GALAPAGOS
LIVING LAB

USFQ

THE UNIVERSITY OF EDINBURGH

Cámara
Ecuatoriano
Británica

# Assessing pathway options for renewable energy systems to support the water-energy-food nexus in Galapagos

Galapagos Living lab for Energy Innovation

Inclusive and Sustainable Decarbonization of the Galapagos Islands

03/07/2023

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# Problem

Access to clean energy, quality water and nutritious food is not sustainable in the Galapagos islands.

A lot of food is imported, the water that is consumed is polluted and the energy, in addition to being subsidized, comes from the combustion of petroleum derivatives.

# Objetive

To model cases to understand the impact of energy generation from renewable resources (solar, wind, biomass, etc.) for the sustainable development of the Santa Cruz Island, focusing on the production of clean water and nutritious food.

# Milestones

**OCT 2022**
Project kick off

**MAR 2023**
End of data collection

**APR 2023**
Data analysis and initial modelling

**MAY 2023**
Final model, analysis and discussion

**JUL 2023**
Results presentation and discussion

# Methodology

DATA GATHERING AND INTERVIEWS WITH LOCALS

- Any solution should be built on available data and the local's perspective, so they can bring added value to the island. Sources: Ministerio de Agricultura y Ganadería, GAD Santa Cruz, Fundación Charles Darwin, Ministerio de Energía, Asociación "Yo solo vendo lo que produzco", etc.

SHARED DATA/DOCUMENTS

- MAG:
  - Study on production costs for main crops
  - Updated info on farming land, crops produces, animal farming, practices, supply chain.
  - Water reservoirs distribution and current status
- GAD:
  - Updated info on population urbanism, local economy
  - Population growth
- Water plant:
  - Water production and electricity generation
- Others:
  - Weather data

# Meetings

WATER TREATMENT PLANT

FARMERS

REPRESENTATIVES

# Isla Santa Cruz as our system

Available data so far:

- Food sales, imports/exports
- Agricultural land use, infrastructure, equipment and heavy machinery
- Organic/inorganic waste management
- Electricity generation and demand
- Fuel consumption
- Water treatment

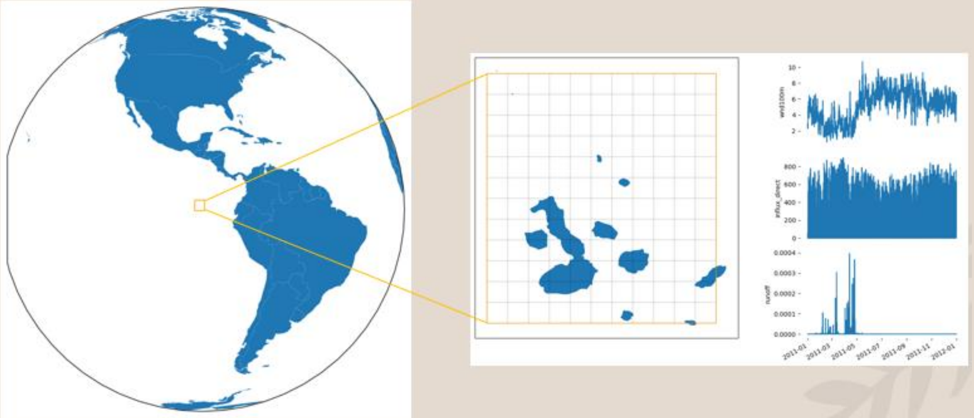

Information/data sources:

Ministerio del Ambiente · Punto Verde · Parque Nacional Galápagos Ecuador · Consejo de Gobierno del Régimen Especial de Galápagos · Fundación Charles Darwin foundation · Galapagos Conservancy — Saving one of the world's great treasures · Ministerio de Agricultura y Ganadería

# Methodology

## RENEWABLE ENERGY AVAILABILITY

- Wind and solar assessment obtained from weather data and modeled using Python. Biomass availability estimated from meat production data.

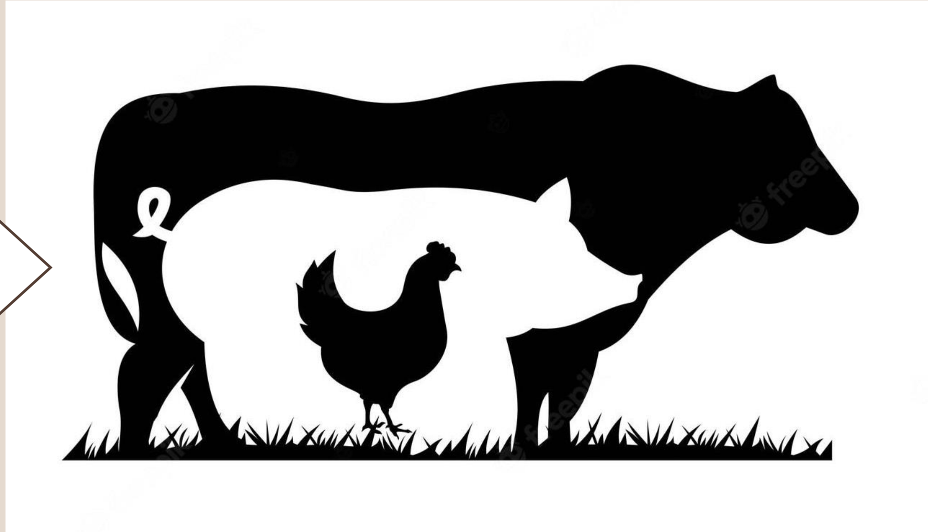


## CASES

- Determined the energy and water needs in meat production to calculate the impact of renewable energy options to improve present supply and impact using EES and Excel.
- The Cases were selected based on data availability and relevance to the concerns of locals.

