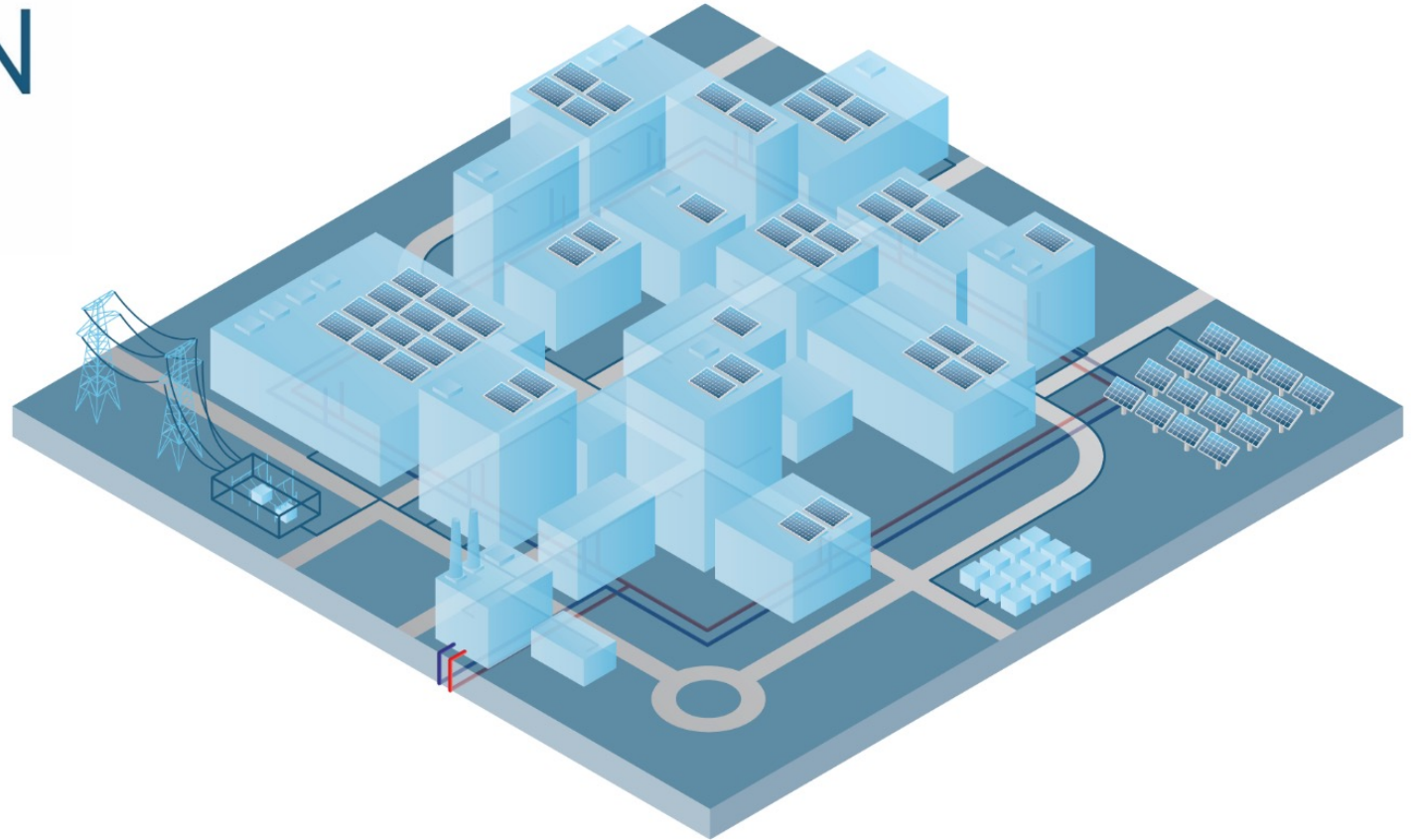URBAN OPT

NREL and LBNL
Ben Polly (PI), Senior Research Engineer, NREL
ben.polly@nrel.gov
Tanushree Charan, Research Engineer, NREL
WBS: 3.5.5.67 (NREL), 3.5.5.68 (LBNL)

Project Summary

Objective and Outcome

This project is focused on developing open-source modeling capabilities that can be used to analyze building decarbonization and electrification in communities.

URBANopt™ capabilities will help ensure that practitioners can appropriately evaluate and optimize the role of buildings in helping achieve equitable decarbonization in districts and communities.
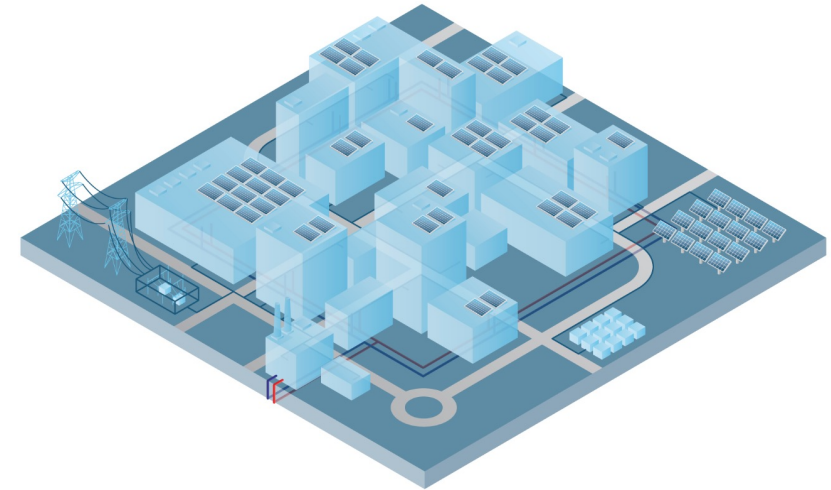

Christopher Schwing, NREL

Team and Partners

National Laboratories: NREL (PI), LBNL (CO-PI)

Industry: Ladybug Tools LLC; Skidmore, Owings, & Merrill (SOM); ENGIE; Tallarna

Universities: University of Colorado – Boulder, Comillas University, Colorado School of Mines, Colorado State University

*Primary BTO URBANopt project team/partners listed above; see reference slides for broader list of URBANopt partners

Stats

Performance Period: 10/1/2018–12/31/2023

DOE BTO Budget (new BA): $2.1M/yr FY19-21, $1.125M FY22, $0.5M FY23

Cost Sharing/Synergistic Funding:
- $400k Wells Fargo IN2 for NREL/Ladybug Tools
- $517k CEC-Funded
- $250k Xcel Energy – DOE ESIF High Impact
- >$500k of synergistic SBIR funding to Ladybug Tools
- $3.6M for URBANopt DES capabilities from DOE AMO/IEDO
- $500k for URBANopt GSHP capabilities from DOE GTO

Key Milestones: Seven major URBANopt SDK spring/fall releases since 2019

Problem

- Decarbonization goals are set at larger scales; communities are where many impacts/benefits will be felt.

