Energy Signature Model for Data Center Infrastructure

Spiros Livieratos

Professor, ASPETE

School of Pedagogical and Technological Education

Email: slivieratos@aspete.gr

Spiros Panetsos, Professor ASPETE

Avgoustinos Fotopoulos, Mechanical Engineer

Data Center definition

- Data center is a complex and energy demanding building environment where primarily electronic equipment used for data processing (servers), data storage (storage equipment), and communications (network equipment) is located. Collectively, this equipment processes, stores, and transmits digital information.

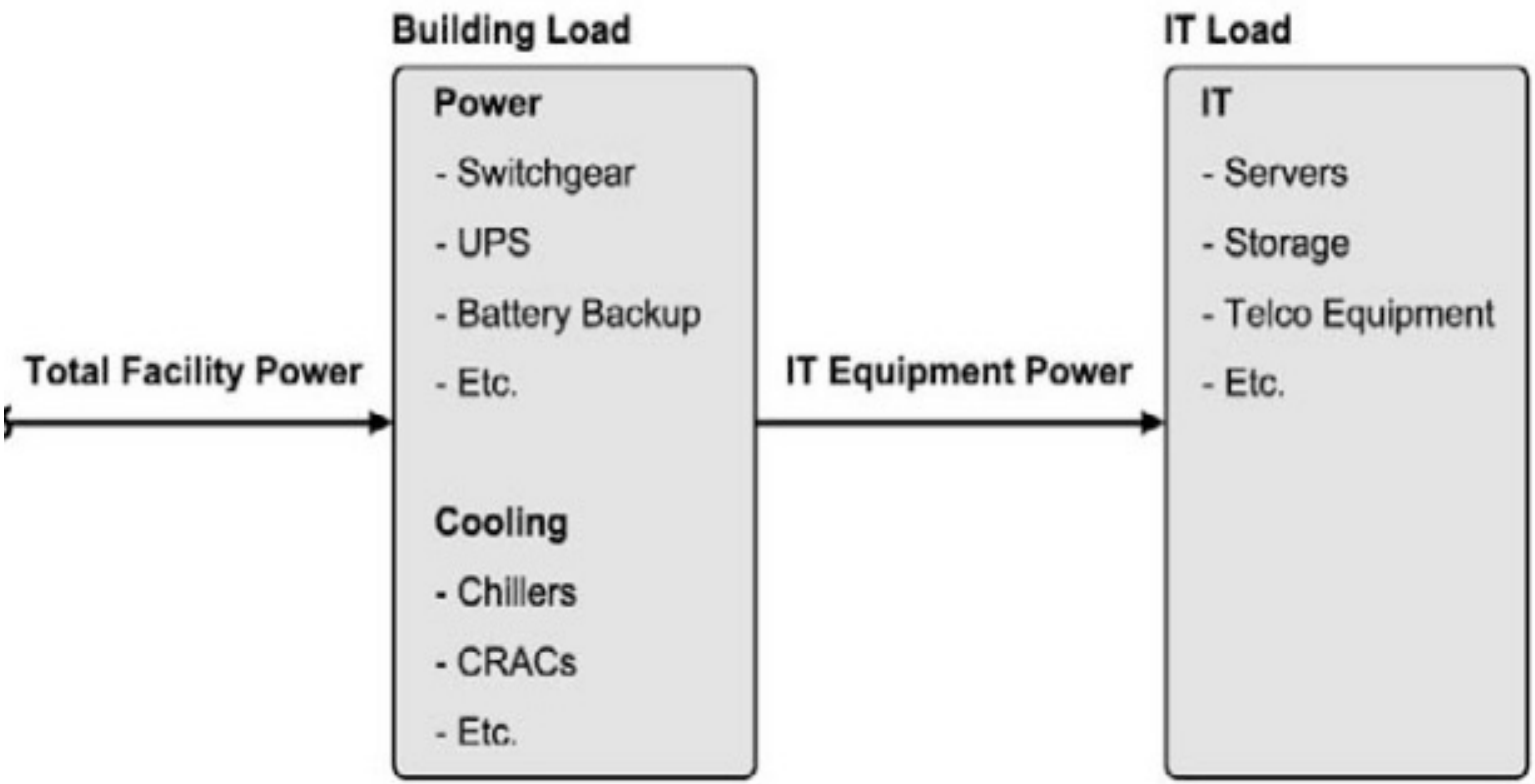
- …or where specialized power conversion and backup equipment is located to maintain reliable, high-quality power, as well as environmental control equipment to maintain the proper temperature and humidity for the ICT equipment.

