Micro-cogeneration: State-of-art and R&D activities

Sonja Kallio, Prof. Monica Siroux
INSA Strasbourg ICUBE

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Oberrhein
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Dépasser les frontières :
projet après projet
Der Oberrhein wächst zusammen,
mit jedem Projekt

Fonds européen de développement
régional (FEDER)
Europäischer Fonds für regionale
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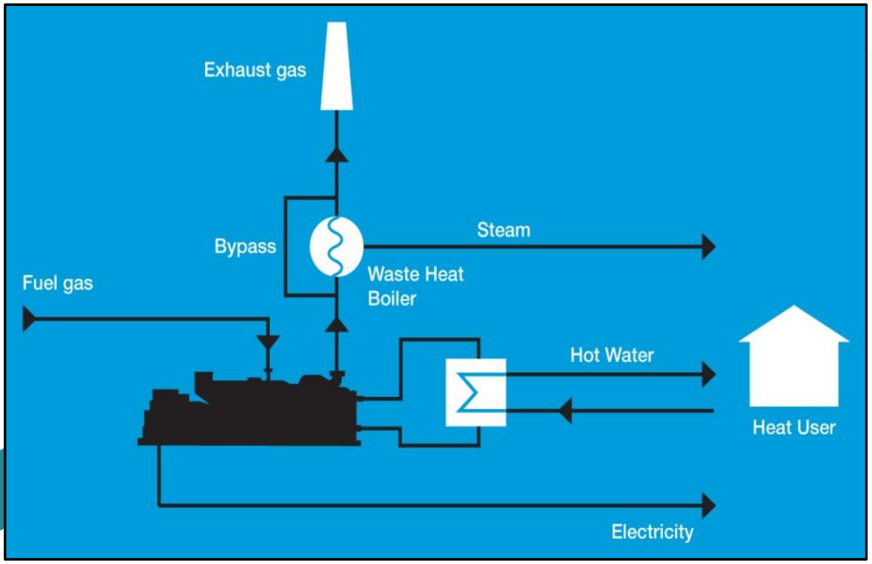
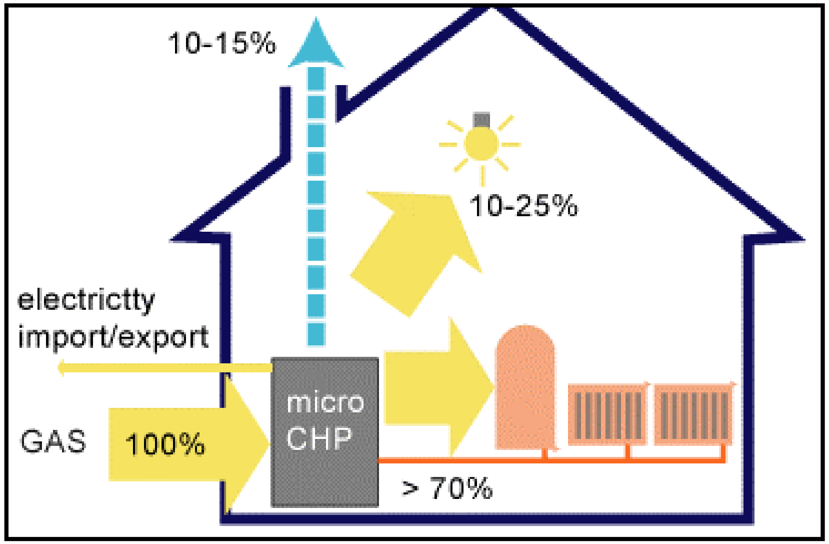
Agenda

- Introduction to micro cogeneration
  - System
  - Pros and cons
  - Prime mover technologies
  - Renewable energy based micro cogeneration
- Research result
- Conclusion and perspectives

What is “combined heat and power” (CHP) or “cogeneration”?

