Going Solar

Guidebook for Houses of Worship

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Introduction

"[W]hile the existing world order proves powerless to assume its responsibilities, local individuals and groups can make a real difference. They are able to instill a greater sense of responsibility, a strong sense of community, a readiness to protect others, a spirit of creativity and a deep love for the land."

–*P*ope Francis, Laudato si'

I began writing this guide with the analogy of a toolbox in mind. Planning a solar project requires certain tools to quantify social and environmental "goods," so it seemed a fitting metaphor. However, the toolbox analogy fails to convey the human dimension that gives each project its own context and purpose. Tools, like people, do not exist in isolation. To use a tired cliché, but one I like nonetheless, the sum of every project must be greater than its parts. For that reason, I consider this guide more a solar cookbook than a toolbox. This guide contains several "ingredients," all of which have been drawn from interviews and literature. While I understand that each congregation and project plan will be different, there are some noteworthy commonalities in the reports I have read and stories related to me by project planners. In writing this guide, I synthesized common themes to inform the solar decision tree and project time line.

I urge the users of this guide to engage with the congregation served by their solar project, not at the end, but at each and every decision point along the way. An inclusive project whose goals are clear and ethically grounded will promote more meaningful social change than one which is poorly communicated and alienates outsiders for their assumed technical "illiteracy." Projects by and for a congregation reflect group convictions and a sense of unity. More often than not, these projects are self-funded. Rather than viewing the need for congregational unity as a liability, an invested community is a tremendous strength. Whether it is a modest rooftop array or an energy park delivering tens of thousands of Watts, a solar project gives creative voice to the congregation because it is their convictions made manifest. With the support of all its members, a solar project visibly declares a congregation's commitment to society, environment, and a higher quality of life for all generations.

Definition of Key Terms

Climate change results from the human expansion of the "greenhouse effect"—warming that results when **greenhouse gases** in the atmosphere trap heat bouncing off the Earth from space. The increased concentration of greenhouse gases creates social and environmental problems like ocean acidification, rising average global temperatures and perturbation of weather systems, especially in the tropics.

Criteria pollutants are commonly found air pollutants including particle pollution (often referred to as *particulate matter*), ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. The United States Environmental Protection Agency (US EPA) identifies these pollutants as harmful to human and environmental health.

Distributed Generation refers to the generation of electricity on-site at the point of consumption, eliminating the need for transmission and distribution.

Fossil Fuels, such as natural gas, crude oil, and coal, formed in the geologic past from the remains of living organisms. When burned, these substances release energy as well as carbon, nitrogen and other elements that combine with oxygen in the atmosphere to form greenhouse gases or remain as microscopic particulate matter hazardous to human health.

Greenhouse gases block heat from escaping the Earth's atmosphere. Typical greenhouse gases include carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and water vapor. The combustion of organic material like coal and oil releases carbon and nitrogen which combines with oxygen in the air to create greenhouse gases. While the Earth has many "natural" sources of greenhouse gases, the added pressure of human industrial and agricultural activities has led to expansion of the greenhouse effect which results in climate change.

Investment Tax Credit (ITC) allows commercial, industrial, and utility owners of PV systems to take a one-time tax credit equivalent to 30% of qualified installed costs. The ITC is not available for non-profit organizations.

Net metering values electricity at the retail price whenever a customer's self-generation system produces more energy than the customer is consuming. Most utilities have a size limit for net metering.

Photovoltaic (PV) panels convert sunlight to electricity through the photovoltaic effect in which exposure to light generates an electric current. This guide uses the terms *PV* and *solar* interchangeably in reference to the panels that convert sunlight to electricity.

Renewable Energy Certificates (RECs) represent the collective environmental benefits, such as avoided mercury, carbon dioxide (CO_2), and other environmentally harmful pollutants, as a result of generating one megawatt-hour (MWh) of renewable energy.

2. How to Use this Guide

As a solar "cookbook," this guide walks through the process of planning a solar project for a house of worship. The steps outlined are not intended to replace the need for a professional consultant or contractor but to better facilitate group understanding and consensus prior to the hiring of technical experts. The intent of each "ingredient" is not to add an overwhelming soup of numbers and jargon, but to make the process clearer and the planning committee's job less difficult.

Software

This guide encourages planners to approach solar projects from many different perspectives, including an analytical one. No software program with a steep learning curve or that requires much prior knowledge has been included. Like much of this guide, this section is intended to provide additional resources and is not a requirement. An engineer or contractor will conduct a technical assessment when consulting for a solar project. However, it is recommended that anyone with a passion for solar examine the suite of programs created by the National Renewable Energy Laboratory (NREL), especially PVWatts and the System Advisor Model (SAM). PVWatts provides a straightforward, quick overview to provide congregation members with solid information when it comes to solar project planning.

All software items have been included in one of three appendix sections: technical assessment, finance, or environmental tools.

The Decision Tree and Project Flow Diagrams

This guide outlines the process of planning a solar project, from initial discussion in a congregational committee to the hiring of contractors to perform the installation. The project flow diagram illustrates how each step of the planning process fits into the overall project, while the decision tree presents a series of Yes/No questions with follow-up steps to be taken. This guide presents only one possible version of each graph but many more are conceivable. Each congregation differs in problem solving and group dynamics so an adaptive approach is strongly encouraged.

Use this guide as a template, but modify it as needed. Adaptation is a core principle of sustainability and one which any congregation can promote long before the first solar panel enters the property.

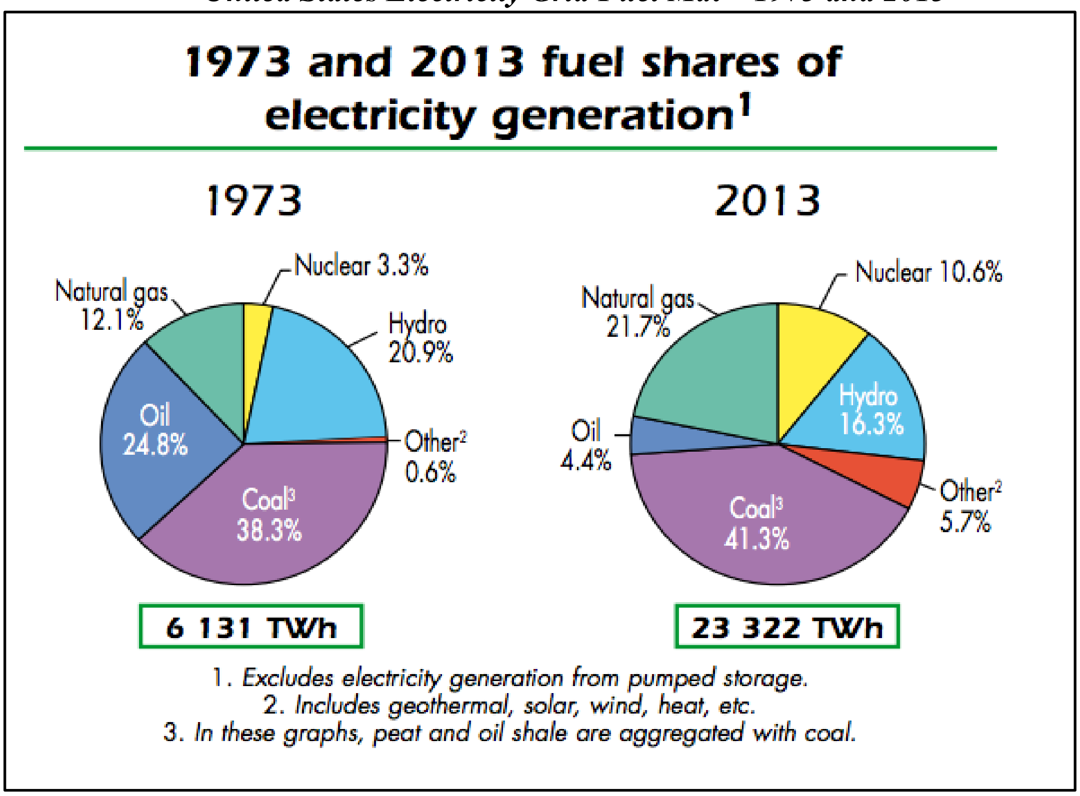
Case Studies

The research for this guide came from interviews as much as white paper reports. Included are case studies for two congregations in southern Michigan: Edgewood United Church of Christ in Lansing and Unitarian Universalist Church in Ann Arbor. Interviews with project planners from these congregations focused on project time lines to inform the decision tree and flow diagram mentioned previously. The case studies present concrete examples of several concepts discussed in this guide and are intended to inspire and inform future solar project planners.

Why Solar?

There are many reasons to adopt solar power: care for the environment in the form of climate change mitigation, pollution reduction, divestment from extractive industries and environmental justice are several that come to mind. To begin the discussion, it is important to consider the current system of electricity generation and distribution in the United States. The vast majority of plants that power the US electricity grid run on **fossil fuels** like coal and natural gas. Burning fossil fuels in power plants emits **greenhouse gases** and **criteria pollutants**, as well as depleting Earth's stock of nonrenewable fuels. Electricity supply occurs for the most part in real-time, as generators come on or off-line and consume more fuel to meet this demand. **Distributed generation** using clean energy sources like solar, wind and hydroelectric power reduces the consumption of grid electricity and associated emissions.

United States Electricity Grid Fuel Mix – 1973 and 2013



Source: http://www.iea.org/publications/freepublications/publication/KeyWorld_Statistics_2015.pdf

The chart above demonstrates the changes in electricity generation in the past forty-odd years, both in terms of fuel shares (%) and in annual energy generation (TWh). While oil as a fuel for electricity has largely been replaced by natural gas, generation from coal has increased slightly in percent, but dramatically in absolute terms—an estimated 9,632 TWh in 2013 compared to 2,348 TWh in 1973 (Over a three-fold increase). Such a trend is disturbing considering the emissions contributions of these different fuel types. The chart below from the US Energy Information Administration (EIA) relates fuel used by the electric power sector to related emissions of CO_2, the primary greenhouse gas responsible for climate change. Coal contributes more than double the CO_2 emissions of the other fuels combined.

CO_2 Emissions – US Power Sector

CO2 emissions from U.S. electric power sector by source, 2015

Source	Million metric tons	Share of total
Coal	1,364	71%
Natural gas	530	28%
Petroleum	24	1%
Other[3]	7	<1%
Total	1, 925	

[3]Other includes CO2 emissions from the combustion of miscellaneous fossil fuel wastes and some types of geothermal power generation.

Source: http://www.eia.gov/tools/faqs/faq.cfm?id=77&t=11

Care for the environment has led Michigan congregations to seek out ways to mitigate climate change, including energy efficiency upgrades to their houses of worship and installing new sources of clean energy, like solar PV. Edgewood United Church of Christ (UCC) in Lansing, featured in one of the case studies in this guide, plans to install a solar array on the rooftop of their house of worship as part of its ongoing effort to reduce its greenhouse gas emissions. Visibility also plays a role in Edgewood UCC's adoption of solar. Solar panels create a visible statement to the congregation and community. It is faith in action and testament to the church's concern for environmental and social well fare. When asked, Jim Detjen of the congregation's environmental taskforce said, "It was the right thing to do."

Greenhouse gas emissions are sometimes falsely portrayed as a "future" problem, but criteria pollutants like SO_x, NO_x, mercury, lead and particulate matter certainly are not. There can be no doubt that these criteria pollutants represent a serious environmental and social concern at home in the US and at present. The appendices contain statistics published by the US Environmental Protection Agency (EPA) detailing emissions of different pollutants by fuel type. In the interest of time, here is the summary: energy resources which are seen now as economically cheap, like coal, are socially and environmentally costly due to the externalities not factored into their current market value. The industrial scale of extraction, processing and distribution destroys ecosystems and creates harmful relationships between the powerful extractors and the disempowered people whose land and water are polluted and destroyed for the cause of so-called "cheap" energy.

In addition to emissions reductions, solar panels provide a means to produce one's electricity locally. Solar, and other forms of distributed generation, decrease reliance on large power plants. Not only do these plants pollute the air and water with substances deleterious to the health of humans and wildlife, they also concentrate power and wealth in extractive industries. A congregation that is interested in developing the local community and divesting from fossil fuels would do well to consider distributed generation using clean sources of power. The purchase or refusal to purchase goods and services, including electricity, sends market signals to those who follow trends in electricity usage, which in turn informs development of infrastructure and energy policy. Distributed generation in the form of solar not only reduces emissions, it can be influential when coupled with a strong environmental message delivered by the people.

