Using Renewable Portfolio Standards to Accelerate Development of Negative Emissions Technologies

Anthony E. Chavez[a1]

ABSTRACT

As society continues to emit greenhouse gases, the likelihood of dangerous climate change occurring increases. Indeed, most analyses project that we must utilize negative emission technologies (NETs) to avoid dangerous warming. Even the Paris Agreement anticipates the implementation of NETs. Unfortunately, NETs are not ready for large-scale deployment. In many instances, their technologies remain uncertain; in others, their ability to operate at the scale required is unknown. Other uncertainties, including their costs, effectiveness, and environmental impacts have yet to be determined.

A means to accelerate the development and implementation of NETs is a policy that already did the same for renewable energy – Renewable Portfolio Standards (RPSs). RPSs require that providers source a predetermined amount of their electricity from renewable energy. RPSs have an established track record of stimulating investment in renewable energy in the United States and elsewhere. These policies incorporate a number of requirements that jurisdictions can tailor to accommodate local resources, industries, and objectives.

Similarly, RPSs can facilitate the investment in and development of NETs. RPSs create markets for technologies that encourage compliance with low-cost alternatives. This incentivizes innovation, which lowers costs. Furthermore, jurisdictions can utilize other tools of RPSs, such as technology carve outs and credit multipliers, to encourage development of specific technologies. Using these provisions, states have incentivized the development and installation of renewable energy in general and solar power in particular.

However, current RPSs are too limited to develop NETs. States need to expand the technologies that satisfy RPS mandates to include NETs, thereby fostering the development of NETs. Over time, states should also expand the economic sectors required to comply with their RPSs to encompass the agriculture, aviation, and manufacturing industries, sectors with emissions that are expensive or difficult to mitigate.

[a1] Professor of Law, Chase College of Law, Northern Kentucky University. Thanks to the participants at the Climate Engineering Conference 2017 for their comments on this topic. Special thanks to Tracy Hester and Albert Lin for their thoughts on earlier drafts of this article. I am also grateful to Dean Jeffrey Standen, Associate Dean Michael Mannheimer, and the Chase College of Law for supporting this effort.

TABLE OF CONTENTS

I. DEVELOPMENT OF NETs IS CRUCIAL

Scientists project that greenhouse gas emission mitigation is occurring too slowly to avert dangerous climate change. Since carbon dioxide remains in the atmosphere for centuries, we cannot rely solely upon earth systems to remove it from the atmosphere. Instead, we will need to use technological means. Scientists recognize that a number of such negative emission technologies may be possible.

A. Dangerous Climate Change Is Becoming Unavoidable

Despite approval of the 2015 Paris Agreement, the planet is increasingly likely to exceed the agreement's targets. Regarding temperature rise, the parties to the Paris Agreement pledged themselves to certain objectives. First, they agreed to increase efforts to hold the rise in global average temperature to "well below 2°C above pre-industrial levels."[1] Second, they also pledged to pursue efforts to limit the temperature increase to 1.5°C.[2] To accomplish these objectives, the parties

[1] Paris Agreement, Article 2, ¶1(a).
[2] *Id*.

agreed to "aim to reach global peaking of greenhouse gas emissions as soon as possible."[3]

Despite the growing concern about climate change reflected by these pledges, emissions – and the consequent warming – are on track to blow past these levels. During the first 15 years of this century, CO_2 emissions grew at an average rate of 2.6%. This contrasts with an average rate of growth of 1.72% during the previous three decades.[4] Furthermore, for every year-on-year period this century except for 2008 to 2009, emissions have increased.[5] Continuing these trends, in 2016 atmospheric carbon dioxide hit an all-time high, increasing at an unprecedented rate.[6]

Policymakers have targeted the 1.5-2.0°C range because scientists consider this to be the threshold of "dangerous" climate change.[7] A rise of 2.0°C is the level at which they anticipate "nonlinear and potentially irreversible disruptions" to the environment may begin.[8] These changes may include the complete loss of Arctic sea ice during the summer and deglaciation of the Greenland ice sheet, the West Antarctic Ice Sheet, and most mountain glaciers.[9] As a result, oceans would rise to a level that would jeopardize many coastal cities, and droughts, floods, and other extreme weather would threaten food sources and biodiversity.[10]

Even a now-expected rise of 1.5°C will cause significant disruptions. Asia's glaciers, for instance, will lose nearly half of their mass.[11] Peak sea levels will rise by one meter.[12] Other changes will include increases in the duration of heat waves, increases in heavy precipitation, and placing substantial portions of coral reefs at risk of bleaching.[13] Scientists also project that restricting warming to a 1.5°C rise will be critical to protecting small island states.[14]

---

[3] *Id*. at Article 4, ¶1.

[4] Niall Mac Dowell, et al, *The Role of CO_2 Capture and Utilization in Mitigating Climate Change*, NATURE CLIMATE CHANGE 243 (April 2017).

[5] *Id*.

[6] Scott Waldman, *Atmospheric Carbon Dioxide Hits Record Levels*, SCIENTIFIC AMERICAN (March 14, 2017), available at https://www.scientificamerican.com/article/atmospheric-carbon-dioxide-hits-record-levels/.

[7] Chris Mooney, *We Only Have a 5 Percent Chance of Avoiding 'Dangerous' Global Warming, a Study Finds*, THE WASHINGTON POST (July 31, 2017).

[8] C. H. Greene, et al, *Geoengineering, Marine Microalgae, and Climate Stabilization in the 21st Century*, EARTH'S FUTURE, 5, 278–284, 278 (2017).

[9] *Id*.

[10] *Id*. at 278-79.

[11] P. D. A. Kraaijenbrink, et al, *Impact of a Global Temperature Rise of 1.5 Degrees Celsius on Asia's Glaciers*, NATURE (September 13, 2017).

[12] Greene, *supra* note 8 at 278-79.

[13] Carl-Friedrich Schleussner, et al, *Differential Climate Impacts for Policy-Relevant Limits to Global Warming: the Case of 1.5°C and 2°C*, EARTH SYST. DYNAM., 7, 327-351, 345 (2016). Actually, scientists have conducted few analyses of the consequences of a 1.5°C warming. Daniel Mitchell, et al, *Realizing the Impacts of a 1.5 °C Warmer World*, NATURE CLIMATE CHANGE 735 (August 2016). Consequently, the Intergovernmental Panel on Climate Change is preparing a special report on the impacts of a 1.5 °C warming, which it plans to complete before the end of 2018. IPCC, Global Warming of 1.5 °C, last visited October 30, 2017, available at http://www.ipcc.ch/report/sr15/.

[14] Laurie Goering, *Carbon-Sucking Technology Needed by 2030s, Scientists Warn*, REUTERS, October 10, 2017.

Because society has failed to rein in its greenhouse gas emissions, the likelihood of staying below the 2°C target, let alone the 1.5°C target, is disappearing rapidly. A study released in 2017 concludes that only a 5% chance remains that we can hold warming to 2°C; for 1.5°C, the likelihood is down to 1%.[15] Furthermore, the authors calculate that the likely range of warming will be 2.0-4.9°C. They further determine the mean anticipated warming to be 3.2°C.[16] Contemporaneously, a separate study concluded that likely committed warming (the warming which would still occur if anthropogenic greenhouse gas emissions were to cease immediately[17]) already has reached 1.5°C.[18]

Another form of analysis reaches a similar conclusion. Scientists calculate a "carbon budget," the amount of carbon dioxide that society can emit with global temperature rise still remaining below a targeted level.[19] Nearly all estimates[20] suggest that the budget remaining to stay under a rise of 1.5°C is nearly exhausted, while the budget to hold to a 2°C rise will run out in a matter of decades. For instance, one representative calculation suggests that between 4 and 15 years remain before the 1.5°C budget will expire. For a 2°C rise, the time remaining ranges from 19 to 32 years.[21]

B. Staying Below Dangerous Global Temperature Levels Will Require Substantial Utilization of NETs

Utilizing technologies that can reverse the increase of carbon dioxide in the atmosphere will be necessary to avoid a 2ºC rise in temperature. Nearly every analysis demonstrates that mitigation alone cannot keep temperatures below this level. Unlike mitigation, these technologies can also help to reverse warming should society fail to mitigate sufficiently to avoid the 2ºC level.

---

[15] Adrian E. Raftery, et al, *Less Than 2°C Warming by 2100 Unlikely*, NATURE CLIMATE CHANGE 1 (2017).

[16] *Id*.

[17] K.C. Armour & G.H. Roe, *Climate Commitment in an Uncertain World*, GEOPHYSICAL RESEARCH LETTERS, VOL. 38, 1 (2011).

[18] Thorsten Mauritsen & Robert Pincus, *Committed Warming Inferred from Observations*, NATURE CLIMATE CHANGE 1 (2017).

[19] World Resources Institute, *Understanding the IPCC Reports*, last visited November 5, 2017, available at http://www.wri.org/ipcc-infographics.

[20] Recently, Millar, et al, calculated that holding warming to less than 1.5°C "is not yet a geophysical impossibility." Millar, et al, *Emission Budgets and Pathways Consistent with Limiting Warming to 1.5 °C*, NATURE GEOSCIENCE 741-47, 741 (September 18, 2017). Even applying the Millar methodology, the budget for a 1.5°C increase would expire by 2030 with only a 66% chance of staying below that level. Ben Sanderson, *1.5ºC: Geophysically Impossible or Not?*, October 4, 2017, available at http://www.realclimate.org/index.php/archives/2017/10/1-5oc-geophysically-impossible-or-not/.

[21] Robert McSweeney & Rosamund Pearce, *Analysis: Just Four Years Left of the 1.5 °C Carbon Budget*, last visited November 5, 2017, available at https://www.carbonbrief.org/analysis-four-years-left-one-point-five-carbon-budget. The range results from the probability of staying within the targeted level that is applied to the calculation. Thus, a higher probability of staying below a given target produces a shorter timeframe before the budget will expire, and a lower likelihood of staying below the target allows a longer timeframe. *Id*.

Because of the level of anticipated warming and its dire consequences, policymakers have begun directing more attention to removing carbon dioxide after it has already entered the atmosphere. Indeed, in addition to the setting of targets for warming, the Paris Agreement parties also set goals concerning carbon sinks. Specifically, they agreed to act "to conserve and enhance" greenhouse gas sinks and reservoirs.[22] Furthermore, they set a target of balancing carbon emissions and sinks by the second half of this century.[23] In light of the hard to control emissions from agriculture and other sectors, the balancing sought by the Paris Agreement can only be accomplished with net negative CO_2 emissions.[24] Thus, the implication of the Paris Agreement is that countries will need to develop NETs to accomplish its goals.

Nevertheless, few countries have included NETs in their Intended Nationally Determined Contributions (INDCs). INDCs identify the steps the parties to the Paris Agreement intend to take after 2020 to achieve the agreement's goals.[25] In their INDCs, no countries have included bioenergy with carbon capture and sequestration (BECCS), the technology most ready for implementation,[26] and only a few nations have included carbon capture and storage.[27]

A number of analyses indicate that NETs will be essential to achieve the Paris Agreement's 2°C goal. Anthropogenic emissions of carbon are overwhelming the ability of natural sources to remove it from the atmosphere. This will almost certainly necessitate the deployment of NETs.[28] Indeed, most analytical scenarios in which warming stays within 2°C, and nearly all in which it stays below 1.5°C, incorporate NETs.[29] For instance, for its Fifth Assessment Report, the IPCC analyzed nearly 900 scenarios from integrated assessment models.[30] 166 of the scenarios had a 66% chance or better that warming would stay below 2°C by 2100.

---

[22] Paris Agreement, *supra* note 1 at Article 5, ¶1.

[23] Glen P. Peters & Oliver Geden, *Catalysing a Political Shift from Low to Negative Carbon*, NATURE CLIMATE CHANGE 1 (2017).

[24] Rockström, J. et al. (2016), *The World's Biggest Gamble*, EARTH'S FUTURE, 4, 465–470, 467 doi:10.1002/2016EF000392.

[25] World Resources Institute, *What Is an INDC?*, available at http://www.wri.org/indc-definition.

[26] *See* Section I.C., *infra*.

[27] Peters & Geden, *supra* note 23 at 1.

[28] National Research Council (NRC), CLIMATE INTERVENTION: CARBON DIOXIDE REMOVAL AND RELIABLE SEQUESTRATION 109 (2015).

[29] David P. Keller, et al, *The Carbon Dioxide Removal Model Intercomparison Project (CDR-MIP): Rationale and Experimental Design*, Manuscript under review for journal GEOSCI. MODEL DEV. 4 (2017). As discussed later in this section, even these scenarios anticipate that global temperatures will actually overshoot these targets before returning to the 2.0°C or 1.5°C levels. *Id*.

[30] Christopher B. Field & Katharine J. Mach, *Rightsizing Carbon Dioxide Removal*, SCIENCE 707 (May 19, 2017). Integrated assessment models incorporate approaches from two or more fields into a single framework. Gilbert Metcalf & James Stock, THE ROLE OF INTEGRATED ASSESSMENT MODELS IN CLIMATE POLICY: A USER'S GUIDE AND ASSESSMENT 5 (2015), available at https://www.belfercenter.org/sites/default/files/legacy/files/dp68_metcalf-stock.pdf. IAMs have become the standard methodological approach in climate change research. Zili Yang, Yi-Ming Wei, & Zhifu Mi, INTEGRATED ASSESSMENT MODELS (IAMS) FOR CLIMATE CHANGE (2016), available at http://www.oxfordbibliographies.com/view/document/obo-9780199363445/obo-9780199363445-0043.xml.

Of these, 101 included some form of NETs.[31] Typically, they included NETs on a "massive" scale.[32] Similarly, prior to the 2015 Conference of the Parties in Paris, researchers were tasked with developing emissions scenarios demonstrating the viability of still holding warming to 2°C. They found that this goal cannot be achieved through plausible and cost-effective mitigation efforts. It requires NETs.[33] Of course, scenarios holding warming to 1.5°C require even greater commitments to NETs.

Even if society were to mitigate its emissions sufficiently to stay within a 1.5°C or 2°C rise, NETs will still play a critical role. Carbon dioxide has a long atmospheric life. Once emissions cease, natural systems will remove greenhouse gases from the atmosphere, but carbon dioxide will remain at an elevated level for centuries or even a millennia.[34] Even though global temperatures will remain flat (but elevated), over centuries regional changes in temperature and precipitation may be substantial, and sea level will continue to rise.[35] Thus, actual removal of anthropogenic carbon dioxide will be essential to reverse climate change and its consequences "on timescales relevant to human civilization."[36]

In reality, most projections conclude that the global temperature will exceed the 2°C target, and we will need to remove carbon dioxide from the atmosphere to return it to the targeted level. In these scenarios, warming for at least some period of time exceeds the targeted level. By 2100, however, after using carbon dioxide removal, the temperature returns to the targeted level. Scientists call these "overshoot" scenarios.[37] Some scenarios indicate that temperatures can still be held under 2°C without overshoot. All 1.5°C scenarios contemplate at least a temporary overshoot.[38] Overshoot scenarios require carbon dioxide removal to compensate for such a rise in CO_2.[39] In fact, these efforts can help compensate for as much of an overshoot as 0.5°C.[40]

Negative emissions technologies consist of "anthropogenic activities that deliberately extract CO_2 from the atmosphere."[41] Typically, "NETs" and "CDR"

---

31 Field & Mach, *supra* note 30 at 707.

32 Guy Lomax, et al, *Investing in Negative Emissions*, NATURE CLIMATE CHANGE, Vol. 5, 498, June 2015.

33 Edward A. Parson, *Climate Policymakers and Assessments Must Get Serious about Climate Engineering*, PNAS Early Edition 1 (2017).

