Computing for the Future of the Planet

Andrew Rice
June 2008

Computing for the Future of the Planet

Andrew Rice
June 2008

Long term research goals for computing
what technology will we need in 100 years?

Cambridge University

- **Colleges and Departments**
  - College looks after the students' well-being
  - Department is responsible for teaching
- **32 Colleges**
  - 1284 (Peterhouse) to 1977 (Robinson College)
- **Computer Laboratory**
  - Founded in 1937 as the Mathematical Laboratory
  - Diploma started in 1953, first CS course in the world

University Library

Legal deposit library

Entitled to claim a free copy of all books, journals, maps, and printed music published in the UK or Ireland
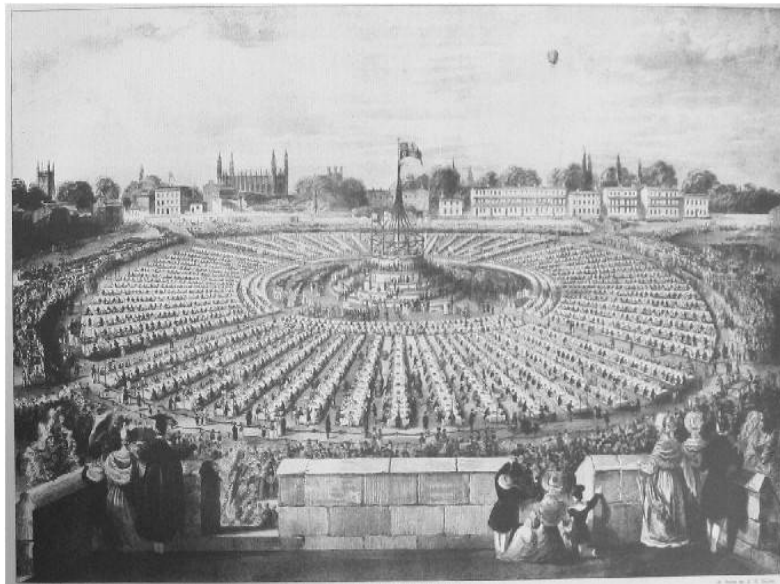
Holds over 7 million volumes
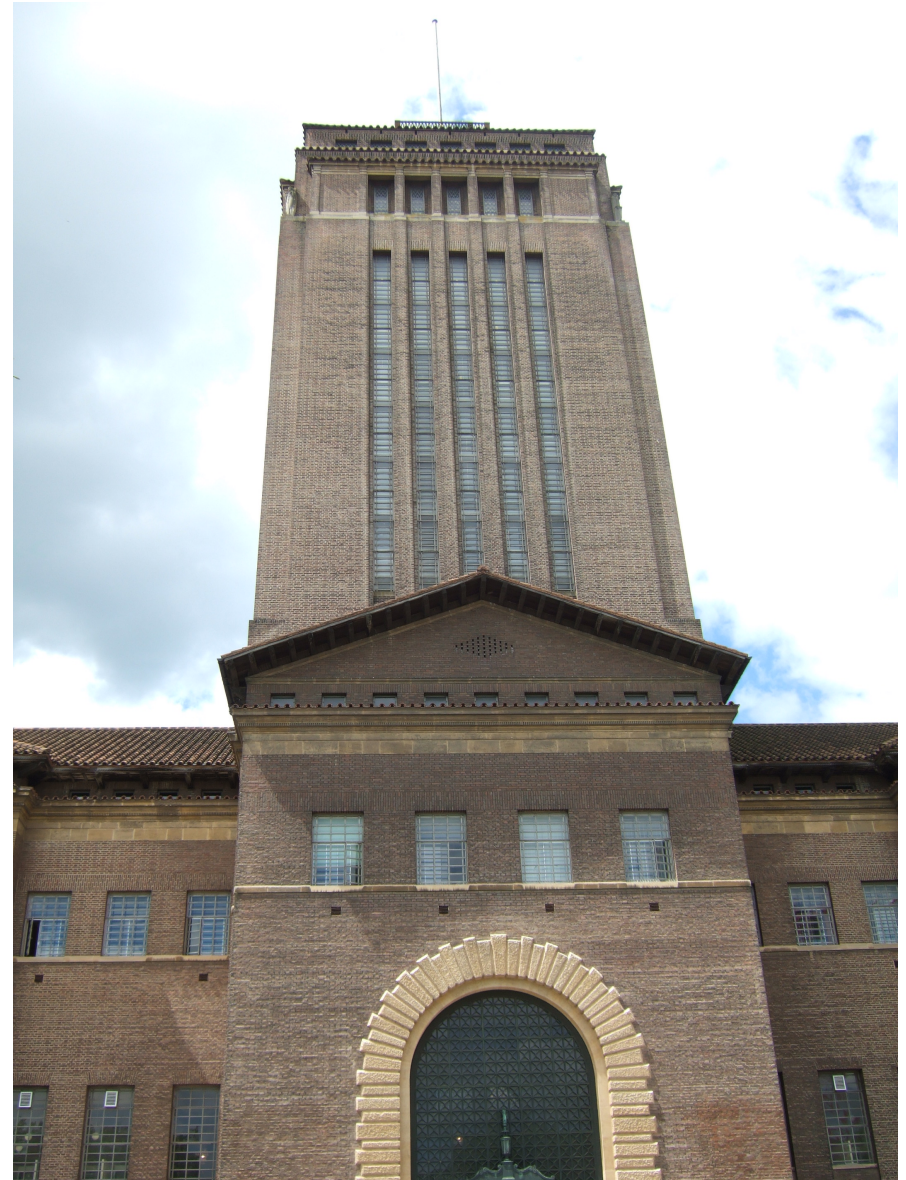
Parker's Piece

Here on Parker's Piece, in the 1800s, students established a common set of simple football rules emphasising skill above force, which forbade catching the ball and 'hacking'. These 'Cambridge Rules' became the defining influence on the 1863 Football Association rules.

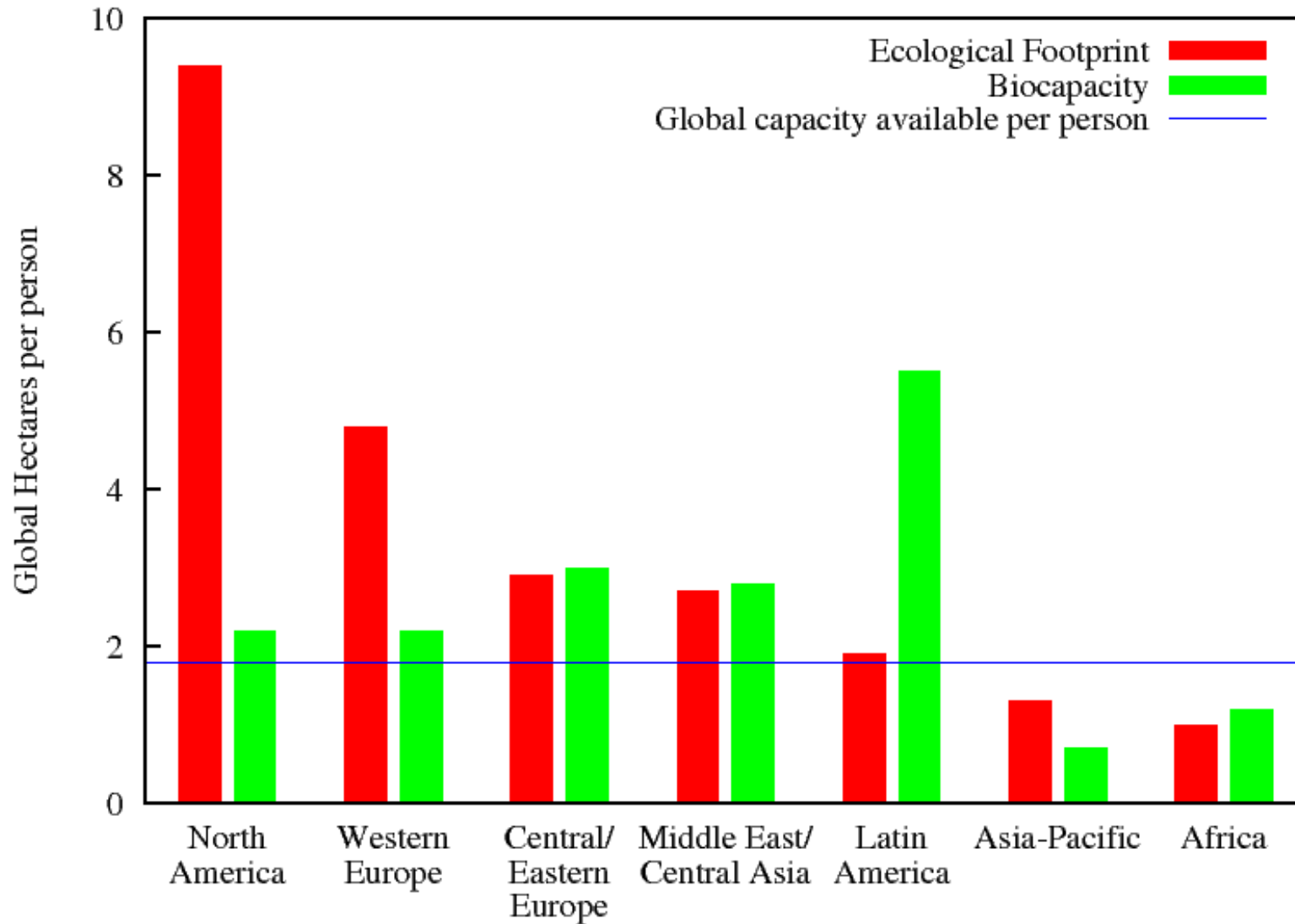1838: a feast for 15,000 guests to celebrate the coronation of Queen Victoria.