Conclusions on climate change are near unanimous, a rarity in the scientific world. It is no longer tenable to act as if we humans through our actions do not impact the Earth's climate on a biological time scale. This agreement comes not just from the scientific community—many faith-based and governmental organizations share this sentiment—demonstrated in the recent Conference of Parties (COP) 21 in Paris. Such a consensus is a call to action. Instead of simply feeling guilty about the carbon footprints of our affluent Western life styles, we should *act* in a way that results in positive social and environmental change. As a conscious, intelligent species, we ought to use those abilities and privileges for the betterment of our "shared home," for present and future generations.

For houses of worship across faith traditions, there are social and environmental justice issues tied into the mitigation of climate change and reduction of criteria pollutants. All too often, it is the poor and disempowered that are hit hardest by environmental degradation.

However, the affluent consumers of the greatest portion of the Earth's fossil fuels have historically done little to aid those negatively impacted by the consequences of this consumption. This July, the African Methodist Episcopal (AME) Church released a Climate Change Resolution with a clear message: climate change and social justice are interlinked. At home, a disproportionate number of low income communities and communities of color live near coal-fired power plants and black children are twice as likely to be hospitalized and die from asthma than white children. Abroad, Africa and the rest of the developing world are "…most vulnerable to the adverse impacts of climate change including floods, droughts, increased spread of infectious diseases, and changing weather patterns that challenge their ability to provide food and livelihood."

In *Laudato si'*, Pope Francis asks us to consider our relationships with society and the environment. Many of his words echoed Quaker thinker Kenneth Boulding who described the perils of a finite planet as early as the mid-sixties. Both would agree that in our haste to use Earth's resources we too often justify the abuse and neglect of other people and the natural world. Progress dependent on the consumption of raw resources is time limited, for we live on a finite, physical world. Even if we could divorce ourselves from this world, as some have suggested, the energy and materials as well as the minds needed to power those technologies would come from Earth. Thus, we must acknowledge not only the fragility of our world but also its necessity and beauty. Let us not be under the illusion that installing one array of solar panels will reverse the accumulation of centuries of industrial pollutants and the destruction of countless natural systems. However, this small act to offset emissions is a step towards building a more just society.

"When we accept that we are part of a great human family… then we will sit, talk, make peace. I pray that this realization will spread throughout our troubled world and bring humankind and the earth to its fullest flowering." –Maha Gosandra, Buddhist Teaching

"The world is green and beautiful, and Allah has appointed you as His stewards over it."
–Prophet Muhammad, Quran

"It is no longer enough, then, simply to state that we should be concerned for future generations. We need to see that what is at stake is our own dignity. Leaving an inhabitable planet to future generations is, first and foremost, up to us." –Pope Francis, Laudato si'

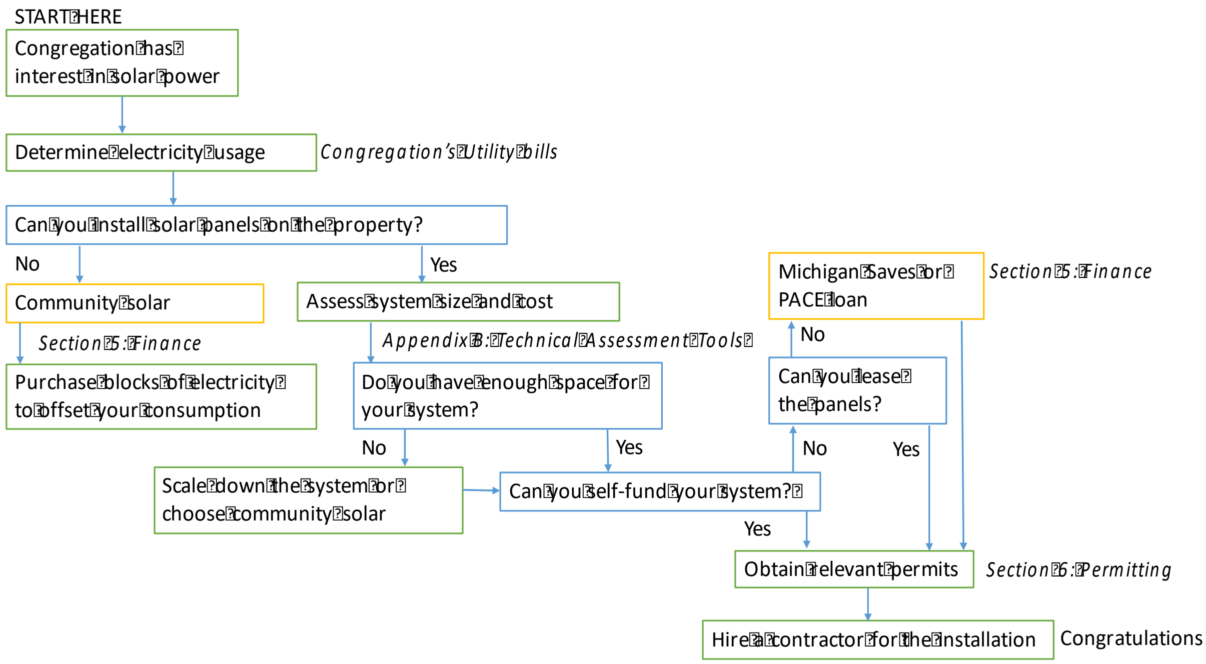
"The earth is but one country, and mankind its citizens." –Baha'u'llah, Bah'ai Teaching

4. Getting Started

Solar Decision Tree

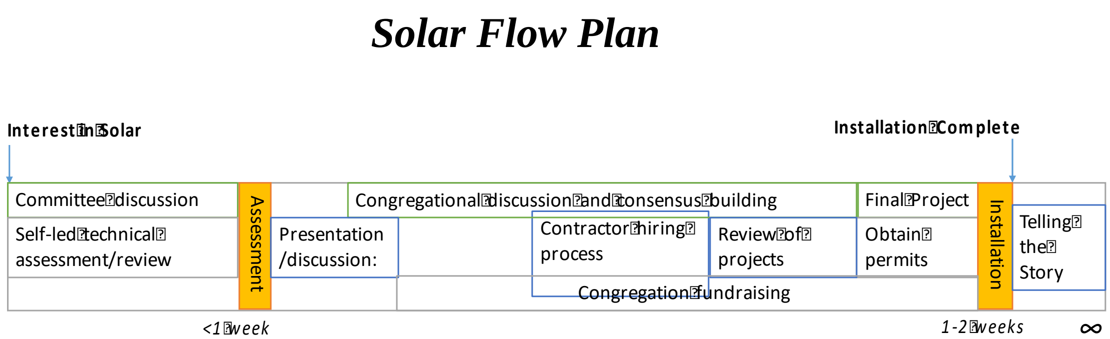
The decision tree identifies a series of questions project planners can ask themselves and their congregation to aid in project selection and determine which actions should be taken next. In planning, users of this guide can refer to both this decision tree and the flow diagram (next page).

Solar Decision Tree for Congregations



Sample Solar Flow Plan

The flow plan represents a series of parallel actions to be taken starting from the first committee discussion to the installation of the solar panels and tracking of the system. Expected times for standard steps like the professional assessment and solar installation have been included—other steps will take vastly different amounts of time depending on the congregation and solar company.



Committee Discussion

A good place to begin the planning process is by creating a small group or committee dedicated to the solar project. To inform the greater congregational conversation about solar power, this planning committee should work collectively to answer questions of technical and financial feasibility as well as community outreach and engagement. Anticipating what the congregation will ask in the larger discussion can help focus efforts as the committee goes through the steps of developing the case for solar. I recommend that the planning committee begin the discussion by first addressing the "why" of solar. Coming to a consensus on the committee's reasons for going solar is a fundamental first step that will guide future decisions and help build enthusiasm for the project.

Self-led Technical Assessment

A technical assessment can include factors like shading, orientation, roof space and solar insolation. Professional consultations should provide much if not all of the information needed to either validate or reject a project from a technical standpoint. However, the discussion need not be hindered by waiting for a formal technical assessment. Nearly all the software tools mentioned in the appendix of this guide are free and easy to learn. Interested members of the planning committee can thus use these tools to "pre-screen" proposed projects well before the professional consultation. An initial, self-led assessment is a quick way to get the discussion started and develop the case for solar.

Professional Evaluation/assessment

After the congregation or sub-committee is willing to move forward, then the formal technical assessment can provide confirmation or bring new ideas to the discussion. Some companies offer site evaluations and should be contacted as soon as possible. Please refer to the list of solar installation companies operating in Michigan for the evaluation and contractor hiring process.

Presentation of Findings

If the planning committee has not yet engaged the greater congregation by this point, it will be necessary to share the committee's findings and address any questions posed by individual members. After the technical assessment, the planning committee should work together to build the case for solar and share their enthusiasm for the project with the rest of the congregation.

Congregational Consensus Building

Depending on the size of and personalities within the congregation, the process of building consensus will be among the longest steps in the project timeline. It should be stated that unlike some of the more finite processes like technical assessments and obtaining permits, building consensus should be an ongoing process. There might be multiple times during the project timeline where either the planning committee or the larger congregation meet to discuss progress and make sure the group is comfortable with what has been done and the direction of the project. This ongoing conversation should be expected and embraced as fundamental to any decision representing the greater congregation.

Fundraising

Another lengthy process will be the ongoing campaign for funds. For each congregation, the planning committee or a separate fundraising committee should spearhead this effort through creative fundraising to engage donors and involve them in the project in some way.

The First Unitarian Universalist (UU) Congregation of Ann Arbor had a novel approach to fundraising in which the energy committee sold landscape tiles with inscriptions. Members dedicated tiles to their loved ones and parents as well as children and grandchildren, fitting for a project that seeks to ensure a bright future for generations to come. Proceeds from the donation campaign went toward roof-mounted solar panels, a small wind turbine, and a ground-mounted solar array with tracking. The tiles are now a feature of the congregation's energy plaza. The landscape tile campaign asked members to contribute but also gave them some visible token of their investment in the project.

Contractor Hiring and Project Proposals

There are now almost fifty Michigan-based companies that conduct solar installations. Congregations that have gone solar like UCC Edgewood relied mostly on word-of-mouth to aid their search. The case studies provide the names of companies that worked well for both congregations. In the appendices I have included a list of currently active solar contractors in Michigan.

Part of the decision process will be a review of contractor proposals. Here, it will be best to compare the scale of the proposed project with the congregation's energy usage, available funds and the results of the preliminary technical and financial assessments conducted by the planning committee. At this point, having already answered questions like "What size system do we need and can afford?" will keep the conversation grounded in reality.

Before any final decisions can be made, the planning committee should meet and reach consensus. The committee should then present their decision to the congregation. Ideally, the congregation will seek consensus before settling on the contractor and finalizing any of the project details.

Installation

This process should be relatively short compared to the extensive planning, discussing, and fundraising that were required to reach this point. Expect an installation time of a few weeks of intermittent work.

Tracking and Telling the Story

The journey continues long after the solar panels have been installed. By this point, the solar project is now part of the congregation. Telling the story of that project is an important step in informing and helping others. Whether it serves as inspiration for future work or simply a way of recording congregational history, someone will have to remember and communicate to others the reasons behind the project.

After completing its combined solar and wind energy project, First Unitarian Universalist Congregation of Ann Arbor (UUAA) continues to monitor the installed system's electricity generation and posts the data on its website, www.uuaa.org/e. Now, anyone can observe the results of UUAA's energy project, as well as read more about the energy system's specifics and the history of the project.

With hope, the success stories of individuals and communities will encourage others and inspire a new, socially, and environmentally conscious generation. It will be hard but essential work hard to preserve our shared home and every success is worth sharing.

5. Finance

Finance looks at the movement of money from the present to the future. Using simple financial formulae, projects can be compared and selected based on economic merit with indicators like return on investment (ROI) and net present value (NPV). Rather than proposing an overhaul or complete rejection of financial decision making, we suggest incorporating finance into the project selection process alongside technical, environmental, and social considerations. Finance will rarely be the "why" a congregation adopts solar, but it should be seen as the "how." Even as early as the committee stage of discussion, congregation members would do well to consider how the congregation will pay for the solar project and estimate the savings in energy and cost. Early discussion of such questions will help refine the scope of a project and clarify the plan to the rest of the congregation.