- **Illustrative Challenge:** for an existing mixed-use neighborhood in Ithaca*, New York, how to effectively:

  - Electrify and decarbonize building loads?

  - Improve building energy efficiency?

  - Integrate renewables, batteries, electric vehicles, etc. with buildings at the transforming grid edge?

  - Upgrade the local electric distribution infrastructure to handle changing loads while improving resilience?

- **How can practitioners analyze all of these areas together to develop customized and equitable solutions?**


Photo by Dennis Schroeder, NREL 19890

Edison Electric Institute estimates that utilities will invest ~$140 billion in 2023 related to reducing emissions and replacing aging grid infrastructure (WSJ 2022).

*Ithaca has goal of 100% building decarbonization by 2030

Problem

- Communities represent unique opportunities for emissions and cost savings beyond typical building-by-building approaches (Pless et al. 2020, Olgyay et al. 2020).

  – E.g., National Western Center in Denver, CO will source ~90% of its heating and cooling through a sewer heat recovery district thermal system with distributed heat pumps (NWC 2023)

- However, industry has been challenged by a lack of transparent, open-source analytical capabilities to support community-scale efforts.

- We are developing URBANopt to address these technical and market challenges.
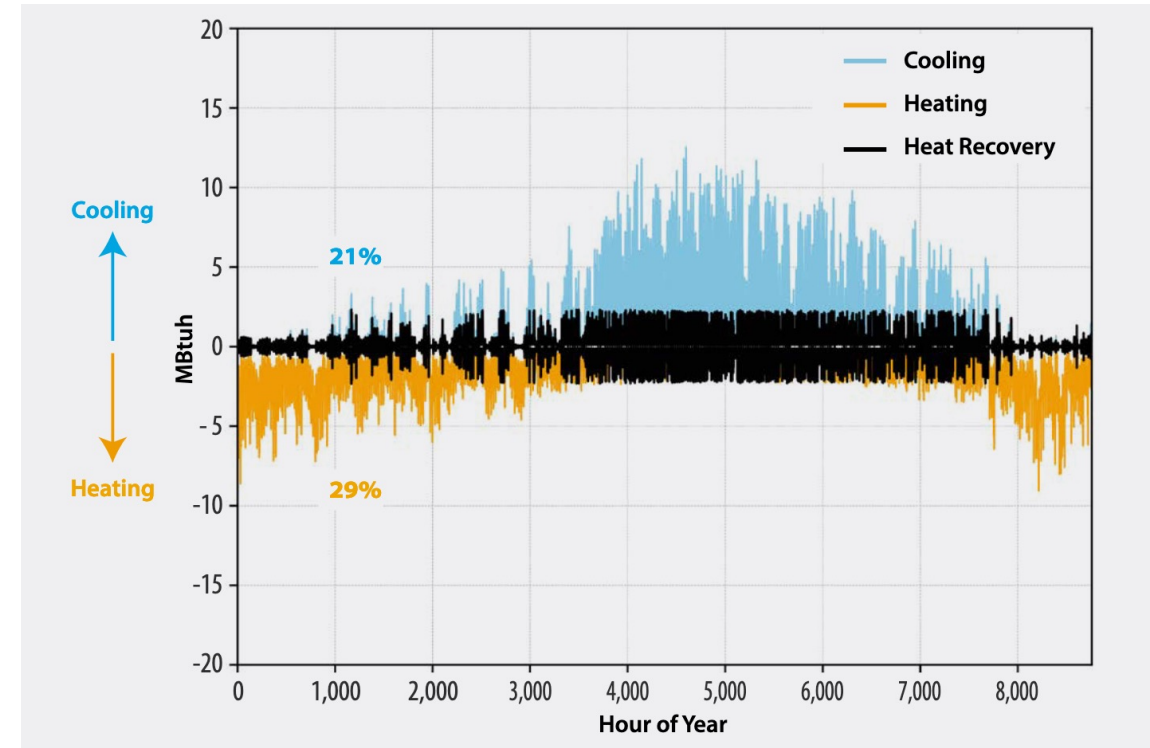
Example URBANopt analysis estimating hourly heating and cooling loads of hypothetical district in Atlanta, GA. The black areas represent overlapping load, indicating potential for energy sharing through a district thermal system (Pless et al. 2020).

Alignment and Impact

Greenhouse gas emissions reductions

50-52% reduction by 2030 vs. 2005 levels

Net-zero emissions economy by 2050

Power system decarbonization

100% carbon pollution-free electricity by 2035

Energy justice

40% of benefits from federal climate and clean energy investments flow to disadvantaged communities

