Prédiction du PUE et SPUE d'un petit DC

BEURRIER Julien

25/03/2025

PUE : power unit efficiency
SPUE : Saisonnal PUE
DC : Data Center

Introduction au PUE et SPUE

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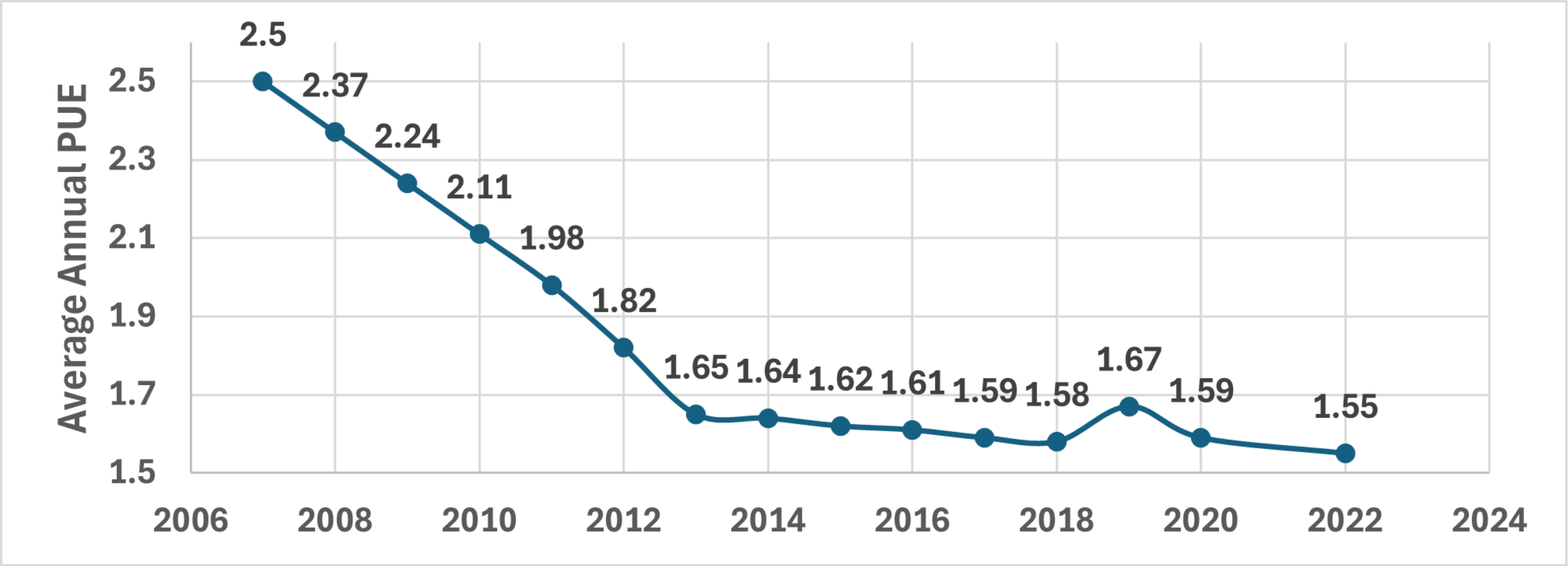
$$\text{PUE} = \frac{E_{\text{total}}}{E_{\text{IT}}} = \int_{t=0}^{T} \frac{P_{\text{total}}(t)dt}{P_{\text{IT}}(t)dt}$$

PUE : power unit efficiency
IT : information technology



[1] "Global trends, performance metrics, and energy reduction measures in datacom facilities," Renewable and Sustainable Energy Reviews, Mar. 2023.

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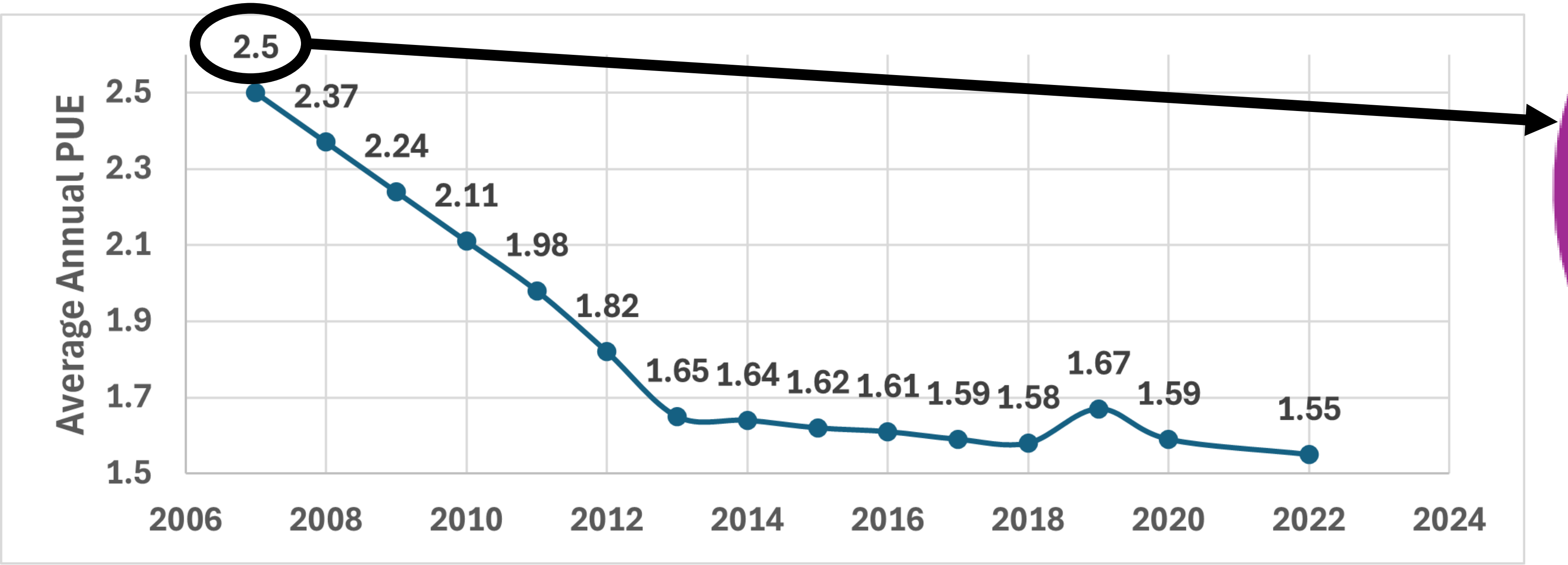

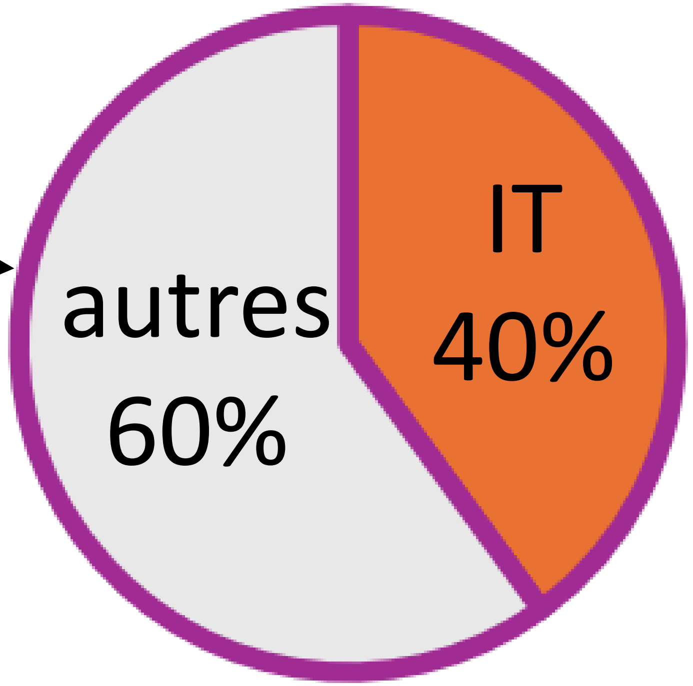

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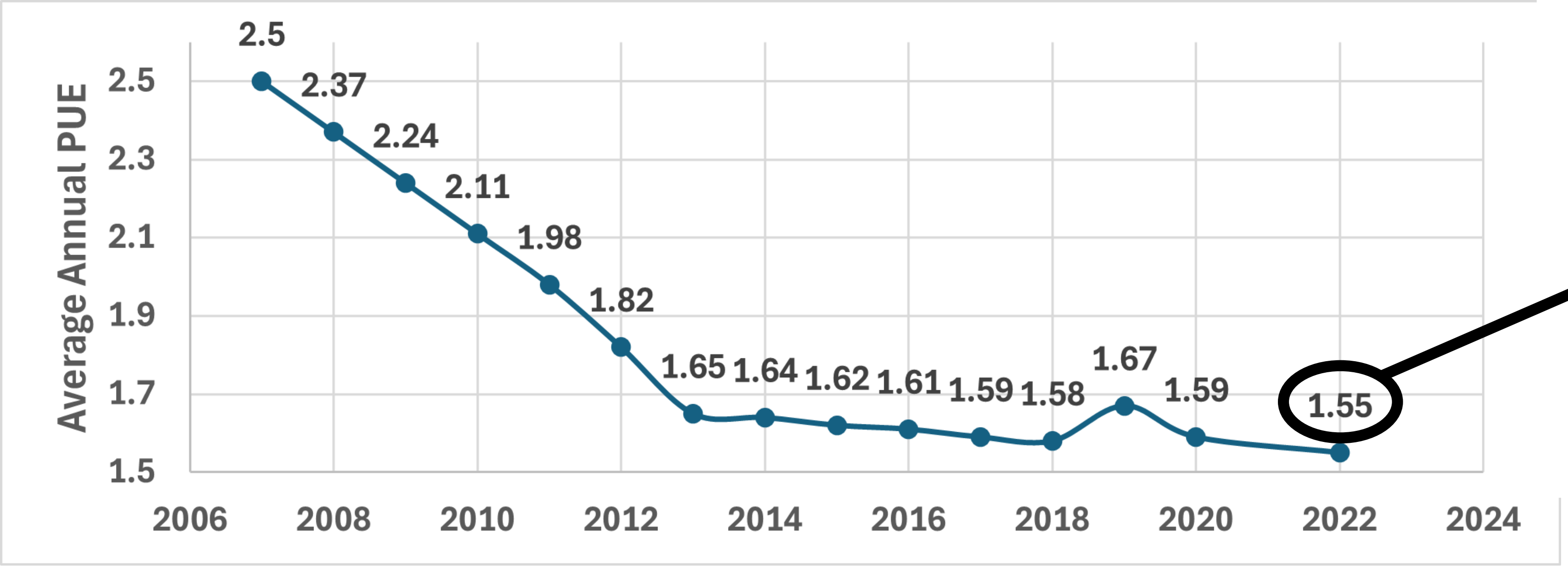

