Economies of energy and cost optimization: The point of view of an operator

PECC - December 10th, 2009

Contents

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Part I – A challenging context

Energy for water, a large item in countries' budgets (1)

- At the scale of countries, a lot of energy is expended on producing and distributing water, and treating wastewater:
  - ➔ In California, 19 % of the state's electricity and 30 % of its natural gas are used for water, either in pumping or treatment. *(Source: California Energy Commission, 2005)*
  - ➔ In the United States, 4% of total power generation is used to supply, purify, distribute and treat fresh water and wastewater *(Source: Managing our future water needs, World Economic Forum, January 2009).*
  - ➔ In Sweden, only 1 % is used for the same purpose *(Source: IWA 21, June 2009)*

Assessment of energy used for water production

	% of energy consumption by country	
	Primary energy	***Electricity***
United States	1.6 %	4.3 %
China	1.7 %	5.5 %
India	8.9 %	30.5 %
Saoudi Arabia	3.7 %	-
France	1.6 %	3.4 %

Source: Water-energy-interactions: a look at the challenges at different levels, Jean-François Bonnet, Zaragoza 2008

Energy for water, a large item in water utilities' budget (2)

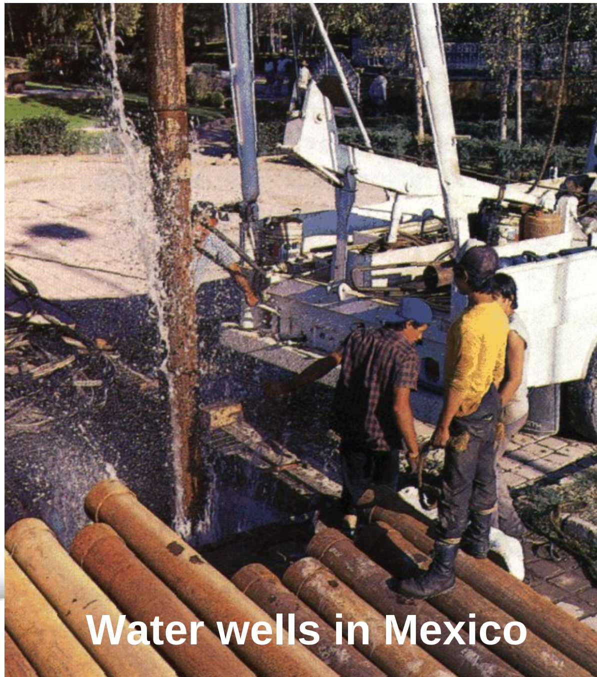
- In the procurement budgets of water and sanitation services, energy is a major item:
  - Typically, electricity accounts for approx. 80 % of municipal water processing and distribution costs in the US *(Managing our future water needs, World Economic Forum, January 2009)*
  - The 16,583 wastewater treatment plants in the US spend about $4 billion a year on electricity and add more than 45 million tons of GHG to the atmosphere *(Source: Water 21, June 2009)*
  - Water requires more advanced technologies, but advanced technologies require more energy, except innovative process invert this trend.

Competition and cooperation between water and electricity

- There is no drinking water without energy, and no energy without water
- The "*green revolution*" allowed India to become self-sufficient in food:
  - ➔ It was based on more productive crop varieties and cheap, plentiful water, thanks to subsidized electricity price for pumping water.
  - ➔ But these hidden electricity subsidies lead to overexploitation of groundwater
- The nexus between energy and water is a critical issues for many PECC countries
  - ➔ Current forecasts place Asian electricity consumption at an annual increase of 5-8 %.
  - ➔ This trend will have significant implications for water resources, since energy generation requires water (*Asian Regional Document, March 2009, 5th World Water Forum*)
- Water and energy are competing for the same resource:
  - ➔ Water withdrawal for energy is much larger than water consumption (as much as 25 times in the US).
  - ➔ American energy production is very much at the mercy of water availability *(US Department of Energy, as reported to the Congress)*
  - ➔ An example of conflict between water management and energy production: cities in Uruguay had to choose whether they want the water in their reservoirs to be used for drinking water or electricity.

