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

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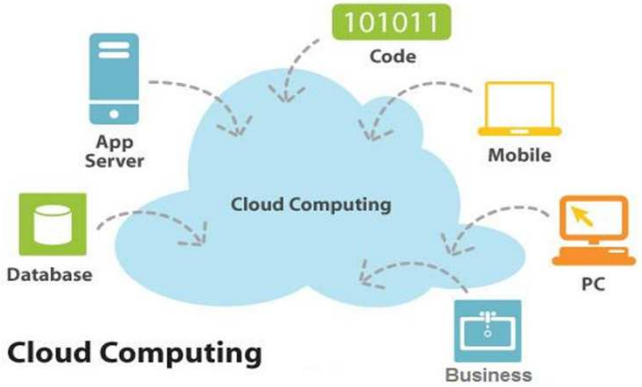
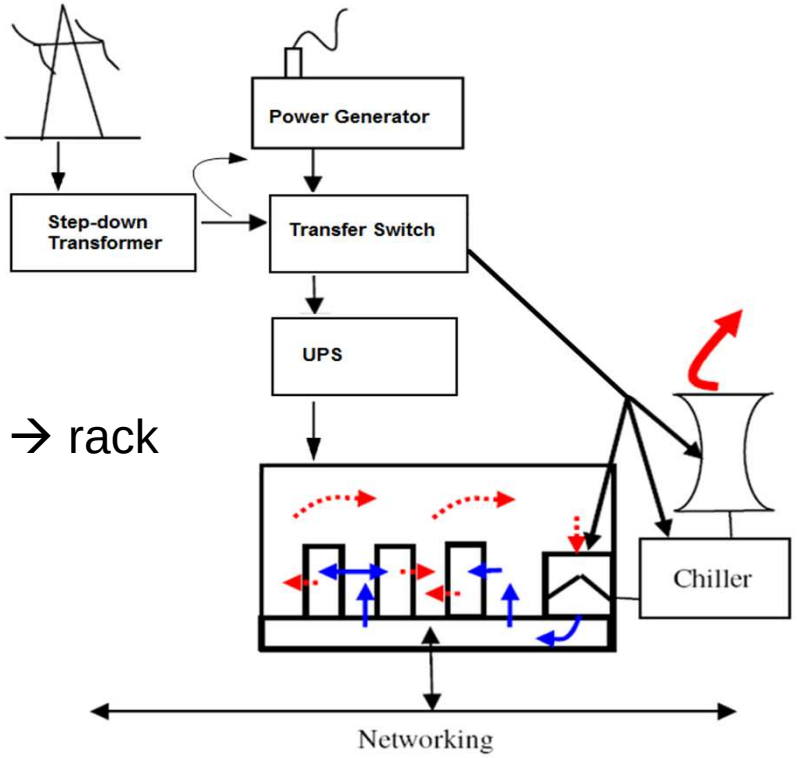
Introduction

- Data centers are growing
- Concern about:
  - Energy Consumption,
  - Environmental Sustainability.
- Fact (Considering U.S.):
  - 2006: 61 billion kWh of electricity consumed,
  - 2011: 100 billion kWh of electricity estimated.
- Sustainable data centers:
  - Least amount of materials,
  - Least energy consumption.
- Availability
- Fault-Tolerance



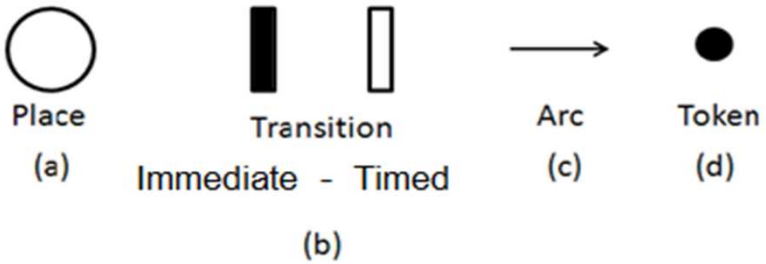
Data Center Infrastructure

- 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



Stochastic Petri Net (SPN)

- Graphical and Mathematical modeling tool
- For modeling:
  - concurrency,
  - synchronization,
  - communication mechanisms,
  - deterministic and probabilistic delays



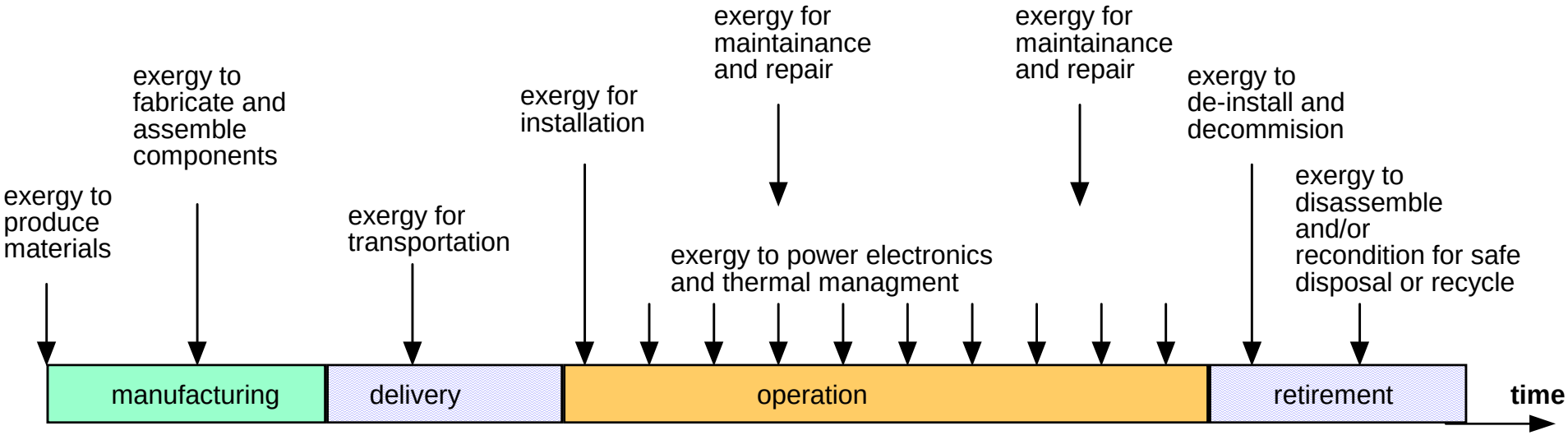
- SPNs extend PNs.
- Each transition has a firing time assigned to it:
  - timed transitions (exponentially distributed)
  - immediate transitions

Exergy

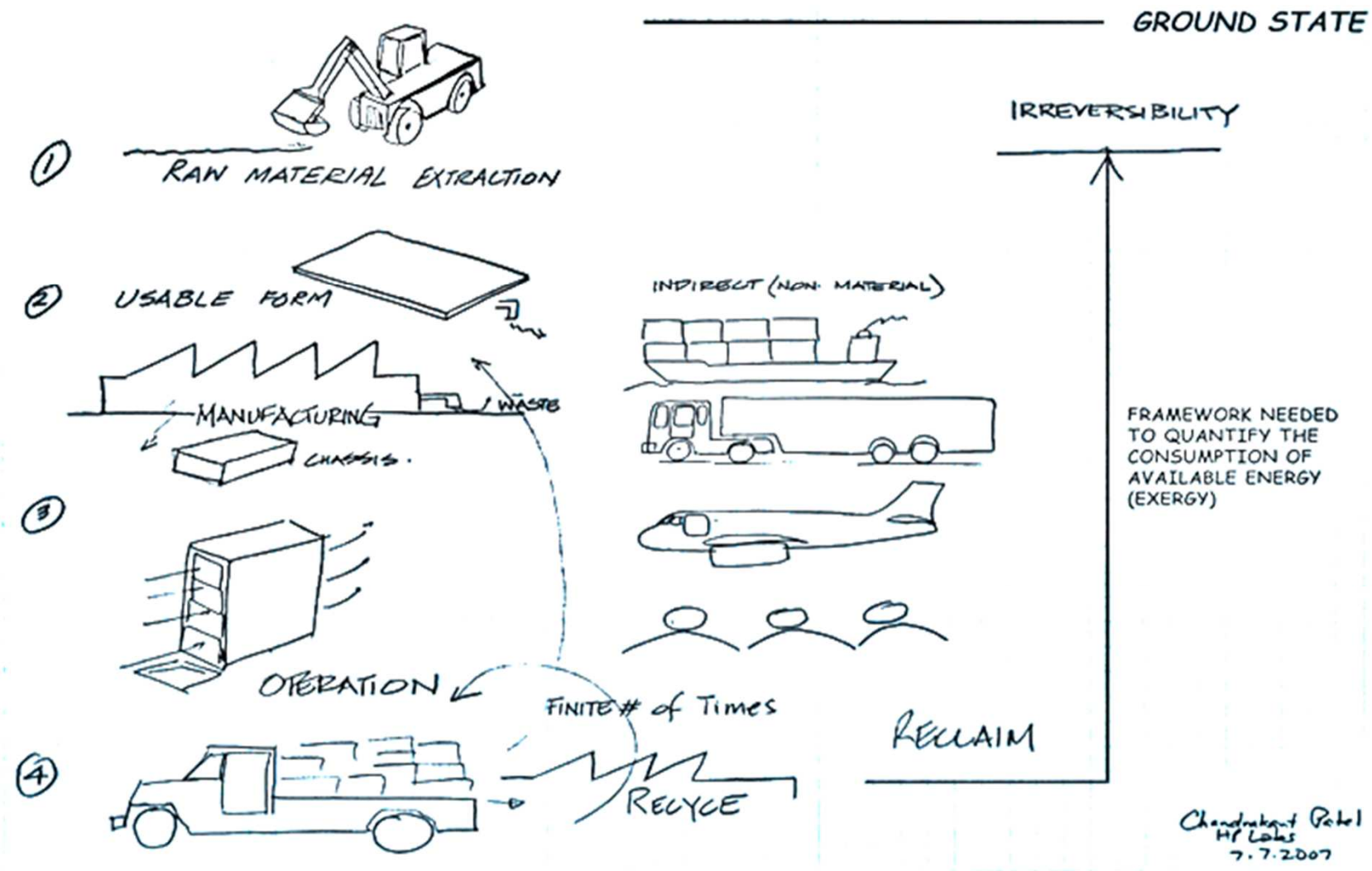
- Exergy (available energy) → Environmental impact
  - Represents energy that can be converted into useful work,