34 Mauritsen & Pincus, *supra* note 18 at 1.

35 Katarzyna B Tokarska & Kirsten Zickfeld, *The Effectiveness of Net Negative Carbon Dioxide Emissions in Reversing Anthropogenic Climate Change*, ENVIRON. RES. LETT. 10, 1 (2015).

36 *Id*.

37 Joeri Rogelj, et al, *Energy System Transformations for Limiting End-of-Century Warming to below 1.5 °C*, NATURE CLIMATE CHANGE 520 (June 2015).

38 S. Fuss, et al, *Research Priorities for Negative Emissions*, ENVIRON. RES. LETT. 11, 2 (2016) 115007.

39 *Id*.

40 *Id*. at 4. Even if temperatures are brought back to below the target, some of the consequences of the overshoot will continue. For instance, sea levels will continue to rise for several centuries. Tokarska & Zickfeld, *supra* note 35 at 9. Furthermore, as NETs remove CO_2 from the atmosphere, oceanic and terrestrial sinks will eventually reverse and release CO_2, thereby increasing the amount of carbon dioxide removal necessary to overcome this outgassing. Keller, *supra* note 29 at 9-10.

41 Fuss, *supra* note 38 at 1.

(carbon dioxide removal[42]) are used interchangeably,[43] as they will be here. These technologies involve the "removal and long-term sequestration of CO_2 from the atmosphere."[44] Broadly speaking, NETs fall into two categories. First, some approaches increase the natural removal of CO_2 by amplifying these processes.[45] Second, some methods capture CO_2 from the atmosphere, concentrate it, and sequester it underground by injecting it under high pressure.[46]

NETs can serve several useful functions. Crucially, they "decouple emissions and emissions control in space and time."[47] Decoupling in space refers to their ability to compensate for CO_2 emissions from sectors where they are difficult or expensive to reduce.[48] Such "recalcitrant" emissions include those from the agricultural sector by livestock.[49] Another source is the transport sector, especially the aviation and marine subsectors.[50] Other difficult to capture emissions derive from cement production[51] and residential heating and cooling.[52] The ability to compensate for emissions from these sectors will be critical, since they account for a significant portion of global emissions.[53]

NETs decouple emissions in time by providing a means to address previously-released emissions.[54] This buys time to develop and install clean energy

---

[42] Carbon dioxide removal traditionally appears as one of two branches under the label of geoengineering or climate engineering. The other branch consists of albedo modification, often called solar radiation management (SRM). The Keith Group, *Geoengineering*, available at https://keith.seas.harvard.edu/geoengineering. Nevertheless, important differences distinguish the two. Since CDR reduces the amount of carbon dioxide in the atmosphere, it is more akin to mitigation than to SRM. NRC, *supra* note 28 at 20. CDR thus seeks to address the root cause of climate change. The Keith Group, *supra*. Conversely, SRM attempts to provide symptomatic relief from only some of the consequences of anthropogenic CO_2. NRC, *supra* note 28 at 20. Besides methodology and effect, substantial differences also abound concerning, among others, the nature of their associated risks, costs to implement, governance, and research needs. *Id*. at 4.

[43] Peter Psarras, et al, *Slicing the Pie: How Big Could Carbon Dioxide Removal Be?*, WIREs ENERGY ENVIRON 1 (2017), 6:e253. doi: 10.1002/wene.253.

[44] NRC, *supra* note 28 at 33.

[45] *Id*.

[46] *Id*.

[47] Elmar Kriegler, et al, *Is Atmospheric Carbon Dioxide Removal a Game Changer for Climate Change Mitigation?*, CLIMATIC CHANGE, May 2013, Volume 118, Issue 1, pp 45–57, 46.

[48] Lomax, *supra* note 32 at 498.

[49] Duncan McLaren, NEGATONNES 8 (2011). The share of global warming directly caused by livestock is approximately 25%. Eloise Gibson, *Cutting Down on Cow Burps to Ease Climate Change*, BLOOMBERG BNA ENVIRONMENT & ENERGY REPORT (November 29, 2017).

[50] Mark Workman, et al, *An Assessment of Options for CO_2 Removal from the Atmosphere*, ENERGY PROCEDIA 4 (2011) 2877-2884, 2877.

[51] *Id*.

[52] Adriana Marcucci, Socrates Kypreos & Evangelos Panos, *The Road to Achieving the Long-Term Paris Targets: Energy Transition and the Role of Direct Air Capture*, CLIMATIC CHANGE 2 August 2017.

[53] Center for Climate and Energy Solutions, *Global Manmade Greenhouse Gas Emissions by Sector, 2013*, https://www.c2es.org/content/international-emissions/ (last visited December 30, 2017). For instance, the entire agriculture sector accounted for 11% of global greenhouse gas emissions in 2013, while the entire transportation sector emitted 15%.

[54] Lomax, *supra* note 32 at 498.

technologies and to replace locked-in emissions sources.[55] This has important intergenerational implications, too. Scientists estimate that emission mitigation costs later in the century will rise rapidly as society begins to impose stronger reductions on difficult to address emissions, such as in the transportation sector,[56] which would be more expensive to control.[57] Energy modelling studies consistently find that limiting warming to 2°C without NETs will be two to three times more expensive than if they are utilized.[58] Thus, NETs will play a critical role in providing a future least-cost energy system.[59] Decoupling in time also allows society to compensate for excessive emissions early in the century that might lead to overshoot.[60] NETs can help to remediate historic emissions, too.[61]

C. NETs Incorporate a Number of Distinct Technologies

NETs is an umbrella term which encompasses a range of methods. These technologies vary in a number of aspects, including their effectiveness, costs, scalability, physical limitations, and stage of development.

Scientists organize NETs in several different ways. As noted previously, one approach distinguishes between methods that amplify natural processes and those that use technological means to capture and sequester CO_2.[62] Another grouping organizes the methods into land based, capture, and sinks.[63] Perhaps the most telling division organizes the methods as mature ecosystem-based, less mature biomass-based, and immature nonbiological.[64]

The label of NETs typically incorporates eight methods. These consist of the following:

Accelerated weathering – this method spreads minerals that naturally absorb CO_2 to accelerate the absorption process.[65] Normally, CO_2 released into the atmosphere turns into carbonate ions dissolved in the oceans. Eventually, the carbonate settles on the ocean floor.[66] The natural weathering process will remove atmospheric carbon, but it will require 100,000 years to return the climate to its

---

[55] *Id*. Carbon emissions and their sources are "locked in" when investments in emitting technologies, infrastructure, and supporting networks constrain future paths, thereby rendering lower-emission alternatives more costly, consequently diminishing the likelihood of their adoption. Peter Erickson, et al, *Assessing Carbon Lock-in*, ENVIRON. RES. LETT. 10, 1 (2015).
[56] Kriegler, *supra* note 47 at 54.
[57] Pete Smith, *Biophysical and Economic Limits to Negative CO_2 Emissions*, NATURE CLIMATE CHANGE, Vol. 6, 42-50, 48 (2016).
[58] Myles Allen, et al, *Certificates for CCS at Reduced Public Cost: Securing the UK's Energy and Climate Future*, ENERGY BILL 2015 2 (2015).
[59] Mac Dowell, *supra* note 4 at 243.
[60] Lomax, *supra* note 32 at 498.
[61] Charles-Francois de Lannoy, et al, *Indirect Ocean Capture of Atmospheric CO_2: Part I. Prototype of a Negative Emissions Technology*, INTL. J. GREENHOUSE GAS CONTROL 1 (2017).
[62] NRC, *supra* note 28 at 33.
[63] Tokarska & Zickfeld,*supra* note 35 at 2.
[64] Field & Mach, *supra* note 30 at 706.
[65] Fuss, *supra* note 38 at 3.
[66] NRC, *supra* note 28 at 46.

preindustrial level.[67] Accordingly, this method seeks to accelerate the weathering reaction by increasing the rate of exposure of CO_2 to the requisite minerals. This might occur in situ among rock formations, in industrial settings, or on the oceans by releasing ground up minerals.[68]

A limiting factor will be the ratio of minerals required to the amount of CO_2 to be removed. The amount of minerals required will need to exceed the amount of CO_2 to be removed by ratios ranging from 1.3 to 3.6 times. To deploy this method at scale would require 100 billion tons per year to offset current emissions. In contrast, global coal production is approximately 8 billion tons per year.[69] Limitations on the land suitable for use will further restrict this process.[70] Consequently, scientists project that weatherization can remove only 0.7 to 3.7 gigatons (billion tons) of carbon dioxide ($GtCO_2$) per year.[71] For perspective, current anthropogenic emissions approximate 35 $GtCO_2$ per year.[72] The cost of weatherization will likely range between $20 and $40 per tCO_2 removed. This estimate, however, incorporates only the costs of grinding and transportation and not the costs of spreading the ground minerals.[73]

Afforestation and Reforestation – afforestation involves the restoration of forests on land without forests for at least 50 years, while reforestation restores forests on lands more recently deforested.[74] The ability of forestation to remove CO_2 from the atmosphere depends upon a number of factors, including the type and age of the trees,[75] temperature, precipitation, and CO_2 concentration.[76] Scientists project possible sequestration from these activities as ranging from 1.5 to 14 $GtCO_2$ by 2030 (the wide range results from the inclusion of other greenhouse gases in the higher calculations).[77] Considerations that limit this approach include the availability of suitable land and sufficient water.[78] Although scientists calculate the costs of these activities to range from as low as $7.50 per tCO_2 to as high as $100

---

[67] Jeremy Deaton, *Earth's "Weathering Thermostat" Keeps Climate in Check over Very Long Periods of Time* (September 18th, 2017), available at https://cleantechnica.com/2017/09/18/earths-weathering-thermostat-keeps-climate-check-long-periods-time/.
[68] NRC, *supra* note 28 at 46-47.
[69] *Id*. at 48.
[70] McLaren, *supra* note 49 at 12. Indeed, studies concerning the environmental impact of dispersion at scale are still in their infancy. Psarras, *supra* note 43 at 13-14.
[71] United Nations Environment Programme (UNEP), THE EMISSIONS GAP REPORT 2017 64 (2017).
[72] J.G.J. Olivier, K.M. Schure, & J.A.H.W. Peters, TRENDS IN GLOBAL CO_2 AND TOTAL GREENHOUSE GAS EMISSIONS: SUMMARY OF THE 2017 REPORT 8 (2017). Olivier, Schure, & Peters also measure CO_2 equivalents, which is a broader, but more meaningful, calculation than just the amount of CO_2 emissions. According to them, in 2016 emissions were nearly 50 $GtCO_2eq$. *Id*. at 3.
[73] McLaren, *supra* note 49 at 12.
[74] UNEP, *supra* note 71 at 60. These processes are necessitated by deforestation, which causes approximately 10% of anthropogenic greenhouse gas emissions. NRC, *supra* note 28 at 39.
[75] In general, net CO_2 removal peaks within 30-40 years, and then it declines to zero as the forest matures. *Id*. at 40.
[76] *Id*.
[77] *Id*.
[78] McLaren, *supra* note 49 at 20.

per tCO_2, most estimates do not exceed $40 per tCO_2.[79] Because of its comparatively low cost, afforestation can serve as a substitute for, or at least a complement to, other NETs methods or mitigation alternatives.[80]

Agricultural land management practices – agricultural practices have released terrestrial carbon to the atmosphere.[81] In fact, agricultural practices have released 10-12% of anthropogenic greenhouse gases.[82] These practices reverse that flow. They either increase soil carbon inputs or reduce soil carbon losses.[83] Methods that increase soil carbon include growing cover crops,[84] leaving crop residues to decay, and applying manure or compost.[85] Soil tends to lose carbon through oxidation, such as when it is plowed.[86] Accordingly, practices that reduce carbon releases include no- or low-till farming.[87] Possible sequestration from agricultural land management practices may be as high as 5.2 $GtCO_2$, but food production and other uses may lower this amount.[88] Some of these practices (such as no-till) may already be cost-competitive with traditional practices. Anticipated costs range from $20 to $100 per tCO_2.[89]

Biochar – this involves storing stable biomass in soil. Without using oxygen, pyrolis combusts biomass at low temperatures to form biochar.[90] Biochar resists decomposition, thereby stabilizing biomass buried in soil.[91] It constitutes a negative emission technology because it fixes atmospheric CO_2 in a stable form that can be easily sequestered.[92] Biochar also can provide several benefits, including increasing soil fertility and improving water and nutrient retention.[93] Scientists project that biochar can sequester as much as 1 $GtCO_2$ by 2030, and possibly up to 9.5 $GtCO_2$, by 2100.[94] Costs of biochar range from $18 to $166 per tCO_2,[95]

Bioenergy with Carbon Capture and Sequestration (*BECCS*) – this system uses conventional power plants to burn biomass and capture the resulting emissions.[96] The process begins with growing biomass – plants or trees – for fuel.

---

79 *Id*.; NRC, *supra* note 28 at 41-42.

80 Ulrich Kreidenweis, et al, *Afforestation to Mitigate Climate Change: Impacts on Food Prices under Consideration of Albedo Effects*, ENVIRON. RES. LETT. 11 (2016).

81 NRC, *supra* note 28 at 42-43.

82 Stefan Frank, et al, *Reducing Greenhouse Gas Emissions in Agriculture without Compromising Food Security?*, ENVIRON. RES. LETT. 12, 2 (2017).

83 UNEP, *supra* note 71 at 61.

84 Farmers plant these crops (such as bean, lentil, and alfalfa) when they are not using their fields to grow market crops. Cover crops increase carbon sequestration. NRC, *supra* note 28 at 43, n.2 and accompanying text.

85 *Id*. at 43.

86 McLaren, *supra* note 49 at 21.

87 NRC, *supra* note 28 at 43.

88 *Id*. at 44.

89 Psarras, *supra* note 43 at 16.

90 NRC, *supra* note 28 at 45.

91 UNEP, *supra* note 71 at 62.

92 Niall McGlashan, et al, *High-Level Techno-Economic Assessment of Negative Emissions Technologies*, PROCESS SAFETY AND ENVTL. PROTECTION 90 (2012) 501–510, 503.

