16-11-2023 – 12H15 – 19H – VUB BRUSSELS

STUDIEDAG ATIC: INDIRECTE VERDAMPINGSKOELING –IEA –ANNEX 85
JOURNEE D'ETUDE ATIC: REFROIDISSEMENT EVAPORATIF INDIRECT –AIE –ANNEXE 85

IEA-EBC-Annex 85 « Indirect Evaporative Cooling »

Vincent LEMORT (and all project partners)

Presentation Outline

- Annex 85 Project
- Objectives
- Subtasks
- Consortium
- Reports
- Some take-away messages

The project

- IEA EBC - Annex 85 – “Indirect Evaporative Cooling”
  - ✓ Starting date: 2020
  - ✓ Ending date: 2025
  - ✓ Operating agent: Dr Xiaoyun Xie, Associate Professor in Tsinghua University

- IEA: International Energy Agency
- EBC: Energy in Building and Communities Programme

“The IEA-EBC Programme is an international energy research and innovation programme in the buildings and communities field. It enables collaborative R&D projects among its 26 member countries” (https://www.iea-ebc.org/)

- Belgian participation supported by ATIC

Objectives

- Identify the main **reasons** why IEC technologies have **not been widely used yet**: feasibility, energy performance, cost, footprint, maintenance, environmental impact (noise, legionella, water treatment, materials…).
- Collect **real-world running data** through field tests on existing IEC installations (different dry regions of the world) => identify means for improving (new) systems performance.
- Develop **theoretical knowledge of IEC processes** to guide the design of different new IEC systems used in different dry climates.
- Assess **electricity**, (heat) and **water** consumption.
- Develop **models** of different IEC technologies for **simulation** in different types of buildings and dry climates.
- Develop **guidelines** for designing IEC systems for different types of buildings under different dry climates and water resource conditions.

Field studies

Fundamental studies

Simulation tools

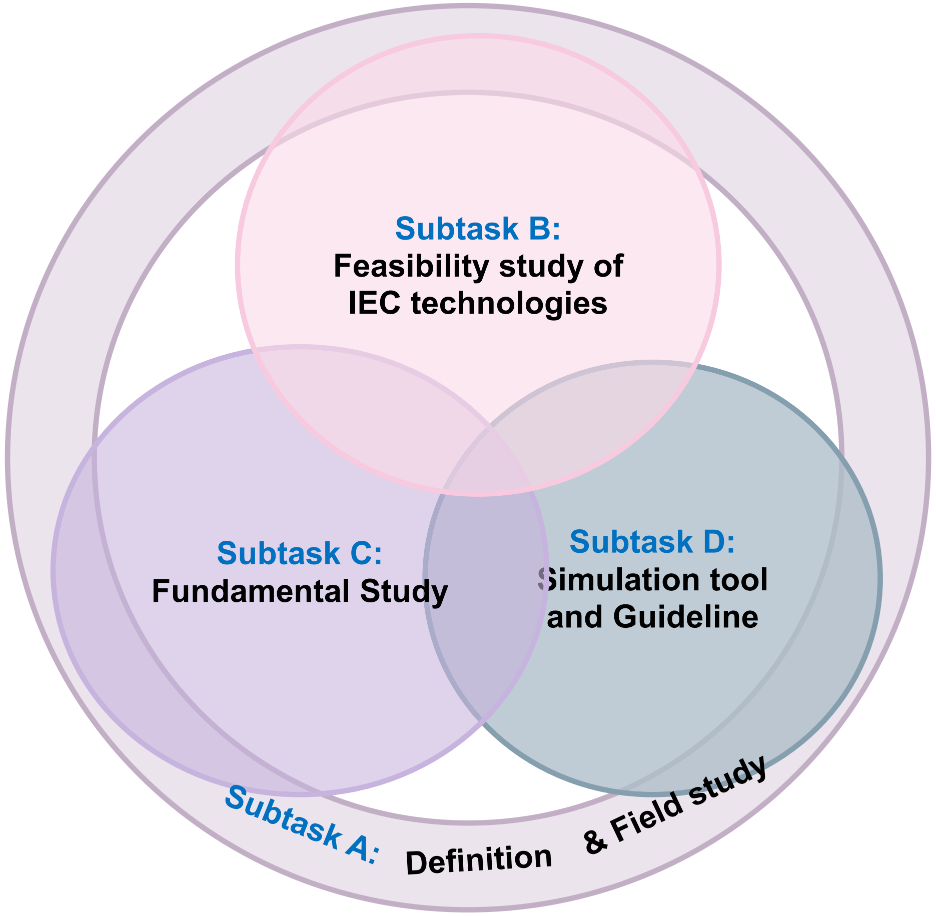
Guidelines

The subtasks

Conducted work to achieve these objectives is organized in 4 subtasks:

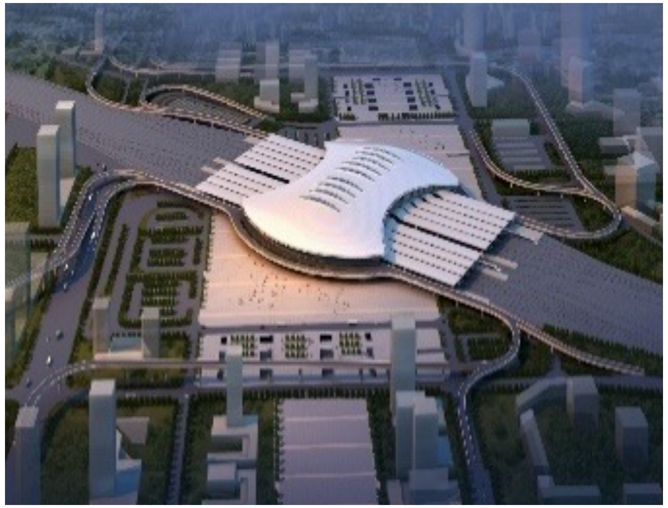
- **Subtask A: Definition & Field study**
- **Subtask B: Feasibility study of IEC technologies**
- **Subtask C: Fundamental Study**
- **Subtask D: Simulation tool and Guideline**

Subtask A:	***Alireza Afshari,*** Professor, Aalborg University, Denmark
Subtask B:	***Kashif Nawaz,*** Research Staff, Oak Ridge National Lab, the United States ***Stefano De Antonellis,*** Professor, Politecnico di Milano, Italy
Subtask C:	***Xiaoyun Xie***, Associate professor, Tsinghua University ***Hasan Demir***, Associate professor, Osmaniye Korkut Ata University, Turkey
Subtask D:	***Vincent Lemort***, Professor, University of Liège, Belgium ***Chadi Maalouf***, Associate professor, University of Reims Champagne Ardenne, France



The subtasks – Subtask A: Definition and field study

- Data collection on existing projects (**running conditions**)
- Identification of key **constraints** (consumption, maintenance, footprint, aging, etc.)
- Impact of climate on performance: identify most **suitable climates**
- Define a **frame for comparison**



High speed railway station in Urumqi, China, IEC water chiller system (Source: Tsinghua University)

Office (university) building: 20 694 m2, 4 floors, 4450 people max, suffer from overheating, Denmark, Desiccant Evaporative Cooling System (Source: Aalborg University)

Office building: 750 m2, 2 floors, 25 people max, Belgium, Indirect Evaporative Cooling System (IEC air cooler) (Source: CeREF)

The subtasks – Subtask B: Feasibility study of IEC technologies

- Same aspects as those considered in subtask A, but here, with a focus on the **design of new facilities**:
  - Cooling performance, cost, electricity consumption, water consumption (equivalent energy consumption, f.i. by desalination)
  - Environmental aspects (legionella, noise, water treatment)
  - Assess the feasibility of IEC technologies according to building type for suitable climatic regions.

=> To give solutions to the main application constraints identified in Subtask A.

=> To propose a unified **assessment frame** for energy/water/environmental performance of different technologies in different climates.

=> To propose a unified method to identify and quantify **most influencing factors**.

The subtasks – Subtask B: Feasibility study of IEC technologies

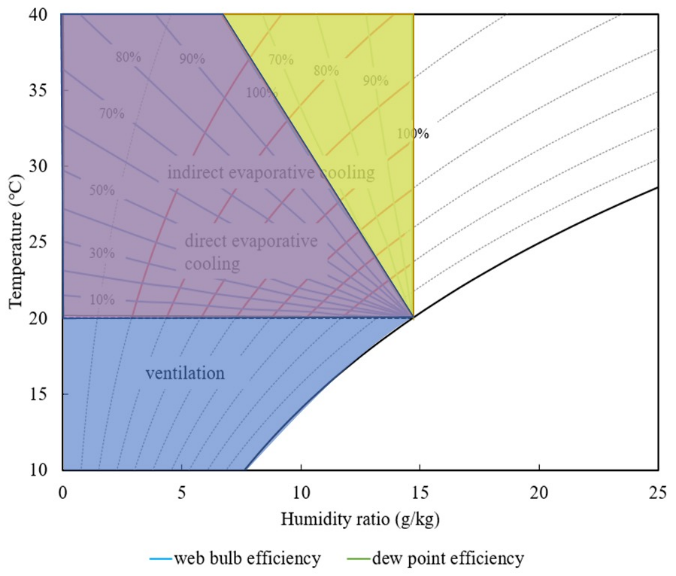
- To investigate **feasibility** (“indicators method")
  - Common method based on iso wetbulb and dewpoint efficiency lines on Mollier/Carrier diagrams