Life Cycle Exergy Assessment (LCEA)

- Can a measure of the total exergy destroyed across a product's lifetime ("lifetime exergy consumption") be a measure of the environmental sustainability?



Life Cycle Exergy Assessment (LCEA)



Objective

- To provide
  - Assessment to support the planning of sustainable data centers with high availability.

Objective

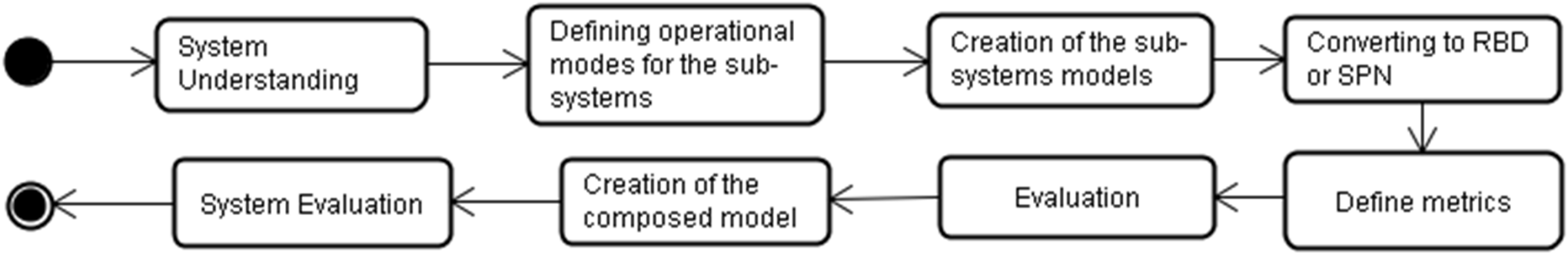
- More specifically, the objectives are:
  - To **construct** formal models (e.g., **RBD** or **SPN**) to represent the data center **power** infrastructure, **cooling** infrastructure as well as the **IT** equipments;
  - To perform the **evaluation** of those models in order to obtain metrics such as **dependability**, **sustainability** and the associated **cost** estimates;
  - **To Develop a tool** that implements the above methodologies and enables a data center designer/administrator **to estimate the sustainability impact**, through the **exergy** metric, of data center systems.

Objective

- To study **hardened computing** and its associated metrics (e.g., **Thermal**, Contamination, **Humid**, **Power dissipation**, System **architecture**);
- To **quantify** the **impacts** of **temperature variation** on data center availability;
- To **quantify** the **impacts** of **humidity variation** on data center availability.

Methodology

- The proposed Methodology



Methodology

- A hybrid modeling technique:
  - advantages of SPN and RBD.

- Two models are generated:
  - power,
  - cooling system.

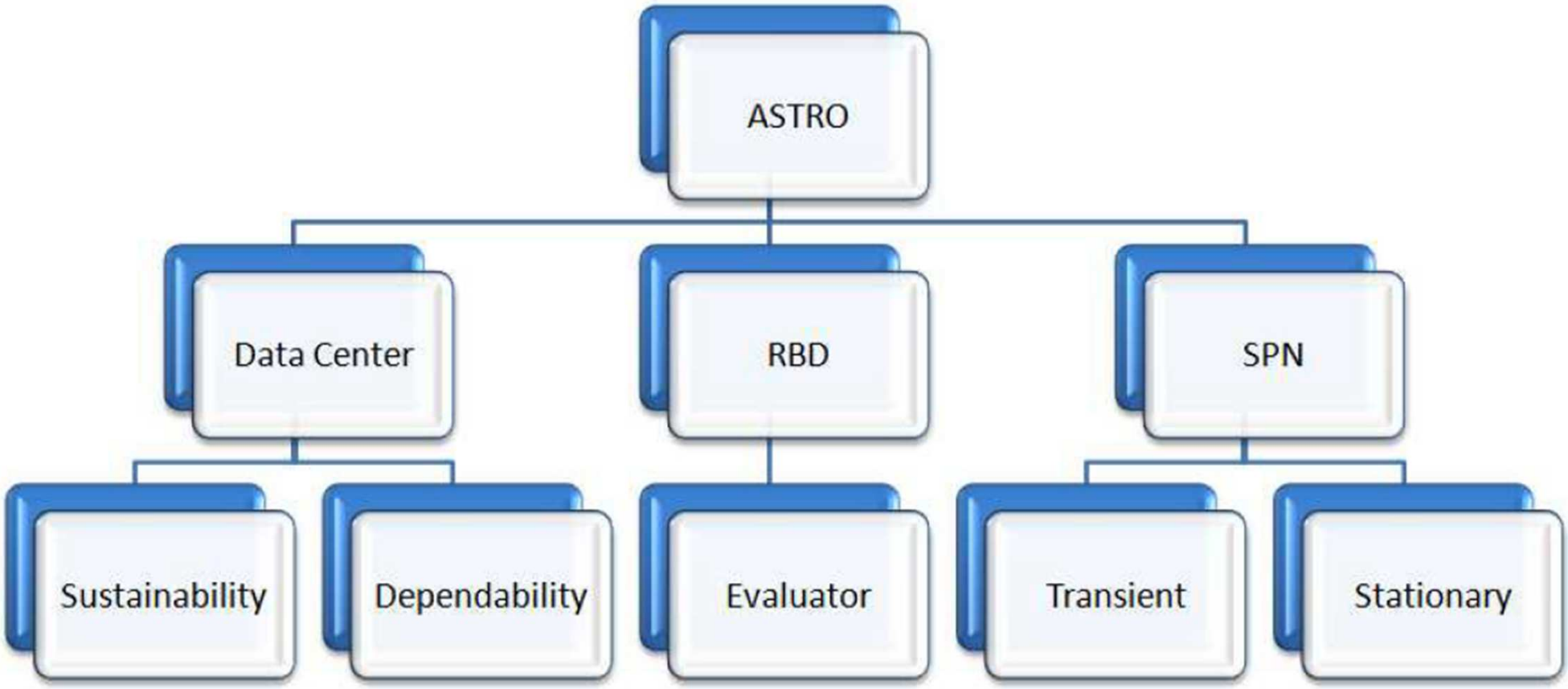
- A high level model is generated in order to compose those models previously evaluated.

MoDCS

Astro Tool

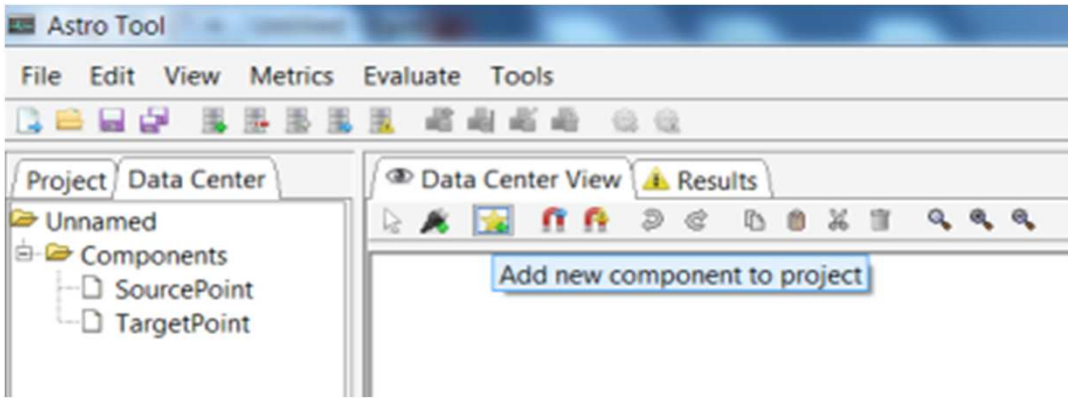
The **A**mazing **S**thocastic Pe**tr**i net/ RBD Simulat**o**r

