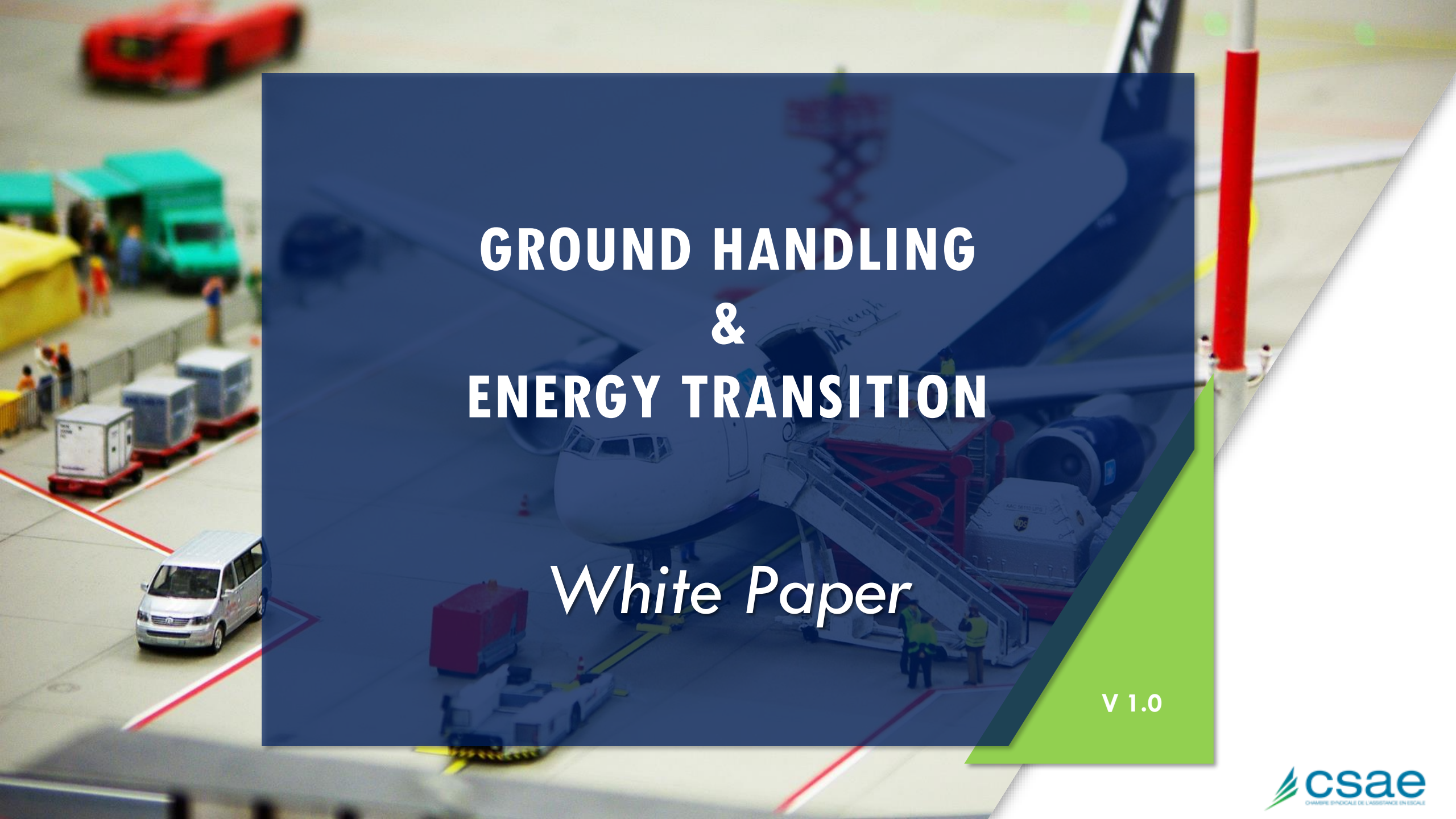

GROUND HANDLING
&
ENERGY TRANSITION

White Paper

V 1.0

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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, fuelling, passenger transport and consulting.

