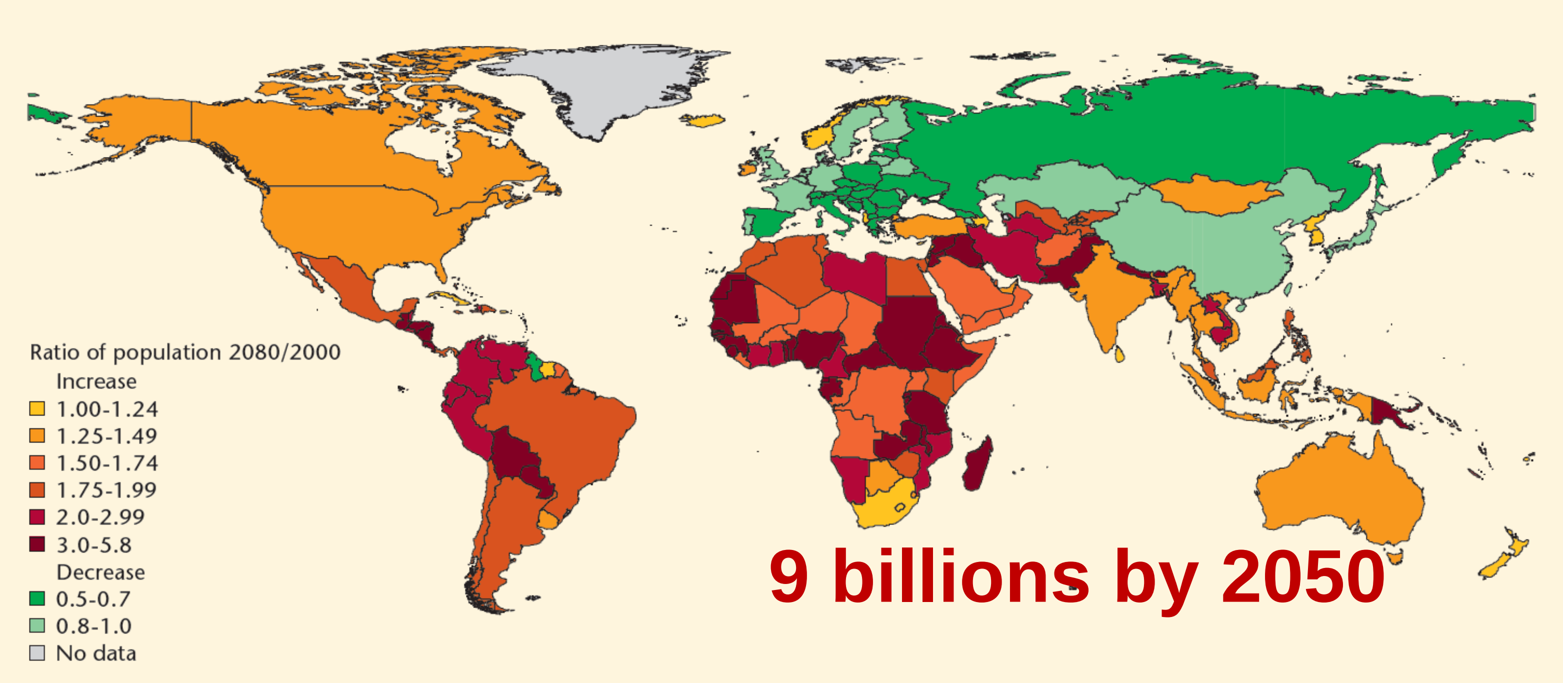
Heat pump for cooling and desalination driven by solar energy

Paul Byrne, Laurent Serres, Thierry Maré, Yacine Ait Oumeziane
Equipe Matériaux Thermo-Rhéologie
Laboratoire Génie Civil et Génie Mécanique EA 3913
Université de Rennes1

Context and objectives

The water issue [1]

Map 2.1 **Expected areas of population growth and decline, 2000-2080**



Source: Lutz, Sanderson, and Scherbov 2008.

