Desalination using ice slurry manufacturing

University of Applied Sciences of Western Switzerland

Geneva Institute of Technology

www.eig.unige.ch/cmefe

Jean-Bernard Michel

michel@eig.unige.ch

Co-authors: O. Sari, P. Egolf, N. Erbeau

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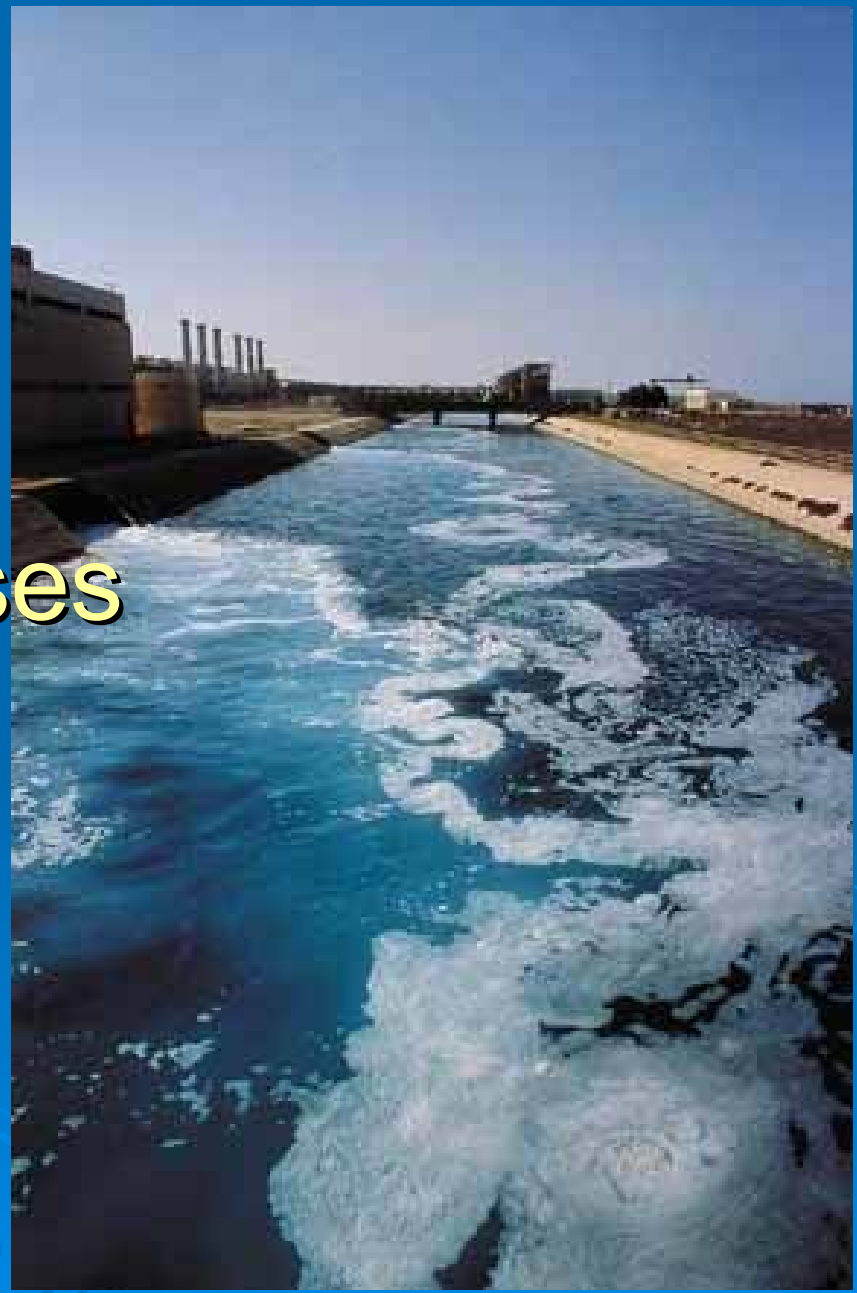

