September 30, 2021

#38 – Comments on DNRs "100% Study"

- *CARES states <u>the intent to have a net-zero carbon emissions grid</u>; a 100% clean electric power system. Maryland's overarching purpose should be climate change mitigation. Without a reliable 100% clean electric power, electrification is not a productive strategy.*
- *CEJA2019 mandates the deployment of devices. 100% clean devices is **<u>NOT</u>** the same as reliable 100% clean systems. 100% CEJA2019 would interfere with the ability eventually achieve a 100% clean system by deploying more intermittent generation than can be easily managed. Ratepayers will eventually be billed for whole system costs which, for 100% intermittent, could be 4x generation cost.*
- *While Maryland needs cold objectivity, the Exeter team demonstrated RPS bias, dismissing Calvert Cliffs using criteria that would dismiss any generation other than natural gas, and no mention of Small Modular Reactors (SMRs) or its transmission advantages (§7).*
- *The Statement of Work (SOW) exhibited little system development expertise. It would be useful to have a consultant with system development expertise and no NREL ties to rework the SOW (§5).*
- *Consider a new Phase 1. Professional staged development would be to first quantify the basic system relationships for 100% clean electric power; the optimal balance of wind, PV, baseload, and storage assuming copper plate transmission, historical load profiles, Maryland resources and a closed boundary. Details progressively added during later stages.*
- *Rational system analysis is functionally bounded (§3), that is, electrical generation must satisfy load every hour for multiple years. Analysts are forced to face the reality of managing intermittency. Beware of system configurations that assume some 3rd party (PJM) is providing free backup services.*
- *The state-of-the-art of modeling systems with intermittent generators is still academic, not investment grade. There are no industry standards or competent validation reports (§8). VCE's WisDOM:P model is proprietary with no insight to accuracy. Hidden assumptions can bias the results.*
- *There is good evidence (§9) that Maryland's minimum cost 100% clean scenarios are likely to be in the neighborhood of 25% intermittent, 75% clean reliable baseload.*
- *CARES is a more effective climate change mitigation policy than CEJA2019 because is addresses whole systems and does not arbitrarily constrain technology choices.*
- *Baseload provides basic system reliability. With the exception of SMRs, Maryland's clean baseload alternatives are poor (§6). It is in Maryland's best interest to pilot Gen-4 nuclear demonstrations to better understand cost/performance/risk, public acceptance, and innovation potential.*
- *Maryland investments must be justified. The purpose of OSW-1 and SMR pilots is to gather data. Any additional OSW-2 or Calvert Cliffs subsidy needs evidence that the technology is a useful component of a 100% clean system.*

1. 100% RPS vs 100% CARES vs 100% clean system?

Exeter proposed a policy comparison, 100% RPS (CEJA2019) vs 100% CARES. Both bills mandate the specified generation technologies such that the electricity produced by these devices equals a certain percentage of Maryland's total electrical energy consumption. 100% CEJA2019 means that the total electricity generated by the specified devices equals total Maryland electricity consumption.

CARES {§7-702.(a)(2)} states that "It is the intent of the General Assembly to: (2) reduce greenhouse gas emissions and achieve a net-zero carbon electric grid by using these resources."

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TWh/yr	CEJA2019	CARES
Solar	9.0	9.0
Wind	13.9	13.9
Tier	2.2	18.6
TBD	36.9	20.5
Total	62.0	62.0

Maryland's current electric power consumption is 62 TWh/yr. For current loads, the energy breakdown for 100% RPS (CEJA2019) and 100% CARES is presented in the adjacent table. The main difference between the two policies is that the CARES Tier category includes nuclear power and carbon capture and storage. The Federal Power Act of 1920 gives Maryland the authority to choose its own generation, and this is how Maryland politics chooses to do so.

The flaw with the policy comparison is that intermittent generation that imposes out-of-market costs (storage, transmission, curtailment) to maintain system reliability. At 100% intermittent (Fig.1), these out-of-market costs can easily be 4x generation costs. CEJA2019 takes credit for wind deployed anywhere accessible by the PJM system. This eliminates not-in-my-backyard opposition and assumes that "somebody else" will pay out-of-market costs. Modeling involves arbitrary assumptions about what other PJM States are doing. If the modeler assumes other States provide low-cost fossil fuel backup, out-of-market costs are low. If the assumption is that all States are doing the same thing as Maryland, out-of-market costs are large. All States are in the same boat and sooner or later all States will be confronted with the reality of 100% clean.

2. THE CLASSIC SYSTEM DEVELOPMENT SEQUENCE

1 Set the goal > 2 Quantify 100% options > 3 Rational choice (vision) > 4 Plan/policy/market design

Starting with Governor Hogan's goal of 100% clean electric power system (1), the next step is to quantify all imaginable reliable whole system options (2) so stakeholders can make rational choices (3). Choice is based on quantified cost, sustainability, fear, and environmental factors such as air pollution, esthetics, waste stream management, land use, life cycle impact… Step 3 is when stakeholders are free to reject nuclear, AFTER they see the numbers. Based on the chosen vision, step 4 develops a plan, a roadmap; crafts fact-based policy; designs electricity markets to provide the right incentives.

