

# Driving Solar Energy in New York City, Hong Kong & Freiburg

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*By Steven Cohen, Hayley Martinez, Alix Schroder, Hilary Osborn and Catalina Villegas*

The global demand for energy is predicted to increase by as much as 40% by 2030 (EIA, 2016). To meet future energy needs of the growing global population, the world needs to transition away from fossil fuels and toward renewable energy. Of the available renewable energy sources, solar power is one of the most promising options for the future, and has a key role to play in the ongoing transition to a sustainable economy. Solar energy use has grown substantially in recent years, both in the United States and globally. Bell Labs developed the first solar battery in 1954; and large-scale solar plants began to appear in the 1980s and 1990s, but it wasn't until the early 2000s that solar technology gained significant popularity. Three factors made this possible: a) advances in solar technology, b) new financial models that made solar technology more affordable and c) strong government policies to support solar energy.

This case study examines the growth of solar and renewable energy worldwide, and discusses general barriers to implementing solar. It will then examine policies that support and incentivize solar energy in three cities: New York City, Hong Kong and Freiburg, Germany. We describe the history and background on sustainability and energy policies in each city, examine the major local barriers to solar, and the drivers of renewable energy policy in each place.

## **The Growth of Solar Energy**

Recent technological advances have led to a rapid expansion of the solar market. Solar technologies include photovoltaic (PV) panels, concentrated solar thermal power (CSP), and concentrating photovoltaics (CPV). Solar PV panels work by turning solar radiation into direct current electricity, while CSP concentrates the energy from the sun to drive steam turbines or engines that then create electricity. With CPV, a large area of sunlight is focused onto the solar cell using an optical device. Between 2006 and 2015, installed solar power grew by over 3000% worldwide (RSM 2016). Global renewable energy capacity is expected to triple by 2035, supplying close to one-third of electricity worldwide, fueled by the increasing cost competitiveness of wind and solar technologies, and by the deployment of renewables in emerging markets (NREL 2013). The solar industry now employs approximately 2.8 million people around the world (IRENA 2016). Global investment in solar has also dramatically increased over the past few decades. In 2015, investment in solar was the highest of all renewable energy sources, with \$2.4 billion in new private investment, up 58% from 2014, and \$10.1 billion in new public investment, up 21% (Frankfurt School 2016). And as the number of solar cells continues to grow, the price of solar energy continues to decline. In a recent study, researchers at Oxford University found that in the short term, the upward swing of solar is unstoppable. The report states that falling manufacturing costs, which have dropped by 10% per year since the 1980s, would increase solar energy's share of global electricity from roughly 1.5% today, to as much as 20% by 2027 (Farmer & Lafond 2015).

China, Germany, and the U.S. are among the top nations in solar power generation and capacity. Solar power in China has grown more than sevenfold since 2012, as the country sought to boost use of solar panels to cut carbon emissions and increase home consumption of renewable energy. In 2015, China surpassed Germany as the nation with the most installed solar PV capacity (IRENA 2016). China currently has 43 Gigawatts (GW) of solar PV capacity, and has plans to more than triple that by 2020. While Germany's solar growth has slowed in recent years – in 2015, it only installed 1.3 GW of new solar PV – it is still the global leader in solar. Despite gray skies, the country has installed an astonishing great deal of solar power per capita. Germany currently has 1.5 million PV installations that provide a generation capacity of 40 GW, and the country has begun to store its excess solar power to enhance local usage. In 2015, about 27% of Germany's net electricity consumption came from renewable sources, with 7.5% of that from solar (Wirth 2016). Germany's strong solar policies have helped reduce costs which dropped from \$4.25 per watt in 2010 to \$2.1 per watt in 2014 for completely installed solar arrays (RMI 2015; Fraunhofer 2016) According to a recent analysis, once all costs are accounted for, the price of commercial solar power in Germany is now equal to retail electricity rates (Eclareon 2014).

In the United States, the installation of solar panels continues to grow. According to a report from the Environment America Research & Policy Center, "The United States has more than 200 times as much solar photovoltaic (PV) capacity installed today as it did in 2002" (Burr et al. 2014). In 2013 the United States saw a 41% increase in solar installations over 2012. Solar energy accounted for 29% of all new electricity generation capacity in 2013, up from 10% in 2012 (SEIA 2013). In 2015, solar was the third largest source of new electricity generating capacity behind natural gas and wind, accounting for 14% of total new energy capacity (Walton 2016). There are now over 22,700 megawatts (MW) of total solar electric capacity operating in the U.S., enough to power more than 4.6 million typical American homes. Experts predict that close to 20,000 MW of solar PV will come online by the end of 2017, representing almost 100% growth over the capacity operating in 2015. Furthermore, the cost of solar energy has continued to drop in recent years. Since 2006, installation costs have dropped over 73%. Between 2010 and 2015, the cost of residential solar installation fell by 45% (SEIA 2016).

Why are we seeing such growth? Solar energy certainly has many advantages over traditional fossil fuel-based energy. Fossil fuels are finite resources and their extraction damages earth's ecosystems. When burned as an energy source, fossil fuels emit greenhouse gases that contribute to climate change, disrupting human settlements, agriculture and infrastructure. Solar energy does not release harmful greenhouse gases (beyond the production of the panels themselves), and solar generation reduces greenhouse emissions by up to 300 million tons per year (IRENA 2016). Solar is more versatile and can be utilized either on or off the electricity grid. The solar energy industry is also an important local job creator, and it is generally less vulnerable to price manipulations and the type of politics that have more than doubled the price of many fossil fuels in the last decade (Whitburn 2012). Despite these many advantages, there are a number of technical and regulatory challenges associated with solar energy use that limit its further deployment.

## Challenges to Solar Expansion

The major obstacles for solar expansion are solar energy storage, conversion of solar energy, connecting to existing power grids, and financial challenges. Today's power grids aren't able to store energy, and solar energy is intermittent, meaning it may generate more or less than is needed at any given time (Williams 2014). Peak solar generation times do not always coincide with peak electricity use, so solar energy often needs to be stored for use at later times. Solar energy must also be sourced elsewhere at

night or during winter months, but battery technology thus far has not been able to store energy on a large enough scale (Whitburn 2012). According to Kate Galbraith, an environmental columnist for the *New York Times*: “cheap, large-scale energy storage is considered the holy grail of renewable power because it would allow wind and solar farms to provide constant energy to the electric grid” (2013).

The energy conversion process from solar is inefficient when compared to traditional sources of energy. Most solar panels convert less than half of the sunlight that reaches them into electricity, and even the best panels on the market have conversion rates of only 35% (Williams 2014). More efficient solar cells are expensive to produce, and while a number of technologies are being developed to overcome these challenges, most are too expensive to use.

