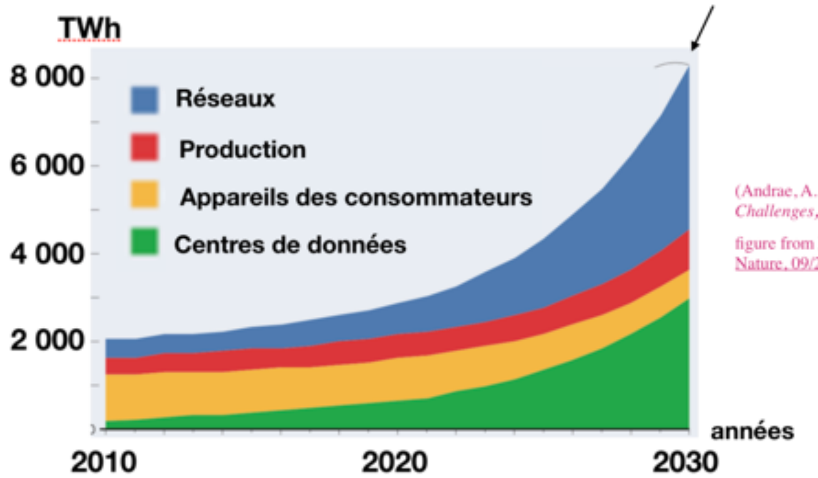
Outline

La transition numérique

- Why do people use computers for calculations?
  - Evolution of Computational power
  - Disruption



(Andrae, A. et Edler, T, *Challenges*, 2015)

figure from Nicola Jones, Nature, 09/2018)

La transition écologique

- More efficient calculations?
  - **The power efficiency of computers**
  - Cooling and data centers
  - ENS Lyon
  - CPER CINAuRA
- Better calculations?
  - Algorithms
- Less calculations?

Outline

- Why do people use computers for calculations?
  - Evolution of Computational power
- **Energy dissipation**
  - **The power efficiency of computers**
  - **Cooling and data centers**
- Cheaper calculations?
  - ENS Lyon
  - CPER CINAuRA
- Better calculations?
  - Algorithms
- Less calculations?
  - The practice of science: substitution effects
- Data, streaming & machine learning

Flop/s / Watt

- Human
  - 0.01 / 100 = 10^{-4} Flop/Ws
- ENIAC
  - 300 / 150 10^3 = 2 10^{-3} Flop/Ws
- Cray-Y/MP
  - 300 10^6 / 250 10^3 = 10^3 Flop/Ws
- Sunway Taihulight
  - 100 10^{15} / 15 10^6 = 10^8 Flop/Ws

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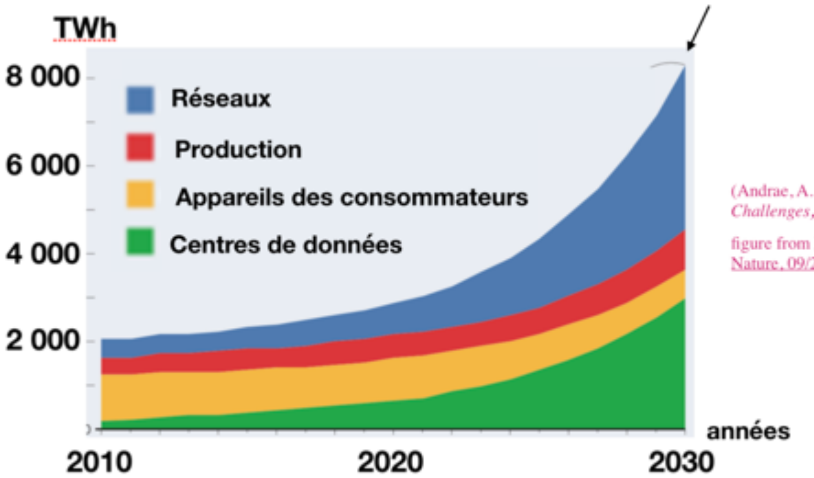

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Power usage effectiveness

https://en.wikipedia.org/wiki/Power_usage_effectiveness

- Power usage effectiveness (PUE) is a ratio that describes how efficiently a computer data center uses energy
- PUE is the ratio of total amount of energy used by a computer data center facility to the energy delivered to computing equipment.
- An ideal PUE is 1.0.

