Focus Area: SUSTAINABLE DEVELOPMENT AND INFRASTRUCTURE
Market Segment: OFFSHORE SOLAR & WIND

SIC: 221114 (SOLAR), 221115 (WIND)
Segment Score: 22

Sample Investments:
- **Privately-owned:** Offshore wind power installations
- **Private-owned:** Floating solar power installations
- **Public:** Above installations for ports & coastal communities

1. Relevance to ADB Ocean Action Plan *(Score: High=3)*

a. Any nation with ocean coastline and EEZ has the opportunity to generate renewable energy with floating solar and offshore wind facilities. Those with high population density and competition for land space are leading the movement to marine renewables. Offshore wind is gaining momentum and may reach parity (Levelized Cost of Energy: LCOE) with onshore wind within 5-10 years. Whilst onshore wind farms cost less to install and operate, offshore can achieve cost parity when considering wind capacity expansion - in addition to less public resistance. whereas floating solar is relatively new.

b. Floating solar projects are popping up across Southeast Asia, notably Thailand and Singapore, where land constraints limit expansion of solar power. Ocean installations need to be more robust than floating solar projects on lakes or rivers because of the more harsh conditions at sea and protections needed against marine growth (eg, barnacles, etc)..

c. Funding is underway for offshore wind/solar power in some DMCs, including:
- Vanuatu Green Energy Fund funded by GCF ($10mn) to achieve 100% electrification and by renewable energy by 2030
- Republic of Marshall Islands Sustainable Energy Development plan ($34mn) supported by World Bank
- Kiribati's OTEC project is supported by the Korea Research Institute of Ships and Ocean Engineering
- Fiji's successful 2018 green bond issue of $50mn has provisions for renewable energy investment

2. Positive Social Impacts: Poverty, Gender, Health? *(Score: High=3)*

a. Poverty: Renewable energy creates jobs and reduces foreign exchange outlays for fossil fuels. Over 10 million people work in renewable energy worldwide, with job growth projected to continue whilst fossil fuel jobs shrink. For developing nations, urban populations benefit from job growth, stable energy prices, lower ongoing household energy expenses and energy independence that supports sustainable development. In rural areas, the same benefits accrue along with sourcing power closer to home and hosting clean energy facilities in communities.

b. Gender: As primary users of household energy for cooking and heating, access to energy for rural women is critical. World Bank studies have estimated that there are more than 1.6 billion people living without reliable sources of energy, and 2.7 billion people relying on open fires and traditional stoves for cooking and heating - we can assume that at least half of these are women. In addition, job opportunities may be more favorable in the renewable energy future versus the record in fossil fuel industries. The latest study conducted by the Environment and Gender Index (EGI) estimated that women occupy only 4% of the World Energy Council (WEC) positions and 18% of the WEC Secretary Positions. Growth in renewables may empower women, especially in developing countries.

c. *Health:* The air and water pollution emitted by coal and natural gas plants is linked with breathing problems, neurological damage, heart attacks, cancer, premature death, and a host of other serious problems. Wind, solar, and hydroelectric systems generate electricity with no associated air pollution emissions. In addition, wind and solar energy require essentially no water to operate and thus do not pollute water resources or strain supplies by competing with agriculture, drinking water, or other important water needs.

3. Positive Environmental Impacts? *(Score: High =3)*

a. The health benefits of renewable energy noted in (2) above summarise the environmental case. Climate mitigation and cleaner air, water, ecosystems are all delivered by offshore wind/solar power, making this sector a high priority for ADB and PEA. Assets have a very low carbon footprint over the project lifespan. Improvements in water quality are notable with floating solar projects due to decreased algae growth.

b. Marine renewable projects need to be resilient and conscious of local ecosystems. Damage to ecosystems can occur during installation and operation of some marine energy systems. Protections must be addressed in every project's Adaptation Plan, Local Environmental Assessment, Planning Consent. Marine Spatial Planning (MSP) is needed to allocate space to floating solar projects, fishing rights, shipping lanes, marine tourism and mariculture A striking example of transition to clean energy is seen in some of China's collapsed coal mines, which are now water basins serving as sites for floating solar facilities.