Property Assessed Clean Energy (PACE)

Property Assessed Clean Energy, or PACE, covers the upfront costs of a project through a private loan paid via a special assessment on the owner's property taxes over the next 10-20 years. Lender consent is required and the minimum project size is $10,000. PACE complements Michigan Saves because it can cover greater sizes of loan and accommodates hybrid projects, like a combination of rooftop solar PV and energy efficiency upgrades.

There are two PACE programs active in Michigan: Ann Arbor PACE and Lean & Green Michigan. Both programs are aimed toward commercial properties but any non-residential property, such as a house of worship, may be eligible. Contact the local PACE administrator (information below) to determine eligibility.

Lean & Green Michigan

- Available for commercial projects; loan covers upfront costs while paying back through assessment on property taxes for 10-20 years; Lender consent is required. Minimum project size is $10,000.
- Counties: Macomb County, Wayne County, Washtenaw County, Genesee County, Huron County, Saginaw County, Bay County, Ingham County, Montcalm County, Eaton County, Kalamazoo County, Calhoun County, Grand Traverse County, Antrim County, Leelanau County, Delta County, Marquette County, Houghton County
- Cities: Troy, Southfield, Royal Oak, Pleasant Ridge, Ferndale, Rochester
- Commercial, Industrial, Nonprofit, Multifamily Residential, Institutional

- Eligible Renewable Energy Technologies: Solar Water Heat, Solar Space Heat, Solar Photovoltaics, Wind (All), Biomass, Geothermal Heat Pumps, Combined Heat & Power, Landfill Gas, Wind (Small), Geothermal Direct-Use
- Eligible Energy Efficiency Technologies: Lighting, Chillers, Furnaces, Boilers, Heat pumps, Air conditioners, Heat recovery, Energy Mgmt. Systems/Building Controls, Caulking/Weather-stripping, Duct/Air sealing, Building Insulation, Windows, Roofs

For more information, visit http://leanandgreenmi.com/

Ann Arbor PACE

- Available in the city of Ann Arbor
- Project costs: $10,000-$350,000, not to exceed 20% of the property's State Equalized Value
- Lien to value of the property cannot exceed 99% of twice the State Equalized Value
- Eligible Renewable Technologies: Geothermal Electric, Solar Thermal Electric, Solar Photovoltaics, Wind (All), Biomass, Hydroelectric, Geothermal Heat Pumps, Landfill Gas, Wind (Small), Geothermal Direct-Use
- Eligible Efficiency Technologies: Clothes Washers, Dishwasher, Refrigerators/Freezers, Dehumidifiers, Ceiling Fan, Water Heaters, Lighting, Chillers, Furnaces, Boilers, Heat pumps, Air conditioners, Programmable Thermostats, Energy Mgmt. Systems/Building Controls, Caulking/Weather-stripping, Duct/Air sealing, Building Insulation, Windows, Roofs, Other EE, Reflective Roofs

For more information, visit http://a2energy.org/.

Solar Leasing

Many companies now offer a short-term lease on the solar panels, after which point the congregation can opt to purchase their solar array outright or continue leasing. This financial model is worthwhile for the company because it is able to capture the **investment tax credit** as well as receiving payments on interest. This option may be suitable for a congregation that needs time to raise the requisite funds to cover the costs of the system fully. Check with the solar installer to see if this option is available.

Power Purchase Agreement

A solar company, or third-party entity, may also provide a Power Purchase Agreement (PPA) to an interested buyer. In this case, the power purchaser agrees to pay the owner of the solar panels at a fixed rate for a period of time, with the excess energy demand met by the utility. As part of the arrangement, the "customer" may arrange for the panels to be installed on his or her property, although the third-party entity technically owns them. This type of contract may be desirable for both parties because the investment tax credit will lower the overall system costs, which in turn allows the owner to build a larger system to provide more energy savings or simply lower upfront expenses.

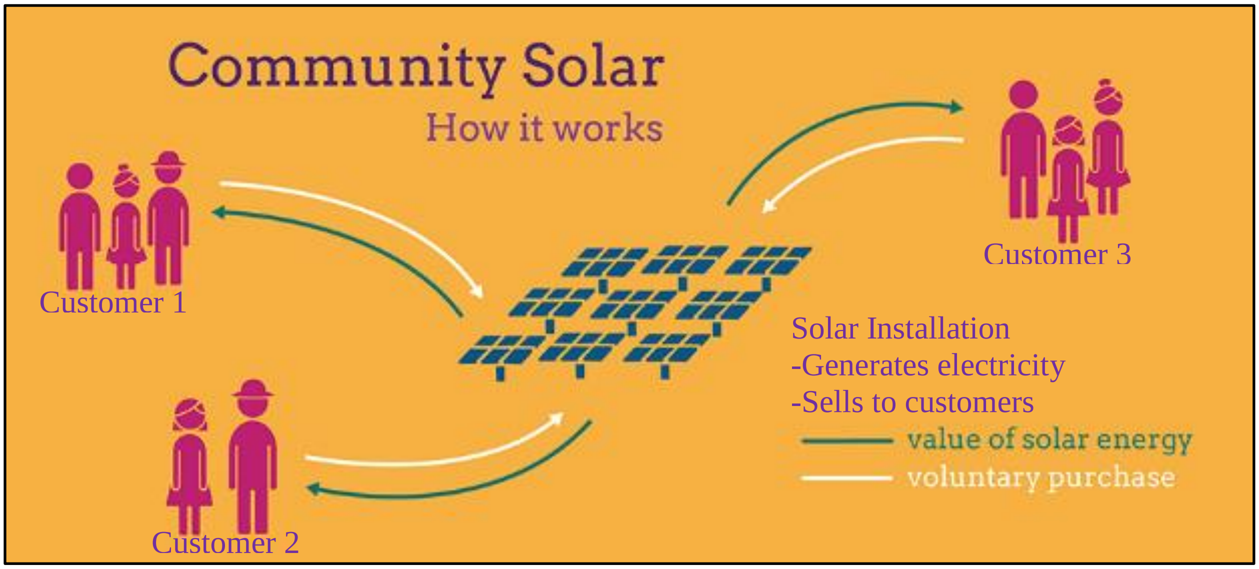
Private Loans

Banks and lending companies can provide a private loan for solar panels. Companies with specific solar lending programs that operate in Michigan include: Admirals Bank, Dividend Solar, Renewable Asset Management Company. Check with lenders to see if they offer this special type of loan.

Community Solar (CS)

Not all congregations will have the option of an on-site solar installation. Funding, physical constraints, or other complications can stymie development. However, that doesn't need to be the end of the discussion if the congregation is serious about solar power. Community solar is a growing option for those unable to install an array on the house of worship's property but who remain interested in offsetting their congregation's electricity consumption and associated environmental impacts.

In general, community solar programs work in the following way: a third party such as a utility or private company owns the solar array and sells monthly subscriptions in units of electricity to interested customers. Customers purchase some quantity of energy which will be credited to their monthly utility bill. The exact quantity credited depends on how much solar energy a customer buys from the community solar facility, as well as its value. Under net energy metering, solar energy is valued at retail price, so the amount a customer purchases yields an equivalent amount credited to his or her utility bill.



Modified from: https://www.energysage.com/solar/community-solar/community-solar-power-explained

Utility-sponsored CS

One advantage of the utility-sponsored model of community solar, where it exists, is its simplicity. Utility shared or community solar programs sell the rights to electricity produced by a specific solar installation. For either an up-front or ongoing payment, utility customers receive a monthly credit on their electricity bill proportional to their contribution as well as that solar system's generation over the given period. Community solar differs from the traditional "green power" pricing schemes in which utilities sell Renewable Energy Credits (RECs) to interested customers.

Non-Utility-sponsored CS

Currently, only utility-sponsored models of community solar exist in the state of Michigan. However, other models of community solar exist in other states and seem to be growing in support.

One financial model of community solar includes the Special Purpose Entity (SPE) model in which community organizers choose to structure the installation as a business and sell rights to the electricity generated by the solar system. Benefits can be dispersed to participating members in the form of credits or sometimes direct payments.

Alternatively, a nonprofit model exists in which local citizens help finance the installation through tax-deductible donations. Unlike other community solar models, in which contributors receive credits proportional to their payment and the system's generation, only the nonprofit benefits directly in the form of energy savings.

Community Solar in Michigan

Community solar projects are nascent but appear to be growing. Publicly owned and co-operative utilities lead in number of new community solar projects. Utilities offering community solar options or are working to develop them are listed below.

Cherryland Electric Cooperative

Solar Up North (SUN) is a community solar project that was launched in April 15, 2013.The initial shares cost $470 to members, who receive a credit on their energy bill proportional to electricity generation. Cherryland has expanded their SUN project to a 144-panel system. Despite the expansion, the SUN program is fully subscribed. To request placement on their waiting list, contact: https://cherrylandelectric.coop/contact/.

Lansing Board of Water and Light (BWL)

Plans were announced in October 2015 to develop two solar parks in East Lansing's Burcham Park, a retired landfill site, and in South Lansing. Each site is expected to have a capacity of 300 kW electric power. Said BWL: "Participants in the BWL program will be able to lease a panel, or panels, for 25 years and receive credit on their BWL electric utility bill for the solar power their lease produces. The lease cost for a 300-watt solar panel is $399."

The pre-registration site is up at micommunitysolar.org. After almost a year, the project has not yet reached its target number of lessees. Construction is scheduled at Burcham Park and South Lansing once 80% of the available solar panels have been leased. If these parks do not achieve their goal of leased panels, all participating customers who have pre-registered will have their money refunded.

Consumers Energy Solar Gardens

Consumers Energy owns two different community solar parks at Grand Valley State University and Western University. Program customers can subscribe in increments of 500 W "solar blocks" to earn energy credits at a cost of $10 per block purchased. Monthly billing will vary because the blocks are earned against a subscriber's energy usage. The program is open to enrollment from new subscribers. More information about the program can be found here: https://new.consumersenergy.com/residential/renewable-energy/solar-gardens

Issues with Community Solar

While gaining support and popularity, at present community solar is not a solution for every congregation in Michigan. Constrained by geography and program availability, only those congregations in serviced locations are eligible, and only if there are solar panels or "blocks" available for purchase. However, the waiting list for Cherryland suggests reasonable demand and may spark interest in future community solar projects. With time, it seems likely to expect more projects, either because of utility action or the result of third party development. However, that period is not at all clear, making CS less appealing for congregations seeking to move quickly on solar power.

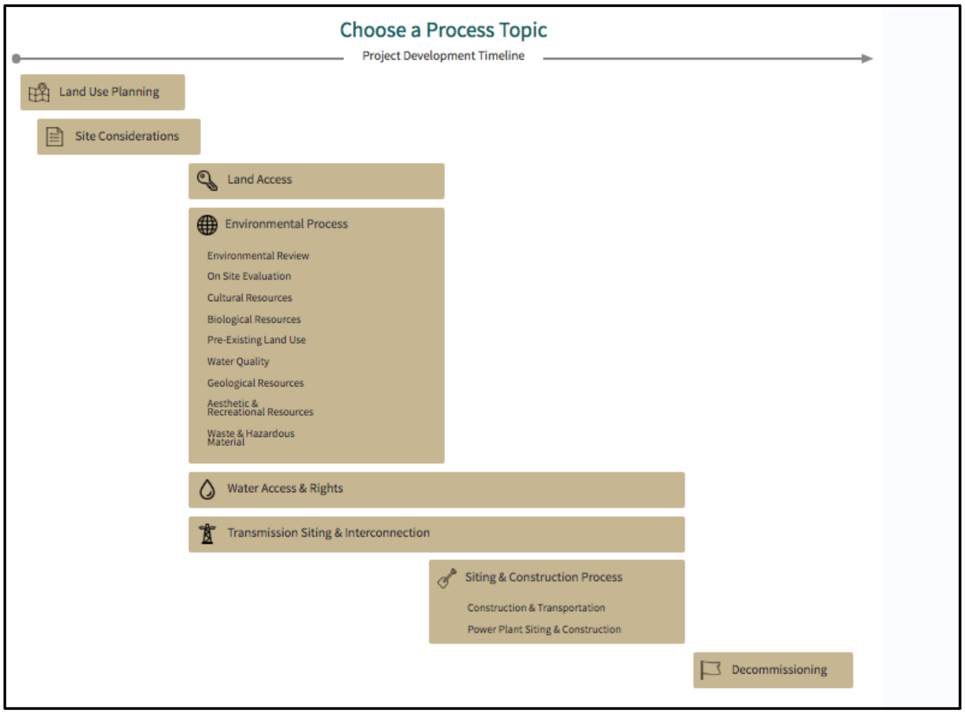
Another concern with community solar is the premium on the customer's utility bill required to subscribe to the program. This cost is said to cover the price of installation and maintenance of the solar panels, which the owner of a solar array would be obliged to pay upfront if installing distributed generation. In that sense, CS solves the high upfront cost problem by allowing customers to spread out their payments for the program. However, unlike a loan with a pre-determined schedule and payback period after which the installed system covers its costs and begins to earn money for its owner, customers continue to pay the premium on their utility bill as long as they maintain their subscription to the CS program. Despite that drawback, CS nonetheless offers what is in effect a fixed rate on the power customers purchase, providing a hedge against future increases in energy prices.

