The Role of Energy Storage in Off- and On-Grid Electric Power Systems

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GEDAE

GROUP OF STUDIES AND DEVELOPMENT OF ENERGY ALTERNATIVES

- Founded in November 1994 at the Federal University of Pará, Brazil

- Activities on Solar and Wind Energy, Hybrid Systems, Energy Efficiency and Energy Quality

- Activities of teaching, research, project development and implementation, consulting, etc.

- Currently has 37 members (5 professors, 1 secretary, 1 technician, and graduate, undergraduate and high school students)

ABENS

BRAZILIAN SOLAR ENERGY ASSOCIATION

- Non-profit legal entity with academic and scientific character

- Founded on February 17th, 1978

- Reactivated on January 24th, 2007

- Promotes Solar Energy *lato sensus* (direct solar, wind, hydro, biomass, etc.)

- Publishes a Scientific Journal (RBENS) and an Informative Report

- Organizes biannual congresses (CBENS) and annual meetings

Introduction

- ✓ Storage is the Achilles' heel of any energy systems
- ✓ There is no way of supplying dispatchable (reliably and continuously) energy without storing it
- ✓ Fuel tank, nuclear fuel depot, water dam, battery, etc.
- ✓ Environmental impacts are mainly due to storage and transportation

Introduction

- ✓ Types of electricity storage frequently used:
  - lead-acid batteries: cheaper, low energy density
  - Redox-flow batteries: longer lifetime, complicated operation
  - Lithium-ion batteries: high energy density, protection required
- ✓ Costs are still a barrier (expected cost drop for batteries)

World´s first microgrid

The Manhattan Pearl Street Station (coal)

September 4th, 1882 (136 years)

DC microgrid (82 consumers / 400 lamps)

In 1884 (508 consumers / 10,164 lamps) –
519 % / 2,441 %

Edison Illuminating Company (T. A. Edison) (now GE)

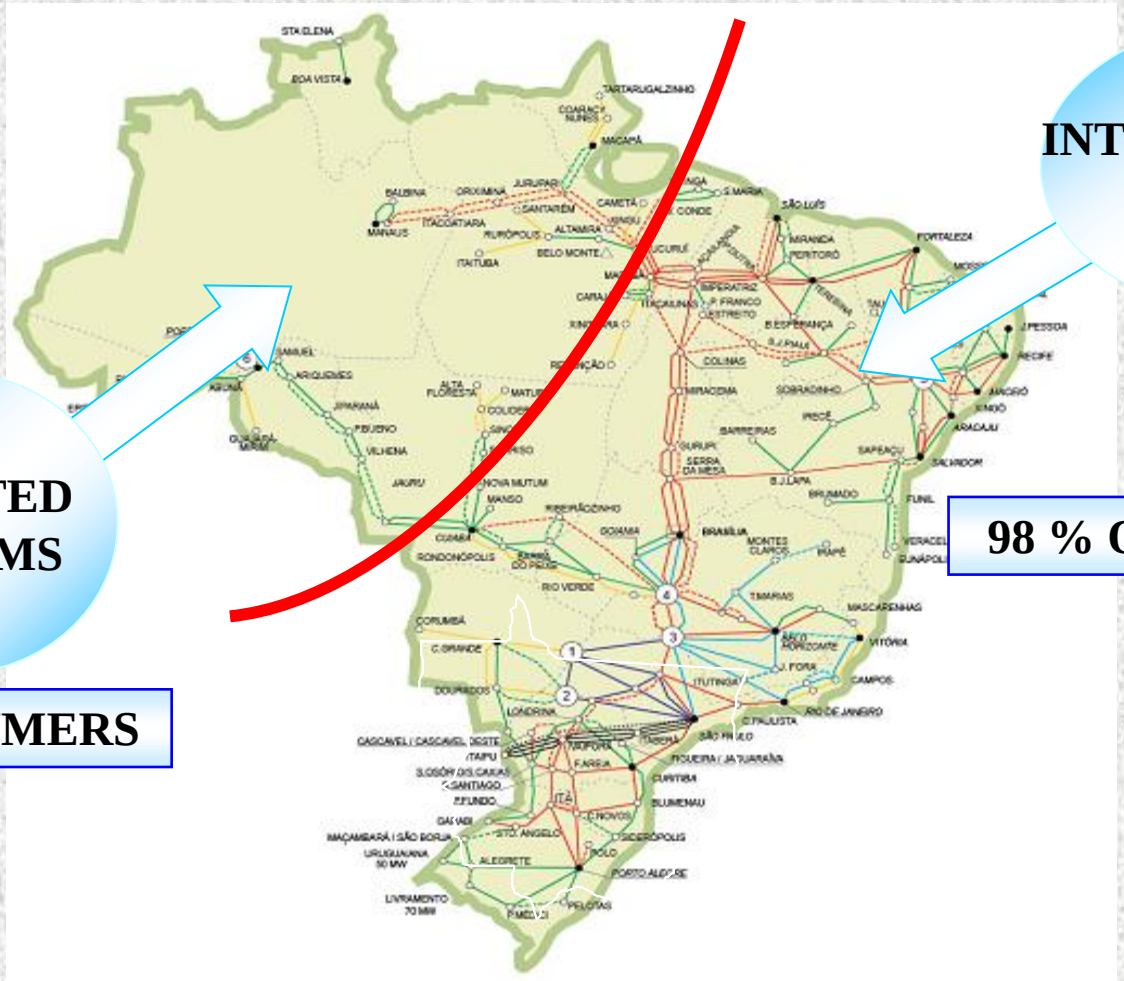
In the following four years 58 DC microgrids were installed

Afterwards, the transformation to AC grids, as monopoly regulated by the government (extinction of the DC microgrids – return after 2009)

Off-grid usage

- ✓ Energy sources frequently used:
  - Fuel generators (diesel)
  - Solar (photovoltaics)
  - Wind (small size)
  - Hydro (small size)
  - Biomass (combustion, gasification, biogas)
- ✓ Hybrid systems (two or more sources and storage)

