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FORD SITE ENERGY STUDY
BEST PRACTICES IN BUILDING DESIGN

RAMBØLL

Krifcon

ENERGY STUDY
BEST PRACTICES IN BUILDING DESIGN

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1. INTRODUCTION

The purpose of this memorandum is to answer Objective 1, Activity 3: Identify best practices in building design to reduce energy demand and strive for net zero emissions.

Some of the legislative and voluntary frameworks for designing low-energy and net-zero energy building projects in Europe and the U.S. are assessed.
We have provided examples of completed or near complete low-energy and net-zero energy projects to highlight that typical buildings can achieve net zero or low energy usage using currently commercially available methods and technologies.

In compliance with our brief, the team has chosen to look further into Danish and German systems to show different approaches in two countries known for their lofty energy efficiency and reduction ambitions, the mandatory and the voluntary. Though Germany does have rigorous mandatory requirements, they are also the origin of the Passive House system.

For the best practice in the U.S., the team has chosen to visit the typical code basis, the 90.1 standard in several versions including the current Minnesota code. Energy requirements of voluntary systems like LEED (Leadership in Energy and Environmental Design), Minnesota SB 2030 and more are based on the same 90.1 standard in one of its versions.

To give a sense of what the different codes and standards accomplish, the team has assembled and estimated typical total design energy use for a score of different building types. Where plug loads are not included in a given code or standard, other sources have been used to provide estimates hereof, so that comparisons are possible.

We touch upon the compatibility of these energy requirements to District Energy Systems, DES and finally we suggest a level of energy usage for the Ford site. This is used by the team as a basis for determining what kind of DES and technology is the best fit for the Ford Site as this is very dependent on the expected size of the energy demand.

2. MINNESOTA ENERGY CODES AND STANDARDS

Current energy codes for commercial and residential buildings in Minnesota are:

- Commercial: ASHRAE[1] Standard 90.1-2004 with MN Amendments
- Residential: 2006 IRC[2] with MN Amendments

In both cases, the U.S. Department of Energy (DOE) evaluates that the Minnesota specific amendments result in less energy efficient buildings than using either ASHRAE 90.1-2004 or 2006 IRC without the amendments.[3]

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[1] ASHRAE: American Society of Heating, Refrigeration, and Air-conditioning Engineers
[2] IRC: International Residential Code

Despite urgings from the DOE, the State of Minnesota has not implemented the 2009 IECC (International Energy Conservation Code) / ASHRAE 90.1-2007 or 2012 IECC / ASHRAE 90.1-2010 for commercial buildings yet. The same is the case regarding the 2009 IRC or 2012 IRC for residential buildings[4]. On September 26, 2014 the DOE issued a Determination Notice saying that States are required to certify that they have reviewed the provisions of their commercial building code regarding energy efficiency, and, as necessary, updated their codes to meet or exceed ASHRAE Standard 90.1-2013 /2015 IECC.[5]

The 2012 IECC / ASHRAE 90.1-2010 is expected to become the new energy code in Minnesota sometime in 2015.

For Minnesota State bonded projects, the energy code is augmented with the Sustainable Building 2030 Energy Standards (SB 2030) that requires a gradual reduction in carbon emission (Site Energy Utilization Intensity (EUI) is currently used as a proxy for carbon emission) starting in 2010 with 60% less than a 2003 code legal building of same location, type, and use, and ending with net-zero carbon emission in 2030. SB 2030 is a localized version of Architecture 2030's 2030 Challenge.

SB 2030 is voluntary to use for any other building project.

Table 1: Overview of current energy codes in Minnesota

Current Energy Codes / Standards	Commercial, civic, institutional incl. multi-residential	One and two-family houses and multi-residential 3 stories or less
Privately funded projects	ASHRAE 90.1-2004 incl. Amendments	2006 IRC incl. Amendments
State Bonded projects	SB 2030	N.A.
Federal projects	ASHRAE 90.1-2010	2009 IECC (and 30% better if cost-effective)

[3] https://www.energycodes.gov/adoption/states/minnesota
[4] https://www.energycodes.gov/sites/default/files/documents/MinnesotaDOEDeterminationLetter05312013.pdf
[5] https://www.energycodes.gov/determinations

3. BEST PRACTICES IN EUROPE

All the European Union's (EU) individual countries have different ways of eventually complying with the EU goal of having all new construction being nearly zero by 2021 as mandated by the Energy Performance of Buildings Directive, EPBD[6].

The national targets for low energy buildings in a group of selected European countries are shown below (Table 2).

Table 2: European Strategies to move towards very low energy buildings. Source: SBI (Danish Building Research Institute) plus other sources.

Country	Low energy target
Austria	Planned: Social housing subsidies only for passive buildings as of 2015 Since 2009, the city of Vienna has required all new single-family homes to be built with a maximum heating demand of 45 $kWh/m^2/yr$ (14.3 $kBtu/ft^2/yr$) without controlled ventilation and maximum 33 $kWh/m^2/yr$ (10.5 $kBtu/ft^2/yr$) with controlled ventilation. Some regions have stricter requirements and offers grants (up to € 28,000) for passive house standards.
Denmark	By 2020, all new buildings shall use 75 % less energy than currently enshrined in code for new buildings. Interim steps: 50 % less by 2015 , 25 % less by 2010 (base year=2006)
Finland	30 – 40 % less by 2010; Passive house standards by 2015.
France	By 2012, all new buildings are low energy buildings (Effinergie standard – average 30 $kWh/m^2/yr$ (9.5 $kBtu/ft^2/yr$) dependent on climate zone); by 2020, new buildings are to be energy-positive.
Germany	By 2020, buildings should be operating without fossil fuel. Some cities in Germany (such as Frankfurt) already require the Passive House Standard for all new buildings constructed on property purchased from the city. In May 2014 the EnEV 2014 provisions was passed which mandate a 25% reduction in primary (source) energy from 2016 compared to the reference building described in EnEV 2009. Among the revised requirements is also a 20% increase in insulation values.
Hungary	New buildings to be zero emission buildings by 2020, for large investments already in 2012
Netherlands	50 % reduction by 2015, 25 % reduction by 2010 both compared to current code plans to build energy-neutral by 2020

[6] http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm

UK (England and Wales)	All new homes from 2016 to mitigate, through various measures, all the carbon emissions produced on-site as a result of the regulated energy use. This includes energy used to provide space heating and cooling, hot water and fixed lighting. There are three core requirements which must all be met for a home to qualify as zero carbon: 1. The fabric performance must, at a minimum, comply with the defined standard known as the Fabric Energy Efficiency Standard (FEES) and 2. Any CO2 emissions that remain after consideration of heating, cooling, fixed lighting and ventilation, must be less than or equal to the Carbon Compliance limit established for zero carbon homes, and 3. Any remaining CO2 emissions, from regulated energy sources (after requirements 1 and 2 have been met), must be reduced to zero. Requirement 3 may be met by either deliberately 'over performing' on requirements 1 and 2 so that there are no remaining emissions, or by investing in Allowable Solutions. Allowable solutions can include a number of options such as supplying low carbon heat to neighboring sites through heat networks. In London, the London Plan requires all major new developments to plan for decentralized energy measures through a hierarchy of solutions involving connection to district heating networks.
Sweden	Total energy use / heated square meter in dwellings and non-residential buildings should decrease. The decrease should amount to 20 percent until 2020 and 50 percent until 2050, compared to the corresponding use of energy in 1995.