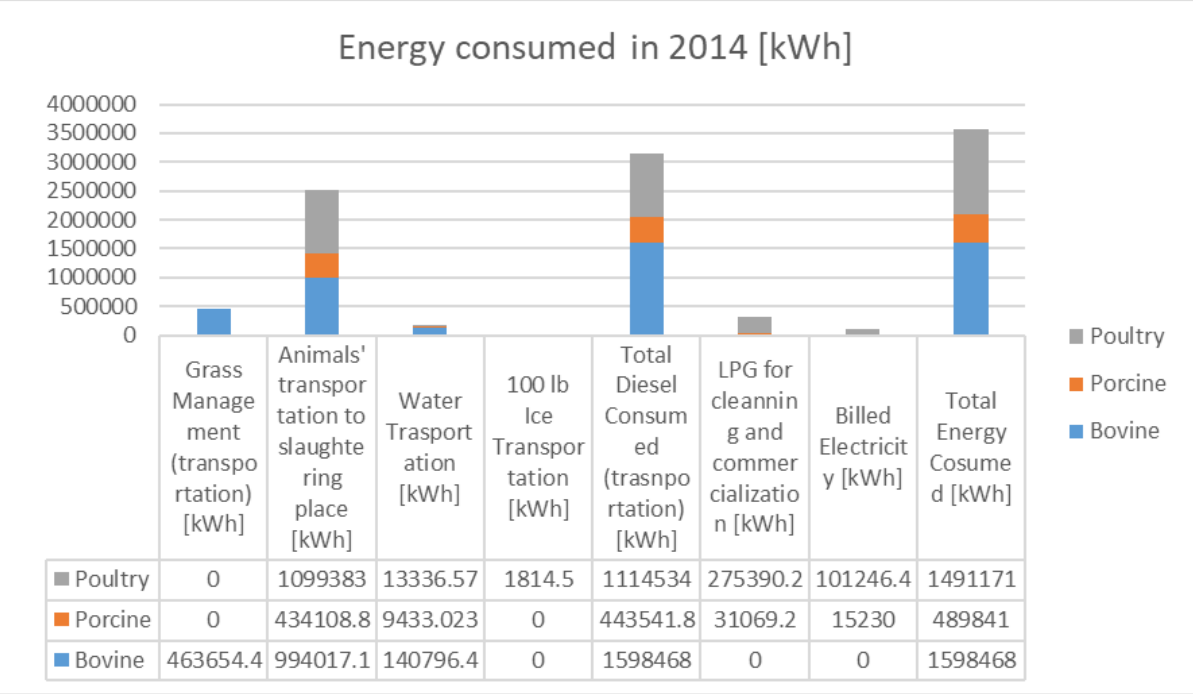
# Meat production (WEF nexus)

- Water
  - Grass
  - Drinking
- Energy (Diesel, LPG, electricity)
  - Transport
  - Refrigeration
  - Cleaning
  - Selling

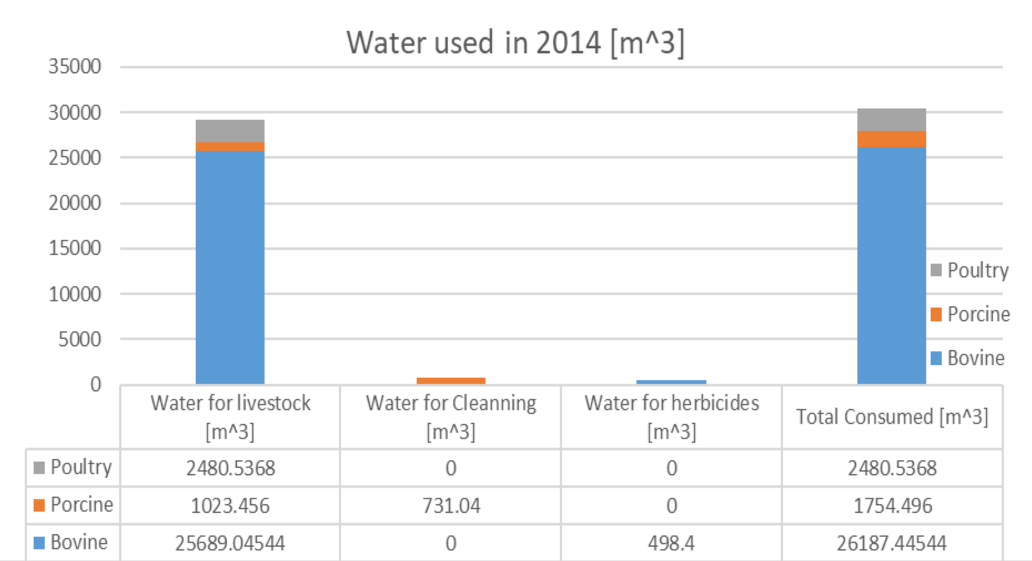


# Meat production

- Santa Rosa and Cascajo are the main farming lands in Santa Cruz. The distribution of agricultural production units (UPA, by its Spanish initials) in these areas is 97 porcine, 124 bovine, and 189 poultry UPAs.
- In 2014, the total meat production was 835616 kg (47% poultry, 41% bovine, 12% porcine).
- Bovine is processed in a centralized slaughter facility (camal) and the rest is processed on each farm.




| | Grass Management (transportation) [kWh] | Animals' transportation to slaughtering place [kWh] | Water Trasportation [kWh] | 100 lb Ice Transportation [kWh] | Total Diesel Consumed (trasnportation) [kWh] | LPG for cleanning and commercialization [kWh] | Billed Electricity [kWh] | Total Energy Cosumed [kWh] |
|---|---|---|---|---|---|---|---|---|
| Poultry | 0 | 1099383 | 13336.57 | 1814.5 | 1114534 | 275390.2 | 101246.4 | 1491171 |
| Porcine | 0 | 434108.8 | 9433.023 | 0 | 443541.8 | 31069.2 | 15230 | 489841 |
| Bovine | 463654.4 | 994017.1 | 140796.4 | 0 | 1598468 | 0 | 0 | 1598468 |