Brazilian electricity system



INTERCONNECTED SYSTEM

98 % OF CONSUMERS

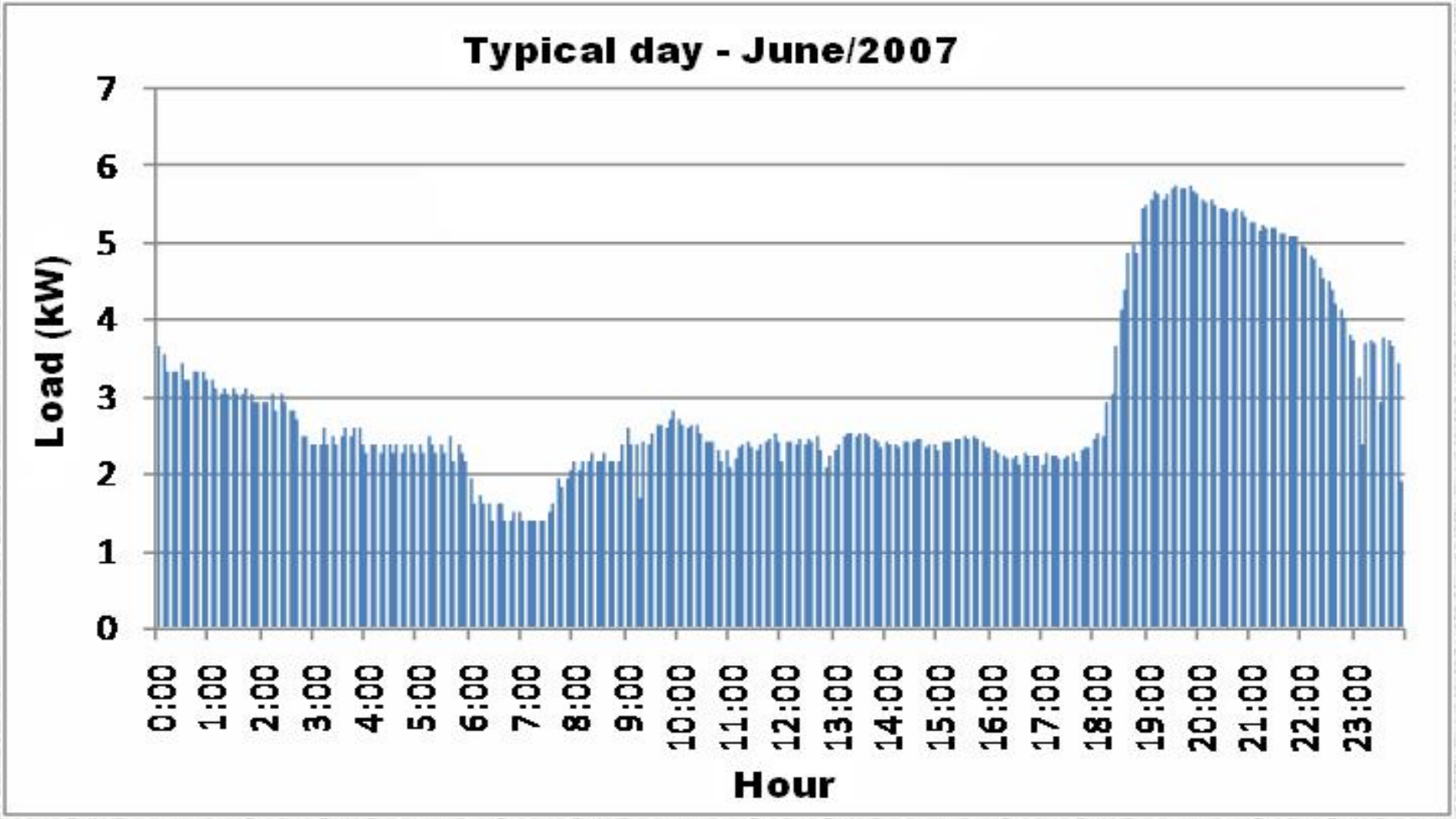
ISOLATED SYSTEMS

2 % OF CONSUMERS

Approx. 8.5 million km²
Almost 200 million inhabitants

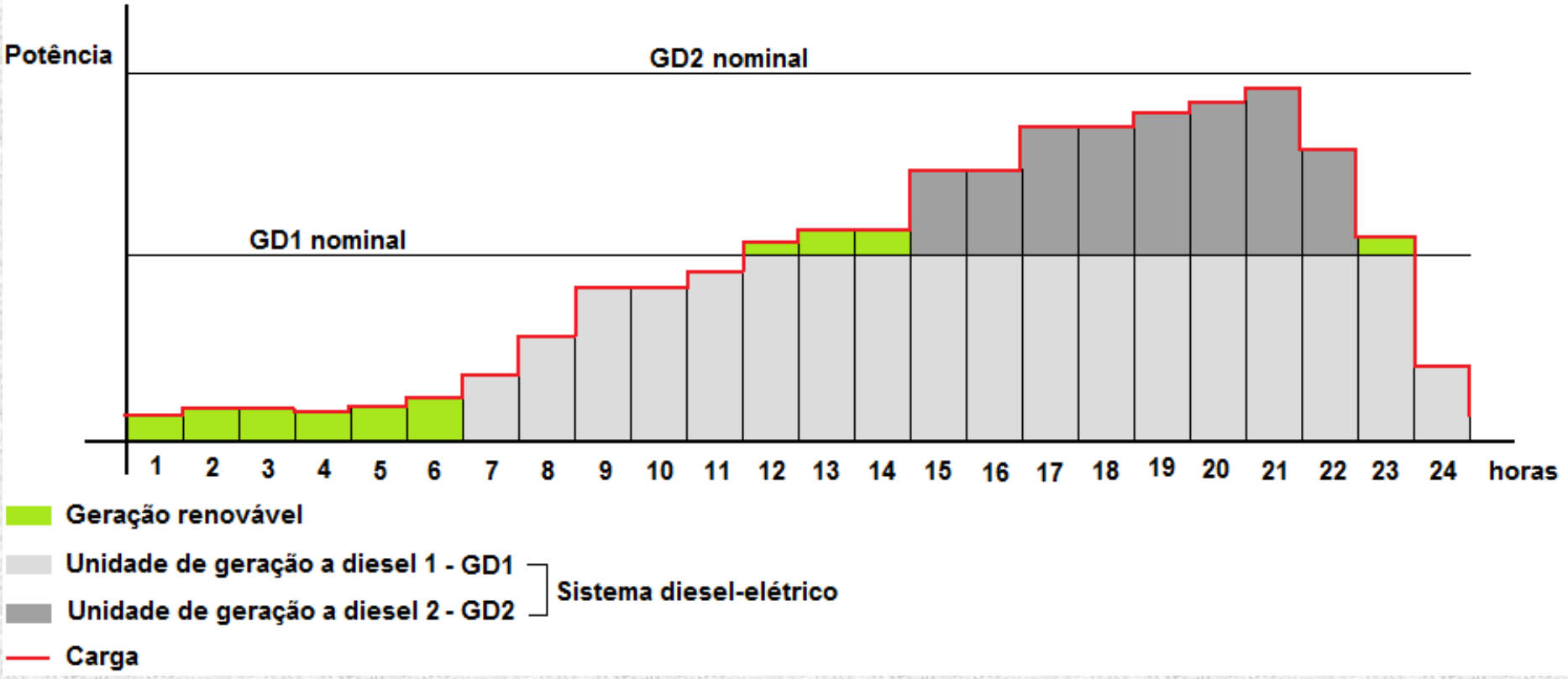
Source: Adapted from MME

Typical off-grid load curves



Priority in the use of resources

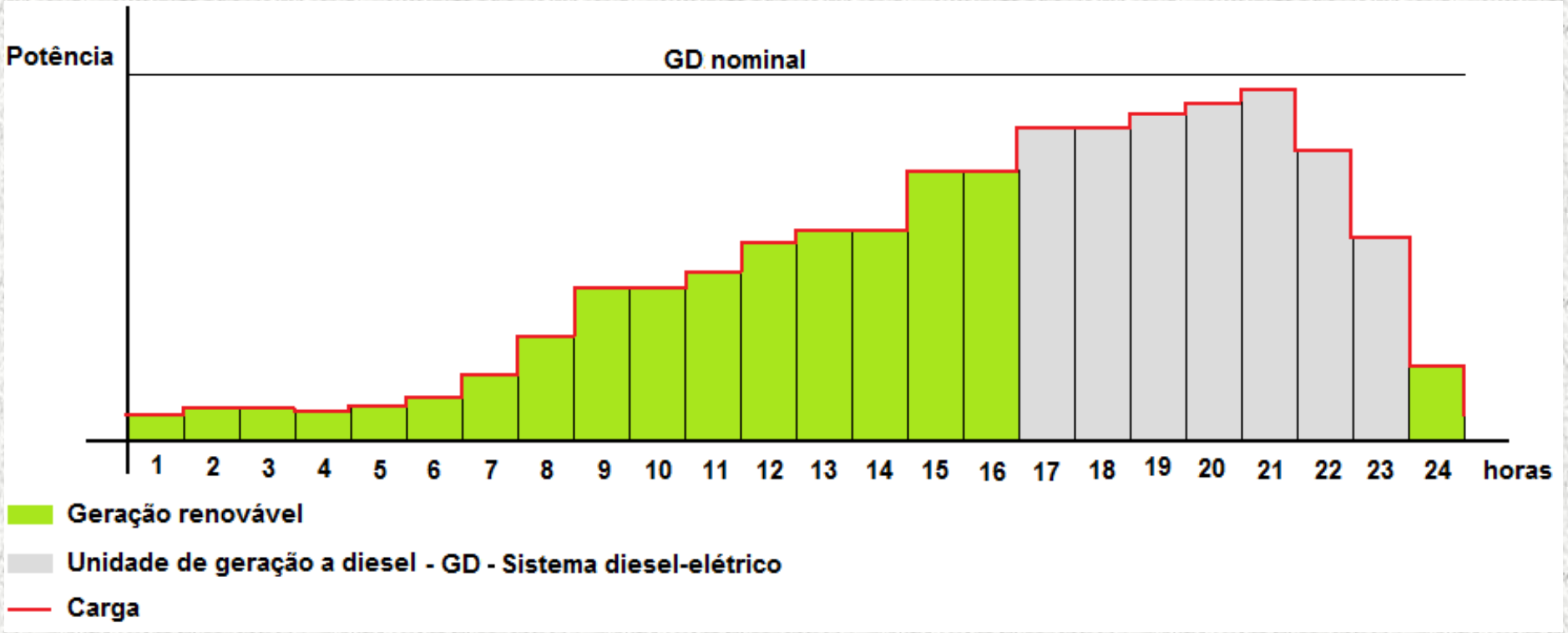
- Systems based on non-renewable resources