The high volatility of energy prices and its impact on water utilities

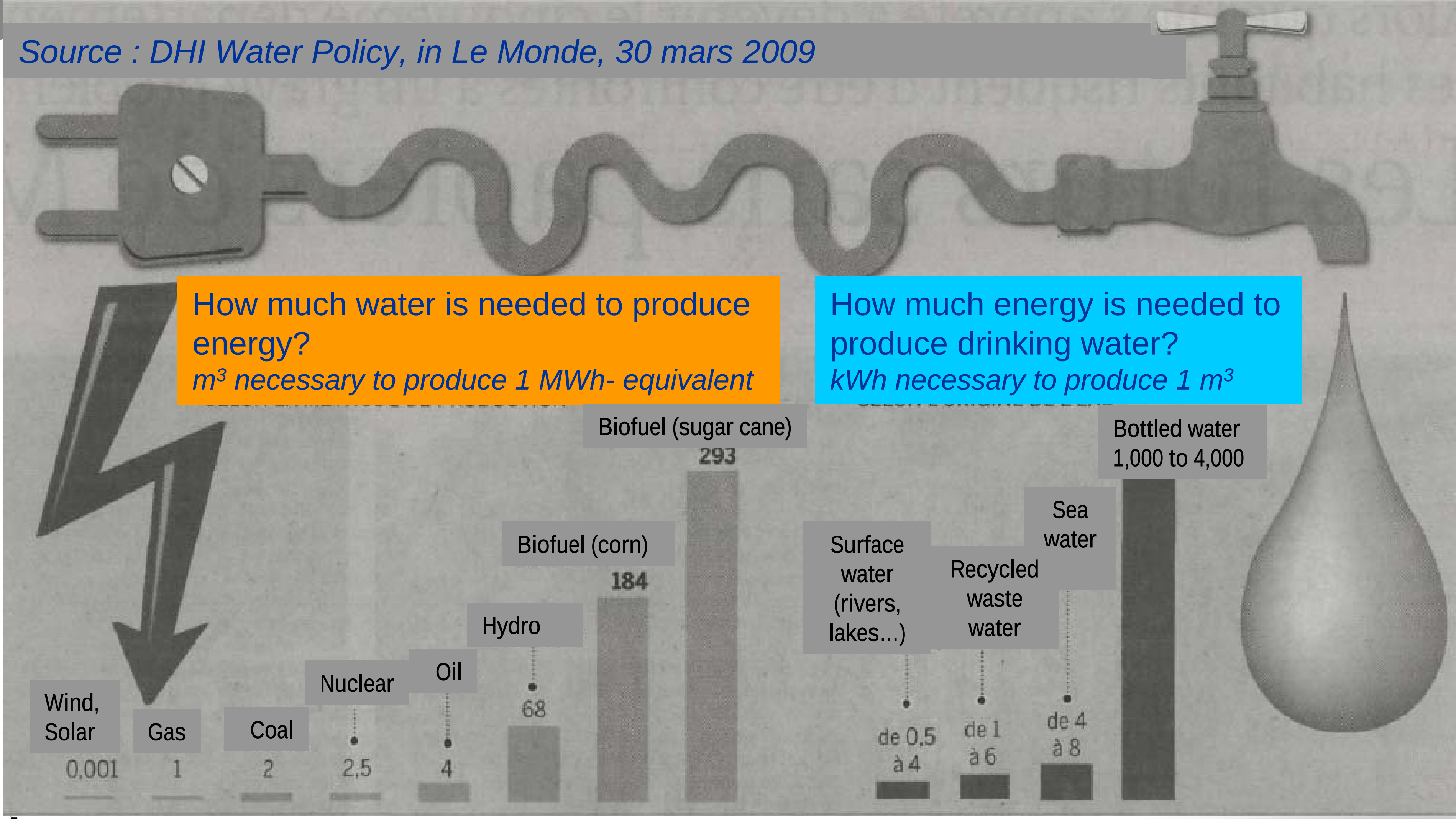
- There are major uncertainties on the cost of energy inputs into water services:
  - The price of a barrel of oil climbed from $10 in 1999 to $145 in July 2008, then plunged to less than $40 in December 2008.
  - Spiking energy prices emphasized the role of the water/energy nexus in development
- Implications of higher energy prices for the water sector:
  - Increase in utility operational costs
  - Water extraction and conveyance become more costly
  - Costs of groundwater increase subsantially
- Price of water versus price of energy:
  - Underpricing water led to its overexploitation.
    Underpricing energy led to wastages.
    And underpricing business risks led to chapter 11...
  - In India, 65% of water OPEX are due to energy costs. In Mali, 80 %. Then every fluctuation in the price of oil throws access to drinking water into question.
  - « *In some countries, when the price of a barrel of oil triplicates, pumping capacity is divided by three* »
    Loïc Fauchon, Chair of the World Water Council, March 19th 2009


