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Centro de Informática U·F·P·E

# Assessment to support the planning of sustainable data centers with high availability

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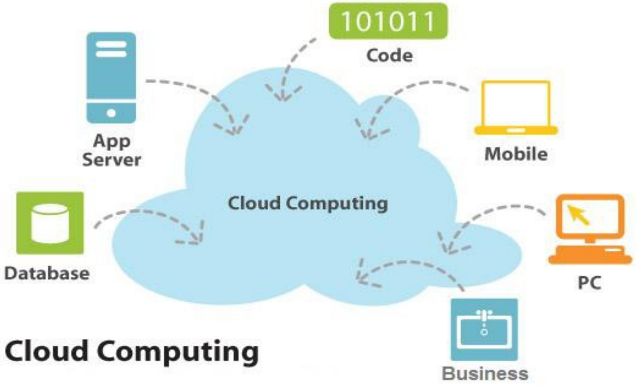
*Orientador: Paulo Maciel*

# Introduction

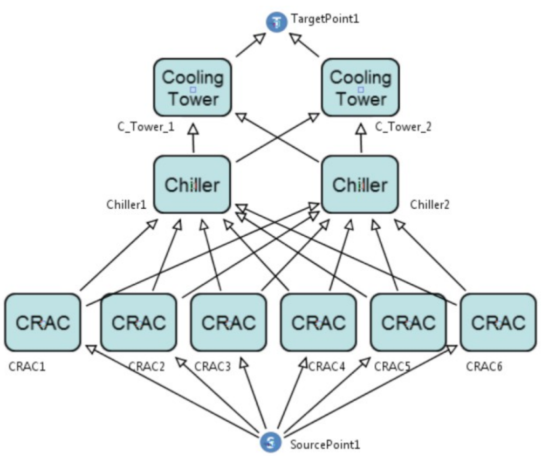
- Data centers are growing
- Fact (Considering U.S.)
  - Data centers consume about 2 %
  - of the whole power generated .
- Concern about
  - Energy Consumption,
  - Environmental Sustainability.
- Sustainable data centers
  - Least amount of materials,
  - Least energy consumption.
- Availability
- Fault-Tolerance

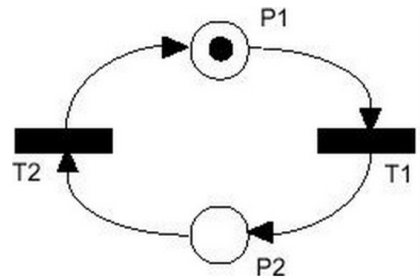


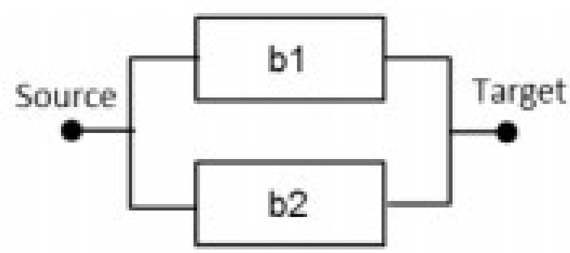
# Objective

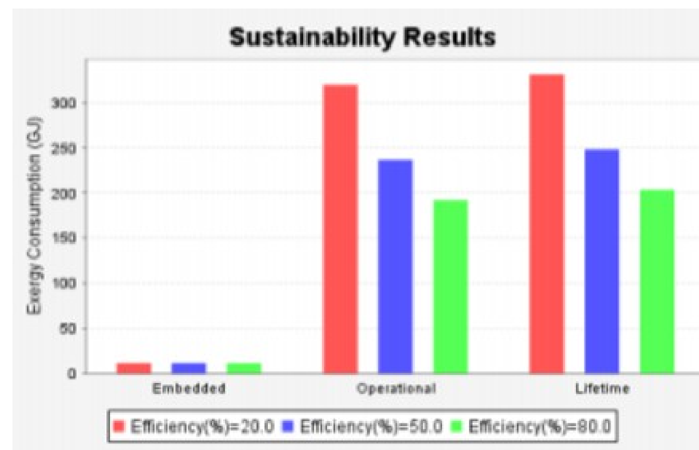
- **To provide:**
  - a set of **models** for the integrated **quantification** of **sustainability** impact, **cost** and **dependability** of data center power and cooling infrastructures.