ASTRO Tool


ASTRO
Data Center
RBD
SPN
Sustainability
Dependability
Evaluator
Transient
Stationary

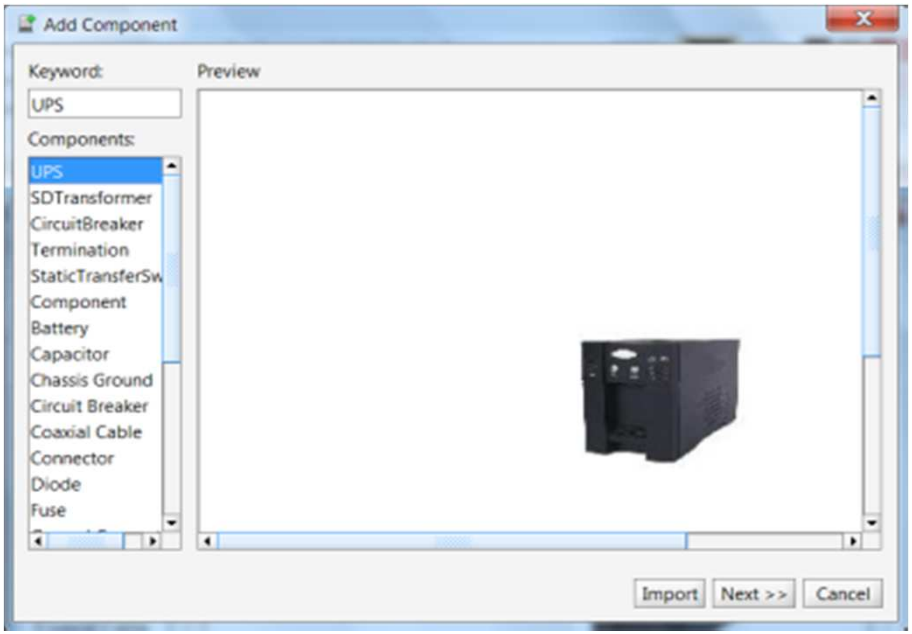
Astro Tool

- Sustainability Evaluation
  - Adding a data center component to the project



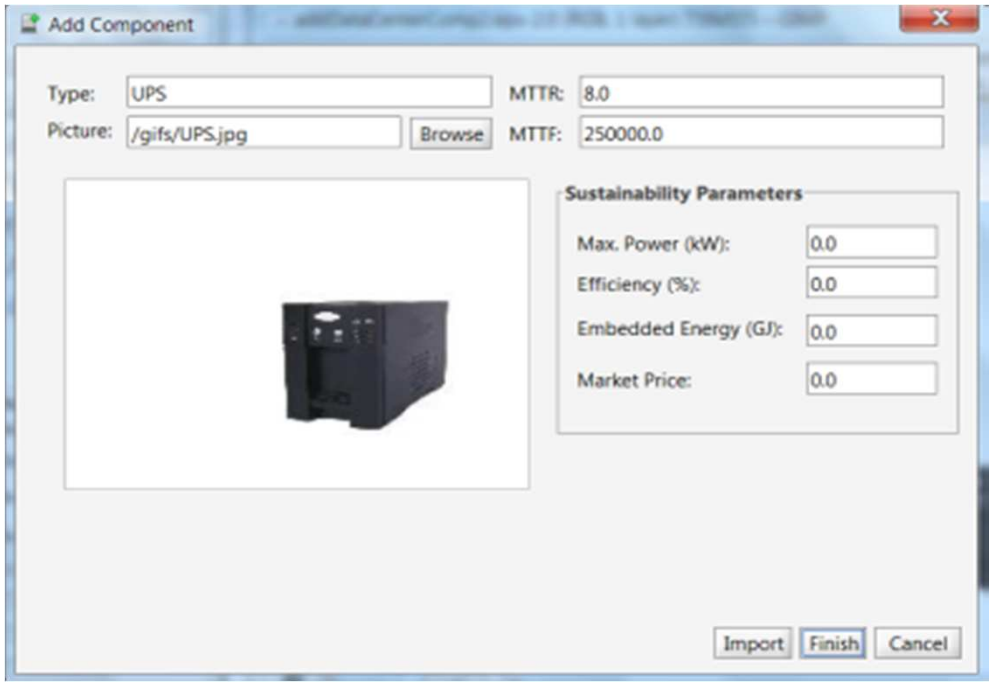
Astro Tool

- Sustainability Evaluation
  - Selecting the data center component to be added



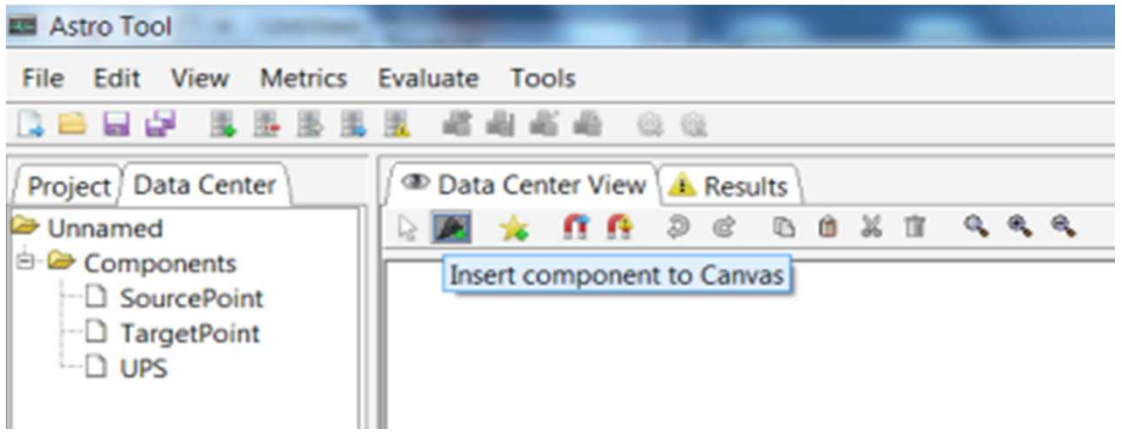
Astro Tool

- Sustainability Evaluation
  - Configuring the sustainability parameters



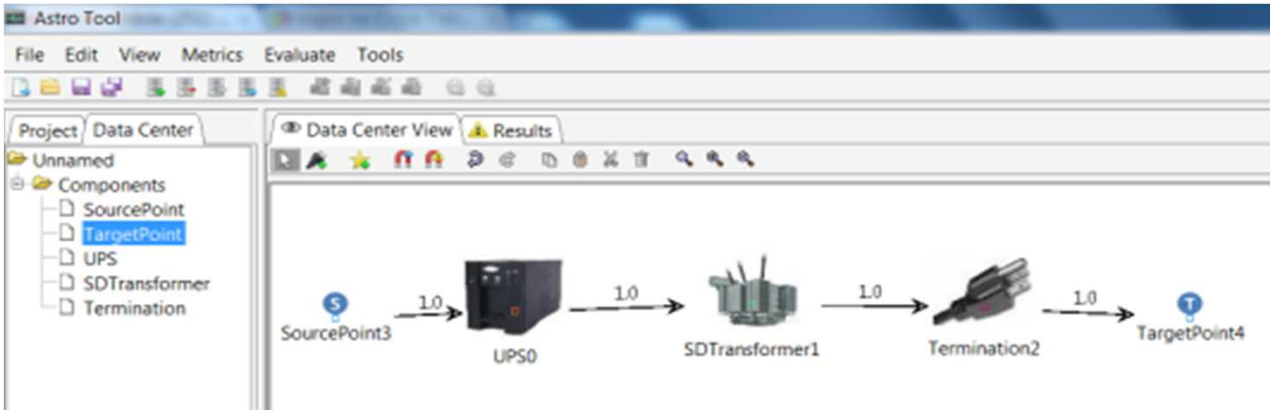
Astro Tool

- Sustainability Evaluation
  - Inserting the component to the model.