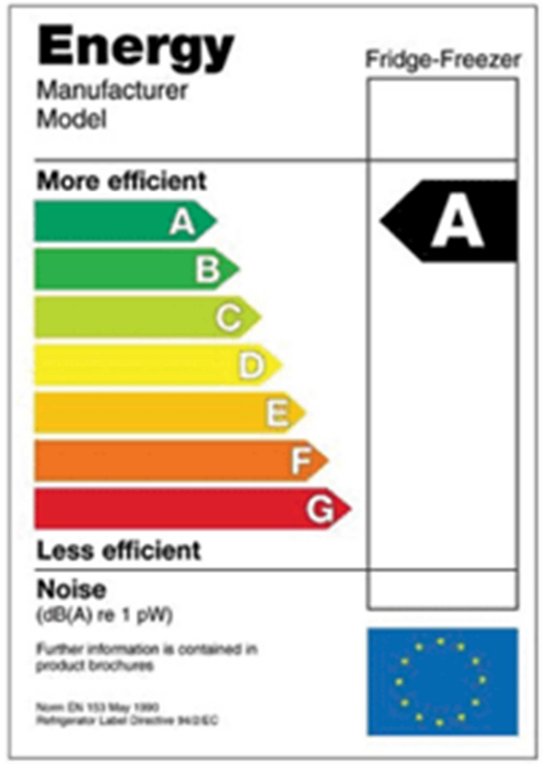
According to EPBD, a nearly zero-energy building is understood to be a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs.

Article 9.1 of the EPBD regulates that "Member States shall ensure that by 31 December 2020, all new buildings are nearly zero-energy buildings and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings."

In addition to the EU directive covering building energy use, another directive 2010/30/EU[7], which extends Council Directive 92/75/EEC for energy labels, targets energy consumption for appliances, light bulbs, air conditioning systems, and commercial products like cold storage rooms, and vending machines (i.e. plug loads).

Figure 1: Example of EU Energy Label



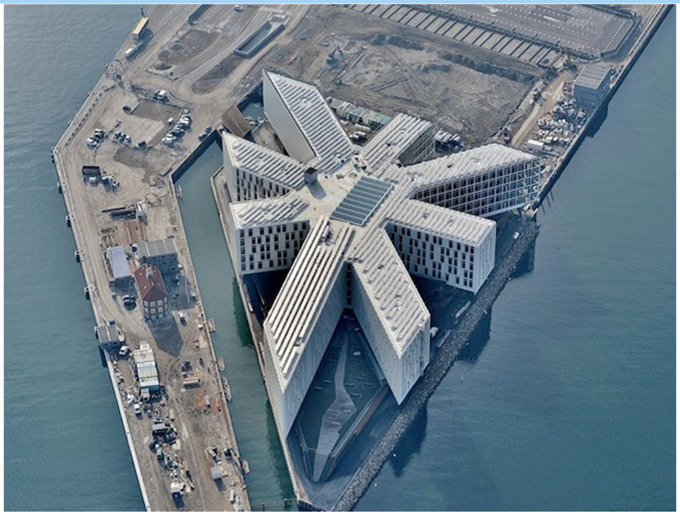
It is mandatory for all covered products sold in the EU to have this energy label. The aim is to make it very clear for consumers which products are energy efficient and very easy to compare products. Most EU member States offer some sort of incentive to people or companies that purchase the best-rated products to further encourage a shift to very energy efficient products. The last revision introduced three new top tiers, A+, A++, and A+++ as a consequence of the system's success in eliminating the worst performers and awarding the top performers.

The directive does not make it mandatory to buy a certain rated appliance, but it has gone a long way to remove the energy hogs within all encompassed product categories from the market. And as such helped curb the growth of the plug loads.

[7] http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/ecodesign/index_en.htm

3.1 Europe – Examples

Below are a few examples of European buildings designed to be low-energy, ultra-low energy, or net-zero site energy.

UN City Copenhagen Copenhagen, Denmark	Main Building Data	Other Information
 *Photo: FN-Byen P/S*	2014 Office building 544,000 ft^2 (50,500 m^2) Design site EUI: 34.9 $kBtu/ft^2/yr$ (110 $kWh/m^2/yr$) District Heating Harbor water cooling 360 kW_p PV system on roof	DK 2008 code Energy Class 1 2012 EU GreenBuilding Award LEED Platinum certification (v3)

Glødelampen Herlev, Denmark	Main Building Data	Other Information
 *Photo: Boligforeningen 3B*	2013 Multi residential 60,000 ft^2 (5,560 m^2) Design site EUI: 9.4 $kBtu/ft^2/yr$ (30 $kWh/m^2/yr$) District Heating	DK 2010 code Energy Class 2015

Carlsberg City District – Area 8 Copenhagen, Denmark	**Main Building Data**	**Other Information**
 *Rendering: Luxigon*	2016 *(expected)* Mixed-use building 869,000 ft^2 (80,668 m^2) Design site EUI: 25.6 kBtu/ft^2/yr (81 kWh/m^2/yr) District Heating and Cooling 200 kW$_p$ PV on the roof	DK 2010 code Energy Class 2015

Ramboll Head Office Copenhagen, Denmark	**Main Building Data**	**Other Information**
 *Photo: Mikkelsen Architects*	2010 Office building 500,000 ft^2 (46,500 m^2) Design site EUI: 35.5 kBtu/ft^2/yr (112 kWh/m^2/yr) District Heating Ground Water Cooling	DGNB Bronze certification

The Crystal Royal Victoria Dock, London	Main Building Data	Other Information
 *Photo: Traxon*	2012 Conference center 68,000 ft^2 (6,300 m^2) Design site EUI: 66.9 $kBtu/ft^2/yr$ (211 $kWh/m^2/yr$) Ground source heating & cooling Solar thermal & 300 kW_p PV on the roof	LEED Platinum certification BREEAM Outstanding certification

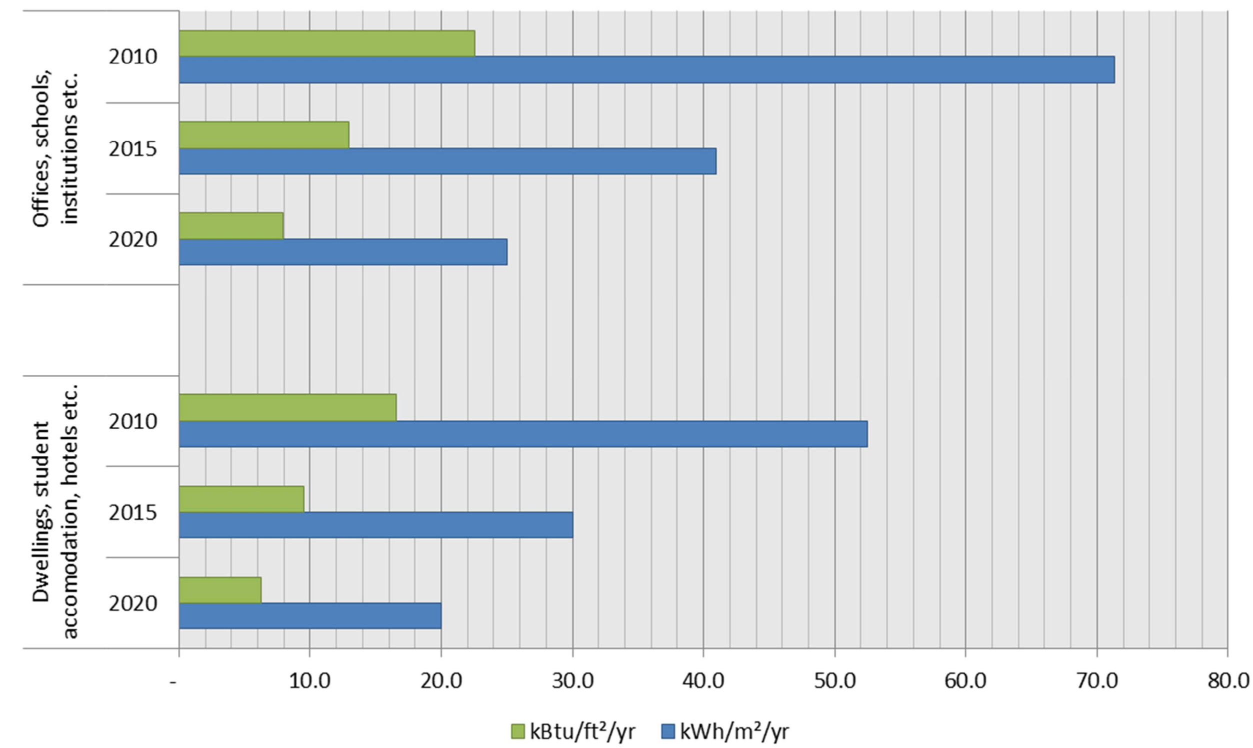
3.2 Denmark – Bygningsreglement 2010 (Building Code 2010)

