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# TECHNICAL FEASIBILITY OF 100% RENEWABLE ELECTRICITY BY 2035

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## A. INTRODUCTION

Two questions are central to assessing the technical feasibility Maryland's 100% Clean Renewable Energy Equity Act (hereafter the "100% Act"):

1. *Renewable energy supply growth*: Can Maryland ramp up renewable energy acquisition fast enough? Apart from the reliability question (see the next item), this is a capacity question: can Maryland build the needed generation resources in-state and contract for the needed resources from outside the state to meet the renewable electricity targets in the 100% Act?
2. *Reliability in the context of variable wind and solar*: How will the reliability of a 100% renewable electricity sector in Maryland be assured? In other words, what happens when the wind doesn't blow AND the sun doesn't shine? This question might also be phrased thus: how do we achieve reliability when wind and solar energy built in the state or acquired via Power Purchase Agreements from elsewhere cannot directly meet the load?

## B. RENEWABLE ELECTRICITY SUPPLY GROWTH

In considering rate of supply growth, I will consider each element separately:

a. In-state solar electricity supply;
b. In-state offshore wind supply;
c. Imports of renewable electricity from the PJM region, i.e., supply not restricted to in-state contracts or targets.

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Much of the renewable energy industry in the United States, notably solar but also wind, has been built up within the last eight to ten years. In considering capacity to ramp up in-state renewables to meet the targets in the 100% Act, it is useful to consider a similar time frame, since there is experience to guide the assessment. We therefore use the 2025 target in the 100% Act as a suitable milestone against which to address whether the near-term targets are achievable. Once capacity to build solar and offshore wind to meet needs to the mid-2020s has been created, subsequent increases in renewable energy requirements are an extension of what would have been accomplished up to that time.

### a. Solar capacity and generation

When considered on a per person basis, comparable levels of solar growth per year or faster have already been achieved elsewhere in the United States. Under the 100% Act Maryland's in-state solar is slated to grow about 3,800 megawatts (MW) between 2019 and 2025 (inclusive). Such a ramping up of the solar industry is both feasible and desirable. Comparable additions to in-state solar have already been achieved in Hawaii and California (on a per person basis). Maryland added almost 300 megawatts of solar in 2016. We propose to increase this to about 500 MW per year until 2024 and about 700 MW per year after that up to 2027, when it ramps up again to 900 MW per year. Maryland's in-state solar capacity under the 100% Act is incentivized by the Maryland Megawatt Block program, which has rebates for residential, commercial, community, and utility-scale solar installations.

### b. In-state offshore wind

The 100% Act has an "in-state" offshore wind target of 1,368 MW by 2027 and 2,468 MW by 2030. On a per person basis, the former is about the same as the Massachusetts 2027 target (required by law) and the latter to New Jersey's 3,500 MW by 2030 that was promised by Governor Murray during his campaign. ("In-state" offshore wind in the 100% Act means wind installations in waters between 10 and 70 miles off the Maryland Coast, connected to the grid on the Delmarva Peninsula.) These targets are achievable and have been set in consultation with the Business Network for Offshore Wind. An important consideration in setting these targets is to ensure that Maryland gets its share of the long-term manufacturing and infrastructure jobs that will accompany the planned boom in offshore wind along the Atlantic Coast. The rate of offshore wind installation is gradually increased in the 100% Act from 200 MW per year in the mid-2020s to 400 MW per year in the 2031-2035 period.

### c. Imports of renewable energy from the PJM grid region

Given the renewable energy requirements and the in-state renewable energy targets in the 100% Act, Maryland will need to import about 21% of its renewable energy requirements in 2035. (Maryland currently imports about 40% of its electricity requirements.)

Prices of electricity from utility-scale solar and onshore wind farms are expected to be broadly comparable from 2020 onward. Assuming a 50-50 split of wind and solar imports will mean Power Purchase Agreements (PPAs) of about 1,800 MW for onshore wind and 3,600 MW for utility-scale solar by 2025, increasing to about 2,500 MW and 5,100 MW respectively by 2029.

