State of the art and challenges in green datacenters: electrical and IT points-of-view

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Current status

Energy use statistics:

- ICT: 2,000 TWh/y, 10% of world electricity demand
- Datacenters only: 200 TWh/y, similar to Turkey or Indonesia
- About 2% of global carbon emissions for ICT

Breakdown of energy consumption by use:

- 50% for servers
- 30-40% for infrastructure (cooling, lighting, etc.) – decreasing
- 10-20% for storage, networks, etc.

Fast increase of hyperscale datacenters

Energy use forecasts

Increase in demand + steady total consumption = better energy efficiency

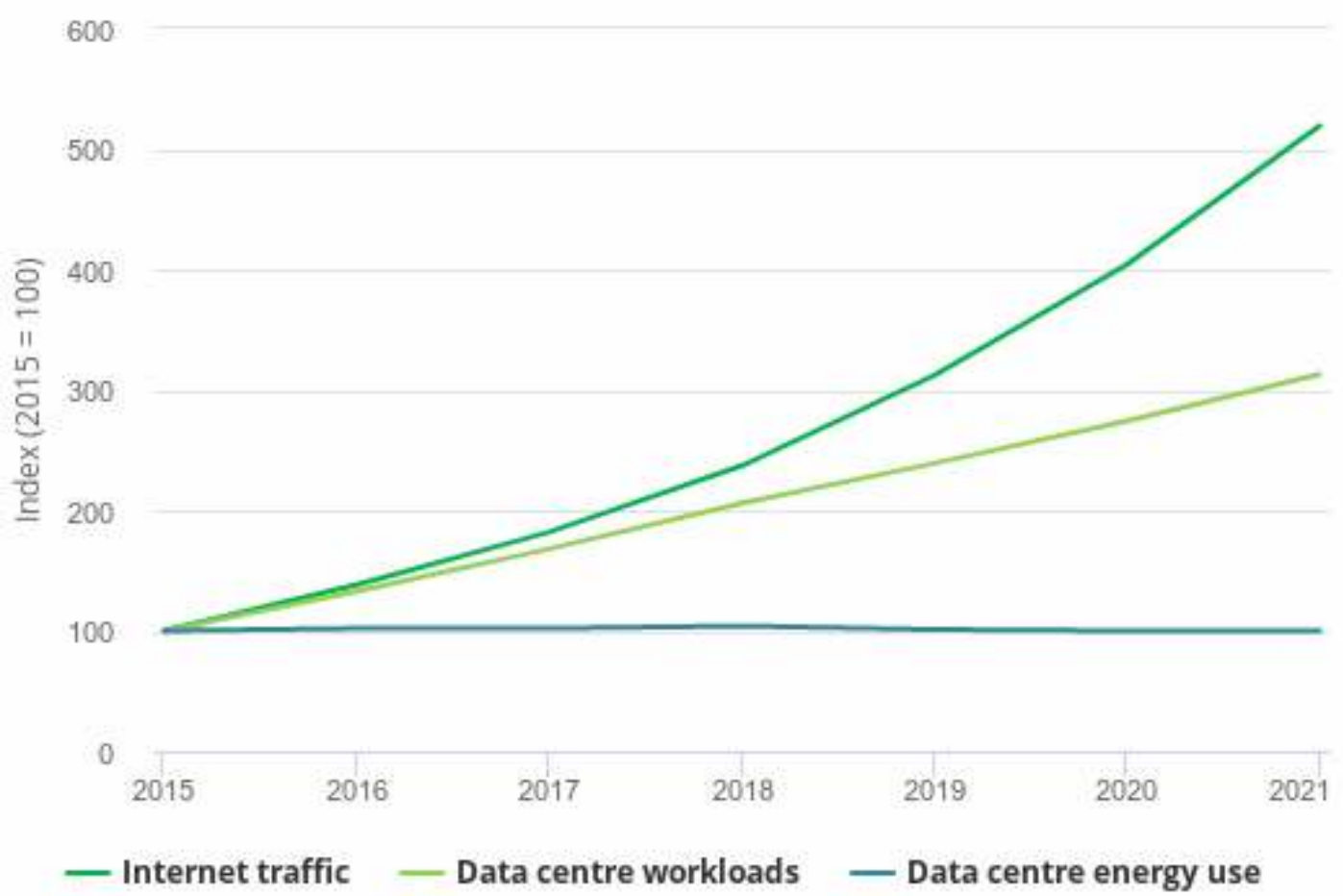

Figure: Historical and forecast workload and energy use of datacenters (Source: iea.org)

