

CONCEPTION, DESIGN AND IMPLEMENTATION OF A SMART VENTILATION MANAGEMENT SYSTEM



Metro de Madrid facts & figures:

302 stations, **294** Km track length

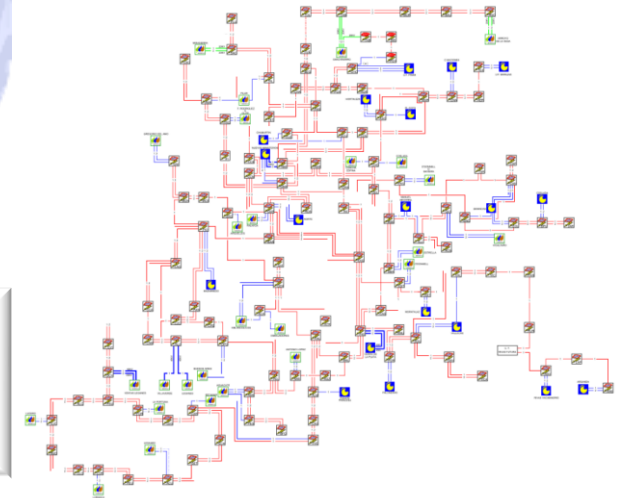
12 Heavy rail lines+ **1** Branch Line + **1** Light rail line

677 million travellers/year (2019)

2400 Cars. **183** million cars·km (2019)

1 GVA installed capacity

Energy Consumption (2019) : **546 GW/year**
≅ 160.000 households



TUNNEL & STATIONS VENTILATION SYSTEM



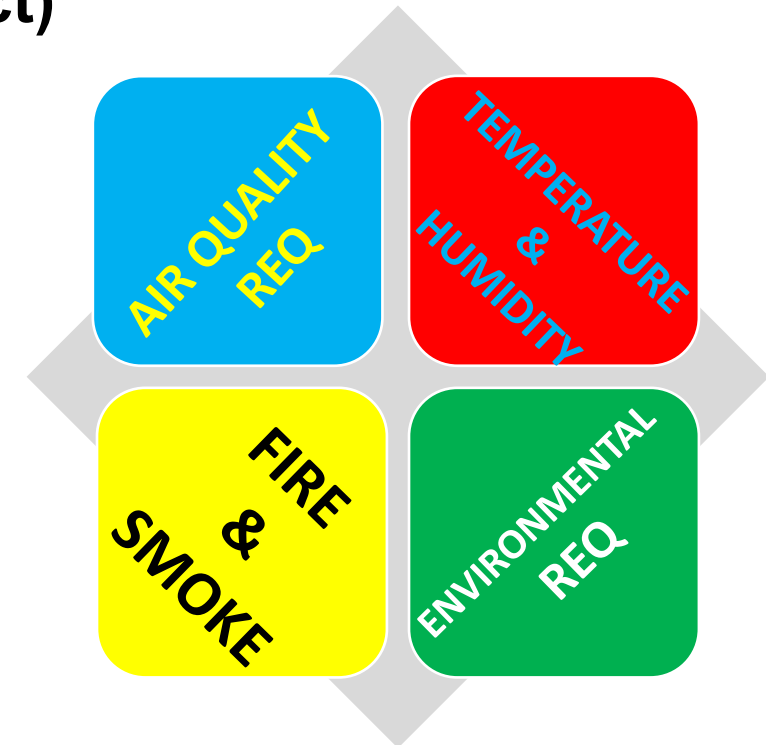
- Inlet-air in stations
- Exhaust-air in tunnels
- Overpressure compensation (piston effect)

640 FAN SHAFTS / **544** BLAST SHAFTS

913 FAN & THEIR ACCOUSTIC EQUIPMENT

VARIABLE FREQUENCY DRIVE

> 20 MW POWER CAPACITY



Energy Saving Plan [PAE] (SINCE 2012)

