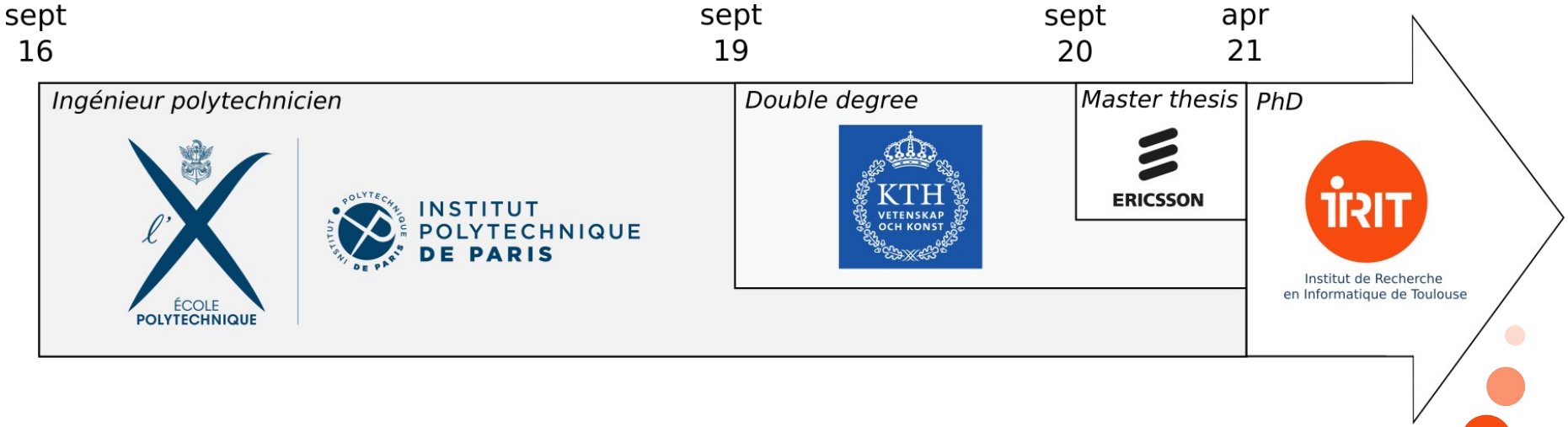
CNRS - INP - UT3 - UT1 - UT2J

Institut de Recherche en Informatique de Toulouse

From the embodied emissions of radio base stations to involving the user in environmental-aware clouds

About me

- **Now: PhD thesis at SEPIA team IRIT (Toulouse)**
  - Supervisors: Georges DA COSTA and Jean-Marc PIERSON

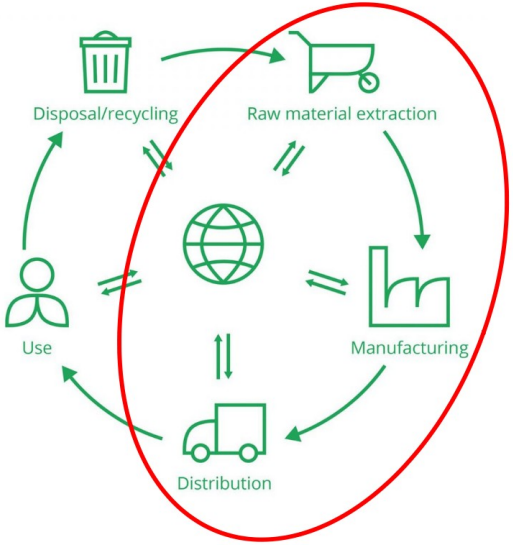


Part1: Master’s thesis

Parameterized Embodied Emissions Calculator (**PEEC**) for telecommunication networks equipment

Topic

- **Base station = 1G / 2G / 3G / 4G / 5G**



Embodied emissions
= ”cradle-to-gate” emissions

Results: **PEEC**, a streamlined tool

- **Simplified LCA, to be used by different users**

PEEC - Parameterized Embodied Emission Calculator for telecom network equipment

Total embodied emissions: **1175 kg CO2eq**

Module assessed: Indoor cabinet RBS 6201

Instructions
Enter the informations about the module assessed in the "Hardware specs" box. Emission factors for the different life cycle process units can be selected from a drop-down menu. A custom value is selected by default and can be tuned in the other tabs of this workbook. Refer to the manual for more instructions.

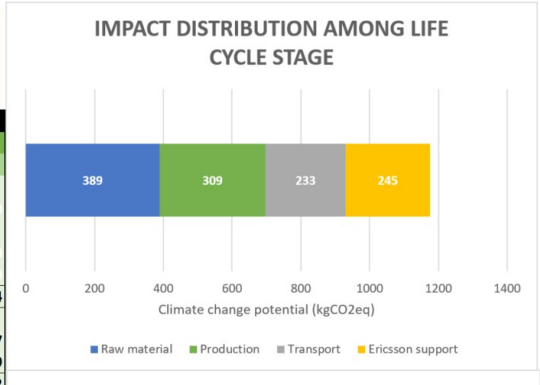
Disclaimer
The results given by this tool are only estimations of the carbon footprint of the module. They should not be used for comparison with other LCA unless all assumptions and modelling choices are equal.

