THE FUTURE OF ARENA DESIGN:

DESIGNING A PATH TOWARDS ZERO NET ENERGY

DENVER GREEN TEAM INNOVATION INCUBATOR RESEARCH | FALL 2019

INDEX:

THE TEAM:

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For nearly a quarter of a century, Perkins and Will has been at the vanguard of the sustainability movement. Passionate about designing places where human life can thrive and entire ecosystems flourish, we've developed a reputation for challenging the status quo. For blazing trails into uncharted territory.

Today, we're still at it. We're redefining sustainability as one of several interconnected parts to a greater, more meaningful whole. It's a philosophy we call Living Design. By seamlessly incorporating sustainability, resilience, regeneration, inclusion, and well-being into each of our projects, we can help sustain life on earth—today, tomorrow, and beyond.

Our research is inspired by our practice. Our practice is informed by our research. We believe research holds the key to greater project performance. Our researchers and designers work in partnership from project start to completion. Together, they assess our clients' goals and innovate ways to achieve them. We've always believed collaboration is the key to scientific advancement. Through our innovation incubator and nonprofit AREA Research, we partner with colleagues in design and academia to discover and apply new knowledge across the design profession.

walter p moore

Dirk Kestner
Principal
Director of Sustainable Design

Erin Kueht
Principal

Walter P Moore is an international company of engineers, architects, innovators, and creative people who solve some of the world's most complex structural, technological, and infrastructure challenges. Providing structural, diagnostics, civil, traffic, parking, transportation, enclosure, technology consulting, and construction engineering services, we design solutions that are cost- and resource-efficient, forward-thinking, and help support and shape communities worldwide.

Walter P Moore understands that creating a sustainable built environment is one of the foremost challenges of our generation. We embrace our responsibility and welcome the challenge to develop integrated solutions for high-performance buildings and infrastructure that use our resources responsibly. We welcome an active role in the design process and while we are prepared to provide solutions within the bounds of current rating systems, we prefer the challenge of transformation and addressing those beyond the current checklist. Our teams focus to educate ourselves, our clients, and our peers on innovative and elegant solutions that reduce our environmental impact. Our goal is to practice sustainable design in a way that benefits our community, our environment, our clients, and our business.

me engineers

Jamy Bacchus
Senior Associate

At ME Engineers, we design environments to live, work, and perform in, led by technical expertise, inspired by genuine innovation, and propelled by a persistence to find a better way. Headquartered in Denver, Colorado, we are a full service mechanical, electrical, plumbing, lighting, and telecommunications engineering firm with offices throughout the US and across the globe. In over 35 years we have delivered some of the world's most recognized buildings across North America and the world. Our clients include developers, end users, project managers, architects, facility managers, and government agencies.

Our projects range from new construction to renovations and energy retrofits. Our work includes multifamily residential developments, commercial offices, educational buildings and campus facilities, government facilities, professional sports projects, collegiate sports projects, justice centers, health sciences laboratories, healthcare facilities, and nearly all other commercial or institutional building types. We bring our national experience to each project, and we believe this project can benefit accordingly.

With well over 250 projects receiving green building certifications, we have defined the advancement of sustainability in buildings. We commit to sustainability as a foundation for all our design processes. We accelerate the adoption of best practices, assist design teams in achieving complete building integration, and encourage eco-visioning early in the design stage to make sustainability affordable and

INTEGRAL GROUP

Tom Hootman
Associate Principal

Integral Group provides a full range of deep green building systems design and energy analysis services with a staff regarded as innovative leaders in their fields. Our integrated services including MEP engineering, energy modeling, analysis and auditing, sustainability consulting, lighting and daylighting design, technology design, and commissioning.

Our design approach differs dramatically from traditional MEP engineering firms - unlike our competitors, we focus exclusively on highly energy efficient and sustainable design projects. An innovative leader in building MEP systems design, we were the first US MEP firm to achieve 9 LEED Platinum buildings and currently have over 55 LEED Platinum Certified projects, as well as more than 100 Zero Net Energy projects completed or in design (with 5 Certified by ILFI), and 9 Living Building Challenge projects in design. The barriers we encounter to sustainable strategies in our projects are frequently those of actual or perceived cost premium for additional "green features." Our experience in many projects has taught us to find a way to break through these cost barriers and make sustainable buildings affordable.

ABSTRACT:

Arenas are large, expensive, non-continuously-used, energy-intensive luxuries. To date, there have been no arenas built that meet any definition of “zero net energy building.” How do we move beyond the AIA 2030 Challenge, and design ecologically sustainable Net Zero energy Arenas? Perkins and Will is committed to the AIA 2030 Challenge, meaning our buildings need to reduce their fossil fuel energy consumption by 90% in 2025, and become completely carbon neutral by 2030. Many jurisdictions have adopted Leadership in Energy Efficient Design (LEED) certification or other recognized rating systems, and energy codes become more restrictive with each new iteration. While Perkins and Will has generally made great progress towards meeting the 2030 goals, strategies for achieving the necessary reductions depend to some degree on the building typology. Within the Sports, Recreation, and Entertainment (SRE) segment of the firm portfolio, arenas represent a particularly challenging problem compared to other SRE projects due to their size, enclosed volume, program, and typical usage patterns.

While this initial research seeks to develop strategies that ultimately lower the operational energy in arenas, we will also investigate the nature of the embodied carbon that goes into arenas where carbon refers to life cycle greenhouse gas emissions, measured as the Global Warming Potential (GWP). By looking at both ZNE and ZNC we are able to indicate more accurately the environmental impacts of Arenas. Critically, we maintain focus within the footprint of the arena in order to promote ideas and strategies that we, as designers, can directly control. Typically, variables such as vehicular traffic and facility operations cannot be dictated by the design team. This research focuses on the Zero Net Energy (ZNE) and Zero Net Carbon (ZNC) directly related to the design and construction of a typical mid-size arena that constitutes the bulk of the projects undertaken by the SRE group at Perkins and Will. Our approach follows.

First, we identify how much energy is used and the categories of energy consumption for a baseline model arena operating a schedule of annual events typical for the arena’s program.

Second, we identify which of these uses represent opportunities to reduce power consumption by use of engineering or architectural solutions.

Third, we examine the effect of site selection as a major variable in considering strategies for attaining a net zero building.

Fourth, we have compiled a appendix of additional considerations and possible research areas related to, but beyond the scope of this effort.

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PREFACE:

Area's of Focus for this Article

ENERGY

STRUCTURE

MECH / HVAC

Future Areas of Research: See Appendices

MATERIAL HEALTH

LIGHTING

ENVELOPE

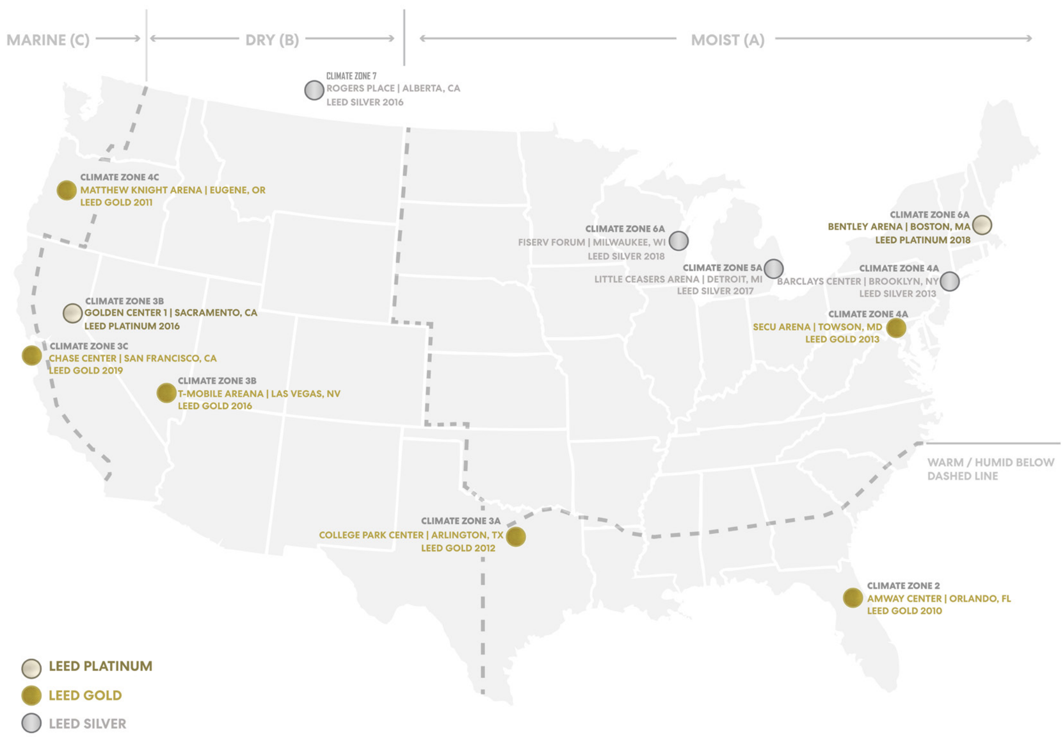
SITE

OCCUPANCY

WATER

TRANSPORTATION

In our initial research proposal, we looked at 11 recently constructed arenas throughout North America that have obtained the highest levels of LEED certification. We considered LEED certified buildings, as LEED is the most widely implemented sustainability rating system. Several arenas have obtained various levels of certification, all coming short of achieving Zero Net Energy (ZNE). The challenges of reaching ZNE with this building type lies within magnitude of scale, amount of controlled volume and typical usage patterns. Ultimately these challenges vary based on the climate (see map 4.1, below).



Graph 4.1 LEED Arenas in North America | Graphics by PW Denver

We proposed a toolkit of building components in the proposal, consisting of ten criteria evaluated as applicable across each of the eight climate regions in the U.S. (refer to the ASHRAE climate map, 6.1). Further research has emphasized the relatively climate insensitive nature of this building typology, particularly when refrigerations systems for ice making is included, and the importance of optimizing the building's mechanical systems. Furthermore, these facilities often have lifespans not exceeding 30 years, so the embodied energy becomes important in considering the total life cycle cost. Therefore, we focused our research on the relative merits of site (climate), architectural design, and building lifespan influences in determining how much on-site renewable energy generation is required in making zero energy arenas.

