Energy Screening of the SPUR Urban Center

654 Mission Street, San Francisco
Energy efficiency and decarbonization in commercial and public buildings
28 April 2022

Danish Energy Agency

SPUR

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Disclaimer

The conclusions and recommendations in this report are made on the basis of an energy screening carried out by the Danish consultancy company Viegand Maagøe, which is responsible for the inventory, analysis of efficiencies, calculation of baseline and potential energy savings. The recommendations are made by the Danish Energy Agency based on the screening report from the consultancy and input from the management of the SPUR Center and San Francisco Department of the Environment.

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Credits

Cover photo from SPUR homepage, other photos Anne Svendsen and Bjørn Skjøldt Sørensen.

Foreword

As part of the G2G program between the Danish Energy Agency and the California Energy Commission, an energy screening was carried out in December 2021 in the SPUR Urban Center, located at 654 Mission Street, San Francisco. A screening report was prepared by the Danish consultant Viegand Maagøe. The results of the screening report were presented to SPUR and the San Francisco Department of the Environment (SFE) at a virtual meeting in January 2022. This report was prepared by the Danish Energy Agency based on the screening report and the meeting. The report serves several purposes with respect to energy use at the SPUR Urban Center:

- Establish a baseline for energy consumption and estimate the potential for energy saving;
- Suggest immediate actions that can improve the efficiency of installations and the operation of the building and reduce unintended losses;
- Make recommendations for measures that eliminate onsite greenhouse gas emissions while answering these questions:
    1. How can the building be decarbonized by 2035;
    2. What is the fastest and most cost-effective way to decarbonize the building;
    3. How fast can the building be decarbonized with available technology.

The recommendations and conclusions in this report are informed by a dialogue with the SPUR staff members managing the project, Laura Feinstein and Lawrence Lee. The screening report is based on an analysis of the energy consumption data from bills from the last four years and a physical screening of the building, in which the following participated: Greg Lunkes and Vince Hoenigman, who were involved in the planning and design of the building, Barry Hooper from SFE, Bo Riisgaard Pedersen and Sander de la Rambelje from the Danish consulate in Palo Alto and Anne Svendsen from the Danish Energy Agency in Copenhagen.

Method

A screening of the building was carried out on December 8, 2021, by the energy consultant Bjørn Skjødt Sørensen from the Danish consulting company Viegand Maagøe. Before the visit at the building, the consultants gathered the following data:

- Energy bills for electricity and gas from the last five years (taking into consideration that the energy consumption for 2020 and 2021 was much different due to COVID-19)
- Technical drawings (as built)
- Asset reserve analysis prepared in 2014 by Ventura Partners

How to use this report

This report contains information from the screening report as well as an introduction from Laura Feinstein of SPUR. It provides a snapshot of the energy consumption of the building in its current condition at the time of the screening (December 2021) and is not a comprehensive analysis of the technical installations. Conclusions are based on the data and the screening as well as information supplied by SPUR staff. No measurements took place during the screening.

Several assumptions have been made about, for example, temperatures in the building, number of visitors, occupancy times and the operation of the installations, and some of the recommendations are based on practical experience as well as existing standards. This report may be used by the Staff and Board of the SPUR organization in preparing an energy efficiency / decarbonization plan but is not the plan itself.

Executive summary

The City of San Francisco is ambitiously working toward decarbonizing the building stock in San Francisco. This means eventually replacing all natural gas consumption in buildings with electrical consumption. In order to evaluate the possibilities and potential of that goal, the Danish Energy Agency (DEA) in cooperation with the San Francisco Department of the Environment (SFE) has carried out an energy screening of a commercial building in the center of San Francisco, under the cooperation framework between the DEA and the California Energy Commission (CEC). The screening work was carried out by the company Viegand Maagøe with representatives from DEA, SPUR and SFE in December 2021.

San Francisco is targeting citywide net zero carbon by 2040; the 2021 San Francisco Climate Action Plan acknowledges that to meet this goal virtually all buildings must be fully electrified. Therefore, the scope of the screening has included possible ways to electrify the building.

San Francisco has stated its intent to require that commercial buildings shall eliminate onsite fossil fuel consumption by 2035. This will require buildings to eliminate the use of natural gas for heating and cooking by that deadline.

To support the decarbonization strategy, the Danish Energy Agency proposed conducting an energy screening of a commercial building, and SF Environment suggested the SPUR building at 654 Mission Street in downtown San Francisco. This building is from 2009 with a footprint of 2,100 sqft/200 m^2, four floors and a total area of approx. 11,000 sqft or approx. 1,000 m^2.

The building is LEED-certified, which means sustainability measures have been applied in the design and construction phase to ensure very low energy consumption and a good indoor climate. The building is used for exhibitions, gatherings, events and meetings, plus one floor of offices. The usage time is normal office hours with occasional events and conferences outside those hours.

Heating is supplied through a gas-feed ventilation system located on the roof. Cooling is produced in the same unit using electricity. Direct electrical instant heaters produce hot water for showers and for the restrooms; hot water for washing up is produced in two electric heaters with storage tanks. So the only need for gas is for heating. Given the mild climate in the San Francisco area, the need for heating is relatively low.

DEA collected and analyzed building information including drawings, technical specifications and energy consumption before the screening took place. The energy consumption of the building for the last two years has been significantly influenced by the COVID-19 pandemic, which lowered the activity level in the building and decreased energy consumption.

A decarbonization of this building would be fairly easy and not necessarily expensive, since it would primarily consist of replacing the rooftop ventilation unit with an all-electric unit. But this report also seeks to discover if it is possible to reduce energy consumption before changing the ventilation system. If so, it may also be possible to procure a smaller rooftop unit and reduce the grid load.

Even though the SPUR building is rather new, the report identified several energy conservations measures (ECM), –including some with short payback times.

The energy-saving measures identified mainly involve the ventilation system, the production of hot water and the lighting system.

Summary of energy-saving measures

Short-term measures:

Ventilation: We suggest the damper controlling fresh air intake be controlled automatically according to the needs in the rooms. Air should be recirculated when room occupancy is low. Control of the heating and cooling set points can be improved.

Energy-saving potential can also be realized by improving the efficiency of the fans and motors in the rooftop units (RTUs), changing the filter type and minimizing heat loss through the entrance door and windows.

Production of hot water: Due to the low consumption of hot water, we suggest replacing the electric water heater tanks with instant-demand heaters that only heat the necessary amount of water (as installed in the restrooms).

Lighting: Save energy by replacing the remaining fluorescent lighting with LEDs in the staircases and basement and adding daylight control as well as movement control in the rooms that do not have this.

Longer-term measures:

Full decarbonization of the building: It is possible to replace the existing RTUs (there are four) with all-electric units with a heat pump using the same compressor to produce cooling and heating and with direct driven, variable speed fans. However, since the expected remaining lifetime of the RTUs is about 5-10 years, our team recommends waiting until then to replace them with high-efficiency RTUs with combined heat pumps for cooling and heating. It is possible to replace them now (the technology exists today) but since their gas consumption is very low and the gas price at the moment is low, there would only be a small gas savings/CO_2 savings and no economic savings. From a purely financial point of view we therefore recommend reducing the need for heating as much as possible and waiting until the projected end-of-life of the RTUs, expected to be between 2030-2035.

If the RTUs are replaced earlier for demonstration reasons and for the social benefit (inspiration to others, good case example, etc.), it's important to use equipment with the highest efficiency available on the market today. An additional note: the remaining lifetime of the roofing material may only be 10 years, in which case it would make sense to change the roofing felt and replace the RTUs at the same time.

Suggestions for building management (short-term ECM):

1. Separate the circuits for the lighting on the staircase towards Mission Street into an emergency circuit and a circuit for decorative illumination of the building, so that the decorative lighting can be turned off, e.g., when there is sufficient daylight. For emergency lighting, it may be possible to reduce the lighting level to a minimum when there is no one present and then use either motion sensors or acoustic sensors to increase the lighting level as needed.
2. Replace all fluorescent lighting units with LED and install motion sensors where possible. In particular, the current lighting in the two staircases uses a high proportion of the building's energy.
3. Make an analysis of the cost of installing more meters (e.g., per floor or for each RTU). Meters do not save energy, but they give an overview of where energy is used.
4. Investigate whether the CO_2 sensors in the rooms are working and if they can be connected to the RTU controls, which would enable them to control the inlet dampers and increase recirculation of air when room occupancy is low (not while COVID remains an

issue and not on the office floor, where there normally are more people working at the same time).

5. Check if the dishwashing machines on the second floor and in the basement can run directly on tap water with internal heating and evaluate if the water heater is necessary.
6. Look at the temperature set points for cooling and heating.
7. If the HVAC units will be in use for another 10 or more years, get a price and an energy-saving calculation from the maintenance company on changing the fans in the RTUs to variable speed fans that are not belt driven and change if cost-effective (payback period shorter than life of unit, estimated to be maximum 10 years). Change to a different filter type with a lower resistance.
8. Change the exhaust ventilator on the roof servicing the toilets to one with a higher efficiency and variable speed drive and ensure that the speed is reduced at night.

