RESEARCH INSTITUTE FOR SUSTAINABLE URBAN DEVELOPMENT (RISUD)

News Article for RISUD Emerging Frontier Area (EFA) Scheme

		Name	Department
1.	**Principal Investigator**:	Dr. Sunliang Cao	BEEE
2.	**Name of EFA:**	Seashore Zero-Energy Community and Ocean Energy Development	
3.	**Project Title:**	Development of the frontier ocean energy technologies to utilize the renewable and storage resources of sea for supporting the seashore residential zero-energy communities	

4. **Annual Progress/Achievement (***in layman's language, no more than two A4 pages, pls attach photos***)**

Brief introduction of the project

The zero-energy buildings (ZEBs) and communities (ZECs) are internationally recognized as the ultimate goals to reduce primary energy consumptions and equivalent CO_2 emissions of the building sector. However, most of the applied ZEBs and ZECs are based on the conventional inland renewable and storage resources, whereas the sea-sourced resources were barely utilized for these zero-energy applications. Moreover, the special conditions in the densely-populated coastal regions, such as the intense urbanization and limited above-/under-ground space, further restrict the utilization of the inland resources, whereas the sea-sourced resources present a higher potential. The above conditions hereby stimulate the core research idea of this project, which focuses on the development of the frontier ocean energy technologies in order to fully utilize the renewable and storage resources of sea for supporting the seashore and coastal zero-energy communities. In the 3rd year, we have further investigated more novel solutions and conducted optimizations to optimally activate the flexibility resources from the ocean generation side, storage side, and seawater transportation side. The impact of existing and new business models has also been taken into account for refining the novel hybrid ocean system designs and control strategies.

Research teams in this project

We have a very outstanding and multi-disciplinary team in this project, as shown in Figure 1. The PI of this project is Dr. Sunliang Cao from BEEE, while the Co-Is are Dr. Xiaolin Zhu (LSGI), Dr. Yang Xu (LSGI), Prof. Vivien Lin Lu (BEEE), and Prof. Shengwei Wang (BEEE). Furthermore, there are four talented research staffs/students involved in this project with different focuses of the ocean energy system, including Mr. Haojie Luo (Offshore wind turbines and wave energy converters for coastal hotel buildings), Mr. Shijie Zhou (Floating photovoltaics and tidal stream generators for coastal high-rise buildings), Ms. Xinman Guo (Ocean energy supported zero-emission boat and hotel integration and interactions), and Mr. Ming Li (Large-scale ocean energy systems and coastal communities).

We also would like to briefly present some highlighted research progresses as listed below:

(1) For the flexibility sources of coastal residential buildings, the battery can achieve effective peak-shaving and reduce annual operational costs. However, the net present value (NPV) was negative due to the high investment required. Hereby, smaller batteries (10-50 kWh) have been selected and the corresponding simulation results have shown cost savings from the improved peak-shaving by reducing the maximum demand by about 10 kW. Notably, the inherent reservoir acted as "wave energy storage", significantly reducing imported energy from the grid and saving approximately 16% of the operational cost. Energy matching performances are improved by up to 10%, while the operational costs are further reduced by up to 16% compared to the reference case.

(2) We have further investigated the fine-tuning control strategies for the active controls of reservoir-integrated wave energy converters with dynamic activation of mechanical energy storage features. The reservoir further acts as an activated mechanical energy storage to actively participate in the novel generation-side flexibility controls. Cost-responsive controls for energy shifting and peak shaving were simultaneously implemented. Different control strategies were compared, in which,

one strategy achieved significant cost reductions by dynamically and optimally constraining and controlling the ocean generator power output. The addition of a battery improved peak shaving but had a limited impact on NPV due to high investment costs. The results demonstrated the effectiveness and feasibility to novelly activate the wave energy converters' mechanical energy storage functions for further enhancing the energy flexibilities and economic performances.

(3) We have further obtained optimal energy flexibility enhancement solutions for coastal zero-emission office buildings by taking the existing and new utility business models into account including the utility incentive demand response programme. The results indicated that the monthly charging/discharging-line-based control could achieve up to 6.1% improvement of NPV_{rel} compared to the annual charging/discharging-line-based control. Furthermore, comparing to the reference case, energy flexibility could improve the economic performance (NPV_{rel}) by up to 74.2%, and the utility demand response programme could enhance the economic performance by more than two times. Based on the research results, we have also suggested the improvement of business model policies which may help to better incentivize and promote the renewable energy penetrations.

(4) We have proposed novel and optimal energy flexibility control strategies using electric boats and hybrid ocean energy systems with wave energy converters and floating photovoltaics to enhance peak-shaving and valley-filling capabilities. The final optimal control strategy can achieve significant operational cost reductions by up to 12.2% and increasement of relative NPV by up to 16.6%. The results also showed that the power management controls are very effective to shave the power peaks, with only 2% of the grid importing is still above the peak benchmark line in the best case. The results also highlighted the importance of monthly discharge and charge limits for boat batteries in flexibility controls.

(5) We have also further examined the integration of electric ferries with nearshore and offshore renewable energy systems in the larger areas of GBA. It focuses on wind turbines and floating photovoltaics as the primary renewable energy sources. We have evaluated the hybrid system's technical, economic, and environmental performances and its economic sensitivity to sea-land costs, submarine cable costs, and renewable energy penetrations. The results can also better support the policy-makers for developing hybrid ocean renewable energy and seawater transportation systems in similar coastal regions in the future.

Figure 1: The research team in this project.

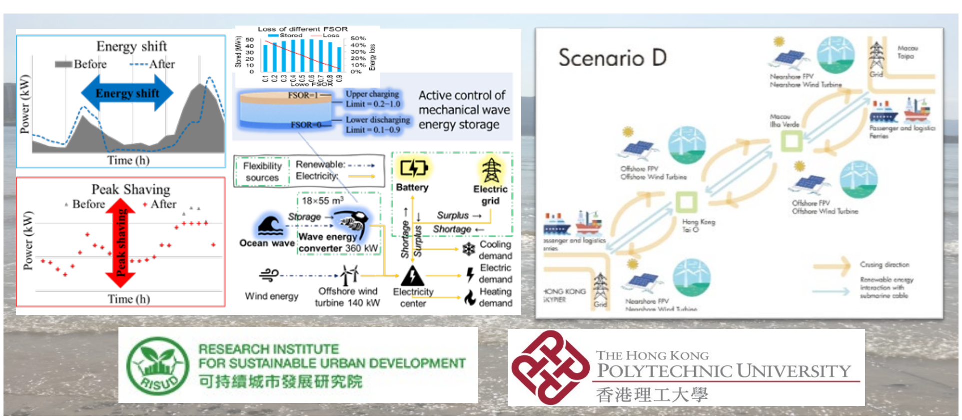

Figure 2: The brief schematic of hybrid ocean energy supported coastal buildings and seawater transportation system.