- Critical characteristics are:
  - high internal loads,
  - low indoor temperature and humidity settings, and
  - continuous (uninterrupted) operation

Data Center market explosion

- The communications industry could use 20% of all the world's electricity by 2025
- Global computing power demand from internet-connected devices, high resolution video streaming, emails, surveillance cameras and a new generation of smart TVs is increasing 20% a year, consuming roughly 3-5% of the world's electricity in 2015, according to Swedish researcher Anders Andrae.
- More than one billion new internet users are expected, growing from three billion in 2015 to 4.1bn by 2020. Over the next five years global IP networks will support up to 10bn new devices and connections, increasing from 16.3bn in 2015 to 26bn by 2020, according to Cisco
- Billions of internet-connected devices could produce 14% of global emissions 2040, according to new research.

Key Data Center subsystems



Modeling Data Center consumption

- A mathematical model that accurately represents the workings of a specific data center, and accepts as inputs the IT load, outdoor weather statistics, etc., could be used effectively in a data center energy management program since:
  - it could estimate the efficiency performance of an operating data center for different IT loads, or for various outdoor temperatures or for industry benchmark conditions, over time,
  - it could identify and quantify the contributions specific devices in the data center power, cooling, and lighting systems are making to the inefficiency of the data center
  - it could benchmark and compare the models of different data centers aiming at classification and/or prioritization purposes.

Data Center cooling calculation model

- Consider
  - the data center physical characteristics and the thermal dynamic characteristics of the IT equipment,
  - the cooling load of the data center mainly comes from
    - IT equipment,
    - envelope,
    - lighting,
    - people and infiltration, etc.

- Among of these, the cooling load caused by people and infiltration compares to the amount generated by the IT equipment is insignificant, which can be neglected.

- Therefore, the total cooling load of data center can be calculated by

$$Q_{cooling} = UA_{envelope}(T_{out} - T_{in}) + Q_{IT}$$

where,
$Q_{cooling}$: cooling load (W)
U: thermal conductivity of the building (W/m^2/K)
$A_{envelope}$: envelope of the building (m^2)
T_{out}: outdoor air temperature (^oC)
T_{in} : indoor air temperature (^oC)
Q_{IT}: IT wasted thermal load (W)

