



D.4.6: Report on replication made on Innovative Lighting and Energy and CO2 efficiency in existing airport Terminals

– PART 1: Innovative Lighting in Cluj-Napoca's Arrivals Terminal

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List of Abbreviations

AB	Advisory Board	HSE	Health, safety and Environment
A-CDM	Airport CDM (certification)	IA	Innovation Action
ACI	Airport Council International	IDEP	Interactive Data Exchange Platform
AI	Artificial Intelligence	IP	Intellectual Property
API	Application Programming Interface	IPR	Intellectual Property Rights
APU	Auxiliary Power Unit	LCA	Life Cycle Assessment
AQ	Air quality	LH2	Liquid Hydrogen
ASTM	American Society for Testing and Materials	LIDAR	Light Detection and Ranging (camera)
BEMS	Building Energy Management System	LTO	Landing and Take-off
BES	Building Energy Simulation	MaaS	Mobility as a Service
BEV	Battery Electric Vehicle	MDO	Multidisciplinary Design Optimisation
BIM	Building Information Modeling	ML	Machine Learning
bioNGV	bio- Natural Gas Vehicle	MXP*	Malpensa airport
CA	Consortium Agreement	MRV	Measurement, Reporting and Verification
CAGR	Compound annual growth rate	NGV	Natural Gas for Vehicle
CAV	Connected and Autonomous Vehicles	OEM	Original Equipment Manufacturer
CDG*	Paris-Charles de Gaulle airport	OMS	Operation Management System
CDM	Collaborative Decision Making	PAX	Passenger
CFS	Certificate on the Financial Statement	PC	Project Coordinator
CLJ*	Cluj Airport	PMC	Project Management Committee
CNG	Compressed Natural Gas	POBT	Predicted Off Block Time
DL	Deep Learning	R&D	Research and Development
EAQM	Emissions and Air Quality Monitoring	RES	Renewable Energy Source
EC	European Commission	RGB	red, green, and blue (camera)
EoL	End of Life	SAF	Sustainable Aviation Fuel



EPC	Engineering Procurement and Contract	SC	Steering Committee
EU	European Union	SME	Small and Medium Enterprise
(P)(H)EV	Plug-In hybrid Electric Vehicle	TRL	Technology Readiness Level
FLW	Food Loss and Waste	UAV	Unmanned Aerial Vehicle
FMS	Fleet Management systems	UFP	Ultra-fine Particles
FP	Framework Programme	VOC	Volatile Organic Compounds
GHG	greenhouse gas	WG	Working Group (of the AB)
GIS	geographic information system	WP	Work Package
GPU	Ground Power Unit	WPL	Work Package Leader
H2020	Horizon 2020	XOPS	Operation / Fleet Management System (RMP4 product)
HEFA	Hydroprocessed Esters and Fatty Acids	ZAG*	Zagreb airport



1. WP4.1.2b - Partial replication of terminal innovative lightning (CLUJ, TUCN)

1.1. Introduction and brief description of the work performed

During the steering committee organized in Paris-CDG, the experimentation site was presented in collaboration with Ingelux, engaging in technical discussions about the production of prototypes and determining the location for the experiment at CLUJ airport. This visit contributed to the deliberation on the upcoming call for tenders to produce these prototypes and the support mission provided by Groupe ADP and Ingelux. The chosen fixtures are from Optelma, with an architectural decision made for a suspension system that offers both direct and indirect lighting. Finally, the project cost was validated for an amount to approximately 8,700 euros. In month 44, different meetings were organized between CLUJ / TUCN / ADP /Ingelux and the manufacturer to align on the technical objectives of the replication, especially with the selection of a tunable white (circadian) lighting.

The next steps include the tender for 39 tunable luminaires with direct/indirect distribution, with CE label, for the whole connecting hall.

