ENE 2XX: Renewable Energy Systems and Control

LEC 00 : Course Introduction

Professor Scott Moura
University of California, Berkeley

Summer 2017

Why take ENE 2XX?

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Learn to view, abstract, and design

renewable energy systems from an optimization

point of view.

Prerequisite Previous Coursework

- Multivariable calculus (Math 53)
- Linear algebra (Math 54)
- Probability and Statistics (CE 93 or EE 126 or STAT 154)
- Numerical computing (E 7 or CS 61)
- Mechanics (Physics 7A)
- Electricity and Magnetism (Physics 7B)
- Thermodynamics or heat transfer (E 115 or ME 40 or ME 105 or ME 109)

Very Helpful (not required) previous/concurrent coursework

- Optimization (CE 191 or EE 127/227)
- Signals & Systems (EE 120) or Dynamic Systems & Feedback (ME 132)
- Linear Systems Theory (EE 221A/ME 232)

Who takes CE 295?

S14 Cohort (19 students): Some of their current job titles:

- Data Scientist @ Facebook
- Algorithm Engineering @ Nest/Google
- System Engineer @ Northrop Grumman Corp
- Energy Engineer @ Itron
- Boston Consulting Group in London, UK

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S15 Cohort (48 students): Some of their current job titles:

- CEO/CTO & Founders of eLum (Energy Data Analytics Start-up)
- Director of Operations @ Lucid Design
- Data Scientist @ STEM (2)
- Data Scientist @ SolarCity
- Data Analyst @ BuildingIQ
- Machine Learning S/W Engineer @ Atigeo
- Applications Engineer @ SunEdison
- Engineering @ Apple
- Mechanical Engineer @ NRG Energy

Who takes CE 295?

S16 Cohort (45 students): Some of their current job titles:

- Data Scientist @ AutoGrid
- Data Scientist @ UrbanSim
- Special Projects Lead @ Bridj
- Lead Analyst @ Advanced Microgrid Solutions (AMS)
- Utilities Engineer @ CPUC
- Engineer @ SRT Consultants
- Energy Engineer @ Partner Energy
- Energy Consultant @ Navigant
- Data & Analytics Consultant @ Deloitte
- Project Engineer @ McCarthy Building Companies
- Sustainability Project Consultant @ Thornton Tomasetti

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Exclusive access to alumni above: Join the CE295 LinkedIn Group:
https://www.linkedin.com/groups/7068321

S17 Cohort (≈60 students): Ugrad degrees:
CEE, ME, EECS, MSE, EnergyE, Math, Physics, ChemE, PetroleumE, Environmental Science, Econ, Spanish and more

Outline

Class Format

Lectures: July 3-7 & July 10-12, 14:00-15:35, Zhiyuan Bldg C3-2011

Website: `https://ecal.berkeley.edu/files/ene2xx/`

Professor Scott Moura
`smoura@berkeley.edu`
WeChat: scott-moura
Office Hours: 15:45 – 17:00 @ C2-F15

TA: Zhou Zhe
`zhouzhe.20080808@163.com`
WeChat: Danrhette
Office Hours: 09:20–12:00 @ C2-F15

Attendance is required to perform well

Technical Content

Lectures/Notes provide control system tools for analysis & management of energy systems.

HWs/Project facilitate motivation and application of control system tools.

Assignment	**System & Control Tool**	**Energy Application**
HW	Linear Program. & Robust Program.	Power System
Project	Second Order Cone Program.	Microgrids

Textbooks

No textbooks are required. Course notes have been developed specifically for CE 295, and will be distributed through the semester online.

The following is officially recommended for additional background:

- G. M. Masters, Renewable and Efficient Electric Power Systems, John Wiley & Sons, 2013
- S. Boyd and L. Vandenberghe, Convex optimization. Cambridge University Press, 2009.

Lecture format:

- Mostly slides, occasionally blackboard
- Slides will be available online
- Supplemental reading materials will be available online

Grading

Straight scale (we may curve up, but probably won't need to):

Homework	20pts	One assignment due Friday July 7
Project	30pts	Assignment due Friday July 14

A total of 50pts are possible. Philosophy: Consistency and transparency

Previous Semester Grades

S14 Grades: Mean: 90% (A-) High: 98.5% (A+) Low: 83% (B)

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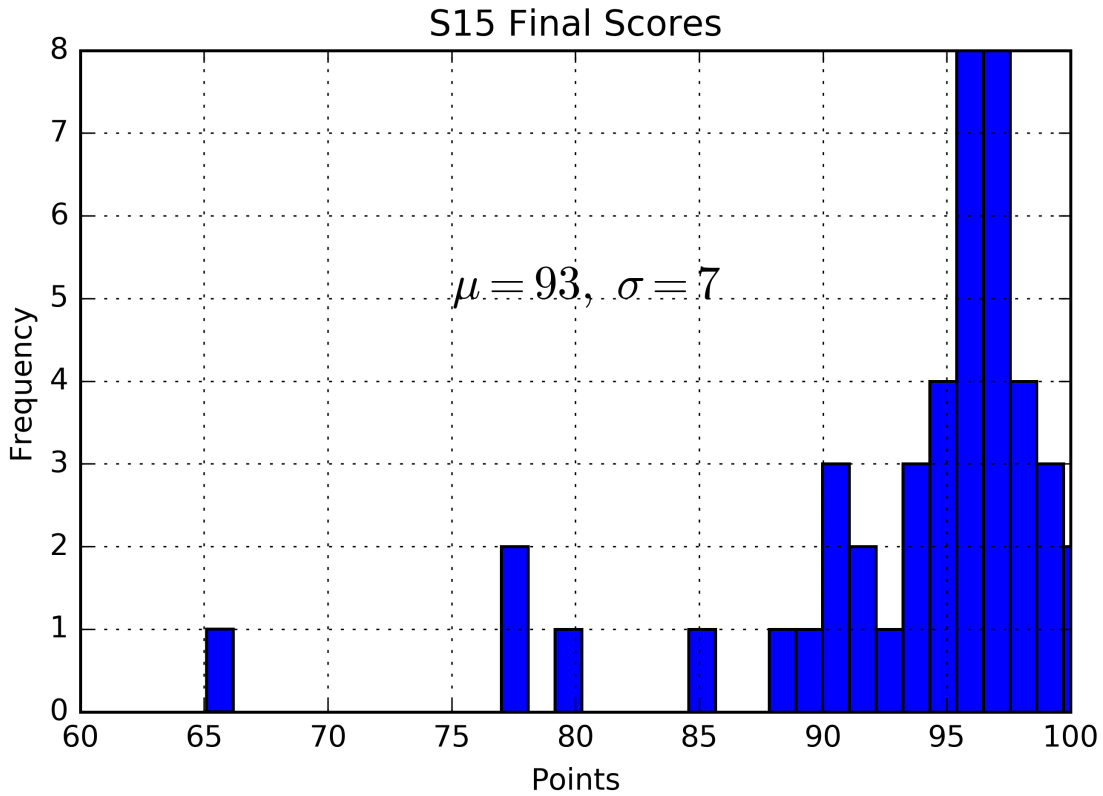
S15 Grades: Mean: 93% (A-) High: 99.8% (A+) Low: 65% (D)



