BUILDING FEASIBILITY REPORT

FOR

NOYES CULTURAL ARTS CENTER

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EVANSTON, IL 60201

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Volume 2: Life Cycle Cost Analysis

VOLUME 2

EVANSTON – NOYES CULTURAL ARTS CENTER

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SUMMARY OF VOLUME 1 / INTRODUCTION TO VOLUME 2

Volume 1 of the Building Feasibility Report for the Noyes Cultural Arts Center, dated February 16, 2024 had some specific goals.

Among these goals were the following:

1. To perform a due diligence inspection of all the existing Mechanical, Electrical, Plumbing, Fire Protection and Technology systems installed at this site.

2. Preparation of a list of MEP/FP/Tech upgrades to these systems, necessary to bring the facility up to current standards and code requirements. While the primary focus of this project is an HVAC modernization, it would be short sighted to install new energy efficient state of the art HVAC systems and leave old outdated Electrical, Plumbing and Technology systems in place.

3. Based on the list of recommended upgrades construction cost estimates were done for the proposed work. For the HVAC systems, a number of new energy efficient systems were estimated for comparison in the phase 2 portion of the study.

The Construction Cost estimates prepared by Vistara Construction Services are the starting point of Volume 2 of this study. For each of the proposed HVAC options identified in Volume 1, a Life Cycle Cost Analysis will be performed to try to identify which system truly has the lowest overall cost and would represent the best value to the City of Evanston.

Volume 2 will present the results of the Life Cycle Analysis and how the recommended project (s) will put this facility on track to comply with the City of Evanston's Carbon Reduction goals by 2035.

The total of all of the construction work identified in the Volume 1 cost estimates were approximately $22 million. Budgetary constraints make a single project of this size very difficult for the City of Evanston to implement. Therefore, two additional subjects evaluated in Volume 2 are:

1. How to best phase the implementation of these projects, such that each phase of work is something that the city can budget and that the total of all of the recommended projects is implemented over the next 5 to 10 years.

2. How to maximize the use of available utility Company Grants, incentives, rebates.

   This would also include third party grants and Federal tax incentives for energy related projects.

   One of the challenges to securing incentives for this project is that it will be a multi-year, multi-phase project. Most of the incentive programs are funded on annual basis, so it may be difficult to get funding commitments if the project is not completed and operational in a given funding year.

2. SYSTEMS TO BE INCLUDED IN LIFE CYCLE COST ANALYSIS

Cyclone Engineering Group created a comprehensive energy model after surveying the site, meeting with the engineers and maintenance employees, evaluating the performance of existing systems, and reviewing calibration data. A number of solar arrays were also evaluated and cost data was provided by a third party. For the life cycle cost analysis, Vistara Construction Services provided initial mechanical system cost estimates, ASHRAE survey data of existing buildings' cost and maintenance lifespan was referenced for the maintenance data. A service life and maintenance cost database was also referenced. Based on discussions with the city of Evanston's utilities team and professional experience, maintenance costs were escalated based on various system types. For example VRF requires more maintenance than heat pump systems based on complexity. The city of Evanston maintenance employees also weighed in on their experiences with fatigue and maintenance upkeep. Assumptions for escalation rates and replacement values are included in the appendix section of this report.

Life cycle cost analysis looks at the initial cost of a system, the cost associated with operation, maintenance, and replacement of that system, any energy savings or operational costs directly attributed to that system, and any cash flows due to incentives, rebates, or grant monies. Service costs associated with electric energy are also included. Based on the escalation rate, future expenditures are accounted for and discounted to an equivalent present value of that money. There are positive and negative values that are added up over the system's life span to derive a single net present value for that system. Based on the fact that natural gas currently has a cheaper cost per BTU than electricity at an order of magnitude of 4, a system comparison has been provided for a party not interested in decarbonization or in net zero energy. The tables provided in the appendix reference an all electric building that has been brought up to current code ventilation rates and mechanical standards. This information has been provided to understand what the savings and cost would be for a public building of equivalent amenities since the current building does not have centralized cooling, even heat distribution, or centralized ventilation.

Energy Usage Intensity (EUI) is another important concept to understand in this context. It references the annual energy usage divided by the building's conditioned square footage. A lower EUI is generally understood to be reflective of a more energy efficient building.