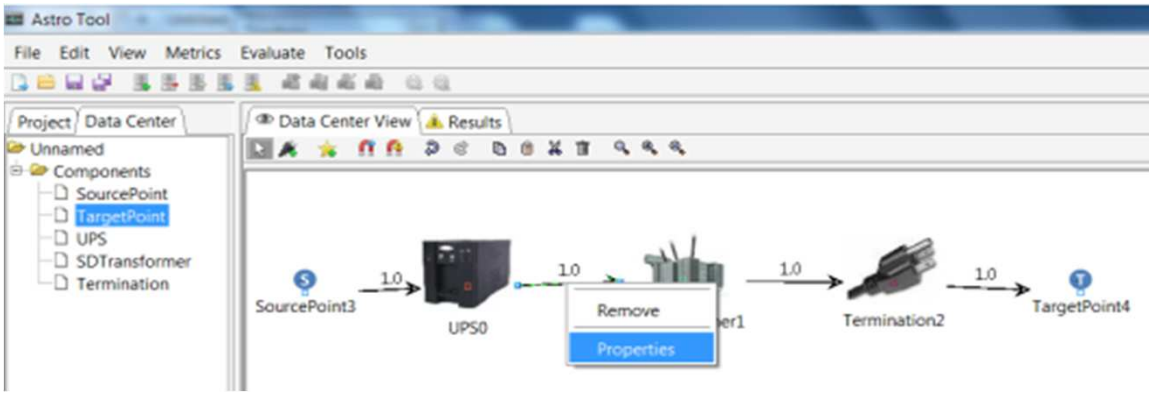
Astro Tool

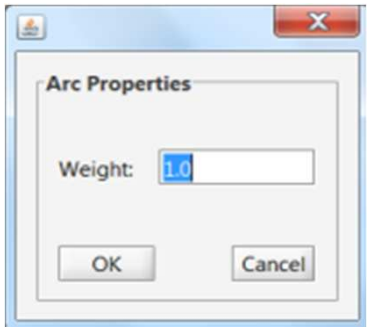
- Sustainability Evaluation
  - An example of data center model



Astro Tool

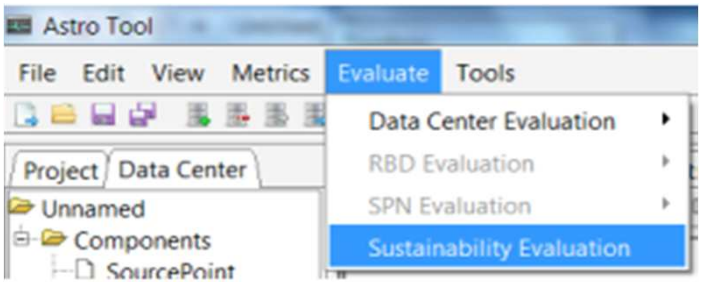
- Sustainability Evaluation
  - Editing edge weight.

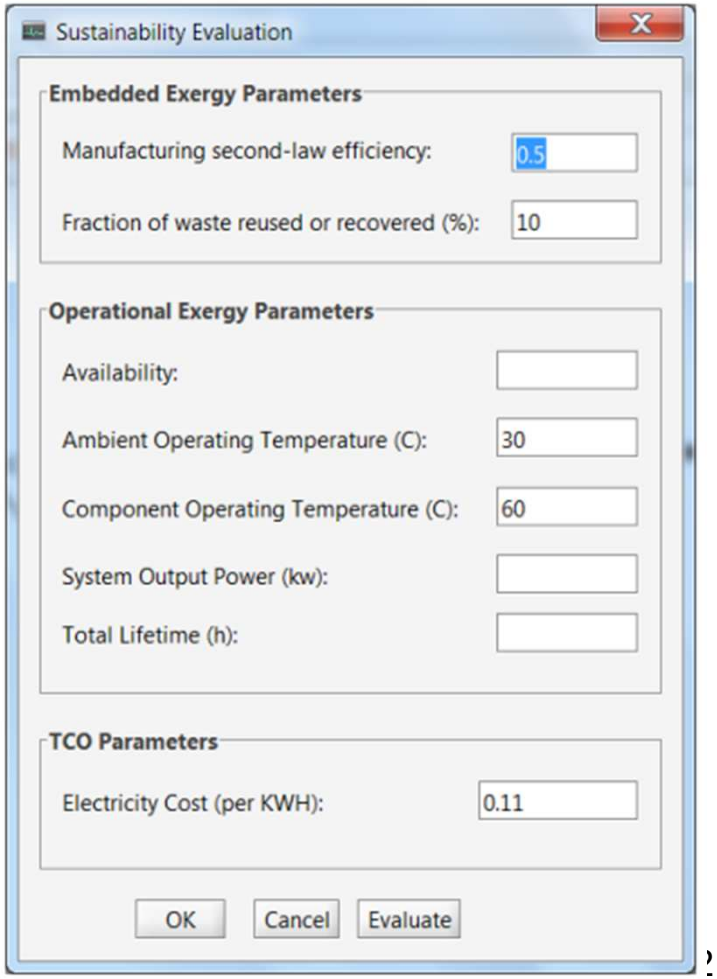




Astro Tool

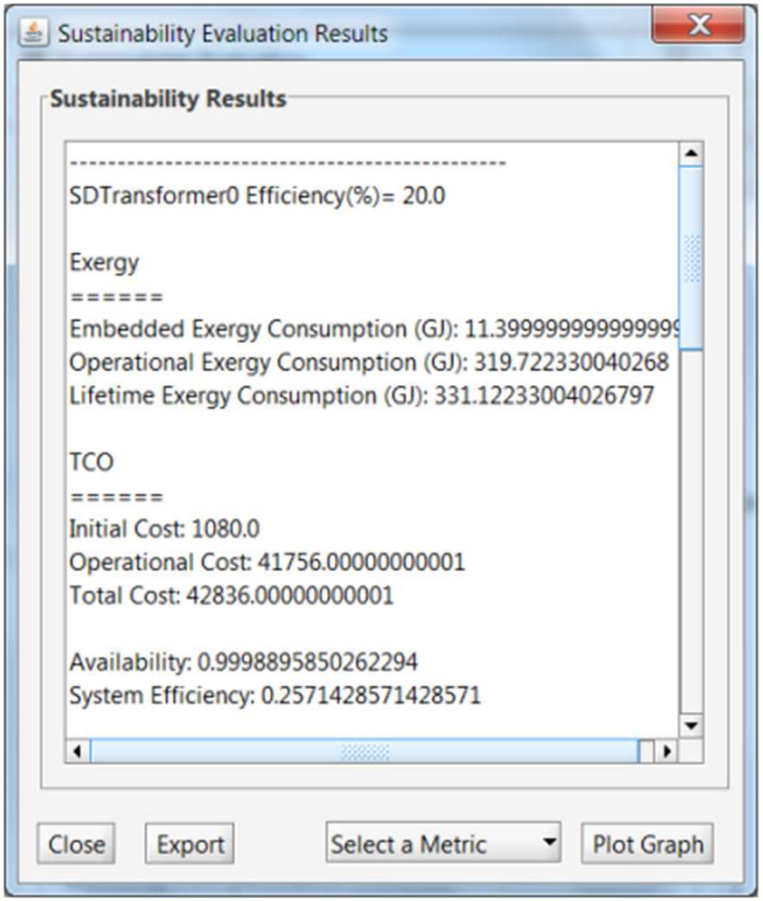
- Sustainability Evaluation
  - Sustainability menu



