Chapter 9 – Subsidizing Solar Technology Deployment

As noted at several points, we strongly favor a comprehensive policy to put a significant price on carbon dioxide (CO_2) emissions, either directly through a tax or indirectly through a cap-and-trade system. Such a regime provides an incentive to reduce CO_2 emissions from electricity generation and all other activities in the most cost-effective manner. Importantly, it provides across-the-board incentives for improving energy efficiency. In the presence of a cap on emissions, subsidies for the deployment of solar generation technologies would increase the cost of meeting the cap. In the presence of a carbon tax, such subsidies would reduce emissions but, by favoring one method of emissions reductions over others, would raise the cost per ton of emissions reductions. Deployment subsidies may nonetheless be justified even in the presence of a comprehensive carbon policy, however, if they contribute to advancing solar technology by producing knowledge that is widely shared. In contrast, subsidies to mature technologies, renewable and non-renewable, should be phased out once a comprehensive policy is in place.

In the absence of a comprehensive policy, subsidizing solar deployment may be justified as part of a second-best CO_2 reduction policy. In addition, ongoing deployment, even at modest scale, is likely to help reduce institutional and other barriers to a rapid scale-up of solar generation in the future while also stimulating industrial efforts to reduce costs and improve performance.

In any case, neither the United States nor most other nations have put a significant price on CO_2 emissions. Instead, governments in many countries have adopted a variety of "market pull" policies to promote the deployment and use of solar generation technologies.[i] It is important to recognize, though, that solar technologies are not unique in this regard. The energy sectors in most nations are shaped by subsidies to multiple energy sources. In the United States, for instance, the U.S. Energy Information Administration (EIA) found that direct federal subsidies to solar energy in fiscal year 2010 were less than those to coal, natural gas and petroleum liquids, nuclear, and wind, and comparable to subsidies for biomass.[3]

In the absence of a comprehensive policy, subsidizing solar deployment may be justified as part of a second-best CO_2 reduction policy.

[i] A detailed discussion and evaluation of alternative technology-specific policy approaches is available in Batlle, Pérez-Arriaga, and Zambrano-Barragán.[1] For an analysis that considers the impacts of alternative policies on choices among renewable technologies, with implications for CO_2 emissions, see Fell, Linn, and Munnings.[2]

While they differ in many respects, most of these policies to promote solar deployment can be usefully grouped into four main types: *price-based, output-based, investment-based,* and *indirect.*[ii] In almost all cases, solar generation of electricity is either treated the same as other renewable generation technologies or, more commonly, is given more favorable treatment. Such policies may be part of a second-best strategy to reduce CO_2 emissions (except in the European Union, where CO_2 emissions are capped) and perhaps to reduce the costs of solar electricity,[9] but they are often described as advancing other objectives as well. Section 9.1 discusses some of these additional objectives.

Our main concern here is with the efficiency of solar deployment subsidies, i.e., with the value of electricity produced per dollar of subsidy spending.

Our main concern here is with the efficiency of solar deployment subsidies, i.e., with the value of electricity produced per dollar of subsidy spending. Sections 9.2–9.5 discuss each of the four main types of renewables policies listed above. Section 9.6 then describes what is known and (mostly) not known about the effectiveness of these policies in the United States, and Section 9.7 provides our recommendations for making U.S. solar deployment subsidies more efficient. We believe there is significant room for improvement.

9.1 OBJECTIVES OF DEPLOYMENT SUPPORT

Some have argued that deployment of solar generating facilities should be subsidized in order to build a competitive solar manufacturing industry in the United States, thus positioning domestic suppliers to take advantage of high expected growth in global demand. The main problem with this argument is that subsidizing purchases of some product in the United States or any other nation does not guarantee that local suppliers will meet that demand, since nations' World Trade Organization obligations greatly restrict their ability to protect domestic suppliers with tariffs or quotas.[10] For example, as a consequence of generous subsidies, particularly in Germany, the European Union (EU) accounted for over 53% of new photovoltaic (PV) module installations in 2012, but European firms accounted for only 11% of global module production.[11] In the complex global PV supply chain, technological knowledge readily travels across national borders, and the design and manufacture of these tradable products tend to be performed in the most cost-effective locations.[12]

Moreover, this argument rests on the assumption that even though the U.S. solar industry would be competitive in global markets with adequate investment, capital markets will not provide the necessary funding. But it has proven possible to raise large amounts of money for risky, long-lived investments in a wide variety of sectors — including projects that produce and use fossil fuels as well as others involving new technologies. We are aware of no evidence indicating that solar or other renewable technologies suffer any *special* handicaps that relate to the capital markets. If the global solar market has great growth prospects, it will attract capital — though not necessarily from the United States or for investment in the United States.

[ii] Unless otherwise stated, information about U.S. policies in this chapter has been drawn from the Database of State Incentives for Renewables & Efficiency (DSIRE), the standard reference for current U.S. federal, state, and local policies to support energy efficiency and renewable energy.[4] Detailed information on all energy-related federal subsidies in fiscal year 2010 is from the U.S. Department of Energy's Energy Information Administration (EIA).[5] Information on support policies in the 28 EU nations and five affiliated nations is from LEGAL.[6] The standard reference for support policies globally is from the Renewable Energy Policy Network for the 21st Century (REN21), updated annually.[7] While we focus on support of solar energy here, it is worth noting that other energy technologies are also subsidized. In fiscal 2010, for instance, solar energy received only 8.2% of U.S. federal subsidies and support for electricity production.[8]

To be clear, it may be desirable to subsidize some domestic manufacturing to aid the process of advancing solar technology. Manufacturing cost is a critical attribute of any new solar technology, and it is often hard to judge manufacturing cost without actually doing manufacturing. But, as we discuss further in Chapter 10, this argument calls for selective support of firms working with promising new technologies rather than broad support of solar manufacturing.