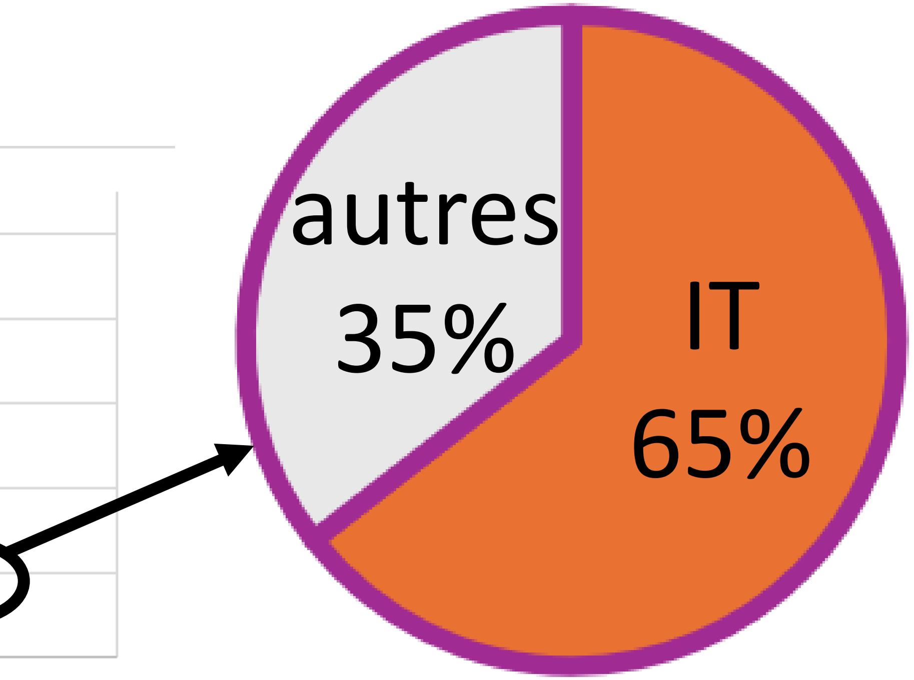

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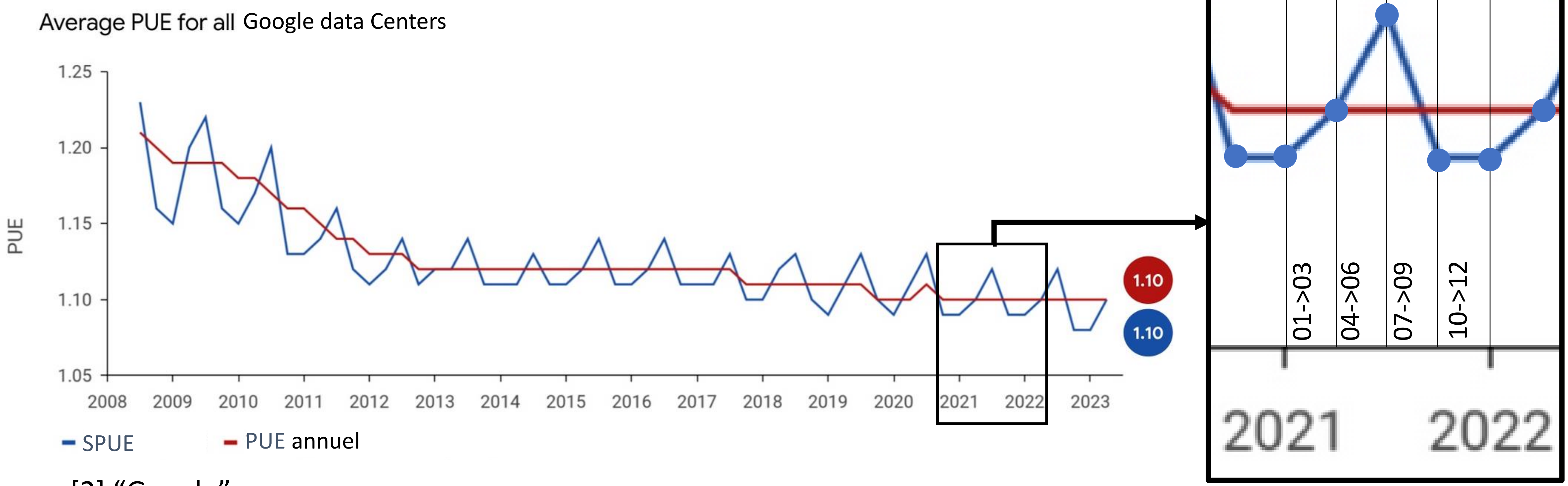
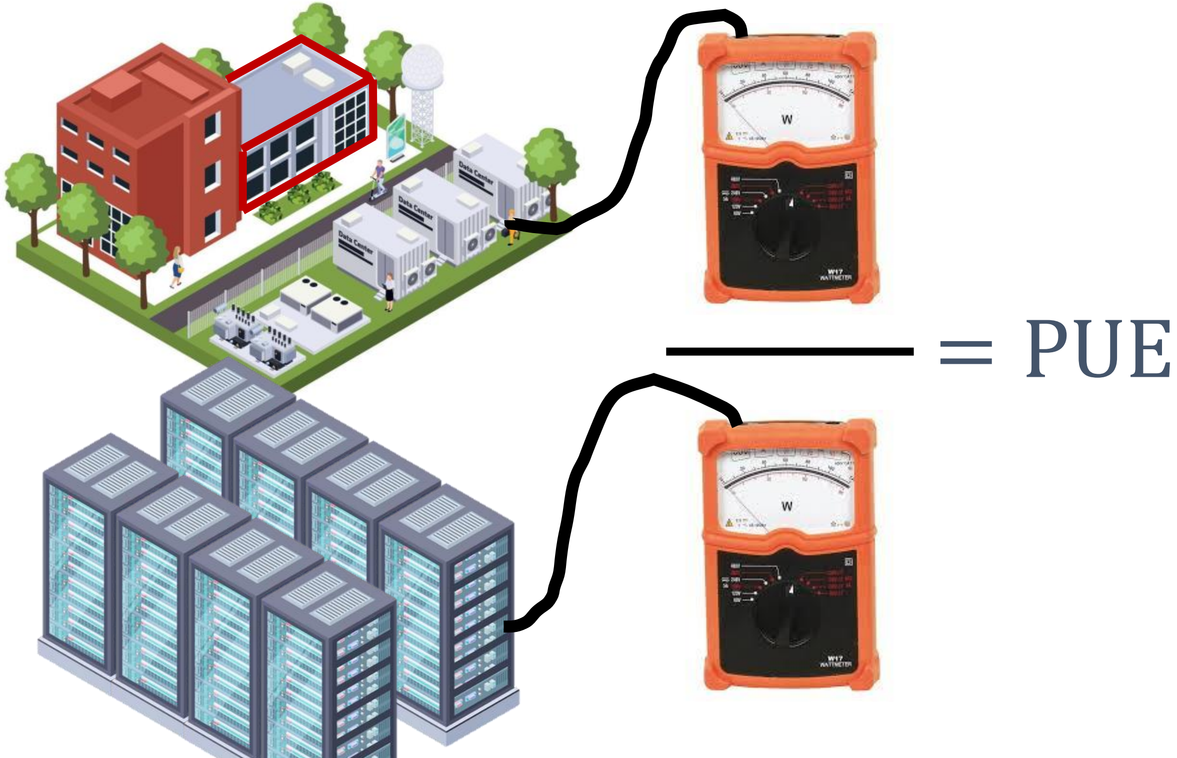
Le **Saisonnal Power Unit Efficiency** est une métrique dérivée du PUE qui évalue l'efficacité énergétique d'un centre de données sur des périodes saisonnières ou plus courte.



[2] “Google” https://datacenters.google/efficiency/

Le PUE est facilement mesurable après la mise en service d’un Centre de Données, mais il est difficilement estimable en amont de la construction.

Mesure :



Prédiction :

[3] N. Lei and E. Masanet,
“Climate- and technology-specific PUE and WUE estimations for U.S. data centers using a hybrid statistical and thermodynamics-based approach,”
Resources, Conservation and Recycling, 2022

[4] “Schneider electrique”
https://www.se.com/ww/en/work/solutions/system/s1/data-center-and-network-systems/trade-off-tools/data-center-efficiency-and-pue-calculator/

[5] Berkeley National Laboratory, PUE Estimator, Jun. 2016.
https://datacenters.lbl.gov/sites/default/files/PUEEstimatorManual_06022016.pdf

Présentation de la méthode de calcul

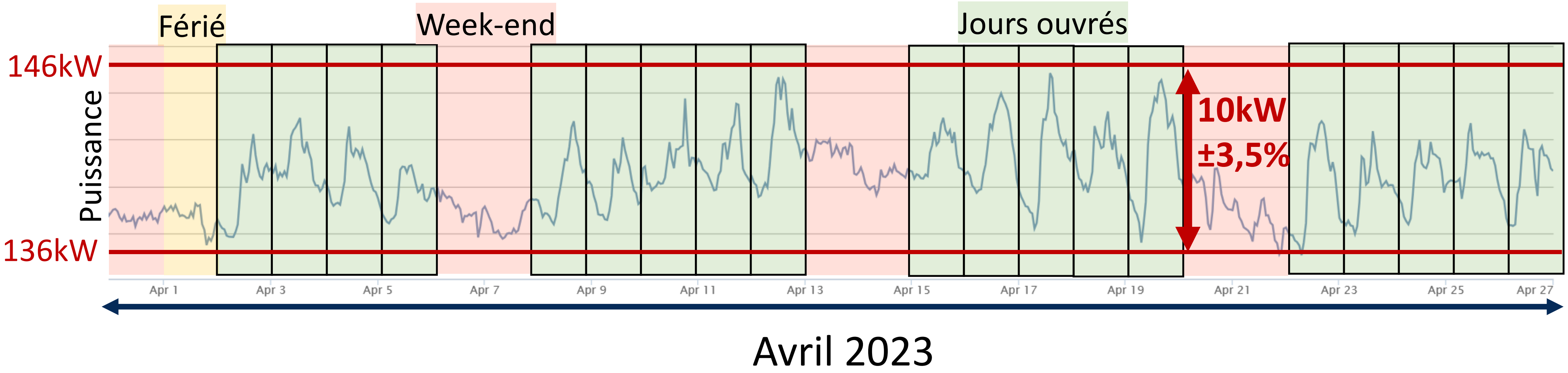
$$\mathrm{PUE} = \int_{t=0}^{T} \frac{P_{\mathrm{total}}(t)dt}{P_{\mathrm{IT}}(t)dt}$$

$$P_{\mathrm{total}} = P_{\mathrm{IT}} + P_{\mathrm{cooling}} + P_{\mathrm{loss}}$$

