OFFSHORE WIND FARMS IN HONG KONG: IS IT COST-EFFECTIVE?

香港建離岸風電場: 是否有成本效益?

Prof. Wyss W.-S. Yim[1, 2] 嚴維樞教授

Prof. Nigel Ridley Thomas[1, 3] 湯馬士教授

1 *Department of Earth Sciences, The University of Hong Kong*
香港大學地球科學系

2 *Institute of Space & Earth Information Science, Chinese University of Hong Kong*
香港中文大學太空與地球信息科學研究所

3 *EGS Asia Limited*
EGS亞洲有限公司

Plan 大綱

(1) **Background** 背景

(2) **Costs** 成本

Short-term - installation including model and foundation 短期 -機組/基樁安裝工程費

Long-term - operation including corrosion, wind and wave damage, insurance

長期-運作費包括腐蝕、風浪破損、保險

(3) **Onshore wind farms on the Dangan Islands as an alternative**

另一選擇: 擔桿群島建岸上風電場

(4) **Summary/conclusions** 總結

Arguments for offshore wind farms

(modified after Synder and Kaiser 2009)

贊成離岸風電場的論點 (據2009年 Synder 與Kaiser著作的修改)

Reduction in water consumption (~2 million gallons per MW) 減少用水 (每兆瓦 , ~2百萬加侖水)

Air quality improvement 改善空氣質素

Jobs 提高就業

Electricity price stability (very limited) 穩定電費 (極有限度)

Higher winds offshore (does not cover higher capital cost) 離岸較大風 (不包含較大投資費用)

Arguments against offshore wind farms

(modified after Snyder and Kaiser 2009)

反對離岸風電場的論點 (據2009年 Synder 與Kaiser著作的修改)

Water vapour is the most important greenhouse gas (not CO_2)

水蒸氣是最重要的溫室氣體 (非二氧化碳)

Navigational safety 航運的安全

Not economically viable 經濟上是不可行

Aesthetics 美學

反對離岸風電場的論點 (據2009年 Synder 與 Kaiser著作的修改)

- **Long-term costs e.g. wind and wave damage** 長遠費用 如風浪破壞
- **Unpredictable power (backup is essential)** 風的不穩定性 (需要後備電)
- **Ecological impacts (birds and fisheries)** 影響生態 (雀鳥與魚)

Changes in stratospheric water vapour
(Solomon* et al. 2010 *Science v. 327*)
平流層水蒸氣的變化

2 important conclusions 兩個重要結論 :

(1) Explains increase and decrease of global surface temperature over 1980-2000 and 2000-2009 respectively. 分別解釋了**1980-2000**年及**2000-2009**年全球表面溫度的上升與下降

(2) Stratospheric water vapour is an important cause of decadal global surface climate change.平流層水蒸氣是每十年全球表面氣候變化的重要因素

NASA's A-train satellites monitoring water vapour
美國航空航天局 的 A-train 衛星正在監察水蒸氣

- **IPCC AR4 lead author**
- 首席作者

Experience gained from European offshore wind farms
歐洲離岸風電場的經驗

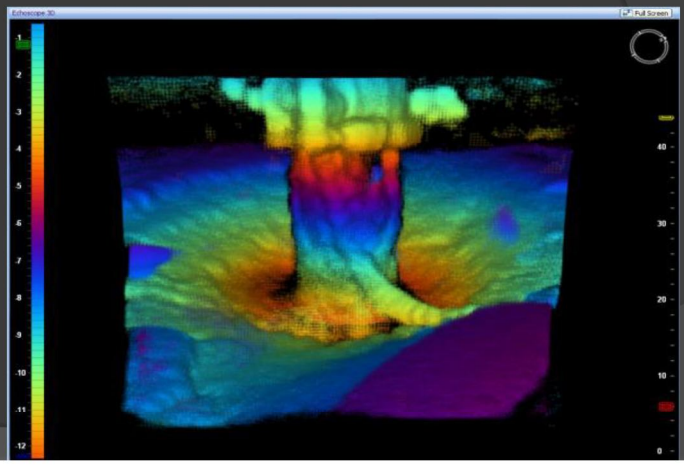
Very calm conditions needed for turbine installations
風車安裝需要非常平靜的環境

Maximum wave height 最高浪高 **15 m**/米
Maximum wind speed 最高風速 **<100 km/h** 公里/小時

North Sea foundation damage by extreme weather
80% offshore turbines 80%北海離岸風車基椿被惡劣天氣破壞

