GROUND ASSISTANCE
&
ENERGY TRANSITION

White Paper

V 1.2

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CHAMBRE SYNDICALE DE L'ASSISTANCE EN ESCALE

About CSAE

The Chambre Syndicale des Assistants en Escale (CSAE) brings together companies providing ground handling services to airlines and their customers at French airports. It also represents companies with similar activities: training, rental and maintenance of ramp equipment, refuelling, passenger transport and consultancy.

Its 25 members employ around 24,000 people in France.

CSAE is a member of the FNAM (Fédération Nationale de l'Aviation Marchande).

EDITORIAL

Didier Montégut, President of CSAE

For over 10 years, French ground handlers have been committed to the energy transition of their activities, in particular by electrifying their fleet of airport vehicles and ramp equipment.

The end of the health crisis has accelerated this transition, highlighting the importance of environmental issues in the expectations of our stakeholders (airlines, airports, authorities, etc.).

This guide is the result of more than a year's collective work by CSAE's Environment Commission. Its aim is to highlight the progress made in the energy transition of fleets, to set targets for 2030 and 2050 and to highlight best practices that can be generalised.

The key word here is collaboration. Collaboration on the one hand with manufacturers on the development of an offer adapted to airport needs; collaboration on the other hand with airports on the adaptation of the energy networks necessary to prepare for the arrival of these new technologies. All with the support of the regulatory authorities to guarantee the economic sustainability of this transition, in a sector that is still too little known to the regulators.

Together, we can make a real difference and contribute to reducing the environmental footprint of the aviation sector.

Enjoy your reading

CONTENTS

* *Auxiliary Power Unit*

SUMMARY

GROUND HANDLERS, KEY PLAYERS IN THE DECARBONISATION OF GROUND OPERATIONS

Findings: **An energy transition already underway by ground handlers**

- CSAE's ground handlers operate more than **3,500 unregistered vehicles and runway equipment** needed to handle passengers and aircraft on the ground (i.e. around 50% of the total airport fleet).
- Until now, the greening of fleets has been focused on **low-powered** vehicles and equipment, and mainly on electric solutions. **43% of the fleet in operation today is clean** (electric, hybrid, gas).
- The objectives are to reduce **direct CO_2 emissions by 20% by 2030** (based on 2019) and to achieve **0 net emissions** (direct and indirect) by **2050.**

Solutions : **Building on heterogeneous technological maturity**

- In the short term, facilitate the use of **already mature electric and gas technologies** through **purchase aid mechanisms,** significant and coordinated **investment** programmes **in energy supply infrastructures,** and **incentive-based energy costs,** as is the case elsewhere in Europe. Transition solutions using HVO (hydrotreated vegetable oil), which is compatible with diesel engines, should also be considered.
- In the medium and long term, develop research into **solutions for high-powered engines** such as long-haul aircraft tractors (using **hydrogen** in particular), to further limit emissions when aircraft are taxiing.

Challenge: **How can we accelerate this transition in a multi-stakeholder context?**

- Ground handlers must respond to the **demands of airlines and airports** by accelerating decarbonisation, particularly of **high-powered vehicles and equipment,** through new **solutions that are economically and environmentally viable,** while **working with airports to develop the** most appropriate energy supply **infrastructures.**

1-THE STATE OF PLAY

GROUND SUPPORT EQUIPMENT FLEETS

ENERGY CONSUMPTION

NEW ENERGIES

COST-SHARING MODELS, BENCHMARK

ENERGY BALANCES

NEW TECHNOLOGIES

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FLEETS OF TRACKSIDE EQUIPMENT

Fleet of non-road ground support equipment operated in France in 2022 by 20 respondent companies

(excluding the Air France and Aéroport de Paris fleets)

Machines	Number of machines per energy source		Total number of machines	Share of electric vehicles
	Electric	Thermal		
TRACTOR	**1086**	**90**	**1176**	**92%**
RUGS	**182**	**345**	**527**	**35%**
FORKLIFT TRUCK	**54**	**5**	**59**	**92%**
AIRCRAFT TRACTOR	20	244	264	8%
PASSENGER STAIRCASE	16	253	269	6%
LIFTING PLATFORM	4	209	213	2%
ACU	4	14	18	22%
WATER & WASTE TRUCK	4	29	33	12%
GPU	2	252	254	1%
PRM TRUCK	1	22	23	4%
OLEOSERVER	1	32	33	3%
REFUELLING TRUCK	1	6	7	14%
DEGIVREUSE		30	30	0%
ASU		38	38	0%
CATERING TRUCK		105	105	0%
TRANSPORTER		52	52	0%
BUS		53	53	0%
TRUCK FREIGHT		62	62	0%
TOTAL	1 375	1 841	3 220	43%

ENERGY CONSUMPTION

Consumption of non-road ground support equipment operated in France in 2022 by 20 respondent companies

(excluding the Air France and Aéroport de Paris fleets)

Machines	RNG fuel consumption (Litres)	Share of fuel consumption	Electricity consumption (kWh)
BUS	**1 259 830**	**16%**	
GPU	**1 199 888**	**15%**	930
PUSH	**1 133 295**	**15%**	503 040
TRUCK FREIGHT	**1 083 317**	**14%**	
RUGS	970 033	12%	581 341
CATERING TRUCK	541 120	7%	
LOADER	424 442	5%	75 468
PASSENGER STAIRCASE	307 621	4%	3 420
TRACTOR	230 751	3%	5 089 342
OLEOSERVER	165 830	2%	24
WATER & WASTE TRUCK	149 895	2%	4 040
TRANSPORTER	94 527	1%	
PRM TRUCK	56 179	1%	15
ASU	56 123	1%	
ACU	54 292	1%	
DEGIVREUSE	28 459	0,4%	
REFUELLING TRUCK	12 321	0,2%	
ELEVATOR	1 711	0,02%	8 640
Grand total	**7 769 632 L**		**6,266,259 KWh**