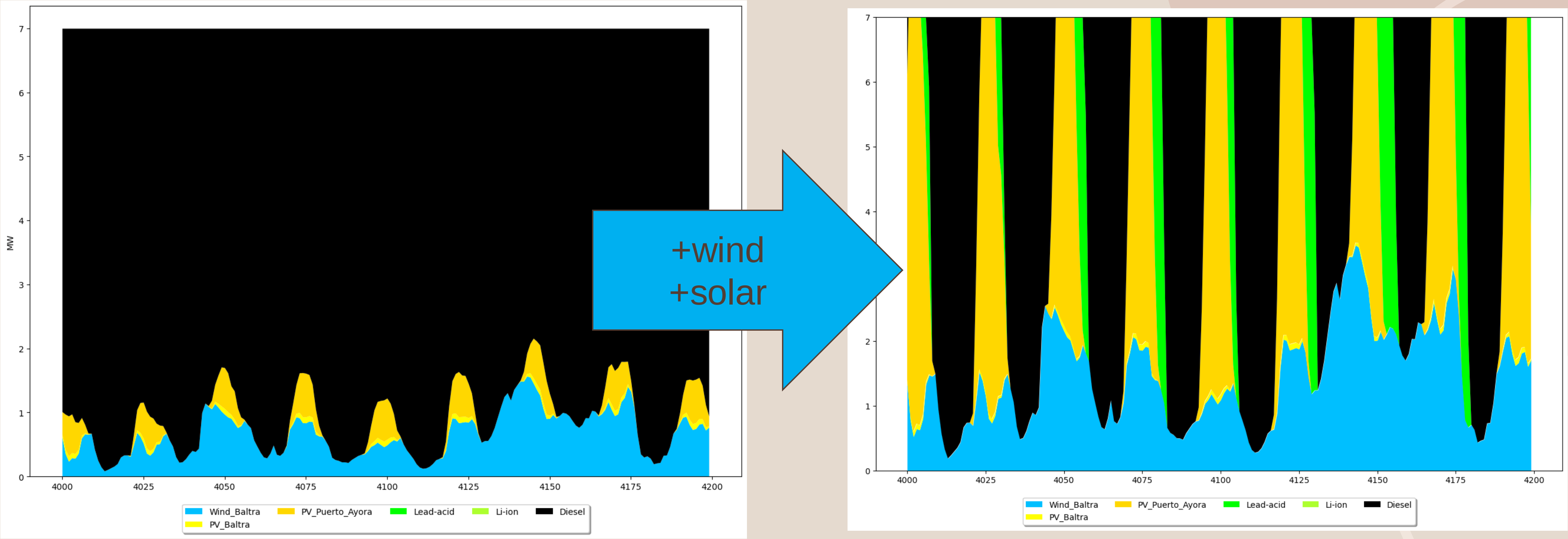



| | Water for livestock [m^3] | Water for Cleanning [m^3] | Water for herbicides [m^3] | Total Consumed [m^3] |
|---|---|---|---|---|
| Poultry | 2480.5368 | 0 | 0 | 2480.5368 |
| Porcine | 1023.456 | 731.04 | 0 | 1754.496 |
| Bovine | 25689.04544 | 0 | 498.4 | 26187.44544 |

# Cases

| Case (Nexus) \ Concern from locals | | No access to renewable energy technology | Lack of electricity for farms | Intermittent urban water supply | Water scarcity for farms |
|---|---|---|---|---|---|
| 1. Large scale renewable energy facilities | (W, E, F) | ✓ | ✓ | ✓ | |
| 2. Water supply for farms | (W, F) | ✓ | | | ✓ |
| 3. Distributed energy generation for water treatment | (E, F) | ✓ | | ✓ | |
| 4. Distributed energy generation for farms | (E, F) | ✓ | ✓ | | |
| 5. Heat and/or electricity from biomass | (E, F) | ✓ | | | |

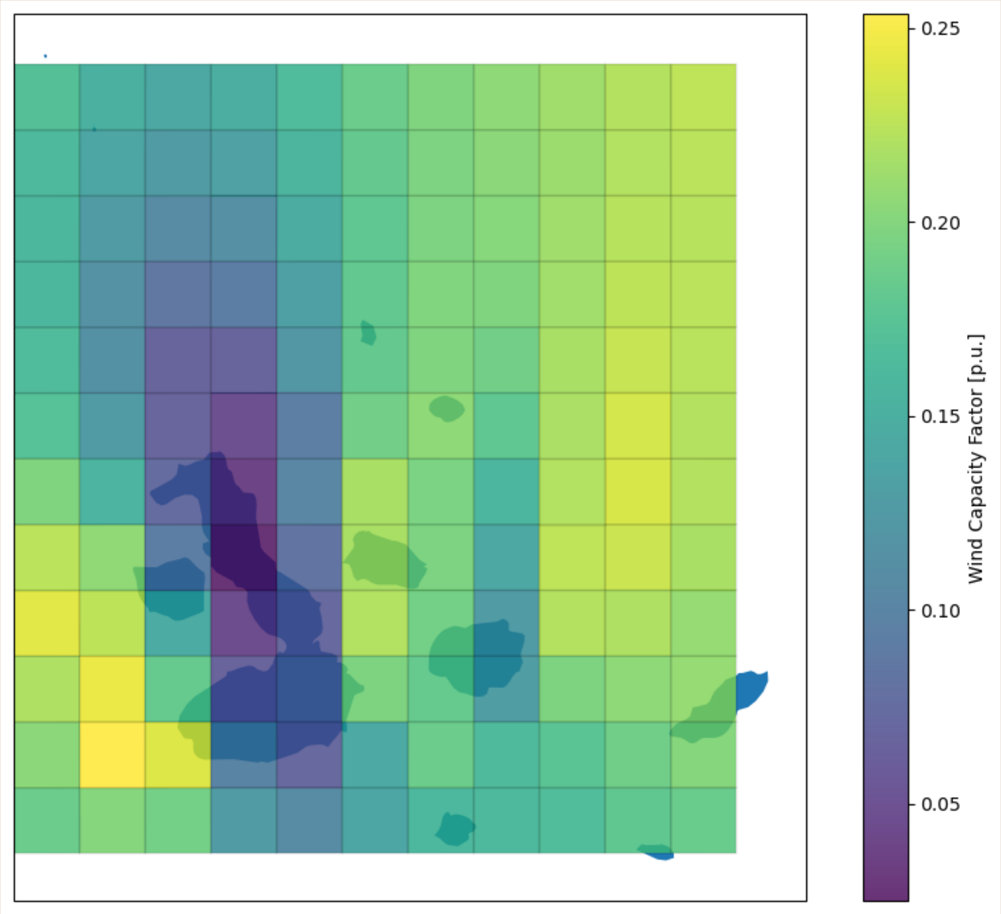
# Case 1: Enhance present installed capacity