93 UNEP, *supra* note 71 at 62.

94 McGlashan, *supra* note 92 at 503.

95 UNEP, *supra* note 71 at 62.

96 McGlashan, *supra* note 92 at 503.

The biomass consumes CO_2 to grow.[97] Mature biomass provides fuel for electricity generation or process heat. It can also serve as the basis for liquid fuels such as ethanol or methanol or gas fuels such as hydrogen.[98] When used with power or manufacturing plants fitted with carbon capture and storage technology, the system traps the released CO_2 for sequestration.[99] Since bio-energy is in theory carbon neutral and in practice low carbon, the capture and sequestration of the process's emissions results in net negative emissions.[100]

BECCS benefits from several advantages over other NETs. It has the greatest technological maturity and can be integrated relatively easily into the present energy system.[101] Indeed, BECCS could contribute significantly to emissions reductions as soon as 2030.[102] BECCS is scalable, too,[103] though extensive expansion may conflict with other land uses.[104] Integrated assessment models estimate that it can satisfy from 15% to 45% of global energy needs.[105] At these levels, BECCS sequesters between 2 and 18 $GtCO_2$ per year.[106] While significant, society is already adding about 35 $GtCO_2$ to the atmosphere every year.[107] A critical advantage of BECCS is that, in addition to the value of its negative emissions, it also produces a salable product, electricity.[108] Finally, most studies project BECCS to cost $50-100 per tCO_2.[109]

If BECCS operates at scale, it may produce several negative consequences. BECCS produced at scale would require 500 million hectares of land, about 1.5 times larger than India.[110] It would likely compete with other land uses, such as food and fiber production, forestry, and biodiversity protection.[111] Using the 500 million hectares as a benchmark, BECCS would require 50 times the amount of land dedicated to U.S. bioethanol production, 50% of global fertilizer production, and more than double current global water withdrawals for irrigation.[112] These

---

[97] *Id*.
[98] NRC, *supra* note 28 at 63.
[99] McGlashan, *supra* note 92 at 503-04.
[100] McLaren, *supra* note 49 at 17.
[101] McGlashan, *supra* note 92 at 504.
[102] *Id*. at 508.
[103] McLaren, *supra* note 49 at 17.
[104] Wil Burns & Simon Nicholson, *Bioenergy and Carbon Capture with Storage (BECCS): the Prospects and Challenges of an Emerging Climate Policy Response* 3, J ENVIRON STUD SCI (2017).
[105] UNEP, *supra* note 71 at 62, n.13 and accompanying text.
[106] *Id*. at 62. *See also* Kriegler, *supra* note 47 at 55 (projecting BECCS deployment limited to a removal of 14-15 $GtCO_2$ per year).
[107] Olivier, Schure, & Peters *supra* note 72 at 8.
[108] McGlashan, *supra* note 92 at 504.
[109] Matthias Honegger & David Reiner, *The Political Economy of Negative Emissions Technologies: Consequences for International Policy Design*, CLIMATE POLICY 3 (2017).
[110] Peters & Geden, *supra* note 23 at 28.
[111] McLaren, *supra* note 49 at 17.
[112] NRC, *supra* note 28 at 65. The NRC presents calculations for BECCS at 200 million hectares of land; this author has extrapolated those impacts linearly to 500 million hectares of land.

impacts would serve as an effective cap on the extent of BECCS use, necessitating that society use BECCS in conjunction with other NETs.[113]

Direct Air Capture (*DAC*) – this method collects CO_2 from the ambient air, processes it, and then buries it.[114] It uses a chemical or physical scrubbing process to separate CO_2 from the ambient air. Similar processes operate in submarines and the International Space Station.[115] DAC systems generate a stream of CO_2, which then is available for manufacturing processes or sequestration.[116] Businesses can use CO_2 to make synthetic gas, liquid fuels, and other chemicals and to stimulate the growth of plants in greenhouses.[117]

The sequestration process is similar to that used with power plants. Since CO_2 is 100 to 300 times more concentrated in natural gas- or coal-fired power plants, however, DAC systems requires 2 to 10 times more energy to capture CO_2 than do power plants using CCS.[118] Consequently, renewable energy sources need to power DAC systems to ensure that they produce truly net negative emissions.[119] This may limit the siting of DAC systems to locations with access to sufficient wind, solar, geothermal, or hydropower.[120] They also require geographic formations which support sequestration of carbon. Conversely, since they pull CO_2 directly out of the air, DAC systems have few other constraints on their siting.[121] Indeed, when compared to BECCS, they impose smaller burdens on productive lands and likely will have lower impacts on ecosystems.[122] Because of DAC's ability to capture and sequester large amounts of CO_2 with few siting or land use concerns, some scientists have concluded that limiting warming to 1.5°C is possible only with DAC.[123]

Although DAC technology is well established, questions remain concerning its scalability and its cost.[124] Cost remains its greatest barrier.[125] Current projections range from \$400 per tCO_2 captured to as high as \$1,000 tCO_2.[126] By contrast, the cost of BECCS ranges from \$50 per tCO_2 to \$100 per tCO_2.[127]

---

[113] Kriegler, *supra* note 47 at 55. As BECCS nears its upper environmental limit of approximately 12 $GtCO_2$ per year, the limitations on biomass production increase the costs of BECCS abruptly, likely making other NETs more cost competitive. NRC, *supra* note 28 at 65.
[114] Fuss, *supra* note 38 at 3.
[115] Yuki Ishimoto, et al, PUTTING COSTS OF DIRECT AIR CAPTURE IN CONTEXT 4 (2017).
[116] NRC, *supra* note 28 at 67.
[117] Katherine Bourzac, *We Have the Technology*, NATURE S67, 12 October 2017.
[118] *Id*. at 68.
[119] UNEP, *supra* note 71 at 63-64.
[120] Psarras, *supra* note 43 at 8. On the other hand, reliance upon renewable energy sources, particularly wind and solar photovoltaics, will diminish one of DAC's advantages over other NETs, which is its relatively minor land footprint. Smith, *supra* note 57 at 46.
[121] *Id*. at 9.
[122] Parson, *supra* note 33 at 2.
[123] Marcucci, *supra* note 52 at 1.
[124] Ishimoto, *supra* note 115 at 4.
[125] UNEP, *supra* note 71 at 64.
[126] NRC, *supra* note 28 at 69-72. As noted previously, this process is substantially less expensive when used in conjunction with a concentrated source, such as a coal plant. In that context, the process costs only \$100 per tCO_2. *Id*. at 72.
[127] Honegger & Reiner, *supra* note 109 at 3.

Concerning scalability, fewer than 20 large-scale projects currently operate. While they capture 40 million tCO_2, this represents only a fraction of the billions of tons that will need to be sequestered.[128]

Ocean alkalinity enhancement – these methods facilitate the storage of carbon in the ocean by altering the equilibrium between atmospheric CO_2 and inorganic oceanic carbon.[129] This term encompasses three different approaches to enhance ocean alkalinity: weathering of silicate and carbonate materials on land to introduce calcium and magnesium into the ocean; adding calcium oxide or calcium hydroxide (often called ocean liming); and electrolysis of sea water.[130] The ocean contains 45 times more carbon than the atmosphere, and the ocean and weathering would eventually return atmospheric carbon to pre-industrial levels over 100,000 to 200,000 years.[131] These methods simply accelerate these natural processes. Ocean alkalinity enhancement methods are scalable,[132] with limitations arising mainly from the ability to scale up mining of minerals and construction of ships for transportation.[133] Costs range from $30 to $60 per tCO_2.[134] If operated at the appropriate scale, this method could sequester sufficient carbon to return the atmosphere to its pre-industrial state.[135]

Ocean fertilization – this method adds nutrients to the ocean to stimulate phytoplankton growth, which consumes CO_2, which is then buried with the organisms at the bottom of the ocean after they die.[136] The fertilization process utilizes iron, phosphate, or nitrogen.[137] Scientists project that ocean fertilization can remove up to 3.7 $GtCO_2$ per year.[138] While early cost estimates were relatively low, $50 per tCO_2[139] or lower,[140] recent estimates have risen. Concluding that the process might be less efficient than previously anticipated and that some leakage may occur of CO_2 back to the surface, a recent study projects the cost of fertilization to be near $450 per tCO_2.[141]

Several concerns complicate this method. First, the extensive ocean environment will render problematic the analysis of the relatively minor changes produced by fertilization.[142] Second, continuous fertilization might impair the food

---

128 Bourzac, *supra* note 117 at S66.
129 UNEP, *supra* note 71 at 64. One unique benefit of this method is that it helps to reverse ocean acidification. *Id*.
130 *Id*.
131 Phil Renforth & Gideon Henderson, *Assessing Ocean Alkalinity for Carbon Sequestration*, REVIEWS OF GEOPHYSICS 637 (2017).
132 McLaren, *supra* note 49 at 18.
133 Renforth & Henderson, *supra* note 131 at 660-61. For instance, extraction and processing of minerals would need to increase at a rate of growth of 12% per year over the next 45 to 60 years. *Id*. at 660.
134 McLaren, *supra* note 49 at 18.
135 T. Kruger, Increasing the Alkalinity of the Ocean to Enhance its Capacity to Act as a Carbon Sink and to Counteract the Effect of Ocean Acidification 4 (2010).
136 Fuss, *supra* note 38 at 3.
137 McLaren, *supra* note 49 at 19.
138 NRC, *supra* note 28 at 61.
139 McLaren, *supra* note 49 at 19.
140 NRC, *supra* note 28 at 61.
141 *Id*.
142 *Id*. at 60.

web and fisheries.[143] Finally, in response to a recent experiment concerning ocean fertilization, in 2014 the parties to the London Convention amended the London Protocol to prohibit all ocean fertilization activities except for scientific research.[144] This suggests that efforts to proceed with ocean fertilization may be vigorously opposed.[145]

II. NETs ARE NOT SUFFICIENTLY DEVELOPED

Despite the importance of NETs to addressing climate change, these technologies remain significantly underdeveloped. Many critical uncertainties remain regarding all NETs. These unknowns include the time required to develop their technologies, development of accounting and legal standards, NETs' ability to operate at the scale required, their environmental impacts, and their actual effectiveness.

Many NETs involve technologies that are still nascent,[146] remaining at the level of applied laboratory research into critical functions.[147] Even the most developed NETs have not progressed beyond the early prototyping stages, and these technologies have limited potential capacities. Where technologies are more developed, their deployment – or even their planned deployment – still falls substantially short of the level necessary.[148] For instance, although BECCS is the most advanced of the NETs, only 15 pilot plants and 1 commercial plant currently operate.[149] Similarly, implementing biochar at scale would require an increase of over 63 times the current charcoal production capacity.[150] Regarding DAC, emissions scenarios anticipate that several thousand will be operating by 2030; planned construction, however, only numbers in the tens.[151] Moreover, parties to the Paris Agreement – an agreement which contemplates deployment of NETs to achieve its targets[152] – display little commitment to developing NETs. The parties' INDCs fail to mention NETs, and only three even recognize carbon capture and sequestration as a priority.[153]

---

[143] *Id*. at 61.
[144] Tim Dixon, et al, *Update on the London Protocol – Developments on Transboundary CCS and on Geoengineering*, ENERGY PROCEDIA 63 (2014) 6623–6628, 6627.
[145] McLaren, *supra* note 49 at 19.
[146] Field & Mach, *supra* note 30 at 706.
[147] McLaren, *supra* note 49 at 32.
[148] Fuss, *supra* note 38 at 4.
[149] Burns & Nicholson, *supra* note 104 at 3. Even though the BECCS technology is relatively advanced, questions remain concerning the extent that its carbon sequestration will sufficiently offset emissions from direct and indirect land use changes. Naomi E Vaughan & Clair Gough, *Expert Assessment Concludes Negative Emissions Scenarios May Not Deliver*, ENVIRON. RES. LETT. 11, 5 (2016).
[150] Niall R. McGlashan, et al, NEGATIVE EMISSIONS TECHNOLOGIES (NETs) 15 (2012).
[151] Glen P. Peters, et al, *Key Indicators to Track Current Progress and Future Ambition of the Paris Agreement*, NATURE CLIMATE CHANGE 121 (February 2017).
[152] Peters & Geden, *supra* note 23 at 1.
[153] Fuss, *supra* note 38 at 7. Moreover, even though the INDCs reduce expected warming below business as usual levels, researchers at MIT project temperatures will still rise 3.1-5.2°C by 2100. Burns & Nicholson, *supra* note 104 at 1.

The lack of current commitment to NETs' development is of particular concern because many of the technologies will require significant time to develop. Despite the significant role they play in many analytical models, most of the technologies are still immature.[154] Fundamental uncertainties remain concerning their effectiveness. For example, when operated at scale, carbon sequestration's geological viability and permanence of storage are unknown.[155] Thus, advancing NETs to maturity and widespread deployment will require "many decades."[156] Nevertheless, progressive deployment would be superior because it would spread the cost over time, minimize future risks, and accelerate technological innovation.[157] As the 2015 report of the United States National Research Council states of NETs, "it is critical now to embark on a research program to lower the technical barriers to efficacy and affordability."[158]

Additional, non-technological concerns support imminent commitment to NETs research and deployment. For instance, a number of legal issues concerning development and deployment of NETs, as well as accounting issues regarding recording and crediting the value of their operations, have yet to be confronted. A number of liability issues, especially concerning NETs that mechanically sequester carbon, arise with these technologies. Liability issues for CCS fall into two categories: operational and post-injection. Operational liability concerns the environmental, health, and safety risks resulting from carbon dioxide capture, transport, and injection.[159] Post-injection liability pertains to injuries to human health, the environment, and property.[160] A specific concern regards possible contamination of water used for drinking or agricultural purposes.[161] Another concern stems from the long-term nature of the sequestration involved.[162] Because liability for the injection site may have been transferred (or the original operators may no longer exist), governments which have already confronted this situation have enacted legislation transferring liability to their governments.[163] Uncertainty concerning liability issues impairs rapid deployment of NETs systems, especially those involving sequestration.[164]

Even land management and forestation methods will require uniform policies. For instance, uniform standards will be necessary to measure carbon, to ensure sequestration, and to verify that these measurements are consistent across natural and technological approaches.[165] Besides liability and measurement issues,

---

[154] Keller, *supra* note 29 at 4.
[155] Kriegler, *supra* note 47 at 55.
[156] Lomax, *supra* note 32 at 499.
[157] Allen, *supra* note 58 at 3.
[158] NRC, *supra* note 28 at 111.
[159] Mark de Figueiredo, et al, *The Liability of Carbon Dioxide Storage* 1 (undated).
[160] *Id*.
[161] Ian Havercroft & Richard Macrory, LEGAL LIABILITY AND CARBON CAPTURE AND STORAGE 11 (2014).
[162] *Id*. at 36.
[163] *Id*. at 37. See also Wendy B. Jacobs, & Debra Stump, *Proposed Liability Framework for Geological Sequestration of Carbon Dioxide* 12 (Working Paper) (November 2010),
[164] *Id*. at i.
[165] Center for Carbon Removal, CARBON REMOVAL POLICY 8 (2017). For instance, a possible supply chain for a BECCS system could span several countries and require detailed

legal regimes can also provide incentives, or remove barriers, to adopt carbon removal farming practices.[166] Similarly, they are needed to support favorable forest management.[167] Ocean fertilization and ocean alkalinization fall within 2013 amendments to the London Protocol, which regulate marine geoengineering activities (though the amendments have not yet been ratified by a sufficient number of parties to enter into force).[168] Finally, carbon dioxide removal efforts could also be facilitated by policies that provide financial encouragement for these practices, such as a carbon tax,[169] carbon trading,[170] tax credits, or other means.[171]

NETs also need to be developed soon because uncertainty remains over the ability of many of these technologies to be utilized at the scale necessary.[172] None of the NETs currently operate at scale, and, in fact, none of them have been developed as a commercial product. Since they do not yet function at this level, uncertainties remain regarding their feasibility, potential, and risks.[173] The ability of biochar, for example, to stabilize carbon is poorly understood.[174] Most NETs may also run into limitations when implemented at scale.[175] For instance, factors such as low CO_2 uptake during some stages of tree growth and constraints on the availability of land suitable for trees will limit sequestration through afforestation and reforestation.[176] Similarly, methods that rely upon reactions with minerals, such as weatherization and ocean liming, will face limitations resulting from the amount of minerals needed to be extracted, processed, and transported.[177] Also, the availability of bio-feedstocks and the land on which to grow them may restrict the application of BECCS.[178]

Another unknown about NETs is their environmental impact. Different methods raise different concerns. Ocean fertilization may disrupt the ecology of

---

accounting over a period of decades with provisions for independent measurement, reporting, and verification. Peters & Geden, *supra* note 23 at 2-3. In fact, a recognized knowledge gap for all NETs concerns consistent accounting rules. Fuss, *supra* note 38 at 7. BECCS and several other NETs will require the adoption of uniform international accounting and accreditation systems. Early development and agreement of these measurements will facilitate timely development of NETs. Lomax, *supra* note 32 at 500.