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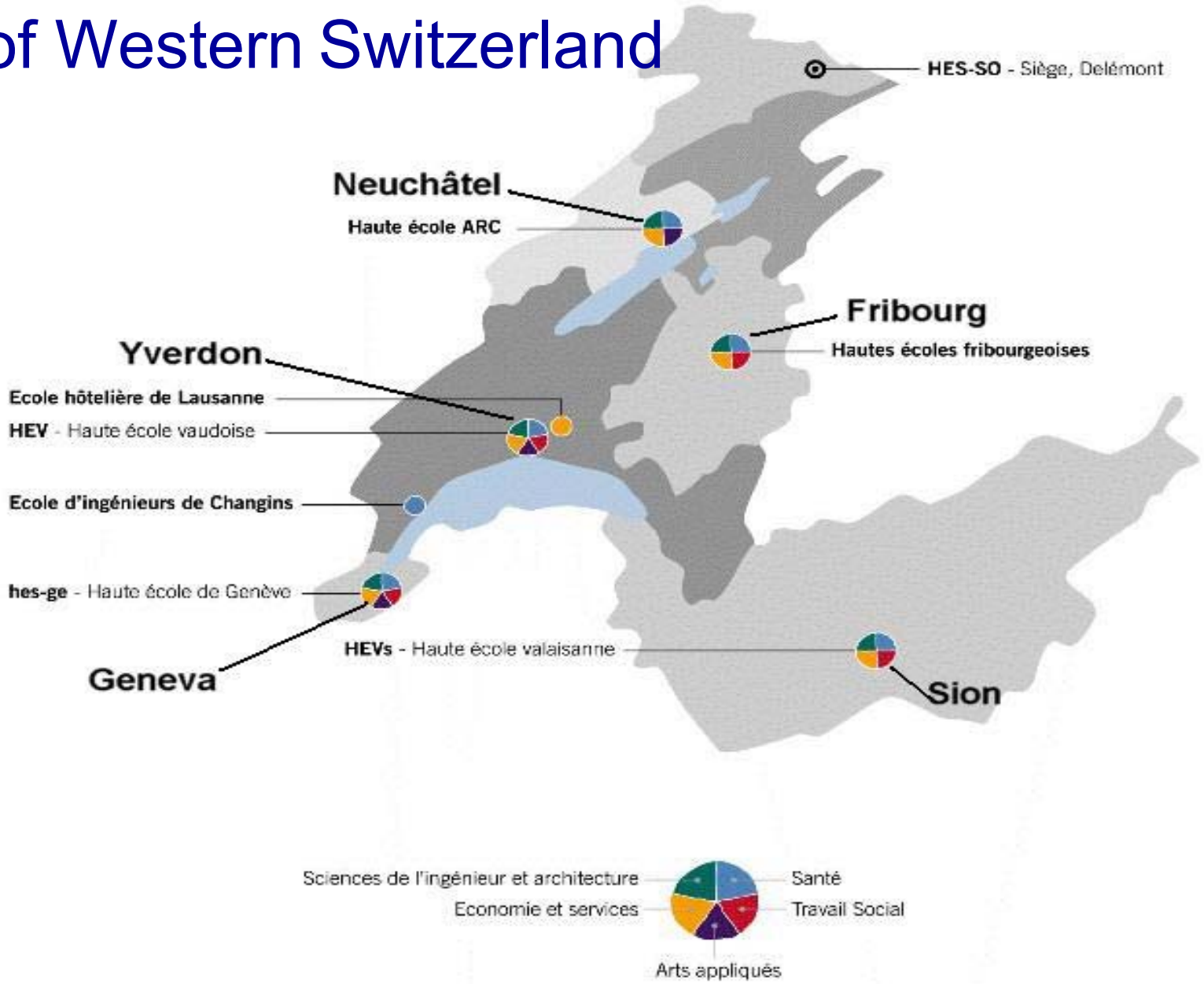

Main R&D activities

- Fluid mechanics and energy conversion systems Lab, Geneva
  - Building design, simulation, HVAC systems
  - Aerodynamics of sport
  - Renewable energies
  - Thermodynamical cycles
- Thermal Engineering Institute, Yverdon
  - Phase change materials and ice slurries (IEA working group)
  - Magnetic cooling
  - Combustion