Energy Flow Model, SPN and RBD → availability, downtime, cost sustainability impact, etc



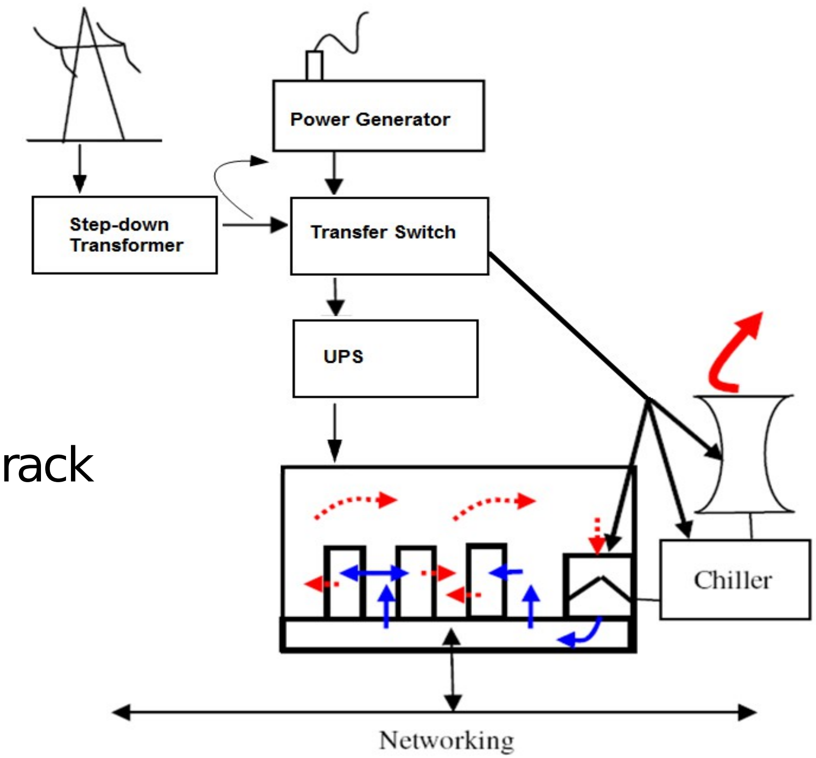



# Data Center Infrastructure

- IT infrastructure:
- Servers,
- Networking equipment,
- Storage devices.

- Power infrastructure:
- SDT → transfer switches → UPS → PDUs → rack

- Cooling infrastructure:
- Extracts heat → prevents overheating
- CRAC, Cooling Tower, Chiller