3. RATIONAL SYSTEM ANALYSIS REQUIRES DEFINED BOUNDARIES

Maryland currently imports 32 TWh/year, 37% of its annual electricity consumption, mainly from coal plants sited at coal mines in W.Va. Since a main purpose of the 100% study is to understand the relationship and proportions of intermittent and baseload assets, it is necessary to decide how to represent this boundary condition.

Other studies (RMI modeling for NJ Integrated Energy Plan) assume that PJM will import/export as required by intermittent generation. A more conservative boundary condition is functionally closed, generation and consumption must always balance, though generation need not be physically located withing Maryland geographic boundaries.

4. CONCEPT MODEL EXAMPLE: 100% CLEAN SYSTEM CONFIGURATIONS FOR THE LA BASIN

Sepulveda et.al. explained the role of clean reliable baseload in deeply decarbonized electric power systems. A clean baseload component provides basic system reliability. The outstanding question is how much baseload is necessary?

Fig.1 is adapted from a validation study we conducted of LA-100, a large NREL study of 100% renewables for the LA-basin. The chart presents system generation cost ($/MWh) as a function of % of energy delivered by generic wind/PV/baseload+storage capacity. 100% baseload is on the left, 100% wind/PV is on the right. The dotted line represents the minimum cost combination of wind + PV for a baseload CAPEX of $6.6/W, the dashed curve $4/W. The former is NREL-AB estimates for Gen 3+ nuclear. The latter is our estimate for Gen 4 SMRs based on international experience. NREL assumed ethanol combustion turbines for renewable energy baseload.

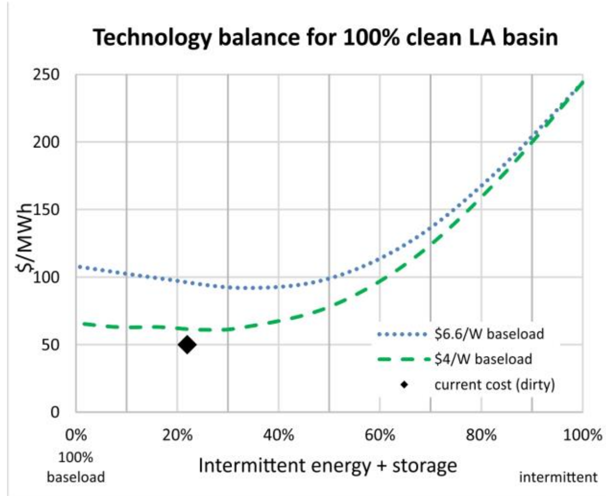

Figure 1

The most salient conclusion is that the low-cost system configurations are on the left, high baseload capacity, low intermittent generation capacity. This confirms Sepulveda, low-cost 100% clean system configurations need baseload. Minimum system generation cost occurs at about 35%/65% intermittent/baseload. Beyond 35-40% system costs hockey stick, 100% wind/PV is impractical. Another notable observation (not apparent on the chart) is that for the numbers used, wind reduced system cost only at >80% intermittent energy. Below 80%, wind always added cost and is not a useful component of a low-cost system. It is also notable that cost estimates at >50% intermittent penetration are soft, likely low, perhaps by a lot. The analysis uses NREL-ATB 2033 cost estimates for 4-hour storage. For intermittent energy scenarios >50% penetration, much longer durations would be required.

5. A PROFESSIONAL STATEMENT OF WORK (SOW)

A professional SOW would focus on the goal of 100% clean, ignore current policy, and quantify the structural relationship among the various idealized technologies. It would proceed in a sequence of phases starting with a small number of variables, adding variables and complexity, and narrowing scope at each stage.

The analysis behind Fig. 1 was a basic EXCEL spreadsheet, idealized "Copper Plate" transmission. We started with CAISO hourly wind/solar/load profiles for the years 2018-2020, scaled the CAISO load down to the LA basin. Wind/PV profiles are scaled to accurately preserve all the temporal, spatial and load correlations. For a given baseload we would matrix wind and solar to find the low-cost optimum mix for that baseload. Each combination of wind/PV/baseload capacity would define a generation cost. Each trial (takes 1-2 sec on a PC), dispatches 29,280 hours (3 years) by incrementing storage. Unit costs are based on NREL-ATB estimates for generic wind/PV/storage/baseload CY2035. Storage system cost was based on the maximum swing over the 3-year period. Fig. 1 is the product of several hundred trials each with different combinations of generic wind/PV/storage/baseload capacity. The next stage would be to constrain storage to 4 hours, then specific types of baseload & PV, then transmission…

The Exeter team proposed 20 full featured WisDOM:P model runs starting with 3 up front. With so many variables, point solutions introduce too much detail too soon. It is difficult to see the big picture, to draw generalized conclusions, such as the value of OSW.

