Understanding and Reducing the Energy Consumption of Distributed Systems

Anne-Cécile Orgerie

IDCHP seminar
1st July 2021, Lyon

1

Outline

- Context
- Understanding the energy consumption
- Reducing the energy consumption
- Concluding broader remarks

2

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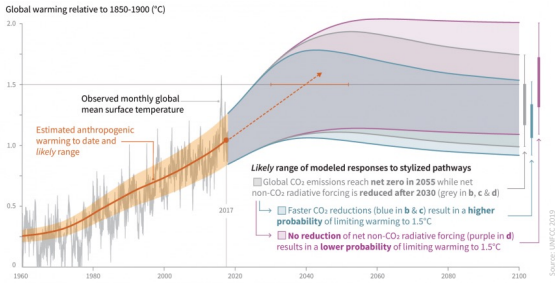
3

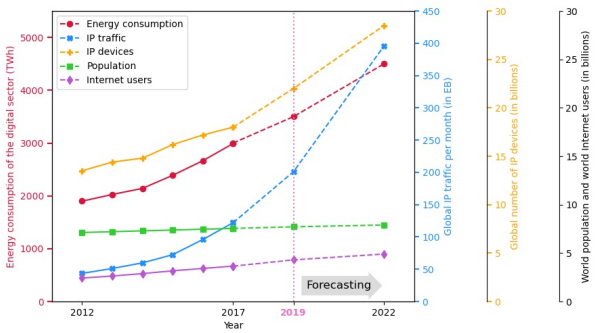
Paris Agreement: 1.5° C



Objective: reducing global greenhouse gas emissions by **8%** each year

4

ICT energy consumption



ICT energy consumption grows by **9%** each year.

Rapport Lean ICT : Pour une sobriété Numérique, 2018, https://theshiftproject.org
Cisco Visual Networking Index: Forecast and Methodology (2013—2019).
World Population: Past, Present, and Future https://www.worldometers.info/world-population 2019.
International Telecommunication Union, *Measuring the Information Society Report*, 2018.

5

My scientific context

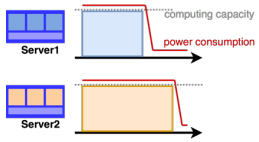
- Energy consumption
- Large-scale distributed sytems
- Computing and networking parts
- Use phase

Started with Grid computing some years ago…

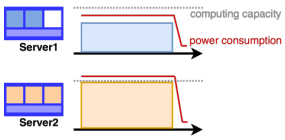
6

Energy efficiency: business as usual?

Computing faster?



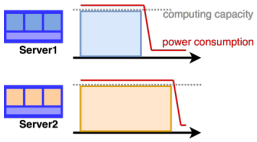
Computing slower?



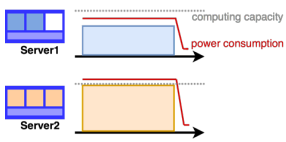
7

Energy efficiency: business as usual?

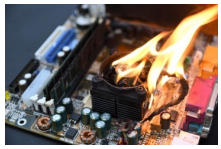
Computing faster?



Computing slower?



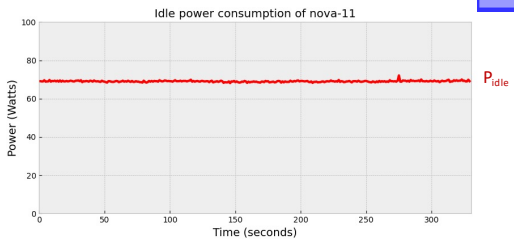
Temperature matters.



8

Wrong idea #1

Idle server consumes nothing or little.



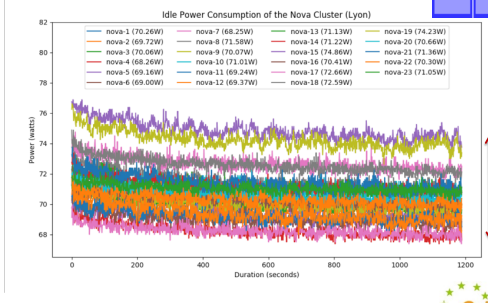
Nova node: 2 x Intel Xeon E5-2620 v4, 8 cores/CPU, 64 GiB RAM, 598 GB HDD (2016)

Grid'5000

9

Wrong idea #2

This server model consumes that amount of power.