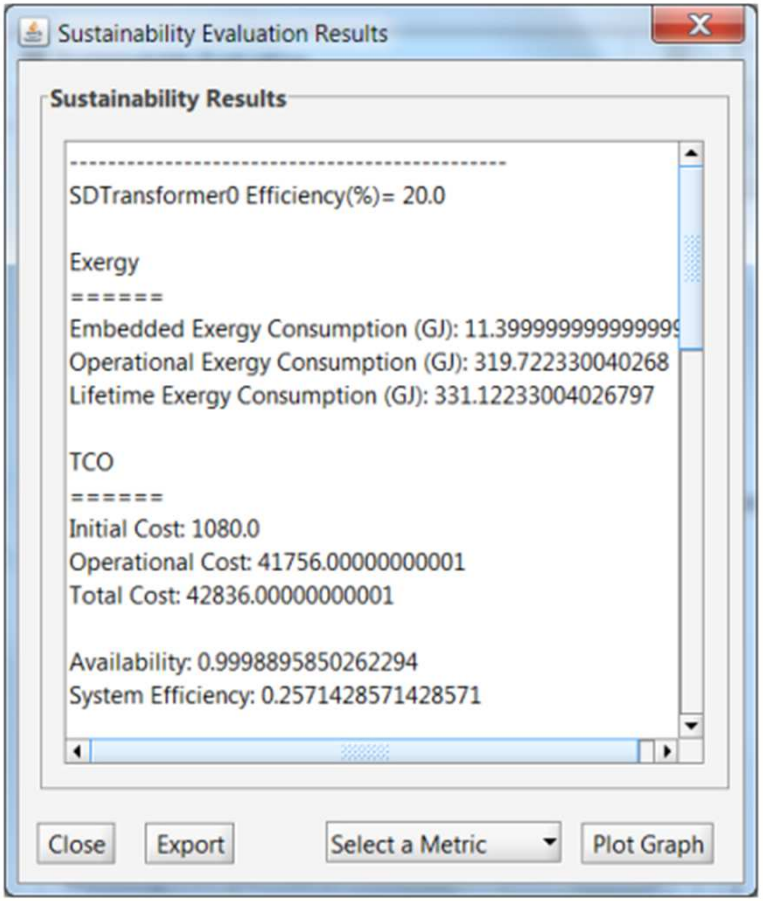


Astro Tool

- Sustainability Evaluation
  - Sustainability Results



- Sustainability Evaluation
  - Export Results to Excel



- Sustainability Evaluation
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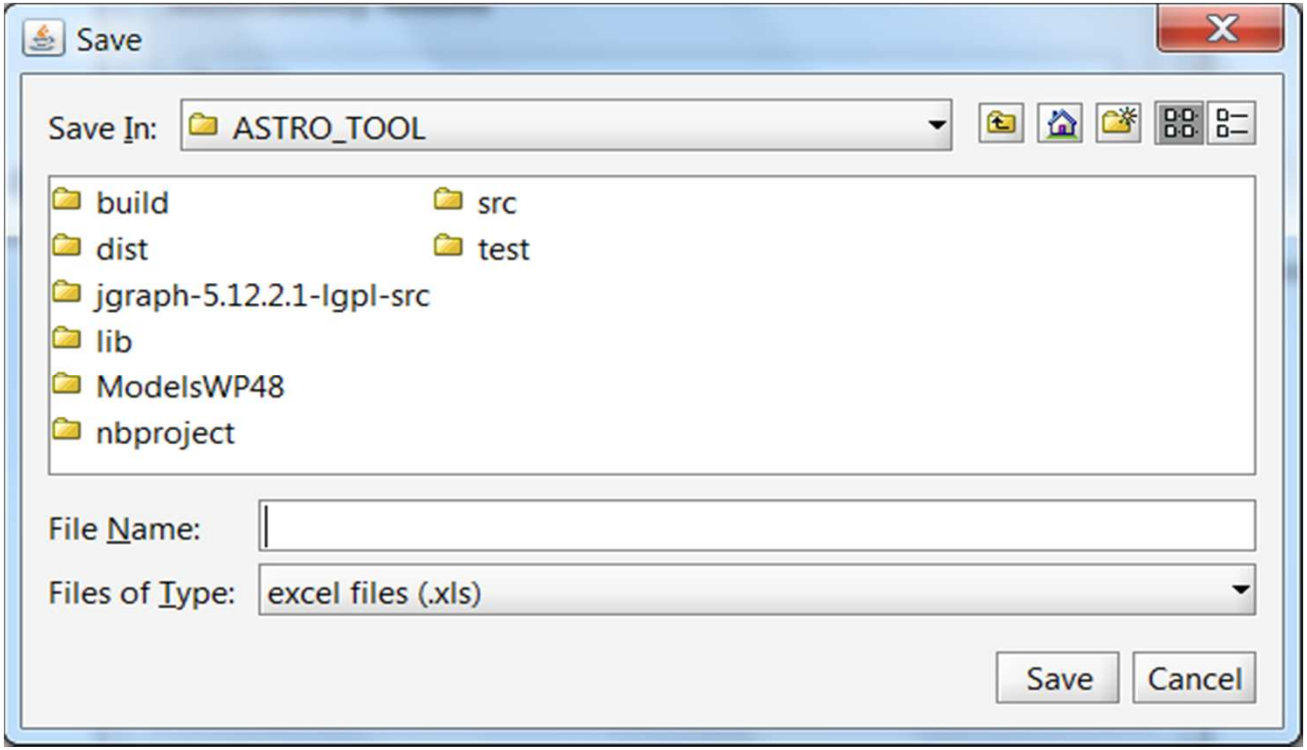
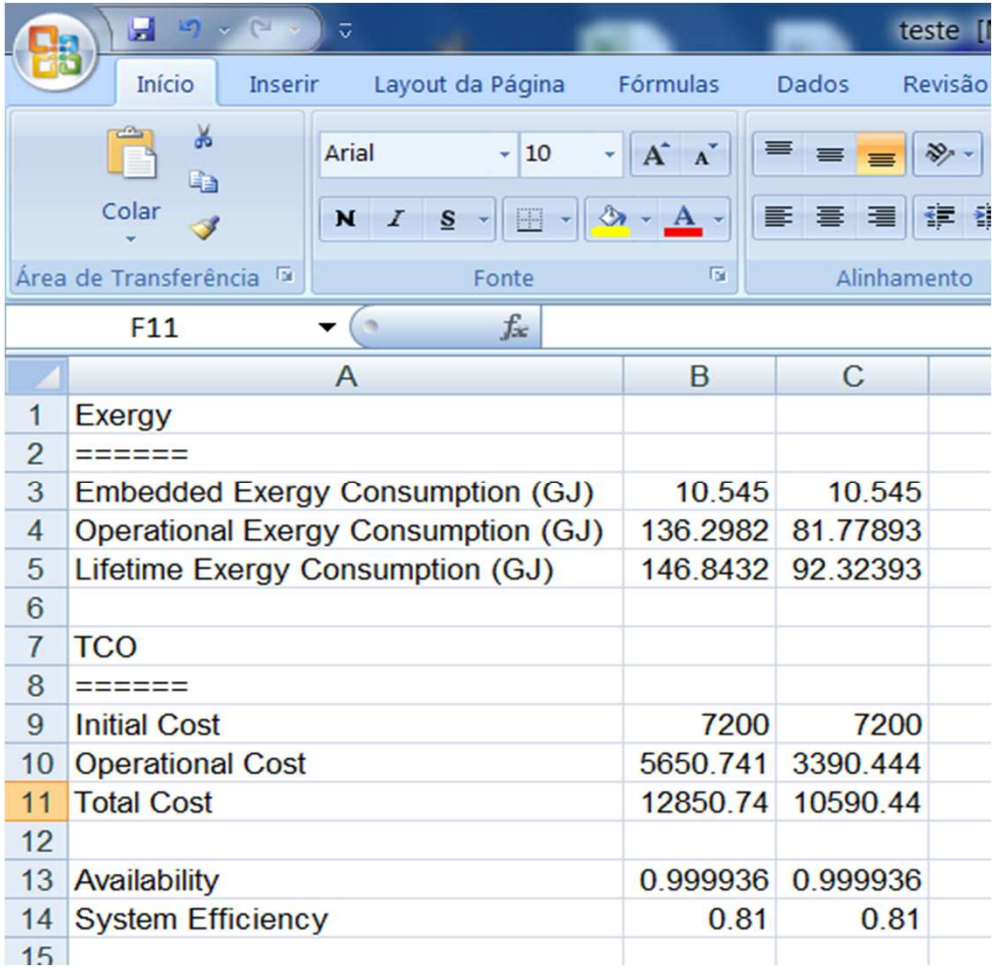


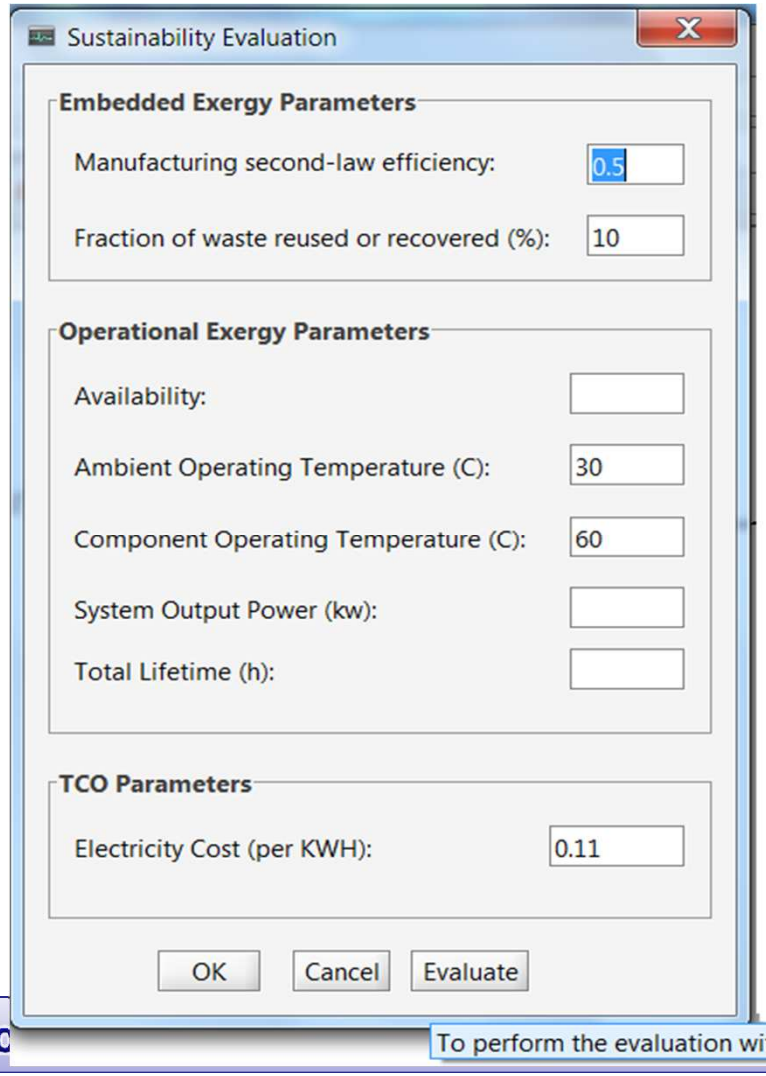
- Sustainability Evaluation
  - Export Results to Excel