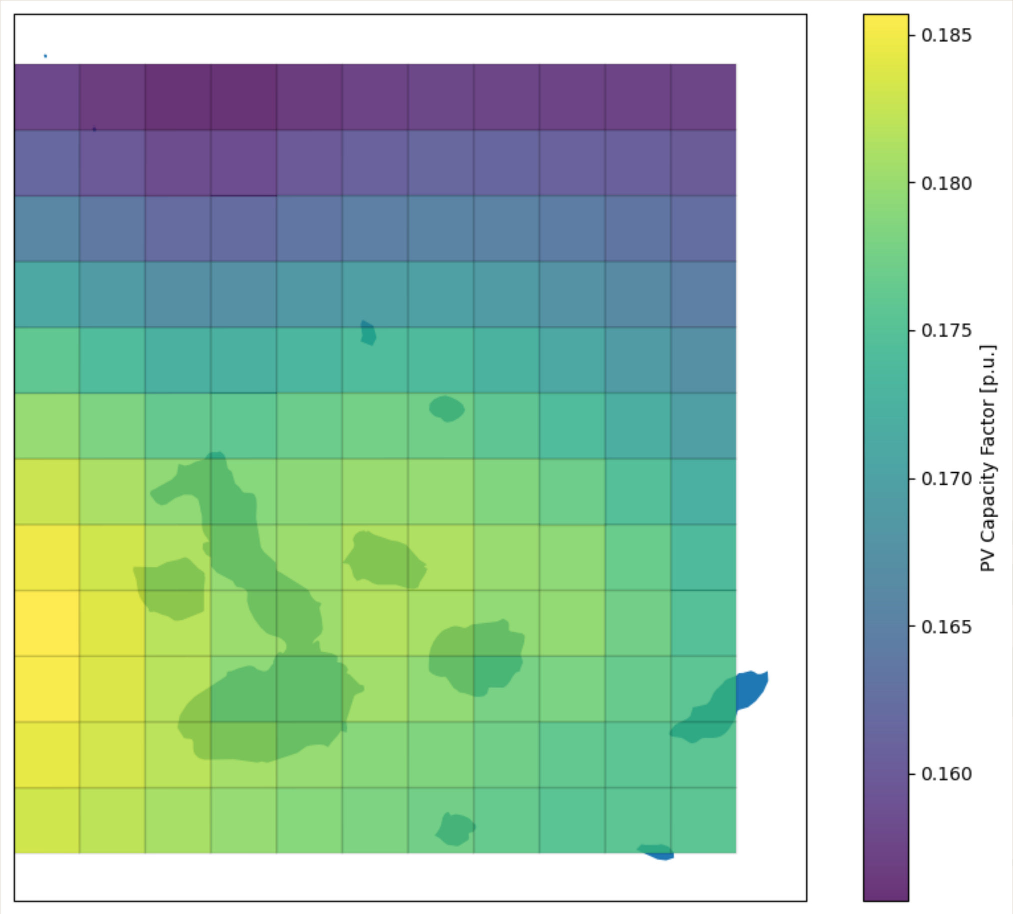



Current power is diesel dominated

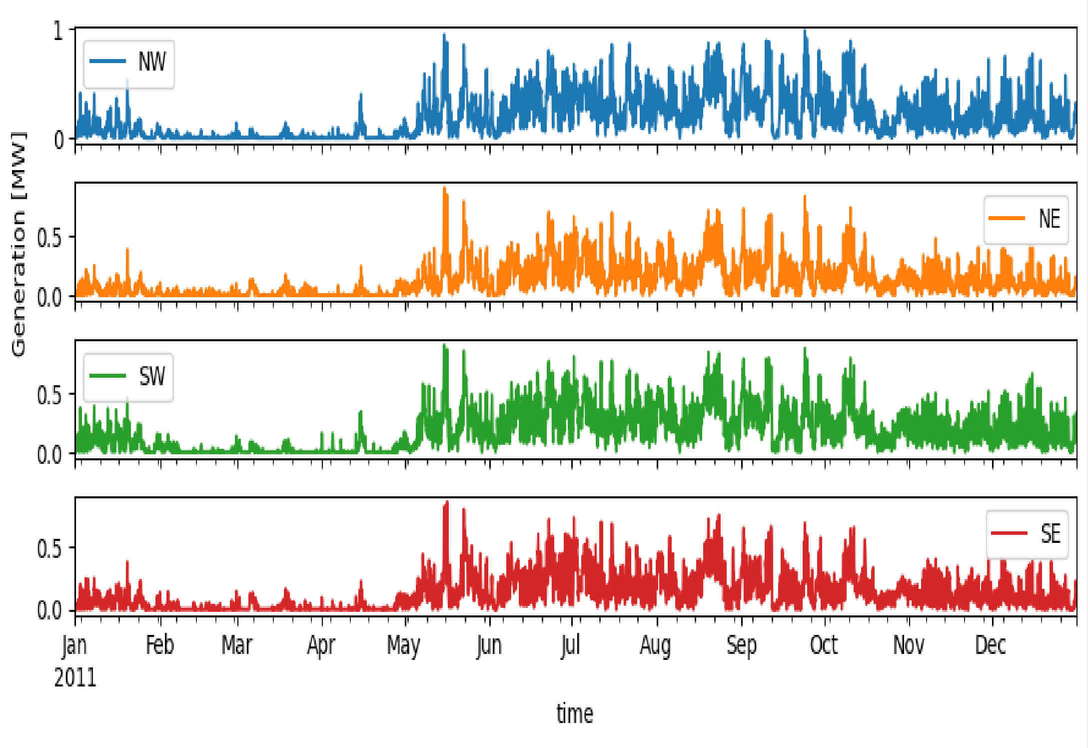
5MW wind and 20MW solar with current storage

