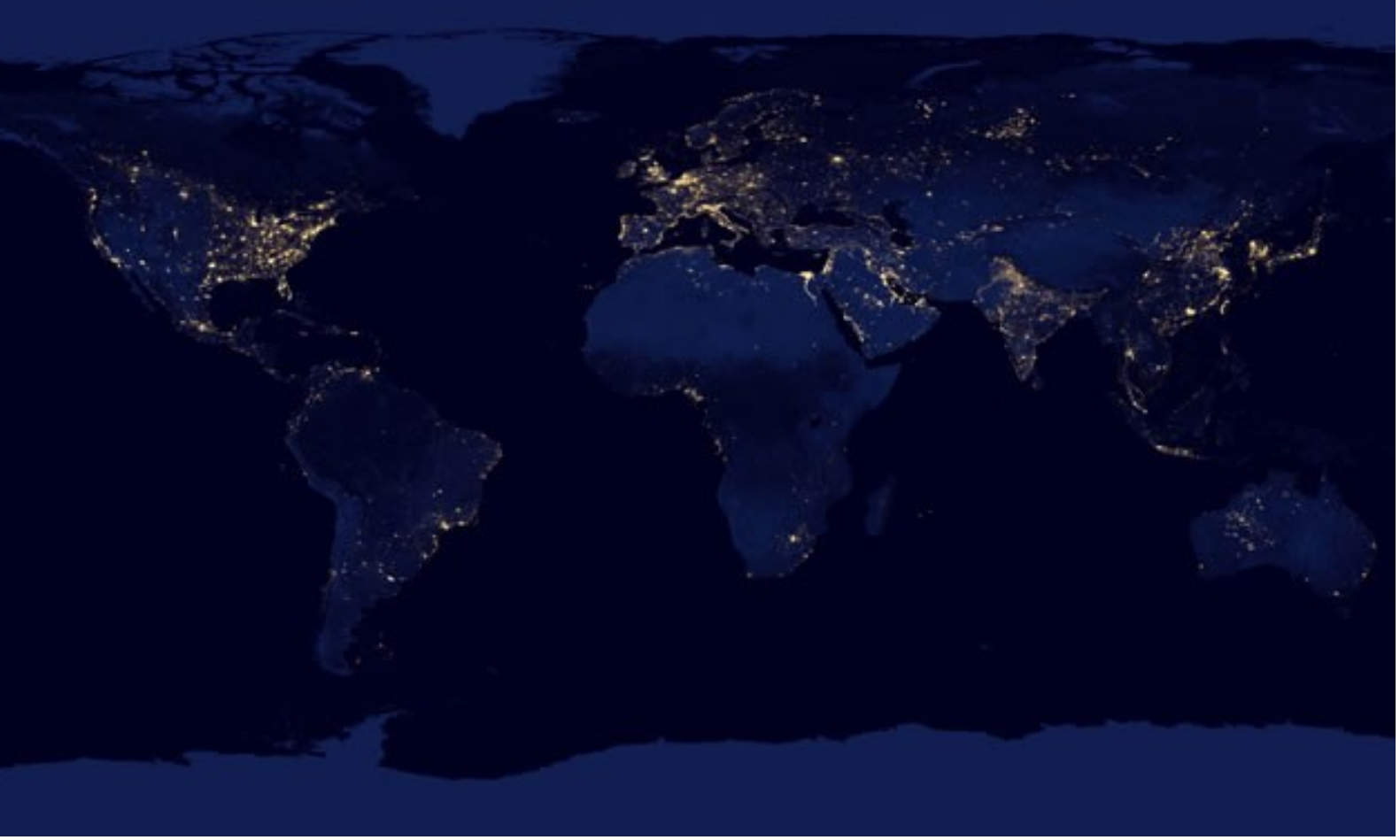
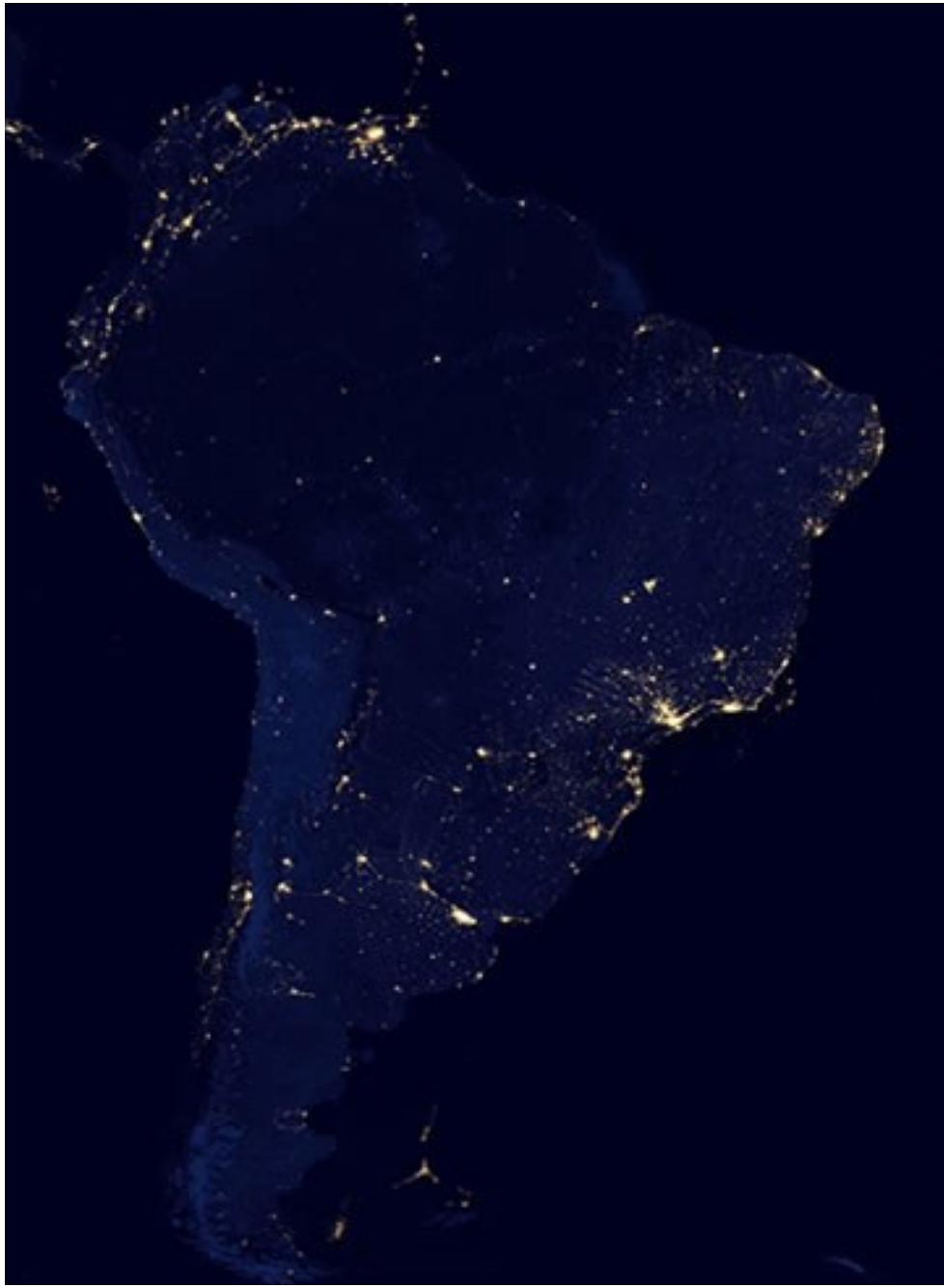
Rural electrification in Amazon: challenges and case studies