Another challenge is connecting solar to existing power grids. Traditional electrical systems are centralized, where electricity is generated at a large-scale power plant and then transmitted (often over long distances) to customers. Solar energy systems, in contrast, are typically a type of distributed energy, which refers to the generation of electricity from sources that are at or near the point of consumption. This type of production can reduce the amount of energy lost in transmitting electricity and reduce the size and number of power lines needed (NREL 2012). However, there are a number of technical, temporal, and spatial restraints to integrating electricity onto the grid in a way that ensures a reliable supply, and there are a number of information barriers for customers. One solution is a “smart grid” that incorporates data across the transmission system and optimizes delivery, efficiency and conservation. One of the main obstacles to decentralized (distributed) renewable energy is the varied set of rules governing access to the power grid by states and utility territories. Barriers include the challenge of raising capital, formulating a legal structure that allows for local ownership, and battling against utilities that may be hostile to local generation because of its threat to the utility’s business model (Farrell 2013).

In addition to these technical challenges, there are financial hurdles both to implementation of solar technologies. Solar energy installations can be especially costly for small home and business owners. People who rent their housing or office space have little incentive to install solar (because they do not own the building, though they would benefit from lower energy bills), and often multi-family residences and apartment buildings don’t meet the requirements for solar installation. On the investment side, renewable energy projects are typically smaller, more complex, and riskier than traditional energy investments. Even with the costs of solar energy declining overall, according to Bloomberg New Energy Finance, investments in clean energy in the U.S. actually fell by 21% between 2011 and 2014, likely an aftereffect of the U.S. stimulus package which enabled significant investment in clean technology (Williams 2014). For these reasons, solar energy research, development, and installation projects often require government policies and incentives.

## **Solar Policies in New York City and New York State**

New York City is the largest city in the United States, with a population of over 8.5 million people. In 2007, under former Mayor Michael R. Bloomberg, New York City adopted an aggressive sustainability program. Until 2013 when Bloomberg left office, the Mayor’s Office of Long-Term Planning and Sustainability led an effort to define sustainability for New York City through implementation of PlaNYC 2030, the city’s comprehensive sustainability plan. PlaNYC brought together over 25 agencies across the city to incorporate sustainability and develop a “greener, greater city.” One of its primary goals was to reduce the city’s greenhouse gas emissions 30% by 2030 – an ambitious goal for a city that was already

considered one of the U.S.'s most carbon-efficient, primarily due to its high density and extensive use of mass transit. The central achievement of PlaNYC was its success in integrating environmental protection and quality of life initiatives into an overall effort to promote urban economic development. At its heart, the plan was not designed to protect the environment, but to make the city better able to attract and retain economic growth.

In 2015 current Mayor Bill de Blasio released his (legally mandated) update of PlaNYC with a new name: *'One New York: The Plan for a Strong and Just City.'* Mayor de Blasio called his plan OneNYC, with the goal of addressing the social, economic and environmental challenges the City is expected to face. It is based on the premise that a more equitable city is a more sustainable city. Under OneNYC, the city pledged to reduce greenhouse gas emissions 80% by 2050 (80x50), an even more aggressive goal than before. This means that the city must reduce emissions by 43 million metric tons per year across power generation, transportation, buildings and solid waste (City of New York 2015). Both PlaNYC and OneNYC plans include aggressive goals to reduce greenhouse gas emissions, and include programs and policies to increase and incentivize the use of solar and other renewable energy sources.

### *Solar Energy Policies*

The City of New York has worked hard to promote and incentivize the use of renewable energy. Under OneNYC, the city has pledged to reduce emissions from City government operations 35% by 2025, with the additional goal of powering 100% of city government operations from renewable sources of energy (City of New York 2015). To this end, in July 2015 de Blasio announced a request for information to identify renewable energy generation capacity. This is the first step in understanding the renewable energy options available to the city. But New York City has already taken important steps to incentivize solar energy use and reduce barriers to solar installation.

As early as 2006, the City University of New York (CUNY), convened stakeholders to collaborate on drafting and implementing strategic solar plans and large scale solar integration for the city, through the NYC Solar Partnership. This partnership is an effort of Sustainable CUNY, the Mayor's Office and the NYC Economic Development Corporation. Through this partnership, CUNY developed 'solar empowerment zones,' or regions that are targeted for solar because they provide technical advantages. In June 2016 the partnership also launched a NY Solar Map and Portal, a public website that contains all information on programs that can help people install and use solar in New York City. Nearly half of all households and businesses in the U.S. can't have PV solar systems on their roof, either because it is not suitable or because they rent. Community and shared solar systems are gaining popularity, as they allow for expanded participation in the solar energy market. Residents and business owners can sign up to contribute to a local solar project, in exchange for some kind of compensation or credit on their utility bill. The solar panel does not have to be physically located on a user's property and it allows for more equitable access to clean energy. Shared projects are built within the community so all the environmental, economic, and public health benefits stay local, and the portal that CUNY released is meant to help facilitate these projects.

The city also launched a 'Solarize NYC' program to reduce market barriers for solar and increase installed solar capacity, particularly for communities that have historically had little solar access. Solarize NYC is a short term, local community-led initiative that brings together solar customers through outreach and education (NYC Solar Partnership, 2016). Customers can then choose solar companies that offer transparent pricing, and the groups can benefit from discounted pricing as a result of pooled demand.

This program was piloted in Brooklyn in fall 2015, and the city successfully surpassed its goal of total installed capacity of 150 kW.

Some of the largest barriers to distributed energy include “soft costs” like permitting and interconnection requirements. The city has streamlined solar permitting to make it easier to install. The Department of Buildings (DOB) has worked to reduce the turnaround time for solar photovoltaic (PV) plan reviews, reducing the time from 4-8 weeks to less than 2 weeks. They made a project advocate available to provide tailored support to applicants. They clarified how those living in flood zones can add solar, through exceptions to the building code’s section on flood-resistant construction. They also simplified the process for small solar projects to apply for permits, and updated building and fire codes to make it easier to install solar PV in more areas (City of New York 2016b).

Through all these efforts, the city has tripled solar installations between 2014 and 2016. The City also installed 5.8 MW of solar on City-owned facilities in the last year, bringing the total to 8.82 MW of renewable solar capacity. Fifteen MW of additional solar installations are planned or already under construction (City of New York 2016b). The City also recently passed legislation to require reporting on the solar power potential of City-owned buildings of at least 10,000 square feet, further emphasizing clean energy as a priority for City assets. According to the OneNYC 2016 progress report, the city has a goal to:

“install 100 megawatts (MW) of solar photovoltaic (PV) capacity on City-owned property by 2025 and to support the development of 250 MW of solar PV on private property through group purchasing and community-shared solar PV projects. Between projects already in operation and those in the queue, the City is on track to be a quarter of the way to its 100 MW goal by 2018 and already about a third of the way to completion of its 250 MW goal.”