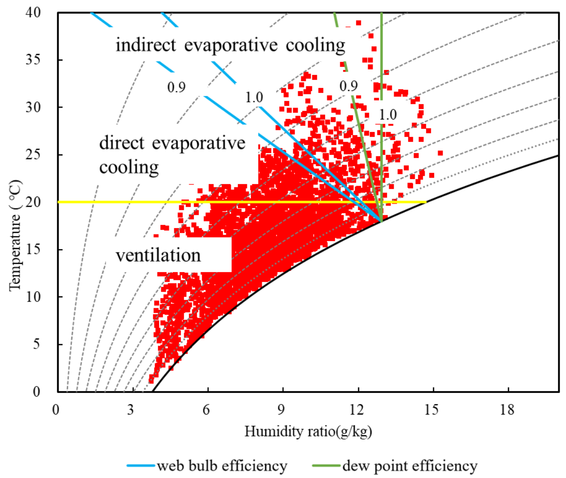
$$\eta_{wet} = \frac{t_{point} - t_{supply}}{t_{point} - t_{wb,point}} \qquad \eta_{dew} = \frac{t_{point} - t_{supply}}{t_{point} - t_{db,point}}$$

  - First, investigate the **feasibility of a climate** (efficiencies <1 and outdoor specific humidity lower than indoor specific humidity set point)

    => feasible, partly feasible and non feasible climates

  - Second, investigate the **feasibility of an IEC equipment**: indicators (efficiencies) of the equipment > desired indicator
  - Third, for different suitable IEC equipment's, introduce other criteria: energy and water consumption, cost, compactness…





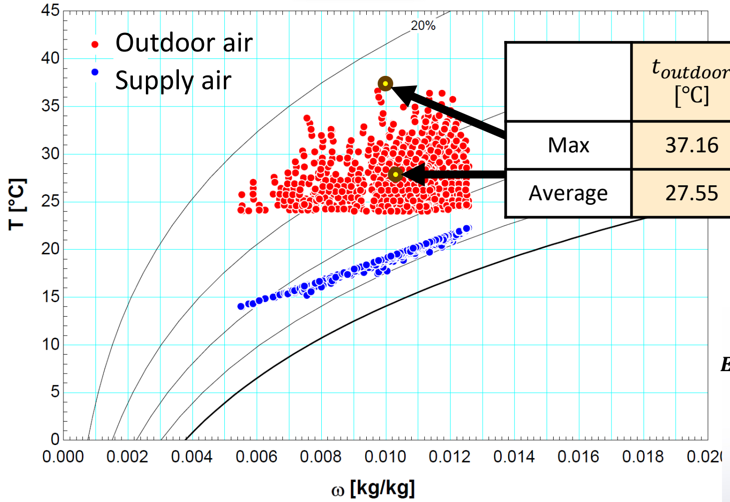
Indicator method for feasibility assessment (source: Tsinghua University)

Atic for HVAC professionals

The subtasks – Subtask C: Fundamental Study

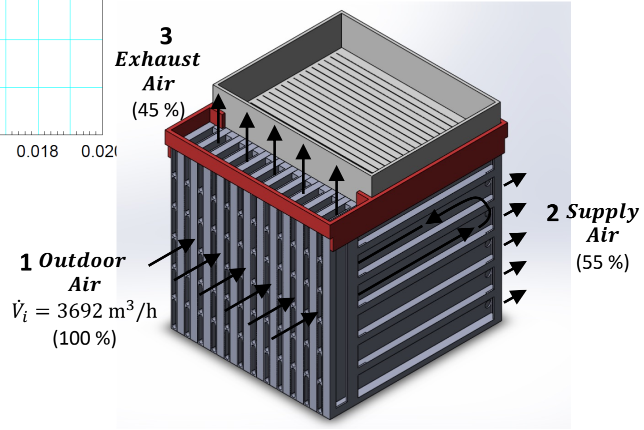
- In-depth theoretical and experimental analysis of **energy conservation** (sensible and latent heat transfer), **mass conservation** (water spray, air humidification, wetting of exchange surfaces, evaporation), and momentum conservation (**pressure losses**) within the considered systems.
- Establish the principles necessary for design of IEC air coolers and water chillers