Energy use forecasts

But perhaps not in the long term: we need carbon-free energy sources even more

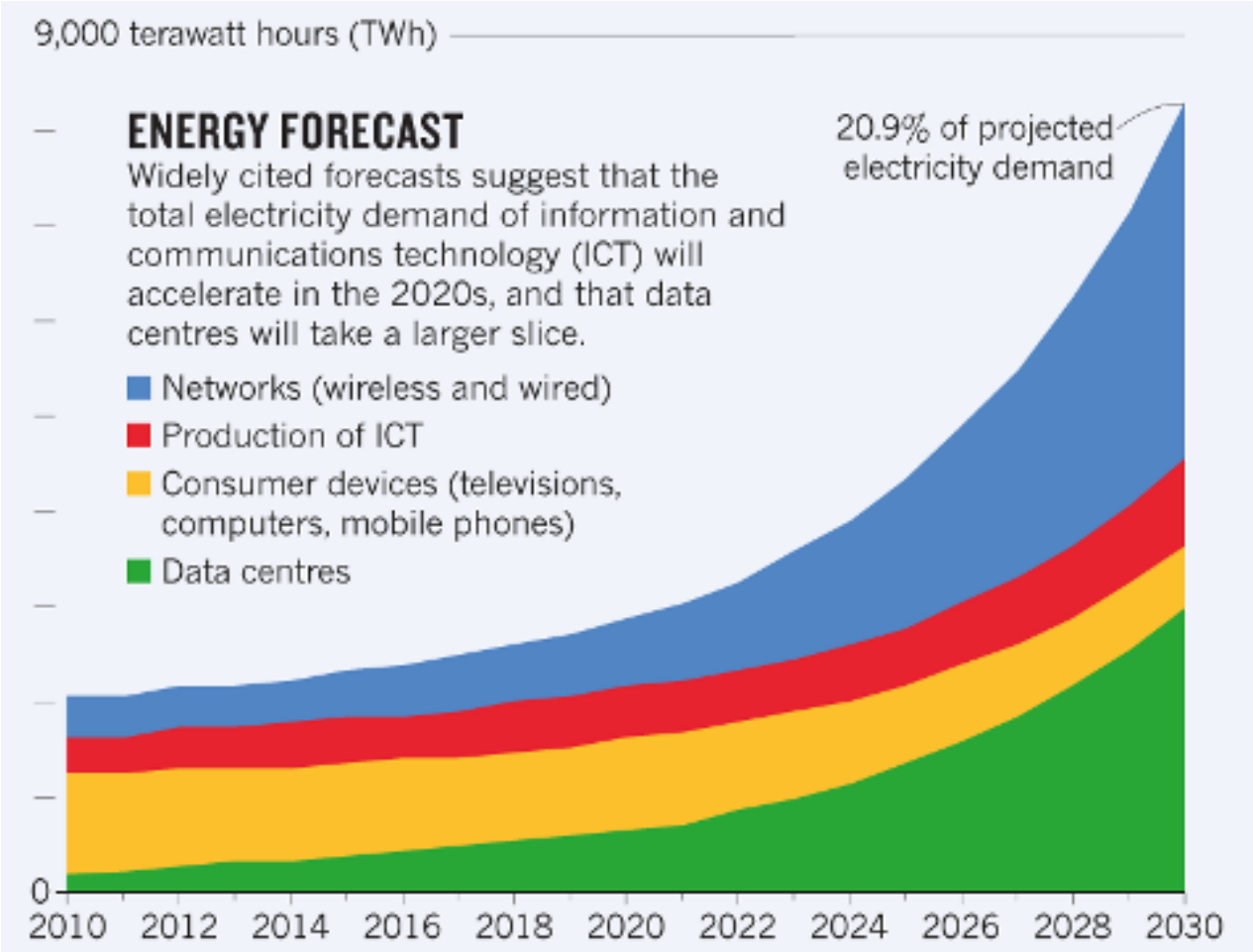

Figure: Historical and forecast energy use of ICT (Source: nature.com)

Where do we start from with renewables?

Not much actually (although this highly depends on countries)...

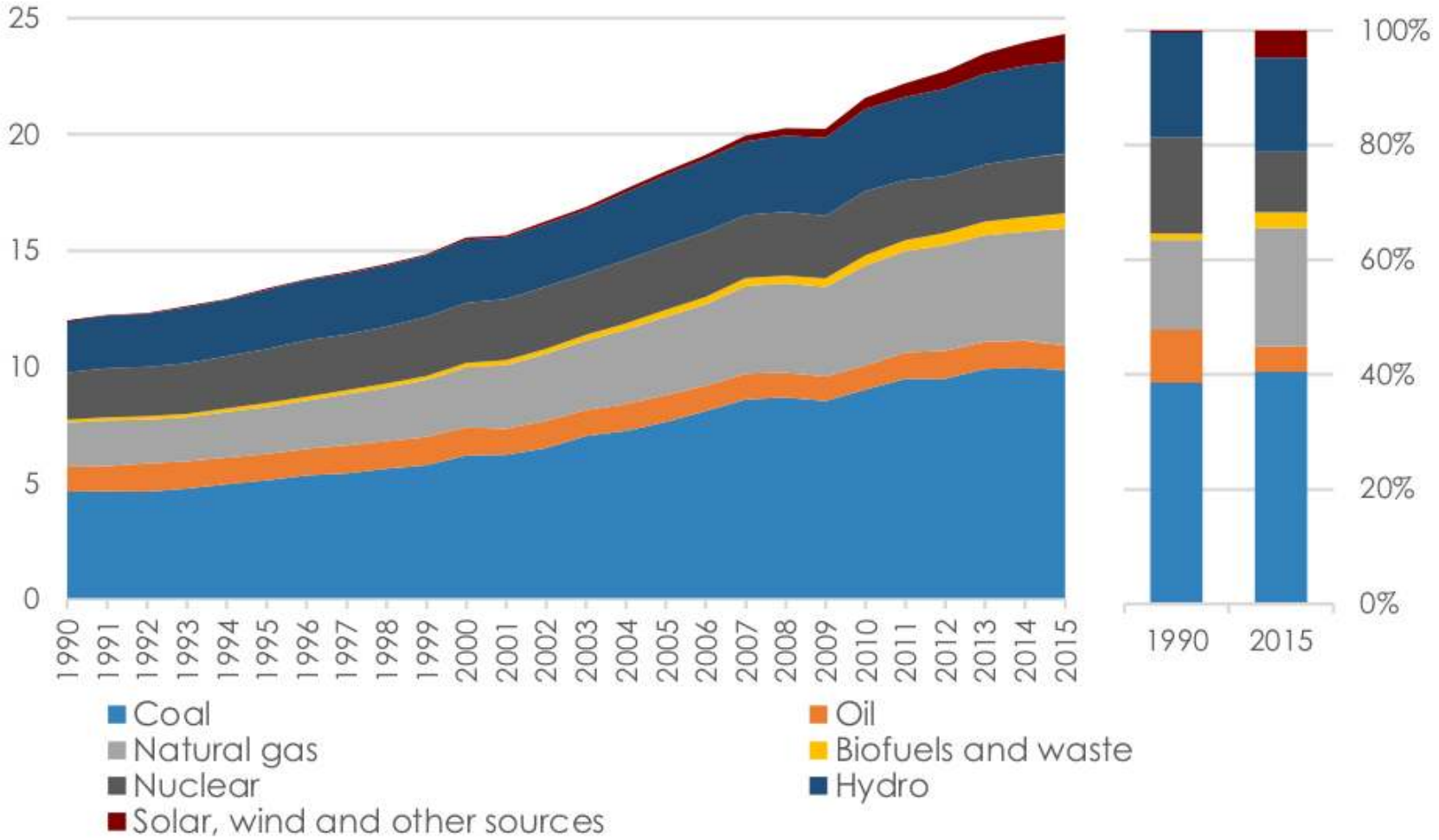

Figure: Breakdown of world electricity generation by source (Source: unstats.un.org)

Datacenter supply schemes

Three integration options:

- Buy RES power from a utility:
  - Simple, economically but not physically clean: electrons have no color
  - Used by large companies like Google and Apple
- Local grid-connected RES supply: rather simple, cleaner
- Local islanded system RES supply: clean, expensive, complex / interesting

