WHITE PAPER

PEREGRINE
TURBINE TECHNOLOGIES

A Road Map to Achieving State of Maine Clean Energy Targets

A DER White Paper 8-25-21

Robert N. Brooks
rbrooks@peregrineturbine.com
Peregrine Turbine Technologies
Wiscasset, ME

ADVANCED TECHNOLOGY ENABLED DER STRATEGY AND POLICY PROPOSAL

Chief Development Officer
Bob is co-founder of Peregrine Turbine Technologies, LLC (PTT) and is serving as the Chief Business Development Officer and COO for the Company. Prior, Robert was a principal at American Capital Ltd., a Group Executive and Cooperate Officer of several diversified Industrial and consumer products companies. He has particular expertise in M & A, value creation and global supply chain development. He also served with the US Army Corps of Engineer.

LEGISLATED ME CLEAN ENERGY TARGETS:

- Provide high impact support to the State of Maine's efforts to "reduce Maine's Greenhouse Gas emissions by 45 percent by 2030 and at least 80 percent by 2050, and with achieving 80 percent renewable energy in Maine's electricity sector – specifically energy consumed in Maine – by 2030 and 100 percent by 2050".
- Significantly increase the number of permanent, Clean Energy Jobs in Maine

VISION:

Deploy Maine-developed and produced, breakthrough Clean Energy power and Energy Storage at or near the point of use that provides Maine's geographically diverse population with lowest delivered cost and and greatest resiliency.

Transmission and distribution costs and line losses account for more that 50% of the delivered cost of electricity to most Mainers. Maine's large geographic footprint and widely dispersed population make yesterdays central power grid a poor fit for the Governor's Energy Goals.

Distributed Energy Resources (DERs) with recent technology breakthrough in power generation and storage provide lower cost of delivered energy, less infrastructure, and greater resiliency are very powerful solutions and opportunities for Maine's energy future.

Peregrine Turbine Technologies' sCO2 power conversion technologies are bringing two very high impact, DER solutions not available before now. They are:

- Large Advance in Energy Storage achieved by Peregrine's sCO2 Turbine power module in conjunction with breakthrough miscibility gap alloy thermal energy storage (TES) .
  - Essentially this advanced technology TES system can provide long duration storage for solar PV and Wind power generation fields at less the 1/3 the cost of Li-Ion battery solutions, with 2 X the life, and without the expensive end-of-life reprocessing costs.
- Step function improvement in biomass power generation achieved by Peregrine's sCO2 Turbine power module in conjunction with KMW Energy's biomass conversion technology.
  - Peregrine's sCO2 enabled, Biomass Conversion technology is 1.7 to 2.7 times the efficiency of the best available steam and organic rankiin cycle (ORC) based systems.
  - The system makes biomass competitive with other mainstream fuel sources.
  - Has broad fuel type conversion capability and is an ideal fit for the 2 million tons of low grade biomass that used to be consumed by Maine's paper mills.
  - Can be efficiently produced at or near the point of use and is "dispatch-able"

Both of PTT's sCO2 enabled systems:

- Can be specifically sized for distributed power generation enabling combined heat and power (CHP) for local and regional applications that directly, and significantly, support Maine's stated goals to reduce greenhouse gas emissions, while having the additional benefits i.e.:
  - Can create new revenue streams and clean energy jobs for local municipalities
  - Can provide cost efficient infrastructure that enables greater EV utilization/market penetration
  - Create local energy micro-economies benefiting the local forestry industry and creating local jobs
  - Solves the problem of disposing of low-value biomass wood products
  - Increases energy resiliency and fuel surety at local municipal and commercial facilities
  - Provides cost competitive CHP for municipalities and businesses located in the State's cities and many towns to satisfy the Governor's Directive #13

Creation of "municipal and/or commercial power islands/clusters" operating on Maine-produced, sustainable biomass energy sources could also potentially provide:

- Support for municipally-owned charging stations for EVs and future electric bus deployment initiatives

ENERGY INFRASTRUCTURE CHANGE:
There has recently been a movement within Maine to establish State ownership and operation of the electric utilities operating within the State. While that movement did not go forward at this time, it is a keystone to bringing improved costs, resiliency and access to energy distribution within Maine.