Water wells in Mexico

Part II – Comparative analysis of water treatment process

Water for energy and energy for water

Source : DHI Water Policy, in Le Monde, 30 mars 2009



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Average electricity consumption of drinking water production, according to treatment process

	Drinking water production process	**Electricticy consumption in Wh /m^3**
Freshwater	Conventional treatment	50 - 150
	Membrane treatment (*ultrafiltration / microfiltration)*	100 - 200
	Advanced membrane treatment	250 - 700
Seawater or brackish water	Brackish water desalination *(nanofiltration or reverse osmosis)*	600 - 1500
	Sea water desalination with energy recovery system *(reverse osmosis)*	3000 - 5000
	Sea water desalination without energy recovery system *(reverse osmosis)*	5500 - 8000
	Thermal desalination (distillation) *	> 6000
Wastewater	Wastewater recycling	25 - 1500
	Sludge treatment	5 - 15

** Electricity + heat converted into electricity equivalent*

Source: TSM n° 9 - 2007

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Comparison of water treatment process, according to energy required

- **Wastewater versus freshwater:**
  - ➔ In average, wasewater recycling consumes 1,000 Wh per m^3. This is at least 2 times more than procuding drinking water from freshwater resources.
- **Seawater versus freshwater:**
  - ➔ Seawater desalination consumes at least 20 times more electricity than conventional treatment of freshwater
  - ➔ And thermal desalination consumes in average 3 times more energy than membrane desalination
- **Wastewater versus seawater:**
  - ➔ Wastewater recycling is a less-energy consuming solution compared with seawater desalination and brackish water desalination
- **Alternative resources versus long distance transportation:**
  - ➔ Wastewater reuse needs less energy than water imports over more than 60 km
  - ➔ In Southern California, pumping water long distances (500 km from Colorado to LA) requires 2,300 Wh per m^3 compared with 4,000 Wh per m^3 for desalination

(Gustaf Olsson, professor emeritus at Lund University, Sweden – Water 21, June 2009)

Carbon footprint of desalination, according to technologies selected

Survey on Veolia Water operated plants: average carbon footprint

	Greenhouse Gas rejected
Reverse osmosis	1.8 kg CO_2 per m^3
Thermal desalination (MED – Multi-Effect Distillation)	18.0 kg CO_2 per m^3
Thermal desalination (MSF – Multi Stage Flash Distillation)	23.4 kg CO_2 per m^3

Comparison: 1 metric ton of wheat	25.0 kg CO_2 per ton

- These are indicative figures since CO_2 emitted is function of the local energy mix.
- For instance, in the case of a reverse osmosis plant consuming 3,000 to 4,000 Wh per m^3, GHG emissions amount to:
  - ➔ 2.1 kg CO_2 with the European energy mix
  - ➔ 0.6 kg CO_2 with the French energy mix

