Energy Efficiency as a New Renewable: Real-Time Energy Monitoring

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Motivation

- Hubbert predicted in 1956 that US oil production would peak in 1965 based on an analysis of the rate of oil discovery
- A global application of Hubbert's peak predicts that oil production will peak this decade
- Similar analyses can be applied to the other nonrenewable energy sources such as nuclear, oil, and natural gas

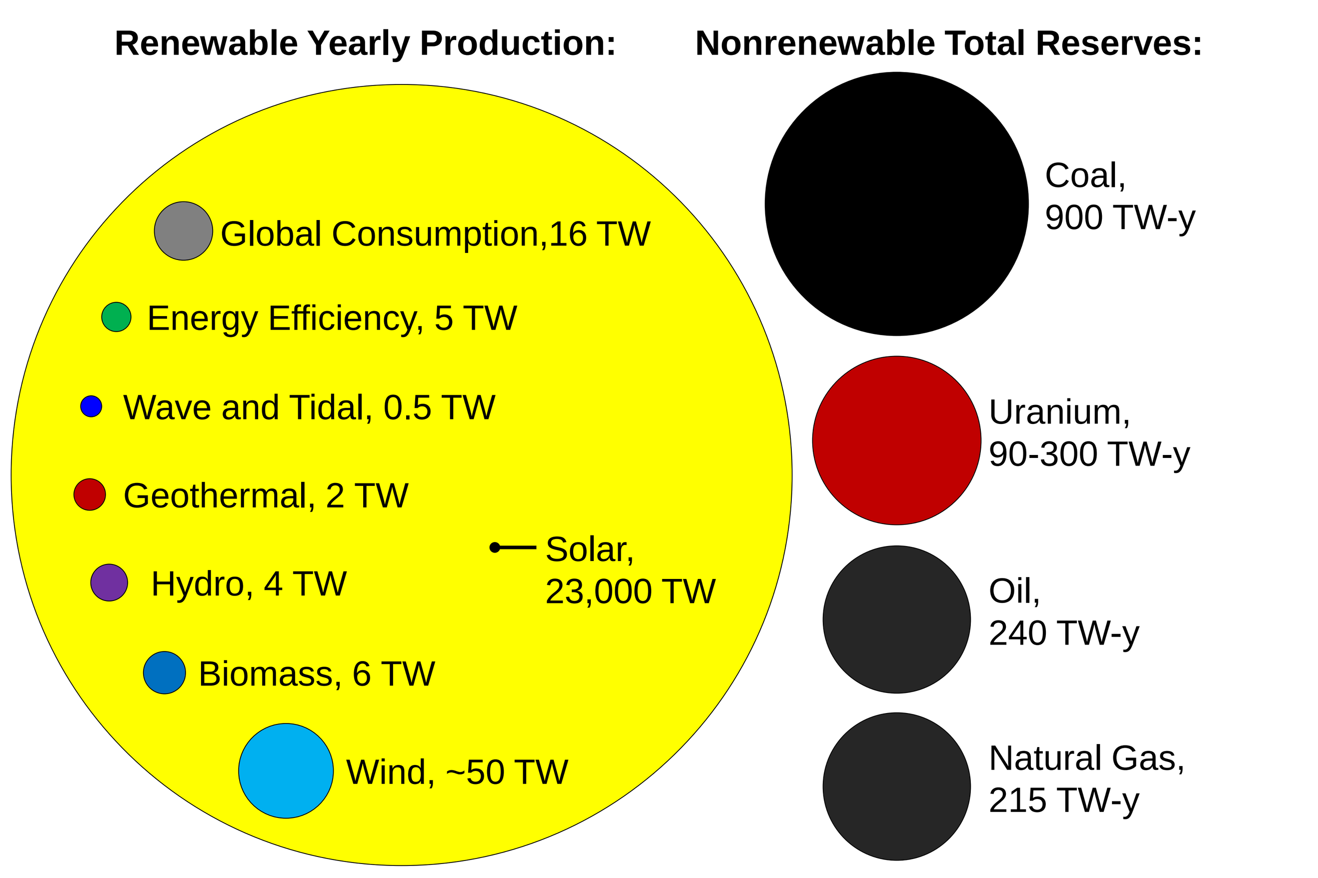

Figure 2. Estimate of finite and renewable planetary energy reserves (TW = 10^{12} watts). Energy efficiency as a "new renewable" offers the same contribution as geothermal, biomass, or hydropower. [3]

