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## Using Renewable Portfolio Standards to Accelerate Development of Negative Emissions Technologies

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# USING RENEWABLE PORTFOLIO STANDARDS TO ACCELERATE DEVELOPMENT OF NEGATIVE EMISSIONS TECHNOLOGIES

ANTHONY E. CHAVEZ\*

## ABSTRACT

As society continues to emit greenhouse gases, the likelihood of dangerous climate change occurring increases.<sup>1</sup> Indeed, most analyses project that we must utilize negative emission technologies (“NETs”) to avoid dangerous warming.<sup>2</sup> Even the Paris Agreement anticipates the implementation of such carbon dioxide (“CO<sub>2</sub>”) removal technologies.<sup>3</sup> 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.<sup>4</sup> RPSs have an established track record of stimulating investment in renewable energy in the United States and elsewhere.<sup>5</sup> These policies incorporate a number of requirements that jurisdictions can tailor to accommodate local resources, industries, and objectives.<sup>6</sup>

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<sup>1</sup> *WMO Greenhouse Gas Bulletin*, WORLD METEOROLOGICAL ORGANIZATION, Oct. 30, 2017, at 1.

<sup>2</sup> See Guy Lomax et al., *Investing in Negative Emissions*, 5 *NATURE CLIMATE CHANGE* 498 (2015).

<sup>3</sup> Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 13, 2015, in Rep. of the Conference of the Parties of the Twenty-First Session, art. 10, ¶ 4, U.N. Doc FCCC/CP/2015/10/Add.1 (2016) [hereinafter Paris Agreement].

<sup>4</sup> WARREN LEON, *THE STATE OF STATE RENEWABLE PORTFOLIO STANDARDS* iii (2013).

<sup>5</sup> *Id.*

<sup>6</sup> *Id.* at 21.

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, generally, and solar power, specifically.

However, current RPSs are too limited to develop NETs. States need to expand the technologies that satisfy RPS mandates to include NETs, thereby fostering RPS development. 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.

I.	DEVELOPMENT OF NETS IS CRUCIAL . . . . .	2
A.	<i>Dangerous Climate Change Is Becoming Unavoidable</i> . . . . .	3
B.	<i>Staying Below Dangerous Global Temperature Levels Will Require Substantial Utilization of NETs</i> . . . . .	5
C.	<i>NETs Incorporate a Number of Distinct Technologies</i> . . . . .	10
II.	NETS ARE NOT SUFFICIENTLY DEVELOPED . . . . .	17
III.	RPSs CAN STIMULATE THE DEVELOPMENT OF NETS . . . . .	21
A.	<i>RPSs Successfully Promoted Development of Renewable Energy</i> . . . . .	22
B.	<i>Two Prominent RPS Successes—Wind and Solar</i> . . .	38
C.	<i>RPSs Can Facilitate the Development of NETs</i> . . . . .	43
	CONCLUSION . . . . .	51

## I. DEVELOPMENT OF NETS IS CRUCIAL

Scientists project that greenhouse gas emission mitigation is occurring too slowly to avert dangerous climate change.<sup>7</sup> Since CO<sub>2</sub> remains in the atmosphere for centuries, we cannot rely solely upon earth systems to remove it from the atmosphere.<sup>8</sup> Instead, we will need to use

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<sup>7</sup> Chris Mooney, *We only have a 5 percent chance of avoiding 'dangerous' global warming, a study finds*, WASH. POST (July 31, 2017), [https://www.washingtonpost.com/news/energy-environment/wp/2017/07/31/we-only-have-a-5-percent-chance-of-avoiding-dangerous-global-warming-a-study-finds/?utm\\_term=.faafe61370c0](https://www.washingtonpost.com/news/energy-environment/wp/2017/07/31/we-only-have-a-5-percent-chance-of-avoiding-dangerous-global-warming-a-study-finds/?utm_term=.faafe61370c0) [<https://perma.cc/KKV4-SSWV>].

<sup>8</sup> Duncan Clark, *How long do greenhouse gases stay in the air?*, THE GUARDIAN (Jan. 16,

technological means. Scientists recognize that a number of such CO<sub>2</sub> removal technologies may be possible.<sup>9</sup>

A. *Dangerous Climate Change Is Becoming Unavoidable*

Despite approval of the 2015 Paris Agreement, the climate is increasingly likely to exceed the Agreement's targets. Regarding temperature rise, the parties to the Paris Agreement pledged themselves to pursue 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."<sup>10</sup> Second, they also pledged to pursue efforts to limit the temperature increase to 1.5°C.<sup>11</sup> To accomplish these objectives, the parties agreed to "aim to reach global peaking of greenhouse gas emissions as soon as possible."<sup>12</sup>

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 fifteen years of this century, CO<sub>2</sub> emissions grew at an average rate of 2.6 percent.<sup>13</sup> This contrasts with an average rate of growth of 1.72 percent during the previous three decades.<sup>14</sup> Furthermore, for every year-on-year period this century, except for 2008 to 2009, emissions have increased.<sup>15</sup> Continuing these trends, atmospheric CO<sub>2</sub> hit an all-time high in 2017 of 403.3 ppm, increasing at an unprecedented rate.<sup>16</sup>

Policymakers have targeted the 1.5–2.0°C range because scientists consider this to be the threshold of "dangerous" climate change.<sup>17</sup> A rise of 2.0°C is the level at which they anticipate "nonlinear and potentially irreversible disruptions" to the environment may begin.<sup>18</sup> These changes

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2012, 2:00 PM), <https://www.theguardian.com/environment/2012/jan/16/greenhouse-gases-remain-air> [<https://perma.cc/7PUN-TEAW>].

<sup>9</sup> See C. H. Greene et al., *Geoengineering, Marine Microalgae, and Climate Stabilization in the 21st Century*, 5 EARTH'S NATURE 278, 278 (2017).

<sup>10</sup> Paris Agreement, *supra* note 3, at art 2, ¶ 1(a).

<sup>11</sup> *Id.*

<sup>12</sup> *Id.* at art. 4, ¶ 1.

<sup>13</sup> Niall MacDowell et al., *The Role of CO<sub>2</sub> Capture and Utilization in Mitigating Climate Change*, 7 NATURE CLIMATE CHANGE 243, 243 (2017).

<sup>14</sup> *Id.*

<sup>15</sup> *Id.*

<sup>16</sup> WMO *Greenhouse Gas Bulletin*, *supra* note 1, at 8.

<sup>17</sup> Mooney, *supra* note 7.

<sup>18</sup> Greene et al., *supra* note 9, at 278–84.

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.<sup>19</sup> 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.<sup>20</sup>

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.<sup>21</sup> Peak sea levels will rise by one meter.<sup>22</sup> Other changes will include longer heat waves, heavier precipitation, and increasing risk of coral reef bleaching.<sup>23</sup> Scientists also project that restricting warming to a 1.5°C rise will be critical to protecting small island states.<sup>24</sup>

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 concluded that only a five percent chance remains that we can hold warming to 2°C; for 1.5°C, the likelihood is down to one percent.<sup>25</sup> Furthermore, the authors calculate that the likely range of warming will be 2.0 to 4.9°C, with a mean anticipated warming of 3.2°C.<sup>26</sup> Contemporaneously, a separate study concluded that likely committed warming (the warming which would still

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<sup>19</sup> *Id.*

<sup>20</sup> *Id.* at 278–79.

<sup>21</sup> P. D. A. Kraaijenbrink et al., *Impact of a Global Temperature Rise of 1.5 Degrees Celsius on Asia's Glaciers*, 549 NATURE 257, 257–58 (2017).

<sup>22</sup> Greene et al., *supra* note 9, at 278–79.

<sup>23</sup> Carl-Friedrich Schleussner et al., *Differential climate impacts for policy-relevant limits to global warming: the case of 1.5°C and 2°C*, 7 EARTH SYS. DYNAMICS 344, 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*, 6 NATURE CLIMATE CHANGE 735, 735–36 (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. *Global Warming of 1.5 °C*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, <http://www.ipcc.ch/report/sr15> [<https://perma.cc/G9S2-DVNJ>] (last visited Nov. 17, 2018).

<sup>24</sup> Laurie Goering, *Carbon-sucking technology needed by 2030s, scientists warn*, REUTERS (Oct. 10, 2017), <https://www.reuters.com/article/us-climatechange-geoengineering/carbon-sucking-technology-needed-by-2030s-scientists-warn-idUSKBN1CF2KY> [<https://perma.cc/Z26P-6ZU5>].

<sup>25</sup> Adrian E. Raftery et al., *Less Than 2°C Warming by 2100 Unlikely*, 7 NATURE CLIMATE CHANGE 637, 637–40 (2017).

<sup>26</sup> *Id.* Moreover, even though non-binding commitments made by the parties to the Paris Agreement reduce expected warming below business as usual levels, researchers at MIT project temperatures to a similar rise of 3.1 to 5.2°C by 2100. Burns & Nicholson, *infra* note 126, at 528.

occur if anthropogenic greenhouse gas emissions were to cease immediately)<sup>27</sup> already has reached 1.5°C.<sup>28</sup>

Another form of analysis reaches a similar conclusion. Climate scientists calculate a “carbon budget,” the amount of CO<sub>2</sub> that society can emit with global temperature rise still remaining below a targeted level.<sup>29</sup> Nearly all estimates<sup>30</sup> 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.<sup>31</sup> For instance, one representative calculation suggests that between four and fifteen years remain before the 1.5°C budget will expire; for a 2°C rise, the time remaining ranges from nineteen to thirty-two years.<sup>32</sup>

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

Utilizing technologies that can reverse the increase of CO<sub>2</sub> in the atmosphere will be necessary to avoid a 2°C 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 2°C level.

Because of the level of anticipated warming and its dire consequences, policymakers have begun directing more attention to removing CO<sub>2</sub> after it has already entered the atmosphere. Indeed, in addition to the

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<sup>27</sup> K.C. Armour & G.H. Roe, *Climate Commitment in an Uncertain World*, 38 GEOPHYSICAL RES. LETTERS 1, 1 (2011).

<sup>28</sup> Thorsten Mauritsen & Robert Pincus, *Committed Warming Inferred from Observations*, 7 NATURE CLIMATE CHANGE 652, 652–54 (2017).

<sup>29</sup> *Understanding the IPCC Reports*, WORLD RESOURCES INST., <http://www.wri.org/ipcc-in-fographics> [<https://perma.cc/G8QK-B9UT>] (last visited Nov. 17, 2018).

<sup>30</sup> Recently, Millar et al., calculated that holding warming to less than 1.5°C “is not yet a geophysical impossibility.” Richard J. Millar et al., *Emission Budgets and Pathways Consistent with Limiting Warming to 1.5 °C*, 10 NATURE GEOSCIENCE 741, 741–47 (2017); Ben Sanderson, *1.5°C: Geophysically impossible or not?*, REAL CLIMATE (Oct. 11, 2017), <http://www.realclimate.org/index.php/archives/2017/10/1-5oc-geophysically-impossible-or-not/> [<https://perma.cc/9PWY-397A>].

<sup>31</sup> Robert McSweeney & Rosamund Pearce, *Analysis: Just four years left of the 1.5C carbon budget*, CARBON BRIEF (Apr. 5, 2017), <https://www.carbonbrief.org/analysis-four-years-4-left-one-point-five-carbon-budget> [<https://perma.cc/VP62-QDLM>].

<sup>32</sup> *Id.* The range results from the probability of staying within the targeted level that is applied to the calculation. *Id.* Thus, a higher probability of staying below a given target produces a shorter timeframe before the budget will expire, while a lower likelihood of staying below the target allows a longer timeframe. *Id.*

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.<sup>33</sup> Furthermore, they set a target of balancing carbon emissions and sinks by the second half of this century.<sup>34</sup> 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<sub>2</sub> emissions.<sup>35</sup> Thus, the implication of the Paris Agreement is that countries will need to develop CO<sub>2</sub> removal technologies to accomplish their 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.<sup>36</sup> In their INDCs, no countries have included bioenergy with carbon capture and sequestration (“BECCS”), the technology most ready for implementation,<sup>37</sup> and only a few nations have included carbon capture and storage.<sup>38</sup>

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 carbon from the atmosphere.<sup>39</sup> This will almost certainly necessitate the deployment of NETs.<sup>40</sup> Indeed, most analytical scenarios in which warming stays within 2°C, and nearly all in which it stays below 1.5°C, incorporate NETs.<sup>41</sup> For instance, for its Fifth Assessment Report, the Intergovernmental Panel on Climate Change analyzed nearly 900 scenarios from integrated assessment

<sup>33</sup> Paris Agreement, *supra* note 3, at art. 5, ¶ 1.

<sup>34</sup> Glen P. Peters & Olive Geden, *Catalysing a Political Shift from Low to Negative Carbon*, 7 NATURE CLIMATE CHANGE 619, 619 (2017).

<sup>35</sup> J. Rockström et al., *The World’s Biggest Gamble*, 4 EARTH’S FUTURE 465, 465–70 (2016).

<sup>36</sup> *What is an INDC?*, WORLD RES. INST., <http://www.wri.org/indc-definition> [<https://perma.cc/G55K-N3F4>] (last visited Nov. 17, 2018).

<sup>37</sup> See discussion *infra* Section I.C.

<sup>38</sup> Peters & Geden, *supra* note 34, at 619. As a result, even after the effect of the INDCs is considered, planetary warming is still anticipated to approach between 2.6 and 3.1°C. Rob Bellamy, *Incentivize Negative Emissions Responsibly*, 3 NATURE ENERGY 532, 532–34 (2018).

<sup>39</sup> NATIONAL RESEARCH COUNCIL (NRC), CLIMATE INTERVENTION: CARBON DIOXIDE REMOVAL AND RELIABLE SEQUESTRATION 110–11 (2015).

<sup>40</sup> *Id.*

<sup>41</sup> David P. Keller et al., *The Carbon Dioxide Removal Model Intercomparison Project (CDR-MIP): Rationale and Experimental Design*, 11 GEOSCIENTIFIC MODEL DEV. 1133, 1133–34 (2018). As discussed later in this Section, even these scenarios anticipate that global temperatures will actually exceed, or overshoot, these targets before returning to the 2.0°C or 1.5°C levels. *Id.*

models.<sup>42</sup> One hundred sixty-six of the scenarios had a 66 percent chance or better that warming would stay below 2°C by the year 2100. Of these, 101 included some form of NETs.<sup>43</sup> Typically, they included NETs on a “massive” scale.<sup>44</sup> 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.<sup>45</sup> They found that this goal cannot be achieved through plausible and cost-effective mitigation efforts.<sup>46</sup> It requires NETs.<sup>47</sup> 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. CO<sub>2</sub> has a long atmospheric life. Once emissions cease, natural systems will remove greenhouse gases from the atmosphere, but CO<sub>2</sub> will remain at an elevated level for centuries or even a millennia.<sup>48</sup> 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.<sup>49</sup> Thus, actual removal of anthropogenic CO<sub>2</sub> will be essential to reverse climate change and its consequences “on timescales relevant to human civilization.”<sup>50</sup>

In reality, most projections conclude that the global temperature will exceed the 2°C target, and we will need to remove CO<sub>2</sub> from the atmosphere to return it to the targeted level.<sup>51</sup> In these scenarios, warming

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<sup>42</sup> Christopher B. Field & Katharine J. Mach, *Rightsizing Carbon Dioxide Removal*, 356 SCIENCE 706, 707 (2017). Integrated assessment models (“IAMs”) 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*, THE HARVARD PROJECT ON CLIMATE AGREEMENTS, Mar. 2015, at 5. 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*, OXFORD BIBLIOGRAPHIES ONLINE (Oct. 11, 2018), <http://www.oxfordbibliographies.com/view/document/obo-9780199363445/obo-9780199363445-0043.xml> [<https://perma.cc/KSM9-TYRM>].