Punting

We consume a lot of energy

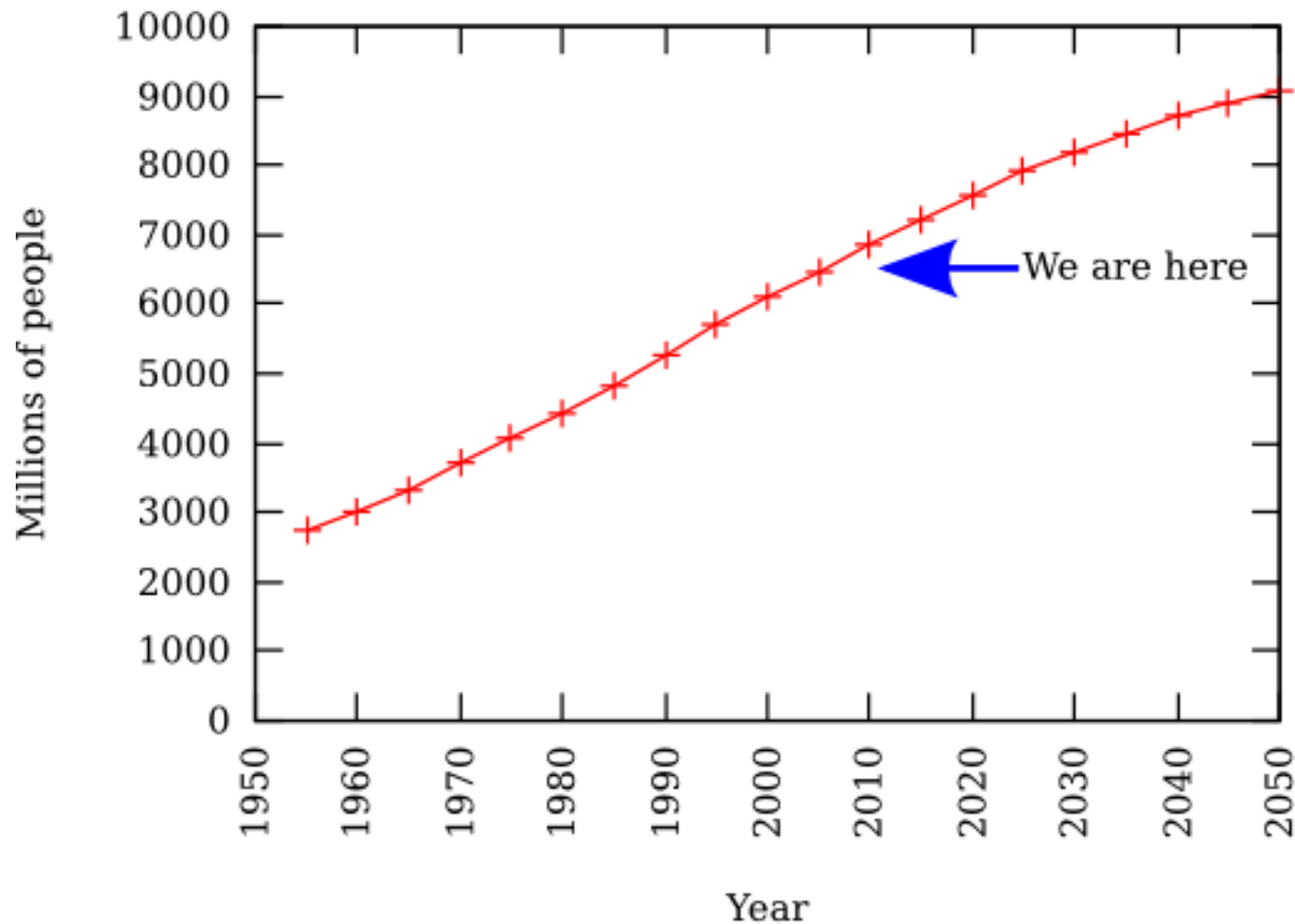Globally consumed: 5×10^{20}J in 2005
per person: 8MJ

This is approximately the same as boiling a kettle
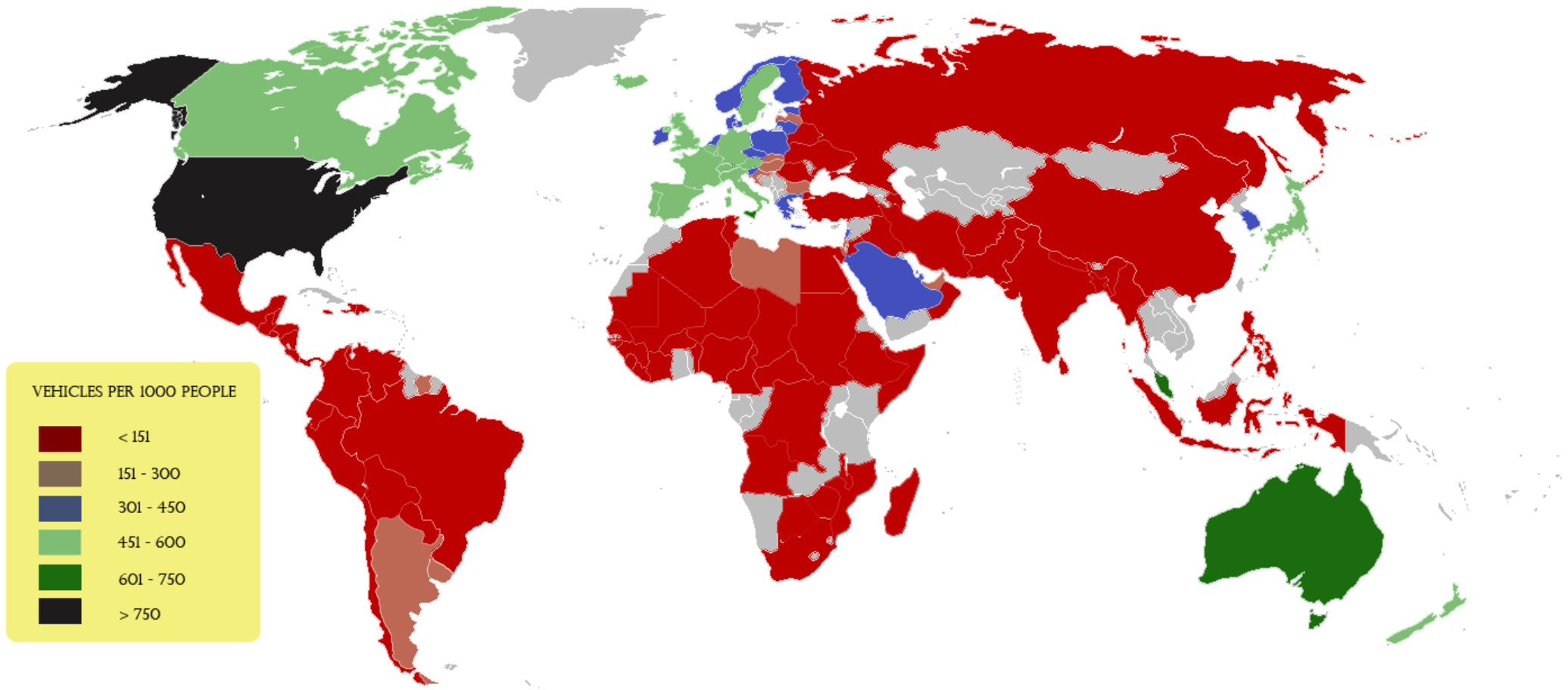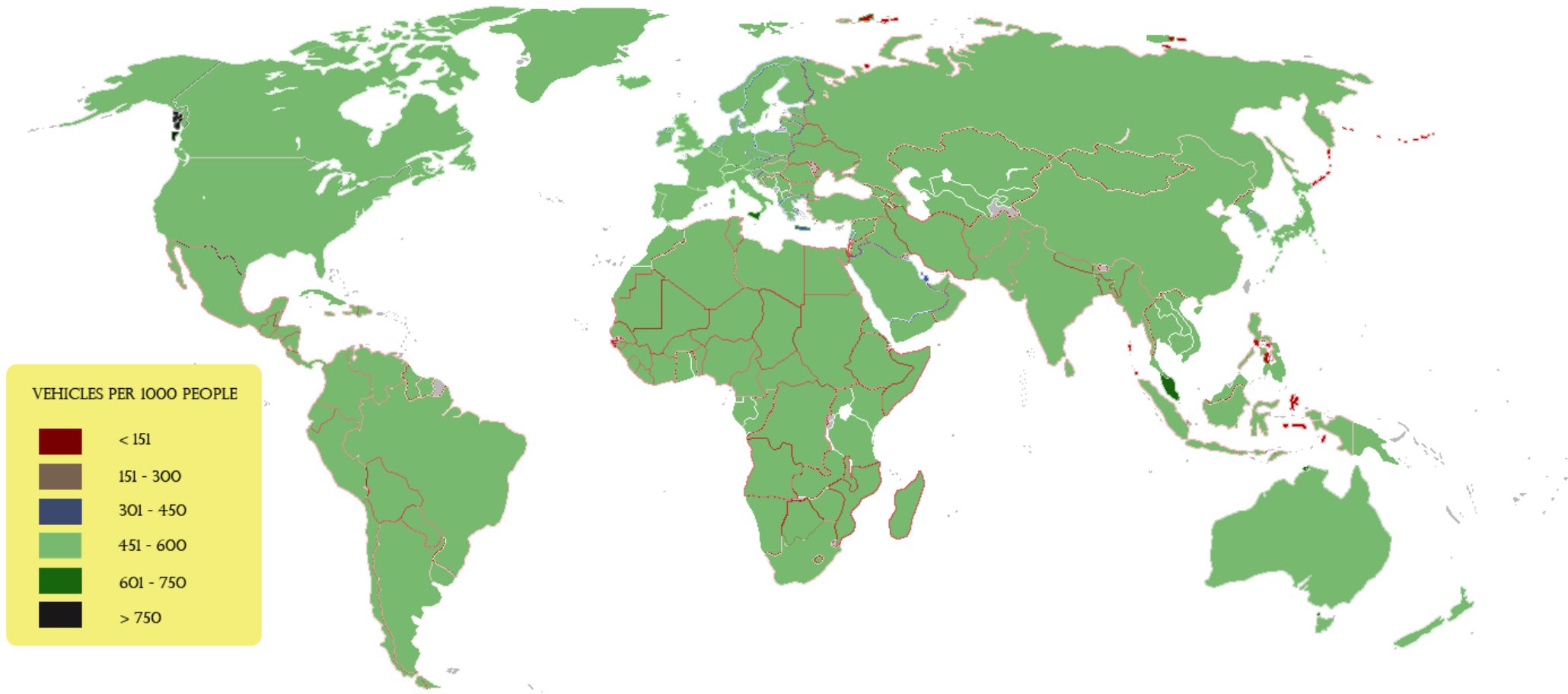for a year