Lecturer: Alessandro Bezerra Trindade (Federal University of Amazonas, Brazil)

3rd May 2023



SOURCE:
https://geology.com/articles/satellite-photo-earth-at-night.shtml
NASA's Suomi satellite



Today’s AGENDA

- Alessandro’s Résumé
- Numbers and Concepts
- Contextualization (World and Brazil)
- Amazon basin (or Amazonia) Challenges
  - Size
  - Seasons issues (including rivers level and temperature)
  - Infrastructure (roads, distance, telecom, etc.)
  - Electrification in the Amazon basin and the rest of the country
- Case studies in rural electrification at the Amazon
- Sustainable Development Goals 2030
- 2023 scenario

Alessandro’s Résumé

- Adjunct Professor of the Department of Electricity (Technology Faculty)
  - Undergraduate courses of Electrical and Computing Engineering (since 2015)
  - Graduate Program of Electrical Engineering (since 2022)
- PhD in Informatics (UFAM/2020), Master in Electrical Engineering (UFAM/2015), Graduation in Electrical Engineering (UFAM/1995)
- Areas of interest:
  - Rural electrification (PV systems mainly, Biomass for biogas production and small power systems)
  - Second life batteries
  - Automatic verification and synthesis of cyber-physical systems
- German-Brazilian Research Cooperation (THI and UFAM): support to 2 teams in off-grid projects at the Amazon basin (prof. Navarro); Khushboo’s Thesis support in off-grid + 2nd life batteries

https://github.com/abtrindade

UFAM

Numbers and Concepts (I)

- **Europe** has 10.2 million km²
- **European Union** has 4.23 million km²
- Brazil has 8.5 million km²
- Amazon Basin has 7 million km²
  - South America area drained by the Amazon River and its tributaries
  - Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela
- Amazon Rainforest or Amazon jungle or Amazonia 5.5 million km²
  - 60% In Brazil
  - Brazilian Amazon basin
- Amazonas State
- Brazil has
  - 214 million of inhabitants
  - 5,565 municipalities
  - 212 isolated municipalities (without accounting the rural communities)
  - ?? isolated communities (mainly at the Amazon Rainforest)

https://en.wikipedia.org/wiki/Europe

https://european-union.europa.eu/easy-read_en

Source:
https://en.wikipedia.org/wiki/Amazon_basin
https://european-union.europa.eu/principles-countries-history/key-facts-and-figures/life-eu_en
https://www.nationsonline.org/oneworld/europe.htm
https://www.ons.org.br/paginas/energia-no-futuro/suprimento-energetico
https://www.ons.org.br/paginas/sobre-o-sin/sistemas-isolados
https://en.wikipedia.org/wiki/Demographics_of_Brazil
https://en.wikipedia.org/wiki/Europe

Numbers and Concepts (II)

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https://en.wikipedia.org/wiki/Amazon_basin

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https://www.nationsonline.org/oneworld/europe.htm
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https://www.ons.org.br/paginas/sobre-o-sin/sistemas-isolados
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Numbers and Concepts (III)

- Europe has 10.2 million km^2
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- Brazil has 8.5 million km^2
- Amazon Basin has 7 million km^2
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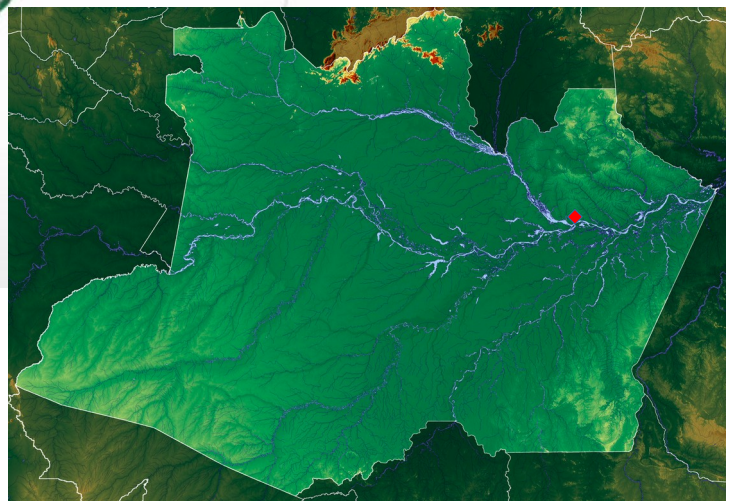
  - Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela
- Amazon Rainforest or Amazon jungle or Amazonia 5.5 million km^2
  - 60% In Brazil
  - Brazilian Amazon basin
- **Amazonas State (18.3% of Brazil's area and 1.9% of the population)**
- Brazil has
  - 214 million of inhabitants
  - 5,565 municipalities
  - 212 isolated municipalities (without accounting the rural communities)
  - ?? isolated communities (mainly at the Amazon Rainforest)