All new buildings and major renovations in Denmark have to comply with the current building code (Bygningsreglement). Practically all of Denmark will fall within a climate zone similar to ASHRAE’s climate zone 5A (like Chicago, IL).

The current Danish building code (BR 2010) defines energy use as the total energy demand of the building for heating, ventilation, cooling, domestic hot water, and lighting per m² of heated floor area. For dwellings, student accommodations, hotels, etc. lighting is not included.

In order to assist the building industry plan for the continued strengthening of the maximum energy usage that are necessary to comply with EPBD’s 2021 goal of nearly zero energy buildings, the current code lists not only the current maximum requirement, but also the 2015, and 2020 iterations of the maximum requirements (See Figure 2 and detailed data below). It is voluntary to use the later requirements. However, municipalities can choose to mandate the 2015 or 2020 maximum requirements for a given area in a local plan.

Figure 2: Maximum Energy Usage in Buildings as required by the Danish Building Code in 2010, 2015, and 2020.



2010 Maximum energy usage

- Dwellings, student accommodation, hotels etc.: 52.5 kWh/m²/year plus 1650 kWh/year divided by the heated floor area (16.6 kBtu/ft^2/yr + 5,630 kBtu/yr divided by the heated floor area in ft^2.)

  Offices, schools, institutions etc.: 71.3 kWh/m²/year plus 1650 kWh/year divided by the heated floor area (22.6 kBtu/ft^2/yr + 5,630 kBtu/yr divided by the heated floor area in ft^2.)

Low energy class 2015 (Expected to become maximum energy usage in the coming 2015 building code)

- Dwellings, student accommodation, hotels etc.: 30 kWh/m²/year plus 1000 kWh/year divided by the heated floor area (9.5 kBtu/ft^2/yr + 3,412 kBtu/yr divided by the heated floor area in ft^2.)

- Offices, schools, institutions etc.: 41 kWh/m²/year plus 1100 kWh/year divided by the heated floor area (13.0 kBtu/ft^2/yr + 3,753 kBtu/yr divided by the heated floor area in ft^2.)

Low energy class 2020 (Expected to become maximum energy usage for public buildings in 2018 and all other in 2020)

- Dwellings, student accommodation, hotels etc.: 20 kWh/m²/year (6.3 kBtu/ft^2/yr)

- Offices, schools, institutions etc.: 25 kWh/m²/year (7.9 kBtu/ft^2/yr)

Electricity consumption from electrical devices (plug loads) are not included resulting in the building code ending up regulating a smaller and smaller part of the total energy use in buildings. This problem is currently being addressed to find a way of setting an upper limit to electrical consumption and encouraging very efficient and smart electronics that have a very low standby use or turn themselves off when not in use.

3.3 Germany – Passivhaus (Passive House)

In Germany, the focus is around Passive House. For a building to be considered a Passive House, it must meet the following criteria:

- The Space Heating Energy Demand is not to exceed 15 kWh per square meter of net living space (treated floor area) per year (1.4 kWh/ft^2 or 4.75 kBtu/ft^2) or 10 W per square meter peak demand.
  In climates where active cooling is needed, the Space Cooling Energy Demand requirement roughly matches the heat demand requirements above, with a slight additional allowance for dehumidification.

- The Primary Energy Demand (Source energy), the total energy to be used for all domestic applications (heating, hot water and domestic electricity) must not exceed 120 kWh per square meter of treated floor area per year (11 kWh/ft^2 or 38.10 kBtu/ft^2).

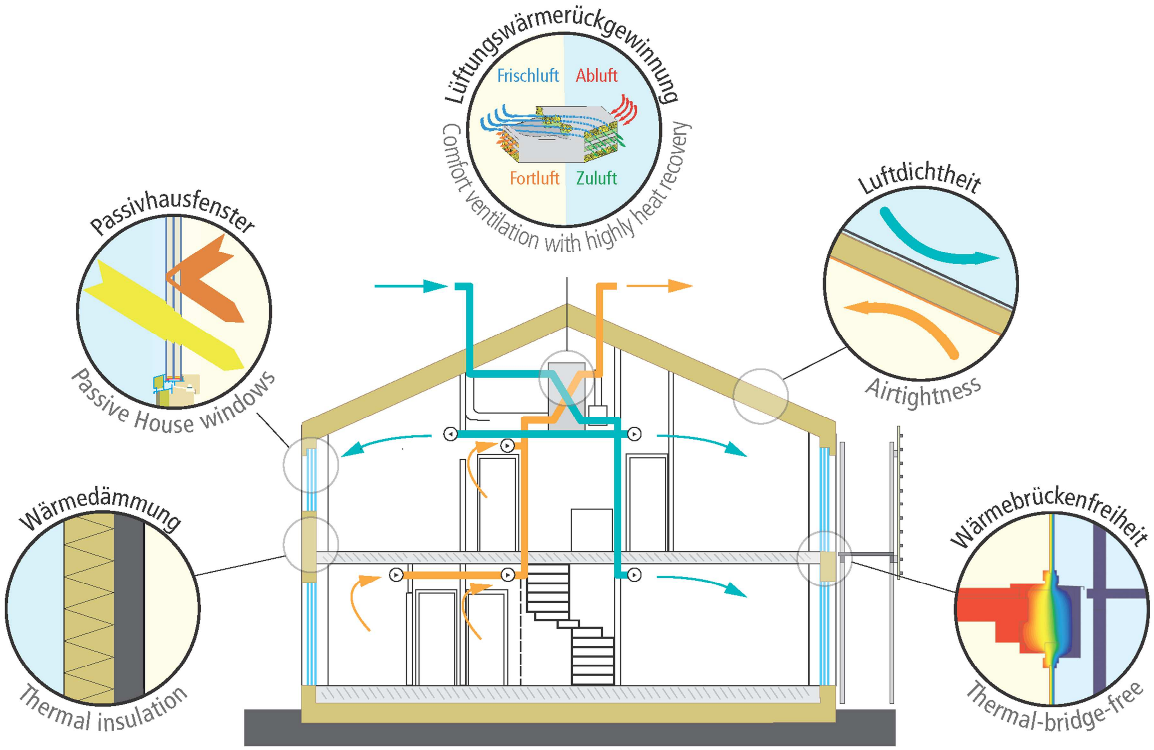
- In terms of Airtightness, a maximum of 0.6 air changes per hour at 50 Pascal pressure (ACH50), as verified with an onsite pressure test (in both pressurized and depressurized states).