RESEARCH PARAMETERS

Operational energy and embodied carbon must be calculated to understand how arenas perform in different climate regions. The following parameters were defined for the purpose of the calculations. First, the size of the arena in terms of floor area, volume, and number of occupants (also referred to as “capacity”). A typical mid-size arena that Perkins and Will commonly designs is on the order of about 250,000 square feet of floor area. To normalize the results, a capacity to area ratio (15,000 capacity / 250,000 sf) of 0.06 was determined. Second, three case studies within this typical size range were used as a basis for material quantities and energy models. The case studies selected are Perkins and Will projects that are either built, under construction or in process of design. Third, a typical schedule of events was determined by the average number and type of events at each of the case study arenas, and used to forecast the operational energy consumption.

SELECTED PROJECTS

PROJECT X

BUILDING SF: 217,000 SF
CAPACITY: 12,000
AREA / CAPACITY RATIO: .05 c/sf

ROOF AREA: 110,000 SF
GLAZING AREA: 8,650 SF
OPAQUE WALL AREA: 82,000 SF

PROJECT Y

BUILDING SF: 260,000 SF
CAPACITY: 14,000
AREA / CAPACITY RATIO: .05 c/sf

ROOF AREA: 128,000 SF
GLAZING AREA: 27,000 SF
OPAQUE WALL AREA: 89,000 SF

PROJECT Z

BUILDING SF: 213,000
CAPACITY: 10,000
AREA / CAPACITY RATIO: .04 c/sf

ROOF AREA: 114,500 SF
GLAZING AREA: 65,200 SF
OPAQUE WALL AREA: 86,300 SF

SCHEDULE OF EVENTS

15 — DIRT EVENTS: MONSTER TRUCK, PBR / SUPERCROSS

31 — HOCKEY GAMES *DOES NOT INCLUDE PLAYOFF GAMES.

41 — BASKETBALL GAMES *DOES NOT INCLUDE PLAYOFF GAMES.

8 — ARENA FOOTBALL *DOES NOT INCLUDE PLAYOFF GAMES.

45 — PERFORMANCE: CONCERTS, FAMILY SHOWS

6 — CONVENTIONS: BOAT SHOW, RV / FARM

TOTAL: 146

5.1 Data and Graphics by Perkins Will Denver

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OPERATIONAL ENERGY

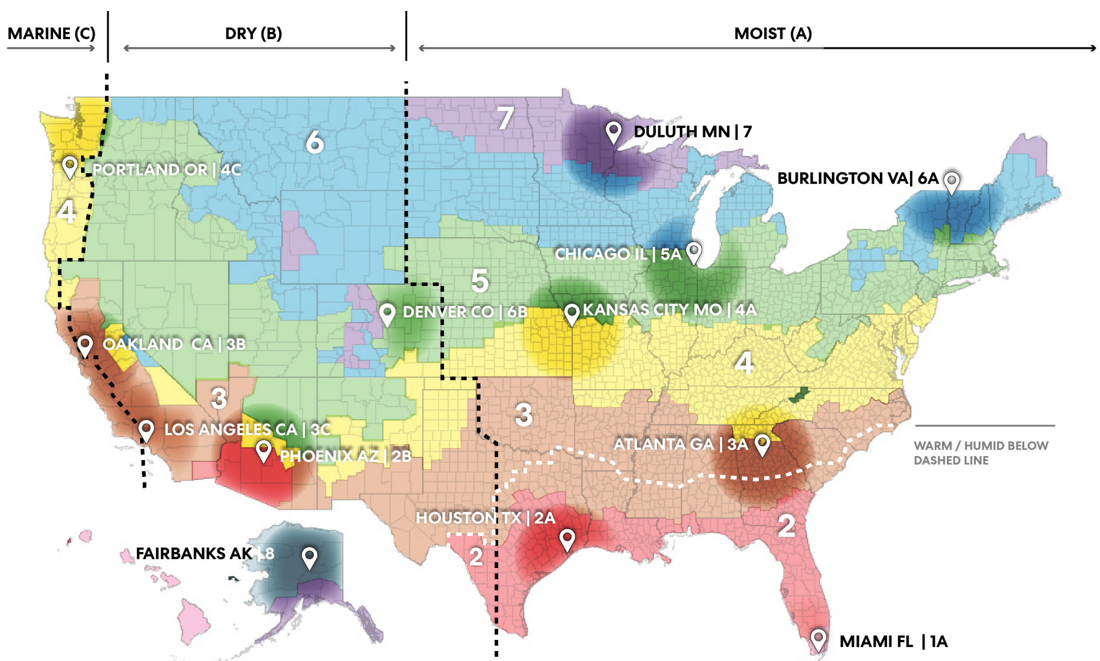
The Nature of Energy Use in Arenas with Ice Sheets

Sources of operating energy for arenas commonly include electricity, natural gas, and possibly district chilled water, hot water or steam. These fuel sources power lighting, cooking, heating, cooling, fans, pumps, equipment, scoreboards, A/V systems, and commercial refrigeration serving kitchens and the ice sheet, if present.

Many of these interior loads will be independent of the building's location and climate zone, such as a scoreboard which will consume the same electricity regardless of where it is in Los Angeles or Philadelphia, but the loads those impose on the space cooling and heating will vary somewhat based on geographic location.

Arenas are largely internally load driven building types. This is to say the main determinants of energy use are not related to the skin loads of the envelope. The loads within the building are main factors in the building's annual energy use. Care should still be used when designing and selecting the envelope components, but realize that their overall impacts will be limited. In general, using the local climate zone's minimum R-value recommendations found in the latest energy codes will result in best practice, while energy modeling may be used for further optimization.

ASHRAE CLIMATE MAP



6.1 ASHRAE Climate Map | Graphic by Perkins Will Denver

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OPERATIONAL ENERGY

The Nature of Energy Use in Arenas with Ice Sheets

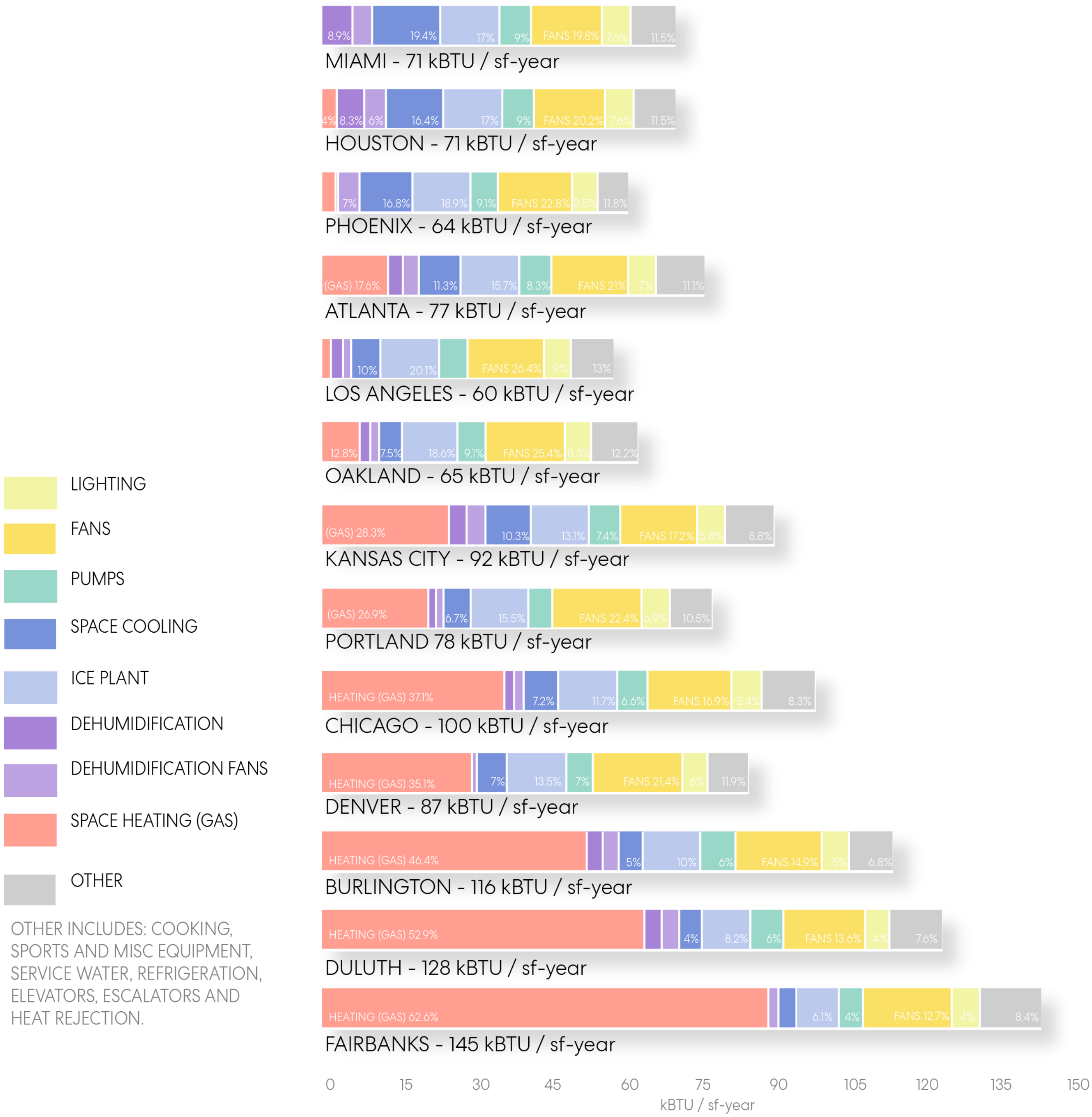
Arenas with ice sheets are the most challenging examples of the type when seeking to optimize energy consumption. These buildings inherently require enormous amounts of energy to power their refrigeration plants that serve the ice sheet, and these loads are largely insensitive to climate. Perhaps less obvious are the air-systems which serve the seating bowl and event floor which require tight humidity controls with the space temperature and relative humidity levels for patron comfort, and, perhaps more importantly, viewing without clouding or fogging occurring near the ice. Fogging can not only obscure play from the spectators but also impede the players from tracking the puck. The 1975 Stanley Cup Finals are a noteworthy example of this phenomenon. Most regions in the US require dehumidification of the outside ventilation air brought into the building and all will require ongoing dehumidification control of recirculating air within the bowl. When games and practice are not occurring, the space conditions could be lessened as can the ice sheet temperature, but unless the ice is covered, the ice and the bowl air will continue to interact. Allowing humidity levels to rise will result in condensation, frosting, and fogging. The ice sheet's chillers then see that moisture deposited on the ice sheet as a new load, thus increasing its energy use just as one seeks to reduce it.