4. Potential for Market Scalability? *(Score: Medium=2)*

a. Although most offshore wind growth has been in developed Asia (China, Japan, Taiwan, South Korea), developing countries should benefit from this strong regional production capacity. During 2018-2019, Asian investments in offshore wind grew from $33bn to $40bn, with China dominating as offshore wind is a strategic priority.

b. However, Southeast Asia has lagged so far. Except for Vietnam, no country in the region has any significant offshore wind pipelines, even in the Philippines where onshore wind prevails. India has plans to add 5 GW of offshore wind power to its mix by 2030, but currently has no offshore wind capacity installed. The need for public infrastructure finance is apparent in this rich-poor gap of offshore wind.

c. Floating solar is a relatively new technology but Asia is in the lead, with more projects underway in Southeast Asia. Modular systems with low anchor/mooring requirements make this technology relatively easy to start and scale. Connecting ocean floating solar platforms to port infrastructure is an obvious solution to operating and usage goals. The Global Floating Solar Panel Industry is projected to grow at a CAGR of 35.42% from 2017 to reach USD 1.9mn by 2025. Whilst on-grid installations dominate with 75% of the market, off-grid systems are increasing.

5. Capacity for Innovation & Growth? *(Score: High=3)*

a. The technology for offshore wind is well-established and floating solar is catching up, as adaptation of platforms to open sea conditions is the only limitation. Offshore wind has addressed environmental challenges and will continue to cross milestones of innovation and growth. Likewise, floating solar benefits from the leadership role, and dropping prices, of onshore solar panels and power systems.

b. Innovation will help drive the sector on several levels: Installation (from on to off-grid facilities), floating applications (offshore platforms and vessels), connectivity (urban and remote), power storage, automation and environmental protections. Especially exciting is the emerging interest in linking offshore renewable energy production to offshore aquaculture or near shore renewable energy production to ports and associated infrastructure. Floating solar has some advantages over wind in this context, like more readily moveable platforms. Asian expertise is an advantage that DMCs should build on for global competitiveness as well as local needs.

6. Benefit from Regional Governance Frameworks? *(Score: High=3)*

a. Because of the vast need for clean power, regional governance has a key role to play in financing installations at scale, complying with global standards, improving connectivity, education and the transition from fossil fuels. Offshore wind leads the way, as the most proven and scalable of marine renewables.

b. Scaling installations and management of offshore wind and floating solar across small island developing states (SIDS) and other coastal nations is the best way to provide affordable, renewable energy to these communities. This requires nations to collaborate within regional frameworks like COBSEA, Sustainable Energy Industry Association of the Pacific Islands (SEIAPI), Pacific Island Development Forum (PIDF), ASEAN's Cooperation on Energy, Telecoms, Transports, and of course ADB's Clean Energy Program.

c. Global renewable energy initiatives and industry groups may also provide support by engaging global industry and standards, for example: Global Wind Energy Council, Global Commission to End Energy Poverty, International Energy Association, International Renewable Energy Association and Global Solar Council.

7. Opportunity for SMEs? *(Score: Medium=2)*

a. Offshore wind and floating solar are generally perceived as large-scale or infrastructure investments, requiring resources beyond those of SMEs. However, SME opportunities exist in the whole value chain of both wind and solar power, with supply and servicing roles. SMEs have also been successful producing specialty turbines for the offshore wind market, and panels for the floating solar market. Project planning and development is often managed by specialty firms with deep expertise.

b. National and regional initiatives may help build capacity in DMCs so that these opportunities can be executed by local SMEs. Given the projected growth of this segment and its importance to national energy independence, projects should be encouraged at the local level - where financing demands are smaller and community engagement around renewable energy may be strong, especially when powering blue economy activities like aquaculture, ports and tourist facilities.

8. Attract Private Investment? *(Score: High=3)*

a. *Banks:* Due to the high investment costs associated with offshore wind farms, projects are generally implemented by project consortia and are credit-financed by private or public banks. Groups of investors include large corporations, banking partnerships and municipal utilities. (*offshore-windenergy.com)*

b. *Insurance:* Ambitious expansion targets for offshore wind energy in various countries are leading to increased numbers of offshore wind farms and to stronger demand for insurance services as a result. Risk management presents a major challenge on account of the large sums invested in offshore wind turbines. There are a range of risks associated with such projects, from ground investigation to offshore transport, to making an offshore wind farm operational.

c. *Green Bonds:* Offshore wind and floating solar projects may now be certified under the Climate Bonds Initiative (Marine Renewables standard) and Green Bond Principles. This is important not only for bond investors but for project financiers, as it provides some assurance of environmental and fiscal value of the whole sector.