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6. MARYLAND BASELOAD OPTIONS

Maryland's clean baseload options are nuclear, hydro, fossil fuel with carbon capture and storage (CCS), ethanol fired combustion turbines and biomass fired coal plants. Maryland has no significant new hydro opportunities. CCS is unproven regarding cost, risk of aquifer contamination and permanence. Burning biofuels to generate electricity has significant environmental impact. Replacing one moderate sized coal plant would require 109 railroad hopper cars per day.

7. DISTRIBUTED GEN IV SMALL MODULAR REACTORS (SMR)

The public needs to see Gen-4 new nuclear pilot demonstrations because much opposition to nuclear power is rooted in vague fear. Since GEN-4 power reactors don't have water moderated cores, they do not require containment domes, large exclusion zones and could eventually be distributed in industrial settings like natural gas plants today. Think of new nuclear SMRs with the dependability of refrigerators.

There are three generic classes of Gen-4 SMRs; high temperature gas reactors (HTGRs), sodium cooled reactors and molten salt. X-Energy (Gaithersburg MD) has formed a partnership to build a HTGR for Grant County, Washington and with Canada; ARC Clean Energy is building a sodium cooled reactors for Canada; TerraPower (Bill Gates) is planning a sodium reactor at a retiring coal plant in Wyoming; Moltex is working through the approval process for a molten salt reactor for Canada. An SMR pilot demonstrations would help stakeholders choose.

The maximum SMR size is ~300 MWe, similar in size to natural gas plants, about 1/6 the size of Calvert Cliffs. A 100% SMR option for Maryland would require 24, perhaps half at Calvert Cliffs, the other half integrated with Maryland distribution utilities. A 100% study should show that SMRs are compatible with rooftop PV and distributed community scale PV.

From a system design perspective, dependability is a unique feature of nuclear options. Existing PJM nuclear has forced outages of only 0.6%. This means that long distance and interregional transmission is unnecessary, transmission within the distribution utility can be reduced and systems will be more resilient than systems with undependable generators.

Cost estimates for US SMRs is uncertain due to no US data. Exeter proposes NREL-ATB nuclear CAPEX estimate of $6.3/W. This ignores international data for nuclear costs in countries with a mature industry, automated supply chains, trained workforce, experienced management, and regulators. China is building reactors under $2/W, South Korea and Japan for $2-4/W, $4/W is not an unreasonable number for a mature US industry. One reason for MD to encourage in-State SMR pilots is to gather data on cost.

8. MODEL VALIDATION

Advocate modelers can make intermittent generation appear to be more reliable than it is by averaging or smoothing generation profiles; ignoring episodic events; various assumptions of independency; and optimistic cost, performance, ageing, operation imperfections and open boundary conditions. Investors need to understand the accuracy of the analysis. Professional engineers, liable for accuracy, either base their analysis on industry standards or have validation reports certifying accuracy. Validation employs hindcasting to assign error bars to model estimates.

Today's known wind & solar performance models are still evolving academic speculations. There is no IEEE or ASME standard for system model validation. For example, NREL's ReEDS model ignores episodic events and averages (smooths) variability resulting in intermittent generation appear significantly more reliable than it really is. VCE's WisDOM:P model is proprietary with no validation report, so conclusions need to be taken with caution. Where data exists, a more conservative approach would simply be to scale historical wind/load/solar power profiles.

9. EVIDENCE FOR 25% INTERMITTENT + 75% BASELOAD

Fig.1 based on the LA-100 system model validation shows the system cost relationship between baseload and intermittent generation. An important lesson is the hockey stick nature of system costs. Intermittent generation can be integrated with little impact on total system costs up to a certain threshold. Beyond that threshold out-of-market costs (transmission, storage, curtailment) to manage intermittency drive overall system costs. For the LA basin with good PV the low-cost optimum is approximately 35% PV + 65% baseload. So where is the threshold for Maryland?

In 2012, PJM funded a renewable integration study using early models that concluded that PJM could manage up to 30% intermittent generation without excessive costs. The wind modeling for that study has been criticized as optimistic and more recent lessons learned is likely to drive that threshold down.

Another data point comes from the experience of real power grids. The adjacent table shows current penetration levels and residential retail electricity rates for several systems that are substantially bounded, little import/export. They have all encountered capacity and stability problems at approximately 20% intermittent penetration levels. Capacity and stability problems can be solved of course but at higher cost that ratepayers have been reluctant to pay, hence blackouts. There are other grids claiming higher penetration levels (e.g. Ireland, Denmark, Germany) but their neighbors currently provide substantial free backup services.

	Intermittent energy	cts/kWh
Hawaii (PV)	16%	30
ERCOT	20%	12
Australia	14%	23
California	22%	19

Based on the idea that the wind is always blowing somewhere, NREL and VCE have argued that a national long-distance transmission system solves the problem. Smith tested this concept by combining data from PJM and MISO. For 2014 PJM wind dropped below 2% of nameplate for 319 hrs, MISO wind for 89 hrs and the combination 59 hrs. Yes, the combination improved reliability but it is not a game changer.

Based on existing data a reasonable estimate for 100% clean for Maryland is <25% intermittent generation, >75% clean baseload.

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