Most modern ice venue dehumidification systems employ a desiccant wheel to dry out the air. Prior to desiccants, the air-systems would more typically have over-cooled the air to condense the moisture out to the desired level, then reheated to the target supply temperature. This process would require low evaporator coil or chilled water temperatures--risking freezing. Lower energy dehumidification systems utilize desiccants, which are hygroscopic substances that absorb moisture. The disadvantage to desiccants is that once they have become saturated with moisture, they must be dried out to be able to maintain effectiveness. That process typically involves blowing hot dry air across them to dry them. That heat for regeneration of the desiccants can use waste heat or other available sources. When no waste heat is available, often a gas furnace is used. This is often the disproportionately large component of energy use, particularly in warm southern climates where one might not expect to find much gas use in air handling units.

Another major determinant in ice venue annual energy use is the number of events in a year. The owners and operators of these facilities would likely want a high utilization rate to produce more revenue. More events means more ventilation, more lighting and more cooking--all resulting in a higher annual energy use. Any goals involving energy use intensities (EUI), net zero energy or net zero carbon will be greatly impacted and made more challenging by having more functions.

OPERATIONAL ENERGY

On-Site Renewable Energy

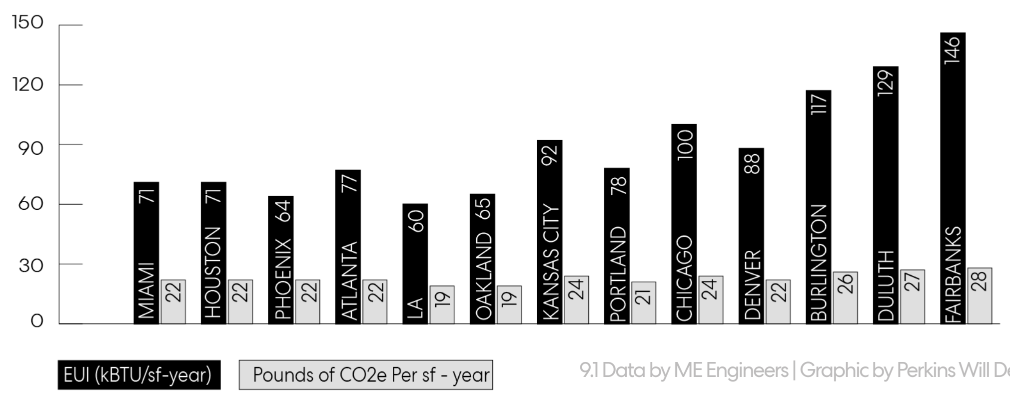


8.1 Data by ME Engineers | Graphic by Perkins Will Denver

OPERATIONAL ENERGY

The Effects of Project Location on Energy Use

Energy codes such as ASHRAE Standard 90.1 and International Energy Conservation Code (IECC) both categorize regions in the US by their number of heating degree days and cooling degree days and whether they are moist, arid or coastal. Refer to climate zone map and legends for extents of these regions. For the purposes of this high level study we analyzed, using an annual energy model, the impacts of project location on energy use and greenhouse gas (GHG) emissions. We took the typical 15,000 seat case study arena and selected various US cities to cover all 13 ASHRAE climate zones (CZ). We included in the model a full hockey season and took the ice sheet down during the offseason. We also scheduled a variety of concerts and other functions throughout the year to simulate a moderate event schedule. We did not assume an all electric building, as natural gas costs are generally cheaper than electric rates and all-electric commissaries are uncommon. No district chilled water, hot water, or steam was assumed or included. To compare these different annual energy uses, we converted the electricity and gas usage to a common unit, and also divided by the conditioned floor area to generate an EUI for each city.



9.1 Data by ME Engineers | Graphic by Perkins Will Denver

Per Table 9.1, warm and dry locations tend to have the least energy use followed by warm and humid locations. On the other extreme is cold climates where heating of the ventilation air drives fuel use upwards. To gauge the opportunities for these buildings to achieve net zero energy in different climates zones, we need to look for places to locate on-site renewables using photovoltaic (PV) panels, specifically we can review the physical space on the arena roof. Assuming 80% of the overall roof area is available for placing PV, we can then review the local solar availability for that city based on regional cloud cover and daylight hours. From the calculations and with proper architectural design maximizing the amount of roof area available for PV, it is possible to mount a 1.4 MW PV array on the roof of a “typical arena”.

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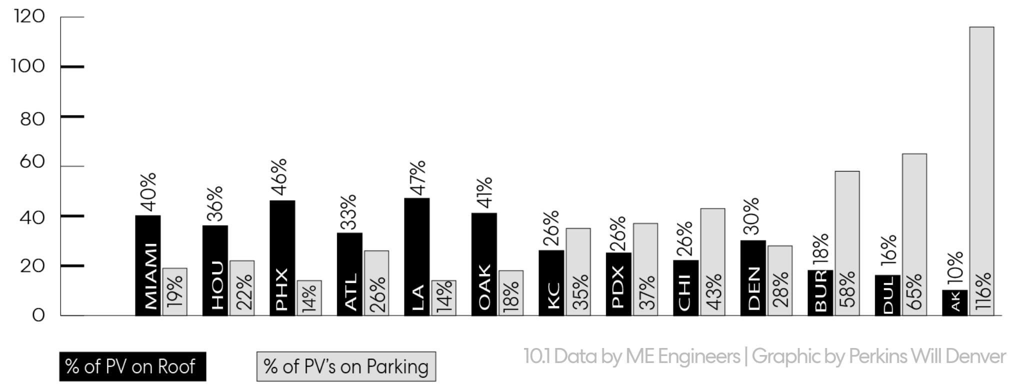
OPERATIONAL ENERGY

On-Site Renewable Energy



10.1 Data by ME Engineers | Graphic by Perkins Will Denver

* 80% coverage (whole roof + parking area)
* Assuming 5,000 Parking Spots, Parking Coverage needed for Net Zero.

Because production from the PVs will vary, based on location and colder climates with more natural gas and less PV production, we can investigate if it is feasible to generate all the energy needed on-site.

As shown in Table 10.1, close to 40% of the energy needed can be obtained from roof-mounted PV for climate zones 1 and 2, with the colder climates only getting about 20% from a roof-mounted array.

Arenas may have surrounding surface parking lots. Assuming a parking ratio around 1 space per every 3 spectator seats would provide the project approximately 5,000 parking spaces that could potentially be covered with PVs. With all of the space for potential PVs above the parked vehicles, another 10 megawatts of power could be accommodated on site. This is sufficient for all but the climate zone for Fairbanks, AK to be net zero in terms of operational energy, even before optimizing the interior mechanical systems or other building aspects.

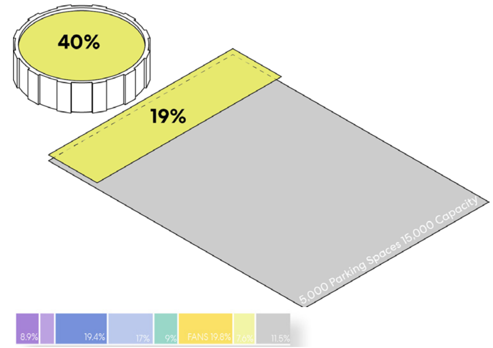
The following pages visually depict the relative size of the necessary PV arrays needed to make a facility net zero, The tables show the percentage of parking spaces out of the 5,000 needed to be covered with a 2kW array in addition to the on-site rooftop array.

Considering the application of on-site renew-ables—photo-voltaic (PV) panels, specifically, we can review the physical space on the roofs of the venues. If one assumes up to 80% of the overall roof area is available for placing PV (a very optimistic, but possible scenario) we can then review the local solar availability for that city based on regional cloud cover and daylight hours. From the calculations, with proper architectural design maximizing the amount of roof area available for PV, it is possible to mount a 1.4 MW PV array on the roof of the typical arena under consideration.

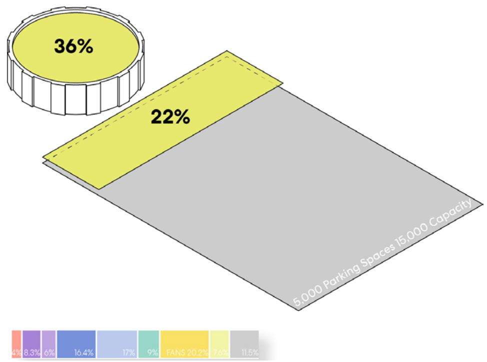
OPERATIONAL ENERGY

On-Site Renewable Energy

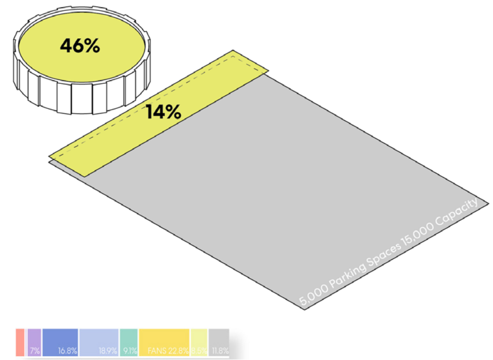
Data by ME Engineers | Graphic by Perkins Will Denver



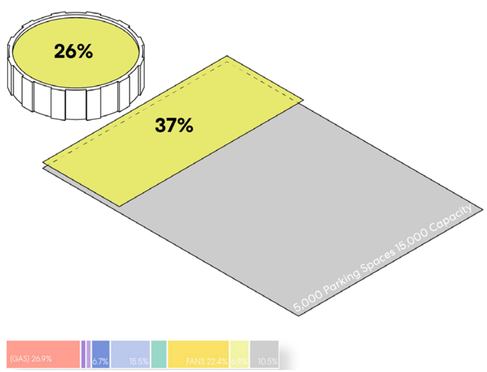
1A | MIAMI
71 EUI (kBTU/sf - year)
22 CO2e (Per sf - year)



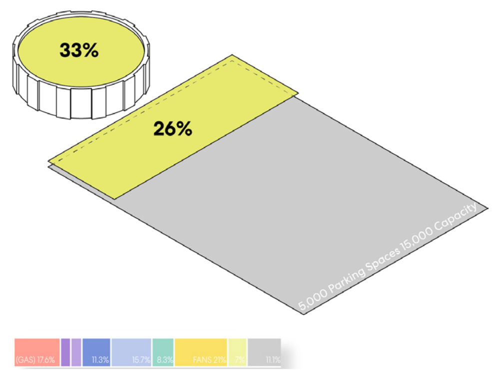
2A | HOUSTON
71 EUI (kBTU/sf - year)
22 CO2e (Per sf - year)