PAE

SET OF ACTIONS to REDUCE ENERGY CONSUMPTION and IMPROVE SUSTAINABILITY

Designed and developed entirely by Metro de Madrid



ENERGY CONSUMPTION 2012: 713,2 GWh

Equivalent annual electricity consumption CITY OF ZARAGOZA

CHALLENGE

ENERGY SAVING 25%

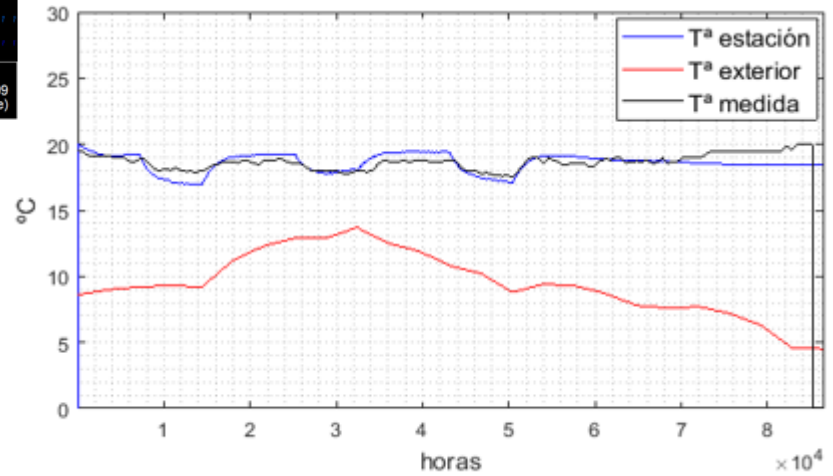