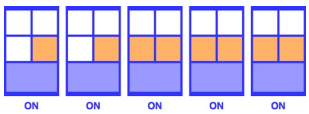


10% difference in idle and more at maximal consumption.

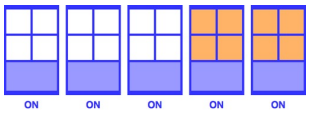
Grid'5000

10

No chance for naive modeling



5 x P_{idle} + 8 x P_{VM} = *X* Watts



5 x P_{idle} + 8 x P_{VM} = *X* Watts

Best configuration for power consumption ?

It depends.

11

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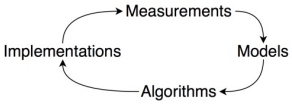
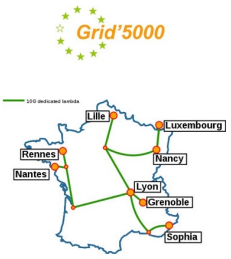
12

Energy consumption: a complex phenomenon

Need for **wattmeters** and sound experimental campaigns

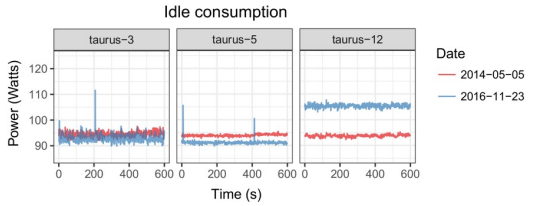
- To understand
- To build robust models
- To get solid instantiations
- To obtain realistic algorithms





13

Reproducibility?

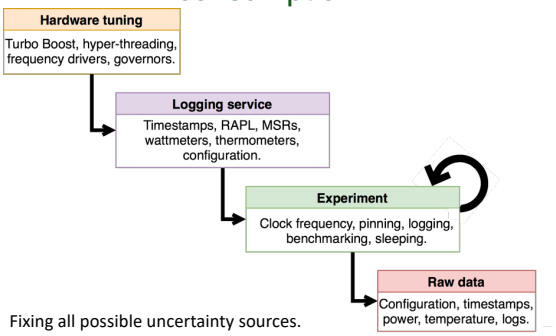


[Cluster 2017]

Idle power consumption varies over time.

14

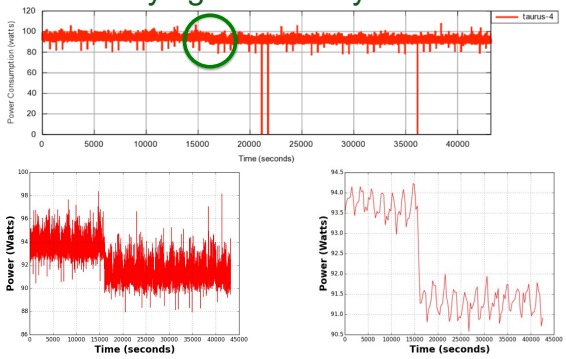
Methodology for measuring server consumption



Fixing all possible uncertainty sources.

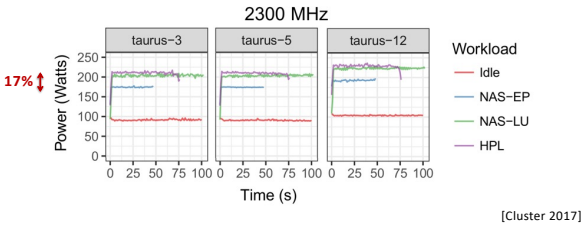
15

Annoying uncertainty sources



16

100% CPU utilization?