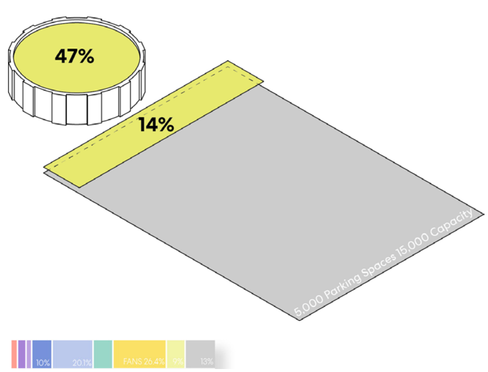
2B | PHOENIX
64 EUI (kBTU/sf - year)
22 CO2e (Per sf - year)



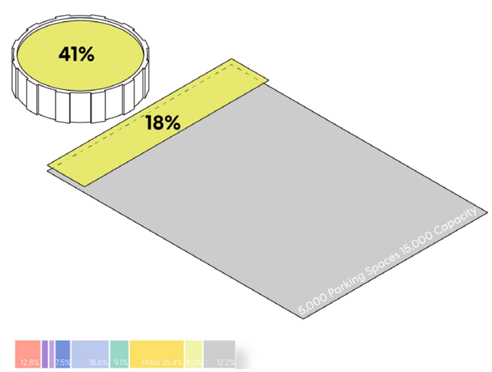
4C | PORTLAND
78 EUI (kBTU/sf - year)
21 CO2e (Per sf - year)



3A | ATLANTA
77 EUI (kBTU/sf - year)
22 CO2e (Per sf - year)



3C | LOS ANGELES
60 EUI (kBTU/sf - year)
19 CO2e (Per sf - year)



3B | OAKLAND
65 EUI (kBTU/sf - year)
19 CO2e (Per sf - year)

LIGHTING
FANS
PUMPS
SPACE COOLING
ICE PLANT
DEHUMIDIFICATION
DEHUMIDIFICATION FANS
SPACE HEATING (GAS)
OTHER

OTHER INCLUDES: COOKING, SPORTS AND MISC EQUIPMENT, SERVICE WATER, REFRIGERATION, ELEVATORS, ESCALATORS AND HEAT REJECTION.

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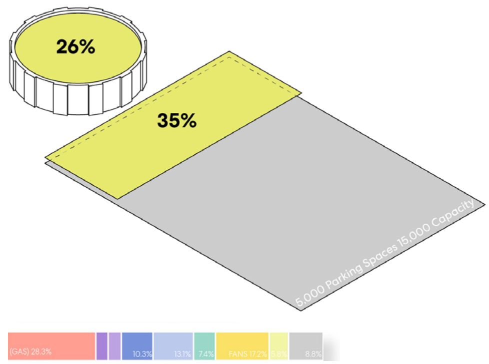
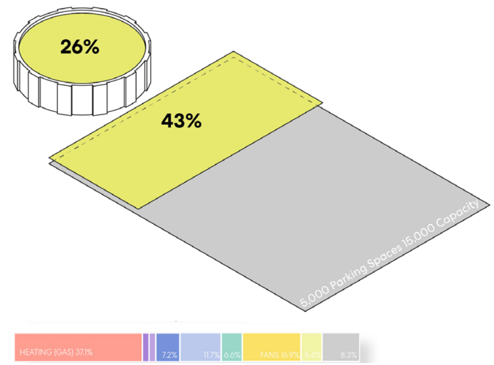
OPERATIONAL ENERGY

On-Site Renewable Energy

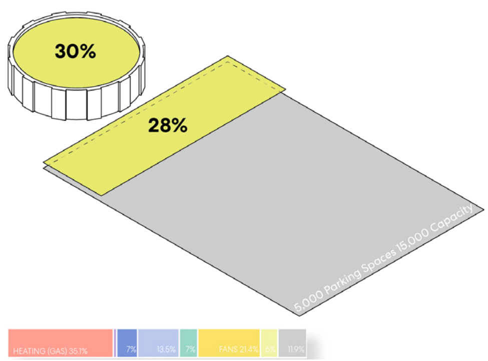
Data by ME Engineers | Graphic by Perkins Will Denver



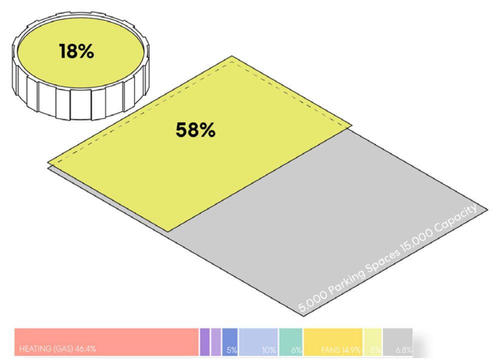
4A | KANSAS CITY
92 EUI (kBTU/sf - year)
24 CO2e (Per sf - year)



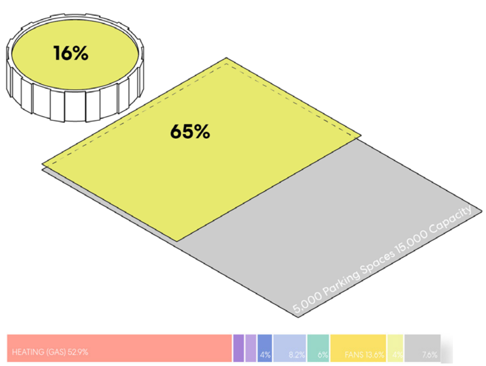
5A | CHICAGO
100 EUI (kBTU/sf - year)
24 CO2e (Per sf - year)



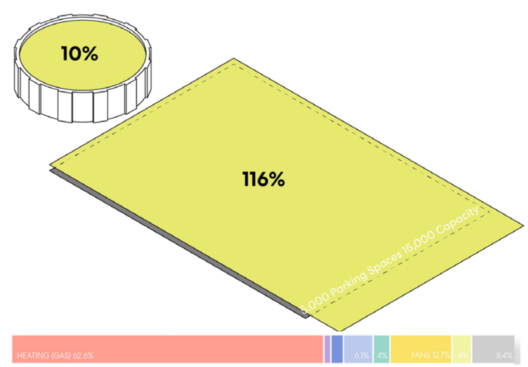
6B| DENVER
88 EUI (kBTU/sf - year)
22 CO2e (Per sf - year)



6A| BURLINGTON
117 EUI (kBTU/sf - year)
26 CO2e (Per sf - year)



7 | DULUTH
129 EUI (kBTU/sf - year)
27 CO2e (Per sf - year)



8 | FAIRBANKS
146 EUI (kBTU/sf - year)
28 CO2e (Per sf - year)

LIGHTING
FANS
PUMPS
SPACE COOLING
ICE PLANT
DEHUMIDIFICATION
DEHUMIDIFICATION FANS
SPACE HEATING (GAS)
OTHER

OTHER INCLUDES: COOKING, SPORTS AND MISC EQUIPMENT, SERVICE WATER, REFRIGERATION, ELEVATORS, ESCALATORS AND HEAT REJECTION.

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OPERATIONAL CARBON

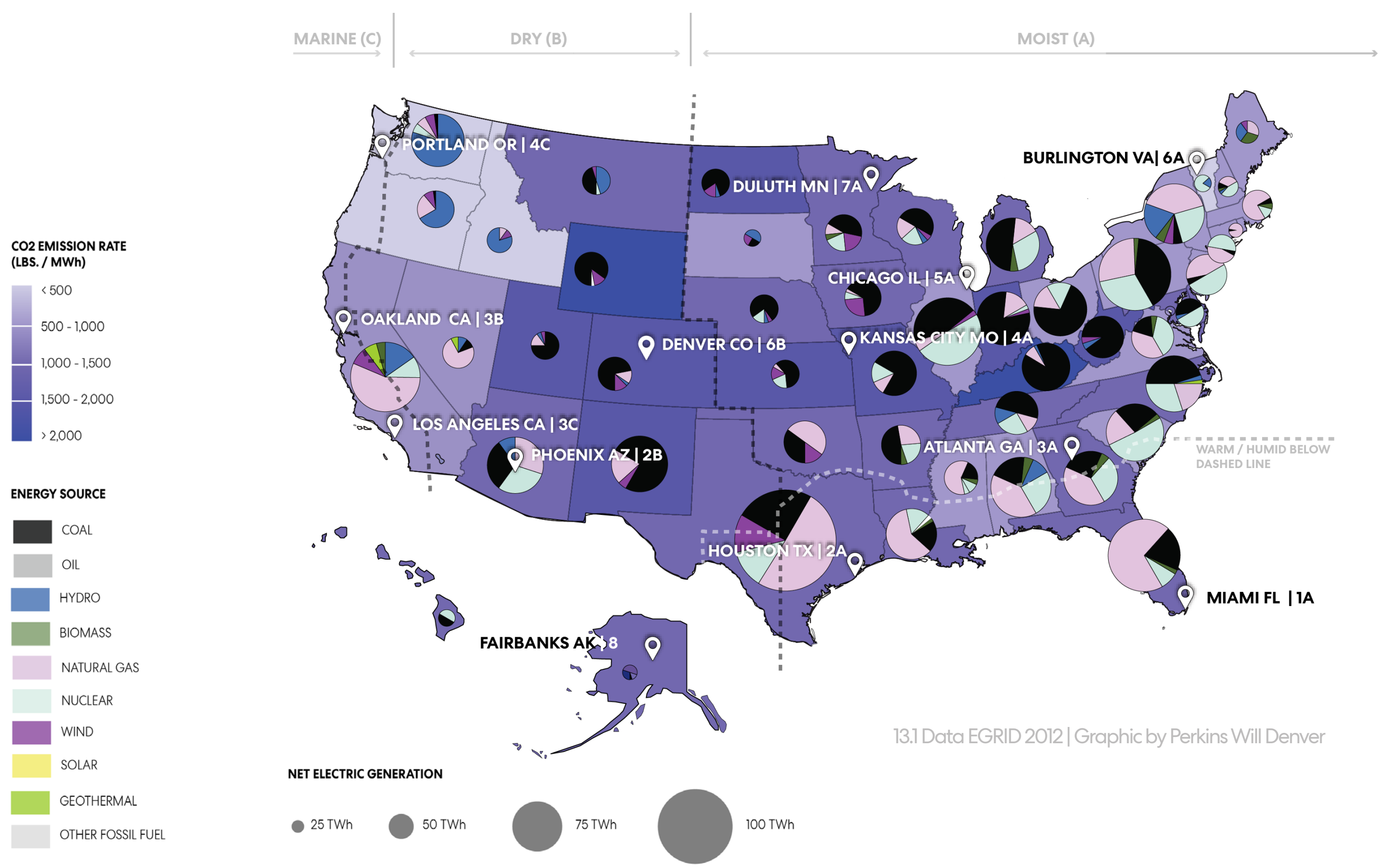
The Effects of Project Location on Energy Use

We can also apply local utility electrical grid emissions and convert the natural gas and electricity into GHG emissions in pounds of CO2e/sf-yr.