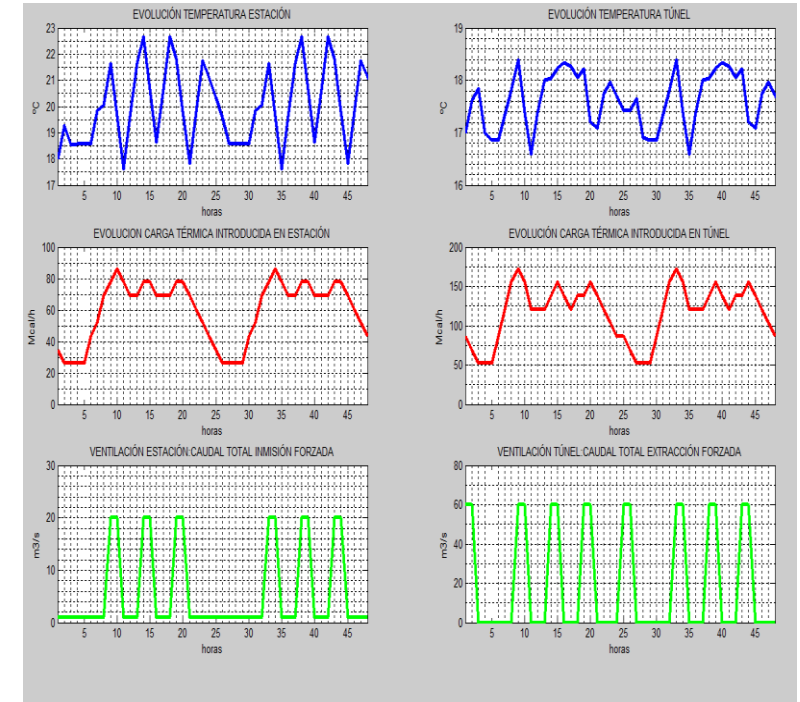
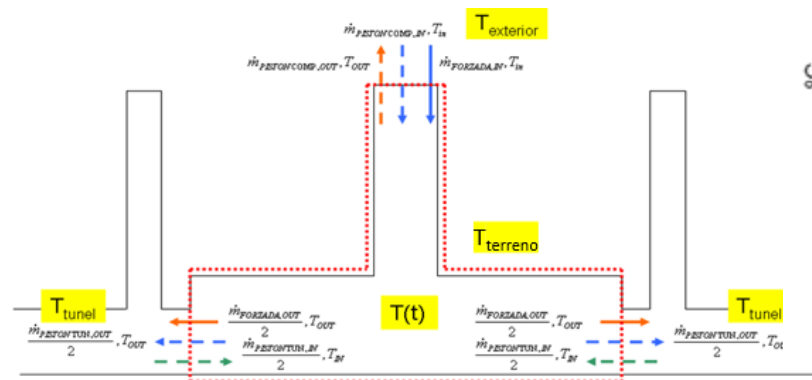
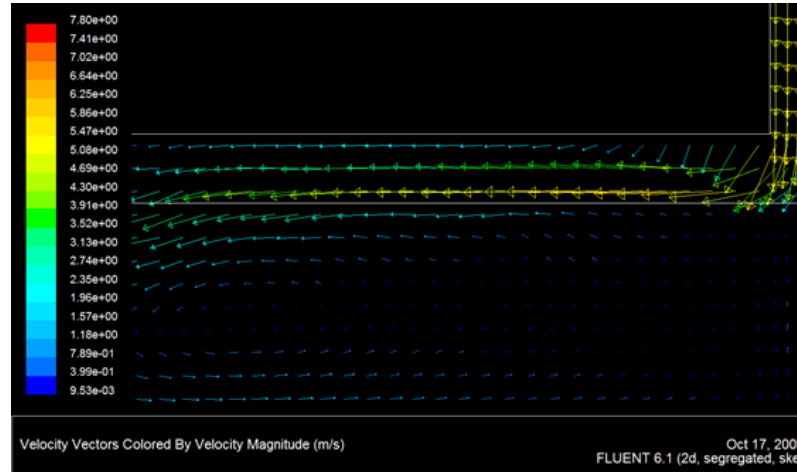
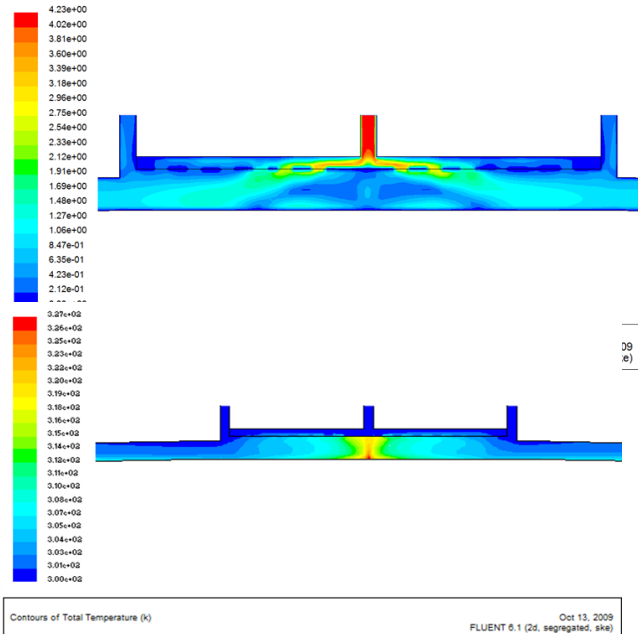
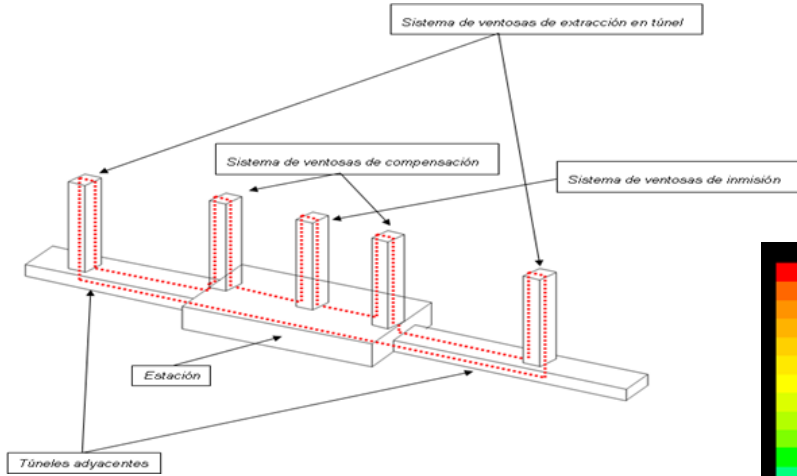
COMFORT: optimization of the tunnel & stations ventilation system