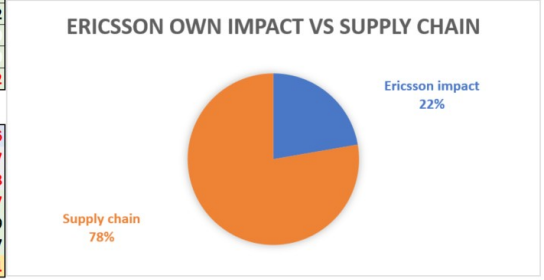
INPUTS Hardware specs	quantity	unit
Electronics		kg
PWB area		m2
PWB layers		#
IC area		cm2
Standard comp		kg
Electromech	2,61	kg
Mechanical parts	80,20	kg
Die casted Alu	1,72	kg
Other mech	78,48	kg
Cable sets	5,40	kg
On-board power		kg
On-board battery		kg
TOTAL	**88,21**	**kg**
(with packaging)	101,44	kg

Estimated carbon footprint (kgCO2eq)	Raw materials			Production		
	Emission factor		Result	Emission factor		Result
System	34,15		0,00			
				PCB combaseB	27,70	0,00
					1,72	0,00
				Standard comp	32,00	0,00
Fan 6201	12,28		32,05	Fan unit	9,25	24,14
Cabinet 6201	3,46		277,79			
				Die casting	13,53	23,27
				Other mechanics	2,02	158,29
Power cable	7,21		38,92	Cables	0,84	4,52
NA	0,00		0,00	NA	0,00	0,00
NA	0,0		0,00	NA	0,00	0,00
			348,76			210,22

Special highlights		
Trspt to customer		
Sea	3500	km
Air	2500	km
Road	1000	km
Train		km
Alu impact factor	*defined at*	
Gold impact factor	*product level*	

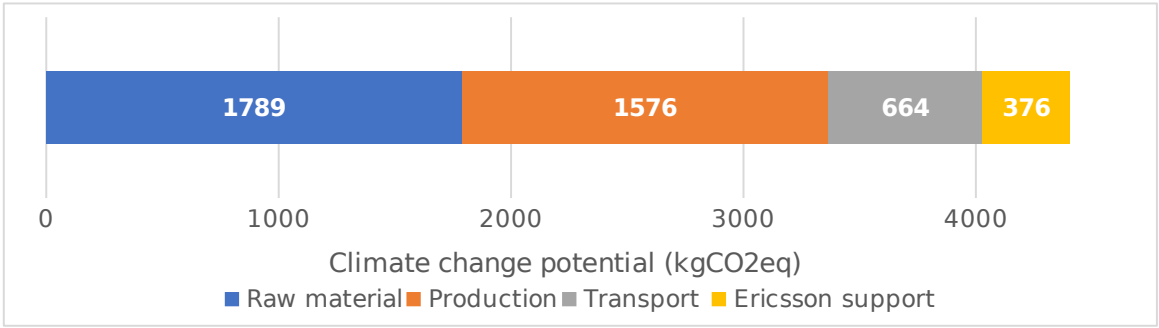
Packaging		1,51	39,96
Transport suppliers to assembly	Distance mtd	NA	33,77
Transport to customer	Avg 2014	1,96	198,78
Assembly	2014	0,97	98,37
Ericsson factories		0,16	16,39
Outsourced factories		0,81	81,97
Ericsson support activities	2014	2,42	245,41





Results: case study 4G base station

= 4,4 tCO_2eq =



- **(embodied = 10-15% emissions over the full life cycle of a BS)**
- **5G: coming soon...**