The bulk of arenas' annual energy use is electricity, with a smaller portion being natural gas. Thus, the annual GHG emissions from a facility are largely from the electricity's upstream power generation emissions.

The EGRID map (13.1) reproduced below is dated and the Environmental Protection Agency (EPA) has not recreated it using newer eGRID 2016 data. Nevertheless, it demonstrates how dependent most regions are on non-renewable fuel sources for their electricity production. Currently, one-in-five Americans now live in a region where the local utility, city or state has committed to decarbonizing their electricity. These are commonly referred to as renewable portfolio standards (RPS). If these utilities, and likely others joining them, are able to reduce or outright eliminate all natural gas, coal, and oil from electricity production, then the customers will benefit from no or very low GHG emissions by mid century—depending on how aggressively they pursue renew-ables and decommissioning obsolete plants.

EGRID 2012 MAP



13.1 Data EGRID 2012 | Graphic by Perkins Will Denver

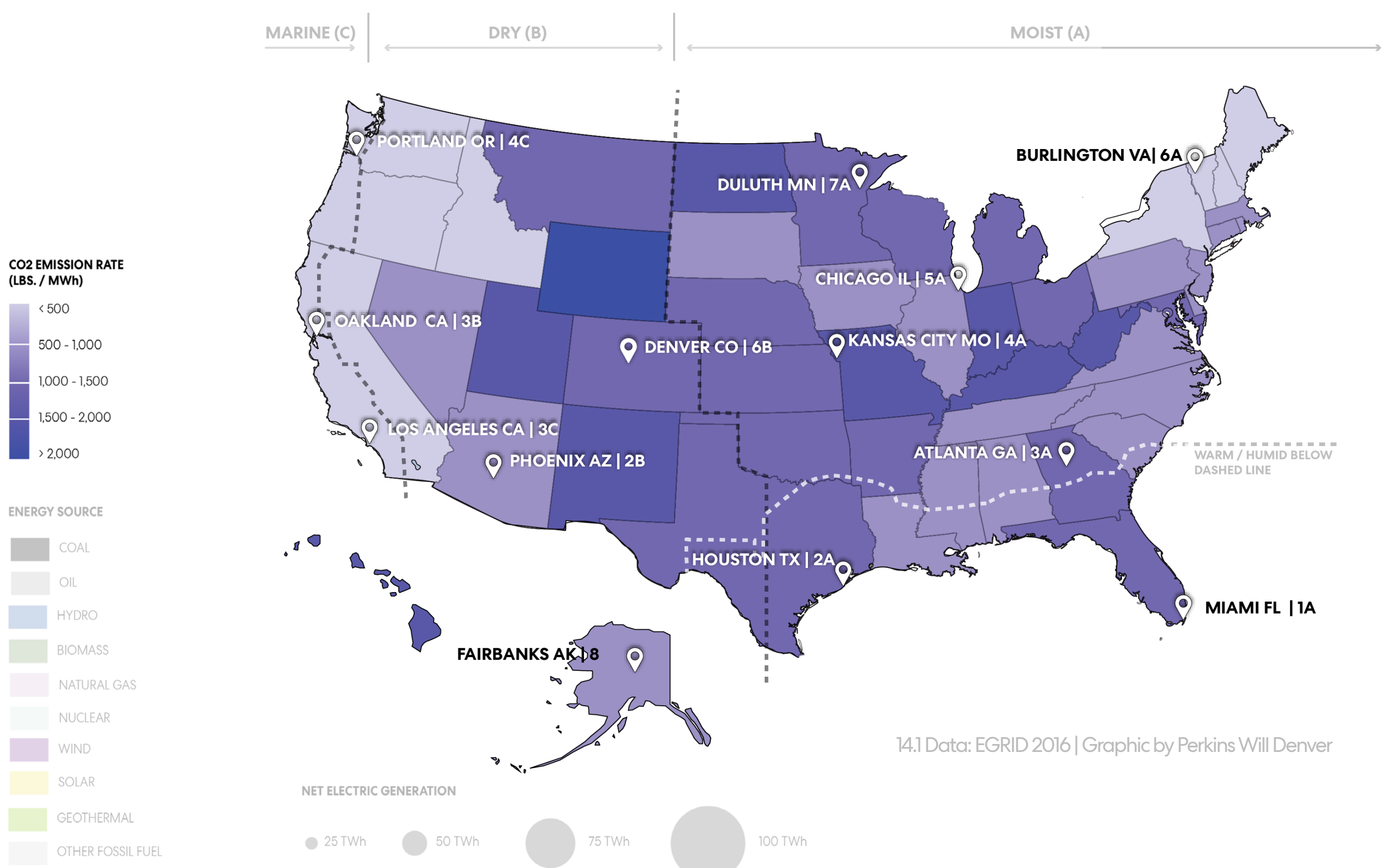
OPERATIONAL CARBON

The Effects of Project Location on Energy Use

Although EGRID, has not released an updated map since 2012, we were able to partially recreate their 2012 map using the data they released in 2016. However, the net electric generation and energy source have either not been published or the data has not been gathered. In map 14.1, you are able to see a general decrease in CO2 emission rates per state and an overall decrease among the United States from the 2012 EGRID Map.

Provided in the series of maps to follow, we were able to look further into how aggressively states and regions are currently pursuing renewable energy. These maps, developed through our research, derived from a combination of different data published by NREL (National Renewable Energy Laboratory), EGRID and the EIA (Energy Information Administration.) The data in maps 14.1, 15.1 and 15.2 not only show the trend in decarbonization of the grid, but also renewable resources per region and which states are developing policy in support of renewables and efficiency.

EGRID 2016 MAP



14.1 Data: EGRID 2016 | Graphic by Perkins Will Denver

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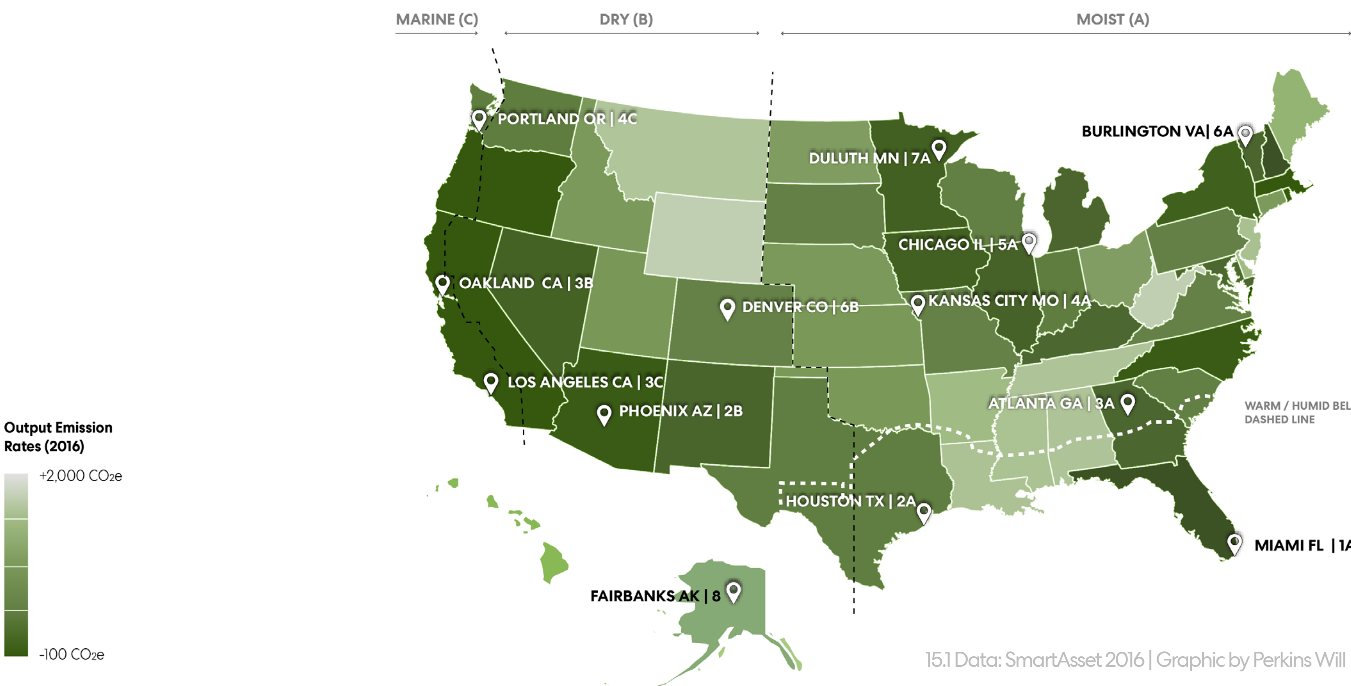
The Effects of Project Location on Energy Use

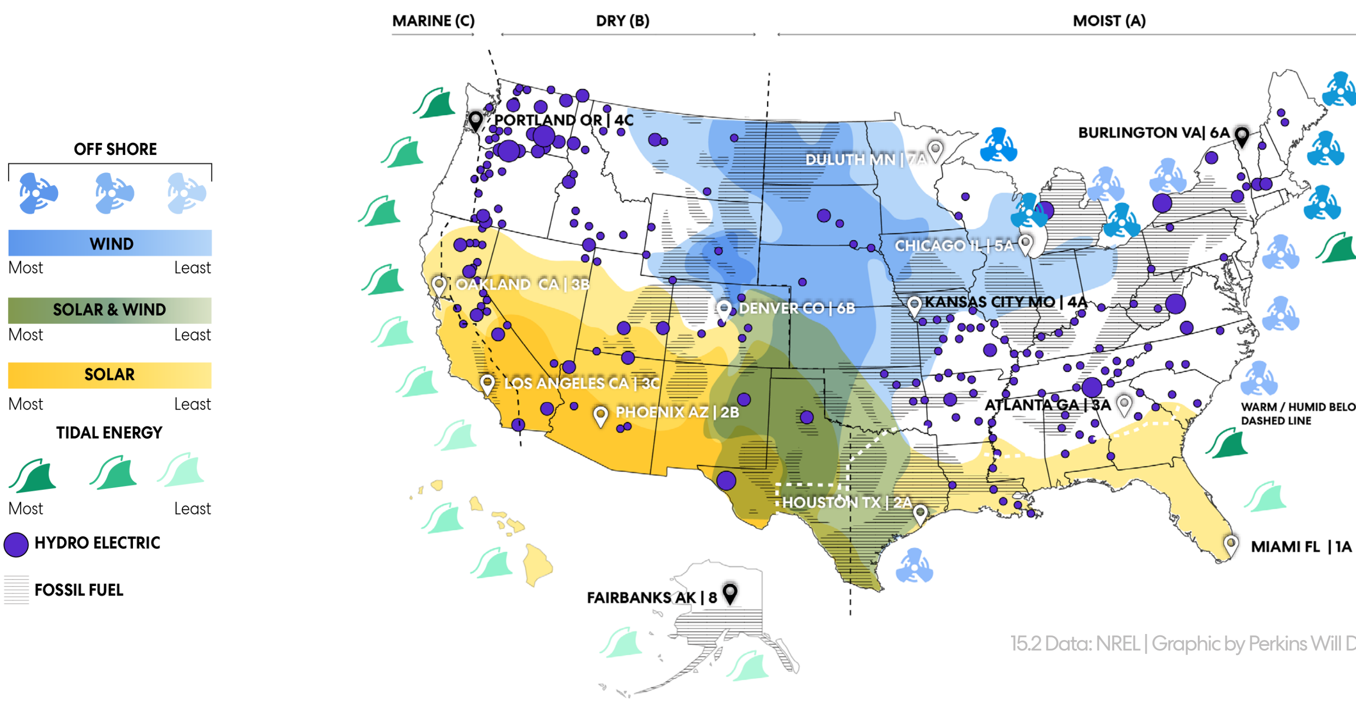
In Map 15.1, “States leading the Charge in Renewable Energy”, we looked at renewable output vs total output, Carbon Emissions per Capita and the number of policies and incentives supporting renewable energy. This data, published by Smart Asset in 2016, gave us the opportunity to map and compare States by non renewable fuel sources vs states starting to implement strategies to reduce non renewable energy.