LIGHTING: implementation of LED technology in stations, maintenance buildings and trains

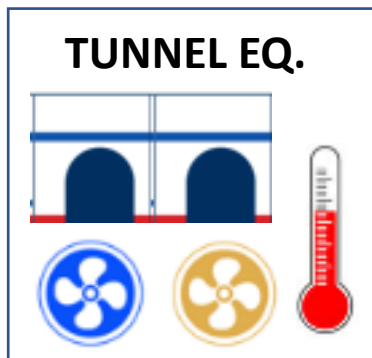
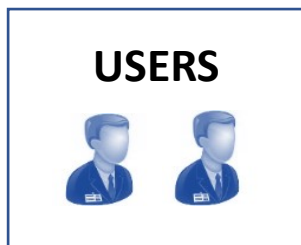
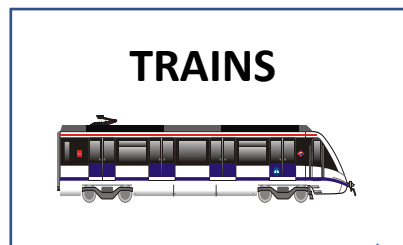
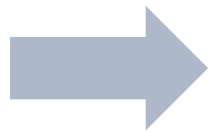
TRACTION: optimization of consumption and increasing of regenerative braking

DESIGN & SIZING

**HIGH
COMPLEXITY**

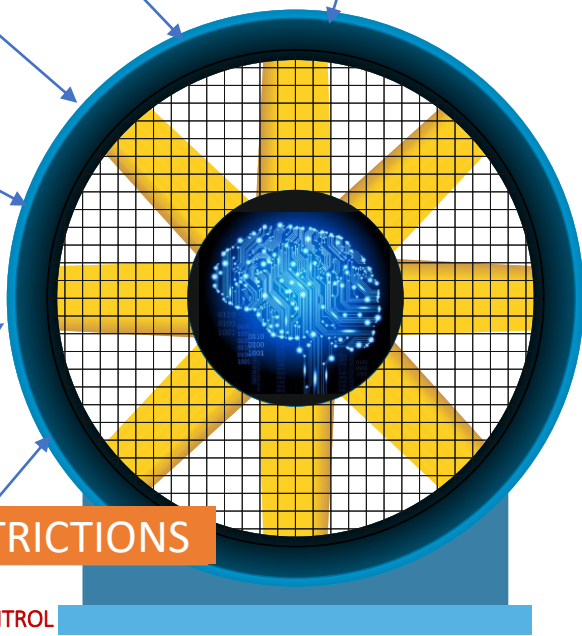
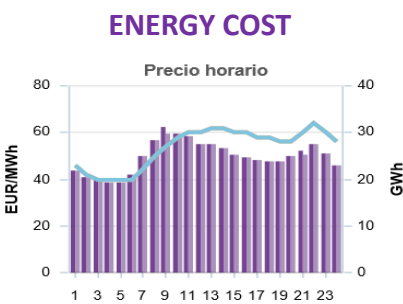


PAE



WEATHER FORECAST

	Hoy	Mañana	Mar	MiÉ	Jue	Vie	Sáb
	14° 4°	9° 4°	8° 4°	11° 3°	13° 5°	14° 6°	12° 6°
08:00		☁	☁	☁	☁	☁	☁
14:00	14°	5°	8°	11°	13°	14°	16°
20:00	12°	5°	8°	10°	12°	13°	15°
Lluvias	0 mm	5.1 mm	16 mm	0.3 mm	1.5 mm	16.2 mm	0.6 mm
Viento	20 km/h	23 km/h	23 km/h	20 km/h	20 km/h	10 km/h	11 km/h



RESTRICTIONS



NOISE CONTROL
MAINTENANCE PLAN
OPERATIVE NEEDS...