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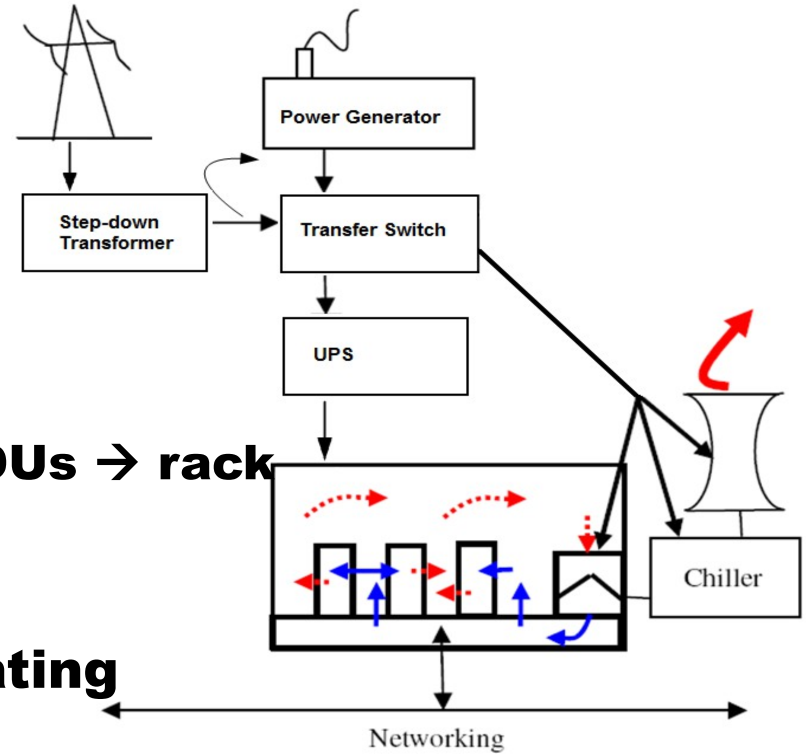


# Metrics

- Dependability
  - Availability
  - Reliability
  - Reliability Importance (RI)
  - Reliability and Cost Importance (RCI)
- Sustainability Impact
  - Exergy Consumption
- Cost
  - Acquisition cost
  - Operational cost

# • Exergy

- **Energy** can **never** be **destroyed** (FLT).
- **Exergy** can be **destroyed** (SLT).
- The **exergy** destruction or **consumption** (**irreversibility**) must be appropriately **minimized** to obtain sustainable development.

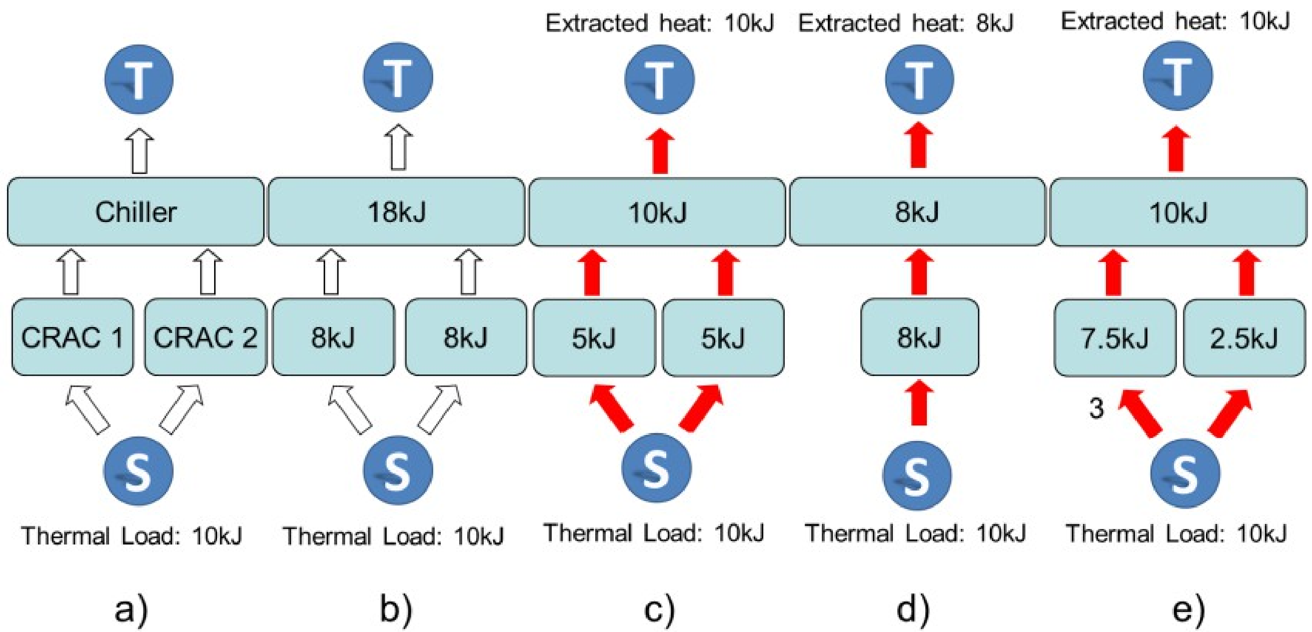
- Exergy (available energy)
- Represents the maximal theoretical portion of the energy that could be converted into work;

