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CS349

ENVIRONMENTAL POLICIES

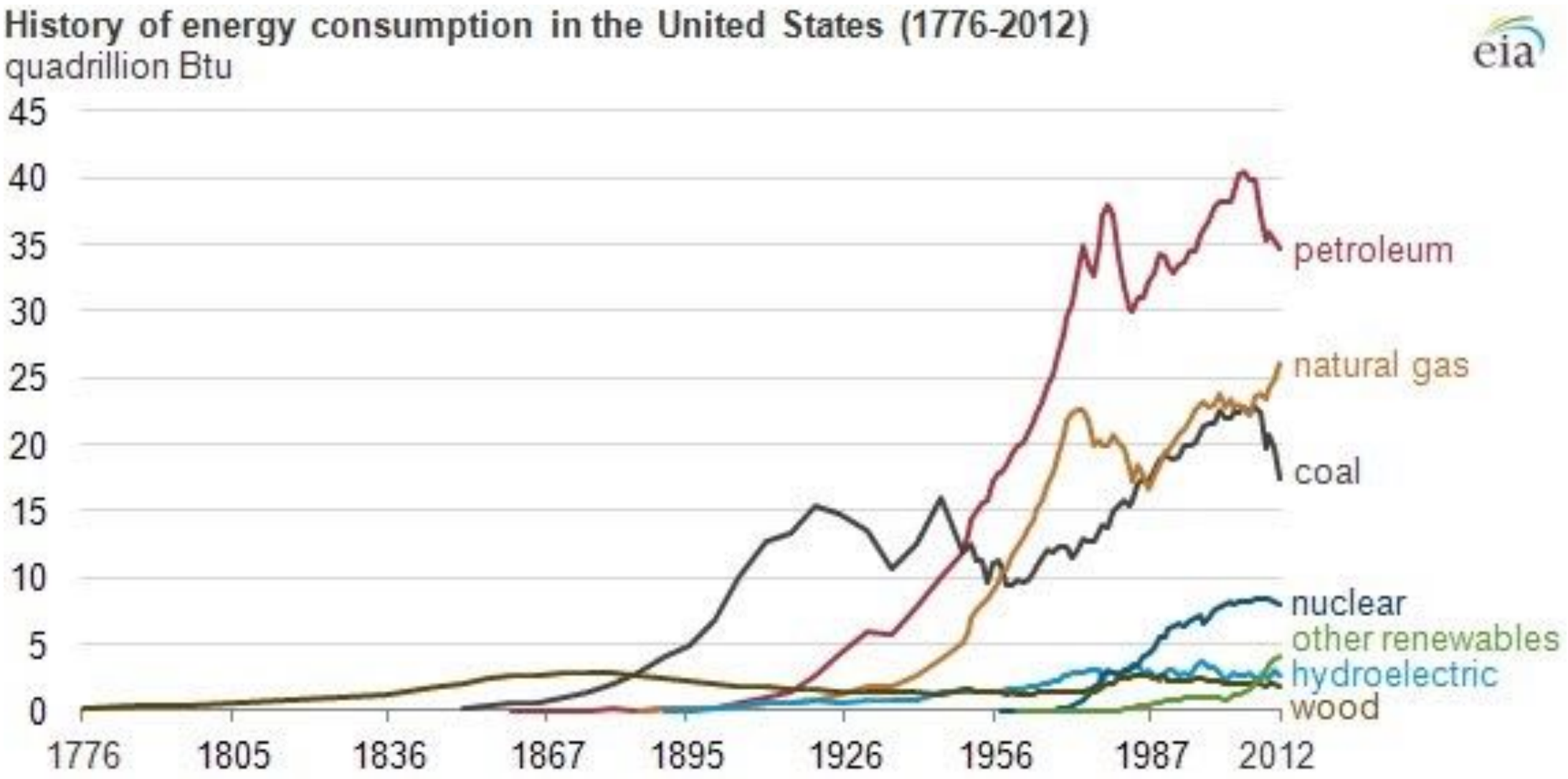
HOW DOES TECHNOLOGY IMPACT THE ENVIRONMENT?