STATES LEADING THE CHARGE



15.1 Data: SmartAsset 2016 | Graphic by Perkins Will Denver

RENEWABLE RESOURCES BY REGION



15.2 Data: NREL | Graphic by Perkins Will Denver

me engineers INTEGRAL GROUP walter p moore Perkins&Will

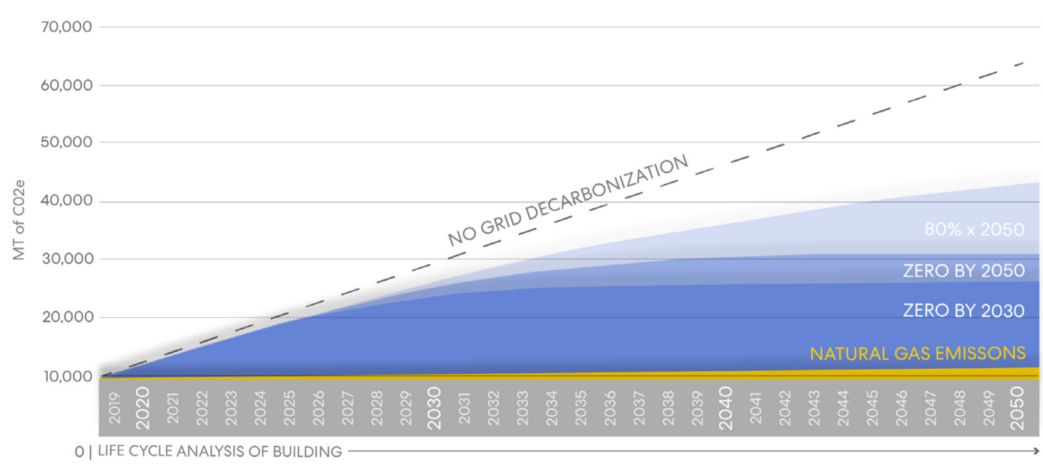
OPERATIONAL CARBON

The Effects of Project Location on Energy Use

Renewable availability as seen in map 15.2, is also vital when we start to understand how quickly the grid as a whole will de-carbonize. Regions such as the Pacific Northwest have taken advantage of Hydro Electric energy in order to obtain a low emission rate, while some states with high wind and solar capacity have yet to find the means to harness it. Future resources, such as Tidal Energy are still being developed but could serve as a viable option for most of the coastal US.

If we assume a worst case scenario that some areas experience no further decarbonization of their local electricity and hold the present 2018 grid emissions data constant from now until 2050, then we can estimate how that compares to a more optimistic scenario that some locations will fully decarbonize and provide carbon neutral energy by 2030. The more likely answer is somewhere between these extremes. As an example, table 16.1 shows a cumulative lifetime GHG emissions plot for Phoenix, AZ. It starts with a base of emissions due to the embodied energy of the materials used for construction—before the building is ever occupied—Year 0. Then each occupied year's annual emissions is added, which for this case we are only capturing the electricity and gas-related emissions, and ignoring emissions related to refrigerants, travel to the venue, and waste water treatment.

Grid De-carbonization



16.1 Data by ME Engineers | Graphic by Perkins Will Denver

Here we see the lifetime emissions are in the range of 25,000 metric tons of CO2e to 65,000 metric tons of CO2e over a 32 yr period. The lifetime of an average arena will be discussed in more detail when we look at embodied carbon, but can range anywhere from 15 to 40 years depending on if it is NBA, NHL or NCAA. The guesses on what the electrical grid will be beyond 2050 is subject to extreme speculation and uncertainty making any guess beyond that error-prone.

me engineers INTEGRAL GROUP walter p moore Perkins&Will

EMBODIED CARBON

While overlooked until very recently, the emissions associated with extracting, processing, shipping, installing, and maintaining the materials used in our buildings are gaining increased prominence. These emissions, collectively referred to as embodied emissions, occur before a building opens, and can never be recovered. Embodied emissions occur for all environmental impacts, and the embodied greenhouse gas emissions are commonly referred to as "embodied carbon". With the urgency to reduce near term greenhouse gas emissions, along with the long term decarbonization of power sources, the reduction of embodied impacts has gained prominence.

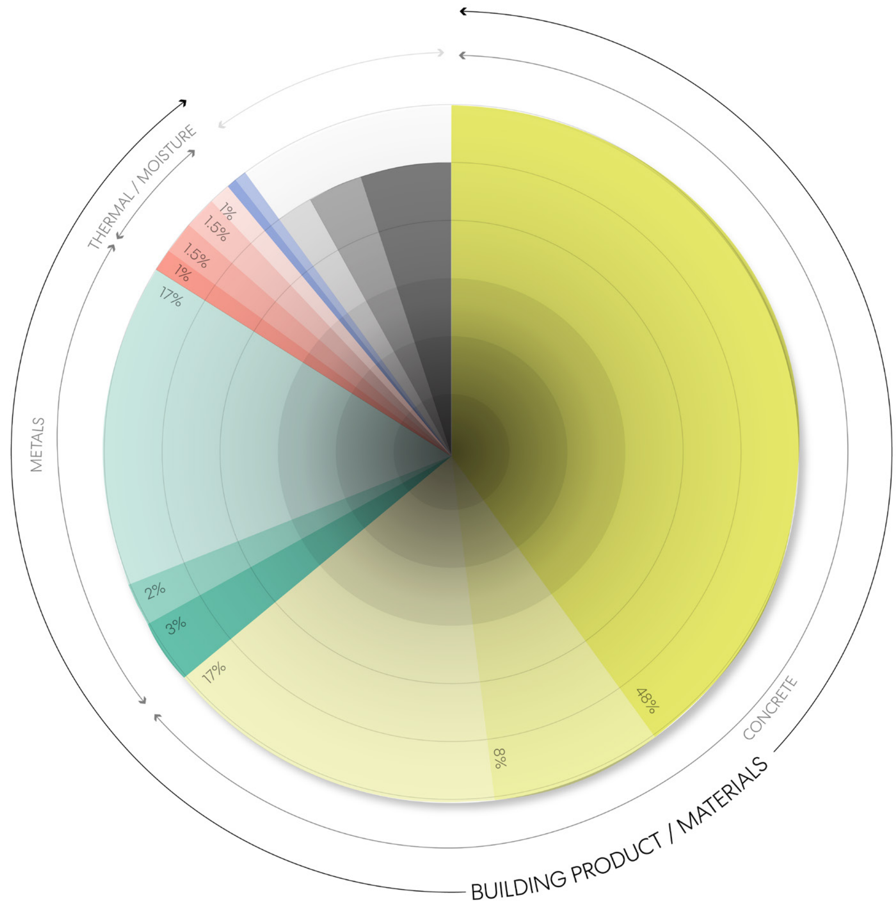
Embodied impacts are quantified through Whole Building Life Cycle Assessment (WBLCA), an environmental accounting process. The WBLCA process combines data from across material supply chains to estimate the overall embodied impacts, illustrate hot spots, and allow design teams to compare the relative scale of embodied emissions with those from operations. Currently, WBCLA is commonly performed on the structure and enclosure. However, as additional information is available for other building products the scope of WBLCA can be expanded to include finishes and building systems.

This study performed WBLCA on the structure and enclosure of the Project X (Fig. 18.1 & 18.2) to both highlight which assemblies make the most significant contributions to the projects embodied carbon, as well as to highlight scenarios of how embodied and operational carbon built over time to represent a building's total carbon. Organizations have set goals to reach a net zero total carbon, including embodied carbon, by 2050. However, this will require both improvements to the manufacturing processes of carbon intensive materials, as well the use of carbon sequestering materials to replace net emitters.

The Project X WBLCA of structure and enclosure illustrates that a large proportion of that project's embodied carbon, approximately 70%, is due to concrete. More specifically, nearly 40% of the overall embodied carbon comes from the cement alone. Concrete and Portland cement also dominate other environmental impacts such as Acidification, Eutrophication, and Smog potential.

This reinforces that efficient use of Portland cement is an essential component of achieving embodied carbon reductions. This is an area of ongoing academic research, and emerging technologies are increasingly becoming available to the design community.

EMBODIED CARBON



GLOBAL WARMING POTENTIAL OF ARENAS

18.1 Data by Walter P Moore | Graphic by Perkins Will Denver

03 CONCRETE

- CAST IN PLACE CONCRETE, CUSTOM MIX
- PRECAST CONCRETE, STRUCTURAL PANEL
- STEEL REINFORCING ROD.