Alignment

- URBANopt directly supports development and deployment of community-scale solutions that:
  - Scale/achieve additional emissions savings compared to a building-by-building approach.
  - Enable broader power system decarbonization through Connected Community approaches.
  - Are co-developed and tailored to the unique needs and opportunities within each community.
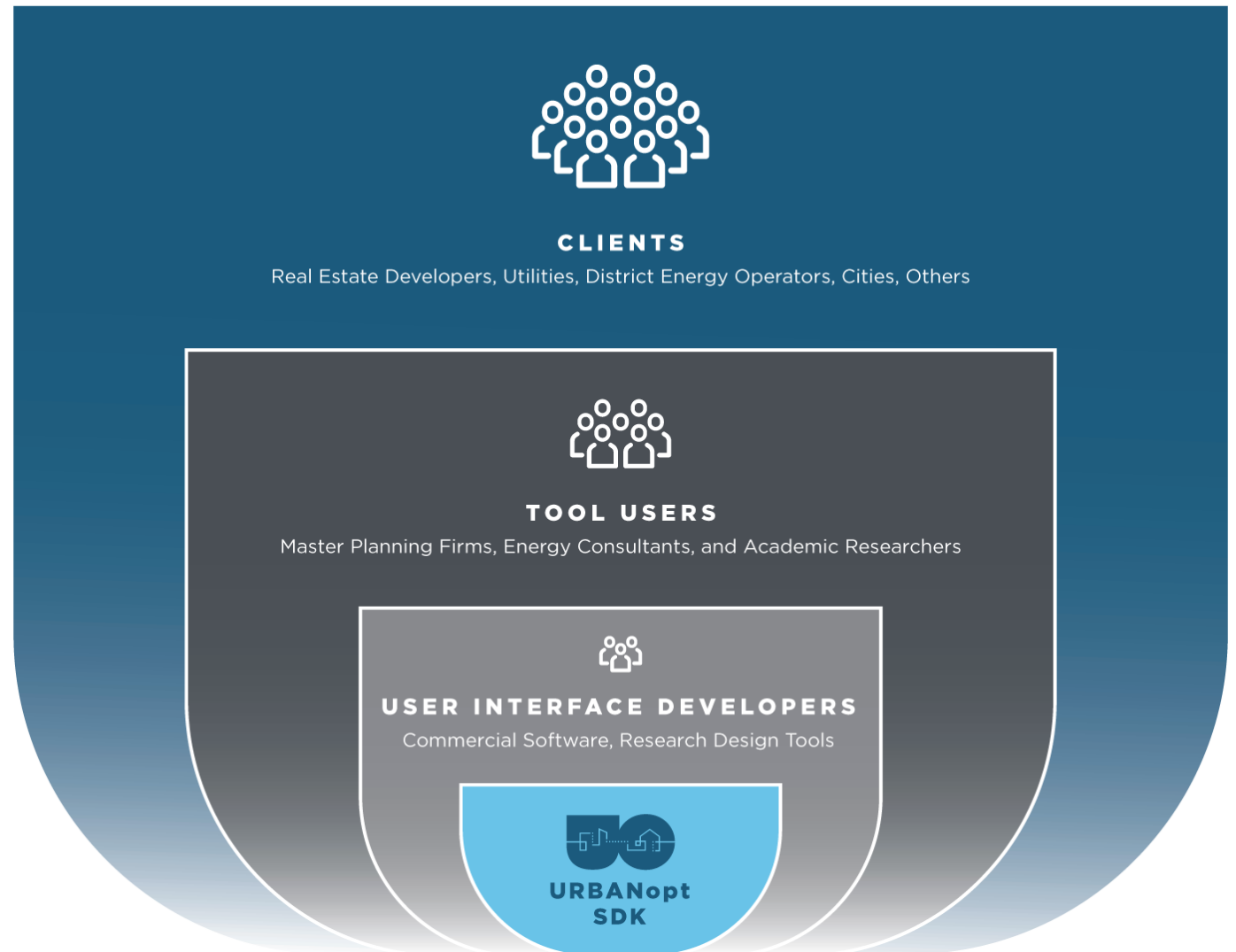
Vision for Success

- URBANopt provides valuable/impactful community-scale analysis capabilities to commercial software developers and industry practitioners.

Key Success Indicators

- Industry commercialization/use of URBANopt capabilities (e.g., # of downloads/users).
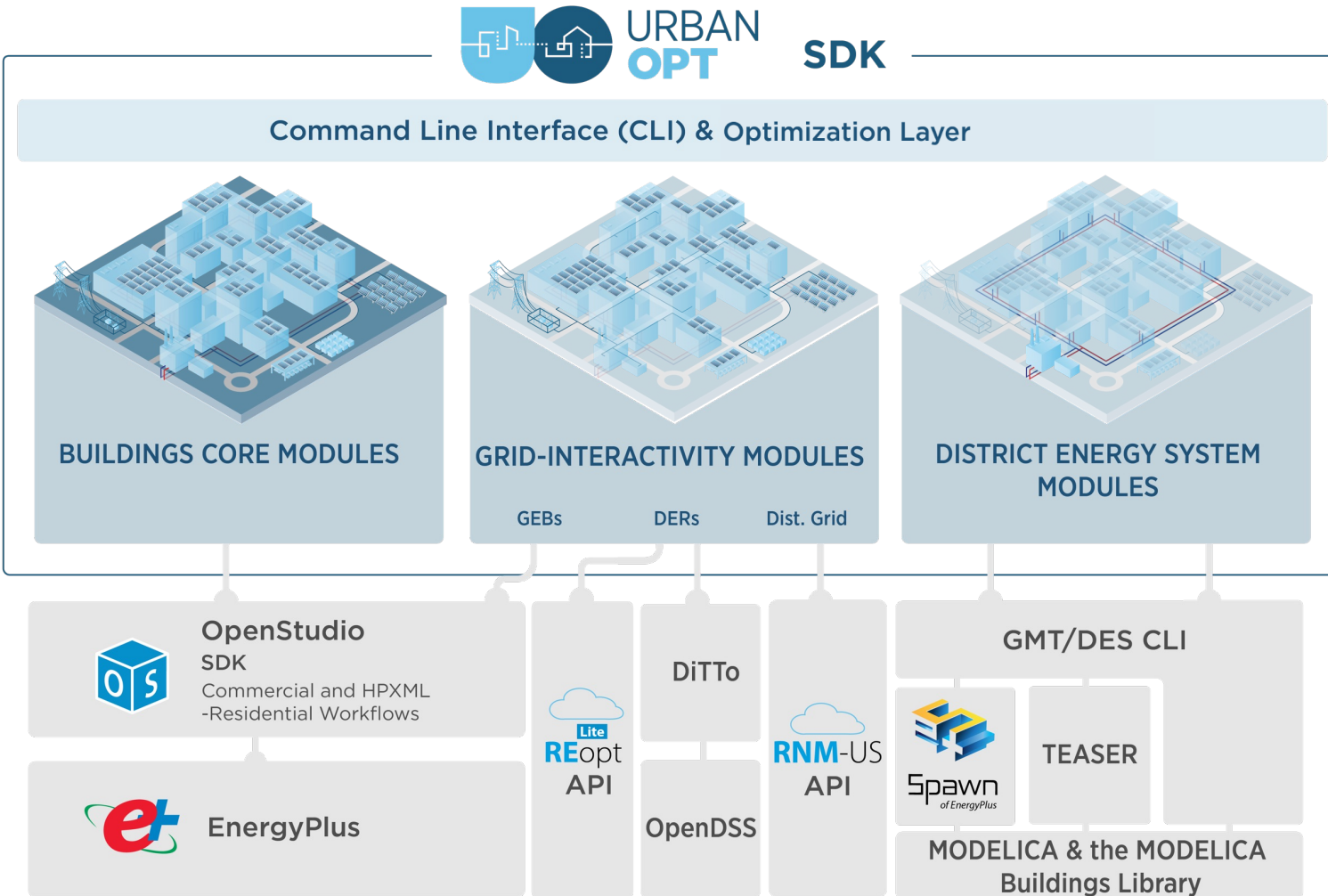- Cross-sector investment/participation in development of capabilities.

