Analyzing Multifamily Building Common Area Electricity Consumption Features and Saving Potentials - Findings from Residential Building Energy Audit Project

Ting-Jui Sun¹; Min-Chia Su¹; Wen-hsiang Lin², Wen-Hua Liao¹; Wei-Huang Hsieh²; Chuan-Yi Su¹; Meng-Tai Fu¹

1. Industrial Technology Research Institute, Taiwan
2. Taiwan Green Productivity Foundation

37th USAEE Conference, Denver, USA (Nov.3-6)
Agenda

• Introduction
• Summary
• Method
• Results
• Conclusion, challenge and future work
Household structure change in Taiwan

- 22% of 8.6 million households living in 6 or more stories building
- Almost 30~45% new real estate property square footage belong to common area, according to the sale information data.

Source: Report on the Survey of Family Income and Expenditure, 2019, National Statistics, Taiwan
Highlights from previous survey

Taiwan residential electricity use flow

Multifamily account for 28% residential electricity use, 20% electricity use in multifamily is common area.

Source:
1. Home Electricity Survey (n = 1800, S.E. = ±2.31%)
2. Multifamily Building Common Area Electricity Survey (n = 518, S.E. = ±4.3%)

Highlights from previous survey
Multifamily management mode

Over 47% condo apart. hire a PMC manager, but 45% PMC are not responsible for M&E maintenance service.

Highlights from previous survey

Who pay the utility bills?

Around **60%** HOAs of utility bills pay by condo fee.


Percent of HOAs

<table>
<thead>
<tr>
<th>Category</th>
<th>Pay by tenants</th>
<th>Some pay by HOA, the other pay by tenants</th>
<th>Pay by HOA/Condo fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large-size</td>
<td>50%</td>
<td>22%</td>
<td>28%</td>
</tr>
<tr>
<td>Median-size</td>
<td>68%</td>
<td>4%</td>
<td>28%</td>
</tr>
<tr>
<td>Small-size</td>
<td>64%</td>
<td>7%</td>
<td>29%</td>
</tr>
<tr>
<td>Micro-size</td>
<td>55%</td>
<td>5%</td>
<td>40%</td>
</tr>
<tr>
<td>Total</td>
<td>59%</td>
<td>11%</td>
<td>30%</td>
</tr>
</tbody>
</table>
Motivation and purpose

More issues after the national survey…
1. SEU end-use features and behaviors?
2. Disaggregation electricity consumption?
3. Saving potentials?

The program started the Phase II with…

- Target: large-size (over 100 households) HOA, residential use only
- Limited resources: 30 samples
- Incentives for survey: free energy diagnosis report

Note: SEU (Significant Energy Use) included (A.C., lighting, elevators, ventilators in parking lots, water supply, and drainage)
Summary

• This study is based on…
  ▪ 13 in-depth interviews and a on-site questionnaire survey with energy audit

• Key driver to electricity consumption in common area
  ▪ Occupied number of households
  ▪ Occupied square feet
  ▪ building heights

• Disaggregation electricity consumption in multifamily
  ▪ Elevator(42%); ventilation(21%); lighting(19%)
  ▪ Share of electricity varies by facility type

• 5.56% technical potentials of large-size multifamily electricity consumption, 4.25% of economic potentials

• Recognizing the multiple benefits of EE with security and health in multifamily
Our survey overview

- **In-person visit questionnaire survey is needed**
  - Too many stakeholders: HOA members, on-site property manager, M&E equipment maintainers (2~3 companies)
  - High turnover rate of stakeholders (1~2 years)
  - Insufficient energy education for stakeholders

- **Our survey response rate was 37.5%**
  - Response rate was much higher than 19.3% for previous survey
  - Strong incentives to HOA: free energy diagnosis report

- **Data quality assurance analysis included**
  - Comparing to previous survey sample structure
  - Measuring the key technical factor to SEU (current, voltage, P.F.)
  - Checking the response rate by subgroups
What information is available for estimating end-use consumption?

