Docket No. 11-IEP-1, Revised Committee Scoping Order
Comments by PODenergy, Inc.

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The Energy Commission should be aware of alternative clean energy resources identified after the December 2009 Integrated Energy Policy Report (IEPR). Specifically, the 2011 update of the IEPR should include three late-breaking developments addressing means to exceed the Governor's goal for 8,000 megawatts of large-scale renewable electricity while reducing the need for energy storage and long new transmission corridors.

PODenergy can provide more details or edited text on request.

Offshore Geothermal Potential more than 10,000 MW

University of California scientists and engineers have recently recognized the potential for more than 10,000 MW of sustainable low-cost geothermal electricity generation from offshore California. Low-cost means less than $100/MWh within 100 miles of California's coastal cities. The potential for offshore geothermal energy is unique to California because of offshore California has young ocean crust rock close to population centers.

Offshore geothermal projects do not impact fresh water resources or cause objectionable seismicity. Indeed, terrestrial geothermal projects can deplete fresh water used for cooling and to replace heat-harvesting fluids, and possibly leak salty and polluted water into fresh water aquifers. Hydrofracturing for enhanced geothermal production introduces many more risks for fresh water and seismic impacts.

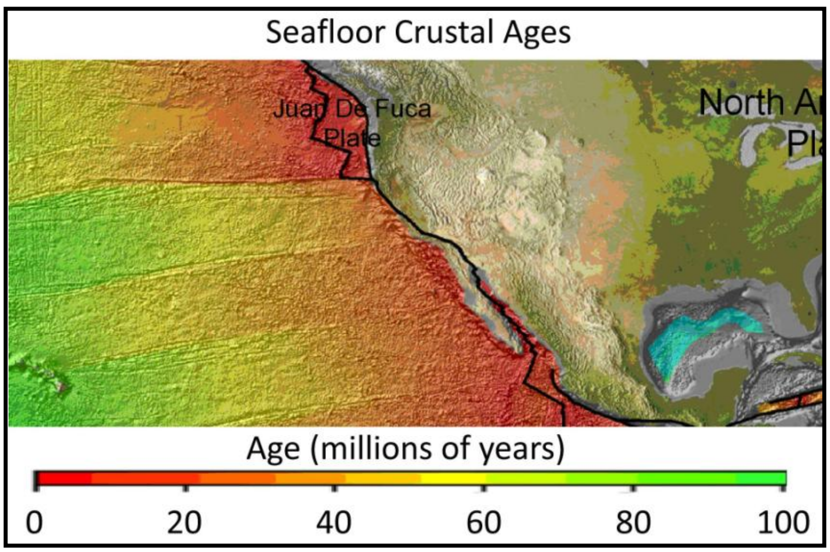

Figure 1. Sub-seafloor crustal age

Figure 1 shows 10 – 20 million-year-old seafloor off California. The upper ~1 kilometer of this young (< 20 million years old) oceanic crust is highly fractured and permeable. It can supply abundant lithospheric heat. Natural seismicity resulting from plate movement acts to keep crustal permeability high. The fractured crust is particularly hot (200-500ºC) where it has been insulated by a few hundred meters of low-permeability sediments.

The PODenergy team geophysicists estimate California's offshore thermal resource may sustain over 100 GW of electricity without hydrofracturing and with relatively shallow sub-seafloor drilling (or no drilling at natural vents).

Offshore geothermal energy takes full advantage of the ocean's renewing heat sink, with a steady supply of 50 – 300ºC fluid, plus the cool ocean water as heat sink. 98% of the world's water is ocean salt water, most of which is less than 10ºC. Using the ocean heat sink has no impact on fresh water supplies.

There are new potential issues when geothermal activities move offshore, which will be addressed with research and development, including: how to avoid causing subsea landslides and associated tsunamis, noise in air or water, avoiding the warming of hydrates, visibility, interference with human fishing and transportation activities, potential vertical currents moving nutrients and associated biologic effects, local changes in turbidity and sedimentation, and the paths and effects of escaped heat harvesting or working fluids. All these potential impacts will be minimal and mitigatable.

