Energy Loadshape Classifier

In order to tackle climate change, we need to massively scale decarbonization projects in the built environment. 40% of emissions can be traced back to buildings, most of these emissions are attributable to the energy required to power and heat buildings. While it will take up to $100 trillion to decarbonize buildings, we can maximize our scarce resources by identifying the decarbonization potential of different types of buildings. By prioritizing the most polluting buildings, we can do more good, more quickly than our current scattershot approach.

Background

We need to be able to measure the impact of potential decarbonization projects, which can be largely done directly using hourly or sub-hourly electricity and natural gas meter data. Building energy use is characterized by a “loadshape”, which is the hourly energy use profile of the building. These “loadshapes” can be used to understand how energy was consumed both before and after a decarbonization project. For both targeting homes with the greatest potential, as well as forecasting the savings of a home where a project was recently installed, we want to be able to predict the impact of certain decarbonization projects. However, this prediction can be challenging, as it typically requires additional information about the building, such as the number of occupants or the type of appliances that were in the building before the project happened. When attempting to implement projects at a massive scale, it can be difficult to acquire this “building metadata”. We want to be able to estimate some of these metadata fields based solely on the building’s loadshape.

Challenge

Imagine you are a Sustainability Officer from an organization with a large portfolio of buildings. You need to target the buildings with the greatest potential for decarbonization, but you only have access to their energy loadshapes. Using the AI tools and machine learning algorithms you find most pertinent, devise a way to estimate the impact of various decarbonization projects on your building.

The NREL dataset (discussed below) includes models of building loadshapes as well as the impact of certain decarbonization upgrades on those buildings. By matching your building's loadshape to those in the NREL dataset, you have the potential to estimate the impacts of projects and target which buildings in your portfolio would most help you achieve your carbon goals.

We would like you to answer a few key questions/tasks:

- How might this information be helpful in scaling up building decarbonization?
- How can you target which buildings have the greatest potential for impact?
- Given the NREL dataset, quantify the potential impact of a given decarbonization project for your buildings.

Ground Truth Dataset

NREL has recently created a massive, multi-terabyte dataset where they generated year-long modeled loadshapes of individual residential (ResStock) buildings across the US. Each of these loadshapes has a unique set of metadata to describe the conditions of the building that were used to produce the loadshape. For example, they may have one loadshape for a single family home in Cambridge, MA that has natural gas heating, insulated walls, with 2 bedrooms, 2 bathrooms, and 4 occupants. They may have another loadshape with similar characteristics, but with only electric heating. This dataset is to be used as the primary training set for the classifier.

Some detailed context for when you are exploring the ResStock data: we will be focusing specifically on the residential dataset of NREL with models that were build using 2018 weather data, which was released in 2022 and named release 1.1.

A set of files containing building metadata can be found here (in CSV or parquet format, one row per building) and the loadshape data files can be found here (parquet files, organized by state, one file per building, in 15-minute intervals). The files are broken down by "upgrade". upgrade=0 references the baseline data (information about the building before any decarbonization project took place) while upgrades 1-10 reference difference decarbonization projects that happened. See the appendix below for the meaning of upgrades 1-10.

The loadshape data contains several columns of disaggregated load, but for the purposes of this challenge you can focus on the "total" energy consumption, which is represented by the following: **out.electricity.total.energy_consumption, out.natural_gas.total.energy_consumption.** Furthermore, there are two additional columns (with the same name but suffixed with *_intensity*) which are that buildings loadshape divided by its square footage.

Classifier Inputs

For each building, assume that you have the following:

- An 8760 hourly gas loadshape
- An 8760 hourly electricity loadshape
- Location about the information of the building including:
    - In.building_america_climate_zone
    - in.county
    - in.state
    - in.weather_file_city
- Some additional basic information about the building:
    - in.geometry_building_type_recs

Hints

There are many metadata columns available in the NREL dataset to use for classifying, but here are some that we believe may be important:

- in.heating_fuel
- in.water_heater_fuel
- in.electric_vehicle

- in.pv_system_size
- in.hvac_cooling_type
- In.hvac_heating_type_and_fuel

The best matches should bias towards those with the closest shapes to the input, even if the overall scale is a bit off. Consider normalizing the time series data to % of annual consumption.