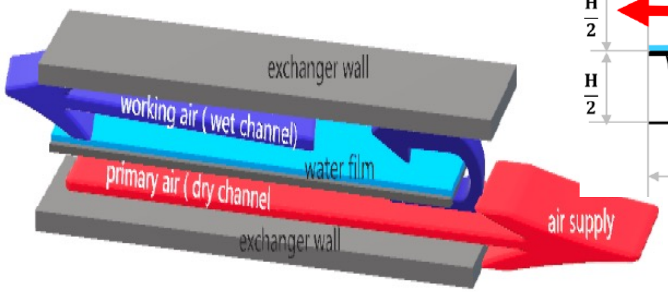
=> Utilization of this analysis for the purpose of **optimal design for various systems**.

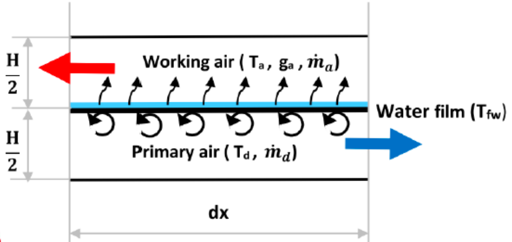


	$t_{outdoor}$ [°C]	$d_{outdoor}$ [g/kg]	t_{supply} [°C]	G_s [m^3/h]	ε_{dp} [-]
Max	37.16	10.04	17.75	23920	0.84
Average	27.55	10.10	19.14	30512	0.63

Results generated by a calibrated dew point indirect evaporative cooler model (source: University of Cordoba)







Cell element in mathematical model of dew point cooler (source: Université de Reims)

Modeling heat transfer and pressure drops in cooling tower paddings (source: Jean Lebrun, ATIC)

The subtasks – Subtask D: Simulation tool and Guideline

- Develop **systems simulation tools** for different types of IEC technologies in different types of building under different climates (and cost of electricity/gas/water)
- These tools and guides should potentially improve the management of existing systems and facilitate the design of new systems, well-suited to the various constraints identified in subtasks A and B.
- To develop **guidelines for IEC design and operation**

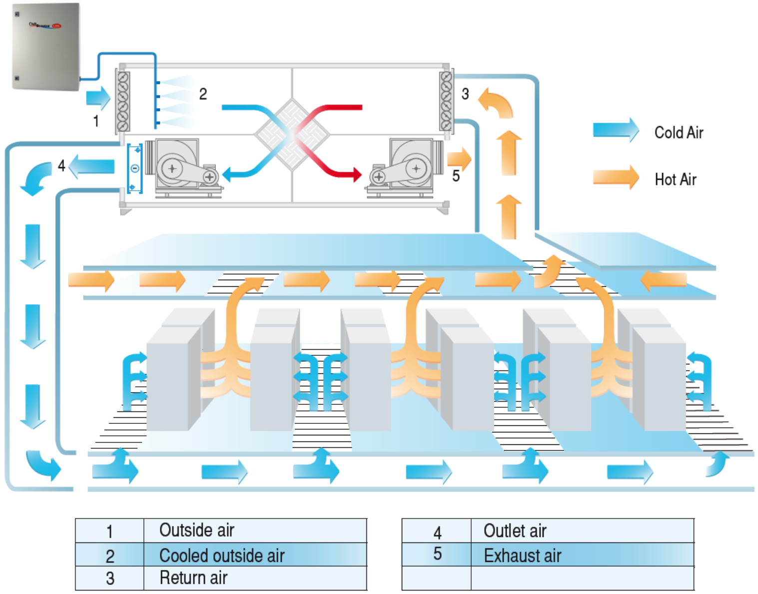


Fig. 7.3 *Indirect air-side free cooling in a data center*

IEC air cooler integrated in a Data Center (source: Carel, Italy)