	A	B	C
1	Exergy		
2	======		
3	Embedded Exergy Consumption (GJ)	10.545	10.545
4	Operational Exergy Consumption (GJ)	136.2982	81.77893
5	Lifetime Exergy Consumption (GJ)	146.8432	92.32393
6			
7	TCO		
8	======		
9	Initial Cost	7200	7200
10	Operational Cost	5650.741	3390.444
11	Total Cost	12850.74	10590.44
12			
13	Availability	0.999936	0.999936
14	System Efficiency	0.81	0.81
15			

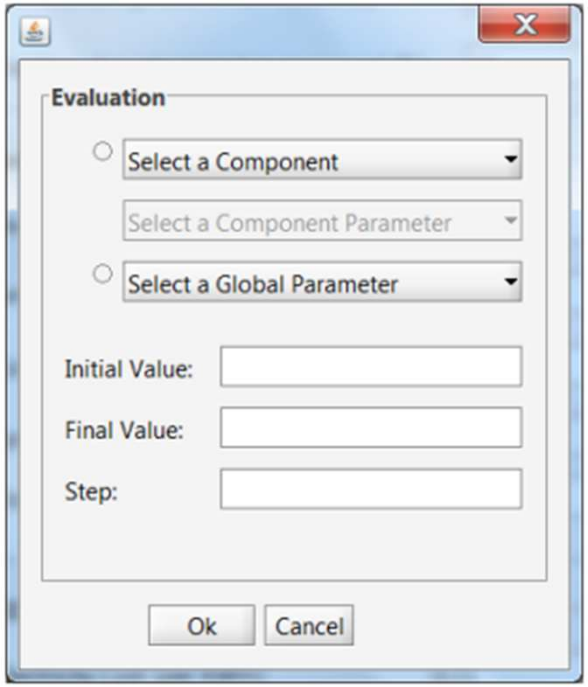
Astro Tool

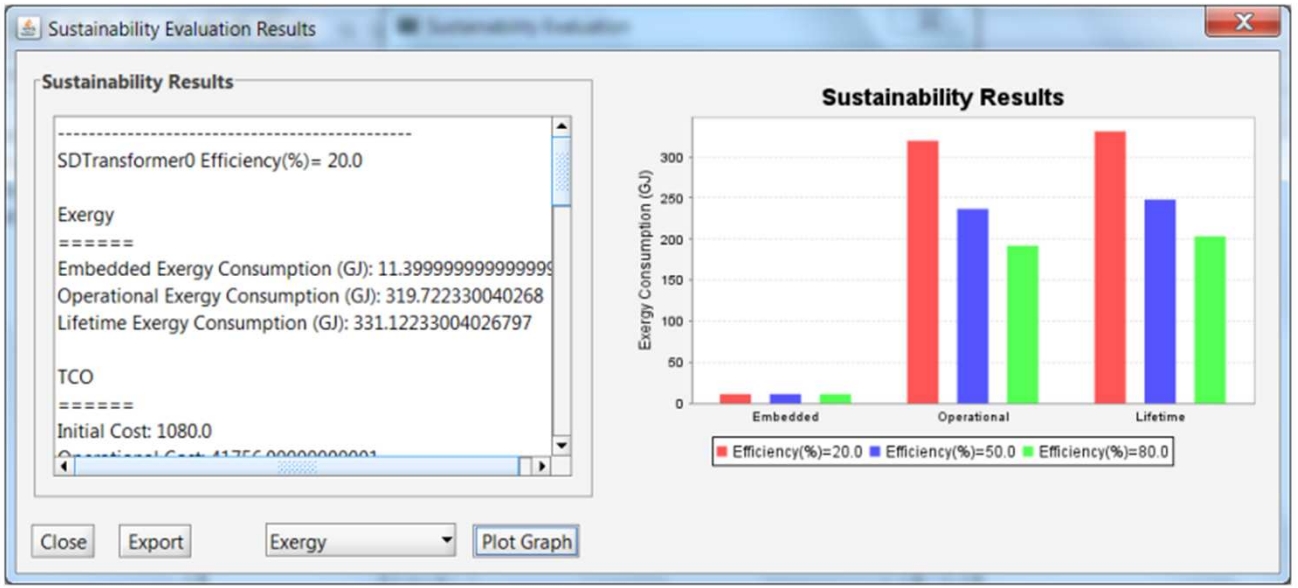
- Sustainability Evaluation
  - Export Results to Excel
  - Evaluation with a parameter range.



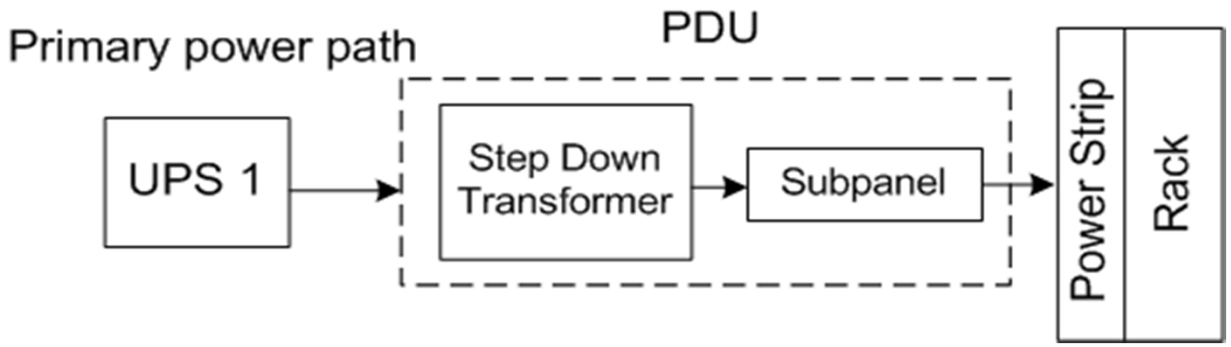
Astro Tool

– Performing an evaluationg considering a range of values for a component parameter.



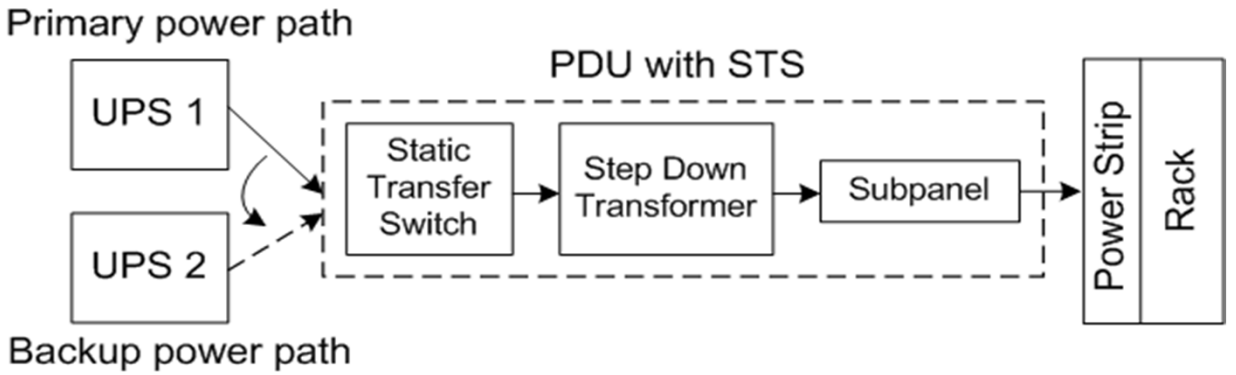


- Data Center Power Infrastructure
  - Five architectures with increasing redundancy



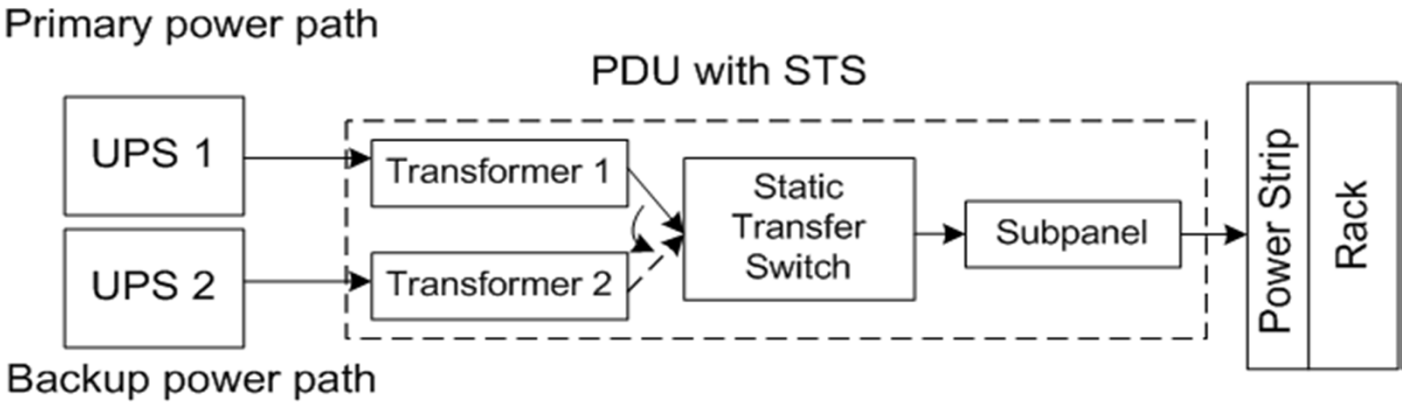
Baseline power delivery architecture (A1)