https://en.wikipedia.org/wiki/Brazil



Manaus:
Amazonas State Capital
53% of the population
80% of the GDP

Source:
https://en.wikipedia.org/wiki/Amazon_basin
https://european-union.europa.eu/principles-countries-history/key-facts-and-figures/life-eu_en
https://www.nationsonline.org/oneworld/europe.htm
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https://en.wikipedia.org/wiki/Demographics_of_Brazil
https://en.wikipedia.org/wiki/Europe

https://pt.wikipedia.org/wiki/Amazonas
https://pt.wikipedia.org/wiki/Manaus

Numbers and Concepts (IV)

- Brazil power grid “backbone”
  - Connects Manaus and to the Brazil’s power transmission grid
  - Manaus + 7 municipalities around Manaus
  - 54 municipalities from the Amazonas State are not connected to the Brazil’s power transmission grid
    - Isolated
    - 57 diesel oil thermoelectric power plants
- Brazil’s energy mix: 74.8% renewable (57.4% hydro, 13.1% wind and 4.3% from PV)

https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-40/topico-70/Cap4_Figuras.pdf

Contextualization (World)

- The United Nation's Sustainable Development Goal 7 is to "ensure access to affordable, reliable and modern energy for all by 2030," including:
  - universal access to electricity and
  - clean cooking,
  - a greater share of renewables in the energy mix,
  - and a doubling of the rate of improvement of energy efficiency.
- Achieving full access by 2030 will require connecting almost 100 million people every year

- High fuel prices account for 90% of the rise in the average costs of electricity generation worldwide, natural gas alone for more than 50%.Price and economic pressures mean that the **number of people without access to modern energy is rising for the first time in a decade.** Around 75 million people who recently gained access to electricity are likely to lose the ability to pay for it, and 100 million people may revert to the use of traditional biomass for cooking.
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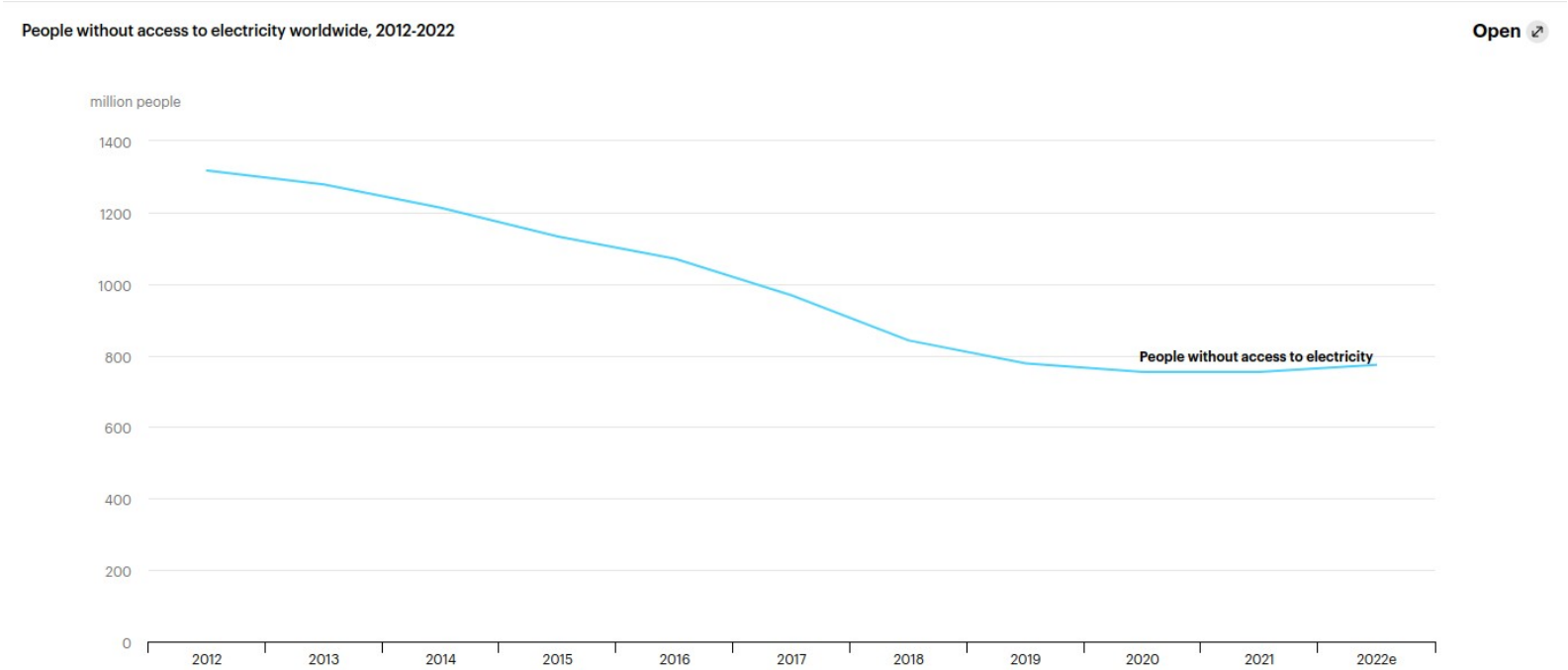
https://www.iea.org/topics/energy-access



https://www.statista.com/statistics/829803/number-of-people-without-access-to-electricity-by-region/

https://www.iea.org/commentaries/for-the-first-time-in-decades-the-number-of-people-without-access-to-electricity-is-set-to-increase-in-2022

Contextualization (Brazil)