URBANopt Approach

- Analytics platform for communities and urban districts.
  - https://docs.urbanopt.net/

- Built on top of OpenStudio, EnergyPlus, and the Modelica Buildings Library.

- Modular, open-source platform; "underlying analytics" that can be integrated into private sector tools.

- Enables multidisciplinary analysis associated with energy master planning; this is necessary to achieve equitable decarbonization.

CLIENTS
Real Estate Developers, Utilities, District Energy Operators, Cities, Others

TOOL USERS
Master Planning Firms, Energy Consultants, and Academic Researchers

USER INTERFACE DEVELOPERS
Commercial Software, Research Design Tools

URBANopt SDK

Christopher Schwing, NREL

URBANopt Approach



Christopher Schwing, NREL

- Buildings core modules:
  - Ensure building technology solutions can be properly evaluated in decarbonization planning.

- Grid-interactive modules:
  - Enable the value-building efficiency and demand flexibility to be considered in conjunction with DERs and grid upgrades.

- District thermal system modules:
  - Foster development of community--scale approaches for decarbonizing heating, energy sharing, and waste heat recovery.

- Integrating with various engines and tools to enable cross-sector analysis.
  - Series simulation/automated data exchanges.
  - Modelica-based modeling for co-simulation of buildings and district energy systems.

- Seven major Spring/Fall releases from 2019-2022; now on one annual Fall major release schedule.

URBANopt Approach: Workflow Details

Grid-Interactive Workflows:

- URBANopt-REopt™
  - Life cycle cost optimal PV/battery sizing and dispatching

- URBANopt-OpenDSS
  - Electric distribution system power flow modeling for building-grid impacts

- URBANopt-RNM
  - Cost-effective distribution feeder design for greenfield/new construction analysis

- URBANopt-DISCO
  - Electric distribution system upgrade/cost analysis for existing community analysis
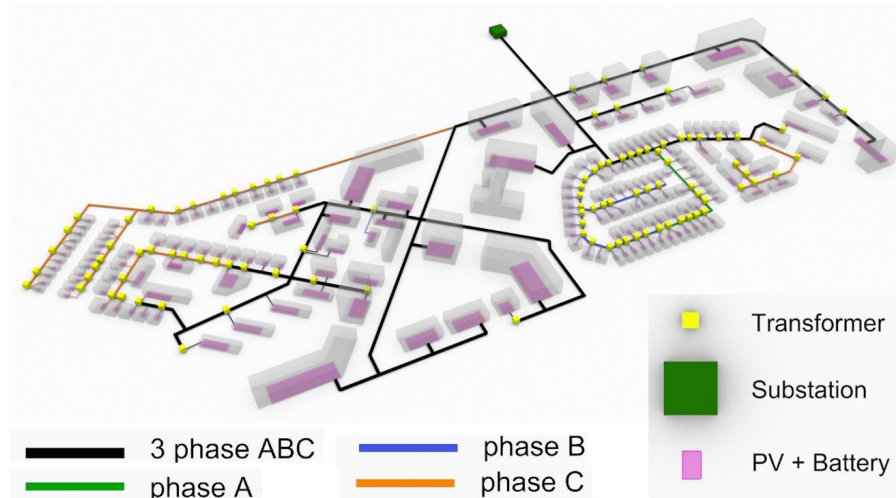
Example URBANopt-OpenDSS analysis of electric distribution system design for mixed-use community.
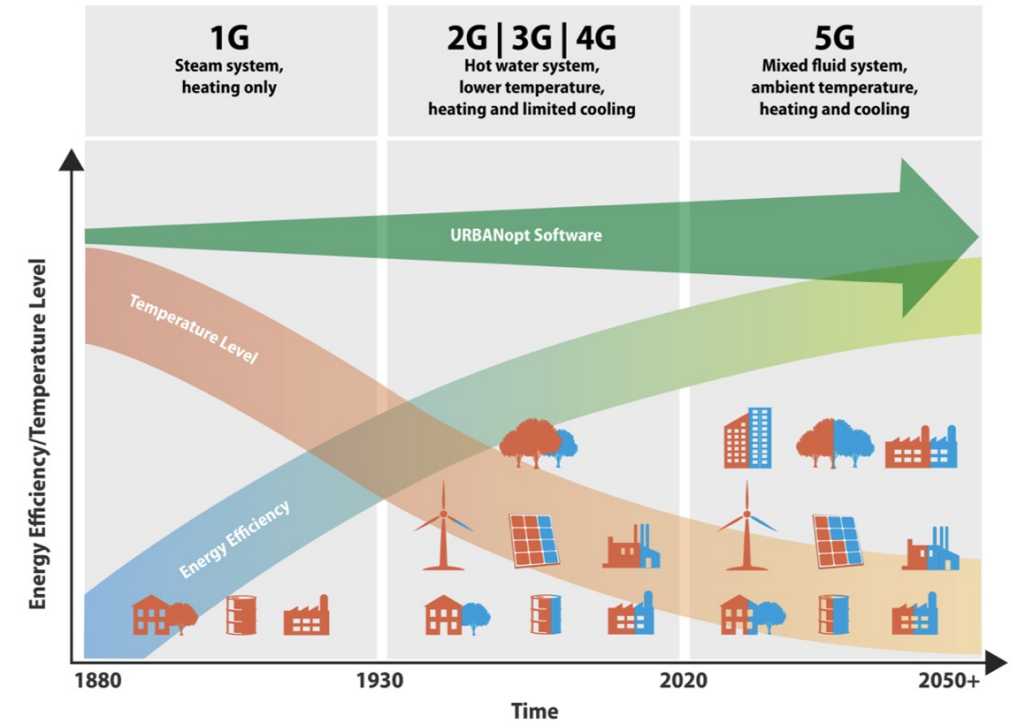
District Energy System Workflows:

- Advanced District Thermal Energy Systems are a key community-scale strategy for decarbonizing space and water heating, waste heat recovery, and peak load mitigation.