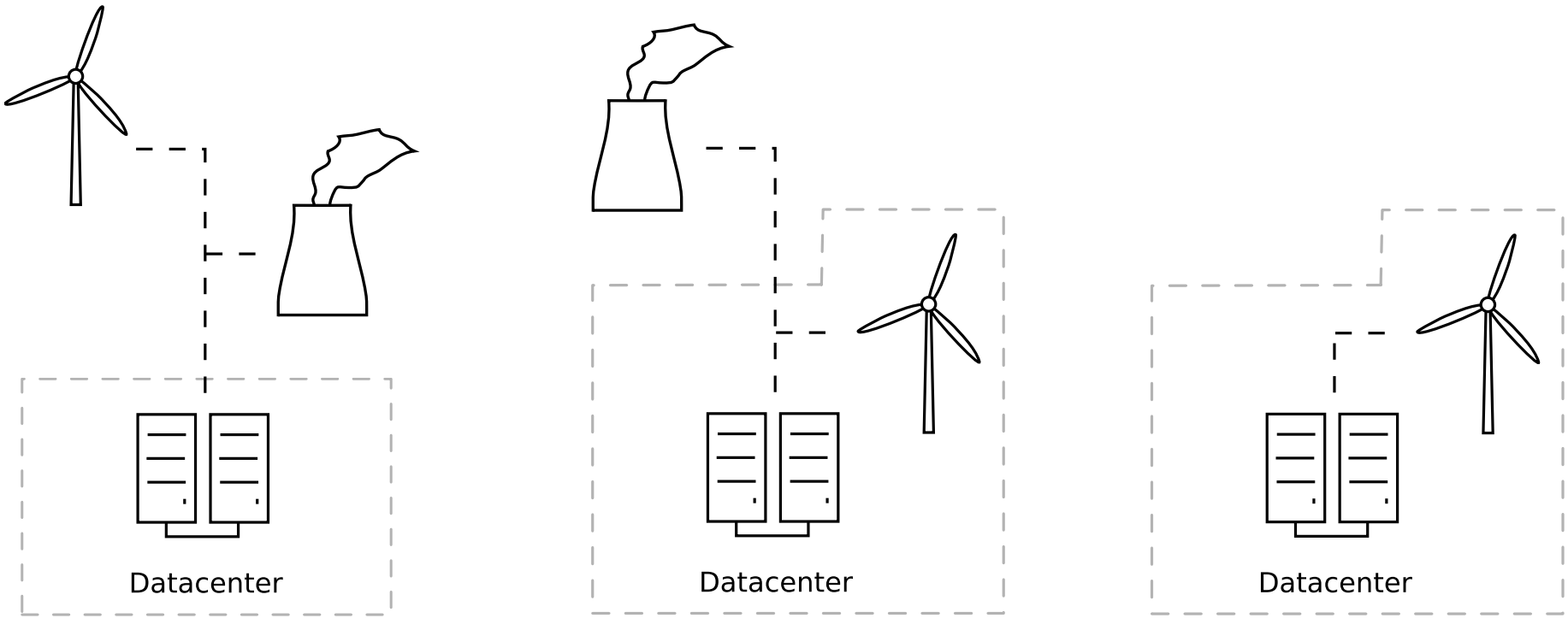

Figure: The 3 main datacenter supply schemes

Selecting a power source: grid or renewables?

The choice of a source mostly depends on:

- Availability and reliability of grid power
- Costs (transmission: 1 MEUR/km)
- Available resources: typical weather conditions, area
- Permitting and regulations (transmission: about 10 years)
- IT application requirements w.r.t. reliability (VOLL: 10-250 EUR/kWh)
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Let's look at grid power pros and cons first:

- Conceptually simple
- Usually reliable but depends on location
- Variable GHG contents: 100% hydro vs. 100% coal
- Cheap if from hydro or nuclear
- Requires large transmission grid with separate supply paths

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- Cost decreased by 77% from 2010 to 2018 (LCOE: 85$/MWh)
- Close to grid parity in some countries
- What about overall costs, i.e., with costs to mitigate variability?

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. . . and most importantly: PV generation is variable and intermittent, unlike conventional generators

Consequence: a very low capacity factor of about 18%

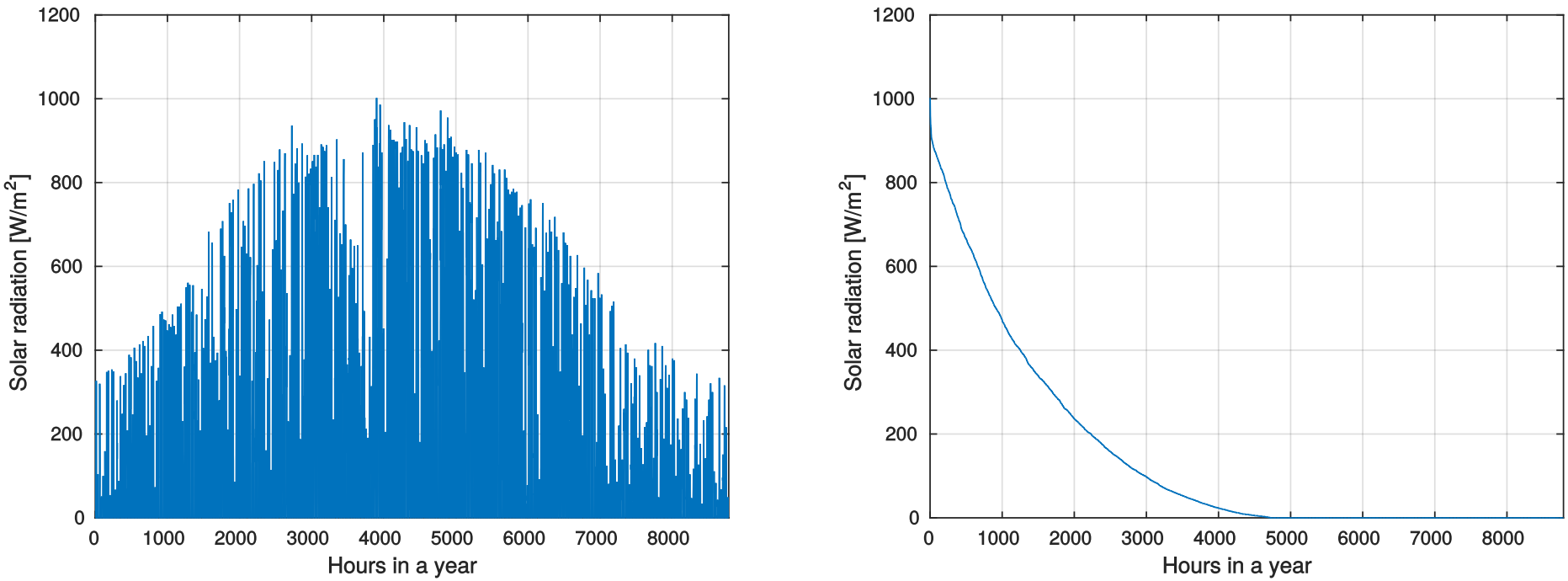

Figure: Solar radiation over a year and duration curve

What about PV now? Some figures

However, generation and demand must match in real-time:
only looking at energy is useless, power **must** be considered