In addition to the NREL dataset, feel free to use other datasets for out-of-sample validation. Here are a few sources, but also feel free to find your own:

- UMass Trace Repository
- EEMeter Sample Data

Feel free to limit to only a specific state (like MA or CA) in order to limit your initial data processing requirements.

Desired Output

For a given building loadshape, the system should provide a set of NREL model buildings (based on the NREL building id) that most closely match that loadshape. These buildings must be in the same **in.building_america_climate_zone** and **in.geometry_building_type_recs** as the input building. Using the selected NREL model buildings, the system should then be able to estimate the impact of a certain type of decarbonization upgrade (for example, what would be the impact of upgrade=7 on the given building?).

Appendix

Upgrade Number to Description Mapping


```
{
  "0": "Baseline",
  "1": "Basic enclosure",
  "2": "Enhanced enclosure",
  "3": "Heat pumps, min-efficiency, electric backup",
  "4": "Heat pumps, high-efficiency, electric backup",
  "5": "Heat pumps, min-efficiency, existing heating as backup",
  "6": "Heat pump water heaters",
  "7": "Whole-home electrification, min efficiency",
  "8": "Whole-home electrification, high efficiency",
  "9": "Whole-home electrification, high efficiency + basic enclosure package (packages 1 & 8)",
  "10": "Whole-home electrification, high efficiency + enhanced enclosure package (packages 2 & 8)"
}
```

Example of one row of loadshape data

{'timestamp': Timestamp('2018-01-01 00:15:00'),
 'out.electricity.ceiling_fan.energy_consumption': 0.008,
 'out.electricity.ceiling_fan.energy_consumption_intensity': 1.2965964343598055e-05,
 'out.electricity.clothes_dryer.energy_consumption': 0.0,
 'out.electricity.clothes_dryer.energy_consumption_intensity': 0.0,
 'out.electricity.clothes_washer.energy_consumption': 0.0,
 'out.electricity.clothes_washer.energy_consumption_intensity': 0.0,
 'out.electricity.cooling_fans_pumps.energy_consumption': 0.0,
 'out.electricity.cooling_fans_pumps.energy_consumption_intensity': 0.0,
 'out.electricity.cooling.energy_consumption': 0.0,
 'out.electricity.cooling.energy_consumption_intensity': 0.0,
 'out.electricity.dishwasher.energy_consumption': 0.0,
 'out.electricity.dishwasher.energy_consumption_intensity': 0.0,
 'out.electricity.freezer.energy_consumption': 0.0,
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 'out.electricity.heating_fans_pumps.energy_consumption': 0.001,
 'out.electricity.heating_fans_pumps.energy_consumption_intensity': 1.620745542949757e-06,
 'out.electricity.heating_hp_bkup.energy_consumption': 0.0,
 'out.electricity.heating_hp_bkup.energy_consumption_intensity': 0.0,
 'out.electricity.heating.energy_consumption': 0.03,
 'out.electricity.heating.energy_consumption_intensity': 4.8622366288492704e-05,
 'out.electricity.hot_tub_heater.energy_consumption': 0.0,
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 'out.electricity.hot_tub_pump.energy_consumption_intensity': 0.0,
 'out.electricity.hot_water.energy_consumption': 0.0,
 'out.electricity.hot_water.energy_consumption_intensity': 0.0,
 'out.electricity.lighting_exterior.energy_consumption': 0.001,
 'out.electricity.lighting_exterior.energy_consumption_intensity': 1.620745542949757e-06,
 'out.electricity.lighting_garage.energy_consumption': 0.0,
 'out.electricity.lighting_garage.energy_consumption_intensity': 0.0,
 'out.electricity.lighting_interior.energy_consumption': 0.015,
 'out.electricity.lighting_interior.energy_consumption_intensity': 2.4311183144246352e-05,
 'out.electricity.mech_vent.energy_consumption': 0.0,
 'out.electricity.mech_vent.energy_consumption_intensity': 0.0,
 'out.electricity.plug_loads.energy_consumption': 0.101,
 'out.electricity.plug_loads.energy_consumption_intensity': 0.00016369529983792545,
 'out.electricity.pool_heater.energy_consumption': 0.0,
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 'out.electricity.pool_pump.energy_consumption': 0.0,
 'out.electricity.pool_pump.energy_consumption_intensity': 0.0,
 'out.electricity.pv.energy_consumption': 0.0,
 'out.electricity.pv.energy_consumption_intensity': 0.0,