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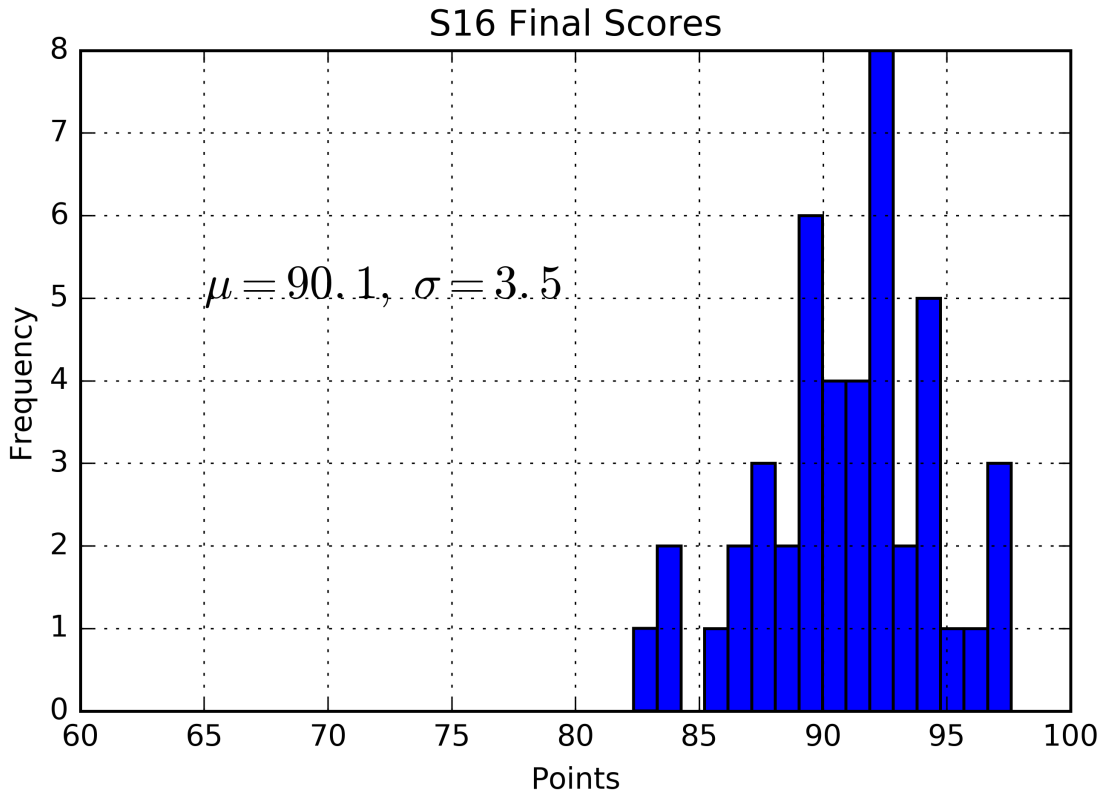
S14 Grades: Mean: 90% (A-) High: 98.5% (A+) Low: 83% (B)

S15 Grades: Mean: 93% (A-) High: 99.8% (A+) Low: 65% (D)

S16 Grades: Mean: 90.1% (A-) High: 97.6% (A) Low: 82.4% (B-)



Remark: SU17 Grades are NOT guaranteed to match S14, S15, S16 distributions

Numerical Computing

Homework assignments require use of MATLAB or Python (you pick).

MATLAB 2017 MATLAB Academy <https://matlabacademy.mathworks.com/> is recommended to learn/refresh.

Python 2.7 is FREE for download at <https://www.python.org/downloads/>. We recommend Anaconda distribution for SciPy packages <https://www.continuum.io/>, and IPython Notebook <http://ipython.org/notebook.html> for an interactive computational environment. Code Academy <https://www.codecademy.com/> is recommended to learn/refresh Python.

Common Question: Can I use another programming language (e.g. R, C++, Java, Fortran, counting on my toes) for the HWs and/or project?

A: Yes. However, the instructional staff will only support MATLAB/Python.

Policies - I

Late Submissions: Two points are subtracted for each 24 hours submitted late (rounded up to nearest integer).

Q: *Do I lose points if I submit at 5:02pm PT?*

Regrade Policy: If you feel a problem was graded incorrectly, you may submit a regrade request to Prof. Moura. This request MUST be submitted within one week of receiving the graded assignment, with a short paragraph justifying the regrade. Any regrade request is subject to a full regrade, i.e. points may be lost.

Policies - II

Planned Absences: You may request to submit assignments early or late. E-mail me your request three days prior to the assignment due date. Requests due to extended holidays will not be granted. Requests due to emergencies will be handled case-by-case.

Late Enrollment: Students require instructor permission to enroll after the first week of classes. Missed assignment deadlines will result in zero credit, unless otherwise arranged with the instructor.

