October 4, 2016

MEMORANDUM

TO: **Power Committee**

FROM: **Massoud Jourabchi**

SUBJECT: **Powering the Internet of Things**

BACKGROUND:

Presenter: Massoud Jourabchi

Summary: Staff has been tracking another emerging technology labeled Internet of Things (IoT). Staff will present on what is IoT, where it has been applied and what does the future holds for this class of emerging technologies and how the IoT will be powered.

This presentation is an introduction to IoT class of technologies which has become more widespread as computer and communication technologies have become more ubiquitous and as cost and power requirement of sensor and communication technologies have come down. Presentation will discuss how IoT equipment could be powered. Options for powering are through grid or through battery or through energy harvesting. As more and more application of IoT are incorporated into the economy, productivity can increase while electricity consumption may be lowered.

Relevance: Understanding application of IoT in residential, business and utility setting helps inform Council's ability to forecast future demands for electricity.

Work plan: Maintain Analytical Capability. Action item ANALYs 2 of the 7th Plan calls for tracking and improving long-term load forecast for emerging markets. This presentation focuses on one such market.

851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Steve Crow
Executive Director

503-222-5161
800-452-5161
Fax: 503-820-2370

Background: Over the past 5 years, staff has been reporting to Council on emerging technologies such as electric vehicles and data centers. This brief presentation on IoT is an introduction to applications of this emerging field.

Emerging Tech
Doing more with less

Power of Internet of Things and how to Power it

(Grid, Energy Harvesting and Energy Storage Systems)

Massoud Jourabchi

October 2016

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Emerging Technologies

In this presentation

- Internet of Things (IoT)
  - What is it?
  - Where it is applied?
  - How it can be powered
    - Grid
    - Energy Harvesting
    - Energy Storage

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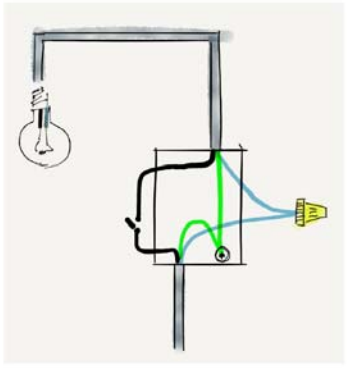
What is IoT
(how to light up a room)

IoT

Traditional



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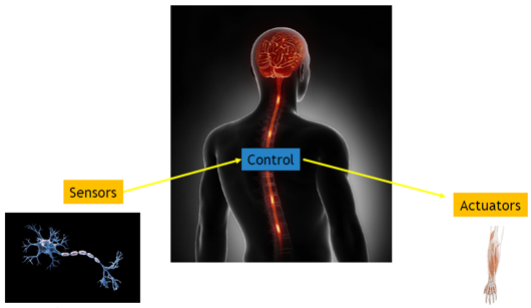
Components of IoT using human analogy



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Reach of IoT

- Residential sector
- Commercial sector
- Industrial/manufacturing sector
- Transportation sector
- Utility sector
- Agriculture
- Conservation and environmental recovery monitoring

IoT at Home

Can smart homes monitor and adapt to our breathing and heart rates?

Personal Health

Baby Sleep

Elderly Health

87% of elderly want to age in place

Apnea test @home

Adapt Lighting and Music to Mood

MIT PROFESSIONAL EDUCATION

The Internet of Things: Roadmap to a Connected World

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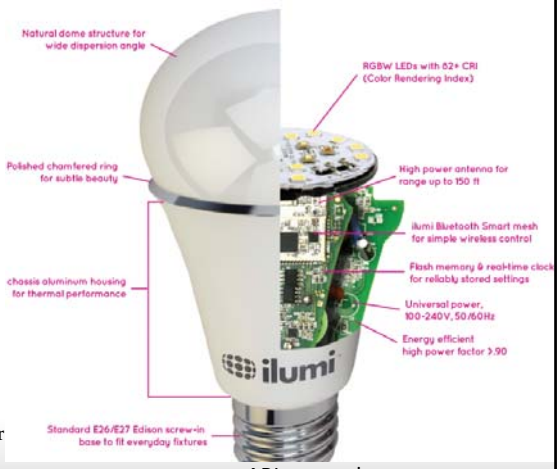
Smart Lighting
(going beyond lighting)