- Since 2003 Federal Government created the ‘Light for All” program
  - 3.5 million of new connections to houses => 16.8 million of people with energy access
  - Mainly with grid extension
  - Isolated areas in the Amazon Forest remained without energy
  - Demand for decentralized generation and low size systems
  - High investment and (probably) low return to the private sector of energy
- 2020: new program focused on the Amazonia (MLA, or “more light to Amazonia”)
  - Target: 70 thousand of families or 300 thousand of people without energy access

https://energiaeambiente.org.br/produto/universalizacao-do-acesso-ao-servico-publico-de-energia-eletrica-no-brasil-evolucao-recente-e-desafios-para-a-amazonia-legal

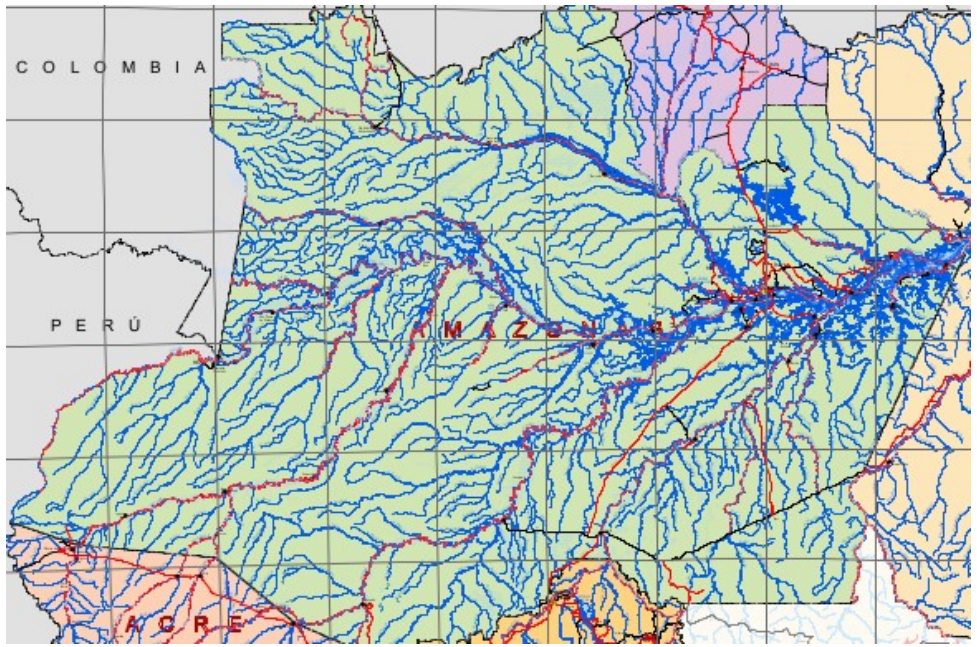
https://epbr.com.br/geracao-propria-no-amazonas-ultrapassa-100-mw-de-potencia/

https://www.nsctotal.com.br/noticias/solucoes-sustentaveis-da-intelbras-levam-energia-solar-a-comunidades-da-amazonia-legal

Challenges of the Amazon State: size

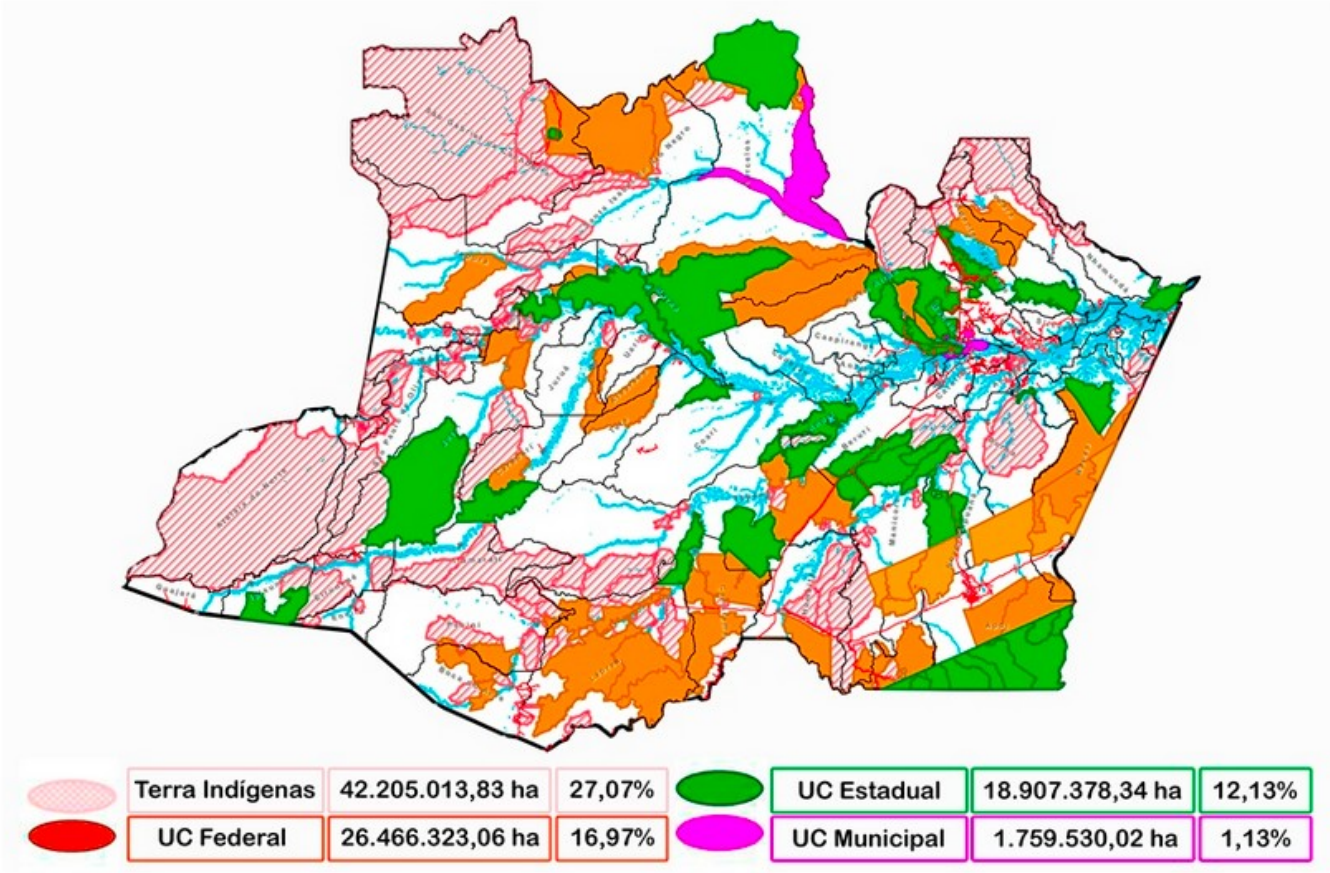
- Germany has 0.36 million km^2
- 84 million of inhabitants
- Amazonas State has 1.57 million km^2 (4.3 times bigger)
- 4 million of inhabitants (21 times less populated)