Q: *Can I submit HW next week, just before final grades are submitted? I enrolled late.*

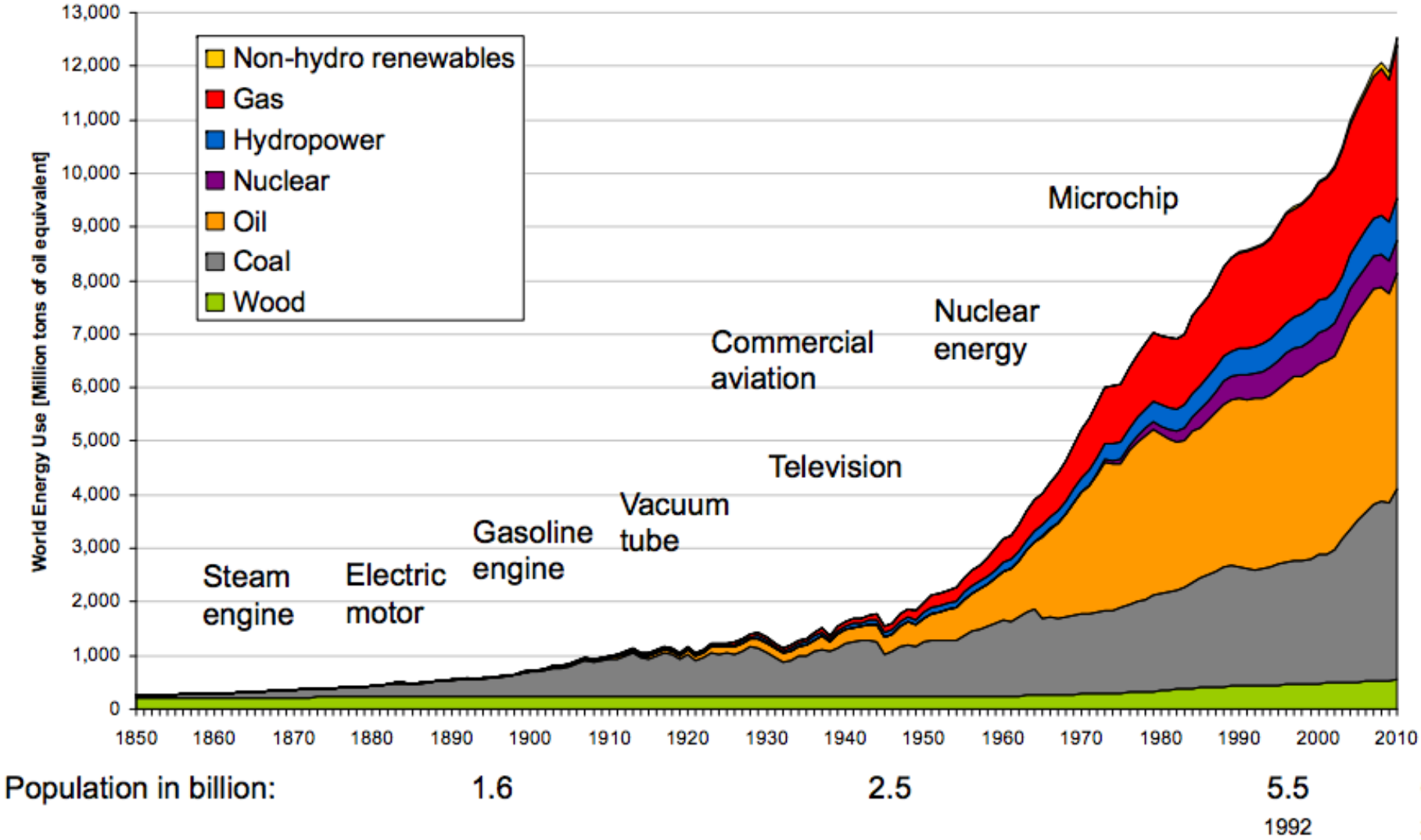
E-mail Correspondence: Use [ENE 2XX] in your message subject. We typically respond within one day, however our ability to help declines as e-mail volume increases. Please be considerate and concise. Do not wait until the due-date to ask questions, otherwise they may not be answered.

Students must abide the Code of Conduct. For further reference, see the Berkeley Campus Code of Student Conduct at `http://sa.berkeley.edu/code-of-conduct`.
If you cheat and I catch you, then you'll receive an automatic zero in ENE2XX.

How to Succeed (in a UC Berkeley or Tsinghua Engineering Course)

- Ask questions in class
- Form a study group
- Read the course notes
- Complete the exercises in the course notes
- Start HW assignments early
- See instructor after class
- See instructor during OH
- See TA during OH
- Send us an e-mail. Use `[ENE 2XX]` in subject.

