs), it is worth analysing them. These MPAs have been mapped in red in the previous slide. The two MAPs that Cameroon has are listed below:

- Estuaire du Rio del Rey. It located in the north side of South-West Region.
- Manyange na Elombo-Campo. This National Park covers part of the South Region.

Although having targets for renewable generation, Cameroon does not consider ocean energy

Future Expectations & Grants

According to the Intended Nationally Determined Contribution, the established target for Cameroon electricity mix implies a 25% of renewable generation by 2035. This percentage of renewables does not include large hydropower plants. The renewable mix is expected to be as shown below:



Targets of renewable electric generation mix for 2035

The EU has collaborated in energy projects in Cameroon, providing funding and technical assistance.

- In collaboration with the World Bank it supports projects in South-West region.
- In 2021, through the EU Development Fund it will give direct aids for renewable projects.
- In partnership with ElectriFI it is also financing renewable energy projects.

https://www.usaid.gov/powerafrica/beyondthegrid/off-grid-solar-assessment/cameroon

Conclusions

- There are 3 coastal regions in Cameroon, where the rural electrification rate is very low, around 20%. The non-electrified households in these areas are 307,000. The mean annual demand per households is around 650kWh.
- The main electric generation source are the fossil fuels (52%) followed by the hydropower plants (47%). The aim of the government is to increase the electrification rate, for what renewable resources could be used.
    - Despite the abundant solar and biomass potential for the electric generation, there are certain barriers that must be overcome like technical, social and economic barriers.
- There are two MPAs that cover a small part of the coast, one in South-West regions and the other one in South region.
- Regarding the bathymetry, it is worth mentioning the shallow waters of Cameroon's coastline.
- The government has set a target of achieving the 25% of the power generation from renewable sources by 2035, for which has established the required increase of each resource. However, it does not include ocean energy.
- There is almost no wave resource in Cameroon's coast and therefore, this country should not be considered as a priority region where develop the market.

There are 17 coastal communities in the south where 232,000 people live without access to the electric grid

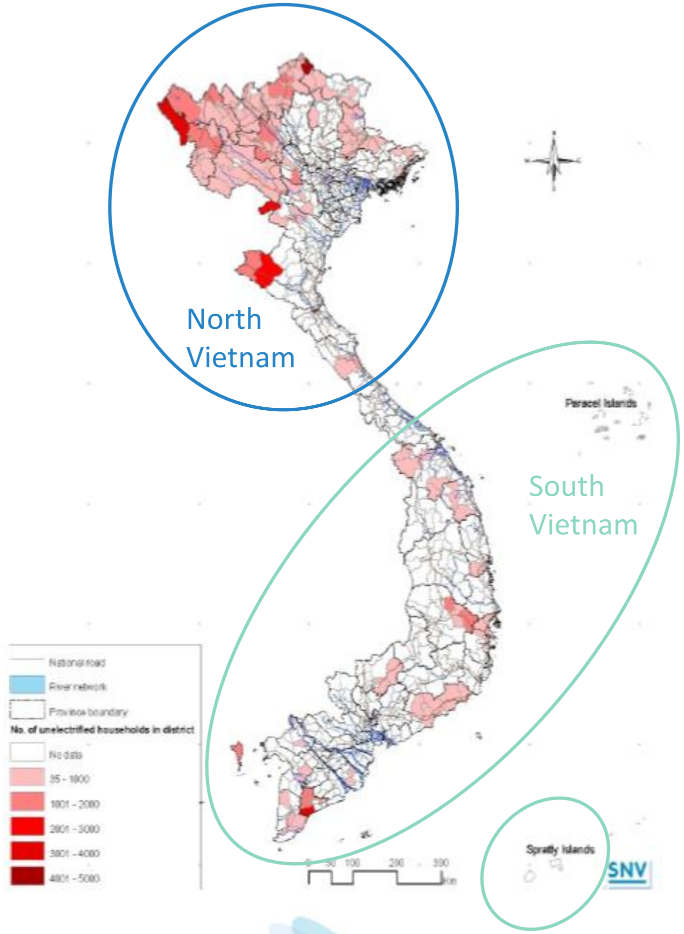
Location of Remote Communities

Vietnam is a country located in the southeast of Asia. It can be divided into North Vietnam and South Vietnam that includes Paracel and Spratly Islands. Most of the households without access to the National Grid are mountainous regions or islands characterized for having a poor living condition.

In 2012, there were 549,131 people without access to electricity and 30,925 more with decentralized electricity supply (diesel or hydropower). As in the North Vietnam the remote communities are in the mountains, the interesting area for wave energy development is the **South Vietnam**. Here, there are 23 communities that are not connected to the National Grid. From those, only **17 communities** are near the coast, up to 50km far away, where around **232,000 inhabitants** live.