The energy from the renewable sources (and/or storage) is used to supply the load during the periods of low demand or to complement the non-renewable generation

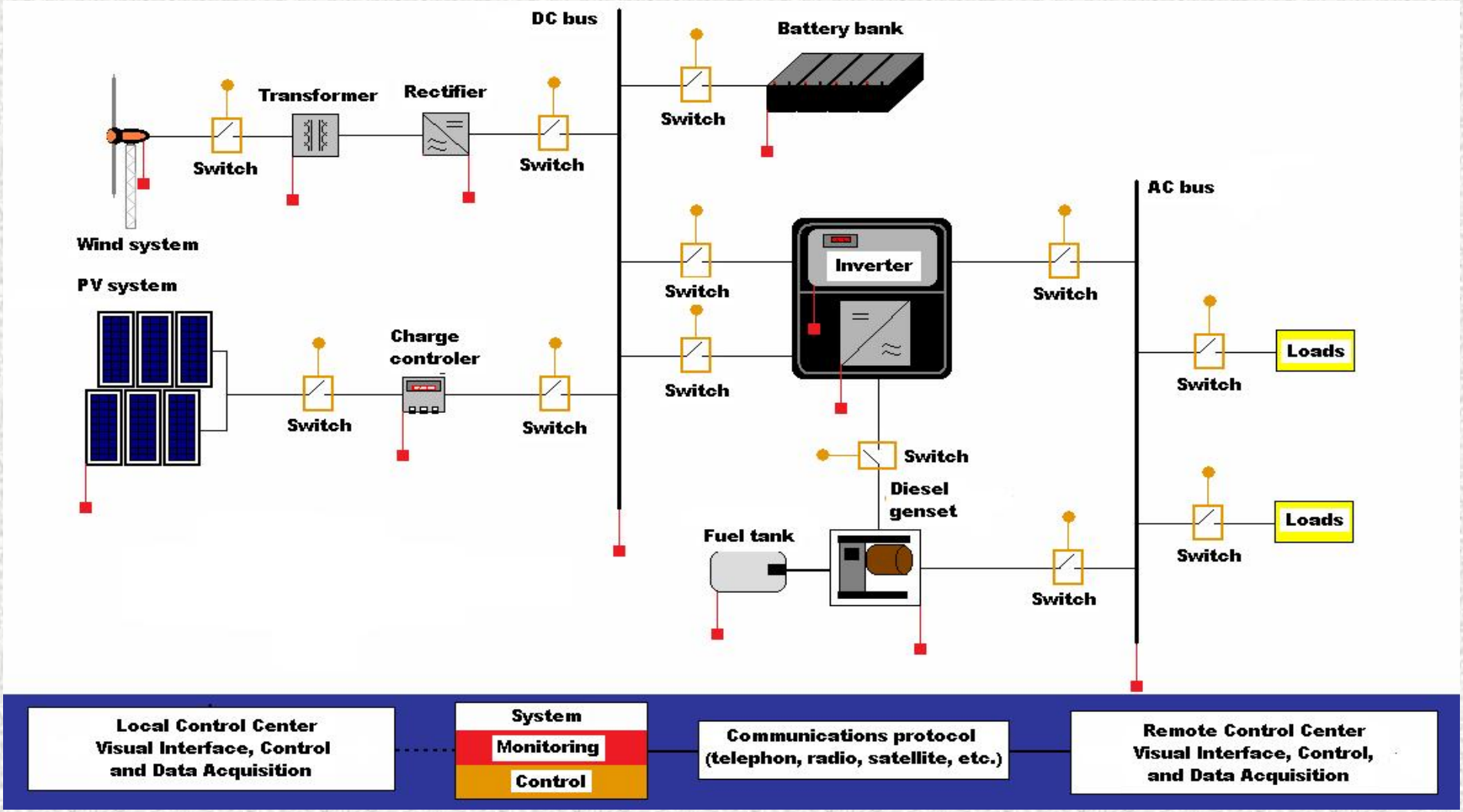
Priority in the use of resources

- Systems based on renewable resources



The non-renewable generation (and/or storage) functions as a back-up system, supplying the load during periods of high demand and low or no renewable generation

