A Brief Introduction of Photovoltaics

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What is renewable energy and why do we need it?
Definition of Renewable Energy (RE)

  - “Energy that is derived from natural processes that are replenished constantly.”

- **Texas legislature:**
  - “Any energy resource that is naturally regenerated over a short time scale and derived directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources.”
Environmental impact of using non-RE
2010/03/22 API=500 (or >500??)
Global Warming: rise of CO$_2$

Atmospheric CO$_2$ at Mauna Loa Observatory

Scripps Institution of Oceanography
NOAA Earth System Research Laboratory

RECENT MONTHLY MEAN CO$_2$ AT MAUNA LOA

PARTS PER MILLION

PARTS PER MILLION

YEAR

2005 2006 2007 2008 2009 2010

4100m
The earth's surface temperature

Variations of the Earth's surface temperature: year 1000 to year 2100

Departs in temperature in °C (from the 1990 value)

Observations, Northern Hemisphere, proxy data

Global instrumental observations

Projections

Several models, all SRES envelope

Bars show the range in year 2100 produced by several models

Scenarios:
- A1B
- A1T
- A2
- B1
- B2
- IS92a

SYR - FIGURE 9-1b
Is it coming to HK??

http://www.weather.gov.hk/climate_change/climate_change_c.htm

28/2/2006
High tide
Benefits and Latest Local/Global Development of RE
Contribution of RE

- Replacing every kWh of non-RE with RE can (depending on type of power-plant):
  - Save 380g of coal
  - Avoid 0.532kg of CO$_2$
  - Save 3L of water
  - Avoid emission of SO$_x$, NO$_x$
World energy generation 2006

Source: IEA “World Energy Outlook 2006”
Cost and future of RE

- Wind, hydro, solar thermal: cost competitive
- Cost of PV generation: relative higher
- More than cost: only RE is possible with “energy pay-back period”; whereas non-RE are talking about “extraction ratio”
- Enormous resources have been invested to RE research in developed countries such as EU and Japan
- Cost per kWh is decreasing as the production capacity of RE equipment increases
Global development of RE

- Rapid in many countries
- Germany and Japan are the leaders
- Target
  - EU 2010: 12% of total consumption, 22% of electricity
  - China 2010: 5% of total energy, 10% of electricity
  - China 2020: 10% of total energy
  - HKSAR: 1% electricity by 2012, 2% by 2017, 3% by 2022 (EMSD study)
- Legislation
  - China: RE law: effective from 1/1/2006
  - HKSAR: NO
- Still no overall framework on energy portfolio / energy security
## RE in Hong Kong: potentials

<table>
<thead>
<tr>
<th>Type</th>
<th>Feasibility</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>✓</td>
<td>Have potential according to EMSD</td>
</tr>
<tr>
<td>Wind</td>
<td>✓</td>
<td>Have potential according to EMSD</td>
</tr>
<tr>
<td>Hydro</td>
<td>✗</td>
<td>Large-scale development not possible</td>
</tr>
<tr>
<td>Biomass</td>
<td>✗</td>
<td>Unlikely unless large-scale import of plants</td>
</tr>
<tr>
<td>Tidal</td>
<td>✗</td>
<td>Unlikely due to low tidal differential</td>
</tr>
<tr>
<td>Wave</td>
<td>✓</td>
<td>Victoria Harbour; or near the shores</td>
</tr>
<tr>
<td>Geothermal</td>
<td>✗</td>
<td>No volcanic activity</td>
</tr>
</tbody>
</table>
Principles of Solar Energy (Photovoltaics)
Principles of PV system

- Traditional PV uses semiconductor materials such as Silicon to fabricate PV cells which generate direct current under sunlight.
- First PV cell: 1954.
- Early applications: space for power supply in satellites.
- It is now commonly used on roof-top for supplementing electricity from utility grid.
PV potential is huge!

Sun at summer cloudiness noon

$1m^2 = 1000W$

80W-300W

1000W
Different PV technology

- **mono-crystalline (m-Si)**
  - Typical efficiency: 15%+

- **poly-crystalline / multi-crystalline (p-Si)**
  - Typical efficiency: 10-15%

- **semi-transparent PV**

- **Amorphous Silicon (a-Si)**
  - Typical efficiency: 4-7%

- **Copper Indium Diselenide (CIS)**
  - Typical efficiency: 9-12%
光電系統的原理

光伏技術

單晶硅：
由單晶硅錠料切片而成，在眾光伏物料中擁有最高的轉化效率。

多晶硅：
由大塊的鑄硅切片而成，其轉化效率及成本較單晶硅略低。

非晶硅：
由薄膜、非晶體的硅製成，其轉化效率較多晶硅略低，但成本卻較後者低一大截。

銅銦硒：
由一種由銅、銦及硒原素組成的薄膜物料製成，其成本與多晶硅接近。

目前光電模塊已模組化，因此極適合作為建築物的一部份，例如外牆及天台組件。
甚麼是光伏？

光伏系統

一般情況下光伏系統產生的電力是直流電。

光伏電池本質上是由硅及少量其他原素組成的固態半導體。
詳細的光伏系統結構圖

大致上光伏系統可分成兩類

獨立應用：
系統獨立運作，系統內一般有充電池連結作儲存電力之用。

聯網應用：
系統與當地電力公司之電網接駁。由光伏系統產生之直流電經過逆變器轉為交流電，並與電力公司之交流電並聯。
Inverter structure
2010/05/13: Arrival of PV modules
2010/05-07: Installation

2010/05/13

2010/07/03
2010/07/09
2010/07-08
Installation of inverter
SHCC PV system structure

5/F meter room

5/F phy lab

Data

Electricity

Remote monitoring

Whole campus
SHCC PV system parameters

Area = 45.2m²

Efficiency = 16.9%

= 185 × 36 = 6600 W_p

= 330 × 4 × 4

= 4 x
SHCC PV system “records”

- 2nd largest school PV system installed in HK (1st: Kei Wai Primary School (Ma Wan))
- Largest school PV system on HK Island
- 1st grid-connected school PV system on HK island
Savings over 1 year:

= 7,392 + 1,850 kWh (estimation)
= HKD 12,000 electricity bill
= 2.3% of SHCC consumption
= 4,800 kg CO₂

Estimated savings over 25 years (min. lifespan of PV system):

= 231,050 kWh (estimation)
= HKD 475,479 electricity bill (HEC tariff, 3% increase per annum)
= 180 tons of CO₂

Payback period = 25 years
Is PV useless in rainy days?

Still have 10% generation!
DAQ system for education

- Solar radiation
- Ambient temperature
- Wind speed
- Sensors installed on roof
- Monitoring 24x7
End
Thank you

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