The consortium

Belgium	China	Denmark	France	Italy	Spain	Turkey	USA	Egypt	Algeria
Jean Lebrun, Professor, ***Vincent Lemort,*** Professor, ***Alanis Zeoli,*** Doctoral student **Essam Elnagar,** Doctoral student **University of Liège** ***Jean-claude MARBAIX,*** Engineer ***Sylvano Tusset,*** Consulting Engineer **ATIC** ***Adrien Pourbaix,*** Assistant Master **Haute Ecole Louvain en Hainaut**	***Yi Jiang*** Professor, ***Xiaoyun Xie,*** Associate Professor, ***Chaoyi Zhu,*** Research Associate, ***Yijie Liu*** Doctoral student ***Zejin Chen*** Master ***Ce Zhao*** Doctoral student ***Yang Jing*** Doctoral student ***Jiale Fan*** Master student **Tsinghua University**	***Alireza Afshari*** professor, ***Alessandro Maccarini*** Researcher, ***Michal Pomianowski***, Associate professor, ***Hicham Johra*** Researcher, ***Mahmood Khatibi*** Assistant professor **Aalborg University**	***Chadi Maalouf,*** Associate professor, ***Tala Moussa*** Assistant Professor **University of Reims Champagne Ardenne** ***Akram Ghanem*** Assistant Professor **ELIZA aerospace**	***Stefano De Antonellis***, Associate professor, ***Manfredo Guilizzoni,*** Associate professor ***Luca Marocco*** Associate professor ***Roberta Caruana*** Doctoral student **Politecnico di Milano** ***Raul Simonetti,*** **CAREL Industries SpA** ***Paolo Liberati,*** Engineer ***Luca Buscemi*** Engineer **Recuperator**	***Manuel Ruiz de Adana,*** Professor, ***Francisco Comino Montilla*** Assistant professor ***Maria Jesús Romero*** Doctoral student **University of Cordoba**	***Hasan Demir ,*** Associate professor, **Osmaniye Korkut Ata University**	***Kashif Nawaz*** R&D staff ***Kyle Gluesenkamp*** Senior R&D scientist **Oak Ridge National Lab**	***Omar Abdelaziz***, Assistant Professor, **The American University in Cairo**	***Djamila ROUAG SAFFIDINE,*** Laboratory head **University of Constantine 3** ***Amel F. BOUDJABI,*** Associate professor, **Université Larbi Ben Mhidi**

1. **We have received the letters of national participation from France, Denmark, Turkey, USA, Italy, Spain, including China, there are seven confirmed countries to participate in this Annex.**
2. **Algeria and Egypt, which are not EBC member countries, participated in this Annex, and Algeria is voted to be observer in Annex 85.**

Reports (under preparation)

- Report #1: Real case investigation and analysis
  - ✓ Case studies in Belgium (IEC in Air Handling Unit), China (IEC water chiller for large building), Denmark (DEC/IEC coupled to desiccant cooling), Italy

- Report #2: Basic modeling and performance analysis of IEC/DEC processes
  - ✓ Modeling, testing, analyzing of IEC water chiller (Belgium, China), cross flow IEC air cooler (Italy), dew point coolers (France, Spain),…

- Report #3: Guidelines for IEC/DEC technologies design and operation
  - ✓ Comparison of the performance of the different technologies
  - ✓ Examples of application of the “indicators method” for feasibility assessment
  - ✓ Recommendations of suitable IEC/DEC equipment for different climates and buildings

Some take-away messages

- ✓ **Feasibility** is the most important criteria, then energy and environmental performance (difference between passive and mechanical cooling)
- ✓ **Dew-point and wet-bulb efficiencies** are useful to assess the performance of heat and mass transfers in the core of IEC technologies (in relation with feasibility assessment of passive cooling). However, the most relevant indicator is the **COP** (fans and pumps consumption).
- ✓ Propose a **common metrics** for assessing electricity, heat and **water consumption** (equivalent energy consumption, economical values…).
- ✓ When assessing feasibility of climate, distinguish **occupation periods** (or assess capacity of cool storage of building structure). Data centers are interesting cases.
- ✓ For partly feasible and non feasible climates, **hybridization of IEC/DEC with active cooling** is necessary (heat driven and vapor compression refrigeration)
- ✓ Hybridization of IEC/DEC/active cooling yields different operating modes for a given equipment => **control** is important.
- ✓ **Experimental data** (at different levels) still welcome.
- ✓ Reliability of **climatic data** is of tremendous importance (temp, humidity): scenario-based future data, heat waves, UHI,…

Thank you for your attention!

Vincent.Lemort@uliege.be

Annex Info & Contact:

Operating Agent
Dr Xiaoyun Xie, Associate Professor
Tsinghua University
Building Energy Research Center, Department of Building Science
School of Architecture
100084 Beijing
CHINA
Tel: +86 10 6279 3591
Email: xiexiaoyun@tsinghua.edu.cn