Offshore geothermal energy can be developed with higher standards of environmental stewardship than terrestrial geothermal energy for the primary reason that it leaves the earth's fresh water undisturbed. Also, improved energy density due to ocean properties and large ambient-pressure heat exchangers help keep the density of the warmed water below the density of warm ocean surface waters. This avoids the possibility of moving deep-water nutrients to the surface.

The 3-dimensional nature of the ocean allows a higher standard of environmental stewardship than is available on land. The terrestrial environment is nearly 2-dimensional,[insert comma] with virtually all the life within 10 meters of the earth's surface. Even the flying creatures are generally within the height of horizontal axis wind turbines. Terrestrial human development generally has a negative effect on natural habitat and other species. However, much of an offshore facility can be submerged suspended and increase habitat surface.

Geothermal-gas hybrids with carbon capture can provide efficiency above 50%

We can obtain nearly 3 times more renewable energy from a given geothermal resource with hybrid power plants. This is because the efficiency of an energy-generation[insert hyphen] process improves with higher temperatures. For example, a pure geothermal-to-electricity process with 200ºC geothermal fluid will operate at less than 20% efficiency. However, employing natural gas to raise the process temperature above 1,200C can provide efficiency above 50%. The net result is reduced geothermal energy extraction environmental impacts per MWh of geothermal energy.

There are also fewer environmental impacts per MWh from the natural gas because of the geothermal energy hybrid combination.

Because a combustion-geothermal hybrid would be more (geothermal) efficient, it is likely to be more economical than the U.S. Department of Energy goal of $100 per MWh. Also, a California company, Clean Energy Systems, has developed an engine which is particularly suited to hybrid operation with geothermal resources and can operate without CO_2 (or other) emissions, making the burning of natural gas carbon free.

Hybrid geothermal-gas power plants may involve terrestrial and offshore geothermal resources.

Ocean Biomass can provide abundant biomethane plus carbon sequestration

PODenergy proposes the simple and natural ecosystem shown in Figure 1 to process algae into separate streams of methane or hydrogen, carbon dioxide, and plant growth nutrients at high pressures between 10 – 60 bar. (10-bar ~ 10 atmosphere ~ 150 psi ~ 100 meters of seawater).