Automatic operation and control

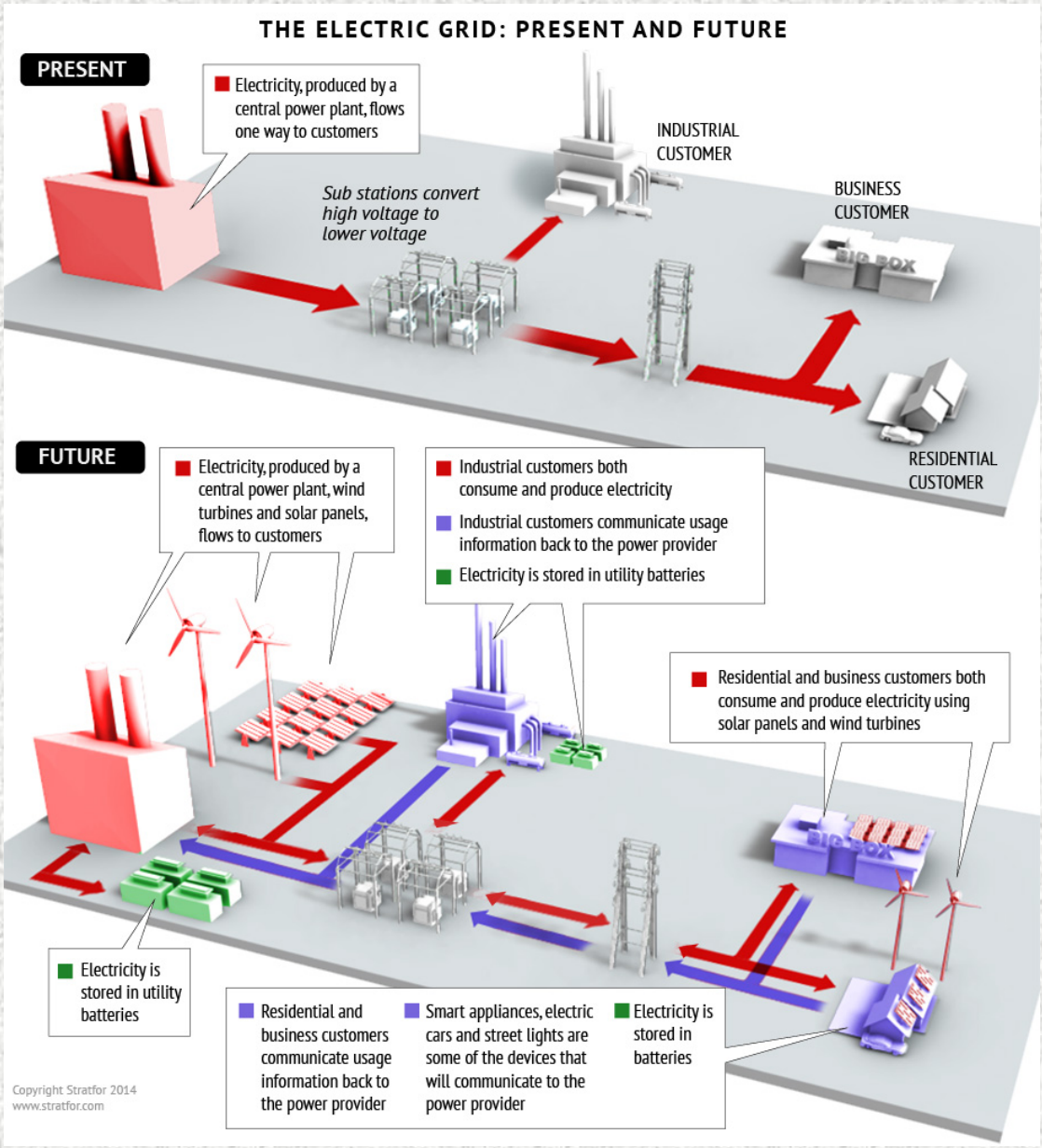


Smartgrids

"A SmartGrid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers, and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies." (*EU Report, 27*)

"A **smart grid** is an electrical grid which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficient resources. Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid." (*United States Federal Energy Regulatory Commission.*

Smart grids


THE ELECTRIC GRID: PRESENT AND FUTURE
PRESENT
Electricity, produced by a central power plant, flows one way to customers
INDUSTRIAL CUSTOMER
Sub stations convert high voltage to lower voltage
BUSINESS CUSTOMER
RESIDENTIAL CUSTOMER
FUTURE
Electricity, produced by a central power plant, wind turbines and solar panels, flows to customers
Industrial customers both consume and produce electricity
Industrial customers communicate usage information back to the power provider
Electricity is stored in utility batteries
Residential and business customers both consume and produce electricity using solar panels and wind turbines
Electricity is stored in utility batteries
Residential and business customers communicate usage information back to the power provider
Smart appliances, electric cars and street lights are some of the devices that will communicate to the power provider
Electricity is stored in batteries
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Smart Microgrids

- ISOLATED: Rural Electrification (limited resources, Storage)

- INTERCONNECTED: “Prosumers” (Distributed Energy Resources – Distributed Generation; Storage; Demand Response; Smart Devices - Inverters, BMS, Meters, etc.)

Smart Microgrids

NECESSARY FUNCTIONAL CAPACITIES

- Monitoring: Knowledge of the situation in real time; Knowledge of energy quality; Flow analyses of distributed load/generation; Use of GIS
- Control: Microgrid management; Distributed Energy Resources (DER) dispatch; Automatic circuit reconfiguration.
- Forecast: Short-term forecast of the DER; Long-term forecast of energy production; Contingency analyses.
- Optimization: Voltage optimization; Energy flow optimization; Adaptive protection.