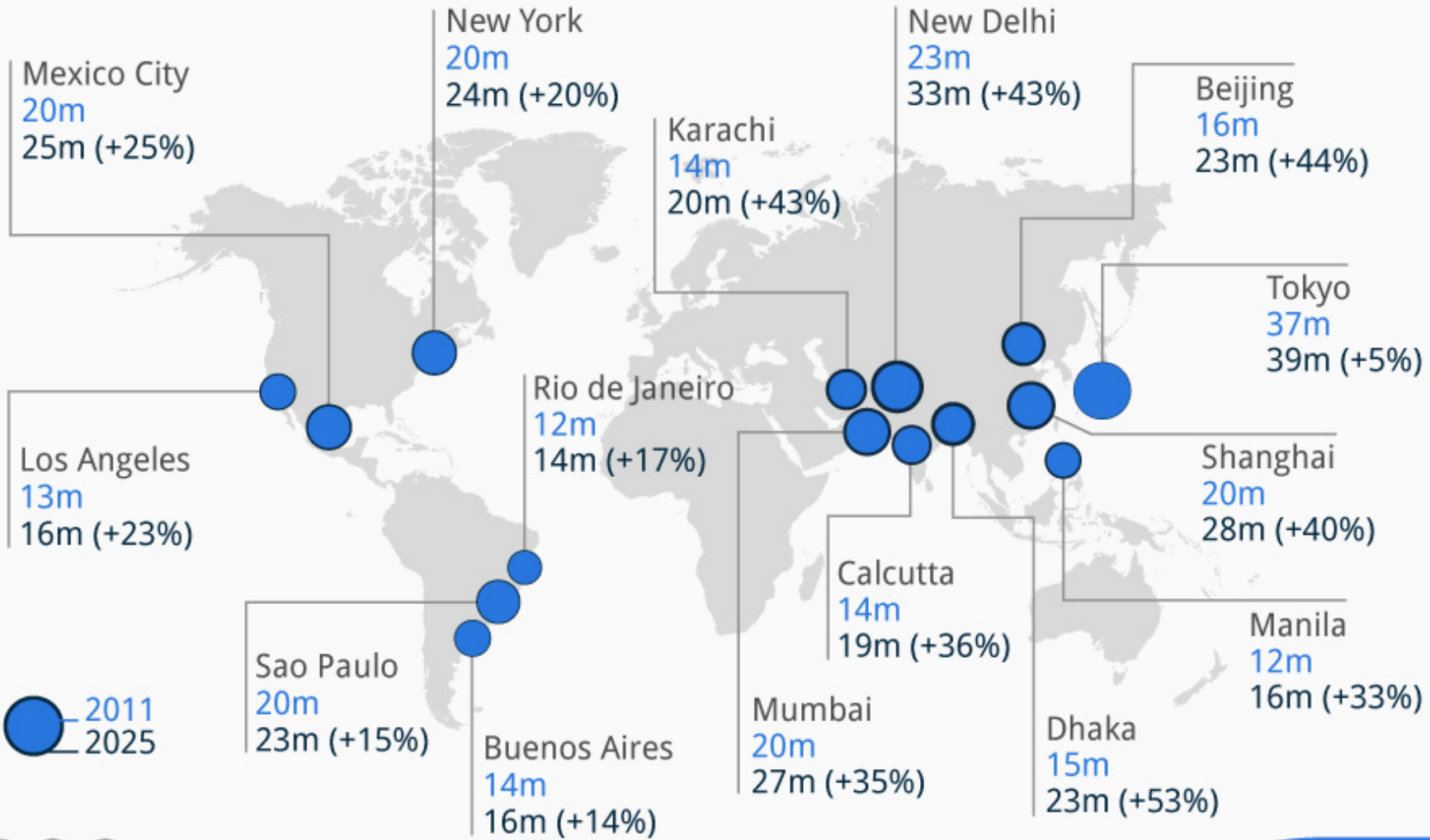
Outline



Compiled from data by Gruebler (1999), BP Statistical Review (2011) Nakicenovic & Gruebler (2000)

The World's Megacities Are Set for Major Growth

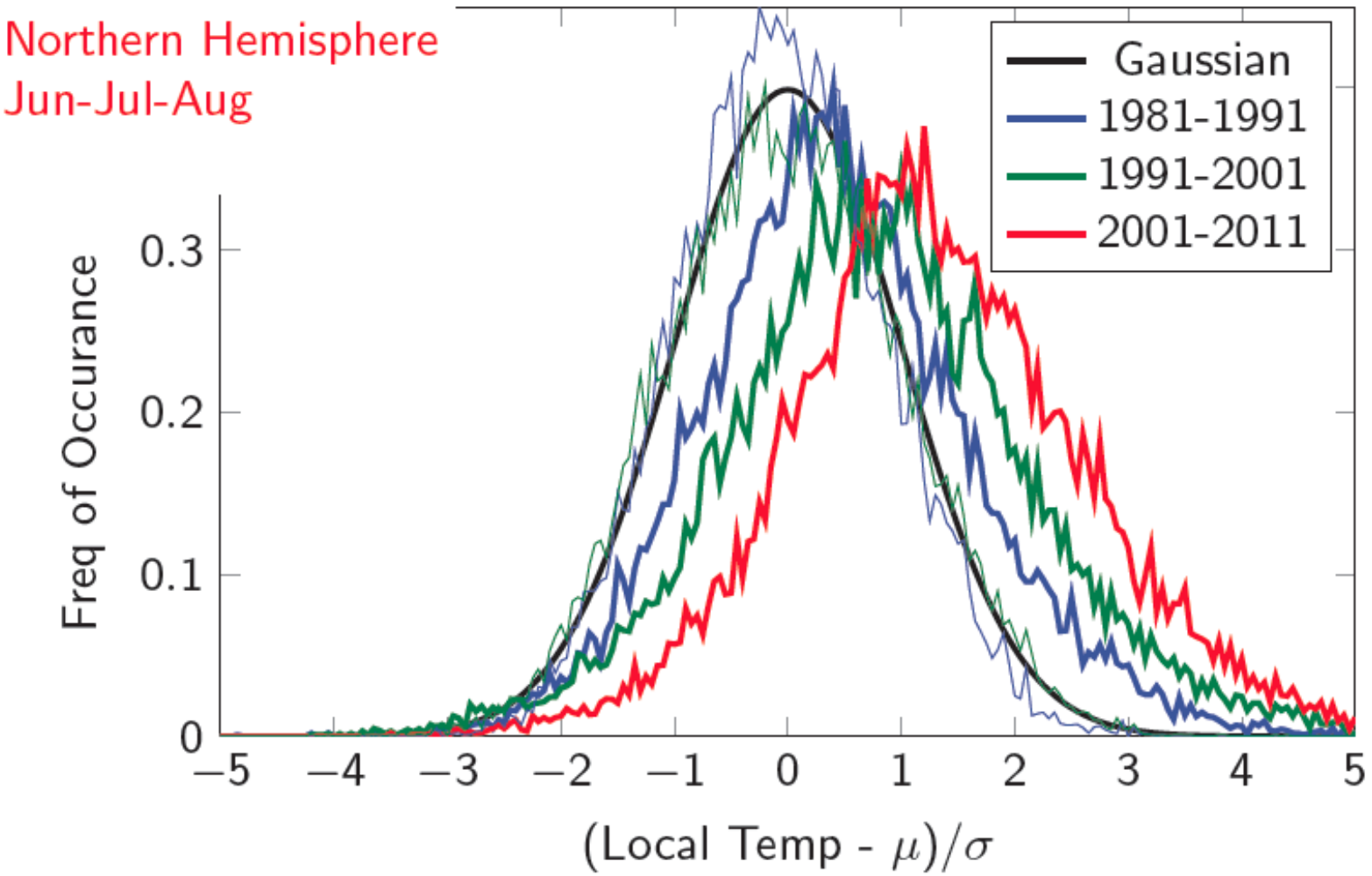
Population growth of the world's top 15 megacities (millions, 2011-2025)