The power available for GSEs at airports will have to be **increased by at least a factor of 10 to achieve the greening objective.**

NEW ENERGIES - SOURCES

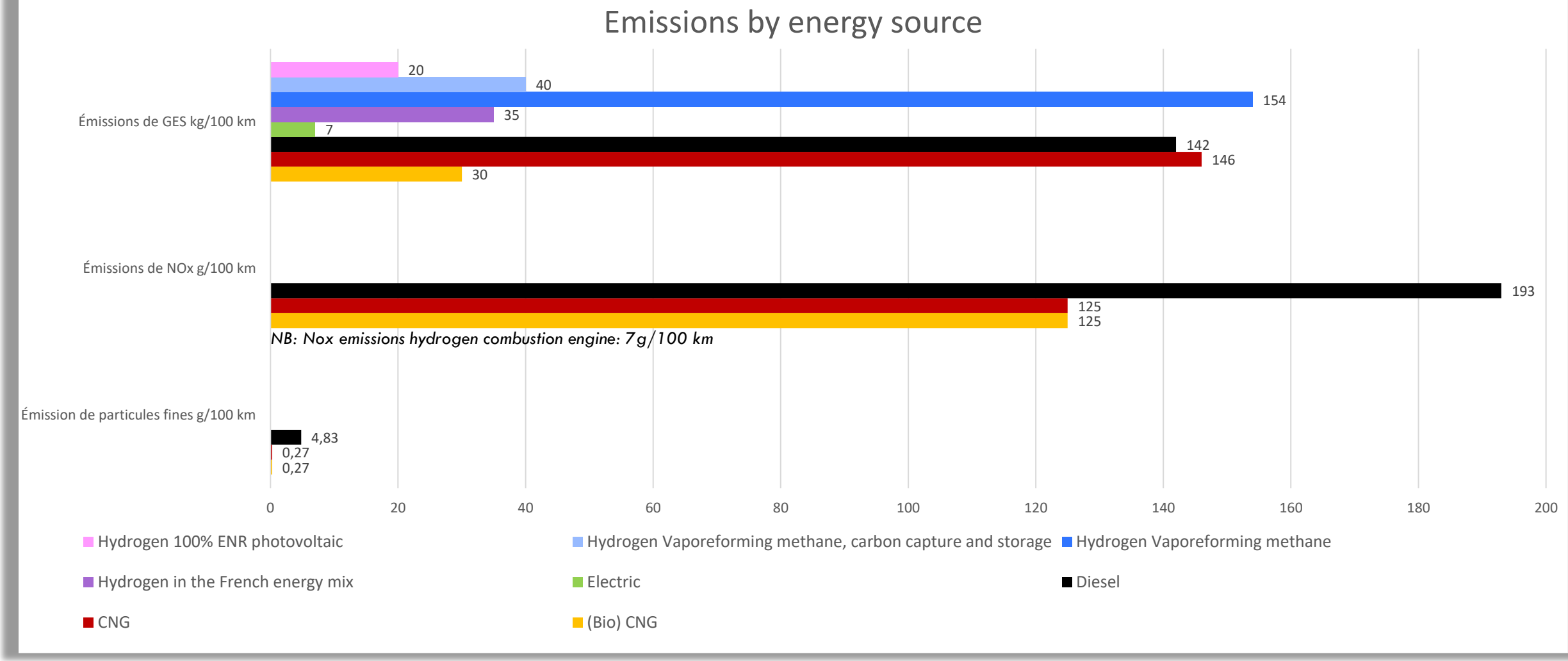
Airport vehicle and equipment fleets will gradually move towards renewable energies

Energy sources	Energy generated	Final consumption
Electricity : • Wind & Solar • Nuclear • Hydropower & Geothermal energy	**ELECTRICITY** **HYDROGEN (electrolysis)**	**Electricity** **Hydrogen**
Methane (CO capture)$_2$ **CO_2 + electricity + H_2** **Vegetable oils/Animal fats** **Biomass**	**HYDROGEN (chemistry)** **SAF/efuel** **EMAG*/HVO**** **BIOGAZ/H_2 (thermolysis)**	**HVO**** **CNG***** **efuel/SAF**

Fatty acid methyl esters / ** Hydrotreated vegetable oil / * Natural gas for vehicles*

Airports will have to secure their energy supply sources according to :
- **Local renewable energy sources and production capacity**
- **Distribution networks near or at airports**
- **Different energy prices**

NEW ENERGIES - EMISSIONS



Data source :

- *BeGreen according to the ADEME carbon base, 2021*
- *ADEME, Impact climatique de l'hydrogène bleu, 2022*
- *France Hydrogène, Mémento de l'hydrogène, sheet 5.1.1, 2021*

COST-SHARING MODELS BY TYPE OF ENERGY

		THERMAL	ELECTRIC		
		DIESEL/HVO/HYDROGEN	BATTERIES		HYDROGEN
GSE	ENGINES	ASSISTANTS / HIRERS	ASSISTANTS / HIRERS		ASSISTANTS / HIRERS
	LOADERS				
	PARKING	ASSISTANTS €/year/sq.m	ASSISTANTS €/year/sq.m		ASSISTANTS €/year/sq.m
ENERGY	INFRASTRUCTURES	DISTRIBUTION STATIONS	NETWORKS	CHARGING STATIONS	DISTRIBUTION STATIONS
	DISTRIBUTION	SERVICE PROVIDERS / AIRPORTS	AIRPORTS	SERVICE SUPPLIERS	SERVICE PROVIDERS / AIRPORTS
	CONSUMPTION	ASSISTANTS €/l & €/kg	ASSISTANTS €/kWh		ASSISTANTS €/kg

THE CHALLENGES OF ELECTRICITY PRICING

The electrification of trackside equipment involves significant additional costs compared with current combustion engines.