Cases 1-2 are variations of the calibrated baseline. Case 1 reflects the current existing condition based on our collected site survey and utility bills provided by the city. Case 2 takes the existing calibrated model and converts it to an all electric system for an apples to apples baseline comparison with the all electric systems being proposed.

The life cycle cost analysis includes seven potential upgrade cases that can be combined together in various ways to improve the performance of the building and achieve varied funding opportunities. Envelope improvements including roof, glazing, and wall are included. LED lighting is an option as well. Additionally, four primary system types: air source heat pump (ASHP), air source variable refrigerant flow (AS-VRF), water source VRF, and water source heat pump. Electric ventilation with dedicated outdoor air systems (DOAS) and air handling units (AHU) are included in each of these system types. Lastly, compressor based ventilation systems are also included in the study because they help strengthen the case for incentives and net zero feasibility while bringing the project up to code minimum standards.

Table 2.1: Upgrade Case Descriptions

#	Name	Description
1	**Calibrated (Gas + Electric)**	Existing Condition - gas steam boilers + sporadic window AC units
2	**Calibrated Cooling + DOAS**	Existing Condition (updated to all electric) + full space conditioning + code Ventilation
3	**Roof + Window Upgrades**	Attic roof upgraded to R-30 insulation, New generation double pane windows; U=0.35; SHGC =0.35. New doors. Reduced infiltration
4	**Lighting**	All remaining spaces upgraded to LED lighting - 44,963 sf (Assumed 30% better than the 2018 IECC W/SF lighting requirement the 2018 IECC W/SF lighting requirement)
5	**ASHP + DOAS**	Air source heat pump terminal units, DOAS + AHUs with energy recovery wheel DOAS: full electric resistance backup. Terminal level: Electric resistance backup is assumed if outside air drops below -13F (Heat COP=3.25; Cooling COP =4)
6	**AS-VRF + DOAS**	Air source VRF terminal units, DOAS + AHUs with energy recovery wheel + DOAS: full electric resistance backup. Terminal level: Electric resistance backup is assumed if outside air drops below -13F (Heating COP= 3.5 Cooling COP = 4.5)
7	**WSHP + Geo + DOAS**	Water source heat pump terminal units, DOAS + AHUs with energy recovery wheel geo loop + An electric resistance boiler should be provided for supplemental and + backup (Heating COP= 3.5; Cooling COP = 6.8)
8	**WSVRF +Geo + DOAS**	Water source VRF terminal units, DOAS + AHUs with energy recovery wheel + geo loop + An electric resistance boiler should be provided for supplemental and backup (Heating COP= 4; Cooling COP = 7.5
9	**WSVRF + Geo + DOAS + Walls**	Water source VRF terminal units, DOAS + AHUs with energy recovery wheel + geo loop + An electric resistance boiler should be provided for supplemental and backup (Heating COP= 4; Cooling COP = 7.5) with R-20 Wall Insulation

Water heating was not considered as a potential system upgrade because of its relatively low impact on operational energy usage. If upgrading water heating equipment is of interest, heat pumps are the best available option relative to electric resistance, but the change won't translate into a meaningful EUI reduction.

SYSTEM TRADEOFFS

Based on the floor to floor height of the building, all systems would have exposed terminal units which allows for easy maintenance access and distribution within the spaces. All systems are very efficient with trade-offs related to their spacing allocation, lifespan, volume of refrigerant and first cost. Systems that have a condenser loop have greater adaptability over time. Geothermal is likely to match the life of the building with minimal maintenance.

Case 5: AS-HP + Geo Space allowance for air source heat pumps is a lower footprint within the building but there will be refrigerant lines connecting each unit to an outdoor unit. Depending on configuration, this limitation will impact the system's ability to perform simultaneous heating and cooling. The distance between the heat pump and condenser units has a limit.

Case 6: AS-VRF + Geo has a low indoor footprint but significantly more refrigerant. Additional refrigerant allows multiple indoor units to share an outdoor condenser unit. The VRF system maintains the ability to heat and cool while sharing the outdoor condenser unit. This factor provides the ability for heat recovery to occur between spaces for added efficiency. However, the added mechanical complexity and refrigerant is a consideration. Refrigerant leaks are difficult to find and pose a life safety risk. They also have the potential to become outdated as lower ozone depleting refrigerants become available. With the added mechanical complexity comes a lower life span.