Focus Area: SUSTAINABLE DEVELOPMENT AND INFRASTRUCTURE
Market Segment: TIDAL, WAVE, GEOTHERMAL (OTEC)

ISIC: 221111 (HydroElectric), 221116 (GeoThermal)
Segment Score: 21

Sample Investments

- *Private/Public:* In-stream tidal energy generation facilities (e.g. vertical or horizontal axis turbines, lagoons, barrage technologies, in-stream generators)
- *Private/Public:* Energy generation facilities using waves, ocean current, river current, ocean thermals*.

*Primarily in equatorial areas, Ocean Thermal Energy Conversion (OTEC) generates consistent ('baseload') electric power through conversion of the temperature differential between surface and deeper waters.

1. **Relevance to ADB Healthy Ocean Action Plan? *(Score: High=3)***
    a. High relevance of this segment, as with the more developed offshore wind segment, for the same macro and regional reasons noted in Segment A. Ocean tides are the most predictable of renewable energy sources, with two technologies: tidal current converters and coastal barrages. Long-term economy and high energy density (ie, little waste) are also major advantages. Wave energy
    b. DMCs should particularly value the collaborative possibilities of tidal and wave systems: Powering aquaculture and algaculture farms, for instance, is an obvious synergy. Large tidal and wave systems are expensive to deploy - primarily funded by public sources at present. But smaller modular systems make tidal, wave and OTEC accessible to DMCs.
2. **Positive Social Impacts (Poverty, Gender, Health)? *(Score: High=3)***
    a. *Poverty:* For the same reasons as described for offshore wind and floating solar, other marine renewables deliver positive social outcomes. The additional value of tidal, wave, ocean thermal and salinity gradients is the lower capital expense to install and operate the systems. This potentially brings more control to the local community.
    b. *Gender:* Newer and lighter technologies tend to favor career opportunities for women. Reduced energy costs and pollution at the home level are also highly beneficial to women.
    c. *Health/Covid19:* The same health benefits noted from offshore wind/solar apply to other marine renewables. Reduced pollution and water use are obvious benefits. In addition, the cooling application of ocean thermal energy conversion (OTEC) is especially promising for hospitals, workplaces and homes in the tropical climates of Asia-Pacific. Increased independence of communities due to Covid19 accelerates the need for energy independence.

3. **Positive Environmental Impacts? *(Score: High=3)***
    a. As noted in the Climate Bonds Initiative background paper on marine renewables: *The probability of significant environmental disruption is considered to be low for in-stream tidal systems (i.e. bottom- mounted turbines in locations with rapid tidal flows) and redeveloped barrage systems (i.e. turbines inserted into existing tidal barriers or structures such as breakwaters), but, depending design, may be higher for new barrage systems and lagoon systems (e.g. negative effects on wetlands).* This is also true for the other technologies noted under *Sample Investments* (above). Environmental assessments and

safeguards are standard procedures for marine renewables.

b. The contribution to climate mitigation and pollution reduction, both of which are now of existential importance to DMCs, makes marine renewable energy a high priority segment. Biofouling of tidal/wave/OTEC systems, similar to floating solar panels, is an operational risk that needs to be managed. Tidal systems must be sited where the high-low differential is large enough to generate sufficient power. Both wave and tidal installations need to be close to shore and utilities to store and distribute the energy, which may create public resistance over siting issues. Wave power is less predictable than tidal and the systems must be able to handle rough seas.