- Thermal comfort must be met for all living areas during winter as well as in summer, with not more than 10 % of the hours in a given year over 25 °C (77 °F).

All of the above criteria are achieved through smart design and implementation of the five Passive House principles: thermal bridge free design, superior windows, ventilation with heat recovery, quality insulation, and airtight construction.

The following basic principles apply for the construction of Passive Houses:

Figure 3: Five Passive House Principles - Source: Passivhaus Institut



- *Thermal insulation*
  All opaque building components of the exterior envelope of the house must be very well insulated. For most cool-temperate climates, this means a heat transfer coefficient of 0.15 W/m²K (0.14 Btu/hr-ft^2-°F) at the most.

- *Passive House windows*
  The window frames must be well insulated and fitted with low-e glazing filled with argon or krypton to prevent heat transfer. For most cool-temperate climates, this means a U-value of 0.80 W/m²K or less, with g-values ~ 50%.

- *Ventilation heat recovery*
  Efficient heat recovery ventilation is key, allowing for a good indoor air quality and saving energy. In Passive House, at least 75% of the heat from the exhaust air is transferred to the fresh air again by a heat exchanger.

- *Airtightness of the building*
  Uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pascal.

- *Absence of thermal bridges*
  All edges, corners, connections, and penetrations must be planned and executed with great care, so that thermal bridges can be avoided. Thermal bridges that cannot be avoided must be minimized as far as possible.

Passivhaus considers plug loads in the sense that there is a total primary (source) energy limit including plug loads. In essence, it means that all appliances etc. needs to be very energy efficient, and thus having a high rating within the EU Energy Label system, comply with Energy Star, etc.

4. BEST PRACTICES IN THE U.S.

There are a number of systems available in the U.S. that promotes green and/or energy efficient buildings. Among those are Energy Star, LEED (Leadership in Energy and Environmental Design), Green Globes, Advanced Energy Design Guides, 2030 Challenge, Living Building Challenge, and Passive House.

Each of these has their pros and cons. Most widespread are Energy Star and LEED. Energy Star does not require much in terms of advanced energy efficiency measures. LEED (V4) offers more points if you use 30-50% less energy than a baseline building according to ASHRAE 90.1-2010, however if you are not aiming for the highest levels of LEED certification, then you can get away with just a 10% improvement. In all practicality, the same goes for Green Globes.

The latest Advanced Energy Design Guides provided by ANSI (American National Standards Institute)/ASHRAE/IESNA (Illuminating Engineering Society of North America) in partnership with American Institute of Architects (AIA), United States Green Building Council (USGBC) and DoE offers design guidance to achieve a 50% energy reduction compared to standard 90.1-2004 for a number of different building types.

The 2030 Challenge[8], and indirectly the Minnesota SB 2030[9] , requires a phased reduction in energy consumption of 60% in 2010, 70% in 2015, 80% in 2020, 90% in 2025, and carbon neutral in 2030. So far, site EUI is used as a proxy for carbon reduction, so in essence the 2015 requirement is 70% below the average energy consumption of a similar building in same region as found in EIA's 2003 CBECS (U.S. Energy Information Administration's 2003 Commercial Buildings Energy Consumption Survey) or in case of SB 2030, the 2015 requirement is 70% below a code legal building in 2003 (ASHRAE 90.1-1999). That is a significant reduction. However, it is a reduction from a quite high energy usage level, so not necessarily pushing the boundaries in the beginning.

Passive House[10] and Living Building Challenge[11] are both more rigorous in their energy requirements.

The Passive House system is basically a full North American adaptation of the German Passivhaus system and was introduced in the U.S. in 2007. Currently more than 120 buildings have received a Passive House certification from the Passive House Institute US (PHIUS).

Living Building Challenge's energy petal requires a net positive energy system. One hundred and five percent of the project's energy needs must be supplied by on-site renewable energy on a net annual basis, without the use of on-site combustion. Projects must provide on-site energy storage for resiliency.

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[8] http://www.architecture2030.org/2030_challenge/the_2030_challenge
[9] http://www.b3mn.org/2030energystandard/
[10] http://www.phius.org/home-page
[11] http://living-future.org/lbc

The International Living Future Institute also offers a Net Zero Energy Certification that requires one hundred percent of the building's energy needs on a net annual basis must be supplied by on-site renewable energy.

The Living Future Institute recently introduced a Living Community Challenge that looks at entire communities or campuses, which more easily allows for some larger district systems that can be shared. All energy has to be supplied on-site by renewable non-combustible sources.

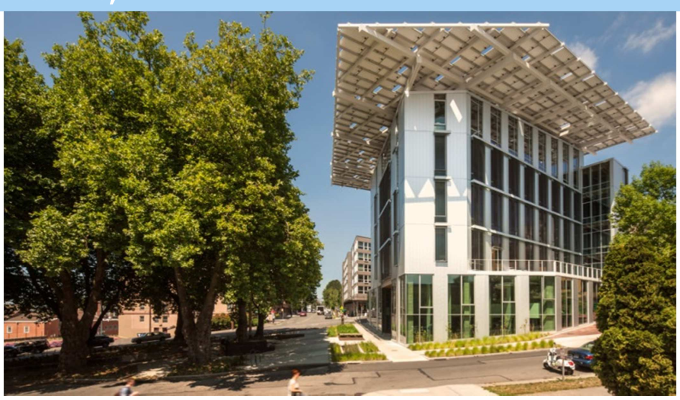
4.1 USA – Examples

Below are a few examples of United States buildings designed to be low-energy, ultra-low energy, or net-zero site energy.

NREL Research Support Facility Golden, CO	Main Building Data	Other Information
 *Photo: NREL*	Office building 360,000 ft^2 (33,500 m^2) Design site EUI: 35.1 kBtu/ft^2/yr (111 kWh/m^2/yr) 2.5 MW_p PV system on roof, guest parking lot and staff parking garage	Net zero site energy building LEED Platinum certification (v2.2 RSF I / v3 RSF II)

Brock Environmental Center Virginia Beach, VA	Main Building Data	Other Information
 *Rendering: Smithgroup JJR*	2014 Educational center and office 10,000 ft^2 (930 m^2) Design site EUI: 18.9 kBtu/ft^2/yr (59.6 kWh/m^2/yr) 39 kW_p PV system on roof 20 kW wind turbines	Net zero site energy building LEED Platinum certification (v3) Living Building Challenge certification (v2)

Bright'n'Green Brooklyn, NY	**Main Building Data**	**Other Information**
 *Photo: Scarano Architects*	2014 Multi Residential 15,000 ft^2 (1,400 m^2) Design site EUI: < 14.3 kBtu/ft^2/yr (<45 kWh/m^2/yr) Solar heating and 38 kW_p PV system on roof and facade	Net zero site energy building Passive House certification Living Building Challenge (v2) certification LEED Platinum certification Green Globe (4/4) certification NGBS Emerald certification

Bullitt Center Seattle, WA	**Main Building Data**	**Other Information**
 *Photo: Bullitt Center*	2013 Office building 52,000 ft^2 (4,800 m^2) Design site EUI: 16 kBtu/ft^2/yr (50.5 kWh/m^2/yr) Ground source heating and cooling 242 kW_p PV system on roof	Living Building Challenge (v2) certification

5. MODEL BUILDING ENERGY USAGE

The total site EUI for the model buildings shown in the table below (Table 3) are only indicative of that type of building's actual energy consumption. However, the same approximate models are used across all the calculations, so they are comparable within their own class. More detailed information about the calculations can be found in Appendix I, II, and III.