$$\text{PUE} = \frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}} = 1 + \frac{\text{Non IT Facility Energy}}{\text{IT Equipment Energy}}$$

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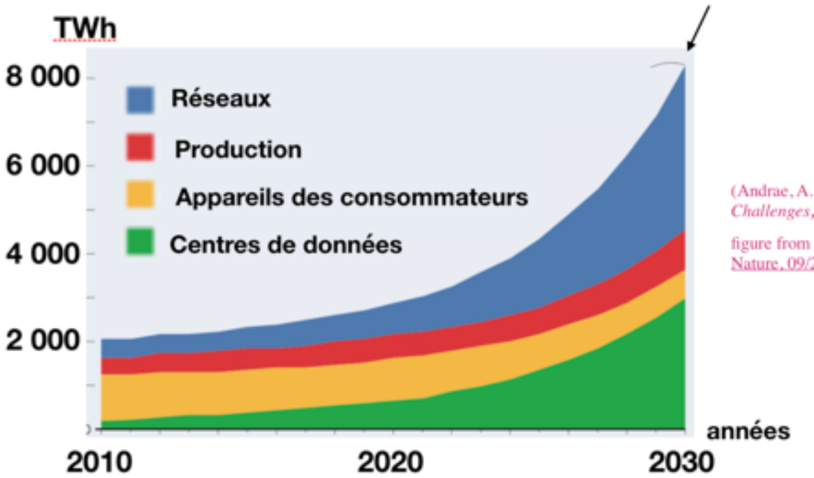

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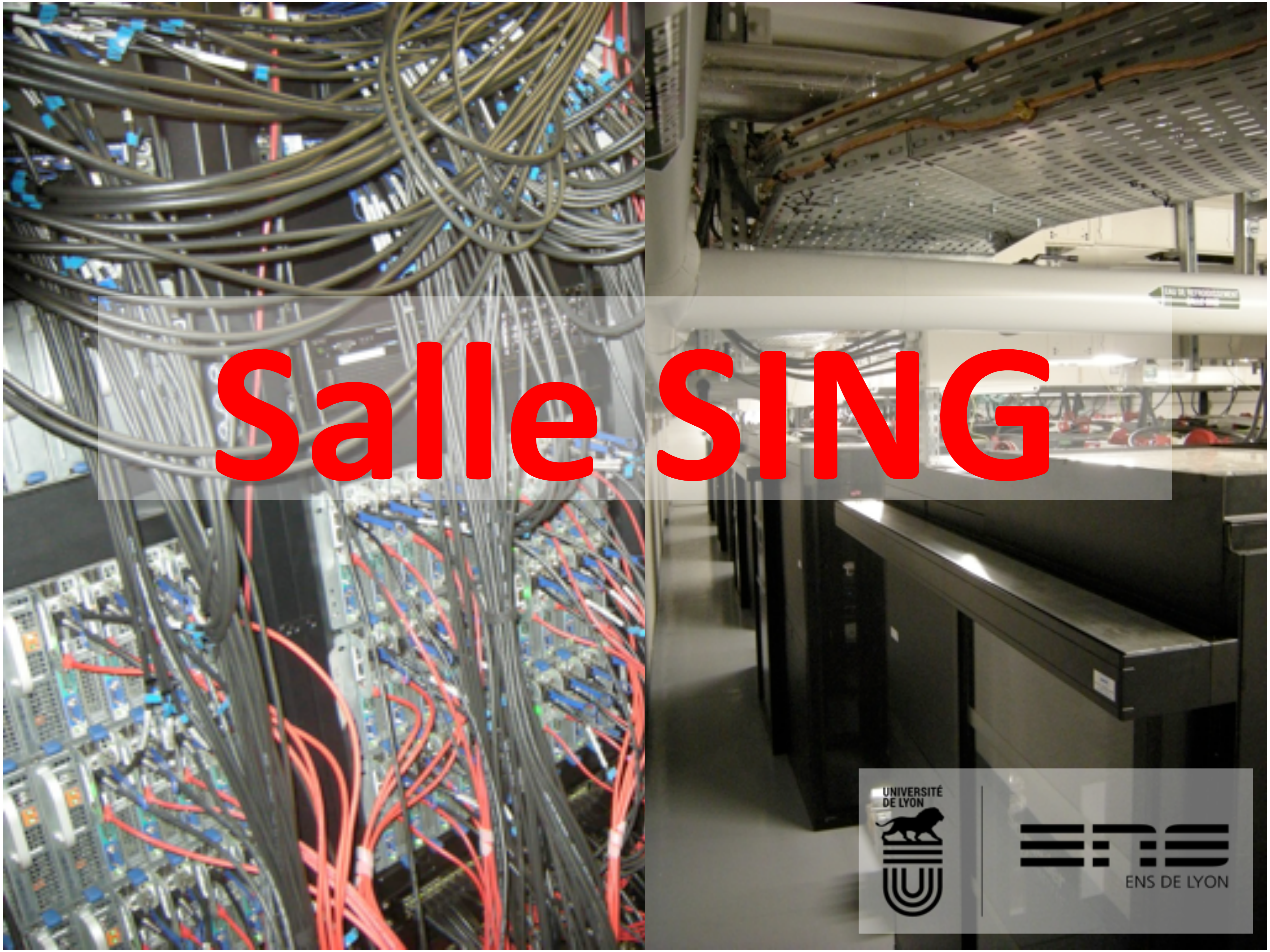
Salle SING