Présentation de la méthode de calcul

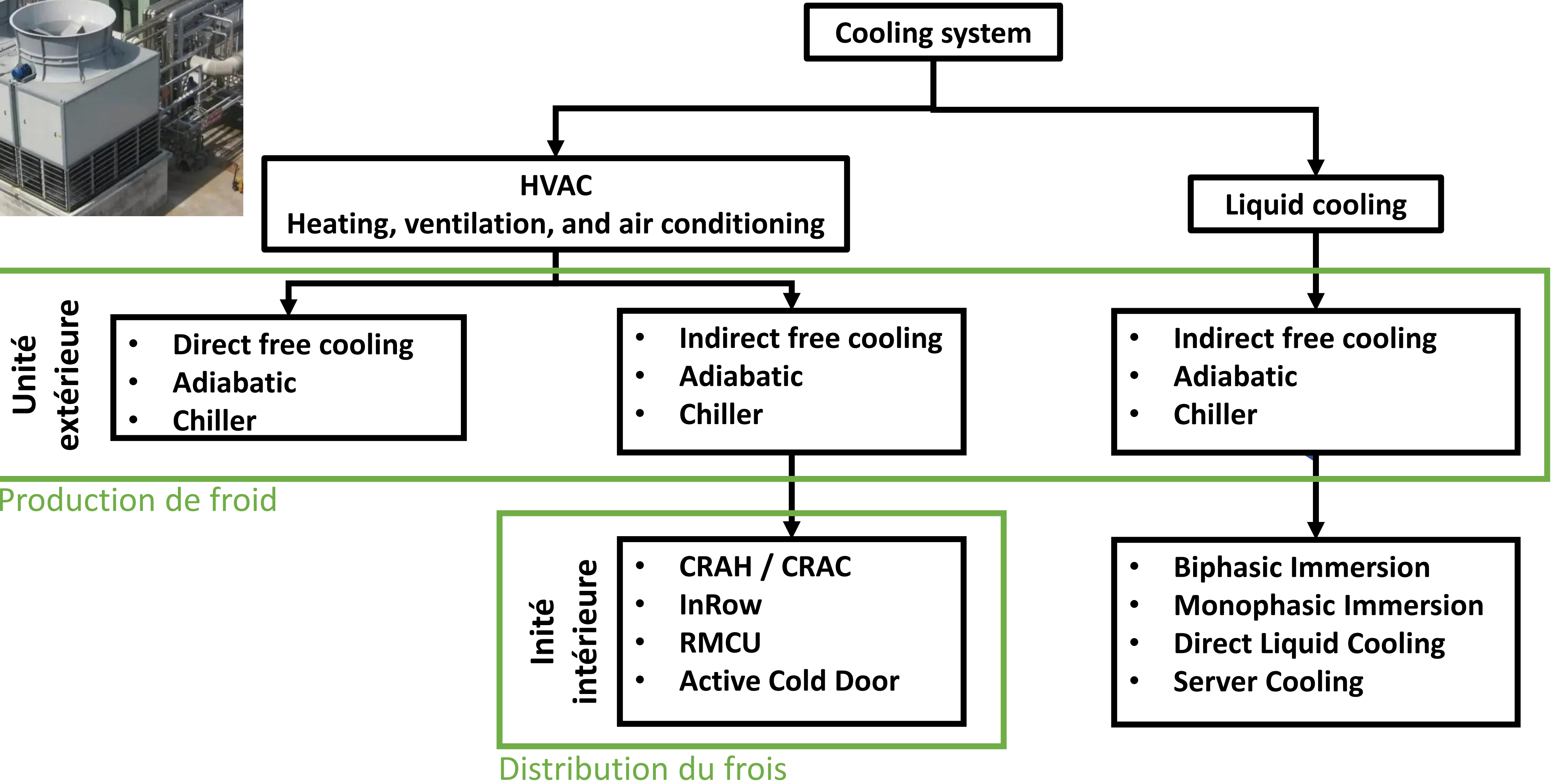
P_{IT}

HPC : High Performance Computing



- Notre étude montre que la variation de consommation électrique est causée la partie HPC
- La variation est négligeable pour estimer le PUE et le SPUE

$P_{cooling}$

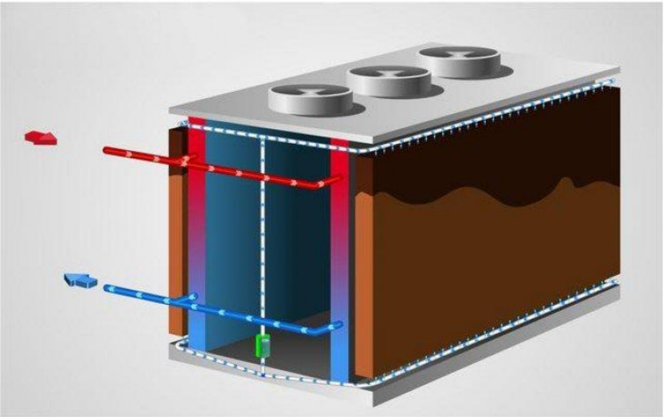

Cooling system
HVAC
Heating, ventilation, and air conditioning
Liquid cooling
Unité extérieure
Direct free cooling
Adiabatic
Chiller
Indirect free cooling
Adiabatic
Chiller
Indirect free cooling
Adiabatic
Chiller
Production de froid
Inité intérieure
CRAH / CRAC
InRow
RMCU
Active Cold Door
Biphasic Immersion
Monophasic Immersion
Direct Liquid Cooling
Server Cooling
Distribution du frois

$P_{cooling}$

EER : Energy Efficiency Ratio
COP : Coefficient Of Performance

Système de refroidissement, unité extérieure :

Adiabatique



Chiller

$$P_{cooling} = \frac{P_{dissipation}}{EER} + P_{auxi} = \frac{P_{IT} + P_{loss}}{EER} + P_{auxi}$$

EER ≡ COP froid

Norme **NF EN 14511-1** impose les constructeurs.
Condition de test pour le calcul de l'EER :

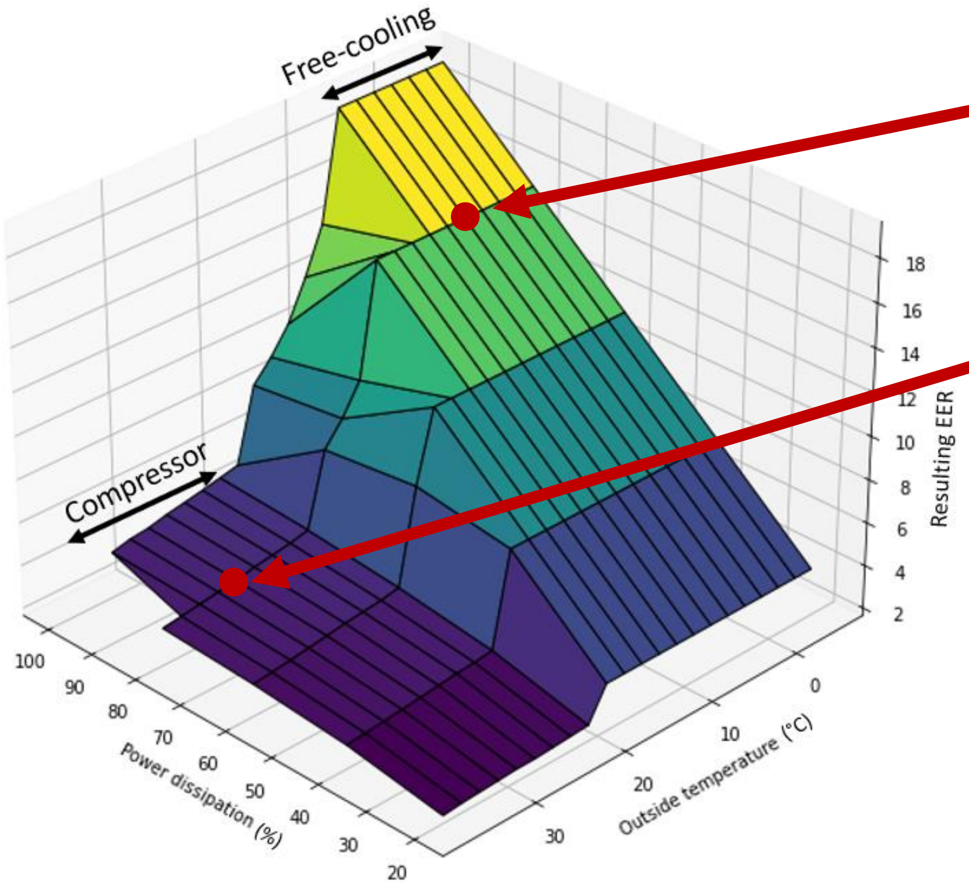
- Température extérieure : 35°C
- Température intérieure : 27°C
- Pour une puissance spécifique

EER => dépendant de la température => dépendant du temps

P_{cooling}

Matrice EER :

Donnée constructeur :