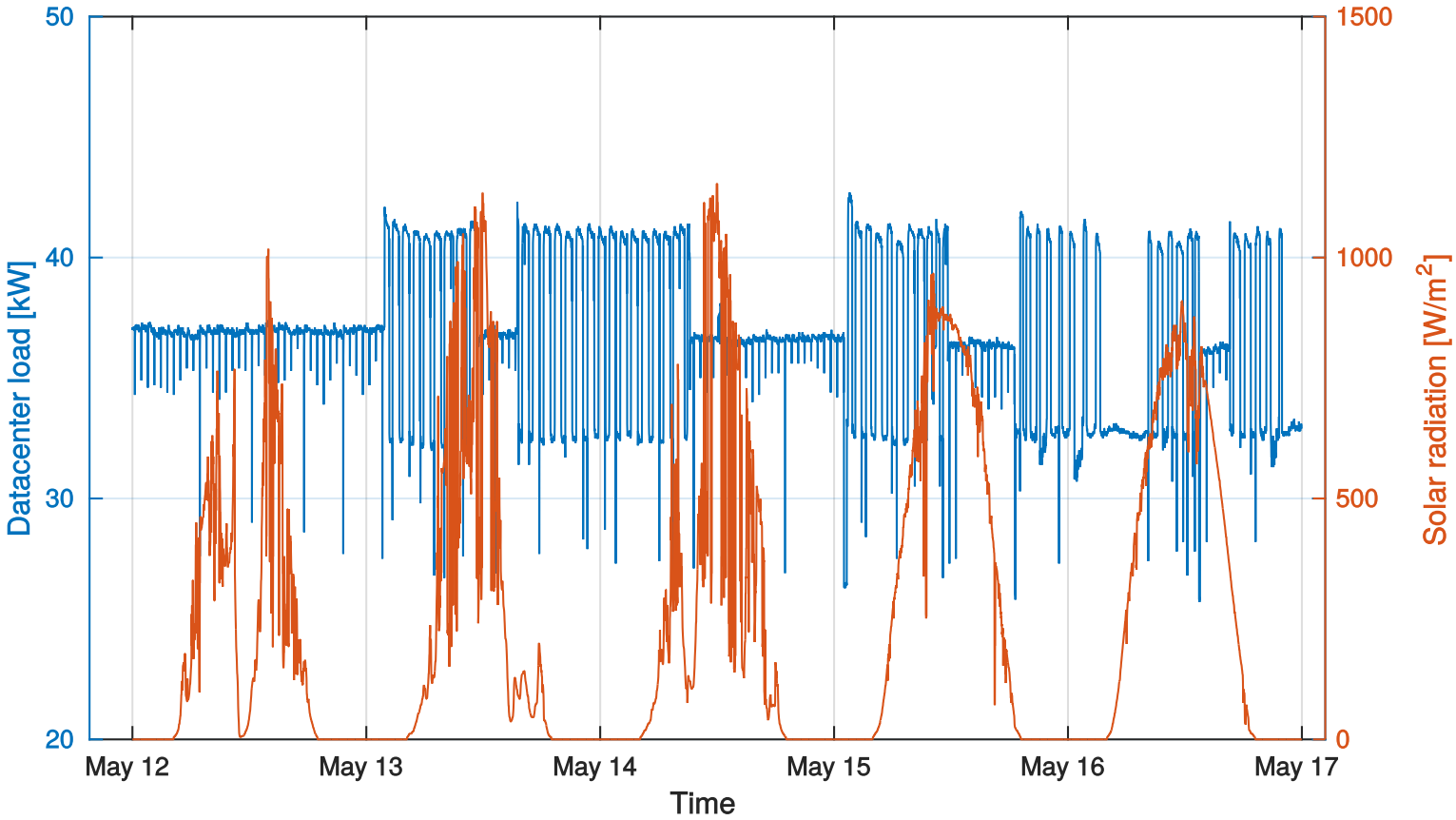

Figure: Comparison of UTBM's datacenter power and solar radiation profiles

Challenge: focus on uncertainty management

Generation is now stochastic, just like demand, but with (much) larger ramps

Forecasting is a challenge, as is uncertainty management

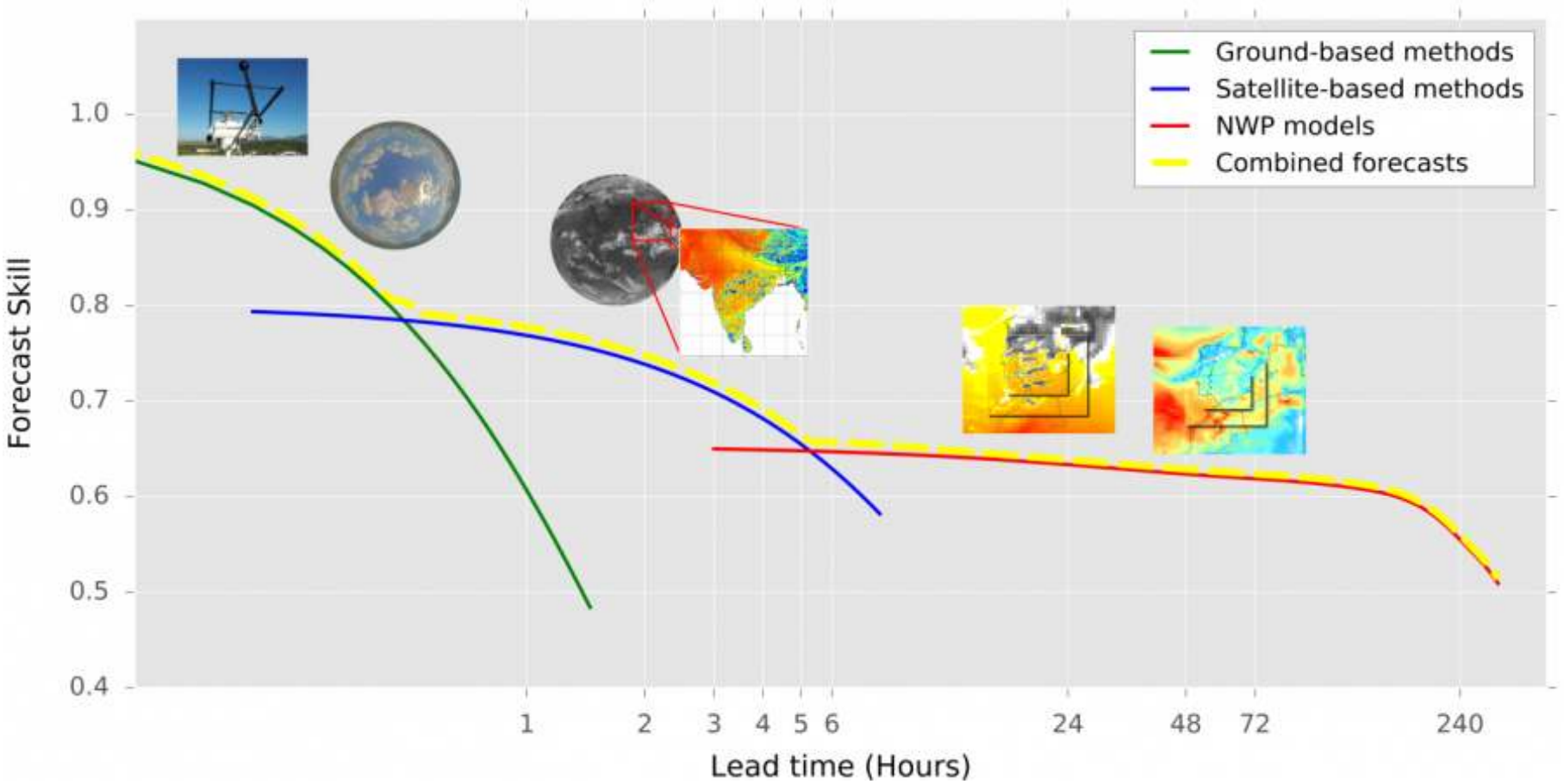

Figure: Solar forecasting horizon, score and technologies

Energy storage

To match generation and demand, energy storage is therefore necessary:

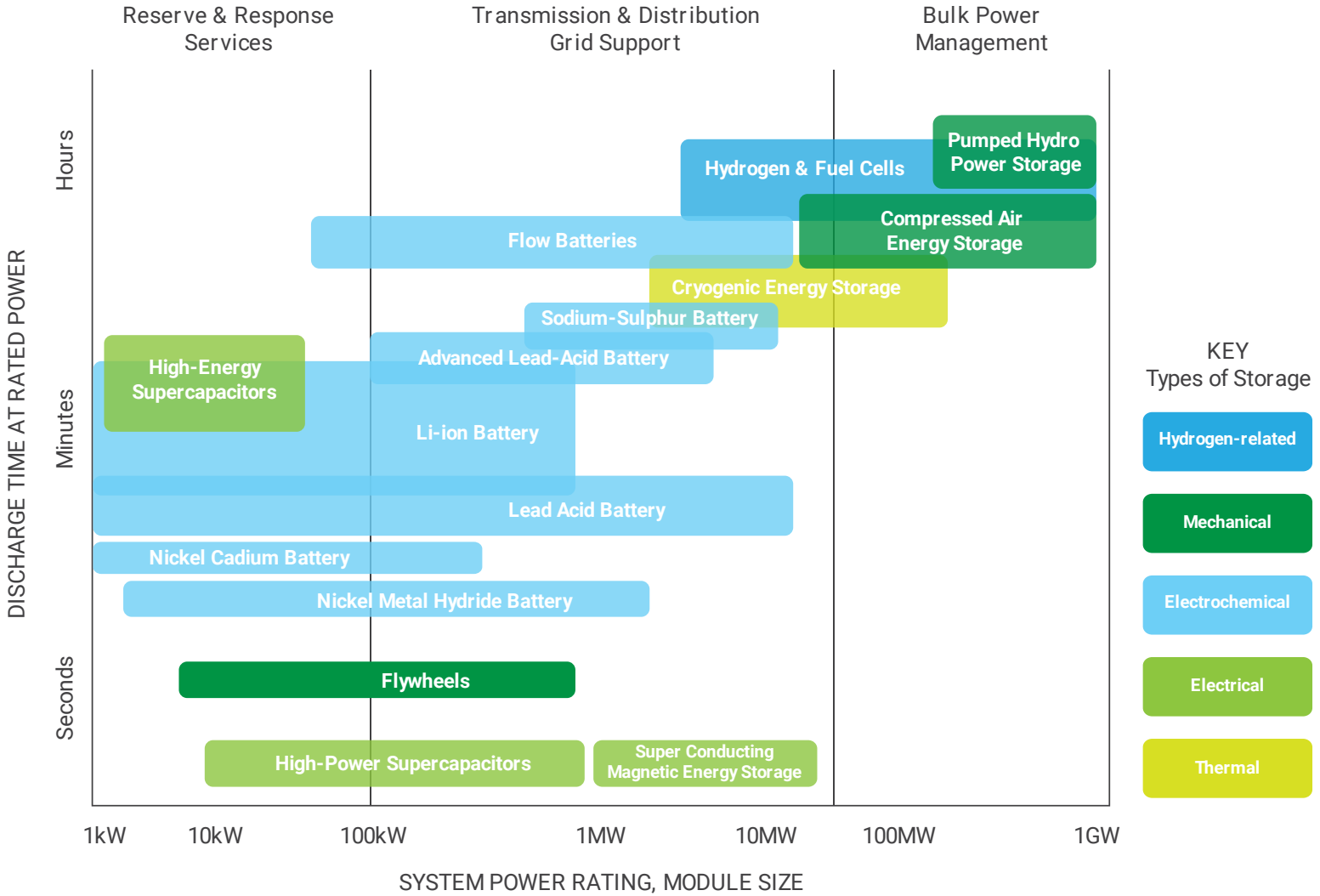

Figure: Power and energy ratings of different storage technologies

Energy storage: focus on hydrogen

Applications:

- Medium to long term storage, high energy
- Replacement of diesel genset / UPS
- Provision of ancillary services
- Co- or tri-generation (electricity, heat, cold)

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Hydrogen solutions only make sense if H_2 is produced from renewable energy!