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Equipments

Subsonic wind tunnel

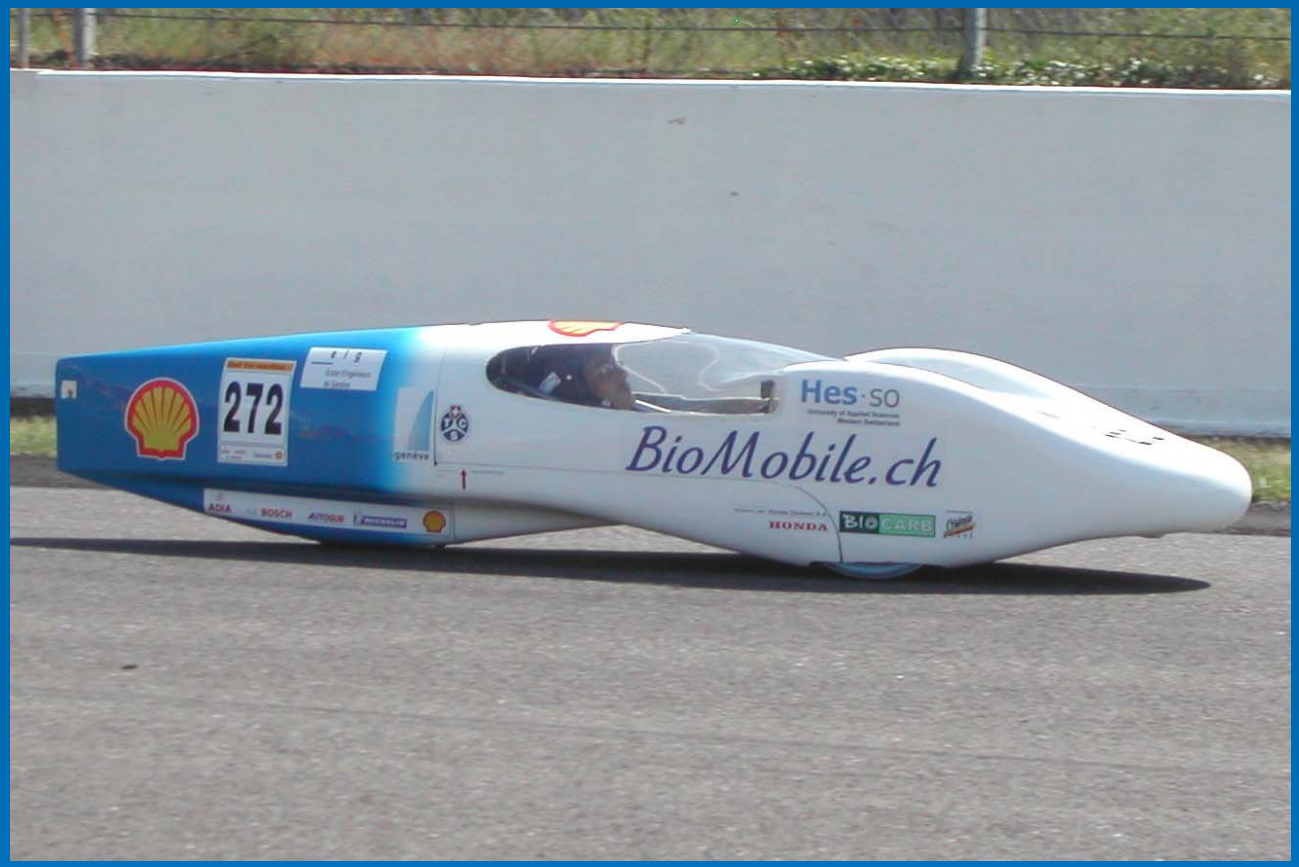
2 veines de mesure : 2.0 x 1.5 [m²] vitesse de 280 [km/h]
3.4 x 3.4 [m²] vitesse de 150 [km/h]

Supersonic wind tunnel

Veine de mesure de 0.12 x 0.08 [m²] vitesse de 3000 [km/h]

Training of french olympic team

Participation to Shell Eco-Marathon race



Shell Eco-marathon

15 et 16 mai 2004

Circuit de Nogaro

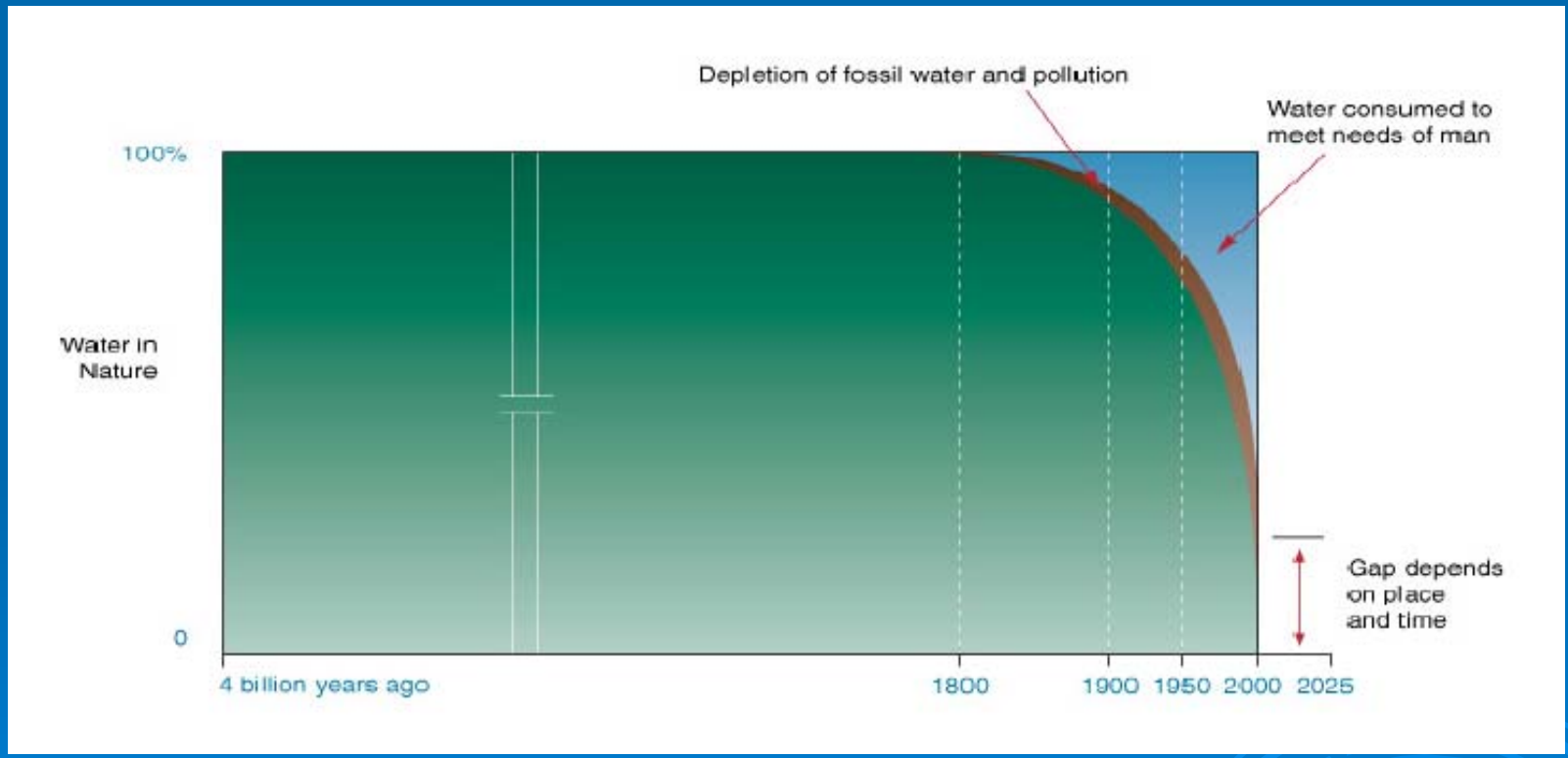
"PRIX DU DESIGN"