Energy-Saving Measures

Ventilation: Increase use or recirculation of air when the number of users is low. Improve temperature settings for both cooling and heating. Improve the efficiency of the fans and motors in the rooftop units (RTU), change filter type and minimize heat loss through main door and windows.
Lighting: Replace remaining fluorescent lighting to LEDs in the staircases and basement and add daylight control as well as movement control in the rooms that do not have this.
Production of hot water: Due to the expected low domestic hot water consumption the electric water heaters can be replaced by instant demand heaters that only heat the necessary amount of water (as installed in the restrooms).

Suggested Decarbonization Strategy

Replace the RTUs at the end of lifetime with high-efficiency RTUs with a heat pump option (same compressor to produce cooling and heating) and with direct driven, variable speed fans.

Danish Energy Agency

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Abbreviations

CEC	California Energy Commission
Cfm	cubic feet / minute = 0.0283 m^3 / min
DEA	Danish Energy Agency
ECM	Energy Conservation Measures
HVAC	Heating, ventilation and air-conditioning
RTU	Rooftop Unit (ventilation system with integrated cooling and heating option)
SFE	San Francisco Department of the Environment
SPUR	A nonprofit public policy organization in the San Francisco Bay Area
Sqft	Square feet = 0.0929 m^2

1. An Introduction from SPUR

By Laura Feinstein, SPUR

This energy screening represents a partnership between the Danish Energy Agency (DEA), the California Energy Commission (CEC), San Francisco Department of the Environment (SFE) and the nonprofit public policy think-tank SPUR.

SPUR is a nonprofit public policy organization in the San Francisco Bay Area. We bring people together from across the political spectrum to develop solutions to the big problems that cities face. With offices in San Francisco, San José and Oakland, we are recognized as a leading civic planning organization and respected for our independent and holistic approach to urban issues.

Climate change is one of the most catastrophic events humankind has faced. It interacts with and exacerbates nearly every other problem facing the globe, from racial and economic inequality to emergence of novel diseases, environmental injustice, biodiversity collapse and natural disasters.

SPUR's sustainability and resilience work is dedicated to eliminating carbon emissions in the Bay Area. To that end, SPUR has adopted a five-year organizational priority of phasing out the use of fossil fuels in buildings in the Bay Area[1]. We strive to realize our policy goals through influencing the public and private sector. In the case of building decarbonization, however, we also have a responsibility and an opportunity to lead through example by decarbonizing our own building, the SPUR Urban Center. To that end, we identified two scenarios to understand through this screening:

Scenario 1: Meet regulatory requirements for electrifying the Urban Center. Eliminate the on-site use of fossil fuels in the Urban Center no later than would meet regulatory requirements (presumably the 2035 deadline laid out in the 2021 San Francisco Climate Action Plan).

Scenario 2: Make the SPUR Urban Center a leader in building electrification. Eliminate the on-site use of fossil fuels in the Urban Center as quickly as is technically and financially feasible for our organization, a mid-size nonprofit. Technical considerations include staff capacity and the availability of appropriate technology. Financial considerations include operating costs, capital costs and our ability to garner external funding for electrification.

Regulatory requirements and Return on Investment will be considered, but they are not the sole factors for SPUR when deciding the pace of decarbonizing the Urban Center. The societal value, organizational impact and our capacity to find external financial support will all be factors when considering how to accelerate the timeline for decarbonization.

To better understand how to decarbonize the Urban Center, we partnered with the Danish Energy Agency and their technical consultant Viegand Maagøe, with additional technical support from San Francisco Department of the Environment.

Our motivating questions were:

1. What are the technical options for electrifying the Urban Center? Since the only use of natural gas in the building was for space heating, this is essentially a question about how to electrify the heating system.

[1] https://www.spur.org/policy-area/sustainability-and-resilience

2. What are the capital and operating costs to electrify the Urban Center? How will those change over time as rates for electricity and natural gas change?

From this screening, we reached the following main conclusions:

1. **The Urban Center could reduce its natural gas use by more than half without replacing any major piece of equipment.** This could be accomplished by adjusting the set points for when heating is needed and by instructing the staff and the users of the building not to use the windows when heating is needed but to rely on the ventilation system with increased recirculation of air (only possible in post-COVID times).
2. **Electrifying the Urban Center is technically feasible with readily available solutions.** The best technical option to electrify space heating in the Urban Center is by replacing the RTUs with new RTUs with a combined heat pump for both cooling and heating. The Urban Center is a very energy-efficient building already with low total demands for space heating. As a consequence, the savings from installing a highly efficient heat-pump for space heating are very low, which will make the Return on Investment for ducted heat pumps look less appealing from a financial standpoint than they might in a building with higher heating bills. To sum up for this solution: There will be no financial savings (extra costs for the use of electricity for the heat pump), and there will be very little CO_2 savings because the consumption is already low and resources (steel, metal, energy, etc.) are needed for the production of new RTUs.
3. **Electrifying the Urban Center will be cost-effective after the year 2030, where it is expected that the existing RTUs are at their end of life and must be replaced anyway.** The extra cost of installing an RTU with a heat pump instead of a gas heater, if any, would be marginal (it may also no longer be possible to buy an RTU with a gas heater at that time). Since the gas consumption is low in this building, the main concern is not Return on Investment but planned maintenance costs and replacement of installations. The consultant gives the following information on costs and potential savings: This approach would likely cost $30,000-50,000 for all the installation but that amount would be needed anyway (the extra cost for a heat pump solution is estimated to be about $500-1,000 per unit). Given projections for fuel costs, where the gas price is expected to rise in the future, building owners with a much higher consumption will save money by converting from gas to heat pump. If the replacement were done in 2030, the annual savings for this building would be approximately $1,000 with ECMs, and $2,000 without ECMs. If the replacement occurred in 2023, the average savings per year over the first 10 years could be around $500 with ECMs and $1,000 without ECMs. The reason for this difference is the expected rise in gas prices. Assuming the same price development continues toward 2045 and the replacement was done in 2035, the average savings per year over the first 10 years would be about $1700 with ECMs and $3400 without ECMs.
4. **The full upfront cost (investment in new RTUs, removal of existing RTUs and installation of new RTUs) to electrify the building is approximately $30,000-50,000, and as mentioned above there may not be any economic benefits.** The social benefit of decarbonizing SPUR will, however, be quite large if SPUR wants to lead by example. The Urban Center has a very large network (+6000) and there may be a high demonstration value if SPUR goes forward with decarbonization, but there will be no costs savings and very little CO_2 reduction.
5. **Time of equipment replacement is a prime opportunity to decarbonize the SPUR Urban Center and reduce total energy demand.** The installed gas-burning appliances are likely to fail between 2025 and 2030. So for the time being it makes sense to

reduce the actual need for heating, either by increased use of recirculating the air and/or by improved control of the system. This should not compromise the quality of the indoor air or the temperatures in the building. We suggest discussing with the building users what the temperature range should be in very cold weather and very hot weather. It is likely that the office floor, where people are sitting still and working, will have the highest temperature requirements and a demand for no draft (cold air from the ventilation system).

6. **Opportunities for energy efficiency remain.** Even in a building like the Urban Center that is already quite energy efficient, there are opportunities to decrease electricity use for ventilation. The ventilation system itself can be upgraded with high efficiency fans with direct drive and VLT, and it may be possible to increase the recirculation of air in less-trafficked areas. Other possibilities for reducing consumption include decreasing energy use for lighting in the stairwells and the basement. SPUR is already buying 100% renewable electricity, so the CO_2 savings are zero on electricity conservation measures. However, from a social perspective decreasing the building's electrical load, especially peak electrical load, is a complementary goal to electrification. First, it can moderate the building's peak load demands, averting the need for costly electrical service upgrades. Second, it minimizes electrical demands on the upstream electricity system. California's goal of transitioning nearly all energy use to electricity will place unprecedented demands on the electrical grid, which in turn can strain reliability and require costly upgrades to infrastructure. Electrification should go hand-in-hand with efforts by end users to reduce peak demands to minimize unintended consequences to the electrical grid.

2. Results from the Screening Report

The SPUR building is a commercial building located on 654 Mission Street, San Francisco, CA 94105-4015.

The building has four floors (ground floor is double height), used for exhibitions and meetings, with some offices on the second floor and meeting rooms on the top floor. The ground area is about 11 m x 23 m = 253 m^2 (2,800 sqft). The total air-conditioned and heated area is about 9,926 ft^2, or 922 m^2.

Figure 1. The SPUR building

The main use of individual floor is:

Level	**Area sqft**	**Usage**
Basement	2,211	Technical installations, storage
Ground floor	2,114	Reception, exhibitions and coffee shop/café
Second floor plan	2,016	Staff offices and a small kitchen
Third floor plan	2,143	Conference room for larger events
Fourth floor plan	1,442	Meeting rooms and smaller events
Total Area	**9,926**	

Table 1. Overview of the usage of each floor. The area in the table is based on the egress calculations, which excludes the exit stairwells, elevator shaft, electrical closets on each floor and the small closet on the fourth floor.