Scour cable exposure (expensive to fix)
電纜受沖刷破壞 (修理費用昂貴)

Echoscope of scour damage
沖刷破壞的聲納成像



INDICATIVE COST OF OPERATION & MAINTENANCE PACKAGES FOR 500MW OFFSHORE WIND FARM (SOURCE: THE CROWN ESTATE, 2013)

500兆瓦離岸風電場的參考運作及保養維修費 (資料來源: 2013英國皇家物業)

1 英鎊 = 12.7港元

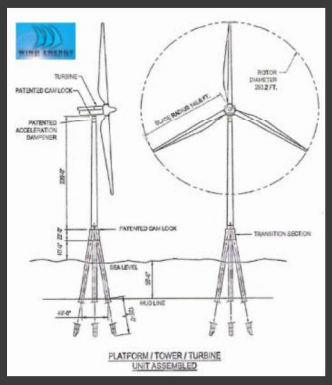
Item 項目	Indicative cost in GBP 英鎊/百萬/年
Onshore logistics 岸上物流	0.4-0.7 million/yr
Workboats 工船	2-3 million/yr
Aviation 飛機	1.5-5 million/yr/aircraft
Crane barge services 釣臂駁船	4-12 million/yr
Offshore accommodation/base離岸住宿/基地	10-20 million/yr
Turbine maintenance 風車維修	2-8 million/yr
Turbine spare parts 風車零件	3-6 million/yr
Offshore substation maintenance離岸分站維修	0.05-0.2 million/yr
Export cable surveys and repairs 電纜勘測維修	0.05-0.2 million/yr
Onshore electrical 岸上電費	0.02-0.1 million/yr

500兆瓦離岸風電場的預估運作及保養維修費 (資料來源: 2013英國皇家物業)

- Array cable surveys and repairs 電纜舖排勘測維修 — 0.2-0.5 million/yr
- Scour and structural surveys 沖刷破壞與結構的勘測 — 0.2-0.6 million/yr
- Foundation repairs基樁維修 — 0.1-0.6 million/yr
- Lifting, climbing & safety equipment inspections 吊高攀爬安全設備檢查 — 0.1-0.2 million/yr
- Supervisory control and data acquisition monitoring 督導控制及數據收集監控 — 0.4-0.8 million/yr
- Marine co-ordination 海上統籌 — 0.4-0.8 million/yr
- Weather forecasting 天氣預測 — 0.04-0.09 million/yr
- Administration 行政費 — 0.2-0.5 million/yr

