Agenda

- Overview

- Deep(er) dives
  - Energy-optimal routing in RPL
  - Smart home data management
  - Telemetry for e-bikes
  - Personal thermal comfort
Today’s Energy Infrastructure
Mostly dirty...
Overprovisioned by design

http://ieso-public.sharepoint.com/
Inefficient

More than two-thirds of the fuel used to generate power in the U.S. is lost as heat

http://www.oe.energy.gov/
Wasteful...
5% better efficiency of US grid
= zero emission from 53 million cars
Aging

Post-war infrastructure is reaching EOL
Poorly measured
Poorly controlled
Times are changing...
Three technology inflection points

- Solar and wind renewable generation
- Storage and EVs
- Pervasive sensing and control
Price history of silicon PV cells in $ per watt

$76.67

Source: Bloomberg, New Energy Finance & pv.energytrend.com
Solar installations each year


Cell phone subscribers (cumulative)

http://stats.areppim.com/stats/stats_mobile.htm
Solar PV is **growing faster than cell phones!**
Storage

Global investment to reach $122 Billion by 2021 – Pike Research

LiON Declining. $600 down to <$200
Electric vehicles

- Spur research on lower-cost storage

Nissan Leaf chassis
Pervasive sensing
+ pervasive computation

Freescale KL02 microcontroller 1.9 mm x 2.0 mm
allows pervasive control
Current energy systems  Smart energy systems

- Fossil-fuel based  •  Renewables-based
- High carbon  •  Low carbon
- Little to no storage  •  Storage rich
- Poorly measured  •  Sensing rich
- Poorly controlled  •  Control rich

*Inefficient*  •  *Energy frugal*
OK, we’re done, right?
Maybe not...
1. Need storage...
... but it is expensive!

- Buying 1 KWh = 10c
- Storing 1 KWh = ~$450!
2. Need control over many time scales
3. Consumers have no incentive to save

- Energy savings of 10%
- $10/month
4. Utilities have no incentive to be efficient!
5. Energy data is personal
6. Sensors are energy-limited
7. EV sales are tiny

EV fraction of vehicle fleet in 2014: 0.1%
Mission

To use information systems and science to
- increase the efficiency
- reduce the carbon footprint

of energy systems
3 Approaches

1. Exploiting equivalency of grid and Internet
2. Designing and building prototype energy systems
3. Mining big data
Grid  Internet

Electrons = Bits
Load = Source
Transmission line = Communication link
Battery/energy store = Buffer
Demand response = Congestion control
Transmission network = Tier 1 ISP
Distribution network = Tier 2/3 ISP
Stochastic generator = Variable bit rate source
Analytic results

- Transformer sizing
- Optimal control for EV charging
- Minimizing storage size to smooth solar/wind sources
- Optimal participation of a solar or wind farm in day-ahead energy markets
- Modeling of imperfect storage devices and solar power
- Optimal operation of diesel generators to deal with power cuts in developing countries

Joint work with O. Ardakanian, Y. Ghiassi-Farrokhfal, S. Singla, and C. Rosenberg
Mining big data

- Analysis of
  - hourly electricity data from ~26,000 meters (>100 GB)
  - hourly water data from ~27,000 meters (> 100GB)
  - PV and load data every second for 3 months
  - 7 years of carshare rental data
  - 10s of thousands of opinions on EV forums
  - 25+ GB of transportation data
  - ...
Conclusions

- Technology is *changing* the energy infrastructure
- Computer Science has a role to play
- Opportunity for *interesting, impactful* research


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EU
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- Microsoft
- IBM
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Backup slides
FOSSIL FUELS ARE EXPRESSED WITH REGARD TO THEIR TOTAL RESERVES WHILE RENEWABLE ENERGIES ARE TO THEIR YEARLY POTENTIAL.

source: DLR, IEA WEO, EPIA’s own calculations.
# Table showing average cost in cents/kWh over 20 years for solar power panels

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<th>Cost</th>
<th>2400 kWh/kWp·y</th>
<th>2200 kWh/kWp·y</th>
<th>2000 kWh/kWp·y</th>
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Storage

“Bytes”
Energy density

“Bits/s”
Power density