In France, **ground handlers alone cannot bear all the costs associated with the electrification of ramp equipment**:

- **Hire or purchase of equipment** (+30% on average compared with combustion equipment)
- The **purchase of electricity** (+45% in 2022 compared with 2020. Some airports plan to charge more per kW than the cost of RNG).
- **Purchase and installation of the distribution infrastructure** (final distribution lines, electrical cabinets, charge points, meters, etc.)
- **Rental of electrified parking spaces** and **parking areas** (with rates increasing by 50% to 85% on certain platforms)

This French pricing system is unique in Europe. Most airports charge a **flat rate for overall energy consumption, taking into** account the infrastructure, at pricing levels close to the free market.

BENCHMARK OF ELECTRICITY COSTS IN FRANCE AND EUROPE

FRANCE	CDG	TLS	LYS	NCE	MRS	NTE
Location GSE only (€/m²/year)	36.41€	6,92 €	1,29 €	18,20 €	10,45 €	43,41 €
Electricity bill (€/kWh/year)	Variable portion of €0.207/kWh/year + fixed part of 71.16€ /KVA/year	0,398 €	0,480 €	0,440 €	0,611 €	0,384 €
Provision of plugs/year	N/A	N/A	N/A	734 €	N/A	777 €

EUROPE	Dublin	Heathrow	Luton	Aena	BRU
Location GSE only (€/m²/year)	46 €	0 €	0€	Rate per kW consumed. If no individual meter, application of a fixed rate per m².	
Electricity bill (€/kWh/year)	0 €	0.446€*	0,484€		Fixed portion between €0.023/kWh and €0.048/kWh

** Tariff including an infrastructure component*

ENERGY BALANCES

Any full-cost pricing of electricity above €360/MWh will put the brakes on the electrification of runway equipment, compared with an energy cost of €2/l for neutral fuels such as HVO.

	GNR ICE$_1$	DIESEL/HVO ICE$_1$	ELECTRICITY BATTERIES	HYDROGEN ICE$_1$	HYDROGEN FC
Quantity of energy / unit	11 kWh/l	11 kWh/l	1 kWh	33 kWh/kg	33 kWh/kg
Price per unit	1,5 €/l	2 €/l	0.36 €/kWh	6€/kg	8.5€/kg
Total return	35% (ICE)	35% (ICE)	70% (Batteries)	35% (ICE)	50% (FC)
Price/useful kWh ratio	0.39/kWh	0.52/kWh	0.51/kWh	0.52/kWh	0.51/kWh
Emission factor CO_2	0.29 kg/kWh	0.29 kg/kWh 0.09 kg/kWh	0.07 kg/kWh	0.09 kg/kWh*** of electricity	0.09 kg/kWh*** of electricity
Carbon tax 100€/T	0.03 €/kWh	0.03 €/kWh 0.01 €/kWh			

[1] **ICE**: internal combustion engine

[2] **Hydrogen FC**: fuel cells

* 70% decarbonation for HVO

** 0.07 issues in France; 0.28 in the UK; 0.61 in Germany

*** Low-carbon hydrogen 3kg CO2 / kg H2

NEW TECHNOLOGIES FOR ENERGY-DRIVEN RUNWAY MACHINES (SUMMARY)

	Biodiesel			Electric			Hydrogen			
	TCO	BC	Maturity	TCO	BC	Maturity	TCO	BC	Maturity	**Recommendation**
AIR COND. UNIT	🔴	🟠	🟢	🟠	🟢	🟢	🟠	🟢	🔴	*Electric 400V / H2 ICE*
AIR START UNIT	🟢	🟠	🟢	🟢	🟢	🟠	🟠	🟢	🔴	*ICE** Hydrogen*
BUS	🔴	🟠	🟢	🟠	🟢	🟢	🟢	🟢	🔴	*800V / H2 FC* ICE** electric*
CATERING TRUCK	🔴	🟠	🟢	🟠	🟢	🔴	🟢	🟢	🔴	*800V / H2 FC* ICE** electric*
WATER-EMPTYING TRUCK	🔴	🟠	🟢	🟠	🟢	🟢	🟢	🟢	🔴	*Electric 800V*
HGV TRUCK	🔴	🟠	🟢	🟠	🟢	🔴	🟢	🟢	🔴	*800V / H2 FC* ICE** electric*
PRM TRUCK	🔴	🟠	🟢	🟠	🟢	🔴	🟢	🟢	🔴	*800V / H2 FC* ICE** electric*
FORKLIFT TRUCK	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟢	🔴	*Electric 80V*
DEGIVREUSE	🔴	🟠	🟢	🟠	🟢	🔴	🟠	🟢	🔴	*800V / H2 FC* ICE** electric*
PASSENGER STAIRCASE	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟢	🔴	*Electric/solar*
GPU	🔴	🟠	🟢	🟢	🟢	🟠	🟢	🟢	🔴	*Electric 400V / H2 ICE** / 400V network*
LOADER	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟢	🔴	*Electrical 80V & 400V*
OLEOSERVEUR	🔴	🟠	🟢	🟠	🟢	🔴	🟠	🟢	🔴	*800V / H2 FC* ICE** electric*
LUGGAGE CARPETS	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟢	🔴	*Electric 80V*
AIRCRAFT TRACTOR	🔴	🟠	🟢	🟠	🟢	🟠	🟢	🟢	🔴	*80 V& 400V / H2 ICE** electric*
LUGGAGE TRACTOR	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟢	🔴	*Electric 80V*
TRANSPORTER	🔴	🟠	🟢	🟠	🟢	🔴	🟠	🟢	🔴	*Electrical 80V & 400V*

🟢 Good / Low

🟠 Medium / Moderate

🔴 Bad / intensive

*Hydrogen **FC**: fuel cell

** **Hydrogen ICE**: internal combustion engine

TCO: Total Cost of Ownership (overall cost of use, including the purchase of the machine, the price of energy and maintenance costs).

