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

## Intro

**Problem:** Access to clean energy, quality water, and nutritious food is unsustainable in the Galapagos islands. Much food is imported, the consumed water is polluted, and the energy is subsidized and comes from the combustion of petroleum derivatives.

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

## Methods

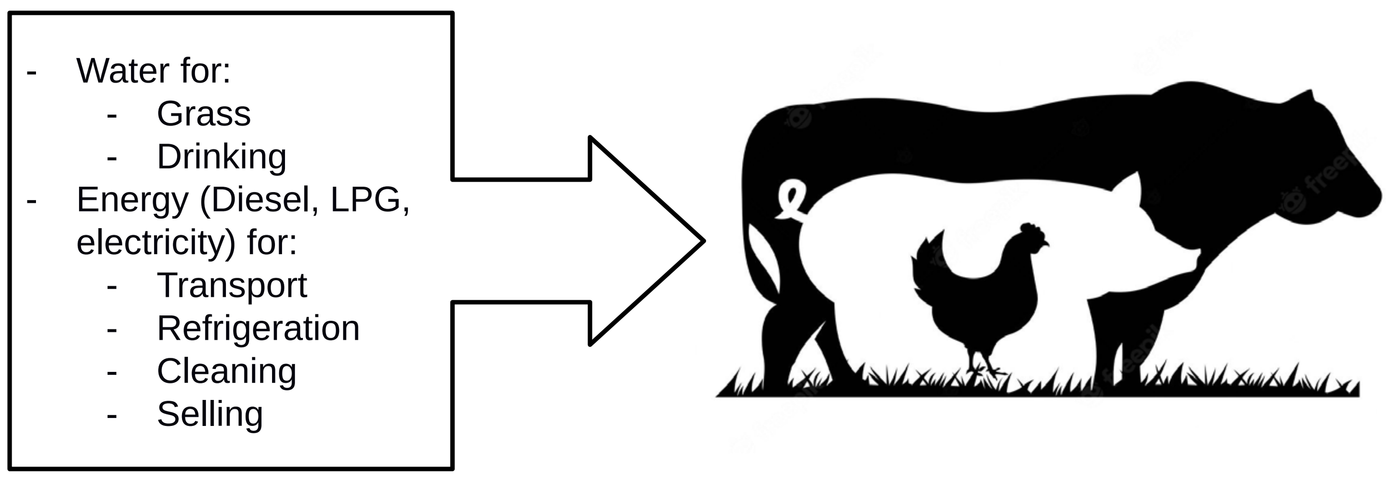
**Data gathering and interviews with locals:** Any solution should be built on available data and the local's perspective, so they can bring added value to the island. Sources: Ministerio de Agricultura y Ganadería, GAD Santa Cruz, Fundación Charles Darwin, Ministerio de Energía, Asociación “Yo solo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

**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. Cases selected based on data availability and relevance to the concerns of locals.