2ème Prix

- 2004: 123.4 km with 0.1 litre of benzine
- 2005, 2006: Use of biobenzine

The water struggle

In the 20th century the world population tripled while water use multiplied six-fold!



Is this sustainable ?

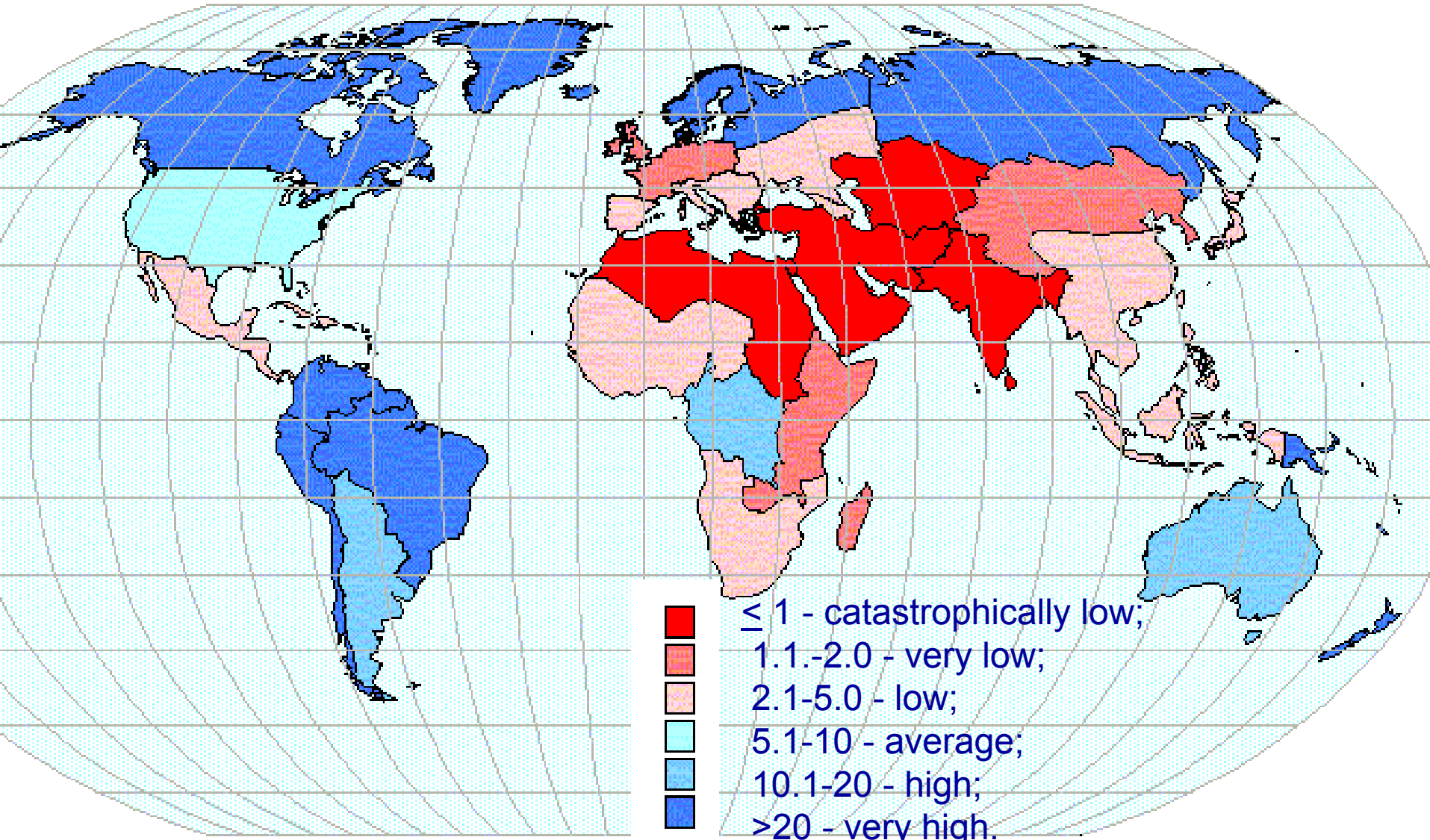
(After Cosgrove, World Water Council)