05 METALS

- STEEL DECK
- STEEL HSS SECTION
- STEEL W SECTION (WIDE FLANGE)

07 THERMAL / MOUSITURE PROTECTION

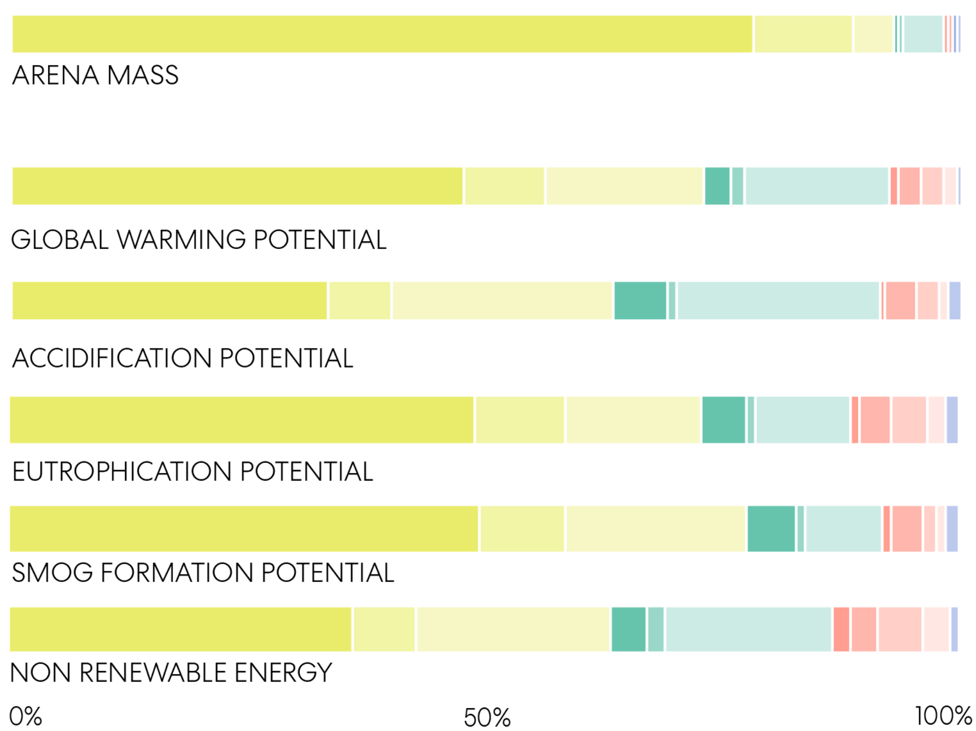
- EXTRUDED POLYSTYRENE (XPS) BOARD
- METAL WALL PANEL (FORMED)
- POLYISOCYANURATE (PIR) BOARD
- TPO ROOFING MEMBRANE

08 OPENINGS / GLAZING

- ALUMINUM MULLION
- GLAZING (DOUBLE PANE)

EXTERNAL FACTORS

- END OF LIFE
- MAINTENANCE / REPLACEMENT
- TRANSPORTATION



RESULTS PER DIVISION - FULL BUILDING SUMMARY

18.2 Data by Walter P Moore | Graphic by Perkins Will Denver

EMBODIED ENERGY

Life Span of Arenas

Metals, and specifically steel, are the other dominant contributor to the overall embodied carbon. The analysis of Project X shows that roughly 15% of the embodied carbon is due to structural steel, and another 15% is due to rebar. Domestic structural steel and rebar are predominantly produced from electric arc furnaces (EAF). EAF furnaces use a high level of recycled content, and a large portion of the carbon emissions from EAF steel are due to electricity production.

Multiple strategies will be required to eventually achieve net zero embodied carbon. While the inclusion of carbon sequestering materials such as mass timber in the structure or natural insulation products in the enclosure can serve as net carbon sinks, we must simultaneously reduce the carbon intensity of carbon emitting assemblies. Some materials, like metals, will become less carbon intensive due to broader decarbonization of energy supply. However, emissions from others, such as concrete, whose emissions are not due to grid related power, will require more complex optimization.

Life Span of Arenas

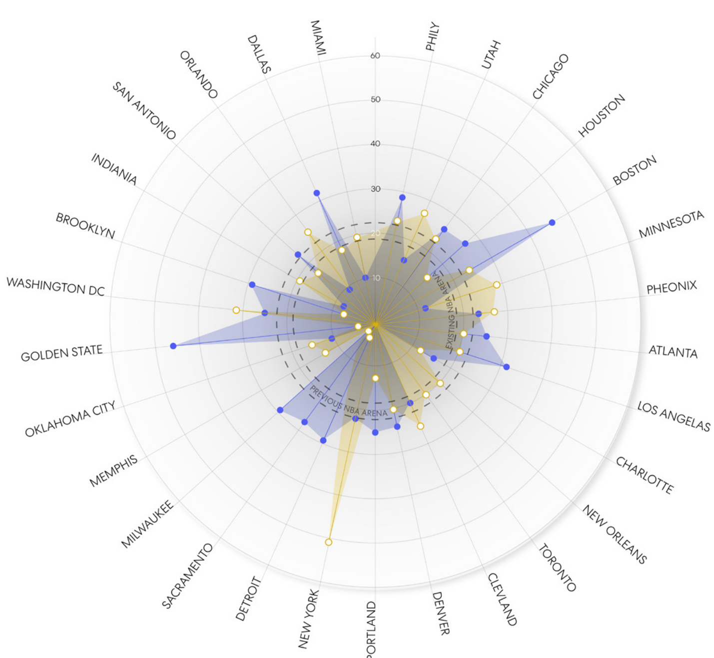
When we take a step back and look at the overall life span of arenas, we begin to understand that value they hold within the region and some of the reasons that they become decommissioned. Existing NBA and NHL arenas have an incredibly short lifespan lasting on average 18 (NBA) and 21 (NHL) years. We see a trend that shows arenas are not lasting as long as they used to, previous NBA and NHL arenas lasted 23 and 34 years respectively.

SHARED AREANA'S NBA &NHL

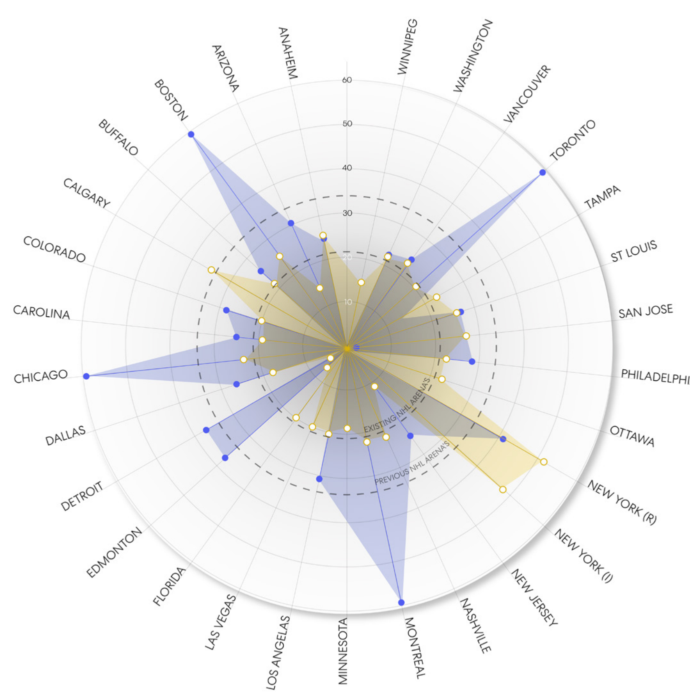
- NEW YORK
- CHICAGO
- BOSTON
- PHILADELPHIA
- WASHINGTON
- COLORADO
- LOS ANGELES
- TORONTO
- DALLAS
- BROOKLYN
- DETROIT

PREVIOUS ARENA

CURRENT ARENA



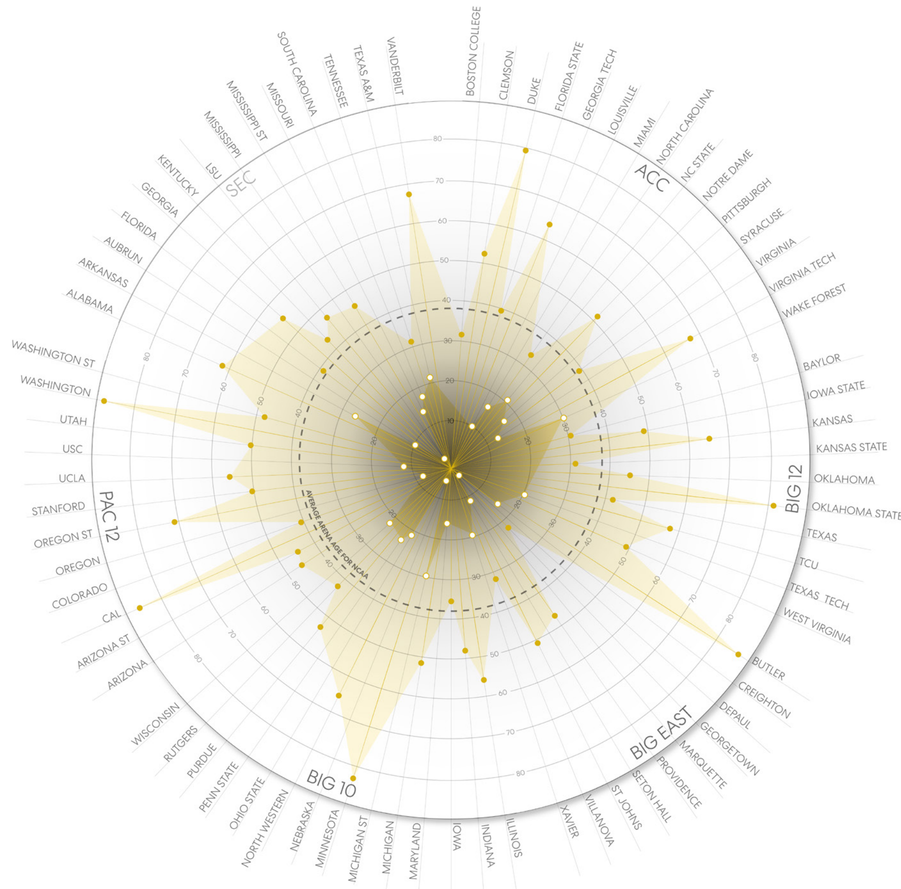
19.1 Life Span of Arena vs. Typical Embodied Energy: NHL



19.2 L life Span of Arena vs. Typical Embodied Energy: NBA

EMBODIED ENERGY

Life Span of Arenas



20.1 Life Span of Arena vs. Embodied Energy: NCAA

Arenas are decommissioned for multiple reasons that span across all of professional sports. A new arena brings new amenities which also increase ticket sales bringing in more revenue for the franchise. There is also sponsorship and naming rights that come along with a brand new Arena. Relocation is another factor, we see franchises moving more frequently to gain a larger audience and fan base.