'out.electricity.range_oven.energy_consumption': 0.0,
'out.electricity.range_oven.energy_consumption_intensity': 0.0,
'out.electricity.refrigerator.energy_consumption': 0.011,
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'out.natural_gas.grill.energy_consumption': 0.0,
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'out.natural_gas.lighting.energy_consumption': 0.0,
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'out.natural_gas.pool_heater.energy_consumption_intensity': 0.0,
'out.natural_gas.range_oven.energy_consumption': 0.0,
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'out.propane.clothes_dryer.energy_consumption_intensity': 0.0,
'out.propane.heating_hp_bkup.energy_consumption': 0.0,
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'out.propane.heating.energy_consumption': 0.0,
'out.propane.heating.energy_consumption_intensity': 0.0,
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'out.propane.hot_water.energy_consumption_intensity': 0.0,
'out.propane.range_oven.energy_consumption': 0.0,
'out.propane.range_oven.energy_consumption_intensity': 0.0,
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'out.site_energy.net.energy_consumption_intensity': 0.00027264634388978924,

'out.site_energy.total.energy_consumption': 0.16822279417999997,
'out.site_energy.total.energy_consumption_intensity': 0.00027264634388978924,
'out.electricity.net.energy_consumption': 0.168,
'out.electricity.net.energy_consumption_intensity': 0.0002722852512155592,
'out.electricity.total.energy_consumption': 0.168,
'out.electricity.total.energy_consumption_intensity': 0.0002722852512155592,
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'out.fuel_oil.total.energy_consumption_intensity': 0.0,
'out.natural_gas.total.energy_consumption': 0.0,
'out.natural_gas.total.energy_consumption_intensity': 0.0,
'out.propane.total.energy_consumption': 0.0,
'out.propane.total.energy_consumption_intensity': 0.0,
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'out.load.heating.energy_delivered.kbtu': 0.106,
'out.load.hot_water.energy_delivered.kbtu': 0.0,
'out.outdoor_air_dryblub_temp.c': 8.425,
'out.zone_mean_air_temp.air_source_heat_pump_airloop_ret_air_zone.c': 0.0,
'out.zone_mean_air_temp.attic_vented.c': 0.0,
'out.zone_mean_air_temp.basement_unconditioned.c': 0.0,
'out.zone_mean_air_temp.central_ac_airloop_ret_air_zone.c': 0.0,
'out.zone_mean_air_temp.central_ac_and_furnace_airloop_ret_air_zone.c': 0.0,
'out.zone_mean_air_temp.crawlspace_unvented.c': 0.0,
'out.zone_mean_air_temp.crawlspace_vented.c': 0.0,
'out.zone_mean_air_temp.furnace_airloop_ret_air_zone.c': 23.3739714605263,
'out.zone_mean_air_temp.garage.c': 0.0,
'out.zone_mean_air_temp.living_space.c': 23.05555490043732,
'out.zone_mean_air_temp.mini_split_heat_pump_airloop_ret_air_zone.c': 0.0,
'out.total.lrmer_95decarbby2035_15_2025start.co2e_kg': 0.0350264028114,
'out.total.lrmer_lowrecost_15_2025start.co2e_kg': 0.0331938896366,
'out.total.lrmer_lowrecost_25_2025start.co2e_kg': 0.025913732098100002,
'out.total.lrmer_midcase_15_2025start.co2e_kg': 0.0397029401461}