2. Task activities

2.1. Work performed for Cluj-Napoca Airport

In 2023, lighting measurements were carried out at the airport without interfering with its operational activities. The measurements were performed using the GL SPECTIS 1.0 Touch spectrophotometer. This handheld device, shown in the figure below, can be used both to measure illuminance levels and to determine colorimetric parameters, such as correlated colour temperature (CCT) and colour rendering index (CRI). In addition, this version of the instrument allows the assessment of flicker levels in the evaluated lighting installation.



Figure 1 - GL SPECTIS 1.0

The measurement campaign was conducted in accordance with established lumino-technical methodologies, ensuring the reliability and accuracy of the collected data. All relevant parameters were systematically recorded, processed, and analysed. The results obtained from this measurement campaign are summarized and presented in the table below, providing a clear overview of the lighting performance in the assessed areas.

Table 1 - Lighting measurement results

Ref · No.	Space	Measured values					Specified values according to SR_EN_12464_2021					
		E _{min} (lx)	E _m (lx)	U ₀	R _a	TCC (K)	Type of task/activity area	Em (lx) requi red	Em (lx) modifi ed	U ₀	R _a	RU GL
1	Security check	99	180	0.55	80.7	7387	Security check areas	300	500	0.6	80	19
3	On the waiting area in face of B5 Gate	64	115	0.56	88.4	6423	Arrival and departure halls, baggage claim areas	200	300	0.4	80	22
4	Between skylights in the waiting area	75	150	0.50	81.2	7689	Arrival and departure halls, baggage claim areas	200	300	0.4	80	22
5	B2 Gate on the desk	70	135	0.52	77	9115	Customs and passport	500	750	0.7	80	19



							control desks					
6	Gate B4 in the middle of the waiting area	87	165	0.53	79	7950	Arrival and departure halls, baggage claim areas	200	300	0.4	80	22
7	WC	276	418	0.66	77.8	9019	Bathrooms	200	300	0.4	80	25
9	Gates B5 – B6 waiting area	201	390	0.52	71.6	2944	Arrival and departure halls, baggage claim areas	200	300	0.4	80	22
10	Gates B5-B6 check-in desk	362	606	0.60	71.6	2940	Customs and passport control desks	500	750	0.7	80	19
11	Lounge on the floor	76	160	0.48	79.7	2947	Waiting areas	200	300	0.4	80	22
12	Lounge on tables	115	210	0.55	79.7	2947	Waiting areas	200	300	0.4	80	22
14	Internal departures Gate A1	82	116	0.71	77.9	8960	Arrival and departure halls, baggage claim areas	200	300	0.4	80	22
15	Check-in on the floor	70	126	0.56	90	2693	Arrival and departure halls, baggage claim areas	200	300	0.4	80	22
16	Check-in desk 1-12	116	172	0.68	90	2693	Security check areas	300	500	0.6	80	19
17	Connecting area from Arrival to Departure	52	130	0.40	75.7	6368	Connecting areas	150	200	0.4	80	22
18	Arrival, access lobby	156	317	0.49	11.3	2014	Arrival and departure halls, baggage claim	200	300	0.4	80	22
19	Conference room on the desks	194	218	0.89	75.9	6593	Conference areas	500	1000	0.6	80	19
20	Conference room, vertical illuminance	-	130	-	75.9	6593		-	-	-	-	-
21	Technical department office	140	154	0.91	77.8	6650	Office	500	1000	0.6	80	19
22	Corridor near the technical department	113	146	0.78	80.4	8463		100	150	0.4	40	28



The results of the measurement campaign are presented in the second column, while the last column shows the reference values established by the European standard SR_EN_12464_2021.

The entire lighting system is operated by a private service provider responsible for the maintenance and day-to-day management of the installation, as well as for ensuring the permanent presence of qualified electrical personnel on site. An electrician is available on a continuous 24/7 basis and oversees the operation of the lighting system, including the switching on and off the luminaires through the electrical distribution panels, in accordance with operational requirements.