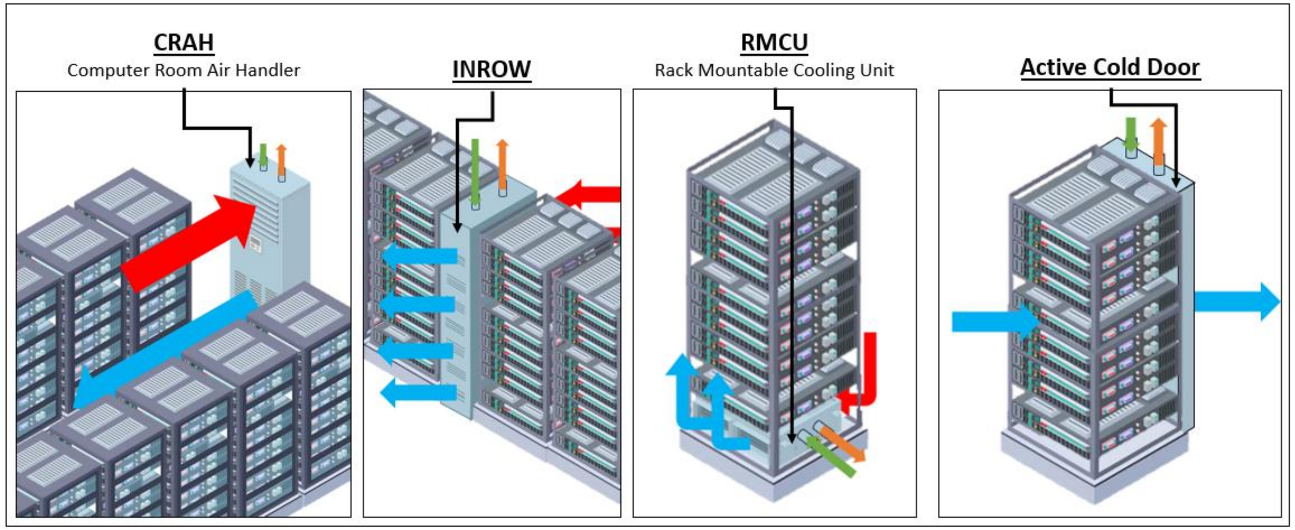


Température extérieure : 5°C
Puissance système : 80%
= EER : 16

Température extérieure : 28°C
Puissance système : 80%
= EER : 4

P_{cooling}

Système de refroidissement, unité intérieure :



$$P_{\text{cooling}} = \frac{P_{\text{IT}} + P_{\text{loss}}}{\text{EER}} + P_{\text{auxi}}$$

$$P_{\text{auxi}} = P_{\text{maxi}} \times \left(\frac{\rho_{\text{air}} \times \Delta_T \times C_{\text{air}}}{Q_{\text{air maxi}} \times P_{IT}}\right)^3 + P_{\text{corr}}$$

P_{maxi} : Consommation maximal de l'unité intérieur
ρ_{air} : 1,292 kg/m3
C_{air} : 1 005 J/K/kg3
Δ_T : Différence de température
$Q_{\text{air maxi}}$: Débit maximal
P_{corr} : Consommation passive

P_{loss}

PDU : Power Distribution Unit.
UPS : Uninterruptible Power Supply.
LV : general Low Voltage panel.

P_{loss} est dépendant de :

Rendement des PDU en fonction de la puissance IT

Mais aussi de des pertes de charge électrique, le rendement de l'UPS et du LV

PDU : η≈99.5%

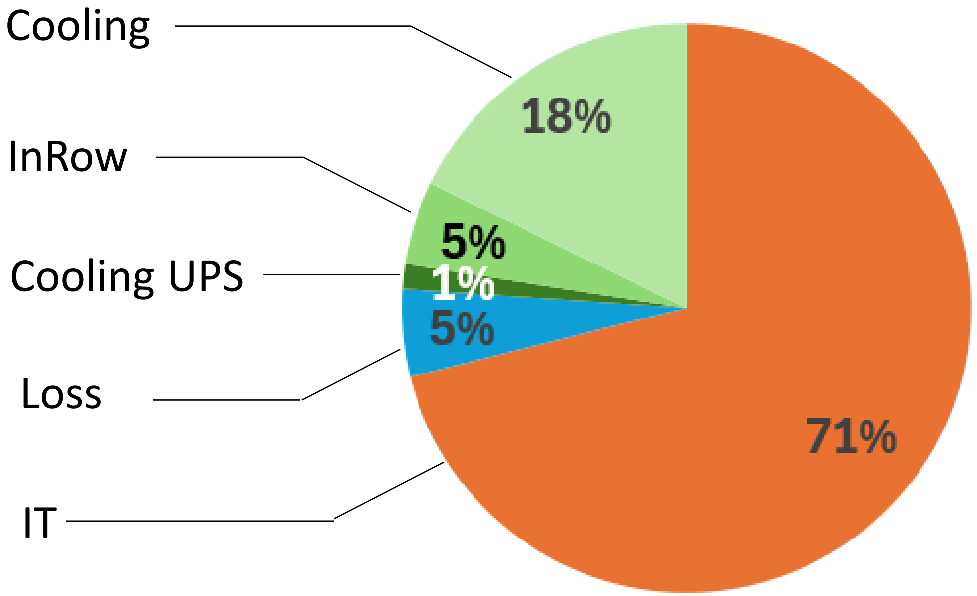
UPS : η≈97%

LV : η≈99%

Estimation du PUE et SPUE

Estimation du PUE et SPUE

$$\text{PUE mesuré} = \frac{1{,}79\ \text{GWh}}{1{,}26\ \text{GWh}} = 1{,}45$$

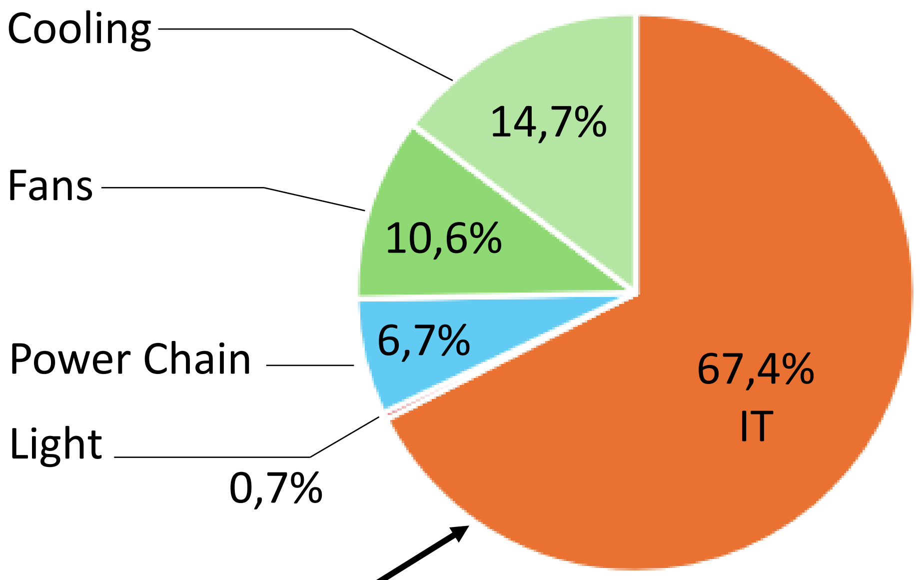


Estimation du PUE à 1,42

Comparaison de notre méthode avec la littérature :

[3] N. Lei and E. Masanet,
=> PUE estimé entre 1,6 et 2,1

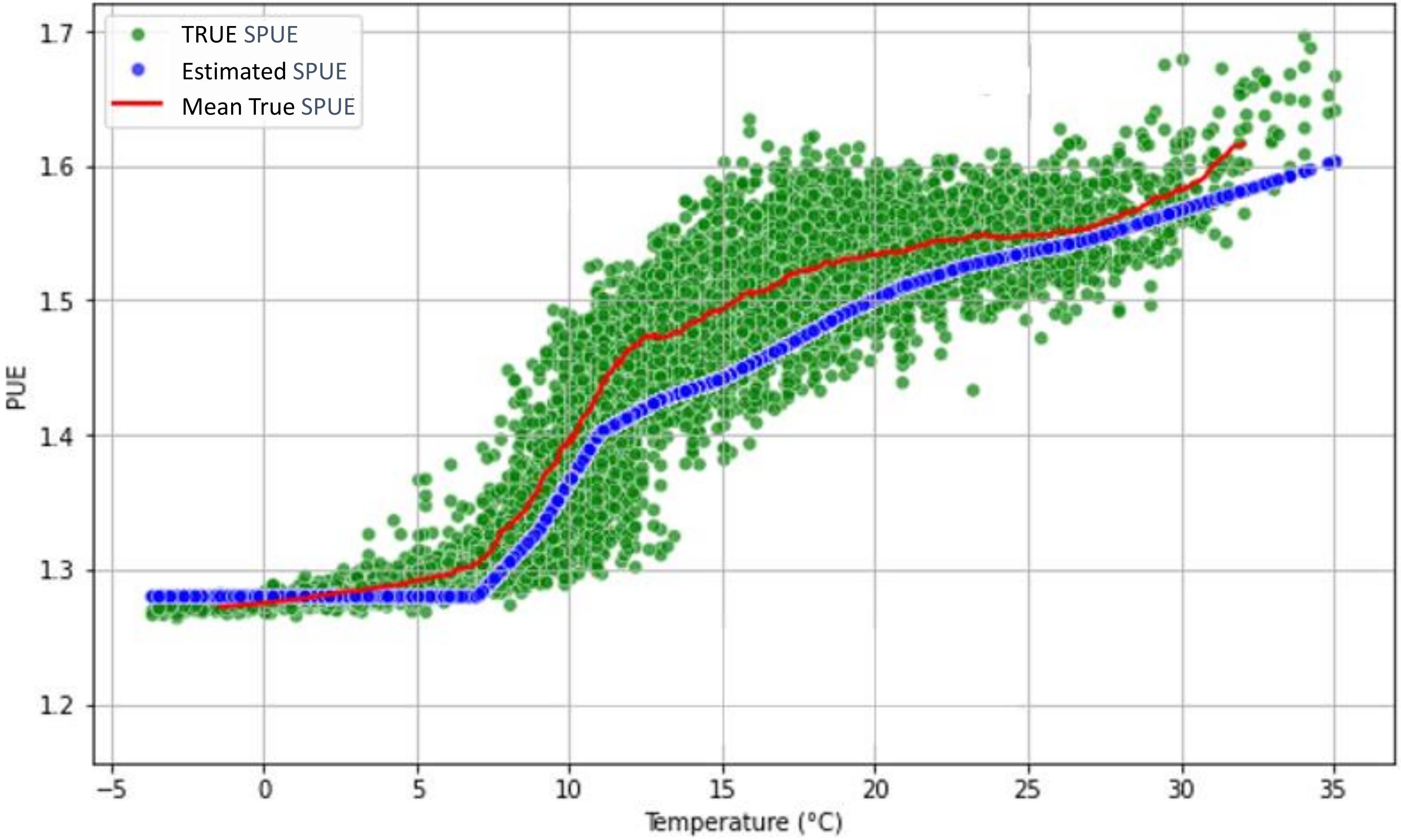
[4] “Schneider electrique”
=> PUE estimé entre 1,93 et 2,68



[5] Berkeley National Laboratory, PUE Estimator, Jun. 2016.
=> PUE estimé à 1,49

Estimation du PUE et SPUE

Pour l'année 2023



Conclusion

Pour une bonne estimation du PUE :

- Le temps c'est important ;
- Les constructeurs sont fiables (grâce au normes) ;
- Une bonne estimation de l'IT est importante.