Most recently, Mayor de Blasio announced that solar capacity of the City has quadrupled, up to 96 MW of electricity, compared to 25 MW at the start of his administration. Between January and September of 2016, the city has installed over 8,000 solar panels, with over 3,000 on public buildings, which means the city has already met several of OneNYC’s goals (Shelter 2016). De Blasio also announced a new target for solar capacity, set to 1,000 MW by 2030, enough to power more than 250,000 households. New York City also became the first city to set an energy storage deployment target of 100 MW by 2020, to support resiliency during outages (City of New York 2016a).

### *Solar in New York State*

New York City is a leader when it comes to local sustainability policy, but the city is largely helped by policy action at the state level, under the leadership of current Governor Andrew Cuomo. New York State has shown a commitment to solar energy through financial incentives, research and development, increased installation of solar panels and increased manufacturing of solar technology statewide. Most recently, the state launched its ‘Reforming the Energy Vision’ (REV) strategy in 2015 to spur clean energy innovation, bring in new investment into the state and improve customer choice and affordability. The goal of REV is to provide a reliable, resilient and affordable energy system, while ensuring continued economic growth for the state.

One initiative that falls under the REV umbrella is the New York Sun Initiative (NY-Sun), a public-private partnership intended to drive the growth of the solar industry in New York, originally started in 2012.

The Initiative brought together and expanded existing programs administered by the New York State Energy Research and Development Authority (NYSERDA), Long Island Power Authority (LIPA), and the New York Power Authority (NYPA), to ensure a coordinated solar energy expansion plan. The Initiative planned to make solar energy more affordable for residents and businesses in order to increase the amount of installed customer-sited PV capacity. NYSEDA and NYPA provided \$40 million dollars in an effort to promote research into reducing the overall equipment and installation costs so that in the future solar energy would be competitive with other forms of electricity and require no government subsidies (Cuomo 2012).

Since 2012, when Cuomo launched NY-Sun, until 2015, solar has grown 575% in New York State. The NY-Sun program will help bring affordable solar electric power to 150,000 new homes and businesses by 2020 (NYSERDA 2016). Approximately 116,000 tons of greenhouse gas emissions have been (and will be) avoided with the installation of these projects, a value equivalent to removing 23,000 cars from the road (NYS DEC 2014). In April 2014 Cuomo further established his commitment to solar with \$1 billion in funding to continue the NY-Sun solar program, aiming to increase solar power tenfold in New York by 2023 and transform the solar industry in New York to a sustainable, subsidy-free sector. The NY-Sun Solar PV Incentive Program offers reduced installation costs for systems up to 25 kW for residential customers and up to 200 kW for commercial customers (NYSERDA 2016). Cuomo also announced other programs to encourage clean energy, like K-Solar, which uses schools as demonstration sites to increase solar energy projects, and the NY Prize competition, which offers \$40 million to boost microgrid development to protect electrical grid disruption (Burgess 2014).

New York State also uses a series of financial incentives to encourage renewable energy deployment. One of the main pillars of REV is the Clean Energy Fund, a 10-year, \$5 billion plan funded by surcharges on electricity bills, with the ultimate goal of promoting large-scale renewable energy projects in the state. The main goals of the CEF are: to achieve greater levels of scale for clean energy in the state economy; foster new investment opportunities to attract private capital to invest in clean energy in New York; and significantly reduce greenhouse gas emissions from the New York energy sector (St. John 2014).

The Clean Energy Fund also provides support to the New York Green Bank. Funding for the Green Bank was first approved by the New York Public Service Commission in 2013, with funds from clean energy ratepayer funds, combined with funds from allowances from the regional carbon cap and trade mechanism, the Regional Greenhouse Gas Initiative (RGGI). It's initial funding was \$165 million (Long 2014). State green banks use public debt to leverage private sector investment and bring elements of predictability and aggregation that reduce overall pricing, reducing a significant market barrier that has long slowed the development of new clean technology (Hendricks & Bovarnick 2014). Green banks can help overcome market barriers such as lack of capital markets and federal policy uncertainty. The New York Green Bank is now a core initiative of the REV plan, directing \$1 billion in investment to green energy projects in New York State.

## Energy Policies in Hong Kong

The city of Hong Kong is an autonomous territory in southeastern China with a population of more than 7 million. Hong Kong ranks 16<sup>th</sup> according to the Sustainable Cities Index, a ranking system developed by the company Arcadis which ranks the world's 100 leading cities based on social, environmental and economic factors. Hong Kong is ranked second after Seoul among Asian cities in the "profit" (economic)

sub-index, and is still one of the leading Asian cities in the “planet” sub-index. Hong Kong received its high ranking because of its place in the world market as a financial hub that promotes transparency and good relations between international companies (Arcadis 2016). However, for Hong Kong to continue being a financial center, it must maintain a livable, attractive environment for its inhabitants and visitors. The city recognizes that it must implement sustainable strategies that use resources efficiently, while still accounting for its growth.

The government of Hong Kong is aware that to maintain its competitive and prosperous economy it must address the pressing issues facing the city, such as increasing municipal solid waste and decreasing landfill space, high local pollution and regional smog, rising property prices, and a low proportion of renewable energy sources. Many of the sustainability initiatives in Hong Kong have come in the form of educational programs meant to encourage public participation in pollution control (Air Quality 2015). As the Vice Chairman of Hong Kong’s Council for Sustainable Development stated, “Hong Kong’s vision statement for sustainable development emphasizes social participation” (Cheng 2005). The government programs are meant to foster an environmentally conscious culture. Their “Public Participation” webpage offers a variety of green living tips, ranging from managing water waste to improving local air, and contains a secondhand market place and a city-wide “Food Wise” project aimed at reducing food waste (GovHK 2015). While Hong Kong has environmental legislation in place—mainly in the form of various emissions and disposal controls—its approach to environmental issues has concentrated on creating partnerships with businesses and the public in order to help them function more sustainably (Business 2015).

### *Hong Kong’s Energy Plan*

Hong Kong’s current energy use is based on imported sources, since Hong Kong has no native fossil fuel resources. Mainland China provides all of Hong Kong’s natural gas while Indonesia is Hong Kong’s main supplier of coal (Census 2015). While mainland China is aggressively pursuing solar energy, Hong Kong’s use of renewable energy is negligible; 100% of Hong Kong’s installed capacity for electricity comes from fossil fuels (World Fact Book 2016). The 2016 Hong Kong Energy Statistics annual report found renewable energy usage so small that there were no independent statistics provided for renewable energy (Census 2015). Hong Kong’s economy is mainly composed of services and finance industries, and this has a great influence on how energy is used in the city. The commercial sector is the largest user of electricity in Hong Kong at 66% of total local consumption, followed by the domestic sector at 26.8%, and the industrial sector using a relatively low amount of 7.2% of the total (Census 2015).