Based on the measurements conducted, the following observations were identified:

- In most cases, the average illuminance levels are below the requirements specified in SR EN 12464-1:2021. Given the high passenger volume and the safety-critical activities performed in these areas, lighting performance is inadequate. At departure gate B2 (check-in area), the illuminance level is approximately eight times lower than the required value. This area is used for document and boarding pass checks, where insufficient lighting may lead to errors and potentially costly delays.
- In public areas, 11.23% of the lighting fixtures were not operational, most likely due to lamp failures. In some cases, the high mounting height makes access to the luminaires difficult.
- There is a clear need for a dedicated storage space for failed lamps. The large number of luminaires (approximately 1,500) combined with long operating hours results in several hundred failed lamps each year, which are classified as hazardous waste.
- The correlated color temperature (CCT) ranges between 2000 K and 9000 K. The CCT is unusually low in the arrivals terminal (high-pressure sodium lamps) and very high in the case of fluorescent lamps (fixtures rated at 10,000 K).
- The color rendering index (CRI) is extremely low in the arrivals terminal, with a value of only 11.30, and in many areas it is below the recommended value of 80.
- The lighting system reflects successive construction phases and lacks a unified design concept. Under the current conditions, a comprehensive LED-based solution is required, featuring a CRI above 80 and a uniform correlated color temperature throughout the facility.

2.2. Luminaire prototype

Most existing airport terminals currently use lighting fixtures selected from standard commercial catalogues, which are generally not optimized for the complex functional, visual, and operational requirements specific to passenger terminals. These luminaires often lack adaptability, uniform



photometric performance, advanced control capabilities, and long-term sustainability features. In response to these limitations, the present proposal focuses on the development of an innovative, modular, and generic luminaire, specifically designed for airport terminal applications, with particular emphasis on refurbishment projects and long-term reduction of energy consumption and environmental impact.

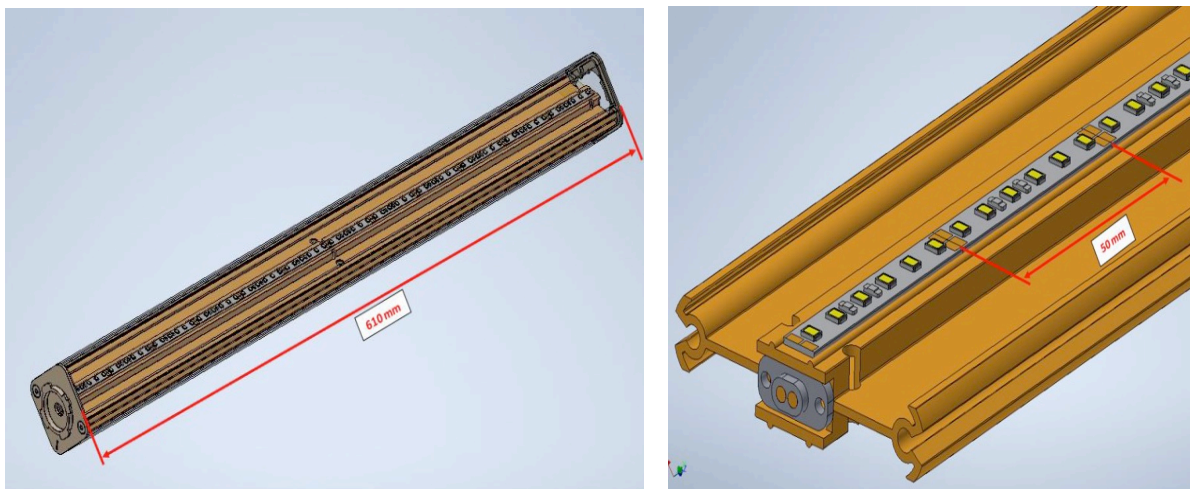


Figure 2 - Groupe ADP / INGELUX Concept

The proposed lighting fixture is conceived as a modular lighting system, capable of forming multiple configurations through the association of standardized lighting modules. This modularity allows the luminaire to be adapted to different architectural geometries, ceiling types, and functional zones within the terminal, including circulation areas, waiting halls, and transition spaces. The design objective is to ensure consistent lighting quality throughout the passenger journey, while maintaining flexibility for future spatial or functional modifications.