最多共 59.3 million 5千9百萬英鎊

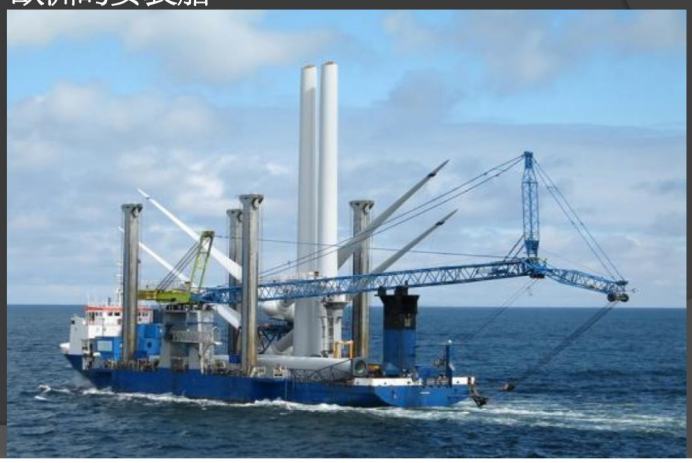
Offshore turbine installation離岸風車安裝



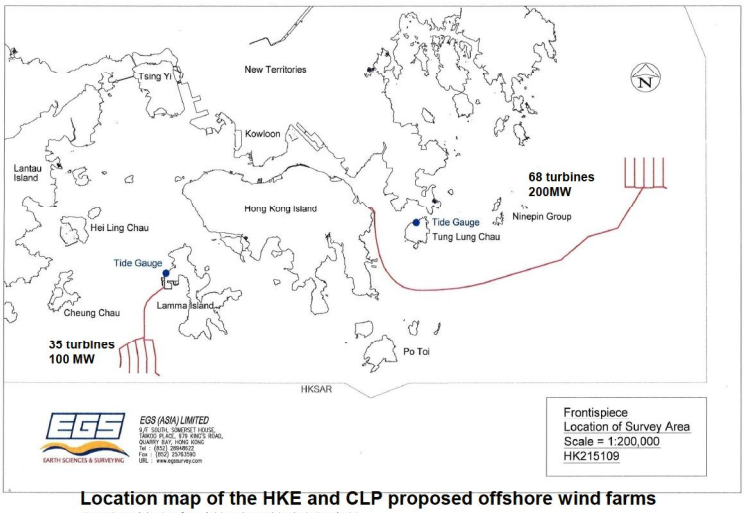
Important to have stable foundation to withstand both wind force and wave force

需要穩固的基樁抵抗強風浪

An installation vessel in Europe 歐洲的安裝船

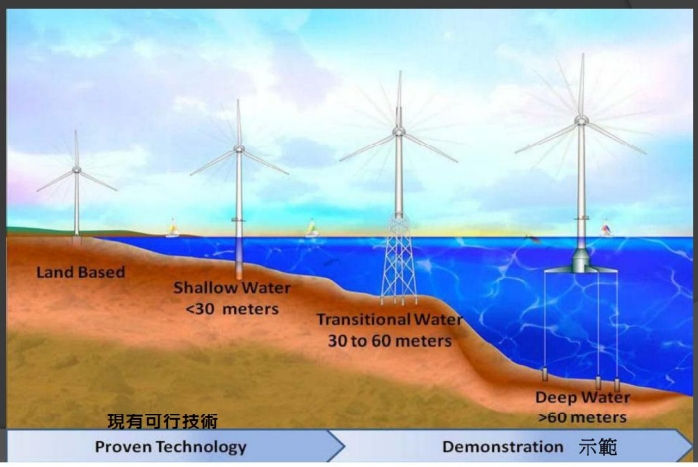


Offshore turbine installation 離岸風車安裝

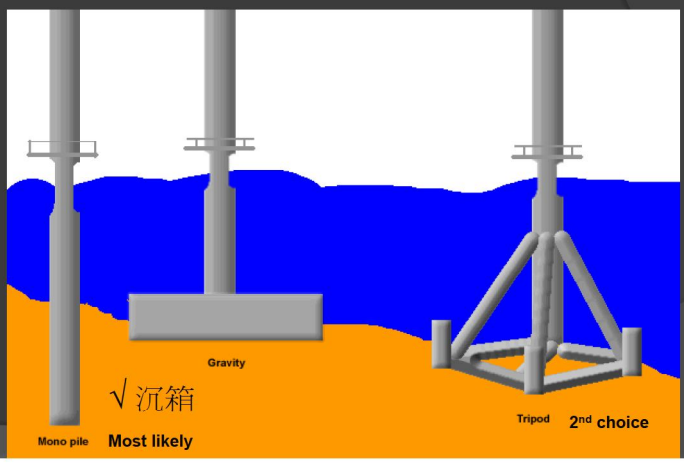


Location map of the HKE and CLP proposed offshore wind farms
擬議港燈和中電的香港離岸風電場

Proposed offshore wind farms in HK – both shallow water 擬議的香港離岸風電場 – 淺水



Foundation choices基樁的選擇



Geological model for Hong Kong's seafloor
香港海床的地質狀況

Unit 單位	Age 年代	Estimated age (ka) 估計年齡 (萬年)	Maximum thickness (m) 最厚度 (米)
M1	Postglacial後冰期	< 8.2	21.5
T1	Last glacial 末次冰期	8.2 – 70	6.5
M2	Last interglacial末次間冰期	90 – 140	15.7
T2	2nd last glacial 第二末次冰期	150 – 180	9.5
M3	2nd last interglacial 第二末次間冰期	190 – 240	12
T3	3rd last glacial 第三末次冰期	250 – 300	7.3
M4	3rd last interglacial 第三末次間冰期	310 – 340	14.1
T4	4th last glacial 第四末次冰期	350 – 370	6
M5	4th last interglacial 第四末次間冰期	380 – 420	3.5
T5	5th last glacial 第五末次冰期	> 440	7

M – marine 海相; T – terrestrial 陸相

Foundation conditions/problems
基椿的情況/問題

Seabed depth range 海床深度	**17-27 m**
Expected bedrock depth below seabed 預估海床下床岩深度	**~60-80 m**
Marine deposits 海沉積物	**up to 5 horizons** 至5層
Engineering properties of marine deposits 工程有關的海沉積物	**soft and compressible** 軟性及可壓性