On-grid usage

The **distribution grid** is expected to become a **platform for the supply and acquisition of products and services** that go beyond the mere electrical energy purchase and/or sale from/to the utilities **(changes the roles of utilities and consumers)**

The possibility not only to **generate electricity** but also to **time-shift its consumption**, for example, plays a major role to address issues such as **feeders overload**, **distribution losses**, **power quality**, and the increase of the admissible level of **non-dispatchable renewable energy** resources such as photovoltaic and wind

On-grid usage

- ✓ Systems can be operated as **controlled units** to meet local needs of the distribution grid
- ✓ System size may vary, depending on policies, and type of service to be provided
- ✓ Amounts of generation and storage capacity must be appropriately adjusted to each other
- ✓ Ancillary services can be offered even by residential and commercial prosumers: arbitrage, according to different tariff posts; reactive power compensation; load-shift; loading limits on feeders; self-consumption; phase balancing, etc.

On-grid usage

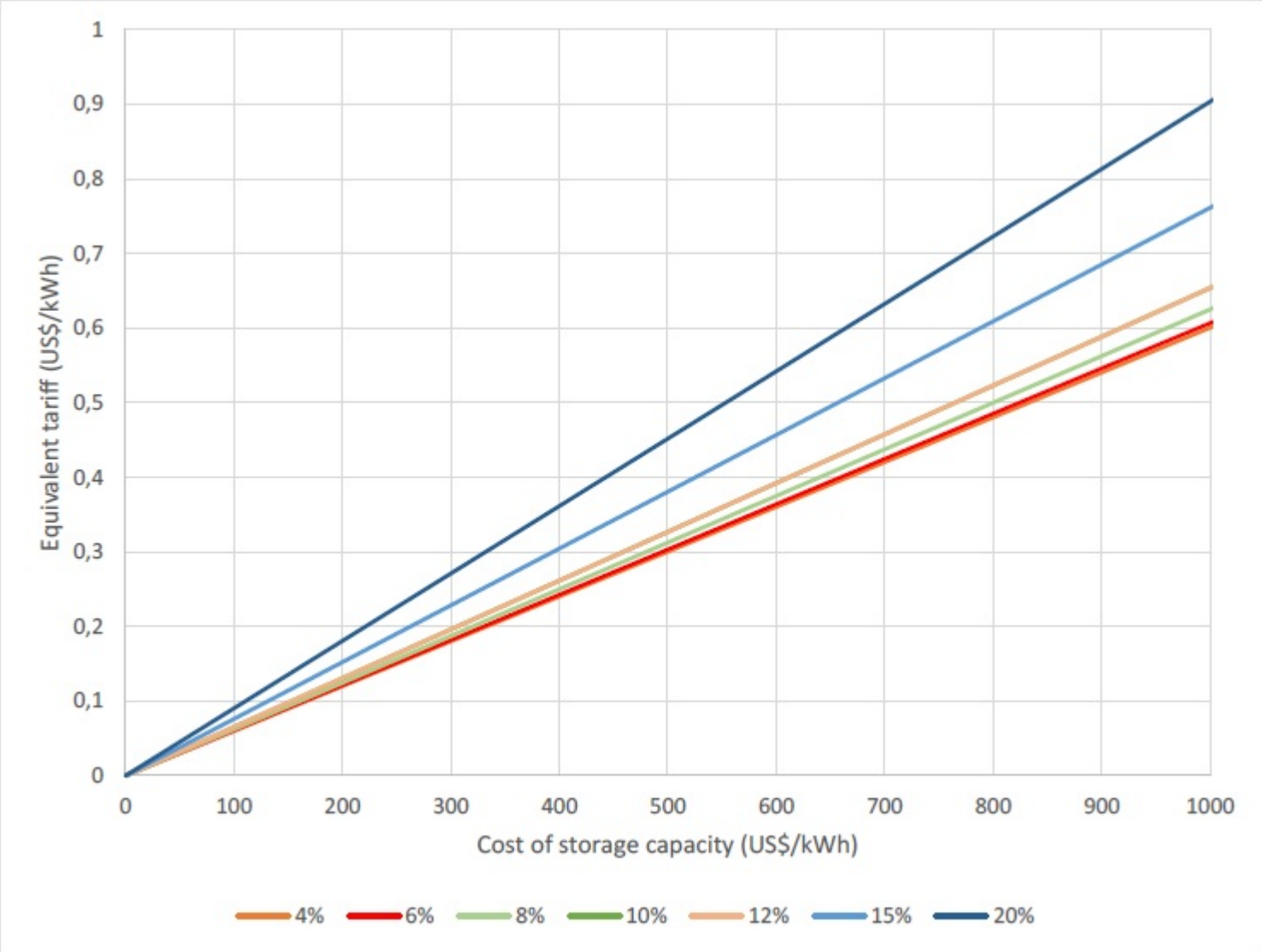


Figure 2 – Equivalent tariff as a function of the battery cost for different interest rates.