[166] Center for Carbon Removal, *supra* note 165 at 17.

[167] *Id*. at 22-23.

[168] Renforth & Henderson, *supra* note 131 at 665.

[169] A carbon tax imposes a fee upon sources for carbon they emit into the atmosphere. Robinson Meyer, *Republicans Blow Their Chance to Pass a Carbon Tax*, THE ATLANTIC, December 20, 2017, available at https://www.theatlantic.com/science/archive/2017/12/republicans-blow-their-chance-to-pass-a-carbon-tax/548891/.

[170] Havercroft & Macrory, *supra* note 161 at 34. Carbon trading involves the purchasing and selling of permits to emit carbon dioxide. Fern, What Is Carbon Trading?, available at http://www.fern.org/campaign/carbon-trading/what-carbon-trading.

[171] Center for Carbon Removal, *supra* note 165 at 10-11.

[172] NRC, *supra* note 28 at 110.

[173] Keller, *supra* note 29 at 4.

[174] McGlashan, NETs, *supra* note 150 at 23.

[175] Fuss, *supra* note 38 at 3.

[176] Lannoy, *supra* note 61 at 1-2.

[177] *Id*. at 1.

[178] McLaren, *supra* note 49 at 17. Similar issues may limit the ability to produce biochar at scale. Workman, *supra* note 50 at 2881.

the oceans.[179] Ocean alkalinity enhancement may have localized effects and detrimental impacts on ocean ecosystems.[180] Carbon injection may increase seismicity.[181] Afforestation and reforestation may disrupt hydrological cycles, ecosystems, and biodiversity.[182] Implementation of BECCS at scale may require land needed for food production, consume scarce water resources, and endanger biodiversity.[183] Because of these consequences, even a combination of NETs with different impacts would still impose significant impacts on either land, water, nutrients, or planetary albedo.[184]

Other benefits will accrue from an earlier commitment to NETs. First, some more mature technologies – such as BECCS, biochar, and weatherization – could begin providing CO_2 reductions.[185] Second, significant investment of resources into NETs will be deferred until policies are adopted that support their development.[186]

III. RPSs CAN STIMULATE THE DEVELOPMENT OF NETs

RPSs[187] require that electricity providers generate or receive a set amount of their electricity from a predetermined type of source.[188] RPSs incorporate a number of specific requirements, which allow for tailoring to accommodate jurisdictional priorities. These policies have stimulated the development of renewable energy in the United States and a number of other countries in Europe and Asia. RPS policy structures can similarly establish markets for NETs, thereby stimulating their innovation and reducing their costs.

A. RPSs Successfully Promoted Development of Renewable Energy

RPSs obligate electricity providers to source a set percentage of electricity from particular types of generation.[189] Usually, they require that a specified percentage of electricity generated or procured be produced from particular types of energy sources, but some RPSs may identify a certain amount of megawatts that

[179] NRC, *supra* note 28 at 61.
[180] Renforth & Henderson, *supra* note 131 at 666. Not all effects may be negative. It may also reduce ocean acidification. *Id.*
[181] NRC, *supra* note 28 at 111.
[182] Keller, *supra* note 29 at 10.
[183] Burns & Nicholson, *supra* note 104 at 3.
[184] Smith, *supra* note 57 at 49.
[185] Lomax, *supra* note 32 at 500.
[186] *Id*.
[187] Jurisdictions and scholars use a range of labels to refer to this concept, including quotas, obligations, targets, and mandates. Felix Mormann, *Constitutional Challenges and Regulatory Opportunities for State Climate Policy Innovation* ("Constitutional Challenges"), 41 HARV. ENVTL. L. REV. 189, 198 (2017). Other interchangeable names include renewable energy standards and and tradable green certificate programs. Ryan Wiser, Galen Barbose, & Edward Holt, *Supporting Solar Power in Renewables Portfolio Standards: Experience from the United States*, ENERGY POLICY 39 (2011) 3894–3905, 3894.
[188] *Id.*
[189] *Id.*

must be produced.[190] RPSs are typically neutral among energy sources, though they can include policies to support specific technologies.[191] RPSs usually require that electricity that satisfies the mandate be generated from renewable energy sources, but some states allow nonrenewable sources to satisfy their mandates.[192] RPS requirements may be either mandatory or voluntary.[193]

RPSs typically provide six criteria with which electricity suppliers must comply. First, they set a minimum percent or amount of electricity required to satisfy the mandate and a timeline for compliance.[194] Often these requirements increase gradually over time. Typically, they start modestly, increase over a period ranging from 10 to 20 years, and then remain at that level indefinitely.[195] Second, RPSs specify the electricity sources that may satisfy the mandate. Third, they identify the parties required to comply with the obligation. Fourth, they indicate whether a party can satisfy its obligation through the purchase of renewable energy credits (RECs). Fifth, they identify an administrator – usually a government agency – for the program. Lastly, RPSs specify their enforcement mechanisms.[196]

Renewable portfolio standards have lengthy and widespread track records. Iowa became the first state to enact an RPS in 1983.[197] Currently, 29 states plus the District of Columbia utilize RPSs, and these policies directly cover 56% of retail electricity sales in the United States.[198] Another eight states have adopted voluntary, non-binding renewable energy goals.[199] Nations which have enacted a form of RPS include Australia, Belgium Canada, China, parts of India, Italy, Japan, Poland, Romania, Sweden, Thailand, and the United Kingdom.[200]

---

[190] Corey N. Allen, *Untapped Renewable Energy Potential: Lessons For Reforming Virginia's Renewable Energy Portfolio Standard From Texas And California*, 35 VA. ENVTL. L. J. 117, 120 (2016).

[191] Mormann, *supra* note 187 at 198

[192] Indiana, for instance, identifies as eligible technologies coal bed methane and clean coal. DSIRE, *Program Overview*, last updated November 20, 2015, available at http://programs.dsireusa.org/system/program/detail/4832. Colorado allows coal mine methane to satisfy its RPS. *Id*., last updated August 5, 2015, available at http://programs.dsireusa.org/system/program/detail/133. Delaware (http://programs.dsireusa.org/system/program/detail/1231) and Maine (http://programs.dsireusa.org/system/program/detail/1231) recognize as eligible technologies fuel cells that use non-renewable fuels to produce hydrogen.

[193] Allen, *supra* note 190 at 120.

[194] *Id*.

[195] Environmental Protection Agency (EPA), ENERGY AND ENVIRONMENT GUIDE TO ACTION 5-10-5-11 (2015)

[196] Allen, *supra* note 190 at 120.

[197] Magali Delmas & Maria J. Montes-Sancho, *US State Policies for Renewable Energy: Context and Effectiveness*, ENERGY POLICY 5 (2011)

[198] Galen Barbose, U.S. RENEWABLES PORTFOLIO STANDARDS: 2017 ANNUAL STATUS REPORT 6 (2017).

[199] National Conference of State Legislatures, State Renewable Portfolio Standards and Goals, available at http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx (last visited September 11, 2017).

[200] Wiser, Barbose, & Holt, *supra* note 187 at 3894; Greg Buckman, *The Effectiveness of Renewable Portfolio Standard Banding and Carve-outs in Supporting High-cost Types of Renewable Electricity*, ENERGY POLICY 39 (2011) 4105–4114, 4106.

Because of the range of characteristics encompassed by RPSs and unique aspects of each state, as many different RPS designs exist as do jurisdictions that have enacted these policies.[201] States have tailored their RPS policies to fit each state's objectives, energy resources potential, and electricity market characteristics.[202] Besides the six criteria described above, RPSs may also differ regarding specifics of qualifying electricity resources and technologies (vintage, location and deliverability), mechanisms used to favor particular resources, and specifics of renewable energy credits (RECs) systems.[203] Some of these characteristics – and the manner in which states have tailored them to their particular circumstances – will be reviewed below.

One key decision that crafters of RPS requirements must address involves their policies concerning RECs. RECs are tradable rights representing attributes related to the generation of electricity from renewable energy sources. Power generators receive one REC for every megawatt of electricity that they produce.[204] For tracking purposes, RECs contain information about the electricity generator, including its energy source, location, and operation date.[205] At the end of each compliance period, a generator must possess the appropriate number of RECs, whether acquired through generation or purchase.[206] The attributes represented by RECs may include, among others, credit for the renewable energy generated.[207]

RPS provisions may allow RECs to be unbundled – traded separately from their electricity generation.[208] Unbundled RECs can benefit both the purchaser and the seller. The seller benefits because its electricity generation produces a second salable product in addition to the actual electricity. This incentivizes renewable power production.[209] Purchasers benefit because the credit enables them to satisfy renewable energy source requirements of RPSs without actually needing to receive the generated electricity (and thereby avoiding the need for physical delivery to the purchaser, thus broadening the geographic market).[210]

Unbundling thus can incentivize additional renewable energy generation in two ways. It encourages overproduction, since generators can sell excess credits.[211]

---

[201] Governors' Wind Energy Coalition, RENEWABLE ELECTRICITY STANDARDS: STATE SUCCESS STORIES 9 (undated).
[202] EPA, *supra* note 195 at 5-2.
[203] Barbose, *supra* note 198 at 7.
[204] Felix Mormann, Dan Reicher, & Victor Hanna, *A Tale of Three Markets: Comparing the Renewable Energy Experiences of California, Texas, and Germany*, 56 STAN. ENVTL. L.J. 55, 78 (2016).
[205] EPA, *supra* note 195 at 5-2.
[206] Allen, *supra* note 190 at 124.
[207] EPA, *supra* note 195 at 5-2.
[208] Allen, *supra* note 190 at 125.
[209] *Id*.
[210] EPA, *supra* note 195 at 5-2. RECs not only can allow shifting of producers and purchasers geographically, they can also shift them temporally. Some states allow RECs to be bankable, which enables purchasers to acquire them in one year, but to apply them in another year. A benefit of this system is it smooths fluctuations in REC prices and electricity production. Allen, *supra* note 190 at 126.
[211] Miriam Fischlein & Timothy M. Smith, *Revisiting Renewable Portfolio Standard Effectiveness: Policy Design and Outcome Specification Matter*, POLICY SCI (2013) 46:277–310, 288.

This can incentivize renewable energy production even in the absence of an RPS mandate.[212] This may be especially important with new technologies, where the costs of production may not be competitive with other methods and market prices do not fully cover costs.[213] As a result, all but three RPS states permit the unbundling of RECs.[214]

RPSs also require states to develop an accounting infrastructure. Indeed, the primary role of RECs is to track electricity generation from renewable sources and to guarantee that generators claim each credit only once.[215] RECs also ensure that credited electricity complies with other restrictions, such as approved energy source or geographic location of the generator.[216] Because of the integral nature of RECs to RPS compliance, nine regional tracking systems have arisen to support them.[217] States require utilities to demonstrate compliance with RPS requirements by filing annual reports. These reports document utilities' ownership and retirement of RECs, which they received by the state for generation or acquired through the regional markets.[218]

RPS designers need to address a number of additional issues. One involves the temporal eligibility of sources. This concerns whether pre-existing facilities (generating electricity from qualifying sources before implementation of the RPS) will receive credit for complying with the subsequent RPS mandate. Even if they do, the designers may choose to tier the credits for compliance, so that facilities of different vintages receive different levels of compliance credit.[219] A second issue concerns the geographic eligibility of sources. Some states recognize only in-state generation as compliant. Some pose no restrictions, while still others allow the electricity to be sourced outside the state's boundaries as long as the generator actually feeds it into the regional grid.[220] Third, RPSs must specify the entities which must comply with its mandate.[221] For instance, RPSs uniformly impose obligations on investor-owned utilities, but they apply mandates to publicly-owned utilities and retail sellers less often.[222] Finally, RPSs also include enforcement mechanisms to ensure compliance. Typically, these consist of financial penalties.

---

212 Allen, *supra* note 190 at 125.

213 Buckman, *supra* note 200 at 4107.

214 Fischlein & Smith, *supra* note 211 at 288.

215 Chip Gaul & Sanya Carley, *Solar Set Asides and Renewable Electricity Certificates: Early Lessons from North Carolina's Experience with Its Renewable Portfolio Standard*, ENERGY POLICY 48 (2012) 460–469, 462. Texas first developed RECs to determine compliance with RPS requirements and to facilitate development of a market for renewable energy generation. EPA, *supra* note 195 at 5-15.

216 Fischlein & Smith, *supra* note 211 at 289.

217 *Id*.

218 EPA, *supra* note 195 at 5-11.

219 Allen, *supra* note 190 at 122.

220 Fischlein & Smith, *supra* note 211 at 291. Often geographic origin requirements serve purposes other than renewable energy promotion, such as assuring receipt of environmental, employment, and financial benefits. *Id*.

221 Allen, *supra* note 190 at 123.

222 Uma Outka, *Prospects for Public Power and Distributed Renewable Energy*, 45 ENVTL. L. REP. NEWS & ANALYSIS 10537, 10539 (2015). *See also* DSIRE, PROGRAMS, last visited January 25, 2018, available at http://programs.dsireusa.org/system/program?type=38& (linking summaries of each state's RPS program).