Full summary of new technologies available in appendix

2-THE OBJECTIVES

ENERGY TRANSITION FOR FLEETS

REDUCING EMISSIONS

CONDITIONS FOR ACHIEVING THESE OBJECTIVES

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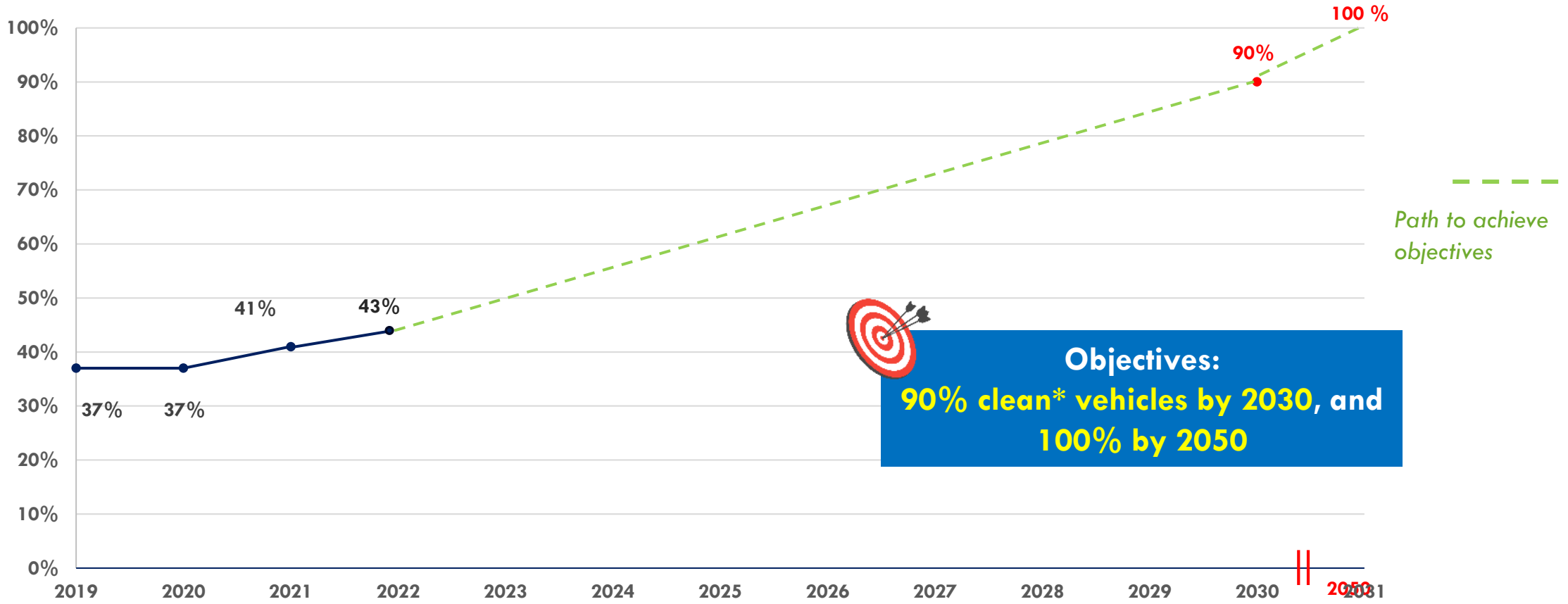
ENERGY TRANSITION FOR FLEETS

Trend in the proportion of clean vehicles* since 2019 and targets for 2030/2050



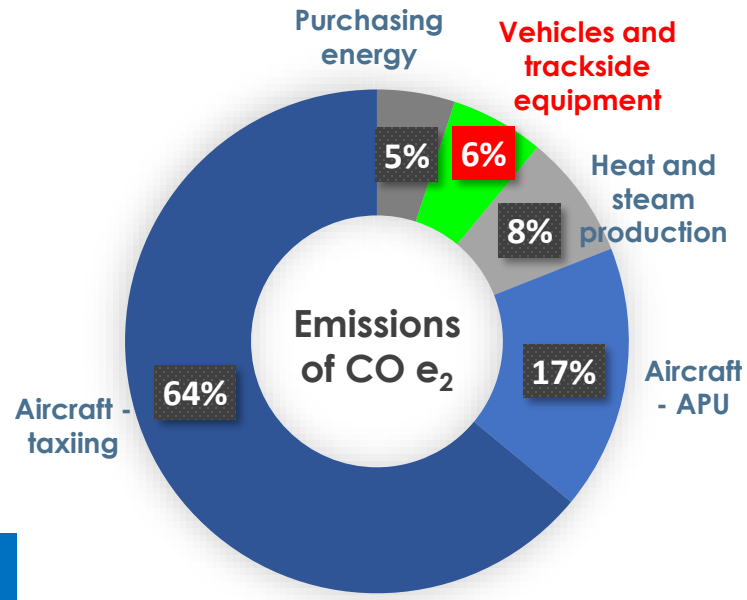
* *electric, hybrid, CNG, biogas, H_2 , HVO*

REDUCING EMISSIONS

- In the overall emissions balance for an airport hub, vehicles and ground support equipment accounted for :
  - **Greenhouse gases: 6% of carbon dioxide emissions** (CO_2), i.e. more than 21,000 tonnes of CO_2 equivalent.
  - **Air quality: 5% of nitrogen oxide** (NOx) **emissions**

- In **2022,** greenhouse gas emissions linked to the combustion of fuel for runway equipment were **19,967 tonnes of CO_2 eq.**
- **Electrification** in France with an emission factor of 0.07kg CO_2 **/kWh would save 75% of the CO_2 emitted.**

CO_2 eq. emissions from vehicles and ground support equipment account for 6% of airport emissions.