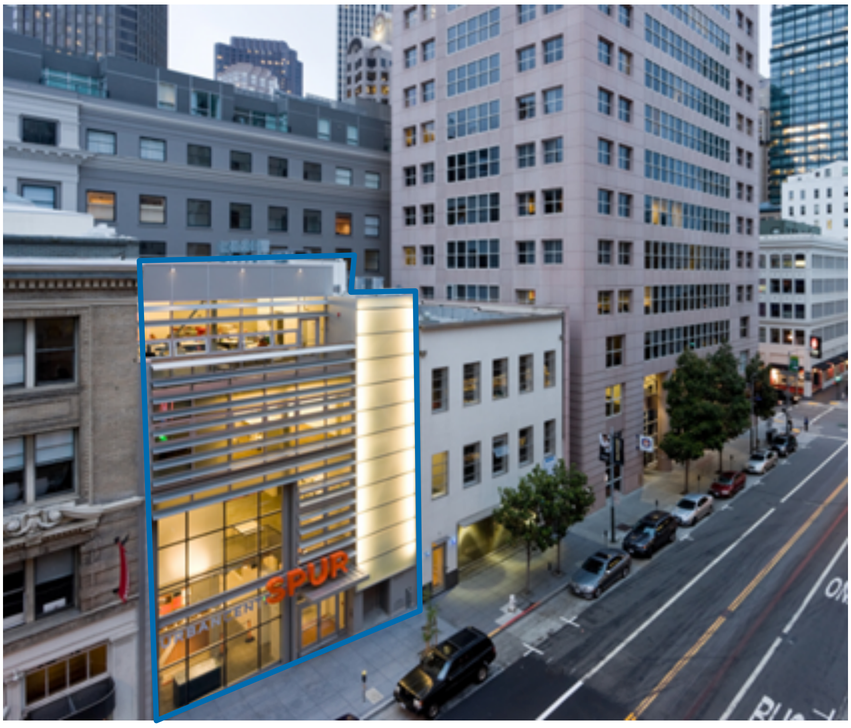

Figure 2. Street view of the SPUR Urban Center

The building was constructed in 2009 as a LEED Silver building. The building is heated and cooled by four natural gas rooftop units (RTUs) supplying heating, ventilation and air conditioning (HVAC), where each unit supplies one floor. Each RTU consists of a gas burner section for heating controlled by thermostats in the building, and a fan for air supply to the gas burner. The air comes in through an air inlet, which can also be used for free cooling if the outdoor temperature is low. There are also fans for the air intake.

An extraction ventilator on the roof level services the restrooms 24 hours per day, seven days a week.

There are also two smaller chillers delivering cooling to the elevator shaft and the computer room in the basement of the building.

Decentralized electrical instant heaters produce hot water for the restrooms. For the café and the staff kitchen's dishwasher, there are also two 30-gallon (114L) electrical hot water tanks, one located in the basement and one on the second floor in the staff kitchen.

2.1 Description of the building

LEED certification means the building was built with sustainability in mind. Below is a list of sustainability initiatives that were implemented when the building was constructed.

2.1.1 Materials

- 95% of the former 654 Mission building was recycled or reused
- Structural steel is 95% recycled material
- Cement is 50% fly ash (a byproduct of coal-fired power plants)
- Paints, doors and carpets used Low Volatile Organic Compounds (VOC)
- Carpets partially made with post-industrial scrap
- Cabinetry made of crushed sunflower seed husks, a rapidly renewable material

- Countertops made of recycled newspaper and natural resin

2.1.2 Heating/Cooling

- The roof is coated with white reflective material to prevent the heat absorption typical of black tar roofs
- Openable windows let in fresh air
- Reflective louvers on the facade reflect direct sunlight, reducing heat load and relieving HVAC system
- HVAC filtration is hyper-efficient, screening out fine particles of pollen and dust
- HVAC uses the most environmentally benign refrigerant chemical on the market at the time of construction (R410a, with a global warming potential of 2,088 times greater than CO_2).[2] If gasses are released, they will not contribute to ozone depletion or greenhouse gasses but they will have a GHG effect and shall therefore not be released into the air when replaced.
- Carbon dioxide sensors in the rooms
- An "economizer" that brings in outside air when temperature is comfortable without conditioning it
- "European"-size system, which has a wider comfort range. Most American systems maintain a specific temperature degree, using more energy.

2.1.3 Plumbing

- Dual-level water-saving flush toilet
- Sensor flush urinals
- Automatic sinks
- Under-sink instant hot water heater

2.1.4 Lighting

- Fluorescent and LED energy-saving lights
- Automatic shut offs
- Motion sensor activated
- Multiple level switches and dimmers
- Master shut-off

[2] https://ww2.arb.ca.gov/resources/documents/high-gwp-refrigerants

3. Energy consumption

Before the screening, the team analyzed data on the last four years of energy consumption. Due to the LEED certification, a substantial amount of documentation was available, including as-built drawings, information on technical installations and energy consumption.

There are two energy meters in the building: one for electricity consumption, located in the basement, and one for natural gas consumption, located just outside the building. There are no secondary meters, so it is not possible to measure the energy consumption for different energy-using appliances or areas.

Thus, the following energy data were obtained:

- Natural gas consumption from 2019 to 2021. The highest possible resolution was daily.
- Electricity data for 2018-2021. The resolution was per 15 minutes.

3.1 Electricity consumption

Four years of data for electricity consumption was obtained. The yearly electricity consumption is shown in the table below:

Year	2018	2019	2020	2021
(kWh)	101.558	78.684	45.926	36.436*

*Data until November 28th

Table 2. Electricity consumption

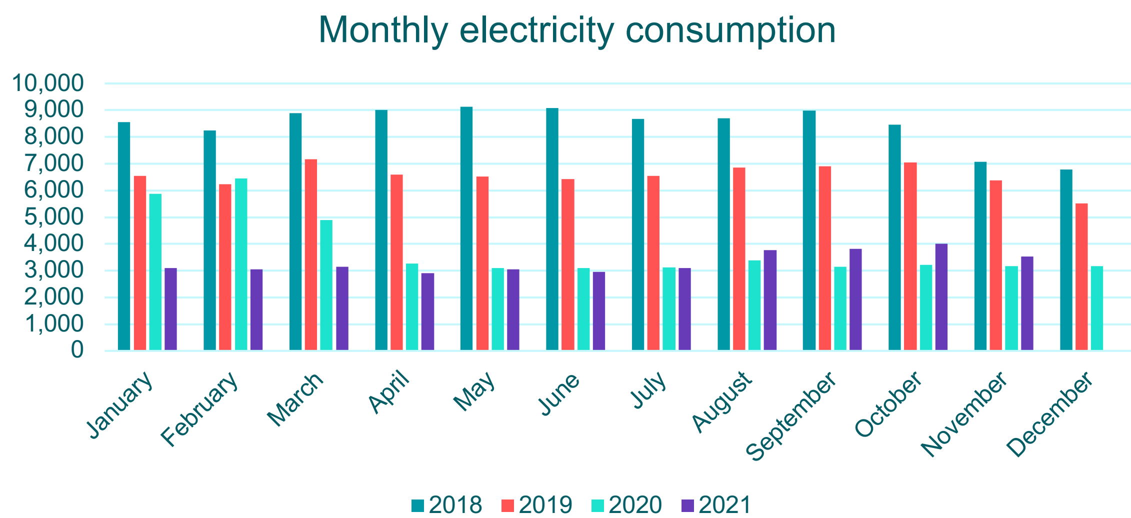

Figure 3. Monthly electricity consumption 2019-2021 (kWh/month)

There has been a continuous decrease in yearly electricity consumption from 2018 to 2021. Consumption in 2020 and 2021 has been affected by the current COVID-19 pandemic and is approximately 40% lower than in 2019.

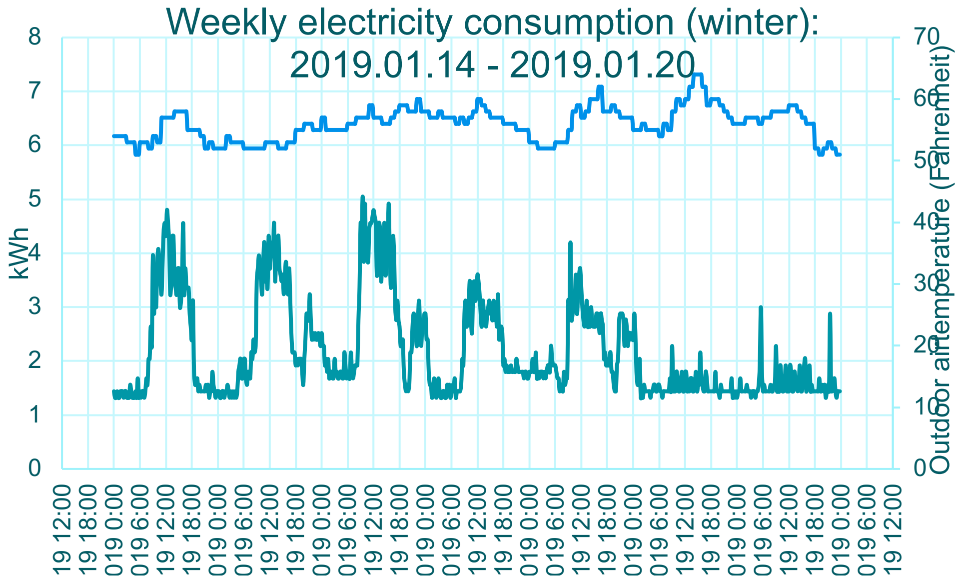

Figure 4. Weekly electricity consumption (winter): 2019.01.14 - 2019.01.20. Blue: Outside temperature (°F, right axis), Green: Electricity consumption (kWh/h, left axis).