A fundamental requirement of the proposed solution is the integration of **Human Centric Lighting (HCL)** principles. The luminaire is designed to provide **tunable white lighting**, enabling dynamic adjustment of the correlated colour temperature (CCT) within the range of **2700 K to 5000 K**, in order to support circadian rhythm alignment, improve visual comfort, and reduce passenger fatigue, particularly in areas with prolonged dwell times.

From an energy efficiency perspective, the proposed luminaire targets a **high luminous efficacy**, exceeding **110 lm/W at module level** and **100 lm/W at system level**, including driver losses, across the entire tunable white spectrum. The lighting system is fully dimmable (20–100%) without



perceptible flicker, enabling adaptive lighting strategies based on occupancy, daylight availability, and time-of-day scenarios.

The luminaire is designed in accordance with eco-design principles and follows a circular economy approach, focusing on:

- reduced use of electronic components,
- extended service life of LED modules and drivers,
- ease of disassembly and component replacement,
- minimization of hazardous waste generation.

The expected operational lifetime of the lighting module is 70,000 hours (L90B10), while the associated drivers are specified for an average lifetime of 100,000 hours, significantly reducing maintenance frequency and life-cycle costs.

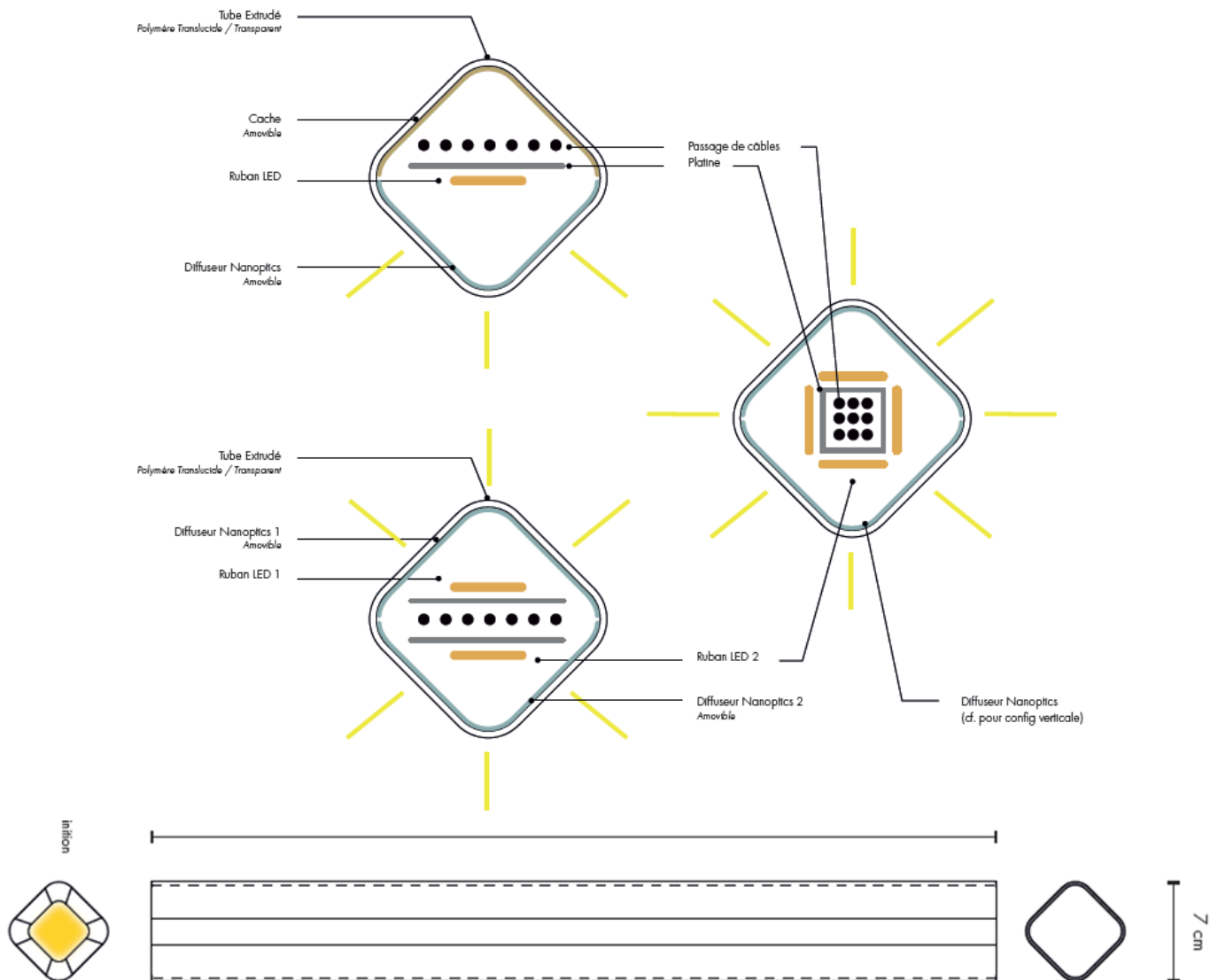


Figure 3 - Form and proportions of the generic module