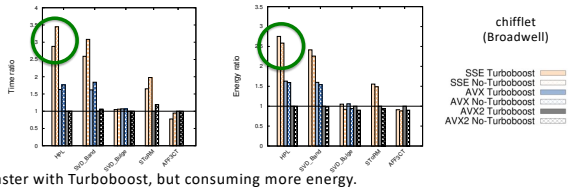


[Cluster 2017]

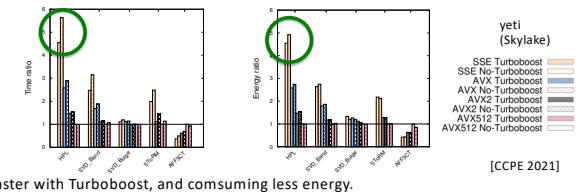
17% difference in consumption for applications fully loading the server.

17

Faster or slower? … It depends.



Faster with Turboboost, but consuming more energy.

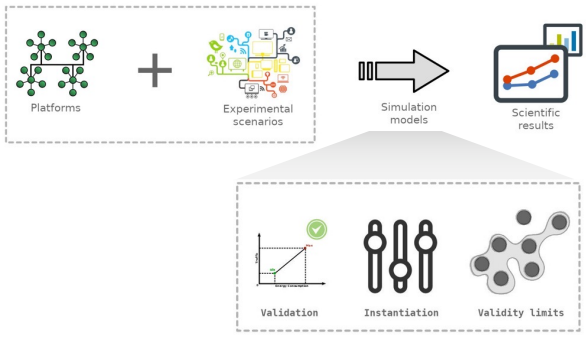


[CCPE 2021]

Faster with Turboboost, and comsuming less energy.

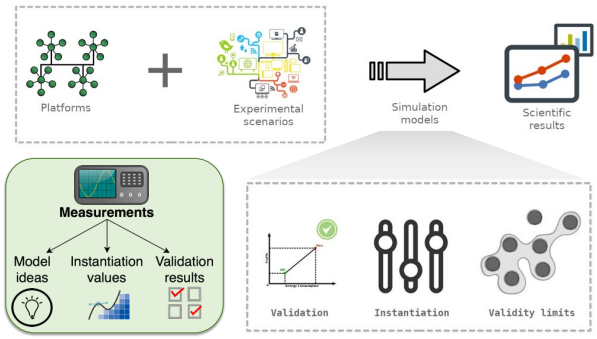
18

Simulating energy consumption



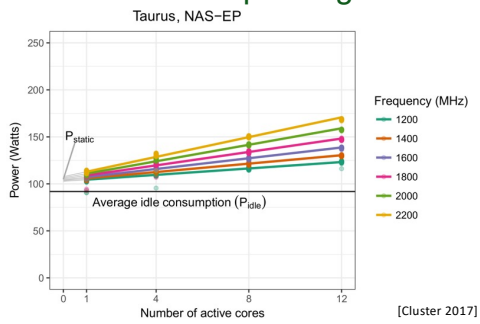
19

Simulating energy consumption



20

Server profiling

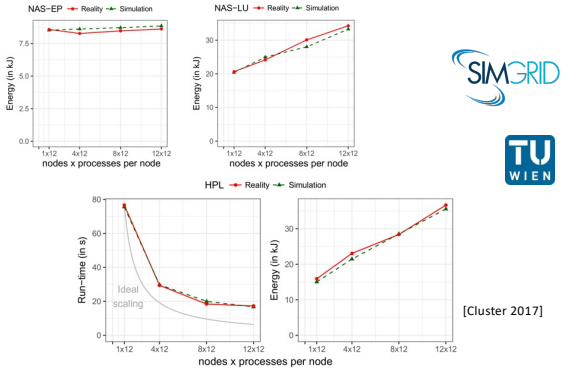


[Cluster 2017]

To do for each computing kernel.
At each frequency.
And each time we want to compare the model to real life.