Its 22 members employ around 22,000 people in France.

CSAE is a member of the FNAM (*French aviation industry federation*).

EDITORIAL

Didier Montégut, President of CSAE

French ground handlers have been committed for over 10 years 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 by 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 of collective work within the CSAE's Environment Commission. Its aim is to highlight the progress of the energy transition of fleets, to set the 2030 and 2050 objectives and to promote good practices to be generalised.

The key word here is collaboration. On the one hand, collaboration with manufacturers on the development of an offer adapted to airport needs; on the other hand, collaboration with airports on the adaptation of the energy networks necessary to prepare for the arrival of these new technologies. All this 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 difference and contribute to reducing the environmental footprint of the aviation sector.

Enjoy your reading

SUMMARY

* *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 over **3,500 unregistered vehicles and ramp equipment** required to handle passengers and aircraft on the ground (approximately 50% of the total airport fleet).
- The greening of fleets has so far focused on **low-powered** vehicles and equipment and on mainly electric solutions. Approximately **40% of the fleet in operation today is clean** (electric, hybrid, gas).
- The objectives are to reduce **direct CO_2 emissions by 20% in 2030** (baseline 2019) and to reach **net zero emissions** (direct and indirect) in **2050.**

Solutions : **Heterogeneous technological maturities to be reinforced**

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

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

- Ground handlers need to 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 sustainable,** while **working with airports on the development of the** most appropriate energy supply **infrastructure.**

1-THE STATE OF PLAY

FLEET OF RAMP EQUIPMENT

ENERGY CONSUMPTION

NEW ENERGIES

NEW TECHNOLOGIES

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FLEETS OF RAMP EQUIPMENT

Fleet of non-road unregistered ground support equipment (GSE) operated in France in 2021 by 11 respondent companies

(i.e. over 90% of the CSAE fleet, excluding the Air France fleet and airports)

GSE	Number of GSE per energy			Total number of GSE	Number of "clean*3 GSE	Share of "clean" equipment*.
	Electric	CNG / Hybrid	Thermal			
LUGGAGE TRACTOR	**1094**	**10**	**98**	**1202**	**1 104**	**92 %**
LUGGAGE BELT	**171**	**-**	**336**	**507**	**171**	**34 %**
AIR COND. UNIT	**-**	**4**	**19**	**23**	**4**	**17 %**
FORKLIFT TRUCK	4	2	55	61	6	10 %
BUS	-	3	69	72	3	4 %
AIRCRAFT TRACTOR	8	-	229	237	8	3 %
PRM TRUCK	1	-	34	35	1	3 %
GPU	5	-	261	266	5	2 %
LOADER	3	1	220	224	4	2 %
PASSENGER STAIRS	1	-	211	212	1	0,5 %
CATERING TRUCK	-	-	89	89	-	-
WATER PUMPING TRUCK	-	-	25	25	-	-
HGV TRUCK	-	-	137	137	-	-
TRANSPORTER	-	-	50	50	-	-
TANK	-	-	4	4	-	-
REFUELING TRUCK	-	-	31	31	-	-
AIR START UNIT	-	-	33	33	-	-
DEICEING TRUCK	-	-	19	19	-	-
TOTAL	1 287	20	1 920	3 227	**1 307**	41%

* *electric, hybrid, gas*

ENERGY CONSUMPTION

Consumption of non-road unregistered ground support equipment operated in France in 2021 by 11 respondent companies

(i.e. over 90% of the CSAE fleet, excluding the Air France fleet and airports)