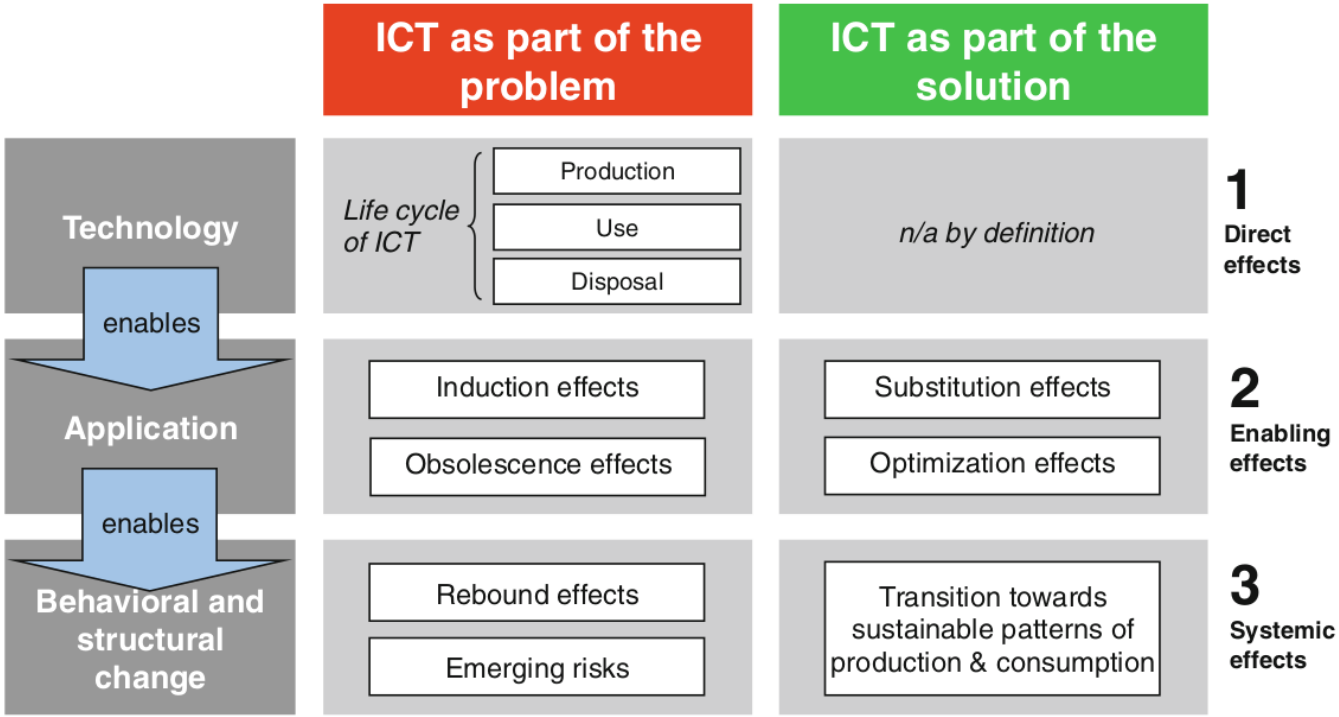
Main takeaway of my Master's thesis

- **Significant uncertainties = challenge in life cycle assessment**
  - No data to test against, instead:
    - Comparison with literature / standards
    - Transparently reported method
    - Systematic discussion about source of uncertainty
    - Sensitivity analysis
- **Interest and risk of simplified tools like PEEC**
- **Sustainability action in tech companies**

Part2: PhD topic

Involving the user in environmental-aware clouds

Starting point of my PhD

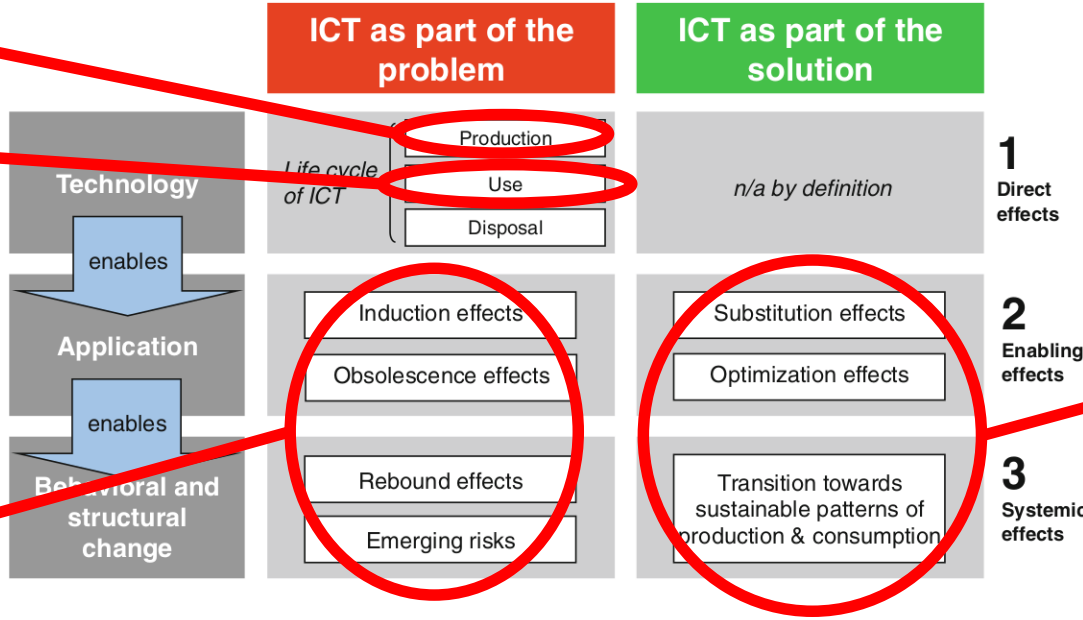


Hilty, L.M., Aebischer, B., 2015. *Ict for sustainability: An emerging research field*, in: ICT Innovations for Sustainability. Springer, pp. 3–36.

Starting point of my PhD

Master's thesis
(see before)

Energy efficiency
(see after)



What risks to happen in fact...

"Technology will save us"
Ericsson?