21

Simulating server clusters

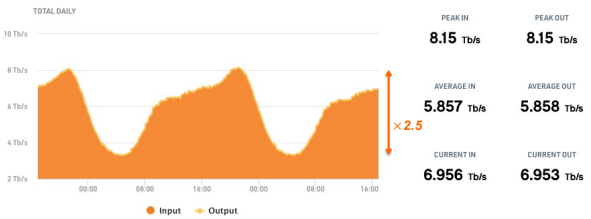


[Cluster 2017]

Reproducible results: https://gitlab.inria.fr/fheinric/paper-simgrid-energy

22

Resource waste



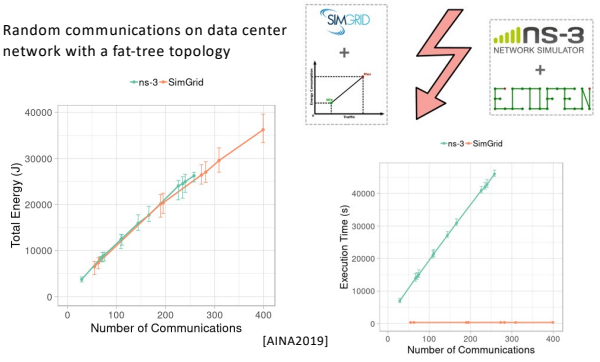
Daily aggregated traffic on AMS-IX(Amsterdam Internet eXchange Point), October 2020.

Networks are lightly of unevenly utilized
- High redundancy
- Overprovisioning

23

Simulating wired networks

Random communications on data center network with a fat-tree topology



[AINA2019]

Reproducible results: https://gitlab.inria.fr/lguegan/flowlvlwiredenergy

24

Models and simulation tools for what?

Capacity and energy planing

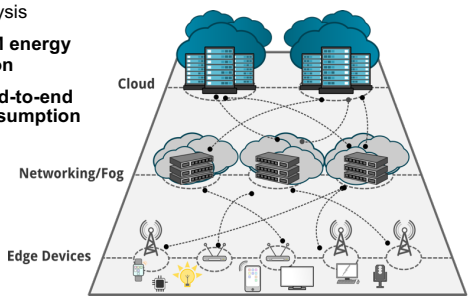
What-if scenarios

Algorithm analysis

Estimating VM energy consumption

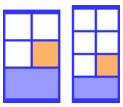
Estimating end-to-end energy consumption

Closing doors



25

VM energy cost models

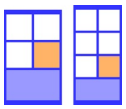


Identical VMs on heterogeneous servers

[SUSCOM 2018b]

26

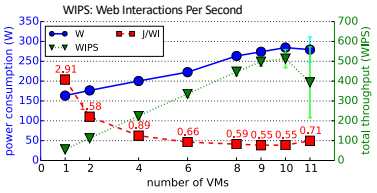
VM energy cost models



Identical VMs on heterogeneous servers

[SUSCOM 2018b]

Overcommit models



[SUSCOM 2018a]

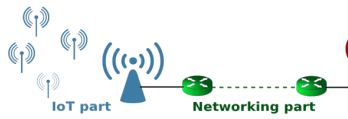
27

Power consumption of IoT

[FGCS 2018]

28

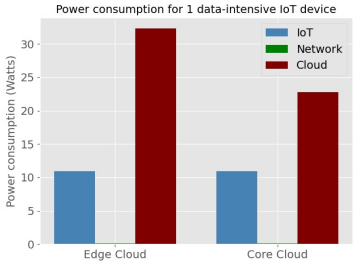
Power consumption of IoT



[FGCS 2018]

Tradeoff between:
- Performance
- Application accuracy
- Energy consumption

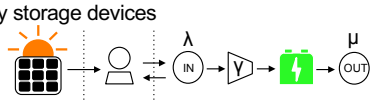
It depends.