- 6 communities have around 6,500 households (small)
- 8 communities have about 12,000 – 13,000 households (medium)
- 2 community has 24,000 households (large)
- 1 community has 48,000 households (very large)

The most crowded communities are located in the south coast.



Location of Vietnam's areas with lower electrification rate

The mean annual power demand of a household in 2010 was of 1MWh and in 2020 it is expected to increase to 3MWh

Power Demand & Energy Source

- Number of remote communities: 17
  - The "large" and "very large" communities are considered as towns, giving back a total of 3 towns located in the southwest.
  - The "small" and "medium" communities are considered as rural plain areas, being a total of 14.
- The power demand varies depending on the type of area: town or rural plain area. In the table below it can be seen the range of power demand of those areas in 2010 and the expected for 2020. It has been calculated the range of demand per community considering the number of households that each has.
  - The **mean annual energy demand per household in** 2010 was of about **1MWh** and in **2020** it is expected to be of **3MWh.**

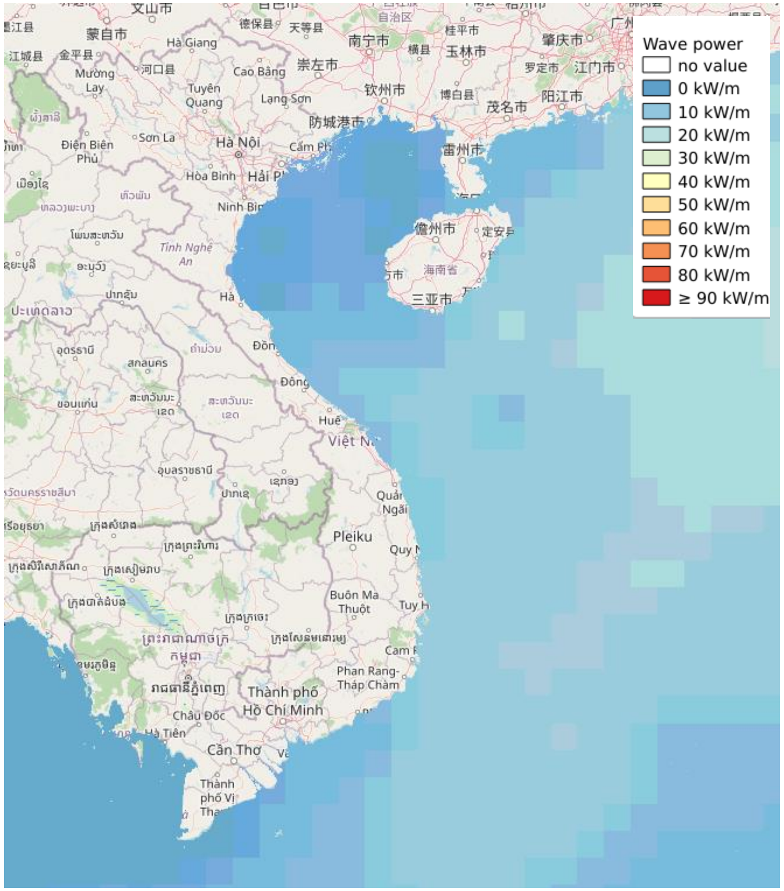
Expected energy demand per rural household/community in Vietnam (MWh/year)

Area	Number communities	Number households	2010		2020	
Town	1	48,000	1.0 - 1.2	48,000 - 57,600	3.0 - 4.0	144,000 - 192,000
	2	24,000		24,000 - 28,800		72,000 - 96,000
Rural plain area	8	12,500	0.8 - 1.0	10,000 - 12,500	2.2 - 3.0	27,500 - 37,500
	6	6,500		5,200 - 6,500		14,300 - 19,500

- Power source: Off-grid power generation usually uses diesel as the main source, which is expensive.
  - While the price range for electricity of connected communities is 0.05 – 0.11$/kWh, in **off-grid areas the electricity costs range** between **0.11 – 0.18$/kWh**. These prices cannot be exceeded thanks to a new regulation.
  - The use of kerosene, LPG and car batteries for lighting is very common in rural areas, covering the 18% of the total consumption.
    - The average consumption of **kerosene** per household is of 18l/year with a price of **0.33$/l**.
  - It is common that after isolated communities gain access to electricity, electric usage level increases.