Case 7: WS-HP + DOAS + Geo An efficiency gain is observed by converting to water. Maintenance is centralized for the central plant and geo-exchange loop. Using water for heat distribution in the building reduces both the amount of refrigerant lines and refrigerant in the building. There is a greater potential for replacement with next generation technology and refrigerants as end of life approaches for the terminal heat pumps. The geo-exchange system has a long life span that should match the life span of the building. Geothermal enables a free exchange of heat with the ground. The system also enables a transfer of heating and cooling within the spaces of the building.

Case 8: WS-VRF + DOAS + Geo This system has the greatest opportunity to transfer heat within the building and the greatest mechanical efficiency within the terminal unit compressors. However, with this system comes a greater mechanical complexity and risk for mechanical issues. Introducing the water source condenser loop coupled with ground source heat exchange helps consolidate the amount of refrigerant that goes into the building while centralizing some of the potential mechanical issues. Rather than having outdoor condenser units, the system has indoor branch selectors that connect multiple indoor terminal units to the condenser loop. Bringing the equipment indoors extends the lifespan of the equipment and reduces the visual footprint of the system. However, this space needs to be accounted for within the building.

In the table below, the system options are ranked on their various benefits and drawbacks in efficiency, cost, and maintenance. A score of 1 reflects the most desirable outcome while a score of 4 reflects the least desirable outcome. Note that the composite rankings reflect equal weight for all factors and do not necessarily represent Evanston priorities.

TABLE 2.2: SYSTEM COMPARISON

	5: ASHP + DOAS	6: AS-VRF + DOAS	7: WSHP + Geo + DOAS	8: WSVRF + Geo + DOAS
Highest Efficiency	4	3	2	1
"Free Heating" / Heat Recovery	4	3	2	1
Lowest Operational Energy Usage	4	3	2	1
Lowest Refrigerant Volume	2	4	1	3
Lowest upfront Cost	1	2	3	4
Lowest Maintenance Cost	2	4	1	3
Longest Life Span	2	4	1	3
Mechanical Simplicity	1	3	2	4
Composite	**20**	**26**	**14**	**20**

3. RESULTS OF LIFE CYCLE COST ANALYSIS

Net present value is a recognized basis for financially comparing different upgrading cases. These results also include a comparison of incremental EUI decreases relative to the calculated net present value. Strategies are bundled together in the different cases to demonstrate the cascading impact of upgrades. However, strategies can also be considered independently as they are shown in Appendix 2.2. The life cycle analysis accounts for annual maintenance, repair, replacement, and energy costs that combine to generate the net present value.

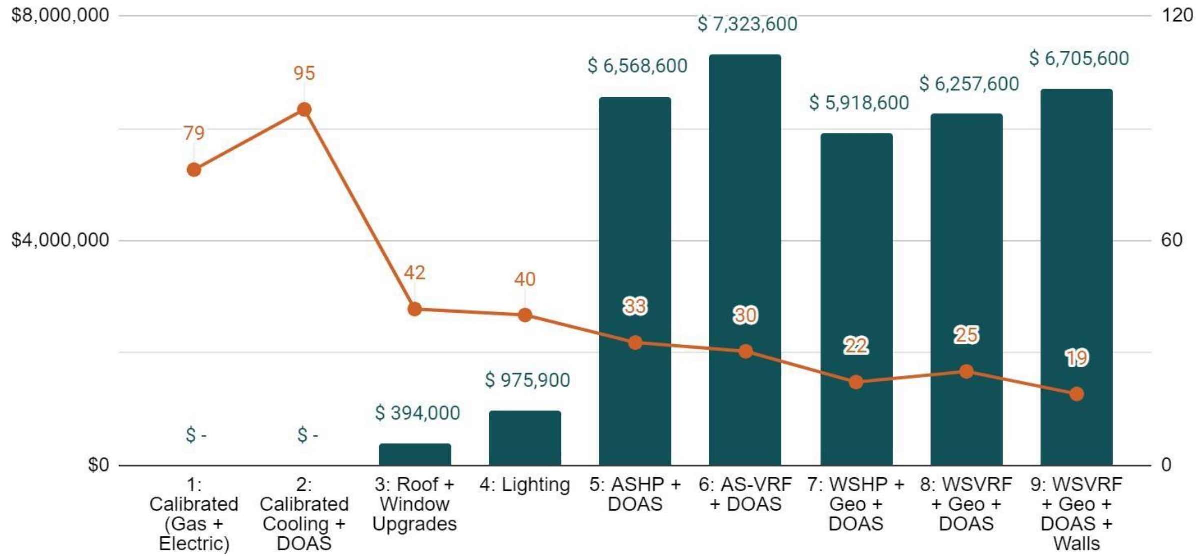
Upgrading the roof insulation and installing double pane windows, performing general air sealing (Case 3), and installing LED lighting would bring the project from an EUI of 95 to 40 with a cumulative life cycle analysis of $976,000. The most impactful upgrades here are upgrading roof and air sealing.