Hilty, L.M., Aebischer, B., 2015. *Ict for sustainability: An emerging research field*, in: ICT Innovations for Sustainability. Springer, pp. 3–36.

Technical leverages for footprint reduction available for data center operators

- **Energy efficiency**
  - Workload consolidation and shut-down techniques
  - Virtualization: packing several virtual machines on the same hardware
  - Dynamic Voltage and Frequency Scaling (DVFS)
  - Heterogeneous computing: power- and thermal-aware scheduling
- **Use of renewable energies**
  - Workload adaptation to power envelope
  - Geographic load shifting
- **Data center environment**
  - Cooling management, waste heat utilization
  - Batteries (UPS, fuel cells, ...)

Usual objectives

- **Maximize performance under energy/CO2 constraints**
- **Minimize energy/CO2 under performance constraints**

  (performance = throughput, makespan, response time, SLA violation, ...)

Being transparent to the user = rebound effects?

Including the user

- **Answer to the demand from users for green services**
  - **Why?** Legal obligations for companies / sustainability-concerned citizens
  - **How?** Users **pay** for green warranty (pricing / green Service Level Agreement)
- **Enable new leverages for footprint reduction**
  - **Which?** Accept delay, degradation, less availability
    - Temporal flexibility: “I accept to delay the execution of my task”
    - Spatial flexibility: “I accept to lower the resources granted to my task”
  - **How?** Users **rewarded** for their flexibility (pricing / eco-label)

=> Opportunity to counteract rebound effect

One example: tuning the size of VMs

David Guyon et al., 2019. Involving users in energy conservation: a case study in scientific clouds.

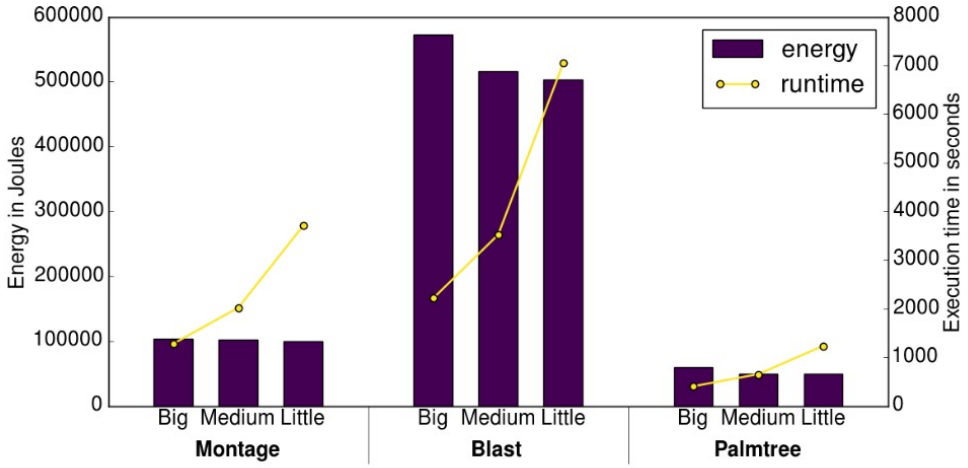


Figure 6 Energy consumption and execution time of each workflow in each execution mode.

- **Model:** IaaS cloud, HPC jobs, consolidation and shut-off techniques
- **User choice:** reduce the size of her VM (big/medium/small)
- **Results:** 50% gain by only allowing consolidation and shut-down, even better (up to 60-65%) the more users choose a small/medium VM size

Going further

- **Limitation of reviewed literature**
  - Simplistic distribution of user requirements
    - Uniformly distributed / fixed pattern => more realistic user model?
    - User requirements likely to evolve with time
  - Unclear how certain approaches can have an overall positive impact on the environment
- **Going further**
  - Study more “extreme” involvement of user
  - Combine user as flexibility and user calling for more sustainability
  - Mechanisms for sufficiency
  - Include an LCA dimension?

Conclusion

- **Thanks for your attention!**
- **Master's thesis: estimation of radio base station's embodied carbon emissions**
  - new and active research field
  - uncertainties
- **PhD thesis: involving the user in environmental-aware clouds**
  - avoid rebound effect
  - I plan to look into highly committed solutions
- **Do not hesitate for questions :-) : mael.madon@irit.fr**

References

Master's thesis:

- M. Madon, *Developing a Parameterized Embodied Emissions Calculator for telecommunication networks equipment (PEEC)*, Master's thesis, KTH Royal Institute of Technology, Stockholm, 2021. http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-292198