We consume too many resources

Kitzes, J., Wackernagel, M., Loh, J., Peller, A., Goldfinger, S., Cheng, D., Tea, K. 2008 Shrink and share: humanity's present and future Ecological Footprint. Philosophical Transactions of the Royal Society 363, 467–475. (DOI 10.1098/rstb.2007.2164.)

Population growth will negate all our efforts

890 million cars in the world

VEHICLES PER 1000 PEOPLE

- < 151
- 151 - 300
- 301 - 450
- 451 - 600
- 601 - 750
- > 750

2003 World Bank and CIA Factbook

2800 million cars in the world

VEHICLES PER 1000 PEOPLE

- < 151
- 151 - 300
- 301 - 450
- 451 - 600
- 601 - 750
- > 750

2003 World Bank and CIA Factbook

3900 million cars in the world

Year: 2050

World population: 9 billion

VEHICLES PER 1000 PEOPLE

■ (dark red)	< 151
■ (brown)	151 - 300
■ (blue)	301 - 450
■ (light green)	451 - 600
■ (dark green)	601 - 750
■ (black)	> 750

2003 World Bank and CIA Factbook

An 80% cut in emissions is needed

We go from 890 million cars to 3900 million cars

Must cut emissions by 80% in order to keep them at the current level

Can computing provide alternatives?

Optimal Digital Infrastructure

- Servers and cooling account for few percent of our total energy usage

- Its growing fast

Koomey, J. G. 2006 Estimating Total Power Consumption by Servers in the U.S. and the World. Lawrence Berkeley National Laboratory, Berkeley, CA.

We need more computing

% of the population with Internet access

66%	United Kingdom
71%	USA
10%	South Africa
4%	Uganda
21%	World

http://www.internetworldstats.com/stats.htm

Satellite Links

Cellular networks

Low infrastructure networks

Delay tolerant networks
(Haggle project)
Trade physical
infrastructure for
digital infrastructure

Servers are often underutilised
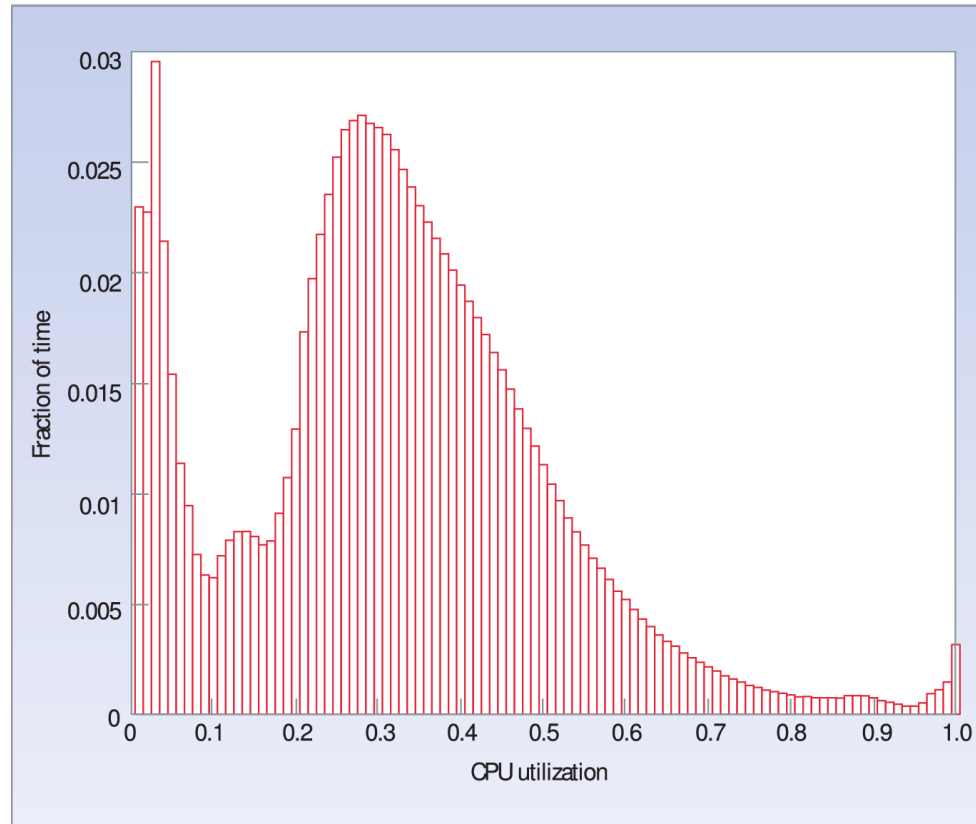
Figure 1. Average CPU utilization of more than 5,000 servers during a six-month period. Servers are rarely completely idle and seldom operate near their maximum utilization, instead operating most of the time at between 10 and 50 percent of their maximum utilization levels.

Consolidation

Load concentration

Migration

Very little energy actually gets to our servers
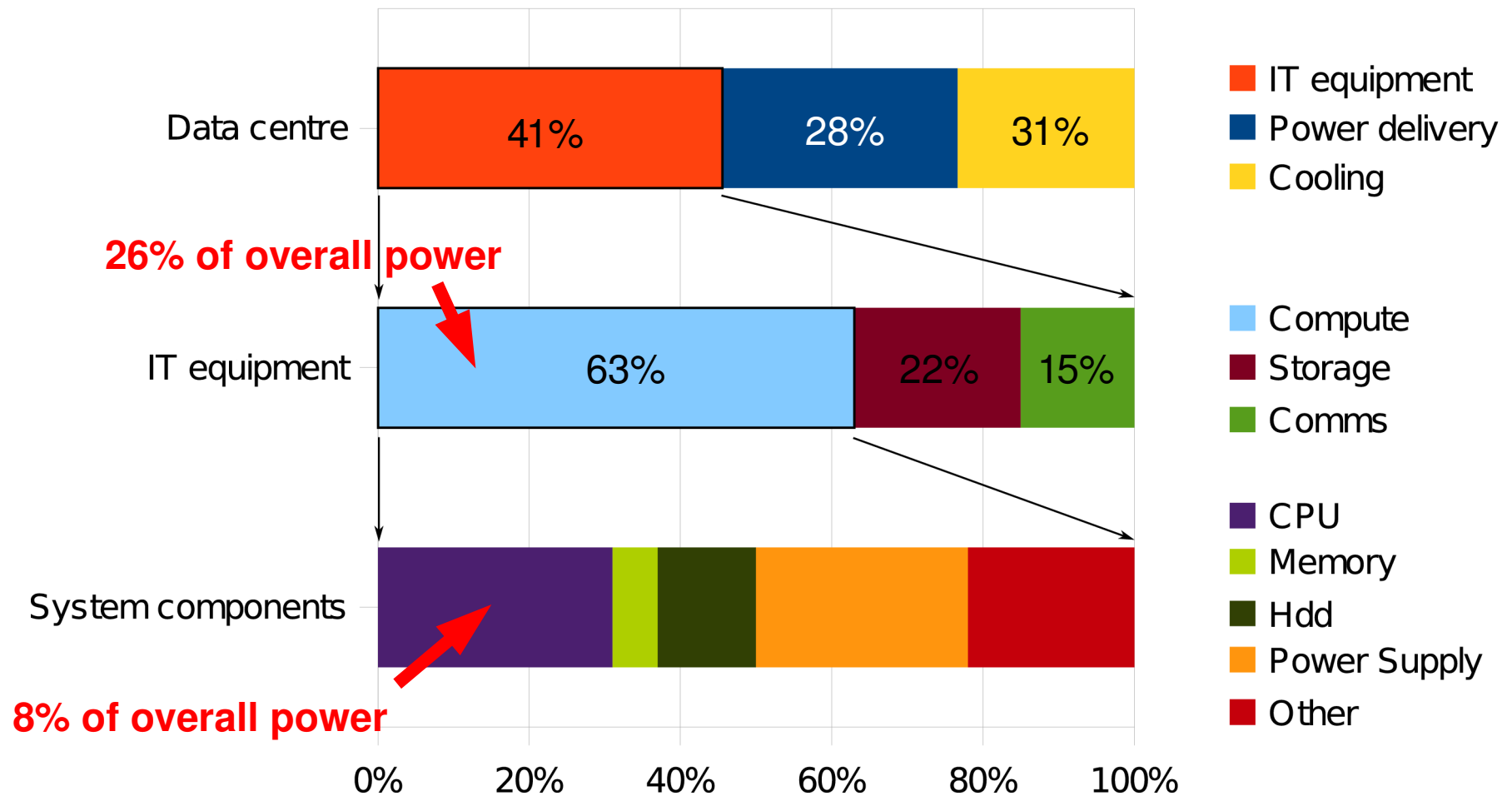
Source: Data Center Efficiency in the Scalable Enterprise,
Dell Power Solutions, Feb 2007