Machines	RNG fuel consumption (Litres)	Share of fuel consumption	Average electricity consumption per machine per hour of operation in kWh/h
GPU	**1 438 679**	**23 %**	30
AIRCRAFT TRACTOR	**1 127 352**	**18 %**	40
TRUCK FREIGHT	**969 135**	**15 %**	23
LUGGAGE BELT	**849 077**	**13 %**	4
CATERING TRUCK	388 676	6 %	18
LOADER	339 220	5 %	12
BUS	303 863	5 %	13
LUGGAGE TRACTOR	184 086	3 %	6
MINIBUS / SHUTTLE	183 878	3 %	10
REFUELING TRUCK	127 434	2 %	12
PRM TRUCK	119 986	2 %	15
STAIRS	89 563	1 %	3
TRANSPORTER	82 127	1 %	8
ACU	64 927	1 %	60
ASU	43 910	1 %	NA
FORKLIFT TRUCK	37 345	1 %	5
DEICEING TRUCK	18 240	0,3 %	NA
TANK	6 038	0,1 %	NA
WATER/DRAINAGE TRUCK	2 500	0,04 %	10
Grand total	**6 376 036 L**		

NEW ENERGIES - SOURCES

Airport vehicle and equipment (AVE) fleets will gradually move towards renewable energy

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

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

Airports will need to secure energy supplies according to :
- **Local renewable energy sources and production capacities**
- **Distribution networks near or at airports**
- **Prices of different energies**

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NEW ENERGIES - COSTS

Diesel

- Type of fuels considered :
  - Fossil: Diesel B7 or off-road diesel
  - bio-fuel: HVO
- Off-road diesel: 1.30€/l (tax free) until 31/12/2023
- Diesel B7: 2€/l (taxed)
- HVO: 2.1€/l (tax free)
- **Carbon neutrality will be achieved through the use of HVO from January 2024 (probable cessation of off-road diesel)**

Electricity

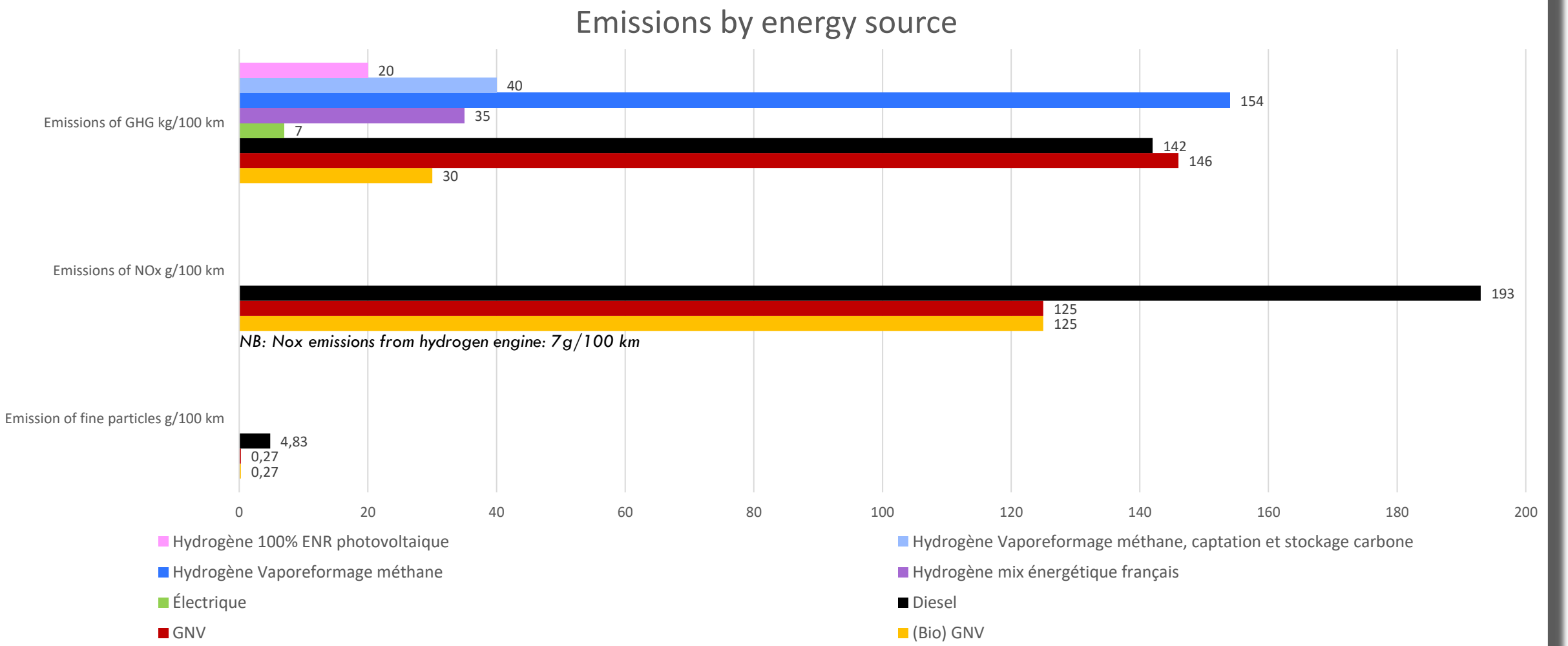
- Cost of low-carbon electricity as a function of production costs :
  - Geothermal energy: 45€ /MWh
  - Hydroelectricity: 20€/MWh
  - Onshore wind: 60€ /MWh
  - Offshore Wind: 150€/MWh
  - Photovoltaic: 75€ /MWh
  - Historic nuclear: 50€ /MWh
  - Nuclear EPR2 or SMR: 100€ /MWh
- Cost of low-carbon electricity based on a mix produced in France: less than 100€ /MWh
- **A selling price of electricity on airport platforms at €350/MWh would make it possible to accelerate the electrification of airports** and to finance the electrical infrastructure by the price differential between the purchase price and the selling price alone