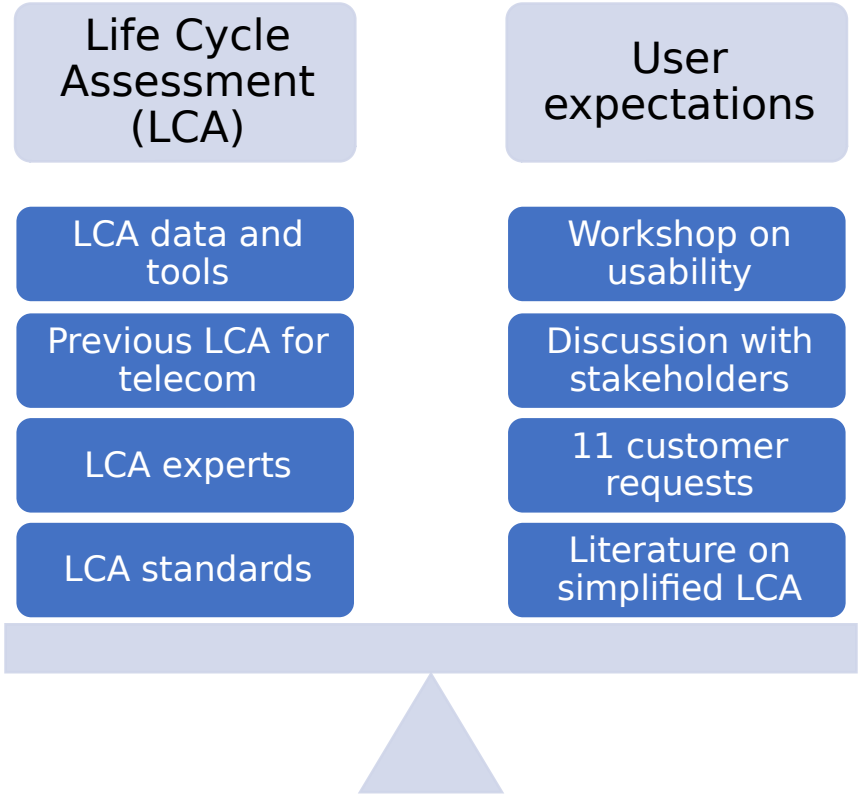
Literature user- and environmental-aware data centers:

- Guyon, D., Orgerie, A.-C., Morin, C., Agarwal, D., 2019. *Involving users in energy conservation: a case study in scientific clouds*. International Journal of Grid and Utility Computing 10, 272–282. https://doi.org/10.1504/IJGUC.2019.099667
- Orgerie, A., Lefèvre, L., Gelas, J., 2008. *Save Watts in Your Grid: Green Strategies for Energy-Aware Framework in Large Scale Distributed Systems*, in: 2008 14th IEEE International Conference on Parallel and Distributed Systems. Presented at the 2008 14th IEEE International Conference on Parallel and Distributed Systems, pp. 171–178. https://doi.org/10.1109/ICPADS.2008.97
- Haque, Md.E., Le, K., Goiri, Í., Bianchini, R., Nguyen, T.D., 2013. *Providing green SLAs in High Performance Computing clouds*, in: 2013 International Green Computing Conference Proceedings. Presented at the 2013 International Green Computing Conference Proceedings, pp. 1–11. https://doi.org/10.1109/IGCC.2013.6604503
- Amokrane, A., Langar, R., Zhani, M.F., Boutaba, R., Pujolle, G., 2015. *Greenslater: On Satisfying Green SLAs in Distributed Clouds*. IEEE Transactions on Network and Service Management 12, 363–376. https://doi.org/10.1109/TNSM.2015.2440423
- Basmadjian, R., Botero, J.F., Giuliani, G., Hesselbach, X., Klingert, S., De Meer, H., 2018. *Making Data Centers Fit for Demand Response: Introducing GreenSDA and GreenSLA Contracts*. IEEE Transactions on Smart Grid 9, 3453–3464. https://doi.org/10.1109/TSG.2016.2632526

Guyon, D., Orgerie, A.-C., Morin, C., 2018. *Energy - Efficient IaaS-PaaS Co-Design for Flexible Cloud Deployment of Scientific Applications*, in: 2018 30th International Symposium on Computer Architecture and High Performance Computing (SBAC-PAD). pp. 69–76. https://doi.org/10.1109/CAHPC.2018.8645888