- Partnering with DOE AMO/IEDO and GTO offices, who are separately funding FY22/23 URBANopt DES work through other projects.

URBANopt Approach

|	Software Development Kit	Modular	Open Source	Multidisciplinary
URBANopt	• Powerful modules and calculation methods that help developers create tools and applications	• Modular software approach where different portions of code can be easily separated, updated, or replaced	• Business-friendly open-source license • Transparent and verifiable calculation approaches	• Addresses a wide variety of energy technologies
Common Alt. Approaches	• Separate individual tools • Develop and maintain their own interfaces and underlying calculation approaches	• Monolithic software approach where portions of code cannot be easily separated, updated, or replaced	• Restrictive software licenses • Non-transparent and non-verifiable calculation approaches	• Targets a narrow set of energy technologies (e.g., only building energy use)

Key Barriers, Challenges, and Risks

Barrier/Challenge/Risk	Mitigation Strategy
• Broad range of use cases, users, and potential needs.	• Prioritizing use cases aligned with equitable decarbonization; • Established URBANopt Technical Advisory Group (TAG) to help inform activities and gather feedback (see extra slides); • Users can submit issues/enhancement requests to URBANopt GitHub; • Commercial partner synthesizing feedback from large number of end users: Dragonfly user community has helped identify URBANopt enhancement needs.
• URBANopt District Thermal Energy System workflows rely on a Modelica-based approach which requires specialized software compilers. • Initially planned to purchase freely distributable license for commercial compiler, however, that approach could not be pursued due to budget limitations.	• Open Modelica solver available for general use, users can pay license for commercial solver if preferred/needed.
• Emphasis on existing community electrification/decarbonization use case has greatly increased since 2018 when project was proposed.	• Added operational carbon calculations and developed initial URBANopt-DISCO integration in FY22/23 to support existing community electrification analysis. • Proposing as future work: A) enhanced URBANopt-DISCO integrations, B) integration of ResStock/ComStock workflows to support development of existing building retrofit models based on local building stock characteristics and probability distributions, and C) demonstration/validation efforts working with utility/grid planners.

Demonstration/Commercialization Success: SOM + Ladybug Tools

- Skidmore, Owings, Merrill (SOM) successfully piloted Dragonfly/ URBANopt core capabilities on district projects.

- SOM found that Dragonfly/URBANopt capabilities streamline modeling, speed up simulation, and capture more detail compared to their conventional modeling approaches (Charan et al. 2021).
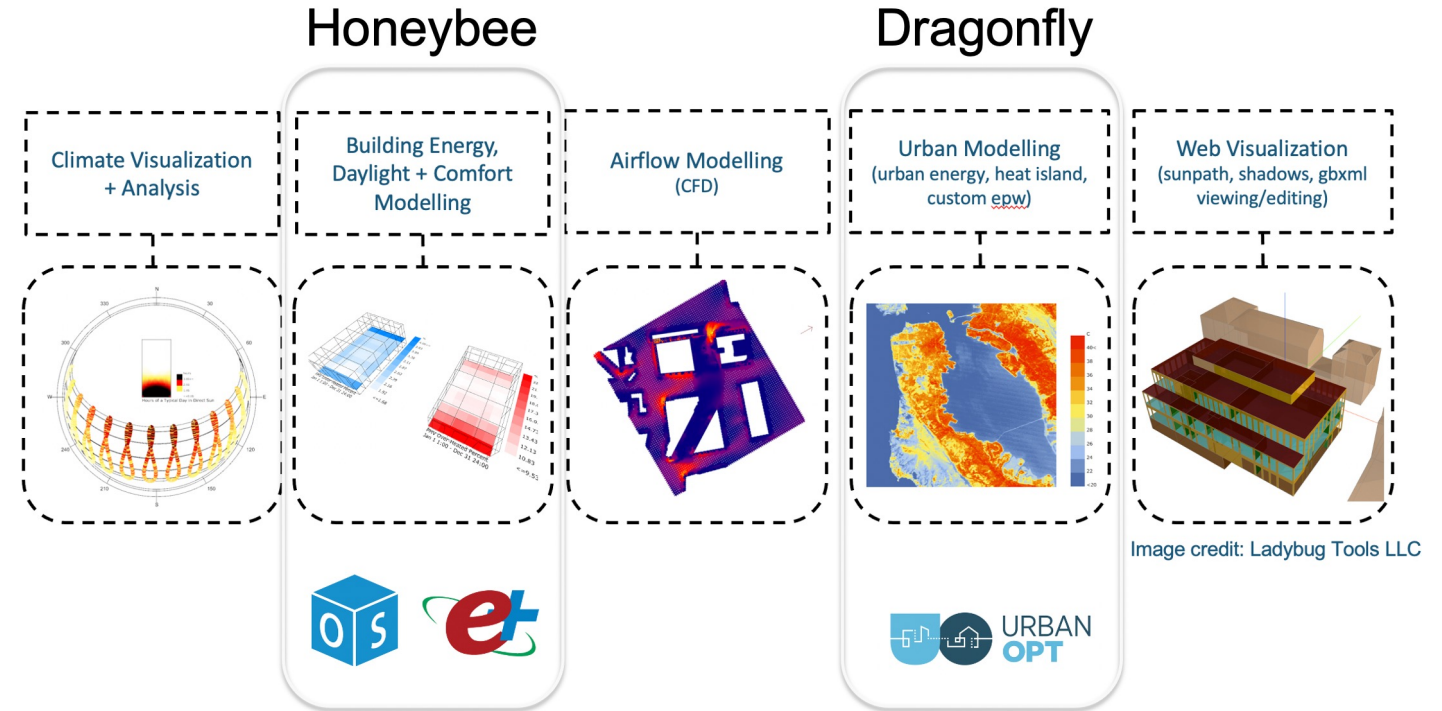
"URBANopt will transform built environment design by providing robust analytical capabilities that allow energy modeling and optimization at a larger district scale."