Salle SING @ ENS de Lyon

- Regrouping of IT in dedicated server rooms since 2010
- Salle SING operational since 2018
  - $200m^2$
  - Electric power supply 1,2MW
  - 65 racks
- Target PUE 1,2
- Summer
  - Free cooling
- Fall/spring
  - Recycling of dissipated energy for heating of MONOD building
- Winter
  - Free cooling, because it seems to be cheaper to use community heating/ chauffage urbaine?!

Le refroidissement à l'huile

https://www.lemagit.fr/actualites/252437021/Le-refroidissement-a-lhuile-est-enfin-au-point

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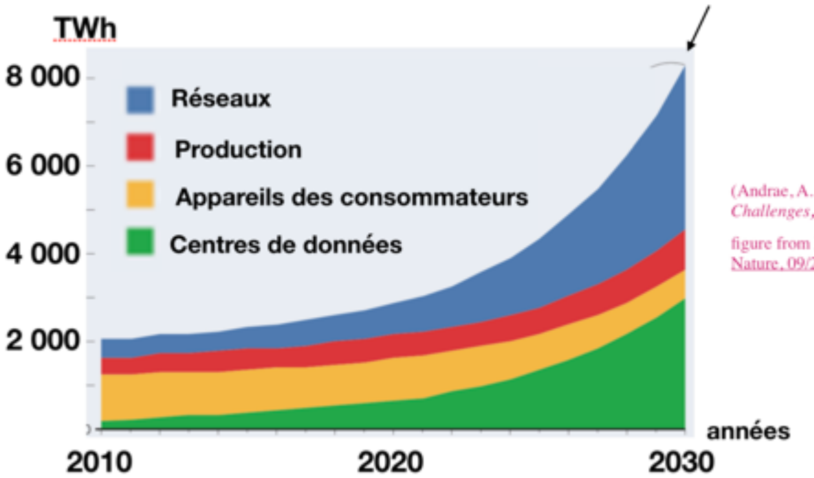