Finally, since global greenhouse gas emissions drive climate change, widespread international adoption of new non-emitting technologies has global benefits and generally benefits the United States as well. Like all trade barriers, impediments to the flow of intellectual property or restrictions on the trade of products in the solar value chain reduce global economic efficiency. In this case, such barriers can only raise the cost to the world as a whole of reducing CO_2 emissions via increased use of solar energy.

FINDING

Barriers to the diffusion of solar technology or to international trade in products in the solar value chain will make it more expensive to slow climate change by reducing global CO_2 emissions.

It is sometimes argued that solar and other renewable energy technologies should be supported by government subsidies because they create more desirable jobs in the domestic economy than alternative energy technologies. There are at least three problems with this position. First, we are unaware of any rigorous studies showing that renewable technologies — particularly solar and wind — in fact have higher labor content, properly measured, per unit of output than relevant alternatives. Second, the notion that labor-intensive technologies deserve special support ignores the fact that labor-saving innovations have been major drivers of economic progress. The mechanization of agriculture destroyed many jobs, for instance, but it helped make large-scale industrialization possible. The main long-term effect of subsidizing labor-intensive technologies is to raise the cost of goods and services provided by the private sector. Finally, if the government were to seek to create jobs in the short term by subsidizing particular industries, it is not evident that choosing renewable energy, rather than, say, infrastructure construction or public education, would be the most cost-effective choice.

Some also believe that the strong public support expressed for solar energy justifies the use of public funds to promote its use even absent a market failure rationale. But it is easy for citizens to be in favor of government spending on renewably-generated programs when this spending is not linked to personal costs or to reductions in other programs they also support. Similarly, while people often respond positively to surveys asking if they are willing to pay non-trivial amounts for renewably-generated electricity, it is well known that the answers to hypothetical questions of this sort overstate real willingness to pay.[13] Thus, even though "green power" was available to about half of U.S. electricity customers in 2012, voluntary purchases of green power accounted for only 1.3% of total U.S. electricity sales in that year, with green power sales to residential customers accounting for only 0.3%.[14]

Finally, adding more solar generation would certainly increase supply diversity in the U.S. electric power system, which is becoming increasingly dependent on natural gas. But adding almost any grid-scale, non-gas technology would also serve this objective, and adding wind, biomass, or nuclear capacity might do so at a lower cost.

9.2 PRICE-BASED POLICIES

Though the United States has not made much use of this policy instrument, many nations have supported solar generation via *feed-in tariffs*, which entitle favored generators to be compensated for electricity delivered to the grid at predetermined, above-market rates for a fixed period of time.[iii] The cost of this subsidy is generally added to the retail cost of electricity. Within nations that employ such policies, differences in the regional penetration of renewable generation — reflecting, for example, differences in insolation — would lead to differences in the cost of electricity. European feed-in tariff schemes generally include systems for equalizing their impacts on electricity prices among sub-national regions.[16] Since the costs of renewable generation are uncertain, change over time, and vary from project to project, the quantitative response to any particular tariff level is uncertain. In recent years, several of these schemes have limited the risk of excessive response by either limiting total spending in any year or by reducing the tariff automatically when quantity milestones are passed.

Though the United States has not made much use of this policy instrument, many nations have supported solar generation via feed-in tariffs.

The first generally recognized use of feed-in tariffs was in the United States, under the Public Utility Regulatory Policy Act of 1978 (PURPA). PURPA required vertically integrated electric utilities to purchase power from facilities defined as "qualified" at prices equal to the utilities' "long-run avoided costs." Avoided costs were to be determined by state regulators who were sometimes overgenerous, notably in California.[iv] This system was largely dismantled by the early 1990s, as generous feed-in tariffs became increasingly unsupportable in the face of declining electricity prices.[18]

In 1991, Germany became the first country to adopt feed-in tariffs explicitly aimed at promoting solar and other renewable technologies; Denmark followed suit the next year. Feed-in tariffs have proven a very popular policy abroad, and in 2008, the EU concluded that "*well-adapted* feed-in tariff regimes are generally the most efficient and effective support schemes for promoting renewable energy."[v] Feed-in tariffs played a major role in boosting solar energy in Germany, Spain, and Italy — EU countries that have led recent growth in the global solar energy market. As of early 2013, 71 countries and 28 states or provinces employed feed-in tariffs, including 17 EU member states.[20] In contrast, this policy mechanism is not widely used in the United States.[vi]

Since solar power is at present one of the more expensive renewable generation options in most regions, feed-in tariffs that apply equally to solar and other renewable technologies could be expected to do very little to encourage solar generation relative to other renewables. Most feed-in tariffs in Europe provide higher rates for more expensive renewable technologies, with an eye to equalizing expected profitability — in these cases, solar generation typically receives the highest rate.[16] The

[iii] For a general discussion of feed-in tariffs and their interaction with output quotas see Cory, Couture, and Kreycik.[15]

[iv] For a useful general discussion of feed-in tariffs, see Lesser and Su.[17]

[v] Emphasis in original source — Commission of the European Communities.[19]

[vi] Rhode Island, California, and Washington have feed-in tariffs for certain small generators. See also Couture and Cory.[21]

German feed-in tariff has been both generous and tilted toward solar, with the result that Germany, not a particularly sunny nation, had 45% of EU solar capacity and 26% of world capacity in 2013.[22]

One very important and desirable property of feed-in tariffs is that they preserve strong incentives for both investment efficiency and operating efficiency. With the price of output fixed, every dollar of investment cost reduction translates into a dollar of profit, and every additional kilowatt-hour (kWh) produced adds to profit.