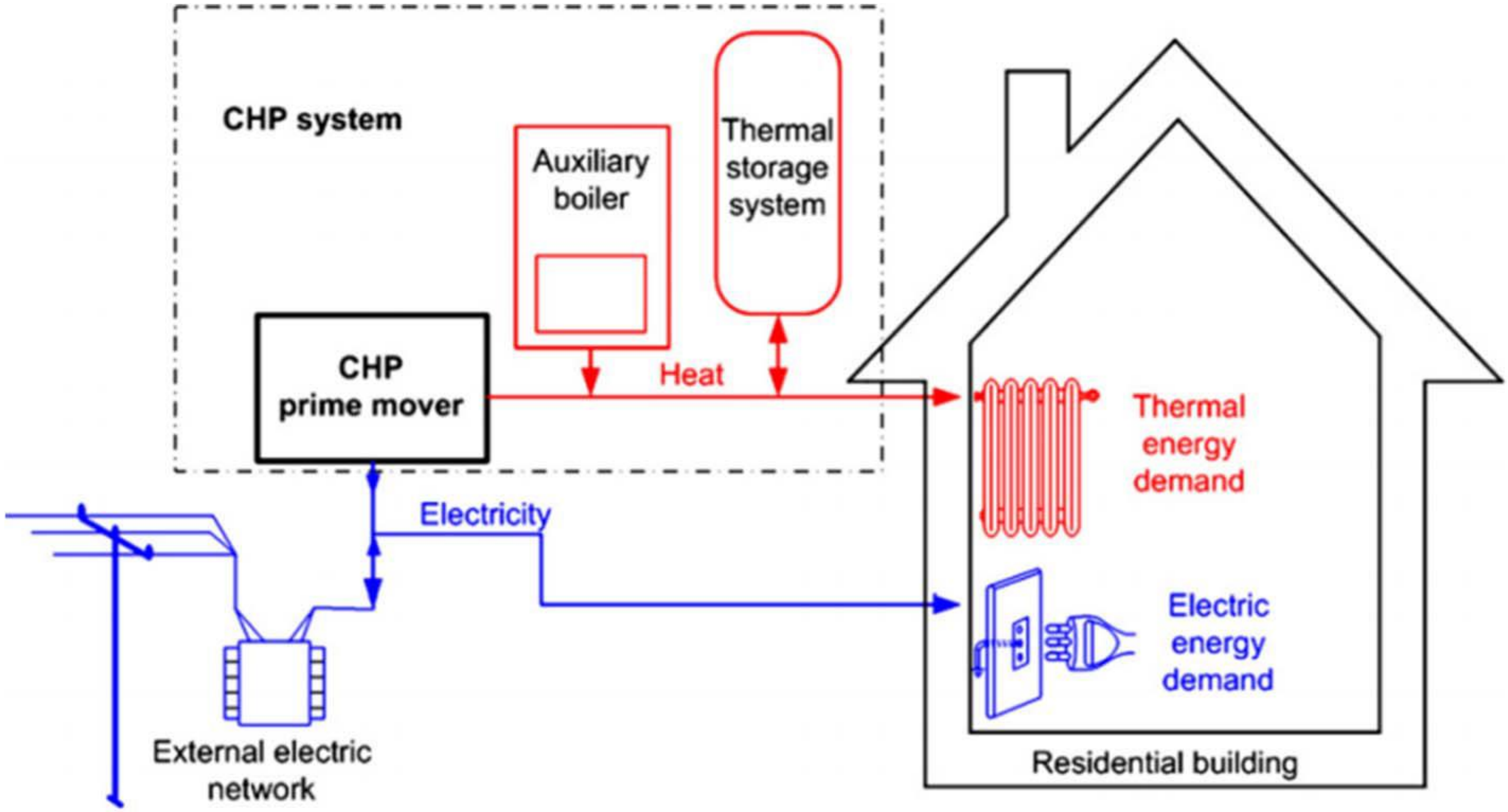


Source: https://www.clarke-energy.com/natural-gas/industrial/

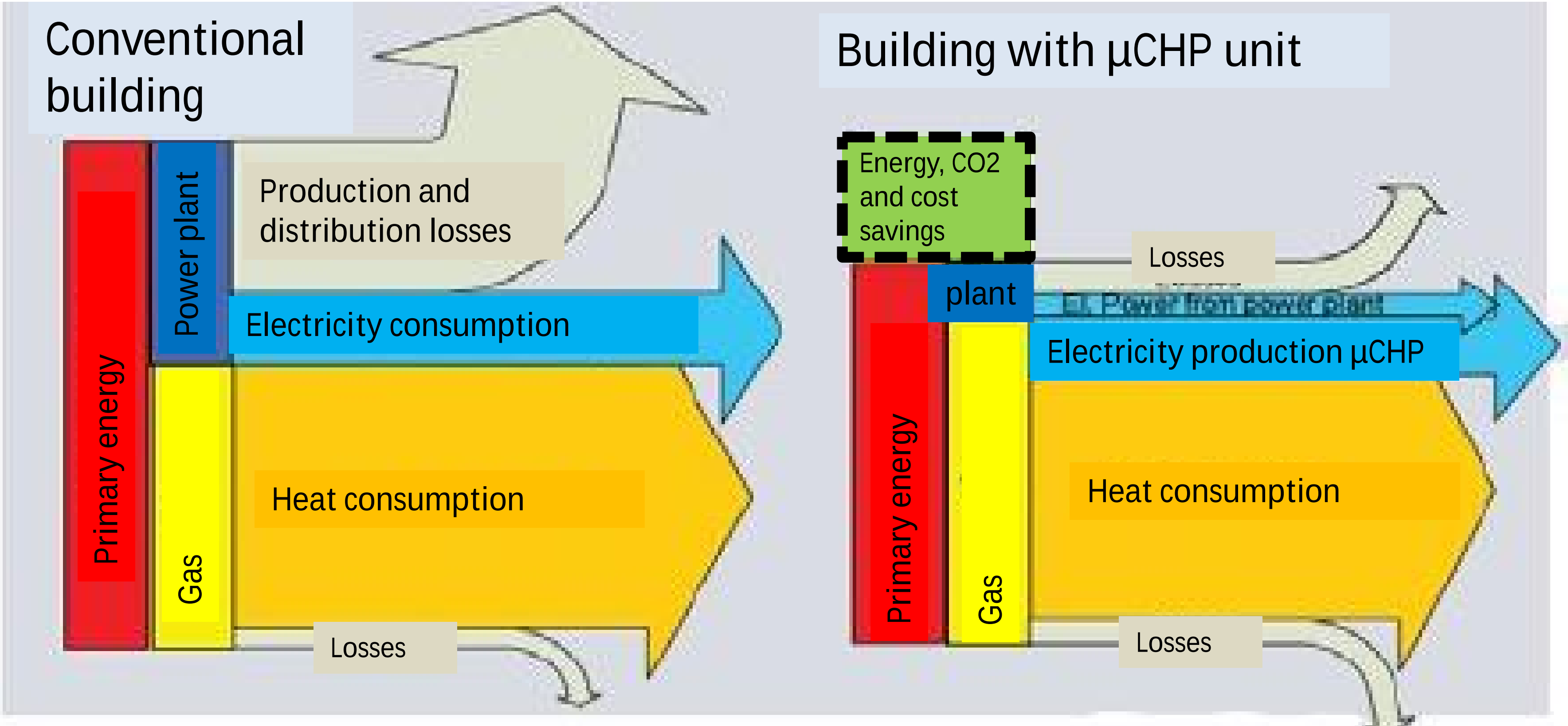


Source: https://sites.google.com/site/fourseasonsarchitecture/micro-chp

Typical integration of a micro CHP unit

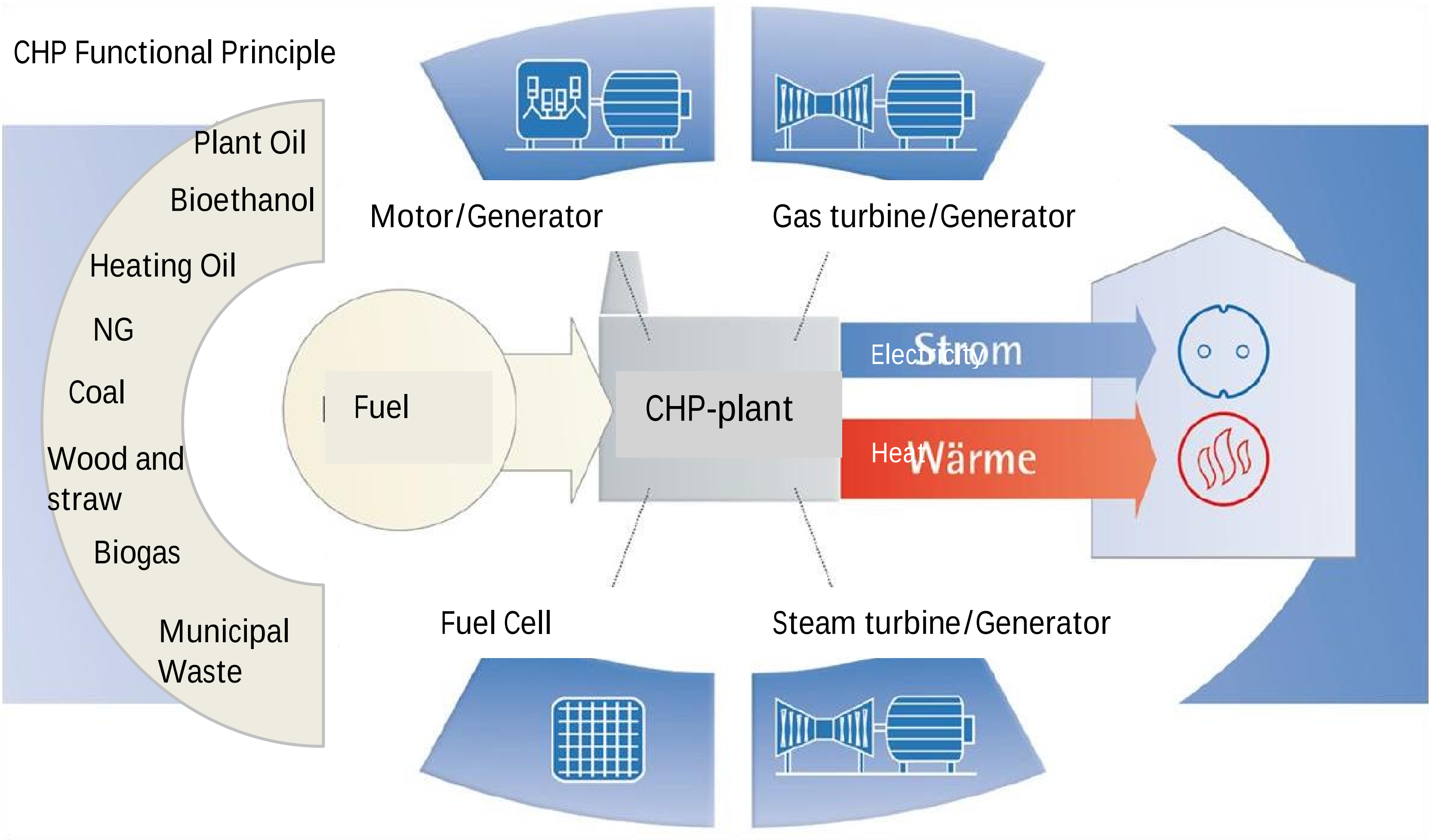


Pro and cons of micro cogeneration



+ Flexibility in fuel use
- High investment costs
- Lack of the information
- Life cycle of the techology

Prime mover technologies



CHP Functional Principle

Plant Oil

Bioethanol

Heating Oil

NG

Coal

Wood and straw

Biogas

Municipal Waste

Fuel

CHP-plant

Electricity

Heat

Motor/Generator

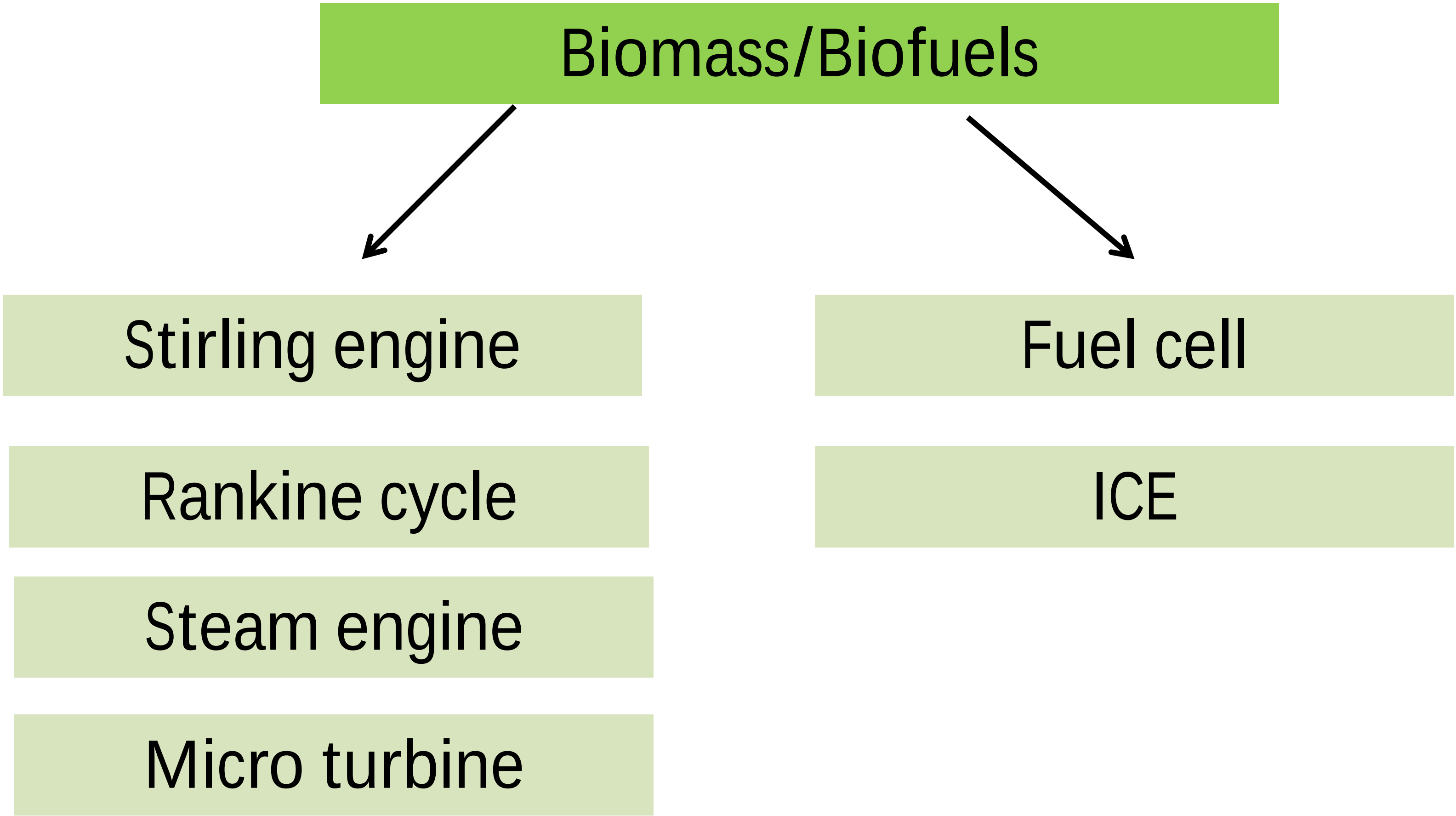
Gas turbine/Generator

Fuel Cell

Steam turbine/Generator

The German Association of Combined Heat and Power, http://www.bkwk.de/aktuelles/Broschur/Broschur_Internet.pdf

