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Puerto Rico Task Force
*via email: prtaskforce@mail.house.gov*

Ladies and Gentlemen:

The need to provide a cheap and reliable power system to Puerto Rico is undeniable. The island needs modern power plants with a reliable distribution system. It appears that two major plants on the south coast could barely suffice. But, we currently have no interconnection capability. Our system is larger than that of any nearby island, including Cuba, yet we are shackled by the seas. Some have proposed delivering electric power to Puerto Rico from Florida via a submarine cable, yet a cable from Florida to Puerto Rico is not presently a viable solution for the problem. The basis for my conclusion is that such an underwater HVDC cable transporting about 2,000 megawatts of power over a very long distance has not yet been built. Construction costs would be predictably quite large, and maintenance costs are difficult to ascertain.

Electrical power could be brought to Puerto Rico and indeed the entire Caribbean from the US mainland via Miami, connecting all the islands. This would help solve Puerto Rico's current problems. Development of the island's economy would be promoted with a safe and reliable, and inexpensive, power supply. In addition to promoting the development, health and welfare of over three million US citizens, similar benefits could accrue to the entire Caribbean region. The urge to immigrate into the US would be greatly reduced by development of the Caribbean area.

The possibility of island hopping with a power cable has previously been presented (e.g. World Bank 2011 report). It would be an excellent technical solution if costs including uncertainty are shown to be reasonable and if political issues can be resolved. Instead of relying on long underwater cable runs, it is relatively easy to connect Cuba, then Hispaniola and Puerto Rico. To estimate the

costs of a future Caribbean grid anchored by Puerto Rico and Florida, I specified a potential route as follows:

| Route | Distance (kilometers) | Above ground or submarine |
|---|---|---|
| Miami to Key Largo, Florida | 109 | Land |
| Key Largo to Matanzas, Cuba | 258 | Underwater |
| Matanzas to Baracoa, Cuba | 946 | Land |
| Baracoa to Cabo Maisí, Cuba | 63 | Land |
| Cabo Maisí to Jean Rabel, Haiti | 108 | Underwater |
| Jean Rabel to Punta Cana, DR | 702 | Land |
| Punta Cana to Cabo Rojo, PR | 142 | Underwater |
| Cabo Rojo to Guayanilla, PR | 52 | Land |

The total length of the route is 2,380 kilometers (1,488 miles). The submarine portion would be 508 kilometers long (318 miles), versus an all-water route measuring 1660 kilometers or 1035 miles from Key Largo to Guayanilla. The overland portion would use transmission towers and very high voltages such as 300 or 500 kilovolts. The estimated cost of this overland route is detailed below (The cost of converter stations is not included):

- 2,380 kilometers of transmission lines at $245,000/kilometer [1], times 1.1 inflation, times 1.5 uncertainty factor, approximately ..... $962,000,000
- 508 kilometers of submarine power cable at $6,200,000/kilometer (from attached table using average unit costs) ..... $3,150,000,000

Approximate total cost ..... $4,112,000,000, say $4.1 billion

Could we build a cable across Cuba? This might be the easiest part of this exercise. Would we be able to reach the necessary agreements? Consider the facts. Cuba's installed capacity is about 6,500 mW (International Energy Statistics, *eia.com*) on an island of almost 12 million people whereas Puerto Rico's (with less than 4 million) is 5,600 mW (*eia.com*). Clearly, development in Cuba

[1] This estimated cost of overhead 138 kV transmission lines is given in "Underground Electric Transmission Lines", Wisconsin Public Service Commission, 2011. The paper states that underground lines are 4 to 14 times more expensive than overhead lines.

must occur [2]. A high-voltage cable from Florida would undoubtedly be attractive to Cuba since it would provide them with additional power and spur their development. Cuba, Haiti and the Dominican Republic would connect into the vast eastern US network as part of this connection to Puerto Rico. This solution would promote economic development and could lower the usual tensions in stagnant island economies. It would also reduce the migratory urge into the US from these locations. But, less electric power would reach Puerto Rico.

The viability of this idea to solve our crisis would also depend on the amount of power transmitted to the ultimate customer, Puerto Rico. What percentage of Puerto Rico's peak demand (currently near 3,300 megawatts) could this connection manage? Would the cable support power levels of 1,000 or 2,000 megawatts? How much power would finally reach Puerto Rico from Florida and how much would we want to buy? The over-island route that costs $4 billion is still quite expensive, and probably not immediately possible due to still-fragile Cuban-American relations.