The east of the South Vietnam together with Paracel Islands have the greatest WED

Wave Energy Resource



Map of the WED in Vietnam

Vietnam's coast is located in South China Sea. The WED of South Vietnam is going to be analysed, as it is the interesting region for the development of wave energy since it is where coastal off-grid communities are located.

The WED is different in each area:

- < 10kW/m in southwest continental coast
- 10 – 20kW/m in the east continental coastline as well as in Spratly Islands
- 20 – 30kW/m in Paracel Islands

Vietnam has a wide variety of natural resources from which isolated communities can take advantage

Competitiveness

Thanks to be an agricultural country with a monsoon tropical climate and a 3.200km of coastline that receives wind from the ocean, Vietnam has diverse clean resources that are potential energy sources.

Wind power

- Potential: it has a potential of 9GW for wind speeds of 8 – 9m/s. The central coast and the south central coast are considered to have the largest wind resource. In this regions, the off-grid provinces of Binh Dinh and Binh Thuan, respectively, are located.
- Current situation: there are more than 1,000 mini wind turbines, about 11 off-grid wind farms and around 7 hybrid facilities, being wind-diesel the most common combination, with a capacity range of 30 – 2,000kW. However, many of the wind turbines are not working currently due to lack of skilled personal and maintenance.
- Estimated average price: this technology has a cost of **0.1 – 0.11$/kWh**, which may be higher depending on the size e.g. a mini wind turbine will be cheaper.

Solar PV power (dismissing solar water heaters)

- Potential: the country has a great constant solar radiation, specially in South Vietnam. The mean solar radiation of all off-grid communities that have been considered is of 5kWh/m^2. In the communities, solar power can be used an average of 300 days per year.
- Current situation: there are more than 4,000 solar systems destinated to supply electricity for public and domestic use. It is considered as the most feasible option to power off-grid communities.
- Estimated average price: the total investment for a rural household with a capacity of 360Wp is of **650 – 1,200$.**

Biomass. Its use for electric generation is minimal due to lack of support systems.

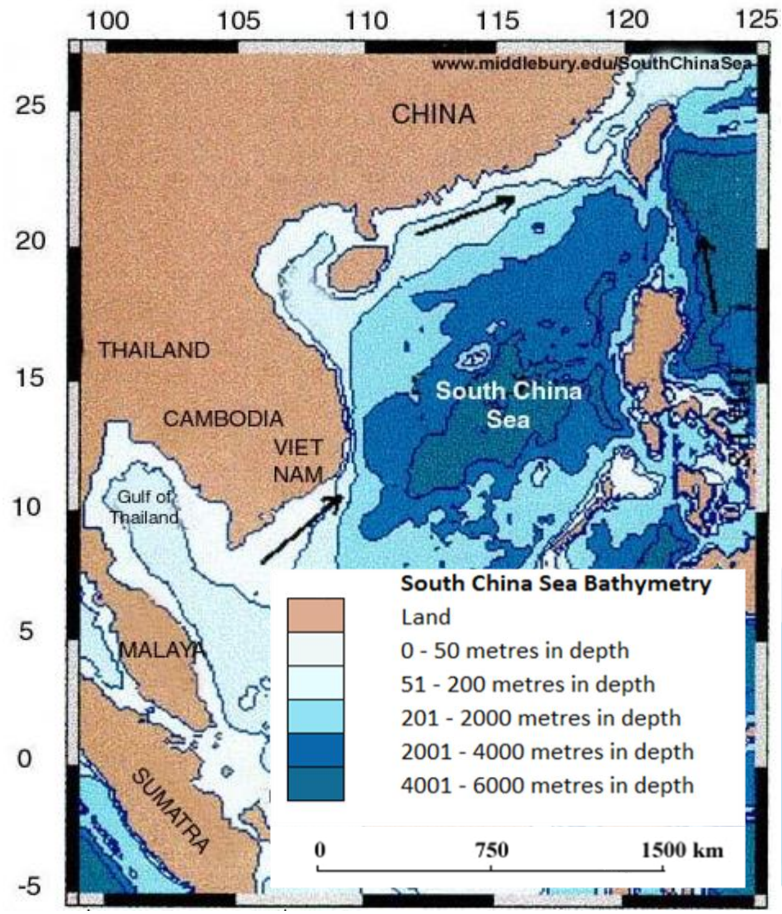
Hydropower. Despite the huge potential that Vietnam has regarding hydropower, its resource is located in North Vietnam or in non-coastal sides and so, it is not going to be considered as a competitive option for wave energy market.

https://snv.org/cms/sites/default/files/explore/download/2014-01-24_off-grid_final_report.pdf

The intermedium waters match with the areas with greatest wave resource while the shallow waters have less resource

Bathymetry of the Coastline

As it can be observed in the bathymetry map, the coastline of the south of the country has shallow waters, up to 50m deep. Regarding the central part of the country, it can be seen that the seabed goes down more rapid, reaching to 200m in few kilometres, what can be considered as intermedium waters. The same happens in Paracel Islands.