-Luke Leung, Director, SOM, LLP

Honeybee

Dragonfly

Climate Visualization + Analysis

Building Energy, Daylight + Comfort Modelling

Airflow Modelling (CFD)

Urban Modelling (urban energy, heat island, custom epw)

Web Visualization (sunpath, shadows, gbxml viewing/editing)

Image credit: Ladybug Tools LLC

- >375k LB Tools Dragonfly downloads from ~100,000 unique accounts since Sep 2020.
- >140k URBANopt project folders based on download stats.
- Active Ladybug Tools User Community:
  - Over 3,000 monthly active forum users.
  - Roughly 6,000 page views per day.
  - Roughly 25 newly posted topics per day.

URBANopt Is a Hub for Community-Scale Analytics

- BTO investments establish/maintain core URBANopt platform and support buildings-to-[X] integrations
- Separate and synergistic investments support cross-sector solutions and collaboration
  - Past/ongoing Projects: DOE AMO/IEDO, DOE GTO, DOE VTO, DOE ESIF High Impact, CEC
- Case studies (separately funded) demonstrate value of URBANopt capabilities across broad range of communities.

URBAN OPT

CASE STUDIES

PEÑA STATION

400-acre new construction mixed-use development targeting deep carbon reductions and high renewable energy integration.

SAN LUIS OBISPO

Community-scale zero net energy feasibility study.

OAK VIEW

Design and analyze a microgrid for the Oak View community focusing on environmental performance and resiliency of the local electric infrastructure.

GEORGIA TECH

Assess technical and economic feasibility of coordinated control at the multi-building scale on Georgia Institute of Technology campus for providing grid services.

Key Lesson Learned: Great value in creating tight feedback loops between deployment-focused modeling/technical assistance efforts and core URBANopt development activities.

URBANopt Multi-Year Vision

Ensure Robust and Updated Building Analytics

- Enter longer-term, year-to-year efforts for core development/ maintenance.

- Annual release: Update URBANopt to latest E+/OS.

- Interim releases: Bug fixes and high priority capability enhancements needed by industry users and partner projects.

Expand Adoption by Commercial Software Developers

- Focus on use cases that will complement/expand impact

- Example:
    - Utility electric distribution planning tools to enable co-design of building-grid decarbonization

Broaden Impact Through New Capability Development

- Identify high-value/impact new module (capability) development needs.

- Each module would be a distinct effort with its own deliverables, industry partners, and metrics for impact.

- Example:
    - Electric vehicle (EV) charging/demand flexibility to support decarbonization and resilience.

## Continue Diversifying Funding for Multi-Disciplinary Hub

- FY25/beyond: >50% funding is from non-BTO sources, demonstrating very high leverage on any further BTO investments.

- High multiplication factor for DOE funding through commercial software developers.

- FY22/23: ~500k GTO shared GSHP/ground heat exchanger modeling, ~600k AMO/IEDO waste heat recovery/ DES modeling.
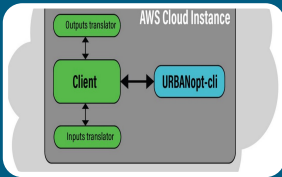
FY2022 and 2023 Progress Highlights

Electrification Pathways
- Initial URBANopt-DISCO integration for existing community decarb. analysis
- URBAN-RNM-US validation workflows for new community non-wires alt. analysis
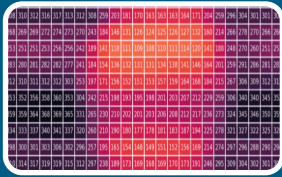
Operational Carbon
- Interim release with operational carbon calculation capabilities

Commercial Software Resources
- Developed resources for cloud-based integration of URBANopt

Prototype Districts
- Developed first prototype district model

Educational Materials/Workforce Development
- Developed URBANopt higher-ed class project

Progress Details: New Resources for Developers and Educators

- Worked with Tallarna to better-understand URBANopt cloud-integration support needs.
- Created new resources on docs.urbanopt.net
- Co-developed and piloted higher-ed URBANopt class project with Colorado School of Mines; Available on docs.urbanopt.net.
- CU-Boulder, The Ohio State University, Georgia Tech planning to use this year.
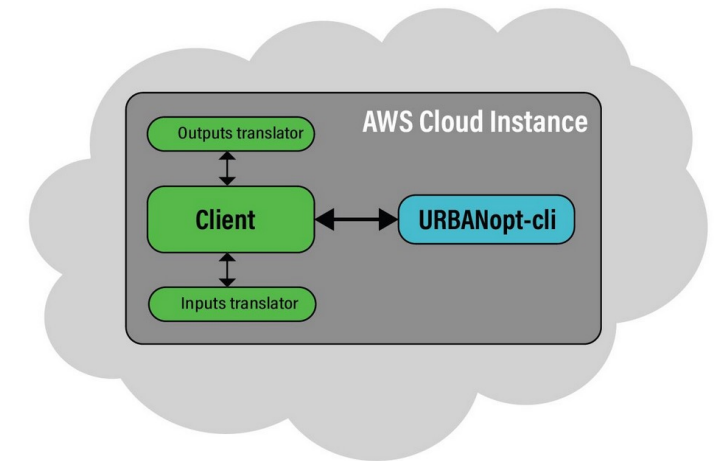
# Progress Details: Joint Building-Grid Decarbonization Solutions

- Completed initial integration of URBANopt-DISCO.

- Supports grid impact analysis of buildings and distributed energy resources (DERs) on the electrical distribution system.

- Analyzes cost upgrades for existing electrical system infrastructure with the objective of mitigating thermal and voltage violations on the grid.

- Reports out number of violations present in the feeder and total cost for each upgraded piece of equipment.

- Piloting for community in Ithaca, NY through separately funded project in collaboration with BlocPower.