Actual energy consumption depends on the actual design, construction quality, maintenance, weather, and occupant behavior.

5.1 Methodology

In order to compare the energy efficiency level of the different codes, standards and systems on an equal footing, we show the total site Energy Utilization Intensity or EUI.
Plug loads are not included in the Danish Building Code, so we have estimated plug load values based on literature and published research of this. See appendix III

For buildings with a high process load and typical requirements for additional ventilation like a restaurant, hospital, etc., the Danish requirements do not easily and adequately consider those and likely underestimate the allowable EUI for these types of buildings.

For the Passive House requirements, a worst-case scenario of all other allowed source energy is grid-supplied electricity using an average US source energy multiplier provides us with a total site EUI.

For SB 2030 we have used the calculator provided at their website to arrive at current total site EUI values for the different building types. Later steps are reduced by the planned percentage. Values have since been verified by Center for Sustainable Building Research at University of Minnesota.

As a point of reference, using the latest LEED v4 rating system that utilizes ASHRAE 90.1-2010 as baseline, a Platinum certification would typically require all the energy points of the 'Optimize Energy Performance' credit (50% better than the baseline). That brings the energy requirement down to a point where it is better than SB 2030's 2020 requirement and the 2010 Danish building code requirement.

Table 3: Comparative site energy utilization intensity

Estimated Site Energy Utilization Intensity (EUI) for different new building types in climate zone 6A (St. Paul) using different energy codes or certification systems.

kBtu/ft²/yr

		~ Current MN Energy Code										
Code / Building Type	Prototype Floor Area (sf)	ASHRAE 90.1-2004	2012 IECC / ASHRAE 90.1-2010	2015 IECC / ASHRAE 90.1-2013	SB 2030 (2010) -60%	SB 2030 (2015) -70%	SB 2030 (2020) -80%	SB 2030 (2025) -90%	German Passive House System	Danish Building Code BR 2010	Danish Building Code Class 2015	Danish Building Code Class 2020
Small office	5,502	53.7	41.8	37.2	64.0	48.0	32.0	16.0	14.3	37.1	25.8	18.7
Medium office	53,628	62.2	46.2	42.8	60.0	45.0	30.0	15.0	14.3	36.1	25.2	18.7
Large office	498,588	99.7	84.8	83.5	60.0	45.0	30.0	15.0	14.3	36.1	25.1	18.7
Stand-alone retail	24,692	107.2	71.9	61.9	58.7	44.0	29.3	14.7	14.3	36.3	25.2	18.7
Strip mall retail	22,500	118.3	85.4	77.9	60.0	45.0	30.0	15.0	14.3	36.3	25.3	18.7
Supermarket	n/a	208.0	145.0	128.7	54.7	41.0	27.3	13.7	14.3	36.0	25.1	18.7
Primary school	73,959	100.1	75.1	67.8	68.0	51.0	34.0	17.0	14.3	36.1	25.1	18.7
Secondary school	210,887	98.4	64.7	56.2	58.7	44.0	29.3	14.7	14.3	36.1	25.1	18.7
Hospital	241,501	179.9	138.5	130.5	158.7	119.0	79.3	39.7	14.3	36.1	25.1	18.7
Outpatient health care	40,946	161.5	123.3	118.8	117.3	88.0	58.7	29.3	14.3	36.2	25.2	18.7
Full-service restaurant	5,502	570.2	470.9	450.8	96.0	72.0	48.0	24.0	14.3	37.1	25.8	18.7
Quick-service restaurant	2,501	781.9	723.0	689.6	105.3	79.0	52.7	26.3	14.3	38.3	26.6	18.7
Small hotel	43,202	87.4	75.8	71.5	84.0	63.0	42.0	21.0	14.3	28.5	19.6	15.0
Large hotel	122,120	151.8	119.1	109.4	88.0	66.0	44.0	22.0	14.3	28.5	19.5	15.0
Warehouse	52,045	35.3	25.2	23.6	40.0	30.0	20.0	10.0	14.3	36.2	25.2	18.7
Mid-rise apartment	33,741	68.0	60.4	57.3	101.3	76.0	50.7	25.3	14.3	28.6	19.6	15.0
High-rise apartment	84,360	72.1	65.8	61.2	105.3	79.0	52.7	26.3	14.3	28.5	19.5	15.0

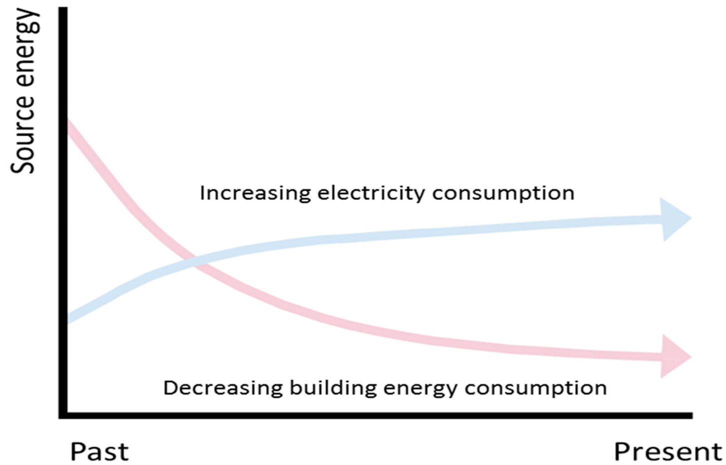
It appears that the different approaches around Europe and North America are moving in the same direction albeit with different time scales.

5.2 Plug loads

Traditional codes and standards offer control over the design and construction of the building related energy. However, there is not a very effective control over plug loads (except partly through the passive house and living building challenge systems), and with the continuing reduction of building related energy, the plug loads will become a larger and larger percentage of the total energy use that is not effectively controlled.

Plug loads are all the electricity used by appliances and electronic equipment that are not a fixed building installation, e.g. refrigerators, vending machines, televisions, computers, smartphone and tablet chargers, etc.
These plug loads are predominately controlled by a building's occupants, whether they are residents or workers. Consequently, it is very difficult to control the usage without treading into a sensitive sphere.

Figure 4: Effect of increased plug loads on total source EUI.



If nothing is done to curb the plug loads for the Ford site, it can be challenging to achieve the goal of net-zero because the reduced energy use by the buildings will be offset by the increased electricity consumption of appliances and electronic devices. Moreover, if this electricity is not from a renewable source, it will likely add to the CO_2, NO_X and SO_X emissions from the region's power plants.

5.3 Cost optimal

The Danish Building Research Institute published a report in 2013 titled "Cost-optimal levels of minimum performance requirements in the Danish Building Regulations"[12] . This report looks at the gap between the calculated cost optimal annual energy use for single-family housing, multi residential housing and office building and the estimated annual energy use calculated using the current 2010 code, Energy Class 2015, and Energy Class 2020. For multi residential and office buildings the cost optimal level is somewhere between the 2010 and 2015 requirements.