Central to Peregrine's "Vision" for an improved Energy Infrastructure, is the establishment of Municipal or Commercial Energy Districts consisting of Power Islands/Clusters that would be provided in 1 MW increments up to a maximum of 5 MW. This would necessitate:

LEGISLATIVE AND REGULATORY PATHWAYS AND APPROVALS:
Legislative and Regulatory pathways and approvals would have to be revised and developed that would expand the current "Behind-the-Fence" power generation regulations to include broader municipal and commercial cluster deployments and enable municipal energy districts.

INCENTIVES AND CONSIDERATIONS:
Adoption of net-power legislation similar to that of roof-top-solar, would significantly accelerate the adoption of biomass enabled power islands/clusters.

BREAKTHROUGH TECHNOLOGY AND SUPPORT:
Maine-based Peregrine Turbine Technologies, LLC (Wiscasset, Maine) has developed and is approaching commercial deployment of two advanced, breakthrough power generation systems:

- A Thermal Energy Storage system that is 1/3 the cost of LI-Ion battery solutions with twice the life and none of the toxic reprocessing issues.
- An advanced biomass fueled power generation system that can operate on a wide variety of woody biomass materials and refuse derived fuels (RDF). The system is 1.7 times the efficiency of best available current biomass and steam technology systems. The system is modular, can be deployable in 1 MW increments, and operates with limited need for operator support.

The Peregrine's supercritical carbon dioxide (sCO2) enabled system is being developed and tested in conjunction with the DOE's Sandia National laboratories, the Air Force Research Laboratory (AFRL), and the Office of Naval Research (ONR) and with funding support from Maine Technology Institute (MTI), as well as over 30 private individuals and family offices. Peregrine is majority owned and operated by its' two Maine-based founders, who are committed to keeping the technology and technical and operating jobs based in Maine. Production of the TES and biomass-fired units will take place in Maine creating hundreds of high-value jobs.

Which of the Governor's Energy goals does this strategy help to achieve?

- Mitigation of greenhouse gas emissions in the State: 45% reduction by 2030, 80% by 2050
- Achieving 80 percent renewable energy in Maine's electricity sector – specifically energy consumed in Maine – by 2030 and 100 percent by 2050".
- Creation of permanent Clean Energy jobs
- Reduced costs for delivered energy and improved resilience

Describe the problem/barrier that this measure will address:

- These systems will provide for the production of heat and power at or near the point of use from Maine-grown and harvested biomass.
- Power Islands/Clusters will provide a high degree of energy resiliency and fuel surety at municipal and local commercial and institutional locations that reduce dependency on State and National power grids and imported fuels sources.
- The reduction or elimination of transmission and distribution infrastructure use offers a net reduction in "delivered" energy costs and provides a cost-effective "non-wires" alternative.
- Heat, cooling and power production can be managed at a local level in response to local demand and conditions.
- Biomass systems can offer complimentary power production to non-dispatchable renewable sources such as solar and wind.

Is there a model for this, either in Maine or in other jurisdictions?

- There are several states supporting expanded aspects of distributed power generation, but none as comprehensive as this proposal and none advantaged with the benefits and capabilities of this advanced, modular biomass system.

What are the benefits of this solution?

- Major leverage towards meeting Maine State Climate Goals
- Local power production from local sustainable fuels
- Substantial improvement in energy surety and independence for Maine communities and businesses.
- Supportive of other energy initiatives i.e. charging stations for EVs, future electric bus, wind and solar
- Contribution to local and State economy.
- Creation of high-value jobs in clean energy generation, manufacturing, engineering and business management

What are the costs?

- Developing legislative and regulatory change and supporting administrative efforts.
- Adoption Incentives
- Capital costs for infrastructure installations may be covered by energy service companies (ESCO's) which would capture part of the value stream. Otherwise, capital costs could be financed by municipalities.

What is the timeframe for implementation? Short-term, mid-term, or long-term? When does implementation begin and what is the expected duration?

- The first sCO2 enabled biomass fueled system could be available for demonstration in 2022/early 2023 with follow-on deployment presuming supporting regulatory and legislative actions.