- Smart, Solid-State Lighting (SSL) that can be controlled and networked allowing a central control/utility to turn on or off, adjust brightness, change color and color temperature via other connected devices.
- The network which SSLs are integrated into can have other uses:
  - Asset management including location and type
  - Time-of-use metering
  - Video monitoring for security and other analytics
  - Chemical and radiation detection for public safety

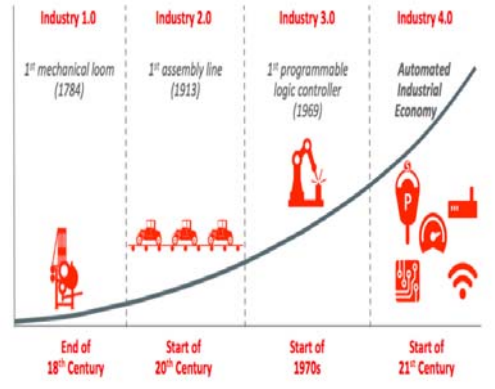


ABI research

IoT in Businesses

- Office buildings
  - Individually optimized lighting and HVAC
  - Security, monitoring indoor air quality
  - Employee monitoring
  - Communication
- Retail establishments
  - Individual shopper discounting
  - Inventory tracking and ordering
  - Monitor store traffic, hot spots, customer behavior
- Medical facilities
  - Fall detection
  - Patient monitoring and recovery.

Industrial Applications



- Integrated Production monitoring
- Predictive analytics and maintenance
- Asset Tracking
- Control Room Consolidation
- Autonomous Robots
- Additive Manufacturing
- Augmented Reality

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Global CEO survey: Ranking of future importance of advanced manufacturing technologies by executives

Advanced Manufacturing Technologies	US	China	Europe
Predictive analytics	1	1	4
Smart, connected products (IoT)	2	7	2
Advanced materials	3	4	5
Smart factories (IoT)	4	2	1
Digital design, simulation, and integration	5	5	3
High performance computing	6	3	7
Advanced robotics	7	8	6
Additive manufacturing (3D printing)	8	11	9
Open-source design/Direct customer input	9	10	10
Augmented reality (to improve quality, training, expert knowledge)	10	6	8
Augmented reality (to increase customer service & experience)	11	9	11

Source: Deloitte Touche Tohmatsu Limited and US Council on Competitiveness, 2016 Global Manufacturing Competitiveness Index

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IoT in transportation

- Continued connectivity
- Car services (Lyft, Uber)
- Autonomous driving cars and buses
- Parking space identification
- Best route selection
- Over the air software updates (Tesla)
- Usage-based auto-insurance
- Predictive analytics

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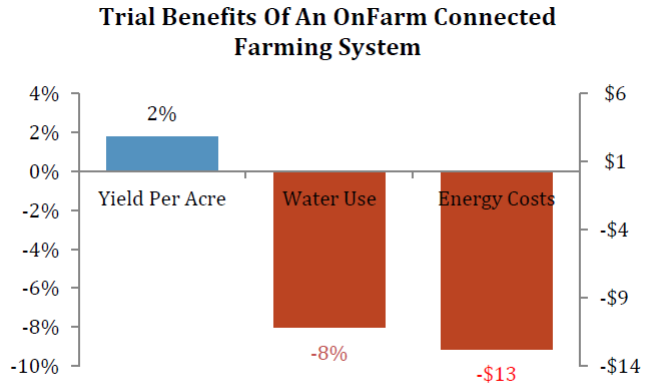
IoT in Agriculture



