# Two Visions of Energy Control Software Platforms

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## Abstract

Building occupants, building physics, HVAC systems, and controls make up a complex dynamical system with continuous and discrete states and interactions, i.e. a hybrid dynamical system. Traditionally, occupant physics and behavior are abstracted from the building engineering through simple room temperature set-points. At most, the interaction between the two systems is captured by changing setpoints based on occupancy. This abstraction neglects the autonomy of users to change setpoints and create over-rides that often forfeit the savings that the control system aimed to achieve. As users increasingly interact with home energy IoT devices, this shared autonomy will grow in significance. This research aims to leverage these interactions to build classes of hybrid-dynamical models of user behavior. Such models will be implemented in model-based estimators of the noisy channel between user desire and the control system reference. This data driven approach will utilize datasets from thousands of occupants from Pecan Street and Ecobee.

## Motivation

- The economic, environmental, and social impacts of HVAC systems have driven a demand for increased efficiency and effectiveness. The **energy consumed by HVAC** systems comprise **14% of all energy consumed** in the US annually [1].
- **Space cooling and heating** account for **nearly 20%** of U.S. **residential** consumption by U.S. eia estimates [2].

"Demand for high performance and adaptive infrastructure increases the complexity of the system dynamics and interactions. How do we create complex systems that users understand and trust? We must share the autonomy of decision making between computer systems and the people they serve."[1]

Fig. 1 Raspberry Pi Zero W

## Materials & Methods

- Two software packages were examined:
  - **openHAB:** A **general IoT** controller that handles automation software for the home, which may focus on HVAC applications. (Utilized for HestiaPi thermostat.)
  - **BEMOSS:** Energy management software focusing on **HVAC, Plug Load, and Lighting** with an emphasis on **security** protocols via Volttron.
- **HestiaPi**'s documentation/source code served as the starting point that transitioned into that companies underlying reliance on **openHAB** as the backend service manager.
- **BEMOSS**' documentation/source code and reliance on **Volttron**'s security software implementations mirrored the relationship of HestiaPi as the "OS" of sorts with openHAB underneath.

## BEMOSS & openHAB Differences and Similarities

### Features

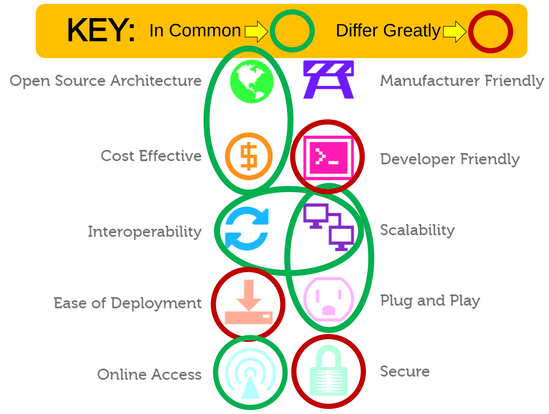
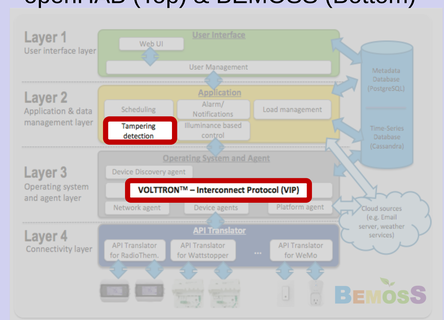
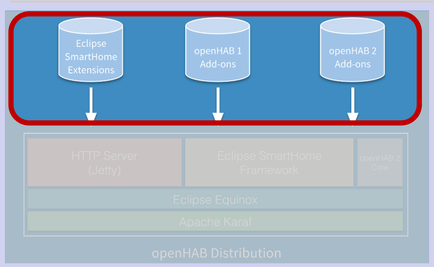



Fig. 2 Features BEMOSS and openHAB share are circled in green throughout while ones that differ greatly are circled in red.

