Challenges in Applications of Renewable Energies for Desalination

TECHNICAL/ SCALE UP

SOCIAL

ECONOMIC/ POLITICAL

SUSTAINABLE/ ENVIRONMENT

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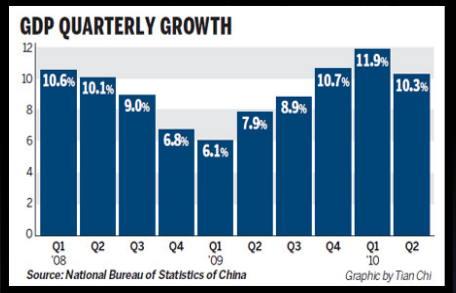
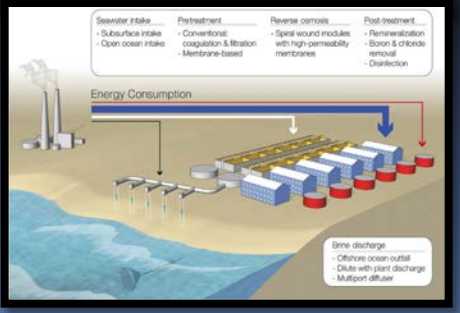
Challenges

- WIND POWER, OCEAN WAVE & TIDAL POWER FOR DESALINATION
- GEOTHERMAL DESALINATION
- SOLAR ENERGY FOR WATER DESALINATION
- HYBRID SYSTEMS
- SCALE-UP & ECONOMIC CONSIDERATIONS
- REGULATORY FACTORS, ENVIRONMENTAL CONCERNS & GLOBALIZATION
- SELECTING MOST SUITABLE RENEWABLE ENERGY TECHNOLOGY FOR DESALINATION





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Global primary energy use in exajoules (EJ), 1970-2006

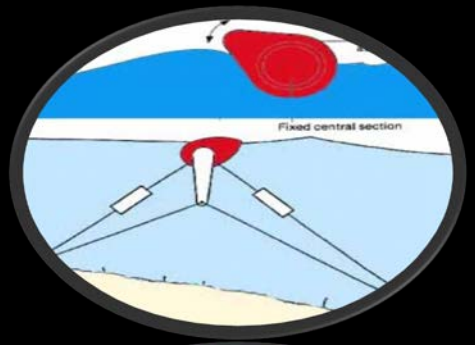
(adapted from Moriarty and Honnery, 2009). In describing national or global energy budgets, it is common practice to use large-scale units based upon the joule; 1 EJ = 10^{18} J.

Energy source	1970	1980	1990	2000	2006
Fossil fuel					
Coal	64.2	75.7	93.7	98.2	129.4
Oil	94.4	124.6	136.2	148.9	162.9
Natural gas	38.1	54.9	75.0	91.8	107.8
Total Fossil fuels	***196.7***	***255.1***	***305.0***	***339.0***	***400.1***
Nuclear	0.7	6.7	19.0	24.5	26.6
Renewable	29.4	37.6	48.5	55.6	66.2
All energy	***216.8***	***299.5***	***372.4***	***419.0***	***492.9***
Renewable (%)	***13.6***	***12.6***	***13.0***	***13.3***	***13.4***

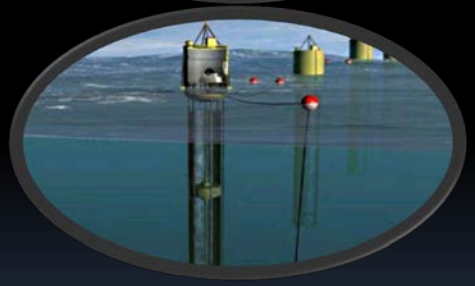
Ocean Wave & Tidal Power for Desalination

Jiangxia pilot tidal plant (Wang et al., 2011)

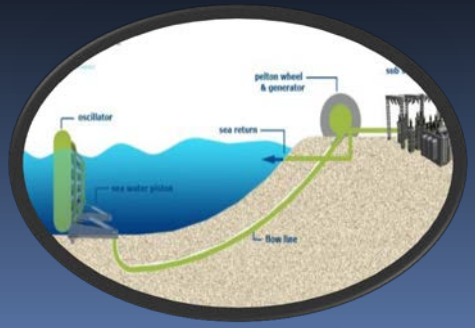
Salter Duck pendulum swings generating electricity (Thorpe, 1999).