Hydrogen

- Cost of hydrogen gas :
  - Electrolysis using electricity from renewable sources: between €6 and €12 per kilogram
  - Steam reforming of methane with carbon capture: between €3 and €4 per kilogram
  - Thermolysis of biomass: €9 per kilogram

Source:
AFHYPAC, Hydrogen Handbook, sheet 3.1.1

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, fiche 5.1.1, 2021*

NEW TECHNOLOGIES OF RAMP EQUIPMENT AND ENERGY AVAILABLE (SUMMARY)

	Biodiesel			Electric			Hydrogen			
	TCO	BC	Maturity	TCO	BC	Maturity	TCO	BC	Maturity	**Recommendation**
AIR COND. UNIT	🔴	🟠	🟢	🟠	🟢	🟢	🟠	🟢	🔴	*Electric 400V / H2 ICE***
AIR START UNIT	🟢	🟠	🟢	🟢	🟢	🟠	🟠	🟢	🔴	*Hydrogen ICE*
BUS	🔴	🟠	🟢	🟠	🟢	🟢	🟢	🟢	🔴	*Electric 800V / H2 FC* ICE***
CATERING TRUCK	🔴	🟠	🟢	🟠	🟢	🔴	🟢	🟢	🔴	*Electric 800V / H2 FC* ICE***
WATER PUMPING TRUCK	🔴	🟠	🟢	🟠	🟢	🟢	🟢	🟢	🔴	*Electric 800V*
HGV TRUCK	🔴	🟠	🟢	🟠	🟢	🔴	🟢	🟢	🔴	*Electric 800V / H2 FC* ICE***
PRM TRUCK	🔴	🟠	🟢	🟠	🟢	🔴	🟢	🟢	🔴	*Electric 800V / H2 FC* ICE***
FORKLIFT TRUCK	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟢	🔴	*Electric 80V*
DE-ICING TRUCK	🔴	🟠	🟢	🟠	🟢	🔴	🟠	🟢	🔴	*Electric 800V / H2 FC* ICE***
PASSENGER STAIRS	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟢	🔴	*Electric /solar*
GPU	🔴	🟠	🟢	🟢	🟢	🟠	🟢	🟢	🔴	*Electric 400V / H2 ICE** / 400V mains*
LOADER	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟢	🔴	*Electric 80V & 400V*
REFUELING TRUCK	🔴	🟠	🟢	🟠	🟢	🔴	🟠	🟢	🔴	*Electric 800V / H2 FC* ICE***
LUGGAGE BELT	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟢	🔴	*Electric 80V*
AIRCRAFT TRACTOR	🔴	🟠	🟢	🟠	🟢	🟠	🟢	🟢	🔴	*Electric 80 V& 400V / H2 ICE***
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 annex