Hong Kong’s dependence on imported fuel and its lack of diversity in energy sources is not sustainable from either an environmental or a political perspective. The city’s high use of fossil fuels has led to poor air quality, and the imported nature of these fuels has also left Hong Kong at the mercy of fluctuating oil prices. In response to its energy problems, Hong Kong has implemented an “Energy Saving Plan for Hong Kong’s Built Environment 2015-2025+” (Environment Bureau 2015). This plan summarizes Hong Kong’s efforts to address its energy problems. According to the Energy Saving Plan:

“Hong Kong has a high-density, high-rise lifestyle. As one of the world’s major financial and commercial centres, where much of our activities take place in tall buildings, we use a substantial amount of energy to power our high GDP economy. Thus, energy saving, especially with respect to buildings and transportation, is our key effort in Hong Kong. Our energy-efficient transport system due to our high urban density has been

internationally recognised since the 1980s, while Hong Kong's green building movement started in earnest in the 1990s" (Environment Bureau 2015).

Hong Kong's focus on saving energy has been effective in stabilizing energy use; while Hong Kong's GDP per capita has seen stable growth over the past decade, its energy consumption has remained fairly constant (World Bank 2016). The plan sets the goal of a 40% reduction in energy intensity by 2025 compared to 2005 levels, with expected reductions even after this deadline. The joint slogans of the program are: being "energy aware" and "energy wise." According to the report, buildings consume 90% of the city's electricity usage, and electricity accounts for 54% of Hong Kong's total annual energy end-use. Therefore the government targets buildings for energy reductions. The plan's energy saving guidelines and priorities call for better building design, improved inhabitant behavior, greater choice of energy efficient appliances, and educational programs. The government will take the lead with their own buildings, public housing and public sector development, and they expect private-sector building owners and managers to reduce their energy consumption by 5% by 2020 compared to 2014 levels, with future goals to be determined by 2020. In addition, the city enacted the Buildings Energy Efficiency Ordinance in 2012 to support these reforms, targeting four business services: air-conditioning installations, lighting installations, electrical installations and lift and escalator installations. The Ordinance requires that developers of new buildings comply with the design standards of the Building Energy Code (BEC), and that any retrofitting of these four building services complies with the BEC, and that commercial buildings undergo an energy audit every ten years (EMSD 2012).

The Energy Saving Plan also describes several successes to date. According to the plan, the city has: provided \$450 million to implement Building Energy Efficiency Fund Scheme (BEEFS) programs; developed a regulatory structure to target energy use in buildings through the Building (Energy Efficiency) Regulation (B(EE)R), Buildings Energy Efficiency Ordinance (BEEO), and the Energy Efficiency Labeling of Products Ordinance (EELPO); and has set a significant goal of achieving the BEAM Plus Gold standard for all major government buildings. The plan also specifies gaps to be filled which include improved and more readily available energy data for the public, mobilizing stakeholders, and increasing the energy efficiency of already existing buildings (Environment Bureau 2015).

#### *What About Solar?*

While the efforts of these programs are effective, they may not be a lasting solution for Hong Kong. Hong Kong will still remain dependent on imported fossil fuels. The use of renewable energy in Hong Kong is very limited, with only a handful of larger scale operations in place. One of the biggest deterrents to developing renewable energy in Hong Kong is the territory's small size and dense population.

The commercial, residential, and industrial buildings in Hong Kong are highly concentrated in a small area of the city. This zone not only consumes most of Hong Kong's energy, but it is also extremely difficult to install and support solar infrastructure here. The government of Hong Kong published a study in 2000 titled, "Study on the Potential Applications of Renewable Energy in Hong Kong." The report outlined the renewable technologies available worldwide at the time, and detailed their use for Hong Kong. The report analyzed two possible solar sources, solar PV systems and solar thermal electric systems. Though solar thermal electric systems are significantly more efficient in their solar-to-energy conversion, they were discarded as a viable option in Hong Kong for two main reasons: they need land and direct sunlight. Hong Kong has neither; land is severely limited, and most undeveloped land is sectioned off for parks. Additionally, Hong Kong has a larger proportion of diffuse solar radiation than



direct solar radiation. The report determined that solar PV systems were the most viable for use in Hong Kong. Solar PV systems are “particularly suitable for the dense urban environment of Hong Kong” because they are “unobtrusive and silent in operation and can be mounted on buildings or elsewhere, using space that is already alienated” (EMSD 2002). These PV systems could be theoretically connected to the grid and contribute to the city’s overall energy sources. However, these PV systems are expensive to install and take many years to return their value to the consumer. Although the report outlines high potential renewable energy production, the estimate was overly optimistic and assumed widespread use of solar technology throughout Hong Kong and an adapted building design for increased access to solar power. Even 16 years after this report was issued, solar is still significantly more expensive for the typical Hong Kong resident, and the infrastructure is still not there.

The most prevalent use of solar PV systems in Hong Kong is solar water heating, though this is still relatively rare. The government promoted solar heating as a simple way that consumers could reduce their energy bills; however, the barriers are significant and once again tied to space. Typically, residential water heating in Hong Kong directly heats water to be used, without using hot water storage tanks. Solar water heating technology is dependent on the availability of a water tank to retain heat. To implement this technology, buildings would have to be adapted, but this is difficult because of already constrained residential space. Larger commercial and institutional installations have a better potential for solar water heating technology use because they have relatively more space. This is why solar water heating is mostly used at sites like hotels, hospitals and sports facilities where centralized water heating and storage is practical. The 2000 report stipulates that use of this technology would have to be assessed on a site-by-site basis, and it also adds that water heating in Hong Kong only accounted for 8% of total energy consumption at the time (EMSD 2002).

Additionally, some small-scale photovoltaic and wind systems have been installed in remote areas to generate nominal electrical power for lighting and on-site data recording equipment. But for solar energy to be used on a widespread scale in Hong Kong, there would have to be large reform on much of the city’s infrastructure and an improvement of the efficiency and adaptability of solar energy technology. In recent years a few buildings and plants have been constructed with the use of renewable energy in mind, but the combined impact of these efforts is so small that they do not appear in annual reports of energy use in Hong Kong. The largest solar PV system in Hong Kong is in the Lamma Power Station. Commissioned by HK Electric, it was installed in July 2010 and has a total installed capacity of 1MW of solar, which is very small compared to the plant’s overall capacity of 3,737 MW (HK Electric 2014). Another, even smaller example of solar energy use in Hong Kong is the city’s first zero carbon building, which uses mixed sources of renewable energy and has a 100 kW solar energy capacity (Environment Bureau 2015; HK RE Net 2014). A variety of other smaller scale projects also exist, and are distributed among public lighting, private commercial or residential use, and some government installations built mostly for educational purposes. Nevertheless, the capacity of these solar energy systems is miniscule compared to Hong Kong’s total energy needs.