Aquabuoy (Chapa, 2007)

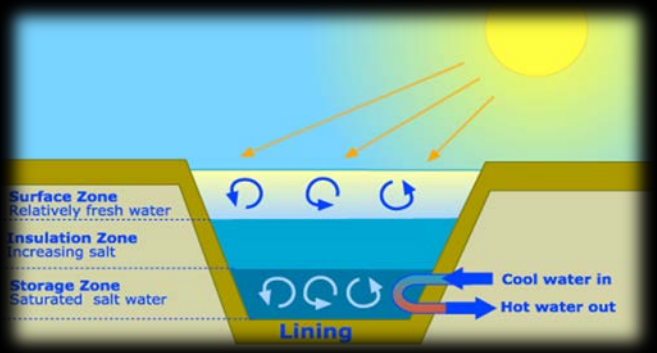


Oyster™ Whittaker *et al.* (2007)

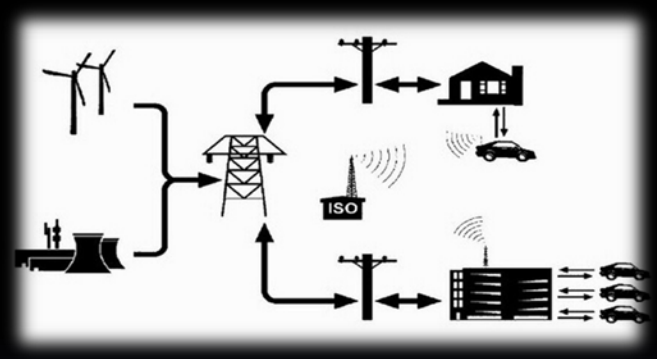


Energy Storage and Hybrid Systems

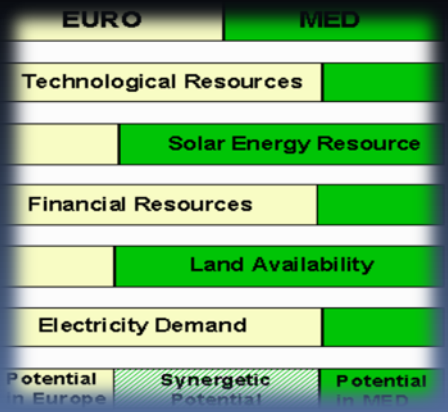
Solar pond for heating purpose
(Wright, 1982; Energy Education, 2011)

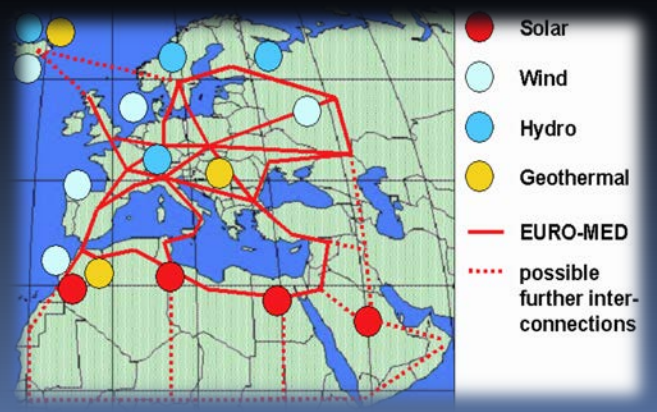


Vehicle-to-grid power (V2G) as storage resource for large-scale wind power
(Kempton and Dhanju, 2006)



Euro-Mediterranean power pool interconnecting sites for renewable electricity generation
(Trieb *et al*., 2002)





Scale-up & Economic Considerations

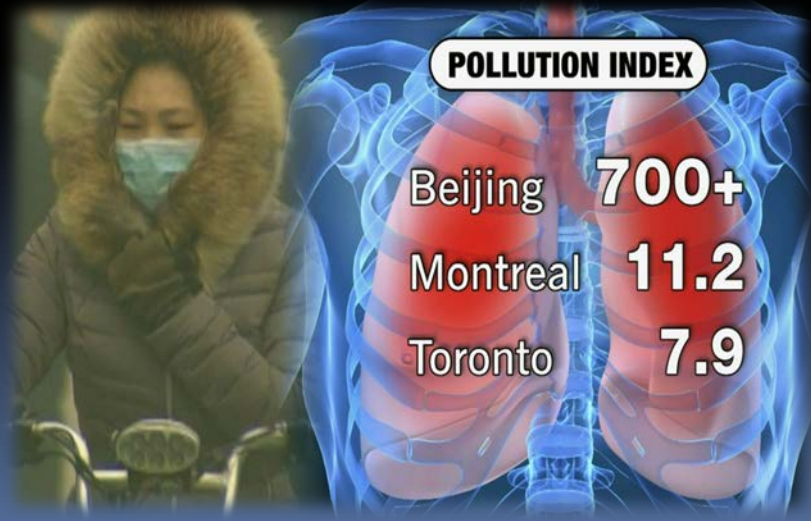
- Factors affecting scale-up and cost-efficiency
  - Large-scale application of solar technologies limited by technology & economics
- Market potential, process selection & risk managment
  - Concentrating solar power (CSP) & RO desalination are most promising fields for medium & large-scale solar desalination
- Promotion of renewable energy policy & reduction in reliance on conventional power generation
  - Government policy instruments can aid in commercialization but can also undermine jobs
  - Frondel et al. (2010) assessed *Renewable Energy Sources Act* focusing on costs & associated job creation & climate protection