From the investors' point of view, fixing the output price removes all risk associated with the supply and demand for electricity. This may be a large part of the reason for the popularity of feed-in tariffs and their potency per dollar of subsidy spending.[vii] But the level of spending understates the true subsidy involved, since shifting risk from renewable generators to other parties in the market for electricity is also a subsidy, albeit one that is essentially invisible.[viii]

An important risk associated with feed-in tariffs is that the quantity of electricity supplied in response to any given level of subsidy is uncertain. With some technologies this would not be a significant problem because it often takes years to build a new generating facility, a long time relative to the time required to change support policies or to adapt the grid to handle new power flows. But PV, particularly residential PV, can be deployed much more rapidly. In 2013, for instance, PV capacity in China nearly tripled, in Japan it more than doubled, and in the United Kingdom it increased by 83%.[24] Between 2011 and the end of 2013, PV capacity in Hawaii increased by 283%, mainly through the installation of distributed PV. By the end of 2013 more than one in nine Hawaiian homes had rooftop solar installed.[25,26] Under the German feed-in tariff regime, deployment targets have sometimes been substantially exceeded despite reductions in support over time. The sensible approach eventually adopted in Germany was to reduce the level of subsidy automatically when deployment targets were met.[ix]

Feed-in tariff schemes generally guarantee the same revenue per kWh regardless of when that power is generated.

Finally, feed-in tariff schemes generally guarantee the same revenue per kWh regardless of when that power is generated. The wholesale spot price of electricity (or system marginal cost in a vertically integrated system in which a single firm controls generation, distribution, and retail sales) often varies dramatically depending on weather, time of day, and other factors. Feed-in tariffs that do not vary with the wholesale price therefore reduce the subsidy (the difference between the feed-in tariff and the market price) when electricity is most valuable, thus distorting incentives regarding the timing of production. Since solar generators that are in operation today have little or no control over the time-shape of their output, this may be a small effect for these technologies, though the timing of planned maintenance

An important risk associated with feed-in tariffs is that the quantity of electricity supplied in response to any given level of subsidy is uncertain.

[vii] Of course, investors still bear the risks related to the performance of the facility involved.[21]

[viii] For a simple model of such risk-shifting, see Schmalensee.[23]

[ix] On the German experience, see Weiss.[27]

outages is generally under the control of the unit's operators.[x] For new systems, however, subsidies that vary with the wholesale price will provide incentives to face PV panels west instead of south.[xi] West-facing panels produce less total electric energy over time compared to south-facing panels, but they tend to produce more during the late afternoon, when demand and prices are higher. And such subsidies would affect both the amount of storage built into new concentrated solar power (CSP) plants and the operation of those plants.

The use of tax credits instead of direct payments reduces the impact of the subsidy per dollar of cost to the government.

Output subsidy mechanisms (also known as premium tariffs or feed-in premiums) differ from feed-in tariffs in that they provide renewable electricity generators a predetermined per-kWh subsidy in addition to whatever revenues they earn from the sale of electricity, rather than a predetermined total price (amount of revenue) per kWh. The subsidy may vary (positively or negatively) with the wholesale price. As with feed-in-tariffs, the cost of the subsidy is generally added to retail electric bills. As with feed-in tariffs generally, this approach does not guarantee a certain level of renewable energy production. It has been notably less popular in Europe than the feed-in tariff.[29]

Beginning in 1993, with lapses and modifications in the intervening years, the U.S. government has provided corporate income tax credits for each kWh produced by certain renewable technologies. Solar-powered generating units were only eligible if placed in service during 2005. Some states, including Arizona and Florida, offer state tax credits for renewable generation.[xii] As we note in Chapters 4 and 5, the use of tax credits instead of direct payments reduces the impact of the subsidy per dollar of cost to the government. The problem is that to take advantage of the tax credit, a firm must have income at least equal to the credit, or must find a partner that does, and incur the significant cost of tax equity financing to obtain some of the benefits. The need to ensure that the tax credit can be used adds a constraint to the project finance problem that reduces the per-dollar impact of this form of subsidy by half, according to one source.[30] That is, spending a certain number of dollars on cash subsidies for renewable generation would induce more renewable generation than a program of tax credits that costs the government the same number of dollars in lost revenue.

The main advantage of an output subsidy as compared to a flat feed-in tariff is that it provides better incentives for producing electricity when the electricity is most valuable.[xiii] In addition, under an output

[x] It is worth noting that in the absence of a feed-in tariff, if a firm owns conventional dispatchable generation, the more solar generation it also owns, the greater the potential profit it can obtain (via higher revenues for solar generation) by restricting conventional generation to raise market prices. If solar generators receive a (fixed) feed-in tariff, this potential profit is eliminated, and thus so is the incentive to exercise market power by restricting output from conventional plants. On the other hand, this potential problem can also be mitigated, at least in principle, by limiting the market shares of conventional generators or by restricting large conventional generators' ownership of solar facilities.

[xi] California recently adopted an explicit incentive for west-facing solar systems.[28]

[xii] All information in this paragraph is from the DSIRE website.[4] As we note below, the federal subsidy for solar did not disappear in 2006: it became an investment tax credit.

[xiii] The system in the Netherlands, in which the subsidy is proportional to the market price, is particularly effective in this regard.[16] In contrast, the system in Spain reduces the premium when the market price is high, presumably on the grounds that a high market price provides sufficient incentive.[31]

subsidy, electricity-market risk is borne by subsidized generators as well as by other market participants, and spreading risk generally increases economic efficiency. While prospective investors in favored technologies would rather not bear risk, it is socially efficient to compensate them for doing so by increasing the subsidy.[xiv]

FINDING:

Among price-based subsidies, direct payments to renewable generators are more efficient than tax credits, and output subsidies provide better incentives for producing power when it is most valuable than flat feed-in tariffs. Because PV can be deployed very rapidly, the deployment response to price-based subsidies may depart rapidly and substantially from expectations.