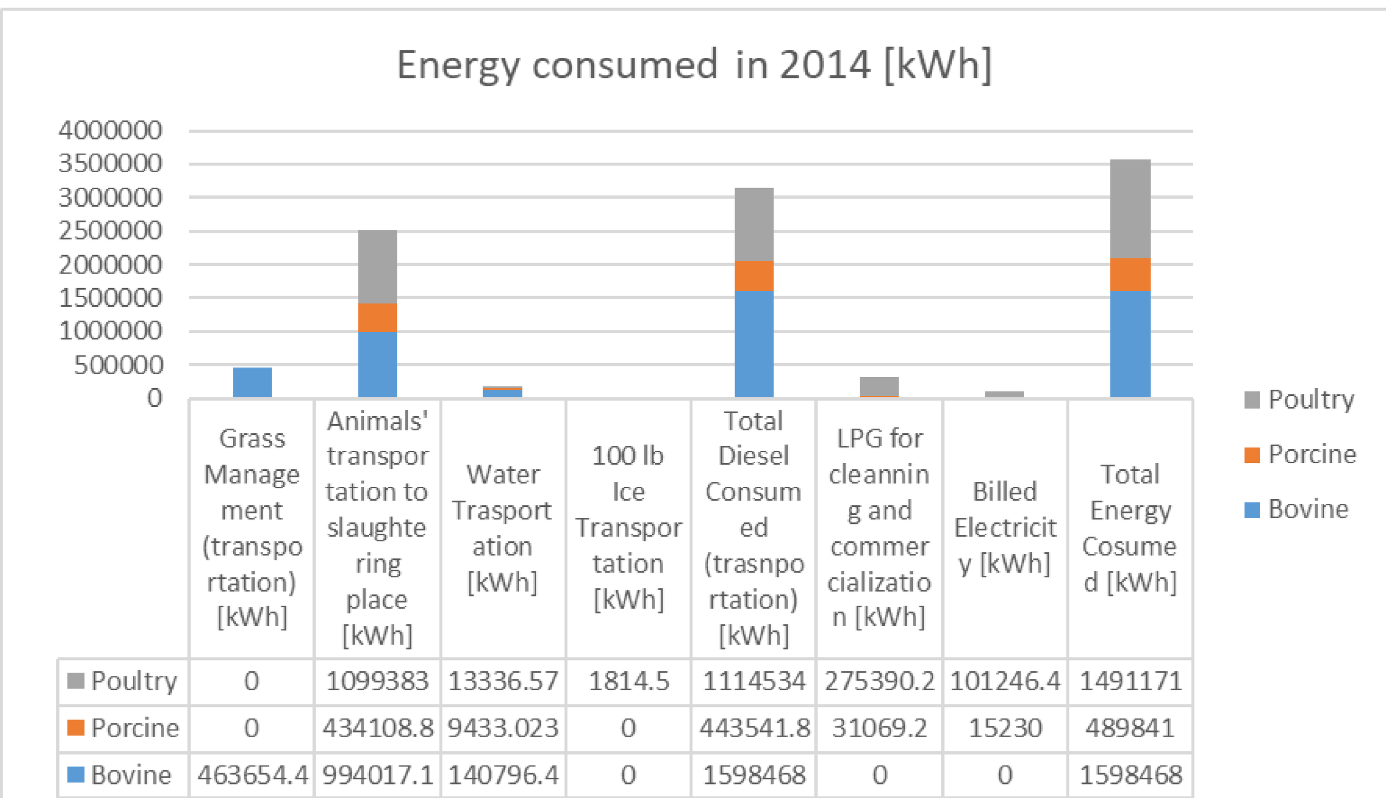
## Meat production in Santa Cruz

**Overview:** 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.



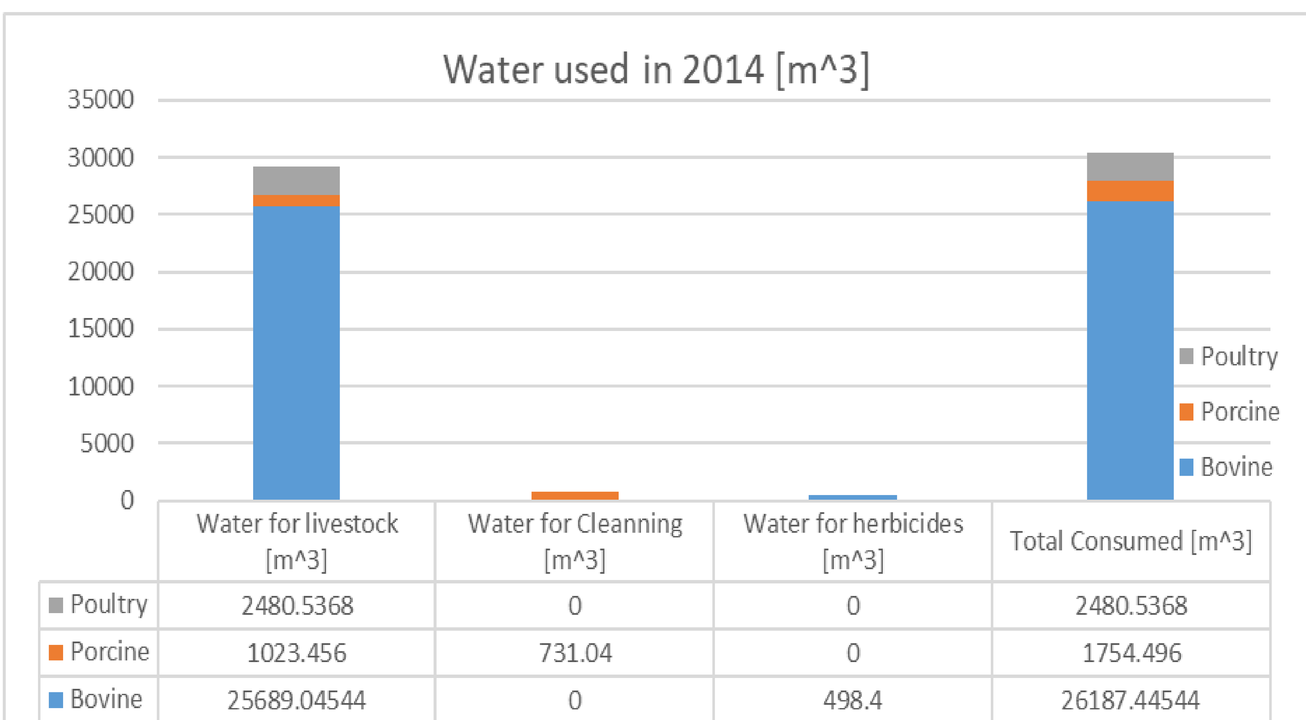

**Challenges**:

- Due to the lack of nearby sweet water sources, centralized/de-centralized reservoirs, and water harvesting stations, each farmer supplies water using tanker trucks.
- The main source of energy is fossil derived. Most of the farms do not have access to electricity.




| | 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 |

**Figure 1. Energy consumption in meat production:** Bovine and poultry are the main energy consumers. Diesel consumption is much larger than LPG and electricity in meat production.