* including metropolitan areas

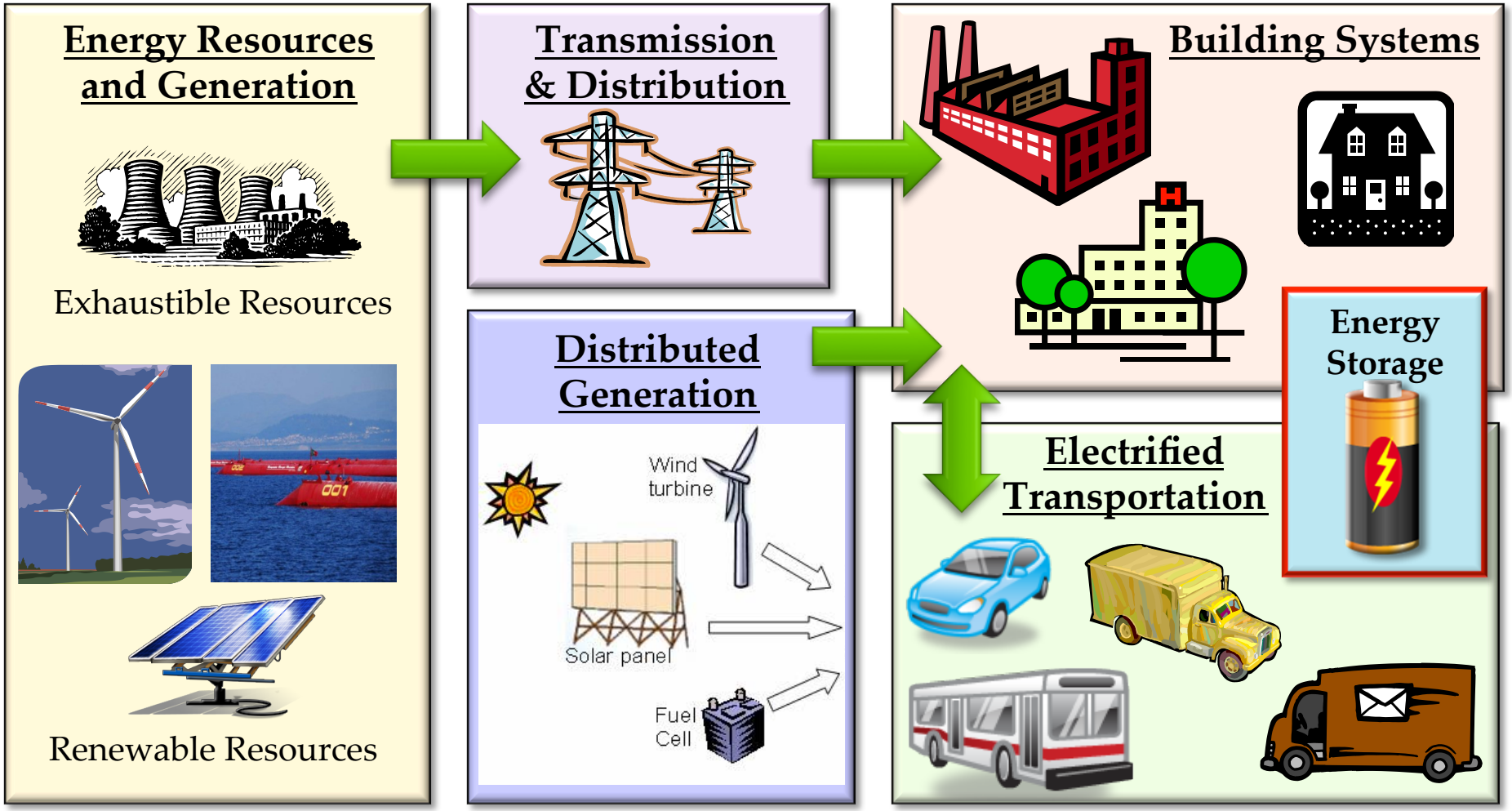
Source: UN Population Division, World Economic Forum

Global Weather Extremes



Hansen, Sato, Ruedy, Perception of climate change, *PNAS*, Aug 2012

Vision for Future Energy Infrastructure



What is a Cyber Physical System (CPS)?