Example of one row of metadata

{**'bldg_id': '7',**
'applicability': 'True',
'in.sqft': '617.0',
'weight': '242.13101272727272',
'in.ahs_region': 'Non-CBSA Pacific',
'in.ashrae_iecc_climate_zone_2004': '3B',
'in.ashrae_iecc_climate_zone_2004_2_a_split': '3B',

'in.bathroom_spot_vent_hour': 'Hour3',
'in.bedrooms': '1',
'in.building_america_climate_zone': 'Hot-Dry',
'in.cec_climate_zone': '10',
'in.ceiling_fan': 'Standard Efficiency',
'in.census_division': 'Pacific',
'in.census_division_recs': 'Pacific',
'in.census_region': 'West',
'in.city': 'In another census Place',
'in.clothes_dryer': nan,
'in.clothes_washer': nan,
'in.clothes_washer_presence': nan,
'in.cooking_range': 'Electric, 120% Usage',
'in.cooling_setpoint': '70F',
'in.cooling_setpoint_has_offset': 'No',
'in.cooling_setpoint_offset_magnitude': '0F',
'in.cooling_setpoint_offset_period': nan,
'in.corridor': 'Double-Loaded Interior',
'in.county': 'G0600730',
'in.county_and_puma': 'G0600730, G06007307',
'in.dehumidifier': nan,
'in.dishwasher': nan,
'in.door_area': '20 ft^2',
'in.doors': 'Fiberglass',
'in.ducts': '10% Leakage, R-4',
'in.eaves': '2 ft',
'in.electric_vehicle': nan,
'in.emissions_electricity_folders':
'data/cambium/LRMER_MidCase_15_2025start,data/cambium/LRMER_LowRECost_15_2025start,data/cambium/LRMER_95DecarbBy2035_15_2025start,data/cambium/LRMER_LowRECost_25_2025start',
'in.emissions_electricity_units': 'kg/MWh,kg/MWh,kg/MWh,kg/MWh',
'in.emissions_electricity_values_or_filepaths':
'/lib/resources/data/cambium/LRMER_MidCase_15_2025start/CAMXc.csv,/lib/resources/data/cambium/LRMER_LowRECost_15_2025start/CAMXc.csv,/lib/resources/data/cambium/LRMER_95DecarbBy2035_15_2025start/CAMXc.csv,/lib/resources/data/cambium/LRMER_LowRECost_25_2025start/CAMXc.csv',
'in.emissions_fossil_fuel_units': 'lb/MBtu,lb/MBtu,lb/MBtu,lb/MBtu',
'in.emissions_fuel_oil_values': '195.9,195.9,195.9,195.9',
'in.emissions_natural_gas_values': '147.3,147.3,147.3,147.3',
'in.emissions_propane_values': '177.8,177.8,177.8,177.8',
'in.emissions_scenario_names':
'LRMER_MidCase_15_2025start,LRMER_LowRECost_15_2025start,LRMER_95DecarbBy2035_15_2025start,LRMER_LowRECost_25_2025start',