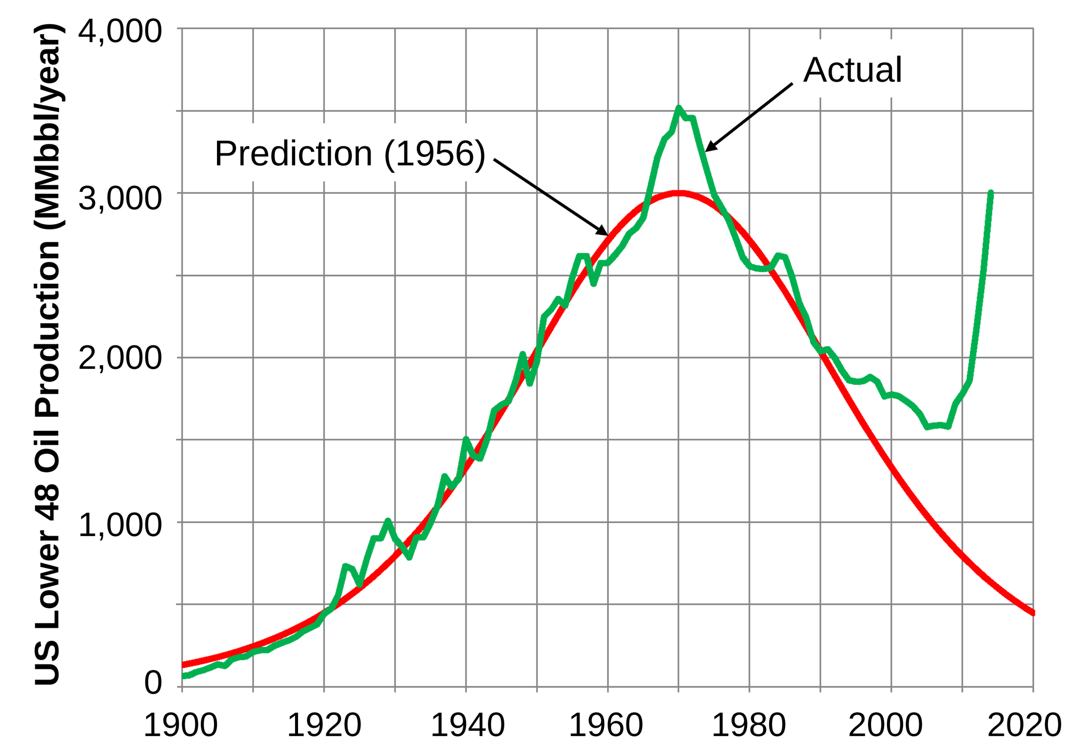

Figure 1. Hubbert's peak analysis for oil reserves in the continental United States. A global analysis predicts that the peak will occur this decade. [1, 2]

- Renewable energy sources and energy efficiency are often referred to as the "twin pillars" of sustainability
- Renewable energy sources are currently not advanced enough to compete with nonrenewables
- Energy efficiency can save consumption at an average cost of 2.8 cents/kWh, as compared to the average electricity cost in America of 10 cents/kWh [4]
- Full implementation of energy-saving measures could delay the impending nonrenewable crisis to 50% later than its current expected arrival, providing more time for research on renewable sources of energy

Energy Monitoring Setup

- To monitor lab-wide energy consumption, we deployed a network of wireless energy monitors called "Wemos" that plug in-line (to the outlet) with lab devices and broadcast power use data to a computer which is recording and processing data
- Devices which do not plug in to walls, such as overhead lights and fume hoods, were monitored by analyzing a live video stream
- This energy monitoring setup not only allows live feedback but also provides a means to test "green" practices such as signage