Challenges II: access



Sources:
https://www.todamateria.com.br/bacia-amazonica/
http://www.meguiabrasil.com/mapadobrasil/mapa-rodoviario-regiao-norte.php

Challenges III: have access to protected areas



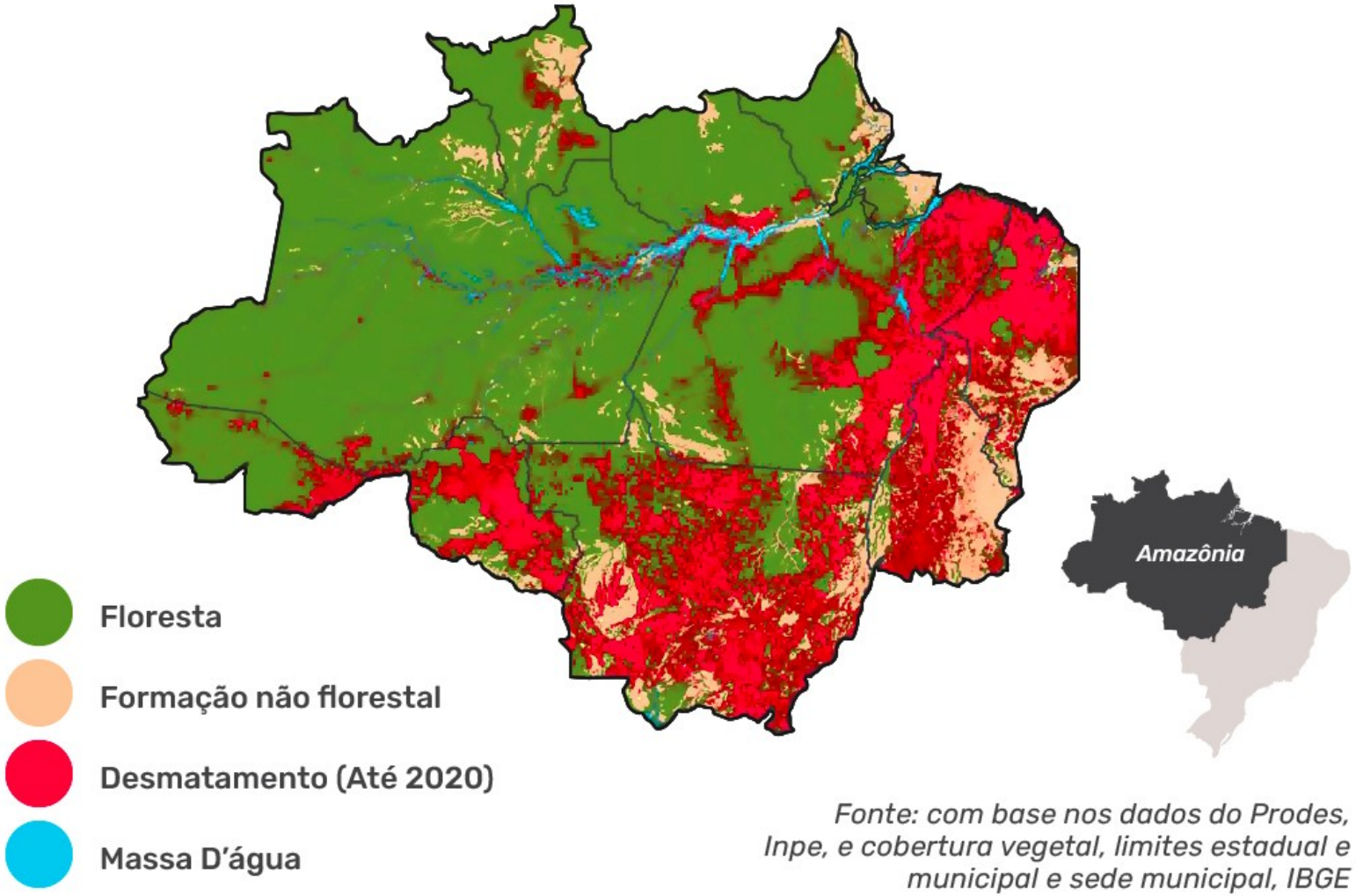
FONTE: http://meioambiente.am.gov.br/unidade-de-conservacao/

- The State of Amazonas, according to SEMA, has 57.3% of protected areas
- Among indigenous reserves, and federal, state and municipal conservation areas
- With this, the state reaches the mark of 97% of its original vegetation cover intact

Challenges IV: river levels during seasons

Challenges V: deforestation

Coverage and deforestation in the Brazilian Amazonia (2020)



https://amazonia2030.org.br/fatos-da-amazonia-2021/

Case studies (2017 - nowadays)

- **Star Energy**
  - Newton Fund project (Institutional Links Grant)
  - Coventry University – UFAM – FAS – Schneider Electric
  - From 2017 to 2019
- **Hybrid Microgrid**
  - GCRF project
  - Univ. of Sheffield – UFMG – UFAM
  - 2019-2021
- **Sempre Luz – (Always Light)**
  - Amazonia R&D project
  - Private sector support (Brazilian battery manufacturer)
  - 2021-2022