Other challenge examples

- Sizing of equipment:
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- Integration of multiple time scales (from μs to years)
- Coupling with heat and cooling management
- DC distribution: availability and maturity of equipment? ROI?
- Real-time, ageing-aware security assessment of hybrid systems
- Stability of inertia-less systems
- Cost competitiveness

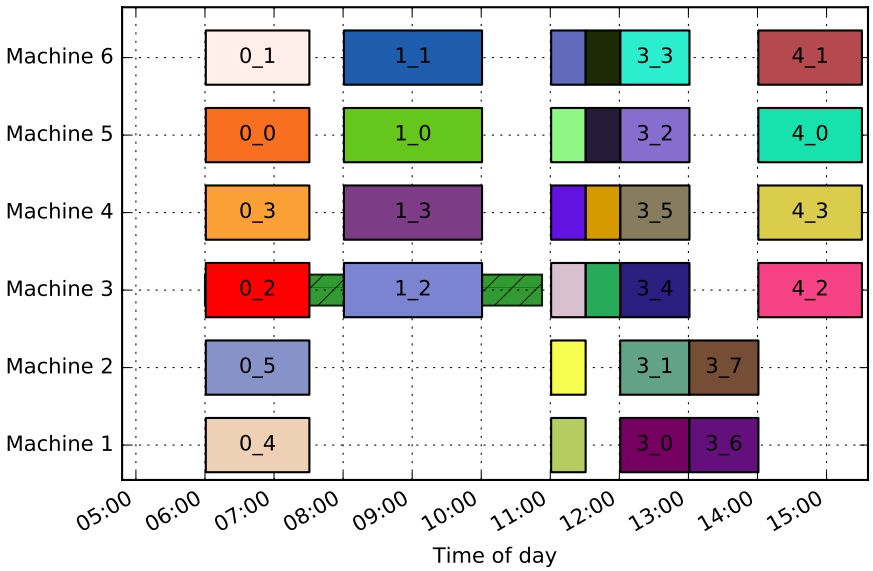
Energy and IT have already deep links

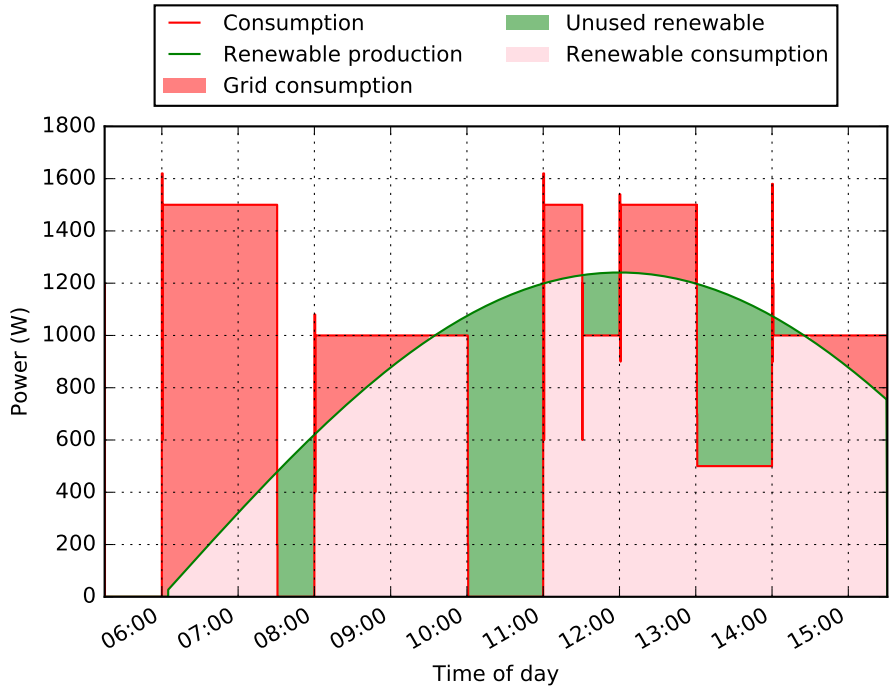
Energy efficiency of large scale distributed systems

- Power models of servers
- Scheduling for heterogeneous servers
  - From a power point of view
  - From a temperature point of view
- Management of uncertainties of tasks (length, workload, ...)

The root of the problem on coarse granularity

Profiles of workload and renewable production are independent





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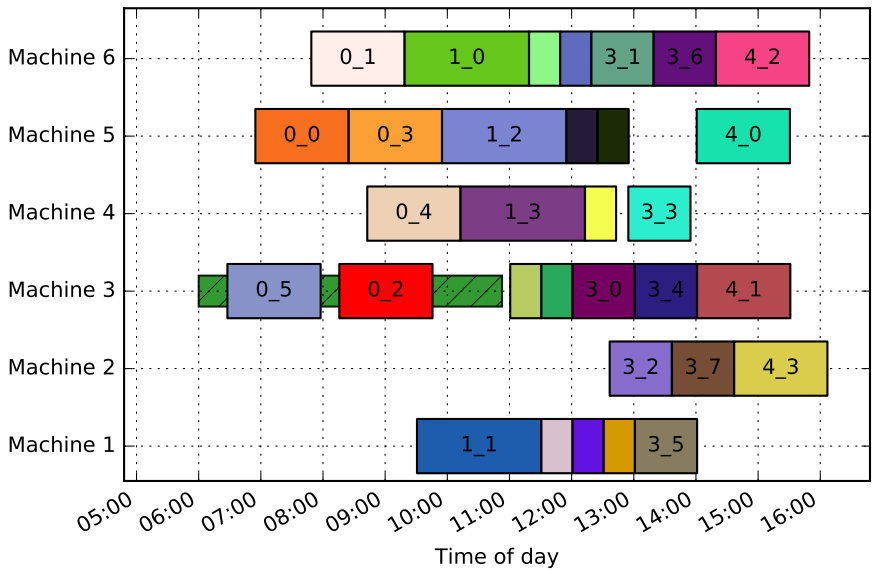
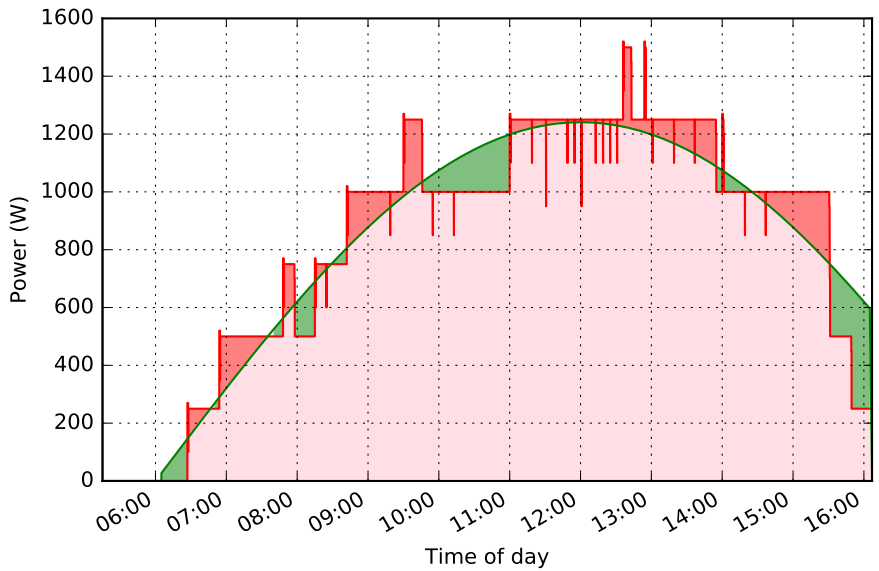