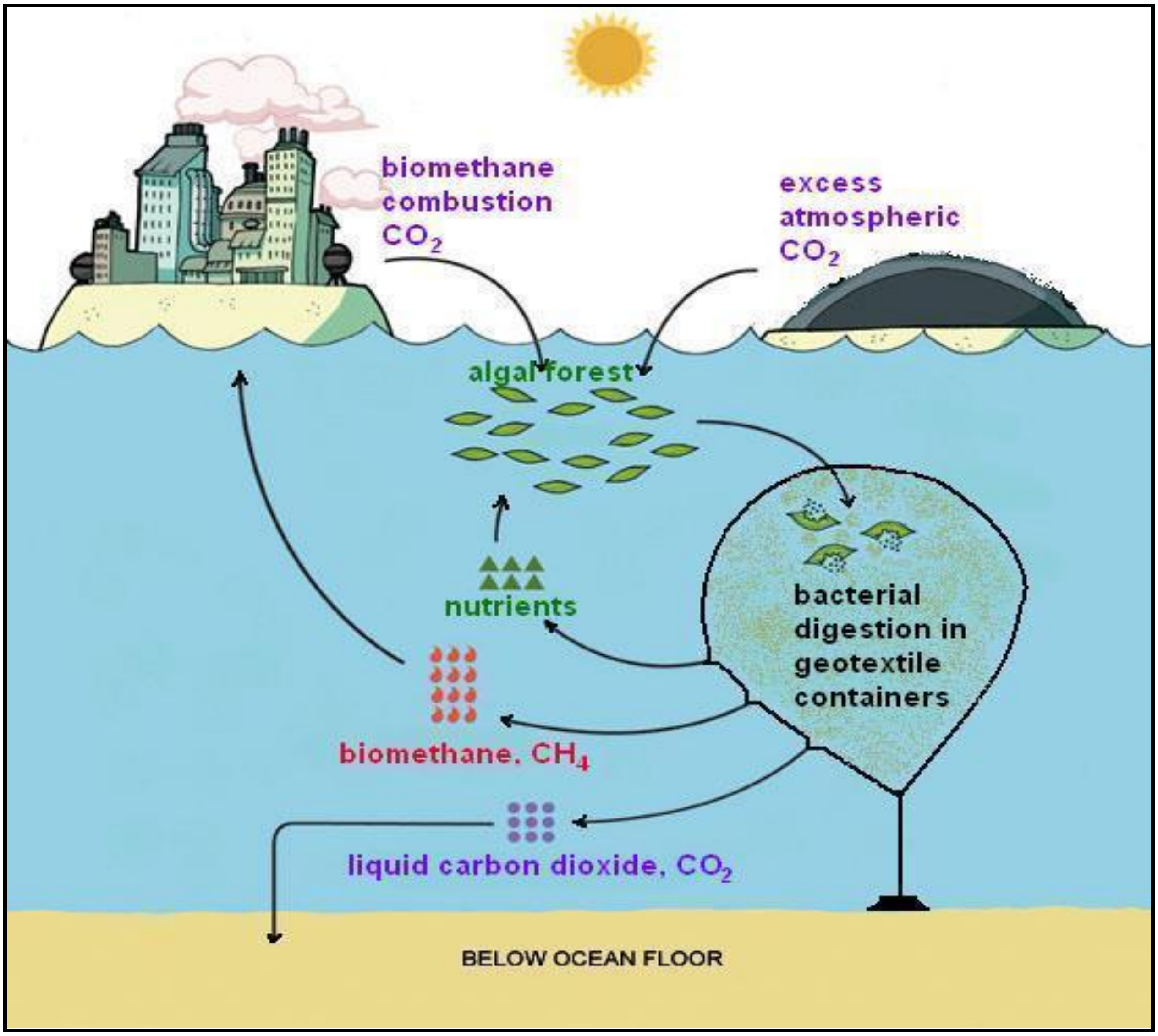

Figure 1 – Schematic of ocean afforestation

The United States has more ocean area within its 200-mile exclusive economic zone than any other nation, 11,351,000 km^2. Much of that area is suitable for sustainable macroalgae forests, which could form the basis for environmentally benign sustainable energy production that would capture greenhouse gases while producing green bioenergy to replace fossil fuels. Algae are not only the largest global absorber of carbon dioxide[1], but they also [insert for not only, but also phrasing] form the basis of all ocean ecosystems. In fact, a kelp forest is similar to a tropical rainforest by providing the habitat for hundreds of marine species, many commercially important.[2] Supporting the expansion of these forests could be termed "ocean algal afforestation."

Figure 1 presents an overview of ocean algal afforestation, which is based on the natural life cycle of algae. But instead of the dying algae being digested by bacteria on the way down or at the bottom of the ocean, where the nutrients might remain for eons, the digestion is done in containers at ocean pressures between 5 – 50 bar (10-bar ~ 10 atmosphere ~ 150 psi ~ 100 meters of seawater), and the products are separated into three separate streams of methane, carbon dioxide, and plant growth nutrients. The methane is piped to shore to replace fossil methane. The carbon dioxide can be sequestered safely for millennia in the ocean floor. The nutrients are retained and can be carefully recycled to support more algae growth than was consumed in the digestion, leading to expanded algal forests. More abundant plant life leads to more abundant marine animal and fish life. Life creates the conditions for more life.

Cost is the driving challenge for biofuels. The "traditional" approach to reduce the cost of algal biofuels is to "engineer" the algae and their growth conditions to maximize the oil yield per watt of solar energy. Higher yields will require less land to grow the algae and less steel, concrete, and equipment to process the algae, reducing unit costs.

Developing ocean algal afforestation opens a second front on the cost challenge. Instead of an area-conserving mono-culture crop and a highly engineered process, we can employ relatively cheap ocean with an "inefficient" but natural process in inexpensive facilities. Anaerobic digestion is natural and robust; our process can be as simple as a sanitary landfill with no mixing, no temperature control, and indiscriminate biomass. In the simple version, the natural bacteria digestion of Figure 1 occurs in an engineered geotextile containing about a million cubic meters of a mixture of algae and seawater. The "starter" bacteria come from ocean sediments and herbaceous fish intestines.