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  - **CPER CINAuRA**
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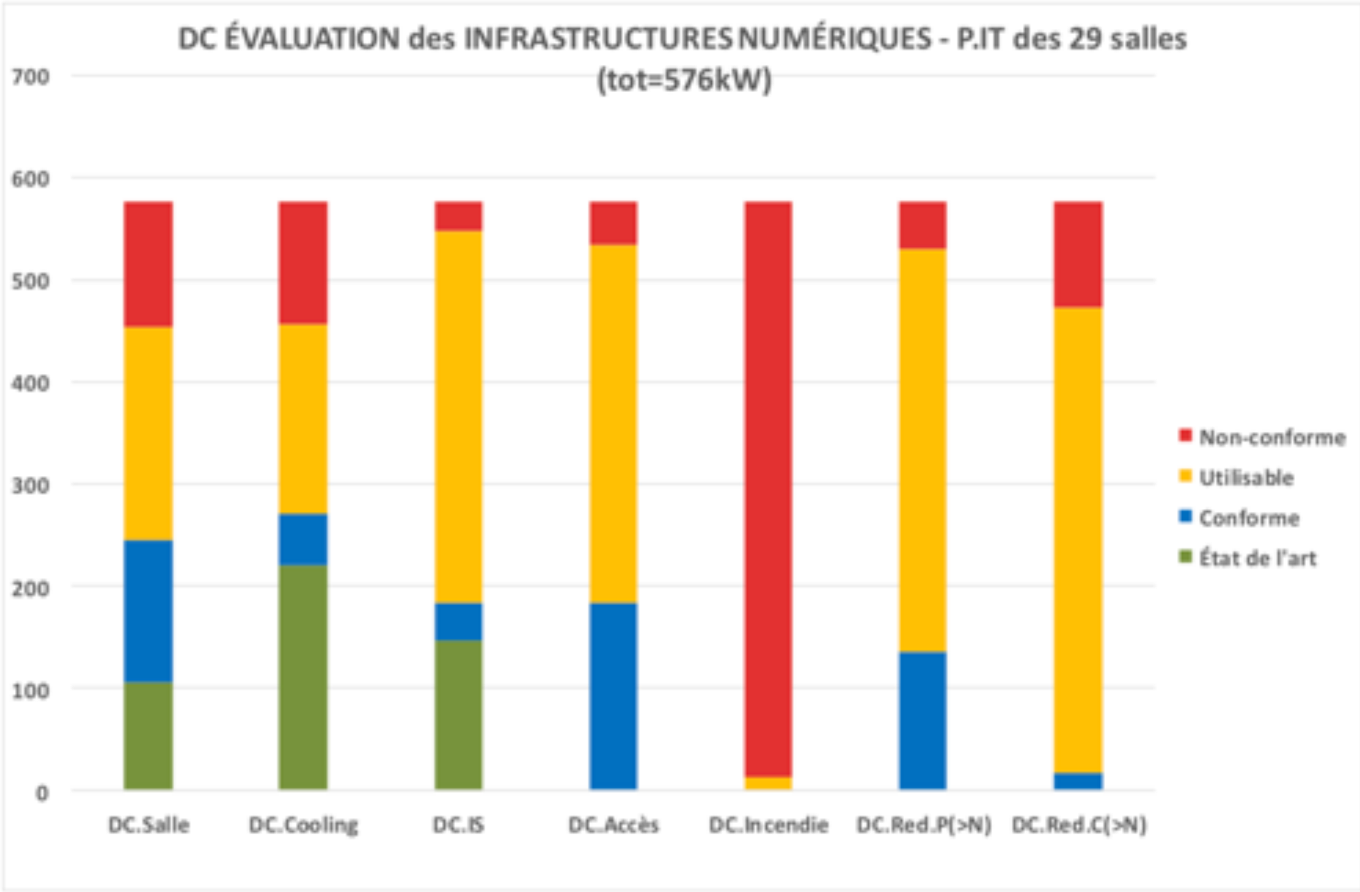
CINAuRA / CCDD

- Situation l'UCB/INSA: 29 salles, PUE ~ 2



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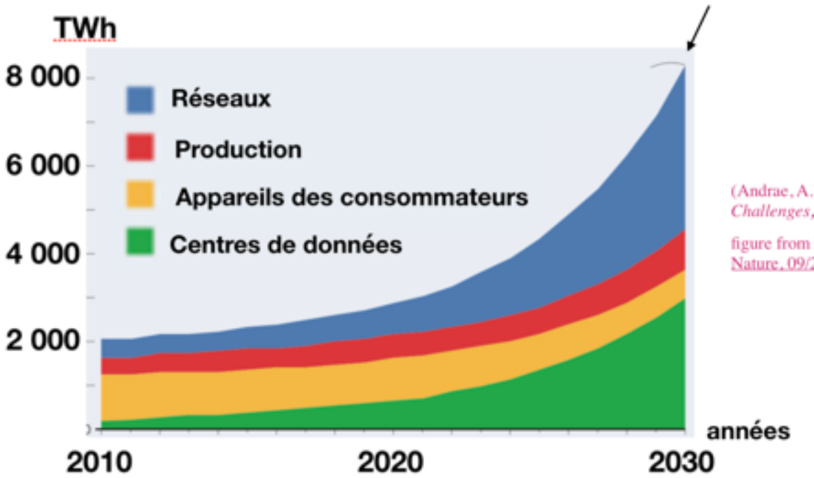