DAMAGE CAUSED BY RECENT TYPHOONS/HURRICANES (TIMES 2013)
近年颱風/颶風造成的損毀 (時代雜誌 2013)

Typhoon/ Hurricane	Year 年份	Wind speed 風速 km/h	Death toll 死亡	Total cost US$ (億美元)
Haiyan	2013	314	> 2,500	14 billion
Sandy	2012	129	234	65 billion
Megi	2010	290	71	727 million
Katrina	2005	201	1833	147 billion
Zeb	1998	270	99	1.3 billion

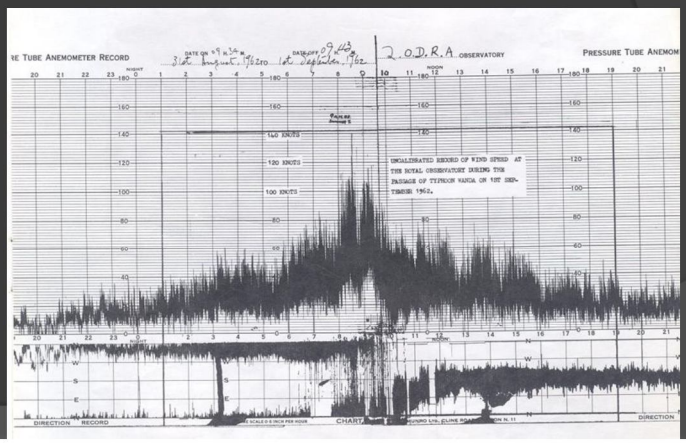
SAFFIR-SIMPSON HURRICANE WIND SCALE
薩菲爾-辛普森颶風量級表

Category 分類	Wind speed km/h風速 公里/每小時
Tropical depression熱帶低氣壓	≤ 62
Tropical storm熱帶風暴	63-118
1	119-153
2	154-177
3	178-208
4	209-251
5	≥ 252

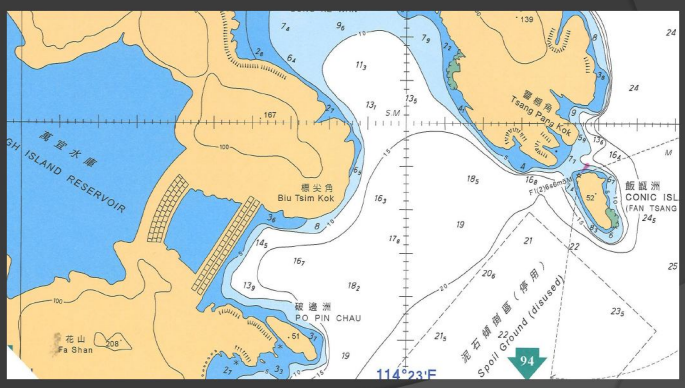
HONG KONG OBSERVATORY'S CLASSIFICATION OF TYPHOONS
香港天文台颱風的區分

Category 分類	Wind speed km/h 風速 公里/每小時
Typhoon颱風	> 118-149
Severe typhoon強颱風	150-189
Super typhoon超強颱風	> 190

Peak wind speed 175 km/h Typhoon Wanda 1962 溫黛颱風最高風速 175公里/小時

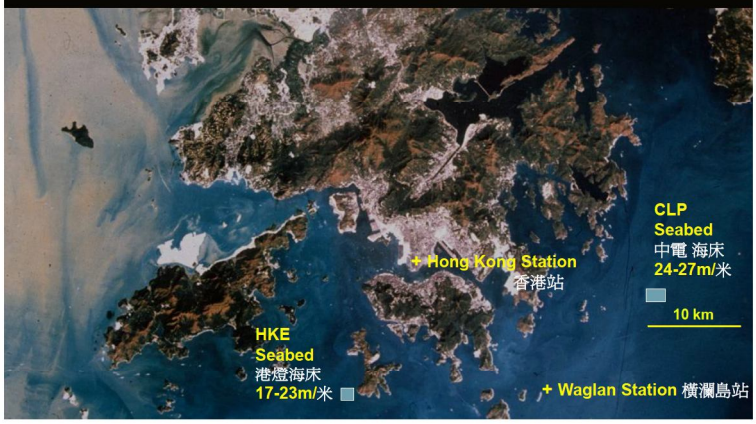


Estimated maximum wave height at East Dam, High Island 西貢糧船灣東壩預估最高浪高 ~9m/米



Source: Marine Department 資料來源: 香港海事處

Location map of the two proposed offshore wind farms, Hong Kong Station and Waglan Island Station
香港擬建離岸風電場選址