9.3 OUTPUT-BASED POLICIES

Outside the United States, output quotas for renewable energy are not as popular as feed-in tariffs. As of early 2013, such policies were in place in only 22 countries at the national level.[20] Output quotas outside the United States are usually implemented via "tradable green certificates." Solar and other renewable generators sell power at the market price and then are able also to sell, in effect, a 1-megawatt-hour (MWh) green certificate for each MWh of electricity they have sold. Distribution utilities or others obliged to source at least a certain percentage of their electricity consumption from renewables can show that they have done so by purchasing an appropriate number of green certificates (often via long-term contracts that also involve purchasing power) and surrendering these certificates to the authorities. In recent years, it has become more popular internationally to have a government agency procure renewable generating capacity centrally; by early 2013, 43 countries, not all of which had output quotas, were using some variant of such centralized procurement.[xv]

Outside the United States, output quotas for renewable energy are not as popular as feed-in tariffs.

The trading feature assures that costs are minimized within the jurisdiction involved, as the cheapest allowable renewable technologies are used to produce green certificates. Since solar is generally one of the most expensive renewable technologies, output quota policies without an explicit tilt toward solar are unlikely to do much to encourage solar generation. It is also important to note that, just as the quantity of renewable generation supplied in response to a fixed feed-in tariff is uncertain, the price of tradable green certificates is also uncertain under a fixed output quota.

Since solar is generally one of the most expensive renewable technologies, output quota policies without an explicit tilt toward solar are unlikely to do much to encourage solar generation.

In the United States, output quotas are universally known as *renewable portfolio standards* (RPSs). Iowa enacted the first RPS in 1983, and such programs are now in force in 29 states and the District of Columbia.[xvi] Many RPS programs treat renewable energy technologies differently. Illinois, for instance, requires that 75% of renewable generation come from wind.

[xiv] A disadvantage is that at high levels of penetration, the market power issue raised in Footnote x above could be important.[1]

[xv] For a discussion of the use of auctions in South America, where they are the main support method, see Battle and Baroso.[32, 33]

[xvi] For a general discussion of RPS programs, see Schmalensee.[23]

As of September 2013, 17 of the 30 state-level RPS programs in the United States included provisions that explicitly favored solar power or distributed generation (which in recent years has been predominantly PV).[34] Several of these programs give extra credit for solar or distributed generation, while Texas gives double credit for non-wind renewable generation. The others have minimum solar requirements of various sorts.

It is not obvious why the output quota or RPS approach is so popular in the United States when experience internationally has made it so unpopular elsewhere.

RPS obligations generally fall on entities that sell electricity to end users. In almost all cases, compliance is demonstrated by retiring "renewable energy certificates" (RECs) that function like the "tradable green certificates" discussed just above.[xvii] Many RECs are sold as a bundle with electricity in long-term deals, so spot markets for RECs are generally thin, with few transactions and large spreads between the price bid and the price asked. In states with explicit requirements for solar generation, the requirement is generally met by retiring solar RECs, which are produced when electricity is generated by qualified solar facilities. Ideally, this trading mechanism would enable renewable electricity to be generated and used where it is relatively most efficient, with utilities elsewhere helping to bear the cost. And, since the potential for renewable generation varies widely among states, nationwide trading of RECs could be an important way of reducing the cost to the nation of meeting a given quantity goal for overall renewable electricity production.

At present, however, only 16 of the 30 U.S. RPS programs permit the use of RECs from facilities that do not deliver to in-state customers to satisfy RPS requirements, and only two programs appear to accept RECs from renewable sources anywhere in the United States.[xviii] Restrictions on trading appear in most cases to be motivated by a desire to promote local economic development. While a national RPS program could, in principle, reduce overall national costs, a national renewable portfolio requirement has never been enacted in the United States, and most proposals for such a policy contemplate leaving the states free to enact more stringent standards.[xix]

It is not obvious why the output quota or RPS approach is so popular in the United States when experience internationally has made it so unpopular elsewhere.[xx] One possibly relevant factor is that the costs of RPS programs are generally built into long-term contracts between utilities and generators and thus are much less visible than the explicit subsidies paid under feed-in-tariff or output subsidy schemes. There is certainly no general economic reason to favor a quantity-oriented

[xvii] See, for instance, Cory and Swezey.[35] New York, Iowa, and Hawaii do not use RECs.

[xviii] See Schmalensee.[23] It is also worth noting that only two RPS programs permit RECs to be banked for an unlimited period; most limit their lives to two or three years. It is not clear what purpose these limits are intended to serve.

[xix] An additional output-based policy deserves mention. The U.S. military, the world's largest energy consumer, has programs in place to meet a statutory mandate of 25% of total facility energy consumption from renewable sources by 2025.[36] While this is ambitious on several levels, the military plans to install only 1.1 gigawatts (GW) of PV capacity between 2012 and 2017, about one-third as much capacity as was installed in the United States in 2012 alone.[37]

[xx] For an examination of the effectiveness of U.S. RPS programs, see Carley.[38]

approach like RPS over the price-oriented approaches generally used internationally; moreover, the quantity approach does not appear to be administratively simpler. Indeed, it is hard to imagine a more complex regime than the multiplicity of different state programs now in place in the United States.

FINDING:

A nationwide RPS program that permitted unlimited interstate trading would have lower costs for any given level of deployment of solar or other renewable generation than the multiple, diverse state programs now in place.

9.4 INVESTMENT-BASED POLICIES

The promotional mechanisms discussed so far all directly reward the production of electricity using solar energy. Policies that reward production are generally superior in terms of return per dollar spent to policies that subsidize investment in solar generation. They provide stronger incentives to reduce investment cost, to locate in areas with high insolation, and to maintain and operate generating units efficiently. With an investment subsidy, a dollar of investment cost overrun reduces enterprise profit by less than a dollar because it also increases the government's subsidy. Moreover, incentives to produce power are less than when production is subsidized or required. Finally, when a facility is owned by its builder rather than purchased from a third party, the fair market value must be estimated in order to compute the subsidy. As discussed in Chapter 4, that estimation is subject to all the difficulties that arise in transfer pricing disputes in tax matters.[xxi]

Policies that reward production are generally superior in terms of return per dollar spent to policies that subsidize investment in solar generation.