- A system which consumes the least amount of exergy is often the most sustainable;

- **Exergy** is **useful** when **measuring** the **efficiency** of an energy conversion process

# Models

- Energy Flow Model
  - The **system** under evaluation can be **correctly arranged**, **but** they **may not** be able to **meet system demand** for electrical energy or therma



# Energy Flow Model

- Algorithms:
  - Verifying the energy flow
  - Quantifying Operational Exergy Consumption
  - Quantifying acquisition and operational costs

# Energy Flow Model

- Algorithms:
  - Verifying the
  - Quantifying

OPERATIONAL EXERGY EQUATIONS OF DIFFERENT DEVICES.

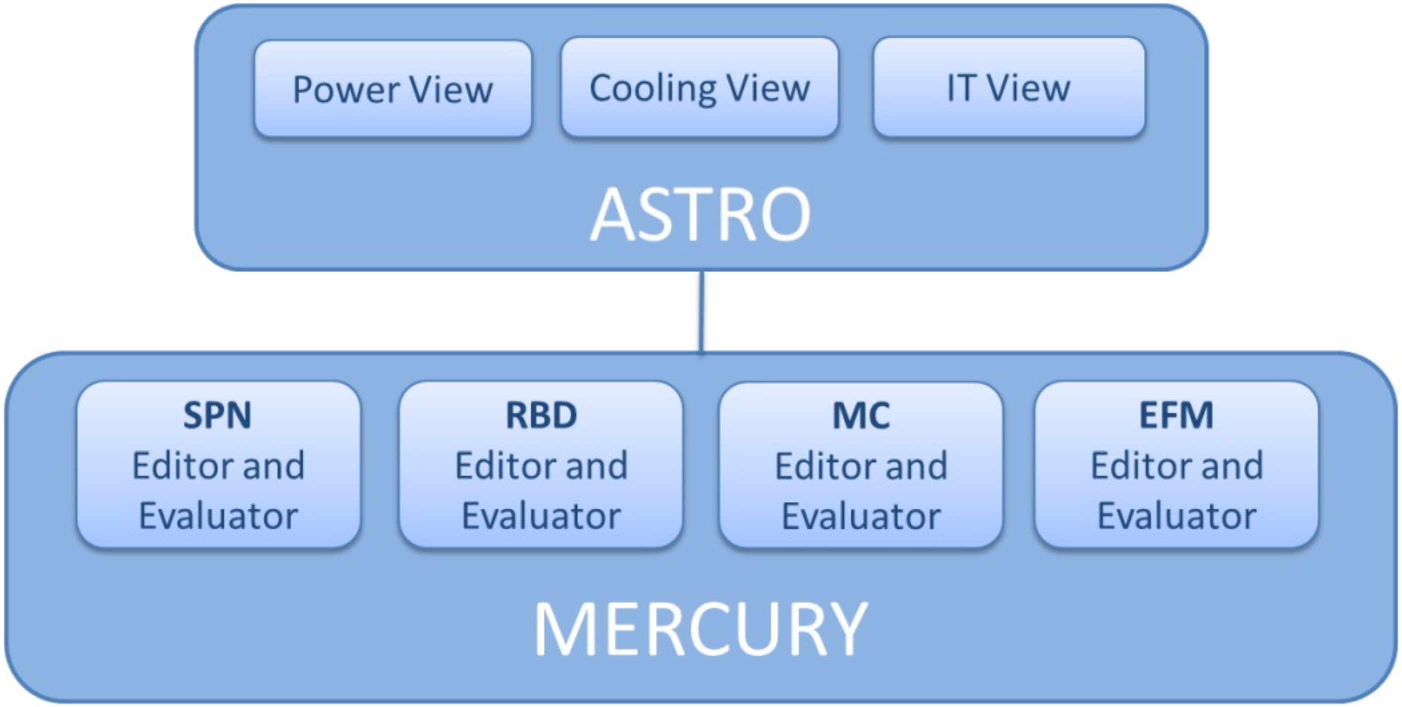
| Device | Operational Exergy Equation |
|---|---|
| Electrical | $P_{in} \times (1 - \eta)$ |
| Diesel Generator | $P_{in} \times \left(\frac{\varphi}{\eta} - 1\right)$ |
| CRAC | $Q_{in} \times \left(1 - \frac{T_{cold}}{T_{room}} + \frac{1}{\mu}\right)$ |
| Chiller | $Q_{in} \times \left(\frac{1}{COP} - \frac{T_{tower} - T_{chilled}}{T_{chilled}}\right)$ |
| Cooling Tower | $Q_{in} \times \left(1 - \frac{T_{amb}}{T_{warm}} + \frac{1}{\mu}\right)$ |