LSF´s and GEDAE´s Systems

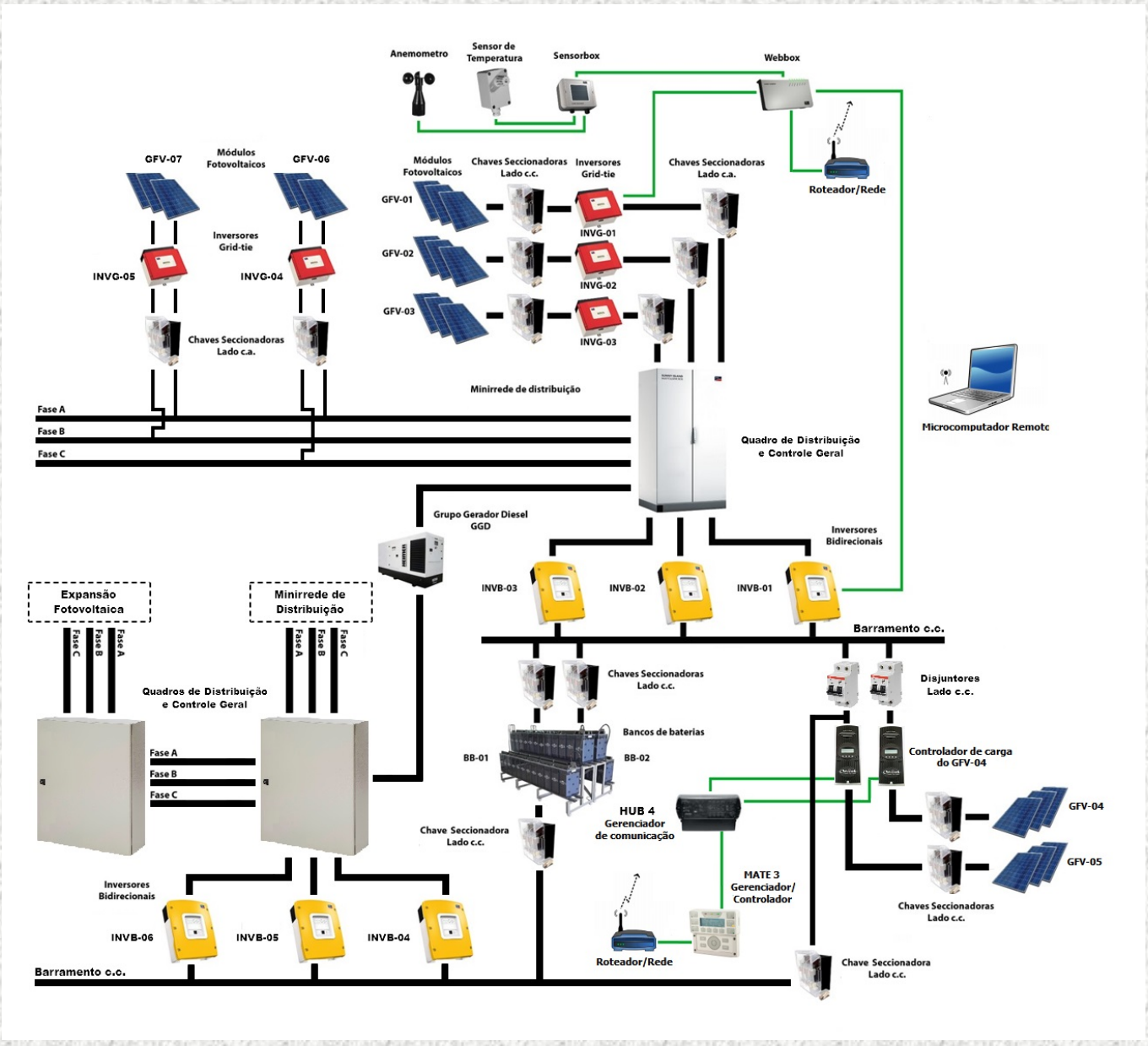
OBJECTIVES

Development of laboratory infrastructures with hybrid systems for electricity generation and smart microgrids

Development of studies and research on these topics

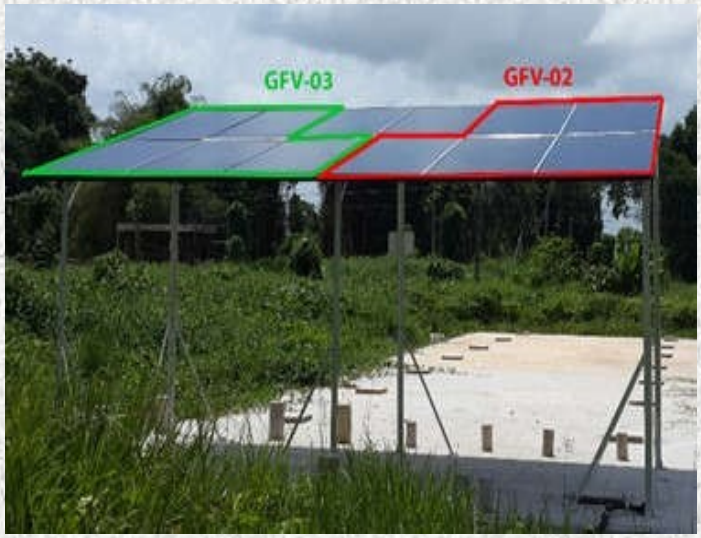
Capacity building at technical, undergraduate and graduate levels

GEDAE´s Microgrid



GEDAE´s Microgrid

PVG-01 and *Sunny SensorBox* (1st module on the right)



PVG-02 and PVG-03

DG and anemometer (roof)

INVB, INVG, GDC

GEDAE´s Microgrid

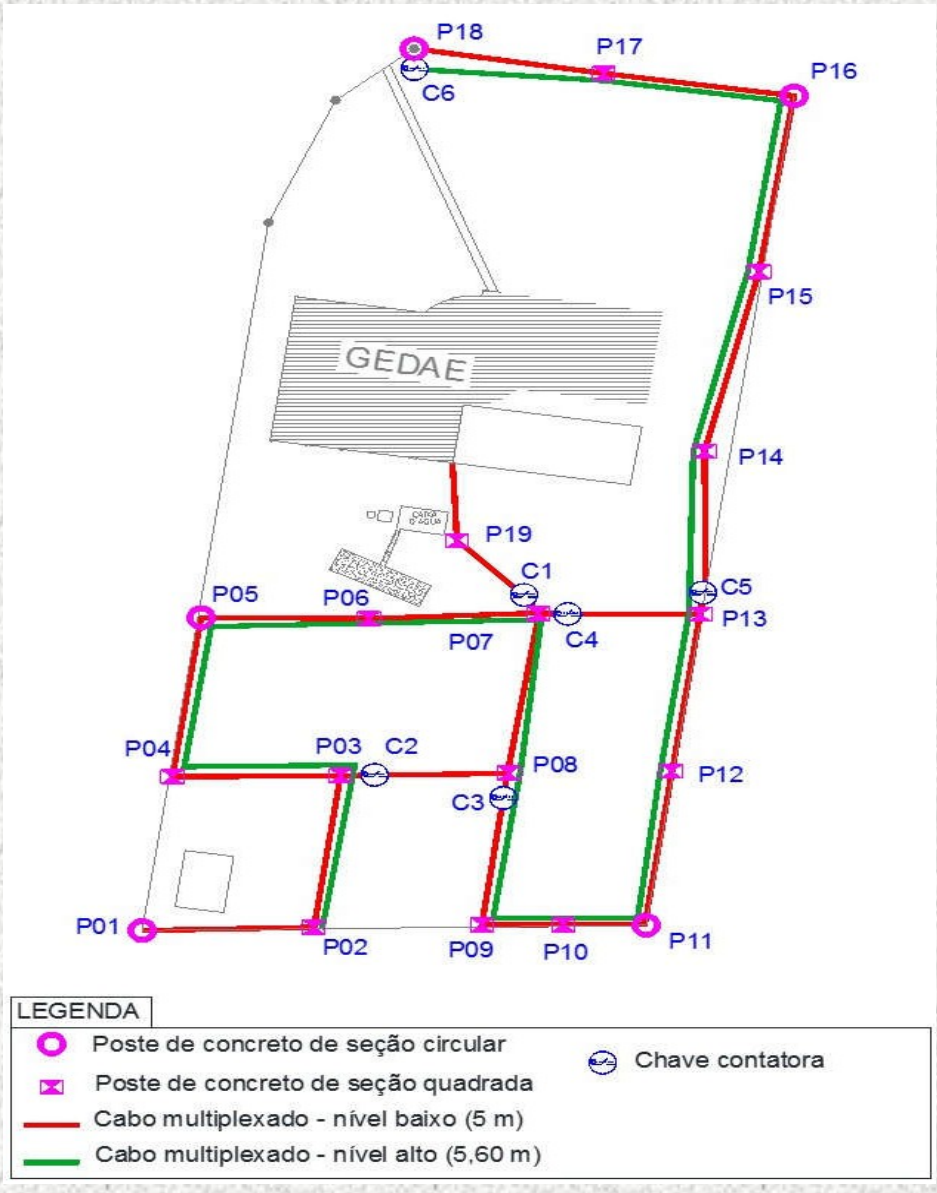
GDC (inside view)