Nonetheless, at least 25 of the 30 countries that are part of the Organization for Economic Co-operation and Development (OECD) have used one or more forms of investment subsidy, generally along with other incentives or policies, to promote solar generation.[40] In some cases, these subsidies take the form of grants or other payments from the government, in which case they may be subject to budgetary pressure. In other cases, these subsidies are delivered as tax reductions, which restrict the investment to those entities that can take advantage of the reduction directly or, more commonly, by means of the tax equity market. In either case, the cost of the subsidy is borne by individuals in their roles as taxpayers rather than as electricity consumers. Electricity consumers generally bear the cost of price-based or output-based subsidies through higher retail electricity prices. Higher retail prices provide incentives to reduce electricity consumption across the board, thus further reducing fossil fuel use and CO_2 emissions. This incentive is absent when taxpayers bear the cost of investment subsidies.[xxii]

[xxi] A recent study estimates that prices reported for tax credit purposes for third-party-owned systems are inflated about 10% on average.[39]

[xxii] Fell et al., provide a quantitative analysis of this difference.[2]

Making REITs or MLPs available to solar developers would allow the government to replace the current investment tax credit entirely or in part and lower the cost of the subsidy to taxpayers without reducing its value to developers.

As discussed in Chapter 5, the U.S. federal government provides two significant investment-based subsidies for solar generation: five-year accelerated depreciation (since 1986) and a 30% investment tax credit (since 2006).[xxiii] A number of observers have pointed to the stability of these policies as encouraging investment in the solar industry. In fiscal year 2010, the investment tax credit alone cost the federal government $616 million.[xxiv] Some solar industry stakeholders and supporters have argued that the federal government should increase investment subsidies by making solar generation projects eligible to be owned by real estate investment trusts (REITs) or, as is the case with pipelines and many other fossil energy projects, master limited partnerships (MLPs). These vehicles would essentially enable solar projects to avoid the corporate income tax and would also eliminate the need for most projects to go through the tax equity market.[xxv] Because of this latter feature, making REITs or MLPs available to solar developers would allow the government to replace the current investment tax credit entirely or in part and lower the cost of the subsidy to taxpayers without reducing its value to developers.[xxvi]

In addition, all U.S. states now provide some subsidy for investments in solar electric generation. These incentives involve various mixtures of grants (direct or through local utilities), low-interest loan programs, reductions in state sales or income taxes, reductions in local property taxes, and tax credits of various sorts. In addition to a production tax credit, for instance, Arizona provides an investment tax credit, exempts solar generating equipment from the state sales tax, and exempts residential solar facilities from local property tax. Cities also provide a variety of investment-based subsidies. For instance, San Francisco and Chicago give cash grants for solar installations; Honolulu offers zero-interest loans; and New York City offers property tax reductions proportional to the costs of PV installations.

[xxiii] Policies were and are in place to provide grants and subsidized financing for entities such as tribes and local governments that do not pay income tax.[37] Also, the American Recovery and Reinvestment Act of 2009, as amended, made it possible for business taxpayers to receive a grant instead of the investment tax credit for solar facilities begun before the end of 2012.[41] By the end of October 2013, $5.2 billion of such grants had been paid.[42] The investment tax credit for residential facilities is scheduled to phase out at the end of 2016, when the credit for commercial facilities is scheduled to fall to 10%.

[xxiv] The federal government has also guaranteed loans taken out to finance the construction of selected PV production facilities, thus providing investment subsidies for those facilities.[43] The EIA has estimated that in fiscal year 2010, federal loan guarantees for solar production facilities provided a subsidy of $173 million.[44] Since the main aim of these loan guarantees seems to have been to advance technology, they are discussed in Chapter 10.

[xxv] For a useful discussion, see Feldman and Settle.[45]

[xxvi] A related financing vehicle, the so-called yield co (YC) has recently become popular.[46] Classically, YCs own operating generating plants — solar and otherwise — that have sold their power under long-term contracts, and they pay most of the resulting cash flow directly to their shareholders. They thus produce bond-like returns for shareholders, but offer somewhat higher returns than can easily be obtained in the bond market. In addition, if most of a YC's plants are relatively new, depreciation will generally exceed revenue so that the YC will have no taxable earnings. In that case, payments to shareholders are treated as returns *of* capital and are accordingly not taxed at that level either. Thus, YCs can be a vehicle for deferring taxes for some years.

FINDING:

Investment-based subsidies, particularly those that take the form of reductions in profit taxes, are less effective per dollar of government cost at stimulating solar generation and displacing fossil fuels than price-based or output-based subsidies.

9.5 INDIRECT POLICIES

Beginning with Massachusetts and Wisconsin in 1982, 43 U.S. states plus the District of Columbia now subsidize the output from small, distributed renewable (including solar) generators by means of *net metering*; internationally, 43 other countries use this mechanism.[xxvii] The federal Energy Policy Act of 2005 requires all utilities to make net metering available to those customers who request it. Net metering compensates these generators at the retail price for electricity they supply to the grid, not at the wholesale price received by grid-scale generators. A large fraction of the cost of running a distribution system is fixed, independent of load, but much or all of this fixed cost is generally recovered from retail customers through a per-kWh distribution charge. When a residential customer installs a rooftop PV generator, that customer's distribution charge payments are reduced. But there is no corresponding reduction in the distribution utility's distribution system costs. As noted in Chapter 7, the subsidy is the corresponding reduction in the utility's revenues, which may be made up by increasing the retail price paid by all customers.