29

Other simulation models

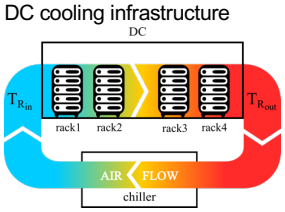
- Energy storage devices

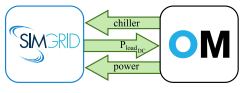


Solar PV | DC | ESD

[PDP2017]

- DC cooling infrastructure





[PADS 2018]

30

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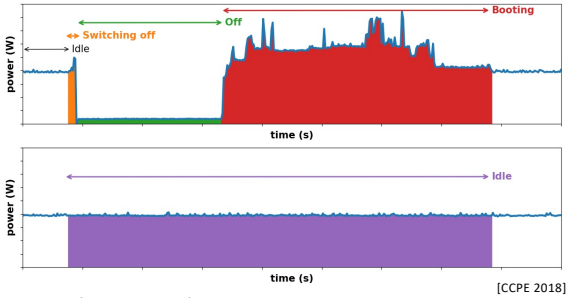
31

Let's switch off unused resources

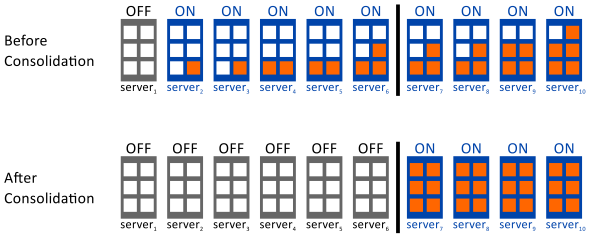


[CCPE 2018]

It takes time and energy.
It impacts electrical infrastructure and cooling system.

32

Let's consolidate the workload

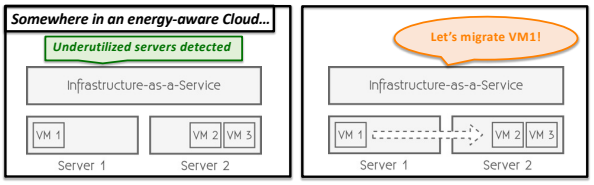


[Springer book chapter 2018]

Bin-packing problem.
Dynamic workload.

33

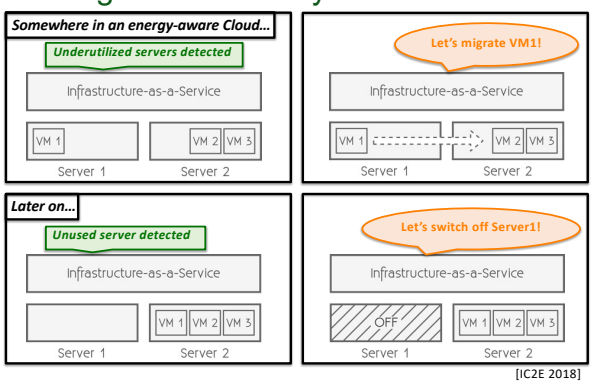
Let's migrate VMs for dynamic consolidation



[IC2E 2018]

34

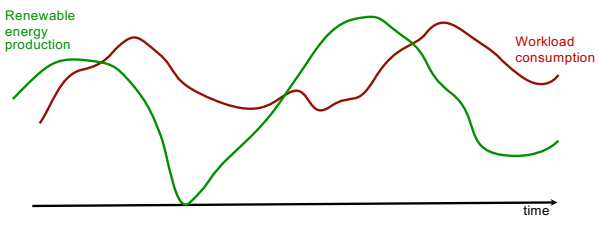
Let's migrate VMs for dynamic consolidation



[IC2E 2018]

35

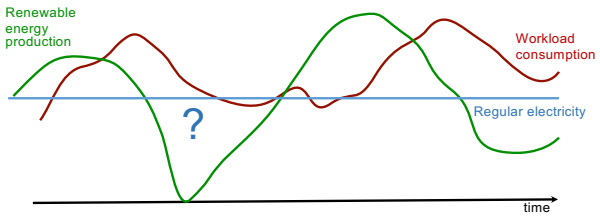
Let's use renewable energy



[Computing 2018]