BB-01 and BB-02

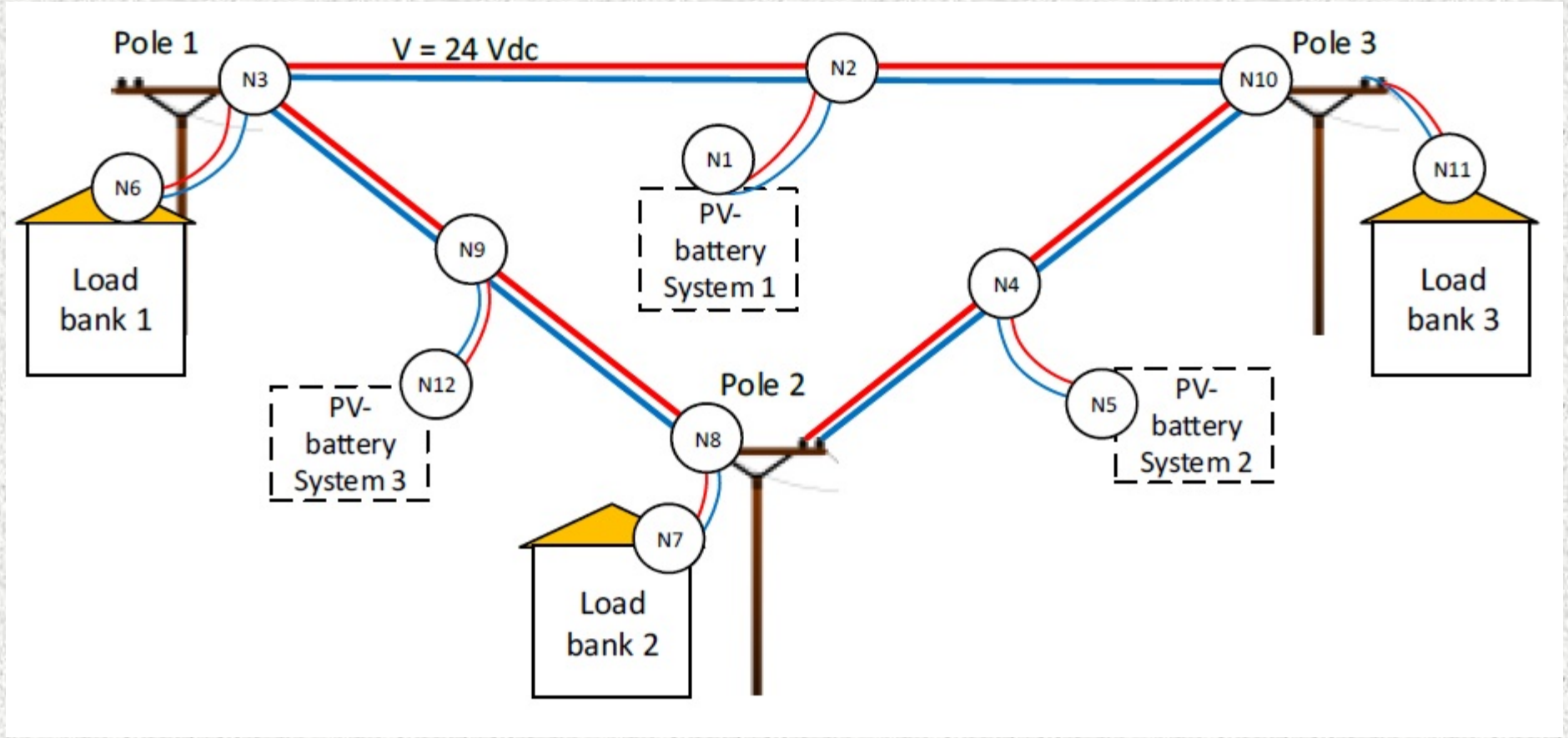
Sunny WebBox and Power Injector **(from bottom to top)**