The optical system is based on nanotechnology-enabled optics, allowing precise control of light distribution while maintaining high optical efficiency (>80%). The nanostructured optical layer can be implemented either as a removable printed film with a thickness below 1 mm or as a nanometric coating applied directly to the luminaire's transparent surface. This approach ensures durability, ease of maintenance, and long-term photometric stability.



The photometric distribution is designed to achieve a batwing light distribution, optimized for uniform horizontal illuminance and reduced glare in large open spaces. The luminaire meets glare control requirements with a target UGR ≤ 22 , in compliance with SR EN 12464-1:2021 for waiting areas and circulation spaces.

Key photometric and colorimetric characteristics include:

- luminous flux per module > 1200 lm,
- color rendering index (CRI) > 80,
- Duv < 0.003 (within 3-step MacAdam ellipses),
- stable color performance across the entire dimming and CCT range.

The luminaire operates on very low voltage direct current (24 V or 48 V DC), enhancing electrical safety and facilitating integration into intelligent building systems. The power supply and driver comply with ZD4i certification and support DALI-2 DT6 communication protocols, enabling precise control of luminous flux and color temperature.

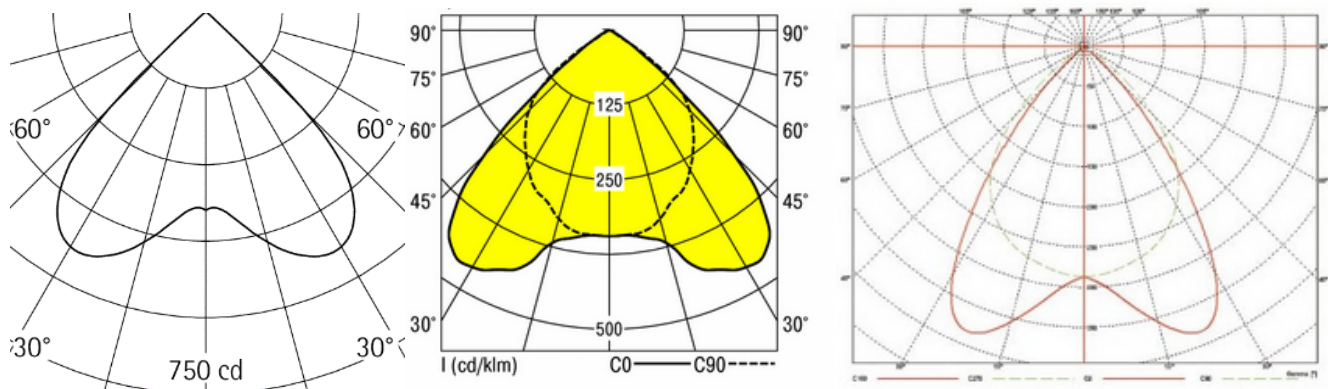


Figure 4 - Photometry shape

The driver supports multiple communication interfaces, including NFC, Bluetooth, and Wi-Fi, allowing configuration, commissioning, and maintenance operations. Advanced driver functions include:

- Constant Lumen Output (CLO),
- thermal, short-circuit, overload, and idle protection,
- flicker-free dimming from 1% to 100%,
- standby power consumption below 0.4 W.