Water withdrawal per person

- Large modern cities : 300-600 l/day per person.
  Trend for Europe and North America:
  - up to 500-800 l/day.
- Developing agricultural countries of Asia, Africa, and Latin America:
  - 50 to 100 l/day.
- Individual regions with insufficient water resources:
  - 10 to 40 l/day of fresh water per person.

Water availability of the world (2025)

(after Shiklomanov)

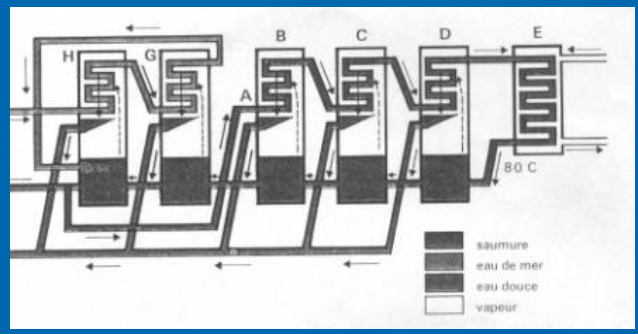


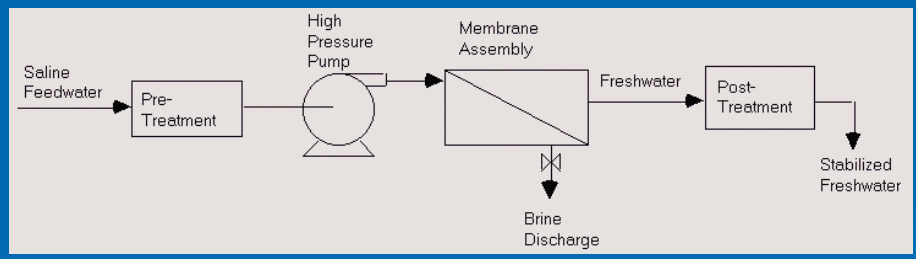
Water desalting

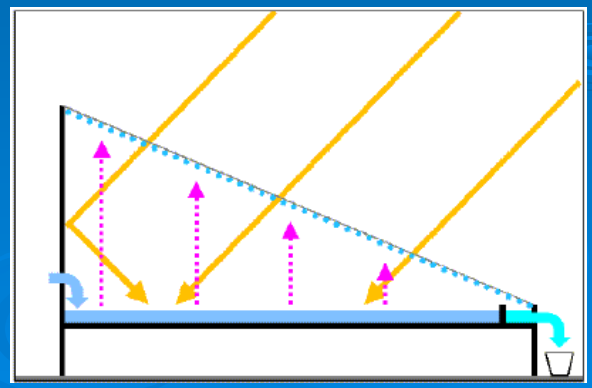
- 1.4 billion people have a catastrophically low water availability (< 1000 m^3/year)
- By 2025, this will increase to 2.3 billion
- Oceans represent 97% of the world water resources
- Large water desalting units produce daily about 20 million m^3 fresh water
- Achieved desalted water cost < 1 Euro/ m^3