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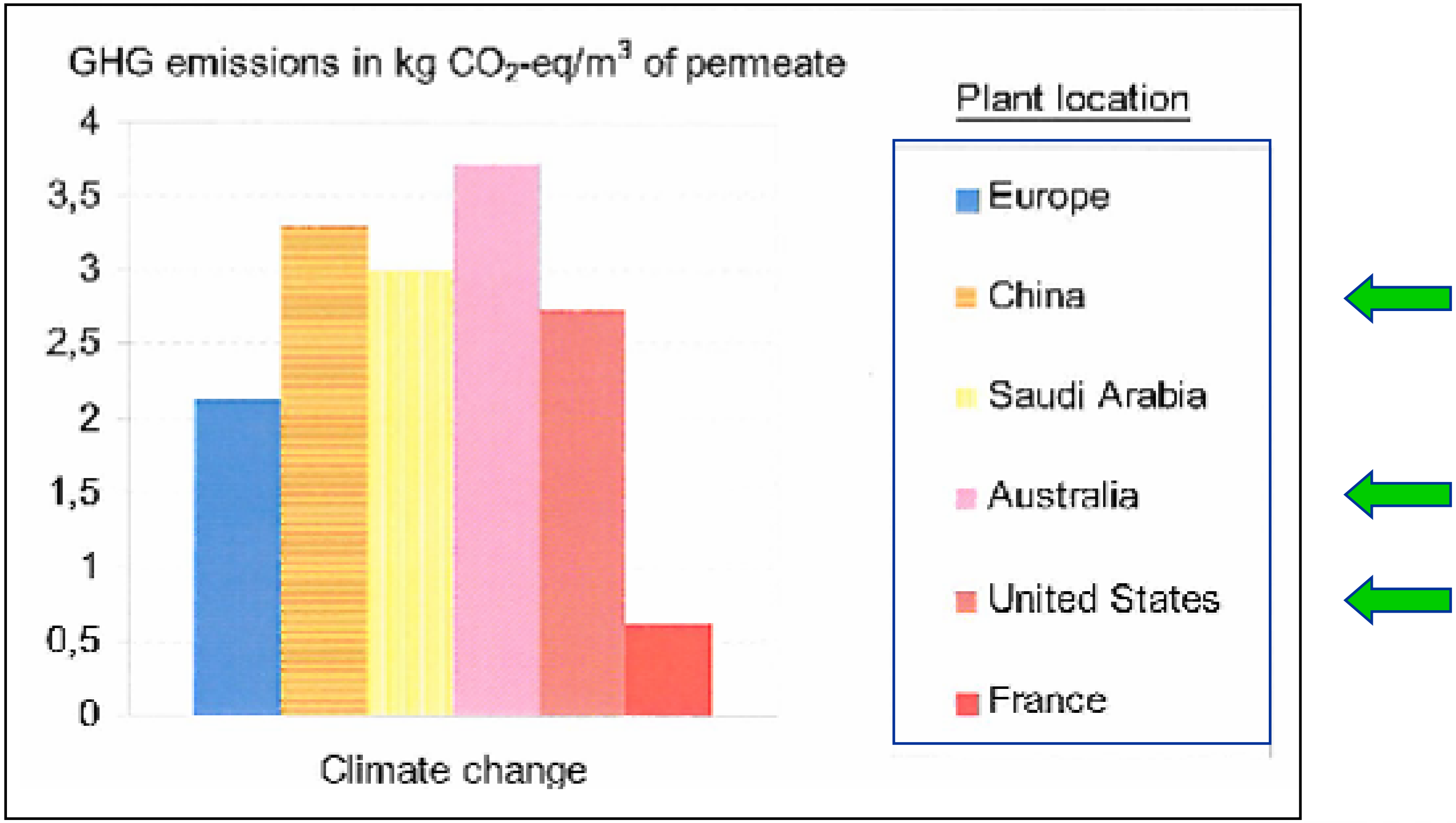
Carbon footprint of desalination, according to energy mix

