Barge-Mounted Diesel Generators
An Attractive Alternative for Special Circumstances

Robert Bacon

Introduction
Barge-mounted diesel generators (BMDs) can represent a useful addition to the array of power generation technologies suitable for developing countries. Where they have been adopted, BMDs have proved highly successful and a relatively low-cost option with low risks for the operator. They are appropriate only for certain circumstances, however. This note introduces BMD generation by describing the technology, explaining why it may or may not be an attractive option, and highlighting cases in which it is likely to be a strong rival to more usual alternatives. Some experience with BMDs in developing countries is also reviewed.

What are BMDs?
BMDs are simply standard diesel engines and generators mounted on offshore barges. The diesels, which can be either slow-speed two-stroke or medium-speed four-stroke engines, usually operate for cost reasons on residual fuel oil supplied by barge or by road tanker. The diesels are standard units (engines are kept in stock by at least one manufacturer) that are installed and tested at the shipyard and then shipped to the site where they will operate. Units are available in a variety of sizes—from 5 MW to 50 MW—and typically several units are mounted on a single barge, so that the total generation available from a barge can be about 100 MW. The units are linked to the grid usually through a shore-based substation.

Attractive Features
BMDs have several features that make them particularly attractive in certain circumstances.

Speed of Implementation
The standardization of the technology, coupled with assembly at the shipyard and the relatively limited amount of on-site construction required (limited to the substation and fuel storage facilities if not assembled on the barge) means that an order can be filled extremely rapidly. For example, the Power Purchase Agreement (PPA) for Porto Quetzal in Guatemala was signed in January 1992 with a local company, which then sold its concession in March 1992, and the plant itself started operation in February 1993. The modularity of design also allows units (i.e., additional barges) to be added as needed to meet the expansion in system demand, thus reducing risks
from incorrect forecasts of demand. Operating and maintenance staff can be trained during the final stages of assembly in the shipyard.

**Plant Mobility**

Unlike land-based plants, the project sponsor can repossess a BMD plant in the case of default and move it to another site (although the project would still have sunk costs of other fittings and costs of disconnection). This mobility is a particularly attractive feature for private-sector financing; the contract could be accepted and the plant ordered even before local financing is in place, since the plant could be shipped to a different site if the project were not finalized. The plant could also begin operation at one site and later be moved to another site.

**Costs**

Experience with BMD plants suggests that capital costs are similar to equivalent land-based diesels and that BMDs are competitive with other forms of generation using the same fuel for outputs between 30 and 100 MW. The costs of such plants inevitably vary; medium-speed engines tend to be less expensive to purchase than slow-speed engines. The prices for power from BMDs lie within the 6 to 9 US¢/kWh range, depending largely on plant utilization and fuel prices. The prices for power are thus below those for steam-based plants using heavy fuel oil, reflecting the greater fuel efficiency of diesels.

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**The Price of Power from BMDs**

Porto Quetzal in Guatemala, which started operation in 1993, had a direct project cost of US$745/ kW, which is about the level for an equivalent land-based diesel plant. The price of power generated is about 6 US¢/kWh over the project lifetime, which is competitive with the country's long-run marginal cost of generating power. The private-sector 90 MW Calaca Batangas barges in the Philippines, which came into operation in 1993, had a project cost of US$867/kW and generate power at between 7 and 8 US¢/kWh.

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**Reliability**

Reliability of BMDs tends to be very high—a privately operated plant in the Dominican Republic has operated at 90% availability over a three year period. However, achieving this performance requires regular and correct maintenance. This is normally accomplished by giving a 5- or 10-year service contract to an experienced contractor. For a medium-speed plant, with expected operation at 75% availability, major rehabilitation every 35,000 hours of operation (5 to 6 years), as well as minor routine maintenance, is required to reach an expected total life expectancy of 100,000 hours.

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**Rockfort's Performance Record**

The Jamaican low-speed diesel, now in its 11th year of operation, has operated at a thermal efficiency of 39% and is the lowest-cost plant on its system. It supplies baseload, has had a forced outage rate of nearly 7%, and an average scheduled outage of nearly 8% over a four-year period. A rehabilitation and improvement program has recently reduced the normal maximum output to 18 MW per unit from 20 MW, and availability has increased to over 90%, with the total expected life of the station now set at 30 years.

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**Site Location**

The use of barges to mount the diesels increases the number of potential sites for locating generating plants in countries that have access to the sea. Small islands, or areas where population is concentrated on a coastal strip, may not have many
suitable new sites for generation so the use of an existing harbor site may be the least problematic. In a few cases, BMDs have been used up-river but this is only likely to be economically attractive when fuel supplies are also available at the up-river sites. The use of a barge pond, or lagoon, to protect the barge from the effects of storms, has proved very effective in Jamaica, where a BMD plant survived a severe hurricane without any detriment to performance.