Does the state of Florida (with 11 investor-owned and municipal utilities) have sufficient power to enter into long-term supply agreements? The Florida-installed net summer capacity is 59,000 megawatts (*eia.gov/electricity/state/florida*) whereas the projected summer and winter peak demands are 46,000 to 49,000 megawatts (*Review of Ten Year Site Plans for Florida's Electric Utilities, Public Service Commission, 2013*); the Florida Public Service Commission requires 15 to 20 percent reserve margins over installed capacities from these utilities, so it is not clear that the Florida utilities have power to spare. Clearly, there are many questions that should be answered in order to formally consult with cable manufacturers and installers regarding probable costs.

To solve the Puerto Rico energy crisis, there are other courses of action that are much more attractive and sensible at this moment. Perhaps this would be the moment to retire, once and for all, the San Juan and Palo Seco Steam plants and bring power with new transmission lines from upgraded plants on the south side of Puerto Rico. The San Juan Steam Plant location and the existing port facilities could eventually be part of an ambitious urban redevelopment program similar to what the Spaniards did in Barcelona for the 1992 Olympics: a city that looked inward was redirected towards the sea. With investment and upgrading of the south Puerto Rico power locations, and with new more-efficient

[2] The EIA gives a value of 6,500 mW. The Cuban National Statistics Office gives a value of 5,914 mW for 2011. See *www.one.cu*, Anuario estadístico de Cuba 2011, Table 10.18.

transmission lines laid northwards, improved new generation facilities together with new transmission and distribution systems will surely help in the solution of our energy crisis.

A stable power supply in Puerto Rico is essential to the island's development. Improvements on the island could also favorably affect the surrounding islands. Puerto Rico could achieve a stable interconnected system, and could further supply power to the islands lying further east and south. A regional development system would surely increase US influence and promote development of the region under free-market scenarios.

A properly-funded Caribbean Power Company could bring power to Puerto Rico while bringing power to at least three nations along the route. Strong congressional support would be necessary, and such support cannot be currently expected for many reasons. But, it is an idea that could be useful in the future, so I present my thoughts to the task force for their consideration.

Respectfully submitted,

Alan R. Crumley, PE

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**Some data copied from Caribbean Business, with additions/corrections**

26-Jun-14

**Table 1.** Worldwide list of noteworthy HVDC submarine cable projects (likely not a complete list), following previous list by Caribbean Business  Miami-San Juan = 1,033 miles