Server power consumption
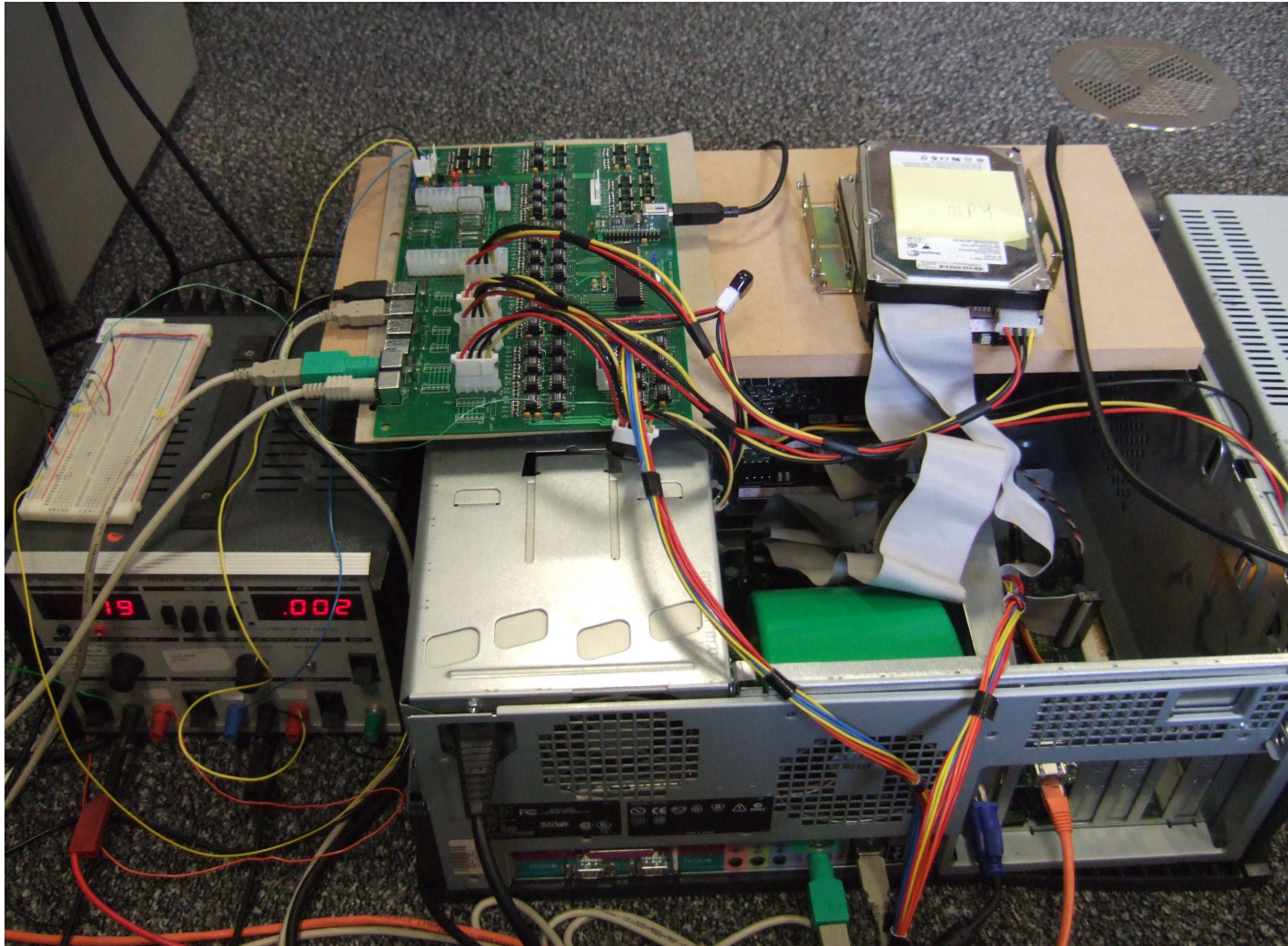
Anthony Hylick

Writing data is cheaper than reading

Energy vs. LBN
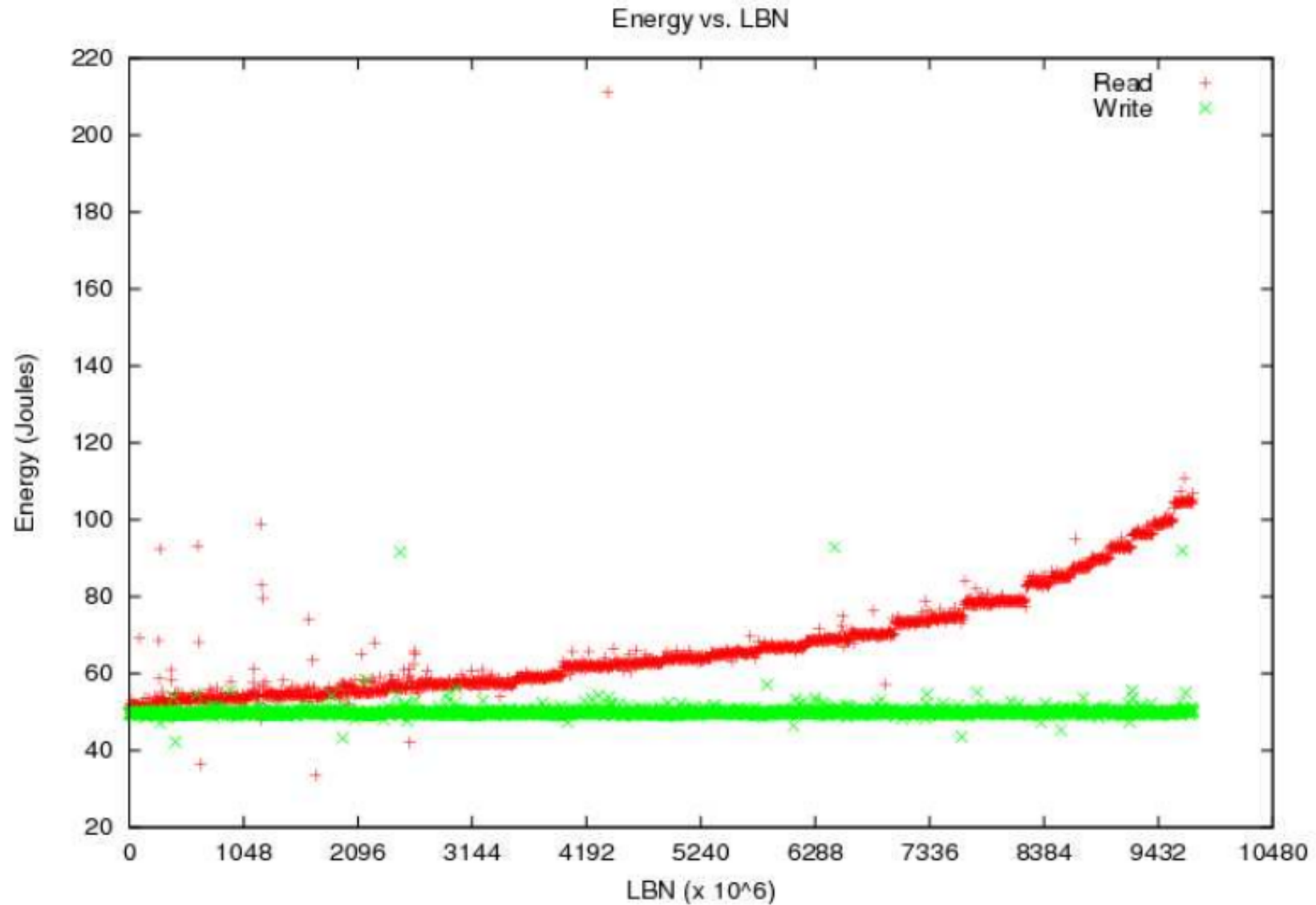