For instance, in Boston in August 2014, the local distribution company, NSTAR, generally charged 9.8 ¢/kWh for electricity, reflecting average wholesale market prices, and 8.9 ¢/kWh to deliver that electricity. But electricity supplied by a rooftop PV array in Boston mainly saves NSTAR only its wholesale electricity cost; the delivery charge serves to cover NSTAR's costs to own and operate the distribution system.[xxviii] Therefore, net metering in Massachusetts involves a substantial subsidy to distributed generation — as it does elsewhere.[xxix] For at least some California retail customers, for instance, the value of the net metering subsidy apparently exceeds the value of the federal investment tax credit.[49]

Moreover, because the distribution utility pays this subsidy, it has strong incentives to make it hard to install distributed generation. So-called decoupling arrangements in some states deal with this problem by automatically increasing per-kWh distribution charges so as to maintain utility profits. But this shifts the burden of covering distribution costs from utility shareholders to those customers who do not or cannot install distributed generation, a group that is likely to be less affluent than those who benefit from net metering.[49] Even at the current relatively low penetration of residential solar, this cost shifting has become controversial in many states. It seems unlikely that the much larger cost shifts that would be induced by substantial penetration of residential solar with net metering would generally be politically acceptable.

[xxvii] Source is REN21, pp. 79, 80.[7]

[xxviii] The installation of significant solar rooftop capacity will likely also require the utility to make incremental investments, as discussed in Chapter 7.

[xxix] For a positive discussion of net metering, see Duke, et al.[47] For a recent quantitative analysis of its impact, see Satchwell, Mills, and Barbose.[48]

In broad terms, the economically obvious solution is to move away from the prevalent design of distribution network charges that recovers fixed distribution costs via volumetric (per-kWh) charges.[xxx]

Over the years, governments at all levels have employed policies that attempt to expand the use of renewable energy sources by means other than incentives or regulations.

As discussed in Chapter 7, the ideal approach would be to recover utilities' distribution costs through a system of charges that reflect each individual customer's contribution to those costs, not their kWh consumption. It is not yet clear how this ideal can best be approximated in practice, however.

FINDING:

By enabling those utility customers who install distributed solar generation to reduce their contribution to covering distribution costs, net metering provides an extra incentive to install distributed solar generation. Costs avoided by households that install distributed solar generation are shifted to utility shareholders and/or other customers. Recovering distribution costs through a system of network charges that is more reflective of cost causation and that avoids the current direct dependence on electricity consumption would remove the extra subsidy and prevent this cost shifting.

Over the years, governments at all levels have employed policies that attempt to expand the use of renewable energy sources by means other than incentives or regulations. These policies, which have been termed "enabling" or "catalyzing," often involve education and information campaigns aimed more generally at building awareness and stimulating demand, as well as training programs designed to enhance supply.[xxxi] Efforts by municipalities in various regions to reduce balance-of-system costs for residential PV by, for example, simplifying and coordinating permitting, installation, and inspection; providing residential consumers with better price information; or adopting widely used standards would also fall in this category.[xxxii] Policies that require grid operators to connect to renewable generators are also present in one form or another in 43 states and the District of Columbia and have likewise been characterized as catalyzing renewables deployment, though it may be more appropriate to consider them as simply offsetting distribution utilities' incentives to resist distributed generators for the reasons discussed above.

Since July 2009, grid operators in the EU have been required to "… give priority to generating installations using renewable energy sources insofar as the secure operation of the national electricity system permits…"[54] This policy aims to provide a less uncertain revenue stream to renewable installations and, perhaps more important, to force system operators and owners of conventional generators to develop operating rules that are compatible with large amounts of renewable generation. Since electricity generated from solar energy has zero

[xxx] For a general discussion, see Kassakian and Schmalensee.[50] An alternative approach that has been discussed in some jurisdictions is to deploy two meters to value solar generation at the utility's avoided cost (which should correspond to the wholesale price) and to charge the consumer at the retail rate for all electricity consumed.[49]

[xxxi] For examples and a general discussion, see Lund.[51] See also Taylor.[52]

[xxxii] For a discussion of statewide efforts of this sort in Vermont, see North Carolina Solar Center.[53]

marginal cost, this might seem consistent with economic (i.e., variable-cost-minimizing) dispatch of generating units. But in fact the EU policy constitutes an invisible, but potentially substantial, subsidy to solar (and other renewable) generation sources, and it increases system operating costs.

As discussed in Chapter 8, in areas with a large penetration of renewable generation, it is possible that at times of low electricity demand, some conventional thermal plants may be forced to shut down to allow renewable sources to be run at capacity. If that happens, energy must be expended (and thus costs incurred) to start the conventional plants up again, and these startup costs could well outweigh the variable cost savings from making greater use of renewable generators.[xxxiii] There are also limits on the rate at which the output from thermal plants can be increased. In contrast, output from some renewable technologies, particularly PV and wind, can be varied without incurring additional costs. A requirement that renewable energy sources always have priority thus implies that costs associated with changing the output levels of conventional generating plants must be ignored in dispatch decisions.

It is unclear at the time of this writing how disruptive the EU's policy has been to European electric power systems or how large a subsidy it has provided to solar and other renewable generation technologies. Even after it resulted in a weeklong shutdown of a nuclear plant in Spain, fossil plant operators have not complained about the policy, probably because the extra costs of units that must stop and restart are generally reflected in wholesale prices. The resulting higher prices are passed on to ultimate consumers and benefit all generators. To the best of our knowledge, no similar requirement exists anywhere outside the EU, although distributed PV generators are effectively given priority since they are not subject to control by grid operators.

9.6 POLICY EFFECTIVENESS IN THE UNITED STATES

As noted above, a wide variety of policies to support solar generation has been employed at the federal, state, and local levels in the United States. The costs of federal support policies, which operate through the federal tax system, are borne by all taxpayers, wherever they live. In contrast, the cost of net metering, RPS programs, and other state and local support policies are borne either by state or local taxpayers or by customers of affected electric distribution companies.

A requirement that renewable energy sources always have priority thus implies that costs associated with changing the output levels of conventional generating plants must be ignored in dispatch decisions.