<sup>43</sup> Field & Mach, *supra* note 42, at 707.

<sup>44</sup> Lomax et al., *supra* note 2.

<sup>45</sup> Edward A. Parson, *Climate Policymakers and Assessments Must Get Serious About Climate Engineering*, 114 PROC. NAT’L ACAD. SCI. U.S. 9227, 9228 (2017).

<sup>46</sup> *Id.*

<sup>47</sup> *Id.*

<sup>48</sup> Mauritsen & Pincus, *supra* note 28, at 652.

<sup>49</sup> Katarzyna B. Tokarska & Kirsten Zickfeld, *The effectiveness of net negative carbon dioxide emissions in reversing anthropogenic climate change*, 10 ENVIRON. RES. LETT. 1 (2015).

<sup>50</sup> *Id.* at 2.

<sup>51</sup> *Id.* at 1.



for at least some period of time exceeds the targeted level.<sup>52</sup> By 2100, however, after using CO<sub>2</sub> removal, the temperature returns to the targeted level; scientists call these “overshoot” scenarios.<sup>53</sup> Some scenarios indicate that temperatures can still be held under 2°C without overshoot.<sup>54</sup> All 1.5°C scenarios contemplate at least a temporary overshoot.<sup>55</sup> Overshoot scenarios require CO<sub>2</sub> removal to reverse such a rise in CO<sub>2</sub>.<sup>56</sup> In fact, these efforts can help compensate for as much of an overshoot as 0.5°C.<sup>57</sup>

NETs consist of “anthropogenic activities that deliberately extract CO<sub>2</sub> from the atmosphere.”<sup>58</sup> Typically, NETs and CO<sub>2</sub> removal<sup>59</sup> (“CDR”) are used interchangeably,<sup>60</sup> as they will be here. These technologies remove CO<sub>2</sub> from the atmosphere via sequestration.<sup>61</sup> Broadly speaking, NETs fall into two categories. First, some approaches increase the natural removal of CO<sub>2</sub> by amplifying these processes.<sup>62</sup> Second, some methods utilize mechanical means to capture CO<sub>2</sub> from the atmosphere, concentrate it, and sequester it underground by injecting it under high pressure.<sup>63</sup>

<sup>52</sup> *Id.* at 2.

<sup>53</sup> Joeri Rogelj et al., *Energy System Transformations for Limiting End-of-Century Warming to Below 1.5 °C*, 5 NATURE CLIMATE CHANGE 519, 520 (2015).

<sup>54</sup> S. Fuss et al., *Research Priorities for Negative Emissions*, 11 ENVTL. RES. LETTERS 4 (2016).

<sup>55</sup> *Id.* at 2.

<sup>56</sup> *Id.*

<sup>57</sup> *Id.* at 4. Even if temperatures are brought back to below the target, some of the consequences of the overshoot will continue. *Id.* For instance, sea levels will continue to rise for several centuries. Tokarska & Zickfeld, *supra* note 49, at 9. Furthermore, as NETs remove CO<sub>2</sub> from the atmosphere, oceanic and terrestrial sinks will eventually reverse and actually release CO<sub>2</sub>, thereby increasing the amount of carbon dioxide removal necessary to overcome this outgassing. Keller et al., *supra* note 41, at 1337.

<sup>58</sup> Fuss et al., *supra* note 54, at 1.

<sup>59</sup> *Geoengineering*, HARVARD'S SOLAR GEOENGINEERING RESEARCH PROGRAM, <https://geoengineering.environment.harvard.edu/geoengineering> [<https://perma.cc/GN68-XSVA>] (last visited Nov. 17, 2018) (explaining that carbon dioxide removal (“CDR”) 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”). See NRC, *supra* note 39, at 20 (explaining that since CDR reduces the amount of CO<sub>2</sub> in the atmosphere, it is more akin to mitigation than to SRM); see also *Geoengineering*, *supra* (explaining that CDR thus seeks to “address the root cause of climate change”); NRC, *supra* note 39, at 20 (noting that SRM attempts to provide symptomatic relief from only some of the consequences of anthropogenic CO<sub>2</sub>); Fuss et al., *supra* note 54, at 4 (noting that besides methodology and effect, substantial differences also abound concerning, among others, the nature of their associated risks, costs to implement, governance, and research needs).

<sup>60</sup> Peter Psarras et al., *Slicing the Pie: How Big Could Carbon Dioxide Removal Be?*, 6 WIRES ENERGY & ENV'T 1, 1 (2017).

<sup>61</sup> NRC, *supra* note 39, at 33.

<sup>62</sup> *Id.*

<sup>63</sup> *Id.*

NETs can serve several useful functions. Crucially, they “decouple emissions and emissions control in space and time.”<sup>64</sup> Decoupling in space refers to their ability to compensate for CO<sub>2</sub> emissions from sectors where they are difficult or expensive to reduce.<sup>65</sup> Such “recalcitrant” emissions include those from the agricultural sector generated by livestock.<sup>66</sup> Another source is the transportation sector, especially the aviation and marine subsectors.<sup>67</sup> Other difficult to capture emissions derive from cement production<sup>68</sup> and residential heating and cooling.<sup>69</sup> The ability to compensate for emissions from these sectors will be critical, since they account for a significant portion of global emissions.<sup>70</sup>

NETs decouple emissions in time by providing a means to address previously released emissions.<sup>71</sup> This buys time to develop and install clean energy technologies and to replace locked-in emissions sources.<sup>72</sup> 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,<sup>73</sup> which would be more

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<sup>64</sup> Elmar Kriegler et al., *Is Atmospheric Carbon Dioxide Removal a Game Changer for Climate Change Mitigation?*, 118 CLIMATE CHANGE 45, 46 (2013).

<sup>65</sup> Lomax et al., *supra* note 2, at 498.

<sup>66</sup> Duncan McLaren, *Negatons—An Initial Assessment of the Potential for Negative Emission Techniques to Contribute Safely and Fairly to Meeting Carbon Budgets in the 21st Century*, 1 FRIENDS OF THE EARTH 1, 8 (2011). See also Eloise Gibson, *Cutting Down on Cow Burps to Ease Climate Change*, BLOOMBERG BNA ENV'T & ENERGY REP. (Nov. 27, 2017), <https://www.bloomberg.com/news/articles/2017-11-29/cutting-down-on-cow-burps-to-ease-climate-change> [<https://perma.cc/59J2-2QAN>] (explaining that the share of global warming directly caused by livestock is approximately 25 percent).

<sup>67</sup> Mark Workman et al., *An Assessment of Options for CO<sub>2</sub> Removal from the Atmosphere*, 4 ENERGY PROCEDIA 2877, 2877 (2011).

<sup>68</sup> *Id.*

<sup>69</sup> Adriana Marcucci, Socrates Kypreos & Evangelos Panos, *The Road to Achieving the Long-Term Paris Targets: Energy Transition and the Role of Direct Air Capture*, 144 CLIMATE CHANGE 181, 182 (2017).

<sup>70</sup> *Global Manmade Greenhouse Gas Emissions by Sector*, CENTER FOR CLIMATE CHANGE AND ENERGY SOLUTIONS, <https://www.c2es.org/content/international-emissions/> [<https://perma.cc/Q6WT-3D77>] (last visited Nov. 17, 2018). For instance, the entire agriculture sector accounted for 11 percent of global greenhouse gas emissions in 2013, while the entire transportation sector emitted 15 percent.

<sup>71</sup> Lomax et al., *supra* note 2, at 498.

<sup>72</sup> *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*, 10 ENVIRON. RES. LETTER 1 (2015).

<sup>73</sup> Kriegler et al., *supra* note 64, at 54.

expensive to control.<sup>74</sup> Energy modeling studies consistently find that limiting warming to 2°C without NETs will be two to three times more expensive than if they are utilized.<sup>75</sup> Thus, NETs will play a critical role in providing a future least-cost energy system.<sup>76</sup> Decoupling in time also enables society to compensate for excessive previous emissions that might cause overshoot.<sup>77</sup> NETs can help to remediate historic emissions, too.<sup>78</sup>

### C. *NETs Incorporate a Number of Distinct Technologies*

NET 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<sub>2</sub>.<sup>79</sup> Another grouping organizes the methods into land based, air capture, and sinks enhancement.<sup>80</sup> Perhaps the most telling division organizes the methods as mature ecosystem-based, less mature biomass-based, and immature nonbiological.<sup>81</sup>

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

*Enhanced weathering*—this method spreads minerals that naturally absorb CO<sub>2</sub> to accelerate the absorption process.<sup>82</sup> Normally, CO<sub>2</sub> released into the atmosphere turns into carbonate ions which dissolve in the oceans.<sup>83</sup> Eventually, the carbonate settles on the ocean floor.<sup>84</sup> The natural weathering process will remove atmospheric carbon, but it will require 100,000 years to return the climate to its pre-industrial level.<sup>85</sup>

<sup>74</sup> Pete Smith, *Biophysical and Economic Limits to Negative CO<sub>2</sub> Emissions*, 6 NATURE CLIMATE CHANGE 42–50 (2016).

<sup>75</sup> Myles Allen et al., *Certificates for CCS at Reduced Public Cost: Securing the UK's Energy and Climate Future, Energy Bill 2015* (SCCS Working Paper No. 2015-04).

<sup>76</sup> MacDowell et al., *supra* note 13.

<sup>77</sup> Lomax et al., *supra* note 2, at 498.

<sup>78</sup> Charles-Francois de Lannoy et al., *Indirect ocean capture of atmospheric CO<sub>2</sub>: Part I. Prototype of a negative emissions technology*, 70 INT'L J. OF GREENHOUSE GAS CONTROL 243, 243 (2018).

<sup>79</sup> NRC, *supra* note 39, at 33.

<sup>80</sup> Tokarska & Zickfeld, *supra* note 49, at 2.

<sup>81</sup> Field & Mach, *supra* note 42, at 706.

<sup>82</sup> Fuss et al., *supra* note 54, at 3.

<sup>83</sup> NRC, *supra* note 39, at 47.

<sup>84</sup> *Id.*

<sup>85</sup> Jeremy Deaton, *Earth's "Weathering Thermostat" Keeps Climate in Check Over Very*

Accordingly, this method seeks to accelerate the weathering reaction by increasing the rate of exposure of CO<sub>2</sub> to the requisite minerals.<sup>86</sup> This might occur in situ among rock formations, in industrial settings, or on the oceans by releasing ground-up minerals.<sup>87</sup>

A limiting factor will be the ratio of minerals required to the amount of CO<sub>2</sub> to be removed. The amount of minerals required will need to exceed the amount of CO<sub>2</sub> to be removed by ratios ranging from 1.3 to 3.6 times.<sup>88</sup> To deploy this method at scale would require 100 billion tons per year to offset current emissions.<sup>89</sup> In contrast, global coal production is approximately 8 billion tons per year.<sup>90</sup> Limitations on the land suitable for use will further restrict this process.<sup>91</sup> Consequently, scientists project that weatherization can remove only 0.7 to 3.7 gigatons (billion tons) of CO<sub>2</sub> (GtCO<sub>2</sub>) per year.<sup>92</sup> For perspective, current anthropogenic emissions approximate 40 GtCO<sub>2</sub> per year.<sup>93</sup> The cost of weatherization will likely range between \$20 and \$40 per tCO<sub>2</sub> removed.<sup>94</sup> This estimate, however, incorporates only the costs of grinding and transportation and not the costs of spreading the ground minerals.<sup>95</sup>

*Afforestation and Reforestation*—afforestation involves the restoration of forests on land without forests for at least fifty years, while reforestation restores forests on lands more recently deforested.<sup>96</sup> The

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*Long Periods of Time*, CLEANTECHNICA (Sept. 18, 2017), <https://cleantechnica.com/2017/09/18/earths-weathering-thermostat-keeps-climate-check-long-periods-time/> [<https://perma.cc/4NZ7-2T8Q>].

<sup>86</sup> NRC, *supra* note 39, at 47.

<sup>87</sup> *Id.* at 46–47.

<sup>88</sup> *Id.* at 41.

<sup>89</sup> *Id.*

<sup>90</sup> *Id.* at 48.

<sup>91</sup> McLaren, *supra* note 66, at 12. Indeed, studies concerning the environmental impact of dispersion at scale are still in their infancy. Psarras et al., *supra* note 60, at 13–14.

<sup>92</sup> U.N. ENVIRONMENTAL PROGRAMME, *The Emissions Gap Report 2017: A UN Environment Synthesis Report* 64 (2017).

<sup>93</sup> European Academies Science Advisory Committee, *Negative emission technologies: What role in meeting Paris Agreement targets?*, 35 EASAC POL'Y REP. 1, 4 (2018) [hereinafter EASAC] (noting that we had emitted more than 200 GtCO<sub>2</sub> in the past five years). *But see* J.C.J. Olivier et al., *Trends in global CO<sub>2</sub> and total greenhouse gas emissions* 4 (PBL Netherlands Environmental Assessment Agency, 2017) (measuring the emissions of CO<sub>2</sub> equivalents, which is a broader, but more meaningful, calculation than just the amount of CO<sub>2</sub> emissions, and asserting that 2016 emissions were nearly 50 GtCO<sub>2</sub>eq).

<sup>94</sup> NRC, *supra* note 39, at 66–67.

<sup>95</sup> McLaren, *supra* note 66, at 12.

<sup>96</sup> U.N. ENVIRONMENTAL PROGRAMME, *supra* note 92, at 60. These processes are necessitated by deforestation, which causes approximately 10 percent of anthropogenic greenhouse gas emissions. NRC, *supra* note 39, at 29.

ability of forestation to remove CO<sub>2</sub> from the atmosphere depends upon a number of factors, including the type and age of the trees,<sup>97</sup> temperature, precipitation, and CO<sub>2</sub> concentration.<sup>98</sup> Scientists project possible sequestration from these activities as ranging from 1.5 to 14 GtCO<sub>2</sub> by 2030.<sup>99</sup> Considerations that limit this approach include the availability of suitable land and sufficient water.<sup>100</sup> Although scientists calculate the costs of these activities to range from as low as \$7.50 per tCO<sub>2</sub> to as high as \$100 per tCO<sub>2</sub>, most estimates do not exceed \$40 per tCO<sub>2</sub>.<sup>101</sup> Because of its comparatively low cost, afforestation can serve as a substitute for, or at least a complement to, other NETs methods or mitigations.<sup>102</sup>

*Agricultural land management practices*—agricultural practices have released terrestrial carbon to the atmosphere.<sup>103</sup> In fact, agricultural practices have released 10 to 12 percent of anthropogenic greenhouse gases.<sup>104</sup> These practices reverse that flow. They either increase soil carbon inputs or reduce soil carbon losses.<sup>105</sup> Methods that increase soil carbon include growing cover crops,<sup>106</sup> leaving crop residues to decay, and applying manure or compost.<sup>107</sup> Soil tends to lose carbon through oxidation, such as when it is plowed.<sup>108</sup> Accordingly, practices that reduce carbon releases include no- or low-till farming.<sup>109</sup> Possible sequestration from agricultural land management practices may be as high as 5.2 GtCO<sub>2</sub>, but food production and other uses may lower this amount.<sup>110</sup> 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<sub>2</sub>.<sup>111</sup>

<sup>97</sup> NRC, *supra* note 39, at 40. In general, net CO<sub>2</sub> removal peaks within 30–40 years, and then it declines to zero as the forest matures.