More severe penalties may consist of temporary suspension or permanent revocation of generators' licenses.[223]

While the failure to establish a national RPS has impeded renewable energy development,[224] many benefits have resulted from their state-level development. As the Supreme Court has noted, states can serve "as laboratories for experimentation to devise various solutions where the best solution is far from clear."[225] Indeed, in the federalism system of the United States, states function as "innovation centers."[226] Not only do they experiment with policies, they also "compete" with other states to "develop the most effective and efficient regulatory program."[227] Indeed, the popularity of RPSs suggests to some that this decentralized policymaking engendered a race to the top.[228] Another advantage of state-level experimentation is that it limits risks to the rest of the country.[229] Also, because of their smaller size, state governments better understand local resources, can respond to developments more nimbly, and best reflect local economic and political interests.[230] Experimentation also provides many parties involved in the electricity system experience with issues that arise with increased reliance upon renewable sources,[231] such as development of new technologies,[232] interconnection to the grid,[233] the "duck curve,"[234] and the financing of projects,[235] among others. Finally, local experimentation rarely risks the environmental consequences that might arise when new technologies are implemented at a global scale.[236]

---

[223] Allen, *supra* note 190 at 127.
[224] Francesca F. Bochner, *Water, Wind, and Fire: a Call for a Federal Renewable Portfolio Standard*, DUKE ENVTL LAW & POLICY FORUM , Vol. XXV:201, 221 (2014).
[225] *United States v. Lopez*, 514 U.S. 549, 581, (1995) (KENNEDY, J., concurring).
[226] Allison C.C. Hoppe, *State-Level Regulation as The Ideal Foundation For Action on Climate Change: a Localized Beginning to the Solution of a Global Problem*, 101 CORNELL L. REV. 1627, 1650 (2016).
[227] *Id*. at 1650-51.
[228] Thomas P. Lyon & Haitao Yin, Why Do States Adopt Renewable Portfolio Standards?: An Empirical Investigation, THE ENERGY JOURNAL, Vol. 31, No.3, 153 (2010).
[229] *Id*. at 1650, n.126.
[230] Hoppe, *supra* note 236 at 1646.
[231] Warren Leon, THE STATE OF STATE RENEWABLE PORTFOLIO STANDARDS 6 (June 2013).
[232] Hydropower Reform Coalition, Renewable Portfolio Standard (RPS), last visited December 31, 2017, available at http://www.hydroreform.org/policy/rps (noting that the goal of most RPSs is to encourage the development of new energy sources).
[233] Debrup Das, et al, *Reducing Transmission Investment to Meet Renewable Portfolio Standards Using Smart Wires* 6 (2010), available at https://www.smartwires.com/wp-content/uploads/2015/01/Smart_Wire_4.pdf (concluding that the adoption of RPSs will necessitate consideration of Smart Grid technologies).
[234] The "duck curve" (named for its resemblance to a duck) illustrates the complications that arise when an intermittent energy source, such as solar energy, provides a significant portion of a system's electricity, but its resource diminishes (because of the setting sun) at the time when demand peaks in the early evening. Office of Energy Efficiency & Renewable Energy, *Confronting the Duck Curve: How to Address Over-Generation of Solar Energy* (October 12, 2017), available at https://energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy.
[235] Wiser, Barbose, & Holt, *supra* note 187 at 3904.
[236] Matteo Muratori, et al, *Global Economic Consequences of Deploying Bioenergy with Carbon Capture and Storage* (BECCS), ENVIRON. RES. LETT. 2 (2016).

Because RPSs have dozens of design elements,[237] they are very flexible policy tools.[238] Since RPSs are state policies and numerous permutations are possible with the many criteria that each RPS must include, the resulting RPSs are highly tailored to the circumstances and needs of each particular state.[239] This flexibility has allowed states with diverse renewable energy potentials to adopt successful RPSs.[240] Indeed, states have crafted RPS programs that are distinct over the range of criteria incorporated in RPSs.[241] Not surprisingly, no two states have identical RPSs.[242]

The inherent flexibility of RPSs facilitates another of their defining experiences: continual revision and strengthening.[243] For instance, from 2015 to 2017, the legislatures in the 29 states with RPSs passed more than 200 RPS-related bills.[244] RPS flexibility has enabled states to learn from experience and modify their policies accordingly. They have tweaked RPS timetables, percentages, technologies, incentives, durations, and other provisions.[245] These modifications have responded to the achievement of program goals, approaching target dates, changing market conditions, and other considerations.[246]

Importantly, these modifications were not enacted to weaken too-demanding standards; quite the contrary, they made the RPSs more ambitious.[247] Two states, California and Texas, provide examples. In 2006, California accelerated its initial deadline for compliance from 2017 to 2010. Next, the state increased its renewable energy targets from 20% to 33% and subsequently to 50%.[248] Similarly, Texas has regularly extended its deadlines and raised its renewable energy requirements. From its original target of 2009, it added new targets for 2015 and then for 2025.[249] Overall, the average RPS obligation rose from 7.6% of total electricity to 17.5%.[250] Since 2013, several states have adopted even more substantial increases in their target mandates. As of July 2017, four jurisdictions (California, New York, Oregon, and the District of Columbia) now

---

[237] Governors' Wind Energy Coalition, *supra* note 201 at 9.
[238] Luke J.L. Eastin, *An Assessment of the Effectiveness of Renewable Portfolio Standards in the United States*, THE ELECTRICITY JOURNAL 127 (2014).
[239] Leon, *supra* note 231 at 10.
[240] Vicki Arroyo, et al, *State Innovation on Climate Change: Reducing Emissions from Key Sectors While Preparing for a "New Normal,"* 10 HARV. L. & POL'Y REV. 385, 398 (2016).
[241] Allyson Browne, *RPS Evolving: States Take on U.S. Climate Goals*, in NATURAL RESOURCES & ENVIRONMENT (Spring, 2017), available on Westlaw at 31-SPG Nat. Resources & Env't 50.
[242] *Id*.
[243] *Id*. at 51.
[244] *Id*.
[245] Leon, *supra* note 231 at 10. Implicit in these constant refinements and strengthening of RPS policies is the need to evaluate RPS progress routinely. EPA, *supra* note 195 at 5-17.
[246] Browne, *supra* note 241 at 51.
[247] Barbose, *supra* note 198 at 9 (noting that more than half of RPS states have raised their overall targets or those of their carve outs).
[248] Allen, *supra* note 190 at 137-38.
[249] *Id*. at 148. In each instance, the state surpassed its goal early, by four, seven, and then ten years, respectively, while increasing installed wind power capacity from 900 MW to 10,000 MW. *Id*.
[250] Fischlein & Smith, *supra* note 211 at 280.

have renewable energy targets of 50% by 2040 or sooner; Vermont has a mandate of 75% by 2032; and Hawaii's is now 100% by 2045.[251]

RPSs inherently incentivize utilization of the least-cost technology. RPSs are market-oriented policies that establish general targets, but they allow market actors – such as utilities, other electricity suppliers, project developers, and other private sector participants – to determine their methods of compliance.[252] These actors typically satisfy RPS requirements by choosing lower-cost and lower-risk technologies.[253] This market pressure to utilize lower-cost methods of production drives innovation. It "concentrates the mind and alters the behavior" of these parties to develop means to comply with the RPS requirements.[254] Thus, RPSs encourage development and adoption of low-cost methods.[255] Then, industrial dynamics, such as economies of scale and efficiencies gained through experience, further drive down costs as markets expand.[256] Numerous examples exist of the interrelation of economies of scale, lowering costs, and expanding markets.[257]

While RPSs are traditionally viewed as a means to increase renewable energy in general, states can and do tailor their RPSs to promote specific technologies that are not yet competitive.[258] Sometimes, states specifically design aspects of their RPSs to diversify renewable energy resources.[259] For instance, the RPSs of 13 states and of the District of Columbia allow electricity generated from at least 15 sources to satisfy their mandates.[260] RPS designers also incorporate

---

[251] Barbose, *supra* note 198 at 6.
[252] Leon, *supra* note 231 at 8.
[253] Wiser, Barbose, & Holt, *supra* note 187 at 3896. The incentive to provide electricity at the lowest cost also incentivizes improving technologies to become more cost competitive. EPA, *supra* note 195 at 5-3.
[254] Leon, *supra* note 231 at 6.
[255] Some commentators suggest that a weakness of RPSs is that they are so market driven that they do not sufficiently encourage investment in less mature technologies. Buckman, *supra* note 200 at 4106-07. As discussed in the next section, RPSs can utilize carve outs or multipliers to stimulate development of these resources. *Id*. at 4107.
[256] John A. Mathews & Hao Tan, *Manufacture Renewables to Build Energy Security*, NATURE 167 (September 11, 2014).
[257] An historic example comes from the auto industry. From 1909 to 1916, the cost of the Ford Model T dropped 62% while sales doubled annually, skyrocketing from 6,000 in 1908 to 800,000 in 1917. *Id*. More recently, the prices of solar panels and wind turbines have dropped as mass production of each has increased. Anna Hirtenstein, *China's Hunger for Solar Boosts Clean Energy Funding Near Record,* BLOOMBERG BNA ENVRIONMENT & ENERGY REPORT (January 16, 2018). For instance, the price of solar installations has decreased 60% since 2008. Sara Matasci, *How Solar Panel Cost and Efficiency Have Changed over Time*, March 16, 2017, available at https://news.energysage.com/solar-panel-efficiency-cost-over-time/. From 2008 to 2016, domestic solar photovoltaic installations have increased from 298 MW to 14,762 MW. Solar Energy Industries Association (SEIA), *Solar Market Insight Report 2016 Year In Review*, available at https://www.seia.org/research-resources/solar-market-insight-report-2016-year-review.
[258] Fischlein & Smith, *supra* note 211 at 286.
[259] Wiser, Barbose, & Holt, *supra* note 187 at 3895.
[260] DSIRE, PROGRAMS, last visited January 25, 2018, available at http://programs.dsireusa.org/system/program?type=38& (linking summaries of each state's RPS program). States allowing at least 15 sources are Arizona, Connecticut, Hawaii, Maryland, Massachusetts, Nevada, New Hampshire, North Carolina, Oregon, Pennsylvania, Utah, Vermont, and Wisconsin.

policy variations to the RPS to subsidize more costly technologies.[261] States utilize these devices to encourage investment in particular technologies whose development is a policy objective of the state.[262] States turn to these methods because the technologies are not currently competitive with other energy sources because of their higher cost, still-developing technology, or other market barriers.[263] Two RPS devices are particularly effective at promoting new technologies. The first are technology carve outs; the second are credit multipliers.[264]

Carve outs (or set asides)[265] identify particular levels of electricity to be produced from a particular type of source. These targets are "carved out" of the overall renewable energy percentage for the state's electricity.[266] Essentially, the set aside establishes a submarket reserved for the particular technology.[267] Some states, however, establish these set asides as electricity to be produced in addition to the overall RPS obligation.[268] One of the most commonly-used carve outs is for solar generation. In fact, solar carve outs have become popular in a manner that was unforeseen when RPSs were first being developed.[269] As of 2015, half of the states with RPSs – 15 – used a solar set aside. 13 of the states use a percentage requirement, ranging from a high of 4.1% in New Jersey by 2027 to a low of 0.2% in North Carolina by 2018. Two other states utilize a requirement stated in megawatts.[270] Not surprisingly, so many states have chosen to use this device because it has proven results. Analysis has found that the use of set asides in RPSs has "heavily influenced" the deployment of solar energy in those states.[271] For instance, a solar carve out in Massachusetts has been quite successful. The state met its first goal (450 MW by 2017) three years early, and it surpassed its next goal

---

[261] Joshua Novacheck & Jeremiah X. Johnson, *The Environmental And Cost Implications of Solar Energy Preferences in Renewable Portfolio Standards*, ENERGY POLICY 86 (2015) 250–261, 251.
[262] EPA, *supra* note 195 at 5-10.
[263] *Id*.
[264] Wiser, Barbose, & Holt, *supra* note 187 at 3897.
[265] Several labels are applied to this concept. They have been called carve outs, set asides, bands, and tiers. *Id*.
[266] EPA, *supra* note 195 at 5-10.
[267] Buckman, *supra* note 200 at 4105.
[268] EPA, *supra* note 195 at 5-10.
[269] Leon, *supra* note 231 at 10.
[270] *Id*. at 5-4-5-5. In addition, another four states require that set percentages of electricity be provided by distributed generation sources. *Id*. These set asides likely will be met by solar energy. Gaul & Carley, *supra* note 215 at 460. While the percentage of electricity provided from solar is a small percent of total state electricity, often these percentages constitute substantial portions of the RPS obligation. For instance, although New Mexico requires only 4% of its electricity to be sourced from solar, this constitutes 20% of its renewable energy requirement. Novacheck & Johnson, *supra* note 261 at 251.
[271] Andrea Sarzynski, Jeremy Larrieu, & Gireesh Shrimali, *The Impact of State Financial Incentives on Market Deployment of Solar Technology*, ENERGY POLICY 46 (2012) 550–557, 551. The authors also note that another successful approach involved states offering cash incentives, such as rebates and grants. *Id*. Combining carve outs with subsidies have been particularly effective in incentivizing solar power. Fischlein & Smith, *supra* note 211 at 286.

(nearly quadrupling solar energy to 1600 MW by 2020) more than two years early.[272]

Multipliers, on the other hand, provide that the generation of electricity by particular energy sources will earn multiples of RECs.[273] For instance, seven states use multipliers for solar, with multipliers of credits ranging from two to three times the standard one credit for each megawatt of generation.[274] Multipliers are credited with successfully supporting high-cost offshore wind development in the United Kingdom.[275]

One advantage that both carve outs and multipliers share is that states can apply these devices to multiple technologies at once, thereby supporting several undeveloped methods at the same time. Delaware, for instance, has instituted multipliers for fuel cells, solar, and offshore wind.[276] New Mexico, on the other hand, carves out minimum percentages of its RPS goals that must be satisfied by solar, wind, and "other renewables."[277]

Despite some similarities, carve outs and multipliers have had disparate track records. As mentioned above, carve outs have been more popular in the United States, with twice as many states utilizing set asides as providing multipliers. European countries, on the other hand, have preferred multipliers.[278] An early comparison of solar set asides and multipliers concluded that carve outs provided greater certainty that the targeted energy would be produced.[279] Indeed, set asides successfully initiated solar generation in a number of states, while multipliers did not demonstrate comparable success.[280] Another comparison of set asides and multipliers comes from Novacheck and Johnson, who analyzed the relative costs and benefits of applying carve outs and multipliers as part of a future extension of Michigan's RPS.[281] They concluded that carve outs could raise costs by requiring the installation of technologies that are not the least cost source.[282]

Carve outs and multipliers do have downsides. As noted previously, RPSs incentivize utilization of the lowest-cost technologies.[283] Since carve outs require utilities to provide electricity generated from sources which would otherwise not be used or used in lower quantities (since they are not the lowest-cost source), carve outs require utilities to replace electricity from lowest-cost sources with electricity from sources which have higher costs. Thus, carve outs will raise energy costs. Conversely, while multipliers demonstrate strong deployment of new technologies, overall they typically yield less of the desired product – electricity generated from

---

[272] Samantha Donalds, *Solar Insights from the 2016 RPS Summit* (January 2, 2017), available at http://www.renewableenergyworld.com/ugc/articles/2017/01/03/solar-insights-from-the-2016-rps-summit.html.
[273] Buckman, *supra* note 200 at 4105. Multipliers are also identified as banding. *Id*.
[274] EPA, *supra* note 195 at 5-4-5-5.
[275] Buckman, *supra* note 200 at 4114.
[276] Fischlein & Smith, *supra* note 211 at 290.
[277] *Id*. at 287.
[278] Buckman, *supra* note 200 at 4107.
[279] Wiser, Barbose, & Holt, *supra* note 187 at 3904.
[280] *Id*.
[281] Novacheck & Johnson, *supra* note 261 at 251.
[282] *Id*. at 256.
[283] Wiser, Barbose, & Holt, *supra* note 187 at 3896.

renewables.[284] This occurs because the state awards credits in excess of the amount of electricity actually generated from renewable sources.[285] Thus, multipliers incentivize particular resources, but they do so at the expense of the overall amount of renewable energy generation.