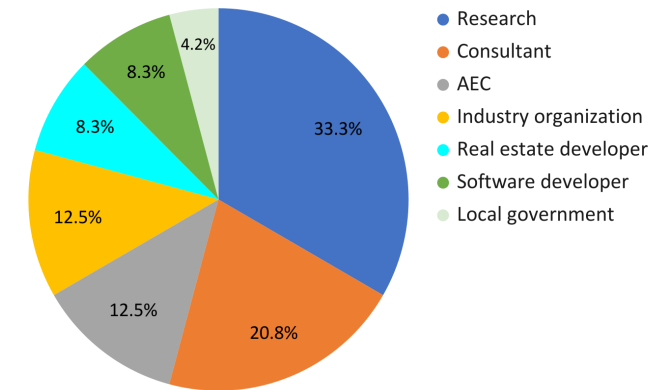Bus violations after voltage upgrades_0

- Source
- Capacitor
- Voltage Regulator
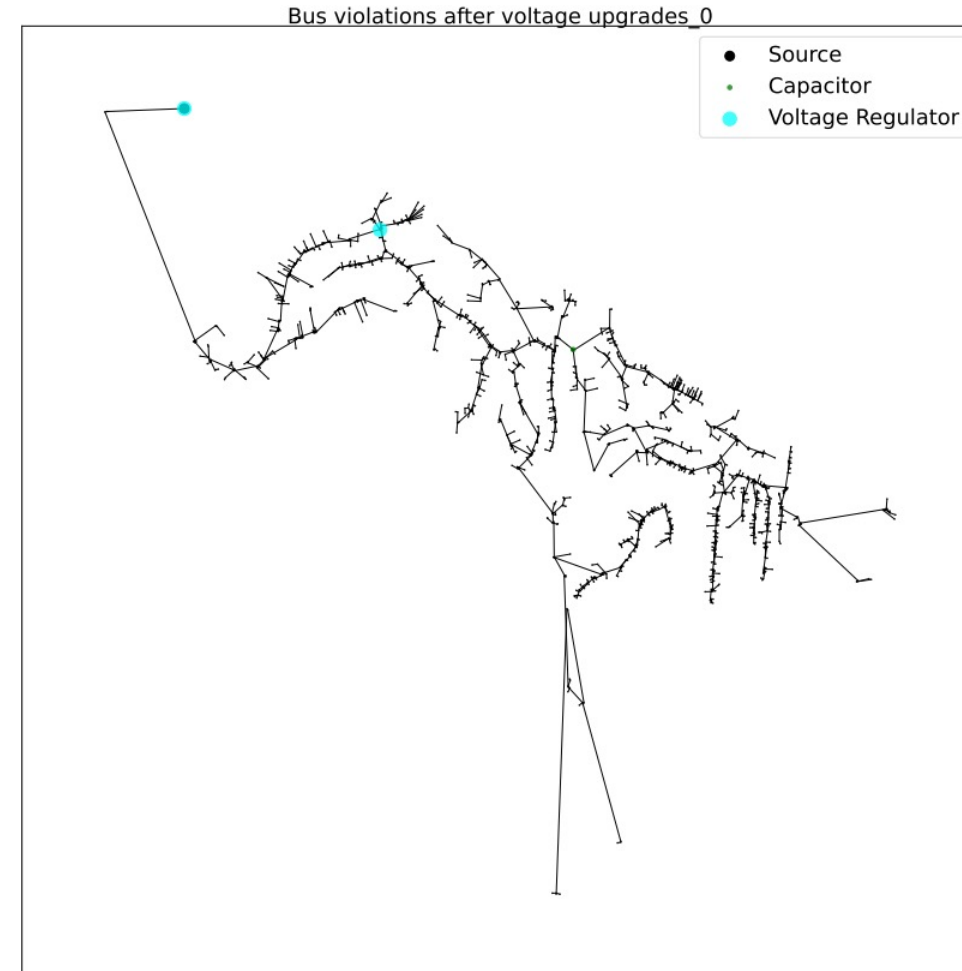
Example DISCO analysis of distribution system voltage violations after of voltage upgrades.

Source: DISCO Documentation, https://nrel.github.io/disco/analysis-workflows/upgrade-cost-analysis.html

Progress Details: Prototype Districts for Streamlining Community Analysis

- Collaborative effort between LBNL and NREL.

- **Vision:** Develop template prototype districts for different district types (e.g., existing/new, urban/suburban/rural) to enable modeling and evaluation of building technologies and control strategies for demand side load reduction, management and decarbonization at district scale.
  - Starting point models for users.
  - Evaluate technologies/solutions across range of community types.

- Industry experts provided feedback on high-priority district types.

- District characteristics were developed with a method where PUMAs representative of a district type were selected, then matched to the ResStock/ComStock building characteristic database and summarized in the scorecard.

- Mixed-use, existing building, urban edge developed as first prototype district in FY22/23.

Research 33.3%
Consultant 20.8%
AEC 12.5%
Industry organization 12.5%
Real estate developer 8.3%
Software developer 8.3%
Local government 4.2%

Industry expert/stakeholder feedback

Prototype district

Plan for Remainder of 2023 and Potential Future Work

Plan for Reminder of 2023

- <u>Spring 2023:</u> update to OpenStudio and EnergyPlus biannual version releases; specific effort focused on updating URBANopt modules to work with Ruby 3.1.3.
- <u>Spring/Summer/Fall 2023:</u> high priority defect fixes and limited smaller enhancements.
- <u>Fall 2023:</u> update to OpenStudio and EnergyPlus biannual version releases.
- <u>Annual URBANopt release:</u> 11/15/2023

Potential Future Work

- Annual release(s) updating to latest EnergyPlus/OpenStudio, with high-priority defect fixes/smaller enhancements.
- Enhanced URBANopt-DISCO integrations.
- Integration of ResStock/ComStock workflows to support development of existing building retrofit models based on local building stock characteristics and probability distributions.
- Demonstration/validation efforts working with utility/grid planners.
- Develop additional prototype district models.
- **Targeted Outcome:** Energy and decarbonization planning becomes integral and common place for community master planning.

Thank You

NREL and LBNL

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Tanushree Charan, Research Engineer, NREL

WBS 3.5.5.67: (NREL), 3.5.5.68 (LBNL)