Community solar is on the rise in Michigan. Whether it will be owned by a utility, private entity, or some other model, congregations should expect to have more options in the future for the types of power they wish to support.

6. Permitting

An understated but necessary part of the project is to ensure that the congregation has obtained the relevant permits for the installation. The project planning committee should consult with their contractor to determine which (if any) steps need to be taken by them and not the contractor. An overview of the general permitting process is detailed below.

Permitting Process Timeline



http://en.openei.org/wiki/RAPID/Solar/Michigan

1. **Land Use Planning** – Applicable for State and Federal land only
2. **Site Considerations** – Asks to consider all other permitting processes
3. **Land Access** – Developer responsible for permitting on private property
4. **Environmental Process** – Agency site visit
5. **Water Access & Rights** – Unnecessary if project does not use water
6. **Transmission Siting & Interconnection** – Developer must acquire right-of-way access if project on private property
7. **Siting & Construction Process** – Acquire a county use permit; transportation permit if large trucks used on state roads

Charts for each section of the permitting process are included in Appendix E.

7. Case Studies

Case Study #1: Edgewood United Church of Christ (UCC)

http://www.edgewooducc.org/outreach-and-service/environment.html

Where
469 Hagadorn Road
East Lansing, MI 48823

What: A 20-kWh solar array to be installed on the rooftop of Edgewood UCC. When completed, the panels will generate an estimated 40% of the church's current electricity usage, offsetting electricity consumption and costs.

Why: The solar initiative's main drivers were reducing the church's environmental impact, mitigating climate change, and sending a visible, green message to the community. Electricity generated by the solar panels will reduce the amount needed to purchase from its local utility, the Lansing Board of Water and Light (LBWL). The vast majority of electricity sold to consumers by LBWL comes from coal and natural gas, sources of greenhouse gases and criteria pollutants.

While the church has completed numerous projects for energy conservation including improving insulation, retrofitting windows and installing more efficient appliances, those upgrades, decreasing the church's energy consumption especially in the winter time, are invisible to most congregants. Unlike those energy retrofits or the purchasing of carbon offsets, Edgewood's solar array will be a visible testament to its concern for the welfare of society and the environment.

Who: The Edgewood United Church of Christ (UCC) congregation and its internal taskforce:
Jim Detjen
John Baumgartner
Dave Kidd

How: Thanks to an enthusiastic fundraising campaign, Edgewood has reached about two-thirds of its $80,000 goal. Peninsula Solar, a Michigan company will handle the installation. Money raised by the congregation goes towards 80 solar panels made by Suniva Optimus, a Michigan company, 80 micro-inverters, roof racks, other electrical equipment, and roof sealant.

When
The project is scheduled for completion in the Fall of 2016
Project Planning Timeline:
Fall 2013: Environmental taskforce met to discuss potential solar projects
Dec 2013: Engineer's assessment determined that the roof could fit up to 180 panels
2013: Discussion and internal decision making process
Dec 2014 - April 2015: Considered bids from contractors
April 2015: Decision made to go with Peninsular Solar
Late Spring 2015 - Summer 2015: Ongoing assessments and evaluation of different proposals
Spring 2016: Final project chosen

Case Study #2: First Unitarian Universalist Congregation of Ann Arbor (UUAA)

Where
Ann Arbor
4001 Ann Arbor-Saline Road
Ann Arbor, Michigan 48103-8739

What: Renewable energy in the form of 10.8 kW rooftop installed solar panels, 2.55 kW standalone tracking panel array, and a single wind turbine rated at 2.5 kW power. Visit "www.uuaa.org/e" for a more detailed look at the installed system's energy generation.

Why: This project follows the 7th Unitarian Universalist principle of "respect for the interdependent web of all existence of which we are a part." Originally stemming from a conversation in which congregants discussed the installation of a wind turbine as a "steeple," the congregation came together to develop this hybrid system. Now rooftop solar and the freestanding solar array join the wind turbine as a visible source of clean, renewable energy. Through distributed generation in the form of solar and wind, the congregation is lowering its carbon footprint and developing its environmental consciousness.

Who: The Renewable Energy Committee of UUAA, comprised of:

Project Management & Construction: David Friedrichs and John Wakeman
Engineering Coordinator: Mark Doman
Permits, Design & Architecture: Jim Carter and Emile Lauzzana
Future Renewable Projects: Tom Ewing and David Hall
Outreach to Spiritual Growth & Development: Cathy Reischl and Paul Morris
Fund Raising Assistance: Marina Brown, Mary Christianson, and Laurie Ryan
Power Estimate, Monitoring & Electrical: Don Winsor and John Frank

With generous contributions from the UUAA community.

How: The project began in discussion and led to enterprising congregants installing an anemometer to measure wind speeds in the area. After their initial assessment, the congregants pursued a combined wind and solar project as solar PV became less expensive and more efficient. Funding came in large part from individual donors in the congregation but also utilized

DTE's Solar Currents incentive program (no longer active) to reduce the cost of the project by $20,000. In front of the church, project coordinators constructed an "Energy Plaza" paved with tiles with inscriptions by individual donors.

When

Phase 1: Completed November 2010: Wind turbine and 48 solar panels on social hall roof
Phase 2: Completed November 2011: 10 solar panels on dual axis tracker array
Phase 3: Completed September 2015: 24 additional panels on social hall

Project Planning Timeline:
2002: Discussion about installing a wind turbine as church's "steeple."
November 2003: Erection of guy-wired 100' anemometer tower to measure wind energy
2007: UUAA launches "Celebrating our Planet," an examination of local and global initiatives to use environmental resources wisely.
2007-2010: Raising of about $100,000 for the Renewable Energy Project in part through the "Energy Plaza" tile initiative.
2010-2015: Construction of Phases 1-3 to develop wind and solar PV – rooftop and dual axis tracker array
2010-present: Monitoring of electricity generation by the various systems at www.uuaa.org/e.

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Appendix A: Solar Installers and Contractors in Michigan

Name	Contact phone	Web	Street address	City	Zip
Homeland Solar	(844) 969-6786	www.HomelandSolar.com		Ann Arbor	
Sur Energy Systems	734-913-9944	http://www.sur.biz/	221 Buena Vista Ave	Ann Arbor	48105
Strategic Energy Solutions, Inc.	248-399-1900	http://sesnet.com/	4000 West Eleven Mile Rd	Berkley	48972
J.D. Stratton Electric Inc.	231-715-1170	http://www.jdstrattonelectric.com	13540 Cinder Rd	Beulah	49617
The Green Panel	886-633-8553	http://www.thegreenpanel.com/	4023 S Old US Hwy 23 #109	Brighton	48114
Mechanical Energy Systems	734-453-6746	http://www.mes1.com/	8130 Canton Center Rd	Canton	48187
Renewable Energy Solutions	734-649-1777	http://www.goforsolar.com/	17700 Garvey Rd	Chelsea	48118
Michigan Solar Solutions	248-923-3456	http://michigansolarsolutions.com/	509 Sherbrooke	Commerce Twp	48382
Contractors Building Supply Inc.	231-378-2936	http://www.cbssolar.com/	16880 Front St	Copemish	49625
Solar Sales of Michigan	248-240-1749	http://www.solarsalesofmichigan.com/	5172 Stimson Rd	Davison	48423
Sunsiaray	810-653-3502	http://www.sunsiaray.com/	4414 N. Washburn Rd	Davison	48423
City Creations	313-241-3869	http://www.citycreationsinc.com/	17168 Hubbel Ave	Detroit	48235
Strawberry Solar	248-227-4164	http://www.strawberrysolar.com/	2727 2nd Ave Ste. 259	Detroit	48201
Skyline Electrical Contracting, Inc.	586-498-9595	http://www.skylineelectrical.com/	22755 Kelly Rd	Eastpointe	48021
BTF Solar	269-236-6179		P.O. Box 409	Fennville	49408
Newkirk Electric Associates, Inc. - Flint	810-742-4400	http://www.newkirk-electric.com/	2751 Lippincott Blvd	Flint	48507
Self Reliant Energy Company	517-256-2322	http://www.selfreliantenergycompany.com/	10192 Sargent Rd	Fowlerville	48836
Great Lakes Solar & Wind Energies	906-428-3300		559 23 ½ Rd	Gladstone	49878
Vander Hyde Service	616-454-5400	http://www.vanderhyde.com/	14200 Ironwood Dr NW	Grand Rapids	49544
Basic Solar & Renewables	269-945-1269		4303 E Center Rd	Hastings	49058
Harvest Energy Solutions	517-788-8800	http://harvestenergysolutions.com/	2218 E High St	Jackson	49203
Eco-friendly Contracting	269-598-1101	http://www.ecofriendlycontracting.com/	5280 Azo Ct.	Kalamazoo	49048
Helios Solar	269-343-5560	http://helios-power.com/	248 West Michigan Ave	Kalamazoo	49008
Kerwin Electric, Inc.	269-375-6543	http://kerwinelectric.com/	7930 South 8th St	Kalamazoo	49009
Solar Winds Power Systems	616-635-7855	http://www.thesolarwinds.com/	2421 Applelane Ave	Kalamazoo	49008
Comfort First Heating and Cooling	517-323-3314	http://www.comfortfirst.net/	3375 N. Waverly Rd	Lansing	48906
Newkirk Electric Associates, Inc. - Lansing	517-322-3012	http://www.newkirk-electric.com/	3010 S. Canal St	Lansing	48823
Four Elements Energy	269-267-1804	http://www.fourelements-energy.com/	54630	Lawrence	49064
Event Horizon Solar & Wind	616-389-3172	http://www.eventhorizonsolar.com/	6080 Knoll Dr	Middleville	49333
J. Ranck Electric, Inc.	1-800-792-3822	https://www.jranck.com/	1993 Gover Parkway	Mt. Pleasant	48858
Newkirk Electric Associates, Inc.	231-722-1691	http://www.newkirk-electric.com/	1875 Roberts St	Muskegon	49442
Srinergy	248-254-6477	http://srinergy.com/	24371 Catherine Industrial Dr	Novi	48375
Nova Consultants	248-347-3512		21580 Novi Rd	Novi	48375
Novi Energy	248-735-6684	http://test.novinutrients.com/wordpress/	23955 Novi Rd	Novi	48375
Maurer Heating & Cooling	989-723-4220	http://www.maurerheating.com/	203 S. Water St	Owosso	48867
Phoenix Environmental	734-449-1266	http://www.phoenixenv.com/	12815 Premier Center	Plymouth	48170
Midwest Energy Connection	888-544-2096		1412 Forest Dr	Portage	49002
Luma Resources	888-733-5862	http://www.lumaresources.com/	2691 Leach Rd	Rochester	48306
Greenwire Systems	248-635-7412	http://www.greenwiresystems.com/	29488 Woodward Ave	Royal Oak	48073
Sunventrix	734-418-7700	http://www.sunventrix.com/		Saline	48176
Full Draw Electric	616-636-8129	http://www.cleanenergyauthority.com/michigan-solar-installers/full-draw-electric/	2550 22 Mile Rd	Sand Lake	49343
Solar Winds Power Systems, Inc.	616-635-7855	http://www.thesolarwinds.com/	5399 Laura Dr	Shelbyville	9344
ecojiva	248-650-3400	http://www.ecojiva.com/	2301 West big Beaver Rd Suite 318	Troy	48084
Bright Power Solutions Inc.	586-991-5244		45100 Sterritt St Suite 106	Utica	48317
Oak Electric Service	800-964-7070	http://www.oakelectric.com/	5492 Dixie Hwy	Waterford	48329

Appendix B: Technical Assessment Tools

The technical assessment looks at a proposed project's physical characteristics—such as location, orientation, shading and system size—and determines its overall feasibility. A typical site evaluation considers all the system parameters as well as historical weather data for a region to estimate the energy output of a certain sized solar system in the given area. When planning a solar project, it is important to understand that the size and siting of a solar system will determine its energy output. A solar system's energy output lessens the producer's consumption of grid electricity, which in turn leads to a reduction in energy-related emissions.

