University of Glasgow

School of Computing Science

Towards zero-carbon computing

The need for low carbon and sustainable computing

June 2021

Wim Vanderbauwhede

Global context

IPCC Sixth Assessment Reports:

- Greenhouse gas emissions must be cut drastically to keep global warming below 1.5°C (IPCC WGI AR6 report).
- They must be cut *now*, we can't afford to wait anymore (IPCC WGI, "Physical Science Basis", AR6 report).
- This is incompatible with unlimited economic growth (IPCC WG III, "Mitigation", AR6 report).

Frugal computing

Computational resources are finite

- Since the 1970s, we have been using increasing amounts of computational resources.
- Growth of performance per Watt has been exponential (Moore's law)
- As a result, increasing use of computational resources has become pervasive in today's society.
- Computational resources have until recently effectively been treated as infinite.

Computational resources are finite

- Growth in demand cannot be offset by increased power efficiency.
  - Moore's law can’t save us (“*the free lunch is over*”).
  - With business as usual, the carbon footprint from computing will become a major contributor to the world total.
- The carbon footprint of device production is also huge.
  - Moore's Law has led to very short lifetimes of compute hardware.
  - The current rate of obsolescence is entirely unsustainable.

We need *frugal* computing

- As a society, we need to start treating computational resources as finite and precious, to be utilised only when necessary, and as frugally as possible.
- As computing scientists, we need to ensure that computing has the lowest possible energy consumption.
- And because the lifetimes of compute devices needs to be extended dramatically, we must achieve this with the currently available technologies.

The scale of the challenge

Meeting the climate targets

Avoiding catastrophic warming

- To limit global warming to below 1.5°C by 2040, a global reduction from 55 to 13 Gtonnes per year is needed.
- Emissions from electricity are currently about 10 $GtCO_2e$.
- Renewables will provide 30% of electricity by 2040.
- Reducing the energy consumption is the only way to avoid catastrophic warming.