REFERENCE SLIDES

Project Execution

	FY2022				FY2023				FY2024			
Planned Budget ($k)	954				623				162			
Spent Budget ($k)	830				342							
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1			
Past Work												
Q1 Milestone: Fall 2021 URBANopt Release	◆											
Q2 Milestone: Operational Carbon: Capabilities Design Document		◆										
Q2 Milestone: Electrification Pathways: URBANopt-DISCO Design Document		◆										
Q2 Milestone: Commercial Software Integration: Design Document (cloud-based)		◆										
Q2 Milestone: Prioritized List of Prototype District Types		◆										
Q3 Go/No Go: Commercial Software Integration Resources/Capabilities (cloud-based)		◆										
Q3 Milestone: Spring 2022 URBANopt Release			◆									
Q3 Milestone: Operational Carbon: Capabilities Interim Release			◆									
Q4 Milestone: Education/Workforce Development: URBANopt Class Project Materials				◆								
Q4 Milestone: Scorecard for Selected High Priority (Prototype) Districts				◆								
Q4 Go/No Go: Prototype District Models Defined in Scorecard/URBANopt Data Model				◆								
Q1 Milestone: Fall 2022 URBANopt Release					◆							
Q2 Milestone: First Prototype District Models						◆						
Q2 Milestone: URBANopt Resources/Capabilities to Support Cloud-Based Integrations						◆						
Q2 Milestone: Defect Fix/Enhancement Prioritization Plan						◆						
Q2 Go/No Go; Proceed with Defect Fix/Enhancement Prioritization Plan						◆						
Current/Future Work												
Q3 Go/No Go: Prototype Districts							◆					
Q4 Milestone: Electrification Pathways: Conference Paper/Journal Article								◆				
Q4 Milestone: Prototype Districts Paper								◆				
Q3 Milestone: URBANopt Progress Report							◆					
Q1 Milestone: URBANopt Annual Release									◆			

Broader URBANopt Team/Partners

- **National Laboratories:** NREL (PI), LBNL (CO-PI).

- **Industry:** Ladybug Tools LLC; Skidmore, Owings, & Merrill (SOM); ENGIE; Tallarna.

- **Universities:** University of Colorado – Boulder, Comillas University, Colorado School of Mines, Colorado State University, The Ohio State University, University of California Irvine, Georgia Institute of Technology.

- **BTO URBANopt Project TAG Affiliations:** Rocky Mountain Institute, Kohn Pedersen Fox Associates, The Energy Coalition, EURAC Institute for Renewable Energy, University of California Irvine, ENGIE Lab, NYSERDA, Savannah College of Art and Design, IDEA Board Member / GLHN Architects & Engineers, Xcel Energy, WSP, Arizona State University, Arup, Georgia Institute of Technology.

URBANopt-Related Publications and Presentation Citations

- Flores R., Houssainy S., Wang W., Robertson J. , Khanh C., Polly B., Faramarzi R., Maclay J., Brouwer J. (2022). Developing and tuning a community scale energy model for a disadvantaged community

- Lämmle, M., Allen, A., Henze, G., Pless, S. (2022). Valuation of Novel Waste Heat Sources and a Path Towards Adoption. ACEEE Summer Study on Energy Efficiency in Buildings.

- Zahra Fallahi, P., Houssainy, S., Ling, J., Leach, M., Klun, L., Slovensky, M. (2022). Designing for Zero Energy and Zero Carbon on a Multi-Building Scale using URBANopt. ACEEE Summer Study on Energy Efficiency in Buildings.

- Charan, T., Mackey, C., Irani, A., Polly, B., Ray, S., Fleming, K., El Kontar, R., Moore, N., Elgindy, T., Cutler, D., Roudsari, M. S., & Goldwasser, D. (2021). Integration of Open-Source URBANopt and Dragonfly Energy Modeling Capabilities into Practitioner Workflows for District-Scale Planning and Design.

- De Rosa, L., Domingo, C. M., Gómez, T., Roman, S., Kontar, R. El, Polly, B., Fleming, K., & Elgindy, T. (2021). Integrated models for electrical distribution network planning and district-scale building energy use. IEEE Madrid PowerTech.

- Hinkelman, Kathryn, Jing Wang, Wangda Zuo, Antoine Gautier, Michael Wetter, Chengliang Fan, and Nicholas Long. (2021). Modelica-Based Modeling and Simulation of District Cooling Systems: A Case Study. Applied Energy.

- Allen, A., Long, N. L., Moore, N., & Elarga, H. (2021). URBANopt District Energy Systems HVAC Measures. National Renewable Energy Laboratory.

- Long, Nicholas, Antoine Gautier, Hagar Elarga, Amy Allen, Ted Summer, Lauren Klun, Nathan Moore, and Michael Wetter. (2021). Modeling District Heating and Cooling Systems with URBANopt, GeoJSON to Modelica Translator, and the Modelica Buildings Library. In Building Simulation 2021. Bruges, Brussels.

- Rawad El Kontar, Ben Polly, Tanushree Charan, Katherine Fleming, Nathan Moore, Nicholas Long, & David Goldwasser. (2020). (PDF) URBANopt: An Open-Source Software Development Kit for Community and Urban District Energy Modeling. ASHRAE/IBPSA-USA Building Performance Modeling Conference And SimBuild.

- Houssainy, Sammy, Faramarzi, Ramin, Farahmand, Farhad, Pande, Abhjieet, and Griesser, Jon. (2020). Community-Scale Energy Efficiency Assessment for Zero Net Energy Using the URBANopt Simulation Platform. ACEEE Summer Study on Energy Efficiency in Buildings, 17-21 August 2020.

- Shanti Pless, Ben Polly, Sammy Houssainy, Paul Torcellini, William Livingood, Sarah Zaleski, Matt Jungclaus, Tom Hootman, & Mindy Craig. (2020). A Guide to Energy Master Planning of High-Performance Districts and Communities. Technical Report, NREL.

- Polly, Benjamin J. (2018). "Zero Energy Districts". United States. IMPACT Conference, St. Paul, Minnesota. Presentation.

- Polly, B., Kutscher, C., Macumber, D., & Schott, M. 2016. From Zero Energy Buildings to Zero Energy Districts. (2016) ACEEE Summer Study on Energy Efficiency in Buildings, August, 1–16.

- Macumber, D., Gruchalla, K., Brunhart-lupo, N., Gleason, M., Robertson, J., Polly, B., Fleming, K., & Schott, M. (2016). City Scale Modelling with OpenStudio. ASHRAE and IBPSA-USA SimBuild 2016 Building Performance Modeling Conference, September, 133–140.

Visit the URBANopt **DES Workflow** page for additional publications related to district energy systems.

Other Citations/References for this Presentation:

Olgyay, Victor, Seth Coan, Brett Webster, and William Livingood. 2020. Connected Communities: A Multi-Building Energy Management Approach. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5500-75528. https://www.nrel.gov/docs/fy20osti/75528.pdf.

NWC, 2023. https://nationalwesterncenter.com/about/what-is-the-nwc/sustainability-regen/energy/

WSJ, 2023. https://www.wsj.com/articles/utilities-plan-huge-electric-grid-upgrades-adding-to-power-bills-11650187802