## **Solar Policies in Freiburg, Germany**

Freiburg is a small city with a population of about 22,000 located in the German state of Baden-Württemberg. Freiburg emerged as a “green city” in the mid-1970s when the community mobilized against plans for a nuclear plant to be built in the nearby village of Wyhl, and successfully caused the cancellation of the plant’s construction (Morris & Pehnt 2012).

In 1986, the city council drafted an “energy supply concept,” an agenda that prioritized better energy practices for the city. The citizens of Freiburg were particularly concerned with energy sources that they considered dangerous, such as coal and nuclear energy. The energy supply concept outlined plans for Freiburg to function without nuclear power, by using energy more efficiently and utilizing renewable energy options like solar and wind. About 50% of electricity in the city is generated using highly efficient combined heat and power plants. The city has also targeted building insulation to achieve its energy goals. The Freiburg low-energy building standard required investment costs to exceed national standards by 5-15% (although national standards caught up after a 5 year period). Freiburg building standards were adjusted in 2008 to include highly effective insulation and the use of combined heat and power systems to conserve energy via a ‘passive house standard’ (Rohracher & Späth 2013). In addition, six wind turbines with a capacity of 1.8 MW each were installed within the city.

Freiburg’s title of “eco city” is held in large part because of the city’s involvement in the solar energy industry. Freiburg is an ideal location for solar energy generation because it is located in one of Germany’s sunniest regions (Janzing 2008). In 1992, the Fraunhofer Institute for Solar Energy Systems built an off-grid solar home in Freiburg, to show that a family could meet all of their energy needs using renewable energy (Morris & Pehnt 2012). This project was supported by the German Federal Ministry for Research and Technology, the state of Baden-Württemberg, and the city, and lasted from 1992 to 1995. The “solar home” generated solar heat and photovoltaic electricity with 4.2 kilowatt peak, accompanied with an electric energy storage battery (Fraunhofer Institute 2016). In Germany, the law requires that every new house built must waste no more than 75 kWh per square meter annually, which is roughly a quarter of the energy that is wasted by traditional Victorian-style houses in Britain. In Freiburg the requirements are even lower at 65 kWh, and may be lowered to between 40 and 50 kWh in coming years (Purvis 2008). In 2007, the city council required that any sections of the city under development needed to hire a consulting firm to judge the feasibility of adjusting to more environmentally sound energy supply options. The standard at that point involved gas-fired boilers combined with solar capture, but developers were required to utilize the more environmentally friendly alternative if it was less than 10% more expensive than the standard implementation (Rohracher & Spath 2013).

Freiburg’s “eco-city” features the neighborhood of Vauban, which has been developed as a ‘sustainable model district.’ Vauban was originally a French military barrack, but was vacated by the military in 1992 (Vauban District 2016). Members of the community were heavily involved in the development of Vauban. The Vauban Forum, a citizens group, advocated for utilizing the former military site for an eco-friendly project. The city of Freiburg upheld the “learning by planning” principle as a guideline for flexibility in development, and allowed for citizen participation throughout the development of the project. The City of Freiburg funded the Vauban sustainable model district project in collaboration with building and development investors, but worked cooperatively with Vauban Forum and other citizens. The initial investment for this project by the city of Freiburg was about 500 million euros (about 562 million USD) (Vauban District 2016).

Known as the “solar settlement,” the community of Vauban was built between 2000 and 2005 and contains 50 PlusEnergy houses, a design concept coined by Freiburg architect Rolf Disch that involves photovoltaic solar trackers and architectural techniques that preserve heat. The Solar Settlement has received multiple awards for housing design, and the residential units have been fully occupied since their completion (Disch 2016). The design of the homes in the neighborhood was a collaboration between private builders and the Baugruppen, a community of building collectives who advocate for equitable housing development. Housing construction focused heavily on energy efficiency, the use of

natural materials such as wood and clay, and green roofs for heat and rainwater management. The key to Vauban's design is its energy generation, which relies heavily on solar energy and storage. More than 450 square meters of solar collectors were completed during the first building phase, and the capacity has continued to be expanded thanks to federal and regional subsidies (Vauban District 2016).

### *The Larger Context: Germany's Energiewende*

The city of Freiburg does not stand as an isolated 'eco-city.' Germany has been a pioneer in renewable energy implementation for the last 50 years. The *Energiewende*, the German term for the transition to a low-carbon, reliable and affordable energy supply, began in response to the oil crisis of 1973, catalyzed by OPEC's oil embargo during the Arab-Israeli war. This embargo cut off oil supply to several countries, causing gas shortages and a spike in oil prices (Office of the Historian 2016). Faced with the uncertainty of traditional energy sources, Germany was motivated to find alternatives. The Federal Environmental Agency of Germany, the country's main environmental protection agency, was founded in 1974, and began regulating buildings' energy demand and insulation to be heated more efficiently, and investing in research and development for renewables (Morris & Pehnt 2012).

The most notable innovation in renewable energy policy was the feed-in tariff. Though other countries such as the United States had used a similar strategy, Germany was the first country to coin "feed-in tariffs" as a way of financing green energy. Feed-in tariffs are policy mechanisms that promote renewable energy by using public funds to pay at-or-above retail price for renewable energy generation using long-term contracts (Imoru, Halidu, Imoru & Tsado 2015). Originally adopted as the "Stromeinspeisungsgesetz" (StrEG), or "Law on Feeding Electricity into the Grid" in 1991, the law required utilities to purchase energy from renewable sources, such as wind, solar, hydropower, and biomass at a percentage of the current retail price. Initially these regulations proved problematic and unsuccessful for the promotion of costlier technologies such as wind and photovoltaic solar. The law was then reconstructed and expanded as a part of the German Renewable Energy Sources Act (in German, the Erneuerbare-Energien-Gesetz, EEG) in 2000 (Federal Ministry for the Environment 2000). This act stated that feed-in tariffs would decrease at specific intervals after initial investments, as renewable energy sources became more prevalent and less expensive. This allows for amendments as the market changes, as a way of encouraging adaptation and development. The flexible nature of the act, and the use of a model that is easily duplicated means that German environmental policy has served as a benchmark for other countries who want to adopt policies to encourage renewable energy. The German Renewable Energy Sources Act is credited for a mass adoption of solar, wind, hydropower and biomass technologies in Germany and across Europe.