When is the outcome realized?

- The benefits are realized immediately upon installation of each system.

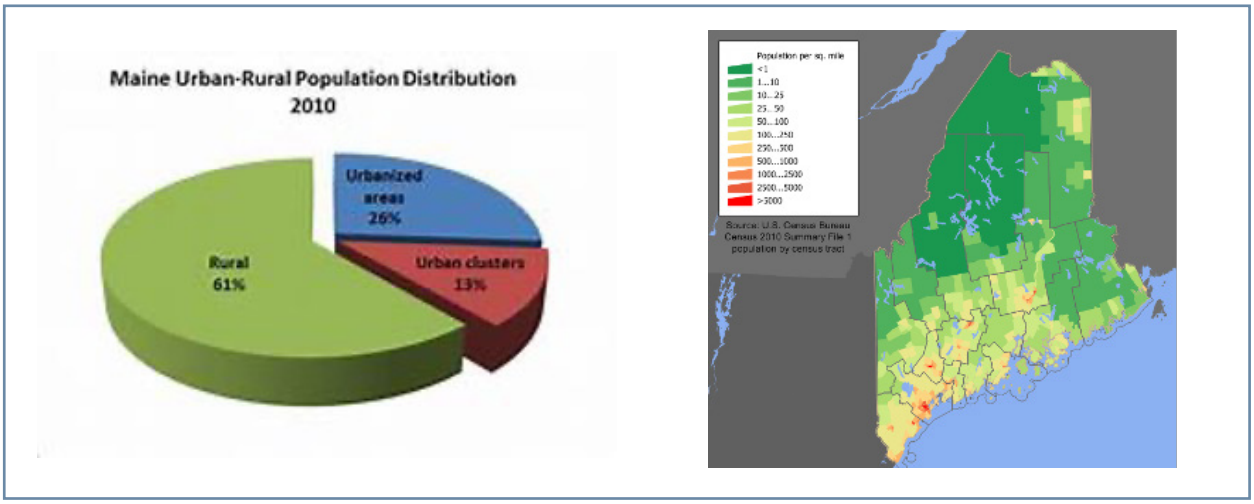
What are some Maine-specific barriers to implementation (resources, time frame, etc.)? Maine-specific advantages?

- **Barriers:**
  - The policies, legislation and regulation in place in the State of Maine were developed and implemented over the past 100+ years when central power generation and distribution was the most cost effective model. The advent of new technologies (wind, solar and now biomass) is rapidly driving a global transition from central power production, transmission and distribution to energy produced at or near the point of use (distributed energy). Central power generation is no longer the lowest cost of delivered energy and energy surety in many circumstance and in most circumstances in the State of Maine. The existing regulations and legislation relative to electric utilities regarding the procurement and distribution of power are very limiting to behind-the-fence power generation and prohibitive of the creation and operation of power islands/clusters as proposed above.
  - Existing financial and performance standards for utilities do not incentivize delivery of electricity at the lowest cost, from clean sustainable energy sources, and with the highest degree of resiliency/surety for the end consumer.
- **Advantages:**
  - Leadership - Governor Mills has set very specific energy and climate goals and deadlines for Maine that will require step-function change to accomplish. The Governor and her Energy Office possess the collective capabilities required to bring about the changes in policy, with the supporting legislation and regulation, necessary to achieve that goal.

What populations, communities, or sectors will benefit from this strategy? Who might be disadvantaged by the strategy?

- Maine's southwestern most population has the best rates power and fuel rates. Both power and fuel rates get progressively more expensive and less reliable the further the distance from there.
- From the 2010 census, Maine has a total population of 1,328,361 across 23 cites with a population of 365,157 or 27.5%.
- The State has 432 towns for a total population of 963,205 or 72.5%. Of that, there are:
  - 4 towns between 20,000 and 15,000 with a total population of 75,183
  - 6 towns between 14,999 and 10,000 with a total population of 142,154

- 21 towns between 9,999 and 6,000 with a total population of 179,685
- 62 towns between 5,999 and 3,000 with a total population of 270,414
- 94 towns between 2,999 and 1,500 with a total population of 193,459
- 64 towns between 1,499 and 1,000 with a total population of 81,203
- 1178 towns below 1,000 with a total population of 21,112



Potential Benefactors:
Potential benefactors literally include all Maine cities and 251 of Maine towns with populations above 1000, and Maine businesses and institutions with a CHP demand exceeding 1 MW.