Considering that, the climate in Denmark is equal to zone 5A and St. Paul, MN is zone 6A the similar cost optimal result in St. Paul, MN having more cold days and thus using more heating energy, should move more towards the energy levels in Energy Class 2015.

Energy in Denmark is highly taxed and thus more expensive than in St. Paul, MN consequently influencing the results. The other side of the equation, however, the material and labor costs used to achieve the lower energy use, are also higher in Denmark than in St. Paul, MN. As such, the cost optimal level for St. Paul, MN is likely to be within the same range.

Given the above, we have used the "Cost-optimal levels of minimum performance requirements in the Danish Building Regulations" report as a guideline to determine the cost optimal recommendation for site EUI requirements for the Ford site development.

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[12] http://www.sbi.dk/miljo-og-energi/energibesparelser/cost-optimal-levels-of-minimum-energy-performance-requirements-in-the-danish-building-regulations

6. DISTRICT ENERGY SYSTEM COMPATIBILITY WITH NET ZERO OR LOW ENERGY BUILDINGS

How District Energy Systems, DES work with net zero emission goals depends on the frame work, code, standard, or other system that is or will be used. ASHRAE 90.1 works well with DES, and there exist well-used guidelines for how DES is modeled in a whole building energy simulation. Consequently, using LEED as a reference works equally well, as LEED's energy requirement is linked to ASHRAE 90.1 and the specific LEED requirements for DES are covered in a separate guideline.

Related to this, LEED also offer a Neighborhood Development certification (LEED ND), were the Green Infrastructure & Buildings category includes a credit that gives points for integrating a DES system into the neighborhood planning covering at least 80% of the projects annual heating and/or cooling consumption[13].

Living Building Challenge is somewhat more problematic in a DES connection in this site context. Living Building Challenge requires all energy to be produced on-site by non-fossil fuel. There are some openings for providing the energy as a district system, but all of it still has to be non-fossil fuel produced within the defined district.

Passive House requirements for heating and cooling are so stringent that the sum of energy in need of distribution is unlikely to be economically feasible to do as a district system. Similarly, the added cost of getting to the low heating and cooling loads are not always cost effective compared to the cost of DES delivered energy if done correctly.

Furthermore, from an environmental point of view, if a Passive House ends up using grid electricity as heating and cooling source, you have effectively replaced a low emission fuel source with source that typically uses about 3.3 times (US average) the energy to produce at the source.

The Danish Building Code generally works well with DES. There are several reasons for this, but mainly a political decision to promote DES, and thus integrate it into local planning and plans mandating the use of a DES. This decision is followed up by strict requirements as to what fuels are used at the CHP plants to produce the hot water or cooled water for heating and cooling respectively. Concurrently, there is a requirement in the building code to design for low-temperature district heating, which allows for using multiple sources of energy, including industrial waste energy, geothermal, heat pumps, and low-grade heat from other sources.

[13] http://www.usgbc.org/node/2612936?return=/credits/neighborhood-development/v4/green-infrastructure-%26-buildings

Table 4: Overview of cost-effective DES compatibility with building design requirement

	Good	Neutral	Poor
ASHRAE 90.1-2004		✓	
ASHRAE 90.1-2010		✓	
ASHRAE 90.1-2013	✓		
SB 2030 (2010)		✓	
SB 2030 (2015)		✓	
SB 2030 (2020)	✓		
SB 2030 (2025)			✓
Passive House			✓
Living Building			✓
DK Building Code	✓		
DK Building Code	✓		
DK Building Code			✓
LEED		✓	

To create the basis for a DES, it is imperative that a project arrives at an energy consumption for the area that is predictable and consistent for planning and design purposes. Which technologies are optimal, strongly depends on the sizing and phasing of the expected future loads.

To illustrate the range of energy consumption that the Ford site can be designed for, the two scenarios (2 and 5) are tentatively calculated using ASHRAE 90.1-2010 and SB 2030 (2025) respectively. For more information on the calculation and assumptions, see Appendix IV.

Table 5: Range of total site energy and district heating (DH) load for the Ford site

	Total site energy			DH part	DH load
REDEVELOPMENT SCENARIOS	MBtu/yr (Million Btu)	MWh/yr (Million Watt-hour)		MWh/yr (Million Watt-hour)	2,100 hrs/yr
2- Light Industrial/ Flex Tech					
2012 IECC / ASHRAE 90.1-2010	166,140	48,691		18,000	9 MW
SB 2030 (2025 requirement)	36,848	10,799		4,000	2 MW
5 - Mixed Use: Transit Village					
2012 IECC / ASHRAE 90.1-2010	140,037	41,041		18,000	9 MW
SB 2030 (2025 requirement)	42,839	12,555		6,000	3 MW

It becomes clear that the optimal technologies and solutions are different for a site using a district heating (DH) system designed for 2 MW or 9 MW.

7. CONCLUSION

The best practice in Europe and the U.S. are typically only best practice because the code and/or voluntary system work with, and are embraced by, the local design and construction industry. In other words, it is often better to focus on a well-known and tried system and improve the goals to achieve a successful outcome.

Based on the interest in pursuing a net zero solution for the Ford site, a cost optimal level, and the discussion during Technical Advisory Group meeting #2 and 3, we suggest that the Ford site energy requirement for buildings be set as a maximum site EUI equal to SB 2030's 2020 requirement, which is 80% below a 2003 code legal building of similar type, usage and location.
However, for residential buildings, we suggest a slightly increased requirement of 85% below SB 2030's baseline because the optimum for residential buildings are lower than SB 2030's 2020 (80%) requirement. In addition, a lower energy consumption requirement in residential buildings necessitate better construction materials, better joints, fewer thermal bridges in the building envelope, etc., that will increase thermal comfort for the residents as well.

The below table shows the suggested site EUI at the Ford site for the most common building types.

Table 6: Suggested Ford Site energy requirements for typical buildings

kBtu/ft^2/yr

Building Type \ Code	Prototype Floor Area (sf)	Suggested Ford Site Requirements	Percent below 2003 baseline
Small office	5,502	32.0	80
Medium office	53,628	30.0	80
Large office	498,588	30.0	80
Stand-alone retail	24,692	29.3	80
Strip mall retail	22,500	30.0	80
Supermarket	n/a	27.3	80
Primary school	73,959	34.0	80
Secondary school	210,887	29.3	80
Mid-rise apartment	33,741	38.0	85
High-rise apartment	84,360	39.5	85

In addition, we recommend that some elements of control of process and plug loads are included in the Ford site development requirements. It could be a strengthened requirement for plug load control and/or only Energy Star certified or better appliances to be installed.

For developers, commercial owners and tenants that means all computers, servers, monitors, printer/copiers, coffee machines, commercial food service equipment, etc. they install are Energy Star certified or better.

For homeowners and residential tenants, information that recommends only using Energy Star certified or better electrical equipment as well as timers, smart use, plug load controls, etc. needs to be provided.

In order to ensure that the above issues are implemented in the design of the buildings on the Ford site, some form of mechanism that can provide that needs to be considered. We suggest some form of binding requirement be integrated into the bid requirements to the master developer or as part of a funding scheme for the area.

One of the key elements of the Chicago Lakeside Development[14] project is the development of a Lakeside Green Building Code that among other things sets maximum values to construction element U-factors (or minimum R-values), site EUI, connection to DES, etc. In order to make this an attractive proposal, the Owner and Developer works with the City of Chicago to create a special zoning of the area that allows projects that follow the Lakeside Green Building Code to have a streamlined permitting process with a goal of getting a permit in 1 week. It is modeled on Chicago's Green Permit Program[15]. Perhaps something similar is possible for the Ford site?