Air and module temperature sensors

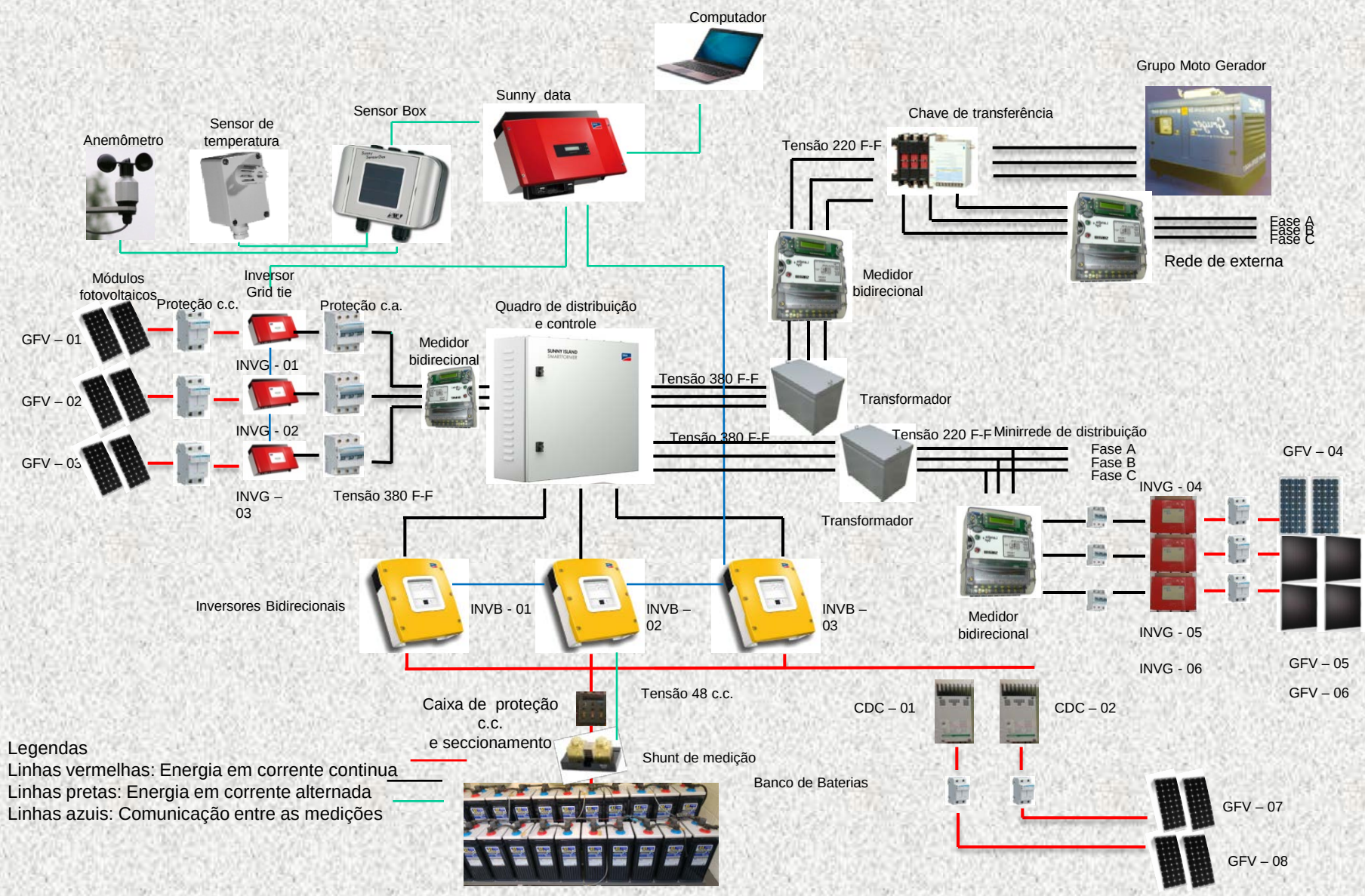
GEDAE´s Microgrid



GEDAE´s DC Microgrid



LSF´s Microgrid



Legendas
Linhas vermelhas: Energia em corrente continua
Linhas pretas: Energia em corrente alternada
Linhas azuis: Comunicação entre as medições

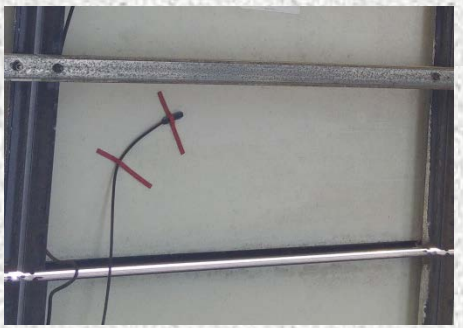
LSF´s Microgrid









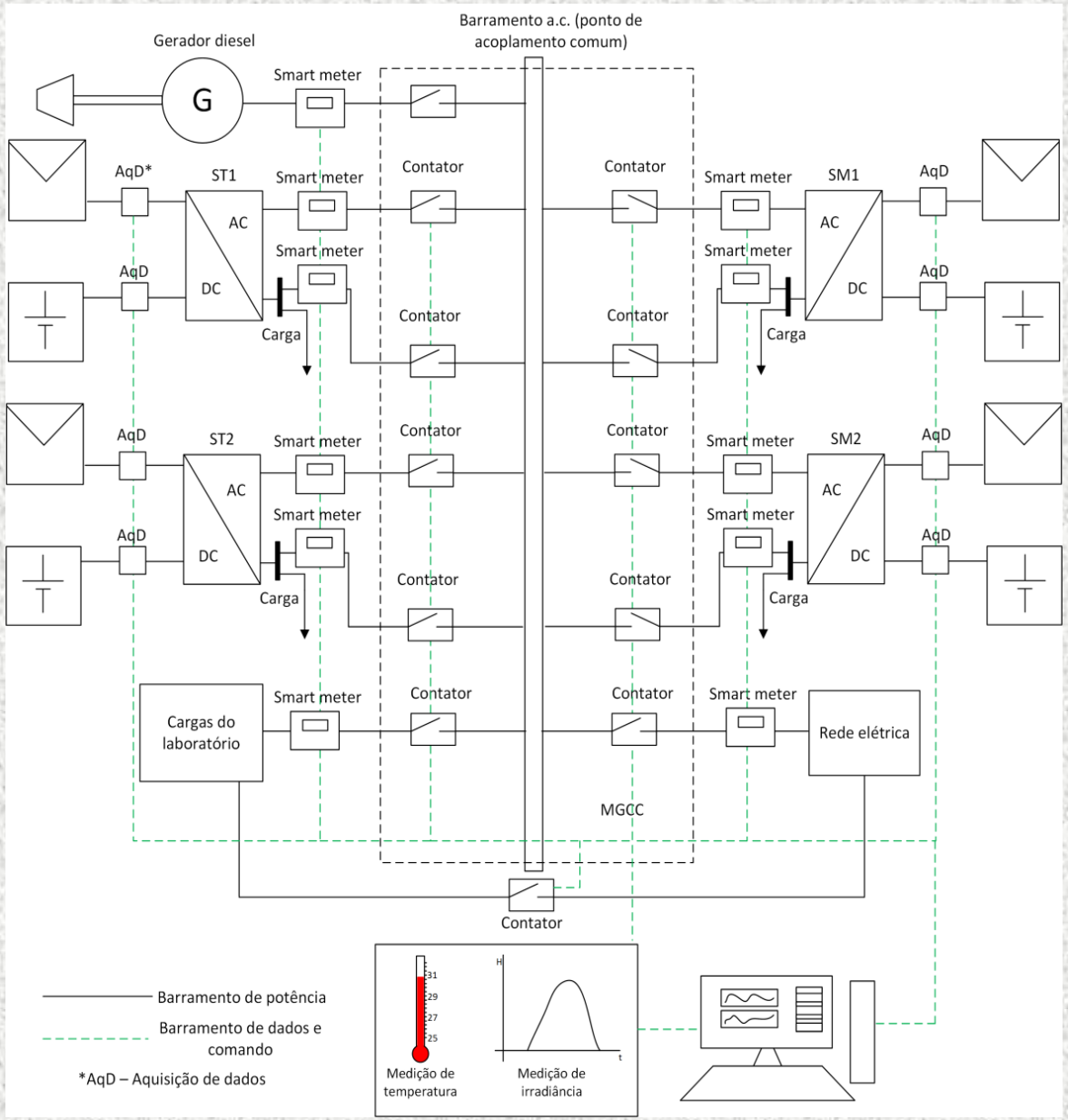


LSF´s Microgrid

LSF´s Microgrid

Operational Strategies

- Hybrid systems as main grid;
- Electric grid supplying energy to all systems, or to one system only;
- Diesel generator supplying all systems, only one system and/or the electric grid.



LSF´s Microgrid

Operational Scenarios	
Sources	**Loads**
Diesel Generator (DG)	HSs
	MG
	MG + HSs
Hybrid Systems (HSs)	HSs
	MG
	MG + HSs
Main Grid (MG)	HSs

CONTACTS

***Homepages*: http://www.gedae.ufpa.br**

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THANKS

FOR YOUR

ATTENTION!