The largest reduction in EUI here, 15, is through upgrading the roof insulation to R-30, which has a life cycle cost of $34,000. LED Lighting is the most expensive upgrade at $976,000. Window upgrades and air sealing is expected to cost $394,000. Adding wall insulation (Case 9) has a life cycle cost of $450,000 and an EUI reduction of 6.

Adding DOAS would put the water source VRF (Case 8) and water source heat pump (Case 7) in the net zero territory with EUIs 25 and below. Therefore, the $2 million Illinois Clean Energy Community Foundation grant has been applied to their life cycle cost assessments. The WSVRF option (8) would have a life cycle cost of $6.2 million and an EUI of 25 while the WSHP option (7) would have a life cycle cost of $5.9 million and an EUI of 22.

As demonstrated by this data, envelope improvements have the most impact when coupled together. Roof insulation upgrades have the biggest incremental energy savings and have the greatest impact relative to cost. Ground source systems achieve the best overall system efficiencies. When coupled with compatible compressor-based heating for ventilation systems, ground source systems achieve lowest possible site energy use. If on-site solar generation is feasible to achieve net zero, ground source systems with compressor-based ventilation systems are the best option and would make the project eligible for ICECF Net Zero Energy grant money application (Reference Section 5 of this report).

Figure 3.1: Upgrade Case vs. Net Present Value and EUI



4. RECOMMENDED NEW SYSTEMS BASED ON THE LIFE COST ANALYSIS

VRF systems (Cases 6, 8, and 9) are not the preference of the city of Evanston maintenance employees and the systems have relatively high upfront, maintenance, and replacement costs. Additionally, the maintenance team is concerned about the quantity of components requiring maintenance, the accessibility of those components, complexity involved in repairing large refrigerant systems, and the changing climate around refrigerant evolution in the coming years.

If the project team decides the goal is to pursue one of the highest performance cases, the water source heat pump with geothermal and DOAS (Case 7) would be the most cost-effective way to get to a low EUI of 25. This system would achieve the electrification requirement and would position the project for being net zero or net zero ready in the future. The system is also reportedly lower maintenance, has a longer life span, and has lower operational energy usage compared to air source heat pumps. Adding wall insulation to this system would further reduce the EUI and size of the solar array needed to reach net zero.

However, if the project team decides to pursue a less expensive route, the air source heat pump with DOAS (Case 5) is the second-best option. The criteria relating to the relative benefits of heat pumps' performance, cost, longevity, and operational energy usage are still realized at a lower life cycle cost.

5. POSSIBLE GRANTS, INCENTIVES, AND REBATES AVAILABLE

Through research and analysis, several funding opportunities were investigated. ComEd incentives will be worthwhile and attainable for higher performing cases. The 179D tax credit is lucrative but will require forming a partnership with a for profit entity. The Clean Energy Investment Tax Credit will be payable directly to Noyes and has been improved by the Inflation Reduction Act. The Historic Preservation Tax Credit would also need to be passed onto a private partner and would require meeting unique eligibility criteria. The Net Zero Energy Building Grant from ICECF is no longer available.

COMED: Comed incentives are the least lucrative and among the most difficult to achieve due to strict performance criteria. They reference a gas and electric baseline, so the incentive only applies once the highest possible performance is achieved. Potential incentives range from $7,000-16,000 based on the HVAC cases that were tested out. Savings reference a reduction in annual utility cost compared to the code referenced baseline.