Source: ADEME, 2018, Breakdown of CO_2 equivalent emissions by emission category (11 airfields)

Objectives:

Reduce direct CO_2 emissions by 20% by 2030 (baseline 2019)

Achieve 0 net emissions (direct and indirect) by 2050

CONDITIONS FOR ACHIEVING THESE OBJECTIVES

1. **Support for investment capacity** to **renew** ground handling **fleets** and **adapt** airport **infrastructures**

2. **Visibility of the deployment of** electric (with associated power and surface area), gas or hydrogen recharging **infrastructures** at airports

3. **Sharing the costs** of deploying infrastructure (chargers, distribution networks) and energy with **airports and airlines**

3-GOOD PRACTICE

ALTERNATIVE MEANS OF TRANSPORT

ELECTRIC CHARGING INFRASTRUCTURE

ECO-DRIVING

RE-ENGINING OF VEHICLES

REGENERATION OF LEAD BATTERIES

SUBSTITUTES FOR APU* (AUTO PARTS UNIT)

Description

- Reminder of the role of an APU: provides electricity, heating and air conditioning when the aircraft's main engines are shut down (passenger boarding and disembarkation, cleaning, maintenance, flight preparation, etc.). It is also needed to start the main engines.
- Fixed APU substitutes (preferred): 400 Hz cable, PCA (Pre-Conditioned Air). These resources are made available by the airports.
- Mobile substitutes (in case of non-operation of fixed installations) : GPU (Ground Power Unit) thermal, GPU battery, converter, ACU (Air Conditioning Unit), ASU (Air Strat Unit). These resources are made available by the ground handlers.

Benefits

- Reduced fuel consumption, resulting in lower greenhouse gas emissions, local pollutants and costs for airlines and assistants.
- Reduced aircraft cockpit congestion in the case of fixed substitutes, and reduced noise.

Key success factors

- Availability of alternative fixed infrastructure for aircraft positions in contact and offshore (power, distribution network)
- Investment capacity of assistants and airports

Partners involved

- Airports, airlines, ground handlers

* *Auxiliary Power Unit* V 1.2

ELECTRIC RECHARGING INFRASTRUCTURE

Description

- **Solution A**: Installation of a small number of high-density (63A-125A) multi-voltage, multi-capacity rapid chargers: this type of charger enables different batteries to be charged on the same day and automatically adjusts its rating to the battery according to its state of charge. Charging takes between 30 minutes and 3 hours. These chargers are particularly suitable for equipment requiring high power levels, such as aircraft tractors, loaders or GPUs. For this type of charger, around 1 charger can be installed for every 4 machines. The prerequisite for this solution is the availability of high-power chargers at the airport, as well as the same plug connection standard (Euro CCS2 standard).
- **Solution B**: Installation of a large number of low-intensity, slow-charge chargers (16A-32A) dedicated to charging a single type of battery: this type of charger requires less power but more space to install the chargers. It allows the vehicles to be left on charge throughout the period of inactivity (at night, for example) for a full charge of between 8 and 15 hours. This type of charger is suitable for low-powered machines, such as baggage tractors or carpets. For this type of charger, around 1 charger can be installed for every 2 machines. This solution is currently the simplest to install and the most widespread at airports, but will have its limits when it comes to electrifying the most powerful ramp vehicles (buses, aircraft tractors, etc.).
- **Solution C**: Installation of on-board chargers directly on electric vehicles, enabling vehicles to be connected to an irregular network (voltage or power variations). The same machine can therefore be connected to different types of socket, depending on the one available nearby when its battery is low, for example. This solution involves the additional cost of adding the charger to the price of the machine.

A mix of these solutions, in consultation with the airports, should be considered to find the best match between the assistants' investment plan and the electrical capacity that the airport can offer.

Benefits

Reduced fuel consumption, greenhouse gas emissions and local pollutants for assistants

Key success factors

- Availability of surface area and electrical capacity at competitive energy costs
- Standardisation of connection standards (OCPP2.0 standard)

Partners involved

Airports, ground handlers, electricity suppliers

ECO-USE

Description

- Eco-driving module integrated into ramp attendant training, at the same time as training on driving equipment.
- Training content: modulating speed and anticipating obstacles, driving smoothly, encouraging the driver to turn off the ignition when stationary.

Benefits

- Reduced fuel consumption, greenhouse gas emissions and local pollutants for assistants.
- Improving runway safety on aprons.
- Reduced wear and tear on vehicles and machinery.

Key success factors

- Frequent involvement and awareness-raising among agents
- Monitoring consumption and use of machinery and vehicles
- Communicating savings

Partners involved

- Training organisations, ground handling agents, airports

RE-MOTORISATION OF MACHINERY

Description

- Retrofitting involves replacing the combustion engine with an electric or hydrogen engine, while retaining the rest of the vehicle's infrastructure.

Benefits

- Cost savings compared with a new electric or hydrogen vehicle: only part of the engine needs changing, not the whole vehicle.
- Reductions in greenhouse gas emissions, linked to the electrification or conversion to hydrogen of the engine, and to the avoidance of emissions during the production of a complete new vehicle.
- Waste reduction: extending the lifespan of old thermal equipment by reusing it rather than scrapping or dismantling it.

Key success factors

- Technical feasibility of the retrofit
- Cost of retrofit (conversion + new engine), which must not be higher than a new solution

Partners involved

- Ground support equipment manufacturers, battery and fuel cell suppliers, maintenance workshops

REGENERATION OF LEAD BATTERIES

Description

- Over time and with repeated recharging cycles, the lead sulphate in batteries can crystallise and the plates can oxidise.
- The principle of battery regeneration involves sending controlled high-power electrical pulses, which gradually break down the crystalline network of lead sulphate and extend the life of the batteries by between 100% and 250%.

Benefits

- Doubling battery life
- Restoring original capacity
- Reducing electricity consumption
- Reduce breakdowns
- Reduce operating costs
- Reducing lead battery recycling waste

Key success factors

- Process reliability
- Fast processing

Partners involved

Ground handling, battery suppliers, maintenance workshops

4-ANNEXES

DETAILS OF TRACKSIDE EQUIPMENT FUNCTIONS

NEW TECHNOLOGIES FOR RUNWAY EQUIPMENT

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DETAILS OF THE FUNCTIONS OF NON-REGISTERED GROUND SUPPORT EQUIPMENT

Auxiliary power unit (GPU)

- Generates electricity for the aircraft, replacing the auxiliary power unit (APU)

Baggage tractor

- Transports baggage from the terminal to the aircraft on one or more trolleys

Crew/passenger bus

- Provides a shuttle service between the aircraft and the terminal for passengers and crew

Air starter unit (ASU)

- Produces a stream of high-pressure air to help start engines by replacing the auxiliary power unit (APU)

Loader platform

- Lifts cargo and containers into the hold of aircraft

Heavy goods vehicles

- Transport a trailer with several containers from the freight area to the aircraft

Air conditioning unit (ACU)

- Produces air-conditioned or heated air to power the aircraft, replacing the auxiliary power unit (APU).