Bibliographie

[1] “Global trends, performance metrics, and energy reduction measures in datacom facilities,” Renewable and Sustainable Energy Reviews, Mar. 2023.

[2] “Google”
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[3] N. Lei and E. Masanet,
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[5] Berkeley National Laboratory, PUE Estimator, Jun. 2016.
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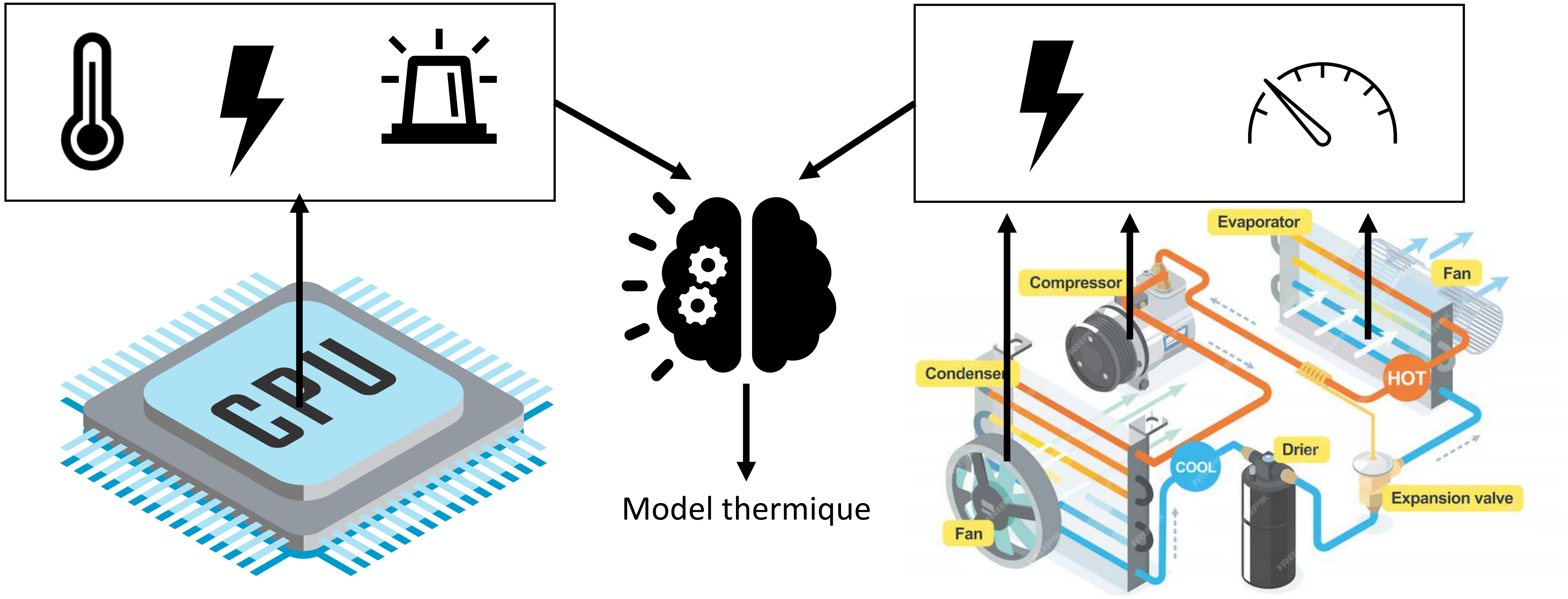
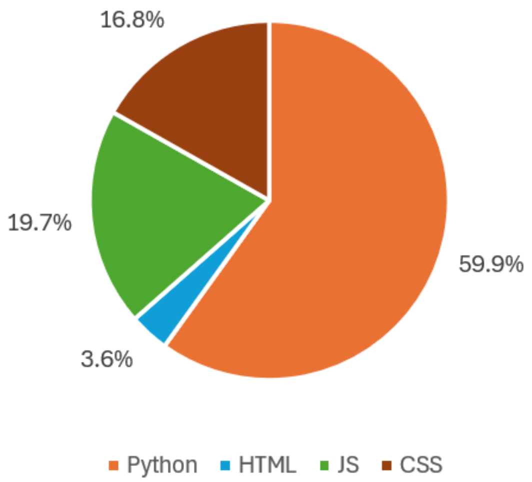
Perspective de ma thèse

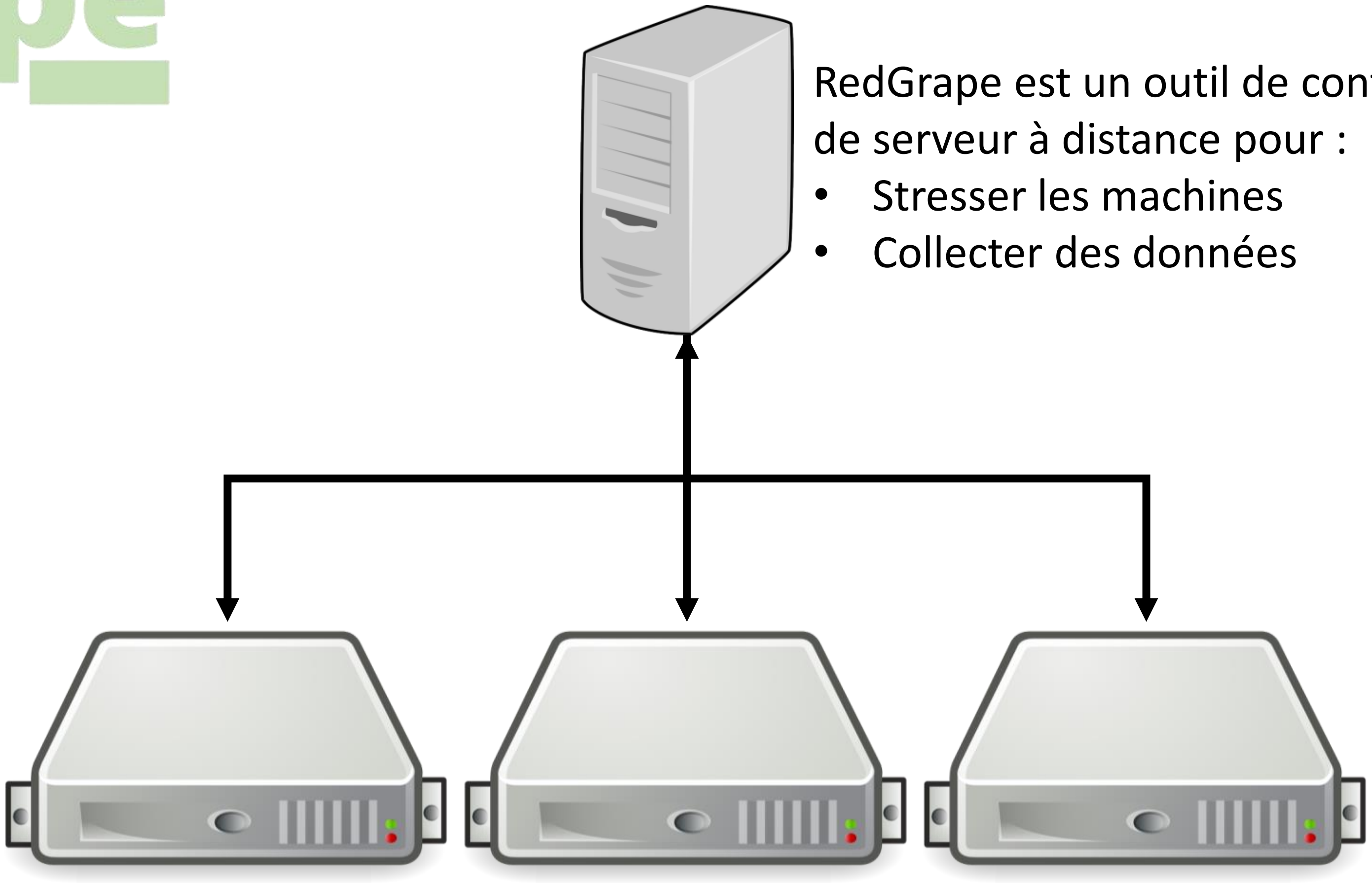
Model IA : CPU ⇔ climatisation :



Perspective de ma thèse

RedGrape





RedGrape est un outil de contrôle de serveur à distance pour :