'in.emissions_types': 'CO2e,CO2e,CO2e,CO2e',
'in.emissions_wood_values': '200.0,200.0,200.0,200.0',
'in.federal_poverty_level': '400%+',
'in.generation_and_emissions_assessment_region': 'CAMXc',
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'in.geometry_building_horizontal_location_sfa': nan,
'in.geometry_building_level_mf': 'Bottom',
'in.geometry_building_number_units_mf': '16',
'in.geometry_building_number_units_sfa': nan,
'in.geometry_building_type_acs': '10 to 19 Unit',
'in.geometry_building_type_height': 'Multifamily with 5+ units, 1-3 stories',
'in.geometry_building_type_recs': 'Multi-Family with 5+ Units',
'in.geometry_floor_area': '500-749',
'in.geometry_floor_area_bin': '0-1499',
'in.geometry_foundation_type': 'Slab',
'in.geometry_garage': nan,
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'in.geometry_stories_low_rise': '3',
'in.geometry_story_bin': '<8',
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'in.geometry_wall_type': 'Wood Frame',
'in.has_pv': 'No',
'in.heating_fuel': 'Electricity',
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'in.heating_setpoint_has_offset': 'Yes',
'in.heating_setpoint_offset_magnitude': '3F',
'in.heating_setpoint_offset_period': 'Night -2h',
'in.holiday_lighting': 'No Exterior Use',
'in.hot_water_distribution': 'Uninsulated',
'in.hot_water_fixtures': '200% Usage',
'in.hvac_cooling_efficiency': 'Room AC, EER 12.0',
'in.hvac_cooling_partial_space_conditioning': '100% Conditioned',
'in.hvac_cooling_type': 'Room AC',
'in.hvac_has_ducts': 'Yes',
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'in.hvac_has_zonal_electric_heating': 'No',
'in.hvac_heating_efficiency': 'Electric Furnace, 100% AFUE',
'in.hvac_heating_type': 'Ducted Heating',
'in.hvac_heating_type_and_fuel': 'Electricity Electric Furnace',
'in.hvac_secondary_heating_efficiency': nan,
'in.hvac_secondary_heating_type_and_fuel': nan,
'in.hvac_shared_efficiencies': nan,
'in.hvac_system_is_faulted': 'No',

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'in.hvac_system_single_speed_ashp_airflow': nan,
'in.hvac_system_single_speed_ashp_charge': nan,
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'in.income_recs_2020': '60000-99999',
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'in.insulation_ceiling': nan,
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'in.insulation_foundation_wall': nan,
'in.insulation_rim_joist': nan,
'in.insulation_roof': 'Finished, R-38',
'in.insulation_slab': 'Uninsulated',
'in.insulation_wall': 'Wood Stud, Uninsulated',
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'in.lighting': '100% LED',
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'in.lighting_other_use': '100% Usage',
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'in.misc_freezer': nan,
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'in.misc_gas_grill': nan,
'in.misc_gas_lighting': nan,
'in.misc_hot_tub_spa': nan,
'in.misc_pool': nan,
'in.misc_pool_heater': nan,
'in.misc_pool_pump': nan,
'in.misc_well_pump': nan,
'in.natural_ventilation': 'Cooling Season, 7 days/wk',
'in.neighbors': '12',
'in.occupants': '1',
'in.orientation': 'Northwest',
'in.overhangs': nan,
'in.plug_load_diversity': '200%',
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'in.puma': 'G06007307',
'in.puma_metro_status': 'In metro area, not/partially in principal city',
'in.pv_orientation': nan,
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'in.radiant_barrier': nan,

'in.range_spot_vent_hour': 'Hour16',
'in.reeds_balancing_area': '11',
'in.refrigerator': 'EF 17.6, 100% Usage',
'in.roof_material': 'Asphalt Shingles, Medium',
'in.schedules': 'Stochastic',
'in.simulation_control_run_period_begin_day_of_month': '1.0',
'in.simulation_control_run_period_begin_month': '1.0',
'in.simulation_control_run_period_calendar_year': '2018.0',
'in.simulation_control_run_period_end_day_of_month': '31.0',
'in.simulation_control_run_period_end_month': '12.0',
'in.simulation_control_timestep': '15.0',
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'in.state': 'CA',
'in.tenure': 'Renter',
'in.units_represented': '1.0',
'in.usage_level': 'High',
'in.vacancy_status': 'Occupied',
'in.vintage': '1960s',
'in.vintage_acs': '1960-79',
'in.water_heater_efficiency': 'Electric Standard',
'in.water_heater_fuel': 'Electricity',
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'in.weather_file_city': 'Miramar Mcas',
'in.weather_file_latitude': '32.87',
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'in.windows': 'Double, Clear, Metal, Air',
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'out.params.floor_area_lighting_ft_2': '617.0',
'out.params.flow_rate_mechanical_ventilation_cfm': '0.0',
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'out.params.roof_area_ft_2': '0.0',
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'out.params.wall_area_above_grade_conditioned_ft_2': '414.7',

'out.params.wall_area_above_grade_exterior_ft_2': '414.7',
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