Estimates of Levelized Cost ($/MWh) of Electricity by Source

(adapted from DeCanio and Fremstad, 2011).

Study Reference	Coal	Nuclear	Wind	Geo-thermal	Solar PV	Solar Thermal
U.S. Energy Information Administration, 2010a, 2010b	100.4	119	149.3	115.7	396.1	265.6
RETI Stakeholder Steering Committee, 2010			90-130	100-160	250-350	240-290
Lazard ltd., 2009	78-144	107-138	84-140	85-120	212-296	199-325
Borenstein, 2008					337-565	
Renewables 2010 Global Status Report			50-90 (Onshore) 100-140 (Offshore)			
Benson and Orr, 2008	43		75		280	200
Greenpeace Int., SolarPACES, and ESTELA,2010						150
IEA/NEA 2005	28-75 (pulverized)	33-74	50-156 (Onshore) 71-134 (Offshore)		226-2031	292
European Commission 2008	52-65 (pulverized)	65-110	97-142 (Onshore) 110-181 (Offshore)		674-1140	220-324
EPRI 2008	64 (pulverized)	73	91			175
IEA/NEA 2010	54-120 (r = 5%) 67-142 (r = 10%)	29-82 (r = 5%) 42-137 (r = 10%)	48-163 (onsh. r = 5%) 101-188 (offsh. r=10%)		215-333 (high load) 600 (low load)	136-243
Average $/MWh	**79**	**84**	**112**	**99**	**491**	**225**

Regulatory Factors, Environmental Concerns & Globalization



Institutional Aspects of Economic Growth:

Assessing the Significance of Public Debt, Economic Governance & Industrial Competition

- Trying to comprehend factors that contribute to economic rise & decline of nations
- There are economic philosophical differences (e.g. Keynesian versus Hayekian type of reasoning)
  - To Hayek, less government involvement meant added economic choice.
  - Keynesian economics believes that dynamic government involvement in marketplace and monetary policy is best way

Goosen, M.F.A. 2013. *OBJ,* 6; 1-13;