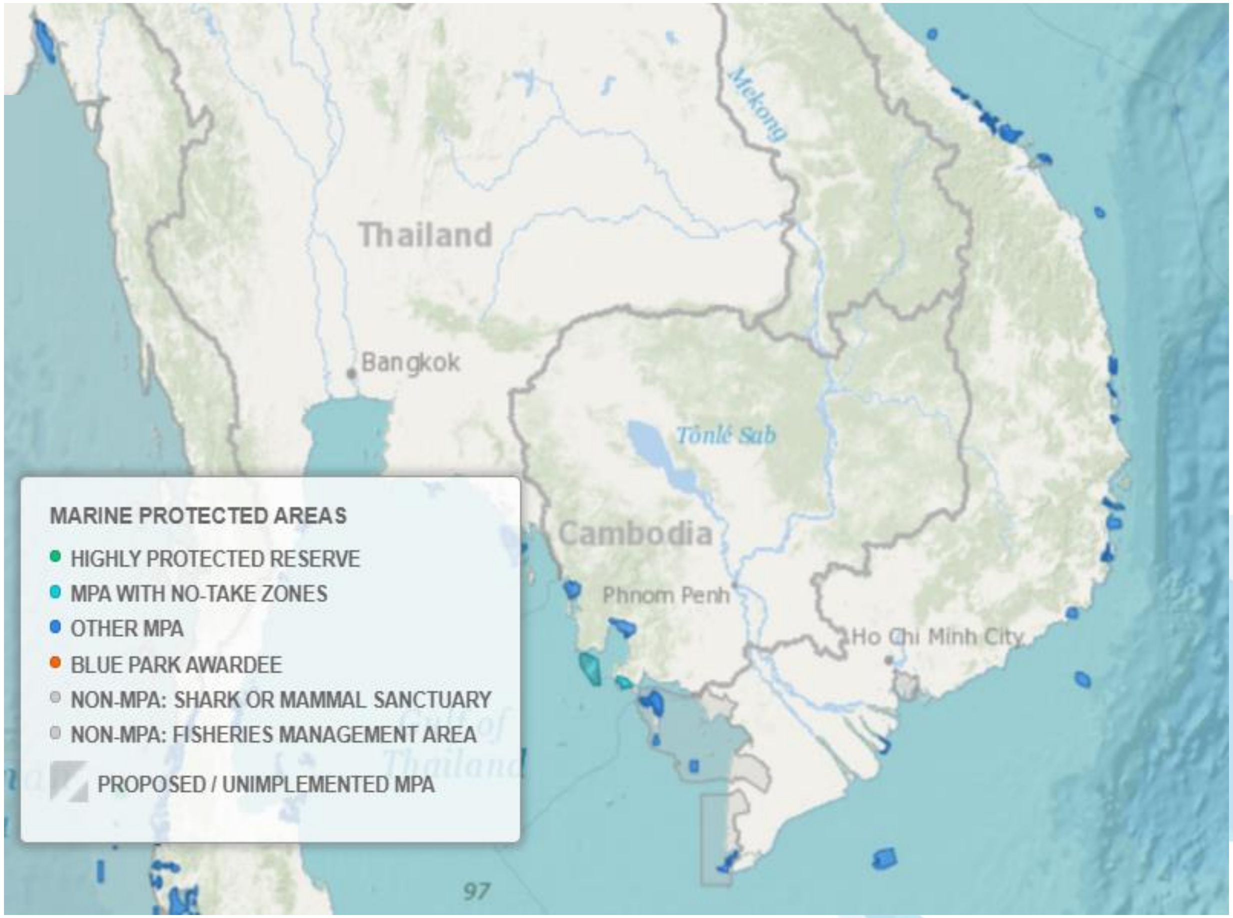


Bathymetry map of Vietnam

There are several marine protected areas along the Vietnam coast

Marine Protected Areas

As WECs cannot be installed in marine protected areas (MPAs), it is worth analysing them. In the South Vietnam there are several MPAs that should be considered since some of them match with the off-grid locations, specially in the southwest coast.