PVWatts

If the planning committee (or a member of the committee) has time only to learn one of these tools, it should be PVWatts. Developed by the National Renewable Energy Laboratory (NREL), PVWatts is an energy calculator that is straightforward to learn and implement. Input an address to locate solar resource data and choose parameters for the desired size of the solar system. Alternatively, the "Draw your System" feature allows users to overlay an area on the map, simulating a rooftop or open lot where the panels are to be installed. Outputs of the calculator include estimated annual generation in kWh (AC), monthly solar radiation and dollar values for the electricity generated. PVWatts provides a quick "first look" at a solar system's estimated output.
http://pvwatts.nrel.gov/

System Advisor Model

Also produced by NREL, the System Advisor Model (SAM) combines system performance with finance to assess a project's long-term viability. The model is more detailed than PVWatts and includes parameters for location and resource, system design and costs, and lifetime factors such as panel degradation, electricity rates and loan finance. SAM relies on several parameters to project into the future, so the more known about the system the better. SAM is most helpful after an initial look at a project using PVWatts.
https://sam.nrel.gov/

Spreadsheet-based

Even for those averse to numerical data, Microsoft Excel and similar spreadsheet-based software simplify project assessment. Estimating annual generation can be done by hand given parameters for a system's electrical output and a region's solar insolation, but the utility of the spreadsheet lies in its organization and flexibility. Given variable parameters, Excel allows for quick assessment and simultaneous comparison of multiple scenarios. Google produces its own free-to-use spreadsheet application, Google Sheets.
https://www.google.com/sheets/about/

Appendix C: Financial Assessment Tools

Spreadsheet-based

Excel and Google Sheets provide financial formulae for calculating Present Value (PV), Future Value (FV), Net Present Value (NPV) and Internal Rate of Return (IRR), as well as the means to calculate annuity payments and net cash flow. Furthermore, financial calculations can be linked to project assessment if both have been conducted on spreadsheets. Better still, combining the technical and financial portions of the assessment on the same spreadsheet simplifies the process and allows for experimentation with project parameters. By linking technical system inputs to financial outputs, one can scale the solar system up or down to determine project viability under a range of different scenarios.

System Advisor Model

Also produced by NREL, the System Advisor Model (SAM) combines system performance with finance to assess a project's long-term viability. The model is more detailed than PVWatts and includes parameters for location and resource, system design and costs, and lifetime factors such as panel degradation, electricity rates and loan finance. SAM relies on several parameters to project into the future, so the more known about the system the better. SAM is most helpful after an initial look at a project using PVWatts.
https://sam.nrel.gov/

JEDI PV

NREL's Jobs and Economic Development (JEDI) model estimates the number of jobs and economic impact of power generation in a local area. The model is best suited to indicate a project's wider social impact after technical and financial details of the project have been determined by some combination of PVWatts, SAM and spread-sheet based modeling.
https://jedi.nrel.gov/

Appendix D: Environmental Assessment Tools

A project's environmental attributes can seem elusive, even daunting to quantify. However, impacts to the environment should always be considered when adopting clean energy technologies. An assessment of the environmental costs as well as dollar values is essential for sustainable development. Clear communication of project goals also relies on the translation of abstract environmental concepts like greenhouse gases into more tangible quantities, such as "number of cars removed from the road."

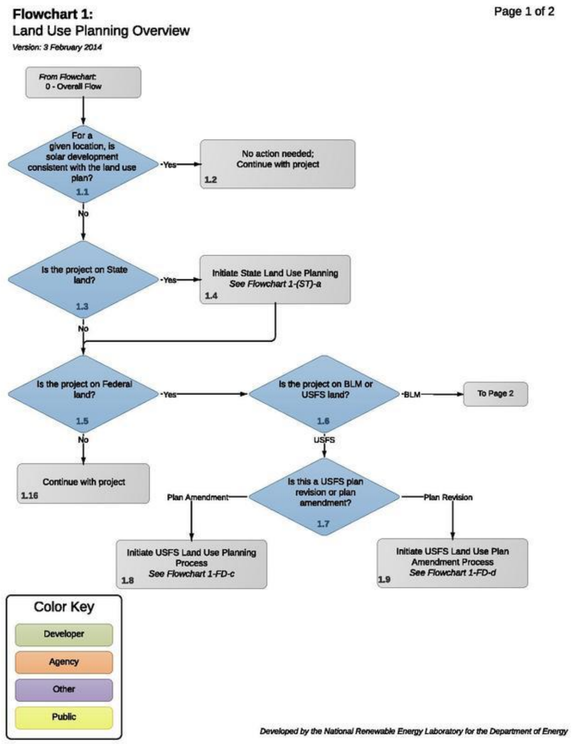
Spreadsheet-based

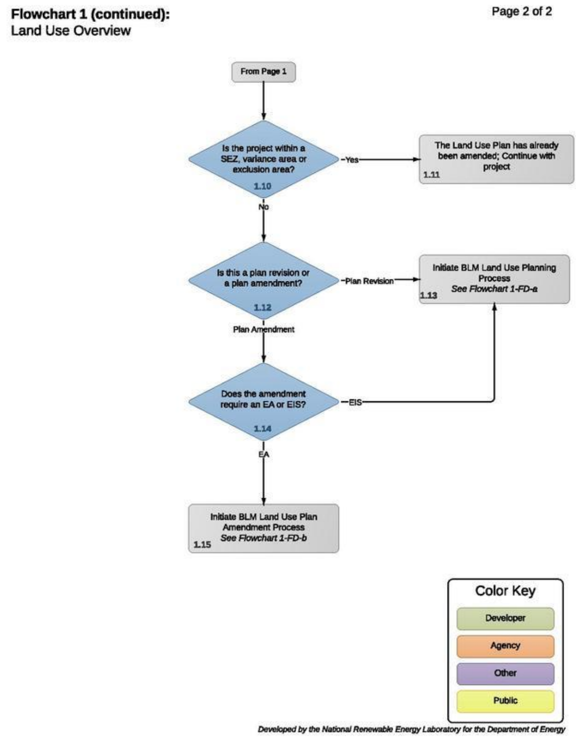
Spreadsheet software like Excel or Google Sheets can be used to track environmental impacts. One approach is to link system energy outputs to environmental impacts, which can be done after obtaining an estimate for system generation. The amount of solar energy generated by the system offsets the owner's electricity consumption. Normally, this energy demand would have been met by the electricity grid, which has its own emissions factors. The US Environmental Protection Agency (EPA) and the Energy Information Agency (EIA) both publish reliable data on conversion factors from grid electricity (kWh) to tons of various pollutants, including carbon dioxide, sulfur dioxide, nitrous oxide, and particulate matter. Convert to units of emissions per energy unit (tons of carbon dioxide per kWh electricity generated) to estimate emissions reduction by the installed system.

It is important to note that this method does not consider the upstream emissions associated with manufacturing the solar system or extraction and refining of fuel resources for the generation of electricity. Upstream emissions factors can be incorporated into this calculation for increased realism.