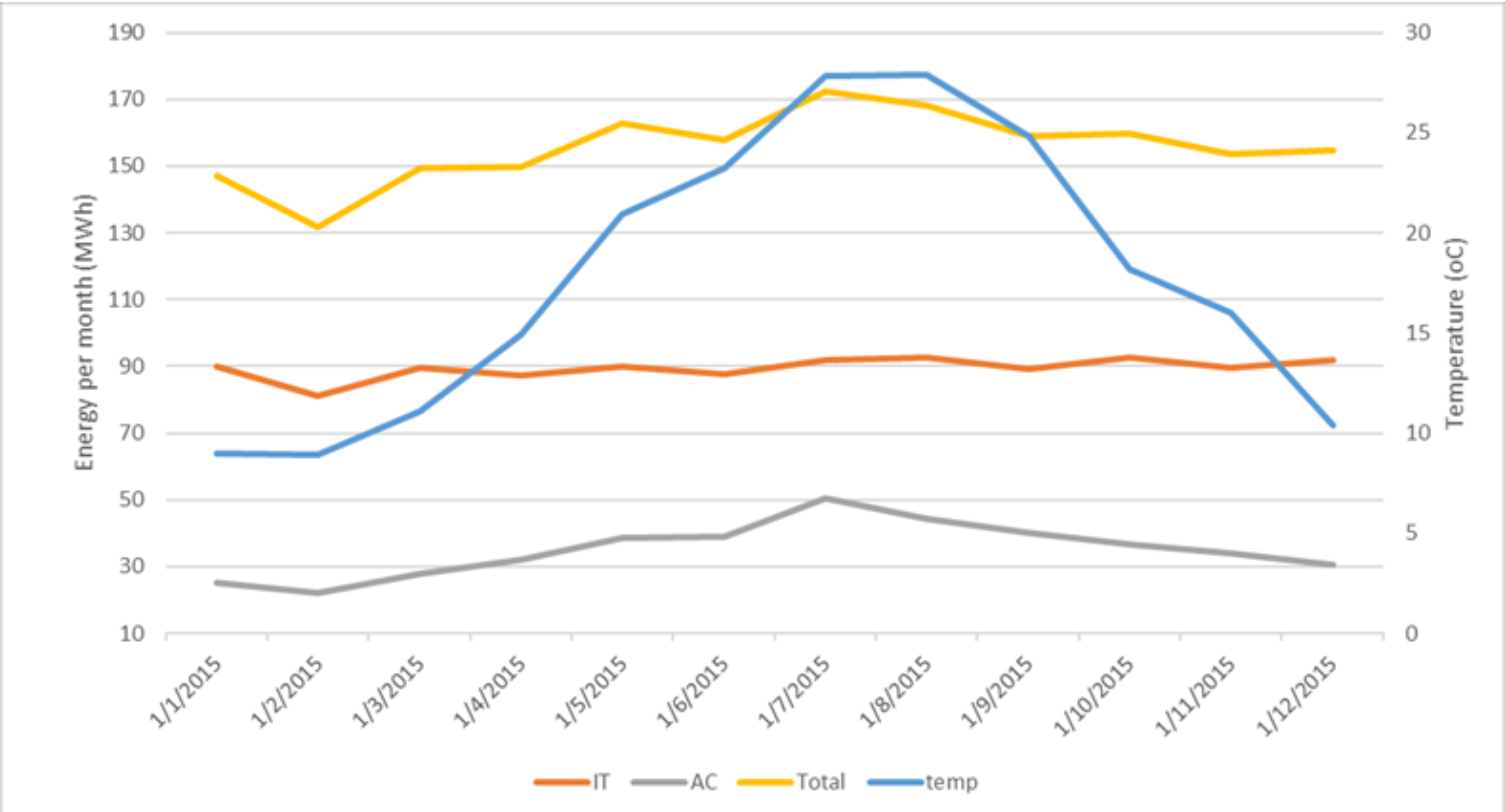
Proposed Data Center baseline model

- $E(MWh) = a_E * T(°C) + b_E * IT(MWh)$, and
- $AC(MWh) = a_{AC} * T(°C) + b_{AC} * IT(MWh)$