$$Ex_{op} = \sum_{i=1}^{n} Ex_{op_i} \times T \times (A + \alpha(1 - A))$$

  - Quantifying acquisition and operational costs

$$OC = P_{input} \times T \times C_{energy} \times (A + \alpha(1 - A))$$

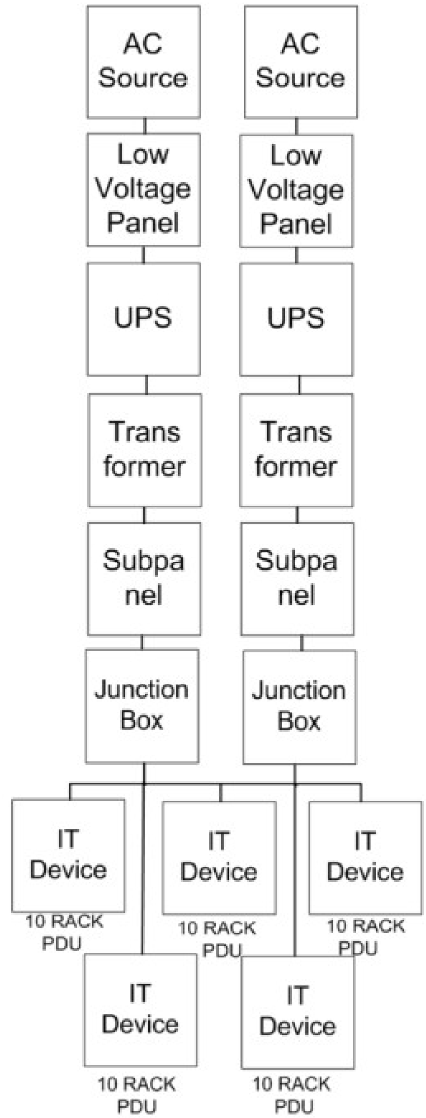
# ASTRO Environment



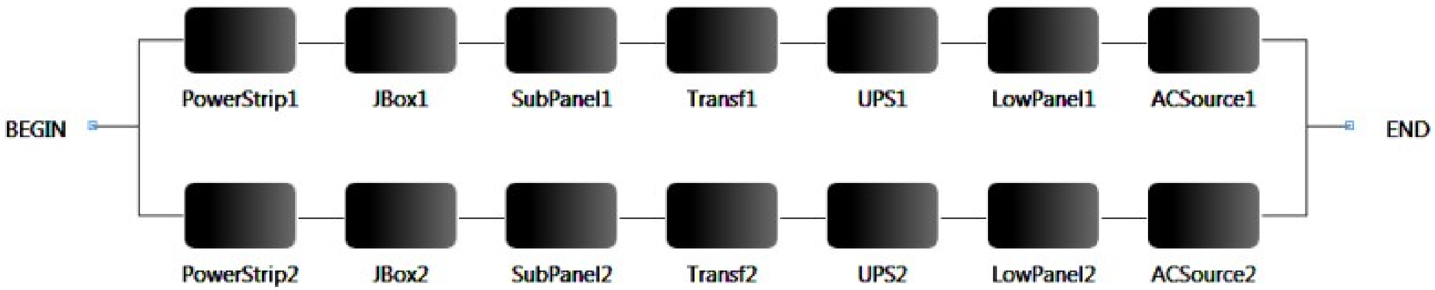
# Case Study

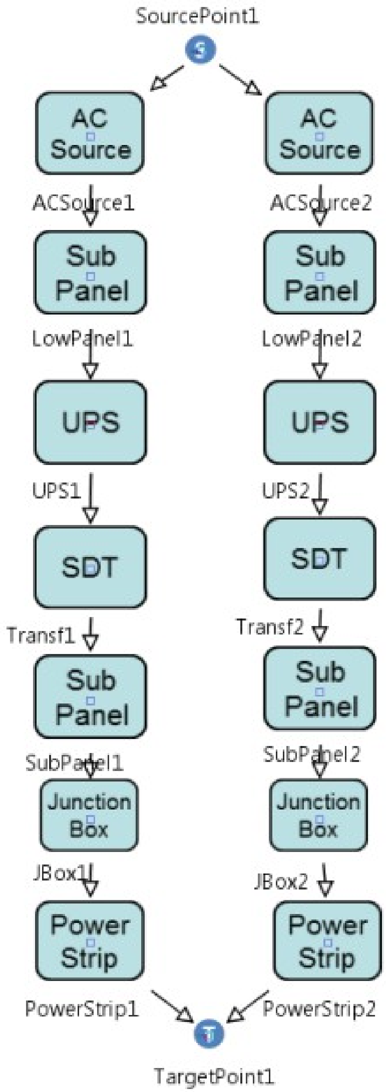
- To illustrate the applicability of the adopted methodology that makes use of a GRASP-based method to optimize:
  - Cost
  - Availability
  - Sustainability

# Architecture



# RBD and EFM Models



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# Results

| Metrics | non-Opt. Results | Optimized Results | | | Diff. |
|---|---|---|---|---|---|
| | | Mean | Std. Dev. | C.I. (95%) | |
| Availability (%) | 99.9961025 | 99.997037 | 0.0000035 | [99.99699, 99.99708] | 1.00001 |
| 9's | 4.409215244 | 4.53083791 | 0.047 | [4.525, 4.537] | 1.02758 |
| Downtime (h) | 0.341 | 0.259 | 0.030 | [0.256, 0.263] | 0.76022 |
| Acquisition Cost (USD) | 174200 | 78090.87 | 11480.81 | [76677.07, 79504.67] | 0.44828 |
| Operational Cost (USD) | 542885.56 | 548789.81 | 15237.43 | [546913.41, 550666.22] | 1.01088 |
| Cost (USD) | 717085.56 | 626880.68 | 18187.32 | [624641.02, 629120.35] | 0.87421 |
| Exergy Consumption (GJ) | 1999.778394 | 2192.861 | 498.692 | [2131.450, 2254.272] | 1.09655 |
| System Efficiency (%) | 0.887445266 | 0.879 | 0.024 | [0.876, 0.881] | 0.98997 |

# Conclusion

- Data center **designers do not have** many **mechanisms** to support the **integrated** sustainability, cost and dependability **evaluation** of data center infrastructures.

- This work aims at **reducing** this **gap** by proposing **models** (supported by the developed environment ASTRO/Mercury)

- As a **future work**, we intend to **analyze other scenarios**.

# Thanks!

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