Community involvement in renewable energy projects is an inherent part of the success of *Energiewende*. The German Renewable Energy Sources Act has been amended multiple times since 2000, and its impact on German communities has varied. In the past 10 years, the number of energy cooperatives in Germany, who coordinate and complete energy projects, has grown from 8 to 800, and 90% of these co-ops specialize in solar power (Harvey 2016). Photovoltaic projects are viewed as the less risky option for investment when compared to wind, because of installation costs and construction processes. In recent years, feed-in tariffs have decreased incrementally over the years as a way of phasing out government funding to encourage private investment. However, the amount of investment in renewable energy projects and co-ops dropped 25% in 2015, according to a survey conducted by Germany's regulation association, the DGRV (Deutscher Genossenschafts- und Raiffeisenverband) (DGRV 2016).

The Renewable Energy Act of 2014 set fixed values for purchasing PV electricity from generation sites, and proposed that the feed-in tariff be replaced with an auction system. This means that proposed renewable energy projects will have to win government funding through auctions, which will be held three times a year by the Federal Network Agency, the German regulatory office for electricity. The purpose of these auctions is to encourage competition between different renewable energy stakeholders in the electricity market, such as community co-ops and energy companies, while keeping to the defined renewable energy “growth corridors” the country has set for itself, set at 2.4 to 2.6 GW PV of annual growth (Wirth 2016).

The concern is that there is not enough stakeholder diversity present in the market for competition to expand the renewables market. However, the government has instituted an exemption for solar projects under 750 kW having to participate in auctions, which is good for smaller community solar projects, as they will continue to receive government funding through the feed-in tariff system (Harvey 2016). Systems with power less than 100kW still qualify for the feed-in tariff, while systems over 100 kW must market the electricity generated. Germany began holding auctions in 2015; in the fifth and most recent auction, held in August 2016, Germany’s Federal Network Agency allocated 130 MW to 25 successful bids (Enkhardt 2016). The average bid amount was about €0.0723 per kilowatt hour, which was slightly less than the €0.0741 average from the fourth auction held in April. President of the Federal Network Agency Jochen Homann believes this is a good sign for the market, and stated that, “The price decline was evidence of the effective competition between ground-mounted PV systems” (Meyers 2016).

Germany is home to a handful of the largest solar parks in the world, such as Solar Park Meuro which opened in 2011, and Neuhausen-Solingen Solar Park which opened in 2012 (Bay Energy Group 2016; Canadian Solar 2016). Germany’s 1.5 million solar power plants account for 40 GW of installed capacity for renewables. As Germany continues to pursue its commitment to solar and other renewable energy sources, development will focus on expansion and storage. In order to reach the country's goals of 200 GW of PV capacity by 2050, 4-5 GW of capacity must be installed annually. Conversion and storage of renewable energy is an important element of Germany’s solar energy future. In 2015, 41% of all new solar installations were equipped with backup batteries.

## Conclusion

The recent expansion of solar energy worldwide has been driven by government policies and incentives aimed at supporting and promoting solar power. Many solar technologies are not yet cost-competitive with conventional energy sources, so governments have encouraged solar energy development through a broad range of fiscal, regulatory, market and other policy instruments. In Germany, for example, the rapid market growth of solar energy can be attributed to the feed-in-tariff system that guarantee attractive returns on investment along with regulatory requirements mandating full grid access and power purchase. In the United States, federal and state incentives are the driver behind the rapid deployment of solar energy (Timilsina et al. 2012). Some local governments in America are also active in this arena.

In Freiburg, the early uptake in thermal solar capacity during the late 1990s was largely driven at the local level, through taxes on electricity and investment subsidies paid out by municipal utilities (Rohracher & Spath 2013). Energy policy in New York City had a large focus on sustainability and renewable energy since the time of former Mayor Bloomberg, but state-level action has also contributed to completion of goals and initiatives at the local level. Hong Kong, by contrast, is largely

limited by its energy dependence, and has relied nearly completely on fossil fuels for energy, without a concerted policy effort to spur investment in solar energy.

The cities of New York and Hong Kong are large, dense, highly populated and growing areas that have to meet the energy needs of millions of residents and visitors. Both cities have very little land available for solar installations, and have many high-rise buildings that are unsuitable for current solar technologies. But New York City is working to overcome this obstacle by utilizing community solar programs, reducing soft costs for residents like permitting and interconnection standards, and taking advantage of state level programs that encourage renewable energy investment. Both New York City and Hong Kong governments have focused effort on government-owned buildings that they directly control. New York City has even gone as far as stating that 100% of government buildings will ultimately be run by renewable energy. Hong Kong, however, depends largely on imported fossil fuels, and has focused largely on energy conservation and energy efficiency measures.

Freiburg and New York City have both placed great emphasis on community mobilization and local input. New York City's Solarize NYC program and the NYC Solar Partnership both rely on the collaboration of community members. New York City's goals under OneNYC were also developed with feedback from local stakeholders and community groups. Freiburg and other cities in Germany have a very inclusive model when it comes to policymaking, seeking local participation whenever possible. All three cities have in some ways targeted the building sector, which is reasonable considering that in urban areas buildings are often the largest consumers of energy and largest emitters of greenhouse gas emissions. They have looked at building insulation standards, building codes, combined heat and power policies, and passive house standards. Each city has also set specific and measurable goals related to energy and greenhouse gas emissions reductions, in order to measure progress. With the demand for energy growing worldwide, and more of the world living in urban areas, cities need to learn how to transition to a sustainable economy based on renewable energy. This largely depends on the technology that reduces the price of renewables, but cities are making the transition nevertheless.

## Discussion Questions

1. What are the benefits of solar energy compared to traditional fossil fuel sources?
2. What are the challenges associated with solar energy deployment and installation in dense urban areas?
3. What is government's role in renewable energy policy? How does this role differ at the local, regional and national level?
4. How can local government ensure public support for renewable energy policies?
5. What is the significance of New York City's commitment to power 100% of government operations from renewable sources?
6. Freiburg is a small city compared to many urban areas; can any of Freiburg's initiatives be replicated on a larger scale?
7. Is solar energy a viable option for Hong Kong's growing needs?
8. If Hong Kong pursues more renewable energy, what lessons can it learn from the cities of New York and Freiburg?
9. What is the importance of setting measurable goals when it comes to sustainability policy?