<sup>98</sup> *Id.*

<sup>99</sup> *Id.*

<sup>100</sup> McLaren, *supra* note 66, at 20.

<sup>101</sup> *Id.*; NRC, *supra* note 39, at 41–42.

<sup>102</sup> Ulrich Kreidenweis et al., *Afforestation to Mitigate Climate Change: Impacts on Food Prices Under Consideration of Albedo Effects*, 11 ENVTL. RES. LETTERS 1, 1 (2016).

<sup>103</sup> NRC, *supra* note 39, at 42–43.

<sup>104</sup> Stefan Frank et al., *Reducing Greenhouse Gas Emissions in Agriculture without Compromising Food Security?*, 12 ENVTL. RES. LETTERS 1, 2 (2017).

<sup>105</sup> U.N. ENVIRONMENTAL PROGRAMME, *supra* note 92, at 61.

<sup>106</sup> NRC, *supra* note 39, at 43, n.2 and accompanying text. Farmers plant these crops (such as bean, lentil, and alfalfa) when they are not using their fields to grow market crops. *Id.* Cover crops increase carbon sequestration. *Id.*

<sup>107</sup> *Id.* at 43.

<sup>108</sup> McLaren, *supra* note 66, at 21.

<sup>109</sup> NRC, *supra* note 39, at 43.

<sup>110</sup> *Id.* at 44.

<sup>111</sup> Psarras et al., *supra* note 60, at 16.

*Biochar*—this involves storing stable biomass in soil. Without using oxygen, pyrolysis combusts biomass at low temperatures to form biochar.<sup>112</sup> Biochar resists decomposition, thereby stabilizing biomass buried in soil.<sup>113</sup> It constitutes a NET because it fixes atmospheric CO<sub>2</sub> in a stable form that can be easily sequestered.<sup>114</sup> Biochar also can provide several benefits, including increasing soil fertility and improving water and nutrient retention.<sup>115</sup> Scientists project that biochar can sequester as much as 1 GtCO<sub>2</sub> by 2030, and possibly up to 9.5 GtCO<sub>2</sub>, by 2100.<sup>116</sup> Costs of biochar range from \$18 to \$166 per tCO<sub>2</sub>.<sup>117</sup>

*Bioenergy with Carbon Capture and Sequestration (“BECCS”)*—this system uses conventional power plants to burn biomass and capture the resulting emissions.<sup>118</sup> The process begins with growing biomass—plants or trees—for fuel; the biomass consumes CO<sub>2</sub> to grow.<sup>119</sup> 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.<sup>120</sup> When used with power or manufacturing plants fitted with carbon capture and storage technology, the system traps the released CO<sub>2</sub> for sequestration.<sup>121</sup> Since bioenergy is in theory carbon neutral and in practice low carbon, the capture and sequestration of the process’s emissions results in net negative emissions.<sup>122</sup>

BECCS benefits from several advantages over other NETs. It “has the greatest technological maturity and [can] be introduced relatively easily into today’s energy system.”<sup>123</sup> Indeed, BECCS could contribute significantly to emissions reductions as soon as 2030.<sup>124</sup> BECCS is scalable, too,<sup>125</sup> though extensive expansion may conflict with other land uses.<sup>126</sup>

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<sup>112</sup> NRC, *supra* note 39, at 45.

<sup>113</sup> U.N. ENVIRONMENTAL PROGRAMME, *supra* note 92, at 62.

<sup>114</sup> Niall McGlashan et al., *High-Level Techno-Economic Assessment of Negative Emissions Technologies*, 90 PROCESS SAFETY & ENVTL. PROTECTION 501, 504 (2012).

<sup>115</sup> U.N. ENVIRONMENTAL PROGRAMME, *supra* note 92, at 62.

<sup>116</sup> McGlashan et al., *supra* note 114, at 503.

<sup>117</sup> U.N. ENVIRONMENTAL PROGRAMME, *supra* note 92, at 62.

<sup>118</sup> McGlashan et al., *supra* note 114, at 503.

<sup>119</sup> *Id.*

<sup>120</sup> NRC, *supra* note 39, at 63.

<sup>121</sup> McGlashan et al., *supra* note 114, at 503–04.

<sup>122</sup> McLaren, *supra* note 66, at 17.

<sup>123</sup> McGlashan et al., *supra* note 114, at 505.

<sup>124</sup> *Id.* at 508.

<sup>125</sup> McLaren, *supra* note 66, at 17.

<sup>126</sup> Wil Burns & Simon Nicholson, *Bioenergy and carbon capture with storage (BECCS)*:

Integrated assessment models estimate that it can satisfy from 15 to 45 percent of global energy needs.<sup>127</sup> At these levels, BECCS sequester between 2 and 18 GtCO<sub>2</sub> per year.<sup>128</sup> While significant, society is already adding about 40 GtCO<sub>2</sub> to the atmosphere every year.<sup>129</sup> A critical advantage of BECCS is that, in addition to the value of its negative emissions, it also produces a salable product, electricity.<sup>130</sup> Finally, most studies project BECCS to cost \$50 to \$100 per tCO<sub>2</sub>.<sup>131</sup>

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.<sup>132</sup> It would likely compete with other land uses, such as food and fiber production, forestry, and biodiversity protection.<sup>133</sup> Using the 500 million hectares as a benchmark, BECCS would require fifty times the amount of land dedicated to United States bioethanol production, 50 percent of global fertilizer production, and more than double current global water withdrawals for irrigation.<sup>134</sup> These impacts would serve as an effective cap on the extent of BECCS use, necessitating that society use BECCS in conjunction with other NETs.<sup>135</sup>

*Direct Air Capture with Carbon Capture and Sequestration* (“DACCS”)—this method collects CO<sub>2</sub> from the ambient air, processes it, and then buries it.<sup>136</sup> It uses a chemical or physical scrubbing process to separate CO<sub>2</sub> from the ambient air. Similar processes operate in submarines and the International Space Station.<sup>137</sup> DACCS systems generate a

*the prospects and challenges of an emerging climate policy response*, 7 J. ENVTL. STUD. & SCI. 527, 529 (2017).

<sup>127</sup> U.N. ENVIRONMENTAL PROGRAMME, *supra* note 92, at 62, n.13 and accompanying text.

<sup>128</sup> *Id.* at 62. See also Krieglner et al., *supra* note 64, at 55 (projecting BECCS deployment limited to a removal of 14–15 GtCO<sub>2</sub> per year).

<sup>129</sup> EASAC, *supra* note 93, at 4.

<sup>130</sup> McGlashan et al., *supra* note 114, at 504.

<sup>131</sup> Matthias Honegger & David Reiner, *The Political Economy of Negative Emissions Technologies: Consequences for International Policy Design*, 18 CLIMATE POL'Y 306, 308–09 (2017).

<sup>132</sup> NRC, *supra* note 39, at 54.

<sup>133</sup> *Id.*

<sup>134</sup> *Id.* 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.

<sup>135</sup> *Id.*; Krieglner et al., *supra* note 64, at 55. As BECCS nears its upper environmental limit of approximately 12 GtCO<sub>2</sub> per year, the limitations on biomass production increase the costs of BECCS abruptly, likely making other NETs more cost competitive. NRC, *supra* note 39, at 54.

<sup>136</sup> Fuss et al., *supra* note 54, at 3.

<sup>137</sup> Yuki Ishimoto et al., *Putting Costs of Direct Air Capture in Context* 4 (Inst. of Applied Energy, Working Paper No. 002, June 30, 2017).

stream of CO<sub>2</sub>, which then is available for manufacturing processes or sequestration.<sup>138</sup> Businesses can use CO<sub>2</sub> to make synthetic gas, liquid fuels, and other chemicals to stimulate the growth of plants in greenhouses.<sup>139</sup>

The sequestration process is similar to that used with power plants. Since CO<sub>2</sub> is 100 to 300 times more concentrated in natural gas or coal-fired power plants, direct air capture (“DAC”) systems require two to ten times more energy to capture CO<sub>2</sub> than do power plants using carbon capture and sequestration (“CCS”).<sup>140</sup> Consequently, renewable energy sources need to power DAC systems to ensure that they produce truly net negative emissions.<sup>141</sup> This may limit the siting of DAC systems to locations with access to sufficient wind, solar, geothermal, or hydro-power.<sup>142</sup> They also require geographic formations which support sequestration of carbon.<sup>143</sup> Conversely, since they pull CO<sub>2</sub> directly out of the air, DAC systems have few other constraints on their siting.<sup>144</sup> Indeed, when compared to BECCS, they impose smaller burdens on productive lands and likely will have lower impacts on ecosystems.<sup>145</sup> Because of DACCS’s ability to capture and sequester large amounts of CO<sub>2</sub> with few siting or land use concerns, some scientists have concluded that limiting warming to 1.5°C is possible only with DACCS.<sup>146</sup>

Although DACCS technology is well established, questions remain concerning its scalability and its cost.<sup>147</sup> Cost remains its greatest barrier.<sup>148</sup> Current projections range from \$400 per tCO<sub>2</sub> captured to as high as \$1,000 per tCO<sub>2</sub>.<sup>149</sup> By contrast, the cost of BECCS should not exceed \$100 per tCO<sub>2</sub>.<sup>150</sup> Concerning scalability, fewer than twenty large-scale projects

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<sup>138</sup> NRC, *supra* note 39, at 67.

<sup>139</sup> Katherine Bourzac, *We Have the Technology*, NATURE, Oct. 12, 2017, at S66, S68.

<sup>140</sup> NRC, *supra* note 39, at 68.

<sup>141</sup> U.N. ENVIRONMENTAL PROGRAMME, *supra* note 92, at 63–64.

<sup>142</sup> Psarras et al., *supra* note 60, at 8. On the other hand, reliance upon renewable energy sources, particularly wind and solar photovoltaics, will diminish one of DACCS’s advantages over other NETs, which is its relatively minor land footprint. Smith, *supra* note 74, at 46.

<sup>143</sup> Psarras et al., *supra* note 60, at 8; Smith, *supra* note 74, at 46.

<sup>144</sup> Psarras et al., *supra* note 60, at 9.

<sup>145</sup> Parson, *supra* note 45, at 2.

<sup>146</sup> Marcucci, Kypreos & Panos, *supra* note 69, at 181.

<sup>147</sup> Ishimoto et al., *supra* note 137.

<sup>148</sup> U.N. ENVIRONMENTAL PROGRAMME, *supra* note 92, at 64.

<sup>149</sup> NRC, *supra* note 39, at 69–72. New technologies may be able to reduce these costs sharply. A recent analysis suggests that a DACCS model may be able to sequester CO<sub>2</sub> at a cost between \$94 and \$232 per tCO<sub>2</sub>. *NET Gains*, 3 NATURE ENERGY, July 10, 2018, at 531.

<sup>150</sup> Honegger & Reiner, *supra* note 131, at 308.



currently operate.<sup>151</sup> While they capture 40 million tCO<sub>2</sub>, this represents only a fraction of the billions of tons that will need to be sequestered.<sup>152</sup>

*Ocean alkalinity enhancement*—these methods facilitate the storage of carbon in the ocean by altering the equilibrium between atmospheric CO<sub>2</sub> and inorganic oceanic carbon.<sup>153</sup> 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.<sup>154</sup> The ocean contains forty-five 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.<sup>155</sup> These methods simply accelerate these natural processes. Ocean alkalinity enhancement methods are scalable,<sup>156</sup> with limitations arising mainly from the ability to scale up mining of minerals and construction of ships for transportation.<sup>157</sup> Costs range from \$30 to \$60 per tCO<sub>2</sub>.<sup>158</sup> If operated at the appropriate scale, this method could sequester sufficient carbon to return the atmosphere to its pre-industrial state.<sup>159</sup>

*Ocean fertilization*—this method adds nutrients to the ocean to stimulate phytoplankton growth, which consumes CO<sub>2</sub>, which is then buried with the organisms at the bottom of the ocean after they die.<sup>160</sup> The fertilization process utilizes iron, phosphate, or nitrogen.<sup>161</sup> Scientists project that ocean fertilization can remove up to 3.7 GtCO<sub>2</sub> per year.<sup>162</sup> While early cost estimates were relatively low, \$50 per tCO<sub>2</sub> or lower,<sup>163</sup>

<sup>151</sup> *Id.* at 313.

<sup>152</sup> Bourzac, *supra* note 139, at S66.

<sup>153</sup> U.N. ENVIRONMENTAL PROGRAMME, *supra* note 92, at 64. One unique benefit of this method is that it helps to reverse ocean acidification. *Id.*

<sup>154</sup> *Id.*

<sup>155</sup> Phil Renforth & Gideon Henderson, *Assessing Ocean Alkalinity for Carbon Sequestration*, 55 *REVIEWS OF GEOPHYSICS* 636, 637 (2017).

<sup>156</sup> McLaren, *supra* note 66, at 18.

<sup>157</sup> Renforth & Henderson, *supra* note 155, at 660–61. For instance, extraction and processing of minerals would need to increase at a rate of growth of 12 percent per year over the next 45 to 60 years. *Id.* at 660.

<sup>158</sup> McLaren, *supra* note 66, at 18.

<sup>159</sup> 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*, in *GeoConvention 4* (2010), [https://www.geoconvention.com/archives/2010/1067\\_GC2010\\_Increasing\\_the\\_Alkalinity\\_of\\_the\\_Ocean.pdf](https://www.geoconvention.com/archives/2010/1067_GC2010_Increasing_the_Alkalinity_of_the_Ocean.pdf) [<https://perma.cc/E2D4-R6TP>].

<sup>160</sup> Fuss et al., *supra* note 54, at 3.

<sup>161</sup> McLaren, *supra* note 66, at 19.

<sup>162</sup> NRC, *supra* note 39, at 61.

<sup>163</sup> *Id.*; McLaren, *supra* note 66, at 19.

recent estimates have risen. Concluding that the process might be less efficient than previously anticipated and that some leakage may occur of CO<sub>2</sub> back to the surface, a recent study projects the cost of fertilization to be near \$450 per tCO<sub>2</sub>.<sup>164</sup>

Several concerns complicate use of this method. First, the extensive ocean environment will render problematic the analysis of the relatively minor changes produced by fertilization.<sup>165</sup> Second, continuous fertilization might impair the food web and fisheries.<sup>166</sup> 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.<sup>167</sup> This suggests that efforts to proceed with ocean fertilization may be vigorously opposed.<sup>168</sup>

## 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 CDR technologies. 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,<sup>169</sup> remaining at the level of concepts, prototypes, or pilot projects.<sup>170</sup> Even the most developed CDR technologies have not progressed beyond the early prototyping stages, and these technologies have limited potential capacities.<sup>171</sup> Where technologies are more developed, their deployment—or even their planned deployment—still falls substantially short of the level necessary.<sup>172</sup> For instance, although BECCS is the most advanced of the NETs, only fifteen pilot plants and one commercial plant currently operate.<sup>173</sup> Similarly,

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<sup>164</sup> *Id.*

<sup>165</sup> NRC, *supra* note 39, at 60.