Anthony Hylick

Moving datacentres to renewable energy sources
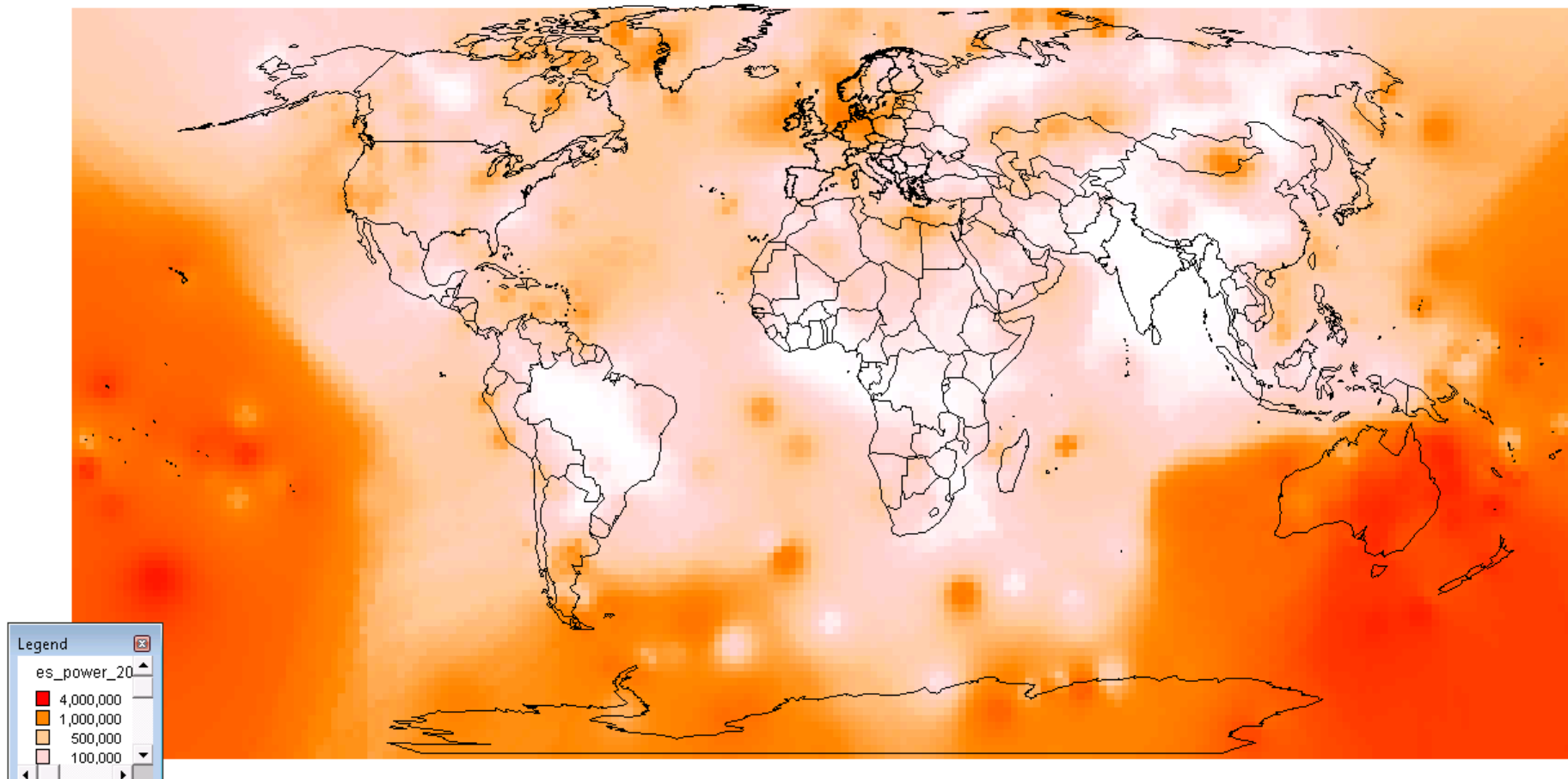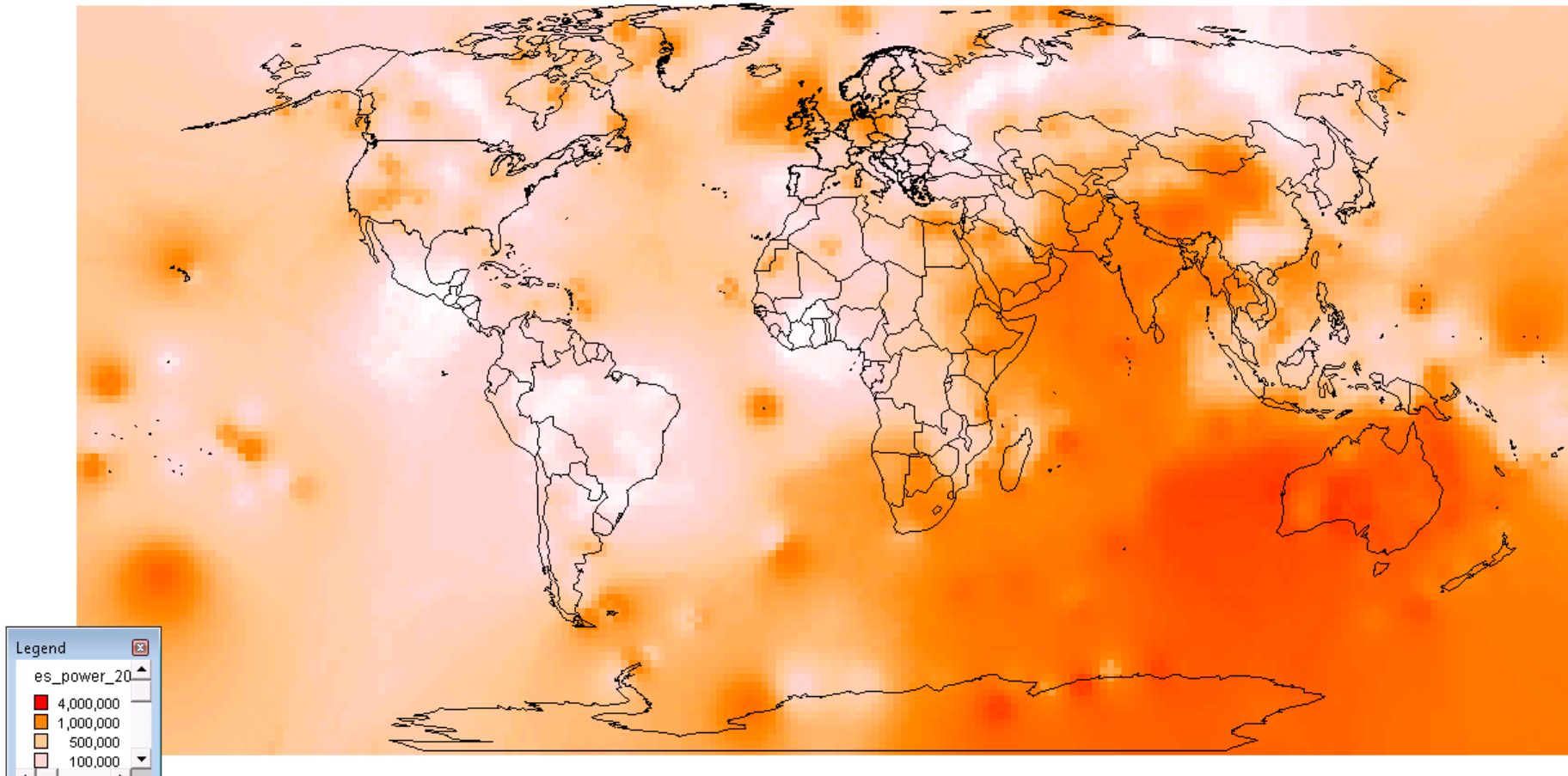
Sherif Akoush