- Energy consumption
- Mining and processing
- Waste and disposal

ENERGY CONSUMPTION

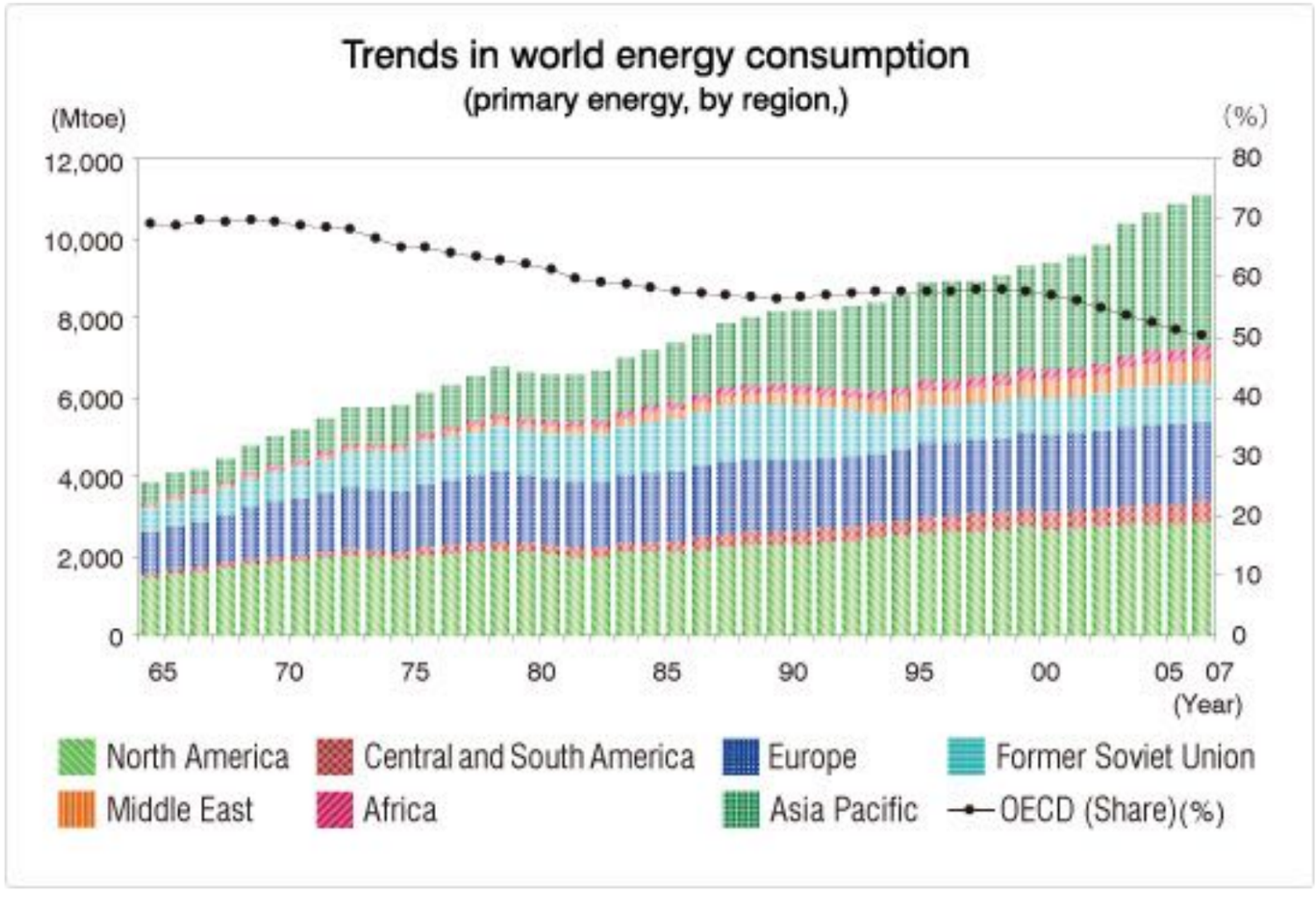
- Population growth and technologies during the industrial revolution drove the need for more and more energy
- Common sources of energy:
  - Coal
  - Natural gas
  - Petroleum
  - Nuclear
  - Renewable resources