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Context and objectives

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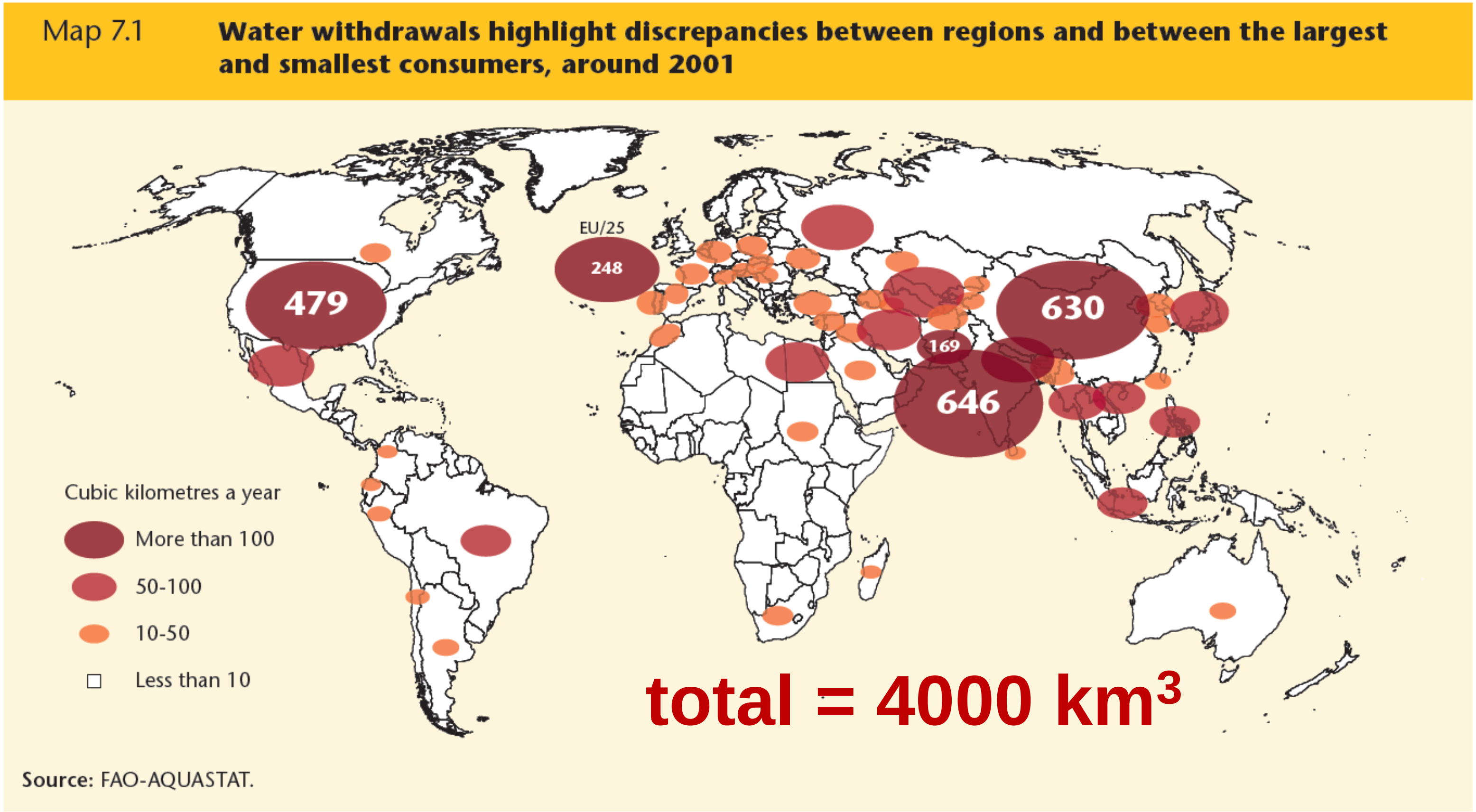
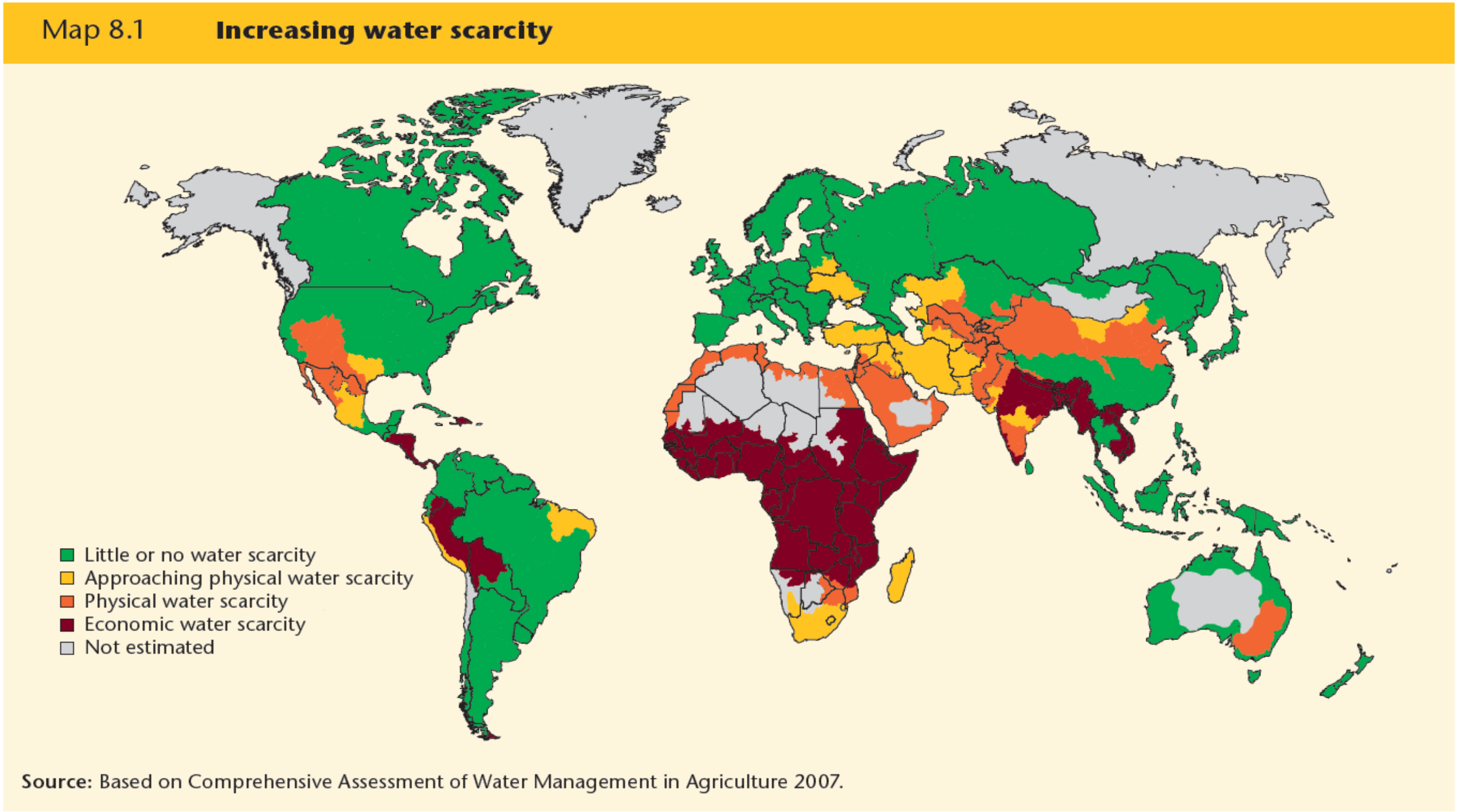