[14] http://chicagolakesidedevelopment.com/

[15] http://www.cityofchicago.org/city/en/depts/bldgs/supp_info/overview_of_the_greenpermitprogram.html

Krifcon Engineering

Ford Site - St. Paul, MN

APPENDIX I

New Construction

Estimated Site Energy Utilization Intensity (EUI) for different building types in climate zone 6A (St. Paul)

kBtu/ft²/yr

	Prototype Floor Area (sf)	~ Current Minnesota Energy Code: ASHRAE 90.1-2004 [1)] National Average Site EUI			2012 IECC / ASHRAE 90.1-2010 [1) 2)]		2015 IECC / ASHRAE 90.1-2013 [2)]		SB 2030					
		National Average Site EUI	**Climate Zone 6 Average Site EUI**	Factor between National and Climate Zone 6A	National Average Site EUI	**Climate Zone 6 Average Site EUI**	National Average Site EUI	**Climate Zone 6 Average Site EUI**	2003 Baseline	2010 60% below	2015 70% below	2020 80% below	2025 90% below	2030 100% below
Small office	5,502	42.4	**53.7**	1.267	33.0	**41.8**	29.4	**37.2**	160.0	64.0	48.0	32.0	16.0	-
Medium office	53,628	49.5	**62.2**	1.256	36.8	**46.2**	34.1	**42.8**	150.0	60.0	45.0	30.0	15.0	-
Large office	498,588	84.5	**99.7**	1.179	71.9	**84.8**	70.8	**83.5**	150.0	60.0	45.0	30.0	15.0	-
Stand-alone retail	24,692	79.5	**107.2**	1.348	53.4	**71.9**	45.9	**61.9**	146.8	58.7	44.0	29.3	14.7	-
Strip mall retail	22,500	83.7	**118.3**	1.414	60.4	**85.4**	55.1	**77.9**	150.0	60.0	45.0	30.0	15.0	-
Supermarket [3)]	n/a	179.0	**208.0**	1.162	*124.8*	**145.0**	*110.8*	**128.7**	136.8	54.7	41.0	27.3	13.7	-
Primary school	73,959	80.1	**100.1**	1.250	60.1	**75.1**	54.2	**67.8**	170.0	68.0	51.0	34.0	17.0	-
Secondary school	210,887	72.9	**98.4**	1.348	48.0	**64.7**	41.7	**56.2**	146.8	58.7	44.0	29.3	14.7	-
Hospital	241,501	170.5	**179.9**	1.055	131.3	**138.5**	123.7	**130.5**	396.8	158.7	119.0	79.3	39.7	-
Outpatient health care	40,946	157.4	**161.5**	1.026	120.2	**123.3**	115.8	**118.8**	293.3	117.3	88.0	58.7	29.3	-
Full-service restaurant	5,502	471.2	**570.2**	1.210	389.1	**470.9**	372.5	**450.8**	240.0	96.0	72.0	48.0	24.0	-
Quick-service restaurant	2,501	653.6	**781.9**	1.196	604.4	**723.0**	576.4	**689.6**	263.3	105.3	79.0	52.7	26.3	-
Small hotel	43,202	73.3	**87.4**	1.192	63.6	**75.8**	60.0	**71.5**	210.0	84.0	63.0	42.0	21.0	-
Large hotel	122,120	123.5	**151.8**	1.230	96.9	**119.1**	89.0	**109.4**	220.0	88.0	66.0	44.0	22.0	-
Warehouse	52,045	25.5	**35.3**	1.381	18.2	**25.2**	17.1	**23.6**	100.0	40.0	30.0	20.0	10.0	-
Mid-rise apartment	33,741	52.1	**68.0**	1.304	46.3	**60.4**	43.9	**57.3**	253.3	101.3	76.0	50.7	25.3	-
High-rise apartment [4)]	84,360	55.3	**72.1**	1.304	50.4	**65.8**	46.9	**61.2**	263.3	105.3	79.0	52.7	26.3	-

1) "ASHRAE Standard Benchmark Energy Utilization Index", October 2009. Data updated with "Enhancements to ASHRAE Standard 90.1 Prototype Building Models", April 2014.

2) DOE Standard 90.1-2013 Final Dertermination Quantitative Analysis, March 2014. Specific climate zone data not available. Data generated using proportional factor from 1)

3) Data only exists for 2004. Approximated value for 2010 and 2013 generated based on retail characteristics

4) National climate zone data not available. Data generated using weights from 2)

5) Significant inconsistency between 2004 value and newer 2010 and 2013 values, mostly due to new requirements in 2010 version of 90.1.

Climate Zone [1]	Mid-rise [1)]	'eights by Zone
1A	39	3.24
2A	39	15.22
2B	38	2.98
3A	38	15.03
3B	36	10.08
3C	33	1.61
4A	42	19.29
4B	37	0.52
4C	38	2.98
5A	47	19.37
5B	41	4.34
6A	54	4.21
6B	48	0.57
7	59	0.51
8	76	0.06
		100.00
Sum Product	4,140.7	
National Weighted Average	**41.4**	

Ford Site - St. Paul, MN

Passive House system
Estimated Site Energy Utilization Intensity (EUI)

Maximum energy consumption for heating, cooling, and domestic hot water:	15.0	kWh/m2/yr
	4.8	kBtu/ft2/yr
Maximum total source energy	120.0	kWh/m2/yr
	38.1	kBtu/ft2/yr
If all other energy aside from heating and cooling is electrial, then total site EUI is:		
120 kWh/m2/yr - 15 kWh/m2/yr = 105 kWh/m2/yr (Source energy)		
105 kWh/m2/yr (Source energy) / 2.5 + 15 kWh/m2/yr =	57.0	kWh/m2/yr (Site)
	18.1	
If all 4.75 kBtu/ft2/yr is provided by hot water then the equal source EUI is	6.1	kBtu/ft2/yr (Source)
If all remaining energy is grid electrical then the remaining source EUI is	32.0	kBtu/ft2/yr (Source)
and the maximum grid electrical site EUI is	9.6	kBtu/ft2/yr
which means the total site EUI is	**14.3**	**kBtu/ft2/yr**
or	**45.2**	**kWh/m2/yr**

Table 1
Source-Site Ratios for all Portfolio Manager Fuels

Fuel Type	Source-Site Ratio
Electricity (Grid Purchase)	3.34
Electricity (on-Site Solar or Wind Installation)	1.0
Natural Gas	1.047
Fuel Oil (1,2,4,5,6,Diesel, Kerosene)	1.01
Propane & Liquid Propane	1.01
Steam	1.21
Hot Water	1.28
Chilled Water	1.05
Wood	1.0
Coal/Coke	1.0
Other	1.0

Ford Site - St. Paul, MN

Danish Building Code - BR 2010

Standard

Dwellings, student accommodation, hotels etc.: 52.5 kWh/m^2/year plus 1,650 kWh/year divided by the heated floor area.

Offices, schools, institutions etc.: 71.3 kWh/m^2/year plus 1,650 kWh/year divided by the heated floor area.

Low energy class 2015 (Expected to become minimum in the coming 2015 building code)

Dwellings, student accommodation, hotels etc.: 30 kWh/m^2/year plus 1,000 kWh/year divided by the heated floor area.