HISTORICAL CONSUMPTION OF ENERGY IN THE US

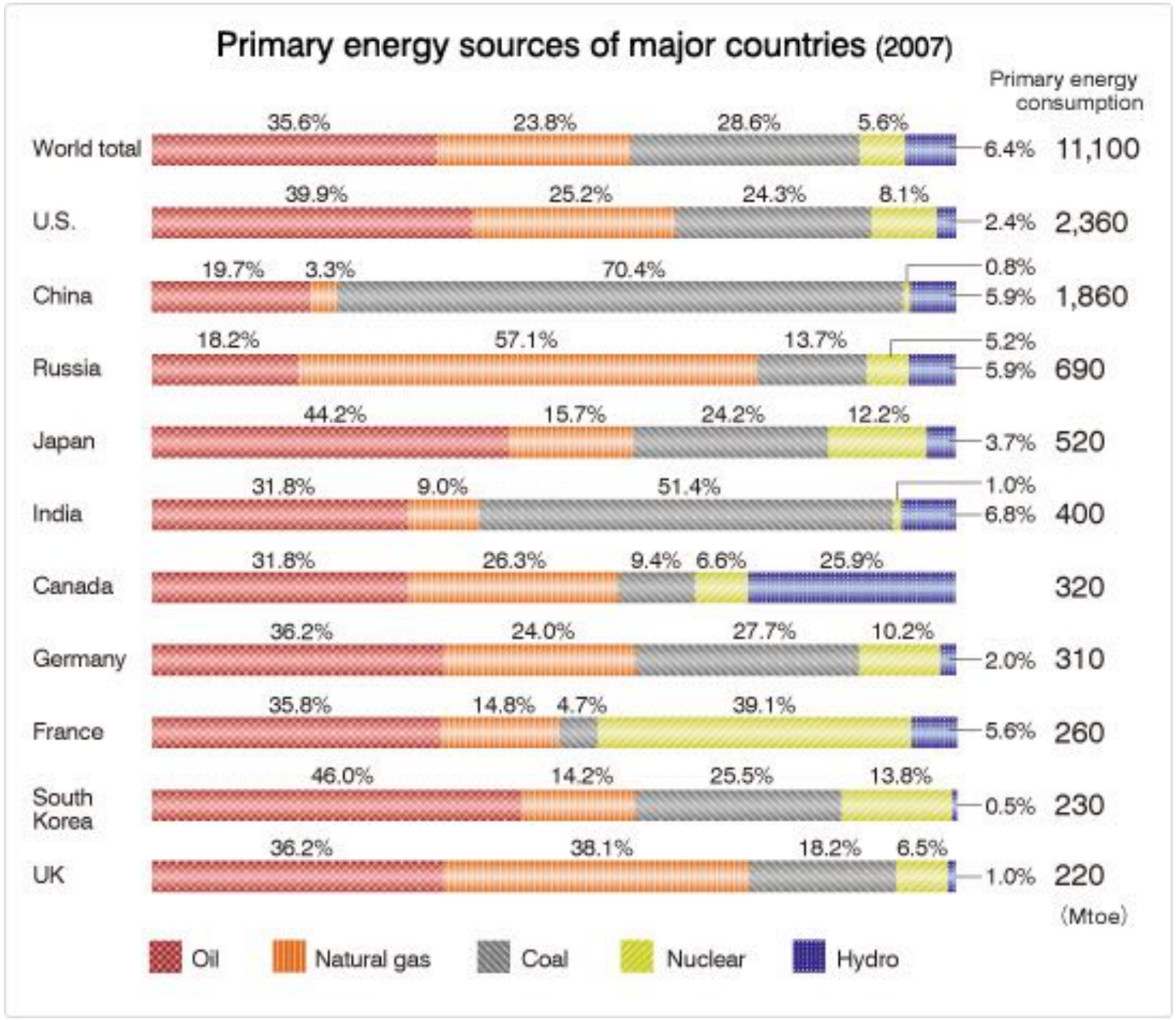


TRENDS IN WORLDWIDE ENERGY CONSUMPTION

- As of 2009, world's largest consumers of energy are:
  1. United States
  2. China
  3. Russia
  4. Japan



SOURCES OF ENERGY BY COUNTRY



FOSSIL FUELS AND GREENHOUSE EFFECT

- Release of heat-absorbing gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) into the atmosphere affects how the earth releases heat
  - Rise of fossil fuels correlates to current increase in CO_2 in the atmosphere
- Result is global changes in climate and weather patterns as well as rising sea levels

MEASURING ENERGY CONSUMPTION IN ICTS?