Micro-CHP systems using renewable energy



Biomass/Biofuels

Stirling engine

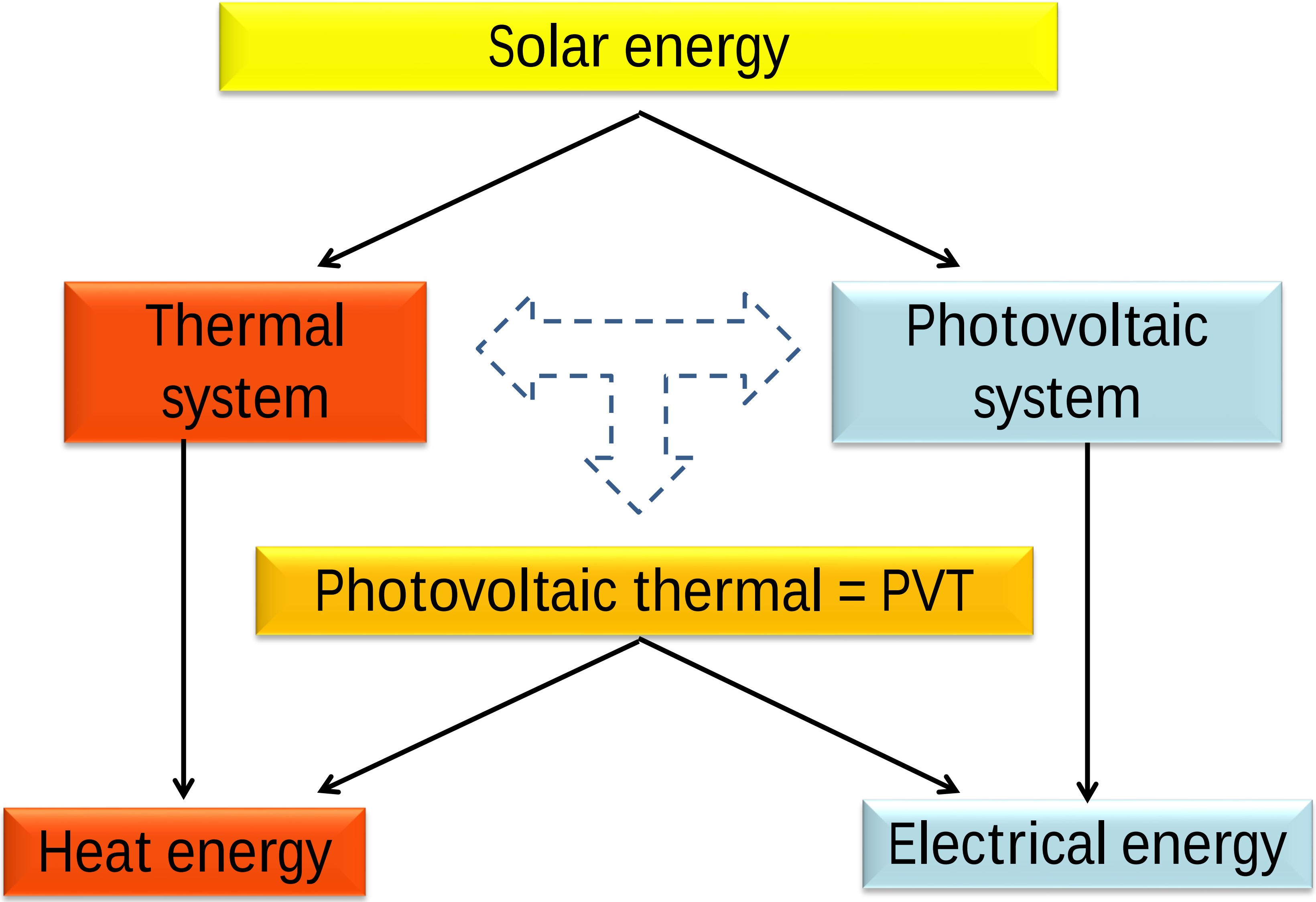
Rankine cycle

Steam engine

Micro turbine

Fuel cell

ICE



Solar energy

Thermal system

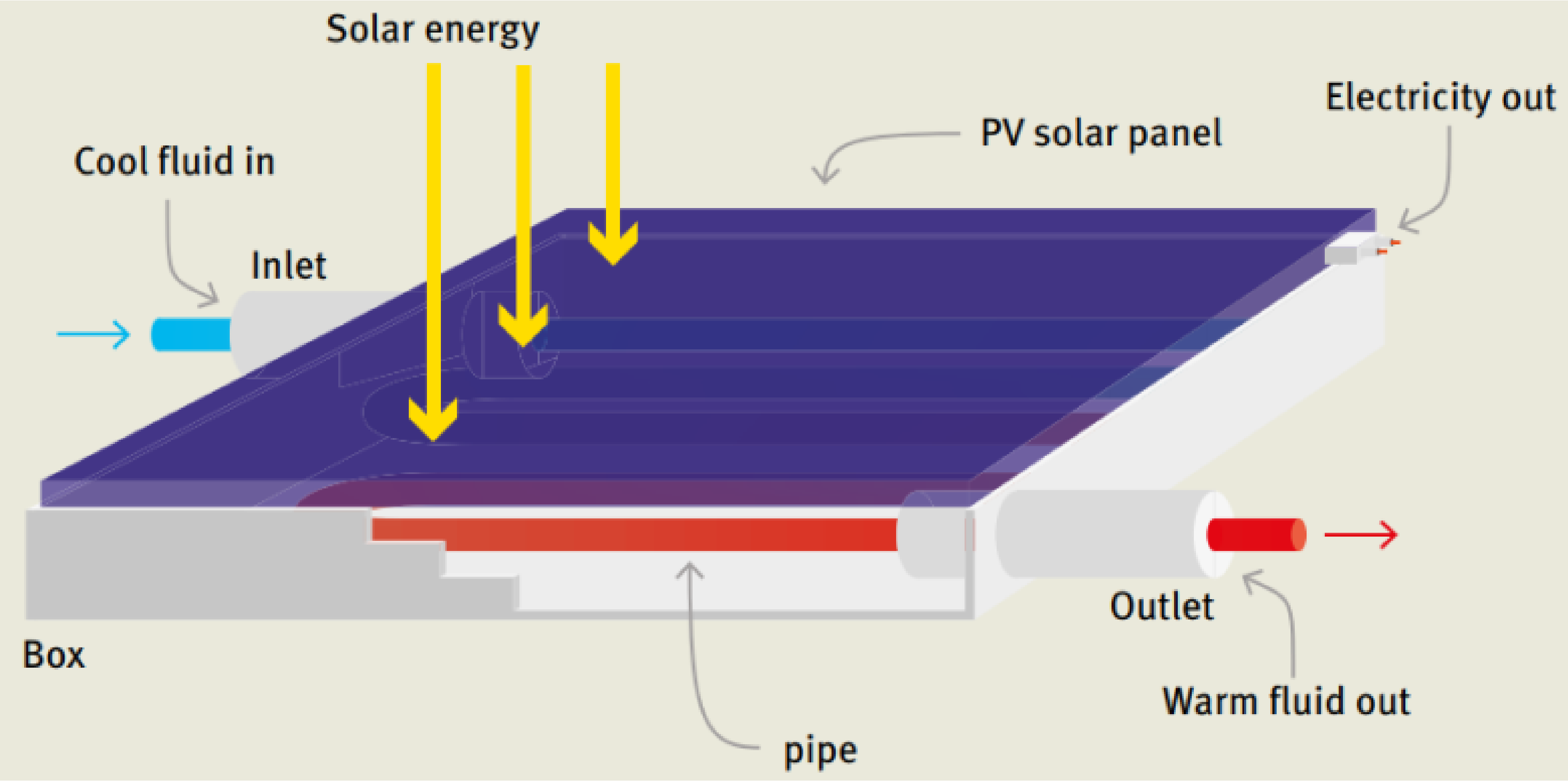
Photovoltaic system

Photovoltaic thermal = PVT

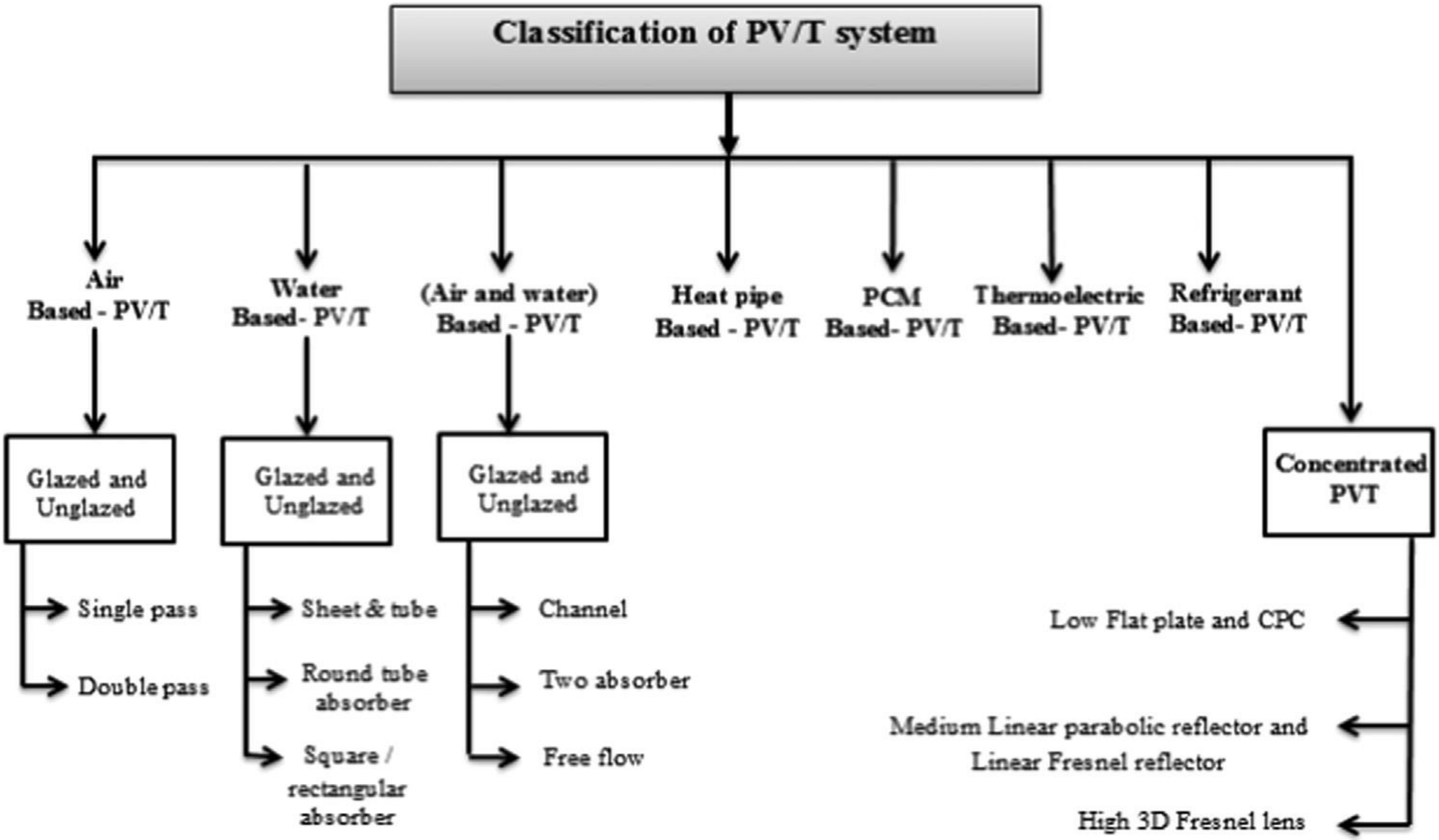
Heat energy

Electrical energy

Water based flat plate PVT collector



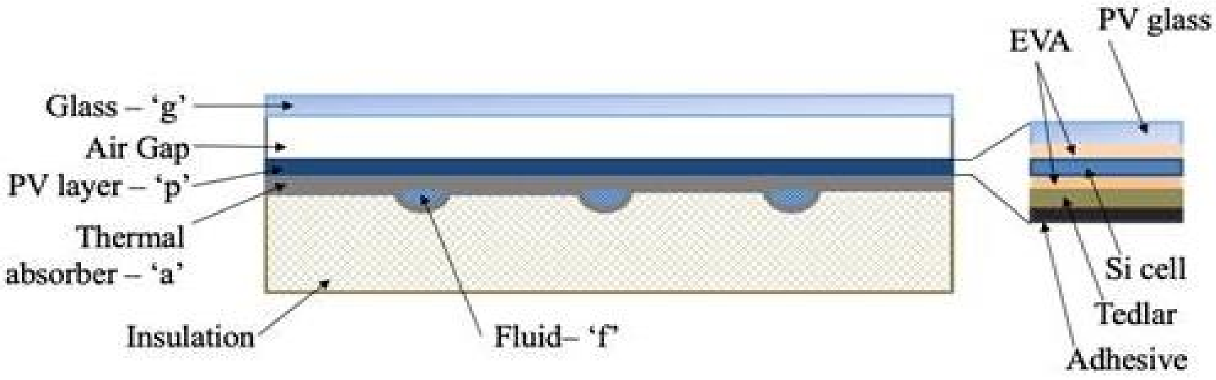
Source: https://wwwf.imperial.ac.uk/blog/chemical-engineering/2018/11/06/one-stone-two-bird-synergies-next-generation-solar-technologies/



Source: A.M. Elbreki & all, The role of climatid-design-operational parameters on combined PV/T collector performance: A critical review

Modelling and simulation of a water based PVT collector

- Mathematical model of the PVT layers



- Energy and exergy analysis of the PVT operation under two different climate conditions