Star Energy

- SusTainAble and Replicable off-grid renewable Energy system for riverside communities in the Amazon, Brazil
- Aim: to electrify a community with a renewable source of energy, to strengthen research in the Brazilian partner through courses and workshops, and to assess the impact of electrification on communities.
- Cooperative project submitted to a Newton Fund/ British Council international call
- Budget of £ 60,000, of which £ 18,000 was allocated to equipment
- Involved 5 institutions from 2 countries: Academy, NGOs and a private company
- Nova Esperança:chosen community
  - 65 km distant from the capital (Manaus)
  - GPS coordinates 2°44'47.8 " S and 60°25'47.4" W
  - Indigenous from Baré ethnicity
  - 36 houses + fundamental school
  - 75 kVA diesel generator used 11h/day

Source: https://www.youtube.com/watch?v=ymM6FXR20Nk

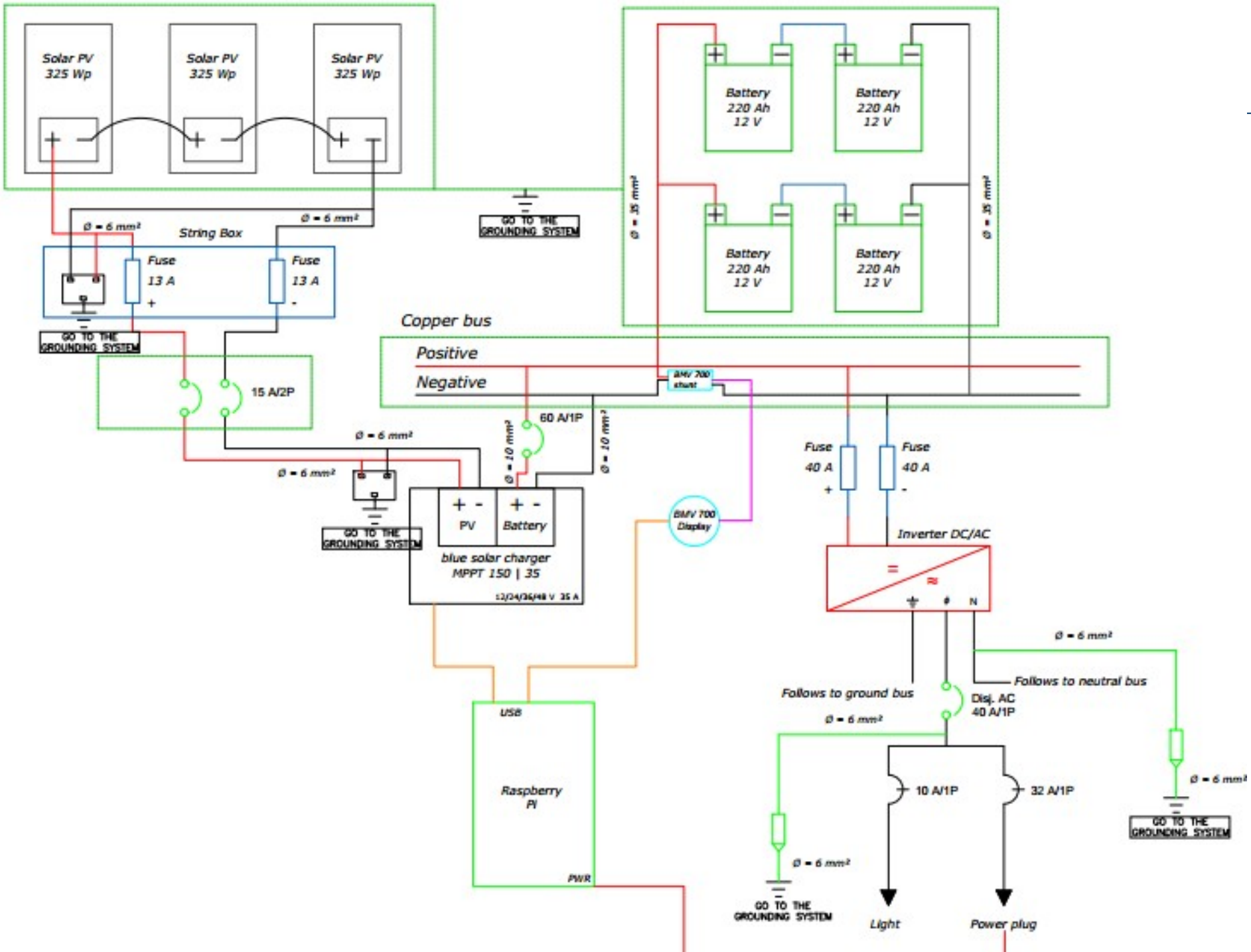
Star Energy: methodology

- Survey to collect data from each family
- The choice of the community (among 14)
- Load curve estimation for every house and the entire community
- Design of the SPV system solution (stand-alone)
- Design of the monitoring system with local storage of data
- Deployment with booklet and dweller's orientation
- Regular visiting to collect data (including temperature and humidity)
- Impact evaluation with interview after 13 months of electrification
- Avoided GHG emissions estimation
- Annual public seminars in Manaus to share the results and best practices
- Annual internal workshop with training among partners
- Community visiting even after the project was finished

Source: Google Maps
https://www.google.com/maps/d/u/0/edit?mid=1ALpUyz-rF2hiGNwAWe6mzIS5N6LIop4&usp=sharing


PURANGA FEIRI YANE ALDEIA UFE
AM BEM VINDOS A NOSSA COMUNI
ELCOME TO OUR COMMUNI


SEMA
IFAM



Electrical diagram of the SPV

Total cost for the 4 houses:
GBP 15,000 (PV system)
GBP 3,000 (monitoring system)
Cost per house: GBP 4,500