- Unfortunately, no sub-metering data support our project.
- End-use consumption must be estimated from the resources:
  - On-site survey
  - Secondary data collection (few programs target multifamily building)
  - In-depth Interview with stakeholders (customers covered 20% market)

\[ \text{Estimates} = f(\text{billing, power consumption, operation hours, eff.}) \]

<table>
<thead>
<tr>
<th>End-use/Var.</th>
<th>N</th>
<th>PCi</th>
<th>ORi</th>
<th>Other var.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air conditioner</td>
<td>Custom</td>
<td>Custom</td>
<td>Custom</td>
<td>Multiple deemed by product spec.</td>
</tr>
<tr>
<td>Lighting</td>
<td>Custom</td>
<td>Custom</td>
<td>Custom</td>
<td>N/A</td>
</tr>
<tr>
<td>Ventilator in Parking lot</td>
<td>Custom</td>
<td>Custom</td>
<td>Custom</td>
<td>Multiple deemed by product spec.</td>
</tr>
<tr>
<td>Elevator</td>
<td>Custom</td>
<td>Multiple deemed by person capacity</td>
<td>Multiple deemed by households</td>
<td>Multiple deemed by product spec.</td>
</tr>
<tr>
<td>Water supply,</td>
<td>Custom</td>
<td>Custom</td>
<td>Custom or Single deemed</td>
<td>Multiple deemed by product origin</td>
</tr>
<tr>
<td>Drainage</td>
<td>Custom</td>
<td>Custom</td>
<td>Custom or Single deemed</td>
<td>Multiple deemed by product origin</td>
</tr>
</tbody>
</table>
How do we measure the saving potentials by end-use?

- Engineering-based calculation
- Focusing on replacing outdated equipment
- Technical and economical saving potential are both recognized
  - Technical saving potential: meeting the replacing standard
  - Economical saving potential: the payback year of EE investment below 3 years

<table>
<thead>
<tr>
<th>End-use /Variable</th>
<th>Replacing Standard (Equipment Age)</th>
<th>Baseline</th>
<th>Projected Reporting Period</th>
<th>Operation Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Equipment specification</td>
<td>Parameters</td>
<td>Equipment specification</td>
</tr>
<tr>
<td>Air conditioner</td>
<td>10 year and above</td>
<td>Nameplate</td>
<td>Industrial Experts</td>
<td>EPS&amp;EERL</td>
</tr>
<tr>
<td>Lighting</td>
<td>14 year and above</td>
<td>Nameplate</td>
<td>N/A</td>
<td>Same as baseline</td>
</tr>
<tr>
<td>Ventilator In Parking lot</td>
<td>15 year and above</td>
<td>Nameplate</td>
<td>Industrial Experts</td>
<td>Same as baseline</td>
</tr>
<tr>
<td>Elevator</td>
<td>12 year and above</td>
<td>Nameplate</td>
<td>Industrial Experts</td>
<td>Same as baseline</td>
</tr>
<tr>
<td>Water Supply</td>
<td>10 year and above</td>
<td>Nameplate</td>
<td>Previous Study</td>
<td>Same as baseline</td>
</tr>
<tr>
<td>Drainage</td>
<td>Non- LED light fixture</td>
<td>Nameplate</td>
<td>Previous Study</td>
<td>Same as baseline</td>
</tr>
</tbody>
</table>

Method

- Engineering-based calculation
- Focusing on replacing outdated equipment
- Technical and economical saving potential are both recognized
  - Technical saving potential: meeting the replacing standard
  - Economical saving potential: the payback year of EE investment below 3 years
## SEU features & behaviors

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Count</th>
<th>Main driver</th>
<th>Penetration rate by HOA</th>
<th>Utilization rate by equipment or area</th>
<th>Operation hours by equipment or area</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.C.</td>
<td>n=107</td>
<td>Square f.t.</td>
<td>66%</td>
<td>70%</td>
<td>Sum.9 hr 30 mins per time, 3 times per day</td>
</tr>
<tr>
<td>Ventilator</td>
<td>n=493</td>
<td>Household</td>
<td>95.5%</td>
<td>89%</td>
<td>Un-know 15 mins per time, 2 times per day</td>
</tr>
<tr>
<td>Elevator</td>
<td>n=170</td>
<td>Households</td>
<td>99%</td>
<td>100%</td>
<td>15 mins per time, 2 times per day</td>
</tr>
<tr>
<td>W. S.</td>
<td>n=280</td>
<td>Bldg. height</td>
<td>99%</td>
<td>100%</td>
<td>15 mins per time, 2 times per day</td>
</tr>
<tr>
<td>Drainage</td>
<td>n=280</td>
<td>Households</td>
<td>86%</td>
<td>79%</td>
<td>Lobby 12 Staircase 9 Parking 24 Other 3</td>
</tr>
<tr>
<td>Lighting</td>
<td>N&gt;18,000</td>
<td>Square footage</td>
<td>80~100%</td>
<td>95~100%</td>
<td></td>
</tr>
</tbody>
</table>
Disaggregation electricity use

Elevator make up 42% of electricity use while ventilation and lighting comprise 21% and 19% respectively, but share of electricity varies by facility type.