- Daily, weekly and yearly simulations of the PVT operation

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Simplified energy balance of the PVT collector

PVT collector:

$$M_{pvt} c_{pv} \frac{dT_{pvt}}{dt} = Q_{losses} + Q_{pvt-f} + Q_{pvt} - E$$

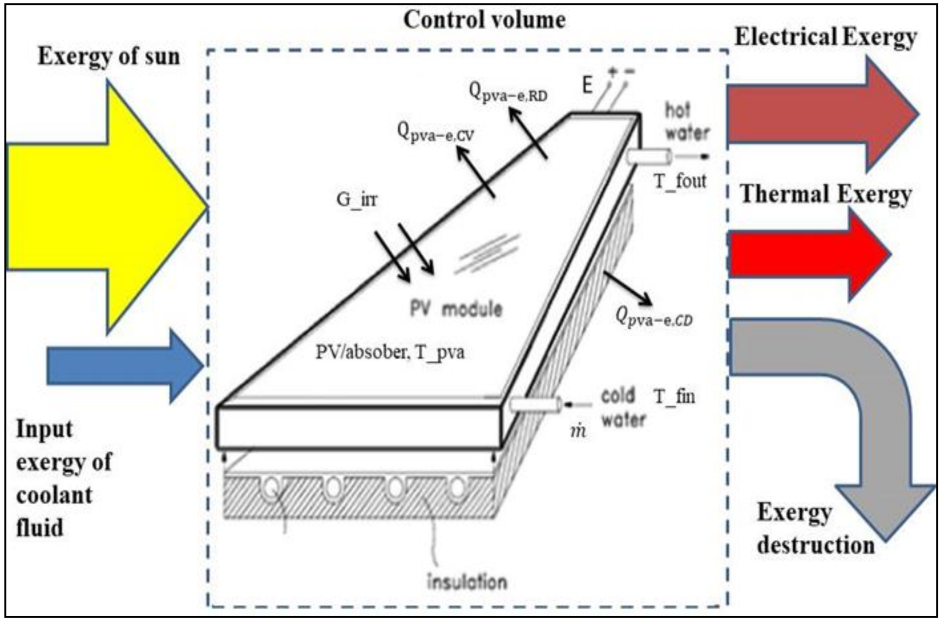
Coolant fluid:

$$M_f c_f \frac{dT_f}{dt} = Q_{f-pvt} + Q_f$$

Assumptions:

- The temperature distribution is uniform
- no heat losses through the edges
- the optical and thermal properties of the materials and fluids are constant
- no surrounding shading or dust is taken into account

Exergy analysis



Exergy balance:

$$\sum Ex_{in} - \sum (Ex_{th} - Ex_{el}) = \sum Ex_d$$

Exergy of solar irradiation:

$$Ex_{in} = A_{pva} N_c G_{irr} \left(1 - \frac{4}{3}\frac{T_0}{T_{sol}} + \frac{1}{3}\left(\frac{T_0}{T_{sol}}\right)^4\right)$$

Exergy of thermal energy:

$$Ex_{th} = \dot{m} c_f \left[(T_{out} - T_{in}) - T_0 \ln \frac{T_{out}}{T_{in}}\right]$$