## References

- Arcadis. (2016). "Sustainable Cities Index." <https://www.arcadis.com/en/global/our-perspectives/sustainable-cities-index-2016/>
- Bay Energy Group. (2016). "Neuhardenberg, 19.69 MWp." <http://www.bayenergy.net/references/solar-power-plant/neuhardenberg/>
- Bloomberg News. (2016). "China's Solar Prices Can Fall 38%, Become Competitive with Coal." <http://www.bloomberg.com/news/articles/2016-05-23/china-s-solar-prices-can-fall-38-become-competitive-with-coal>
- Burgess, J. (2014). "Governor of New York Pledges Another \$1 Billion to NY-Sun Initiative." *Oilprice.com*. <http://oilprice.com/Latest-Energy-News/World-News/Governor-of-New-York-Pledges-Another-1-Billion-to-NY-Sun-Initiative.html>
- Burr, J., Dutzik, T., Schneider, J. and Sargent, R. (2014). "Shining Cities At the Forefront of America's Solar Energy Revolution." Environment Colorado Research & Policy Center and Environment America Research & Policy Center. 1-62.
- Canadian Solar. (2016). "Solarpark Meuro, Germany: World's Largest Solar Power Plant 2011 Produces Power with Canadian Solar Modules." <http://www.canadiansolar.com/solar-projects/solarpark-meuro-germany.html>
- Census and Statistics Department. (2015). "Hong Kong Energy Statistics 2015 Annual Report." *The Government of the Hong Kong Special Administrative Region*. <http://www.censtatd.gov.hk/hkstat/sub/sp90.jsp?productCode=B1100002>
- Cheng, E. (2005). "Sustainable Development in Hong Kong." *Hong Kong Council for Sustainable Development*. <http://www.enb.gov.hk/sites/default/files/susdev/html/en/su/20051214sdhk.pdf>
- City of New York. (2015). "De Blasio Administration Moves to Power 100 Percent of City Government From Renewable Sources of Energy." Office of the Mayor. <http://www1.nyc.gov/office-of-the-mayor/news/478-15/de-blasio-administration-moves-power-100-percent-city-government-renewable-sources-of>
- City of New York. (2016a). "Climate Week: Solar Power In NYC Nearly Quadrupled Since Mayor de Blasio Took Office and Administration Expands Target." <http://www1.nyc.gov/office-of-the-mayor/news/767-16/climate-week-solar-power-nyc-nearly-quadrupled-since-mayor-de-blasio-took-office-and>
- City of New York. (2016b). OneNYC 2016 Progress Report.
- City University of New York. (2016). Solar in New York City. <http://www.cuny.edu/about/resources/sustainability/solar-america.html>
- Cuomo, A. (2012). "Governor Cuomo Announces Comprehensive NY-Sun Initiative to Expand Solar Development." New York State: Office of the Governor. <https://www.governor.ny.gov/press/04192012-sun-initiative>

Devabhaktuni, Vijay, et al. (2013). "Solar energy: Trends and enabling technologies." *Renewable and Sustainable Energy Reviews*, Vol 19. 555-564.  
<http://techno.su.lt/~bielskis/straipsniai%20ir%20knygos/Solar%20energy%20Trends%20and%20enabling%20technologies.pdf>

DGRV. (2016). "DGRV annual survey of energy cooperatives: renewed drop in number of new energy cooperatives." <https://www.dgrv.de/weben.nsf/web/annualsurveyenergycooperatives>

Disch, R. (2016). "The Solar Settlement in Freiburg." *Solar Architektur*.  
<http://www.rolfdisch.de/index.php?p=home&pid=78&L=1#a564>

Eclareon. (2014). "PV Grid Parity Monitor: Commercial Sector." [http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/pv\\_gpm\\_3\\_commercial\\_2014.pdf](http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/pv_gpm_3_commercial_2014.pdf)

Electrical and Mechanical Services Department (EMSD). (2002). "Study on the Potential Applications of Renewable Energy in Hong Kong." *The Government of the Hong Kong Special Administrative Region*.  
[http://www.emsd.gov.hk/en/energy\\_efficiency/new\\_renewable\\_energy/](http://www.emsd.gov.hk/en/energy_efficiency/new_renewable_energy/)

Electrical and Mechanical Services Department (EMSD). (2012). "Buildings Energy Efficiency Ordinance." *The Electrical & Mechanical Services Department*. [http://www.beeo.emsd.gov.hk/en/mibec\\_beeo.html](http://www.beeo.emsd.gov.hk/en/mibec_beeo.html)

Energy Information Administration (EIA). (2016). "Annual Energy Outlook 2016." <http://www.eia.gov/forecasts/aeo/>

Enkhardt, S. (2016). "Germany's Fifth Solar Auction Allocates 130 MW to 25 projects." *PV Magazine*.  
[http://www.pv-magazine.com/news/details/beitrag/germanys-fifth-solar-auction-allocates-130-mw-to-25-projects\\_100025687/#axzz4GT5VwI5u](http://www.pv-magazine.com/news/details/beitrag/germanys-fifth-solar-auction-allocates-130-mw-to-25-projects_100025687/#axzz4GT5VwI5u)

Environment Bureau. (2015). "ENERGY SAVING PLAN For Hong Kong's Built Environment 2015~2025+." *The Government of the Hong Kong Special Administrative Region*. <http://www.enb.gov.hk/en/energysavingplan.html>

Farmer, J. Doyne and Francois Lafond. (2015). "How Predictable is Technological Progress?" Institute for New Economic Thinking (INET), Oxford University. <https://arxiv.org/pdf/1502.05274v4.pdf>

Farrell, J. (2013). "What are the Barriers to Distributed Renewable Energy?" *Renewable Energy World*.  
<http://www.renewableenergyworld.com/rea/blog/post/2013/02/barriers-to-distributed-renewable-energy-slideshow>

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. (2000). Act on Granting Priority to Renewable Energy Sources. Public Relations Division. Berlin, Germany.  
<http://www.bmub.bund.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/res-act.pdf>

Frankfurt School-UNEP Centre. (2016). "Global Trends in Renewable Energy Investment." Report with Bloomberg New Energy Finance. [http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres\\_0.pdf](http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf)

Fraunhofer Institute for Solar Energy Systems. (2016). "Energy Self-Sufficient Storage House." [https://www.ise.fraunhofer.de/en/admin-folder/archiv/areas-of-business-and-market-areas/copy\\_of\\_hydrogen-technology/hydrogen-generation-and-storage/electrolysis/energy-self-sufficient-solar-house](https://www.ise.fraunhofer.de/en/admin-folder/archiv/areas-of-business-and-market-areas/copy_of_hydrogen-technology/hydrogen-generation-and-storage/electrolysis/energy-self-sufficient-solar-house)