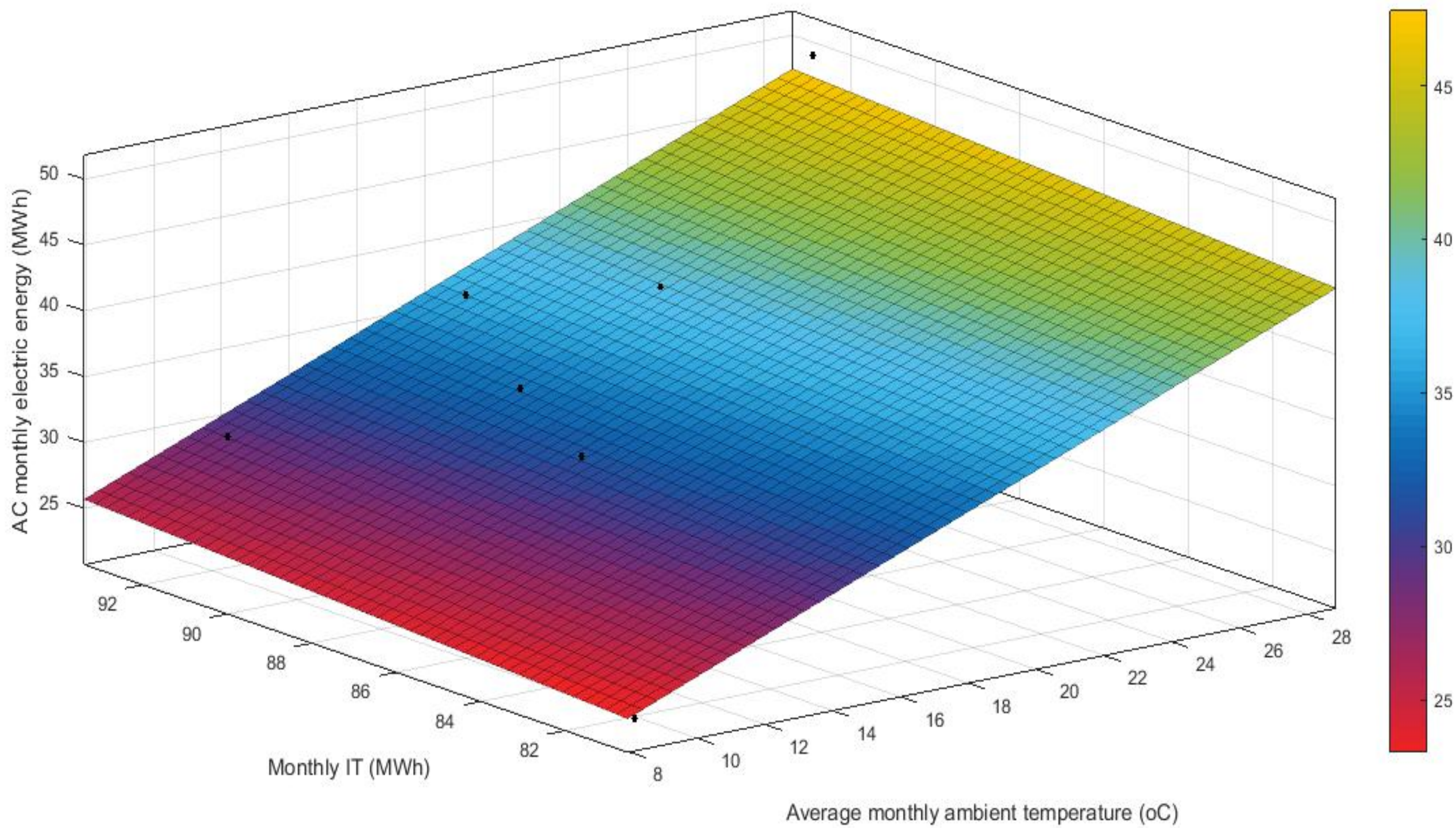
Where

- E is the total monthly electricity consumption
- AC is the total monthly electricity consumption of the entire AC subsystem
- T is the average monthly outdoor air temperature
- IT is the monthly consumption of the IT equipment
- α_E is the temperature slope of E and expresses the additional total energy consumed if the temperature is increased by 1K
- b_E is the IT slope of E and expresses the additional total energy consumed if the IT consumption is increased by 1MWh
- α_{AC} is the temperature slope of AC and expresses the additional AC energy consumed if the temperature is increased by $1K$
- b_{AC} is the IT slope of AC and expresses the additional AC energy consumed if the IT consumption is increased by 1MWh
- $\alpha_E = \alpha_{AC}$