Exergy of electrical energy:

$$Ex_{el} = \eta_{pv} G_{irr} A_{pva}$$

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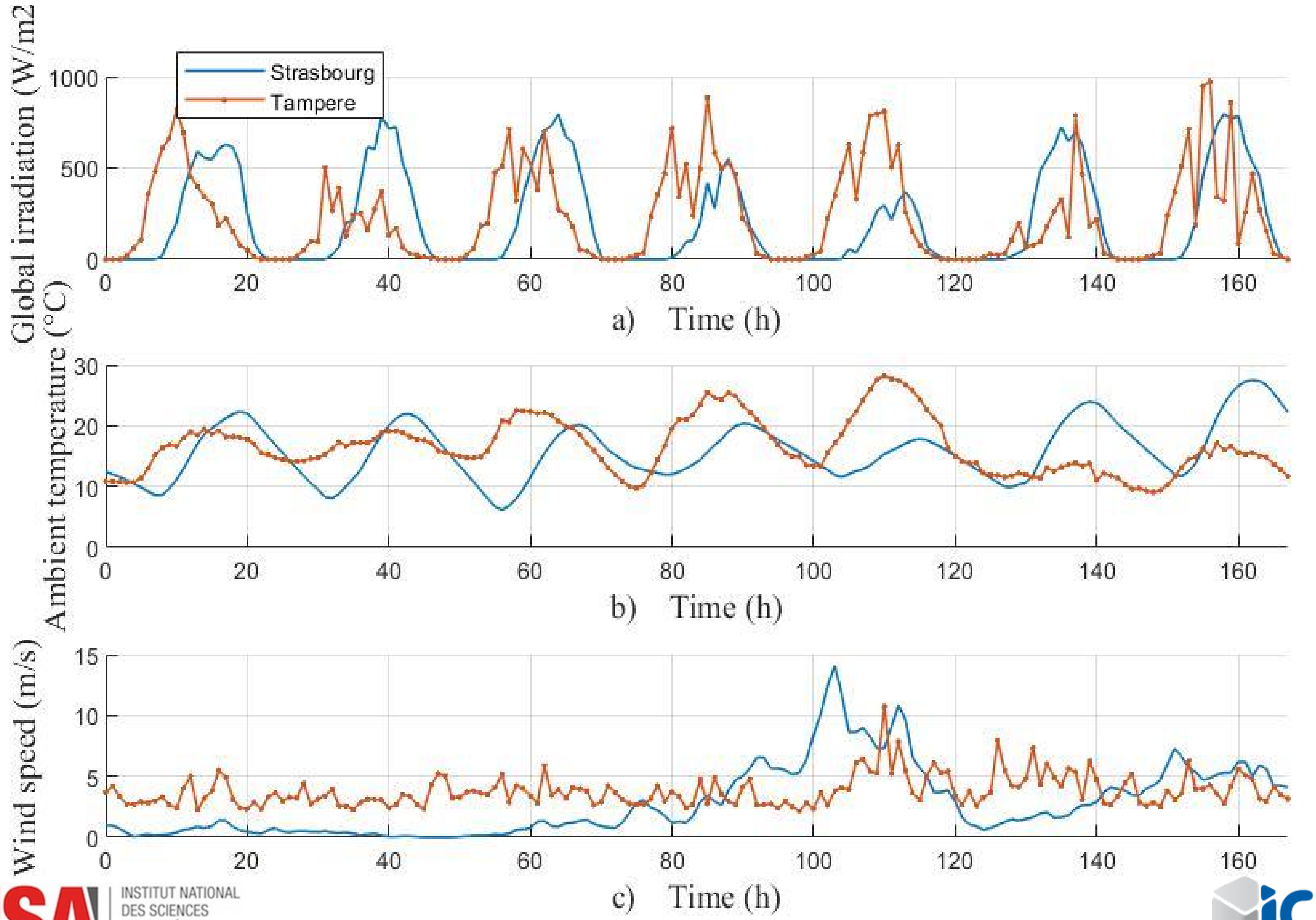
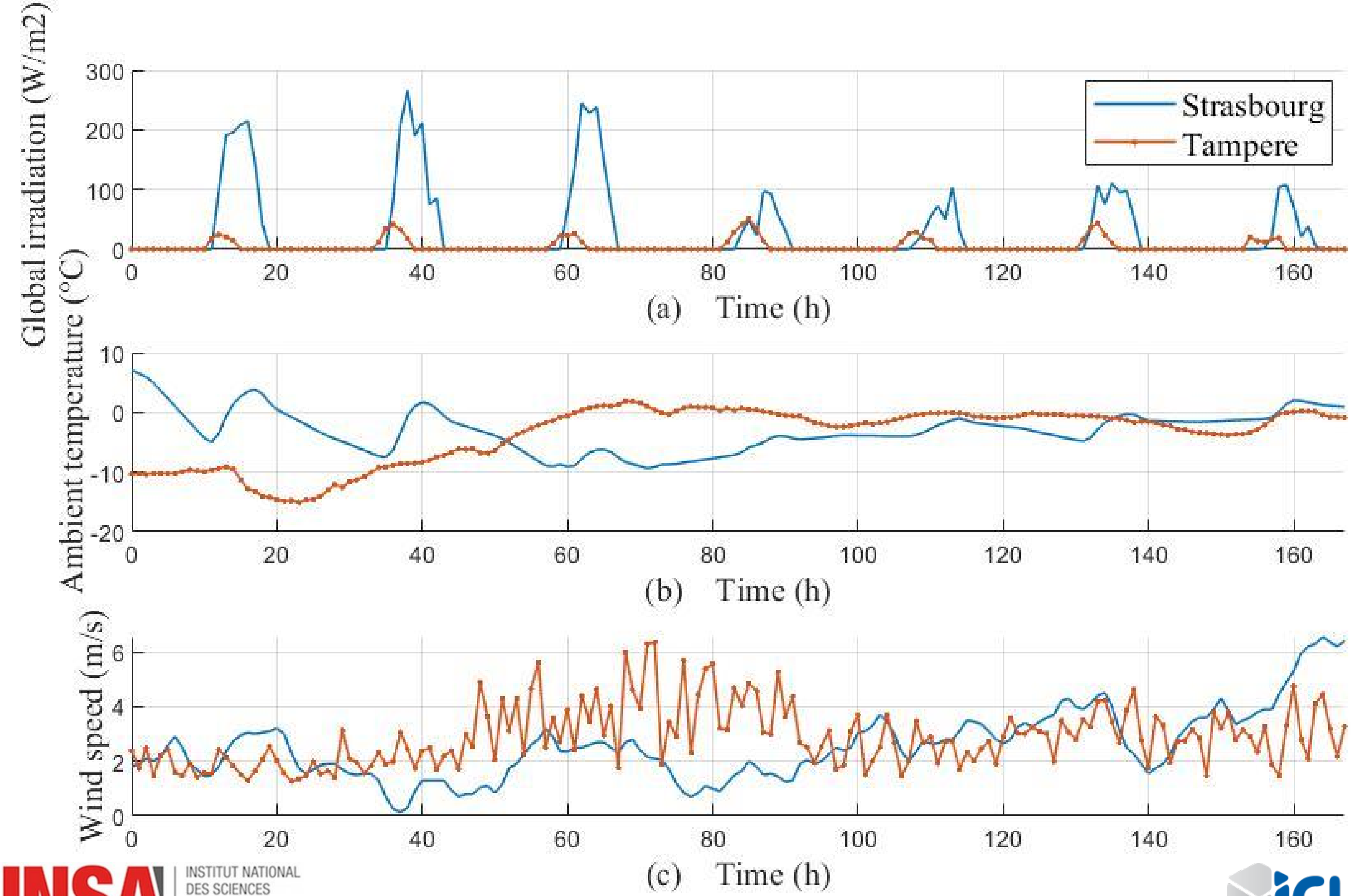
Two different climate conditions