De-icer

- Allows glycol to be applied to the wings to de-ice aircraft before take-off in winter.

Water and waste truck

- Empty the aircraft's waste water tanks or fill the aircraft's drinking water tanks

Tractor plane (pushback)

- Pushes the aircraft out of the car park or tows the aircraft (with its engines off) onto the runways between two parking points.

Forklift trucks

- For transporting and lifting small containers or pallets

Truck for People with Reduced Mobility (PRM)

- Provides access for people with reduced mobility from the tarmac to the aircraft door

Passenger staircases

- Allows passengers and crew to board or alight the aircraft if there are no gangways.

Catering truck

- Loads and unloads trolleys for in-flight catering (meal trays)

Oléoserveur

- Truck distributing fuel to aircraft by connecting them to the airport's underground fuel distribution network (hydrants)

Luggage mat

- Loads baggage directly into the hold from the baggage tractor trolleys.

Carrier

- Pulls one or more containers on trolleys from the terminal to the aircraft

Tanker

- Truck distributing fuel to aircraft directly from an on-board tanker

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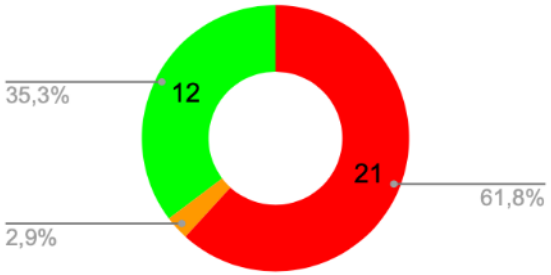
NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (1)

The figures quoted come from a study carried out in 2022 by 4 IENAC students from ENAC as part of a project proposed by CSAE.
For each family, they studied the range from 16 international manufacturers and looked at the propulsion systems.
Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

GPU (Ground Power Unit): 90KVA, 140KVA and 180KVA



34 different models on the market, including :

- 61.8% (21 models) of thermals
- 12% (12 models) electric (400V 50Hz -> 110V 400Hz converters or GPU with 90kWh to 180kWh lithium battery)
- 2.9% (1 model) hybrid
- None powered by hydrogen or solar energy

Power/Usage

Idling and rated power operation 125A -> 75kW 250A -> 150kW	1000h/year Long, regular use several times a day

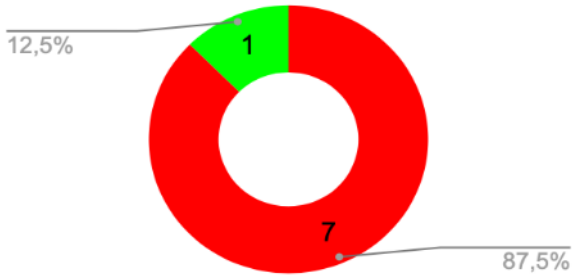
Future developments

- Thermal HVO (transition)
- Mains electric
- Battery electric
- Thermal H_2

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (2)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

ASU (Air Start Unit): 180ppm, 250ppm, 400ppm



8 different models on the market, including :

- 87.5% (7 models) thermal
- 12.5% (1 model) electric (compressed air system and electric compressor)
- None hybrid, hydrogen (fuel cell) or battery electric

- Future developments: H combustion engine$_2$ and H fuel tank$_2$ Gas

Power/Usage

Idling and rated power > 300kW No electric model	50h/year Short, irregular uses

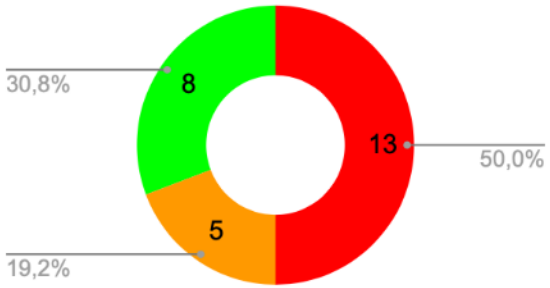
Future developments

- Thermal HVO (transition)
- Thermal H_2

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (3)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

ACU (Air Conditioning Unit): 1.5kg/s, 3kg/s, 5kg/s



26 different models on the market, including :

- 50% (13 models) thermal
- 30.8% (8 models) electric (125A and 250A sockets)
- 19.2% (5 models) hybrids (combustion engine with generator to power an electric air conditioner with mains power)
- No hydrogen or battery electric

Power/Usage

Idling and rated power operation 75 to 150kW	1000h/year Long, regular use

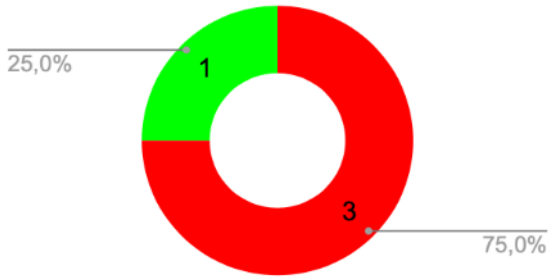
Future developments

- Thermal HVO (transition)
- Mains electric
  - 125A -> 75kW
  - 250A -> 150kW

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (4)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

20t and 30t Cargo Tractors



4 different models on the market, including :

- 75% (3 models) thermal
- 25% (1 model) of battery electrics
- No hybrids
- hydrogen (fuel cell test carried out)

Power/Usage

Idling and rated power operation 10 to 20kW	1500h/year Long, regular use several times a day