- Stresser les machines
- Collecter des données

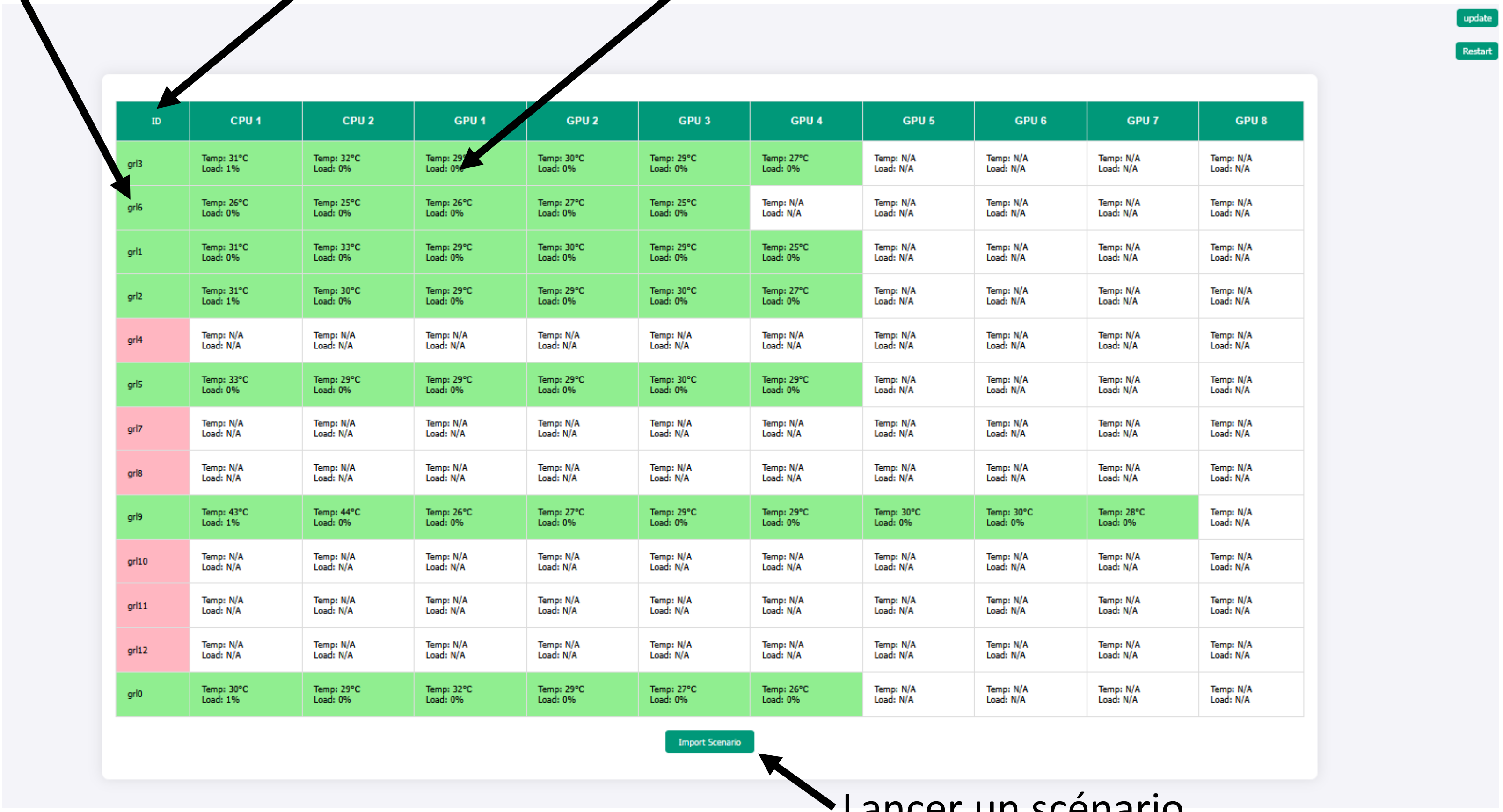
Perspective de ma thèse

Interface graphique du master : RedGrape

ID Serveur

Etat Serveur

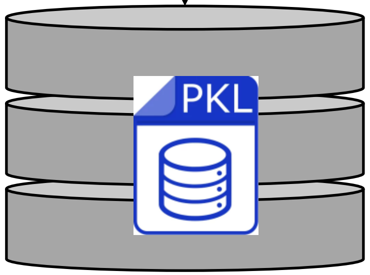
Température et Load composant
+ bouton pour exciter le composant



ID	CPU 1	CPU 2	GPU 1	GPU 2	GPU 3	GPU 4	GPU 5	GPU 6	GPU 7	GPU 8
grl3	Temp: 31°C Load: 1%	Temp: 32°C Load: 0%	Temp: 29°C Load: 0%	Temp: 30°C Load: 0%	Temp: 29°C Load: 0%	Temp: 27°C Load: 0%	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl6	Temp: 26°C Load: 0%	Temp: 25°C Load: 0%	Temp: 26°C Load: 0%	Temp: 27°C Load: 0%	Temp: 25°C Load: 0%	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl1	Temp: 31°C Load: 0%	Temp: 33°C Load: 0%	Temp: 29°C Load: 0%	Temp: 30°C Load: 0%	Temp: 29°C Load: 0%	Temp: 25°C Load: 0%	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl2	Temp: 31°C Load: 1%	Temp: 30°C Load: 0%	Temp: 29°C Load: 0%	Temp: 29°C Load: 0%	Temp: 30°C Load: 0%	Temp: 27°C Load: 0%	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl4	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl5	Temp: 33°C Load: 0%	Temp: 29°C Load: 0%	Temp: 29°C Load: 0%	Temp: 29°C Load: 0%	Temp: 30°C Load: 0%	Temp: 29°C Load: 0%	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl7	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl8	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl9	Temp: 43°C Load: 1%	Temp: 44°C Load: 0%	Temp: 26°C Load: 0%	Temp: 27°C Load: 0%	Temp: 29°C Load: 0%	Temp: 29°C Load: 0%	Temp: 30°C Load: 0%	Temp: 30°C Load: 0%	Temp: 28°C Load: 0%	Temp: N/A Load: N/A
grl10	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl11	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl12	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A
grl0	Temp: 30°C Load: 1%	Temp: 29°C Load: 0%	Temp: 32°C Load: 0%	Temp: 29°C Load: 0%	Temp: 27°C Load: 0%	Temp: 26°C Load: 0%	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A	Temp: N/A Load: N/A