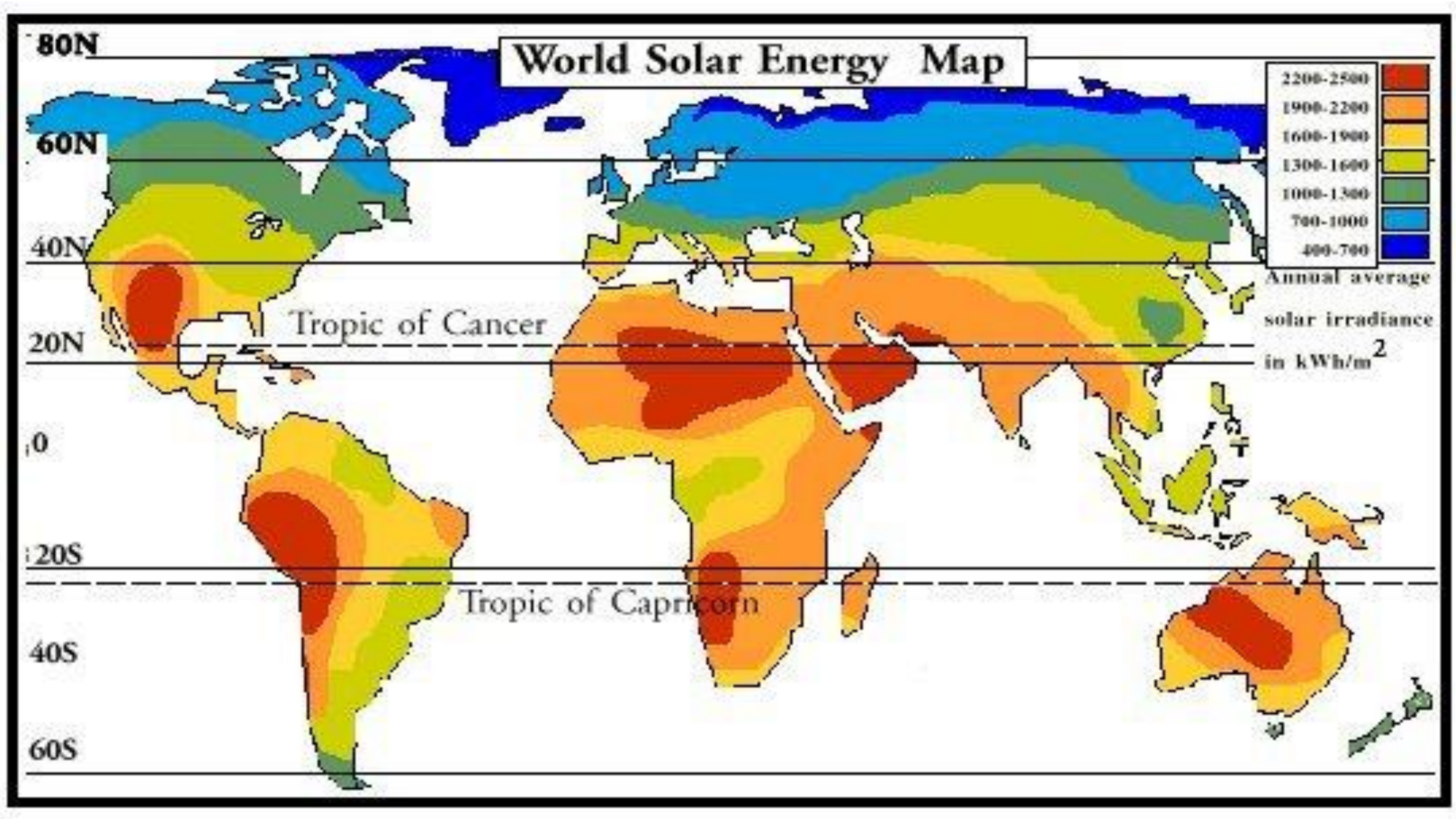
Context and objectives

The water issue [1]