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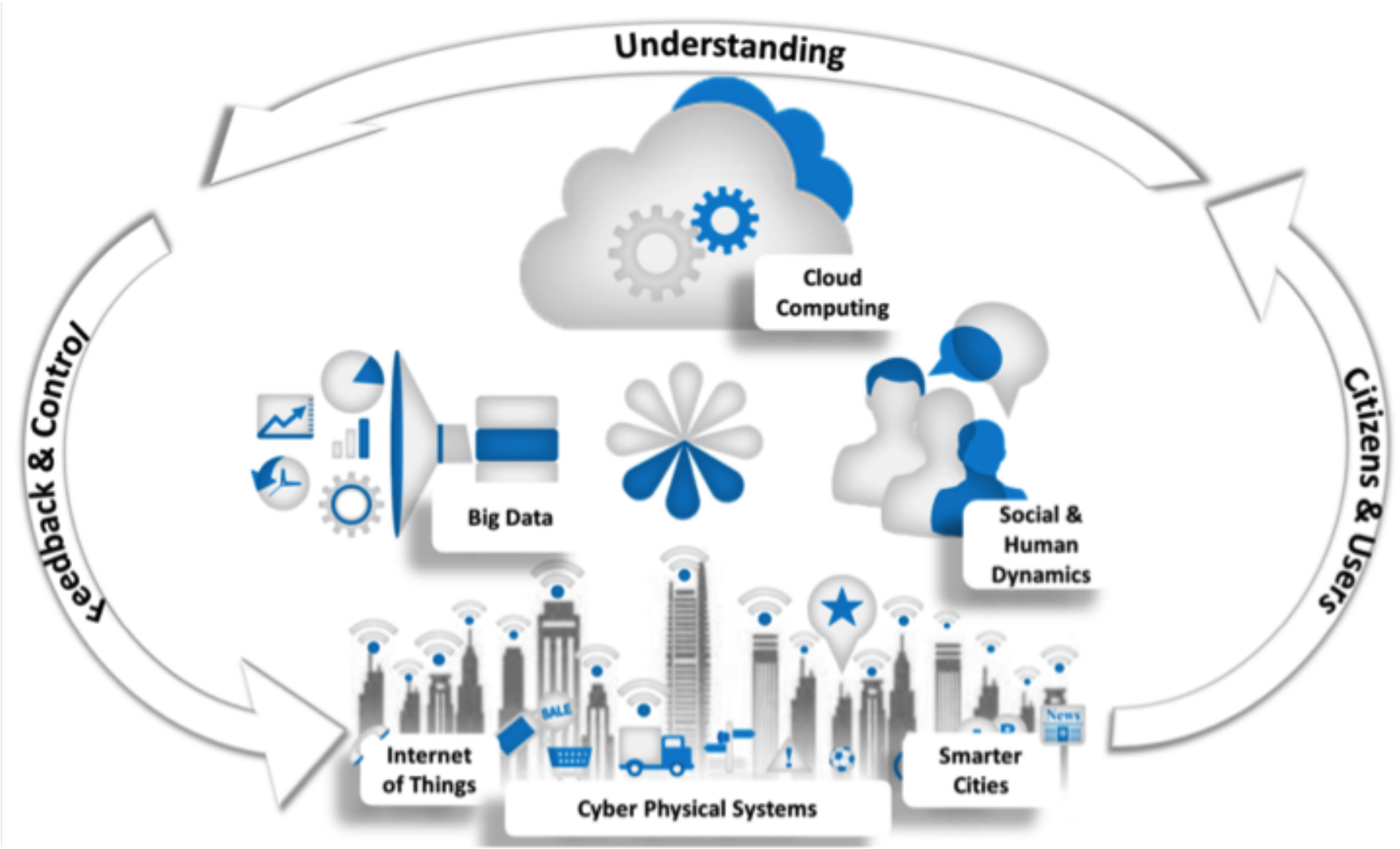
Integration of physical processes with networked computing

What is a Cyber Physical System (CPS)?

Sensing $\rightarrow$ *Understanding* $\rightarrow$ *Managing*



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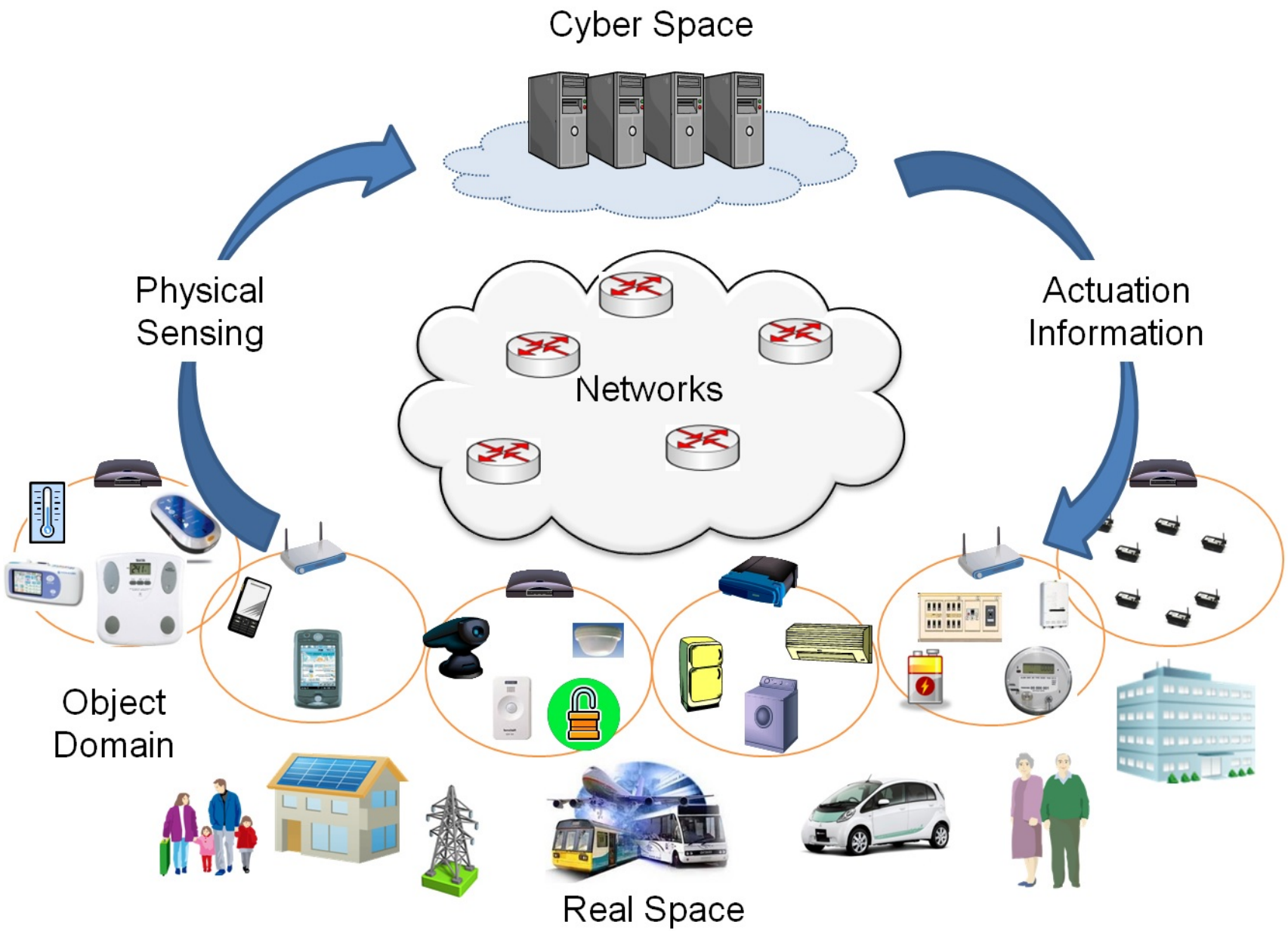