The carbon cost of computing

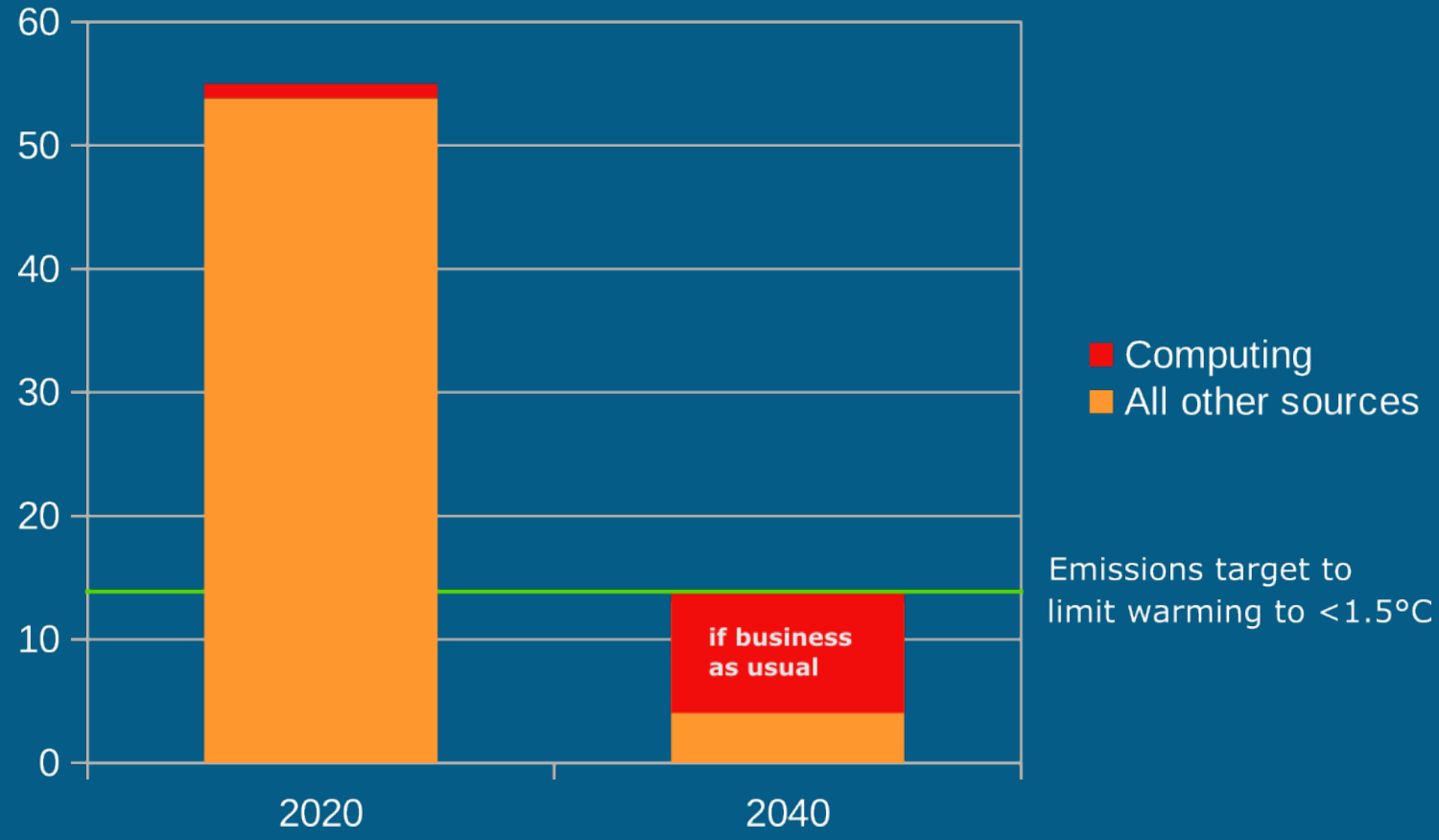
Emissions from using computing

- In 2020, emissions from using computing were between 3.0% and 3.5% of the total.
- By 2040 this will grow to 14% (4x).
- By 2040, energy consumption of compute devices would be responsible for 5 Gtonnes of CO_2

Emissions from production

- Emissions from the production of computing devices exceed those incurred during operation.
- Taking into account this carbon cost of production, computing would be responsible for 10 Gtonnes of CO_2 by 2040,
- This is almost 80% of the acceptable CO_2 emissions budget of 13 Gtonnes of CO_2.

Emissions from computing and other sources



Towards zero carbon computing

Transforming computing

- In less than two decades, we need a radically transformation of the global use of computational resources to meet the climate targets.
- We must dramatically reduce the carbon cost of both production and operation of computing.

Extending the useful life

- We can't rely on next-generation hardware technologies to save energy: the production of this next generation of devices will create more emissions than any operational gains can offset.
- It does not mean research into more efficient technologies should stop.
- But their deployment cycles should be much slower.
- Extending the useful life of compute technologies to several decades must become our priority.

Extending the useful life

- We need a change in business models as well as consumer attitudes. This requires:
  - raising awareness and education;
  - providing incentives for behavioural change;
  - provide economic incentives and policies;
  - infrastructure and training for repair and maintenance.

A vision for computing science

- Develop the computing science to extend the useful life of our devices and increase their capabilities.
- With every advance, effectiveness will increase without any increase in energy consumption.
- Computing technologies for the next generation of devices will increase energy efficiency and lifetime.
- Every subsequent cycle will last longer, until finally the world will have computing resources that last forever and hardly use any energy.

To make this vision reality

- This necessity is a great opportunity for computing scientists in all fields. A few examples:
- We must design software at all layers (firmware, operating system, libraries, applications) to support extended lifetimes. This involves research into algorithms, programming language, systems, human-computer interfaces etc.

To make this vision reality

- We need better software engineering strategies to handle the extended software life cycles, and in particular deal with technical debt.
- Longer life means more opportunities to find vulnerabilities, so we need advances in cyber security.
- We need to develop new approaches to reduce overall energy consumption across the entire system: clients, networks and servers.

Thank you!

For more details and references

https://wimvanderbauwhede.github.io/articles/frugal-computing/