36

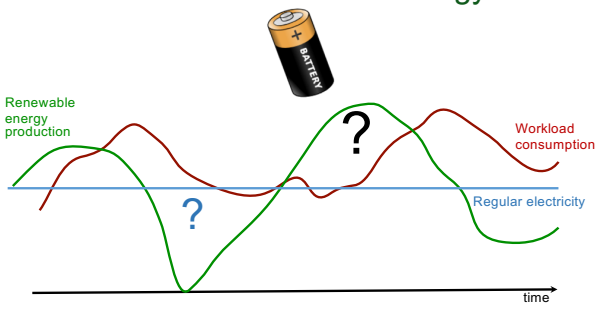
Let's use renewable energy



[Computing 2018]

37

Let's use renewable energy

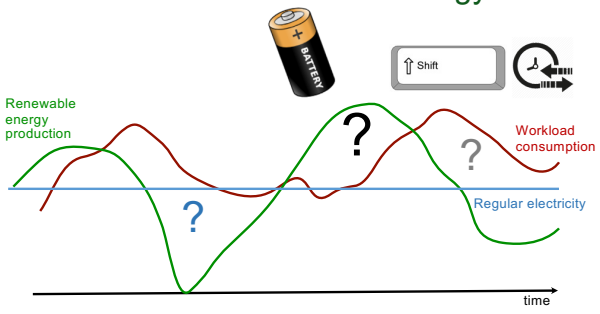


Or selling energy… and buying some other energy…

[Computing 2018]

38

Let's use renewable energy

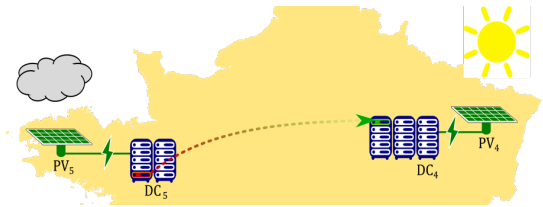


Or selling energy… and buying some other energy…

[Computing 2018]

39

Let's use multiple data centers

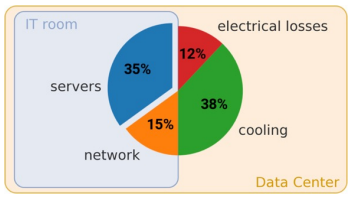


[SBAC-PAD 2018]

- Consumes energy on both locations during the migration
- Uses the telecommunication network (possible bottleneck)
- Needs to avoid oscillation effects (weather prediction)

40

How to measure energy efficiency?



PUE: Power usage effectiveness, metric at data center level

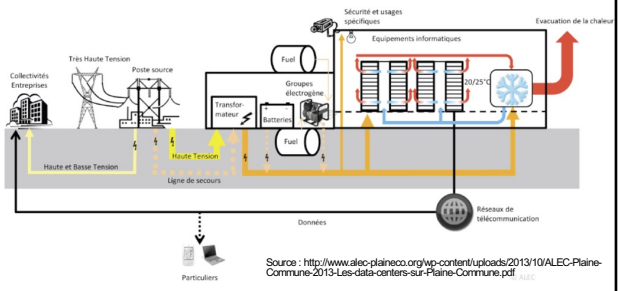
$$PUE = \frac{Total\ Facility\ Power}{IT\ Equipment\ Power}$$

the green grid

"*Green Grid Data Center Power Efficiency Metrics: PUE and DCIE*", Green Grid White Paper, 2008.

41

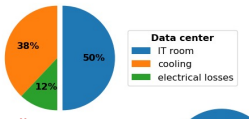
Overall data center view



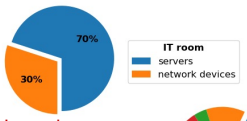
Source : http://www.alec-plaineco.org/wp-content/uploads/2013/10/ALEC-Plaine-Commune-2013-Les-data-centers-sur-Plaine-Commune.pdf