Commercially Available Desalting Processes

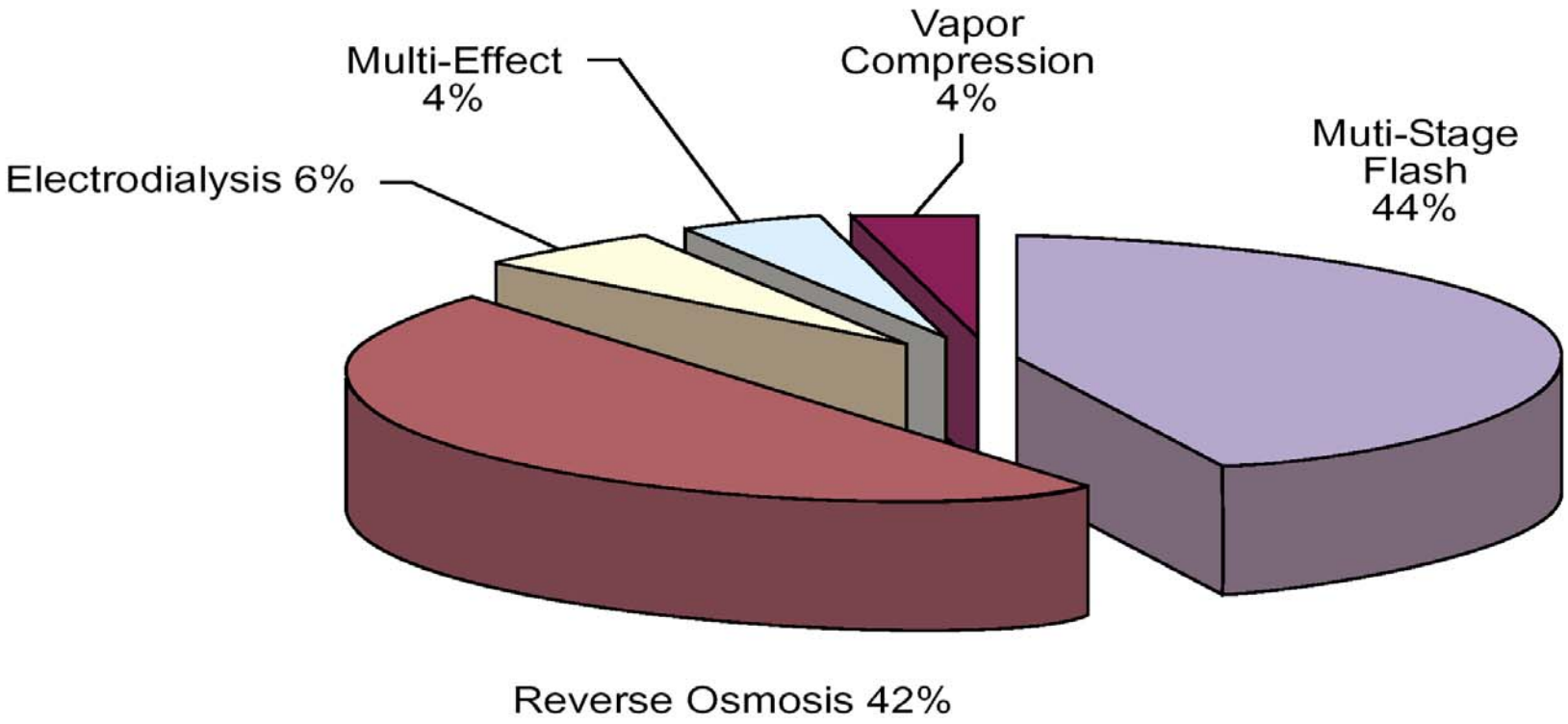
- Major Processes
  - Thermal
    - Multi-Stage Flash Distillation
    - Multiple-Effect Distillation
    - Vapor Compression
  - Membrane
    - Electrodialysis
    - Reverse Osmosis
- Minor Processes
  - Freezing
  - Membrane Distillation
  - Solar Humidification