- Data Center Power Infrastructure
  - Five architectures with increasing redundancy



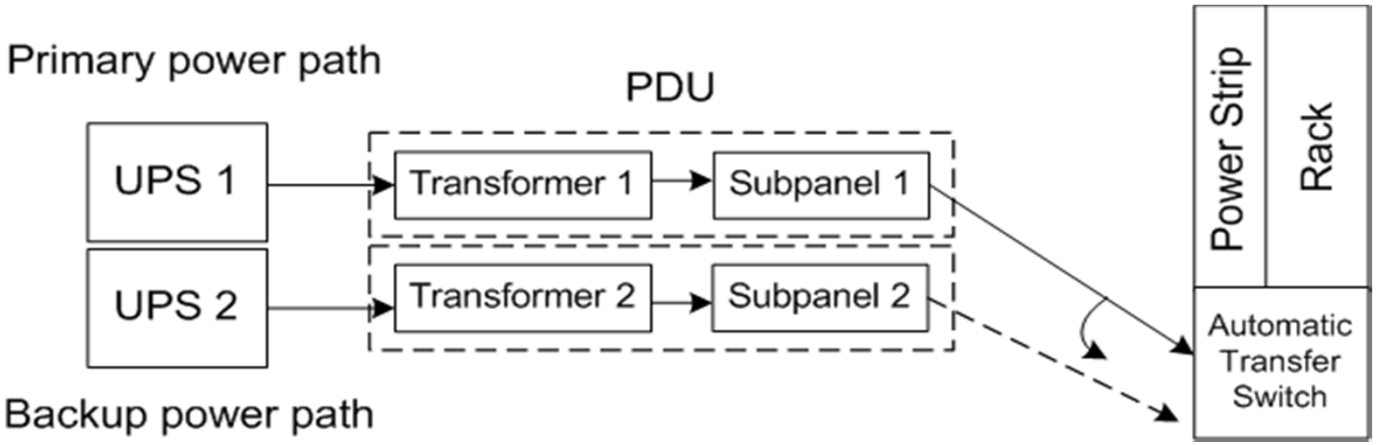
•Architecture A2 with redundant UPS and STS.

- Data Center Power Infrastructure
  - Five architectures with increasing redundancy



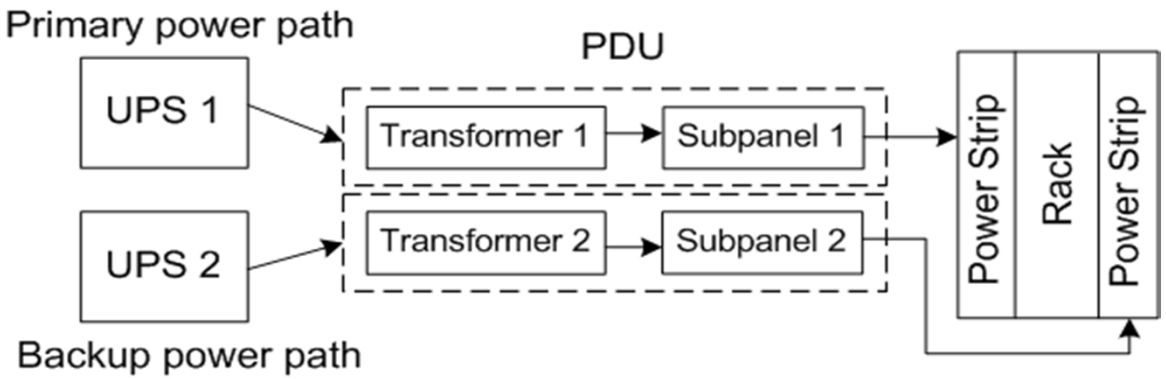
•Architecture A3: redundant UPS and Transformers, including a STS.

- Data Center Power Infrastructure
  - Five architectures with increasing redundancy



•Architecture A4: redundant UPS, Transformers, Subpanel, including an ATS.

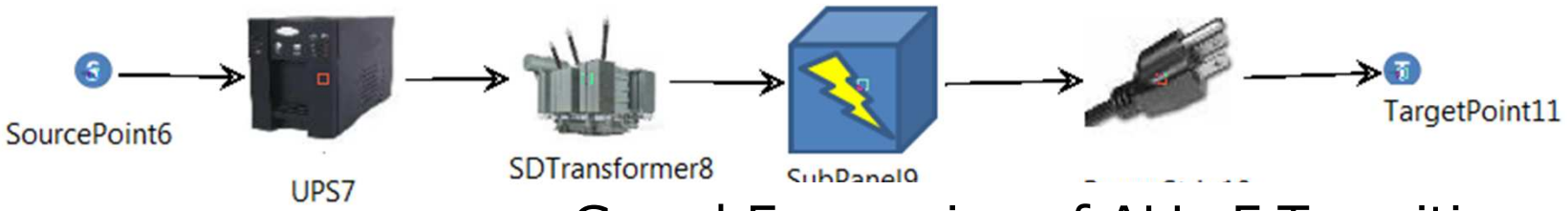
- Data Center Power Infrastructure
  - Five architectures with increasing redundancy



•Architecture A5: all components are redundant

Modeling with ASTRO Tool

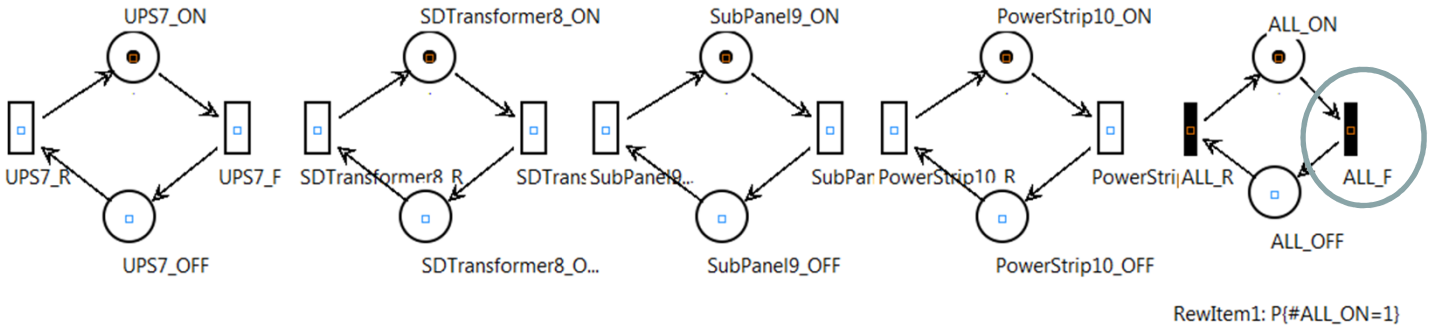
- Architecture 1



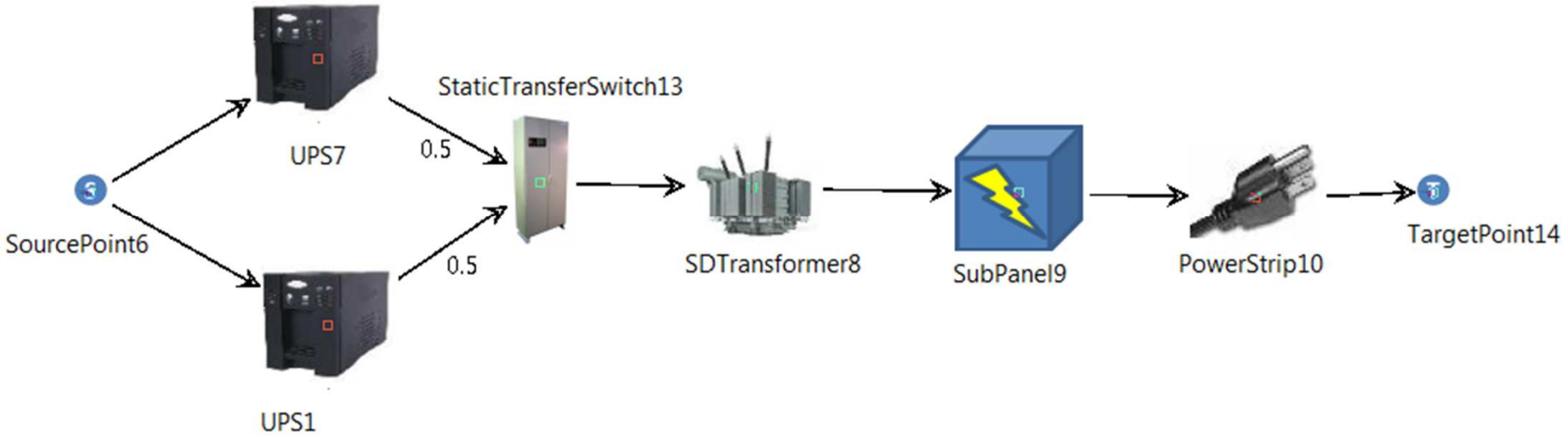
- RBD

Guard Expression of ALL_F Transition:
((#PowerStrip10_ON=0)OR
(#SubPanel9_ON=0)OR
(#SDTransformer8_ON=0)OR
(#UPS7_ON=0))