The lighting control system is fully compatible with **BACnet**, enabling seamless integration into the airport’s Building Management System (BMS). This allows centralized monitoring, control, and optimization of energy consumption and lighting scenarios.

Compliance with Standards and Regulations

The proposed luminaire are designed so as to comply with applicable European and national regulations, including:

- CE marking,
- ENEC certification,
- Eco-design Regulation (EU) 2024/1781,
- Directive 2014/30/EU on electromagnetic compatibility (EMC),
- Romanian standard I7,
- SR EN 12464-1:2021 for indoor workplace lighting.

For waiting areas, the lighting system is designed to achieve:

- maintained average illuminance of **200 lx**,
- uniformity **$U_o \geq 0.40$** ,
- glare limitation **$UGR \leq 22$** .

Table 2 - Reference values for the connecting hall according to SR EN 12464-1:2021

60.5	Waiting area	required	modified	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ (lx)	$\bar{E}_{m,wall}$ (lx)	$\bar{E}_{m,ceiling}$ (lx)
		200lx	300lx	0,40	80	22	50	50	30

The modular design of the luminaire facilitates straightforward installation in suspended ceilings (600 × 600 mm recessed mounting) and allows rapid replacement of individual components in case of failure. A comprehensive maintenance program is proposed in accordance with CIE Publication 97:2005, including monitoring of component lifetime via the DALI system and predictive maintenance strategies. A minimum warranty period of 5 years is required, with a target of 10 years for both the luminaires and the associated HCL control system. Finally, after consultations, an innovative suspended luminaire was proposed with 70% direct lighting and 30% indirect lighting with an



aproximative installed power of 70W and two independent drivers controlled through Casambi app. The shape of the luminaire is square with the possibility to dim only direct or only indirect lighting and with separate tunnable color changing option.



Figure 5 - Luminaire prototype

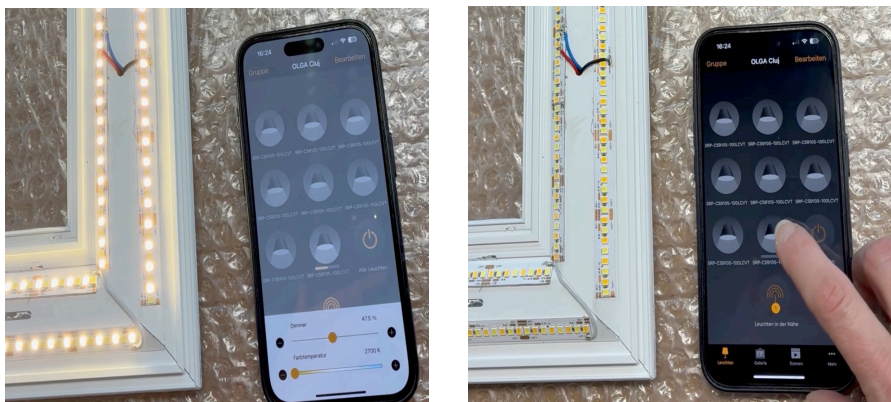


Figure 6 - Luminaire control



2.3. Implemented measures



Figure 7 - Connecting hall

The four luminaires were installed in the connecting hall between the Departures and Arrivals zones of Cluj-Napoca International Airport. The possibility to adjust the colour temperature and the illumination level allows to be adapted to different times of the day, variations in natural light, and the specific operational requirements of the airport. Lighting concept is based on the principles of Human Centric Lighting, with the main objective of creating an indoor environment that supports the well-being of users.