<sup>166</sup> *Id.* at 61.

<sup>167</sup> Tim Dixon et al., *Update on the London Protocol—Developments on Transboundary CCS and on Geoengineering*, 63 ENERGY PROCEDIA 6623, 6627 (2014).

<sup>168</sup> McLaren, *supra* note 66, at 19.

<sup>169</sup> Field & Mach, *supra* note 42, at 706.

<sup>170</sup> Oliver Geden et al., *Integrating Carbon Dioxide Removal into EU Climate Policy: Prospects for a Paradigm Shift*, WIRES CLIMATE CHANGE 1 (2018).

<sup>171</sup> *Id.*

<sup>172</sup> Fuss et al., *supra* note 54, at 4.

<sup>173</sup> Burns & Nicholson, *supra* note 126, at 3. Based upon the build rate of CCS projects required to meet the 2°C goal, the current build rate is nearly 100 times too slow. R. Stuart

implementing biochar at scale would require an increase of over sixty-three times the current charcoal production capacity.<sup>174</sup> Regarding DAC, emissions scenarios anticipate that several thousand will be operating by 2030; planned construction, however, only numbers in the tens.<sup>175</sup> Moreover, parties to the Paris Agreement—an agreement which contemplates deployment of NETs to achieve its targets<sup>176</sup>—display little commitment to developing CDR technologies. The parties' INDCs fail to mention NETs, and only three even recognize carbon capture and sequestration as a priority.<sup>177</sup>

The lack of current commitment to developing NETs 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.<sup>178</sup> Fundamental uncertainties remain concerning their effectiveness. For example, when operated at scale, carbon sequestration's geological viability and permanence of storage are uncertain.<sup>179</sup> Thus, advancing NETs to maturity and widespread deployment will require “many decades.”<sup>180</sup> Nevertheless, progressive deployment would be superior because it would spread the cost over time, minimize future risks, and accelerate technological innovation.<sup>181</sup> 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.”<sup>182</sup>

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

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Haszeldine et al., *Negative Emissions Technologies and Carbon Capture and Storage to Achieve the Paris Agreement Commitments*, 376 PHIL. TRANS. R. SOC. A1, 1 (Oct. 28, 2018).

<sup>174</sup> Niall R. McGlashan et al., *Negative Emissions Technologies*, 8 Grantham Institute for Climate Change Briefing Paper (October 2012), at 15.

<sup>175</sup> Glen P. Peters et al., *Key Indicators to Track Current Progress and Future Ambition of the Paris Agreement*, 121 NATURE CLIMATE CHANGE 1, 4 (2017). The first commercial DACCS plant commenced operations in 2017. EASAC, *supra* note 93, at 9.

<sup>176</sup> Peters & Geden, *supra* note 34, at 619.

<sup>177</sup> Fuss et al., *supra* note 54, at 7.

<sup>178</sup> Keller et al., *supra* note 41, at 1334.

<sup>179</sup> Kriegler et al., *supra* note 64, at 55. Global storage capacity estimates vary widely, and even regional level differences are sufficient to necessitate individual assessments. Naomi E. Vaughan et al., *Evaluating the use of biomass energy with carbon capture and storage in low emission scenarios*, 13 ENVTL. RES. LETTERS 4, 6 (2018).

<sup>180</sup> Lomax et al., *supra* note 2, at 499.

<sup>181</sup> Allen et al., *supra* note 75, at 3.

<sup>182</sup> NRC, *supra* note 39, at 111.

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.<sup>183</sup> Operational liability concerns the environmental, health, and safety risks resulting from CO<sub>2</sub> capture, transport, and injection.<sup>184</sup> Post-injection liability pertains to injuries to human health, the environment, and property.<sup>185</sup> A specific concern regards possible contamination of water used for drinking or agricultural purposes.<sup>186</sup> Another concern stems from the long-term nature of the sequestration involved.<sup>187</sup> 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.<sup>188</sup> Uncertainty concerning liability issues impairs rapid deployment of NETs systems, especially those involving sequestration.<sup>189</sup>

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.<sup>190</sup> Ocean fertilization and ocean alkalization fall within 2013 amendments to the

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<sup>183</sup> Mark de Figueiredo, *The Liability of Carbon Dioxide Storage* (Jan. 12, 2007), [https://sequestration.mit.edu/pdf/Mark\\_de\\_Figueiredo\\_PhD\\_Dissertation.pdf](https://sequestration.mit.edu/pdf/Mark_de_Figueiredo_PhD_Dissertation.pdf) [<https://perma.cc/C6EN-YM7Q>].

<sup>184</sup> *Id.* at 1.

<sup>185</sup> *Id.*

<sup>186</sup> Ian Havercroft & Richard Macrory, *Legal Liability and Carbon Capture and Storage: A Comparative Perspective* 11 (Global Carbon Capture and Storage Institute/UCL Laws 2014), <http://hub.globalccsinstitute.com/sites/default/files/publications/179798/legal-liability-carbon-capture-storage-comparative-perspective.pdf> [<https://perma.cc/NH74-H3XB>].

<sup>187</sup> *Id.* at 36.

<sup>188</sup> *Id.* at 37. See also Wendy B. Jacobs & Debra Stump, *Proposed Liability Framework for Geological Sequestration of Carbon Dioxide* 12 (Emmitt Env'tl. L. & Pol'y Clinic, Working Paper, 2010).

<sup>189</sup> *Id.* at i.

<sup>190</sup> CTR. FOR CARBON REMOVAL, CARBON REMOVAL POLICY: OPPORTUNITIES FOR FEDERAL ACTION 8 (2017), <https://static1.squarespace.com/static/5b9362d89d5abb8c51d474f8/t/5b9427cd8a922dd0d7451136/1536436200923/Carbon%2BRemoval%2BPolicy%2Bopportunities%2Bfor%2BAction+%281%29.pdf> [<https://perma.cc/92YX-UQYN>]. For instance, a possible supply chain for a BECCS system could span several countries and require detailed accounting over a period of decades with provisions for independent measurement, reporting, and verification. Peters & Geden, *supra* note 34, at 620–21. In fact, a recognized knowledge gap for all NETs concerns consistent accounting rules. Fuss et al., *supra* note 54, 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 et al., *supra* note 2, at 500.

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).<sup>191</sup> Besides liability and measurement issues, legal regimes can also provide incentives, or remove barriers, to adopt carbon removal farming practices.<sup>192</sup> Similarly, incentives are needed to support favorable forest management.<sup>193</sup> Finally, carbon dioxide removal efforts could also be facilitated by policies that provide financial encouragement for these practices, such as a carbon tax,<sup>194</sup> carbon trading,<sup>195</sup> tax credits, or other means.<sup>196</sup>

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.<sup>197</sup> 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.<sup>198</sup> The ability of biochar, for example, to stabilize carbon is poorly understood.<sup>199</sup> Most NETs may also run into limitations when implemented at scale.<sup>200</sup> For instance, factors such as low CO<sub>2</sub> uptake during some stages of tree growth and constraints on the availability of land suitable for trees will limit sequestration through afforestation and reforestation.<sup>201</sup> 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.<sup>202</sup> Also, the availability of bio-feedstocks and the land on which to grow them may restrict the implementation of BECCS.<sup>203</sup>

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<sup>191</sup> Renforth & Henderson, *supra* note 155, at 665.

<sup>192</sup> CTR. FOR CARBON REMOVAL, *supra* note 190, at 17.

<sup>193</sup> *Id.* at 22–23.

<sup>194</sup> A carbon tax imposes a fee upon sources for the carbon they emit into the atmosphere. Robinson Meyer, *Republicans Blow Their Chance to Pass a Carbon Tax*, THE ATLANTIC (Dec. 20, 2017), <https://www.theatlantic.com/science/archive/2017/12/republicans-blow-their-chance-to-pass-a-carbon-tax/548891/> [<https://perma.cc/GKV5-3NTG>].

<sup>195</sup> Havercroft & Macrory, *supra* note 186, at 34. Carbon trading involves the purchasing and selling of permits to emit carbon dioxide. *What is carbon trading?*, FERN, <http://old.fern.org/campaign/carbon-trading/what-carbon-trading> [<https://perma.cc/2Z48-YEEF>] (last visited Nov. 17, 2018).

<sup>196</sup> CTR. FOR CARBON REMOVAL, *supra* note 190, at 10–11.

<sup>197</sup> NRC, *supra* note 39, at 110.

<sup>198</sup> Keller et al., *supra* note 41, at 1338.

<sup>199</sup> McGlashan et al., *supra* note 174, at 23.

<sup>200</sup> Fuss et al., *supra* note 54, at 3.

<sup>201</sup> de Lannoy et al., *supra* note 78, at 243–44.

<sup>202</sup> *Id.* at 243.

<sup>203</sup> McLaren, *supra* note 66, at 17. Similar issues may limit the ability to produce biochar at scale. Workman et al., *supra* note 67, at 2881.

Another unknown about NETs is their environmental impact. Different methods raise different concerns. Ocean fertilization may disrupt the ecology of the oceans.<sup>204</sup> Ocean alkalinity enhancement may have localized effects and detrimental impacts on ocean ecosystems.<sup>205</sup> Carbon injection may increase seismicity.<sup>206</sup> Afforestation and reforestation may disrupt hydrological cycles, ecosystems, and biodiversity.<sup>207</sup> Implementation of BECCS at scale may require land needed for food production, consume scarce water resources, and endanger biodiversity.<sup>208</sup> 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.<sup>209</sup>

Other benefits will accrue from an early commitment to NETs. First, some more mature technologies—such as BECCS, biochar, and weatherization—could begin providing CO<sub>2</sub> reductions.<sup>210</sup> Second, until policies are adopted that support the development of NETs, significant investment of resources into them will likely be deferred.<sup>211</sup>

### III. RPS CAN STIMULATE THE DEVELOPMENT OF NETS

RPSs<sup>212</sup> require that electricity providers generate or receive a set amount of their electricity from a predetermined type of source.<sup>213</sup> 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

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<sup>204</sup> NRC, *supra* note 39, at 61.

<sup>205</sup> Renforth & Henderson, *supra* note 155, at 666. Not all effects may be negative; it may also reduce ocean acidification. *Id.*

<sup>206</sup> NRC, *supra* note 39, at 111.

<sup>207</sup> Keller et al., *supra* note 41, at 1337.

<sup>208</sup> Burns & Nicholson, *supra* note 126, at 3.

<sup>209</sup> Smith, *supra* note 74, at 49.

<sup>210</sup> Lomax et al., *supra* note 2, at 500.

<sup>211</sup> *Id.*

<sup>212</sup> 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*, 41 HARV. ENVTL. L. REV. 189, 198 (2017). Other interchangeable names include renewable energy standards and tradable green certificate programs. Ryan Wiser et al., *Supporting Solar Power in Renewables Portfolio Standards: Experience from the United States*, 39 ENERGY POLY 3894, 3894 (2011).

<sup>213</sup> *Id.*

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.<sup>214</sup> 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 must be produced.<sup>215</sup> RPSs are typically neutral among energy sources, though they can include policies to support specific technologies.<sup>216</sup> 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.<sup>217</sup> RPS requirements may be either mandatory or voluntary.<sup>218</sup>

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.<sup>219</sup> Often these requirements increase gradually over time.<sup>220</sup> Typically, they start modestly, increasing over a period ranging from ten to twenty years, and then remaining at that level indefinitely.<sup>221</sup> Second, RPSs specify the electricity sources that will satisfy the mandate.<sup>222</sup> Third, they identify

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<sup>214</sup> *Id.*

<sup>215</sup> 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).

<sup>216</sup> Mormann, *supra* note 212, at 198.

<sup>217</sup> See, e.g., *Clean Energy Portfolio Standard: Indiana*, DSIRE, <http://programs.dsireusa.org/system/program/detail/4832> [<https://perma.cc/PA3F-MATL>] (last updated June 18, 2018) (identifying as eligible technologies coal bed methane and clean coal); *Clean Energy Portfolio Standard: Colorado*, DSIRE, <http://programs.dsireusa.org/system/program/detail/133> [<https://perma.cc/3RCX-Z7EW>] (last updated June 14, 2018) (allowing coal mine methane to satisfy its RPS); *Clean Energy Portfolio Standard: Delaware*, DSIRE, <http://programs.dsireusa.org/system/program/detail/1231> [<https://perma.cc/4JWN-RBQ6>] (last updated July 3, 2018) (recognizing as eligible technologies fuel cells that use non-renewable fuels to produce hydrogen); *Clean Energy Portfolio Standard: Maine*, DSIRE, <http://programs.dsireusa.org/system/program/detail/452> [<https://perma.cc/VBQ8-QDZZ>] (last updated July 12, 2018) (recognizing the same fuel cells as Delaware).

<sup>218</sup> Allen, *supra* note 215, at 120.

<sup>219</sup> *Id.*

<sup>220</sup> See U.S. ENVTL. PROT. AGENCY (EPA), ENERGY AND ENVIRONMENT GUIDE TO ACTION 5-10 (2015).

<sup>221</sup> *Id.*

<sup>222</sup> Allen, *supra* note 215, at 120.

the parties required to comply with the obligation.<sup>223</sup> Fourth, they indicate whether a party can satisfy its obligation through the purchase of renewable energy credits (“RECs”).<sup>224</sup> Fifth, they identify an administrator—usually a government agency—for the program.<sup>225</sup> Lastly, RPSs specify their enforcement mechanisms.<sup>226</sup>

Renewable portfolio standards have lengthy and widespread track records. Iowa became the first state to enact an RPS in 1983.<sup>227</sup> Currently, twenty-nine states plus the District of Columbia utilize RPSs, and these policies directly cover 56 percent of retail electricity sales in the United States.<sup>228</sup> Another eight states have adopted voluntary, non-binding renewable energy goals.<sup>229</sup> 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.<sup>230</sup>

Because of the range of characteristics encompassed by RPSs and the unique aspects of each state, as many different RPS designs exist as do jurisdictions that have enacted these policies.<sup>231</sup> States have tailored their RPS policies to fit each state’s objectives, energy resources potential, and electricity market characteristics.<sup>232</sup> 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 RECs systems.<sup>233</sup> Some of these characteristics—and the manner in which states have tailored them to their particular circumstances—will be reviewed below.

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<sup>223</sup> *Id.*

<sup>224</sup> *Id.*

<sup>225</sup> *Id.*

<sup>226</sup> *Id.*

<sup>227</sup> Magali Delmas & Maria J. Montes-Sancho, *US state policies for renewable energy: context and effectiveness*, 39 ENERGY POL’Y 2273, 2275 (2011).

<sup>228</sup> GALEN BARBOSE, U.S. RENEWABLES PORTFOLIO STANDARDS: 2017 ANNUAL STATUS REPORT 6 (2017).

<sup>229</sup> *State Renewable Portfolio Standards and Goals*, NAT’L CONFERENCE OF STATE LEGISLATURES, <http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx> [https://perma.cc/6RG3-RYUY] (last updated July 20, 2018).

