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

History of energy consumption in the United States (1776-2012)

- Petroleum
- Natural gas
- Coal
- Nuclear
- Other renewables
- Hydroelectric
- Wood

quadrillion Btu

1776 1805 1836 1867 1895 1926 1956 1987 2012
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 (CO2), methane (CH4), nitrous oxide (N2O), chlorofluorocarbons (CFCs) into the atmosphere affects how the earth releases heat.

- Rise of fossil fuels correlates to current increase in CO2 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  - A lot of contradictory and out of date information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 CO2 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 CO2 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) supercomputer 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
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
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 worldwide.
  - 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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