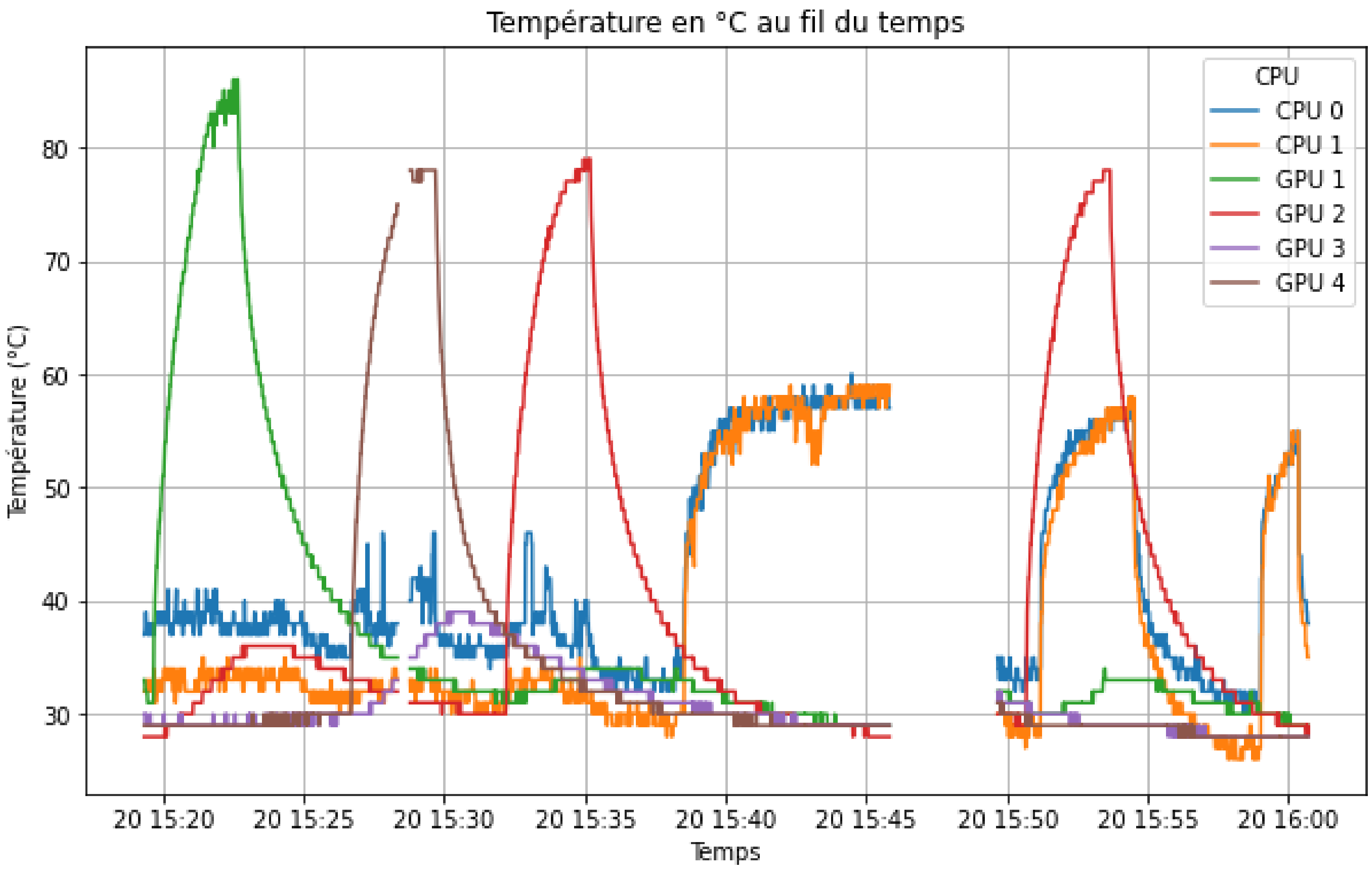
Lancer un scénario

Slave

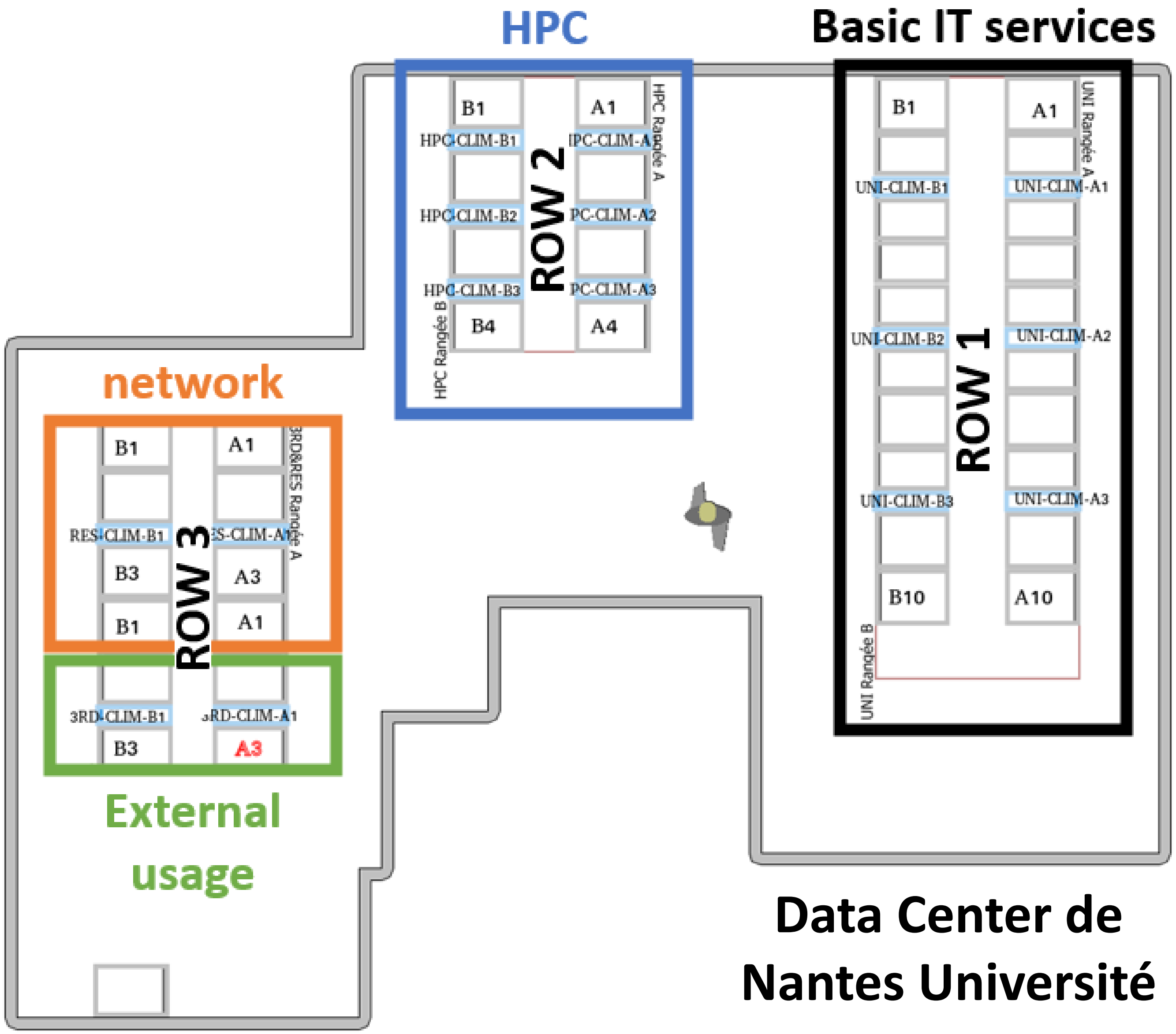


Base de données collecté complète.

Perspective de ma thèse

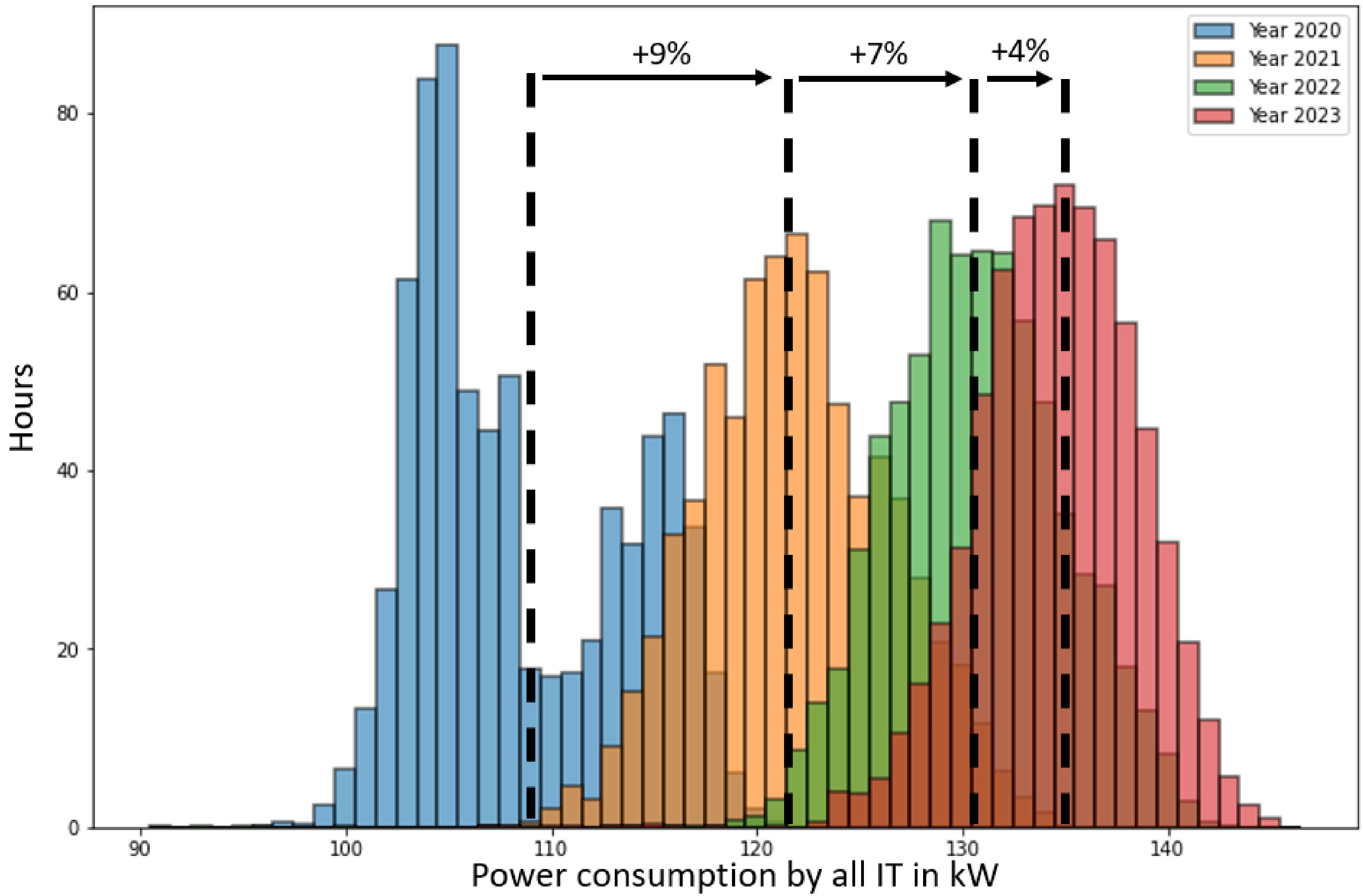


Annexe



Data Center de Nantes Université

Annexe



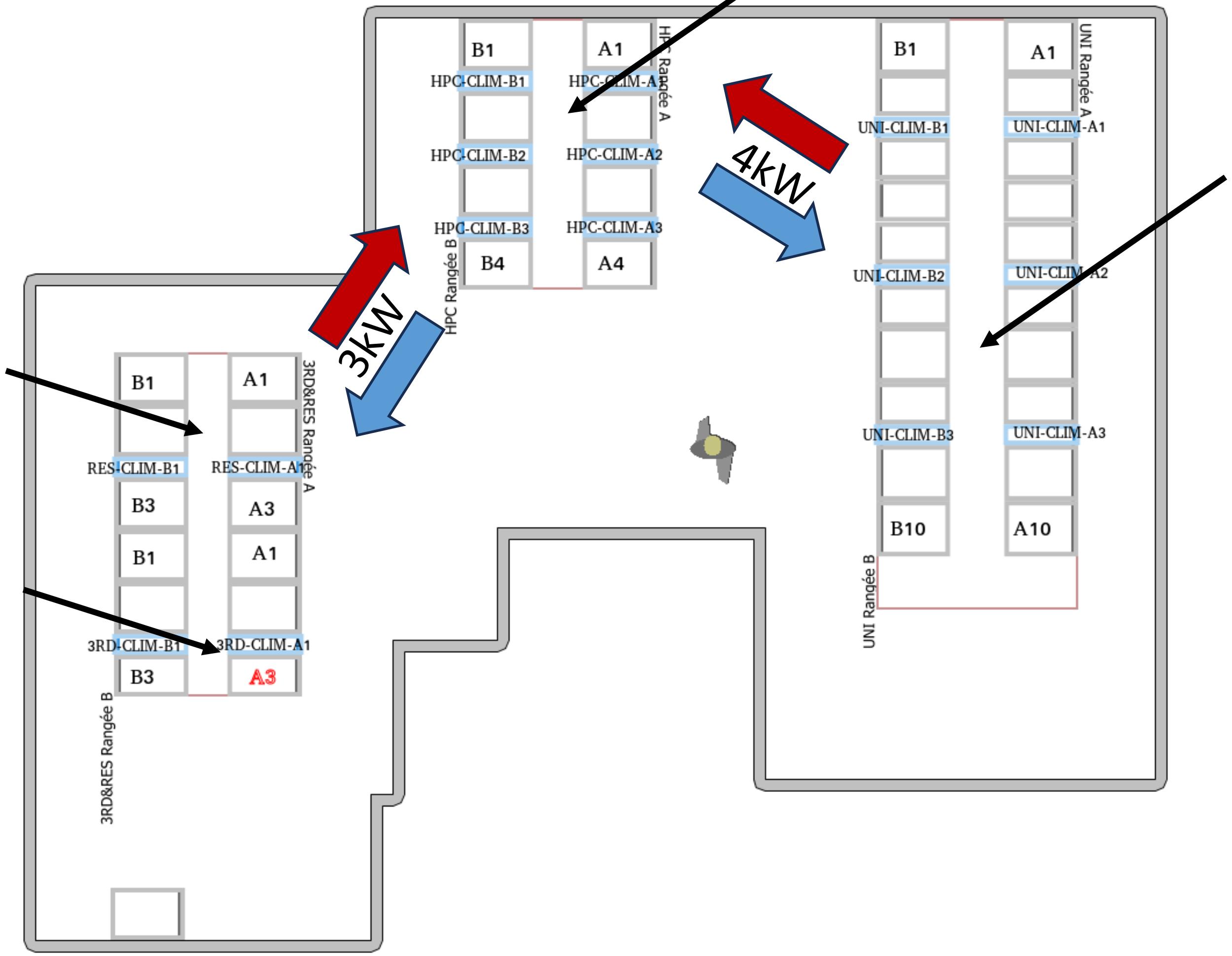
+9%
+7%
+4%
Year 2020
Year 2021
Year 2022
Year 2023
Hours
0
20
40
60
80
90
100
110
120
130
140
Power consumption by all IT in kW