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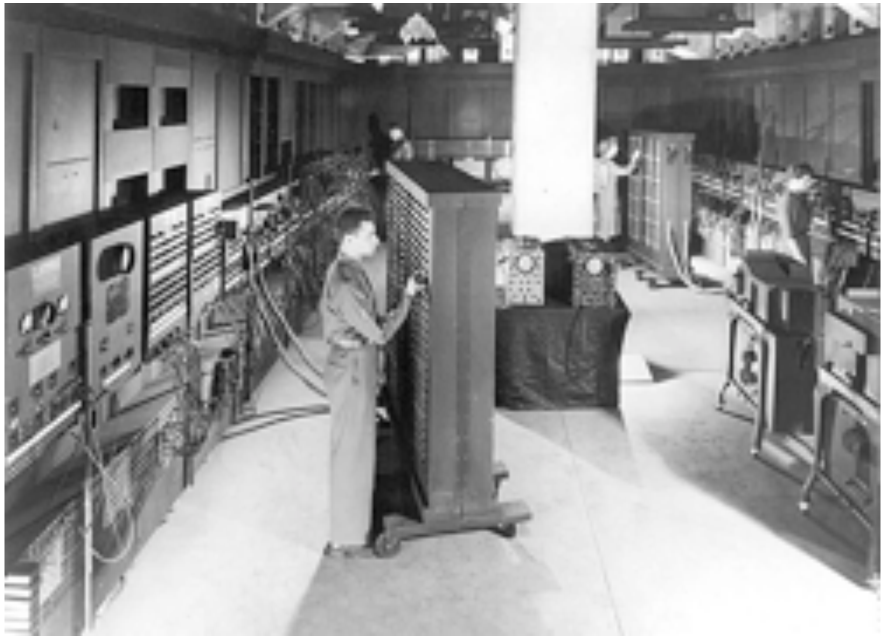
Enumerating the Ising model



- Round generously
  - 10^3 microstates/sec
- Work for one year
  - 10^7 sec/year

- **10^{10} microstates**
- **6x6 or 3x3x3 Ising model**

Enumerating the Ising model

- Round generously
  - – 10^{17} microstates/sec
- Work for one year
  - – 10^{7} sec/year

- **10^{24} microstates**

Enumerating the Ising model

2	16	16.
3	512	512.
4	65 536	65 536.
5	33 554 432	3.35544×10^{7}
6	68 719 476 736	6.87195×10^{10}
7	562 949 953 421 312	5.6295×10^{14}
8	18 446 744 073 709 551 616	1.84467×10^{19}
9	2 417 851 639 229 258 349 412 352	2.41785×10^{24}
10	1 267 650 600 228 229 401 496 703 205 376	1.26765×10^{30}

	256.
	1.34218×10^{8}
	1.84467×10^{19}
	4.25353×10^{37}
	1.05312×10^{65}
	1.7918×10^{103}
	1.34078×10^{154}
	2.82401×10^{219}
86 542 167 660 429 831 652 624 386 837 205 668 069 376	1.07151×10^{301}

Enumerating the Ising model

- Round generously (« exascale »)
  - 10^{18} microstates/sec
- Multiply by atoms in the universe
  - 10^{56} g (ordinary mass)
  - 10^{23} atoms/g
- Start at big bang
  - 10^{10} years x 10^{7} sec/year

- **10^{114} microstates**
- **7x7x7 Ising model**

Enumerating the Ising model

?

“Wait” for another 10^{40} speedup in supercomputer power?