Offices, schools, institutions etc.: 41 kWh/m^2/year plus 1,100 kWh/year divided by the heated floor area.

Low energy class 2020 (Expected to become minimum for public buildings in 2018 and all other in 2020)

Dwellings, student accommodation, hotels etc.: 20 kWh/m^2/year

Offices, schools, institutions etc.: 25 kWh/m^2/year

Plug loads

Average DK family uses	5,200	kWh/yr in electricity each year in a 140 m^2 house.				
Of this lighting is	16%	or	832.0	kWh/yr ->	5.9	kWh/m^2/yr
Remaining is plug loads	84%	or	4,368.0	kWh/yr ->	31.2	kWh/m^2/yr

	2015	*2020*
Lighting energy for dwelling, dorms, hotels, etc. is considered proportional to building load reduction. Share compared to 2010.	57.1%	38.1%
Plug loads are expected to be reduced with significantly less. Share compared to 2010	90%	80%

Commercial plug loads in typical office buildings designed after BR 08 will use about 200 kWh/m^2/yr as primary (source) energy. Of this 79% is electricity according to a 2008 report from SBI (National Building Institute). 53% is plug loads, or as site energy: 42.4 kWh/m^2/yr

			2010					2015					2020				
	Prototype Floor Area		Code	Lighting 1)	Plug loads	Total		Code	Lighting 1)	Plug loads	Total		Code	Lighting 1)	Plug loads	Total	
Building Type	ft^2	m^2	kWh/m^2/yr	kWh/m^2/yr	kWh/m^2/yr	kWh/m^2/yr	kBtu/ft^2/yr	kWh/m^2/yr	kWh/m^2/yr	kWh/m^2/yr	kWh/m^2/yr	kBtu/ft^2/yr	kWh/m^2/yr	kWh/m^2/yr	kWh/m^2/yr	kWh/m^2/yr	kBtu/ft^2/yr
Small office	5,502	511	74.5	-	42.4	116.9	37.1	43.2	-	38.2	81.3	25.8	25.0	-	33.9	58.9	18.7
Medium office	53,628	4,982	71.6	-	42.4	114.0	36.1	41.2	-	38.2	79.4	25.2	25.0	-	33.9	58.9	18.7
Large office	498,588	46,320	71.3	-	42.4	113.7	36.1	41.0	-	38.2	79.2	25.1	25.0	-	33.9	58.9	18.7
Stand-alone retail	24,692	2,294	72.0	-	42.4	114.4	36.3	41.5	-	38.2	79.6	25.2	25.0	-	33.9	58.9	18.7
Strip mall retail	22,500	2,090	72.1	-	42.4	114.5	36.3	41.5	-	38.2	79.7	25.3	25.0	-	33.9	58.9	18.7
Supermarket	n/a	n/a	71.3	-	42.4	113.7	36.0	41.0	-	38.2	79.2	25.1	25.0	-	33.9	58.9	18.7
Primary school	73,959	6,871	71.5	-	42.4	113.9	36.1	41.2	-	38.2	79.3	25.1	25.0	-	33.9	58.9	18.7
Secondary school	210,887	19,592	71.4	-	42.4	113.8	36.1	41.1	-	38.2	79.2	25.1	25.0	-	33.9	58.9	18.7
Hospital	241,501	22,436	71.4	-	42.4	113.8	36.1	41.0	-	38.2	79.2	25.1	25.0	-	33.9	58.9	18.7
Outpatient health care	40,946	3,804	71.7	-	42.4	114.1	36.2	41.3	-	38.2	79.4	25.2	25.0	-	33.9	58.9	18.7
Full-service restaurant	5,502	511	74.5	-	42.4	116.9	37.1	43.2	-	38.2	81.3	25.8	25.0	-	33.9	58.9	18.7
Quick-service restaurant	2,501	232	78.4	-	42.4	120.8	38.3	45.7	-	38.2	83.9	26.6	25.0	-	33.9	58.9	18.7
Small hotel	43,202	4,014	52.9	5.9	31.2	90.1	28.5	30.2	3.4	28.1	61.7	19.6	20.0	2.3	25.0	47.2	15.0
Large hotel	122,120	11,345	52.6	5.9	31.2	89.8	28.5	30.1	3.4	28.1	61.6	19.5	20.0	2.3	25.0	47.2	15.0
Warehouse	52,045	4,835	71.6	-	42.4	114.0	36.2	41.2	-	38.2	79.4	25.2	25.0	-	33.9	58.9	18.7
Mid-rise apartment	33,741	3,135	53.0	5.9	31.2	90.2	28.6	30.3	3.4	28.1	61.8	19.6	20.0	2.3	25.0	47.2	15.0
High-rise apartment	84,360	7,837	52.7	5.9	31.2	89.9	28.5	30.1	3.4	28.1	61.6	19.5	20.0	2.3	25.0	47.2	15.0

1) Lighting is included in code requirement for offices, schools, instituitions, etc.

Ford Site - St. Paul, MN

Tentative Energy Calculation

		Residential units						Square Feet Other Uses			Total site energy		DH part	DH load
REDEVELOPMENT SCENARIOS		Single-Family	Town-home	Multi-family low density (3-10 units per building - 1 to 4 stories)	Multi-family med density (10-40 units per building - 4 to 8 stories)	Multi-family high density (40 or more units per building - 8 stories or taller)	TOTAL Resid. Units	Office/ Institu.	Retail	Industrial	MBtu/yr (Million Btu)	MWh/yr (Million Watt-hour)	MWh/yr (Million Watt-hour)	2,100 hrs/yr
2- Light Industrial/ Flex Tech		87	36	250	251	-	624	250,000	135,000	590,000				
2012 IECC / ASHRAE 90.1-2010	kBtu/yr	21,297,260	3,263,948	18,133,043	18,205,576	-	60,899,827	14,400,689	13,604,519	77,235,352	166,140	48,691	18,000	9 MW
SB 2030 (2025 requirement)	kBtu/yr	8,914,455	1,366,200	7,590,000	7,620,360	-	25,491,015	3,833,333	1,953,000	20,355,000	51,632	15,132	6,000	3 MW
5 - Mixed Use: Transit Village		-	-	300	730	320	1,350	375,000	194,000	-				
2012 IECC / ASHRAE 90.1-2010	kBtu/yr			21,759,652	52,948,487	24,177,391	98,885,530	21,601,033	19,550,197	-	140,037	41,041	18,000	9 MW
SB 2030 (2025 requirement)	kBtu/yr			9,108,000	22,162,800	9,715,200	40,986,000	5,750,000	2,806,533	-	49,543	14,519	7,000	3 MW

Average site EUI's for Office and Retail used.
Industrial is equaled to average health-care as no data for industrial is available.
Apartments in multiresidential buildings are estimated to be an average of 1,200 ft^2

Single Family homes and Town Homes would be covered by the 2012 IRC, but for this purpose is estimated using the 2012 IECC.
Average new single familiy home was 2,700 ft^2 in 2014 1Q. Site EUI for mid-rise used with a 50% addition. 90.7 $kBtu/ft^2/yr$ = 286.0 $kWh/m^2/yr$
Average townhouse is about 1,200 ft^2 per unit. Site EUI for Mid-rise used with a 25% addition. 75.6 $kBtu/ft^2/yr$ = 238.3 $kWh/m^2/yr$

It is likely that electrical plug loads are underestimated in the SB 2030 (2025) case, as most models assign a 25% addition to building loads for plug loads, but with significant reduction in building loads, this percentage will likely be too low.