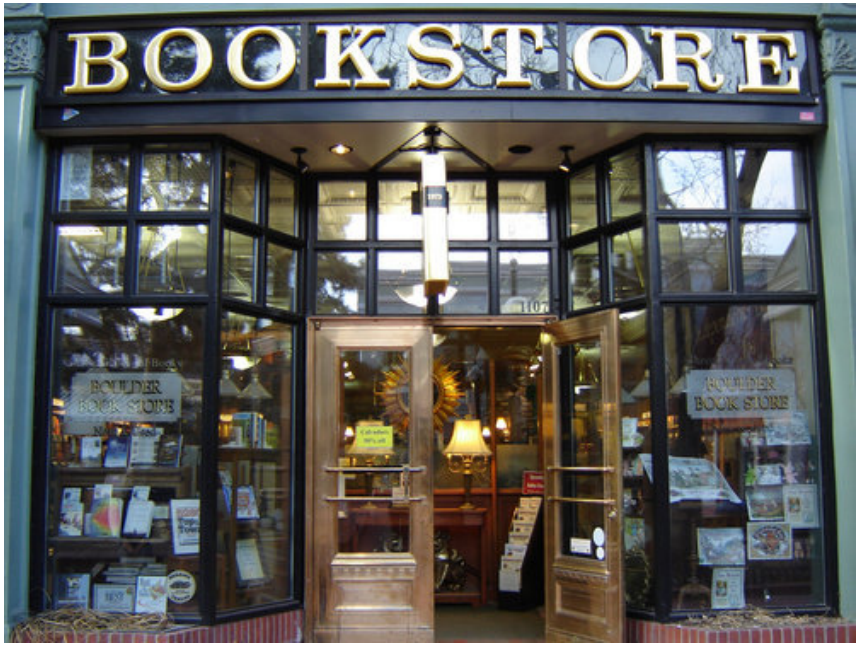
What is a Cyber Physical System (CPS)?

Five Pillars of CPS

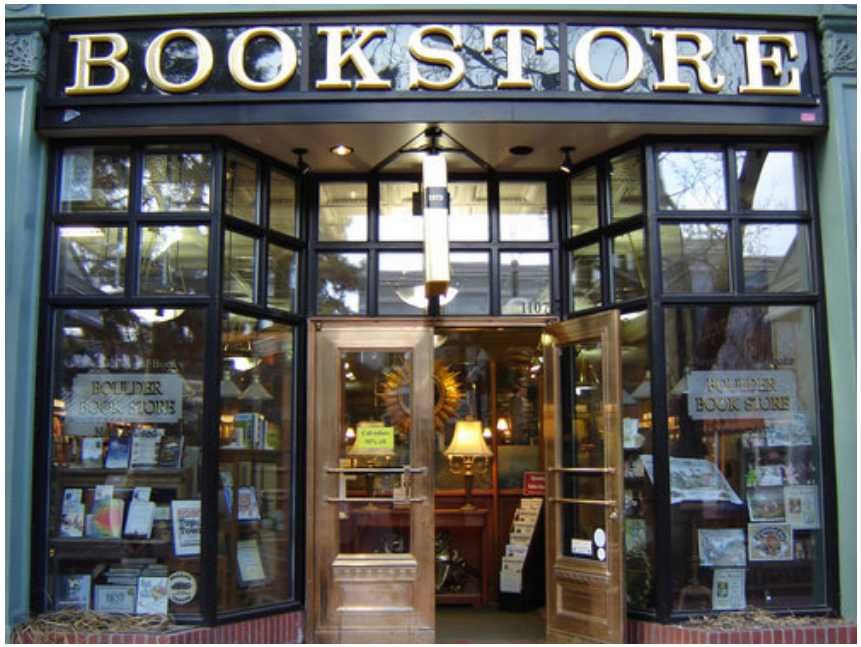
1. infrastructure systems;
2. sensing;
3. actuation;
4. connectivity;
5. **controls & optimization!**