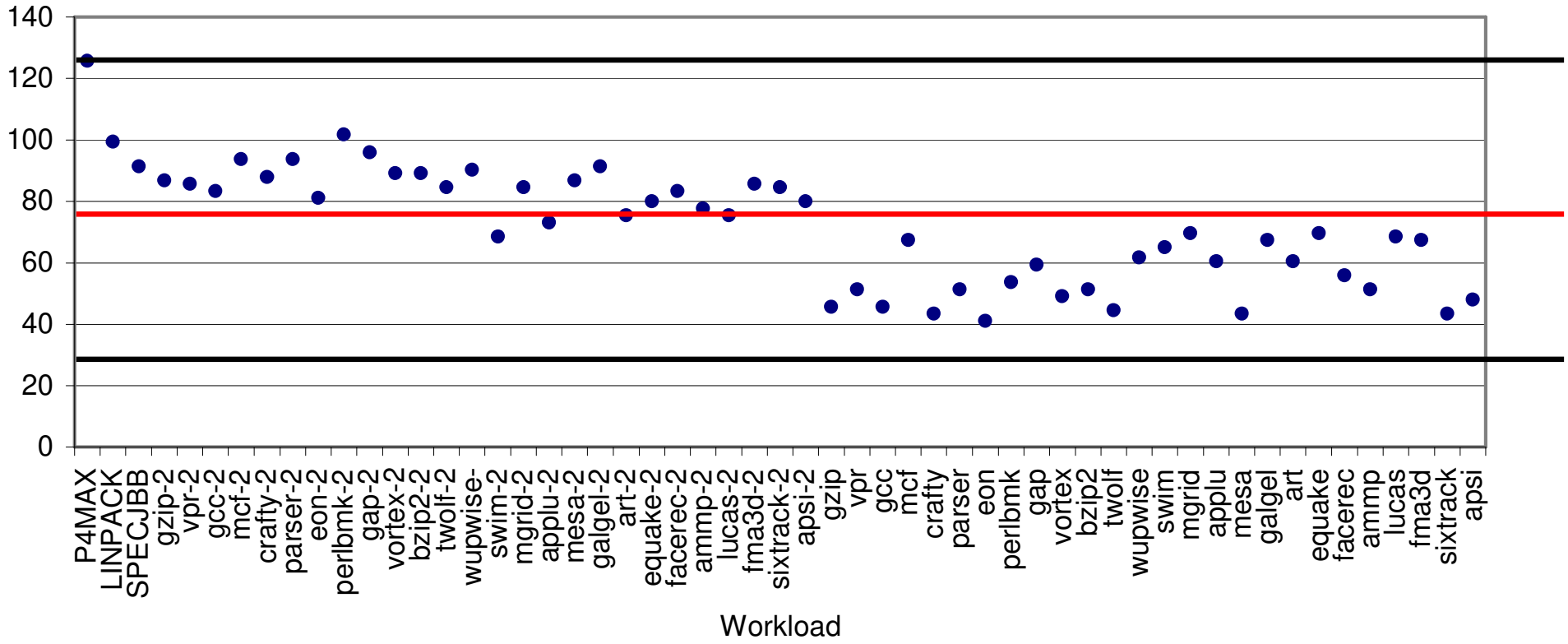


Leverage workload flexibility to follow renewable production

Reactive methods at fine granularity

DVFS and Power Capping

- Scheduling is at the second/minute scale
- DVFS (Dynamic voltage and frequency scaling) and Power Capping