Source: OnFarm, Michigan Farm News, 2015

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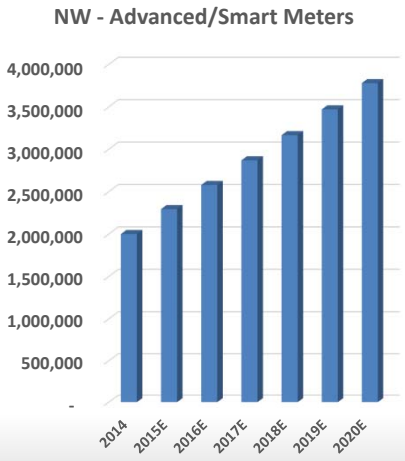
Electric Utilities and Smart Meters

Some of the benefits of installing smart meters :

- Providing real-time billing and usage information
- Allowing the power company to remotely turn on and off power
- Power-failure notifications
- Preventing energy theft
- Reducing the number of workers needed to check meters

- EPRI study indicates that the US could reduce electricity use by more than 4% by 2030 through the use of smart meters and the implementation of smart energy grids.
- Savings of $20.4 billion, according to the study.



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Smart Cities

Here are some examples of :

- Sensors placed in city parking
- The city has deployed smart LED streetlights
- Public garbage bins with sensors
- Bus stations are also connected to the fiber-optic network.
- Smart energy meters in all of the city government's buildings
- Sensors throughout the water management system, and implemented remote irrigation control for the city's green spaces.
- Street lighting
  - Use fixtures for WiFi
  - Dimming based on traffic volume
  - Law enforcement

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THE MARKET IS EXPECTED TO BE ASTRONOMICAL

2015:
- 10 billion connected things
- $1.9 billion from IoT services

2020:
- ABI: 250,000 connected cars
- IDC: $7 billion from IoT services
- Gartner: $300 billion from IoT products
- IDC: Global IoT market $7.1 trillion
- ABI: 40 billion IoT devices

2035
- GE: $10-15 trillion added to GDP
- Cisco: $19 trillion
- ABI: 450 million IoTcars

http://www.eetimes.com/author.asp?doc_id=1326597

PROFESSIONAL EDUCATION

The Internet of Things: Roadmap to a Connected World

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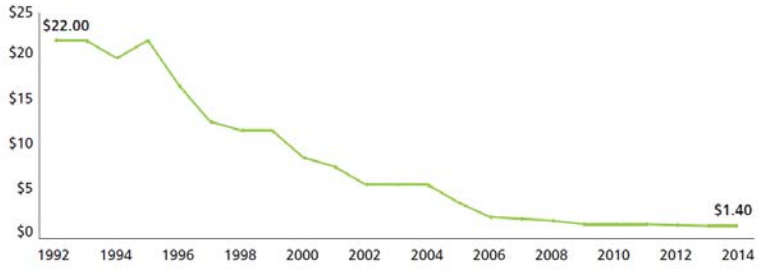
Cost of Sensors Declining

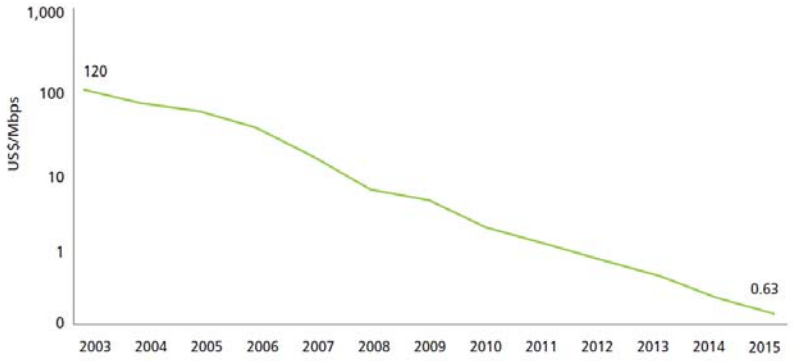
Figure 5. Sensors prices on the decline over the last 25 years



Source: Rob Lineback, IC Insights Inc. "The market for next-generation microsystems: More than MEMS!," http://itac.ca/uploads/events/execforum2010/rob_lineback_10-6-10-2.ppt, June 10, 2010, accessed January 28, 2015; Lee Simpson and Robert Lamb, *IoT: Looking at sensors*, Jeffries Equity Research, February 20, 2014, p. 4.