The primary cost advantage of the process is i the relatively inexpensive facility. Typical wastewater treatment plant concrete or steel anaerobic digesters cost about $500 per m^2 of surface area. Ocean-supported, tensile fabric structures made from engineered geotextiles (quality plastic fabrics and films) can be formed into large containers costing less than $10 per m^2. The relatively inexpensive process volume allows for relatively inexpensive anaerobic digestion with long detention times, which can use biomass with high water content, needs no biomass pre-treatment, and supports nutrient recycling.

The primary sustainability advantage is the separation of nutrients from the energy. After the bacteria have run out of "food" for methane production, the container is full of all the nutrients needed to grow more algae and dissolved carbon dioxide with a little dissolved methane. Much of the ocean is a nutrient desert because any nutrients produce quick blooms, which then sink below the depth of sunlight penetration. The PODenergy process quickens the nutrient recycle similar to the way sunlight powers fast water recycling in tropical rainforests. The energy of

[1] Nellemann C, Corcoran E, Duarte CM, Valdés L, De Young C, Fonseca L, Grimsditch G (2009) Blue carbon. A rapid response assessment. United Nations Environment Programme, GRID-Arendal, www.grida.no

[2] Graham, MH, 2004, Effects of local deforestation of the diversity and structure of southern California giant kelp forest food webs, *Ecosystems* 7:341-357; Graham, MH *et al.* 2007, Global ecology of the giant kelp *Macrocystis*: from ecotypes to ecosystems, *Oceanography and Marine Biology: an Annual Review* 45:39-88.

carbon dioxide bubbles coming out of the solution can be employed to pump the nutrient- laden slurry to the ocean surface.

Typical anaerobic digestion output mixtures of 60% methane and 40% carbon dioxide production from landfills, dairies, and wastewater treatment plants are common at 1 – 2 bar. This process has the following advantages:

- Higher pressure enables recovery of over 90% pure methane. This has been demonstrated by the City of Los Angeles while injecting partially digested wastewater biosolids into deep (1,500 meters deep) saline aquifers. The saline aquifers are much warmer than the deep ocean while having high pressures. Pressures between 10 – 60 bar (100 to 600 meters deep) would be just as effective for capturing the dissolved carbon dioxide.

- The process also allows relatively inexpensive separation, capture and storage of the produced carbon dioxide. This is CO_2 from a renewable source (algae), which can result in a net reduction in CO_2 concentrations in the ocean and can offset CO_2 emissions from fossil fuel burning.

- The inexpensive processing containers will not be visible to humans while remaining very close (generally less than 5 kilometers horizontally and 500 meters vertically) to the growing biomass. The resulting high-pressure methane may be transported as isor converted to electricity or liquid fuel, or converted to plastic on-site. Land-based processes generally move the biomass feedstock and the nutrients needed to grow more biomass over much longer distances.

- The hydrogen and methane are produced at a location where inexpensive containers can be employed to produce liquid fuel via a Fischer-Tropsch (F-T) process. F-T can operate as low as 150 °C – 200 °C and several tens of atmospheres of pressure. Lower temperatures and higher pressures lead to higher conversion rates and also favor formation of long-chained alkanes, both of which are desirable. In the ocean, adjacent to the PODenergy ocean algal afforestation, a pressure of 100 bar may be contained in a 25 mil plastic film at a depth of 1,000 meters. The average depth of the ocean would permit processing at pressures near 400 bar in large inexpensive containers, if such proved beneficial.

- The PODenergy team computer models and cost estimates suggest the produced methane will cost about $4 per MMBtu. That is slightly less than the typical cost for U.S. natural gas produced by hydrofracturing. On a mass basis $4/MMBtu is $0.20 per kg or about $28 per barrel at 140 kg per barrel. That implies we could spend another $4/MMBtu ($28/barrel) employing the ocean-based F-T process to produce syn-gasoline or syn-diesel at $56/barrel. (We do not have a cost model for the ocean-based F-T process.)