Greenhouse gases emissions
for seawater desalination by reverse osmosis



Part III – Reducing energy consumption in drinking water production

Changing pumps can save energy and money

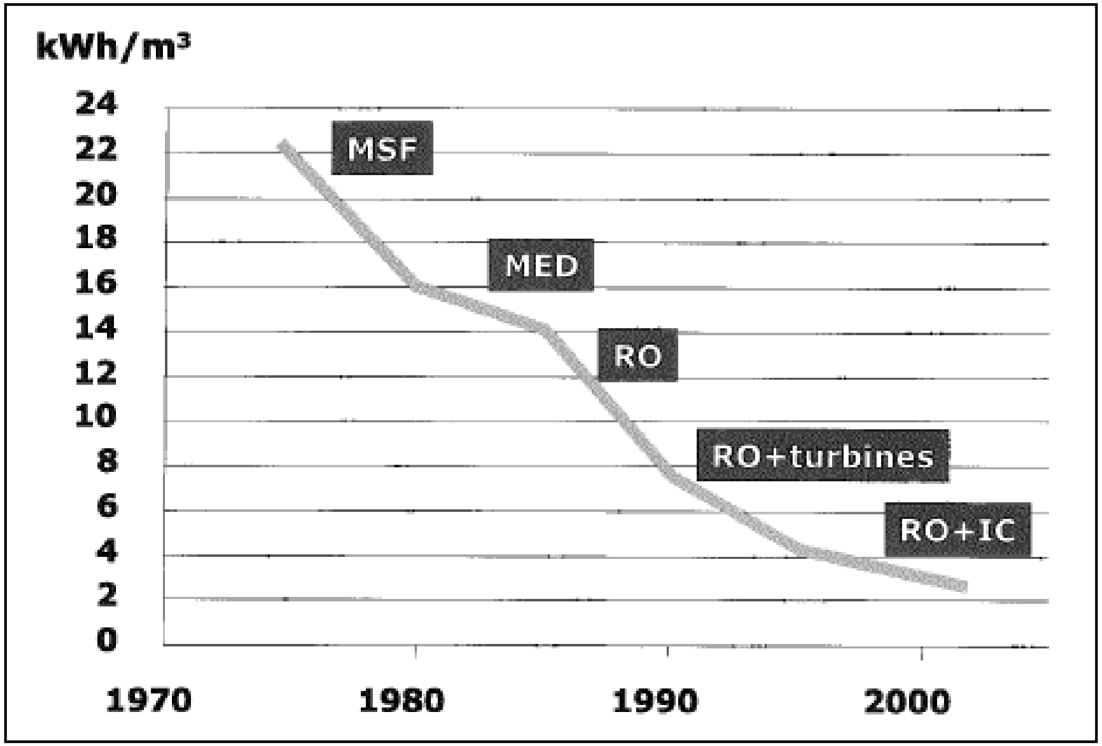
- Pumping frequently uses more than 80 % of sites electricty consumptions. This is clearly where efforts should focus on.
- The example of Hohhot (China) - 2.5 million inhabitants
  - In 2004, Veolia Water was awarded the 30 year contract for managing the wells' field and drinking water production plant of Hohhot (capacity: 515 000 m^3 / day)
  - In 2008, Veolia Water made a study to renew 14 boosting pumps and 15 deep-well pumps.
  - By carefully selecting energy efficient pumps and properly adapting pumps to specific needs and conditions, the project could save 7.2 million kWh / year
  - This is equivalent to:
    - 3,700 tons of coal;
    - US $400,000 savings on the annual electricity bill (2.9 million Yuan)
  - The total investment amounts to US $250,000 (1.8 million Yuan). The payback is shorter than 1 year.
- It is often worthwhile to anticipate pumps renewal

Tianjin pumping station

Impressive progress were made since 1970's in terms of energy consumption and costs for desalination

- In terms of energy used

Evolution of energy consumption per m³ desalinated water



Source: Advances in environmental aspects of desalination: the Canary islands experience - Manuel Hernandez-Suarez

- In terms of costs

- In 1965, the cost of desalination was:
  - ➔ $ 6.80 per m^3 with distillation
  - ➔ $2.20 per m^3 with membrane technologies.
- In 2000, the cost of desalination was:
  - ➔ $1 per m^3 with thermal desalination
  - ➔ $0.60 per m^3 with reverse osmosis.

Source: L'eau, géopolitique, enjeux, stratégies. Franck Gallad, CNRS Editions, 2008

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On-going research programs on energy for water (1)

- Today, over 50 % of operating cost is still due to electricity bill.
- Energy consumption of desalination has been divided by 2 between 1990 and today: 8 kWh / m^3 in 1990 to 4 kWh / m^3 today.
- However, further gains in energy efficiency, and hence in cost reduction, will be increasingly difficult. Energy savings will be more and more expensive.
- Current research aims:
  - ➔ to lower the energy consumption of membrane processes even more (for desalination and reuse). Veolia Water on-going programs aim to reduce by 30% to 50% energy consumption of reverse osmosis
  - ➔ to supply membrane desalination facilities with electricity produced in part from renewable sources
- Thermal desalination is a more mature technology and less progress is hoped with regards to energy consumption.