Inventory

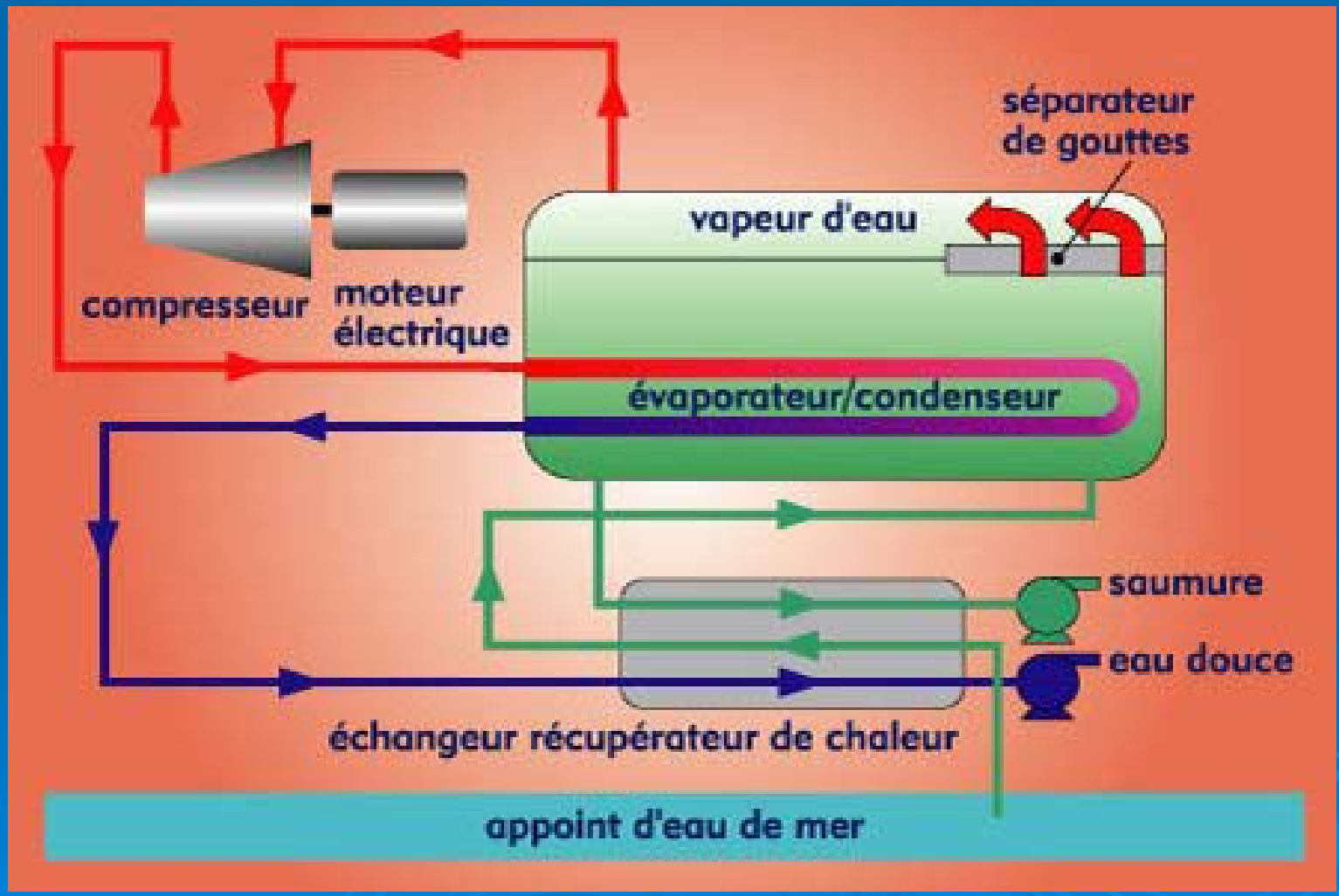


Installed desalination capacity by process

Source — 1998 IDA Inventory

1998: World capacity of 22.7 million m^3/d

Vapour compression distillation



Current technical problems

- Thermal processes
  - Energy consumption reduction by multiple boiling in several successive vessels (Lower P and T)
  - Scale control ($CaSO_4$) : control the concentration level of seawater and/or control the top temperature of the process > 110°C

Ice generation methods

- Advantage: lower energy requirement
  Water ➡ Ice - 330 kJ/kg
- Generator with moving parts:
  - Blade system
  - Brush system
- Without moving parts:
  - Falling film
  - Direct injection of refrigerant