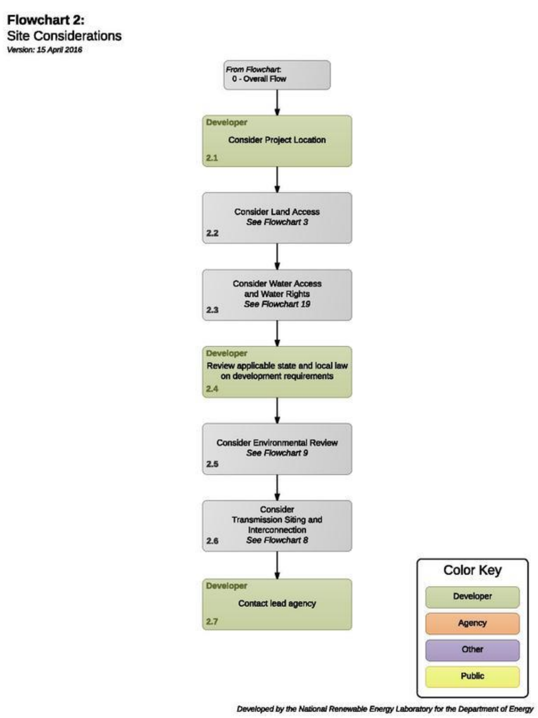
Appendix E: Permitting

Land Use Planning

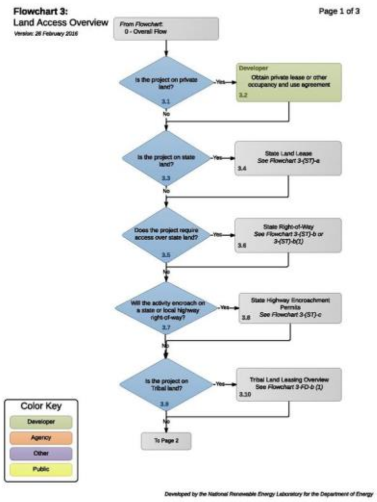


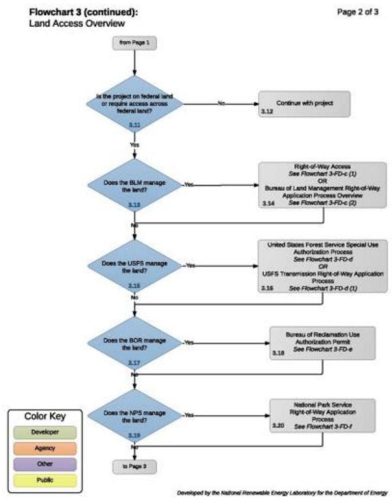


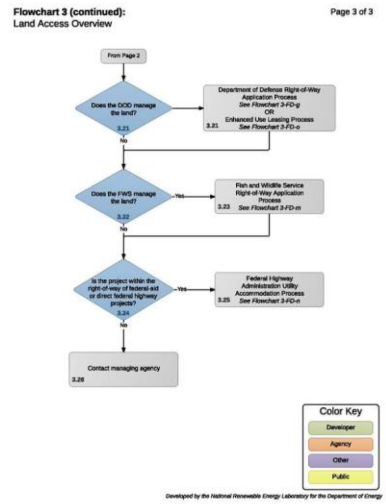
Site Considerations



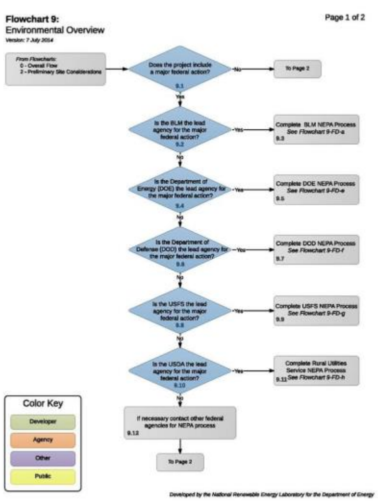
Land Access Permitting

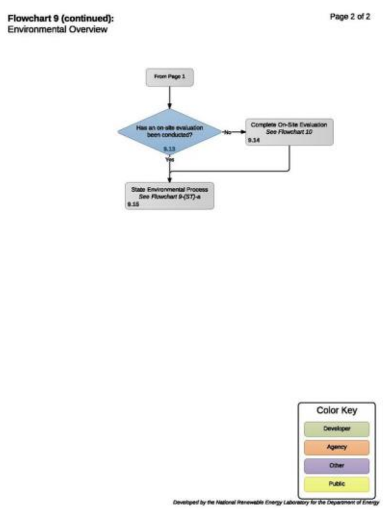


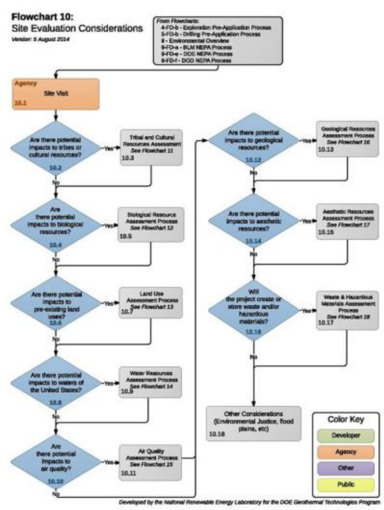




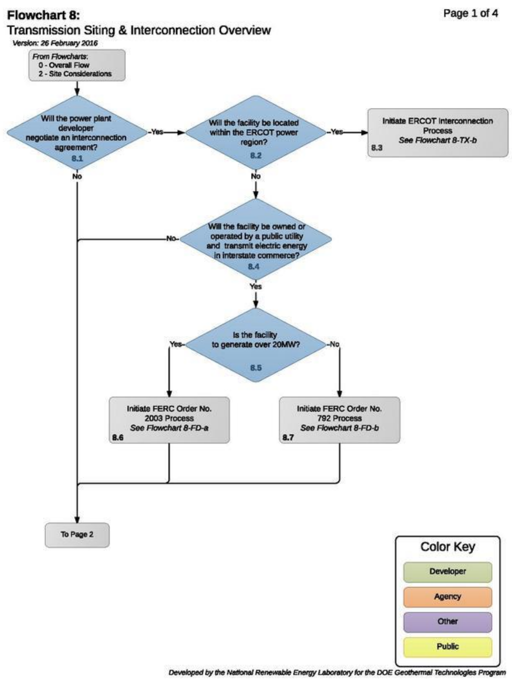
Environmental Permitting

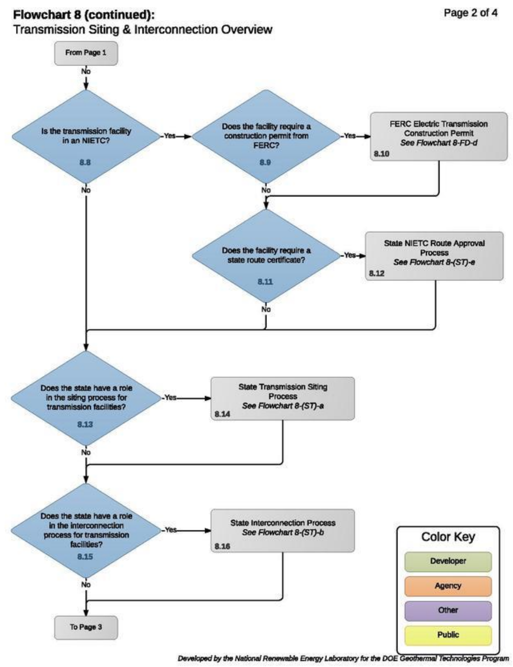


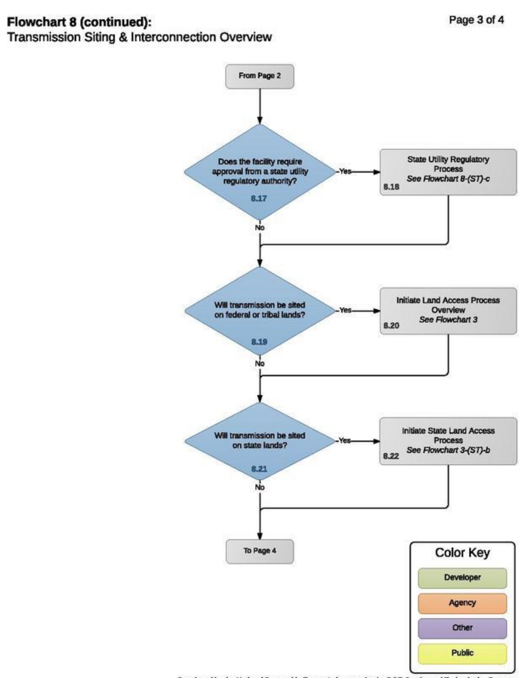


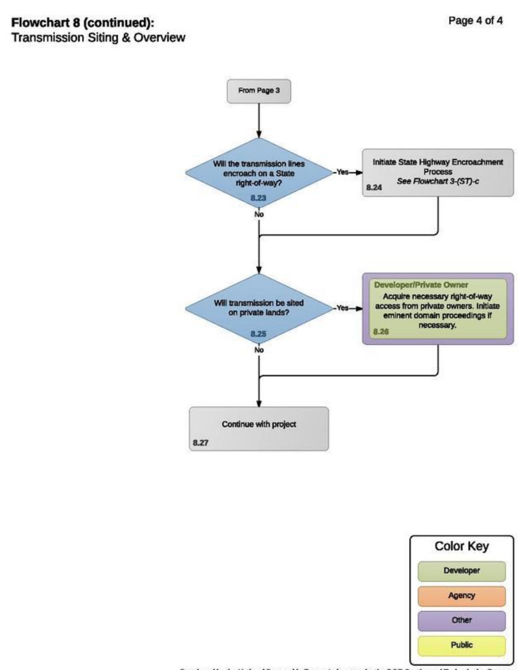


Transmission Siting

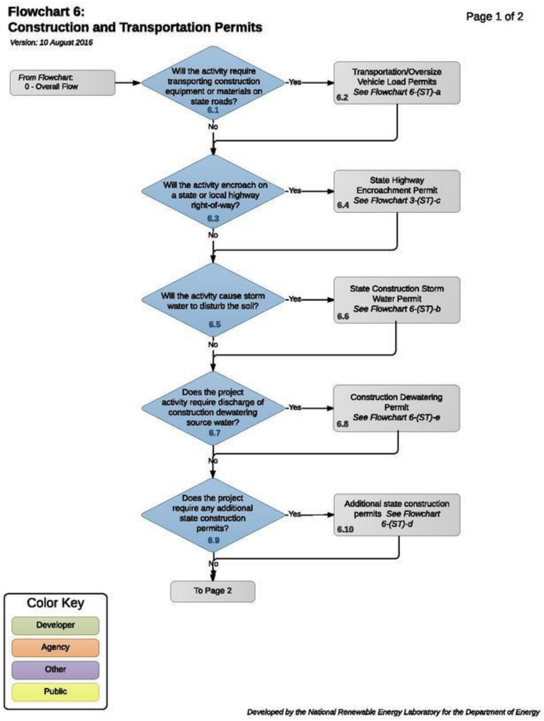


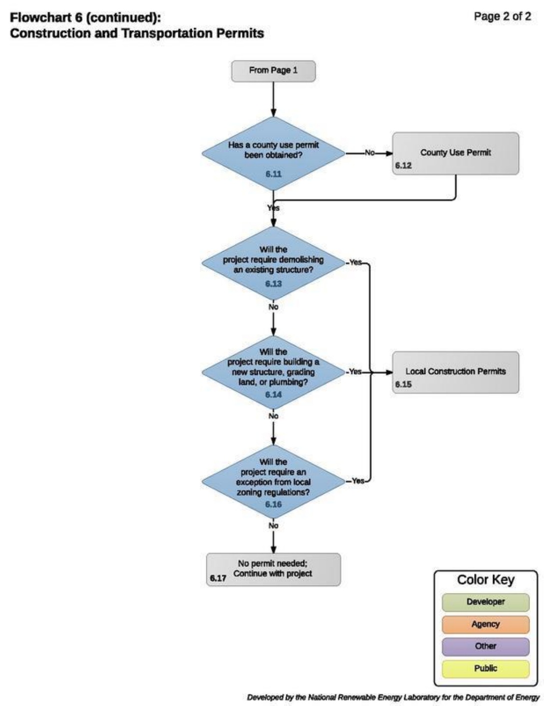




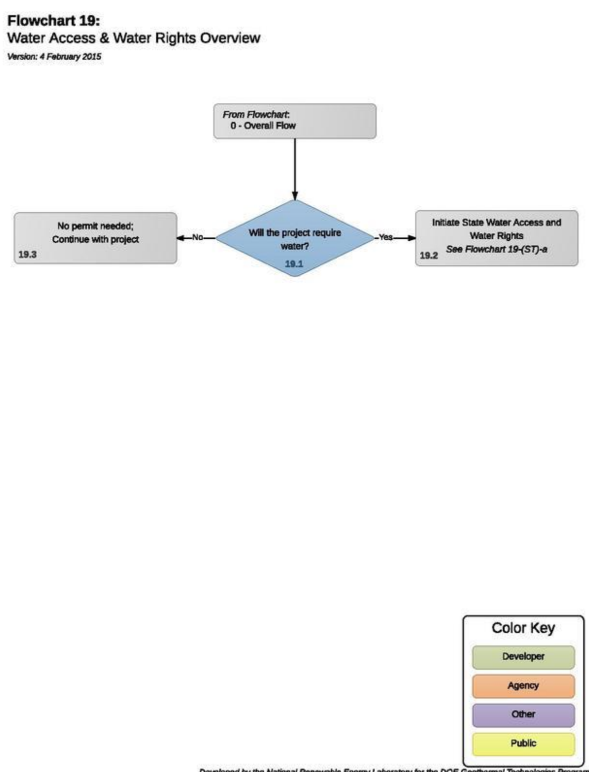


Construction Permitting





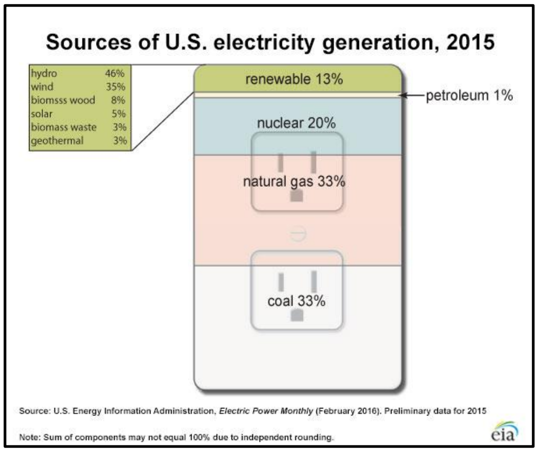
Water Permitting



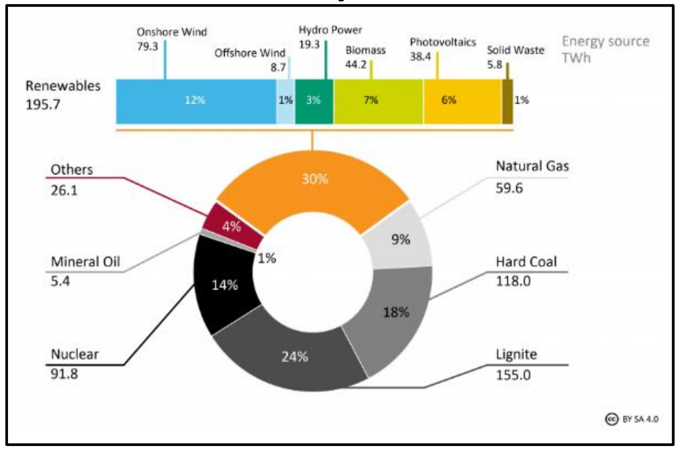
Appendix F: Fuel Mix, Power Sector – US, Germany, World Forecast