<table>
<thead>
<tr>
<th>Facility Type (number of entertainment &amp; leisure facilities)</th>
<th>Total (30)</th>
<th>Luxury (14)</th>
<th>Basic (8)</th>
<th>Econ. (8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>192MWh</td>
<td>277MWh</td>
<td>149MWh</td>
<td>86MWh</td>
</tr>
<tr>
<td>Drainage</td>
<td>8%</td>
<td>10%</td>
<td>6%</td>
<td>1%</td>
</tr>
<tr>
<td>Water supply</td>
<td>8%</td>
<td>8%</td>
<td>6%</td>
<td>11%</td>
</tr>
<tr>
<td>Elevator</td>
<td>42%</td>
<td>38%</td>
<td>45%</td>
<td>54%</td>
</tr>
<tr>
<td>Ventilation</td>
<td>21%</td>
<td>25%</td>
<td>19%</td>
<td>8%</td>
</tr>
<tr>
<td>A.C.</td>
<td>3%</td>
<td>4%</td>
<td>3%</td>
<td>8%</td>
</tr>
</tbody>
</table>

Facility Type (number of entertainment & leisure facilities) : Luxury (4 and above E&L facilities), Basic (1~3 E&L facilities) Economic (without E&L facilities)
Saving potential assessment

- **100.7 GWh** technical potential have been recognized, almost comprising **5.56%** of large-size multifamily electricity consumption.
- **77.05 GWh** economical potential still untapped, contributing **4.25%** of large-size multifamily electricity consumption.

Unit: MWh

Lower utilization rate, and higher initial investment

Too low utilization rate

24-hours operation

Higher operation hours
## Conclusion and future work

### Conclusion
- Occupied number of households, square feet, building heights could drive energy service demand in common area of multifamily sector
- Critical factor to cost-effective EE investment: Utilization rate, energy price and initial investment
- Recognizing the multiple benefits of EE with security and health in multifamily

### Future work
- Expanding the sample size to 60 HOAs
- Building **saving potential curve** for multifamily sector

### Table: Target and Measures

<table>
<thead>
<tr>
<th>Year</th>
<th>Target</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>Overall Multifamily Building (n=518)</td>
<td>✓ Equipment penetration ✓ Number of equip. ✓ Number of meters ✓ Utility bill</td>
</tr>
<tr>
<td>2018</td>
<td>Over 100 HH residential use only building (n=30)</td>
<td>✓ Equipment spec. ✓ Operation hours ✓ Utility bill</td>
</tr>
<tr>
<td>2019</td>
<td>Over 100 HH mixed use building (n=30)</td>
<td>✓ Equipment spec. ✓ Operation hours ✓ Utility bill</td>
</tr>
</tbody>
</table>

### Conference Schedule
- 6th IAEE Asian Conference
- 37th USAEE Conference
- 7th IAEE Asian Conference
Questions?
Acknowledgements

Government Institute
- Bureau of Energy, Ministry of Economic Affairs in Taiwan
- New Taipei City Government
- Taichung City Government
- Kaohsiung City Government

Academic Partner
- Huei-Chu Liao (TKU)
- Jen-Yi Hou (TRI)
- Ssu-li Chang (NTPU)
- Kuan-Hsiung Yang (NSYSU)
- Jin-Xu Lin (CYCU)

Industrial Partner

Thank you for active participation for all participants
Contact us !!

More Residential Energy Research and Promotion Program in Taiwan…

Energy Park
https://www.energypark.org.tw/

Household Energy Calculator
https://saving.energypark.org.tw

Ting-Jui(Ray) Sun, Multifamily Building Electricity Consumption Survey
Survey Project Manager
itriA40450@itri.org.tw

Wen-Hua(Rose) Liao, Home Electricity Consumption Survey
Survey Project Manager
rose0224@itri.org.tw
Appendix - Diverse end-use energy use

Partial Public Amenities (divided by bldgs.)
✓ Staircase → Lighting
✓ Elevator
✓ Water pump (Option)

Whole Public Amenities
✓ Lobby → A.C
✓ Parking lot (lighting, Ventilation)
✓ Leisure facilities (A.C. and lighting)
✓ Water pump (Option)
✓ Sewage pump (Option)

This Case:
✓ 121 hh
✓ 7 bldgs.
✓ 8 meters
Appendix - Population & sample in this survey

Our survey only focus on condominium multi-family building

- No rental housing
- No single-owned housing
- No affordable housing (below 0.1% market)