Cost of internet transit Declining

Figure 9. Internet transit prices in the United States



Note: Transit prices are plotted on a logarithmic scale.

Source: DrPeering.net, http://drpeering.net/white-papers/Internet-Transit-Pricing-Historical-And-Projected.php, accessed January 21, 2015.

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Powering the Digital Future

Traditional Network Connected Devices
- Mobile Devices (smart phones, tablets)
- PCs and laptops
- Home Entertainment (smart TVs, set-top Boxes)

Cloud
Data Centers

Network
infrastructure

IoT Devices powered by (grid / battery / harvested energy)
M2M and M2H applications (augmented behavior technologies)

Smart and integrated:
- Homes(lighting, appliances, security)
- Streets (smart lighting, crime prevention)
- Manufacturing (predictive analytics, loss prevention)
- Healthcare (patient monitoring, in-home recovery)
- Transportation(connected cars, on air-updates, user based insurance, ownership)

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Where does the energy for IoT go to?

- In majority of cases electric power goes to meeting the standby needs.
- Some IoT technologies will use Energy Harvesting and will not be connected to the Grid.
- Grid connected devices examples, smart homes, smart appliances, smart roads and smart street lighting. These applications are expected to have greater proliferation.

Energy Sources for IoT

- Main energy sources
  - Grid provided
  - Energy harvesting (examples)
    - Thermoelectric generators (TEG)
    - Indoor renewables (solar radiation)
    - Kinetic convertors (direct conversion of mechanical energy to electricity)
    - Frequency harvesting
  - Energy Storage
    - Augmented Rooftop Solar + Storage

Standby Power Consumption

Category	Device	Average Standby Power [W]
Smart Lighting	Smart LED Bulbs	1.0
	Gateways	1.6
Home Automation	Gateways	1.7
	IP Camera	2.2
	Mains Connected Sensors	0.6
	Mains Connected Actuators	1.0
Smart Appliances	Appliances	0.4
	Gateway	1.6
Smart Street Lighting	Luminaires	0.4
	Master Luminaire	2.0
Smart Roads	Roadside Units	8.0
	IP Camera	4.0

Source: I EA 4E EDNA report, Energy efficiency of the internet of things, technology and energy assessment report . April 2016

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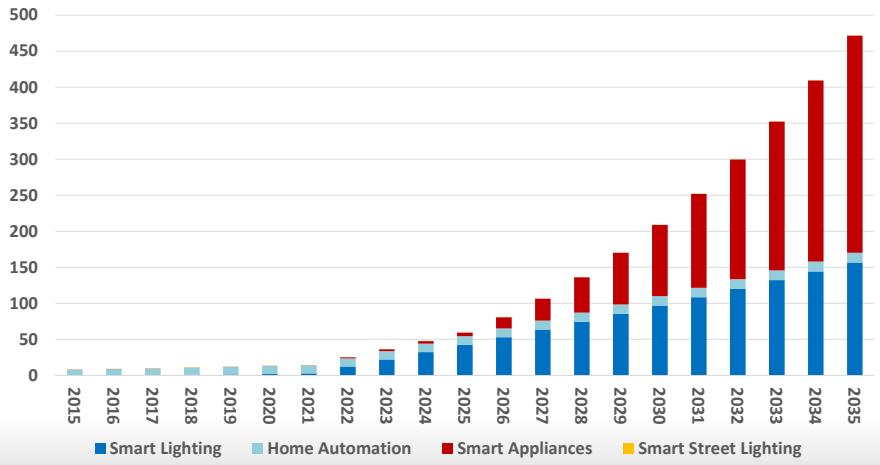
Estimated IoT Standby Consumption In the Northwest (aMW)
Without and with technological improvements
(with tech. improvements by 2035 IoT standby demand may be as low as 80 aMW)