CHALLENGE MAIN PARAMETERS

Not enough to anticipate the behavior of some of the factors...

OPTIMIZING implies finding the BEST SOLUTION in a complex, high dimensional & multivariable search domain.



SAVING



COMFORT



GIV

A.I. CONCEPTUAL MODEL



VENTILATION SCHEDULE



OPTIMIZATION METAHEURISTICS

○ CONSTRAINTS

○ VARIABLE INPUT

○ RESTRICTIONS



PHYSICAL APPROACH



NUMERICAL SIMULATION (SES)



MEASUREMENTS DATABASE

WEATHER FORECAST ○

TRAIN FREQUENCY ○

TRAVELLERS FLOW ○

PREDICTIVE ANALYTICS

○ PLATFORM TEMPERATURE



REINFORCEMENT LEARNING

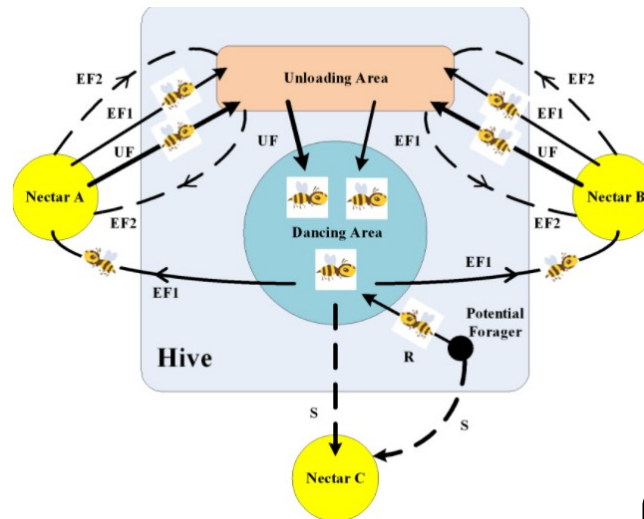


ARTIFICIAL BEE COLONY (ABC)

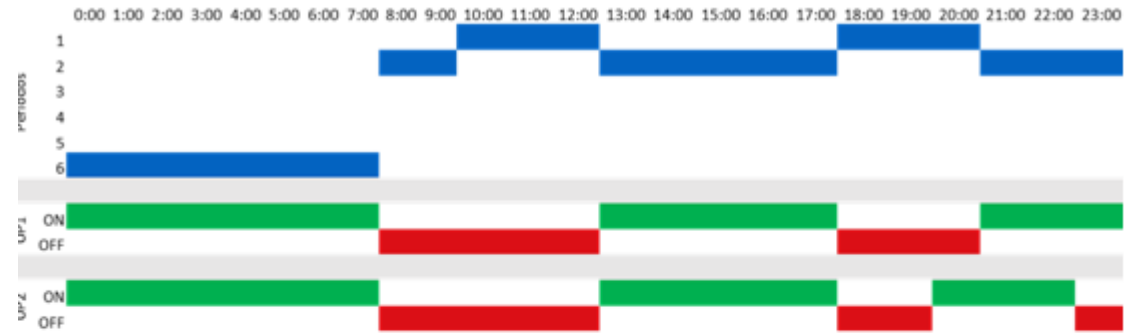
[KARABOGA, 2005]



Flower fields → FEASIBLE SOLUTIONS DOMAIN
 Nectar quality → FUNCTIONAL TARGET VALUE