42

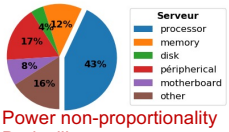
Wasted energy at all levels



Cooling
Power generators
Batteries
…



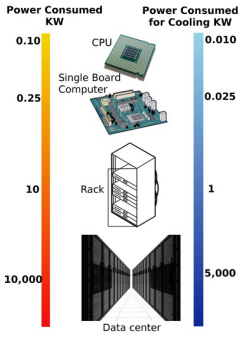
Unused servers
Overprovisioning
Redundancy
…



Power non-proportionality
Dark silicon
Unused components
…

43

Possible energy savings at every level



Low power processors (big.LITTLE)

Multi-core architectures

Energy-efficient dedicated architectures (FPGA, **GPU**)

Dynamic Voltage Frequency Scaling

Workload consolidation techniques

On/off policies

Hot spot management

Workload peak reduction

Dynamic adaptation

Software stack optimization

44

Outline

- Context
- Understanding the energy consumption
- Reducing the energy consumption
- Concluding broader remarks

45

Increasing energy efficiency ≠ reducing consumption

46

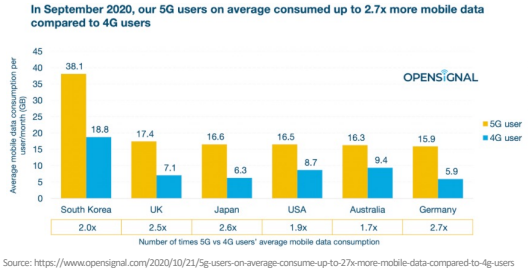
Increasing energy efficiency ≠ reducing consumption

Energy **optimization** → Resource cost reduction → Usage increase → Energy consumption **increase**

Beware of rebound effects!

47

Larger networks ⟹ more traffic



Source: https://www.opensignal.com/2020/10/21/5g-users-on-average-consume-up-to-27x-more-mobile-data-compared-to-4g-users

Higher bandwidths, higher data volumes,
which impacts on infrastructures?

48

Questioning promises and uses

The Korea Herald

More than half a million 5G network users returned to 4G: report

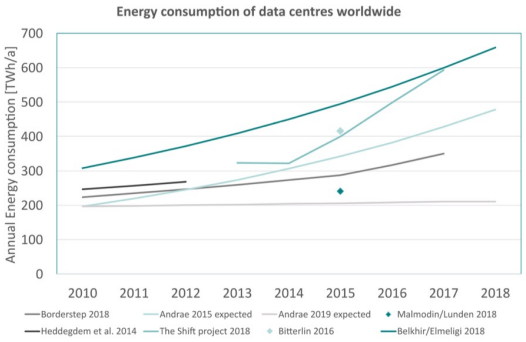
By Shim Woo-hyun Published : Oct 7, 2020 - 17:24 Updated : Oct 7, 2020 - 17:24

The number of 5G network **users who returned to 4G** network services has surpassed half a million -- 562,656 users who downgraded from their 5G subscriptions -- accounts for **6.5 percent of the total 5G network subscribers in South Korea**, according to the report by Rep. Hong Jung-min, who belongs to the Science, ICT, Broadcasting and Communications Committee at the National Assembly.

The lawmaker pointed out that many 5G users have gone back to the lower-speed network service as the **high-priced** new network system failed to offer quality **connection** and **coverage**.

49

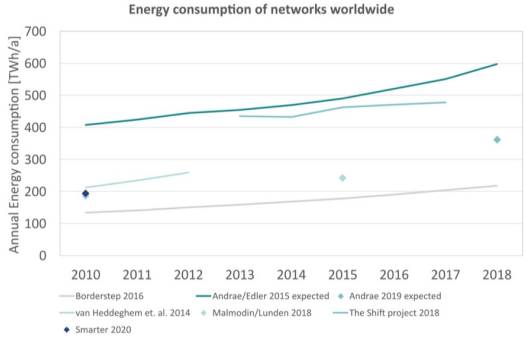
Data centers worldwide



Source: Montevecchi, F., Stickler, T., Hintemann, R., Hinterholzer, S. (2020). Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market. Final Study Report EC.