<sup>230</sup> Wisner et al., *supra* note 212, at 3894; Greg Buckman, *The Effectiveness of Renewable Portfolio Standard Banding and Carve-Outs in Supporting High-Cost Types of Renewable Electricity*, 39 ENERGY POL’Y 4105, 4106 (2011).

<sup>231</sup> See GOVERNORS’ WIND ENERGY COALITION, RENEWABLE ELECTRICITY STANDARDS: STATE SUCCESS STORIES 9 (2013).

<sup>232</sup> EPA, *supra* note 220, at 5-2.

<sup>233</sup> BARBOSE, *supra* note 228, at 7.



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.<sup>234</sup> Power generators receive one REC for every megawatt of electricity that they produce.<sup>235</sup> For tracking purposes, RECs contain information about the electricity generator, including its energy source, location, and operation date.<sup>236</sup> At the end of each compliance period, a generator must possess the appropriate number of RECs, whether acquired through generation or purchase.<sup>237</sup> The attributes represented by RECs may include, among others, credit for the renewable energy generated.<sup>238</sup>

RPS provisions may allow RECs to be unbundled—traded separately from their electricity generation.<sup>239</sup> Unbundled RECs can benefit both the purchaser and the seller.<sup>240</sup> The seller benefits because its electricity generation produces a second salable product in addition to the actual electricity.<sup>241</sup> This incentivizes renewable power production.<sup>242</sup> 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).<sup>243</sup>

Unbundling thus can incentivize additional renewable energy generation in two ways. It encourages overproduction, since generators can sell excess credits.<sup>244</sup> This can incentivize renewable energy investment even in the absence of an RPS mandate.<sup>245</sup> This may be especially

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<sup>234</sup> Felix Mormann, Dan Reicher & Victor Hanna, *A Tale of Three Markets: Comparing the Renewable Energy Experiences of California, Texas and Germany*, 35 STAN. ENVTL. L.J. 55, 78 (2016).

<sup>235</sup> *Id.*

<sup>236</sup> EPA, *supra* note 220, at 5-2.

<sup>237</sup> Allen, *supra* note 215, at 124.

<sup>238</sup> EPA, *supra* note 220, at 5-2.

<sup>239</sup> Allen, *supra* note 215, at 125.

<sup>240</sup> *Id.*

<sup>241</sup> *Id.*

<sup>242</sup> *Id.*

<sup>243</sup> EPA, *supra* note 220, at 5-2. RECs not only can allow shifting of procedures and purchasers geographically, they can also shift them temporally. *Id.* 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 215, at 126.

<sup>244</sup> See Miriam Fischlein & Timothy M. Smith, *Revisiting Renewable Portfolio Standard Effectiveness: Policy Design and Outcome Specification Matter*, 46 POL'Y SCI. 277, 288 (2013).

<sup>245</sup> Allen, *supra* note 215, at 125.

important with new technologies, where the costs of production may not be competitive with other methods and market prices do not fully cover costs.<sup>246</sup> Not surprisingly, all but three RPS states permit the unbundling of RECs.<sup>247</sup>

RPSs also require states to develop an accounting infrastructure.<sup>248</sup> Indeed, the primary role of RECs is to track electricity generation from renewable sources and to guarantee that generators claim each credit only once.<sup>249</sup> RECs also ensure that credited electricity complies with other restrictions, such as approved energy source or geographic location of the generator.<sup>250</sup> Because of the integral nature of RECs to RPS compliance, nine regional tracking systems have arisen to support them.<sup>251</sup> States require utilities to demonstrate compliance with RPS requirements by filing annual reports.<sup>252</sup> These reports document utilities' ownership and retirement of RECs, which they received by the state for generation or acquired through the regional markets.<sup>253</sup>

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.<sup>254</sup> A second issue concerns the geographic eligibility of sources. Some states recognize only in-state generation as compliant, some impose 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.<sup>255</sup> Third, RPSs must specify the entities which must comply with its mandate.<sup>256</sup> For

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<sup>246</sup> Buckman, *supra* note 230, at 4107.

<sup>247</sup> Fischlein & Smith, *supra* note 244, at 288.

<sup>248</sup> Chip Gaul & Sanya Carley, *Solar Set Asides and Renewable Electricity Certificates: Early Lessons From North Carolina's Experience with its Renewable Portfolio Standard*, 48 ENERGY POLY 460, 462 (2012).

<sup>249</sup> *Id.*

<sup>250</sup> Fischlein & Smith, *supra* note 244, at 289.

<sup>251</sup> *Id.*

<sup>252</sup> EPA, *supra* note 220, at 5-11.

<sup>253</sup> *Id.*

<sup>254</sup> Allen, *supra* note 215, at 122.

<sup>255</sup> Fischlein & Smith, *supra* note 244, at 291. Often geographic origin requirements serve purposes other than renewable energy promotion, such as assuring receipt of environmental, employment, and financial benefits. *Id.*

<sup>256</sup> Allen, *supra* note 215, at 123.

instance, RPSs uniformly impose obligations on investor-owned utilities, but they apply mandates to publicly owned utilities and retail sellers less often.<sup>257</sup> Finally, RPSs also include enforcement mechanisms to ensure compliance. Typically, these consist of financial penalties.<sup>258</sup> More severe penalties may consist of temporary suspension or permanent revocation of generators' licenses.<sup>259</sup>

While the failure to establish a national RPS has impeded renewable energy development, many benefits have resulted from their state-level development.<sup>260</sup> 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."<sup>261</sup> Indeed, in the federalism system of the United States, states function as "innovation centers."<sup>262</sup> Not only do they experiment with policies, they also "compete" with other states to "develop the most effective and efficient regulatory program."<sup>263</sup> Indeed, the popularity of RPSs suggests to some that this decentralized policymaking engendered a race to the top.<sup>264</sup> Another advantage of state-level experimentation is that it limits risks to the rest of the country.<sup>265</sup> 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.<sup>266</sup> Experimentation also provides the many parties involved in the electricity system experience with issues that arise with increased reliance upon renewable sources,<sup>267</sup> such as development

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<sup>257</sup> See Uma Outka, *Prospects for Public Power and Distributed Renewable Energy*, 45 ENVTL. L. REP. NEWS & ANALYSIS 10537, 10539 (2015); see also *Programs*, DSIRE, <http://programs.dsireusa.org/system/program?type=38&> [<https://perma.cc/4JEP-2TVZ>] (last visited Nov. 17, 2018) (linking summaries of each state's RPS program).

<sup>258</sup> *Id.*

<sup>259</sup> Allen, *supra* note 215, at 127.

<sup>260</sup> Francesca F. Bochner, *Water, Wind, and Fire: A Call for a Federal Renewable Portfolio Standard*, 25 DUKE ENVTL. L. & POL'Y F. 201, 221–22 (2014).

<sup>261</sup> *United States v. Lopez*, 514 U.S. 549, 581 (1995) (Kennedy, J., concurring).

<sup>262</sup> 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).

<sup>263</sup> *Id.* at 1650–51.

<sup>264</sup> Thomas P. Lyon & Haitao Yin, *Why Do States Adopt Renewable Portfolio Standards?: An Empirical Investigation*, 31 THE ENERGY J. 133, 153 (2010); see *infra* notes 284–89 and accompanying text (most states have raised their quotas, with several states now requiring from 50 percent to as much as 100 percent of electricity from renewable energy).

<sup>265</sup> Lyon & Yin, *supra* note 264, at 1650, n.126.

<sup>266</sup> Hoppe, *supra* note 262, at 1646.

<sup>267</sup> LEON, *supra* note 4, at 6.

of new technologies,<sup>268</sup> interconnection to the grid,<sup>269</sup> the “duck curve,”<sup>270</sup> and the financing of projects,<sup>271</sup> among others. Finally, local experimentation rarely risks the environmental consequences that might arise when new technologies are implemented at a global scale.<sup>272</sup>

Because RPSs have “dozens of design elements,”<sup>273</sup> they are very flexible policy tools.<sup>274</sup> 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.<sup>275</sup> This flexibility has allowed states with diverse renewable energy potentials to adopt successful RPSs.<sup>276</sup> Indeed, states have crafted RPS programs that are distinct over the range of criteria incorporated in RPSs.<sup>277</sup> Not surprisingly, no two states have identical RPSs.<sup>278</sup>

The inherent flexibility of RPSs facilitates another of their defining experiences: continual revision and strengthening.<sup>279</sup> For instance, from 2015 to 2017, the legislatures in the twenty-nine states with RPSs passed more than 200 RPS-related bills.<sup>280</sup> RPS flexibility has enabled

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<sup>268</sup> *Renewable Portfolio Standard (RPS)*, HYDROPOWER REFORM COALITION, <http://www.hydroreform.org/policy/rps> [<https://perma.cc/R4TE-6NXW>] (last visited Nov. 17, 2018) (noting that the goal of most RPSs is to encourage the development of new energy sources).

<sup>269</sup> See Debrup Das et al., Note, *Reducing Transmission Investment to Meet Renewable Portfolio Standards Using Smart Wires* 6 (2010), [https://www.smartwires.com/wp-content/uploads/2015/01/Smart\\_Wire\\_4.pdf](https://www.smartwires.com/wp-content/uploads/2015/01/Smart_Wire_4.pdf) [<https://perma.cc/4FYR-VNHA>] (concluding that the adoption of RPSs will necessitate consideration of Smart Grid technologies).

<sup>270</sup> See OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY, *Confronting the Duck Curve: How to Address Over-Generation of Solar Energy* (2017), <https://energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy> [<https://perma.cc/HS3C-ZHPW>] (explaining that 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).

<sup>271</sup> Wiser et al., *supra* note 212, at 3904.

<sup>272</sup> See Matteo Muratori et al., *Global Economic Consequences of Deploying Bioenergy with Carbon Capture and Storage (BECCS)*, 11 ENVTL. RES. LETTERS 2 (2016).

<sup>273</sup> GOVERNORS’ WIND ENERGY COALITION, *supra* note 231, at 9.

<sup>274</sup> Luke J.L. Eastin, *An Assessment of the Effectiveness of Renewable Portfolio Standards in the United States*, 27 THE ELECTRICITY J. 127 (2014).

<sup>275</sup> LEON, *supra* note 4, at 6.

<sup>276</sup> 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).

<sup>277</sup> Allyson Browne, *RPS Evolving: States Take on U.S. Climate Goals*, 31 NAT. RES. & ENV’T 50, 50 (2017).

<sup>278</sup> *Id.*

<sup>279</sup> *Id.* at 51.

<sup>280</sup> *Id.*

states to learn from experience and modify their policies accordingly.<sup>281</sup> They have tweaked RPS timetables, percentages, technologies, incentives, durations, and other provisions.<sup>282</sup> These modifications have responded to the achievement of program goals, approaching target dates, changing market conditions, and other considerations.<sup>283</sup>

Importantly, these modifications were not enacted to weaken too-demanding standards; quite the contrary, they made the RPSs more ambitious.<sup>284</sup> Two states, California and Texas, provide examples. In 2006, California accelerated its initial deadline for compliance from 2017 to 2010.<sup>285</sup> Next, the state increased its renewable energy targets from 20 percent to 33 percent and subsequently to 50 percent.<sup>286</sup> 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.<sup>287</sup> Overall, the average RPS obligation rose from 7.6 percent of total electricity to 17.5 percent.<sup>288</sup> 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 have renewable energy targets of 50 percent by 2040 or sooner; Vermont has a mandate of 75 percent by 2032; and Hawaii's is now 100 percent by 2045.<sup>289</sup>

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.<sup>290</sup> These actors typically satisfy RPS requirements by choosing lower-cost and lower-risk technologies.<sup>291</sup> This market pressure

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<sup>281</sup> *Id.*

<sup>282</sup> LEON, *supra* note 4, at 10. Implicit in these constant refinements and strengthening of RPS policies is the need to evaluate RPS progress routinely. EPA, *supra* note 220, at 5-17.

<sup>283</sup> Browne, *supra* note 277, at 51.

<sup>284</sup> BARBOSE, *supra* note 228, at 9 (noting that more than half of RPS states have raised their overall targets or those of their carve outs).

<sup>285</sup> Allen, *supra* note 215, at 137-38.

<sup>286</sup> *Id.*

<sup>287</sup> *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.*

<sup>288</sup> Fischlein & Smith, *supra* note 244, at 280.

<sup>289</sup> BARBOSE, *supra* note 228, at 6.

<sup>290</sup> LEON, *supra* note 4, at 8.

<sup>291</sup> Wiser et al., *supra* note 212, at 3896. The incentive to provide electricity at the lowest

to utilize lower-cost methods of production drives innovation.<sup>292</sup> It “concentrates the mind and alters the behavior” of these parties to develop means to comply with the RPS requirements.<sup>293</sup> Thus, RPSs encourage development and adoption of low-cost methods.<sup>294</sup> Then, industrial dynamics, such as “economies of scale” and efficiencies gained through experience, further drive down costs as markets expand.<sup>295</sup> Numerous examples exist of the interrelation of economies of scale, lowering costs, and expanding markets.<sup>296</sup>

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.<sup>297</sup> Sometimes, states specifically design aspects of their RPSs to diversify renewable energy resources.<sup>298</sup> For instance, the RPSs of thirteen states and of the District of Columbia allow electricity generated from at least fifteen sources to satisfy their mandates.<sup>299</sup> RPS designers also incorporate policy mechanisms to subsidize more costly technologies.<sup>300</sup> States utilize these devices

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cost also incentivizes improving technologies to become more cost competitive. EPA, *supra* note 220, at 5-3.

<sup>292</sup> See LEON, *supra* note 4, at 6.

<sup>293</sup> *Id.*

<sup>294</sup> 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 230, at 4106–07. As discussed in the next Section, RPSs can utilize carve outs or multipliers to stimulate development of such resources. *Id.* at 4107.

<sup>295</sup> John A. Mathews & Hao Tan, *Manufacture Renewables to Build Energy Security*, 513 NATURE 166, 167 (Sept. 11, 2014).

<sup>296</sup> *Id.* An historic example comes from the auto industry. From 1909 to 1916, the cost of the Ford Model T dropped 62 percent while sales doubled annually, skyrocketing from 6000 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 ENV’T & ENERGY REP. (Jan. 16, 2018). For instance, the price of solar installations has decreased 60 percent since 2008. Sara Matasci, *How solar panel cost and efficiency have changed over time*, ENERGY SAGE (Mar. 16, 2017), <https://news.energysage.com/solar-panel-efficiency-cost-over-time/> [<https://perma.cc/WT97-SPN9>]. From 2008 to 2016, domestic solar photovoltaic installations have increased from 298 MW to 14,762 MW. *Solar Market Insight Report 2016 Year in Review*, SOLAR ENERGY INDST. ASS’N (SEIA), <https://www.seia.org/research-resources/solar-market-insight-report-2016-year-review> [<https://perma.cc/PV3G-CY3Y>] (last visited Nov. 17, 2018).

<sup>297</sup> Fischlein & Smith, *supra* note 244, at 286.

<sup>298</sup> Wisner et al., *supra* note 212, at 3895.