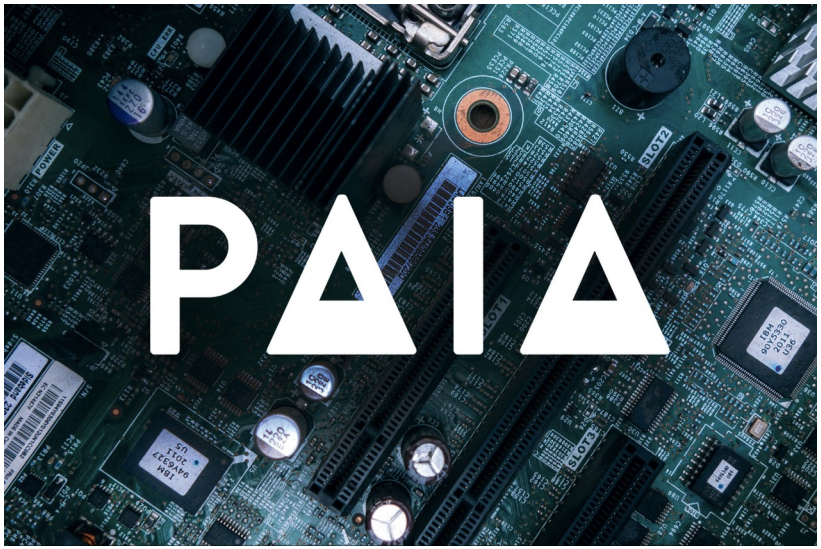
ANNEX

Method: streamlining LCA

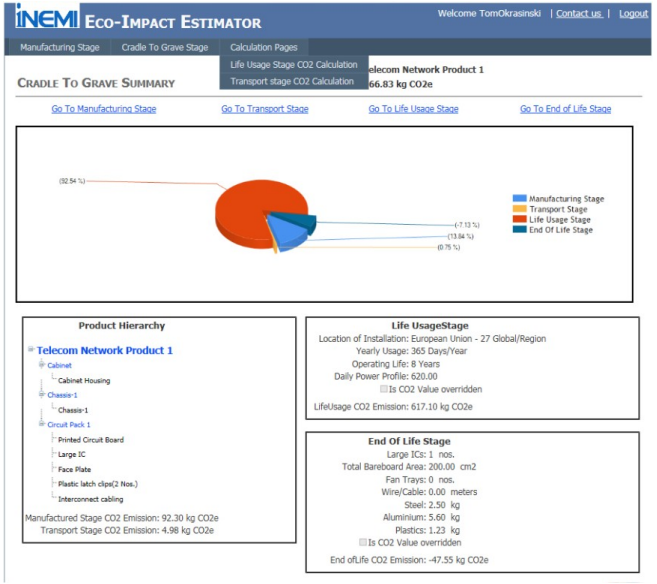


Similar work

PAIA (MIT and Quantis)