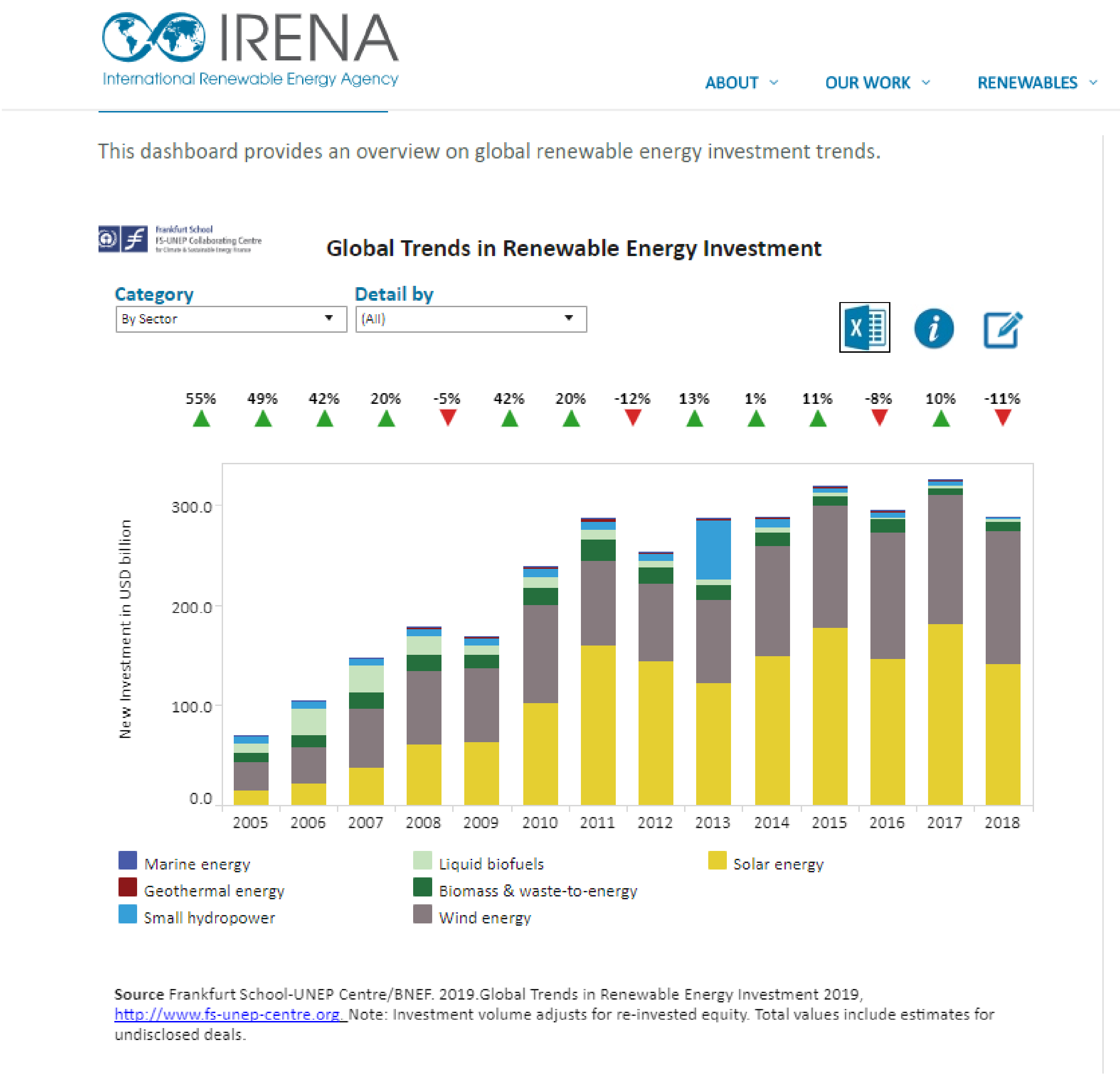
4. **Market Scalability? *(Score: Medium=2)***
    a. A consensus estimate is that global tidal energy potential could exceed 120GW. For wave energy, potential may be 500GW based on 40% energy conversion of the 2% of the world's coastline that has wave power density of >30 Kw/meter. OTEC has the highest potential of all marine renewables, with 98 nations identified as having viable sites within their EEZs. Pacific and Indian Ocean island nations are particularly well-suited with OTEC resources within 10km of most shorelines. So far, only 1MW OTEC plants have been built. Plants up to 10MW could be built and generate very inexpensive clean power, if public funding is available to develop and deploy the systems.
    b. All these newer marine renewables are subject to limitations of high upfront capital costs, fragmented supply chains, installation and operational expertise. Therefore, while the potential is vast and especially exciting for DMCs, this segment is still in early stages and will need more participation of industry expertise and public funding for the potential to be realised.

5. **Capacity for Innovation and Growth? *(Score: High=3)***
    a. Technology convergence has not yet occurred in new marine renewables. New applications continue to emerge: floating tidal installations; floating / underwater data 'farms;' wave power for carbon capture and storage; high voltage lines connecting offshore and onshore installations. Technologies vary in terms of capital costs, ratio of costs to power generation over a device's lifetime, and net capacity (i.e. ratio of actual to potential energy output) as well as climate benefits and environmental effects. The supply chains offer opportunities for local servicing and site work, as well as larger scale infrastructure projects.
    b. Therefore, the capacity for innovation and growth is high, although the pathway is not clear for each system. Much progress is being made in supporting tech development at regional accelerators like European Marine Energy Center (EMEC) and, in Asia, Singapore's EPS MaritimeTech Accelerator powered by Techstars. Since marine energy resources are so vast and beneficial for many DMCs, developing this sector holds great promise for jobs that retain youth and talent.
6. **Benefit from Regional Governance Frameworks? *(Score: Medium=2)***
    a. Regional governance can support maritime hubs, accelerators and incubators for the development of patents and jobs. For such a high growth sector with sustainability benefits, we recommend marine renewables be given high priority by national and regional governments. COBSEA does not cite marine renewables as a strategic focus, however, so we have given this a Medium score to reflect current status of regional governance - which we hope will change.