On-going research programs on energy for water (2)

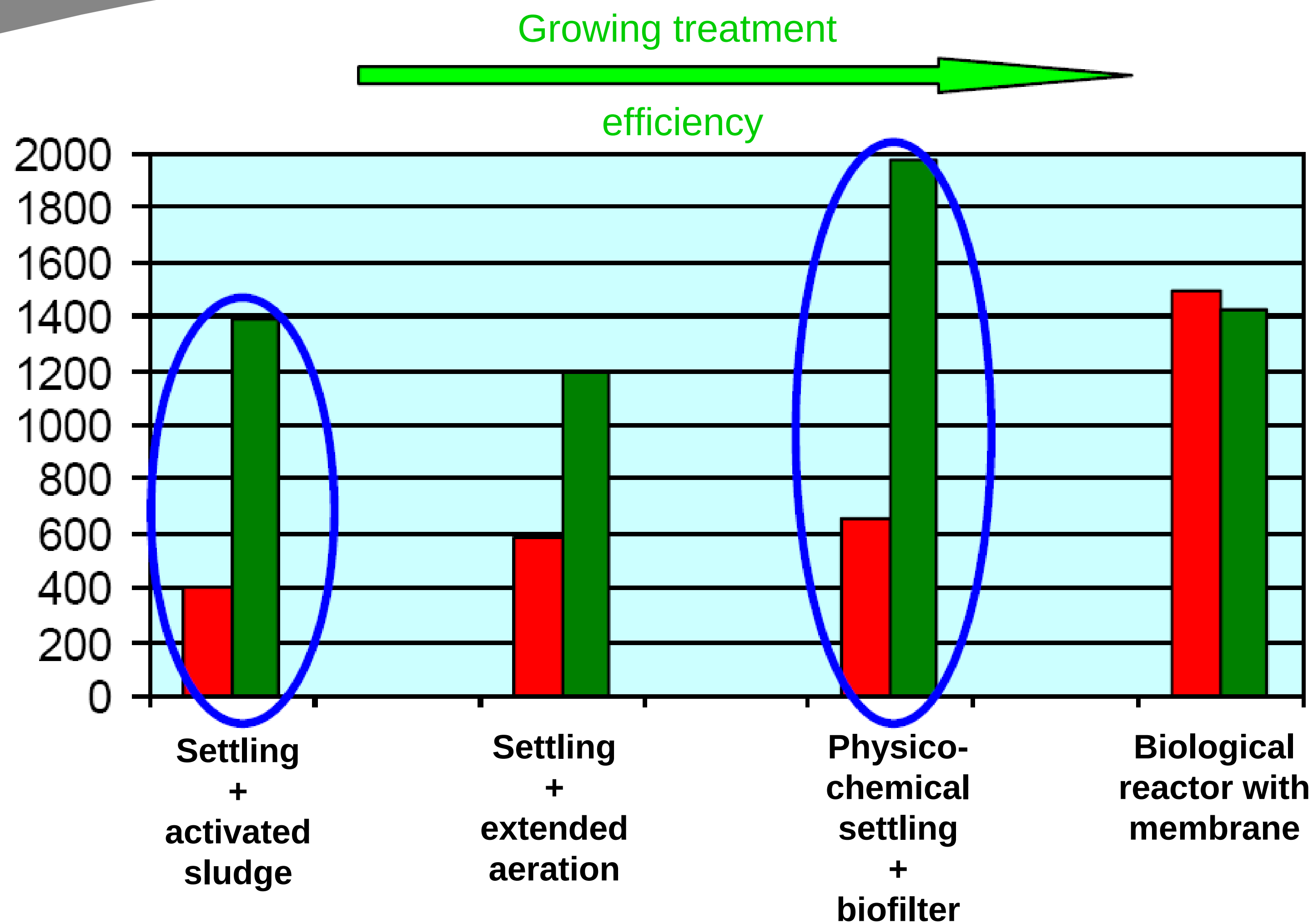
- R&D programs are of the utmost importance to reduce energy consumtion and price in desalination.
- Developing low energy desalination plant is a key driver for research. But whatever future progress, seawater desalination will **never** compete with freshwater treatment:
  - ➔ in the world, for private operators, the average electricity consumption for water production is assessed at 500 Wh per m^3
  - ➔ the theoretical energy requirement for desalinating 1 m^3 of seawater is 900 Wh.
- However, a "*Green desalination plant*" is feasible subjected that large renewable energy source is available (e.g.: with wind energy for desalination in Sydney…).