Predicted maximum wave height during typhoons at the two sites 兩址颱風時預估最高浪高

Location 選址	Seabed depth* 海床*	Wave height 浪高
Southeastern site 中電東南面	24-27 m/米	12-14 m/米
Southwest Lamma site 港燈西南南丫	17-23 m/米	9-12 m/米

* Source: CLP and HKE reports 資料來源：中電和港燈

Loss experience (based on Munich Re Group)
根據 慕尼克 Munich Re Group 的虧損經驗

Question 問題–
Insurance coverage is high risk and may not be profitable long term
投保: 高風險, 長遠不會有利潤

Case of Cyclone 03A June 6, 1998 West coast of India
1998 年6月6日 印度西岸 颱風損害個案

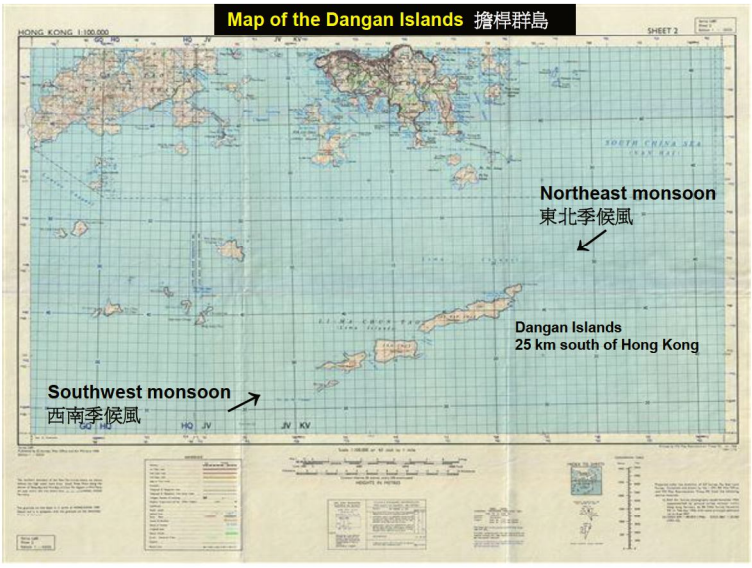
Peak wind speed 最高風速	240 km/h
Estimated wave height 預估浪高	5-6 m
Damaged 260 of the 782 wind turbines	(> 1 in 3)

782支風車, 損毀了260 支 約1/3 風車
130 were torn down and destroyed
130 支拆除及被毀
Damage to turbines/power lines > 8 figures
造成> 8位數字的損失

*Advantages of wind farms on Dangan Islands south of Hong Kong*擔桿群島建岸上風電場的優點

(1) Total cost reduction by ~3/4 through節省約3/4 總成本：
  (a) Lower ground investigation cost 較低研究成本
  (b) Lower construction cost 較低建築成本
  (c) Storm wave damage free 免颱風巨浪破壞
  (d) Lower operation cost 較低運作成本
  (e) Lower maintenance cost 較低保養維修成本
(2) No obstruction of shipping channels 航道不受阻
(3) No loss of fishing grounds 漁場可保
(4) Orientation of islands is favourable for capturing the northeast monsoon and the southwest monsoon.
地理上, 擔桿群島有利捕捉東北及西北季候風

Map of the Dangan Islands 擔桿群島



Summary/conclusions 總結

(1) Long-term cost of offshore wind farms in Hong Kong have been examined. 要審計香港建離岸風電場長遠成本

(2) Offshore wind farms are a waste of money because CO_2 is not mainly responsible for climate change. 離岸風電場是浪費金錢因爲二氧化碳不是主要影影響氣候轉變

(3) Cost subsidies will be needed. 需撥款資助

(4) Offshore wind farms in Hong Kong are extremely risky in a typhoon-prone region. 離岸風電場是極度危險因香港受颱風影響

(5) Onshore wind farms on Dangan Islands is a cheaper option worthy of exploration.
擔桿群島建岸上風電場較便宜, 值得探討