179D: The 179D Tax incentive is a more attainable funding opportunity and has a potential for $103,000. This incentive is granted on the basis of energy and power cost percentage reductions/savings in reference to the ASHRAE 90.1-2007 baseline. An important criteria to note here is that the building must be brought up to code minimum ventilation rates in order to receive the incentive. Since the project is a government entity, the incentive could be passed along to other project team members like the architect. Language relating to 179D has changed with the introduction of the Inflation Reduction Act, but the language clarifying the changes is still being fine-tuned. How these changes apply to Noyes isn't yet clear. Changes include the change of the applicable baseline but also shows an increase in the money available. The calculations reflect 179D incentives prior to the changes made in the Inflation Reduction Act.

Inflation Reduction Act: The Inflation Reduction Act also enables government entities to take advantage of the Clean Energy Investment Tax Credit. Now, the credit would be directly paid to government entities because of their tax exemptions. Up to 30% of the costs of clean energy property improvements can be compensated via this credit. Energy storage systems, PV, geothermal, and dual heating and cooling systems are examples of upgrades that would fall under this credit.

Historic Preservation Tax Credit: A Historic Renovation Tax Credit is feasible for the project to achieve but would require establishing a partnership with a for-profit business investor and how much money is available to the project is unclear. Additionally, the project would need to become a National Historic Preservation site, a process that takes about a year to complete. However, the tax credit could be applied for simultaneously. Eligibility for the tax credit is based on exceeding a substantial rehabilitation test equation that follows

Cost of Substantial Renovation > Purchase Price of Property - Cost of Land at Time of Purchase - Depreciation + Cost of Capital Improvements

The cost of substantial renovation only includes upgrades done to the building itself so it would exclude the cost of solar. For the federal tax credit, 20% of costs could be recouped by the tax credit with no cap. The state tax credit is more complex and competitive to attain. Online submissions must be completed immediately upon the application's release and the credit currently expires at the end of the year. Its renewal is not yet certain. MIA architect Erica Ruggiero offered to connect the project team with financial advisers if pursuing either historical preservation credit is of interest.

ICECF Net Zero Energy Building: Illinois Clean Energy Community Foundation (ICECF) had a Net Zero Energy Building Grant of up to $2 million or 80% of the project's renovation costs, but it is no longer accepting applications and its future is unclear.

Table 5.1: Upgrade Cases vs. EUI and Grant Money

Case	Utility Cost	Annual kBtu	EUI (kBtu/sf)	GHG Emissions	Approx. Net Zero PV Array Size (kW)	Case 2 Cost % Savings	179D % Cost Savings	179D % Energy Savings	179 D Incentive
1	$ 22,585	4,326,435	79	284	1060	-	-	-	-
2	$ 139,376	5,207,750	95	686	1270	-	-	-	-
3	$ 61,241	2,288,264	42	301	560	35%	n/a	n/a	n/a
4	$ 58,888	2,200,333	40	290	540	38%	n/a	n/a	n/a
5	$ 48,115	1,797,810	33	237	440	49%	68%	68%	$ 103,009
6	$ 44,696	1,670,050	30	220	410	53%	71%	71%	$ 103,009
7	$ 32,669	1,220,652	22	161	300	65%	78%	78%	$ 103,009
8	$ 36,822	1,375,856	25	181	340	61%	76%	76%	$ 103,009
9	$ 28,025	1,047,160	19	138	260	70%	82%	82%	$ 103,009

6. POSSIBLE – PHASING SCENARIOS

The total of the recommended work items to be done at the Noyes Cultural Arts Center, in March 2023 dollars is approximately $22 million.

If the primary goal is to have this project implemented by 2035 when the City of Evanston's carbon reduction goals kick in, then one possible scenario would be to break the total project into 5 approximately equal cost phases. Each phase would be approximately $5 million.

We assume that the first phase would need some extra time to start implementation. The project needs to formally be approved, a funding plan needs to be developed and the design work needs to be started.

The first phase of the project might start construction in 2025, and subsequent phases every 2 years thereafter 2027, 2029, 2031 and 2033. We would recommend the following pieces be done in each phase:

2025 Phase 1:	Major infrastructure New electric service, geothermal field, hydronic distribution
2027, Phase 2:	Renovation of Basement Façade upgrades, windows, sealing, insulation Install DOAs unit 1 in basement.
2029, Phase 3 :	Renovation of 1st floor
2031 Phase 4:	Renovation of 2nd floor & Attic Install DOAs unit 2 in attic.
2033, Phase 5:	Final decommissioning and removal of old systems, boiler, etc. Installation of PV Systems sized to achieve net zero energy.