Besides set asides and multipliers, states have combined RPSs with other tools to increase renewable energy generation. For instance, some states provide direct monetary subsidies.[286] One quarter of RPS states provide subsidies for solar, and researchers have found these subsidies to provide important support for the technology.[287] Another policy that six states have incorporated into their RPSs are feed-in tariffs (FIT).[288] A FIT requires utilities to purchase electricity from independent producers at fixed amounts, usually above-market rates, and for set periods of time.[289] California, for instance, has instituted its Renewable Market Adjusting Tariff (ReMAT), which is a feed-in tariff program for small renewable generators who produce no more than 3 MW of electricity.[290] The program requires utilities to enter into fixed-price 10-, 15- or 20-year standard contracts with these generators. The state divides eligible generators into three categories based upon their energy resource: Baseload (bioenergy and geothermal), As-Available Peaking (solar), and As-Available Non-Peaking (wind and hydro).[291]

This inherent flexibility of RPSs is important because of the discretion that it allows policymakers. Studies have concluded that, in general, policies enabling discretion promote innovation and increase productivity.[292] Flexible policies stimulate innovation because they do not limit producers to "best-available" technologies, thus encouraging competition to develop more efficient means to comply with the mandates.[293] In the specific context of RPSs, their market-based approach pushes producers to utilize lower-cost methods of production, which drives innovation.[294] Furthermore, government policies are most effective when they provide long-term certainty to market actors.[295] Many RPSs achieve this objective by instituting mandates that extend 10 to 20 years into the future.[296] In

---

[284] Novacheck & Johnson, *supra* note 261 at 254.
[285] *Id*. at 251.
[286] Fischlein & Smith, *supra* note 211 at 286.
[287] *Id*.
[288] DSIRE *Summary Tables: Feed-in Tariff*, last visited October 4, 2017, available at http://programs.dsireusa.org/system/program?type=92&.
[289] Mormann, *Constitutional Challenges*, *supra* note 187 at 199.
[290] California Public Utilities Commission, Renewable Feed-In Tariff (FIT) Program, last visited September 22, 2017, available at http://www.cpuc.ca.gov/feedintariff/.
[291] DSIRE, *Renewable Market Adjusting Tariff (ReMAT)*, last visited September 22, 2017, available at http://programs.dsireusa.org/system/program/detail/5665.
[292] Fischlein & Smith, *supra* note 211 at 297.
[293] *Id*. The authors cite one study finding that the most successful policies set clear and ambitious goals and then allow producers sufficient time and flexibility to achieve them. This opportunity to determine the means for compliance fosters innovation. *Id*.
[294] Nathaniel Horner, Iñes Azevedo & David Hounshell, *Effects of Government Incentives on Wind Innovation in the United States*, ENVIRON. RES. LETT. 8, 6 (2013).
[295] Leon, *supra* note 231 at 9.
[296] Paul Dvorak & Nathaniel Horner, *RPS Policies Are Driving Wind Turbine Innovation*, February 28, 2014, available at http://www.windpowerengineering.com/design/rps-policies-driving-wind-turbine-innovation/. These long-term signals provided by RPSs contrast with federal

this way, RPSs' fostering of innovation to lower costs helps "move technologies to maturity."[297]

States with RPSs have experienced significant increases in renewable energy generation during the past two decades. The Lawrence Berkeley National Laboratory concluded that RPSs are "key driver[s]" for renewable energy generation.[298] Approximately half of the growth in renewable energy in the United States since 2000 is attributable to satisfying RPS requirements.[299] In several regions – notably the West, Mid-Atlantic, and Northeast – RPSs currently account for 70-90% of renewable energy capacity additions.[300] Consistent with these numbers, all but four states have met their RPS quotas. Of those four, two still achieved at least 90% of their target.[301]

Contrasting the differences between renewable energy installations in RPS states and non-RPS states further demonstrates RPSs' impact. One analysis considered the change in renewable energy production from 1997 (or the date of adoption for RPS states if later) to 2011. In non-RPS states, renewable energy production increased by 128.5%. In RPS states, it increased by 666.6%.[302]

While half of renewable energy additions were attributable to RPSs since 2000, this broad statistic masks meaningful underlying trends. Up to 2012, the amount of total renewable energy additions that occurred in RPS states was 67%.[303] By 2016, however, this percentage fell to only 44%.[304] The fact that an increasing percentage of renewable energy additions is occurring in non-RPS states reflects another benefit of RPSs. Consistent with their ability to incentivize innovation, over time RPSs drive increased efficiencies, thereby lowering costs. While initially utilities build renewable energy additions to satisfy RPS targets, as electricity generation costs decline, they become competitive against other sources, and

---

energy policies, which Congress has instituted primarily through the tax code. Leon, *supra* note 231 at 9. For instance, a primary support for wind power, the production tax credit (PTC), has experienced a rather irregular pattern. Since its initial establishment in the Energy Policy Act of 1992, Congress has allowed the PTC to expire on six occasions, and it has renewed it six times. Union of Concerned Scientists, *Production Tax Credit for Renewable Energy*, last visited December 31, 2017, available at https://www.ucsusa.org/clean-energy/increase-renewable-energy/production-tax-credit#.WkkAh0xFw5s. The PTC first expired in 1999. Since then, Congress has typically extended it for one- or two-year periods. America Wind Energy Association, *Production Tax Credit*, last visited December 31, 2017, available at https://www.awea.org/production-tax-credit. As a result, investment has followed a boom-and-bust pattern driven by the short-term cycles of expiration and renewal of the credit. Figure 2, *infra*, illustrates this pattern, as investors rushed to install wind capacity in 2001, 2003, and 2012, prior to expirations (and subsequent extensions) in 2002, 2004, and 2013. A similar rush to install wind power occurred in 2009; Congress extended the PTC in 2010 prior to its expiration. Union of Concerned Scientists, *supra*.

[297] Governors' Wind Energy Coalition, *supra* note 201 at 4.

[298] Arroyo, *supra* note 240 at 398.

[299] Barbose, *supra* note 198 at 3.

[300] *Id*.

[301] *Id*. at 28. Similarly, 12 of 16 states with solar carve outs satisfied them, and a 13th exceeded more than 90% of its quota. *Id*.

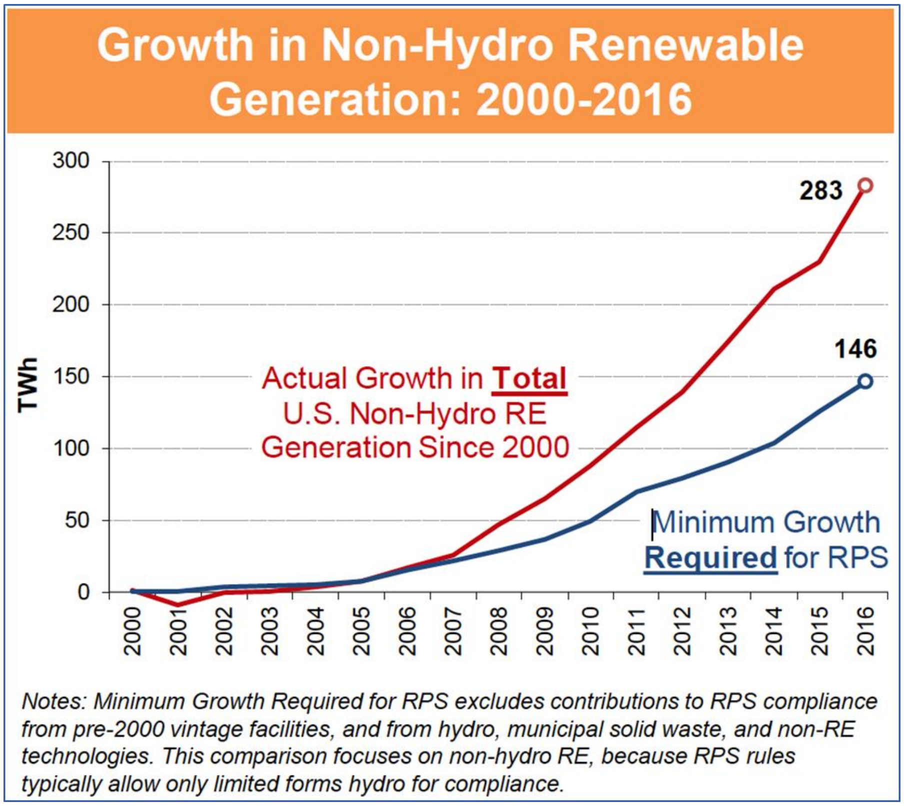
[302] Eastin, *supra* note 238 at 132.

[303] Leon, *supra* note 231 at 4.

[304] Barbose, *supra* note 198 at 3.

utilities install renewable energy even though not required to do so by RPS quotas. Figure 1 demonstrates this pattern.

Figure 1



As Figure 1 illustrates, until 2007, utilities made nearly all renewable energy additions to satisfy RPS quotas. However, since that time, investments in renewables increasingly were not tied to RPS mandates – investments occurred in RPS states in excess of RPS mandates or in states without RPS quotas.

Despite these laudable statistics, analyses of the effects of RPSs on renewable energy installation have failed to reach consensus.[305] Indeed, one study noted that studies of RPSs have found "all possible impacts ranging from negative to none to positive."[306] On the other hand, one analyst has noted that attempts to generalize the effects of RPSs may be misplaced.[307] Impacts of RPSs also vary across states.[308] Not surprisingly, the very flexibility inherent in RPSs complicates

---

[305] Karen Maguire & Abdul Munasib, *The Disparate Influence of State Renewable Portfolio Standards on Renewable Electricity Generation Capacity*, LAND ECONOMICS, August 2016, 92 (3): 468–490, 468.
[306] Gireesh Shrimali, et al, HAVE STATE RENEWABLE PORTFOLIO STANDARDS REALLY WORKED? 33 (2012).
[307] Maguire & Munasib, *supra* note 305 at 487.
[308] *Id*. at 468.

analysis of them. Furthermore, the effectiveness of RPSs depends upon the characteristics of the RPS and the state's electricity market.[309]

A number of factors cloud comparisons of RPS systems. One consideration is the policies of surrounding states. Approximately three quarters of all electricity in the United States is traded before reaching customers, and it often crosses state lines.[310] Initially, the presence of RPS policies in neighboring states positively impacts in-state renewable energy generation. However, as policies allow interstate trading and the trading zone increases, in-state generation tends to decrease, and generation concentrates in a few states – those that are most cost effective.[311] This effect of deployment increasing in other states occurs even when those states do not utilize RPSs.[312] Renewable energy additions in 13 states without RPSs were actually made to comply with RPSs of other states. These installations accounted for 10% of renewable energy additions.[313] Magnifying this tendency, most RPSs do not require that renewable energy be generated in state to receive credit.[314] This may not be surprising since parties have filed several challenges to RPSs' in-state generation requirements on Commerce Clause grounds.[315]

Other considerations also impact the perceived success of RPSs. Some states allow pre-existing renewable electricity production to count to the state quota, which has the obvious effect of minimizing investment into new renewables.[316] Another factor which can depress renewable energy investment is the inclusion of energy efficiency as a means of compliance.[317] Typically, these states credit investment in energy efficiency to satisfy RPS mandates for one of two reasons. In some instances, they seek to reduce greenhouse gas emissions, and are less concerned about stimulating renewable energy generation.[318] In others, states include energy efficiency as a means to minimize the amount of investment in renewable energy sources, thereby reducing the costs of compliance while also lowering the nominal renewable goal.[319]

Another factor that often plays a significant role in states achieving their RPS targets is the enforcement mechanism of their RPSs. States are less likely to achieve their RPS targets when their RPSs fail to penalize noncompliance or enable

---

[309] *Id*. at 487.
[310] Fischlein & Smith, *supra* note 211 at 279.
[311] Shrimali, *supra* note 306 at 34.
[312] Barbose, *supra* note 198 at 16.
[313] *Id*.
[314] Fischlein & Smith, *supra* note 211 at 279.
[315] Mormann, Constitutional Challenges, *supra* note 187 at 203-09. The Tenth Circuit upheld a finding that Colorado's RPS did not violate the Dormant Commerce Clause. *Id*. at 205. The Eighth Circuit, conversely, upheld a ruling that a "negative" sourcing mandate (requiring that "no person" shall import power that would contribute to the state's CO_2 emissions) constitutes impermissible extraterritorial regulation in violation of the Dormant Commerce Clause. *Id*. at 206. Massachusetts settled a challenge to the in-state generation requirement of its RPS by repealing that provision. *Id*. at 204.
[316] Fischlein & Smith, *supra* note 211 at 282.
[317] *Id*. at 285.
[318] Environmental Protection Agency, CUTTING POWER SECTOR CARBON POLLUTION: STATE POLICIES AND PROGRAMS 25 (2016).
[319] Fischlein & Smith, *supra* note 211 at 285.

utilities to circumvent their mandates.[320] Although most RPSs include some form of enforcement mechanism, states have notoriously failed to enforce them, in many instances waiving or excusing penalties.[321] In fact, only two states, Texas and Connecticut, have assessed penalties for shortfalls in compliance.[322] In addition to insufficient penalties and enforcement, the success of RPSs can also be impacted by their reporting and verification procedures.[323] Analyses have suggested that current enforcement is sufficiently weak that RPS targets could actually be "much lower" if loopholes were closed.[324]

In light of these considerations, the seeming "contradictory" findings of analysts trying to determine the impact of RPSs is hardly surprising.[325] Attempts to determine an average effect for RPSs fail to take into account the unique factors of the states, their RPS policies, and those of surrounding states.[326] Once analysts factor in these differences, correlations between RPS enactment and renewable energy generation emerge.[327] More recent analysis finds significant correlations between RPS enactment and renewable electricity generation.[328] Analysts have also found factors that strengthen the connection between RPSs and renewable energy generation. For instance, the stringency[329] of RPSs has a positive and significant impact on renewable energy deployment.[330] Similarly, REC unbundling also increases renewable energy generation.[331]

The bottom line: consistent with their market-based approach to incentivize innovation, RPSs tend to be more effective than other domestic policies at driving innovation.[332]

B. Two Prominent RPS Successes – Wind and Solar

Another means to evaluate the effectiveness of RPSs considers their impact upon specific renewable energy technologies. Two obvious examples arise: wind