# Wind offshore? Solar PV?

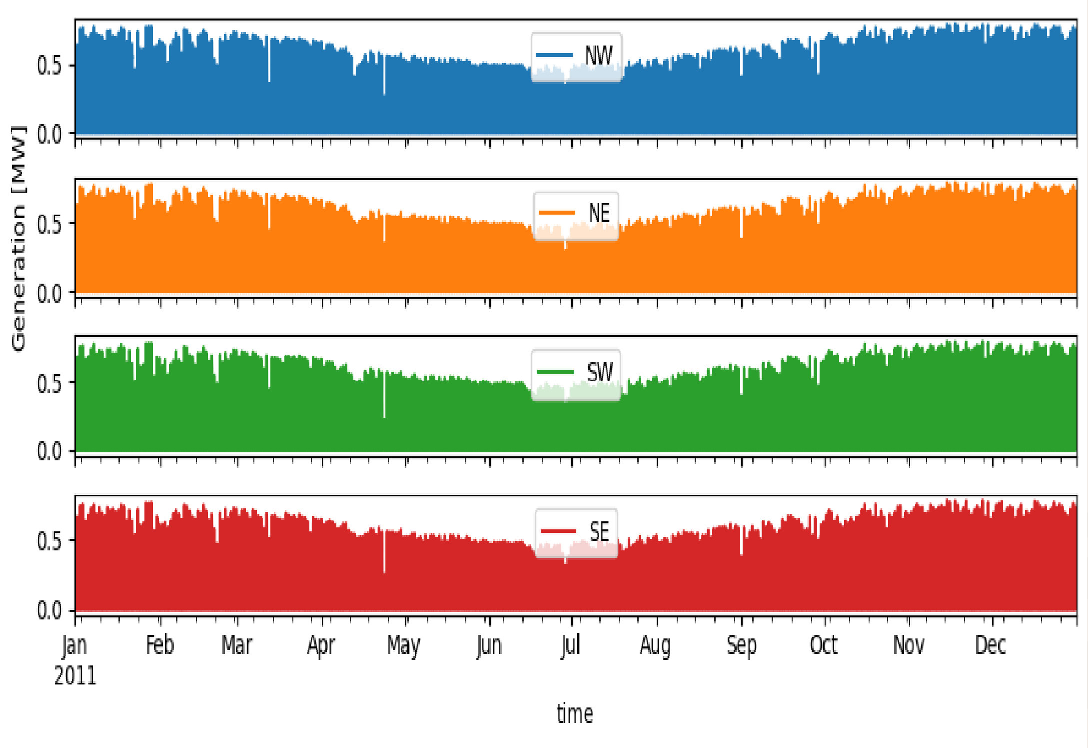


# Seasonality of wind and solar




Wind generation



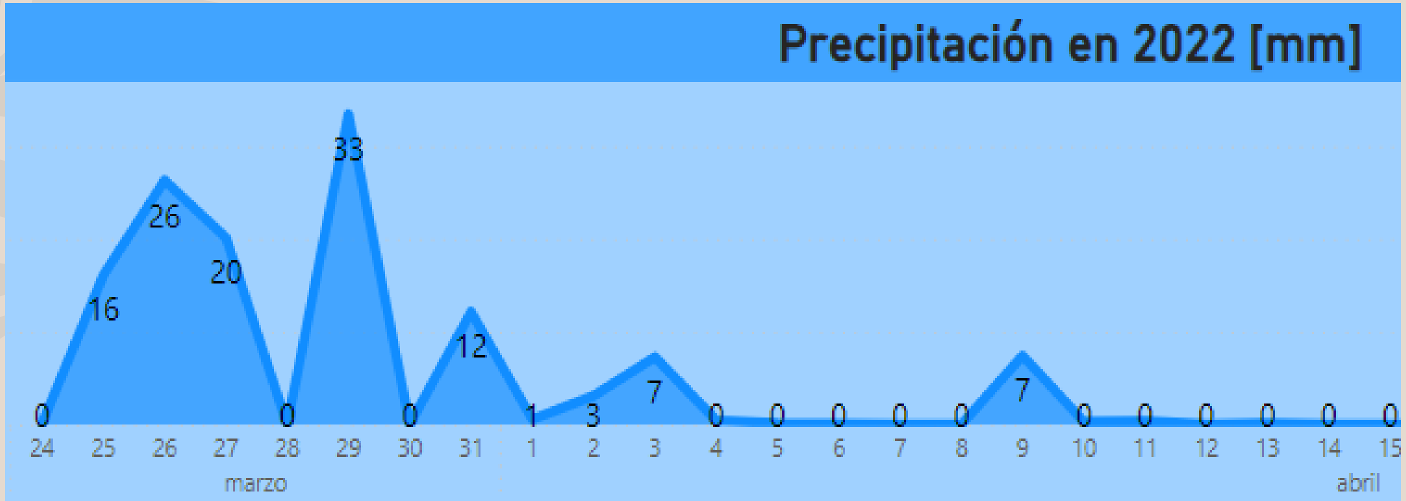

Solar PV

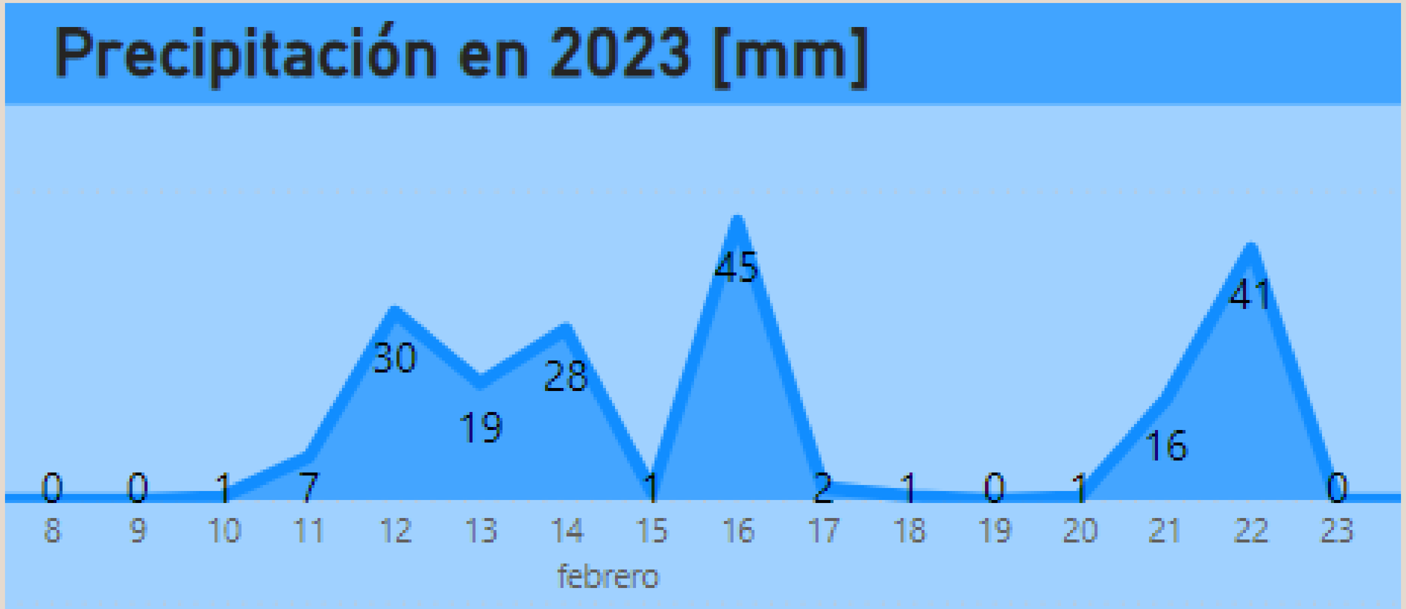
# Case 2: Water supply for farms

- Passive rainwater and/or fog harvesting are not enough to cover water needs.
- High relative humidity areas (in Cascajo and Santa Rosa); constantly foggy.
- Renewable resources could power active fog harvesting to supply enough water to fulfill the needs for meat production.