The PJM grid has more than 13,000 MW of solar interconnection requests whose in-service dates are between 2019 and 2021.[2] The vast majority of these projects will only get built if they have clients who have signed PPAs. This is because PPAs guarantee the main revenue stream against which project

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[2] Generating facilities that will sell electricity into the interstate PJM grid must make an "interconnection request" to PJM, the grid operator. There is normally a queue of such requests for new power plants waiting for approval.

financing can be secured.[3] The PJM grid also has about 7,000 MW in the interconnection queue with in-service target dates between 2019 and 2021. These projects also typically depend on PPAs if they are to be built.

It is clear that there is no capacity constraint for Maryland to import the needed amount of solar and wind electricity. Contracts for import of renewable energy are typically in the form of Virtual Power Purchase Agreements (Virtual PPAs). Once PJM gives the go ahead, no further transmission planning is required. It is part of PJM's job to ensure that transmission is available because the power is sold into the interstate PJM grid. In a typical Virtual PPA, the purchaser pays the owner the agreed price per megawatt-hour. If the grid price is above the PPA contract price the purchaser is reimbursed all or most of the difference (depending on contract terms) and vice versa when the grid price is below the contract price.

There are ample solar and wind resources in the states and areas that are part of the PJM grid; resource limitations will not play a role in getting to 100% renewable electricity even if all the states in the region decide to pursue such a course. Of course, planning, transmission, and other technical, economic, and regulatory issues must be addressed.

### d. Conclusions regarding meeting renewable energy targets in the 100% Act up to the mid-2020s

The in-state targets in the 100% Act are reasonable and achievable. The main thing that is needed is certainty of the target so that the industry can sustainably build up capacity without boom and bust cycles. Certainty for industry will be achieved when the 100% Act is passed.

The import targets can be comfortably achieved with adequate planning – i.e., timely issuance of requests for proposal for PJM-wide acquisition of resources and timely PPAs pursuant to those RFPs.

## C. RELIABILITY

Reliability will not be an issue in the period up to the mid-2020s. Maryland's renewable energy target under the 100% Act is 38% in 2025. Similar or greater renewable electricity targets as a percentage of sales have already been achieved in several areas (states/countries). Similar targets have been achieved even if we narrow the definition of renewable energy to wind and solar. The degree of complexity required to get to high penetration of wind and solar depends in part on whether the area/region/state/country under consideration is part of a larger grid, and if so whether it is a small or big part of that grid.

Table 1 shows examples of high penetration of wind and solar that have already been achieved to date. Note that a large amount of electricity storage (as a fraction of sales) has not played a part in any of these, though local storage can and has helped iron out local congestion and reliability issues in the last couple of years. The small overall role of storage so far has two causes: (i) electricity storage in batteries

[3] PJM interconnection queues can be downloaded at http://pjm.com/planning/generation-interconnection/generation-queue-active.aspx for all types of generation and for any particular type alone (e.g. wind, solar, natural gas, etc.) The data provided included project status and planned in-service dates. Typically in-service dates for utility-scale solar and wind projects extend about three or four years into the future.

has been expensive until that last year or so; (ii) large-scale electricity storage is not needed when an area with high variable penetration (up to, say, 50%) is part of a much larger grid.

Table 1: Solar and wind penetration already achieved in other U.S. states and in Denmark as a percent of sales, compared to the penetration that will be achieved through the 100% Act targets

| Region | solar + wind % | Part of a larger grid? | Size of state electrical load compared to the entire grid | Comments |
|---|---|---|---|---|
| California (achieved) | 24% in mid-2016 | Yes (Western Interconnect) | About 50% | Mix of solar and wind; driven by renewable energy targets (33% by 2020) |
| Iowa (achieved) | 44% in 2016 | Yes (MISO) | Less than 10% | Almost all wind (driven by favorable resource for jobs, revenue, and energy exports) |
| Hawaii (achieved) | 17% in 2016 | No | 100% | Mix of solar (dominant) and wind. Driven by renewable energy targets and plans. |
| Denmark (achieved) | 50% in 2015 | Yes (northern and western Europe) | Small | Almost all onshore and offshore wind. Driven by renewable energy targets (50% by 2020) and buildup of a large wind turbine export industry |
| Maryland (2025 target in the 100% Act) | 38% in 2025 | Yes (PJM) | Less than 10% | Mix of solar and wind (offshore and some onshore), in-state and imports from PJM |

Within the United States, the 100% Act target for Maryland in the mid-2020s is most comparable to the present situation in Iowa, which is a small part of the Midwestern grid, MISO. Maryland is a comparably small part of the PJM grid (less than 10%). Wind generation in Iowa was already significantly greater in 2016 (about 44%) than Maryland's 38% target for 2025. The 100% Act target of 52% for 2027 is comparable to wind energy penetration already achieved in Denmark in 2015. Denmark, like Maryland is part of a much larger grid system in Northern and Western Europe.