Map of the MPAs of Vietnam

There is a lack of support to renewable energy projects

Future Expectations

- The Vietnam's government has a target of ensuring the **100% of electricity access by 2020**, for what is going to invest and support the development of local power resource.
    - In 2009, the electrification rate was of 96%.
- However, there is a **lack of supportive policy** for investment and development of **renewable energy projects** both in on-grid and off-grid isolated areas.
- There are **not projects** related with **marine energy** in the country.

https://snv.org/cms/sites/default/files/explore/download/2014-01-24_off-grid_final_report.pdf

Conclusions

- Due to the location of the isolated communities, the study area is South Vietnam, where there are 17 isolated communities with 232,000 inhabitants. North communities are left out since they are in mountainous regions.
- The annual mean power demand in 2010 was of 1MWh per household and in 2020 is expected to increase until 3MWh.
- The communities connected to the main grid are paying around 0.05 – 0.11$/kWh while off-grid communities are paying the double. This is because the use of diesel as main electric resource. This can change by taking advantage of the natural resources that the country has.
    - Solar energy has a great potential and because of that, there is an extensive number of installations. It has competitive prices to be capable of replace the diesel generators.
    - Despite the potential of the wind in Vietnam, most of the projects are stopped because of lack of qualify workers.
    - Regarding the WED, it must be highlighted that only in the central part there is enough resource, between 10 – 20kW/m. This means that out from the 17 isolated communities, only 7 are optimum for installing a wave energy farms, 6 small communities and 1 medium.
- As the MPAs are small, not covering the whole coast and so, they do not affect to the remote communities.
- Today, there are no targets set by the government that will support the development of renewable energies.

1. Introduction
2. Overview of the niche market
3. Analysis of the isolated power systems
4. **Main conclusions**

Conclusions of the Isolated Power Systems (1/2)

- Isolated Power Systems are communities or regions that do not have access to the main electric grid such as islands or remote areas. Although there are isolated power systems worldwide, some of the more interesting regions for wave energy development in terms of current cost of energy and different energy resource availability are Canada, United States including both Alaska and Hawaii, Indonesia, the Pacific Islands, the Antilles, Cameroon and Vietnam.

- The main problem that they are currently facing are the high costs (0.3 – 0.7$/kWh) of their main resource, which commonly is diesel. There is a secondary problematic which is the low electrification rate. This implies the necessity of new power systems.

- The main competitors for wave energy are hydropower, in the regions where there is resource, and solar energy, which has more competitive prices and an easy installation and maintenance.

- Canada and Alaska are in a similar situation. On the one hand, they have a low number of remote communities suitable for the wave energy development, around 40 and 25 respectively. This means that those communities have enough wave energy density (WED) in their coasts and are not affected by any Marine Protected Area (MPA). On the other hand, the power demand per community is quite high, between 1 – 6GWh/year per community.

- Hawaii has similar characteristics. Four of its islands are suitable considering both WED and the location of MPAs. Although the number of isolated islands is low, their total power demand is very high, around 9,000GWh/year. The Antilles have as well the same characteristics as Canada and Alaska tough a lower WED. Its approximately 10 suitable parishes have an average power demand of 5GWh/year per parish. The power demand of these two regions is supplied mainly by fossil fuels with a mean cost of 0.4$/kWh.

Conclusions of the Isolated Power Systems (2/2)

- In the case of Indonesia, the low electrification rate is the main problem of certain regions. After taking into account the WED and the location of the MPAs, only 18% of its remote communities are considered suitable for wave energy development, though this implies a quite relevant number of up to 1,600 cases. However, the power demand of each community is very low, of 29MWh/year. In this country there are already targets that benefit the investment in marine energies.

- As it happens with Indonesian communities, out of the total number of remote communities in the Pacific Islands, only 28% are suitable, 880 communities. In this case, the high cost of the fossil fuels, which are the main resource, is the main problematic. The electric tariffs vary between 0.2 – 0.8$/kWh. The mean power demand per community is of 3.6GWh/year. All the countries have ambitious targets for the renewable energies.

- Out of the studied countries, Cameroon is the one with less interest in wave energy development due to its low wave potential. Although it is not at the same level of Cameroon, Vietnam’s wave potential is quite low comparing it with the rest of selected regions and so, it could be not interesting for this niche market.

- To sum up, **Canada** and **Alaska** are probably the most suitable countries to develop wave energy due to their great wave energy potential and the high cost of the main competitor. Although there is not a large number of communities in these regions, it could be suitable for the first deployment of commercial wave energy converters. Another relevant region is the **Pacific Islands** follow thanks to the huge number of remote communities that have. However, the investments that they can afford could not be enough; this will depend on the cost of the fossil fuels which varies from county to country. It must be highlighted the huge potential of **Hawaii** for developing wave energy.

All the bibliography used is in an additional file.

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