| Number | Name | Location | Comments | Energy Capacity | Underwater Length | Dates Built | Cost (n/a = not available, not found) |
|---|---|---|---|---|---|---|---|
| 1 | HVDC Gotland | Sweden to Gotland island, Baltic Sea | First commercial HVDC line Decomissioned 1986 | 30 mW (originally 20) | 61 miles | 1954 | n/a |
| 2 | SACOI | HVDC to Sardinia and Corsica | | 300 mW | 65 mi Italy to Corsica, 10 miles Corsica to Sardinia | 1968 upgraded 1992 | n/a |
| 3 | British Columbia | British Columbia to Vancouver Island | Submarine HVDC lines from 1968 near end of operating life, being replaced by three-phase AC lines | 300 mW | 21 miles (total, two sections) | 1968 | n/a |
| 4 | HVDC Inter Island | Connects south & north islands of New Zealand across Cook Strait | Decomissioned 2012 | 600 mW | 25 miles | 1965 | n/a |
| 5 | Cross-Skagerrac | Norway to Denmark | | 1050 mW | 79 miles | 1977 | n/a |
| 6 | HVDC Gotland 2 | Sweden to Gotland island | Similar situation as project #1 | 130 mW | 61 miles | 1983 | n/a |
| 7 | HVDC Cross-Channel | England to France | World's largest capacity undersea cable | 2,000 mW | 45 miles | 1986 | n/a |
| 8 | HVDC Gotland 3 | Sweden to Gotland island | Similar situation as project #1 | 130 mW | 61 miles | 1987 | |
| 9 | Konti-Skan | Kontek HVDC Sweden to Denmark | Across Baltic Sea | 300 mW | 14 miles | 1988 | n/a |
| 10 | Fenno-Skan | Sweden to Finland across Baltic Sea | Danebo Sweden to Rauma Finland Gulf of Bothnia | 500 mW | 145 miles | 1989 upgraded 2013 | n/a |
| 11 | HVDC Inter Island 2 | New Zealand across Cook Strait | | 500 mW | 25 miles | 1992 | n/a |
| 12 | SACOI 2 | HVDC Sardinia Corsica | | 300 mW | 66 miles | 1992 | n/a |
| 13 | Baltic Cable HVDC | Germany to Sweden | | 600 mW | 160 miles | 1994 | n/a |
| 14 | Kontec | Germany to Denmark (Zealand) | Beneath Baltic Sea | 600 mW | 32 miles | 1995 | n/a |
| 15 | HVDC Leyte | Leyte to Luzon, Phillipines (beneath San Bernardino Strait) | Phillipines | 440 mW | 280 miles total 13 miles underwater | 1998 | n/a |
| 16 | Kii Channel (repeated twice on the CB list) | Japan Shikoku to Kihoku, Honshu | Formerly largest capacity system in the world | 1,400 mW | Entire project includes two 31-mile underwater segments | 2000 | n/a |
| 17 | SwePol | Poland to Sweden | Beneath Baltic Sea | 600 mW | 158 miles | 2000 | n/a |
| 18 | HVDC Italy to Greece | Italy to Greece across Adriatic Sea | At one time deepest underwater power cable | 500 mW | 99 miles | 2001 | n/a |
| 19 | Moyle Interconnector EirGrid | Ireland to Scotland | Completed 2001, then out of service due to faulting, then (2012) partially back | 500 mW | 34 miles | 2001 | Repairs to be completed 2016 or 2017 |
| 20 | Cross Sound Cable | Long Island, New York to New Haven, Connecticut | | 330 mW | 25 miles | 2003 | sold 2006 $213m |
| 21 | Estlink | Estonia to Finland | Across Gulf of Finland | 350 mW | 65 miles, 46 miles underwater | 2006 | $150m |
| 22 | Basslink Victoria | Australia, Victoria to Tasmania | Bass Strait | 500 mW | 230 miles (in two segments) | 2006 | $470m projected, cost $750m |
| 23 | Neptune Cable | New Jersey to Long Island New York | | 660 mW | 65 miles | 2007 | $600m |
| 24 | NorNed | Norway to Netherlands, North Sea | World's longest high voltage undersea cable, according to Caribbean Business | 700 mW | 360 miles | 2008 | $750 budgeted, $815 actual |
| 25 | Trans Bay | San Francisco, California | Beneath San Francisco Bay | 400 mW | 52 miles | 2009 | $400 million |
| 26 | SAPEI | HVDC from Sardinia to Latina, south of Rome | Deepest undersea cable in the world, depth of 5,400 feet. 2006 launched for design, 2011 completed | 1,000 mW | 260 miles | 2011 | $990 million |
| 27 | Fenno-Skan 2 | Sweden to Finland | Damaged 2012, repair cost $105 million | 800 mW | 125 miles | 2011 | $195 million |
| 28 | BritNed | Netherlands to United Kingdom North Sea | | 1000 mW | 160 miles | 2011 | $820m |
| 29 | Fenno-Skan 2 | | | 800 mW | 125 + 64 miles | 2011 | n/a |
| 30 | EW1 East-West Interconnector | Ireland to Wales, Irish Sea | | 350 mW | 84 miles | 2012 | $600m |
| 31 | HVDC Inter Island 3 | New Zealand across Cook Strait | | 735 mW | 25 miles | 2013 | n/a |
| 31 | Germany | North Germany to Heligoland | Various connections | 800 mW | 30 miles | 2014 | n/a |
| 32 | Proposed new: IceLink | Geothermal power from Iceland to Britain | Under discussion, possibly completed by 2022 | 700 to 1000 mW (could go to 1,000) | 930 miles | **Proposed** | $7.3 bn acc to The Guardian |
| 33 | Proposed new: Euro Asia Connector | Israel, Cyprus to Greece | When built, deepest ocean cable at depth of 6,500 feet | 2,000 mW | 620 miles | **Proposed** | $2bn |
| 34 | Proposed new: Champlain Hudson Express | Montreal to New York city along Lake Champlain and Hudson River | | 1,000 mW | 335 miles, assumed 308 miles within New York | **Proposed** | $2.2 billion for the portion in the state of New York |
| 35 | Proposed new: Atlantic Wind Connection | Virginia, Delaware, New Jersey and New York | | 3000 mW | 350 miles | **Proposed** start construction 2016 | $1.7 billion, first 170 mile phase $5 billion, remaining 180 miles, second phase |
| 36 | Proposed new: Newfoundland, Labrador and Nova Scotia | Canada | | 500 mW | 102 miles | **Proposed** Construction begins 2014 | $240 m |
| 37 | Proposed new: NordBalt | Baltic Sea, connecting Klaipeda, Lithuainia and Nybro, Sweden | | 700 mW | 280 miles | **Proposed** Construction began 2014 To be completed 2015 | $790 m |
| 38 | Proposed new: Juan de Fuca Crossing | British Columbia to Washington | Below channel, to be installed under seabed using Horizontal Directional Drilling | 550 mW | 22 miles | **Proposed** | $500 million as of December 2013 Awaiting financial closure, 2105 |
| 39 | Proposed new: Nordlink | Norway to Germany Baltic Sea | | 1,400 mW | 370 miles | **Proposed** To be complete 2018 | $2.0 to 2.7 billion |
| 40 | Proposed new: HVDC Norway-UK | UK to Norway, North Sea | | 1,400 mW | 442 miles | **Proposed** Expected complete 2020 | $2 billion |
| 41 | Proposed new: Hawaii Power Bridge | NextGrid Interconnection Oahu-Maui | | 200 mW | 116 miles | **Proposed** | $553 to $963 million |
| 42 | Proposed new: HVDC Italy - Montenegro | Proposed, awaiting permits Villanova, Italy to Tivat, Montenegro | | 1,000 mW | 259 miles total | **Proposed** 2010 Interim agreement | $1,030 million |
| - | *Isle of Man Interconnector* | *Isle of Man to England beneath Irish Sea* | *Longest underwater AC cable in the world - presented for sake of comparison with DC* | *40 mW* | *65 miles* | *2000* | *n/a - AC transmission cable, for information* |