- In 2010, direct consumption of electricity for Internet use was around 10% of total consumption in the US
  - Includes user PCs, data centers, LANs, other user equipment, and IP core network
- Difficult to further break down these numbers
  - A lot of contradictory and out of date information
- Regardless, managing energy is critical as population, information consumption, and processing needs increase

HOW MUCH ENERGY DO YOUR PERSONAL DEVICES USE?

PC POWER CONSUMPTION AND CO2 GENERATION

- A desktop computer plus speakers and printer consumes 200W/hr on average
  - Used 8 hours a day, uses around 600kWh and emits 175kg of CO_2 per year
- A laptop computer consumes between 50-100W/hr on average
  - Used 8 hours a day, uses between 150-300kWh and emits 44 to 88kg of CO_2 per year
- The average smartphone uses about 2kWh per year and the average tablet uses about 12kWh per year

WHO SHOULD BE MANAGING THIS?

- Hardware manufacturers?
  - Considerations of battery life and heat output already requisite
- Developers?
  - Power consumption varies based on application and implementation
- Consumers?
  - Good practices (turning off monitors, speakers, peripheries, etc) and choosing for power-efficiency can lower a household's carbon footprint

WHAT ARE THE OTHER BIG CONSUMERS OF ENERGY?

SUPERCOMPUTING

- In 2015, the Tianhe-2 (33.9 PFLOPs, 3.12M processor) super computer in China's National Supercomputer Center used 17.8MW of power
  - Equivalent to power usage of ~14,000 households in the US (1MW per ~800 households)
  - Performance-to-power ratio of 2-to-1
- Each MW costs about $1M per year
  - Strong economic reasons to push for compute efficiency

TOWARD ENERGY-EFFICIENT SUPERCOMPUTING

- Green500 ranks the top 500 supercomputers in terms of energy efficiency in addition to performance
  - Good for raising publicity and awareness
- Hardware improvements for data movement, data storage, and cooling can greatly reduce energy use
- Software improvements for coordinating processors and workload can lower energy cost

DATA CENTERS

- In 2014, data centers in the US consumed ~70B kWh
  - 1.8% of total US energy consumption
  - Increase by 4% from 2010-2014
  - Increase by 90% from 2000-2005
- Data center consumption expected to reach ~73B kWh in 2020
  - Decrease in growth related to more efficient centers and practices