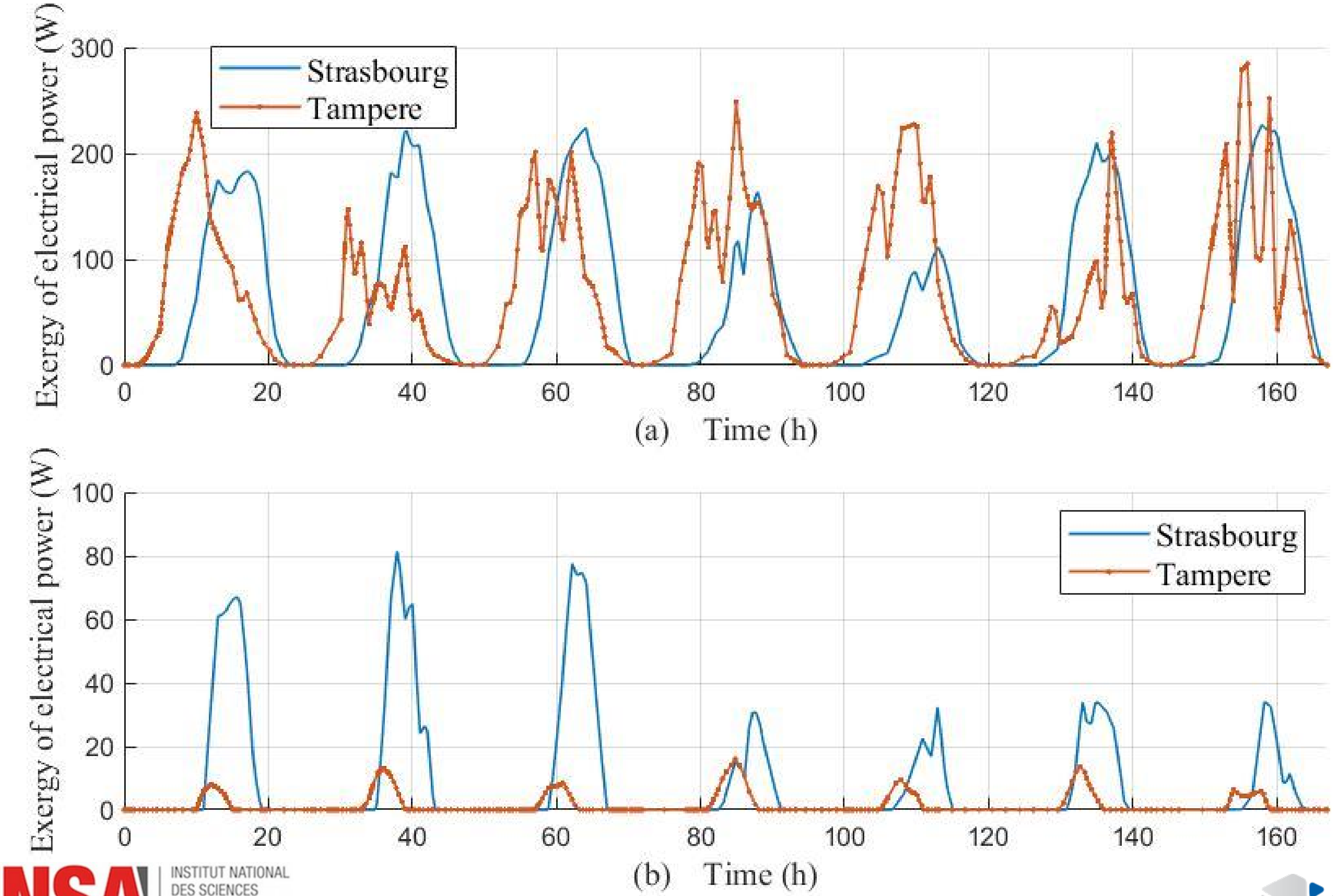
Tampere, Finland and Strasbourg, France



Winter week

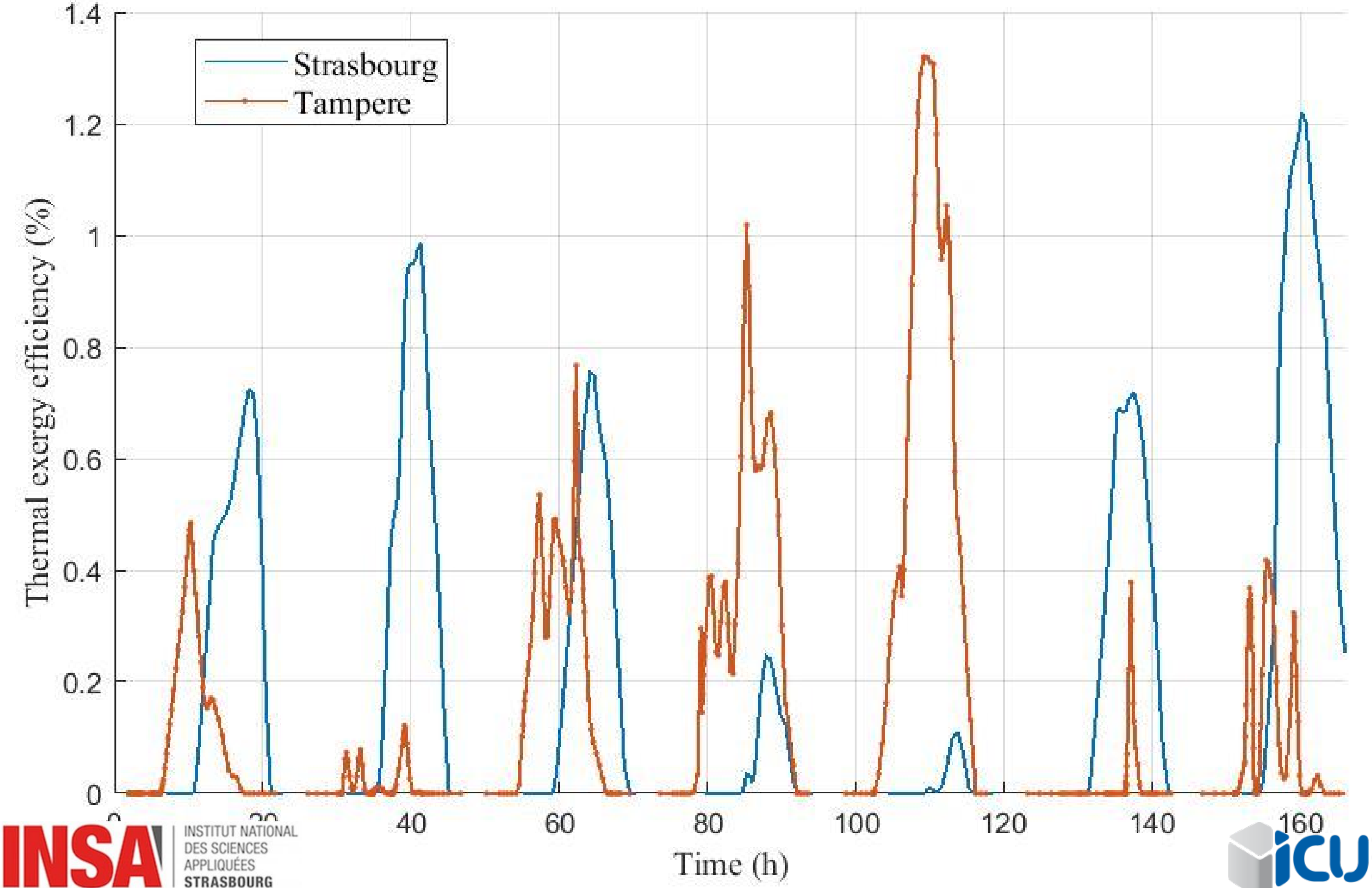

Global irradiation (W/m2)
300
200
100
0
Strasbourg
Tampere
0
20
40
60
80
100
120
140
160
(a) Time (h)
Ambient temperature (°C)
10
0
-10
-20
(b) Time (h)
Wind speed (m/s)
6
4
2
0
(c) Time (h)