In summertime, the electricity consumption is more directly connected to the outdoor temperature, due to the need for cooling.

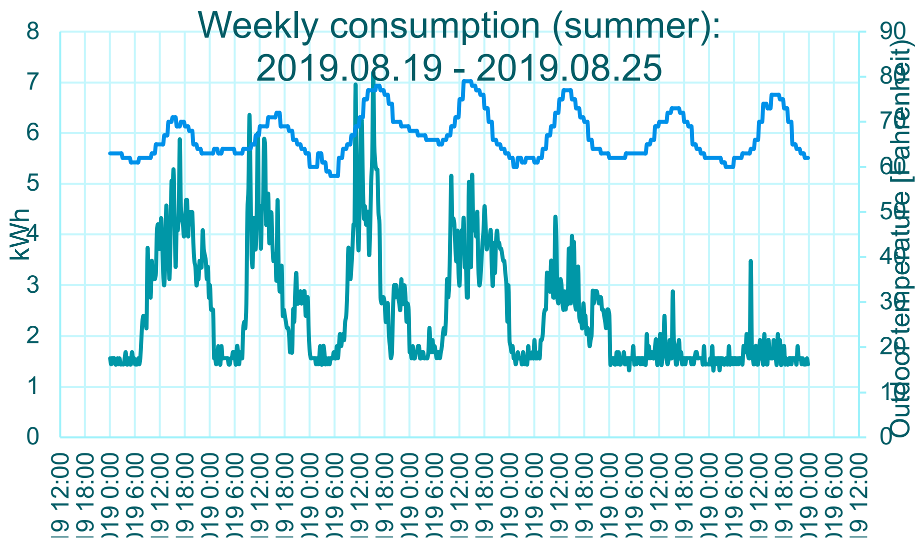

Figure 5. Weekly electricity consumption (summer): 2019.08.19 - 2019.08.25. Blue: Outside temperature (°F, right axis), Green: Electricity consumption (kWh/h, left axis).

3.2 Natural gas consumption

Three years of data for natural gas consumption was delivered. The yearly gas consumption is shown in the table below:

Year	2019	2020	2021
Therms	456	207	36*
kWh	13,360	6,065	1,055

*Data until November 28th 2021

Table 3. Natural gas consumption

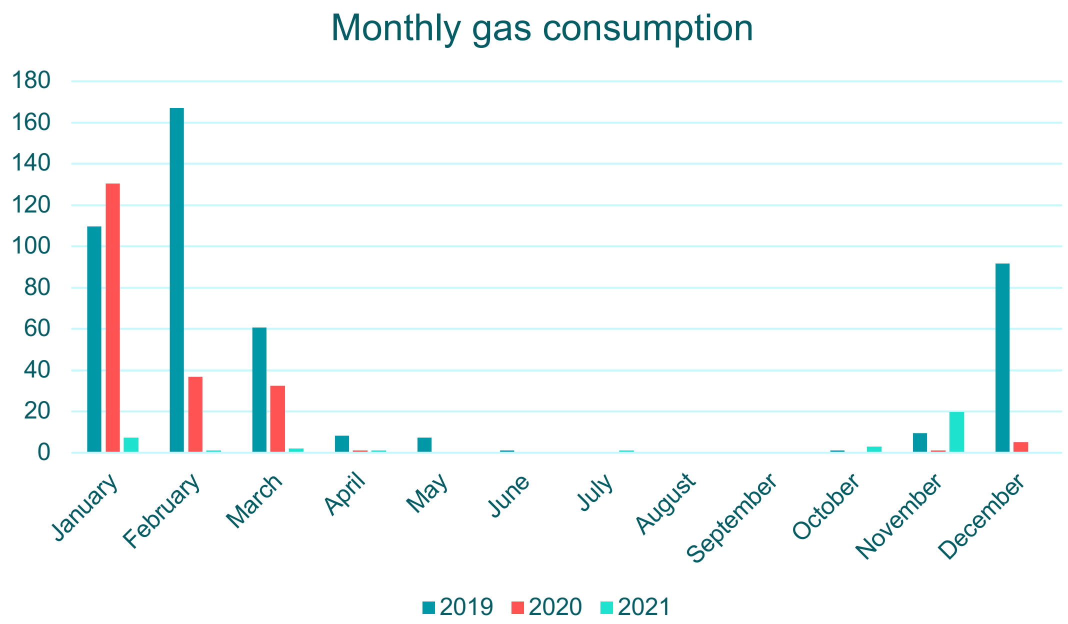

Figure 6. Monthly gas consumption 2019-2021 (Therms/month)

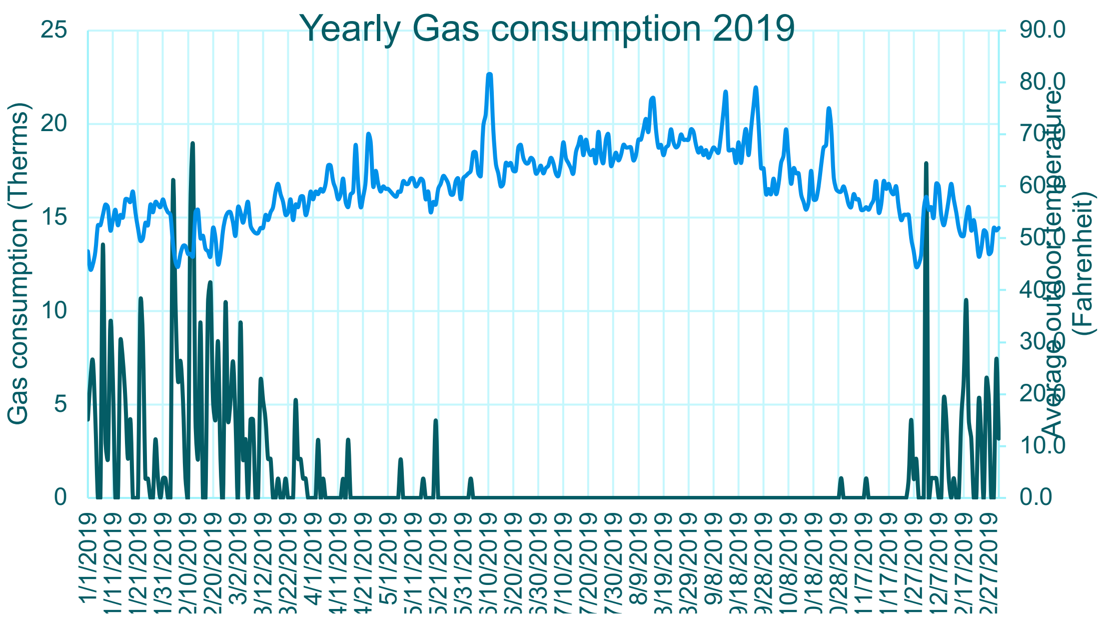

Figure 7. Yearly gas consumption and the average outdoor temperature. Blue: Outside temperature (°F, right axis), Green: Gas consumption (Therms/day, left axis).

3.3 Distribution of energy consumption

The distribution of energy consumption is shown in the figure below. Due to the lack of sub-meters, the distribution is based on certain assumptions about the technical data on installations and usage.

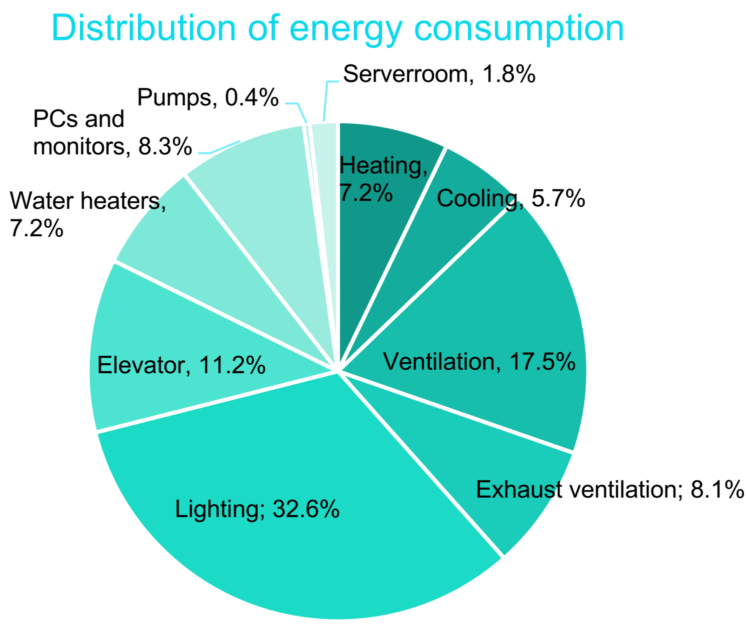

Figure 8. Distribution of energy consumption

As seen in Figure 8, artificial lighting is estimated to account for almost a third of the total energy consumption. This is mainly because of the fluorescent lighting in the staircase, which is turned on 24/7/365 due to safety requirements. According to SFE, motion-controlled bi-level lighting in egress stairwells is allowed by Fire Code and may result in savings of about 50% for lighting. Heating and cooling of the building accounts for a total of 13%, while ventilation has a share of 17.5 %.