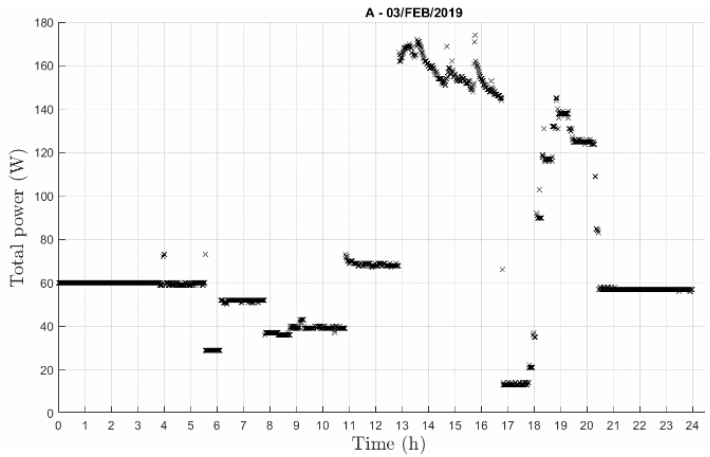
This cost do not include the cost of transport from Manaus to the community (in-kind by FAS)

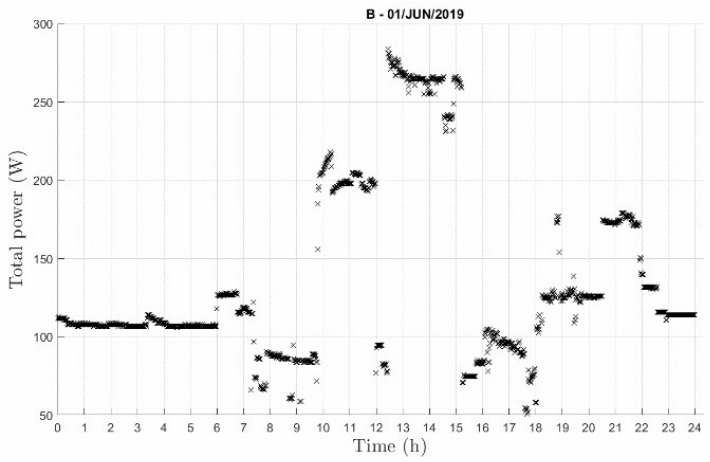
In 2019, even after the end of the project, two more houses were electrified (SE equipment donation and UFAM in-kind deployment)

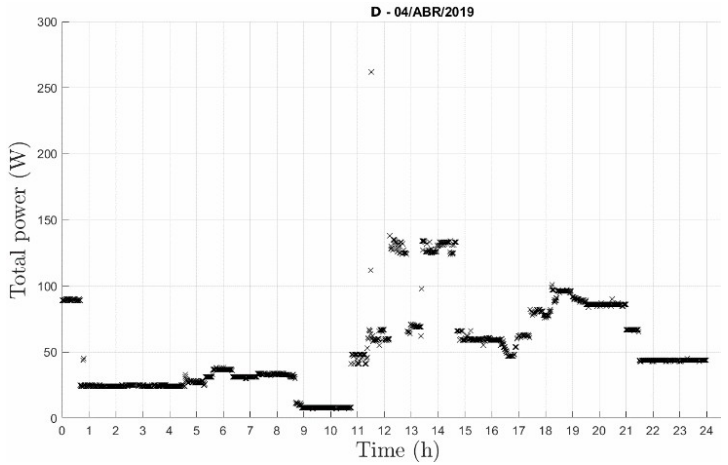
Star Energy: outcomes I

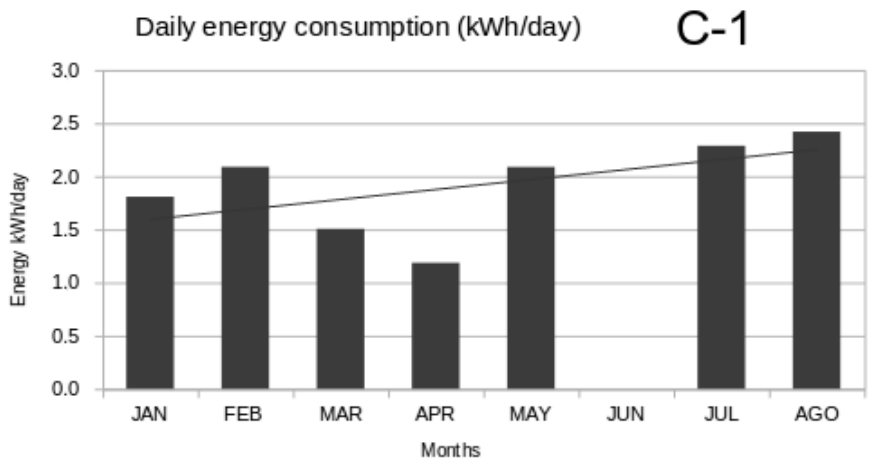
- 3 Forms were created to collect data from the communities and from the dwellers;
- 3 scholarships for undergraduate electrical engineering courses plus one PhD scholarship;
- 14 surveyed communities with GPS coordinates and photograph of the houses;
- Design of the SPV;
- Design of the monitoring system (Raspberry Pi, Coventry University);
- Deployment of 6 SPVs;
- several months of visiting;
- 2 cooperative agreement signed among the partners;
- Two data sets were built from data collected from the dwellers and from the monitoring system
- 2 journal papers and 2 congress papers