## Seasonal rain collection

# Case 2




## Water Generation

<u>Water Gen Model L</u>

Scenario 1

Cost: 52359.72 USD

Production: 2160 $m^3$ Annually

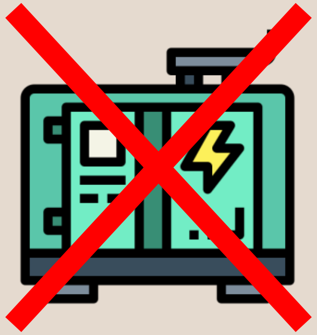
2.7 $tCO_2$ reduced

- X1 unit Porcine or Poultry water consumption

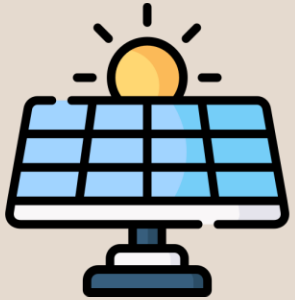
- Scenario 2
  Cost: 628509.84 USD
- Production: 26187.44 $m^3$ Annually
- 341 $tCO_2$ reduced

- X12 Units Bovine water consumption

# Case 3: Solar photovoltaics to power water treatment



- Rooftop urban area ≈390000 $m^2$ distributed in 4700 buildings.
- If covered with solar panels, 26% of these rooftop areas would supply the total energy demand (Tian et al, 2021)
- Only 1.6 % of rooftop area needs to be covered to supply water treatment energy demand (≈138k $m^3$ potable water per month → 1 kWh/m3)
- ≈810 tons of $CO_2$ reduced per year

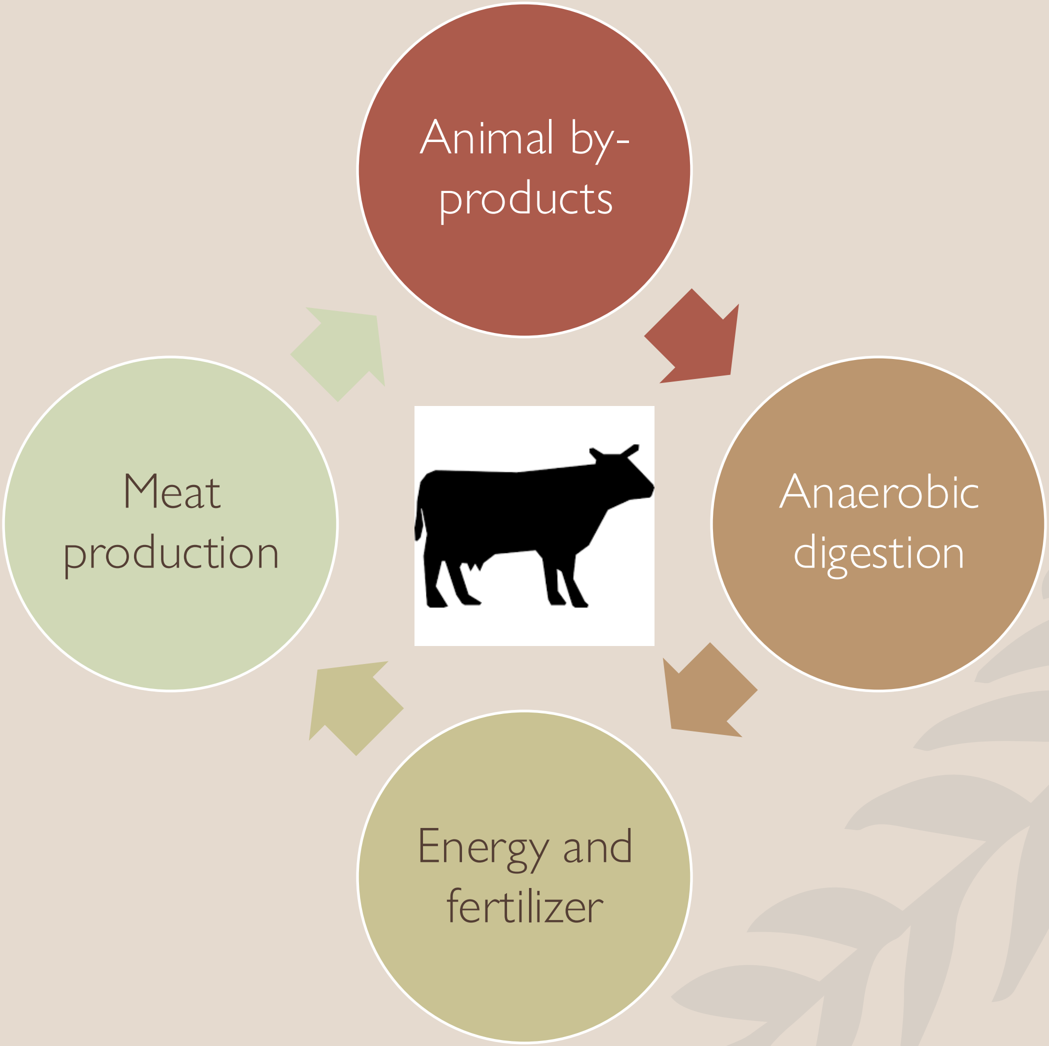


# Case 4: Solar photovoltaics to power small farms

- Many farmers need access to electricity.
- Many need to learn how to access technology to produce electricity.
- Most UPAs can significantly benefit from ≈1.5 kW off-grid installations to increase their quality of life and productivity.
- More data needed on individual energy demand.

# Case 5: Biomass to power the slaughter facility

- Biomass from the slaughter facility produces a lot of Greenhouse Gases (GHG) and are landfilled.
- If the animal by-products (8 cows/day) were anaerobically digested to produce biogas and generate electricity, 190 MWh of energy could be obtained, enough to power GAIAS and GSC (USFQ).