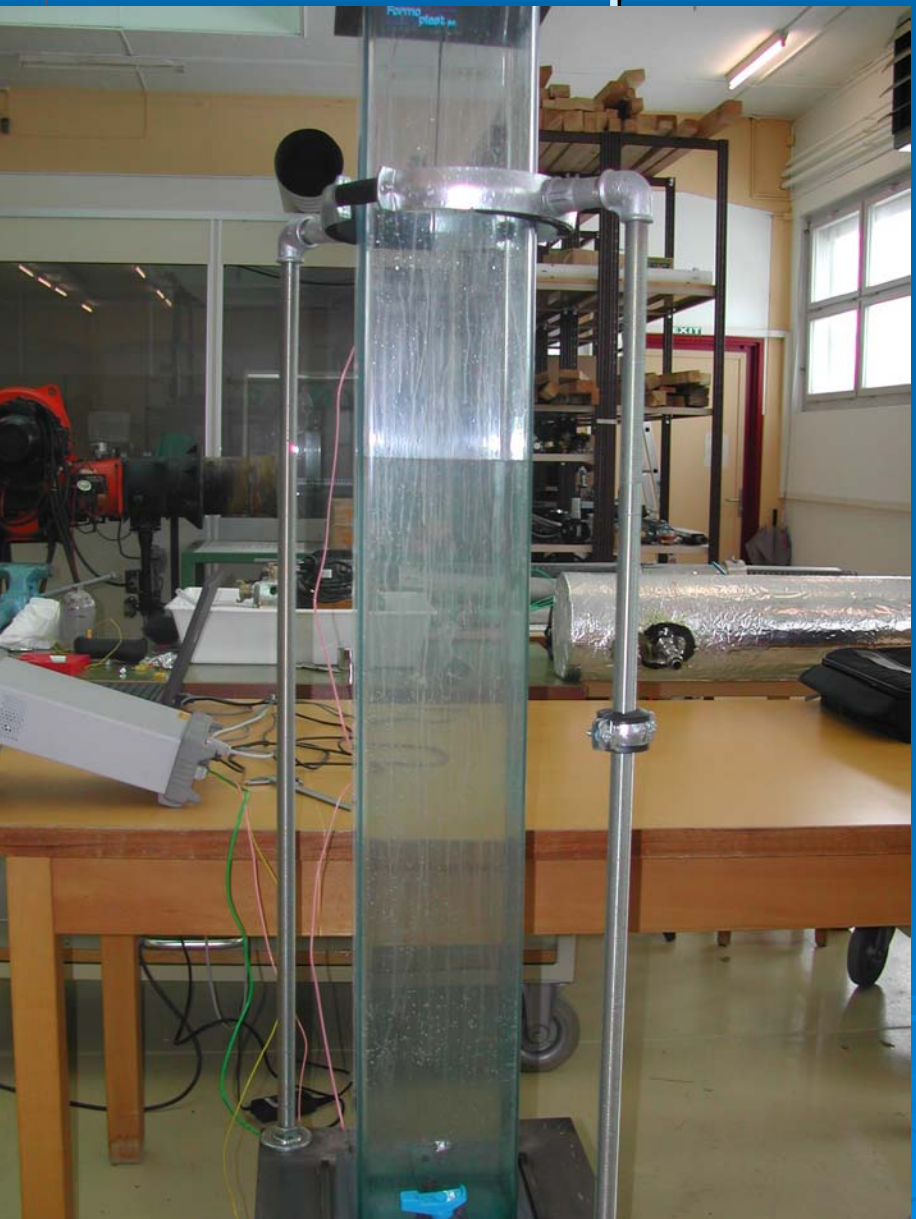
Freezing

- Extensive work was done in the 1950s and 1960s to develop freezing desalination.
- Theoretically, some advantages over distillation:
  - lower energy requirement for single stage operation
  - reduced potential for corrosion
  - few scaling or precipitation problems.
- The disadvantage cited:
  - handling ice and water mixtures mechanically complex to move and process.
- Several plants built over last 50 years

Advantages of direct contact freezing

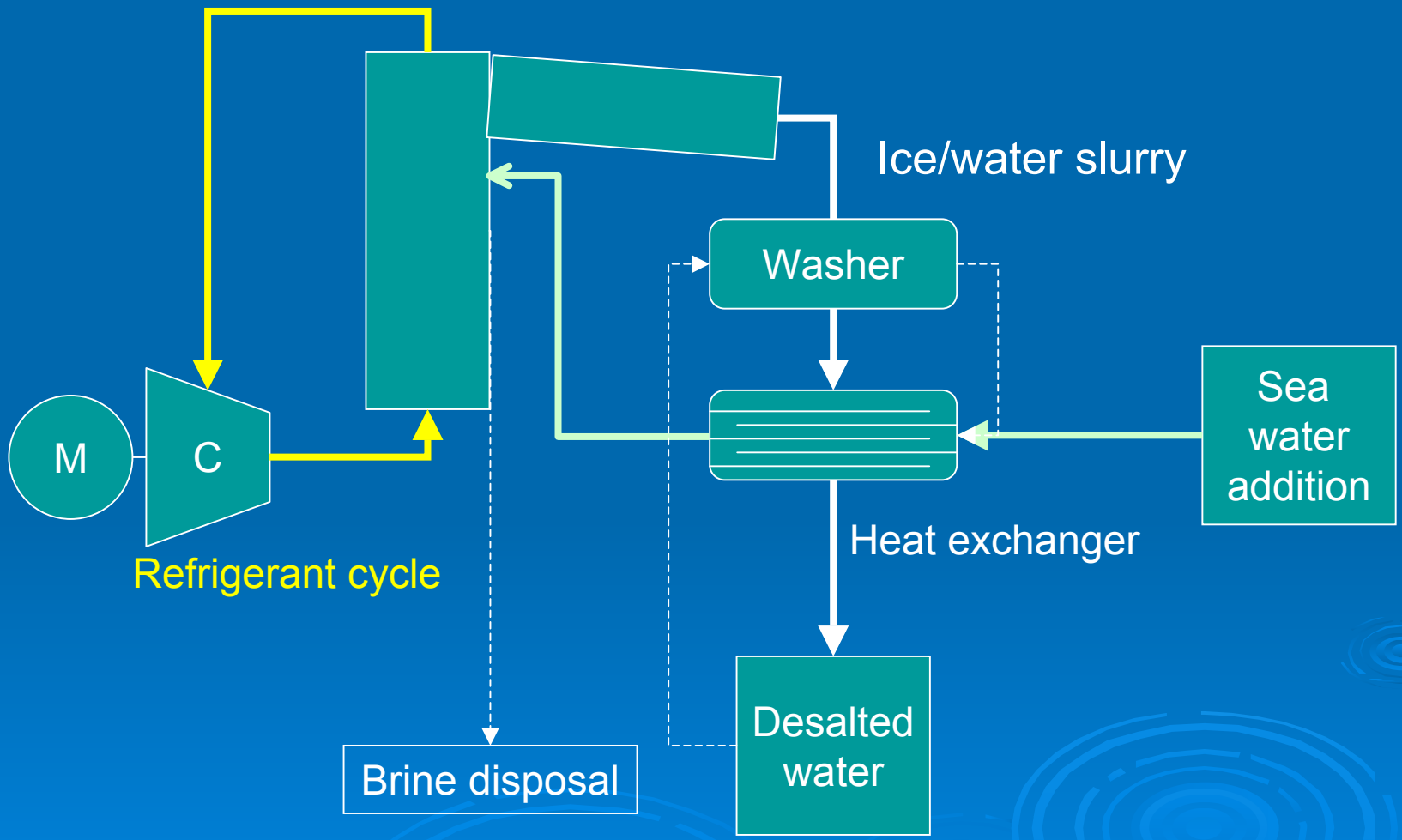
- Much higher heat-exchange rate ➡ higher throughput
- Lower mechanical energy requirements

Experiments in Yverdon



Direct injection of refrigerant

Principle of the process (one stage)



Future work

- Raise funds
- Establish project organisation
- Develop & test prototype(s)