METAHEURISTIC APPROACH...
 ...ESTRICTLY OPTIMAL [MATH SENSE]...
 NOT WARRANTED



OPTIMAL SCHEDULE PROCESSING

OP1	22° C	1000€	Selected
OP2	22° C	1100€	

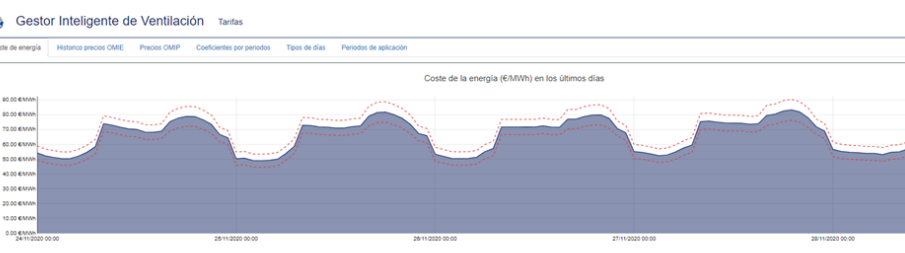
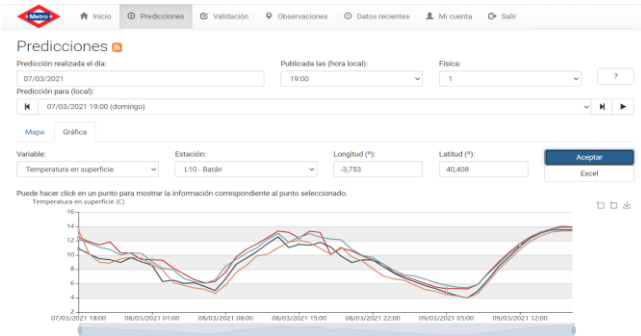
...BUT HIGH COMPUTATIONAL EFFICIENCY...



Control Panel



Programa	Aplica hora día	Restricción	Pozo de ventilación	Creado por	Motivo	Fecha de inicio	Fecha de fin
⊖	Parada 24 horas por obras en L7	PV CANAL ANEJO 2	p1954		obras en pozos L7 (SAC)	02/01/2018 00:00	08/01/2018 00:00
⊖	Parada 24 horas por obras en L7	PV CANAL ANEJO 1	p1954		obras en pozos L7 (SAC)	02/01/2018 00:00	08/01/2018 00:00
⊖	Parada 24 horas por obras en L7	PV GREGORIO SANABON ANEJOS	p1954		obras en pozos L7 (SAC)	02/01/2018 00:00	08/01/2018 00:00
⊖	Parada 24 horas por obras en L7	PV ALONSO CANO ANEJO 1	p1954		obras en pozos L7 (SAC)	02/01/2018 00:00	08/01/2018 00:00
⊖	Parada 24 horas por obras en L7	PV ALONSO CANO ANEJO 2	p1954		obras en pozos L7 (SAC)	02/01/2018 00:00	08/01/2018 00:00
⊖	Ruido obra n.º 6	PV ARTILLEROS ANEJO 1	p1971		Medición de ruidos fuera de normativa	25/01/2018 21:00	17/06/2018 08:00
⊖	Ruido obra n.º 7	PV ARTILLEROS ANEJO 1	p1971		FUERA DE NORMATIVA	26/01/2018 14:00	26/01/2018 18:00
⊖	TRABAJOS COTIDIANOS	PV ALONSO MATEOS COLON	p1759		Trabajo de retirada de anclaje en tunnel	07/04/2018 23:45	08/04/2018 10:00
⊖	TRABAJOS COTIDIANOS	PV BLASCO ALONSO MARTINEZ	p1759		Trabajo de retirada de anclaje en tunnel	07/04/2018 23:45	08/04/2018 10:00
⊖	TRABAJOS COTIDIANOS	PV COVALETA	p1759		Trabajo de retirada de anclaje en tunnel	07/04/2018 23:45	08/04/2018 10:00