iNEMI Eco-Impact Estimator



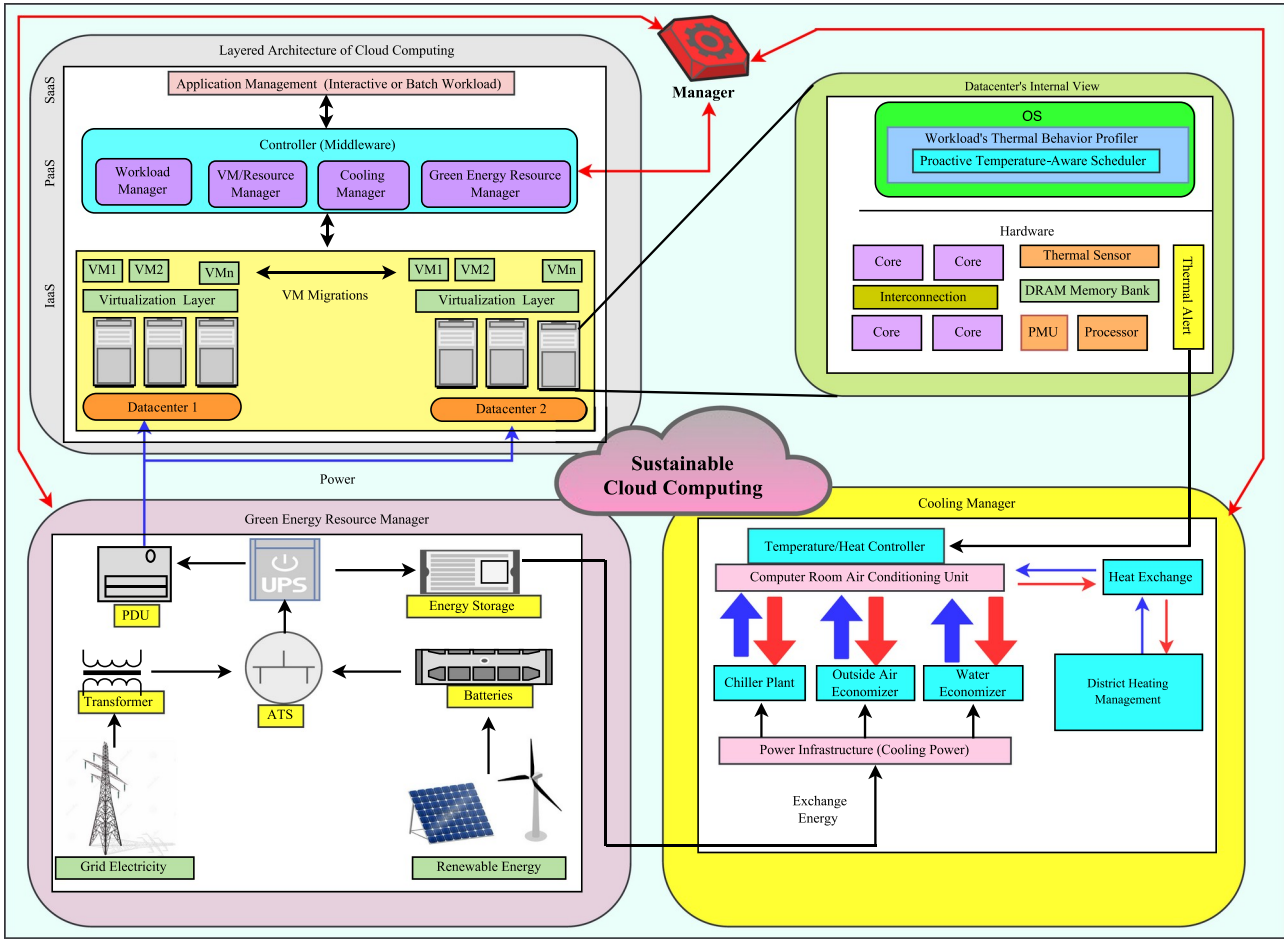
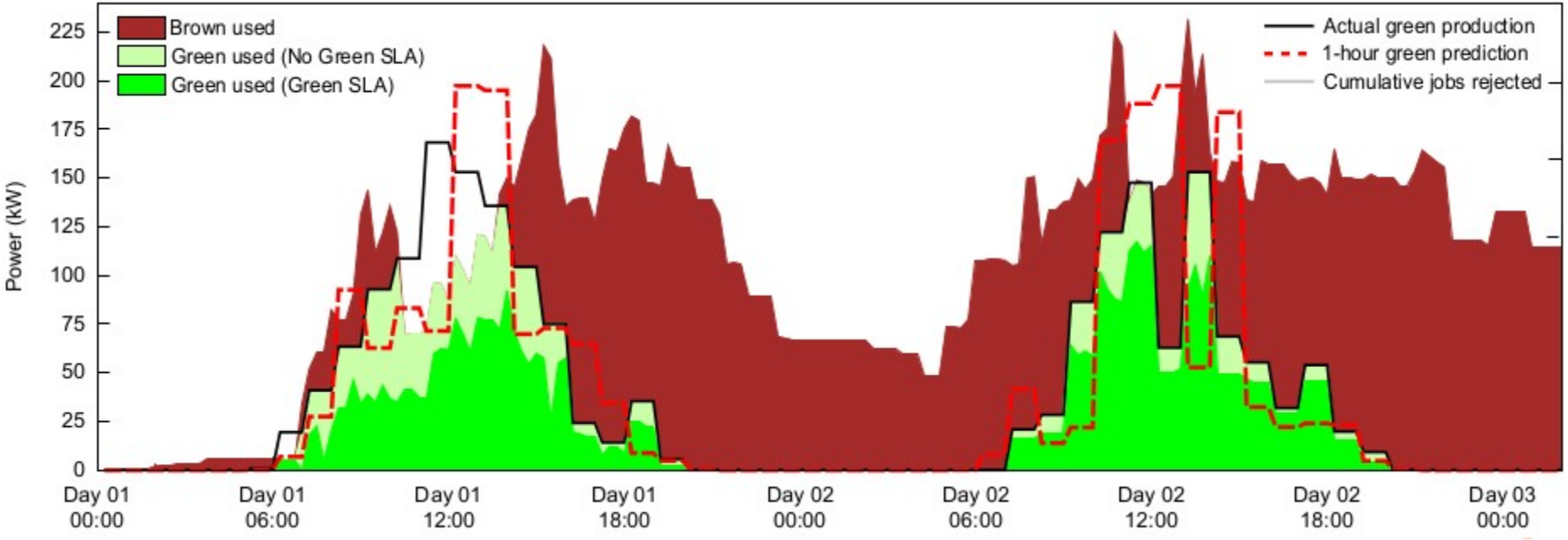


Fig. 38. Conceptual model for sustainable cloud computing.