# Conclusions

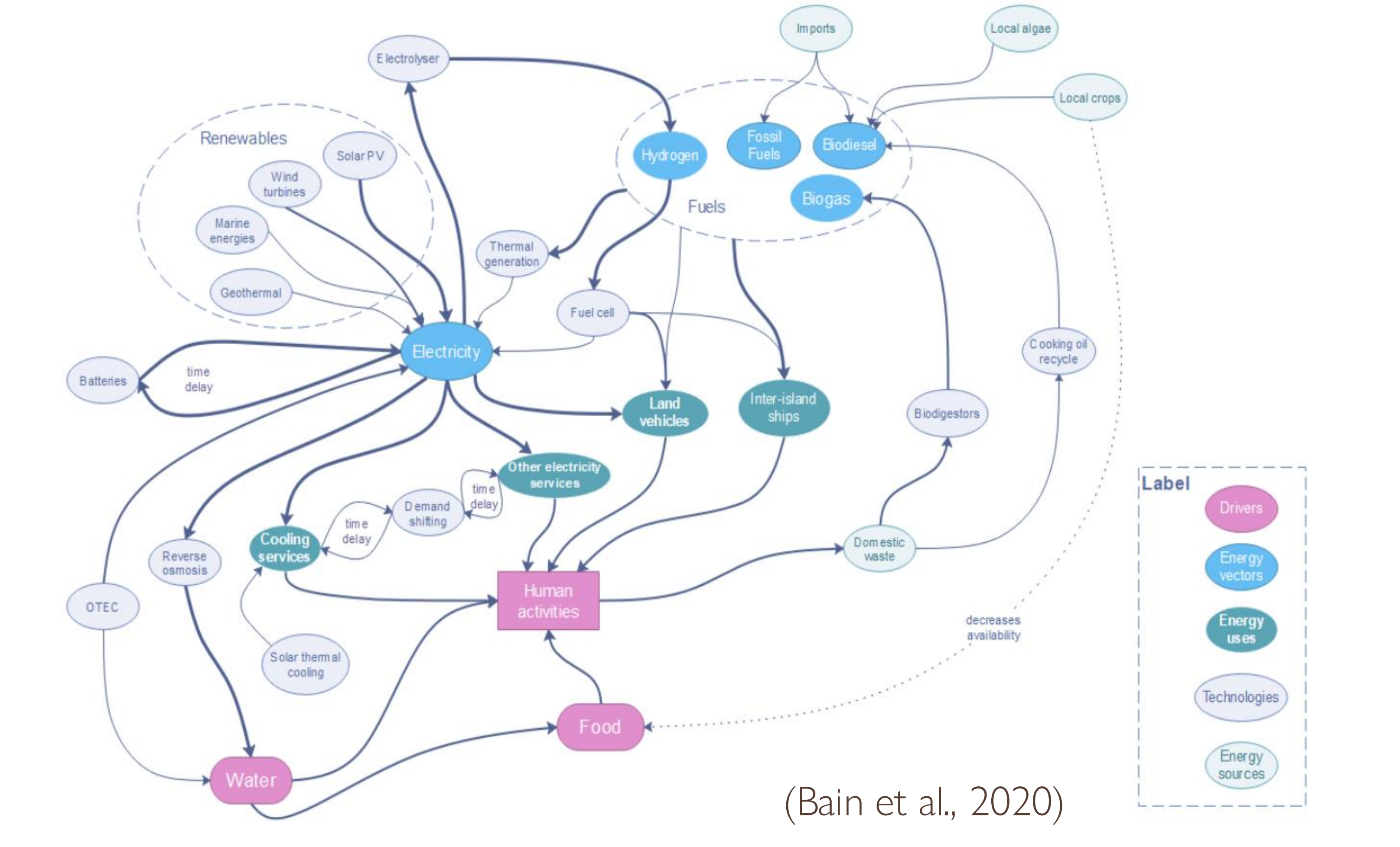
- Data from 2014 and 2022 was available for the estimations in the project. More recent data is needed to improve the analysis of the cases.
- Multiple renewable energy resources can reduce diesel consumption and its environmental impact. For example, unutilized waste biomass that produces GHG in landfills; untapped solar and wind resources.
- Lack of access to technology and economic limitations prevent farmers from producing their own water and energy to strengthen the WEF nexus.
- Fossil fuel subsidies are a barrier to transition into a decarbonized Santa Cruz.

# Next steps

- Explore optimization pathways to expand the impact of renewable resources.
- Publish collected WEF nexus-related data online (Power BI and Excel files).
- Identify other opportunities for WEF connections specific to Santa Cruz.
- Engage with relevant stakeholders interested in these WEF connections. Use their knowledge to scrutinize the modeling outputs.
- Pilot off-grid installation for small farms (First system sponsored by Kubienergy).
- Extrapolate this project to other island systems.
- Explore funding opportunities: Prima, Horizon, MAF, GIZ…

# Next steps

Desalination, irrigation, and land use identified as enablers for WEF nexus




(Bain et al., 2020)

Water is key need for improved provision and quality – needs to also consider energy and food

More detailed assessment for connecting electricity to desalination and irrigation, and mapping land use

## PAUL SAFFO, STANFORD UNIVERSITY

“The goal of forecasting is not to predict the future but to tell you what you need to know to take meaningful action in the present.”

# References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- Barbaran, Gustavo & Sbroiavacca, Nicolás & F. S. Cepeda, Maricruz & Insuasti, Sebastián & Lallana, Francisco & Nadal, Gustavo & Sagardoy, Ignacio & Soria, Rafael & Dubrovsky, Hilda & Moreno, Adrián & Pólit, Renato. (2020). Resumen Ejecutivo: Escenarios de Demanda y Oferta Energética y Opciones de Política Energética. Archipiélago de las Islas Galápagos. República del Ecuador.
- Lyden, A., Flett, G., & Tuohy, P. G. (2021). PyLESA: A Python modelling tool for planning-level Local, integrated, and smart Energy Systems Analysis. SoftwareX, 14, 100699.
- Tian, A., Zünd, D., & Bettencourt, L. (2021). Estimating rooftop solar potential in urban environments: a generalized approach and assessment of the Galápagos Islands. Frontiers in Sustainable Cities, 49.