If we take a look at the lifespan of NCAA arenas shown in figure 18.1, we notice that the average lifespan is much greater than professional venues. The average age of an NCAA arena is 39 years. While we do see a very competitive arms race to have the best facilities for recruiting, these arenas are tied to an institution and provide more history and tradition making renovations more likely than constructing a whole new arena.

Assumptions can be made that with this short of lifespan, the embodied carbon of the materials used to construct the arena are still present when the building is decommissioned, but without more data and research, this is still unclear. However, we do know that overtime the embodied carbon in these arenas do become less impactful.

CONCLUSION

While our initial research proposal aimed to develop a toolkit and component of parts in order to design Zero Net Arenas, we found that these buildings tend to be internally dominated from an energy perspective. Along with the heating and cooling loads, a significant amount of operational energy is used to maintain and de humidify the sheet of ice. In addition, the optimization of mechanical systems is somewhat limited by current technology, and energy efficiency of non-event spaces can be as dependent on the architectural design as any other building typology. Therefore, we analyzed what are the factors driving energy demand in arenas and what type of effort is required to make a net zero energy arena.

Lack of existing energy data on current arenas led to assumptions on how these buildings perform, and as a result, the data and conclusions in this report are often at a general level of detail, based on “typical” case study arenas that Perkins and Will commonly designs. Organizations such as the Green Sports Alliance have been pushing for more data on the efficiency of arenas, but it has been difficult to get organizations and franchises to report their buildings energy performance.

To summarize, we first determined what the major uses of energy are. We discovered that space heating is the most variable energy use and tends to be the greatest expenditure of energy in cooler climate zones. In warmer climates, the ice plant and dehumidification tend to be equal to the space cooling. Other functions represent the smallest portion of the energy use, and effort to achieve efficiencies here should be employed proportionally.

Another factor affecting how an arena reaches net zero, or indeed any building, is the state of adoption of renewable sources of energy in its local grid. From the 2012 EGrid map reproduced earlier in the presentation, we can see that most states still rely on energy that is not renewable. Should decarbonization of the grid proceed at an increasing rate, the urgency for optimizing energy use in arenas may be reduced, but this time line for decarbonization remains speculative.

CONCLUSION

We also expanded the scope beyond operational energy and looked at arenas more holistically to consider the impact of embodied carbon and operational carbon. The Life cycle of the materials along with the environmental impacts are extremely important due to the life span of most arenas. In order achieve zero carbon arenas, we must simultaneously look into different building technology's, reduce carbon intensity of carbon emitting assemblies as well the carbon of the overall grid.

Although we determined that a Zero Net Energy Arena is possible with off site renew ables, the scale, volume and multiple variables prove that multiple strategies and additional research will be required to eventually achieve both net zero energy and zero carbon. Given the previous factors, we determined how much renewable energy must be produced to achieve a net zero energy arena given the climate type and location. This investment in on-site energy generation could be offset by increasing energy efficiency through architectural and engineering strategies.

These strategies might involve the envelope construction, orientation and amount of glazing, natural ventilation, or other techniques. Other strategies may focus on how facility managers operate arenas, and improved operator training and automation systems may improve the realized efficiency of these buildings. Given the scale, impact and variables within an Arena, we have organized and compiled an appendix of additional considerations and possible research areas that represent additional opportunity to understand the challenges in creating sustainable arenas.

APPENDIX

EXTERIOR ENVELOPE

This kit of components will look into the building sections of high performing, and if possible, Net Zero buildings for each of the 8 climate regions in the US. These components will include wall, roof, fenestration/glazing, and floor assemblies and rank them on a scale of highest performing to lowest, as well as highest cost to lowest. A bonus goal would be to include a life-cycle analysis on the higher costing items to use in our work and provide to clients. We realize moving our studio directly into Net Zero arenas is not an achievable goal, so we'd like to compile a range of options to get us on the path to Net Zero. Project teams would be able to use our toolkit to guide their decisions during the design process to reach a higher performing standard for arena design.

OCCUPANCY

The occupancy of arenas vary immensely. Larger arenas in more populated markets that host multiple professional sports teams, concerts, and other various events may be occupied around 70-80% of the time, while smaller arenas in different markets may be occupied 30-40%. While larger market arenas may be occupied more frequently, They still only have the maximum amount of occupants for a few hours at a time, cause peak loads to happen in bursts while leaving the space nearly vacant throughout the other hours of the day.

WATER

Arenas typically have a large enough mass and surrounding site area to collect vast amounts of water. Despite a handful of attempts, no buildings have yet achieved complete water independence. For us to achieve water independence, we need to be able to divide available sources of water into categories and treat them accordingly. Rainwater is relatively clean, and can be converted into drinking water with a minimum of processing. Grey water can be cleaned by filtering it through a biological wastewater treatment system such as the Living Machine, a sort of wetlands in a box containing plants, bacteria, plankton, even snails and clams. This will be key in how we analyze the immediate landscape and vast amounts parking surrounding the site. Water, like most of our components will have to be analyzed individually by climate type and develop solutions based on the areas needs or local restrictions on water collection.

APPENDIX

LIGHTING

Arenas require lighting above and beyond that of a typical commercial building to sufficiently light a very large volume for concerts, games,and presentations. In addition to these powerful lights, display boards in arenas, on the facade, and around concessions require an extra level of energy beyond a typical building. Several manufacturers for lighting and display boards are making great strides to make their products more energy efficient, and we want to know what those are, how much energy they require, and plug this data into an overall building energy use to compare to the renewable energy potential.

TRANSPORTATION

How do we consider the energy burden for a given project that results from transportation to and from the facility? We seek to establish a consistent way to calculate, holistically and on a life-cycle basis, the costs of access to a facility in terms of EUI.

How do contemporary trends in transportation affect how arenas are accessed? The three most conspicuous and revolutionary trends at the moment include: 1) Shared Mobility 2) Electrification 3) Autonomous Driving. What combination of these trends will be most energy efficient? How do we as designers accommodate these trends, while maintaing accessibility and walk ability, and create generally pleasant community experiences around arenas.

What strategies can be employed to extend the concept of a net-zero arena to the surrounding community? A toolkit will be developed investigating possible strategies including the effects of: demand pricing, location, on-site electrical generation, etc.

Site considerations, of course, strongly factor into questions regarding transportation.

APPENDIX

SITE

The landscape of property around arenas tends to consist primarily of parking where arenas are not located in dense urban environments. The specific location of the arena may lead to different opportunities for on-site renewable energy generation aside from the aforementioned solar power considered in the body of this research. Examples might include: wind, geothermal, hydroelectric, or perhaps more exotic forms in the future, like ocean thermal energy conversion (OTEC) or tidal energy.

Other site considerations include the user catchement and proximity to different types of transportation. More dense areas may benefit from more mass transit, pedestrian use, or less energy-intensive forms of transport in general that benefit stakeholders by requiring less provision of parking facilities for personal automobiles.

MATERIAL HEALTH

Throughout our research we found that materials (exterior and interior) have a low impact on the operational energy but carry a certain load in terms of embodied carbon. Interior finishes and materials also have significant influences when looking at other categories of impact. Overall building health and resilience are crucial when it comes to the SRE sector, especially Arenas. Depending on the occupancy of professional or collegiate, these buildings vary in life cycle. Collegiate are typically built to stay and last generations, While professional have a much shorter life span. Second, some Arenas even serve as a cities “place of refuge” in case of an emergency (natural disaster, etc). Third, millions of people utilize arenas each year, making the health and resilience of these buildings even more important.

Exterior and interior materials have a large impacts on the health of the building and its occupants. We are finding that more and more materials on the market are not as “healthy” as they claim to be. Especially materials that are typically used in heavy use buildings, like Arenas. We are seeing that material specifications typically used for sports, recreation, and entertainment buildings, that are considered industry standard, are calling for materials that raise significant red flags in terms of material health. For example: quartz counter tops, epoxy flooring, epoxy paint, etc.

SRE projects are traditionally specifying materials due a specific use of a space, maintenance associated with a product and durability/ life span of a product. We are seeing that durability and product maintenance are main drivers when selecting materials for these types of clients and spaces. This is mainly due to the desired longevity of these buildings. How can we better select healthy materials for these building types while weighing all drivers?

GLOSSARY

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): is an organization devoted to the advancement of indoor-environment-control technology in the heating, ventilation and air conditioning (HVAC) industry.

Cooling Degree Days (CDD): is a measurement designed to quantify the demand for energy needed to cool buildings. It is the number of degrees that a day's average temperature is above 65o Fahrenheit (18o Celsius).

CO2e: The total climate change impact of all greenhouse gases caused by a behavior or product and is expressed in terms of carbon dioxide.

Electric Arc Furnace (EAF): is a furnace that heats charged material by means of an electric arc. Industrial arc furnaces range in size from small units of approximately one ton capacity (used in foundries for producing cast iron products) up to about 400 ton units used for secondary steel making.

Energy Use Intensity (EUI): Energy Use Intensity is a building's annual energy use per unit area. It is typically measured in thousands of BTU per square foot per year (kBTU/ft2/yr) or kWh/m2/yr.

Green House Gas (GHG): a gas that contributes to the greenhouse effect by absorbing infrared radiation, e.g., carbon dioxide and chlorofluorocarbons.

Global Warming Potential (GWP): The cumulative radiative forcing, both direct and indirct effects, over a specified time horizon resulting from the emission of a unit of gas related to some reference gas [CO2: (IPCC 1996)]

Heating Degree Days: (HDD) is a measurement designed to quantify the demand for energy needed to heat a building. It is the number of degrees that a day's average temperature is below 65o Fahrenheit (18o Celsius), which is the temperature below which buildings need to be heated.

Ocean Thermal Energy Conversion (OTEC): is a marine renewable energy technology that harnesses the solar energy absorbed by the oceans to generate electric power.

Sports Recreation and Entertainment (SRE): A sector in the architecture industry specifically related to Sports, Recreation and Entertainment projects.

Renewable Portfolio Standards (RPS): is a regulation that requires the increased production of energy from renewable energy sources, such as wind, solar, biomass, and geothermal.

Whole Building Life Cycle Assessment (WBCLA:) is a methodology whose importance has been steadily growing in the construction industry, as a reliable way to assess the environmental impacts of a building through its whole life-cycle.

Zero Energy Building (ZEB): produces enough renewable energy to meet its own annual energy consumption requirements, thereby reducing the use of non-renewable energy in the building sector.

Zero Net Carbon (ZNC): An energy-efficient building that produces on-site, or procures enough carbon-free renewable energy to meet building operations energy consumption annually.

Zero Net Energy (ZNE): An energy-efficient building where, on a source energy basis, the actual annual consumed energy is less than or equal to the on-site renewable generated energy.

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