Share of Energy Sources for Power Sector

US

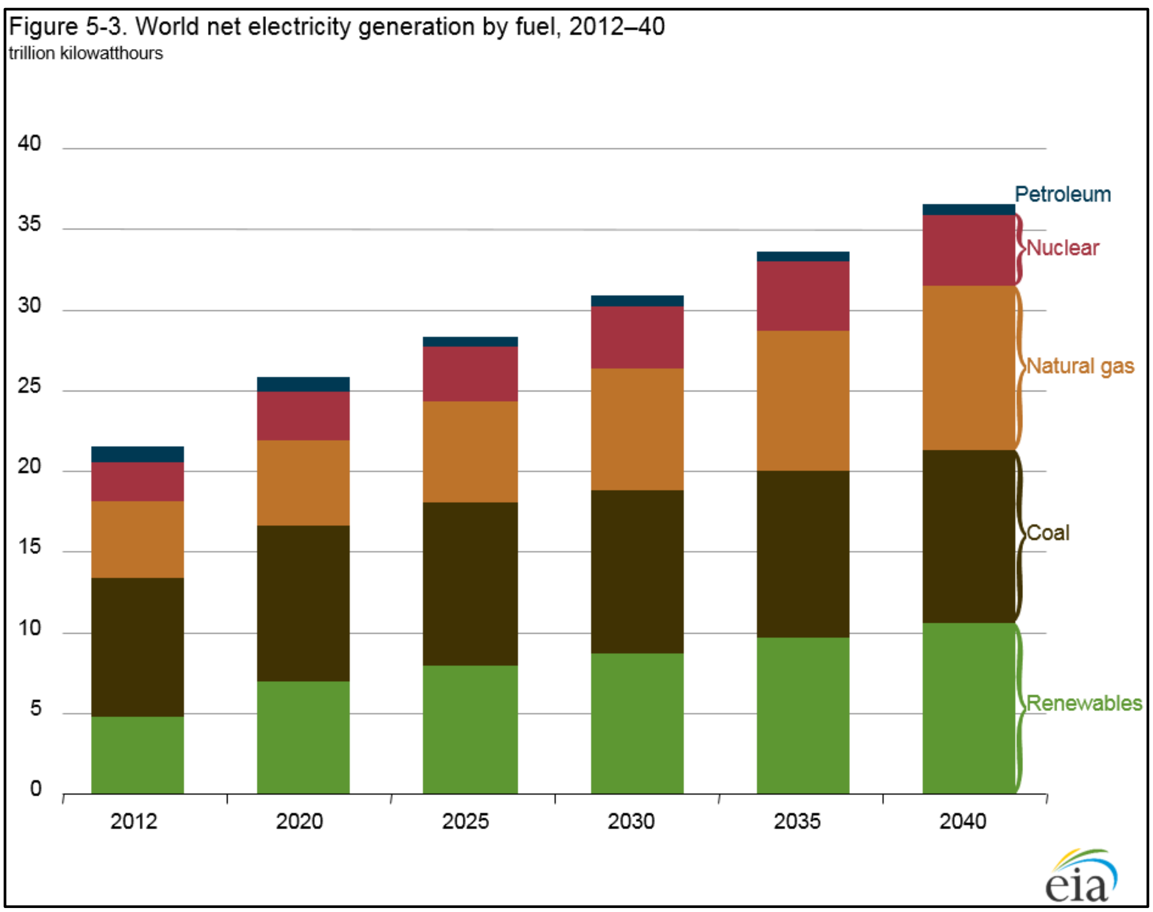


Germany



Source: http://www.eia.gov/energyexplained/index.cfm?page=electricity_in_the_united_states
Source: https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts

Share of Energy Sources for Power Sector, World Forecast



Source: http://www.iea.org/publications/freepublications/publication/KeyWorld_Statistics_2015.pdf

Appendix G: US EPA Emissions Factors

Anthracite Coal

Table 1.2-2. EMISSION FACTORS FOR CO AND CARBON DIOXIDE (CO_2) FROM UNCONTROLLED ANTHRACITE COAL COMBUSTORS[a]

Source Category	CO		CO_2	
	Emission Factor (lb/ton)	EMISSION FACTOR RATING	Emission Factor (lb/ton)	EMISSION FACTOR RATING
Stoker-fired boilers[b] (SCC 1-01-001-02, 1-02-001-04, 1-03-001-02)	0.6	B	5,680	C
FBC boilers[c] (no SCC)	0.6	E	ND	NA

[a] Units are lb of pollutant/ton of coal burned. To convert from lb/ton to kg/Mg, multiply by 0.5. SCC = Source Classification Code. ND = no data. NA = not applicable.
[b] References 2,9,12.
[c] Reference 11. FBC boilers burning culm fuel; all other sources burning anthracite coal.

Table 1.2-1. EMISSION FACTORS FOR SO_x AND NO_x COMPOUNDS FROM UNCONTROLLED ANTHRACITE COAL COMBUSTORS[a]

Source Category	SO_x		NO_x	
	Emission Factor (lb/ton)	EMISSION FACTOR RATING	Emission Factor (lb/ton)	EMISSION FACTOR RATING
Stoker-fired boilers[c] (SCC 1-01-001-02, 1-02-001-04, 1-03-001-02)	39S[b]	B	9.0	C
FBC boilers[d] (no SCC)	2.9	E	1.8	E
Pulverized coal boilers[e] (SCC 1-01-001-01, 1-02-001-01, 1-03-001-01)	39S[b]	B	18	B
Residential space heaters[e] (SCC A2104001000)	39S[b]	B	3	B

[a] Units are lb of pollutant/ton of coal burned. To convert from lb/ton to kg/Mg, multiply by 0.5. SCC = Source Classification Code.
[b] S = weight percent sulfur. For example, if the sulfur content is 3.4%, then S = 3.4.
[c] References 9-10.
[d] Reference 11. FBC boilers burning culm fuel; all other sources burning anthracite coal.
[e] Reference 2.

Source: https://www3.epa.gov/ttn/chief/efpac/comments.html

Bituminous Coal

Table 1.1-3. EMISSION FACTORS FOR SO_x, NO_x, AND CO FROM BITUMINOUS AND SUBBITUMINOUS COAL COMBUSTION[a]

Firing Configuration	SCC	SO_x[b] Emission Factor (lb/ton)	SO_x[b] EMISSION FACTOR RATING	NO_x[c] Emission Factor (lb/ton)	NO_x[c] EMISSION FACTOR RATING	CO[d,e] Emission Factor (lb/ton)	CO[d,e] EMISSION FACTOR RATING
PC, dry bottom, wall-fired[f], bituminous Pre-NSPS[g]	1-01-002-02 1-02-002-02 1-03-002-06	38S	A	22	A	0.5	A
PC, dry bottom, wall-fired[f], bituminous Pre-NSPS[g] with low-NO_x burner	1-01-002-02 1-02-002-02 1-03-002-06	38S	A	11	A	0.5	A
PC, dry bottom, wall-fired[f], bituminous NSPS[g]	1-01-002-02 1-02-002-02 1-03-002-06	38S	A	12	A	0.5	A
PC, dry bottom, wall-fired[f], sub-bituminous Pre-NSPS[g]	1-01-002-22 1-02-002-22 1-03-002-22	35S	A	12	C	0.5	A
PC, dry bottom, wall fired[f], sub-bituminous NSPS[g]	1-01-002-22 1-02-002-22 1-03-002-22	35S	A	7.4	A	0.5	A
PC, dry bottom, cell burner[h] fired, bituminous	1-01-002-15	38S	A	31	A	0.5	A
PC, dry bottom, cell burner fired, sub-bituminous	1-01-002-35	35S	A	14	E	0.5	A

Table 1.1-3 (cont.).

Firing Configuration	SCC	SO_x[b] Emission Factor (lb/ton)	SO_x[b] EMISSION FACTOR RATING	NO_x[c] Emission Factor (lb/ton)	NO_x[c] EMISSION FACTOR RATING	CO[d,e] Emission Factor (lb/ton)	CO[d,e] EMISSION FACTOR RATING
PC, dry bottom, tangentially fired, bituminous, Pre-NSPS[g]	1-01-002-12 1-02-002-12 1-03-002-16	38S	A	15	A	0.5	A
PC, dry bottom, tangentially fired, bituminous, Pre-NSPS[g] with low-NO_x burner	1-01-002-12 1-02-002-12 1-03-002-16	38S	A	9.7	A	0.5	A
PC, dry bottom, tangentially fired, bituminous, NSPS[g]	1-01-002-12 1-02-002-12 1-03-002-16	38S		10	A	0.5	A
PC, dry bottom, tangentially fired, sub-bituminous, Pre-NSPS[g]	1-01-002-26 1-02-002-26 1-03-002-26	35S	A	8.4	A	0.5	A
PC, dry bottom, tangentially fired, sub-bituminous, NSPS[g]	1-01-002-26 1-02-002-26 1-03-002-26	35S	A	7.2	A	0.5	A
PC, wet bottom, wall-fired[f], bituminous, Pre-NSPS[g]	1-01-002-01 1-02-002-01 1-03-002-05	38S	A	31	D	0.5	A
PC, wet bottom, tangentially fired, bituminous, NSPS[g]	1-01-002-11	38S	A	14	E	0.5	A
PC, wet bottom, wall-fired sub-bituminous	1-01-002-21 1-02–002-21 1-03-002-21	35S	A	24	E	0.5	A

Table 1.1-3 (cont.).

Firing Configuration	SCC	SO_x[b]		NO_x[c]		CO[d,e]	
		Emission Factor (lb/ton)	EMISSION FACTOR RATING	Emission Factor (lb/ton)	EMISSION FACTOR RATING	Emission Factor (lb/ton)	EMISSION FACTOR RATING
Cyclone Furnace, bituminous	1-01-002-03 1-02-002-03 1-03-002-03	38S	A	33	A	0.5	A
Cyclone Furnance, sub-bituminous	1-01-002-23 1-02-002-23 1-03-002-23	35S	A	17	C	0.5	A
Spreader stoker, bituminous	1-01-002-04 1-02-002-04 1-03-002-09	38S	B	11	B	5	A
Spreader Stoker, sub-bituminous	1-01-002-24 1-02-002-24 1-03-002-24	35S	B	8.8	B	5	A
Overfeed stoker[j]	1-01-002-05/25 1-02-002-05/25 1-03-002-07/25	38S (35S)	B	7.5	A	6	B
Underfeed stoker	1-02-002-06 1-03-002-08	31S	B	9.5	A	11	B
Hand-fed units	1-03-002-14	31S	D	9.1	E	275	E

Table 1.1-4. UNCONTROLLED EMISSION FACTORS FOR PM AND PM-10 FROM BITUMINOUS AND SUBBITUMINOUS COAL COMBUSTION[a]

Firing Configuration	SCC	Filterable PM[b]		Filterable PM-10	
		Emission Factor (lb/ton)	EMISSION FACTOR RATING	Emission Factor (lb/ton)	EMISSION FACTOR RATING
PC-fired, dry bottom, wall-fired	1-01-002-02/22 1-02-002-02/22 1-03-002-06/22	10A	A	2.3A	E
PC-fired, dry bottom, tangentially fired	1-01-002-12/26 1-02-002-12/26 1-03-002-16/26	10A	B	2.3A[c]	E
PC-fired, wet bottom	1-01-002-01/21 1-02-002-01/21 1-03-002-05/21	7A[d]	D	2.6A	E
Cyclone furnace	1-01-002-03/23 1-02-002-03/23 1-03-002-03/23	2A[d]	E	0.26A	E
Spreader stoker	1-01-002-04/24 1-02-002-04/24 1-03-002-09/24	66[e]	B	13.2	E
Spreader stoker, with multiple cyclones, and reinjection	1-01-002-04/24 1-02-002-04/24 1-03-002-09/24	17	B	12.4	E
Spreader stoker, with multiple cyclones, no reinjection	1-01-002-04/24 1-02-002-04/24 1-03-002-09/24	12	A	7.8	E

Table 1.1-4 (cont.).

Firing Configuration	SCC	Filterable PM[b]		Filterable PM-10	
		Emission Factor (lb/ton)	EMISSION FACTOR RATING	Emission Factor (lb/ton)	EMISSION FACTOR RATING
Overfeed stoker[f]	1-01-002-05/25 1-02-002-05/25 1-03-002-07/25	16[g]	C	6.0	E
Overfeed stoker, with multiple cyclones[f]	1-01-002-05/25 1-02-002-05/25 1-03-002-07/25	9[h]	C	5.0	E
Underfeed stoker	1-02-002-06 1-03-002-08	15[j]	D	6.2	E
Underfeed stoker, with multiple cyclone	1-02-002-06 1-03-002-08	11[h]	D	6.2[j]	E
Hand-fed units	1-03-002-14	15	E	6.2[k]	E
FBC, bubbling bed	1-01-002-17 1-02-002-17 1-03-002-17	[m]	E	[m]	E
FBC, circulating bed	1-01-002-18 1-02-002-18 1-03-002-18	[m]	E	[m]	E

[a] Factors represent uncontrolled emissions unless otherwise specified and should be applied to coal feed, as fired. To convert from lb/ton to kg/Mg, multiply by 0.5. SCC = Source Classification Code.