As you can see for the 10-year period from 2025 through 2035 the building will be disrupted due to the construction activities going on.

Further, throughout this transition period, two HVAC systems will be operating to serve the building, the existing steam heating system and the new water sourced heat pump units. The true energy savings and utility cost reductions will not be achieved until the last phase of construction is completed.

It may be advantageous to reduce the number of construction phases to minimize the disruption. Ideally, if the building could be vacated and the construction done in one or two phases, that would be the least disruptive.

7. COST CONSIDERATIONS

The total cost of all of the recommended upgrades for the Noyes Cultural Arts Center is $22 million, based on 2022/2023 costs, as estimated by Vistara Construction Services.

Knowing that this project will be phased over a number of years brings to the forefront a more complex subject of escalation/inflation. The organization FRED (Federal Reserve Economic Data) tracks U.S.U.S. economic indices over time. One item they track is the Producer Price Index, and they do it by industry. For the construction category of new office building construction, they have indicated an increase in the Production Price Index of 34.646 points from January of 2022 (173.184) to January of 2023 (207.830). This is a 20% rate of inflation over the past year.

Currently, the 2023 rate of inflation is approximately 5.8%.

While we would expect that this rate will settle down as time goes on, we cannot guarantee it.

For these reasons, we are choosing to include a 5% per year inflation rate over the course of the implementation of the project.

We are anticipating that the project would be done in 5 phases of approximately project equal current construction cost. For the $22 million total cost, that would be $4.4 million per project phase.

We have anticipated the following construction schedule:

2023 study completed, estimated construction cost	$22 million
2024	
2025 Phase 1 $4.4 million + 2 yrs escalation =	$4,851,000.00
2026	
2027 Phase 2 $4.4 million + 4 yrs escalation =	$5,348,228.00
2028	
2029 Phase 3 $4.4 million + 6 yrs escalation =	$5,896,420.00
2030	
2031 Phase 4 $4.4million + 8 yrs escalation=	$6,500,804.00
2032	
2033 Phase 5 $4.4 million + 10 yrs escalation =	$7,167,136.00
2034	
2035 Project completion to meet 2035 CARP goals.	

This would represent an approximate $30 million total construction cost.

While the above scenario represents a more affordable implementation plan, it does represent a fairly disruptive schedule for the occupants of the building. They would have to put up with 10 years of construction, temporary facilities, cut overs, etc.

The least disruptive scenario, if it were possible would be to totally vacate the building moving all of the current tenants, programs, etc. to temporary facilities and do all of the construction as a single project. This would eliminate the 5 construction phases each taking about a year and replace it with one construction phase taking approximate 2 years.

Another benefit of doing a single project is in the pursuit of incentives, grants, rebate and tax deductions. Most of these programs are funded on a yearly basis and some are possibly expiring in the next few years. So, assumptions made as to what funds might be available for this project might be gone by the time the phases are implement. Also, most all of these project funds are only paid out upon project completion, So, Evanston would not be able to recapture these amounts for years to come.

8. ACHIEVING EVANSTON'S CARBON REDUCTION GOALS

The Noyes Cultural Arts Center can reduce carbon emissions through a variety of means including upgrading the envelope, lighting, and HVAC systems to reduce operational carbon associated with annual energy usage. These topics are well covered in Section 3. Operational carbon usage can also be reduced through generating renewable energy for the center to use. A detailed study of this inquiry is outlined below.

While carbon reduction is achieved by reducing energy consumption, the effort could be furthered through the addition of a sizable solar array. Several array options were investigated for feasibility (reference appendix 2.3). One on-site parking, two remote parking, and two roof cases were tested out. If achieving net zero energy usage is an added goal of this project, a combination of arrays from 260-660 kW would be required. A case worth bringing up here is the Sun Style Roof option, which has an unknown estimated cost at this time but could be around 150 kW and would account for a significant portion of the space needed to produce solar energy. Implementing an offsite parking solar array has a large generation potential but also has the added cost of running conduit from the parking lot to the site.