Gestor Inteligente de Ventilación



Monitorización

Mantenimiento

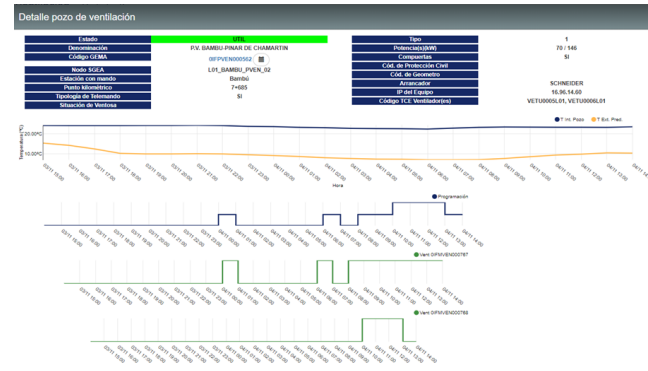
Restricciones

Tarifas

Simulación

Optimización

Administración



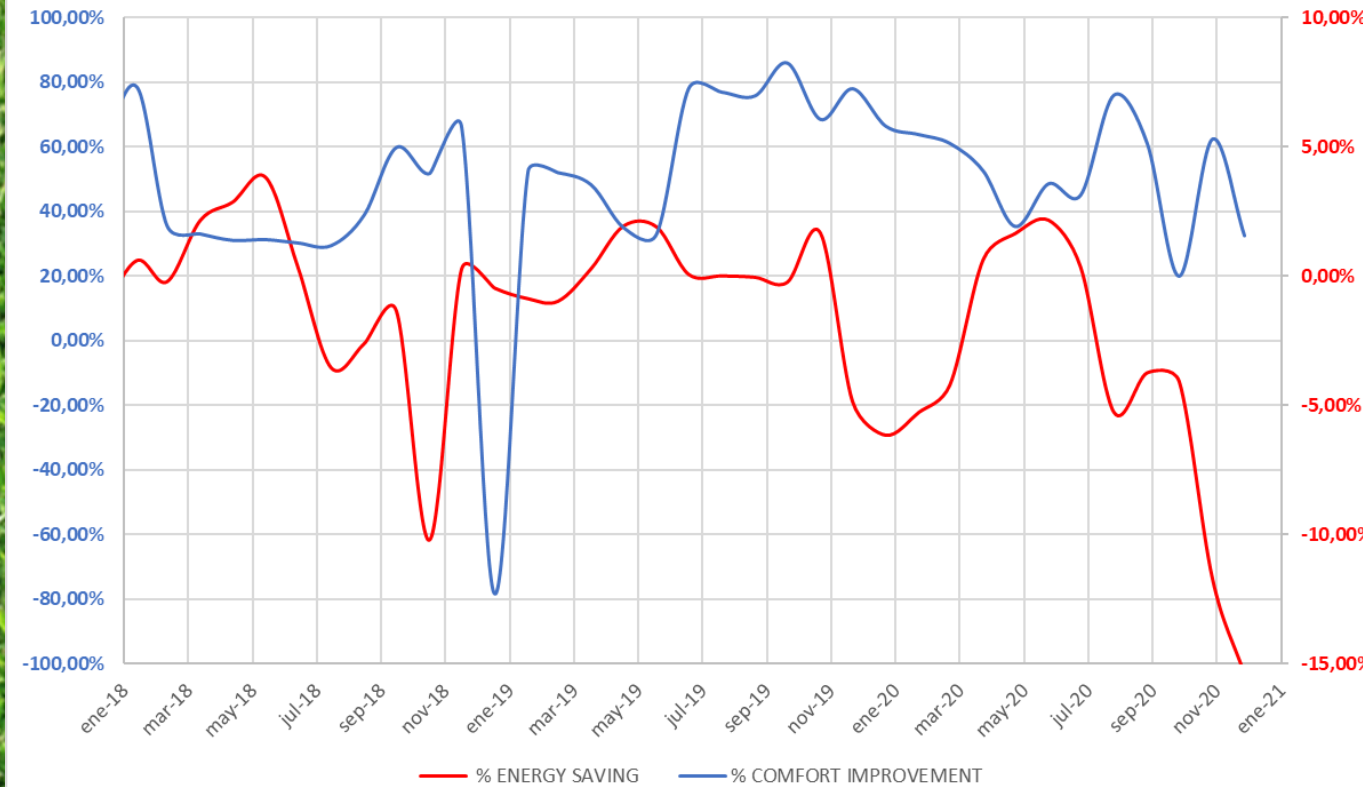
CHALLENGE RESULTS

Reduction in ancillary consumption over **19.6%** (before July 2020 - COVID)
Equivalent Reduction in CO₂ footprint