Energy available from Wind + Solar

Legend
es_power_20
4,000,000
1,000,000
500,000
100,000

Sherif Akoush

Energy available from Wind + Solar

Sherif Akoush

Energy available from Wind + Solar

Sherif Akoush

Energy available from Wind + Solar

Sherif Akoush

Cloud cover

Sherif Akoush
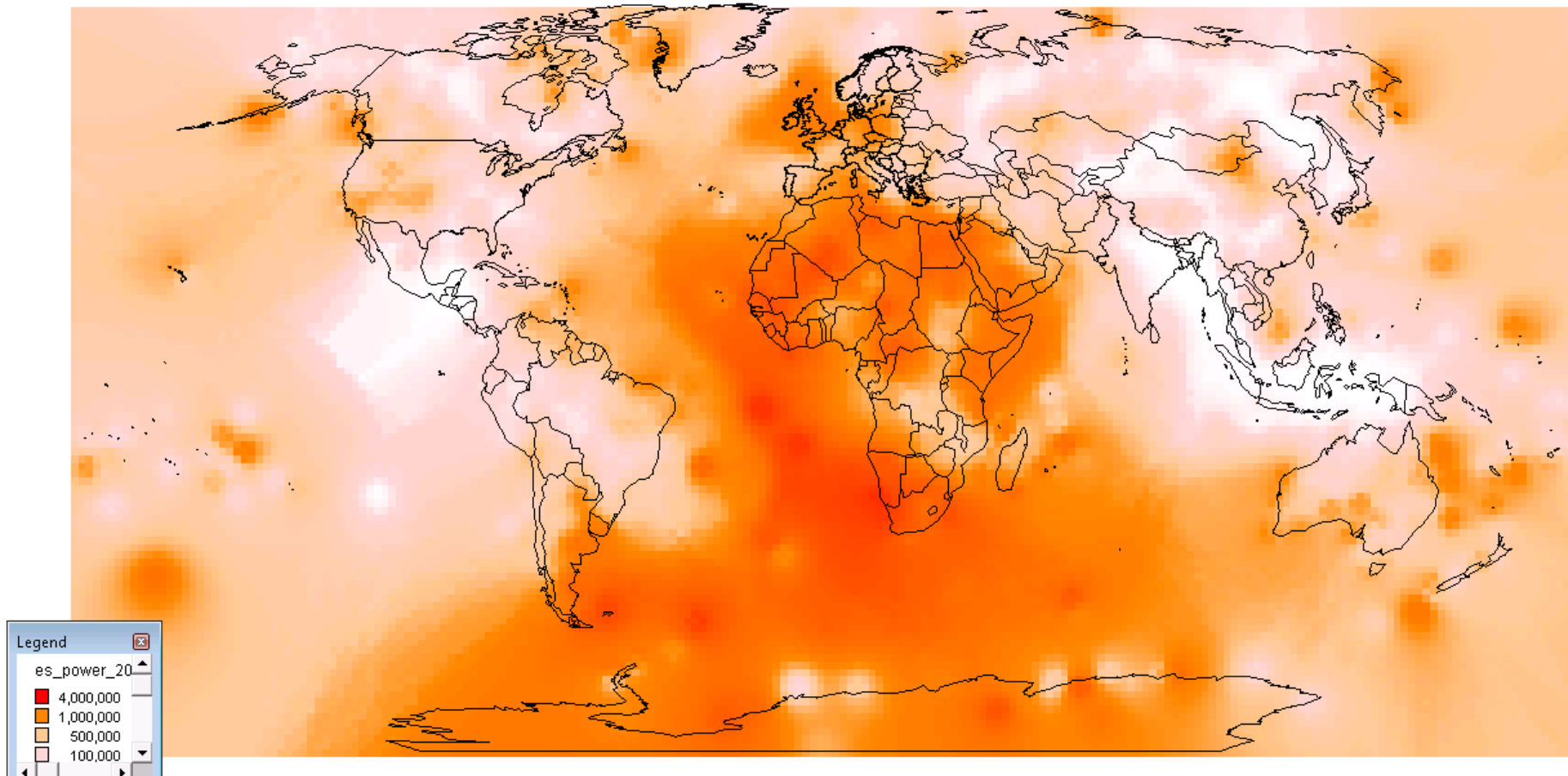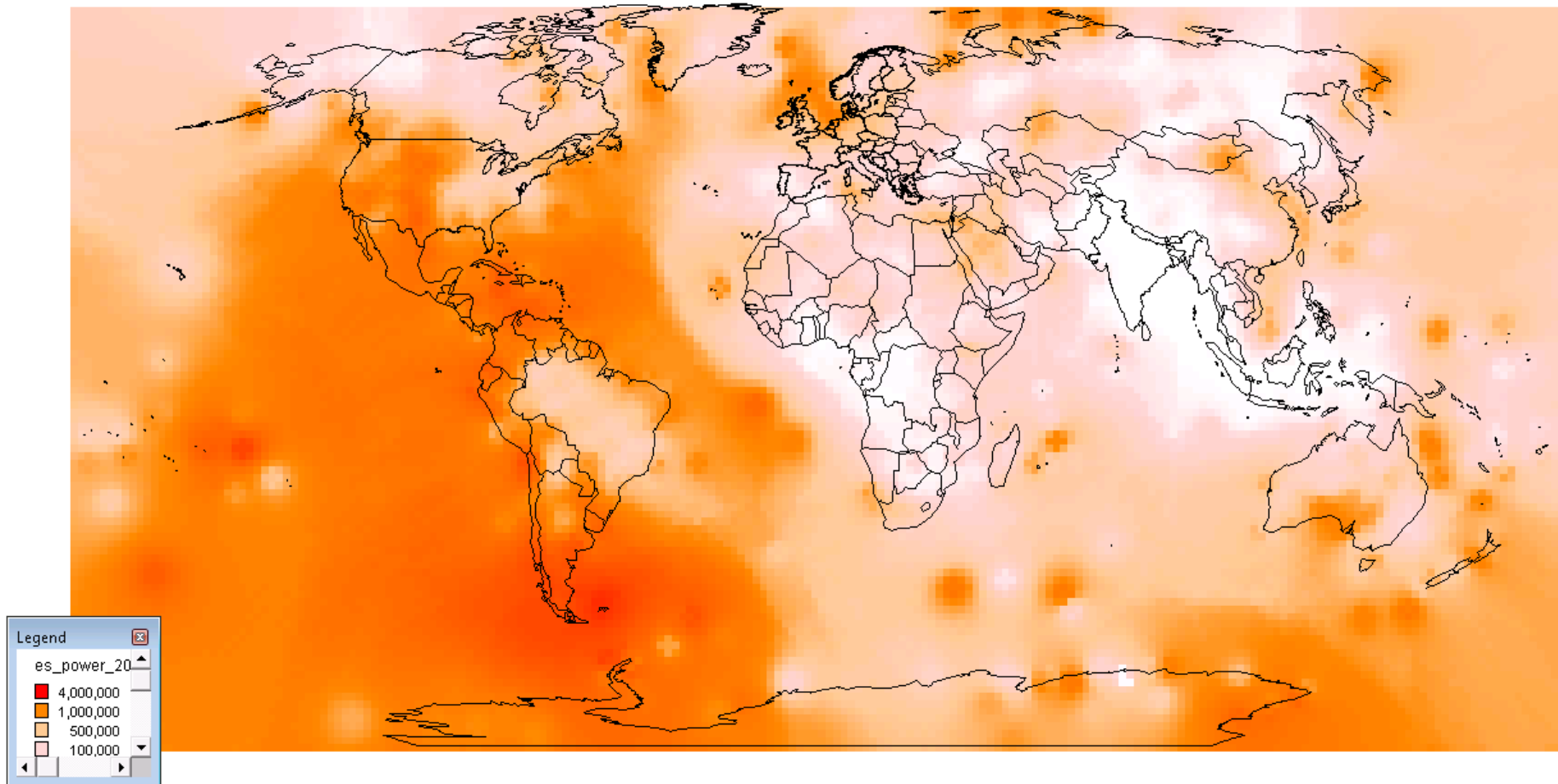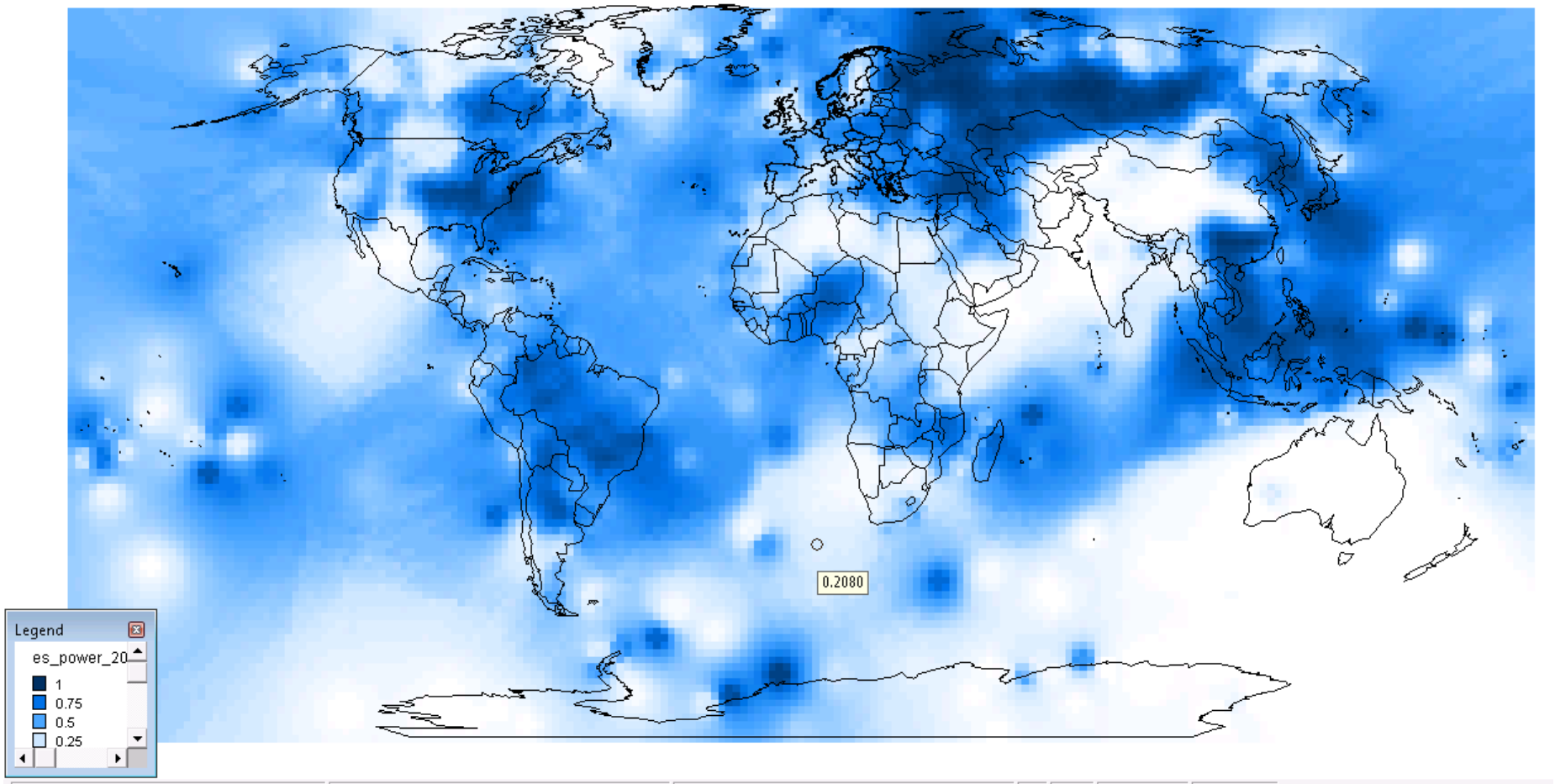
Optimal Digital Infrastructure
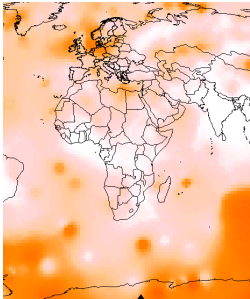
Our Optimal Digital Infrastructure underpins the other aspects of the project