Energy consumption estimates convey that around 400 kW of solar would put the project in net zero energy territory if the team opts for the air source VRF and DOAS combination (Case 6). This size array would offset around 60% of carbon emissions annually. This result is to be expected. The mismatch in net zero energy versus net zero carbon emissions is due to the utility grid being cleaner during the day than at night, so the highest emissions occur during times when renewable energy production from solar is not available. Opting for a higher performing HVAC case and investing in other energy saving strategies will bring down the size of the solar array needed to meet a net zero energy goal. The carbon emissions offset metric will decrease proportionally to the size of the array.

The Noyes Cultural Arts Center is expected to use the most energy from 8 am to 5 pm during hours of peak occupancy. Winter heating loads are significantly higher than summer cooling loads. Additionally, lighting loads are slightly lower in the summer due to the availability of more daylight. Energy production peaks in the summer months and decreases during the winter due to the availability of daylight. The array has both a longer amount of time and better visibility of the sun during the summer months.

Carbon emissions were modeled assuming a solar array size of 390 kW and an annual energy consumption 400 MWh/year (case 8). In this scenario, peak carbon emissions occur November - February from 4-6 pm when solar is unavailable but the Noyes Center is at peak occupancy and energy usage. During this window, carbon emissions are roughly 40 kg/hour, which, for reference, is about the weight of a baby calf. At peak energy production, the Noyes Center emits negative carbon emissions of -20 kg/hour, mostly during the months of July and August from 11 am to 2 pm. In this time frame, the buildings solar array generates more energy than the building consumes, so energy is ultimately sent back to the utility grid.

9. CONCLUSION

There is definitely a path to achieve the City of Evanston's goal of having all city facilities carbon neutral by 2035 at the Noyes Cultural Arts Center. It is also feasible to achieve the added goal of having a net zero energy facility.

It will be expensive as the primary source of heating for the building is currently a gas fired steam boiler plant. This will be replaced by a system of heat pumps (air or water sourced). A shift away from gas towards electricity, will because a need to increase the capacity of the incoming electric service. The electrical distribution throughout the building is old and needs replacement.

In addition to the primary HVAC renovations a large number of other systems throughout the facility need attention. Many systems do not meet current code requirements and energy consumption standards. It is definitely the right thing to do, to renovate all systems in the facility that need it, so that you have a building with new modern systems that will last well into the future.

The total project costs, upgrading all systems as described herein is approximately $22 million based on current 2023 local construction costs. Phasing of the project could ease budgetary constraints. However, it then needs to be understood that this adds this adds costs overall. The deferred phases will cost more due to inflation, escalation, and complexity, and complexity. Plus, there will be some inefficiencies in having to operate multiple systems simultaneously during the years of phased construction.

We have recommended taking the total project and dividing it into 5 phases each at a cost of approximately $5 million. The first phase would start in 2025 and the subsequent 4 phases, every two years thereafter. This would complete all of the work at the Noyes Cultural Arts Center by the end of 2034. Ahead of the 2035 carbon neutrality goal.

2.1 GLOSSARY

AHU	Air Handling Unit(s)	**EUI**	Energy Usage Intensity
AS or WS HP	Air Source or Water Source Heat Pump	**Geo**	Geothermal
AS or WS VRF	Air Source or Water Source Variable Refrigerant Flow	**kg**	Kilogram
BTU	British Thermal Unit	**kW**	Kilowatt
COP	Coefficient of Performance	**MWh**	Megawatt hour
DOAS	Dedicated Outdoor Air System		

2.2 SYSTEM NARRATIVES

HVAC Case 5: DOAS, ASHPs, and AHUs Initial Capital Cost: $2,351,700 (HVAC only)

We are proposing to eliminate the current boiler, piping, and radiators. Install electric storage or instantaneous water heater for domestic hot water usage.

For all spaces except the three theaters, DOAS and air source heat pumps (ASHPs) are proposed. DOAS is modeled with an energy recovery wheel (65% latent and sensible heat effectiveness) with outdoor air of 9,500 CFM. DOAS has air source heat pump heating with HSPF of 8.5 and full electric resistance backup. It also has DX cooling with a compressor COP of 4.5. The unit should have VFD on the fan and DCV control. If there is no product that can handle 9500 CFM OA with heat pump heating. Two DOAS units can be an alternative.

Each room is served by an air source heat pump (ASHP) with a heating COP of 3.25 rated at 47 F and a cooling COP of 4. Electric resistance backup is provided when outside air drops below 35F. Compressors are shut off at 2F then electric resistance should provide the full capacity of heating. The ASHPs have EC motors that are capable of at least two-speed operation.