Part IV – Towards energy self-sufficient wastewater treatment plants

Optimizing energy consumption at a wastewater treatment plant

- Energy is usually the 3rd budget line of wastewater treatment plant
- Aeration is generally the 1rst electricity consumer, followed by the air treatment (if there is one) and the sludge treatment (when there are centrifuges).
- For Veolia Water plants altogether,
  - ➔ Approx. 80% of energy is used to aerate the biological basins;
  - ➔ Odour treatment systems account for up to 20% of total energy consumed;
  - ➔ Pumping represents most of the remaining energy consumption (~15%).
- Sludge can have and should have a second life:
  - ➔ Sludge should always be seen as a source of energy;
  - ➔ Once dried, the Calorific Value of sludge reaches 4 to 5 kWh / metric ton. This is equivalent to wood;
- Wastewater treatment plants are really energy production plants:
  - ➔ Usually, energetical valorization of sludge (sludge digestion + biogas production) offers to cover 60 % of energy needs of wastewater treatment plants.
  - ➔ Achieving neutral wastewater treatment plant is a realistic middle-term objective

Energy needs and potential energy sources according to the type of wastewater treatment process

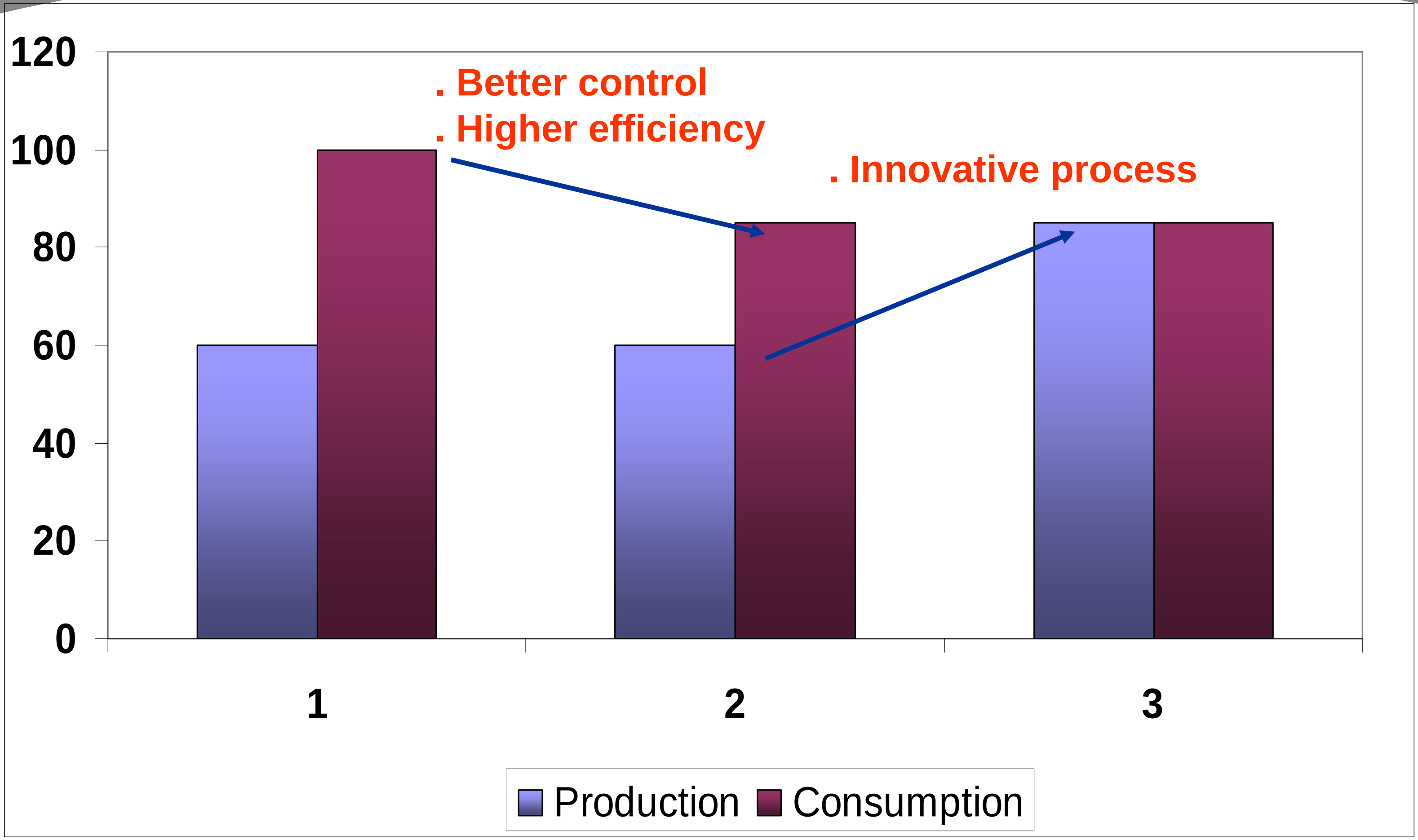


In red: electrical needs in Wh / m^3 produced

In green: energy contained in sludge (Wh Low Calorific Value / m^3)

- In blue circles: the 2 most interesting process in terms of gap between energy needed and energy produced

The move towards self-sufficiency wastewater treatment plant



1) Starting point: 60% covering ratio currently achieved in Central Europe
2) Consuming less energy
3) Producing more energy from biogas

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The contribution of solar energy in water and wastewater services

- In only 40 minutes, the sun sends to the Earth all the energy needed by humankind during one year!
- Mobilizing solar energy requires large areas.
- There is an undervalorized potential on water treatment and wastewater treatment plants, since these plants are usually « *space consumers* »;
  - ➔ Roof solar power station can equip drinking water plant or wastewater treatment plant to provide one part of electricity;
  - ➔ At the Hague wastewater treatment plant (1.7 million population-equivalent), basins are covered by 450 m^2 of solar panels. Thanks to biogas production by sludge digesters and additional solar energy, energy independence ratio amounts to 50 %.