Computing becomes a mandatory resource which everyone has access to

Sense and Optimize
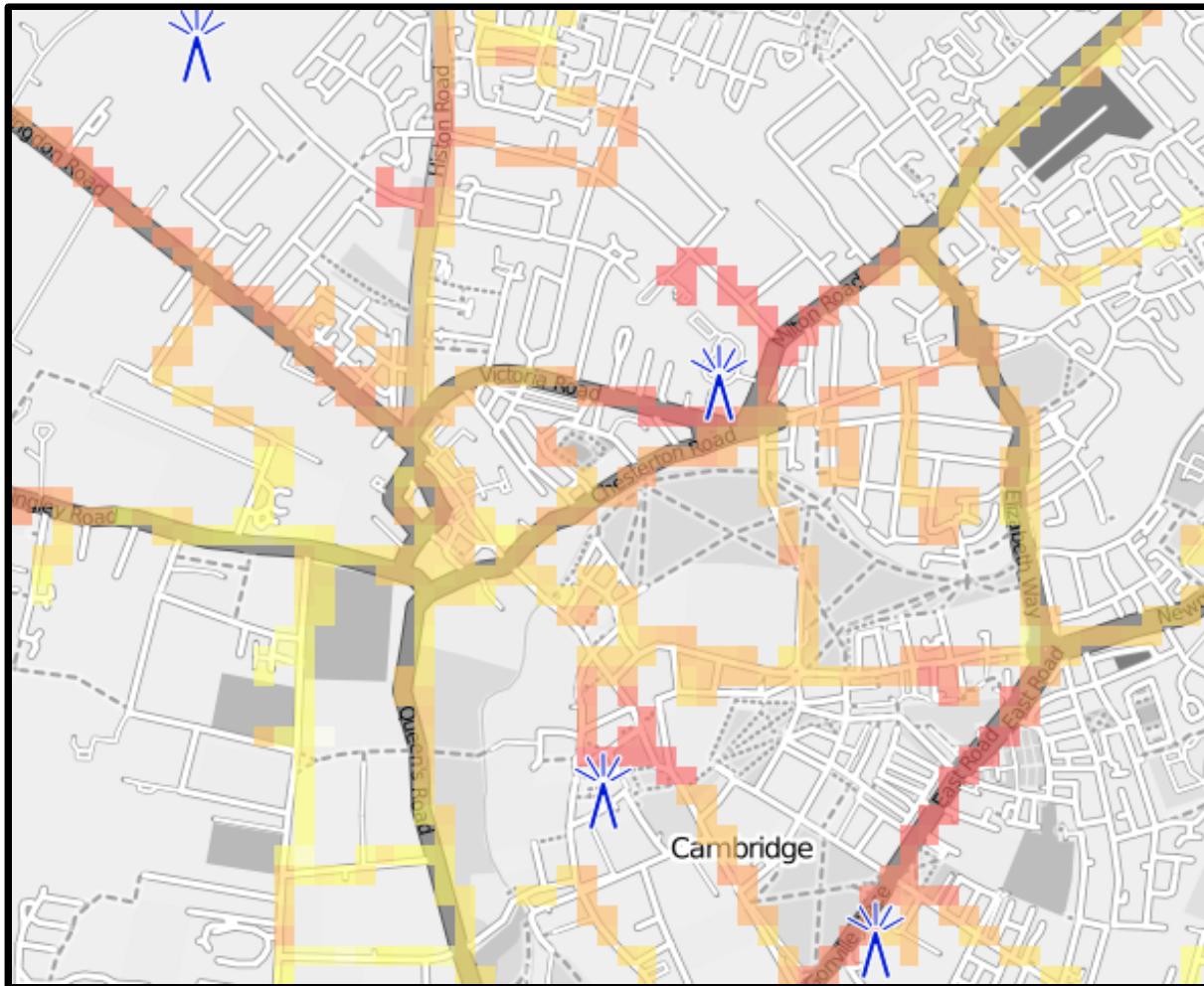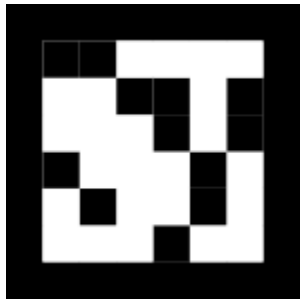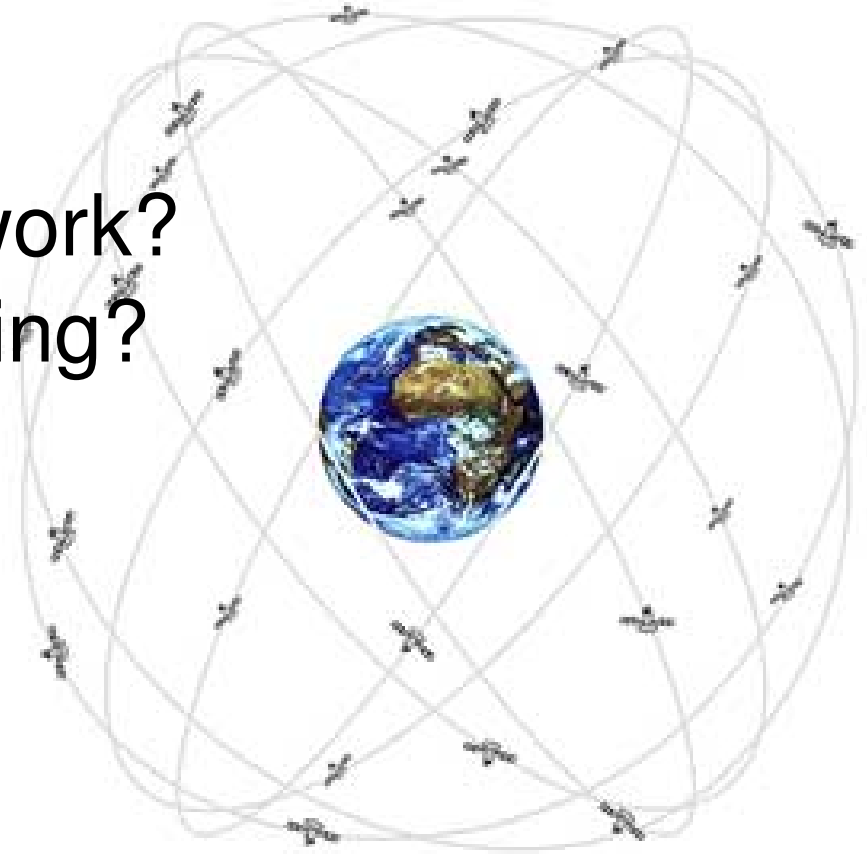

Jon Davies and David Cottingham

Doomsday GPS

What's the cost of GPS?
What about where it doesn't work?
What happens if it stops working?
(or it gets switched off)

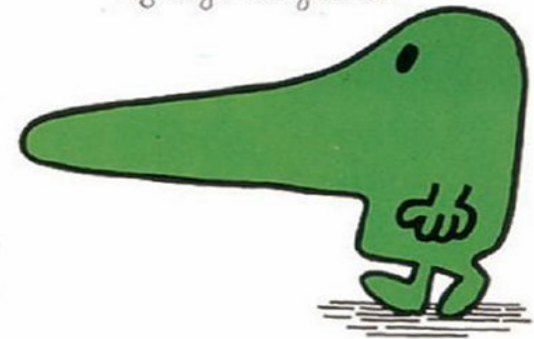low infrastructure
location systems

Tom Craig

Sensing the Planet

- Conventional Sensing
  - huge scale and diversity
  - maintenance, upgrade and management are significant problems

- Alternative: use people as sensors
  - self-repairing, self-recharging
  - autonomous, mobile
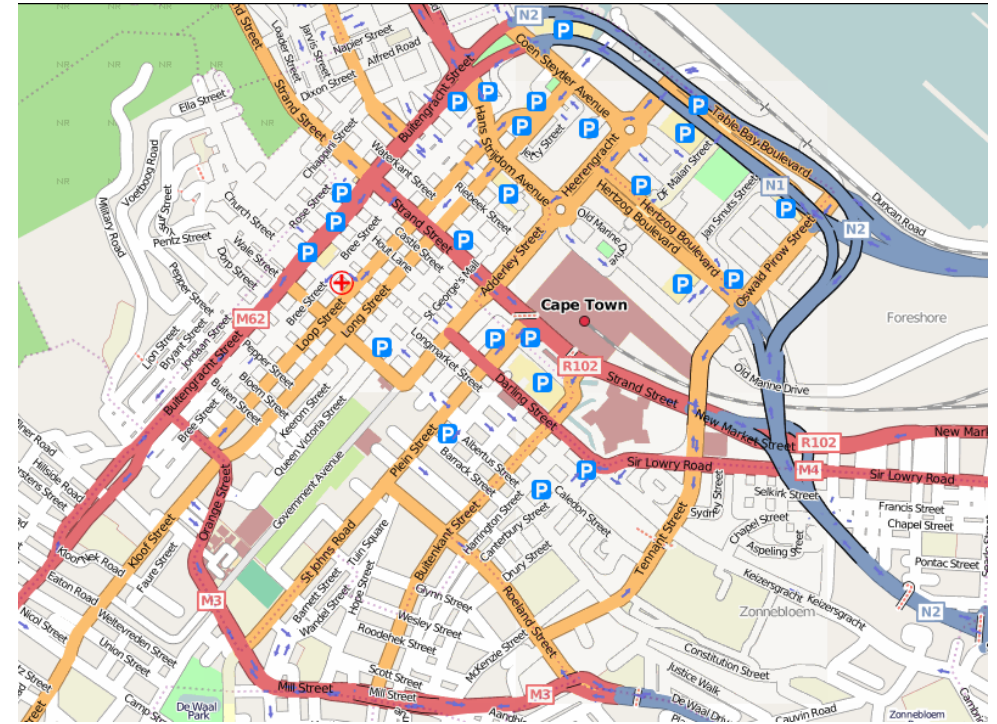 - sophisticated sensors