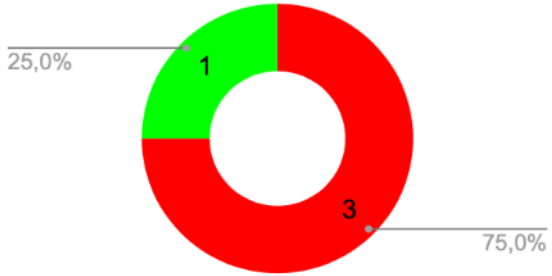
Future developments:

- Thermal HVO (transition)
- Battery electric
- Electric Fuel cell

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (5)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

20t runway tractors



4 different models on the market, including :

- 75% (3 models) thermal
- 25% (1 model) electric
- No hybrids, hydrogen or solar power

Power/Usage

Idling and rated power operation 10 kW	1000h/year Long, regular use several times a day

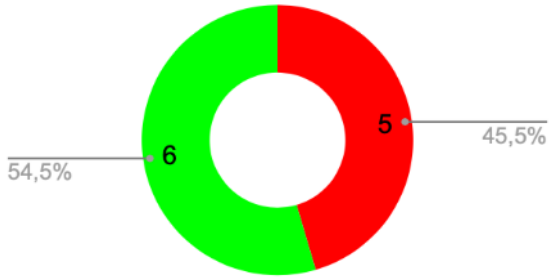
Future developments:

- Thermal HVO (transition)
- Battery electric
- lithium

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (6)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

20t luggage tractors



11 different models on the market, including :

- 54.5% (6 models) electric (lead or lithium batteries)
- 45.5% (5 models) of thermals
- No hybrids, hydrogen or solar energy

Power/Usage

Idling and rated power operation 10 kW	800h/year Long, regular use several times a day

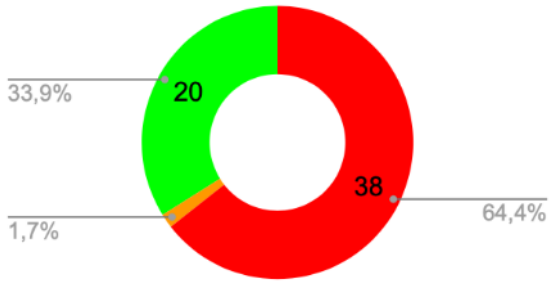
Future developments:

- Battery electric
- Lead or lithium

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (7)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Aircraft tractors with tiller: small, medium and large aircraft



59 different models on the market, including :

- 64.4% (38 models) of thermals
- 33.9% (20 models) electric
- 1.7% (1 model) hybrids (battery electric with combustion engine and electric generator)
- No hydrogen or solar energy

Power/Usage

Idling and rated power operation	800h/year to 1200h/year
75 to 150 kW	Short, regular uses several times a day

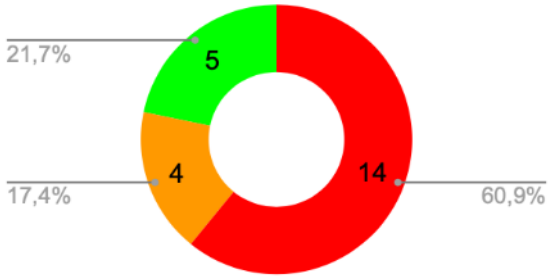
Future developments:

- Thermal HVO (transition)
- Small push electric lithium battery
- Thermal H_2 big push

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (8)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Helmless aircraft tractors



23 different models on the market, including :

- 60.9% (14 models) of thermals
- 21.7% (5 models) electric
- 17.4% (4 models) hybrids (battery electric with combustion engine and electric generator)
- No hydrogen or solar energy

Power/Usage

Idling and rated power operation	800h/year to 1200h/year
75 to 150 kW	Short, regular uses several times a day

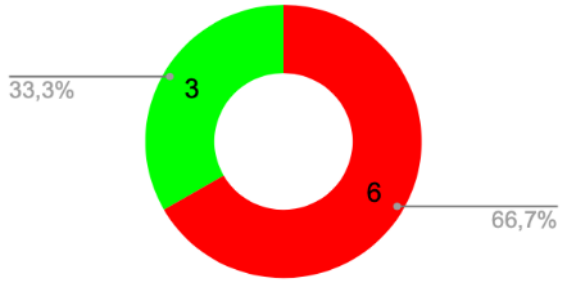
Future developments:

- Thermal HVO (transition)
- Small push electric lithium battery
- Thermal H_2 big push

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (9)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Luggage carpets



9 different models on the market, including :

- 66.7% (6 models) thermal
- 33.3% (3 models) electric
- No hybrids, hydrogen or solar power

Power/Usage

Idling and rated power operation	800h/year to 1200h/year
35 kW	Short, regular uses several times a day

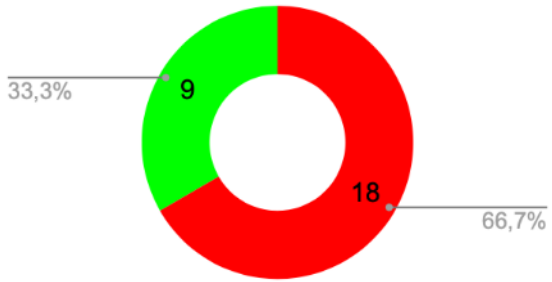
Future developments

- Thermal HVO (transition)
- Battery electric

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (10)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Loaders: 3.5T, 7T, 14T, 35T



27 different models on the market, including :

- 66.7% (18 models) of thermals
- 33.3% (9 models) electric
- No hybrids, hydrogen or solar power

Power/Usage

Idling and rated power operation	800h/year to 1200h/year
50 kW to 150kW	Short, regular uses several times a day