---

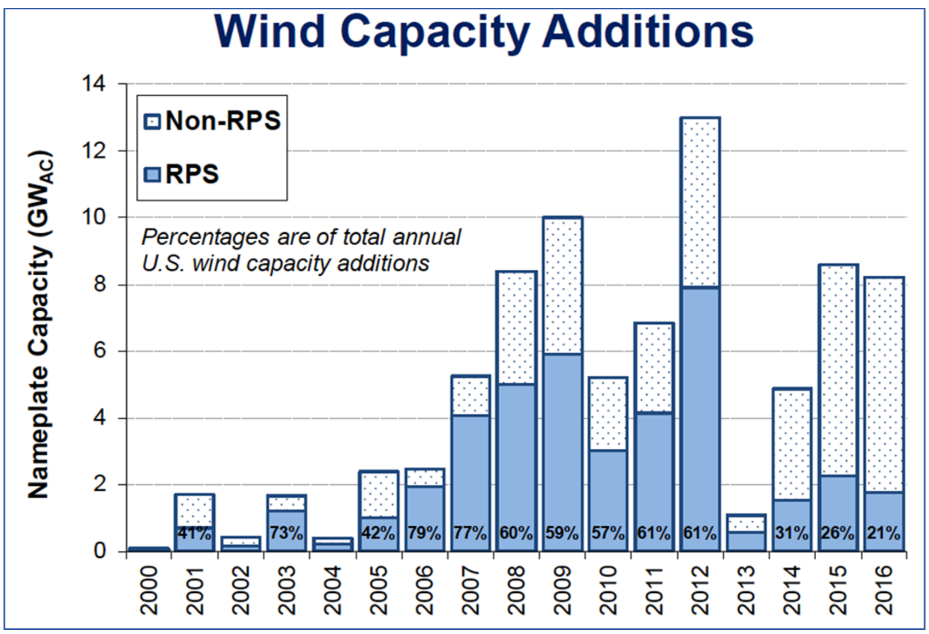
[320] *Id*. at 281.
[321] Ivan Gold & Nidhi Thakar,*A Survey of State Renewable Portfolio Standards: Square Pegs for Round Climate Change-Holes?*, 35 WM. & MARY ENVTL. L. & POL'Y REV. 183, 195 (2010).
[322] *Id.* at 292.
[323] Horner, Azevedo & Hounshell, *supra* note 294 at 7.
[324] *Id*. at 304.
[325] Shrimali, *supra* note 306 at 33.
[326] Maguire & Munasib, *supra* note 305 at 469.
[327] Fischlein & Smith, *supra* note 211 at 304.
[328] Matthew J. Denneny, STATE-LEVEL RENEWABLE PORTFOLIO STANDARDS: EVALUATING THEIR EFFECTIVENESS IN INCREASING RENEWABLE ELECTRICITY GENERATION AND REDUCING CARBON EMISSIONS 29 (2015).
[329] For these purposes, "stringency" focuses on the incremental, as opposed to the nominal, requirement of the RPS policy. Haitao Yin & Nicholas Powers, *Do State Renewable Portfolio Standards Promote In-State Renewable Generation*, ENERGY POLICY 38 (2010) 1140–1149, 1147.
[330] Shrimali, *supra* note 306 at 33.
[331] *Id*. at 34.
[332] Horner, Azevedo & Hounshell, *supra* note 294 at 7. They further suggest that the best combination of policies to encourage innovation would be a combination of an RPS with aggressive targets and meaningful penalties. *Id*.

and solar. As discussed below, throughout the past two decades, RPS policies have uniquely supported these two sources. Both technologies were only minimally deployed domestically before the adoption of RPSs. Installations of each have increased substantially since the enactment of these policies.

Several indicators demonstrate that RPSs have significantly and positively impacted wind energy. Indeed, because of RPSs' low-cost focus,[333] wind power especially benefitted from RPS policies.[334] Of non-hydro, renewable resources, wind had been the most developed and widely available.[335] As a result, utilities typically turned to wind power to satisfy RPS mandates. Indeed, the Department of Energy estimates that between 1998 and 2011 utilities used wind to satisfy 89% of RPS obligations.[336]

Wind development illustrates another result of RPS policies. RPSs stimulated renewable energy investment in covered states. As this investment incentivized innovation and lowered costs, utilities in other states invested in this now-competitive technology. Thus, over time, new investments in these technologies shifted disproportionately to non-RPS states, as illustrated by Figure 2 below.

Figure 2



[333] Wiser, Barbose, & Holt, *supra* note 187 at 3896.
[334] Governors' Wind Energy Coalition, *supra* note 201 at 13.
[335] *See* Wind Europe, History of Europe's Wind Industry, last visited December 31, 2017, available at https://windeurope.org/about-wind/history/, for a history of European policies and subsequent milestones of its wind industry in the 1980's and 1990's.
[336] Governors' Wind Energy Coalition, *supra* note 201 at 13.

By 2016, only 21% of annual new wind capacity was added to meet RPS requirements.[337] In other words, 79% of wind power additions either were in RPS states but exceeded RPS mandates or were installed in non-RPS states.

In addition to impacting wind power deployment, RPSs have positively impacted the domestic wind industry, too. During the five years from 2006 to 2011, the domestically-sourced content of wind projects nearly doubled, jumping from 35% to 67%.[338] Furthermore, the largest wind turbine producers, with the exception of GE, were based in other countries,[339] but they began manufacturing components domestically. In 2004, only one of the top ten manufacturers had factories in the United States. By 2016, this had increased to eight in ten.[340] RPSs have also positively impacted domestic wind power innovation.[341] Notably, the period of RPS enactments coincided with a significant increase in wind turbine patenting.[342] As noted previously, this results because RPSs are inherently technology forcing. By requiring compliance within a market system, RPSs force suppliers to reduce production costs, thereby stimulating innovation.[343]

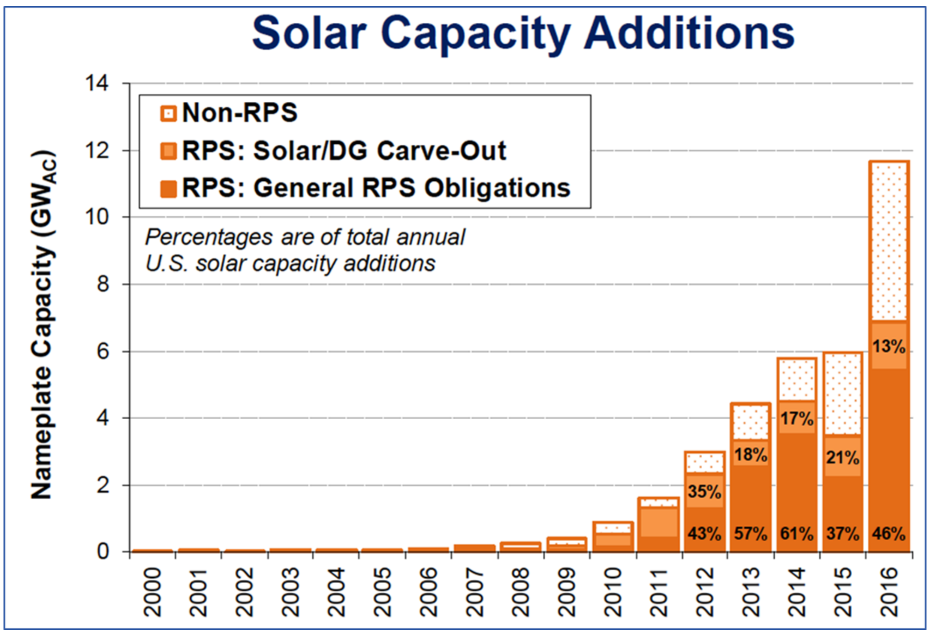
RPSs have also been instrumental in the development of solar power. Solar, however, started from a very different position from that of wind. Prior to the adoption of most RPSs, wind technology was already established and available for commercial use.[344] Solar technology, on the other hand, was relatively undeveloped.[345] Nevertheless, RPSs successfully drove development in and deployment of solar technology.[346] As mentioned previously, half of RPS states utilize solar carve outs.[347] In addition, six states provide multipliers for solar, and a seventh allows a multiplier for distributed generation,[348] fulfillment of which typically involves solar power.[349] Initial growth of solar was concentrated in these states. Specifically, between 2005-2009, 65-81% of solar installations outside of California occurred in states with solar carve outs.[350]

---

[337] Ryan Wiser & Mark Bolinger, 2016 WIND TECHNOLOGIES MARKET REPORT 67 (2016).
[338] *Id*.
[339] Veronika Henze & Catrin Thomas, *Vestas Reclaims Top Spot In Annual Ranking Of Wind Turbine Makers*, BLOOMBERG NEW ENERGY FINANCE, February 22, 2017.
[340] *Id*.
[341] Horner, Azevedo & Hounshell, *supra* note 294 at 1.
[342] Dvorak & Horner, *supra* note 296.
[343] Horner, Azevedo & Hounshell, *supra* note 294 at 6.
[344] Mitchell Schmidt, *Iowa's Status As a Renewable Energy Leader: How We Got Here, and What's Next*, THE GAZETTE (July 9, 2017), available at http://www.thegazette.com/iowaideas/stories/energy-environment/iowas-status-as-a-renewable-energy-leader-how-we-got-here-and-whats-next-20170709.
[345] For instance, as of 2000, global solar photovoltaic installations totaled 1,250 MW. For comparison, by 2017, this number is estimated to reach 368,000 MW. Wikipedia, Growth of Photovoltaics, last visited December 31, 2017, available at https://en.wikipedia.org/wiki/Growth_of_photovoltaics#cite_note-93.
[346] Wiser, Barbose, & Holt, *supra* note 187 at 3894.
[347] EPA, *supra* note 195 at 5-4-5-5.
[348] *Id*. Distributed generation refers to the generation of electricity near the point of consumption rather than by a centralized source such as a power plant. Department of Energy, *Renewable Energy: Distributed Generation Policies and Programs*, last visited January 1, 2018, available at https://energy.gov/eere/slsc/renewable-energy-distributed-generation-policies-and-programs.
[349] Gaul & Carley, *supra* note 215 at 463.
[350] Wiser, Barbose, & Holt, *supra* note 187 at 3900.

Comparisons of new installations of wind and solar reveal another RPS pattern – RPSs help drive technologies to maturity, at which point their deployment becomes widespread. For instance, as discussed previously, through 2011 wind power provided 89% of the installed capacity required to satisfy RPS mandates.[351] Through 2016, wind still constituted 61% of all RPS installations.[352] In 2016, however, solar accounted for 79% of all new builds.[353] Just as wind was used primarily to meet RPS requirements and subsequently came to be installed as additional capacity in RPS states or as new capacity in non-RPS states,[354] solar is beginning to follow a similar trajectory. Figure 3 illustrates this transition.

Figure 3



Through 2014, approximately 80% of solar installations occurred in RPS states, In both 2015 and 2016, however, more than 40% of new solar has been installed in non-RPS states.[355] Thus, as RPSs have helped drive innovation in solar and reduce its costs,[356] it has become increasingly popular as a resource even in states without any mandates for its adoption. Both the actual number of solar installations and the

[351] Governors' Wind Energy Coalition, *supra* note 201 at 13.
[352] Barbose, *supra* note 198 at 17.
[353] *Id.*
[354] *Id.*
[355] Barbose, *supra* note 198 at 18.
[356] Since 2008, the price of solar panel installation has declined 60%. Solar panel efficiency also has improved approximately 60% during this period. Matasci, *supra* note 257. During this period, total United States installations increased nearly fifty-fold. SEIA, *supra* note 257.

proportion of installations not required by RPS-mandates have increased substantially.

Thus, with two different technologies in very different circumstances, RPSs have promoted the improvement, adoption and growth of each. Especially instructive is the example of solar energy. RPS policies established markets for a technology that previously was expensive and rarely utilized. These policies led to technological innovations that fostered investment. As prices fell in RPS markets, these prices attracted investment in solar not required by RPS mandates.

C. RPSs Can Facilitate the Development of NETs

RPS-type systems, or RPSs themselves, could successfully incentivize NETs' investment and eventual deployment. A number of considerations suggest that RPSs should also be successful in fostering the development of NETs. RPSs can establish markets for multiple technologies, enabling the development of several NETs at once. Through their markets, RPSs have a track record of attracting financing that helps to stimulate innovation and drive down costs. RPSs also allow for local tailoring to address regional differences. In addition, RPSs have developed accounting systems, which will be essential for NETs.

States could expand current RPSs to incorporate NETs as a means to satisfy their requirements. As discussed previously, RPSs could incorporate carve outs or multipliers to target NETs as means for compliance. To the extent that the states adopted their RPSs to limit atmospheric CO_2 (through the reduction of carbon emissions),[357] the inclusion of NETs will further this goal. Alternatively, states could establish a separate program, an NPS, solely dedicated to the development of NETs.

One reason why RPSs can help to develop NETs is because these policies can promote multiple technologies at once. States using RPSs often set a goal of diversifying their renewable energy sources.[358] To this end, states typically identify a broad range of technologies eligible to satisfy their RPS requirements. For instance, Wisconsin's RPS identifies 26 eligible technologies.[359] Furthermore, RPSs are sufficiently flexible to enable states to revise their RPSs to add new technologies as they are developed.[360] As discussed previously, RPSs also often include carve outs or multipliers to target specific resources for development.[361]

This ability of RPSs to encompass multiple technologies will be critical when applied to NETs. Of the eight identified categories of NETs, the potential of each is limited when implemented at scale.[362] These limits range from costs,[363] to

---

[357] Ottmar Edenhofer, Ramón Pichs-Madruga, & Youba Sokona (eds.), SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION 18 (2012).
[358] Wiser, Barbose, & Holt, *supra* note 187 at 3895.
[359] DSIRE, *Program Overview: Wisconsin*, last updated November 18, 2015, available at http://programs.dsireusa.org/system/program/detail/190.
[360] Leon, *supra* note 231 at 10.
[361] *Supra* at note 264 and accompanying text.
[362] Fuss, *supra* note 38 at 3.
[363] Cost is the most significant barrier to implementation of DAC. UNEP, *supra* note 71 at 64.

land availability,[364] to food security,[365] to biodiversity risks.[366] Because of these limitations, we can anticipate that society will need to rely upon a portfolio of different NETs.[367] Furthermore, scientists project that the suite of anticipated NETs will not be able to remove the required amount of carbon dioxide from the atmosphere. Even if society were to commence implementing NETs immediately, they would fall short of sequestering the carbon necessary to avoid planetary warming of 2°C.[368] Not only will we likely utilize most of the currently-known NETs, we will almost certainly need to identify and implement additional technologies. Thus, the ability of RPSs to include a range of technologies and to incorporate new technologies as they are developed will be critical.

By establishing markets for NETs, RPSs will provide a critical service to their development. As noted previously, RPSs create markets for new technologies.[369] Such markets will be essential for the development of NETs. Specialized, niche markets are especially important to foster innovation. Development of new technologies requires opportunities for the technologies to be tested and improved while being supported by actual markets.[370] Financing of NETs at the scale required will also be critical. Attracting this level of financing will require strong and certain policy and price signals.[371] By creating markets for these technologies, RPSs provide long-term visibility for cash flows and routes to market. Both of these encourage investors and entrepreneurs to engage in these technologies.[372] For at least one technology, DAC, the establishment of markets will be crucial. Because of the high-risk, high-return nature of DAC, business startups are especially involved in developing this method.[373] The establishment of markets for this important technology will help to encourage additional investment.