Simulation results



Simulation results

Summer week



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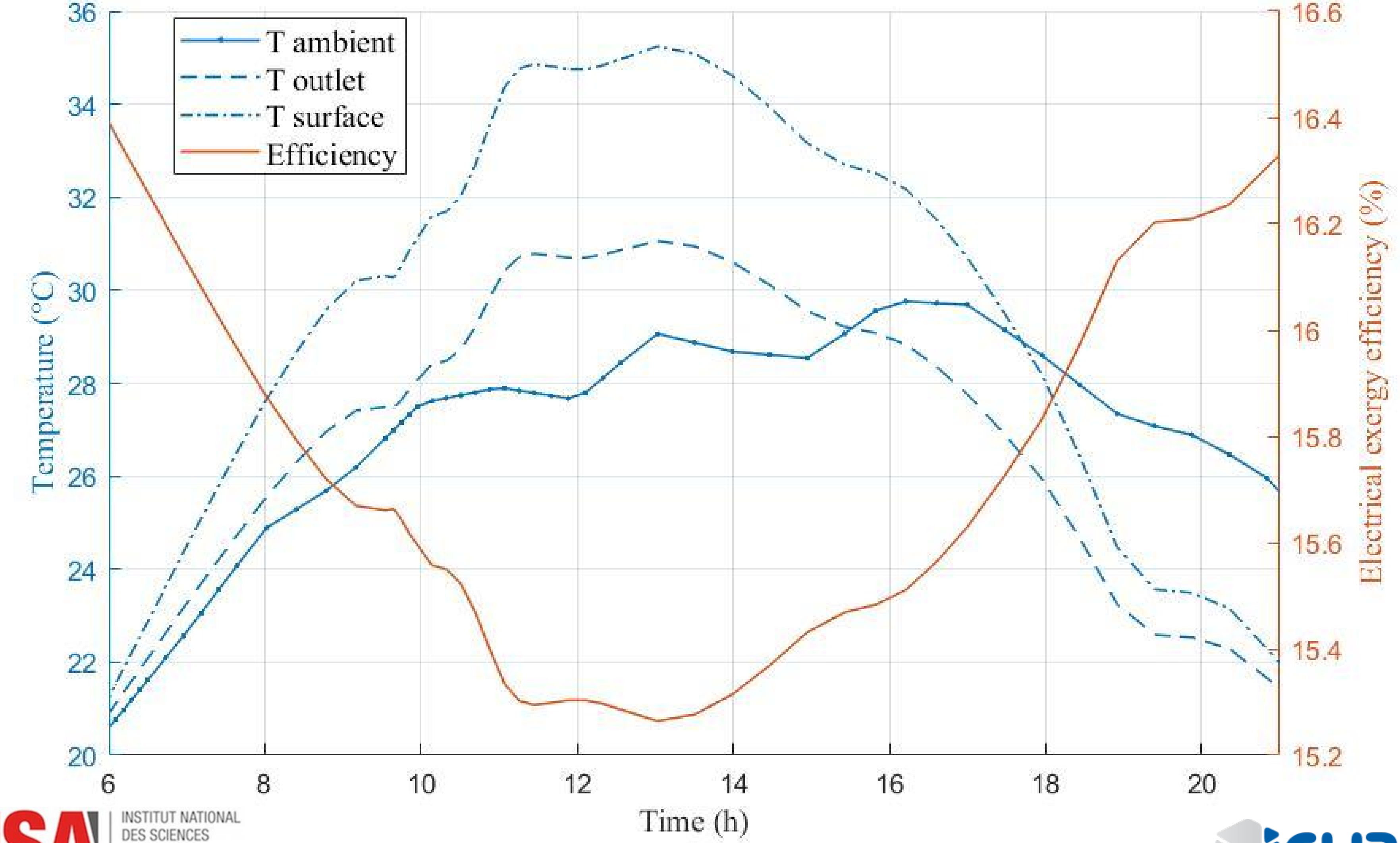
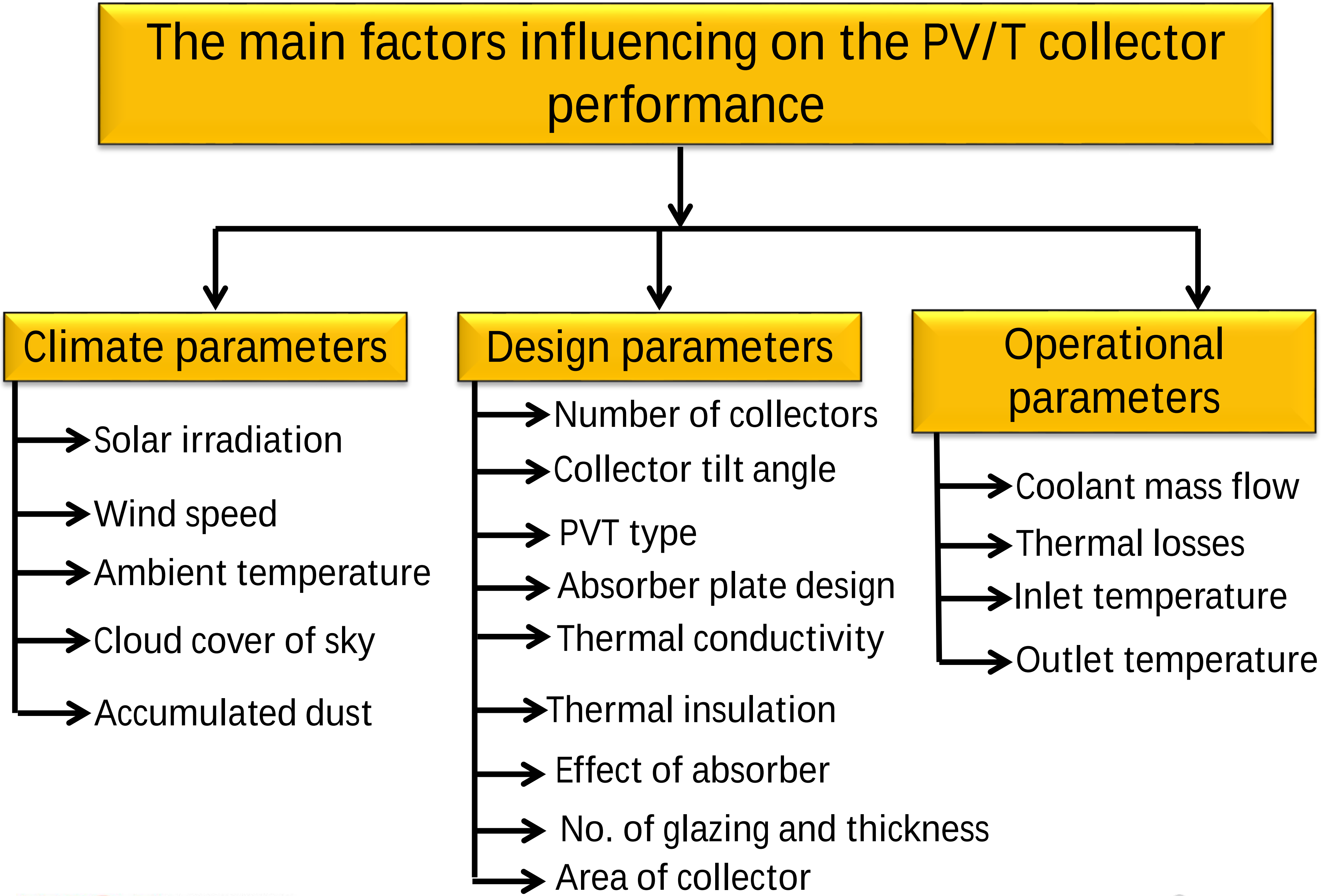
Simulation results

Summer day

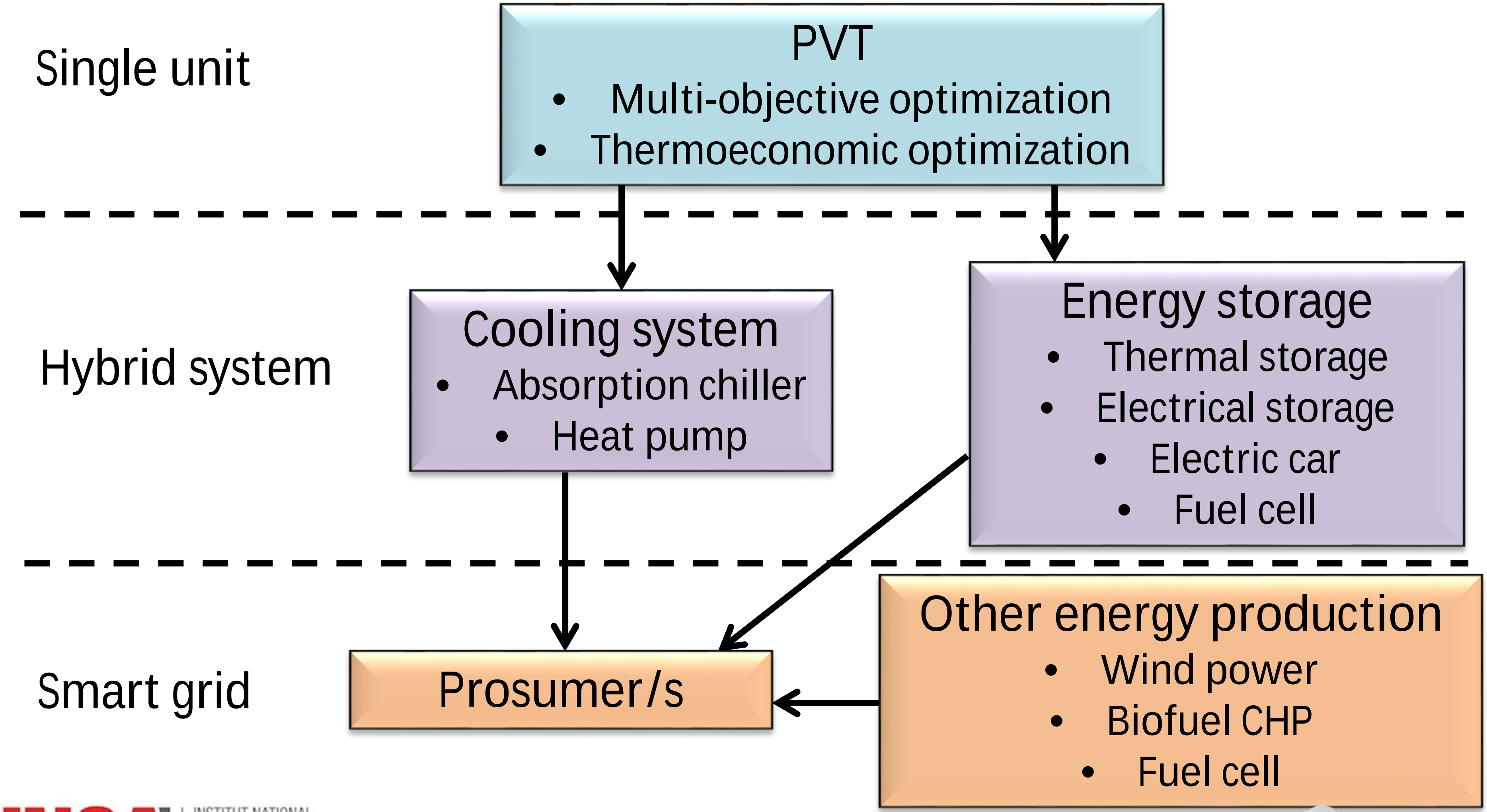


The main factors influencing on the PV/T collector performance



- Climate parameters
  - Solar irradiation
  - Wind speed
  - Ambient temperature
  - Cloud cover of sky
  - Accumulated dust
- Design parameters
  - Number of collectors
  - Collector tilt angle
  - PVT type
  - Absorber plate design
  - Thermal conductivity
  - Thermal insulation
  - Effect of absorber
  - No. of glazing and thickness
  - Area of collector
- Operational parameters
  - Coolant mass flow
  - Thermal losses
  - Inlet temperature
  - Outlet temperature

Conclusion and perspectives
From a single unit to the smart grid



Single unit

PVT
- Multi-objective optimization
- Thermoeconomic optimization

Hybrid system

Cooling system
- Absorption chiller
- Heat pump

Energy storage
- Thermal storage
- Electrical storage
- Electric car
- Fuel cell

Smart grid

Prosumer/s

Other energy production
- Wind power
- Biofuel CHP
- Fuel cell

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Conclusion and perspectives

- Intelligent energy management system

  → minimize the operation costs and power exchange between the main grid and smart grid

- Co-operation with project partners

  → experimental study of the behaviour of a hybrid system including PVT

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Questions?

