Working Document of the NPC Study:
Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources
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Paper #7-11

POWER SOLUTIONS IN THE ARCTIC

Prepared for the
Technology & Operations Subgroup

On March 27, 2015, the National Petroleum Council (NPC) in approving its report, *Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Technology & Operations Subgroup. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 46 such working documents used in the study analyses. Appendix D of the final NPC report provides a complete list of the 46 Topic Papers. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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Topic Paper (Prepared for the National Petroleum Council Study on Research to Facilitate Prudent Arctic Development)		
7-11	**Power Solutions in the Arctic**	
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SUMMARY

An opportunity exists to leverage enhanced power delivery systems used in supporting combat operations in remote Iraq and Afghanistan to improve electrical power infrastructure in the Arctic. Although diesel-electric systems remain the preferred choice due to high reliability rates, coupling generation with high efficiency micro-grid technology improves power delivery efficiency while reducing the resulting carbon footprint contained in air emissions. A combination of study work and demonstration testing is recommended to show the benefit of this alternative technology. This work could be conducted by industry and government working in partnership.

PURPOSE

This paper introduces the performance and efficiency benefits of hybrid and microgrid power solutions for remote Arctic onshore and offshore operations.

BACKGROUND/ONGOING RESEARCH

With little or no access to grid-supplied electricity, remote military, oil & gas, and construction camps rely on diesel and natural gas fueled generators to supply electrical power for drilling, pumping, HVAC, communications and hotel electrical loads. These types of activities typically have highly variable power needs based on time of day, seasonality, and scale of operations over time. Power generators must therefore be oversized for peak load demand and high load transients (or load blocks) and, as a result, operate at low average loads.

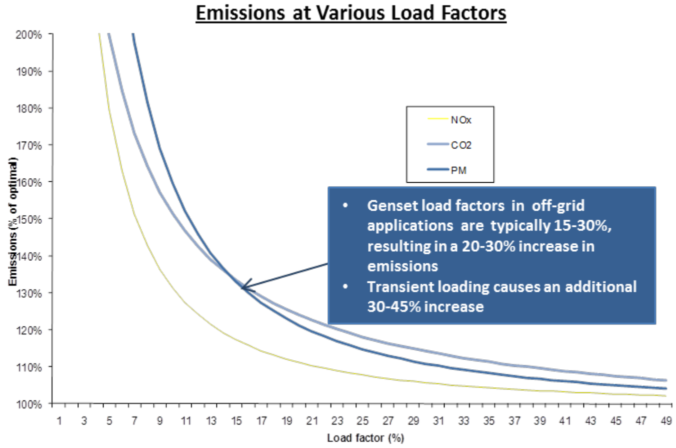
1. Internal combustion and gas turbine generator sets operating at low average loads are exponentially less efficient in three critical areas (as shown in the EPA charts below):
    a. Fuel consumption
    b. Hazardous emissions
    c. Maintenance
2. In remote operations, the cost of producing a kilowatt hour of electricity is a function of initial power generator cost (CAPEX), plus the ongoing cost of fuel, maintenance, and

environmental mitigation (OPEX). In arctic operations those OPEX costs are typically high, driven by distance, lack of transportation infrastructure, seasonal and acute weather conditions, vehicle and supply vessel availability, and environmental limitations on physical footprint and transport.

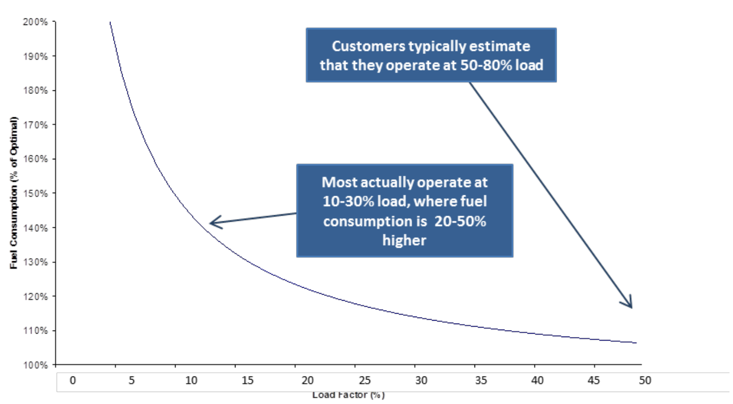
Hybrid and microgrid power technologies offer an alternative to gas diesel generator sets with potential benefits of improved efficiency and cleanliness. These technologies have advanced meaningfully in the past five years, driven by military research for battlefield applications.. Specific advances include:

a. U.S. Army (CERDEC) development of a 5 kilowatt rugged, outdoor Silicon Carbide Power Converter for Remote Power and Communications integrating lithium manganese oxide battery storage, 2014
b. U.S. Army development of a 300 kilowatt Forward Operating Base Mobile Microgrid using lithium titanate battery storage, 2013
c. Ongoing field testing of battery and ultracapacitor technology pilots in land and offshore drilling, 2014
d. North Carolina State University: Definitive Analysis of the Effects of Solid State Generation in an Islanded Microgrid to Reduce Combustion Engine Emissions, 2014
e. Two major lithium titanate battery OEM’s ongoing development of high C-rate (50+) cell design, 2014

Emissions at Various Load Factors



Generator Fuel Consumption



Source: EPA

DISCUSSION/POTENTIAL AREAS OF FURTHER RESEARCH

The most important next step in development of hybrid and microgrid power solutions for arctic operations is validating emissions reductions in coordinated field trials for two key oil & gas applications: Drilling and Camp power.

1. The NCSU study above, performed under lab conditions at a 200 kilowatt power rating, documented the following emissions reductions of EPA-regulated pollutants:
    a. NOx – 63% reduction (graph below)
    b. CO – 58% reduction (graph below)
    c. O2 – 55% reduction
    d. H2 – 52% reduction
2. These empirical results suggest that hybrid and microgrid power technology has the capability to meaningfully reduce emissions across all categories of power generation, but the data requires validation in the field under actual operating conditions and electrical load profiles.
3. Given the ongoing industry development of solutions specifically for microgrid camp power and hybrid land drilling, those two applications present the most immediate opportunities for further emissions research as well as immediate positive impact on actual operations.
    a. The same field trials could be optimized by collecting data on additional operational savings in fuel, maintenance, environmental mishaps, and power system reliability.
4. Separately, the above mentioned development of high C-rate lithium titanate battery cells is critical for offshore hybrid power applications including drilling and Dynamic Positioning (DP). These applications require both high power (2-20MW) and high energy (1-2 minute durations), but have mass, volume, and marine classification constraints. Successful cell design is the first developmental step, which must be followed by high-efficiency modularization, thermal, and mechanical packaging at the energy storage system level to enable offshore application.

RECOMMENDATION(S)

Hybrid and microgrid power systems, specifically those incorporating advanced energy storage technologies, have the opportunity to increase reliability and power quality, while reducing the fuel consumption, emissions, and maintenance of remote diesel, natural gas, and renewable power systems currently used in drilling, pressure pumping, artificial lift, camp power, and logistics operations. The net result of improved reliability and efficiency is a reduction in the environmental impact of power generation in remote arctic logistics and infrastructure. Specific recommendations include:

1. Develop and execute an emissions study of a camp power microgrid supporting arctic operations.
    a. Measure all EPA (and BOEM) regulated pollutants using exhaust sensors over a period of 1 year.
    b. Document fuel and maintenance costs compared to previous years' operations, normalized for scale.

2. Develop and execute an emissions study of a hybrid land drill rig operating in the arctic.
    a. Measure all EPA (and BOEM) regulated pollutants using exhaust sensors over a period of 1 year.
    b. Document fuel and maintenance costs compared to previous years' operations, normalized for scale.
3. Create a 2-year offshore technology development roadmap targeting pilot applications on vessels and rigs. Preliminarily, the roadmap should include high C-rate battery cell design, modularization, thermal control, mechanical packaging, marine classification, and field pilots.

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