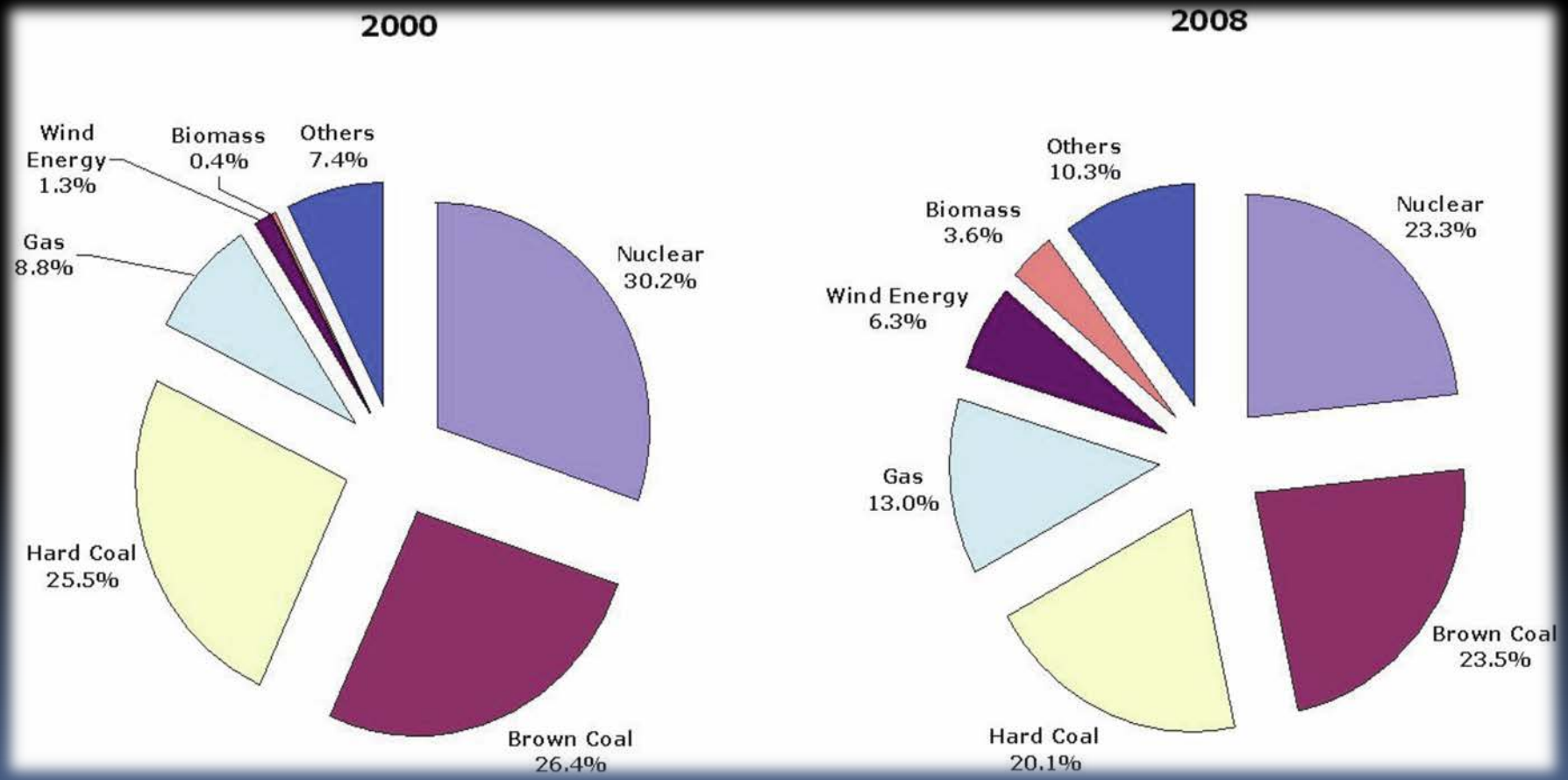
Gottinger, H., and Goosen, M. F. A, (Eds), 2012. "*Strategies of Economic Growth and Catch-up: Industrial Policies and Management",* Nova Science Publ Inc, Hauppauge, NY

Environmental Awareness through Integration of Research & Education: A Case Study from Two Elementary Public Schools in Puerto Rico

Rivera-Rentas et al IJEP 31 2007

Gross Electricity Production in Germany in 2000 and 2008

(Frondel *et al.*, 2010).



Selecting the Most Suitable Renewable Energy Technology for Desalination Processes

Recommended renewable energy-desalination combinations

(Mathioulakis *et al*., 2007).