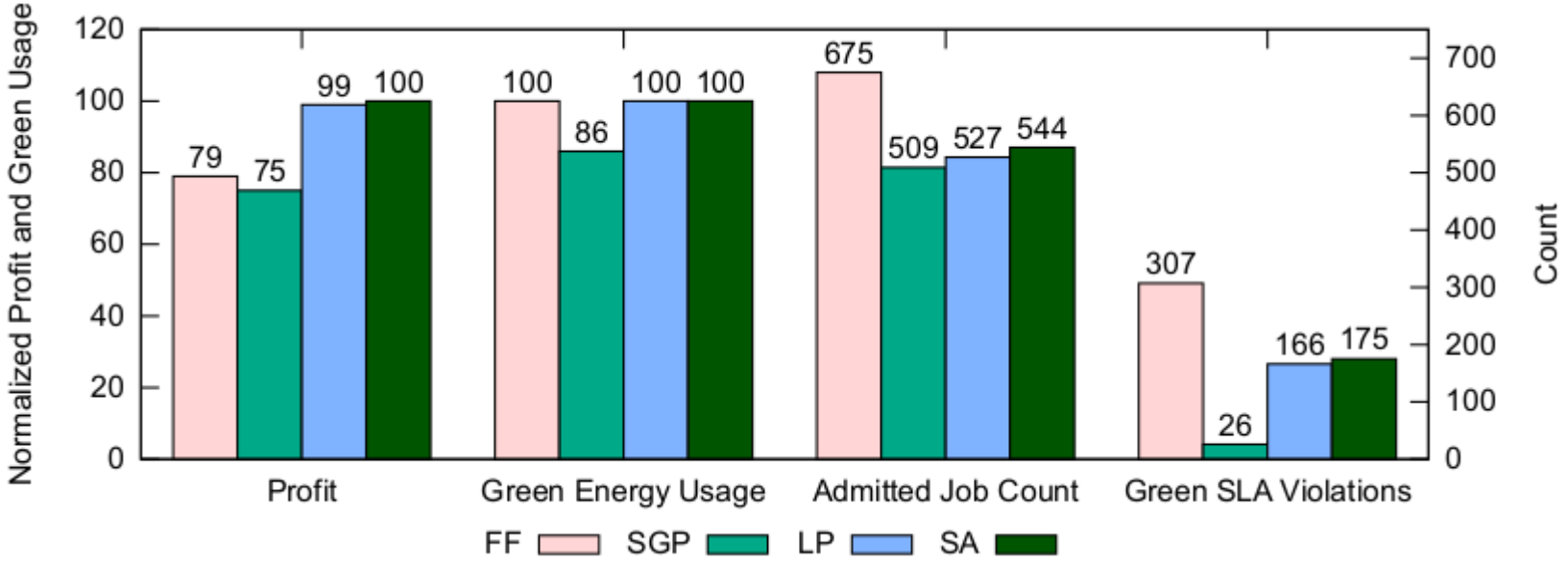
Source: Gill, S.S., Buyya, R., 2018. A Taxonomy and Future Directions for Sustainable Cloud Computing: 360 Degree View.

Static distribution of power purchase agreement?



Source: Haque et al. 2013

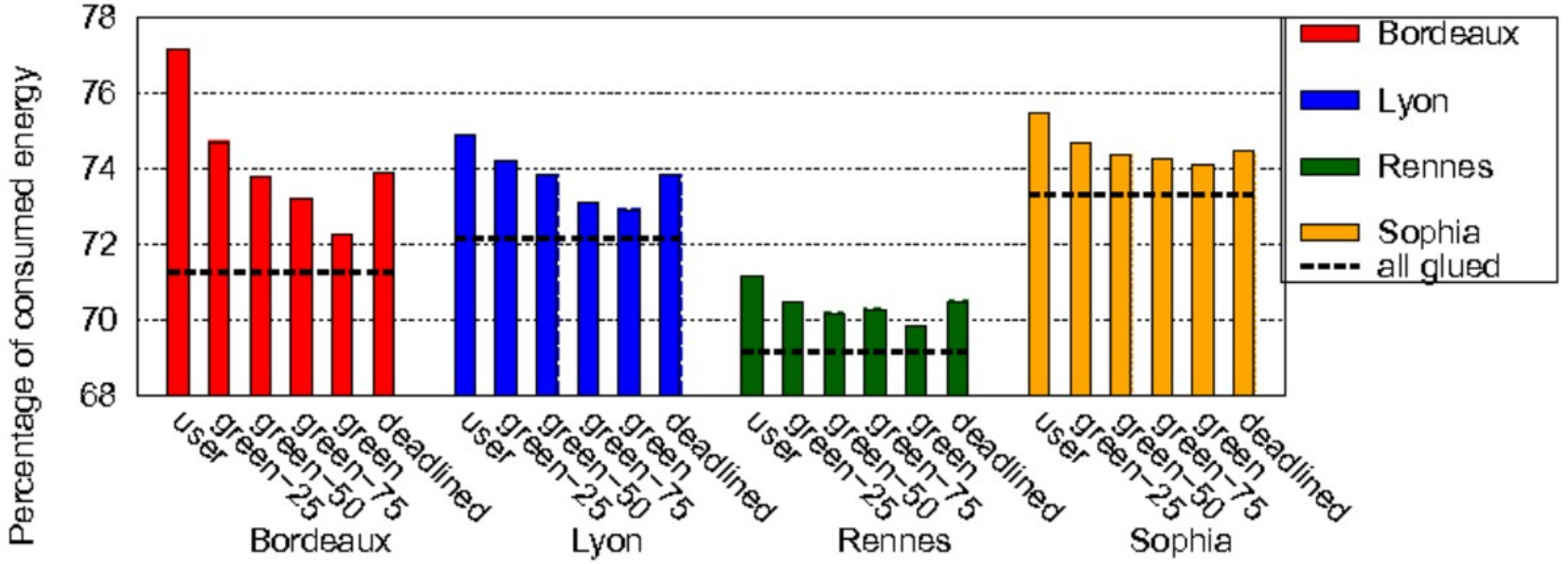
Less violations by rejecting more SLAs?



Source: Haque et al. 2013

- Rejected / dissatisfied user: where will she run her tasks?

Limited results



Source: Orgerie et al. 2008