Our discussion of these policies in the foregoing sections has been largely theoretical, and it would be extremely useful to supplement it with analysis of the actual effectiveness of these policies along several dimensions. At the very least, it would be useful to be able to compare generation per dollar of spending on various programs to support solar and other renewable energy technologies. It would be even better to compare the cost per ton of CO_2 emissions

[xxxiii] Thermal generating units fueled by biomass may have marginal costs significantly above those of other thermal units. Giving priority to biomass units would then clearly increase system costs.

avoided via subsidies of various sorts to solar technologies with the per-ton costs of emissions reductions via subsidies to other renewable technologies, as well as the per-ton costs of other programs aimed at reducing greenhouse gas emissions.[xxxiv]

Even if good estimates of emissions avoided were available, however, neither comparison would be possible. In the first place, there is no authoritative compilation of total spending to support the deployment of solar technologies — at the national level or for any particular state — let alone a breakdown of total spending across subsidy programs.[xxxv] Even if these data were available, it would be essentially impossible to apportion credit for increasing renewable generation or reducing CO_2 emissions among the multiple support policies that are currently in place in the United States.

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And, of course, states' deployment of solar or other renewable technologies depends on more than the support policies in force. California is the clear leader in U.S. PV deployment with 35% of the nation's capacity in 2012.[xxxvi] Is that mainly because of California's aggressive RPS regime and many other renewable support policies or does it mainly reflect the fact that California is a large state with lots of sunshine in many places and very high marginal electricity rates? Arizona comes second with 20% of national capacity. It has an RPS policy that is much less aggressive than California's, but it has a number of other support policies in place, and it also has a lot of sunshine. Finally, New Jersey is third with 7.4% of the nation's PV capacity. New Jersey is a small state without abundant sunshine that offers neither production nor investment tax credits, but it has had an RPS with a very strong solar requirement.

FINDING:

It is not known how much has been spent in the United States or in any individual state to support the deployment of solar generation. There is no empirical support for assessments of the cost effectiveness of individual support policies or of overall U.S. support for expanding solar generation or reducing CO_2 emissions.

In common with the policies of many other countries, **deployment support policies in the United States generally favor distributed, residential-scale PV generation over utility-scale PV generation**. As we noted above, net metering policies have this effect. Because the per-watt investment costs for residential PV are much higher than for utility-scale PV, the federal investment tax credit and accelerated depreciation contribute more per watt at the residential scale than at the utility scale. Both policies have the effect of lowering investment costs by a fraction, and because residential investment costs are larger per watt, so is the per-watt dollar subsidy implied by that fraction. Finally, some state RPS programs have a requirement for distributed generation and distributed generation is mainly solar PV.

[xxxiv] For a recent attempt to measure the cost effectiveness of subsidies to wind power in Texas, see Cullen.[55]

[xxxv] It would thus be impossible to compare solar subsidies in the United States with those in China, even if we knew the level of subsidies in China, which, of course, we do not.

[xxxvi] The state-specific numbers in this paragraph are from EIA.[56]

If the objective of deployment support policies is to increase solar generation at least cost, favoring residential PV makes no sense. The results in Chapter 5 indicate that the per-kWh subsidy necessary to make residential PV competitive in central Massachusetts is 2.2 times the subsidy necessary to make utility-scale PV competitive.[xxxvii] In California, this ratio is 2.9. With a $40/tonne tax on CO_2 emissions, these ratios become 2.4 and 4.1, respectively. That is, any given total subsidy outlay borne by taxpayers and/or electricity consumers — if it is devoted to subsidizing residential-scale PV — will produce only a fraction of the solar electricity that would be produced if the same amount of subsidy were devoted to supporting utility-scale PV generation.[xxxviii] Moreover, as Chapter 7 demonstrates, adding material amounts of distributed PV generation to existing distribution systems will require incremental investments to handle reverse power flows.

FINDING:

Subsidizing residential-scale solar generation more heavily than utility-scale solar generation, as the United States now does, will yield less solar generation (and thus less emissions reductions) per dollar of subsidy than if all forms of solar generation were equally subsidized.

If the objective of deployment support policies is to increase solar generation at least cost, favoring residential PV makes no sense.

9.7 CONCLUSIONS AND RECOMMENDATIONS

At least until the United States introduces a nationwide cap or tax on CO_2 emissions from fossil fuels, there is a case for promoting the use of solar and other renewable technologies that serve to displace fossil fuels. Such deployment is likely to provide additional benefits by reducing local air pollution, contributing to the advancement of solar technologies, and reducing institutional barriers to large-scale future solar deployment. The nature of the climate problem argues for minimizing the total cost of using solar and other generation technologies with negligible CO_2 emissions by any nation, which in turn argues against trying to restrict the flow of technological knowledge or the location of any of the operations in the solar value chain. Policies that aim to restrict the flow of knowledge are unlikely to succeed in any case.

At least until the United States introduces a nationwide cap or tax on CO_2 emissions from fossil fuels, there is a case for promoting the use of solar and other renewable technologies that serve to displace fossil fuels.

[xxxvii] Table 5.1 shows base-case costs for central Massachusetts of 27.6 ¢/kWh for residential PV and 16.1 ¢/kWh for utility-scale PV. Comparing these figures with the 6.69 ¢/kWh cost for a natural gas combined cycle plant yields subsidy requirements of 20.91 ¢/kWh and 9.41 ¢/kWh, respectively. The ratio of the first of these to the second is 2.2. The other numbers in this paragraph are derived similarly, using the southern California base-case costs and then using 8.19 ¢/kWh as the natural gas combined cycle cost with a $40/tonne carbon tax.

[xxxviii] It is worth noting that, despite the high cost of subsidies necessary for residential PV to be competitive, the actual subsidies in force are sufficient to fuel continued rapid growth. Between the first half of 2012 and the first half of 2014, the installed capacity of residential PV in the United States more than doubled. However, even though the existing subsidy regime favors residential PV, the capacity of utility-sale PV quadrupled over the same period.[57]

RECOMMENDATION:

Policies that attempt to restrict trade, investment, or knowledge transfers in solar technologies are generally undesirable since they make it harder to reduce global carbon dioxide emissions and advance solar technologies, and they are unlikely to yield sustainable national competitive advantage.