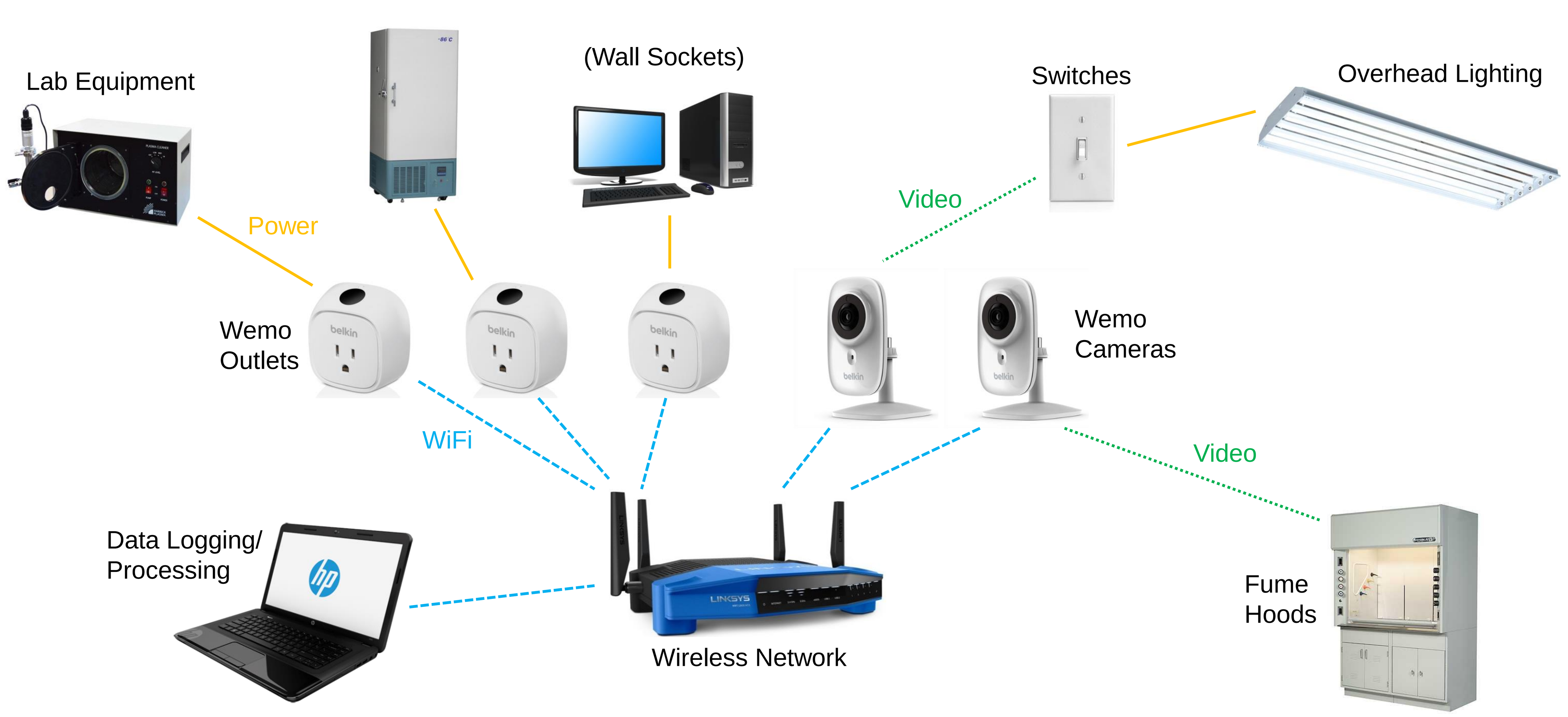

Figure 3. Schematic of the fully integrated lab space with power consumption monitoring and logging. A local wireless network connects the Wemo outlets and cameras to the data logging and processing unit. The Wemo outlets are able to directly measure power consumption of lab equipment that plugs in to wall sockets. Meanwhile, the Wemo cameras feed live video of energy consuming devices that are typically harder to log data for without intrusive hardware, such as overhead lighting and fume hoods, to the data processing unit, where custom image processing software determines the power consumption of these units in real time.

Data Analysis and Image Processing

- Data is collected from the Wemos and can be analyzed to find opportunities to save energy
- While heaters required the most power during the experiment in Figure 4, they actually consumed the least energy – instead, lighting and plasma cleaning are the areas to be targeted for the highest energy savings
- Image processing schemes for the lights (monitoring switches) and fume hoods (monitoring sash) are shown in Figure 5 below