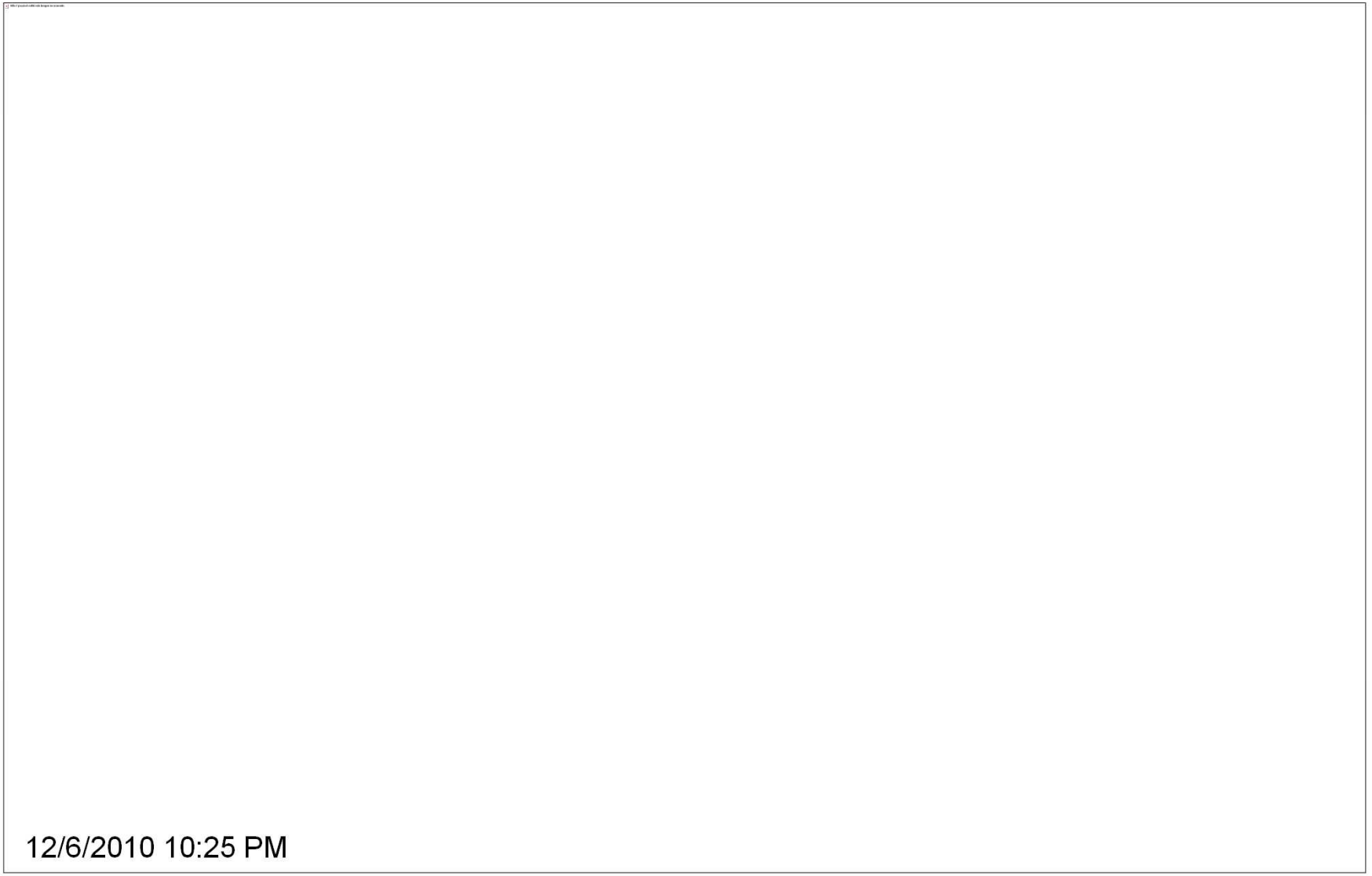
- SPN



- Architecture 2



Results



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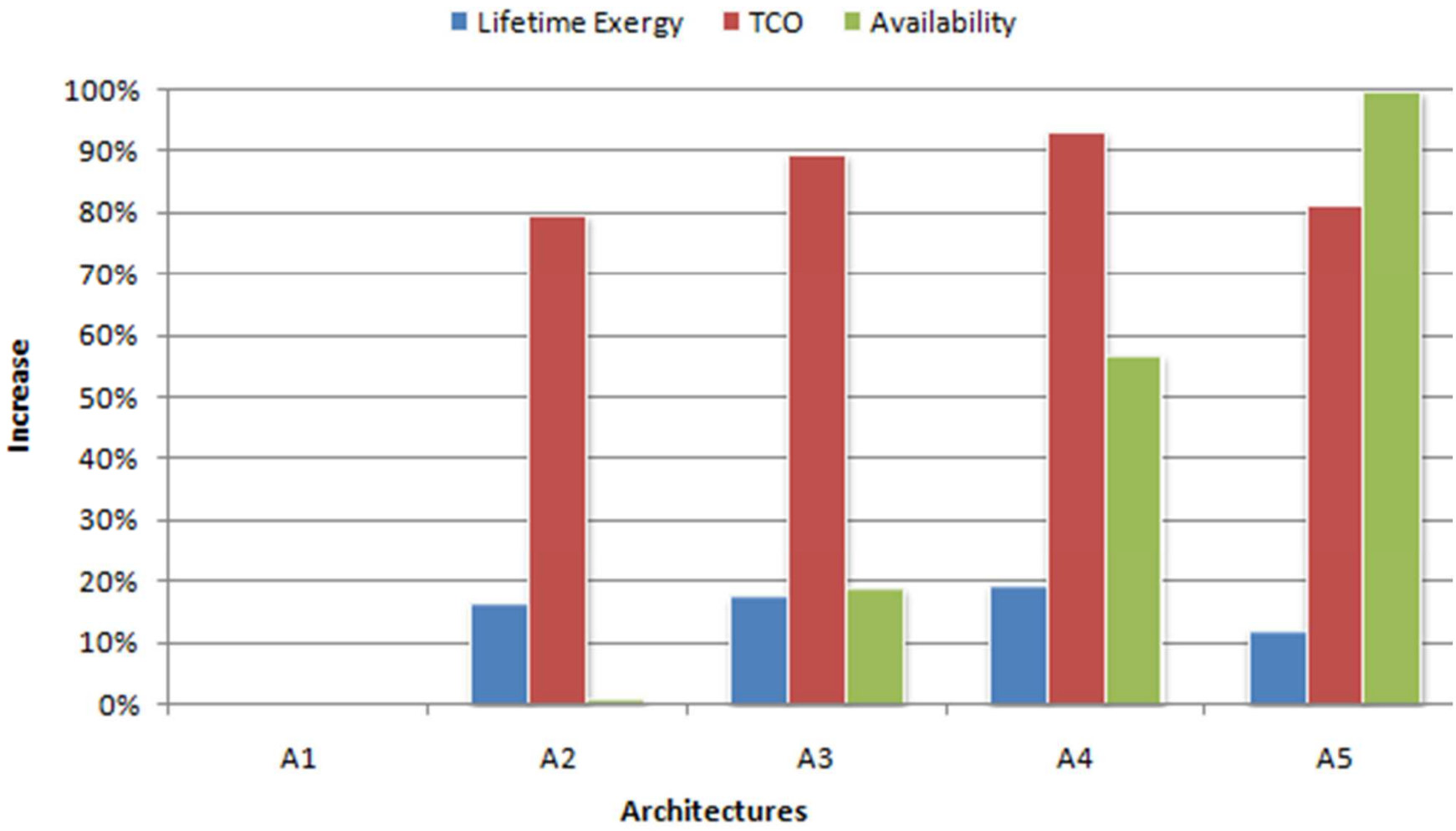
Lifetime Exergy
TCO
Availability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Increase
A1
A2
A3
A4
A5
Architectures

Future Work

- To validate sustainability results
- To study IT System
- To consider sustainability in the performance evaluation of IT Systems (e.g., amount of work / exergy destroyed).

Papers / Technical Visit

- Technical Visit
  - Sustainable IT Ecosystem Laboratory at **HP Labs**, Palo Alto, USA, 2009.
- Papers:
  - *Quantifying the Sustainability Impact of Data Center Availability*. In: GreenMetrics 2009.
  - *Impact Analysis of Maintenance Policies on Data Center Power Infrastructure*. In: IEEE Conference on Systems, Man and Cybernetics (SMC 2010).
  - *A Tool for Dependability Evaluation of Data Center Infrastructures.* In: IEEE Conference on Systems, Man and Cybernetics (SMC2010).
- Submitted:
  - *Impact Analysis of Maintenance Policies on Data Center Power Infrastructure.* In: IEEE Transactions on Reliability