Context and objectives

Correlation with solar irradiance



Outline

Presentation of the heat pump

- PV power supply
- HP for simultaneous needs
  - Cooling ► refrigerated cabinet or space cooling
  - Heating ► desalination

Vapour transfer (heat and mass)

- Equations and model validation

Simulation results

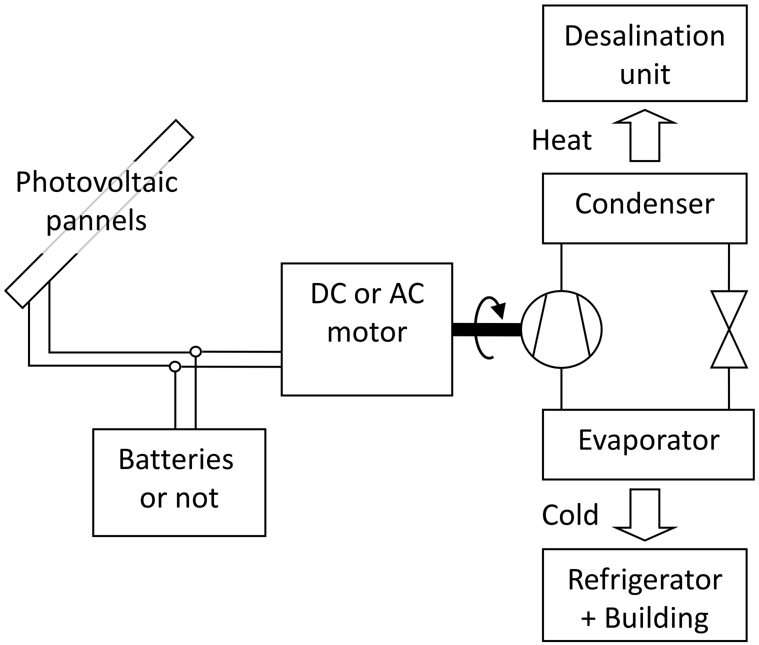
Conclusions et perspectives

Examples of applications

- **Cooling and drinkable water demand**
  - Refrigerated cabinets, space cooling
  - Desalination or brakish water treatment
  - ► food storage, marine or buildings on coastlines

- **Membrane distillation**
  - micro-porous - 0.1 to 1 μm
  - Hydrophobic – PVDF, PE
  - grad T ➔ grad Pv

Heat pump for desalination



- Modelling and simulation TRNSYS [4], EES [5] and Matlab
  - Coupling and co-solving method (dt = 1 h)