There is no obvious short-run environmental case for singling out solar energy for more aggressive deployment support than other renewable technologies; moreover, since solar tends to be more expensive than other renewable technologies (particularly onshore wind), there is a clear short-run economic cost. On the other hand, as we have noted at several points, the potential of solar power to be scaled up dramatically to meet global energy needs in a low-carbon future means that the long-run benefits of advancing solar technology and addressing the problems associated with dramatically increasing its use may exceed those of advancing other renewable technologies. And it seems plausible that ensuring a market for PV and concentrated solar power contributes to the advancement of those technologies. However, subsidizing the deployment of currently available solar technologies is not likely, by itself, to improve U.S. competitiveness or achieve other goals that have been discussed in this context, particularly in the absence of barriers to the free flow of goods, ideas, and investment capital.

The potential of solar power to be scaled up dramatically to meet global energy needs in a low-carbon future means that the long-run benefits of advancing solar technology and addressing the problems associated with dramatically increasing its use may exceed those of advancing other renewable technologies.

RECOMMENDATION:

Policies to support the deployment of solar technologies should be justified by their impact on global CO_2 emissions, on local air pollution, and, if appropriate, on the advancement of solar technology and the reduction of institutional and other barriers to substantially increasing its penetration.

This chapter's main message is that the current regime of U.S. policies for promoting solar-powered electricity generation is needlessly inefficient and delivers much less generation bang for the subsidy buck than obvious alternatives could produce. That regime, with its vast array of federal, state, and local subsidy and regulatory programs, many of which have hidden costs, stands in stark contrast to the simple and transparent support regimes used in many other nations. The United States can get much more solar generation per dollar of taxpayer and ratepayer expenditure by moving toward well-designed, national policies. In order to increase reliance on solar energy substantially at politically acceptable costs, it will likely be necessary both to reduce the cost of solar electricity through research, development, and demonstration (RD&D), as discussed in the next chapter, and, as discussed in this chapter, to increase the $/kWh efficiency of solar deployment support policies. Output subsidies, feed-in tariffs, and renewable portfolio standards are all superior in principle to subsidizing investment via the tax system. Such subsidies are the federal government's main incentive device and are also widely used at the state and local levels. Using tax credits rather than direct expenditures reduces both transparency and generation per dollar of public expenditure. If tax credits must be used, the need for solar project developers to access the tax equity market should be reduced or eliminated, perhaps by making tax credits freely tradable.

RECOMMENDATION:

Subsidies for solar and other renewable technologies should reward generation, not investment, and should reward generation more when it is more valuable.[xxxix] Tax credits should be replaced by direct grants, which are more transparent and more effective. If this is not possible, steps should be taken to avoid dependence on the tax equity market.

State RPS regimes generally do not reward generation more when it is more valuable. Even putting this serious problem aside, the current system of multiple, incompatible state RPSs with limited interstate trading needlessly inflates nationwide costs for any level of renewable generation attained. If an output quota approach like RPS is employed, it should be employed uniformly across the nation and phased out when a comprehensive carbon policy is in place and the subsidized technology is mature. If a nationwide RPS is not feasible, state programs should permit unlimited interstate trading to avoid forcing renewable generators to be built at undesirable locations.

RECOMMENDATION:

RPS programs should be replaced by subsidy regimes that reward generation more when it is more valuable. If that is not feasible, state RPS programs should be replaced by a uniform nationwide program. If a nationwide RPS is not feasible, state RPS programs should permit interstate trading to reduce costs per kWh generated and should adopt common standards for renewable generation to increase competition.

Finally, as we have discussed at several points, because residential PV generation is much more expensive than utility-scale PV generation, the subsidy cost per kWh of residential PV generation is substantially higher than the per-kWh subsidy cost of utility-scale PV generation. There is no compensating difference in benefits and thus there is simply no good reason to continue to provide more generous subsidies for residential-scale PV generation than for utility-scale PV generation.

RECOMMENDATION:

Residential PV generation should not continue to be more heavily subsidized than utility-scale PV generation. Eliminating this uneconomic disparity will require replacing per-kWh distribution charges with a system for recovering utilities' distribution costs that reflects network users' impacts on those costs.

[xxxix] This assumes that the market power issue mentioned in Footnote x can be directly addressed by restrictions on the ownership of generation facilities.[58]

Net metering with per-kWh charges to cover distribution cost is an important reason why residential PV generation is more heavily subsidized than utility-scale PV generation. In addition, net metering raises equity issues: it is far from obvious that it is fair for consumers with rooftop PV generators to shift the burden of covering fixed distribution costs to renters and others without such systems. Chapter 7 discusses the use of reference network models to allocate distribution costs among utility customers according to how their network usage profile contributes to those costs.[58]
The discussion in Chapter 7 also notes the existence of a host of implementation issues, however, including the political acceptability of potentially very different charges for apparently similar network users. Because of the problems associated with net metering, research directed at developing a more efficient, practical, and politically acceptable system for covering fixed network costs should be a high priority.

While the current system of policies to support solar deployment in the United States is needlessly wasteful, it does not follow (and we do not believe) that such support should be ended. As noted at several points, we favor continued support of solar deployment in order to encourage industrial research and develpment and work on institutional and other barriers to greater reliance on solar energy and to produce environmental benefits. As the recommendations above make clear, however, we believe that the system of solar support policies should be reformed to increase its efficiency, so that more solar generation is produced per taxpayer and electricity-consumer dollar spent.

RECOMMENDATION:

Research should be undertaken to develop workable methods for using reference network models to design pricing systems that cover fixed network costs via charges that depart from simplistic proportionality to electricity consumption and that respect the principle of cost causality.

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