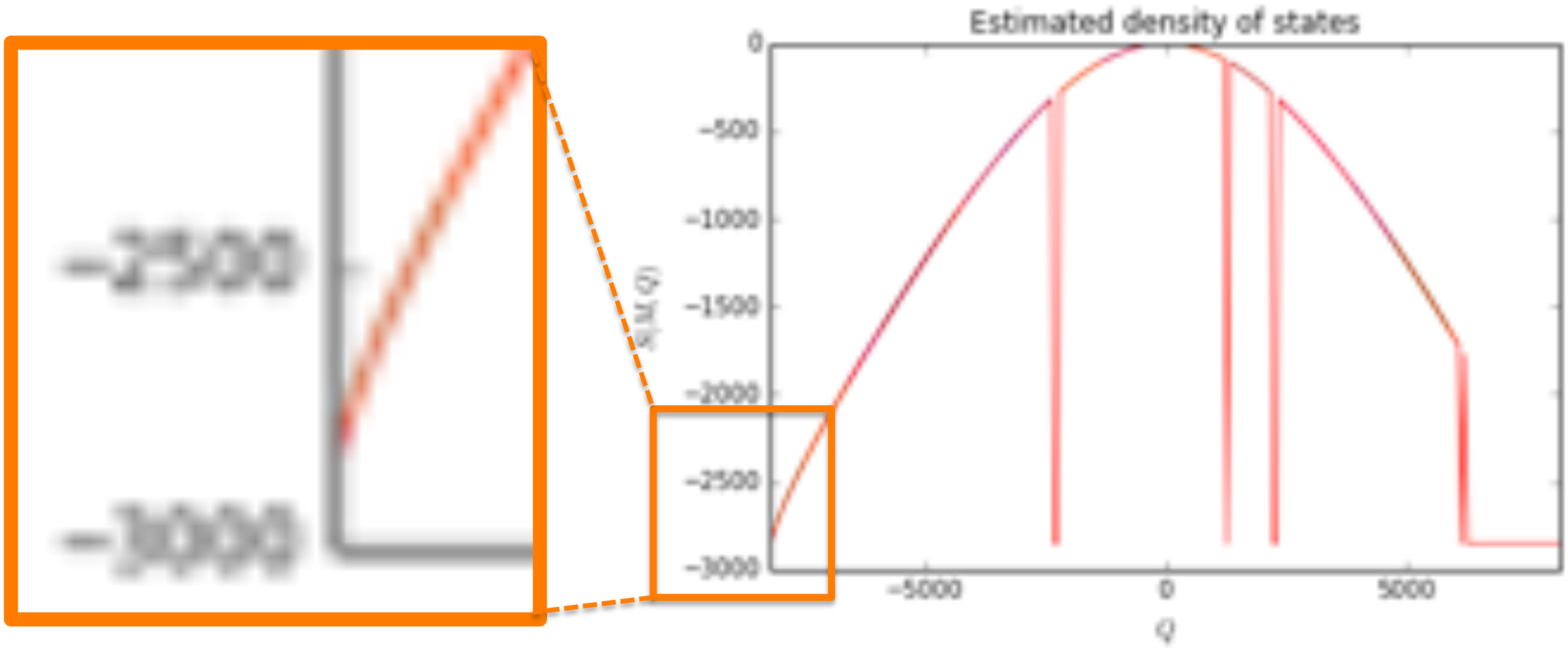
- **10^{154} microstates**
- **8x8x8 Ising model**

Try something else?

MC!

- **10^{1233} microstates**
- **(8x8)x(8x8) Ising model**

We have seen (almost) all of them!



- 10^{1233} = Exp[2839] microstates
- (8x8)x(8x8) Ising model

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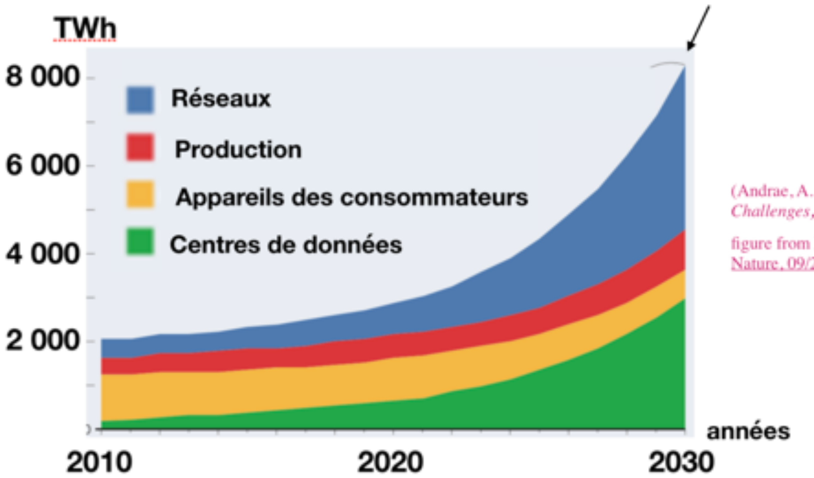

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How much IT for Science?

- Better algorithms and faster computers
  - Bigger systems, longer runs, more data, more complexity…
- But is this necessary?
  - Or is computing just lazy thinking?
- How good is good enough?
  - State of the art
- Technological change is a driver of science
- Progress/improvements create demand