3.4 Energy prices

Natural gas prices are expected to increase rapidly toward the year 2034 with an expected increase of 83% from 2020. Electricity prices are expected to increase only modestly, rising by about 13% in the same time. Below is a projection of energy prices through 2034 received from SFE in connection with this screening.

Year	Source	Statewide Electric Nonresidential Average Rate Escalation Above Inflation (%/year, real)	Natural Gas Nonresidential Core Rate Escalation Above Inflation (%/year, real)	Bundled Electric Rate ($/kWh)	Bundled Gas Rate ($/th)	Increase from 2022 baseline (using annual rate from prior year, starting in 2022) - E	Increase from 2022 baseline (using annual rate from prior year, starting in 2022) - G
2020	E3 2019	2.00%	4.30%	NA	NA		
2021	E3 2019	2.00%	4.30%	0.24	0.97		
2022	E3 2019	2.00%	2.70%	0.25	1.00	1.00	1.00
2023	E3 2019	2.00%	4.00%	0.25	1.04	1.02	1.03
2024	2022 TDV	0.70%	7.70%	0.25	1.12	1.04	1.07
2025	2022 TDV	0.50%	5.50%	0.25	1.18	1.05	1.15
2026	2022 TDV	0.70%	5.60%	0.26	1.24	1.05	1.21
2027	2022 TDV	0.20%	5.60%	0.26	1.31	1.06	1.28
2028	2022 TDV	0.60%	5.70%	0.26	1.39	1.06	1.35
2029	2022 TDV	0.70%	5.70%	0.26	1.47	1.07	1.43
2030	2022 TDV	0.60%	5.80%	0.26	1.55	1.08	1.51
2031	2022 TDV	0.60%	3.30%	0.26	1.60	1.08	1.60
2032	2022 TDV	0.60%	3.60%	0.26	1.66	1.09	1.65
2033	2022 TDV	0.60%	3.40%	0.27	1.72	1.10	1.71
2034	2022 TDV	0.60%	3.40%	0.27	1.78	1.10	1.77

Figure 9. Expected projection of future energy price development for electricity and gas. Provided by San Francisco Department of the Environment.

3.5 Operation time

Pre-pandemic, the building was mainly used from 8.30 a.m. to 7 p.m. Once or twice a week there were evening events.

An average of two-thirds of the staff (about 23 people) occupied the building in a given week. Typically, 50-100 people attended meetings and events.

3.6 HVAC installations

The building is heated and cooled by ducted air prepared in four RTUs placed on the roof. The air is heated using gas in the RTU and cooled electrically.

3.7 Heating, Cooling and Ventilation

There are four ventilation systems, supplying each floor. The location of the ventilation systems can be seen in figure 11 and the capacity of each ventilation system is shown in the table below.

Figure 10. Overview of the technical installations on the roof.

The ventilation system is a balanced system with possibility for recirculation. There are four units located on the roof. Each ventilation system can supply both heating and cooling.

		Supply fan	Gas fired heating	Cooling Coil		Cooling Efficiency
Name	**Supplying**	**(CFM)**	**Output (MBH)**	**Capacity, total (MBH)**	**Capacity, sensible (MBH)**	**BTU/W**
AC-1	Ground floor/ basement	4,750	148.4	144.3	121.6	12.5
AC-2	Level 2	2,850	111.5	97.3	82.5	12.5
AC-3	Level 3	3,100	111.5	82.8	76.6	12.5
AC-4	Level 4	1,750	60.8	59.9	48.3	12.5

Table 4. Efficiencies of RTUs

AC-1, AC-2 and AC-3 are located on the roof of level 3, while AC-4 is located on the roof of level 4.

AC-1

AC-2

AC-3

AC-4

Figure 11. Ventilation system – AC-1 to AC-4.

For each RTU there is a bypass for outdoor air (fresh air) located next to the RTU. The ventilation damper that controls the amount of fresh air to be supplied to the ventilation system is, however, locked in a fixed position, so it seems impossible to regulate the amount of fresh air being let into the ventilation system.

Filters on the air inlets are changed every three months. Filters used are MERV-13 filters with an initial resistance of 0.34 w.c. at 500 cfm.

3.8 Heating

Heating is supplied by a gas burner in the ventilation unit and a heating surface. The overall combined efficiency of the gas heating system is about 80%. The gas burner in each RTU is controlled by a Google Nest thermostat on each floor.

3.9 Exhaust from restrooms, kitchen, fire-pump room and AV room

There are three exhaust systems supplying the toilets, the second-floor kitchen and the AV room in the basement, as shown below.

	Location	Supplying	Fan			Motor	
			CFM	RPM	BHP	HP	Effect [W]
EF-1	Roof	Toilets, kitchen	1.87	1634	0.54	0.75 HP	560
EF-2	Basement	Fire pump	200	900	0.11	83 W	83
EF-3	Level 2	AV room	300	1111	0.15	144 W	144

Table 5. Exhaust ventilation

The exhaust ventilation runs 24/7/365 without recirculation or heat recovery.

Figure 12. EF-1 exhaust fan on roof. No regulation or heat recovery observed.

3.10 Cooling of technical installations

There are two 410A Scroll compressors on the roof supplying cooling for the server room and the machine room for the elevator. The cooling system has two levels dependent on the deviation from the set point. The outlet temperature from the condenser controls fans and compressor (on/off).

Figure 13. Cooling compressors on the roof.

Cooling installation	Supply (CFM)	Cooling capacity (MBH)
AC-5	1,000	28.8
AC-6	1,000	28.8

Table 6. Cooling compressors

3.11 HVAC control

In the indoor areas, the temperature is set on the Nest thermostats to 68F in winter and 74F in summer. Cooling and heating are controlled by the same set points.

The building operates with night ventilation to cool the building during the night. Night cooling is used until the outdoor temperature is below 50F and operates from 6PM to 9AM. Night cooling is controlled by the Nest thermostats. The building manager has access to all thermostats on a computer.

The temperature control may, however, be changed multiple times during the day by the users of the building. The thermostat is currently programmed to reset 5 times per day to the predetermined temperature; otherwise the building manager has to override user changes to the control.

Figure 14. Nest thermostat and CO2 sensor

Heating and cooling are controlled by Nest thermostats connected to the HVAC system. There are four modes:

- Off
- Heating
- Cooling
- Fans only

There is one thermostat for each floor.

The thermostats control only heating and cooling, not airflow. Fans can be regulated to change the airflow. At the screening, the airflow was constant.

CO_2 sensors are installed at each floor, but during the screening, it was not clear if they are connected to the thermostats. There is no access to monitoring the set points for the CO_2 regulation or a way to change them.

There are no motion sensors (e.g., PIR sensors) installed to identify activity in the building. The building manager can see if there are people in the room by using cameras located in the rooms.

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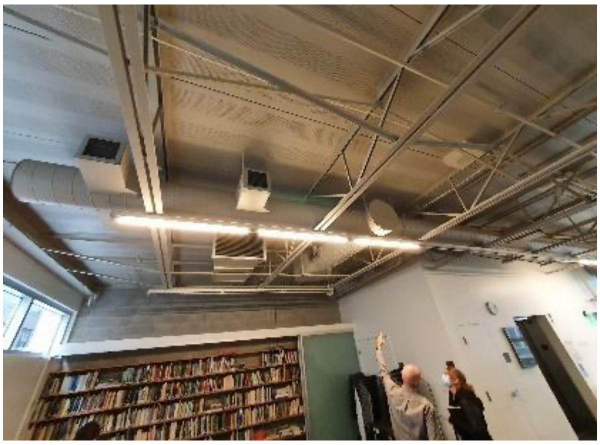
3.12 Hot Water

Two hot water tanks of 30 gallons (approx. 114 L) are installed. One is in the staff kitchen on the second floor and one is in the basement for the café kitchen and showers.

Figure 15. Hot water tanks placed in the kitchen on the 2nd floor and in the basement

3.13 Lighting

The building was built with fluorescent lamps. Most of the fluorescent lamps have been converted to LED over the years, floor by floor through multiple projects.



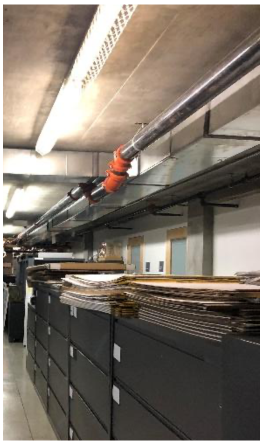


Figure 16. Lighting

There are still fluorescent lamps in the basement and the staircases. In the staircases, the lights are kept on due to fire safety since the staircases are escape routes. Our team recommends upgrading these to LED and considering motion sensors.

Figure 17. Vertical lighting in the staircase toward Mission Street is part of the outside illumination of the building and turned on 24/7.

Around the windows in the staircase toward Mission Street there are also fluorescent tubes for decorative purpose. These are on all day and night. The team recommends considering another illumination strategy and installing daylight control so that the decorative light (which should also be upgraded to LED) is on only when needed. The team learned that this light is on the same circuit as the emergency light for the staircase; we recommend investigating whether this can be separated.