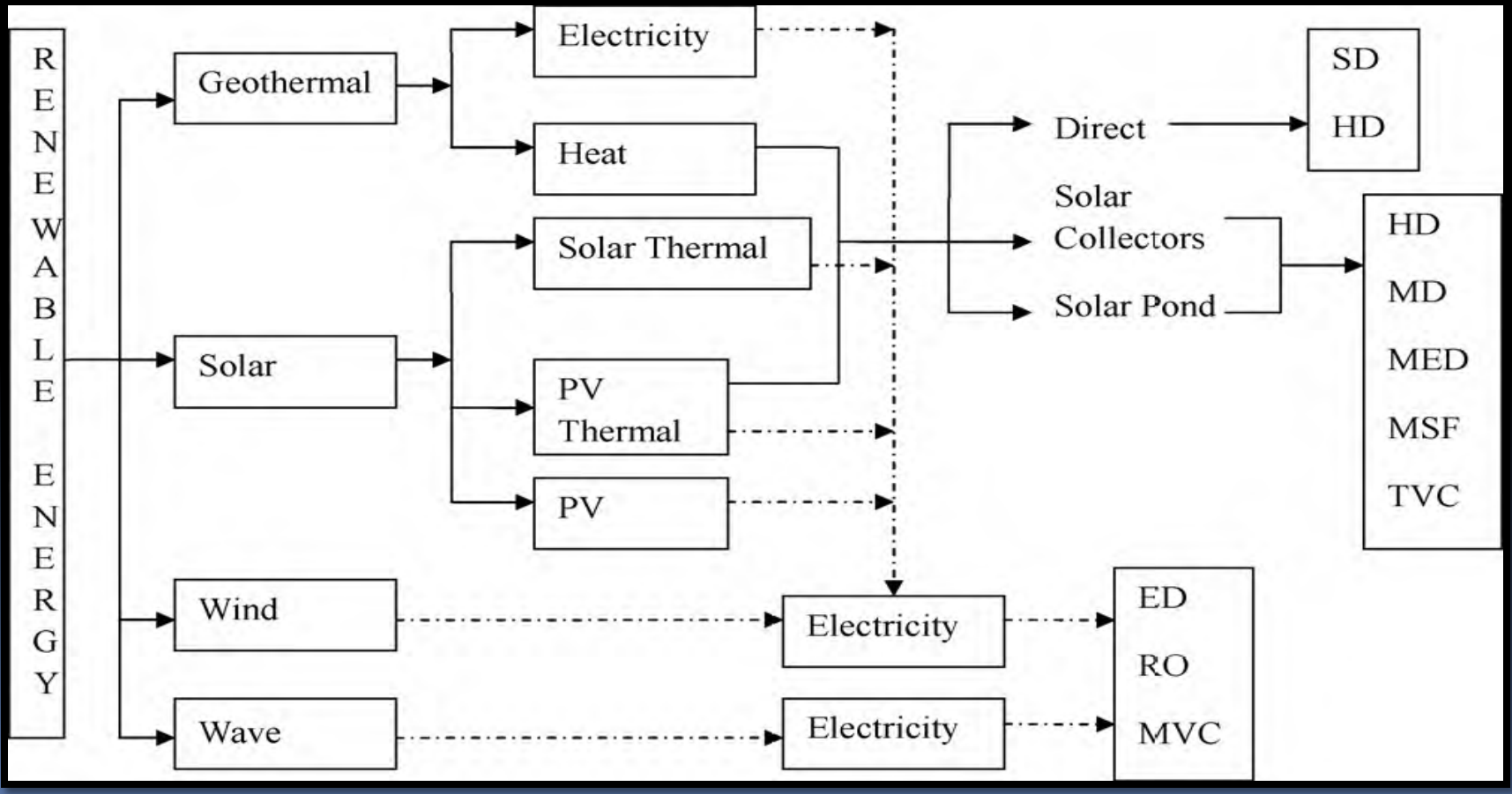
Feed water quality	Product water	RE resource available	System size: Small (1-50 m^3d^{-1})	System size: Medium (>50 m^3d^{-1})	System size: Large (>>50 m^3d^{-1})	Suitable combination
Brackish water	Distillate	Solar	X			Solar distillation
	Potable	Solar	X			PV-RO
	Potable	Solar	X			PV-ED
	Potable	Wind	X	X		Wind-RO
	Potable	Wind	X	X		Wind-ED
Seawater	Distillate	Solar	X			Solar distillation
	Distillate	Solar		X	X	Solar thermal-MED
	Distillate	Solar			X	Solar thermal-MED
	Potable	Solar	X			PV-RO
	Potable	Solar	X			PV-ED
	Potable	Wind	X	X		Wind-RO
	Potable	Wind	X	X		Wind-ED
	Potable	Wind		X	X	Wind-MVC
	Potable	Geothermal		X	X	Geothermal-MED
	Potable	Geothermal			X	Geothermal-MED

PV= photovoltaic, RO= reverse osmosis, ED= electrodialysis, MED= multi effect distillation, MVC= mechanical vapour compressor

Possible combinations of renewable energy sources with desalination processes

(Gude *et al*., 2010; Bourouni *et al*., 2011).

SD = solar distillation, HD = humidification-dehumidification, MD = membrane distillation, MED= multi effect distillation, MSF = multi stage flash, TVC = thermal vapour compression, PV= photovoltaic, RO= reverse osmosis, ED= electrodialysis, MVC= mechanical vapour compressor



Conclusions

- Large-scale application of solar technologies limited by technology & economics
- Concentrating solar power (CSP) & RO desalination are most promising fields for medium & large-scale solar desalination
- Key drawback of renewable energy systems is variability of energy supply
- Hybrid power systems can reduce supply interruption
- Rapid growth of emerging global economies has resulted in significant pollution
- Government policy instruments can aid in commercialization but can also undermine jobs
- First choice is conventional energy source in conjunction with renewable energy