<sup>299</sup> DSIRE, *supra* note 257. States allowing at least fifteen sources are Arizona, Connecticut, Hawaii, Maryland, Massachusetts, Nevada, New Hampshire, North Carolina, Oregon, Pennsylvania, Utah, Vermont, and Wisconsin. *Id.*

<sup>300</sup> Joshua Novacheck & Jeremiah X. Johnson, *The environmental and cost implications*

to encourage investment in particular technologies whose development is a policy objective of the state.<sup>301</sup> 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.<sup>302</sup> Two RPS devices are particularly effective at promoting new technologies.<sup>303</sup> The first are technology carve outs; the second are credit multipliers.<sup>304</sup>

Carve outs (or set asides)<sup>305</sup> 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.<sup>306</sup> Essentially, the set aside establishes a submarket reserved for the particular technology.<sup>307</sup> Some states, however, establish these set asides as electricity to be produced in addition to the overall RPS obligation.<sup>308</sup> One of the most commonly used carve outs is for solar generation.<sup>309</sup> In fact, solar carve outs have become popular in a manner that was unforeseen when RPSs were first being developed.<sup>310</sup> As of 2015, half of the states with RPSs—fifteen—used a solar set aside.<sup>311</sup> Thirteen of the states use a percentage requirement, ranging from a high of 4.1 percent in New Jersey by 2027 to a low of 0.2 percent in North Carolina by 2018.<sup>312</sup> Two other states utilize a requirement stated in megawatts (“MW”).<sup>313</sup> Not surprisingly, so many states have chosen to use this device because it has proven

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*of solar energy preferences in Renewable Portfolio Standards*, 86 ENERGY POL'Y 250, 251 (2015).

<sup>301</sup> EPA, *supra* note 220, at 5-10.

<sup>302</sup> *Id.*

<sup>303</sup> Wisner et al., *supra* note 212, at 3897.

<sup>304</sup> *Id.*

<sup>305</sup> *Id.* Several labels apply to this policy tool. *Id.* They include carve outs, set asides, bands, and tiers. *Id.*

<sup>306</sup> EPA, *supra* note 220, at 5-10.

<sup>307</sup> Buckman, *supra* note 230, at 4105.

<sup>308</sup> EPA, *supra* note 220, at 5-10.

<sup>309</sup> LEON, *supra* note 4, at 10.

<sup>310</sup> *Id.*

<sup>311</sup> EPA, *supra* note 220, at 5-4, 5-5.

<sup>312</sup> *Id.*

<sup>313</sup> *Id.* 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 248, 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 percent of its electricity to be sourced from solar, this constitutes 20 percent of its renewable energy requirement. Novacheck & Johnson, *supra* note 300, at 251.

results. Analysis has found that the use of set asides in RPSs has “heavily influenced” the deployment of solar energy in those states.<sup>314</sup> For instance, a solar carve out in Massachusetts has been quite successful.<sup>315</sup> The state met its first goal (450 MW by 2017) three years early, and it surpassed its next goal (nearly quadrupling solar energy to 1600 MW by 2020) more than two years early.<sup>316</sup>

Multipliers, on the other hand, provide that the generation of electricity by particular energy sources will earn multiples of RECs.<sup>317</sup> 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.<sup>318</sup> Multipliers are credited with successfully supporting high-cost offshore wind development in the United Kingdom.<sup>319</sup>

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.<sup>320</sup> Delaware, for instance, has instituted multipliers for fuel cells, solar, and offshore wind.<sup>321</sup> New Mexico, on the other hand, carves out minimum percentages of its RPS goals that must be satisfied by solar, wind, and “other renewables.”<sup>322</sup>

Despite some similarities, carve outs and multipliers have had disparate track records.<sup>323</sup> As mentioned above, carve outs have been more popular in the United States, with twice as many states utilizing set asides as providing multipliers.<sup>324</sup> European countries, on the other hand, have preferred multipliers.<sup>325</sup> An early comparison of solar set asides and multipliers concluded that carve outs provided greater certainty that

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<sup>314</sup> Andrea Sarzynski et al., *The Impact of State Financial Incentives on Market Deployment of Solar Technology*, 46 ENERGY POL’Y 550, 551 (2012). The authors also note that another successful approach involved states offering cash incentives, such as rebates and grants. *Id.* Combining carve outs with subsidies has been particularly effective in incentivizing solar power. Fischlein & Smith, *supra* note 244, at 286.

<sup>315</sup> See Samantha Donalds, *Solar Insights from the 2016 RPS Summit*, RENEWABLE ENERGY WORLD (Jan. 2, 2017), <https://www.renewableenergyworld.com/ugc/articles/2017/01/03/solar-insights-from-the-2016-rps-summit.html> [<https://perma.cc/CBQ9-8FZ3>].

<sup>316</sup> *Id.*

<sup>317</sup> Buckman, *supra* note 230, at 4105. Multipliers are also identified as banding. *Id.*

<sup>318</sup> EPA, *supra* note 220, at 5-4, 5-5.

<sup>319</sup> Buckman, *supra* note 230, at 4114.

<sup>320</sup> Fischlein & Smith, *supra* note 244, at 290.

<sup>321</sup> *Id.*

<sup>322</sup> *Id.* at 287.

<sup>323</sup> Compare EPA, *supra* note 220, at 5-4, 5-5, with Buckman, *supra* note 230, at 4107.

<sup>324</sup> EPA, *supra* note 220, at 5-4, 5-5.

<sup>325</sup> Buckman, *supra* note 230, at 4107.



the targeted energy would be produced.<sup>326</sup> Indeed, set asides successfully initiated solar generation in a number of states, while multipliers did not demonstrate comparable success.<sup>327</sup> 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.<sup>328</sup> They concluded that carve outs could raise costs by requiring the installation of technologies that are not the least cost source.<sup>329</sup>

Carve outs and multipliers do have downsides. As noted previously, RPSs incentivize utilization of the lowest-cost technologies.<sup>330</sup> 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.<sup>331</sup> 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 renewables.<sup>332</sup> This occurs because the state awards credits in excess of the amount of electricity actually generated from renewable sources.<sup>333</sup> 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.<sup>334</sup> For instance, some states provide direct monetary subsidies.<sup>335</sup> One quarter of RPS states provide subsidies for solar, and researchers have found these subsidies to provide important support for the technology.<sup>336</sup> Another policy that five states have incorporated into their RPSs are feed-in tariffs ("FITs").<sup>337</sup> A FIT requires utilities to purchase electricity from independent producers

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<sup>326</sup> Wiser et al., *supra* note 212, at 3904.

<sup>327</sup> *Id.*

<sup>328</sup> Novacheck & Johnson, *supra* note 300, at 251.

<sup>329</sup> *Id.* at 256.

<sup>330</sup> Wiser et al., *supra* note 212, at 3896.

<sup>331</sup> *Id.*

<sup>332</sup> Novacheck & Johnson, *supra* note 300, at 254.

<sup>333</sup> *Id.* at 251.

<sup>334</sup> See Fischlein & Smith, *supra* note 244, at 286.

<sup>335</sup> *Id.*

<sup>336</sup> *Id.*

<sup>337</sup> *Summary Tables: Feed-In Tariff*, DSIRE, [http://programs.dsireusa.org/system/program?typer=92&\[https://perma.cc/T7KZ-WWX3\]](http://programs.dsireusa.org/system/program?typer=92&[https://perma.cc/T7KZ-WWX3]) (last visited Nov. 17, 2018). These states are California, Hawaii, Michigan, Vermont, and Washington. *Id.*

at fixed amounts, usually above-market rates, and for set periods of time.<sup>338</sup> California, for instance, has instituted its Renewable Market Adjusting Tariff, which is a FIT program for small renewable generators who produce no more than 3 MW of electricity.<sup>339</sup> The program requires utilities to enter into fixed-price ten-, fifteen- or twenty-year standard contracts with these generators.<sup>340</sup> 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).<sup>341</sup>

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.<sup>342</sup> Flexible policies stimulate innovation because they do not limit producers to “best-available technolog[ies]”, thus encouraging competition to develop more efficient means to comply with the mandates.<sup>343</sup> In the specific context of RPSs, their market-based approach pushes producers to utilize lower-cost methods of production, which drives innovation.<sup>344</sup> Furthermore, government policies are most effective when they provide long-term certainty to market actors.<sup>345</sup> Many RPSs achieve this objective by instituting mandates that extend ten to twenty years into the future.<sup>346</sup> In

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<sup>338</sup> Mormann, *supra* note 212, at 199.

<sup>339</sup> *Renewable Feed-In Tariff (FIT) Program*, CAL. PUB. UTIL'S COMM'N, <http://www.cpuc.ca.gov/feedintariff/> [<https://perma.cc/VT2G-QQCS>] (last visited Nov. 17, 2018).

<sup>340</sup> *Id.*

<sup>341</sup> *Renewable Market Adjusting Tariff (ReMAT)*, DSIRE, <http://programs.dsireusa.org/system/program/detail/5665> [<https://perma.cc/479Y-AX6Q>] (last visited Nov. 17, 2018).

<sup>342</sup> Fischlein & Smith, *supra* note 244, at 297.

<sup>343</sup> *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. *Id.* This opportunity to determine the means for compliance fosters innovation. *Id.*

<sup>344</sup> Nathaniel Horner et al., *Effects of Government Incentives on Wind Innovation in the United States*, 8 ENVTL. RES. LETTERS 1, 6 (2013).

<sup>345</sup> LEON, *supra* note 4, at 9.

<sup>346</sup> Paul Dvorak & Nathaniel Horner, *RPS policies are driving wind turbine innovation*, WINDPOWER (Feb. 28, 2014), <http://www.windpowerengineering.com/design/rps-policies-driving-wind-turbine-innovation/> [<https://perma.cc/2TK9-RZHP>]. These long-term signals provided by RPSs contrast with federal energy policies, which Congress has instituted primarily through the tax code. LEON, *supra* note 4, 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 the credit six times. *Production Tax Credit for Renewable Energy*, UNION OF CONCERNED SCIENTISTS, [https://www.ucsusa.org/clean-energy/increase-renewable-energy/production-tax-credit#.W-zr\\_2NReUk](https://www.ucsusa.org/clean-energy/increase-renewable-energy/production-tax-credit#.W-zr_2NReUk) [<https://>

this way, RPSs' fostering of innovation to lower costs helps "move technologies to maturity."<sup>347</sup>

States with RPSs have experienced significant increases in renewable energy generation during the past two decades.<sup>348</sup> The Lawrence Berkeley National Laboratory concluded that RPSs are "key driver[s]" for renewable energy generation.<sup>349</sup> Approximately half of the growth in renewable energy in the United States since 2000 is attributable to satisfying RPS requirements.<sup>350</sup> In several regions—notably the West, Mid-Atlantic, and Northeast—RPSs currently account for 70 to 90 percent of renewable energy capacity additions.<sup>351</sup> Consistent with these numbers, all but four states have met their RPS quotas; of those four, two still achieved at least 90 percent of their target.<sup>352</sup>

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.<sup>353</sup> In non-RPS states, renewable energy production increased by 128.5 percent.<sup>354</sup> In RPS states, it increased by 666.6 percent.<sup>355</sup>

While half of renewable energy additions were attributable to RPSs since 2000, this broad statistic masks a meaningful underlying trend. Up to 2012, the amount of total renewable energy additions that occurred in RPS states was 67 percent.<sup>356</sup> By 2016, however, this percentage fell to

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perma.cc/G7PQ-EJKM] (last visited Nov. 17, 2018). The PTC first expired in 1999. Since then, Congress has typically extended it for a one- or two-year period. *Tax Policy*, AM. WIND ENERGY ASS'N, <https://www.awea.org/policy-and-issues/tax-policy> [<https://perma.cc/97BP-Z7MC>] (last visited Nov. 17, 2018). As a result, investment has followed a boom-and-bust pattern driven by the short-term cycles of expiration and renewal of 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*.

<sup>347</sup> GOVERNORS' WIND ENERGY COALITION, *supra* note 231, at 4.

<sup>348</sup> Arroyo et al., *supra* note 276, at 398–99.

<sup>349</sup> *Id.*

<sup>350</sup> BARBOSE, *supra* note 228, at 3.

<sup>351</sup> *Id.*

<sup>352</sup> *Id.* at 28. Similarly, twelve of sixteen states with solar carve outs satisfied them, and a thirteenth exceeded more than 90 percent of its quota. *Id.*

<sup>353</sup> Eastin, *supra* note 274, at 132.

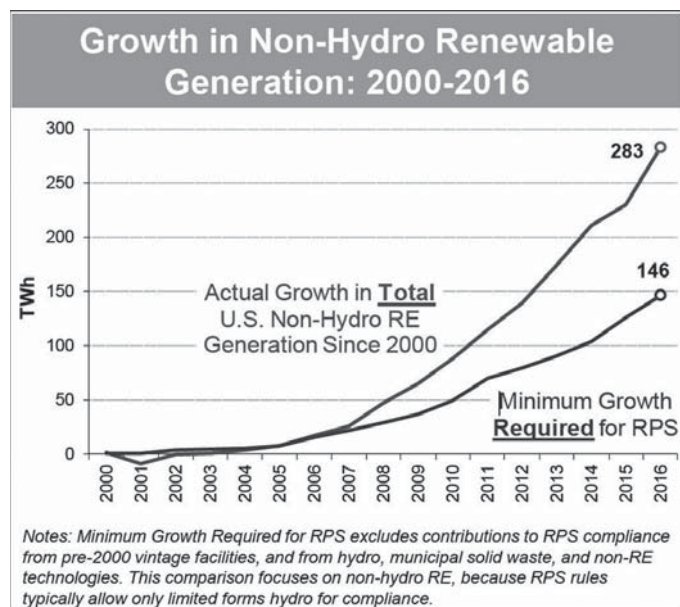
<sup>354</sup> *Id.*

<sup>355</sup> *Id.*

<sup>356</sup> LEON, *supra* note 4, at 4.

only 44 percent.<sup>357</sup> 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. Initially, utilities build renewable energy additions to satisfy RPS targets. Yet, as electricity generation costs decline, they become competitive against other sources, and utilities install renewable energy even though not required to do so by RPS quotas. Figure 1 demonstrates this pattern.

**Figure 1**<sup>358</sup>



As Figure 1 illustrates, until 2007, utilities made nearly all renewable energy additions to satisfy RPS quotas.<sup>359</sup> 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.<sup>360</sup>

<sup>357</sup> BARBOSE, *supra* note 228, at 3.

<sup>358</sup> BARBOSE, *supra* note 228, at 12.

<sup>359</sup> *Id.*

<sup>360</sup> *Id.*

Despite these laudable statistics, analyses of the effects of RPSs on renewable energy installation have failed to reach a consensus.<sup>361</sup> Indeed, one author noted that studies of RPSs have found “all possible impacts ranging from negative to none to positive.”<sup>362</sup> On the other hand, another analyst concluded that attempts to generalize the effects of RPSs may be misplaced.<sup>363</sup> Impacts of RPSs also vary across states.<sup>364</sup> Not surprisingly, the very flexibility inherent in RPSs complicates analysis of them. Furthermore, the effectiveness of RPSs depends upon the characteristics of the RPS and the state’s electricity market.<sup>365</sup>

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.<sup>366</sup> 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.<sup>367</sup> This effect of deployment increasing in other states occurs even when those states do not utilize RPSs.<sup>368</sup> Renewable energy additions in thirteen states without RPSs were actually made to comply with RPSs of other states. These installations accounted for 10 percent of renewable energy additions.<sup>369</sup> Magnifying this tendency, most RPSs do not require that renewable energy be generated in-state to receive credit.<sup>370</sup> This may not be surprising since parties have filed several challenges to RPSs’ in-state generation requirements on Commerce Clause grounds.<sup>371</sup>

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<sup>361</sup> Karen Maguire & Abdul Munasib, *The Disparate Influence of State Renewable Portfolio Standards on Renewable Electricity Generation Capacity*, 92 LAND ECON. 486, 486 (Aug. 2016).