50

Networks worldwide



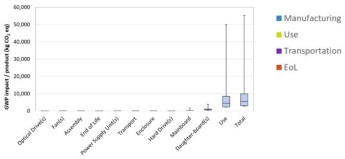
Source: Montevecchi, F., Stickler, T., Hintemann, R., Hinterholzer, S. (2020). Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market. Final Study Report EC.

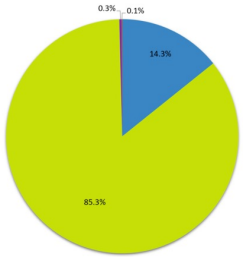
51

Full life cycle of servers

Dell PowerEdge R430 (Nova cluster)

Estimated carbon footprint (by Dell):
8,150 kgCO2e





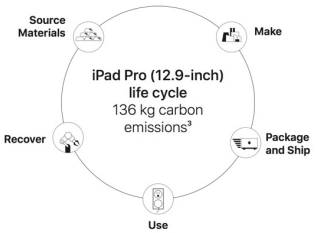
Assumptions for calculating product carbon footprint:

Product Weight	26.3 kg	**Server Type**	Rack	**Assembly Location**	EU
Product Lifetime	4 years	**Use Location**	EU	**Energy Demand (Yearly TEC)**	1760.3 kWh
HDD/SSD Quantity	x2 1TB 3.5" HDD	**DRAM Capacity**	16GB	**CPU Quantity**	2

Source: Dell PowerEdge R430 carbon footprint, 2019.

52

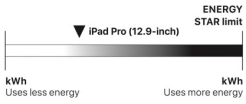
Life cycle of end devices



iPad Pro (12.9-inch) life cycle carbon emissions

83%	Production
11%	Transport
6%	Use
<1%	End-of-life processing

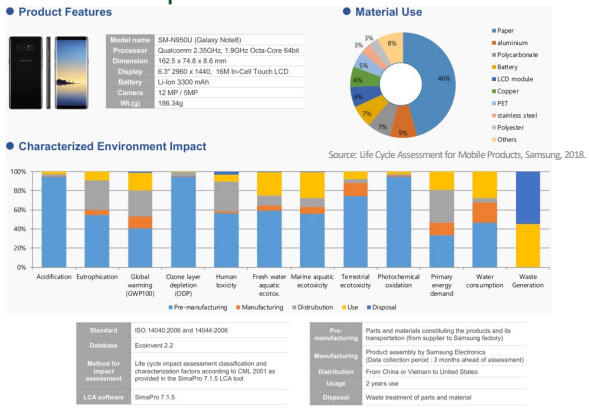
4 years of use



Source: Product environmental report, Apple, 2018.

53

Other impacts of end-user devices



54

What you can do

Completely switch off unused devices

Remove unused applications

Erase useless (old) emails, photos, etc.

Be careful when sending emails (attachments, receivers)

Be careful when coding (image size, active loops, etc.)

Look at eco-labels when buying new equipment

Keep devices longer if they are still working

Avoid capability overlap

Stay energy-aware…

55

Opportunities

To think differently

To propose new things

To build differently

To design a sustainable future

Sobriety

Resilience

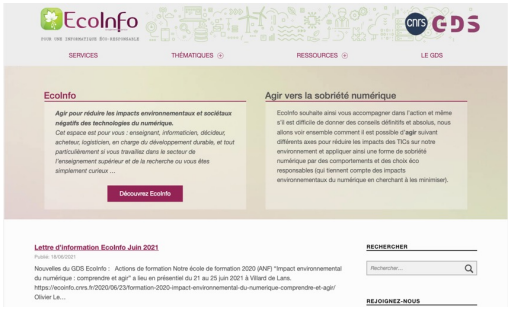
Low-tech

Sustainable computing

Computational sustainability

56

Studying environmental impacts of ICT



https://ecoinfo.cnrs.fr

57

Thank you for your attention

http://people.irisa.fr/Anne-Cecile.Orgerie

58