All lighting in the rest of the rooms is LED but manually controlled (on/off) except a few storage rooms and toilets with sensors. The team recommends motion sensors and timers (during operation hours there should be a longer period before the light goes out than outside of operation hours).

3.14 Indoor environmental quality

An air pollution sensor installed in the building monitors the amount of indoor particulate matter (PM). Several outdoor sensors are located near the building monitoring the outdoor air quality.

Below is a comparison of air quality indoors at SPUR and outdoors at 965 Folsom (a street close to the SPUR building) for the month of November 2021. Air quality is measured as concentration of particulate matter of 2.5 microns and smaller (PM 2.5 ug/m3). The data show that SPUR’s indoor air quality follows the same trends as the outdoor air quality, but typically has about half the concentration of PM 2.5 as the outdoor air. Since this dataset is from a period during which the building has been closed due to COVID-19 and windows have been used more frequently, it may not be a picture of the normal situation and it would be best to look at other periods during which the building was in use.

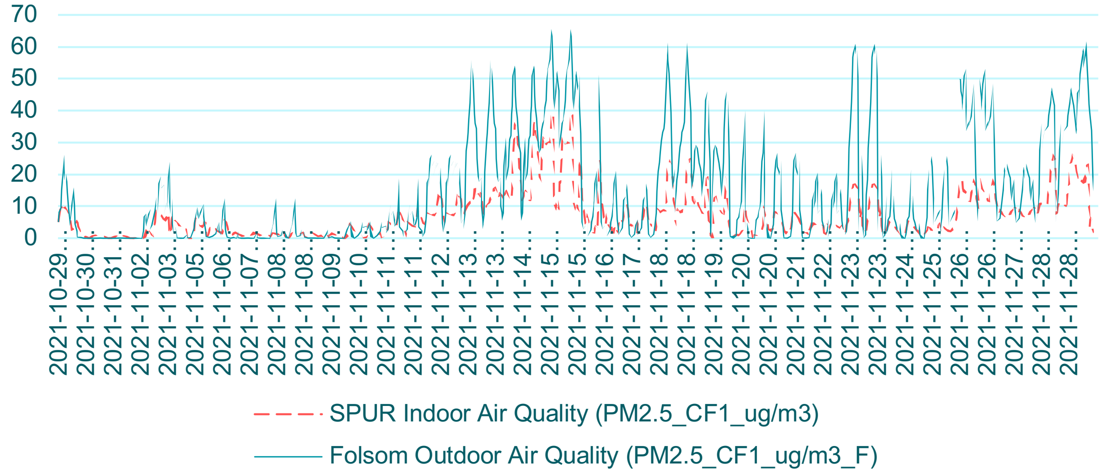


Figure 18. The correlation between indoor and outdoor air quality measured by the concentration of PM2.5 particles.

The US EPA's standard for outdoor PM 2.5 under the Clean Air Act is an average of 12.0 micrograms per cubic meter (µg/m3) over three years. If the air quality for November 2021 were extrapolated to a three-year period, SPUR's indoor air quality would meet this standard (7 ug/m3), but the neighborhood's outdoor air quality would not (15 ug/m3).

3.15 Energy management information systems

There is no Building Energy Management System. Central control was removed when the building was value-engineered in the design process. There are four thermostats, one for each floor. The ground floor thermostat also controls the basement temperature (where there generally are no people).

4. Energy conservation measures (short term)

Following are the energy conservation measures observed during the energy screening.

4.1 Lighting

Most light sources have been replaced with LED, especially in areas with high usage, which has resulted in savings. However, some light sources in the basement and in the staircases are still fluorescent and should be replaced with LED. About 40 fluorescent tubes in the staircase (which stay on 24/7) and 22 tubes in the basement can be replaced. With coil losses, the tubes should have consumption of about 42W each. New retrofits normally consume about 14-18W for the same lumen output. The cost is about $10 per tube, and the total savings potential is estimated to be 11,000-12,000 kWh/year (the basement lighting is motion controlled).

Furthermore, almost all lighting is manually operated. Lighting is also kept on in the windows in the staircase toward Mission Street during the day. The reason for this is that the window illumination and the emergency lighting are on the same circuit. Ideally, this should be changed so that each is on its own circuit. (See case from Emerging Technologies here: http://e3tnw.org/ItemDetail.aspx?id=108) In general, 20% savings should be expected with better lighting controls.

Installing PIR or motion sensors as well as daylight dampers could also optimize the use of electric lighting throughout the building (as mentioned above, the basement and some rooms already have motion sensors).

4.2 Ventilation

The ventilation damper on the RTU that controls the amount of fresh air supplied to the ventilation system is set manually. It was not possible to see the setting of the damper, but the amount of fresh air supplied to the ventilation system is estimated at a fixed 50%.

According to the California standard[3] for ventilation, the minimum fresh air rate requirement for office spaces is the higher of 5 cfm/person or 0.06 cfm/ft^2. Both amounts are significantly lower than the combined capacity of 12,450 cfm of the four units.

The team recommends installing an automated damper control for the fresh air inlet. This should control the positioning of the dampers and thereby the level of recirculation of air to the building. Some ways to control the fresh air rate include:

1. According to the number of people in the building. This can be done by using a digital people-count device on the main entrance of the building or on each floor.
2. Use of CO_2 sensors. These should be carefully located, so they only measure the background CO_2 level indoors and not CO_2 peaks resulting from people gathering in a small area (or reactivating the existing CO_2-sensors).
3. Connect the control of the ventilation system with a calendar system, so the flow is adjusted when meetings or gatherings are scheduled.

In addition to the automated control, it should also be possible to manually define the damper settings so that staff can set or program the fresh air intake according to the situation. For example, during the heat-up phase in the morning in wintertime, 100% circulation should be programmed to prevent unnecessary heat losses.

[3] https://up.codes/viewer/california/ca-mechanical-code-2016/chapter/4/ventilation-air#4

Depending on the setup and the use of the building, there could be a 50-75% reduction of fresh air volume, which would reduce the need to heat or cool outside air. The exact savings are hard to quantify as the actual fresh air rate is unknown, but if fresh air intake is currently ~50%, upwards of 40-60% savings should be expected on both heating and cooling. Currently, because of COVID-19, SPUR wants to maximize the flow of fresh air into the building to reduce the risk of infection; therefore this measure is proposed for a post-pandemic situation.

Besides energy savings, being able to control the fresh air intake has a range of other benefits:

- More efficient and quicker heating and cooling with less fresh air intake
- Improved capacity to meet high cooling demands at large gatherings
- Extended lifetime of air filters with fewer pollutants running through
- Better air quality as less polluted outside air is taken in
- During wildfires and times with high pollution, heating and cooling will still work

4.3 Temperature set points and tolerances

During the past few years, the ventilation units have been connected to a Google Nest thermostat system that controls the temperature in the building. The system operates with four control modes:

1. Off
2. Cooling
3. Heating
4. Fans only

The Nest thermostat has an upper and lower temperature. In summer it will cool when exceeding 74F and heat when dropping below 68F. The tolerance margins are 1F and cannot be changed directly.

The Nest controls only the temperature and not the air speed/air volume or the fan speed. The SPUR building manager operates the system according to a time schedule. The thermostats run from 9 a.m. to 9 p.m. At night, the system is shut off.

According to the building manager, the temperatures may be changed during the day by the occupants and then reset.

It is important to ensure that heating and cooling settings are not fighting each other when ambient temperatures are fluctuating around the set point.

Around 10-15% of heating and cooling consumption can be eliminated by introducing higher tolerances, as the climate in San Francisco fluctuates around the current set points most of the year.

4.4 Better control of RTU fan speeds

It may be possible for the Nest thermostat to incorporate fan speed control based on inputs from CO_2 sensors or other input signals. If VLT control is installed on the fans of the RTUs, it will be possible to regulate air flow by continuously monitoring the inside air quality. It is expected that the flow rate is currently quite high in this building (partly due to current COVID mitigation measures). In combination with the low recirculation rate, this induces a higher energy consumption than necessary.

The inlet flow rate should be determined by the need for heating and cooling and by the CO_2 level. Ideally, the Nest can incorporate both the fresh air damper and the fan speed controls based on individual signals and optimize the operation accordingly. If not, it's worth considering other control systems.

This control optimization is best upgraded in parallel with replacing the RTUs at the end of their service life. On top of the savings from optimizing the fresh air intake, we estimate that 30% of the electricity consumption from the fans could be eliminated.

4.5 Additional metering and Key Performance Indicators

Currently the building only has one main meter for gas and one for electricity. Additional meters should be installed for improved monitoring of energy consumption. There should be at least one meter per floor, and these meters should ideally feed into an interface where the consumption can be monitored continuously and in real time. This is done by establishing a number of energy Key Performance Indicators (KPIs) to monitor.

Examples of KPIs to be established (for each floor):

- Cfm of air supply (fan load)
- % fresh air intake (damper position)
- MBTU or cu ft. gas consumption per hour or per day
- kWh cooling consumption per hour or per day (compressor power)
- Electricity consumption ventilation unit
- Electricity consumption for each floor

It is more important to get a good data processing and monitoring tool (e.g., a cloud solution) than to spend money on expensive meters with high accuracy. There are some inexpensive systems available.