- Towns and areas with populations below 1000 and/or with power demand below 1 MW would likely not be able to economically support the deployment of these biomass systems. The adoption of net power incentives could alter that circumstance.
- Maine Forest Products Industry

Disadvantaged:
Constituencies disadvantaged by this proposal include current utilities, fuel and service providers. Existing resources/data that could help implement this strategy:

- An empowered, committed constituency such as is the Maine Climate Council, supported by the Governor and State Legislators, the Maine PUC and the Maine Public Advocate collaborating to remove barriers and build the pathway to implementation is required.

Are there major data gaps related to this strategy?

- Local and regional thermal (heating/cooling) and electrical demand requirements, cost information broken down by municipal, commercial, and institutional on a monthly basis are significant data gaps. The utilities in Maine have this data but will not make it available to the State of private energy entities.

Modeling suggestions:

- A high-level feasibility model can be created once the information in the data gaps above is available. Lacking that, CHP examples could be modeled at the 1 MW through 5 MWe levels.

Are there rules or legislation that might help enact this strategy?

- Legislation and supporting regulatory policies will need to be designed and implemented to enable the implementation of this clean energy strategy.

POTENTIAL MW DISPLACEMENT:

Until more definitive demand and peak energy usage data is available for modeling, it is difficult to determine the potential reduction in oil and natural gas-based fuels used for heating, cooling and transportation, as well as in imported electricity. Assuming regulatory and legislative changes that enable the approach outlined are in place, the electrical displacement alone is estimated between 500 MW and 700 MW. The number could be much higher as penetration of EV's increases and drives demand. Transmission and delivery infrastructure of the current grid is not likely to support the envisioned increase and would require large capital improvements, especially in Northern parts of the state where biomass is plentiful.

POTENTIAL THERMAL (HEATING, COOLING AND TRANSPORTATION) DISPLACEMENT:

The PTT sCO2 power generation systems are CHP capable and can generate approximately 1:1 electric to thermal output. The thermal out put can be used to provide "comfort" heating and cooling or process heat for commercial and institutional applications. An application where thermal and electrical consumption are well match would yield a fuel burn efficiency approaching 90%.

OTHER COLLATERAL OPPORTUNITIES:

Maine homes are heavily dependent on imported oil for home heating fuel. Technologies are being developed to produce the equivalent of No. 2 heating fuel and engine-ready diesel fuel. Given Maine's extensive forest coverage, the State potentially could benefit from programs to encourage the development of biomass to liquid fuels industries. The liquid fuel generation systems would create off-gases and waste thermal energy that could be the energy sources (fuels) for the PTT sCO2 distributed CHP systems, thus providing an even broader opportunity for energy surety and less dependence on imported fuels.

SUMMARY:

The deployment of sCO2 enabled Thermal Energy Storage (TES)systems and biomass CHP generation systems at 1 MW – 5 MW levels in municipal, industrial and institutional applications, have the potential to displace a large portion of "imported to Maine" electricity, natural gas and oil currently consumed in Maine and provide a large portion of the "reduced carbon solution" targeted in the Governor's Energy Plan.

The development of power islands/clusters would provide additional benefits of energy surety at the local and regional level based on Maine-produced biomass, a significant market opportunity for low value Maine based biomass materials. It also would provide important support to non-dispatchable renewable energy sources like solar and wind.

Never-before available, highly efficient, modular, biomass-based energy technology will be entering the rapidly growing Distributed Energy markets at the end of 2022 and will impact energy markets around the world.

The State of Maine has the opportunity to lead the nation in the strategic deployment of these technologies to drive achievement of climate change goals in a way not previously available. Enabling the strategy will require Maine to also lead in the development and implementation of the policy, legislation and regulatory backbone required to break the current energy paradigms.