# Thanks

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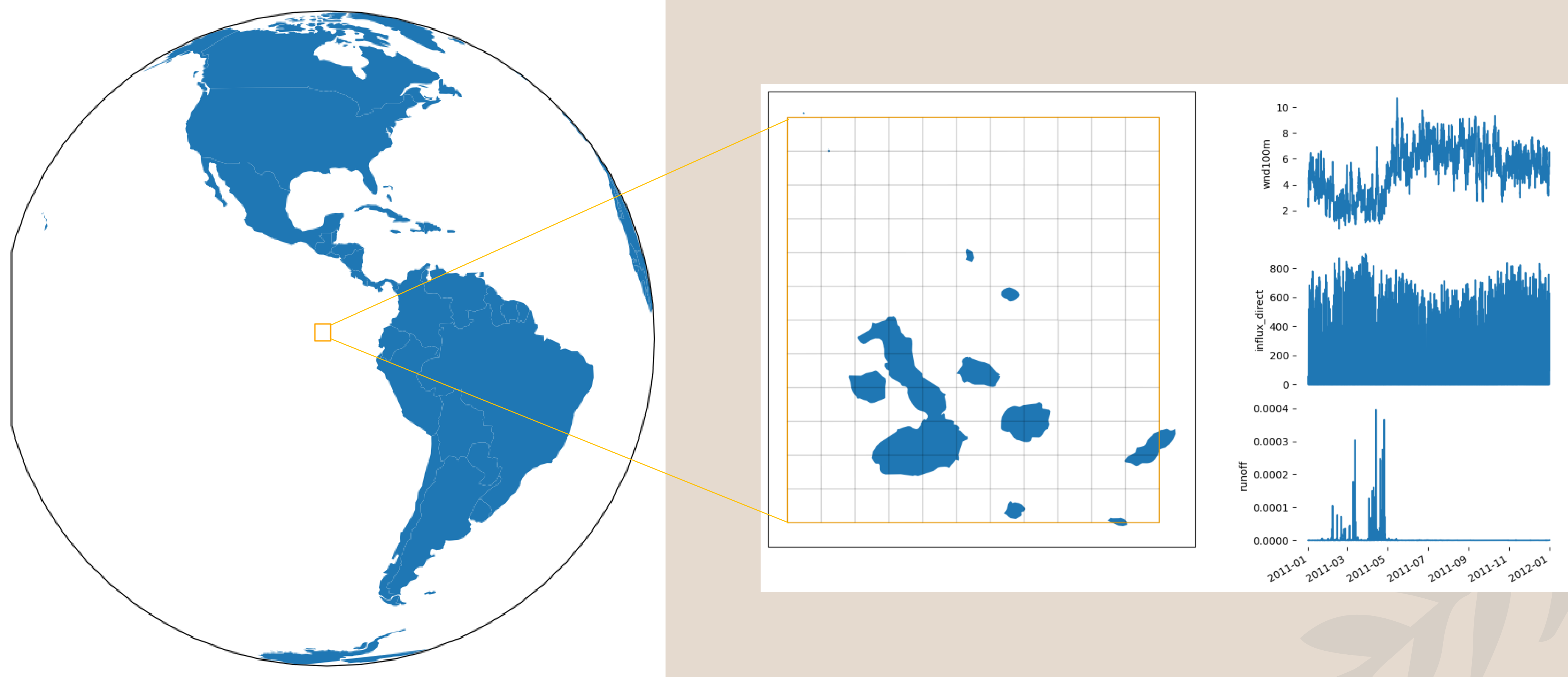
# Additional slides

# Outcomes

Based on a clear understanding of the Water-Energy-Food connection, we will innovate the design of renewable energy systems for a more sustainable Santa Cruz Island.

# Renewable resources assessment



# Buscamos su apoyo

## COMUNIDAD, PRODUCTORES Y EMPRENDEDORES

- Líderes comunitarios
- Agricultores
- Comerciantes
- Transportistas

## EMPRESAS, PROVEEDORES Y OTROS

- Energías alternativas
- Purificación de agua
- Agrícolas, Agroindustriales
- Estudios demográficos, Consultoras, Logísticas,
- ONGs, etc.

# Lo que no sabemos

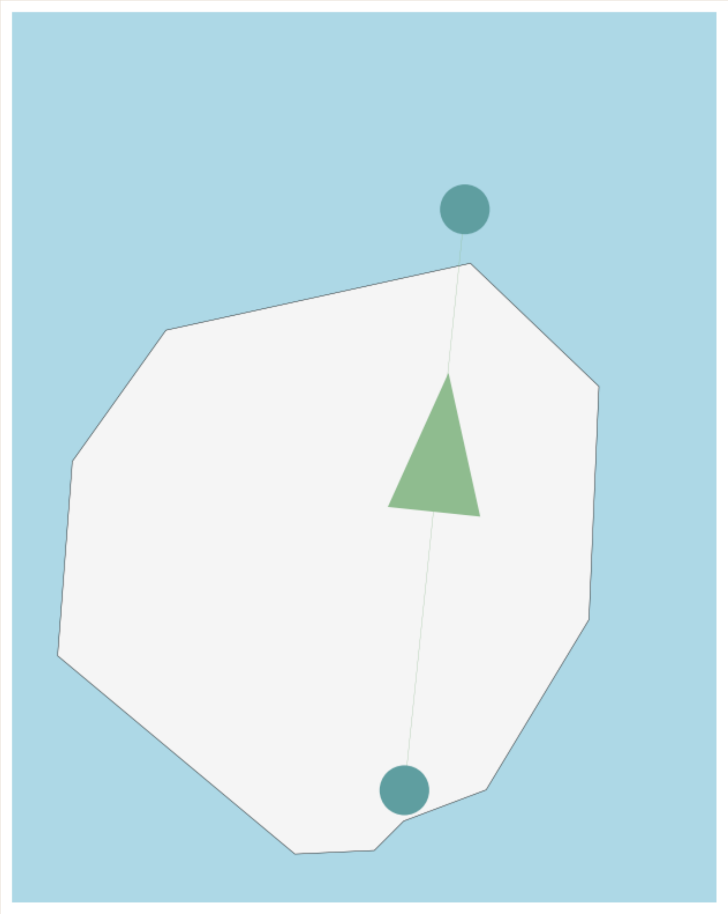
## AGRICULTURA Y ENERGÍA

- o Temporadas de siembra, cosecha.
- o Energía consumida en la agricultura.
- o Retos de la agricultura en Santa Cruz.

## AGUA Y ENERGÍA

- o Reservorios de agua natural en la isla.
- o Fuentes tradicionales de agua para cultivos.
- o Energía en el tratamiento de agua.

# Santa Cruz electrical system

# From meeting the locals

THEIR CONCERNS

- Water scarcity for agriculture (P)
- Lack of reservoirs to collect water (P)
- Water being transported using tanker trucks uphill (P)
- Lack of electricity in the farming zones (P)
- Lack of renewable energy supply chain for off-grid needs (G)
- Farms are in poor/degraded soil areas (P)

SHARED DATA/DOCUMENTS

- MAG:
  - Study on production costs for main crops
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  - Water reservoirs distribution and current status
- GAD:
  - Updated info on population urbanism, local economy
  - Population growth
- Water plant:
  - Water production and electricity generation
- Others:
  - Weather data

# $CO_2$ Reduction scenarios

Case 1: Direct replacement for electric power - Big investment

Solar PV and wind turbines replace-support the power grid

- It eliminates the necessity of fossil fuels
- Requires equipment sizing

Case 2: Creation of water reservoirs near the cattle land - Small investment (producción y seguridad alimenticia)

Reservoirs avoid the necessity of water transportation

- It will reduce 10% of the diesel used for transport
- All the diesel consumption for transport represents the 70% of the energy consumed

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# Data in Power BI/Excel

- Available for 2014 or 2022, multiple islands
- Food, water
  - Production, imports/exports
  - Consumption, usage
  - Waste
- Energy
  - Resource
  - Installed capacity