### Architecture

openHAB (Top) & BEMOSS (Bottom)

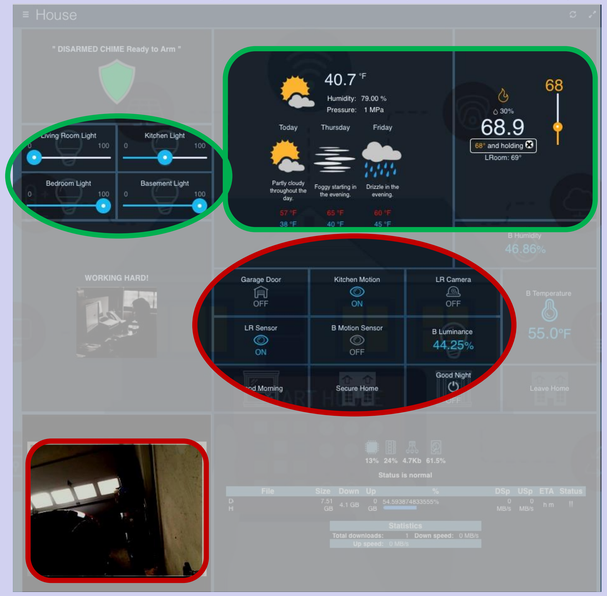


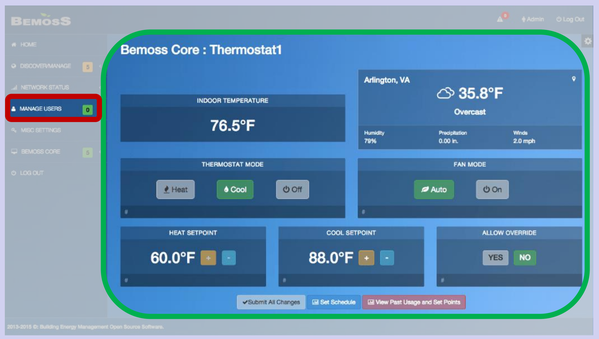

openHAB relies on add-ons from it's sizeable user-base of 20,000+ members for many functions.

### openHAB & BEMOSS GUI

**openHAB (Top)** has much greater extensibility than **BEMOSS (Bottom)** but does not emphasize security.




openHAB can accommodate virtually any IoT device the end-user desires to include, and modify the GUI to suit their needs and uses. However, openHAB can only support a single user. **No multi-user support**.




Even in the GUI BEMOSS does not lose it's focus on Security. Notice the "MANAGE USERS" button that openHAB does not support.

## Results

- For enterprise or home applications where **security, and ease of scalability**, BEMOSS is the clear choice for such cases. Focusing solely on HVAC, Plug Load, and Lighting control and security allow **BEMOSS** to maintain a tight focus and implement those things very well.
  - **Security Features:**
    - Automatically generates an encryption key and enables CurveMQ by default on all TCP connections.
    - Method for verifying credentials during initial exchange against a list of accepted peers.
- For enterprise or home applications where variety of add-ons (**extensibility**), an **active user-base** of 20,000+, and a **compatibility** with many IoT devices including HVAC, Plug Load, and Lighting controllers, openHAB is the better choice.
- Security Concerns Regarding openHAB:
  - lacks multi-user support, and the ability to restrict access through http(s) for certain users. In fact, "there is no authentication in place, nor is there a limitation of functionality or information that different users can access."[4]

## Conclusions

- BEMOSS is the more **robust, professional, and secure** platform for Energy Management.
  - BEMOSS supports multi-node scalability allowing for theoretically any size network.
- openHAB is not suitable for any enterprise Energy Management application.
  - openHAB is novel in it's extensibility but lacks key features that would be critical to enterprise level applications.

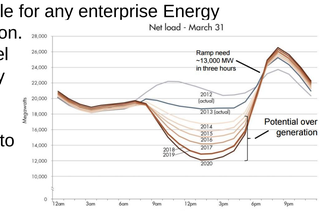



Fig. 3 California Energy Load Curve

## Future Research

Implementation of a control system using a digital twin of the structure that could effectively "share decision-making autonomy between users and a building energy management system, allowing the users to focus on thermal comfort… while the automatic controls balance the dynamics between the HVAC system, energy storage/generation." [1]

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**Research Experiences for Undergraduates Pathways Opening World Energy Resources" (REU - POWER)**
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**References:**
[1]: Kane, Michael B. "Modeling Human-in-the-Loop Behavior and Interactions with HVAC Systems." June 2018. AMERICAN CONTROL CONFERENCE
[2]: "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." *FREQUENTLY ASKED QUESTIONS*, 3 May 2018, https://www.eia.gov/tools/faqs/faq.php?id=96&t=3.
[3]: https://volttron.readthedocs.io/en/latest/core_services/messagebus/VIP/VIP-Authentication.html
[4]: "Securing access to openHAB" openHAB, 08 June 2018, https://www.openhab.org/docs/installation/security.html.

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