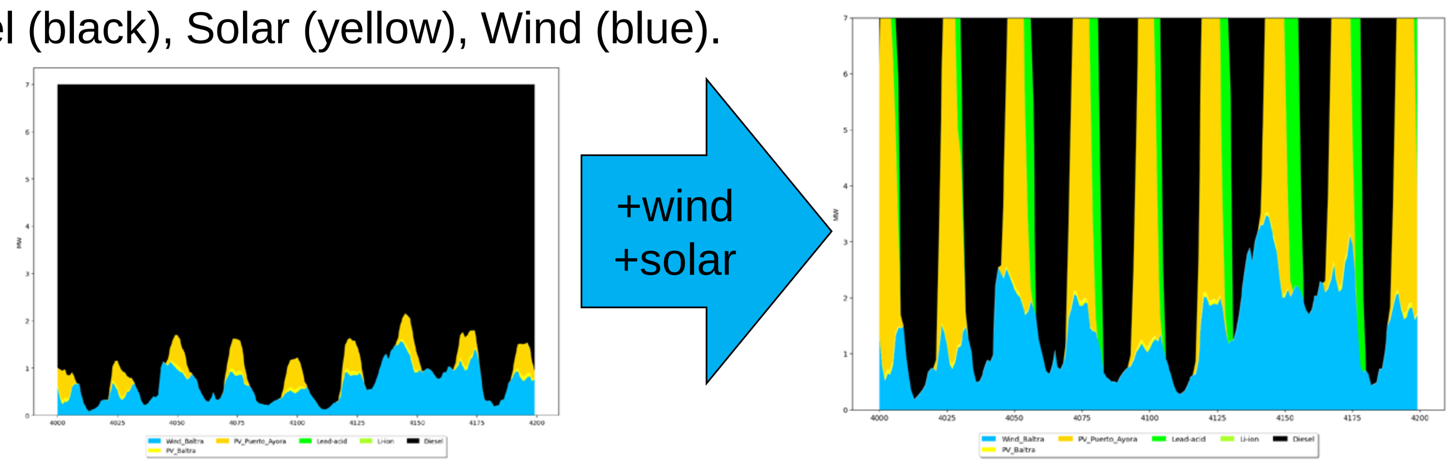



| | Water for livestock [m^3] | Water for Cleanning [m^3] | Water for herbicides [m^3] | Total Consumed [m^3] |
|---|---|---|---|---|
| Poultry | 2480.5368 | 0 | 0 | 2480.5368 |
| Porcine | 1023.456 | 731.04 | 0 | 1754.496 |
| Bovine | 25689.04544 | 0 | 498.4 | 26187.44544 |

**Figure 2. Water consumption in meat production:** Bovine is the main consumer. Overall, livestock consumption is the larger demand for water in meat processing.

## Results

**Case 1.** Installing 5MW of wind power and 20MW of photovoltaic electric generation, with no additional storage capacity, will allow reducing diesel consumption by half. Diesel (black), Solar (yellow), Wind (blue).




**Case 2.** More than water harvesting from rain collection in ceilings or fog traps is required to replace the water supply from tankers. Active water harvesting in the high relative humidity areas in Cascajo and Santa Rosa can supply enough water to fulfill the needs for meat production; however, this technology should be powered with solar/wind/biomass renewable energy.

**Case 3.** Water treatment consumes ≈1 kWh/m³ of water. Solar photovoltaic systems, either centralized or decentralized, can replace the electricity provided by diesel generators. When land use restricts the installation of extensive PV facilities, Puerto Ayora has more than enough space to produce this energy with rooftop installations connected to the grid. Only 10% of the available rooftops used for electricity generation will suffice to produce energy for the water treatment plant, reducing 810 tCO2eq yearly. Nowadays, regulation allows using rooftops for energy purposes.

**Case 4.** Many farmers need access to electricity. Moreover, 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.

**Case 5.** Biomass from the slaughter facility produces a lot of Greenhouse Gases (GHG), especially from blood, tissue, and manure degradation. 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).

**Table 1. Studied cases.** Check marks show the connection between cases and concerns. (W= Water, E= Energy, F=Food)

| 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) | ✓ | | | |

## Conclusions

- Data from 2014 and 2021 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…

## Relevant references


Bain, A. A., Maximov, S., Crane de Narváez, S., & García Ferrari, M. S. (2020). Social, environmental and energy context of the Galapagos Islands.

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.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