EXAMPLES OF TRANSFORMATIVE INNOVATIONS WHEN ADDING A CYBER LAYER

Retail



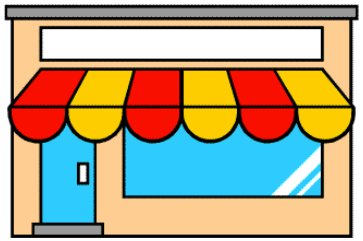
Retail

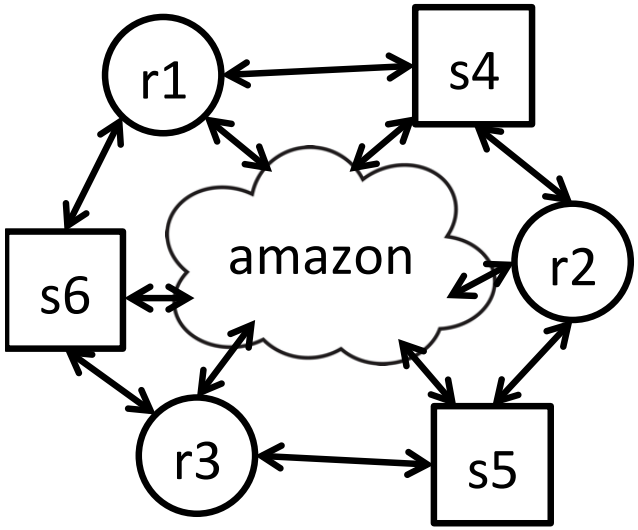


Cyber

amazon

Physical



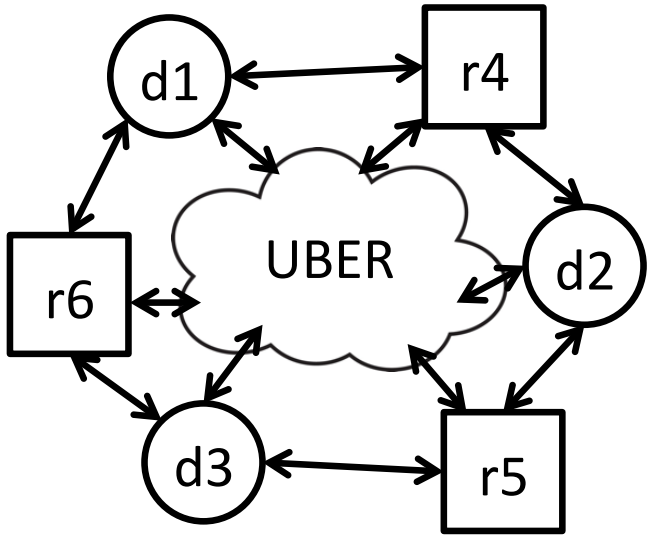


Mobility

Mobility

Cyber | UBER

Physical | 



Social Interaction

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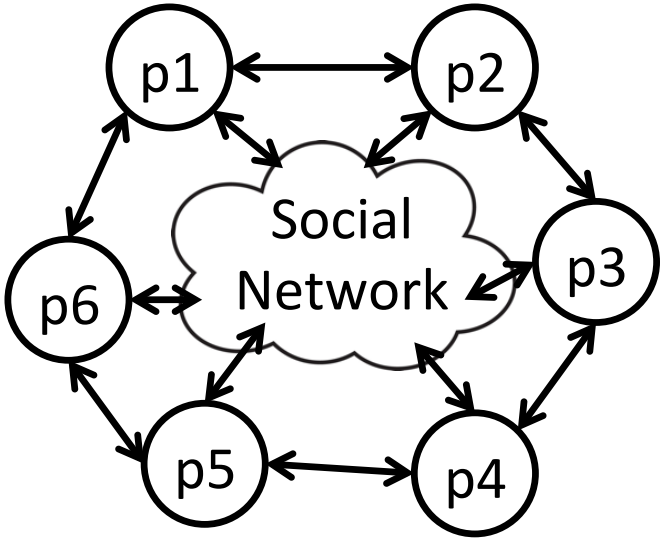


TINDER FOR ENERGY?

eBay for Energy?

a.k.a. “Internet of Energy”

APPENDIX

Related Courses

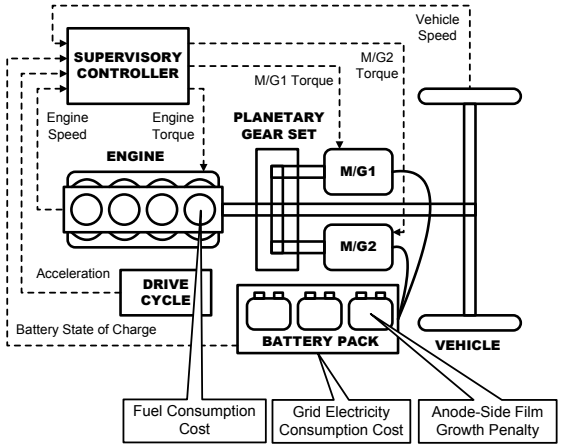
incomplete list

Systems & Control	**Energy**
CE 191 (Systems Analysis)	CE 107 (Climate Change)
EE 221A (Linear Systems)	ER 200 (Energy & Society)
ME C134 / EE C128 (FB Control)	ER 254 (Power Systems)
ME C231A / EE C220B (Experiential Ctrl)	Arch249 / ER 290 (Bldg Energy)
ME C232 / EE C220A (Adv Control)	ER 290-1 (Energy Analysis)
ME 234 (Multivar Control)	CE 290:003 (Alt. Fuels)
ME 237 / EE 222 (Nonlinear Control)	CE 256 (Sustainable Trans.)
CE 290I (Internet-based Systems)	EEP 147 (Reg. Energy & Env.)
CE C291F (Distributed Param Sys)	ARE 264 (Empirical Energy Econ)
CE 271 (Sensors & Signals)	Law 270.6 Energy Reg. & Env.
CE 263N (Scalable Spatial Analytics)	Law 270.7 (RE & Alt. Fuels)

M.S. Curriculum in Energy Systems [link]
Course Recommendations for eCAL Research [link]

Example 1: Transportation

Model S Battery Pack



PHEV Drivetrain

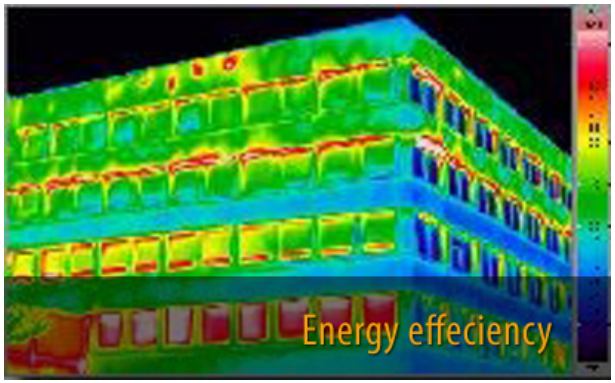
Velib Bicycles

- State-of-charge estimation
- State-of-health estimation

- Optimal energy management
- Speed forecasting and adaptation to traffic

- Redistribution problem
- Optimal station location

Example 2: Buildings



Building Environmental Monitoring

Plug Loads

Nest Thermostat

- Building model identification
- Temperature estimation
- Occupancy estimation

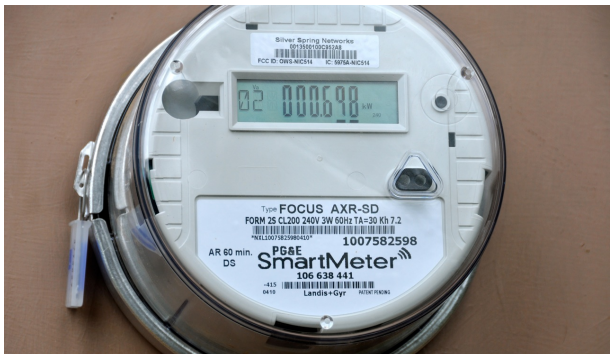
- Energy Management of Plug-Loads

- Machine Learning
- Model predictive control

Example 3: Smart Grid

Solar and Wind Power

Grid-scale Battery Energy Storage



Smart Meter

- Robust Investment Planning
- Risk limiting dispatch
- Wind/Solar Forecasting

- Management of Energy Storage
- Frequency Regulation
- Load Control

- Model predictive control
- Load aggregation