As an example, the company Remoni (www.remoni.com) offers solutions that should be sufficient for the purpose. A full set costs around $2,000 and includes a cloud solution to present data in real time, set up alarms and integrate foreign sensors and meters through MBUS signals.

The effect of this initiative is difficult to quantify, but being able to act on a better understanding of the building's energy use should yield around 5% improvement.

4.6 Improve efficiency of existing RTU units

The existing ventilators/fans use belt-driven motors. Energy is lost when transferred via the belts.

Figure 19. Belt-driven fan

Installing direct-driven motors on the ventilation units will reduce electricity consumption for driving the fans by 5-10%. The motors have an effect of 1-5 HP (0,75-3,75 kW) according to the design specifications.

Replacing the motors can also reduce electricity consumption. As the building is from 2009, the motors were most likely produced around the same time. In 2007 in the US the Energy Independence and Security Act raised the Minimum Energy Performance Standards (MEPS) to the equivalent of IE2 level[4]. Replacing the existing motors with motors complying with IE4 could bring a 5% increase in efficiency.

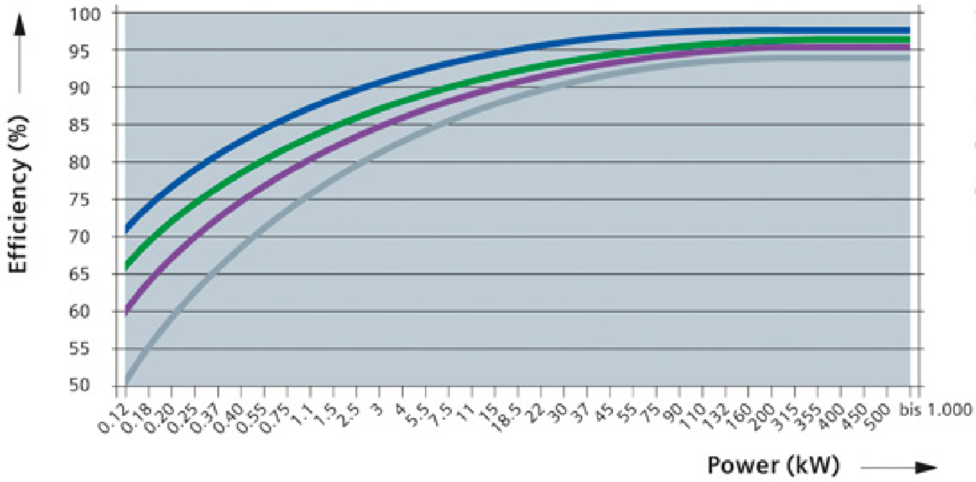


Figure 20. Efficiency of motors[5] *.*

Especially when replacing the RTUs, the TCO cost should be evaluated, and high efficiency motors and drives should be considered. Combined potential of the above is 10%.

4.7 Change filter type

The RTUs use MERV 13 dust filters, which can filtrate fresh air for pollen, PM2.5 particles and other pollutants. Filters generate a pressure loss in the ventilation system due to the initial resistance that the fans must overcome. Minimizing the pressure loss saves electricity. The MERV 13 filters currently used have a rated initial resistance of 0.34 w.c. or 82.20 pascal measured at a rated velocity of 500 cfm.

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[4] https://www.iec.ch/government-regulators/electric-motors

[5] https://ec.europa.eu/energy/sites/ener/files/documents/20141211_GuidelinesElectricMotors%20cover.pdf

Figure 21. Picture of the filters currently used in the RTUs. Rating is MERV 13, which is common for this need.

There are filters on the market with a lower pressure loss, such as filters from Best Air Pro[6]. As seen below, the pressure drop at 500 cfm is only about 0.05 w.c. at 500 cfm for a 4" filter.

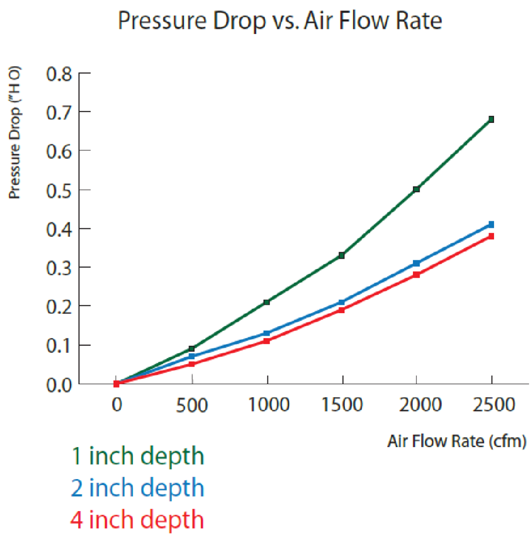

Figure 22. Pressure drop graph on Best Air Pro Filters.

Changing the filter supplier could lead to a 10% savings on the fans. At the same time, it may be possible to extend the service interval and thereby save maintenance costs.

4.8 Alarms from ventilation units not registered

Currently, when there is an alarm on the ventilation units, it can only be seen from inside the unit itself. Last year this resulted in a leak that was not detected until the maintenance crew came for a routine check. Our team recommends investigating whether the units can be set up to send alarms directly to the maintenance crew or the building manager so they can react quickly on future failures and thereby minimize the consequences in terms of both energy and repair costs.

[6] https://leeduser.buildinggreen.com/sites/default/files/credit_documentation/EQc5_MERV13%20filter.pdf

4.9 Replace water heaters with on-demand heaters

As described in section 6.1, hot water for the kitchens in the basement and on the second floor is supplied by 30-gallon electric water heaters. However, especially in periods of low use of hot water, the losses are high as the temperature of the water is kept at 120-140°F.

By replacing the water heaters with on-demand heaters like the ones for the restroom sinks, these losses could be avoided. Based on experience and the known activity in the building, we estimate that the yearly consumption for hot water preparation is about 6.000 kWh, of which the losses could be as high as 50%.

The dishwasher in the kitchen on the second floor (type Bosch) has its own water heater and should therefore not rely on a hot water supply, as is common in Europe.

4.10 Improve efficiency of exhaust fans from kitchens and restrooms

The roof exhaust fan extracting air from the restrooms runs continuously at full load. With a 560W motor, the yearly consumption is about 4.900 kWh.

The fan is not controlled, which means it always runs at full speed. This consumes an unnecessary amount of energy and causes a heat or cooling loss from the building.

Our team proposes replacing the fan with a more modern, energy-efficient type with variable speed drive. The fan could be controlled by a fixed pressure differential set point and automatic dampers installed at each exhaust point, controlled by motion sensors or similar. There could also be a timer control reducing the speed at night when the building is unoccupied.

The savings potential is estimated to be roughly 50% plus the reduced heating and cooling loss in the building, which has not been quantified.

4.11 Losses from doors and windows

The building is fitted with openable windows on each floor. However, using the windows counteracts the ventilation and the air-conditioning system, increases energy consumption and increases the amount of air particles in the building. It’s best to use the ventilation system, not the windows, for temperature regulation whenever possible.

Also, the entrance has a ½-inch gap between the two doors, where it does not seal properly.

Figure 23. Air gap at the entrance door

This allows a constant loss of heating or cooling, but it also affects the working environment at the front desk by creating a draft. It's possible the door could be improved to seal better or a small windbreak could be built at the entrance. Both suggestions are recommended but the savings potentials have not been quantified.

5. Decarbonization Measures

San Francisco's Climate Action Plan has an overall target of being "net-zero" by 2040. Below is a breakdown of the larger goals in the City Climate Action Plan.[7]

- Reduce GHG emissions 61% below 1990 levels by 2030
- Reach net-zero emissions by 2040, which is defined as reducing emissions 90% below 1990 levels and sequestering the rest in natural solutions like trees and green spaces
- Use 100% renewable electricity by 2025 and phase out all other fossil fuels
- Increase compact infill housing production near transit
- Reduce food waste and embrace plant-rich diets
- All buildings will be required to be electrified, with different timelines for different sectors:
    - By 2021, require zero onsite fossil fuel emissions from all new buildings by electrifying energy use
    - **By 2035, require zero onsite fossil fuel emissions from all large existing commercial buildings (this target applies to the SPUR Urban Center)**
    - By 2040, require zero onsite fossil fuel emissions from all buildings

For the purpose of this assessment, SPUR will regard 2035 as a presumed regulatory deadline for eliminating the use of fossil fuels in the Urban Center.

In the SPUR building, direct CO_2 emissions come from using gas in the RTU for heating. In 2019 the gas consumption was 456 therms, or 13.360 kWh, which is very low. The gas heaters are rated at 80% efficiency, which means that the useful heat was then 365 therms or about 10.600 kWh. However, with the current consumption pattern, actual heater efficiency is most likely lower than that.

Installing resistance electric heaters to replace the gas burners in the HVAC units would be an easy way to eliminate gas consumption and decarbonize the building, but this is not an option, because the California Energy Code does not allow replacement of the current gas heating system with electric heat resistance.[8] This aspect of the energy code is intended to prevent overreliance on energy-intensive electric resistance heaters, which have the potential to require costly upgrades to upstream electrical grid capacity, which in turn would drive up electrical rates.