For the three theaters, heat pump condensing units and AHUs are proposed. The AHUs should have air source heat pump heating with HSPF of 8.5 and full electric resistance backup. It also has DX cooling with a compressor COP of 4.5. The supply fans should have at least two speed controls.

HVAC Case 6: DOAS, ASVRFs, and AHUs Initial Capital Cost: $2,818,900 (HVAC only)

We are proposing to eliminate the current boiler, piping, and radiators. Install electric storage or instantaneous water heater for domestic hot water usage.

For all spaces except the three theaters, DOAS and air source variable refrigerant flow units (ASVRFs) are proposed. DOAS is modeled with an energy recovery wheel (65% latent and sensible heat effectiveness) with outdoor air of 9,500 CFM. DOAS has air source heat pump heating with HSPF of 8.5 and full electric resistance backup. It also has DX cooling with a compressor COP of 4.5. The unit should have VFD on the fan and DCV control. If there is no product that can handle 9500 CFM OA with heat pump heating. Two DOAS units can be an alternative.

Each room is served by an air source variable refrigerant unit (ASVRF) with a heating COP of 3.5 rated at 47 F and a cooling COP of 4.5. The VRFs should have full capacity at -13F. Electric resistance backup is assumed if outside air drops below -13F. The ASVRFs should have EC motors that are capable of at least two-speed operation.

For the three theaters, heat pump condensing units and AHUs are proposed. The AHUs should have air source heat pump heating with HSPF of 8.5 and full electric resistance backup. It also has DX cooling with a compressor COP of 4.5. The supply fans should have at least two speed controls.

HVAC Case 7: DOAS, WSHPs, AHUs, and Geo-Exchange

Initial Capital Cost: $3,418,700 (HVAC only)

We are proposing to eliminate the radiators and install electric storage or instantaneous water heaters for domestic hot water usage.

A 200 Ton geo exchange loop is proposed to provide condenser water to both heating and cooling applications. An electric resistance boiler should be provided for supplemental and backup.

For all spaces except the three theaters, DOAS and water source heat pumps (WSHPs) are proposed. DOAS is modeled with an energy recovery wheel (65% latent and sensible heat effectiveness) with outdoor air of 9,500 CFM. DOAS has water source heat pump heating with COP of 3.7 and water-cooled DX cooling with a compressor COP of 7. The unit should have VFD on the fan and DCV control. If there is no product that can handle 9500 CFM OA with heat pump heating. Two DOAS units can be an alternative.

Each room is served by water source heat pumps (WSHPs) with a heating COP of 3.5 and a cooling COP of 6.8. The WSHPs should have EC motors that are capable of at least two-speed operation.

For the three theaters, AHUs are proposed. The AHUs should water source heat pump heating with COP of 3.7 and water-cooled DX cooling with a compressor COP of 7. The supply fans should have at least two speed controls.

DOAS, WSHPs, and AHUs should all connect to the geo-exchange loop.

HVAC Case 8: DOAS, WSVRFs, AHUs, and Geo-Exchange

Initial Capital Cost: $3,652,300 (HVAC only)

We are proposing to eliminate the radiators and install electric storage or instantaneous water heaters for domestic hot water usage.

A 200 Ton geo exchange loop is proposed to provide condenser water to both heating and cooling applications. An electric resistance boiler should be provided for supplemental and backup.

For all spaces except the three theaters, DOAS and water source variable refrigerant flow system (WSVRFs) are proposed. DOAS is modeled with an energy recovery wheel (65% latent and sensible heat effectiveness) with outdoor air of 9,500 CFM. DOAS has water source heat pump heating with COP of 3.7 and water-cooled DX cooling with a compressor COP of 7. The unit should have VFD on the fan and DCV control. If there is no product that can handle 9500 CFM OA with heat pump heating. Two DOAS units can be an alternative.

Each room is served by a water source variable refrigerant unit (WSVRF) with a heating COP of 4 and a cooling COP of 7.5. The WSVRFs should have EC motors that are capable of at least two-speed operation.

For the three theaters, AHUs are proposed. The AHUs should water source heat pump heating with COP of 3.7 and water-cooled DX cooling with a compressor COP of 7. The supply fans should have at least two speed controls.

DOAS, WSVRFs, and AHUs should all connect to the geo-exchange loop.

APPENDIX