These are actual achievements. No speculation is required as to whether Maryland can rapidly increase its acquisition of solar and wind power as required by the 100% Act and that it can do so while maintaining reliability up to about 2025.

We now consider the period beyond 2025.

When a state, like Maryland, is a small part of the grid, the requirements of a renewable energy system beyond about 30% variable wind and solar generation will depend on what is happening in the rest of PJM. If other regions in PJM do not increase their variable generation significantly, adjustments would be needed mainly at the local level (i.e., within the state and its regions), to accommodate growing distributed solar generation, for instance. If, on the other hand, other large states like Pennsylvania, Virginia, and Ohio (which are part of PJM) also greatly increase their solar and wind generation, major adjustments to the technical, economic and regulatory arrangements will be needed.

Many of the changes that are needed go under the rubric of a "smart grid" – which is a communications system built in parallel with the electric power system. *Such a system is needed in any case to increase resilience and reliability*. With increasing distributed generation owned by consumers, who would also become producers of electricity (the so-called "prosumers") the role of regulated distribution utilities like BGE and Pepco would change.[4] Instead of mainly selling electricity they acquire from companies with large scale generation stations, they would become platforms for purveying electricity goods and services (generation, aka "electrons, voltage stability, frequency stability, etc.) provided by others, who would number in the hundreds of thousands. The business model of this "grid-of-the-future" would be very different from the one that prevails today. If done right, the change will accompany vast opportunities, including jobs, increasing resilience, and better health.

The 100% Act directs Maryland's Public Service Commission to conduct a full-scope proceeding on the grid-of-the-future, including reliability, equity, the transition from the present business model to a new one and so on. The overall purpose of the proceeding is set forth in the 100% Act is as follows:

> The Commission shall study current utility regulations and business models to determine the changes that are necessary to achieve a 100% renewable electricity system by 2035 that is reliable and resilient.[5]

A number of specific requirements for the proceeding are set forth in the 100% Act, including changing the business model of a distribution utility from mainly selling electricity to consumers via the distribution system "to serving as platform provider for distributed energy resource development and deployment, including all technical, economic, institutional, and business-model aspects that would be necessary for such a transformation."[6] Thus Maryland will be ready to proceed to 100% renewable electricity even if other states in the PJM region or the entire PJM region moves towards a 100% renewable electricity system. In fact, by acting now, Maryland can benefit from the very substantial experience so far from areas that have achieved high levels of variable renewable energy penetration, and also become a leader in setting an ambitious, achievable goal to promote jobs and prosperity in the context of climate protection.

My own detailed assessment of a 100% renewable electricity system in Maryland, including hour-by-hour modeling, showed that all the elements of a reliable, economical renewable electricity system are present. We only need to (i) set a firm course towards that goal and (ii) create at a suitable regulatory and business model to get there.[7] The 100% Act provides for both.

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[4] To a large extent, the role of merchant generation need not change in principle, though investments would have to shift from conventional resources to renewable resources.
[5] Article 7-707(B)(1)(I)
[6] Article 7-707(B)(1)(II)1.
[7] See Arjun Makhijani, *Prosperous, Renewable Maryland*. Takoma Park, Maryland: Institute for Energy and Environmental Research 2016. On the web at http://ieer.org/wp/wp-content/uploads/2016/11/RenewableMD-Roadmap-2016.pdf. This report considered renewable electricity by 2050 in the context of electrification of that vast majority of transportation and fossil fuel space and water heating. Expansion of renewable generation under the 100% Act is expected to continue after 2035 to accommodate conversion of transportation and heating to electricity, while maintaining a fully renewable electricity system.