Therefore the option to replace gas heaters with heat pumps is the only viable path to electrify the Urban Center. While occupying less capacity on the electrical installations and grid, a heat pump solution will also provide 3-4 times lower future heating costs. As a result, the profitability of a heat pump will occur sooner than with electric resistance heaters.

We are therefore looking at four scenarios here:

Business as Usual (BaU): No changes are made to the building; this scenario is used as a baseline.

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[7] https://sfenvironment.org/climateplan

[8] https://energycodeace.com/site/custom/public/reference-ace-2019/index.html#!Documents/section1404prescriptiverequirementsforspaceconditioningsystems.htm

Energy Conservation Measures (ECM): The energy-saving measures mentioned before are carried out. The scenario assumes that the electricity consumption can be reduced by about 45% and that the gas consumption/need for heat can be reduced by 50%**.** It also assumes that the RTUs are replaced in 2030 with gas units at a cost of $45,000.

Decarbonization now: The RTUs are replaced now with all-electric high-efficiency units with a minimum COP of 3 (the higher the COP the better the business case). The efficiency of the gas units is estimated to be 80%. The total costs are estimated to be about $50,000.

Decarbonization in 2034: The RTUs are replaced in 2034 to high-efficiency all-electric heat pump units with a minimum COP of 3 at a cost of $55,000.

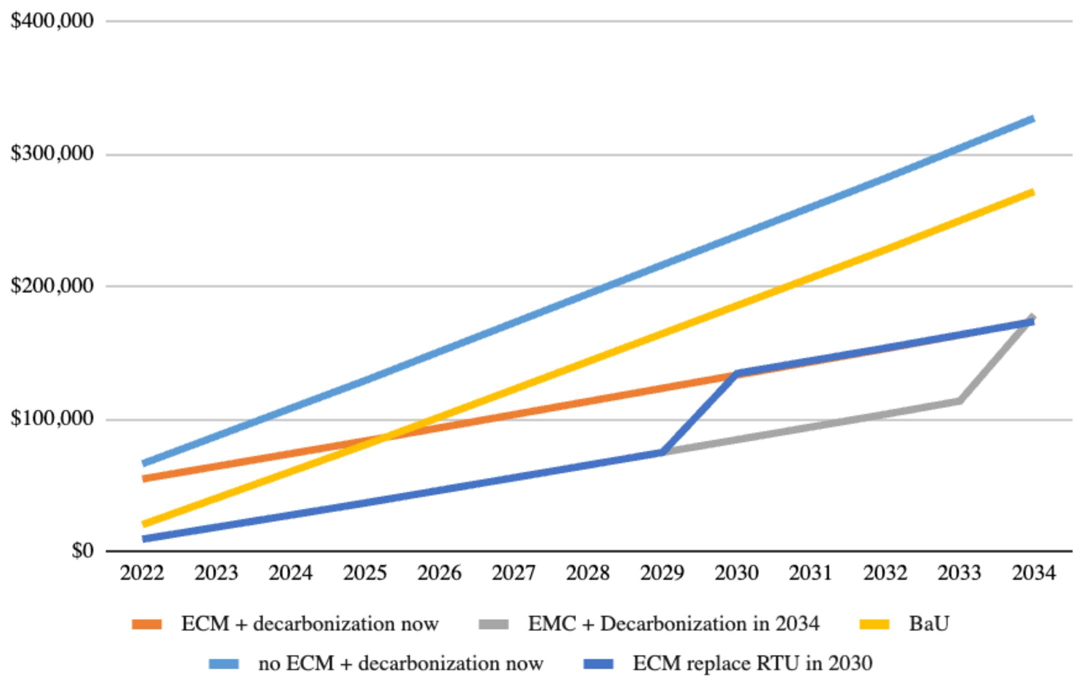

Figure 24. Accumulated savings when ECM are carried out.

As can be seen from the figure, there will be no savings without the ECM, whereas for the scenarios above with ECM the total accumulated savings in 2034 (whether the replacement takes place now or later) will be approximately $93,000.

The total costs (2022-2034) for the different scenarios can be seen in Figure 25 (the light blue is without ECM):

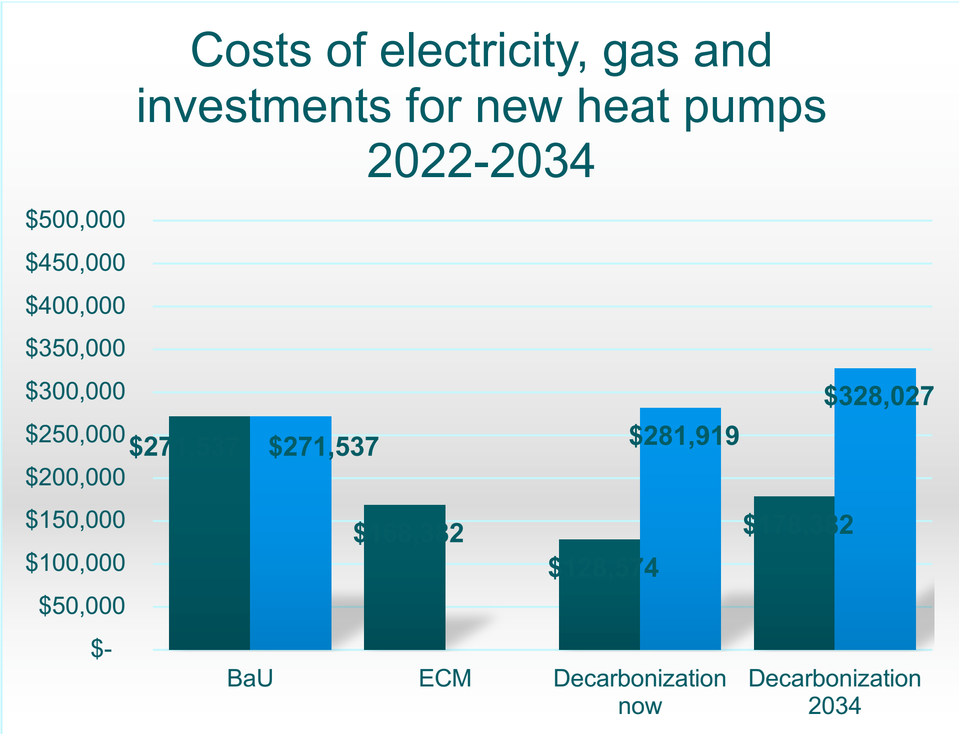

Figure 25. Total costs (2022-2034).

The conclusion from this analysis is that the energy savings would pay for the investment in decarbonization. An important factor is the remaining lifetime of the installations and how big the potential for other savings is.

For this building the scenario is not so different whether the RTUs are replaced now or in 2034, but for buildings where the remaining lifetime of the installations is less than 10 years, the team recommends converting now to heat pumps even though the requirement may not come into force until 2035.

We therefore recommend that SFE focus on identifying energy savings and encourage building owners with installations that must be replaced in the period from now to 2035 to change to heat pumps with high COP and high efficiency.

6. Conclusion and recommendations for decarbonization

Based on the current very low gas consumption and the current cost of gas, it is difficult to justify an immediate replacement of the current heating installation. Both from an economic and an environmental perspective it does not seem favorable to replace or retrofit the current RTUs with new heat pump solutions mid-life. Costs are expected to be in the range of $6,000-10,000 per unit, for a total of $24,000-40,000.

Instead, the team recommends evaluating and realizing all feasible energy conservation measures (ECMs), which will reduce the overall consumption by ~50%. These suggestions will bring down the consumption now but will also benefit any future installation.

As the end-of-life of the current ventilation system approaches, the cost-effectiveness of switching to heat pump-equipped RTUs will increase. Modern RTUs can be delivered with a reversing valve option that effectively enables both heating and cooling from the same unit (cooling circuit), rather than having two separate systems. This setup can typically be included for an additional $500-1,000 (ref. SFE).

In 2030-2032, when the current RTUs are expected to wear out, and with ECMs implemented, the savings potential is expected to be around $1,000 per year and rising, which makes this extra investment attractive for the Urban Center.

When it is time to replace the RTUs, consider the following to determine the best solution:

- Proper sizing – evaluate necessary size after ECMs and consider the future need for heat in all areas (it is likely that the existing systems are oversized).
- High SEER - seasonal energy efficiency rating: (>15 MBH/kWh)
- High-efficiency fans with direct drive and VLT
- Integrated economizer and/or heat recovery
- Automatic control of recirculation damper using CO_2 sensors
- Evaporative condensers vs. air cooled condensers (EC 20% more efficient but use water)
- Efficient control system that can be integrated with existing systems
- Easy to maintain and with alarm systems connected to control system
- Is heating and cooling necessary on all floors, including basement?
- Floor 1: Size HVAC with the knowledge that the floor is typically unconditioned and that it may not be necessary to condition the basement.

7. References

California Energy Commission https://www.energy.ca.gov/

Building Code California https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2019-building-energy-efficiency

San Francisco Climate Action Plan https://sfenvironment.org/climateplan

Danish Energy Agency https://ens.dk/en