Galbraith, K. (2013). "Filling the Gaps in the Flow of Renewable Energy." *New York Times*.  
[http://www.nytimes.com/2013/10/03/business/energy-environment/Filling-the-Gaps-in-the-Flow-of-Renewable-Energy.html?\\_r=0](http://www.nytimes.com/2013/10/03/business/energy-environment/Filling-the-Gaps-in-the-Flow-of-Renewable-Energy.html?_r=0)

GovHK. (2015). "Public Participation."  
<http://www.gov.hk/en/residents/environment/air/#/en/residents/environment/public/>

Harvey, R. (2016). "NIMBYism, Co-operatives, and Germany's Energy Transition." *Co-operative News*.  
<http://www.thenews.coop/108839/news/co-operatives/nimbyism-co-operatives-germanys-energy-transition/>

Hendricks, B. and Bovarnick, B. (2014). "Banking on Clean Energy: State Leadership in Financing a Greener Future." *Center for American Progress*. <http://www.americanprogress.org/>

HK Electric. (2014). "The Power Behind Hong Kong."  
[https://www.hkelectric.com/en/MediaResources/Documents/LPS\\_2014.pdf](https://www.hkelectric.com/en/MediaResources/Documents/LPS_2014.pdf)

HK RE Net. (2014). "Solar Photovoltaic Example projects."  
[http://re.emsd.gov.hk/english/solar/solar\\_ph/solar\\_ph\\_ep.html](http://re.emsd.gov.hk/english/solar/solar_ph/solar_ph_ep.html)

Imoru, O., Halidu, Y., Imoru, R.M.A., & Tsado, J. (2015). "Analyses of Photovoltaic Systems in Europe & The U.S.A." *Journal of Multidisciplinary Engineering Science and Technology*. Vol. 2, Issue 4, 652-59.

International Renewable Energy Agency (IRENA). (2016). "Summer of Solar."  
<http://resourceirena.irena.org/gateway/dashboard/?topic=8&subTopic=43>

Janzing, B. (2008). "Solar City Freiburg." *German Business Review*. 7-8, 5.

Kunzig, Robert. (2015). "Germany Could Be a Model for How We'll Get Power in the Future". *National Geographic*.  
<http://ngm.nationalgeographic.com/2015/11/climate-change/germany-renewable-energy-revolution-text>

Long, C. (2014). "New York opens its Green Bank." *Reuters*. <http://blogs.reuters.com/muniland/2014/02/11/new-yorks-opens-its-green-bank/>

Meyers, G. (2016). "Germany Green Electricity 130 MW Solar Bids Won Fifth Solar Auction." *Planet Save*.  
<http://planetsave.com/2016/08/10/germany-green-electricity-130mw-solar-bids-won-fifth-solar-auction/>

Morris, C. & Pehnt, M. (2012). "Energy Transition: The German Energiewende." *Heinrich Böll Foundation*.  
[http://energytransition.de/wp-content/themes/boell/pdf/en/German-Energy-Transition\\_en.pdf](http://energytransition.de/wp-content/themes/boell/pdf/en/German-Energy-Transition_en.pdf)

National Renewable Energy Laboratory (NREL). (2012). "Distributed Energy Basics." Office of Energy Efficiency and Renewable Energy. [http://www.nrel.gov/learning/eds\\_distributed\\_energy.html](http://www.nrel.gov/learning/eds_distributed_energy.html)

New York State Department of Environmental Conservation (NYS DEC). (2014). "Solar Energy in New York."  
<http://www.dec.ny.gov/energy/43231.html>

New York State Research and Development Authority (NYSERDA). (2016). "NY-Sun."  
<http://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun>



New York State. (2016). "Reforming the Energy Vision (REV)". <https://www.ny.gov/programs/reforming-energy-vision-rev>

NYC Solar Partnership. (2016). "Solarize NYC." <http://nysolarize.com/solarize-nyc/>

Office of the Historian. (2016). "Oil Embargo 1973-1974." Bureau of Public Affairs, United States Department of State. <https://history.state.gov/milestones/1969-1976/oil-embargo>

Purvis, A. (2008). "Freiburg, Germany: Is This the Greenest City in the World?" *The Guardian*. <https://www.theguardian.com/environment/2008/mar/23/freiburg.germany.greenest.city>

Rocky Mountain Institute (RMI). (2016). "The Economics of Grid Defection." [http://www.rmi.org/electricity\\_grid\\_defection#economics\\_of\\_grid\\_defection](http://www.rmi.org/electricity_grid_defection#economics_of_grid_defection)

Rohracher, H. & Späth, P. (2013). "The Interplay of Urban Energy Policy and Socio-technical Transitions: The Eco-cities of Graz and Freiburg in Retrospect." *Urban Studies Journal*. 1-17. 10.1177/0042098013500360

RSM Global. (2016). "Global Trends in Renewable Energy." <http://www.rsm.global/insights/economic-insights/global-trends-renewable-energy>.

Shelter, M. (2016). "Major Solar Expansion in New York City." New York League of Conservation Voters. <http://nylcv.org/news/major-solar-expansion-new-york-city/>

Solar Energy Industries Association (SEIA). (2013). "Solar Industry Data." <http://www.seia.org/research-resources/solar-industry-data>

Solar Energy Industries Association (SEIA). (2016). "Solar Industry Data." <http://www.seia.org/research-resources/solar-industry-data>

St. John, J. (2014). "New York Proposes \$5B for Clean Energy Fund to Replace Mandates." *GreenTech Media*. <http://www.greentechmedia.com/articles/read/New-York-Proposes-5B-for-Clean-Energy-Fund-New-Regulatory-Model>

The World Factbook. (2016). "Hong Kong." *Central Intelligence Agency*. <https://www.cia.gov/library/publications/the-world-factbook/geos/hk.html>

Vauban District. (2016). "An Introduction to Vauban District: Abstract". <http://www.vauban.de/en/topics/history/276-an-introduction-to-vauban-district>

Walton, R. (2016). "Solar and wind comprise 61% of 2015 capacity additions, gas contributes 35%." *Utility Dive*. <http://www.utilitydive.com/news/solar-and-wind-comprise-61-of-2015-capacity-additions-gas-contributes-35/411813/>

Whitburn, G. (2012). "13 Fundamental Advantages and Disadvantages of Solar Energy." *Exploring Green Technology*. <http://exploringgreentechnology.com/solar-energy/advantages-and-disadvantages-of-solar-energy/>

Williams, B. (2014). "The 3 Challenges Solar Energy Needs to Overcome to Continue its Growth." *SolarEnergy.net*. <http://solarenergy.net/News/3-challenges-solar-energy-needs-overcome-continue-growth/>

Wirth, H. (2016). "Recent Facts about Photovoltaics in Germany." Fraunhofer ISE.

<https://www.ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/recent-facts-about-photovoltaics-in-germany.pdf>