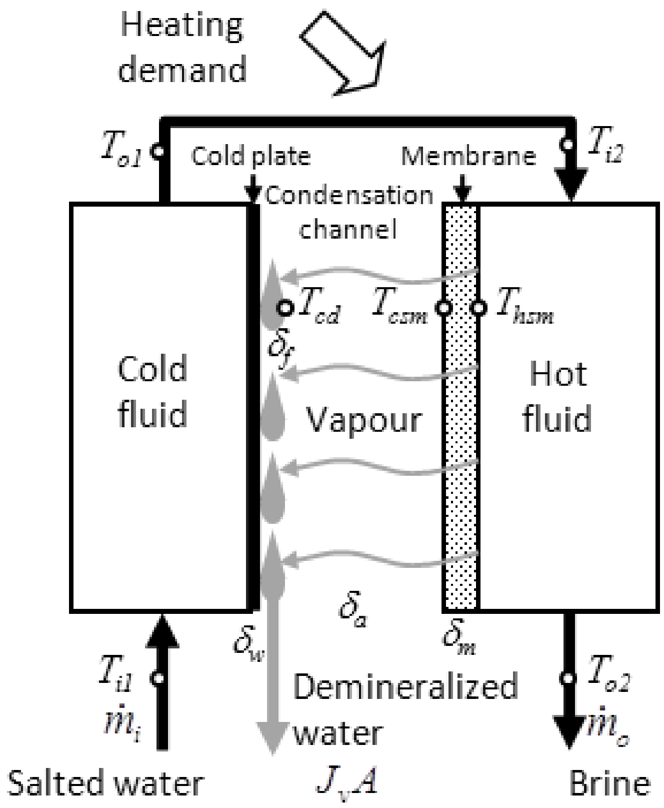
Heat and Mass transfer

- **Mass balance**

$$\dot{m}_e = \dot{m}_s + J_v A$$

- **Vapour flux**

$$J_v = K \Delta p_v$$



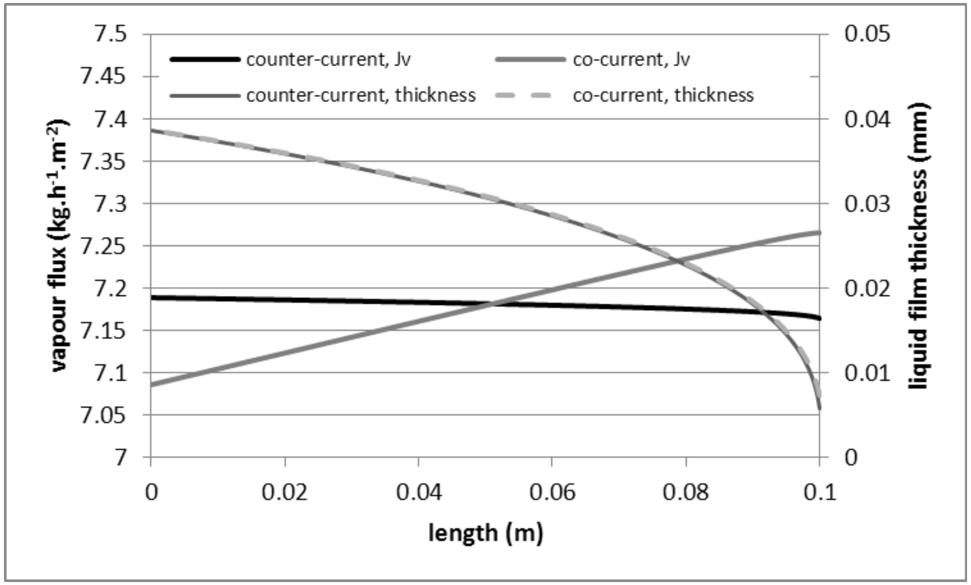
- **K, membrane permeance**
  - Molecular diffusion model

Unit optimization

parameters	Model	Reference [6]
air gap thickness (mm)	1.2	10
membrane thickness (mm)	0.12	0.11
hot seawater temperature (°C)	40	40
hot seawater flow rate (m^3/h)	3.2	5
vapour flux ($kg.h^{-1}.m^{-2}$)	**7.09**	1.01