Improvement customer comfort (% hours into comfort range) over **4%**

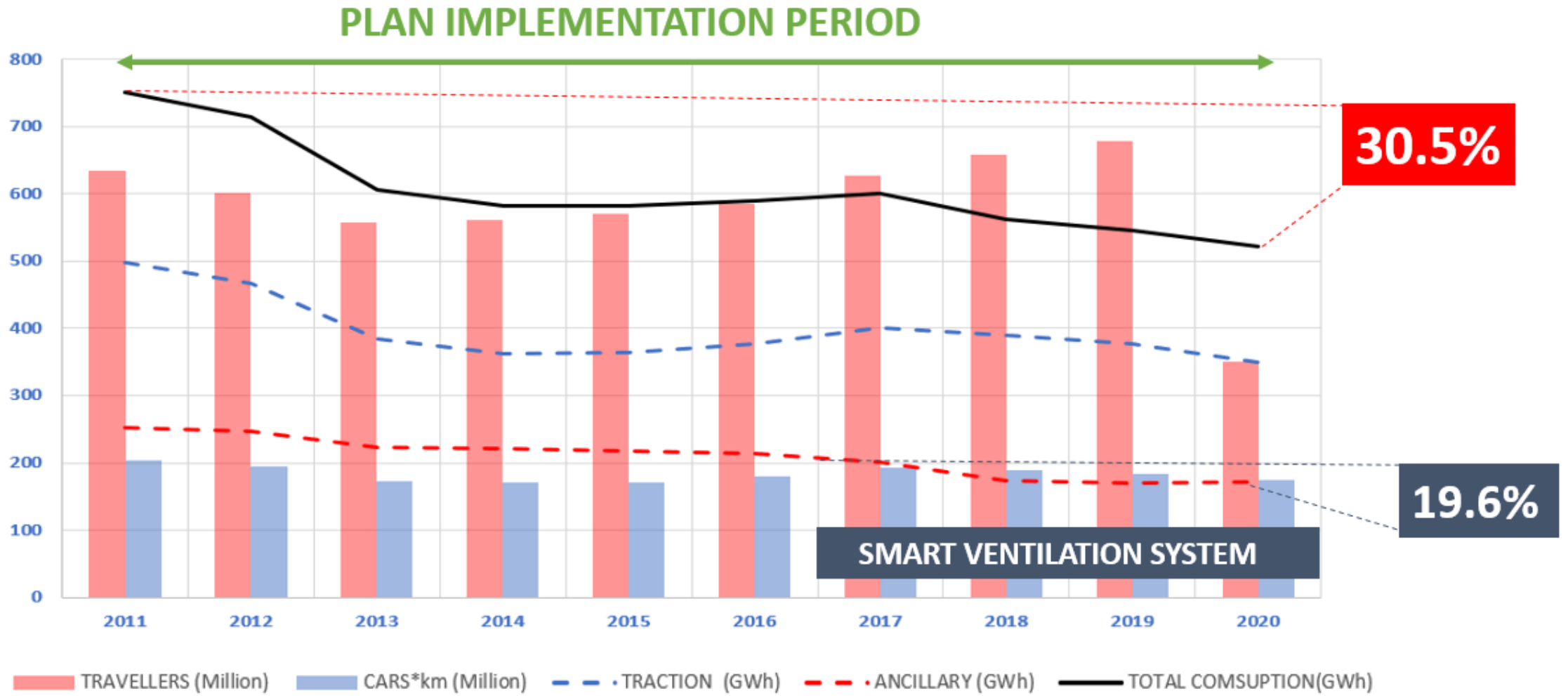


RELATIVE IMPROVEMENTS COMFORT & ENERGY SAVING



MAE
Temperature Forecast **0.9°C**

Global Results Energy Saving Plan





THANK YOU



***GESTOR
INTELIGENTE
DE VENTILACIÓN***