Table 1: Selected International Experience with Barge-Mounted Diesel Power Plants

<table>
<thead>
<tr>
<th>Plant name</th>
<th>Capacity</th>
<th>Type</th>
<th>Year of commissioning</th>
<th>Owner</th>
<th>Average price (US$/kWh)</th>
<th>Contract type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jamaica</td>
<td></td>
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<tr>
<td>Rockfort</td>
<td>2 x 20 MW</td>
<td>Low-speed units</td>
<td>1985</td>
<td>Jamaican National Power Company</td>
<td>7 to 8</td>
<td></td>
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<tr>
<td>Old Harbour</td>
<td>8 x 9.5 MW</td>
<td>Medium-speed units</td>
<td>1995</td>
<td>Wartsila of Finland with PPA with JPSC</td>
<td>8 to 10</td>
<td>BOO</td>
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<tr>
<td>Philippines</td>
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<tr>
<td>Calaca Far East Barges</td>
<td>90 MW</td>
<td>n.a.</td>
<td>1993</td>
<td>National Power Company (NPC)</td>
<td>7.2 to 7.4</td>
<td>BOT</td>
</tr>
<tr>
<td>Mindanao Power Barges I and II</td>
<td>4 x 50 MW (Two barges)</td>
<td>Two-stroke low-speed unit</td>
<td>1994</td>
<td>National Power Company (NPC)</td>
<td>N/A</td>
<td>BTO</td>
</tr>
<tr>
<td>Calaca Batangas Barges</td>
<td>90 MW</td>
<td>n.a.</td>
<td>1993</td>
<td>Far East Levingston, Singapore</td>
<td>4.5 (not incl. of fuel cost) at 70% plant utilisation</td>
<td>Lease</td>
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<td>Tacoma Island, Delpan</td>
<td>105 MW</td>
<td>n.a.</td>
<td>1994</td>
<td>Sabah Shipyard, Malaysia</td>
<td>2.4 (not incl. of fuel cost) at 70% plant utilisation</td>
<td>Lease</td>
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<tr>
<td>Guatemala</td>
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<tr>
<td>Porto Quetzal</td>
<td>20 x 5.5 MW (Two barges)</td>
<td>Medium-speed units</td>
<td>1993</td>
<td>Private company with PPA with EEGSA</td>
<td>6 (at 80% plant utilization)</td>
<td>BOO</td>
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<tr>
<td>Dominican Republic</td>
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<td>Sto. Domingo (Estrella del Norte)</td>
<td>5 x 6.36 MW</td>
<td>Medium-speed units</td>
<td>1991</td>
<td>Private company with PPA with CDE</td>
<td>8.7 (at 76% plant utilization)</td>
<td>BOO</td>
</tr>
<tr>
<td>Puerto Plata (La Isabela)</td>
<td>9 x 5.7 MW</td>
<td>Medium-speed units</td>
<td>1994</td>
<td>Private company with PPA with CDE</td>
<td>7</td>
<td>BOO</td>
</tr>
</tbody>
</table>

a The prices given are estimates; actual prices may vary due to terms in the Power Purchase Agreements relating to fuel prices, inflation, taxes, plant utilization, and mooring fees.

b BOT: Build-Operate-Transfer; BOO: Build-Own-Operate; BTO: Build-Transfer-Operate.
Private Sector Involvement

The characteristics of BMDs result in low risks to the generator and mean that they are particularly attractive to private sector financing. BMDs are in fact privately owned with only a few exceptions – Rockfort diesel is publicly owned by the Jamaican Public Service Company, and some of the projects in the Philippines are Build-Transfer-Operate (BTO) schemes. In the case of one of the Dominican Republic projects, the initial PPA was for a 36-month period, thereafter to be renegotiated, which suggests that the private producer felt that the project was sufficiently low in risk to offset the need for a long term contract.

Possible Problems

Certain features of BMDs can reduce their attractiveness and must be taken into account in assessing their potentiality.

Maintenance

Given the high level of availability expected from any diesel plant, maintenance is especially important. The limited space available on board the barges makes maintenance more difficult and it is necessary to ensure that local staff are trained to carry out such procedures efficiently under the engine supplier’s supervision. Alternatively, it may be necessary to contract out maintenance to experienced foreign firms (this has occurred in the Dominican Republic and in the Philippines).

Environmental Issues

Although the use of barges avoids damage to land sites when few environmentally insensitive sites are available, locating and operating a generating station in a harbor may have environmental implications. BMDs may raise specific environmental concerns, in addition to those attached to any diesel generator, such as: oil spills, sewage and other waste disposal, discharge of heated water used for cooling, and noise and atmospheric emissions.

Environmental Impact of Rockfort

A detailed environmental assessment of the operation of the Jamaican Rockfort project was carried out that found that emissions were within World Bank guidelines, except for NOx where a direct comparison could not be made since the Bank standards were based on steam units. There was no evidence that fish stocks in the locality had been affected by the cooling water, which is taken from the harbor and then discharged into the barge pond. The barge pond also contained accidental spills and discharges. Monitoring for oil leaks and discharges was recommended, as is usual in any environmentally sensitive area.

Links to the Grid

The attractiveness of BMDs depends on their proximity to the existing system. If the harbor is remote from the transmission system or an isolated center of demand, constructing the extra transmission line can raise project costs substantially.

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