Conclusion

Linking water, energy and climate

- Many recent technologies are water intensive:
  - In the water sector: technologies required to mobilize alternative water resources are energy intensive;
  - In the energy sector: hydrogen economy would require much more water.
- Looking at water use and energy use simultaneously generate valuable insights that do not arise from separate policy.
- This combined approach is all the more necessary since energy security may be conflicting with water security:
  - The dilemma is that energy enable us to reduce water scarcity and that water enables us to reduce energy scarcity…
  - Energy is a potential limiting factor in water scenarios, and water is a potential limiting factor in energy scenarios
- Example of synergy combining desalination plant and power production plant:
  - As for new thermal desalination projects, desalination plants are increasingly being installed in conjunction with energy production installations;
  - The heat produced (when hydrocarbons are burnt to produce electricity) is used to vaporise sea water;
  - These hybrid solutions allow optimal use of thermal power stations.

The need of new water and energy cultures

- Water efficiency should be given a priority by energy planners. And energy efficiency should be given a priority by water planners
  - ➔ South Korea aims at improving energy independence of public sewerage facilities from 0.8 % in 2007 to 45 % in 2030 *(Chong Chun KIM, Korean Ministry of Environment – Incheon World City Water Forum, August 21rst, 2009)*
- At the world scale, it needs half a century to deeply change the breakdown of energy consumption according to primary sources of energy. Therefore, implementing energy savings measure are much more quick-acting.
- Saving water means saving energy:
  - ➔ In California, *"rationalising water use saves more energy than introducing other measures of energy efficiency"* (California Energy Commission, 2005)
  - ➔ Preserving freshwater resources for drinking water production is the best way to save energy, compared to alternative water resource mobilization. However, in many dry areas (eg: Australia), it is impossible
  - ➔ It is necessary to save all kind of energy and water, not only some of them. It would be a non-sense to save one type of energy and to waste another type,..
- Being energy and carbon neutral is feasible for wastewater treatments plants. The issue is then disseminating innovation on the field.

Thank you for your attention