   b. Cooperation with industry and science leaders is important, as the region must be connected to state-of-the-art development of marine energy. There are a number of industry groups and universities working together (as noted above with Singapore). National maritime clusters and port authorities often serve as hubs for bringing these stakeholders together (see References). At the global level, Ocean Energy Systems (OES) is an intergovernmental collaboration between countries which operates under the International Energy Agency (IEA) in Paris.

7. **Opportunity for SMEs? *(Score: High=3)***
   a. Some projects are capital-intensive, requiring imports of technology and expertise on a large scale - at least in the deployment stage. However, even these infrastructure projects engage local suppliers for site preparation, local connectivity, servicing and ongoing management. Given the projected growth of this emerging sub-sector, we project substantial opportunity for local/regional SMEs.
   b. Owning patented technologies is the larger opportunity for SMEs, beyond servicing and ongoing management of marine renewable utilities. This depends on some level of public support, as noted under (5) and (6) above. Collaboration with industry suppliers (strategic venturing model), research groups, governments and financiers is certainly needed for the region to secure IP on certain technologies. We recommend OTEC as a sub-sector where DMCs may play a strong role in developing and testing applications, due to the ideal natural conditions for this technology especially among SIDS.

8. **Attract Private Investment? *(Score: Medium=2)***
   a. Because of the early-stage and fragmented nature of new marine renewables, public funding and grants are needed to accelerate the development and installation of systems in DMCs. Risk levels and the cost of small systems are simply too high for most private investors. Blended finance is needed to attract private capital, as it has successfully done for onshore and now offshore solar/wind.
   b. Investment trends may be tracked for each technology via this link



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APPENDIX

Table 1. Examples of recent bonds in the marine renewable energy sector
Source: Climate Bonds Initiative

ISSUER	DESCRIPTION
Type: Certified Climate Bond (coupon 1.3%)16 Date: 2017 Value: EUR 650M Issuer/borrower: Three Gorges Corporation	For wind projects, both offshore and onshore, in Germany and Portugal. Attracted investors from Germany, France, Switzerland, UK, Italy, Norway, Netherlands, Portugal, Spain, UAE, Singapore, South Korea, Japan and Malaysia.
Type: 10-year green bond (coupon 1.125%) Date: 2016 Value: EUR 1BN Issuer/borrower: Iberdrola	Proceeds will be used to finance and refinance onshore and offshore wind power projects in Spain, Portugal and the UK. Second opinion from Vigeo Eiris.
Type: Peer-to-peer funding (coupon 8%, term 5- year) Date: 2017 Value: GBP 4.3M Issuer/borrower: Atlantis Resources Lender: Peer-to-peer investors	To produce the next generation of subsea technology and progress more tidal power opportunities, including development of the second phase of MeyGen tidal project off the coast of Scotland.
Type: Debt finance Date: 2014 Value: GBP 7.5M Issuer/borrower: MeyGen Lender: Atlantis Resources / Scottish Enterprise Renewable Energy Investment Fund	For installation of four 1.5MW offshore tidal turbines and onshore infrastructure.17
Type: 5-year loan facility Date: 2014 Value: USD 20M Issuer/borrower: Carnegie Wave Energy Limited Lender: Clean Energy Finance Corporation	Commercial scale demonstration project for CETO array system (wave power units).18 Revenue from sale of electricity and desalinated water.
Type: Green bond Date: 2016 Value: USD 1.1BN Issuer/borrower: TenneT IPO-TTH.AS (Dutch state-owned grid operator)	Investment in transmission cables from German offshore wind farms.19
Type: 5-year green bond (coupon 1.875%) Date: 2015 Value: USD 500M Issuer/borrower: Swedish Export Credit Corporation	For clean energy marine technologies (water and wastewater). Includes other renewable energy, energy efficiency, recycling, water, sustainable construction / materials / transport). Second opinion from CICERO.