Case study: Data Center of GRNET

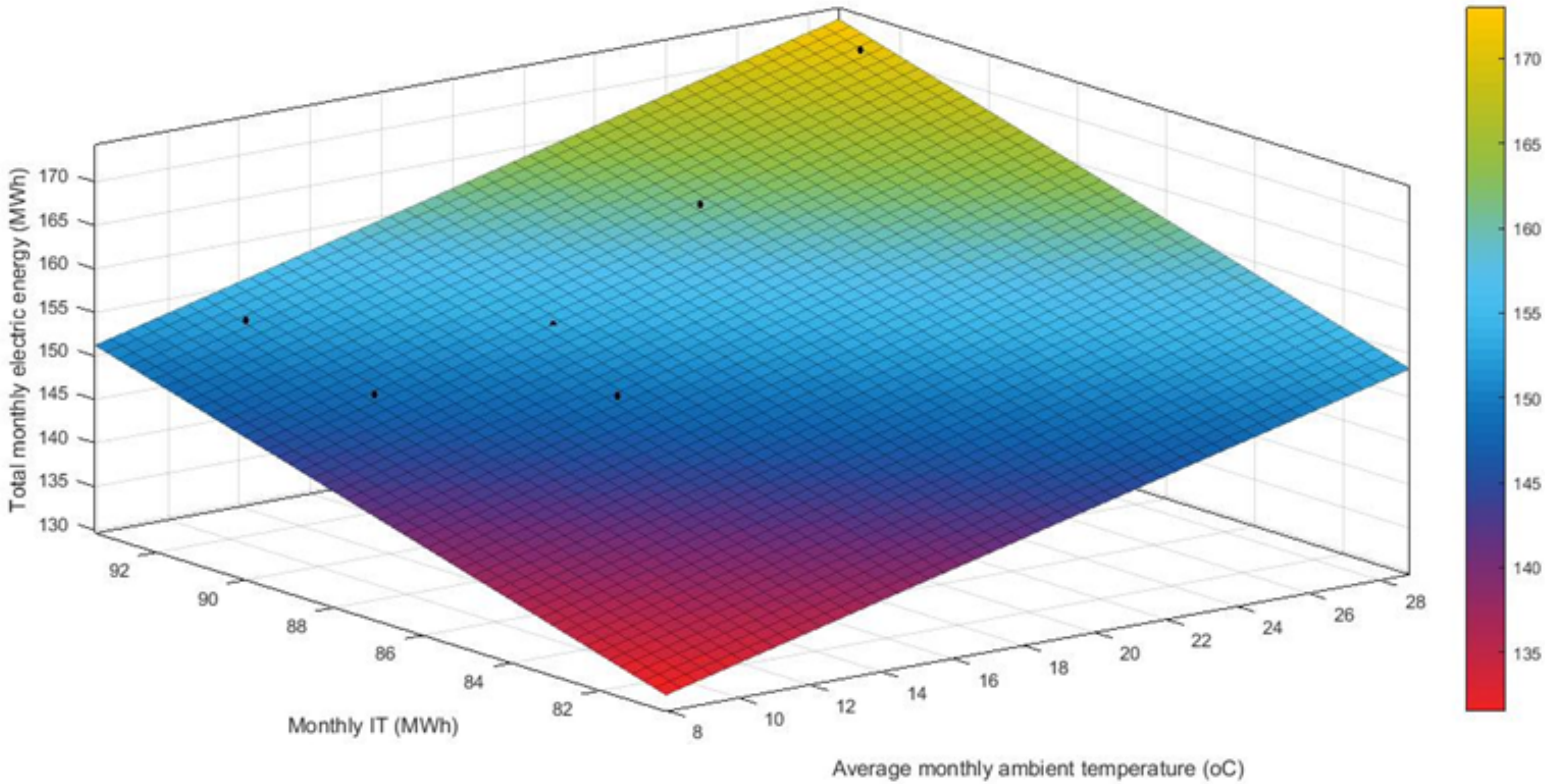


Case Study: AC baseline



α_{AC}=1.041 (MWh/K) b_{AC}=0.1864 R^2 =93.7%

Case Study: Energy baseline



α_E=1.041 (MWh/K) b_E=1.531 R^2 =95.6%

Meaning of the model parameters

- $a_{AC} = a_E \sim \frac{1}{CoP}$ and ~Building Load Coefficient
- $b_{AC} \sim \frac{1}{CoP}$
- $b_E \sim \frac{1}{CoP}$ and ~other electric losses
- If the a.m. parameters are studied over time e.g. moving 12month intervals and under normalized climate and IT conditions their variation can indicate better or worse performance or energy strategy changes, e.g.
  - $a_{AC} \uparrow \Rightarrow$ CoP↓
  - if, in addition, b_E remains approximately the same it is likely that other losses were limited.

Interpretation of the results

- $EUE = \frac{Total\ Facility\ Energy\ (per\ month\ or\ per\ annum)}{IT\ Equipment\ Energy\ (per\ month\ or\ per\ annum)}$
- $EUE_{mean} = 1.737$
- $EUE_{actual} = 1.531\ (b_E = \frac{\partial E}{\partial IT})$
- $EUE_{scalability} = \frac{EUE_{actual}}{EUE_{mean}} (\times 100\%) = 88.14\%$
- α_{AC}=1.041 (MWh/K)=a_E
- b_{AC}=0.1864
- For every additional Watt-hour consumed by IT (incremental consumption)
  - 0.5310 Wh consumed by the entire installation
  - 0.1864 Wh consumed by AC
  - 0.3446 Wh consumed by other loads (distribution, UPS, rectifiers, lighting, fans, etc.)

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