See "List of HVDC projects" in Wikipedia for more complete list. Also see Wikipedia "Submarine Cables".

The most complete list that I found is at  www.ece.uidaho.edu/hvdcfacts/Projects/March2012_HVDC_Projects _List.

**Alan R. Crumley, PE**

**Some data copied from Caribbean Business, with many additions/corrections**

26-Jun-14

**Table 2.** From worldwide list of noteworthy HVDC submarine cable projects, E >= 500 mW, L>= 230 miles

| Number | Name | Location | Comments | Energy Capacity | Underwater Length | Dates Built | Cost (n/a = not available, not found) | Apparent unit cost $million/mile | Projected cost, $m Florida to PR |
|---|---|---|---|---|---|---|---|---|---|
| 22 | Basslink Victoria | Australia, Victoria to Tasmania | Bass Strait | 500 mW | 230 miles (in two segments) | 2006 | $470m projected, cost $750m | $3.3 | $3,368 |
| 24 | NorNed | Norway to Netherlands, North Sea | World's longest high voltage undersea cable, according to Caribbean Business | 700 mW | 360 miles | 2008 | $750 budgeted, $815 actual | $2.3 | $2,339 |
| 26 | SAPEI | HVDC from Sardinia to Latina, south of Rome | Deepest undersea cable in the world, depth of 5,400 feet. 2006 launched for | 1,000 mW | 260 miles | 2011 | $990 million | $3.8 | $3,933 |
| 32 | Proposed new: IceLink | Geothermal power from Iceland to Britain | Under discussion, possibly completed by 2022 | 700 to 1000 mW (could go to 1,000) | 930 miles | **Proposed** | $7.3 bn acc to The Guardian | $7.8 | $8,108 |
| 33 | Proposed new: Euro Asia Connector | Israel, Cyprus to Greece | When built, deepest ocean cable at depth of 6,500 feet | 2,000 mW | 620 miles | **Proposed** | $2bn | $3.2 | $3,332 |
| 34 | Proposed new: Champlain Hudson Express | Montreal to New York city along Lake Champlain and Hudson River | | 1,000 mW | 335 miles, assumed 308 miles within New York | **Proposed** | $2.2 billion for the portion in the state of New York | $7.1 | $7,379 |
| 35 | Proposed new: Atlantic Wind Connection | Virginia, Delaware, New Jersey and New York | | 3000 mW | 350 miles | **Proposed** start construction 2016 | $1.7 billion, first 170 mile phase $5 billion, remaining 180 miles, second phase | $19.1 | $19,775 |
| 37 | Proposed new: NordBalt | Baltic Sea, connecting Klaipeda, Lithuainia and Nybro, Sweden | | 700 mW | 280 miles | **Proposed** Construction began 2014 To be completed 2015 | $790 m | $2.8 | $2,915 |
| 39 | Proposed new: Nordlink | Norway to Germany Baltic Sea | | 1,400 mW | 370 miles | **Proposed** To be complete 2018 | $2.0 to 2.7 billion | $6.4 | $6,561 |
| 40 | UK to Norway HVDC Norway-UK | North Sea | | 1,400 mW | 442 miles | **Proposed** Expected complete 2020 | $2 billion | $4.5 | $4,674 |
| 42 | Proposed new: HVDC Italy - Montenegro | Proposed, runs from Villanova, Italy to Tivat, Montenegro | Awaiting permits | 1,000 mW | 259 miles total | **Proposed** 2010 Interim agreement | $1,030 million | $4.0 | $4,108 |
| See "List of HVDC projects" in Wikipedia for more complete list. Also see Wikipedia "Submarine Cables". | | | | | | | Excluding four highest costs above, average is: | | $3,524 |

The most complete list that I found is at www.ece.uidaho.edu/hvdcfacts/Projects/March2012_HVDC_Projects _List.