Cost considerations also support RPSs as appropriate mechanisms for NETs. Partly because of the nascent status of NETs, the range of estimates of their costs remains quite broad. For instance, the NRC divided the costs of NETs into their two components operations: carbon capture and its sequestration. The NRC projected the costs of carbon capture as ranging from \$50 to more than \$1,000 per tCO_2.[374] The costs of sequestration, it estimated, would range from \$6 to hundreds

---

[364] Afforestation and reforestation are available only to the extent of suitable land. McLaren, *supra* note 49 at 20.
[365] Ocean fertilization may impair ocean food resources, NRC, *supra* note 28 at 61; land required to grow BECCS feedstocks may also be needed for food production. McLaren, *supra* note 49 at 17.
[366] *Id*.
[367] Jan C. Minx, et al, *Fast Growing Research on Negative Emissions*, ENVIRON. RES. LETT. 12, 2 (2017).
[368] Psarras, *supra* note 43 at 16. Specifically, scientists project that NETs could remove up to 1,000 $GtCO_2$ by mid-century. However, to avoid a 2°C rise in global mean temperature, we would need to sequester 1,800 $GtCO_2$ by 2050. *Id*.
[369] Leon, *supra* note 231 at 8.
[370] Ishimoto, *supra* note 115 at 12.
[371] Mac Dowell, *supra* note 4 at 244.
[372] McGlashan, NETs, *supra* note 150 at 17.
[373] *Id*. at 13.
[374] NRC *supra* note 28 at 106. Part of this range derives from the method of carbon capture. Capture from an emissions source is dramatically less expensive than from the ambient air.

of dollars per tCO_2.[375] Estimated costs of specific technologies cover similarly broad ranges. For example, projections of the costs of DAC range from below $100 to more than $1,000 per tCO_2.[376] Similarly, the range of projections for mineral carbonation are wide ranging. Part of this results from the different circumstances in which weathering may occur – in the ocean or on land. As a result, its costs range from $100 per tCO_2 to as much as $1,000 per tCO_2 for terrestrial operations.[377] While land management methods will be substantially less expensive, even their costs are difficult to predict. Currently, experts project their costs to range from $20 to $100 per tCO_2.[378]

These wide cost ranges suggest two considerations, both of which support utilization of RPSs. First, in view of the wide possible range of costs of NETs overall and seemingly of each technology in particular, utilizing mechanisms that will drive innovation and lower costs will be critical. With their market-driven approaches, RPSs excel at these objectives.[379] Second, because of the magnitude of carbon which will need to be captured and sequestered, reducing the overall costs of NETs will be essential. The scale of NETs will be substantial. The overall system to capture and bury carbon will likely need to be as extensive as that which extracted it.[380] Thus, the ability to deploy NETs at scale at as low a cost as possible will be critical. Using RPSs to develop these technologies will help to minimize their costs.[381]

Geographical considerations also favor using RPSs to facilitate NETs' development. Some NETs technologies are geographically constrained as to where they can be effectively implemented. BECCS is an example of a technology that is regionally dependent.[382] Conversely, one of the primary advantages of DAC is that DAC facilities may be placed "virtually anywhere."[383] Because of the RECs system used by RPSs, RECs can facilitate taking advantage of the geographic diversity of NETs. RECs can allow RPS programs to award credits, for instance, to BECCS installations which cannot be located within the RPSs' jurisdictions. Conversely, DAC facilities, which can be sited nearly anywhere, need not be restricted to the territorial boundaries of the jurisdictions awarding credits. This

---

Accordingly, the latter may cost up to ten times more than capture directly from an emissions source. Psarras, *supra* note 43 at 4.

375 NRC *supra* note 28 at 106.

376 Lomax, *supra* note 32 at 498.

377 Psarras, *supra* note 43 at 16.

378 *Id*.

379 EPA, *supra* note 195 at 5-3.

380 NRC *supra* note 28 at 105.

381 Feed-in tariffs (FITs) are another policy mechanism used successfully to incentivize renewable energy. U.S. Energy Information Administration, *Feed-in tariff: A Policy Tool Encouraging Deployment Of Renewable Electricity Technologies* (May 30, 2013), available at https://www.eia.gov/todayinenergy/detail.php?id=11471. FITs mandate that utilities purchase electricity from producers of renewable energy at premium prices. Lincoln L. Davies & Kirsten Allen, *Feed-in Tariffs in Turmoil*, 116 W. VA. L. REV. 937, 938 (2014). While a comparison of these two policies is beyond the scope of this article, it is worth noting that recently Germany, Spain, and South Korea abandoned their FITs because of the high costs of the resulting electricity. *Id*. at 1000.

382 Psarras, *supra* note 43 at 5.

383 *Id*. at 9.

may free them up to be sited in locations with cheaper land, better access to roads, abundant renewable energy sources, or other favorable conditions.

Another aspect of RPSs that will fit well with NETs is their established accounting systems. The removal of carbon dioxide by NETs will present significant issues of tracking and accounting.[384] These issues will arise from the unique nature of NETs operations as well as the breadth of their markets. Capturing and sequestering greenhouse gases is more complicated than other forms of environmental accounting, such as tracking emissions.[385] Furthermore, consistent accounting rules have not been established for NETs processes.[386] Complicating this recordkeeping will be the novel ecosystems, soils, and biomass involved in NETs.[387] Finally, NETs likely will involve multi-jurisdictional transactions necessitating independent measurement, reporting, and verification of activities.[388]

While these will be novel issues for RPSs to address, they benefit by having already-established tracking systems for RECs transactions.[389] RPS states typically require annual reports of RECs transactions demonstrating compliance with RPS obligations.[390] To facilitate the development of robust RECs markets, many states participate in regional tracking systems. These regional systems are sufficiently compatible to enable future interconnection and expansion.[391]

If a favorable environment is provided for NETs, experts anticipate that they can achieve significant growth. BECCS, for instance, has the technological potential to contribute significantly to carbon removal as soon as 2030.[392] DAC, for its part, has been projected to have the potential to develop into a major industry. This would require, however, a maturing of the technology and a dropping in prices.[393] For example, analysts expect that increasing the number of CCS plants will create a virtuous cycle. Construction of new plants will lower their costs, which will facilitate building of more facilities.[394] Similarly, projections for DAC technologies anticipate that their costs will fall to \$200 per ton of CO_2; that cost may be further cut in half in a medium-term timeframe.[395] Other technologies will likely require at least two decades before they can increase to scale.[396] RPSs, of course, have established track records of fostering both increased investment and reduced costs over multiple decades.[397]

---

[384] Lomax, *supra* note 32 at 499.
[385] *Id*. Among other complications, carbon dioxide removal can vary by time and external factors, emissions may result from direct and indirect land use changes, and, since carbon is not completely separated from the natural carbon cycle (it is buried in some manner), the permanence of sequestration is uncertain. *Id*. at 499-500.
[386] Fuss, *supra* note 38 at 7.
[387] Lomax, *supra* note 32 at 499.
[388] Peters & Geden, *supra* note 23 at 3.
[389] Arroyo, *supra* note 240 at 399.
[390] EPA, *supra* note 195 at 5-11.
[391] Leon, *supra* note 231 at 6.
[392] McGlashan, et al, *supra* note 92 at 508.
[393] Field & Mach, *supra* note 30 at 707.
[394] Bourzac, *supra* note 117 at S67.
[395] *Id*. at S68.
[396] McGlashan, et al, *supra* note 92 at 508.
[397] *Supra* at note 197 and accompanying text.

This will be critical because of a significant difference between renewable energy and NETs. Renewable energy not only produces a valuable product, electricity, it also provides a number of additional benefits. Besides electricity generation, renewable energy reduces the amount of greenhouse gases in the atmosphere,[398] stabilizes and reduces energy costs,[399] improves the resiliency of the energy grid,[400] fosters energy independence,[401] creates jobs,[402] and improves health by reducing pollution.[403]

Conversely, few NETs produce valuable services in addition to carbon sequestration. BECCS generates electricity.[404] Conceivably, CCS systems produce a salable product – the captured carbon dioxide. Carbon capture and utilization (CCU) systems apply the captured CO_2 to a number of processes, including enhanced oil recovery, mineral carbonation, food and beverage carbonation, polymer processing, microalgae production, and enhanced coal bed methane recovery.[405] Nevertheless, at least one analysis concludes that CCU is unlikely to make CCS commercially profitable.[406] Biochar can generate energy or enrich agricultural lands.[407] Finally, ocean liming could use spent lime sorbent from solid looping CCS processes, thereby using material from a process that generates a primary product (power and possibly heat), and thus possibly facilitating liming's early deployment.[408]

Since few NETs confer any additional benefits besides CO_2 removal, encouraging their adoption may be more difficult than promoting renewable energy was. To overcome this obstacle, adoption of NETs will need to be incentivized, and utilization of an approach such as an RPS becomes more critical. Incorporating NETs into RPSs, however, will require states to address several considerations. First, states will need to identify the parties required to consider or comply with a NETs requirement. Initially, states could simply add NETs to the technologies available to utilities for RPS compliance. While every NETs – with the exception of BECCS – does not provide electricity, to the extent the RPS seeks to mitigate

---

398 Edenhofer, Pichs-Madruga, & Sokona, *supra* note 357 at 18.

399 Lazard, LAZARD'S LEVELIZED COST OF ENERGY ANALYSIS – VERSION 11.0 5 (2017) (illustrating that several renewable energy sources provide cheaper electricity in a narrower price range than do conventional energy sources).

400 David J. Unger, *Are Renewables Stormproof? Hurricane Sandy Tests Solar, Wind*, THE CHRISTIAN SCIENCE MONITOR (November 19, 2012), available at https://www.csmonitor.com/layout/set/print/Environment/Energy-Voices/2012/1119/Are-renewables-stormproof-Hurricane-Sandy-tests-solar-wind..

401 Rebecca Harrington, *There's Only One Way for the US to Reach Energy Independence*, BUSINESS INSIDER (Jul. 15, 2017), available at http://www.businessinsider.com/how-can-america-be-energy-independent-adopt-renewables-2017-7.

402 Union of Concerned Scientists, CLEAN POWER GREEN JOBS 1 (2009) (finding that renewable energy creates three times as many jobs as producing an equivalent amount of electricity from fossil fuels).

403 Edenhofer, Pichs-Madruga, & Sokona, *supra* note 357 at 20.

404 McGlashan, et al, *supra* note 92 at 504.

405 Jennifer Wilcox, Peter C Psarras & Simona Liguori, *Assessment of Reasonable Opportunities for Direct Air Capture*, ENVIRON. RES. LETT. 12, 2 (2017).

406 Mac Dowell, *supra* note 4 at 247.

407 Workman, et al, *supra* note 50 at 2881.

408 *Id*.

carbon emissions, NETs provide comparable substitutes for renewable energy.[409] Furthermore, RPSs already apply to utilities, so limiting application to them may minimize resistance.

Next, states will need to phase in the NETs requirement. A phase in will be both necessary and helpful. It will be necessary because, as discussed previously, most NETs currently are not ready for implementation.[410] Extended implementation will also allow jurisdictions to modify their accounting systems to measure and track the capturing and burying of carbon dioxide. Jurisdictions will need to develop methods to measure the carbon captured, the amount successfully sequestered, the permanence of sequestration, and provide comparable measurements across different environments and technologies.[411]

Phasing in implementation will also enable states to expand coverage of RPSs to sectors beyond energy. Currently, RPS mandates apply only to parties involved in the provision of electricity – utilities and retail suppliers.[412] For NETs to yield truly negative emissions, however, they must also compensate for the emissions from additional sectors. For instance, current estimates project that, even though emissions in the U.S. electricity sector will decline over the next decade, emissions will continue to rise in the industrial and agricultural sectors.[413]

Despite the significance of emissions from other sectors, current efforts to reduce emissions do little to address them. For instance, California has one of the most extensive regulatory systems to address climate change. Nevertheless, its RPS covers only investor-owned utilities and municipal utilities.[414] The Golden State also has the fourth largest cap-and-trade program in the world. Nevertheless, it covers only large electric power plants, large industrial plants, and fuel distributors.[415]

Thus, states need to extend their RPSs' coverage to include non-electricity sectors. The inclusion of these new sectors will require a phased-in transition. China currently is planning to institute such a program. In 2018, China is initiating an emissions trading system, which will utilize a phase-in process. After developing rules for the system and testing it through simulated trading, China will then require compliance by its electricity sector. In a final phase targeted to being by 2020, China will extend its trading program to non-ferrous metal and cement

---

[409] Honegger & Reiner, *supra* note 109 at 2.

[410] Keller, *supra* note 29 at 4.

[411] Center for Carbon Removal, *supra* note 165 at 8. *See also* Feifei Shen, *China's Prep for Carbon-Market Trading May Take Up to Two Years*, BLOOMBERG BNA ENVIRONMENT & ENERGY REPORT (Dec. 21, 2017) (noting that China may spend up to two years preparing data reporting and other systems before starting trading in its new carbon market). China's program is discussed *infra*.

[412] DSIRE, PROGRAMS, last visited January 25, 2018, available at http://programs.dsireusa.org/system/program?type=38& (linking summaries of each state's RPS program).

[413] Kate Larsen, et al, TAKING STOCK 2017: ADJUSTING EXPECTATIONS FOR US GHG EMISSIONS 4-5 (2017).

[414] DSIRE, PROGRAM OVERVIEW: CALIFORNIA, last updated April 19, 2017, available at http://programs.dsireusa.org/system/program/detail/840.

[415] Center for Climate and Energy Solutions, *California Cap and Trade*, available at https://www.c2es.org/content/california-cap-and-trade/.

sectors.[416]

States should not only include NETs in their RPSs, they should similarly phase in implementation and broaden the scope to include non-power sectors. A phased-in implementation can serve several purposes. First, as with China's cap-and-trade program, it can provide needed time to develop and test procedures and measurements for the inclusion of new technologies.[417] Second, it will allow previously-uncovered industries time to adjust to the new regulations. Finally, by rolling NETs into current RPSs, the initial investments will come from the power sector, which is already well experienced with RPS mandates. Then, as NETs become more abundant and their costs drop,[418] they may provide a preferable alternative to emissions mitigation in difficult to control sectors.[419]

CONCLUSION

Negative emissions technologies will become essential to avoid the worst consequences of climate change. Unfortunately, these technologies are not sufficiently developed to serve this role. Renewable portfolio standards, which were instrumental in incentivizing the development and installation of renewable energy in the United States, can do the same for NETs.

---

[416] *See* Dean Scott, *China's Trimmed Carbon Trading Will Still Boost Worldwide Action*, BLOOMBERG BNA ENVIRONMENT & ENERGY REPORT (Dec. 21, 2017) (noting that China's carbon trading system will initially cover power generators but subsequently expand to encompass metals, chemicals, and building materials).
[417] *Id*.
[418] *See supra*, notes 256-57 and accompanying text.
[419] Honegger & Reiner, *supra* note 109 at 6.