MR. NOSEY
by Roger Hargreaves

Maps are being generated from GPS traces

Data from OpenStreetMap

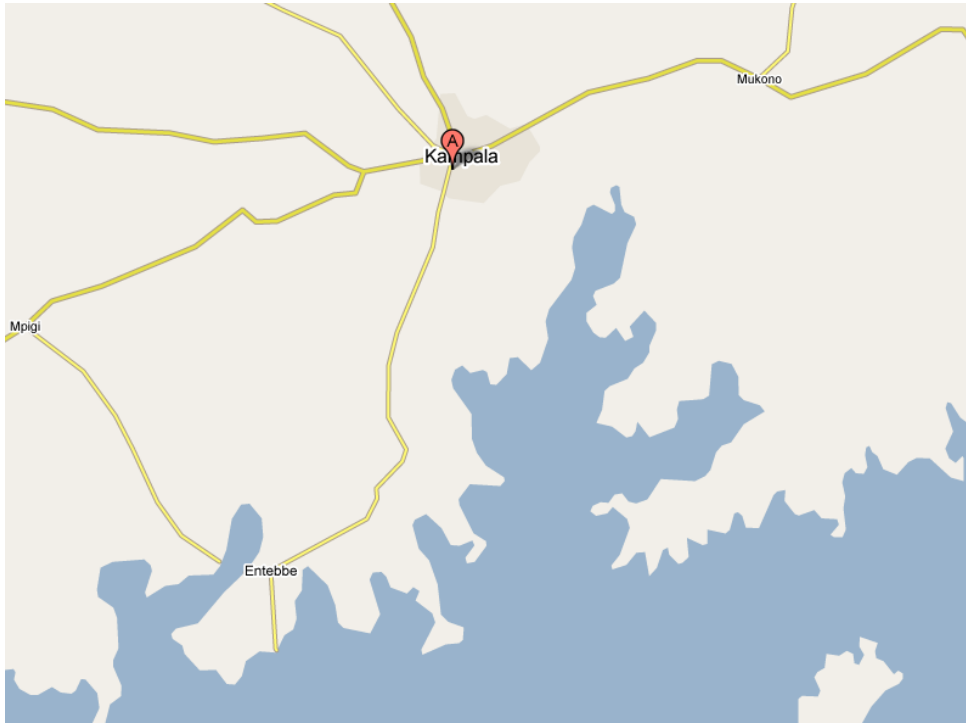# Some have more information that commercial counterparts

Data from Google

Data from OpenStreetMap
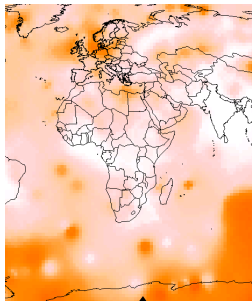
And some are just getting started...
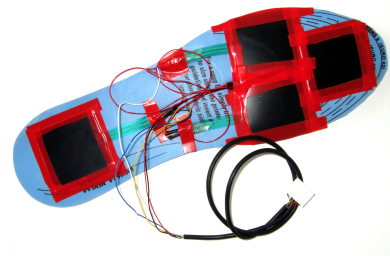

Data from Google

Data from OpenStreetMap

Collate and process sensor data into a World Model

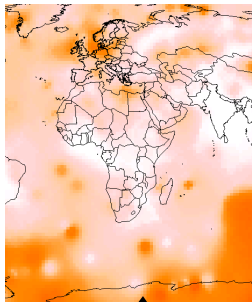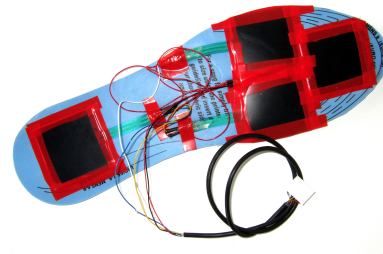Optimal Digital Infrastructure

Sense and Optimize

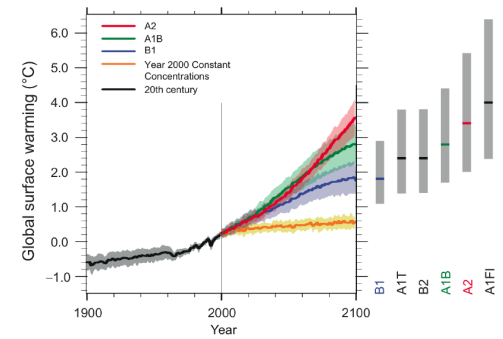# Use computer models to predict future trends

Optimal Digital Infrastructure

Predict and React

Multi-model Averages and Assessed Ranges for Surface Warming

A2
A1B
B1
Year 2000 Constant Concentrations
20th century

Global surface warming (°C)

1900   2000   2100

Year

B1 A1T B2 A1B A2 A1FI

Sense and Optimize

Predict and React

Multi-model Averages and Assessed Ranges for Surface Warming
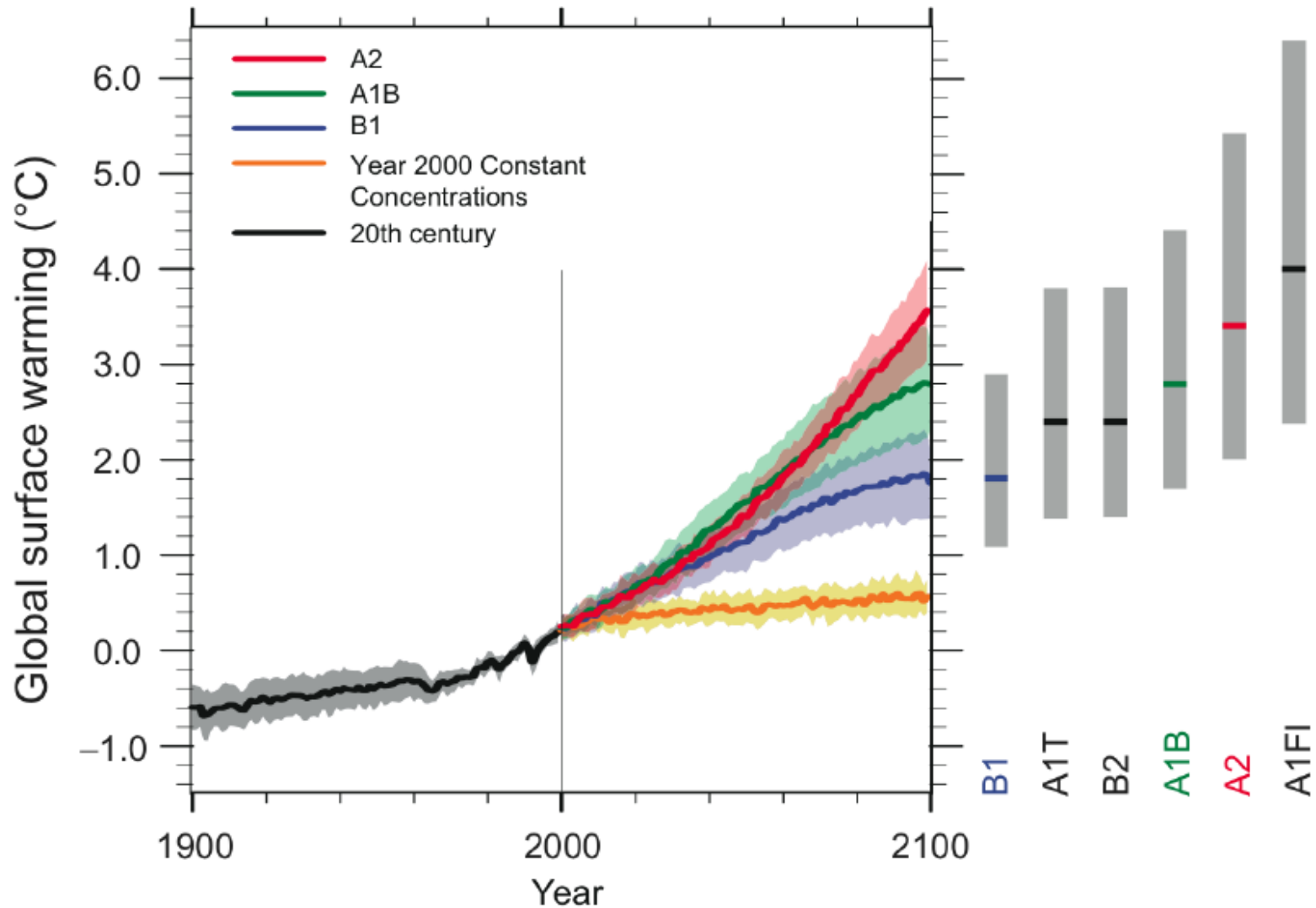
Research points

- Models as part of a control loop

- Trustworthiness and dependability

- Separating algorithm from implementation
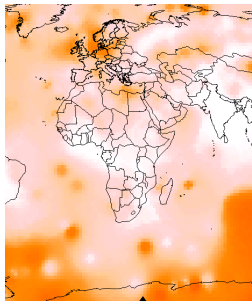
Physical to Digital

vs

vs

GuardianUnlimited network
TIMESONLINE

Inge Reichart and Roland Hischier "The Environmental Impact of Getting the News: A Comparison of On-Line, Television, and Newspaper Information Delivery", in Journal of Industrial Ecology 2006

No clear wins yet for Physical to Digital

- Our computing infrastructure has a significant cost

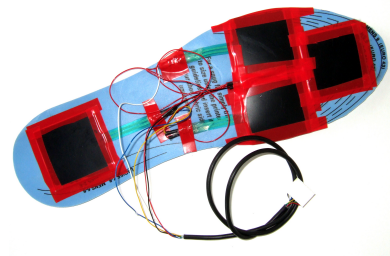- Teleconferencing has been shown to **increase** travel!

Physical to Digital

Predict and React

Optimal Digital Infrastructure

Sense and Optimize

Multi-model Averages and Assessed Ranges for Surface Warming