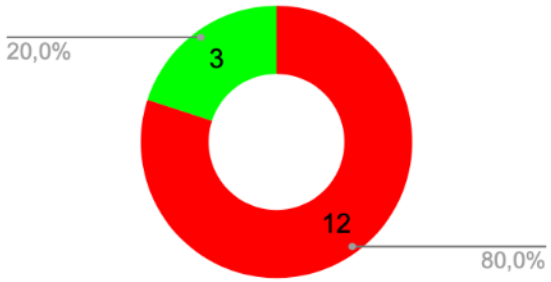
Future developments

- Thermal HVO (transition)
- Electric battery (3.5T, 7T)
- Thermal H_2 (14T, 35T

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (11)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Freight carriers



15 different models on the market, including :

- 80% (12 models) thermal
- 20% (3 models) electric

Power/Usage

Idling and rated power operation	800h/year to 1200h/year
50 kW to 100kW	Short, regular uses several times a day

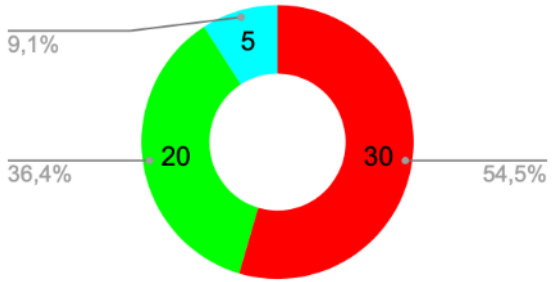
Future developments

- Thermal HVO (transition)
- Electric lithium battery
- Thermal H_2

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (12)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Passenger stairs



55 different models on the market, including :

- 54.5% (30 models) of thermals
- 36.4% (20 models) battery electrics
- 9.1% (5 models) solar power
- No hybrids or hydrogen

Power/Usage	
Idling and rated power operation	200h/year to 600h/year
20 kW to 35kW	Short, regular uses several times a day

Future developments

- Thermal HVO (transition)
- Battery electric for self-propelled staircases
- Electric with battery and solar panels for towable staircases

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (13)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

De-icers

Various models are available on the market, including :

- Thermal: Industrial and commercial chassis
- Hybrids: Thermal chassis and electric battery functions
- Electric batteries

Power/Usage	
Idling and rated power operation	100h/year to 300h/year
75 kW to 150kW	Short, irregular uses several times a day 6 months/year

Future developments

- Thermal HVO (transition)
- Battery electric
- Thermal H_2

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (14)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Trucks for transporting people with reduced mobility (PRM)

Various models are available on the market, including :

- Thermal (industrial and commercial chassis)
- Battery-powered (industrial chassis)

Power/Usage	
Idling and rated power operation 50 kW to 100kW	1000h/year to 1500h/year Short, regular uses several times a day

Future developments

- Thermal HVO (transition)
- Battery electric (industrial chassis)
- Thermal H_2

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (15)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Catering and cabin trucks

Various models are available on the market, including :

- Thermal (commercial chassis)
- Studies underway on commercial electric chassis

Power/Usage	
Idling and rated power operation	1000h/year to 1500h/year
100 kW to 150kW	Short, regular uses several times a day

Future developments

- Thermal HVO (transition)
- Battery electric
- Thermal H_2

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (16)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Freight pallet trucks

Alternative solution:

Cargo tractor with pallet carriers

CF cargo tractor leaflet

Various models are available on the market, including :

- Thermal (commercial chassis), electric tri-pallets
- Studies underway on commercial electric chassis

Power/Usage	
Idling and rated power operation 100 kW to 150kW	1000h/year to 1500h/year Short, regular uses several times a day

Future developments

- Thermal HVO (transition)
- Battery electric
- Thermal H_2

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (17)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Aircraft service trucks (drinking water and toilets)

Various models are available on the market, including :

- Thermal (commercial and industrial chassis)
- Electrical (commercial and industrial chassis)

Power/Usage

Idling and rated power operation	1000h/year to 1500h/year
50 kW to 100kW	Short, regular uses several times a day

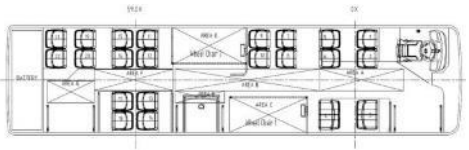
Future developments

- Thermal HVO (transition)
- Electric batteries
- Thermal H_2

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (18)

Colour code: RED thermal, GREEN electric, ORANGE hybrid, BLUE solar

Passenger buses



Various models are available on the market, including :

- Thermal (commercial and industrial chassis)
- Electric (commercial and industrial chassis) (lithium batteries from 120kWh to 400kWh)

Power/Usage

Idling and rated power operation	1000h/year to 1500h/year
50 kW to 100kW	Long, regular use several times a day

Future developments

- Thermal HVO (transition)
- Electric batteries
- Electrical H_2
- Thermal H_2

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (16)

In addition to the apparatuses described above, others not included in the study deserve attention:

- **De-icers**: the first electric versions are arriving on the market and a world first has been put into operation at Clermont Ferrand Airport.
- **Truck for transporting people with reduced mobility**: similarly, helps are now available in an electric version. Examples are in service at CDG airport.
- **Catering lorry**: To date, there are no lorries other than the classic diesel lorries.

NEW TECHNOLOGIES FOR TRACKSIDE EQUIPMENT (17)

- **Freight lorries (specific to Paris-CDG airport)**: these lorries are used in France only at Roissy CDG airport, and research carried out abroad shows that there is nothing similar elsewhere. This niche market would require the development of a specific electric truck, for which the current development costs for electric vehicles are not competitive with a diesel-powered solution.

- **Trackside buses**: electric buses already exist. Hydrogen-powered versions also exist, but their cost is currently too high.

- **Trucks and servos for loading aircraft fuel**: the first electric vehicles have been put into service

Version	Date	Nature of the review
1.0	23/03/2023	Creation
1.1	22/12/2023	Fleet and energy consumption updates
1.2	26/01/2024	Addition of the sections "The challenges of electricity pricing", "Cost-sharing models by type of energy", "Benchmark of electricity costs in France and Europe" and "Energy balances".

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