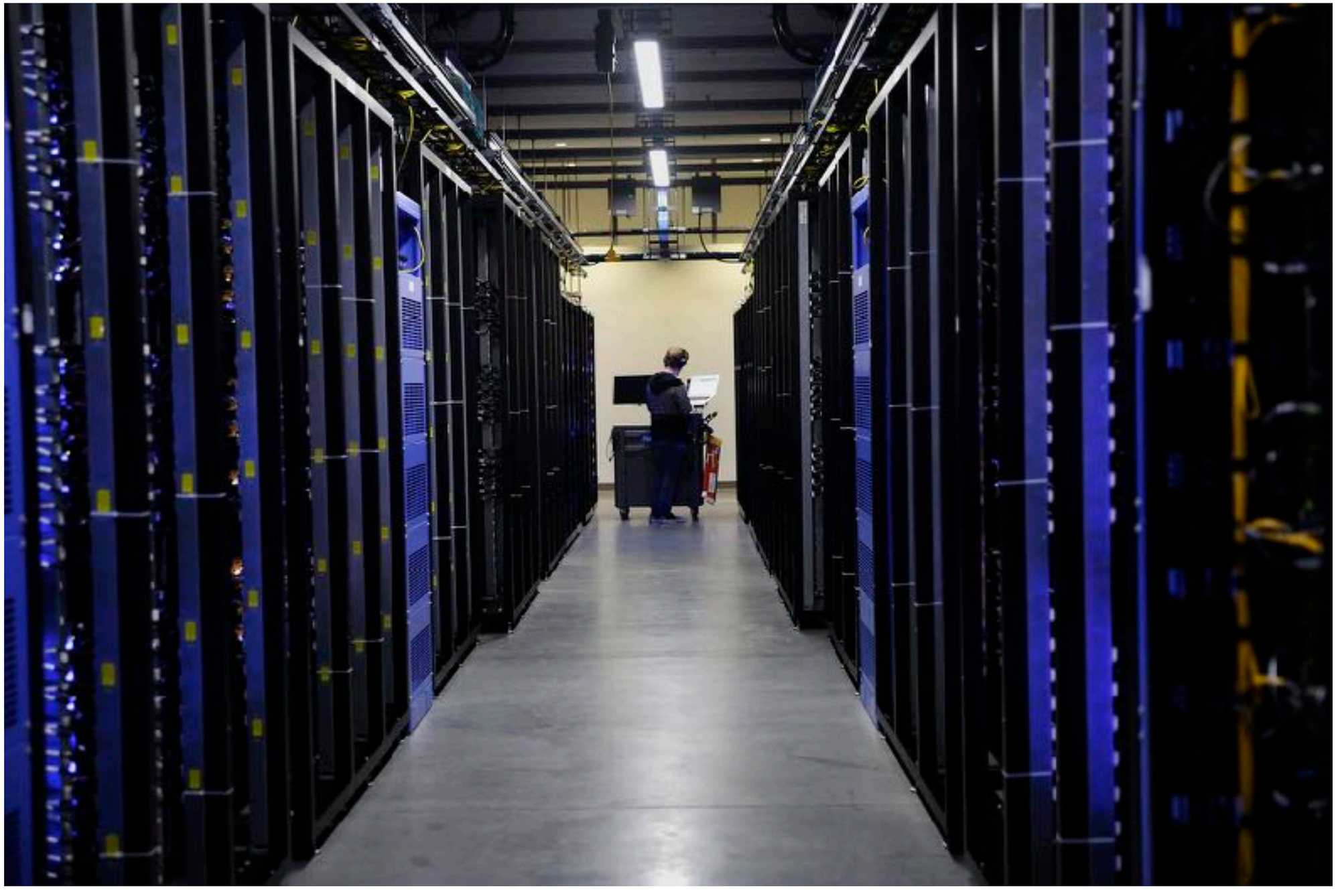
MAKING DATA CENTERS ENERGY EFFICIENT

- Good business practices in line with good environmental policies
- Large-scale data centers run by companies like Google, Apple, Facebook, Amazon, etc have lowered their carbon footprint
  - As of 2013, Apple used 100% renewable resources for its data centers
  - Cold climes popular for reducing data center cooling costs
  - Access to hydro and thermal energy in Scandinavian countries

WHAT ABOUT DATA DELIVERY?

- Internet exchange points, critical infrastructure, and non-private sectors (i.e. hospitals, universities, governments, banks etc) remain inefficient and carbon positive
- Not as well studied or as visible as data centers and supercomputers

WHAT CAN WE DO ABOUT THIS?



MINING AND PROCESSING

- What materials do we need to create microprocessors?
- Where do those materials come from?