Cooperation of geo-distributed datacenters

Follow the Sun, Follow the Wind

- Sharing of energy production
- Computation follow energy production

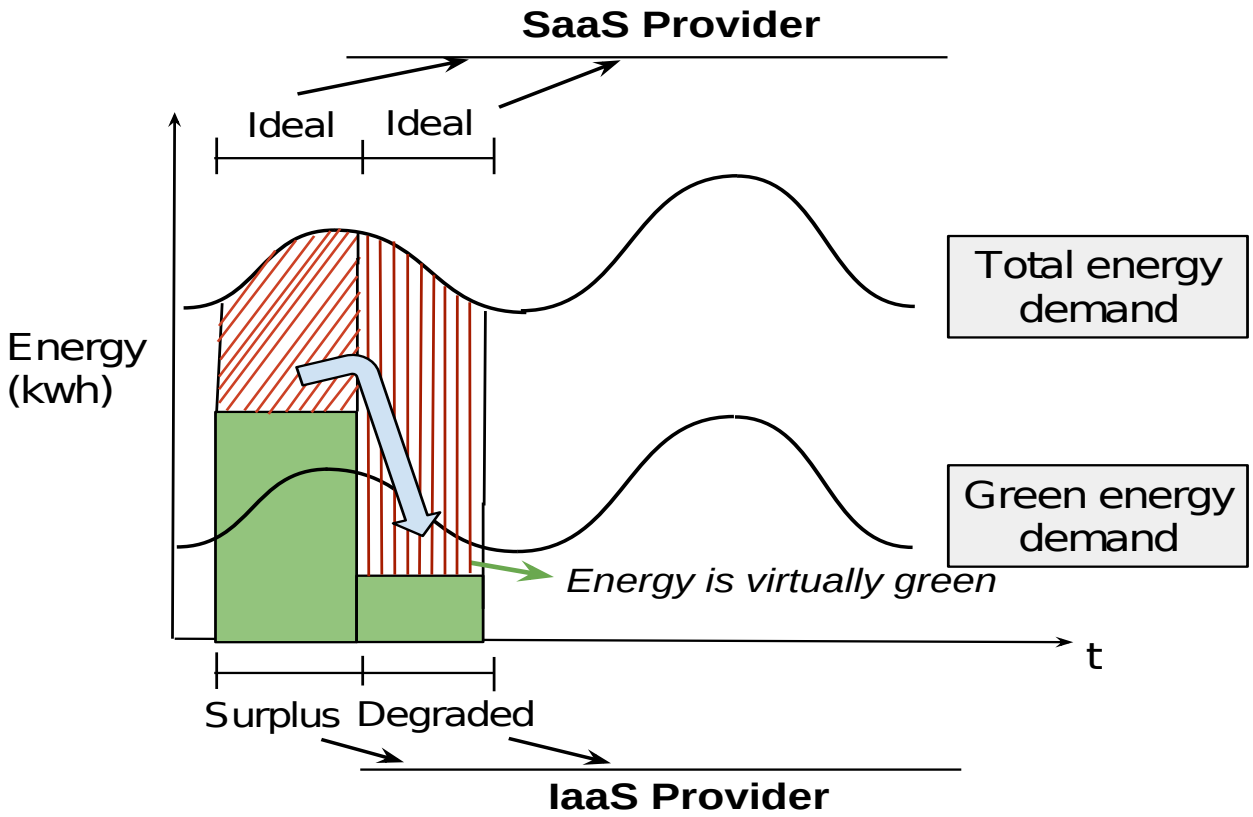
Environmental flexibility

- Use server (room) temperature as energy buffer
- Cool when excess renewable energy
- Reduce cooling when energy is lacking

Adapting contract

New economical interactions through green SLAs

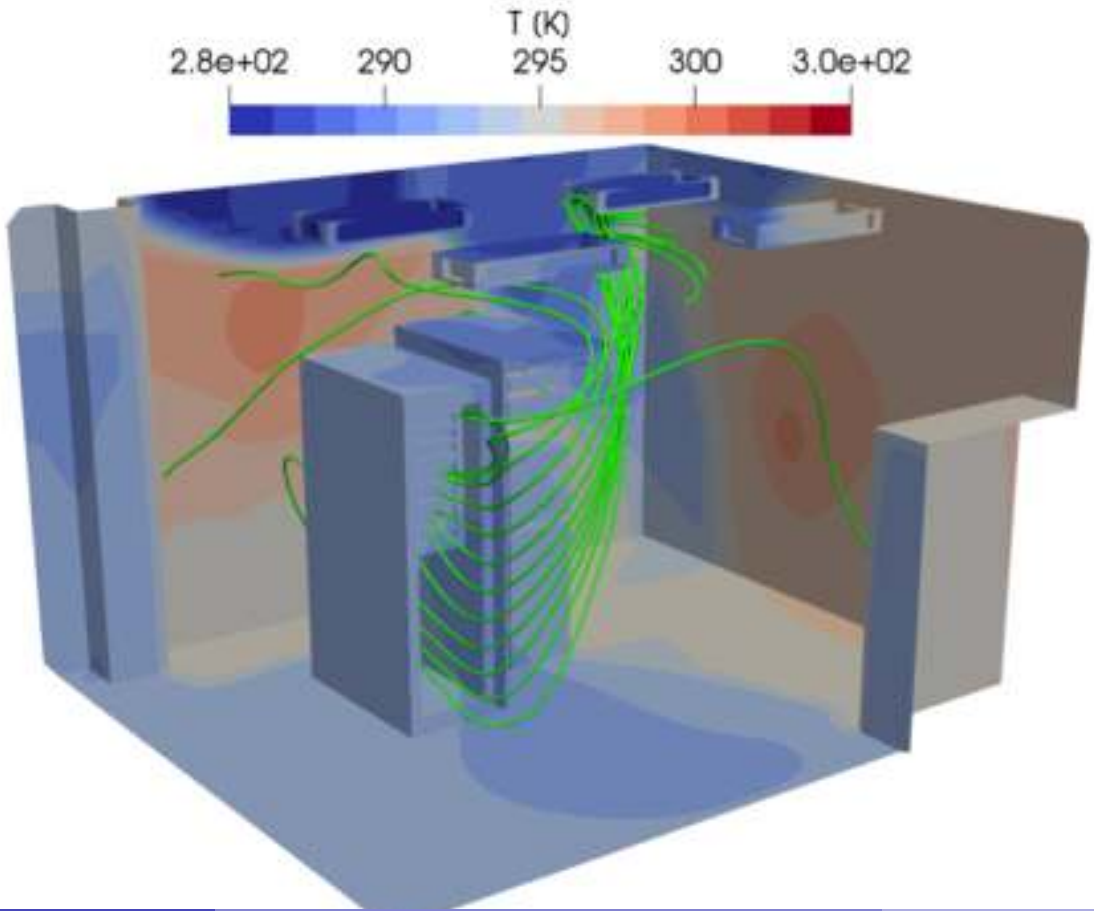
- Capability to express electricity source in SLA
- Implicit: Different prices depending on Green/Brown energy
- Explicit: Energy source as a constraint (Best-effort)



Experimental and simulation platforms

Validation of theoretical approaches

- Co-simulation: from electrical to IT simulation
  - Low availability of full stack platform (example SeDuCe, Catalyst)
  - Complexity of models from electricity to thermal one
- Low availability of users/operators/SLAs models and precise behaviors
- Comparison and reproducibility are difficult and no consensus on metrics



Conclusion

We can observe:

- Progress in renewables integration
- Progress in IT flexibility and efficiency
- Multiple challenges to tackle in both fields
- Need of joint work between the two communities

A literature survey paper was written by the DATAZERO team and is currently under review

The round table will enable us to discuss these topics