<sup>362</sup> GIREESH SHRIMALI ET AL., HAVE STATE RENEWABLE PORTFOLIO STANDARDS REALLY WORKED? 33 (2012).

<sup>363</sup> Maguire & Munasib, *supra* note 361, at 487.

<sup>364</sup> *Id.* at 468.

<sup>365</sup> *Id.* at 487.

<sup>366</sup> Fischlein & Smith, *supra* note 244, at 279.

<sup>367</sup> SHRIMALI ET AL., *supra* note 362, at 34.

<sup>368</sup> BARBOSE, *supra* note 228, at 16.

<sup>369</sup> *Id.*

<sup>370</sup> Fischlein & Smith, *supra* note 244, at 279.

<sup>371</sup> Mormann, *supra* note 212, 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”

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.<sup>372</sup> Another factor which can depress renewable energy investment is the inclusion of energy efficiency as a means of compliance.<sup>373</sup> 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.<sup>374</sup> 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.<sup>375</sup>

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 utilities to circumvent their mandates.<sup>376</sup> Although most RPSs include some form of enforcement mechanism, states have notoriously failed to enforce them, in many instances waiving or excusing penalties.<sup>377</sup> In fact, only two states, Texas and Connecticut, have assessed penalties for shortfalls in compliance.<sup>378</sup> In addition to insufficient penalties and enforcement, the success of RPSs can also be impacted by their reporting and verification procedures.<sup>379</sup> Analyses have suggested that current enforcement is sufficiently weak that RPS targets could actually be “much lower” if loopholes were closed.<sup>380</sup>

In light of these considerations, the seeming “contradictory” findings of analysts trying to determine the impact of RPSs is hardly surprising.<sup>381</sup>

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shall import power that would contribute to the state’s CO<sub>2</sub> 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.

<sup>372</sup> Fischlein & Smith, *supra* note 244, at 282.

<sup>373</sup> *Id.* at 285.

<sup>374</sup> U.S. ENVTL. PROT. AGENCY, CUTTING POWER SECTOR CARBON POLLUTION: STATE PROGRAMS AND POLICIES 25 (2016).

<sup>375</sup> Fischlein & Smith, *supra* note 244, at 285.

<sup>376</sup> *Id.* at 281.

<sup>377</sup> Ivan Gold & Nick Thaker, *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).

<sup>378</sup> *Id.* at 250, n.467.

<sup>379</sup> Horner et al., *supra* note 344, at 7.

<sup>380</sup> Gold & Thaker, *supra* note 377, at 205.

<sup>381</sup> SHRIMALI ET AL., *supra* note 362, at 33.

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.<sup>382</sup> Once analysts factor in these differences, correlations between RPS enactment and renewable energy generation emerge.<sup>383</sup> More recent analysis finds significant correlations between RPS enactment and renewable electricity generation.<sup>384</sup> Analysts have also found factors that strengthen the connection between RPSs and renewable energy generation. For instance, the stringency<sup>385</sup> of RPSs has a positive and significant impact on renewable energy deployment.<sup>386</sup> Similarly, REC unbundling also increases renewable energy generation.<sup>387</sup>

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.<sup>388</sup>

### 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 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.<sup>389</sup> Installations of each have increased substantially since the enactment of these policies.<sup>390</sup>

Several indicators demonstrate that RPSs have significantly and positively impacted wind energy. Indeed, because of RPSs' low-cost focus,<sup>391</sup>

<sup>382</sup> Maguire & Munasib, *supra* note 361, at 468.

<sup>383</sup> Fischlein & Smith, *supra* note 244, at 304.

<sup>384</sup> MATTHEW J. DENNEY, STATE-LEVEL RENEWABLE PORTFOLIO STANDARDS: EVALUATING THEIR EFFECTIVENESS IN INCREASING RENEWABLE ELECTRICITY GENERATION AND REDUCING CARBON EMISSIONS 29 (2015).

<sup>385</sup> 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?*, 38 ENERGY POL'Y 1140, 1147 (2010).

<sup>386</sup> SHRIMALI ET AL., *supra* note 362, at 33.

<sup>387</sup> *Id.* at 34.

<sup>388</sup> Horner et al., *supra* note 344, 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.*

<sup>389</sup> *Id.* at 1.

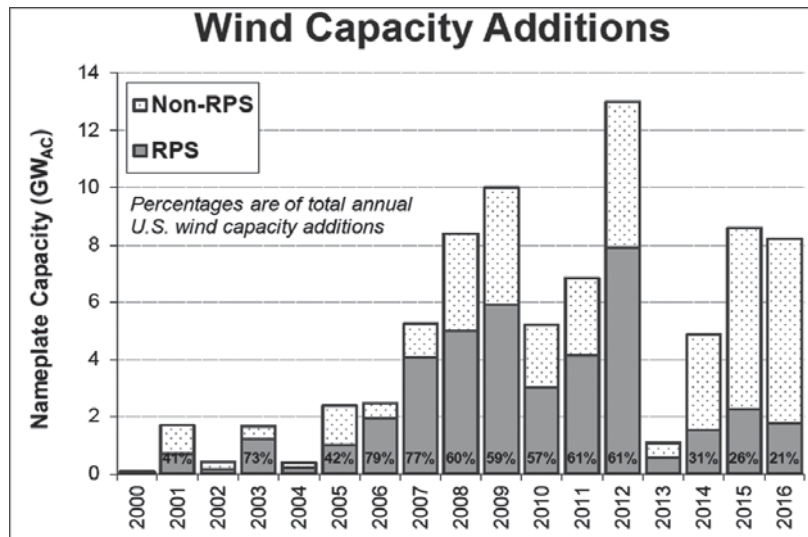
<sup>390</sup> *Id.*

<sup>391</sup> Wiser et al., *supra* note 212, at 3896.

wind power especially benefitted from RPS policies.<sup>392</sup> Of non-hydro renewable resources, wind was the most developed and widely available at the time that states enacted their RPSs.<sup>393</sup> 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 percent of RPS obligations.<sup>394</sup>

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<sup>395</sup>



<sup>392</sup> GOVERNORS' WIND ENERGY COALITION, *supra* note 231, at 13.

<sup>393</sup> See *History of Europe's Wind Industry*, WIND EUROPE, <https://windeurope.org/about-wind/history> [<https://perma.cc/N974-PTYV>] (last visited Nov. 17, 2018) (for a history of European policies and subsequent milestones of its wind industry in the 1980s and 1990s).

<sup>394</sup> GOVERNORS' WIND ENERGY COALITION, *supra* note 231, at 13.

<sup>395</sup> BARBOSE, *supra* note 228, at 18.



By 2016, only 21 percent of annual new wind capacity was added to meet RPS requirements.<sup>396</sup> In other words, 79 percent of wind power additions either were in RPS states but exceeded RPS mandates or were installed in non-RPS states.<sup>397</sup>

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 percent to 67 percent.<sup>398</sup> Furthermore, the largest wind turbine producers, with the exception of GE, were based in other countries,<sup>399</sup> but they began manufacturing components domestically. In 2004, only one of the top ten manufacturers had factories in the United States.<sup>400</sup> By 2016, this had increased to eight in ten.<sup>401</sup> RPSs have also positively impacted domestic wind power innovation.<sup>402</sup> Notably, the period of RPS enactments coincided with a significant increase in wind turbine patenting.<sup>403</sup> 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.<sup>404</sup>

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.<sup>405</sup> Solar technology, on the other hand, was relatively undeveloped.<sup>406</sup> Nevertheless, RPSs successfully

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<sup>396</sup> RYAN WISER & MARK BOLINGER, 2016 WIND TECHNOLOGIES MARKET REPORT 67 (2016).

<sup>397</sup> *Id.*

<sup>398</sup> *Id.*

<sup>399</sup> Veronika Henze & Katrin Thomas, *Vestas reclaims top spot in annual rankings of wind turbine makers*, BLOOMBERG NEW ENERGY FINANCE (Feb. 22, 2017), <https://about.bnef.com/blog/vestas-reclaims-top-spot-annual-ranking-wind-turbine-makers/> [<https://perma.cc/W369-YDT9>].

<sup>400</sup> *Id.*

<sup>401</sup> *Id.*

<sup>402</sup> Horner et al., *supra* note 344, at 1.

<sup>403</sup> Dvorak & Horner, *supra* note 346.

<sup>404</sup> Horner et al., *supra* note 344, at 6.

<sup>405</sup> Mitchell Schmidt, *Iowa's status as a renewable energy leader: How we got here and what's next*, THE GAZETTE (July 9, 2017), <http://www.thegazette.com/iowaideas/stories/energy-environment/iowas-status-as-a-renewable-energy-leader-how-we-got-here-and-whats-next-20170709> [<https://perma.cc/S9XC-UUQP>].

<sup>406</sup> For instance, global solar photovoltaic installations were negligible in 2000. By 2017, installations reached 402,500 MW. INT'L ENERGY AGENCY, 2018 SNAPSHOT OF GLOBAL PHOTOVOLTAIC MARKETS 6 (2018).

drove development and deployment of solar technology.<sup>407</sup> As mentioned previously, half of RPS states utilize solar carve-outs.<sup>408</sup> In addition, six states provide multipliers for solar, and a seventh allows a multiplier for distributed generation,<sup>409</sup> fulfillment of which typically involves solar power.<sup>410</sup> Initial growth of solar was concentrated in these states. Specifically, between 2005 to 2009, 65 percent to 81 percent of solar installations outside of California occurred in states with solar carve-outs.<sup>411</sup>

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 percent of the installed capacity required to satisfy RPS mandates.<sup>412</sup> Through 2016, wind still constituted 61 percent of all RPS installations.<sup>413</sup> In 2016, however, solar accounted for 79 percent of all new builds.<sup>414</sup> 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,<sup>415</sup> solar is beginning to follow a similar trajectory. Figure 3 illustrates this transition.

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<sup>407</sup> Wisner et al., *supra* note 212, at 3894.

<sup>408</sup> EPA, *supra* note 220, at 5-4, 5-5.

<sup>409</sup> *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. *Renewable Energy: Distributed Generation Policies and Programs*, U.S. DEP'T OF ENERGY, <https://energy.gov/leere/slsc/renewable-energy-distributed-generation-policies-and-programs> [<https://perma.cc/923E-6YJ4>] (last visited Nov. 17, 2018).

<sup>410</sup> Gaul & Carley, *supra* note 248, at 463.

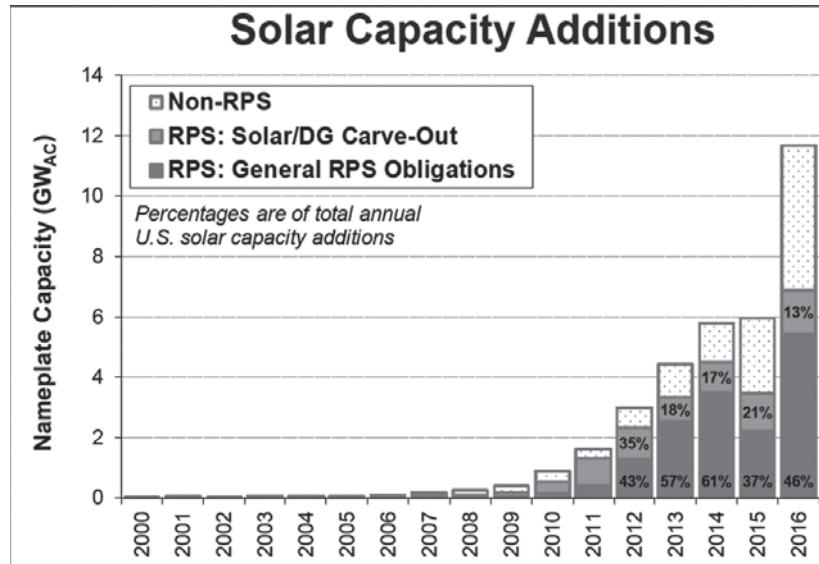
<sup>411</sup> Wisner et al., *supra* note 212, at 3900.

<sup>412</sup> GOVERNORS' WIND ENERGY COALITION, *supra* note 231, at 13.

<sup>413</sup> BARBOSE, *supra* note 228, at 17.

<sup>414</sup> *Id.*

<sup>415</sup> *Id.*

Figure 3<sup>416</sup>

Through 2014, nearly 80 percent of solar installations occurred to satisfy RPS mandates; in both 2015 and 2016, however, more than 40 percent of new solar was installed outside RPS requirements.<sup>417</sup> Thus, as RPSs have helped drive innovation in solar and reduce its costs,<sup>418</sup> 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 proportion of installations not required by RPS mandates have increased substantially.<sup>419</sup>

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

<sup>416</sup> BARBOSE, *supra* note 228, at 17.

<sup>417</sup> *Id.* at 18.

<sup>418</sup> Since 2008, the price of solar panel installation has declined 60 percent. Solar panel efficiency also has improved approximately 60 percent during this period. Matasci, *supra* note 296. During this period, total United States installations increased nearly fifty-fold. SEIA, *supra* note 296.

<sup>419</sup> Matasci, *supra* note 296.

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.<sup>420</sup> RPSs also allow for local tailoring to address regional differences. In addition, RPSs have developed accounting systems, which will be essential for NETs.<sup>421</sup>

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<sub>2</sub> (through the reduction of carbon emissions),<sup>422</sup> the inclusion of NETs will further this goal. Alternatively, states could establish a separate program, an RPS, 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.<sup>423</sup> To this end, states typically identify a broad range of technologies eligible to satisfy their RPS requirements. For instance, Wisconsin's RPS identifies twenty-six eligible technologies.<sup>424</sup> Furthermore, RPSs are sufficiently flexible to enable states to revise their RPSs to add new technologies as they are developed.<sup>425</sup> As discussed previously, RPSs also often include carve outs or multipliers to target specific resources for development.<sup>426</sup>

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<sup>420</sup> LEON, *supra* note 4.

<sup>421</sup> *Id.*

<sup>422</sup> OTTMAR EDENHOFER ET AL., SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION 18 (2012).

<sup>423</sup> Wiser et al., *supra* note 212, at 3895.

<sup>424</sup> *Renewable Portfolio Standard Program Overview: Wisconsin*, DSIRE, <http://programs.dsireusa.org/system/program/detail/190> [<https://perma.cc/7C9T-NFG3>] (last updated May 31, 2018).

<sup>425</sup> LEON, *supra* note 4, at 10.

<sup>426</sup> *Supra* note 304, and accompanying text.

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.<sup>427</sup> These limits range from costs,<sup>428</sup> to land availability,<sup>429</sup> to food security,<sup>430</sup> to biodiversity risks,<sup>431</sup> among others. Because of these limitations, we can anticipate that society will need to rely upon a portfolio of different NETs.<sup>432</sup> Furthermore, scientists project that the suite of anticipated NETs will not be able to remove the required amount of CO<sub>2</sub> from the atmosphere.<sup>433</sup> 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.<sup>434</sup> 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.<sup>435</sup> Such markets will be essential for the development of NETs. Specialized, niche markets are especially important to foster innovation.<sup>436</sup> Development of new technologies requires opportunities for the technologies to be tested and improved while being supported by actual markets.<sup>437</sup> 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.<sup>438</sup> By creating markets for these technologies,

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<sup>427</sup> Fuss et al., *supra* note 54, at 3.