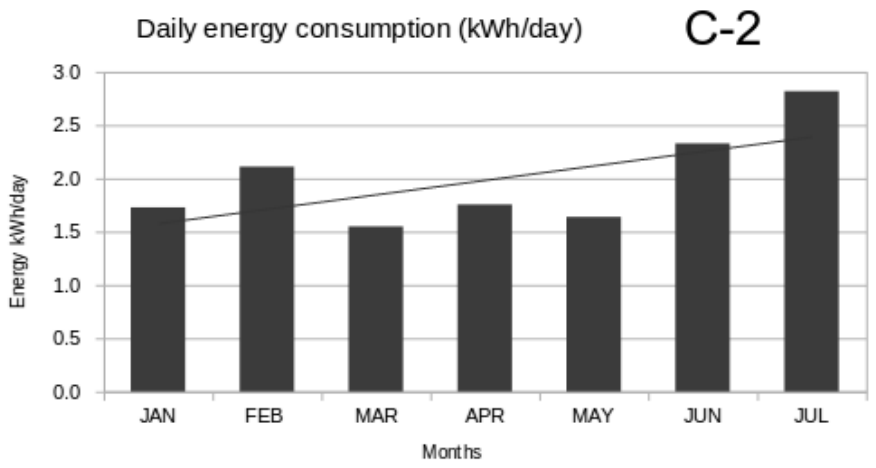
Star Energy: outcomes II











Star Energy: outcomes III

- **Maximum outdoor temperature: 38.8 °C**
- Minimum outdoor temperature: 21.4 °C
- Average outdoor temperature: 27.0 °C
- **Maximum indoor temperature: 41.9 °C**
- Minimum indoor temperature: 23.7 °C
- Average indoor temperature: 30.6 °C
- Average wind speed: 0.74 km/h
- Maximum humidity: 99%
- Average humidity: 84.6%

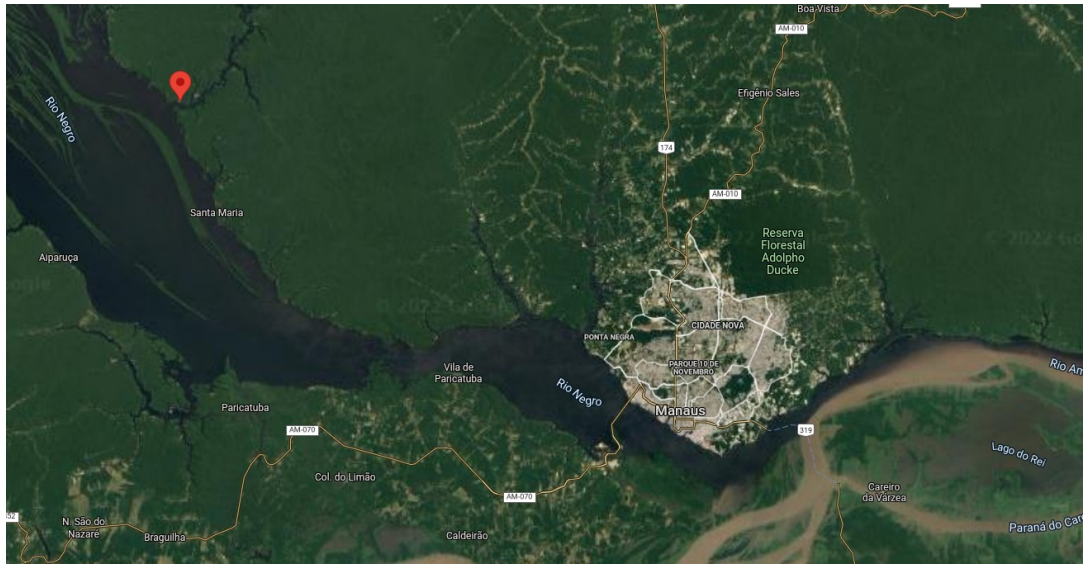
- Every community:
  - Has a diesel generator
    - Donated by a politician
    - Or belonged to the school (used during the teaching time at the business days)
- Average of 4 people/house
- Greater benefits for residents with 24h/7day energy:
  - better housing and living conditions, support for neighbors in case of illness, work and produce handicrafts at night

Hybrid Microgrid

- Sustainable energy access for isolated rural communities with hybrid solar and biogas micro-grids
- Shefield – UFMG – UFAM (GBP 7,000 from GCRF)
- To choose one community with biomass availability and to perform a hybrid energy generation
  - gas generator with biogas + PV
  - Design and deployment
- Local monitoring (visiting): NGO FAS supporting with the speedboat

Hybrid Microgrid project details

- Chosen community: Três Unidos
- Community belongs to Manaus
- 42 families
- Indigenous ethnicity
  - Well organized
  - Good leadership
  - Produces handicrafts
  - Receives visits from tourists
- GPS coordinates:
  - 2°49'16.9"S 60°30'10.2"W



Hybrid Microgrid project details II

- Mario Kambeba's house
- Biodigestor deployed in SEP-2021 (HomeBiogas 7.0)
- 3.3kWp solar PV system deployed in March 2022. With 200Ah Lithium-ion batteries
- Biogas used just for cooking (pandemic delayed the execution of the project and the purchase of the gas generator)

Sempre Luz (Always Light)

- R&D Project (regional law to foster projects)
- Community target: Santa Helena do Inglês
  - Community had grid extension but with low availability and low quality of energy
  - Main source of income: fishing
- Company from private sector supporting the proje
- NGO FAS as head of the project

Sempre Luz (Always Light)

- PV with 132 panels of 400Wp (52.8 kWp) and 54 LFP batteries of 100Ah
- 3-hybrid: grid + diesel generator as backup

Whats the main issue related to research projects?

- What happens when the project ends?
  - Maintenance
  - Technical support
- Therefore, electricity can´t be the end of the project
  - Energy must generate employment and income

Scenario 2023

- “Mais Luz para a Amazônia” program (More Light for the Amazonia)
  - 520 stand-alone systems deployed at the Black River in January and February
  - 80 kWh system
  - 1 Li-ion Battery (48 V, 150 Ah)
- Suitable to houses
- Solution not indicated for small businesses or manufacturing systems

[Source: evfriendly.ca]

ps://brasilamazoniaagora.com.br/2023/energia-solar-comunidades-amazonia/

Sustainable Development Goals (SDG) for 2030

- The Sustainable Development Goals or Global Goals are a collection of 17 interlinked objectives designed to serve as a **"shared blueprint for peace and prosperity for people and the planet, now and into the future"**
- Formulated in 2015, is known as Agenda 2030 and emphasize the interconnected **environmental, social and economical aspects of sustainable development**.

Thank you

Questions?!?

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  - https://github.com/abtrindade