In the case of these prototypes, lighting management is carried out via the Casambi application, which provides a flexible solution for controlling and adapting lighting scenarios. This approach enables fast adjustments according to the current needs of the space, without major interventions to the existing infrastructure. The use of a control system contributes to the efficient operation of the lighting installation and to the seamless integration of modern solutions within an airport undergoing continuous development and modernization. An energy meter was installed for this four luminaires, to monitor the real consumption according to different dimming and color temperatures

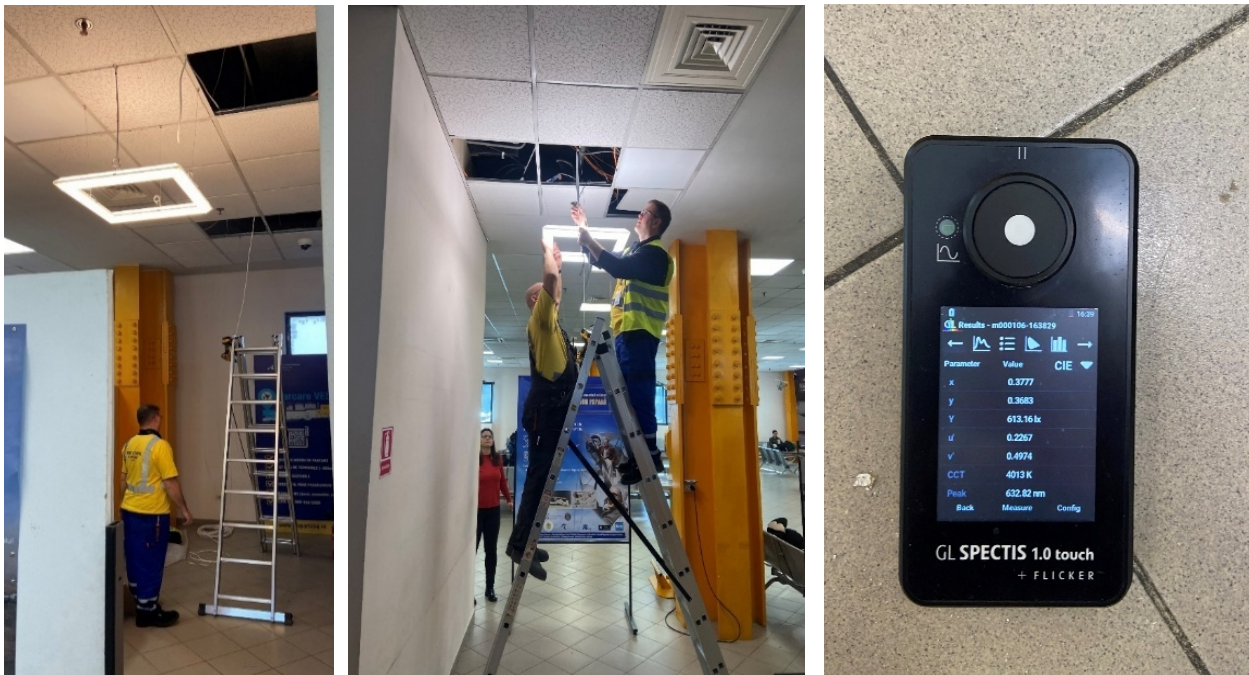


Figure 8 - Installation of luminaires

3. Conclusion and outlook

The next steps of the replication project at Cluj will be followed by the finalization of the purchase tender on Cluj's side. Subsequently, production and installation will take place at Cluj Airport. A visit to Romania will be possibly organized for the ADP and Ingelux teams to conduct tests and measurements.

The proposed solution, based on consultation based on consultations between ADP, Ingelux, UTCN and Cluj Airport is with 39 luminaires with an installed power of 40.4 W (total installed power 1576 W). Compared with previous 83 luminaires 4 x 18 W fluorescent lamps with magnetic ballast, which had an installed power of 84 W and a total installed power of 6972 W, the new solution installed power is only 22.60% of the previous one and taking into account the fact that the new solution is dimmable, the energy consumption will be around 10-15% of the previous one.