Source: https://www3.epa.gov/ttn/chief/efpac/comments.html

Natural Gas

Table 1.4-1. EMISSION FACTORS FOR NITROGEN OXIDES (NO_x) AND CARBON MONOXIDE (CO) FROM NATURAL GAS COMBUSTION[a]

Combustor Type (MMBtu/hr Heat Input) [SCC]	NO_x[b]		CO	
	Emission Factor ($lb/10^6$ scf)	Emission Factor Rating	Emission Factor ($lb/10^6$ scf)	Emission Factor Rating
Large Wall-Fired Boilers (>100) [1-01-006-01, 1-02-006-01, 1-03-006-01]				
Uncontrolled (Pre-NSPS)[c]	280	A	84	B
Uncontrolled (Post-NSPS)[c]	190	A	84	B
Controlled - Low NO_x burners	140	A	84	B
Controlled - Flue gas recirculation	100	D	84	B
Small Boilers (<100) [1-01-006-02, 1-02-006-02, 1-03-006-02, 1-03-006-03]				
Uncontrolled	100	B	84	B
Controlled - Low NO_x burners	50	D	84	B
Controlled - Low NO_x burners/Flue gas recirculation	32	C	84	B
Tangential-Fired Boilers (All Sizes) [1-01-006-04]				
Uncontrolled	170	A	24	C
Controlled - Flue gas recirculation	76	D	98	D
Residential Furnaces (<0.3) [No SCC]				
Uncontrolled	94	B	40	B

TABLE 1.4-2. EMISSION FACTORS FOR CRITERIA POLLUTANTS AND GREENHOUSE GASES FROM NATURAL GAS COMBUSTION[a]

Pollutant	Emission Factor ($lb/10^6$ scf)	Emission Factor Rating
CO_2[b]	120,000	A
Lead	0.0005	D
N_2O (Uncontrolled)	2.2	E
N_2O (Controlled-low-NO_X burner)	0.64	E
PM (Total)[c]	7.6	D
PM (Condensable)[c]	5.7	D
PM (Filterable)[c]	1.9	B
SO_2[d]	0.6	A
TOC	11	B
Methane	2.3	B
VOC	5.5	C

Table 1.4-1. EMISSION FACTORS FOR NITROGEN OXIDES (NO_x) AND CARBON MONOXIDE (CO) FROM NATURAL GAS COMBUSTION[a]

Combustor Type (MMBtu/hr Heat Input) [SCC]	NO_x[b]		CO	
	Emission Factor ($lb/10^6$ scf)	Emission Factor Rating	Emission Factor ($lb/10^6$ scf)	Emission Factor Rating
Large Wall-Fired Boilers (>100) [1-01-006-01, 1-02-006-01, 1-03-006-01]				
Uncontrolled (Pre-NSPS)[c]	280	A	84	B
Uncontrolled (Post-NSPS)[c]	190	A	84	B
Controlled - Low NO_x burners	140	A	84	B
Controlled - Flue gas recirculation	100	D	84	B
Small Boilers (<100) [1-01-006-02, 1-02-006-02, 1-03-006-02, 1-03-006-03]				
Uncontrolled	100	B	84	B
Controlled - Low NO_x burners	50	D	84	B
Controlled - Low NO_x burners/Flue gas recirculation	32	C	84	B
Tangential-Fired Boilers (All Sizes) [1-01-006-04]				
Uncontrolled	170	A	24	C
Controlled - Flue gas recirculation	76	D	98	D
Residential Furnaces (<0.3) [No SCC]				
Uncontrolled	94	B	40	B

[a] Reference 11. Units are in pounds of pollutant per million standard cubic feet of natural gas fired. To convert from $lb/10^6$ scf to $kg/10^6$ m^3, multiply by 16. Emission factors are based on an average natural gas higher heating value of 1,020 Btu/scf. To convert from $1b/10^6$ scf to lb/MMBtu, divide by 1,020. The emission factors in this table may be converted to other natural gas heating values by multiplying the given emission factor by the ratio of the specified heating value to this average heating value. SCC = Source Classification Code. ND = no data. NA = not applicable.
[b] Expressed as NO_2. For large and small wall fired boilers with SNCR control, apply a 24 percent reduction to the appropriate NO_X emission factor. For tangential-fired boilers with SNCR control, apply a 13 percent reduction to the appropriate NO_X emission factor.
[c] NSPS=New Source Performance Standard as defined in 40 CFR 60 Subparts D and Db. Post-NSPS units are boilers with greater than 250 MMBtu/hr of heat input that commenced construction modification, or reconstruction after August 17, 1971, and units with heat input capacities between 100 and 250 MMBtu/hr that commenced construction modification, or reconstruction after June 19, 1984.

TABLE 1.4-2. EMISSION FACTORS FOR CRITERIA POLLUTANTS AND GREENHOUSE GASES FROM NATURAL GAS COMBUSTION[a]

Pollutant	Emission Factor ($lb/10^6$ scf)	Emission Factor Rating
CO_2[b]	120,000	A
Lead	0.0005	D
N_2O (Uncontrolled)	2.2	E
N_2O (Controlled-low-NO_X burner)	0.64	E
PM (Total)[c]	7.6	D
PM (Condensable)[c]	5.7	D
PM (Filterable)[c]	1.9	B
SO_2[d]	0.6	A
TOC	11	B
Methane	2.3	B
VOC	5.5	C

[a] Reference 11. Units are in pounds of pollutant per million standard cubic feet of natural gas fired. Data are for all natural gas combustion sources. To convert from $lb/10^6$ scf to $kg/10^6$ m^3, multiply by 16. To convert from $lb/10^6$ scf to 1b/MMBtu, divide by 1,020. The emission factors in this table may be converted to other natural gas heating values by multiplying the given emission factor by the ratio of the specified heating value to this average heating value. TOC = Total Organic Compounds. VOC = Volatile Organic Compounds.
[b] Based on approximately 100% conversion of fuel carbon to CO_2. $CO_2[lb/10^6 \text{ scf}] = (3.67)(CON)(C)(D)$, where CON = fractional conversion of fuel carbon to CO_2, C = carbon content of fuel by weight (0.76), and D = density of fuel, $4.2x10^4$ $lb/10^6$ scf.
[c] All PM (total, condensible, and filterable) is assumed to be less than 1.0 micrometer in diameter. Therefore, the PM emission factors presented here may be used to estimate PM_{10}, $PM_{2.5}$ or PM_1 emissions. Total PM is the sum of the filterable PM and condensible PM. Condensible PM is the particulate matter collected using EPA Method 202 (or equivalent). Filterable PM is the particulate matter collected on, or prior to, the filter of an EPA Method 5 (or equivalent) sampling train.
[d] Based on 100% conversion of fuel sulfur to SO_2. Assumes sulfur content is natural gas of 2,000 $grains/10^6$ scf. The SO_2 emission factor in this table can be converted to other natural gas sulfur contents by multiplying the SO_2 emission factor by the ratio of the site-specific sulfur content ($grains/10^6$ scf) to 2,000 $grains/10^6$ scf.

Source: https://www3.epa.gov/ttn/chief/efpac/comments.html

Fuel Oil

Table 1.3-1. CRITERIA POLLUTANT EMISSION FACTORS FOR FUEL OIL COMBUSTION[a]

Firing Configuration (SCC)[a]	SO_2[b]		SO_3[c]		NO_x[d]		CO[e]		Filterable PM[f]	
	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSIO N FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING
Boilers > 100 Million Btu/hr										
No. 6 oil fired, normal firing (1-01-004-01), (1-02-004-01), (1-03-004-01)	157S	A	5.7S	C	47	A	5	A	9.19(S)+3.22	A
No. 6 oil fired, normal firing, low NO_x burner (1-01-004-01), (1-02-004-01)	157S	A	5.7S	C	40	B	5	A	9.19(S)+3.22	A
No. 6 oil fired, tangential firing, (1-01-004-04)	157S	A	5.7S	C	32	A	5	A	9.19(S)+3.22	A
No. 6 oil fired, tangential firing, low NO_x burner (1-01-004-04)	157S	A	5.7S	C	26	E	5	A	9.19(S)+3.22	A
No. 5 oil fired, normal firing (1-01-004-05), (1-02-004-04)	157S	A	5.7S	C	47	B	5	A	10	B
No. 5 oil fired, tangential firing (1-01-004-06)	157S	A	5.7S	C	32	B	5	A	10	B
No. 4 oil fired, normal firing (1-01-005-04), (1-02-005-04)	150S	A	5.7S	C	47	B	5	A	7	B
No. 4 oil fired, tangential firing (1-01-005-05)	150S	A	5.7S	C	32	B	5	A	7	B
No. 2 oil fired (1-01-005-01), (1-02-005-01), (1-03-005-01)	142S[h]	A	5.7S	C	24	D	5	A	2	A
No.2 oil fired, LNB/FGR, (1-01-005-01), (1-02-005-01), (1-03-005-01)	142S[h]	A	5.7S	A	10	D	5	A	2	A

Table 1.3-1. (cont.)

Firing Configuration (SCC)[a]	SO_2[b]		SO_3[c]		NO_x[d]		CO[e]		Filterable PM[f]	
	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING
Boilers < 100 Million Btu/hr										
No. 6 oil fired (1-02-004-02/03) (1-03-004-02/03)	157S	A	2S	A	55	A	5	A	9.19(S)+3.22[i]	B
No. 5 oil fired (1-03-004-04)	157S	A	2S	A	55	A	5	A	10[i]	A
No. 4 oil fired (1-03-005-04)	150S	A	2S	A	20	A	5	A	7	B
Distillate oil fired (1-02-005-02/03) (1-03-005-02/03)	142S	A	2S	A	20	A	5	A	2	A
Residential furnace (A2104004/A2104011)	142S	A	2S	A	18	A	5	A	0.4[g]	B

a To convert from lb/103 gal to kg/103 L, multiply by 0.120. SCC = Source Classification Code.
b References 1-2,6-9,14,56-60. S indicates that the weight % of sulfur in the oil should be multiplied by the value given. For example, if the fuel is 1% sulfur, then S = 1.
c References 1-2,6-8,16,57-60. S indicates that the weight % of sulfur in the oil should be multiplied by the value given. For example, if the fuel is 1% sulfur, then S = 1.
d References 6-7,15,19,22,56-62. Expressed as NO2. Test results indicate that at least 95% by weight of NOx is NO for all boiler types except residential furnaces, where about 75% is NO. For utility vertical fired boilers use 105 lb/103 gal at full load and normal (>15%) excess air. Nitrogen oxides emissions from residual oil combustion in industrial and commercial boilers are related to fuel nitrogen content, estimated by the following empirical relationship: lb NO2 /103 gal = 20.54 + 104.39(N), where N is the weight % of nitrogen in the oil. For example, if the fuel is 1% nitrogen, then N = 1.
e References 6-8,14,17-19,56-61. CO emissions may increase by factors of 10 to 100 if the unit is improperly operated or not well maintained.
f References 6-8,10,13-15,56-60,62-63. Filterable PM is that particulate collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. Particulate emission factors for residual oil combustion are, on average, a function of fuel oil sulfur content where S is the weight % of sulfur in oil. For example, if fuel oil is 1% sulfur, then S = 1.
g Based on data from new burner designs. Pre-1970's burner designs may emit filterable PM as high as 3.0 1b/103 gal.
h The SO2 emission factor for both no. 2 oil fired and for no. 2 oil fired with LNB/FGR, is 142S, not 157S. Errata dated April 28, 2000. Section corrected May 2010.
i The PM factors for No.6 and No. 5 fuel were reversed. Errata dated April 28, 2000. Section corrected May 2010.

Table 1.3-2. CONDENSABLE PARTICULATE MATTER EMISSION FACTORS FOR OIL COMBUSTION[a]

Firing Configuration[b] (SCC)	Controls	CPM - TOT[c, d]		CPM - IOR[c, d]		CPM - ORG[c, d]	
		Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING
No. 2 oil fired (1-01-005-01, 1-02-005-01, 1-03-005-01)	All controls, or uncontrolled	1.3[d, e]	D	65% of CPM-TOT emission factor[c]	D	35% of CPM-TOT emission factor[c]	D
No. 6 oil fired (1-01-004-01/04, 1-02-004-01, 1-03-004-01)	All controls, or uncontrolled	1.5[f]	D	85% of CPM-TOT emission factor[d]	E	15% of CPM-TOT emission factor[d]	E

[a] All condensable PM is assumed to be less than 1.0 micron in diameter.
[b] No data are available for numbers 3, 4, and 5 oil. For number 3 oil, use the factors provided for number 2 oil. For numbers 4 and 5 oil, use the factors provided for number 6 oil.
[c] CPM-TOT = total condensable particulate matter.
CPM-IOR = inorganic condensable particulate matter.
CPM-ORG = organic condensable particulate matter.
[d] To convert to lb/MMBtu of No. 2 oil, divide by 140 MMBtu/10^3 gal. To convert to lb/MMBtu of No. 6 oil, divide by 150 MMBtu/10^3 gal.
[e] References: 76-78.
[f] References: 79-82.

Source: https://www3.epa.gov/ttn/chief/efpac/comments.html