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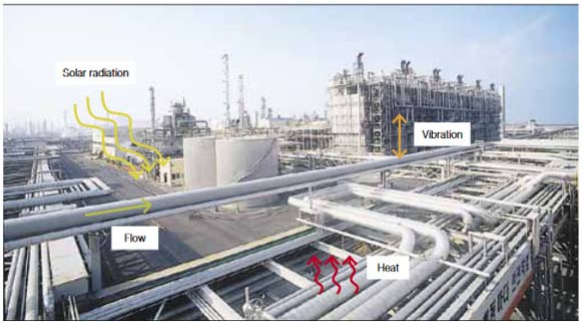
Energy Harvesting

- Thermoelectric generators (TEG)
- Indoor renewables (solar radiation)
- Kinetic convertors (direct conversion of mechanical energy to electricity)
- Frequency harvesting

Few examples of Energy Harvesting in an industrial setting



Estimated global number and energy used to manufacture small conventional rechargeable and disposable batteries

Figure 18: Estimates for worldwide annual battery consumption related to Io'

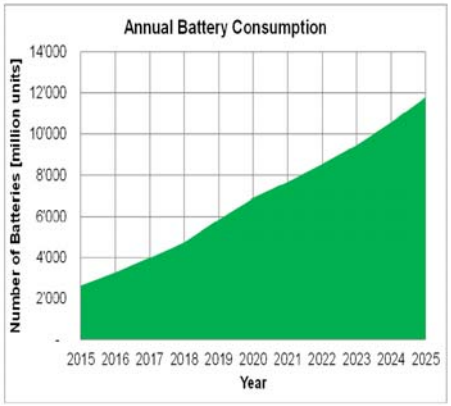
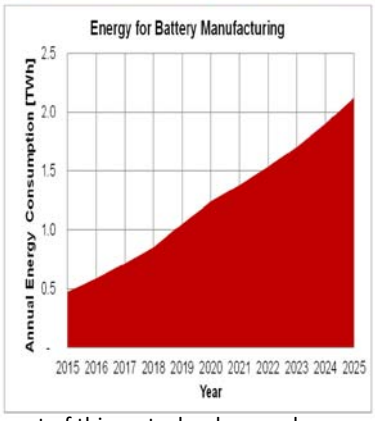


Figure 19: Estimates for worldwide energy consumption for IoT battery manufacturing



IEA 4E EDNA report, Energy efficiency of the internet of things, technology and energy assessment report (April 2016).

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Large Scale Batteries would be operating in all areas

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Net energy effects of IoT is not clear

Potential Change in Enduse Demand in Residential

	Low	High
Smart Thermostats	**1-4%**	**1-4%**
Smart Lighting **Baseline (mix)** **Baseline (LED)**	 **3%** **-1%**	 **7%** **-2%**
Smart Plugs	**2%**	**5%**

Source: Smart Technologies and Connected Products: Early Adopter Toys or Gateways to Energy Savings? Navigant Consulting Inc. 2016 ACEEE Summer Study on Energy Efficiency in buildings

Summary and Next Steps

IoT has a far reaching impact on potentially every aspect of the economy.
One of the main drivers for IoT is demand to improve productivity in the economy.

As cost of sensors, networks and processing of integrated devices is brought down and more and more devices are made smart, energy consumption in homes, businesses and transportation can decrease resulting in a negative impact IoT meaning lower demand and higher convenience and productivity.

Spread of IoT has many concerns including privacy, security, standards for integration.

High demand on batteries adds another dimension to these concerns, that of security and reliability of the sources for the battery material and environmental concern on safe disposal of used batteries.

In future presentations on batteries we will be discussing these concerns.