Worker in rare earth metal mine in Jiangxi province, China

CHEMICALS USED IN ELECTRONICS

- Magnesium, Radium, Barium, Niobium, Osmium, Cobalt, Manganese, Titanium, Hafnium, Tungsten, Germanium, Gold, Silver, Copper, Mercury, Bismeth, Silicon, Gallium, Zinc, Iron, Sulfur, Phosphorus, Cadmium, Palladium, Tantalum, Platinum, Aluminum, Carbon, Lead, Nickel, Boron, Chromium, Potassium, Fancium, Casium, Sodium, Lithium, Calcium, Nitrogen, Oxygen, Arsenic, Neodymium, Selenium, Tin

RARE EARTH METALS

- Elements and metals found in earth's upper crust that are essential in many modern technologies, and inefficient to extract
- Rare earth metals include:
  - Rare earth elements Scandium, Yttrium, Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, Lutetium
  - Platinum group elements
  - Byproduct metals in gold, copper, uranium, phosphates, iron, and zinc ores
- China supplies 97% of rare earth metals
- Other major exporters: Australia, Russia, India, Brazil, Thailand, Vietnam, Malaysia

RARE EARTH ISSUES

- Many of these materials have no known substitutes in modern technologies
  - i.e. 99% of dysprosium comes from one mine in China (used for magnets in wind turbines and electric cars)
- All rare earth metals contain radioactive elements like uranium and thorium
  - Potential contaminants of local water and soil
- Metals like arsenic, barium, copper, aluminum, lead and beryllium may be released during mining
- Rare earth refinement requires toxic chemicals that must be disposed of properly
- Demand for rare earth rising but extraction is becoming increasingly expensive

MINERAL ORIGINS?

- Wiring made of copper, gold, and silver
  - Democratic Republic of Congo (DRC) and Zambia are main exporters
- Micro-capacitors and circuit boards use tantalum, platinum, and palladium
  - Tantalum extracted from Coltan ore in DRC, Rwanda and Uganda
  - Platinum exported from South Africa, Russia, and Zimbabwe
  - Palladium exported from Russia, South Africa, and Canada/US
- Hard drives and Lithium-ion batteries use cobalt
  - Primarily mined in DRC

CONFLICT MINERALS

- Section 1502 of the Dodd-Frank Act finalized in 2012 requiring companies to review supply chain for conflict minerals
- Conflict minerals are tin, tungsten, tantalum, and gold (3TG)
- Commonly mined in the DRC or adjoining countries
- Companies must ensure that their supply chain does not fund armed groups in eastern DRC
  - Vetting supply chain can cost $200M-$600M per year
  - In 2014 Intel, Google, Apple, and Amazon admitted they could not fully verify their supply chains as conflict-free

COBALT

- Not included in the Dodd-Frank Act as a conflict mineral
- In 2014, an Amnesty International investigation revealed that 20% of the DRC's cobalt exports came from mines that likely used child labor
  - Laborers had no protective clothing and worked in 12 hour shifts for $1-$2 dollars a day
  - Children as young as 7 employed as miners
  - Beaten by security guards and extorted by police officers sent in by state officials

WHAT CAN WE DO ABOUT THIS?

SUPPLY CHAIN REFORMS

- In 2017, Apple pledged to treat cobalt as a conflict mineral and reform its supply chain practices to eliminate child labor
- In 2018, Apple began talks to buy cobalt directly from mines rather than using Chinese supplier
- Apple also began an initiative to recover rare earth from recycled sources rather than relying on mining
- Reforms good for PR and long-term manufacturing costs

WASTE AND DISPOSAL

- The rise of affordable electronics had led to an increase in consumption and disposal of hazardous materials
- Other issues are planned obsolescence, cost-saving manufacturing techniques, and societal expectations of consumerism
- In 2014 41.8M tons of electronic waste (e-waste) was generated world wide
  - Only 16% of this was recycled worldwide
  - The US generated 11.7M tons of e-waste
- The US recycled around 30% of e-waste in 2012
- Recycling 1M cellphones would recover over 20,000lbs of copper, 20lbs of palladium, 550lbs of silver, and 50lbs of gold

EXPORTING E-WASTE

- The Basel Convention is an international treaty designed to reduce hazardous waste export between nations
  - Signed but not ratified by the US
  - EPA does not consider many e-waste items hazardous except lead-lined glass cathode ray tubes
- 80% of US e-waste is exported to Asia (primarily China)
  - Ghana also major destination
  - Sites of e-waste dumping release toxic chemicals into the water, air, and soil
  - Many local people “recycle” the valuable material without access to necessary safety equipment

WHAT CAN WE DO ABOUT THIS?

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