Thank you!

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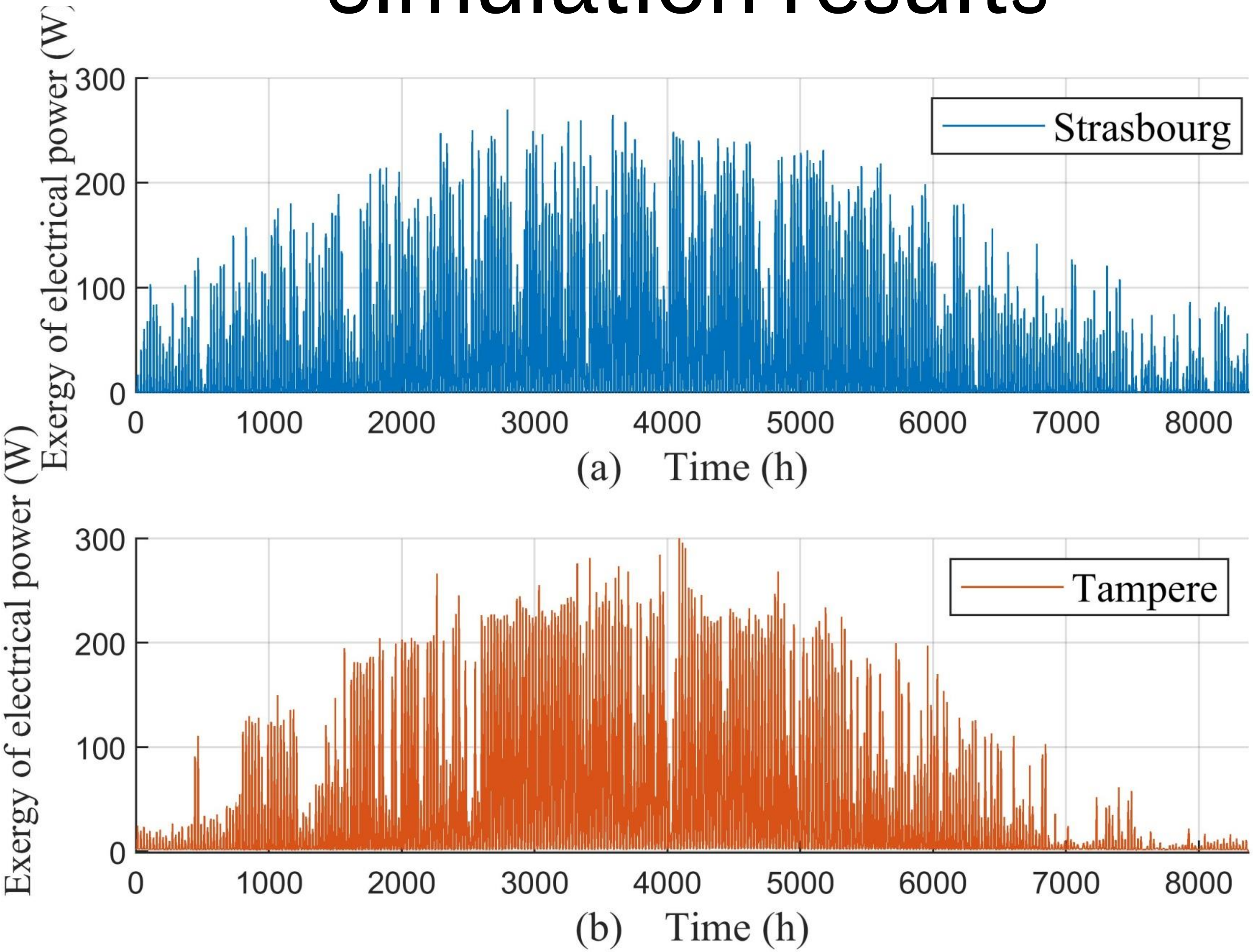

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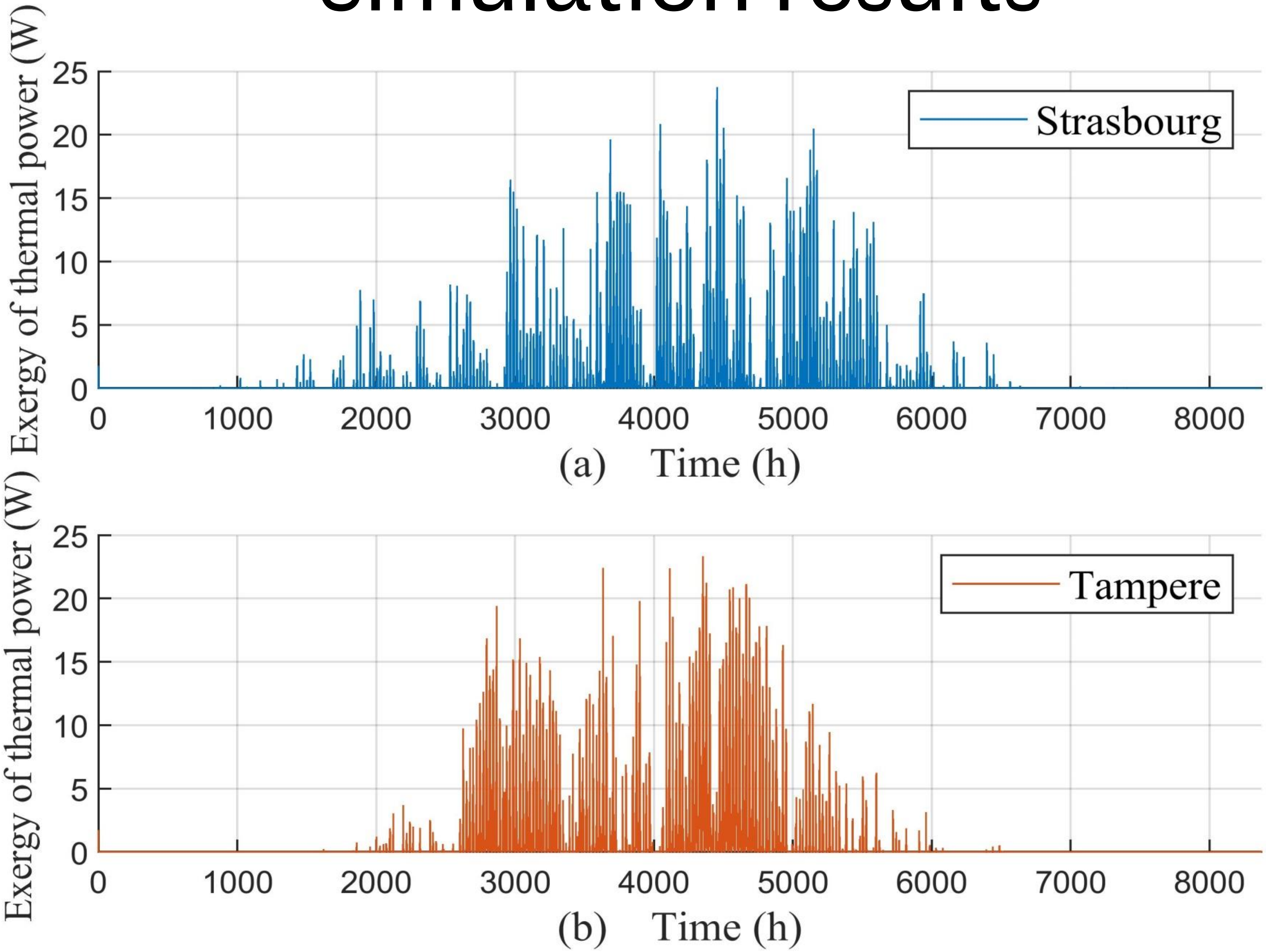

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Parameters used in the model

The inlet temperature of the coolant fluid is 20 °C

*Table 1. The main geometrical, thermo-physical and optical properties of the PVT collector. With * the parameter varies with time.*

Property	Glass	Air gap	PV	Thermal absorber	Fluid	Insulation	Unit
Emissivity (ε)	0.9	-	0.96	-	-	-	-
Absorbance (α)	0.1	-	0.9	-	-	-	-
Transmittance (τ)	0.93	-	-	-	-	-	-
Thickness (H)	0.004	0.02	0.006	0.001	-	0.04	m
Area (A)	2	2	2	2	-	2	m^2
Mass flow	-	-	-	-	0.019	-	kg/s
Density (ρ)	2200	-	2330	2699	1050	16	kg/m3
Specific heat (c)	670	-	900	800	4180	1120	J/(kgK)
Thermal conductivity (k)	1.1	*	140	237	0.615	0.035	W/(mK)

Correlation for forced convection and relation for electrical efficiency

- Correlation for the heat transfer coefficient of forced convection
- depends on the wind speed

$$h_{pva-e,CV} = \begin{cases} 5.7 + 3.8v_w, & \text{for } v_w < \frac{5m}{s} \\ 6.47 + v_w^{0.78} & \text{for } v_w > \frac{5m}{s} \end{cases}$$

$$\eta_{EL(T)} = \eta_{STC}[1 - \beta_{PV}(T_{pva} - T_{ref})]$$

Sensitivity analysis