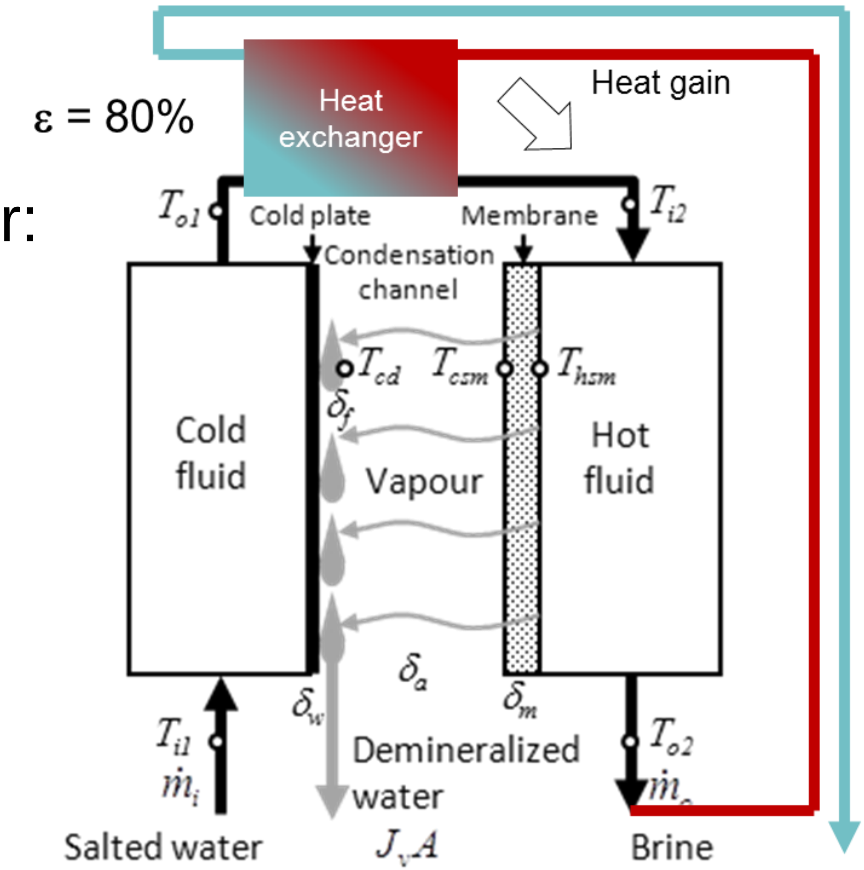
Latest developments using Matlab

- 2 D model using matlab
- Influence of liquid film



Simulation results

- **Validation with Banat's works [6]**
- **Simulations**
  - Reference unit [6]: 21630 kWh/m^3
  - With heat exchanger: 1687 kWh/m^3
  - Optimized unit: 358 kWh/m^3
  - Reverse osmosis: 3 kWh/m^3



Conclusions

- **Definition of performance ratios: C_{elec}/m_{water}**
- **Simulation results :**
  - Encouraging efficiency
  - PV : « free » electric energy
  - HP : « free » heating energy

Perspectives

- **Prototype and refinement of models**
  - Solar electric power supply
  - Membranes
  - System optimization
- **Contribution to subtasks B and C**
  - Modelling of heat pump systems
  - Demo project

National research agency project

Innovative solar cooling and desalination

- WP1: Coordination
- WP2: Solar PV energy supply
- WP3: HP + membrane distillation
- WP4: Ice slurry + cristallisation
- WP5: Comparison of systems
- WP6: Dissemination

National research agency project

Selection process:

- 1st short proposition validated
- 2nd complete proposition to be submitted in May
- Final decision in mid-July

Partners:

References

[1] Water in a changing world, The United Nations World Water Development Report 3, Unesco Publishing, 2009

[2] A.M. Alklaibi, N. Lior. Membrane-distillation desalination: status and potential. Desalination 2004, vol. 171, pp. 111-131

[3] C. Charcosset. A review of membrane processes and renewable energies for desalination. Desalination 2009, vol. 245, pp. 214-231

[4] S.A. Klein, W.A. Beckman, J.W. Mitchel, J.A. Duffie, N.A. Duffie, T.L. Freeman. TRNSYS Manual, University of Wisconsin, Madison, Wisconsin, USA, 2000

[5] S.A. Klein, F.L. Alvardo. EES – Engineering Equation Solver. User's Manual, Version 9.170, F-Chart Software, Madison, Wisconsin, USA, 2012

[6] F.A. Banat. Membrane distillation for desalination and removal of volatile organic compounds from water. Doctoral Thesis, McGill University, Montreal, Canada, 1994