Annexe

Puissance IT : 66kW
Puissance froide : 73kW

Puissance IT : 9kW
Puissance froide : 6kW

Puissance IT : 9kW
Puissance froide : 9kW



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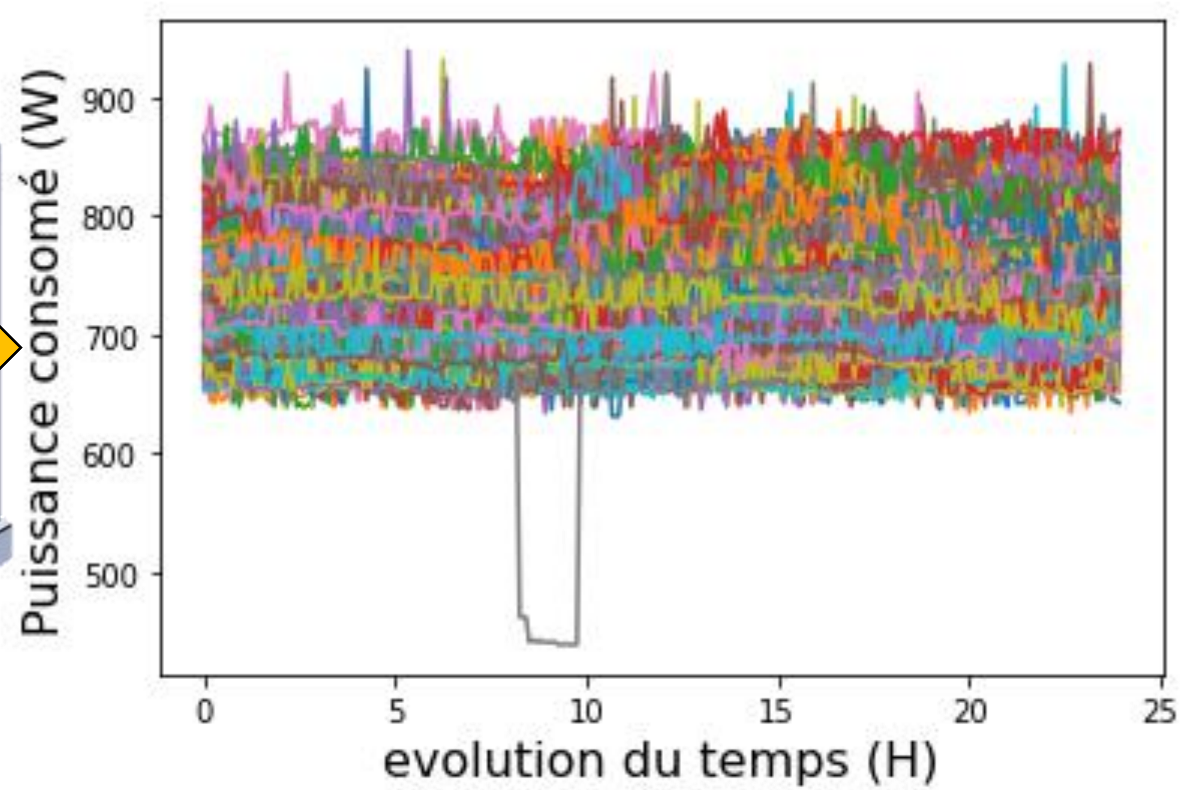
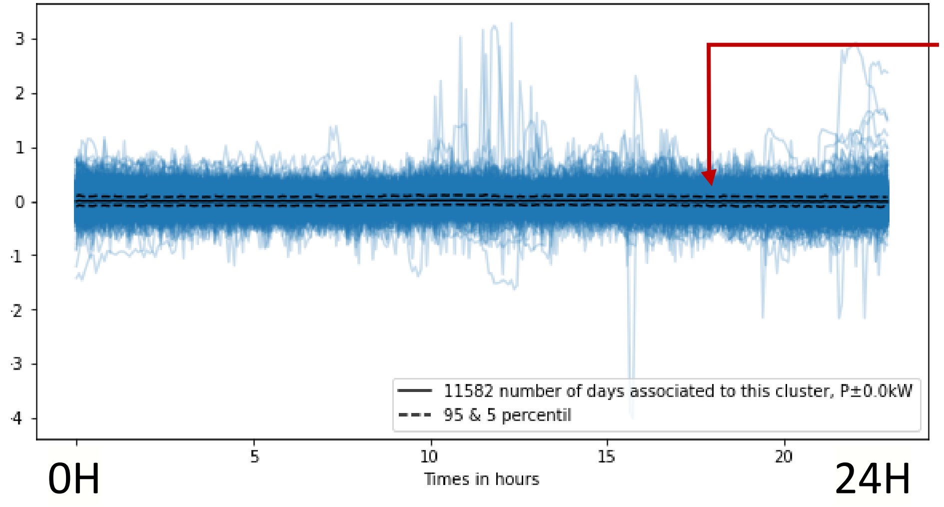


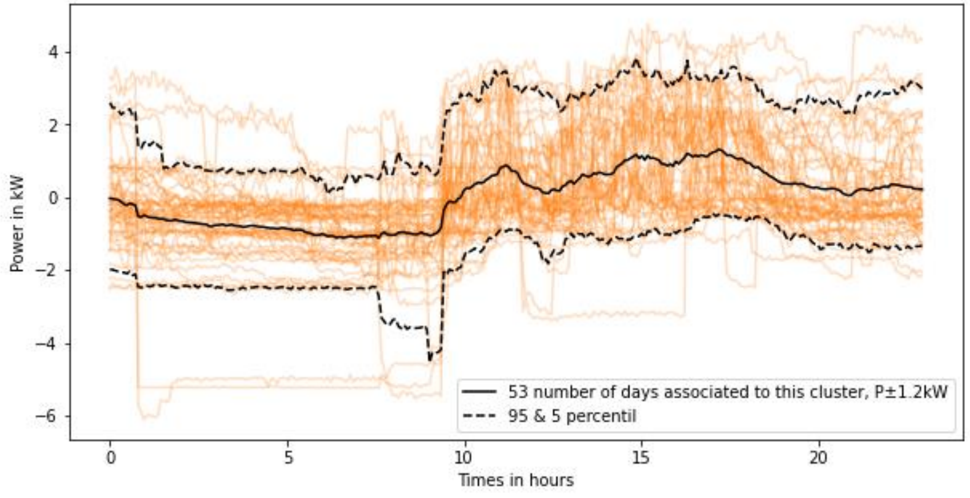
Le graphique contient 365 courbes.
Chaque courbe correspond à la consommation électrique des serveurs dans la baie pendant 24H.

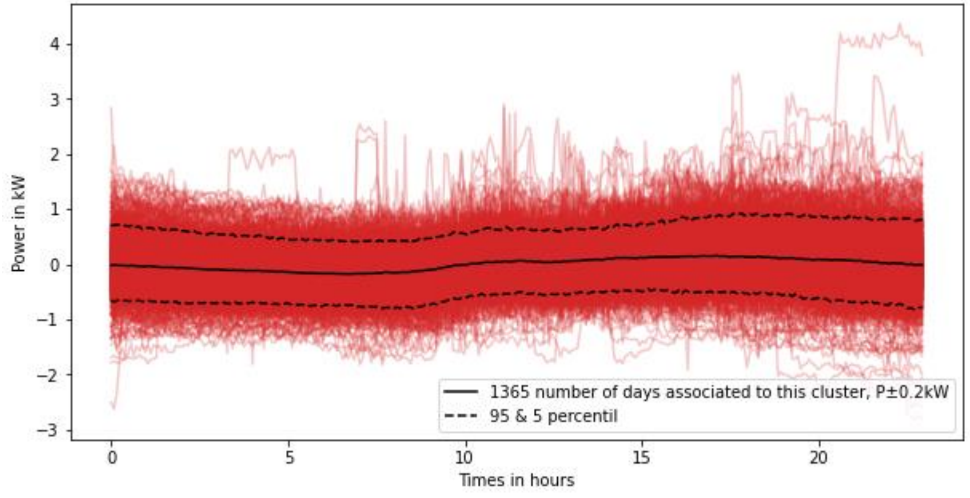
Annexe

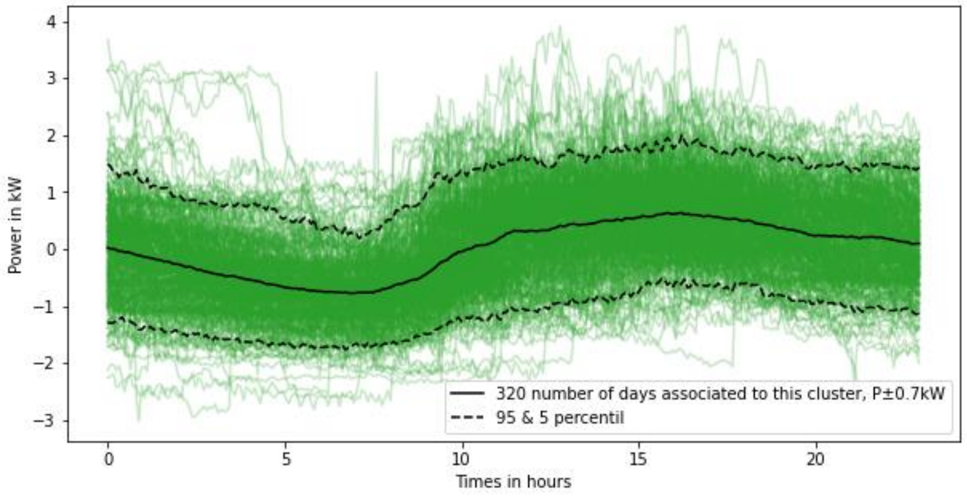
Puissance en kW
Autour de la valeur moyenne



Moyenne
&
Écart 5% et 95%







Annexe

Répartition pour chaque baie pour
4 clusters différents :