Development of Distributed Energy Resources for Large-Scale, Energetically Self-Sufficient Buildings

Andrea Miramontes Serrano[1] | Joseph Skovira[2]

[1] School of Electrical and Computer Engineering | [2] School of Electrical and Computer Engineering I Cornell University, NY 14853, USA

RATIONALE

In **2018**, EPA estimated that 56% of global Greenhouse Gas (**GHG**) emissions derive from energy consumption (27% coming from electricity production and 22% from industry). Over the past decades, there has been international interest in reducing these figures.

Major trends in Renewable Energy Technologies (**RETs**) innovation include incorporating distributed energy resources (**DERs**). Instead of being connected to the commercial grid, these small-scale generators focus primarily on private use. Examples of these include photovoltaic rooftops and panels aimed at achieving energetic self-sufficiency. A large-scale implementation of these resources could significantly reduce EPA's reported electricity production emissions, and potentially the industry's too.

To explore alternative pathways to energetic autonomy, this research focuses on ready-available kinetic energy. Specificallly, the rise of home-owned fitness equipment leads to the study of stationary bicycles and their potential in supplying power to prvate buildings.

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METHODOLOGY

SCOPING DEMAND

Question:
How much electricity is needed to maintain carbon neutral buildings?

Strategy:
Analyze data from 229 buildings across 68 NYS locations.

Figure 1 – Geographic Distribution

STUDYING TECHNOLOGY

Question:
What components maximize power output given low budgets?

Strategy:

Explore

1. Current technologies
2. Power storage, rectifiers & distribution systems
3. Motors & Generators

DEVELOPING HARDWARE

Question:
Test theoretical conclusions and identify practical concerns.

Strategy:

Build a bicycle powered generator. Determine areas of improvement.

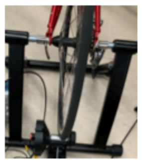


Figure 2 – Bicycle Generator

RESULTS

SCOPING DEMAND

- **Real** time and **static** data
- 183 data structures
- HVAC, lighting, office equipment

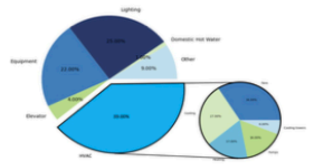


Figure 3 – Classification of Commercial Building Energy Consumption

STUDYING TECHNOLOGY

Current Technologies
- Private Sector
- Adacemia
- Open Source

Power Storage, Rectifiers and Distribution Systems:
- Low voltage, DC minimizes losses

Motors & Generators :
Cost effective, impractical.

DEVELOPING HARDWARE

Maximum:
51V

Average:
20V

Minimum:

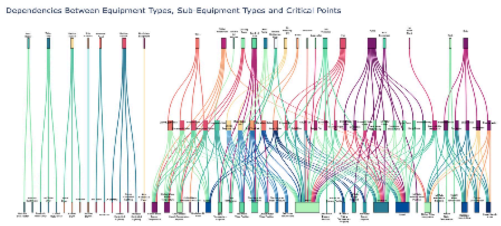
2V

Challenges:
Circuitry was damaged.

Solution:
Combination of buck and boost converters protected the battery.

THE DATABASE

Figure 4 – Equipment Types (Top) Associated with Subequipment Types (Middle) and Point (Bottom) Dependencies



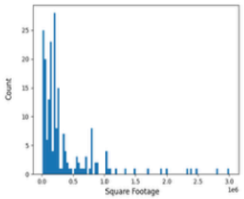


Figure 5 – Distribution of the square footage of building database

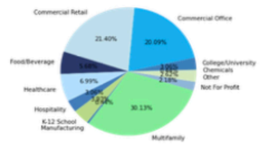


Figure 6 – Representation of 11 Building Categories in Dataset

CALCULATIONS

The most relevant calculation surrounding the power generation mechanism determined the KV rating of the motor so that average pedaling speeds will yield **9-15V.**

$$\omega_{tire} = \frac{15mi}{1h} * \frac{1h}{60min} * \frac{1609344mm}{1mi} = \frac{402336mm}{1min}$$

$$= \frac{402336mm}{1min} * \frac{1rev}{1910mm} = \frac{210rev}{1min} = 210rpm$$

$$\omega_{dw} = \mathcal{R} * \omega_{tire} = 210rpm * 63.67 = 13370rpm$$

$$\mathcal{KV} = \frac{\omega_{dw}}{12V} = \frac{13370rpm}{12V} \approx 1114$$

CONCLUSIONS I

Conclusion 1: The conducted literature review suggested that regular office spaces distribute their demand as indicated in with **HVAC** systems ranking highest, particularly fans, followed by **lighting** and **office equipment.**

Conclusion 2:

1. Bicycle Generators have been developed by:
- Private entities – yielding nonprofitable business plans..
- Academia – low power output, mainly educational.
- Open source developer - low cost, impractical models.

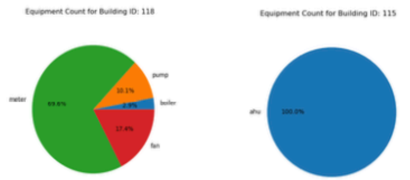
2. Optimal results were found in Tesla's inverters, DC microgrids, low voltages.

3. Brushless DC motors.

CONCLUSIONS II

Conclusion 3: The voltage outputs for the individual device were within the expected ranges. However, these results are very reliant on the dimensions of the bicycle used. Whereas a single bicycle generator **cannot power an entire house**, it can charge wide ranges of electrical appliances.

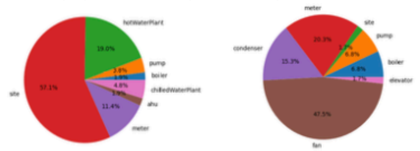
CONFIRMING DATA INTEGRITY



The installed measuring devices determined that HVAC systems consumed most electricity **yet:**

Not enough buildings provided **HVAC** sub-equipment data - e.g. Fan Coil Units (**FCUs**), fans, Air Handling Units (**AHUs**) – to:

- Determine application-specific energy demand
- Develop a consumption hierarchy
- Identify systems to be powered by human kinetic energy.



RESEARCH CONTINUITY

SCOPING DEMAND
- Strengthening access to energy consumption data
- Ensure meter coherence
- Detect meter anomalies and faults

STUDYING TECHNOLOGY
- Analyze stochastic controls and generation cycles.
- Explore different fitness equipment

DEVELOPING HARDWARE
- Minimizing the Generator Cost
- Maximizing power output
- Increasing User Comfort
- Consider different tire-wheel ratios

FURTHER REFERENCES & PARTNERS

[1] Edwin Cowen
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[3] Tesla Inc
[4] NYSERDA
[5] Cornell EMCS Portal
[6] Maha Haji
[7] Steve Mandl
[8] Robert Feldstein
[9] Kaylin Chan

am2389@cornell.edu
jfs9@cornell.edu