<sup>428</sup> Cost is the most significant barrier to the implementation of DACCS. U.N. ENVIRONMENTAL PROGRAMME, *supra* note 92, at 64.

<sup>429</sup> Afforestation and reforestation are available only to the extent of suitable land. McLaren, *supra* note 66, at 20.

<sup>430</sup> Ocean fertilization may also impair ocean food resources. NRC, *supra* note 39, at 61. Land required to grow BECCS feedstocks may also be needed for food production. McLaren, *supra* note 66, at 17.

<sup>431</sup> *Id.*

<sup>432</sup> Jan C. Minx et al., *Fast Growing Research on Negative Emissions*, 12 ENVTL. RES. LETTERS 2 (2017).

<sup>433</sup> See Psarras et al., *supra* note 60, at 16.

<sup>434</sup> *Id.* Specifically, scientists project that NETs could remove up to 1000 GtCO<sub>2</sub> by mid-century. However to avoid a 2°C rise in global mean temperature, we would need to sequester 1800 GtCO<sub>2</sub> by 2050. *Id.*

<sup>435</sup> LEON, *supra* note 4, at 8.

<sup>436</sup> Ishimoto et al., *supra* note 137, at 12.

<sup>437</sup> *Id.*

<sup>438</sup> MacDowell et al., *supra* note 13, at 244.

RPSs provide long-term visibility for cash flows and routes to market.<sup>439</sup> Both of these encourage investors and entrepreneurs to engage in these technologies.<sup>440</sup> For at least one technology, DACCS, the establishment of markets will be crucial. Because of the high-risk, high-return nature of DACCS, business startups are especially involved in developing this method.<sup>441</sup> 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.<sup>442</sup> The NRC projected the costs of carbon capture as ranging from \$50 to more than \$1,000 per tCO<sub>2</sub>.<sup>443</sup> The costs of sequestration, it estimated, would range from \$6 to hundreds of dollars per tCO<sub>2</sub>.<sup>444</sup> Estimated costs of specific technologies cover similarly broad ranges. For example, projections of the costs of DACCS range from below \$100 to more than \$1,000 per tCO<sub>2</sub>.<sup>445</sup> 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.<sup>446</sup> As a result, its costs range from \$100 per tCO<sub>2</sub> to as much as \$1,000 per tCO<sub>2</sub> for terrestrial operations.<sup>447</sup> While land management methods will be substantially less expensive, even their costs are difficult to predict.<sup>448</sup> Currently, experts project their costs to range from \$20 to \$100 per tCO<sub>2</sub>.<sup>449</sup>

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,

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<sup>439</sup> McGlashan et al., *supra* note 174, at 17.

<sup>440</sup> *Id.*

<sup>441</sup> *Id.* at 13.

<sup>442</sup> NRC, *supra* note 39, at 106.

<sup>443</sup> *Id.* 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. Accordingly, the latter may cost up to ten times more than capture directly from an emissions source. Psarras et al., *supra* note 60, at 4.

<sup>444</sup> NRC, *supra* note 39, at 106.

<sup>445</sup> Lomax et al., *supra* note 2, at 498.

<sup>446</sup> See Psarras et al., *supra* note 60, at 16.

<sup>447</sup> *Id.*

<sup>448</sup> *Id.*

<sup>449</sup> *Id.*

utilizing mechanisms that will drive innovation and lower costs will be critical. With their market-driven approaches, RPSs excel at these objectives.<sup>450</sup> Second, because of the magnitude of the 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.<sup>451</sup> 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.<sup>452</sup>

Geographical considerations also favor using RPSs to facilitate NETs' development. Some NETs technologies are geographically constrained as to where they can be effectively implemented.<sup>453</sup> BECCS is an example of a technology that is regionally dependent.<sup>454</sup> Conversely, one of the primary advantages of DACCS is that DACCS facilities may be placed "virtually anywhere."<sup>455</sup> 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, as the vast majority of RPSs already allow for renewable energy generation outside the jurisdiction.<sup>456</sup> Conversely, DACCS facilities, which can be sited nearly anywhere, need not be restricted to the territorial boundaries of the jurisdictions awarding credits.<sup>457</sup> This may free them up to be sited in locations with cheaper land, better access to roads, abundant renewable energy sources, or other favorable conditions.

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<sup>450</sup> EPA, *supra* note 220, at 5-3.

<sup>451</sup> NRC, *supra* note 39, at 105.

<sup>452</sup> FITs are another policy mechanism used successfully to incentivize renewable energy. *Feed-in Tariff: A policy tool encouraging deployment of renewable electricity technologies*, U.S. ENERGY INFORMATION ADMINISTRATION (May 30, 2013), <https://www.eia.gov/todayinenergy/detail.php?id=11471> [<https://perma.cc/7MAC-L6UP>]. 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 Germany, Spain, and South Korea recently abandoned their FITs because of the high electricity costs resulting from their FITs contracts. *Id.* at 1000.

<sup>453</sup> Psarras et al., *supra* note 60, at 5.

<sup>454</sup> *Id.*

<sup>455</sup> *Id.* at 9. Nevertheless, constraints may arise concerning the sufficiency of particular sinks for long-term sequestration, their capacities, and commercial availability. See Haszeldine et al., *supra* note 173, at 14.

<sup>456</sup> Fischlein & Smith, *supra* note 244, at 279.

<sup>457</sup> See *Direct Air Capture (2018)*, CARBON ENG., <http://carbonengineering.com/about-dac/> [<https://perma.cc/UY9L-498A>] (last visited Nov. 17, 2018).

Another aspect of RPSs that will fit well with NETs is their established accounting systems.<sup>458</sup> The removal of CO<sub>2</sub> by NETs will present significant issues of tracking and accounting.<sup>459</sup> 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.<sup>460</sup> Furthermore, consistent accounting rules have not been established for NETs processes.<sup>461</sup> Complicating this record-keeping will be the novel ecosystems, soils, and biomass involved with NETs.<sup>462</sup> Finally, NETs likely will involve multi-jurisdictional transactions necessitating independent measurement, reporting, and verification of activities.<sup>463</sup>

While these will be novel issues for RPSs to address, they benefit by having already-established tracking systems for RECs transactions.<sup>464</sup> RPS states typically require annual reports of RECs transactions demonstrating compliance with RPS obligations.<sup>465</sup> To facilitate the development of robust RECs markets, many states participate in regional tracking systems.<sup>466</sup> These regional systems are sufficiently compatible to enable future interconnection and expansion.<sup>467</sup>

If a favorable environment is provided for NETs, experts anticipate that they can achieve significant growth.<sup>468</sup> BECCS, for instance, has the technological potential to contribute significantly to carbon removal as soon as 2030.<sup>469</sup> DACCS, for its part, has been projected to have the potential to develop into a major industry.<sup>470</sup> This would require, however, a maturing of the technology and a dropping in prices.<sup>471</sup> For example, analysts expect that increasing the number of CCS plants will create

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<sup>458</sup> Lomax et al., *supra* note 2, at 499.

<sup>459</sup> *Id.*

<sup>460</sup> *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.

<sup>461</sup> Fuss et al., *supra* note 54, at 7.

<sup>462</sup> Lomax et al., *supra* note 2, at 499.

<sup>463</sup> Peters & Geden, *supra* note 34, at 622.

<sup>464</sup> Arroyo et al., *supra* note 276, at 399.

<sup>465</sup> EPA, *supra* note 220, at 5-11.

<sup>466</sup> LEON, *supra* note 4, at 6.

<sup>467</sup> *Id.*

<sup>468</sup> McGlashan et al., *supra* note 114, at 508.

<sup>469</sup> *Id.*

<sup>470</sup> Field & Mach, *supra* note 42, at 707.

<sup>471</sup> *Id.*



a virtuous cycle. Construction of new plants will lower their costs, which will facilitate building of more facilities.<sup>472</sup> Similarly, projections for DACCS technologies anticipate that their costs will fall to \$200 per ton of CO<sub>2</sub>; that cost may be further cut in half in a medium-term timeframe.<sup>473</sup> Other technologies will likely require at least two decades before they can increase to scale.<sup>474</sup> RPSs, of course, have established track records of fostering both increased investment and reduced costs over multiple decades.<sup>475</sup>

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,<sup>476</sup> stabilizes and reduces energy costs,<sup>477</sup> improves the resiliency of the energy grid,<sup>478</sup> fosters energy independence,<sup>479</sup> creates jobs,<sup>480</sup> and improves health by reducing pollution.<sup>481</sup>

Conversely, few NETs produce valuable services in addition to carbon sequestration. BECCS generates electricity.<sup>482</sup> Conceivably, CCS systems produce a salable product—the captured CO<sub>2</sub>. Carbon capture and utilization (“CCU”) systems apply the captured CO<sub>2</sub> to a number of processes, including enhanced oil recovery, mineral carbonation, food and beverage carbonation, polymer processing, microalgae production, and

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<sup>472</sup> Bourzac, *supra* note 139, at S67.

<sup>473</sup> *Id.* at S68.

<sup>474</sup> McGlashan et al., *supra* note 114, at 508.

<sup>475</sup> *Supra* note 227, and accompanying text.

<sup>476</sup> EDENHOFER ET AL., *supra* note 422, at 18.

<sup>477</sup> See LAZARD, LAZARD'S LEVELIZED COST OF ENERGY ANALYSIS—VERSION 11.0 5 (2017), <https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf> [<https://perma.cc/LT38-HBFP>] (illustrating that several renewable energy sources provide cheaper electricity in a narrower price range than do conventional energy sources).

<sup>478</sup> See David J. Unger, *Are renewables stormproof? Hurricane Sandy tests solar, wind*, THE CHRISTIAN SCIENCE MONITOR (Nov. 19, 2012), <https://www.csmonitor.com/Environment/Energy-Voices/2012/1119/Are-renewables-stormproof-Hurricane-Sandy-tests-solar-wind> [<https://perma.cc/22TH-F5CX>].

<sup>479</sup> Rebecca Harrington, *There's only one way for the US to reach energy independence*, BUSINESS INSIDER (July 15, 2017), <http://www.businessinsider.com/how-can-america-be-energy-independent-adopt-renewables-2017-7> [<https://perma.cc/S4ZD-3A4A>].

<sup>480</sup> UNION OF CONCERNED SCIENTISTS, FACT SHEET: CLEAN POWER GREEN JOBS 1 (2009), [https://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean\\_energy/Clean-Power-Green-Jobs-25-RES.pdf](https://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_energy/Clean-Power-Green-Jobs-25-RES.pdf) [<https://perma.cc/5REU-TEXN>] (finding that renewable energy creates three times as many jobs as producing an equivalent amount of energy from fossil fuels).

<sup>481</sup> EDENHOFER ET AL., *supra* note 422, at 20.

<sup>482</sup> McGlashan et al., *supra* note 114, at 504.

enhanced coal bed methane recovery.<sup>483</sup> Nevertheless, at least one analysis concludes that CCU is unlikely to make CCS commercially profitable.<sup>484</sup> Biochar can generate energy or enrich agricultural lands.<sup>485</sup> 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.<sup>486</sup>

Since few NETs confer any additional benefits besides CO<sub>2</sub> 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. A helpful starting point would be to establish carve outs for BECCS, which will assure some development and installation of that technology. While the other NETs do not produce electricity, to the extent the RPS seeks to mitigate carbon emissions, NETs provide comparable substitutes for renewable energy.<sup>487</sup> Furthermore, RPSs already apply to utilities,<sup>488</sup> 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.<sup>489</sup> Extended implementation will also allow jurisdictions to modify their accounting systems to measure and track the capturing and burying of CO<sub>2</sub>. Jurisdictions will need to develop methods to measure the carbon captured, the amount successfully sequestered, and the permanence of sequestration, all of which will need to produce comparable values of carbon capture and sequestration across different environments and technologies.<sup>490</sup>

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<sup>483</sup> Jennifer Wilcox et al., *Assessment of Reasonable Opportunities for Direct Air Capture*, 12 ENVTL. RES. LETTERS 2 (2017).

<sup>484</sup> MacDowell et al., *supra* note 13, at 247.

<sup>485</sup> Workman et al., *supra* note 67, at 2881.

<sup>486</sup> *Id.*

<sup>487</sup> Honegger & Reiner, *supra* note 131, at 308.

<sup>488</sup> DSIRE, *supra* note 424.

<sup>489</sup> Keller et al., *supra* note 41, at 1335.

<sup>490</sup> CTR. FOR CARBON REMOVAL, *supra* note 190, at 8. *See also* Fiefie Shen, *China's Prep for Carbon-Market Trading May Take Up to Two Years*, BLOOMBERG BNA ENV'T & ENERGY

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.<sup>491</sup> 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.<sup>492</sup>

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.<sup>493</sup> The Golden State also has the fourth largest cap-and-trade program in the world.<sup>494</sup> Nevertheless, it covers only large electric power plants, large industrial plants, and fuel distributors.<sup>495</sup>

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 a broad-reaching program.<sup>496</sup> 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.<sup>497</sup> In a final phase targeted to begin by 2020, China will extend its trading program to non-ferrous metal and cement sectors.<sup>498</sup>

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REP. (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*.

<sup>491</sup> DSIRE, *supra* note 424.

<sup>492</sup> KATE LARSEN ET AL., TAKING STOCK 2017: ADJUSTING EXPECTATIONS FOR US GREENHOUSE GAS EMISSIONS 4–5 (2017), <https://rhg.com/research/taking-stock-2017-us-greenhouse-gas-emissions/> [<https://perma.cc/EZ4U-3AB6>].

<sup>493</sup> *Renewable Portfolio Standard Program Overview: California*, DSIRE, <http://programs.dsireusa.org/system/program/detail/840> [<https://perma.cc/52LQ-BBAS>] (last updated Sept. 24, 2018).

<sup>494</sup> *Id.*

<sup>495</sup> *California Cap and Trade*, CTR. FOR CLIMATE CHANGE AND ENERGY SOLUTIONS, <https://www.c2es.org/content/california-cap-and-trade/> [<https://perma.cc/VMR5-TFNT>] (last visited Nov. 17, 2018).

<sup>496</sup> *Id.*

<sup>497</sup> *See id.*

<sup>498</sup> *See* Dean Scott, *China's Trimmed Carbon Trading Will Still Boost Worldwide Action*, BLOOMBERG BNA ENV'T & ENERGY REP. (Dec. 21, 2017), <https://news.bloombergenvironment.com/environment-and-energy/chinas-trimmed-carbon-trading-will-still-boost-world>

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.<sup>499</sup> 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,<sup>500</sup> they may provide a preferable alternative to emissions mitigation in difficult to control sectors.<sup>501</sup>

#### 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.

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wide-action [<https://perma.cc/ZMJ9-UYY7>] (noting that China's carbon trading system will initially cover power generators but will subsequently expand to encompass metals, chemicals, and building materials).

<sup>499</sup> *Id.*

<sup>500</sup> See *supra* notes 295–96 and accompanying text.

<sup>501</sup> Honegger & Reiner, *supra* note 131, at 314.