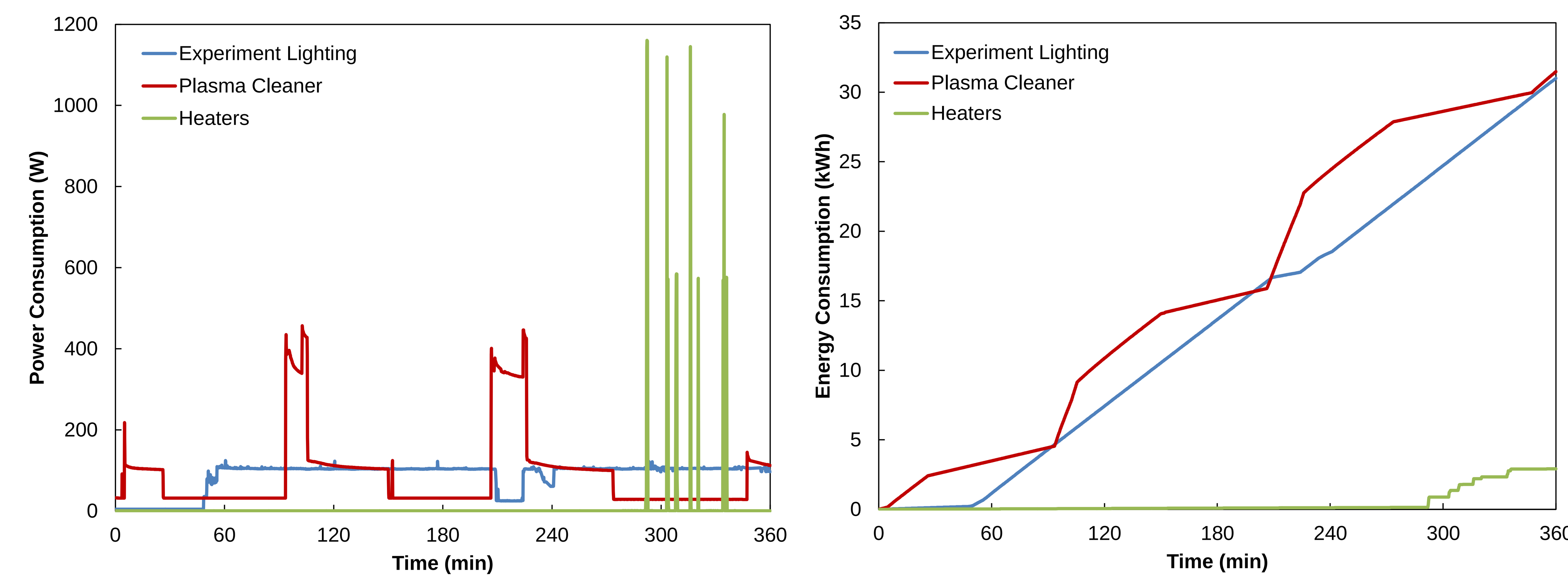

Figure 4. Data logging during a typical experiment in the lab that consisted of lighting to visualize a sample (blue), plasma cleaning the sample (red), and heating the sample (green). The plot on the left shows the instantaneous power consumption during the experiment over time, and the plot on the right shows the cumulative energy consumption, which is the integral of the data on the left.

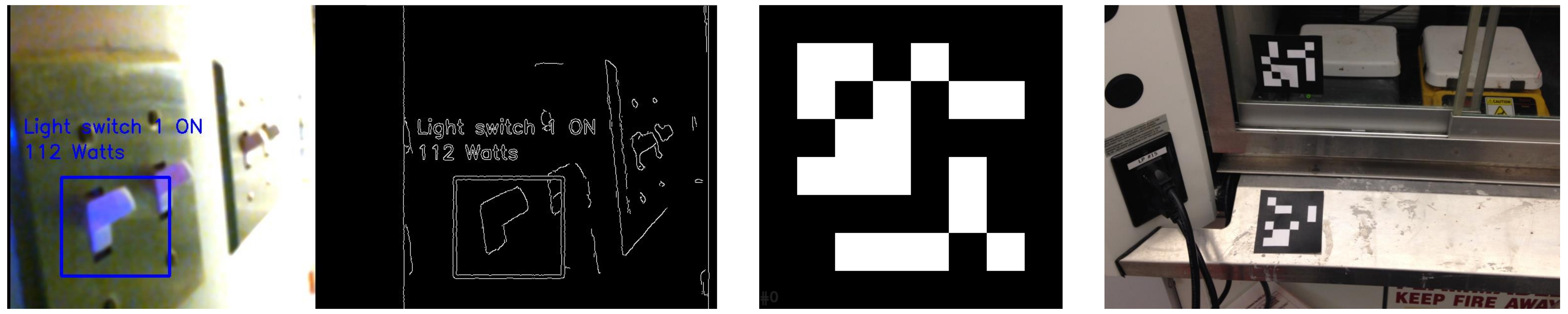

Figure 5. Image processing of a live video stream of a panel of light switches (left). The method was tested in every configuration of switches and had a 100% success rate. For the fume hoods, a pattern similar to a QR code (center) is used because it is easily recognized by image processing software, which then allows the software to determine whether the sash is open or closed (right).

Future Work

- **Lab Energy Assessment Centers** (LEACs) will be founded at MIT and at affiliate universities
  - The LEACs will have their own set of assessment tools similar to the network shown in Figure 3
  - Assessments will be conducted a team of undergraduates supervised by a grad student and a faculty member
  - Results will be presented in a report to assessed labs – the report will detail methods to save energy tailored to the specific lab
  - Affiliate university LEACs will provide collaboration and synergy, particularly if these affiliate LEACs are at schools with IACs
- **MechE Lab-Assist Program**
  - Half of the funding for this program will go to implementation of a department-wide glove recycling program
  - The other half of the funding will be awarded to innovative "green" ideas proposed by members of the department
- **Stand-alone fume hood monitoring device**
  - Designing and building a device which monitors a fume hood and alarms when the fume hood is left open and not in use
  - This effort is being performed in collaboration with Kristina Haslinger from the Prather group at MIT

Acknowledgements

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References

[1] US Energy Information Administration Reports. [2] Deffeyes, K. *Hubbert's Peak: The Impending World Oil Shortage* (2001).
[3] Perez, M., and R. Perez. *A Fundamental Look at Supply Side Energy Reserves for the Planet* (2015).
[4] The Economist [News Magazine]. *Invisible fuel* (2015).