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2-THE OBJECTIVES

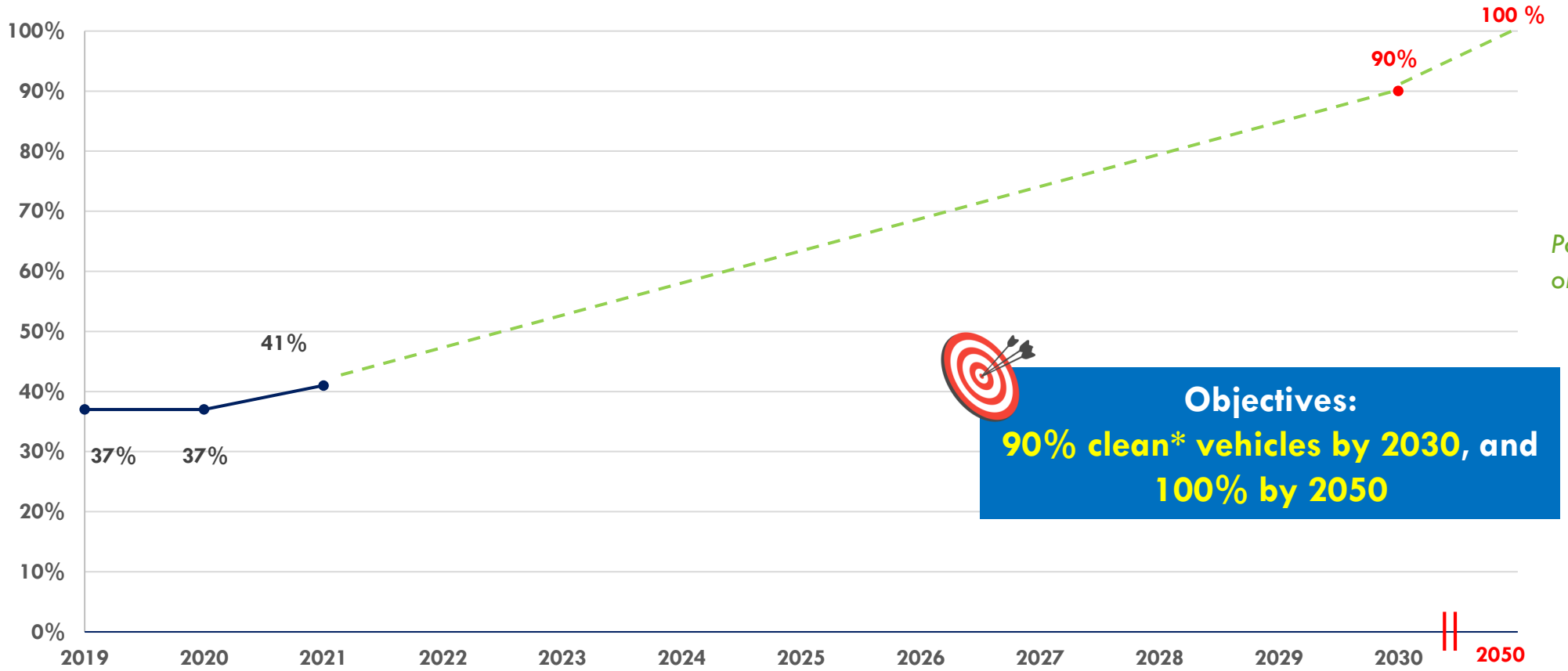
ENERGY TRANSITION OF FLEETS

REDUCTION OF EMISSIONS

CONDITIONS FOR ACHIEVING THESE OBJECTIVES

ENERGY TRANSITION OF FLEETS

Evolution of the share of clean* ramp equipment since 2019 and 2030/2050 targets



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

REDUCTION OF EMISSIONS

- In the overall emissions balance of an airport hub, ramp vehicles and 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**

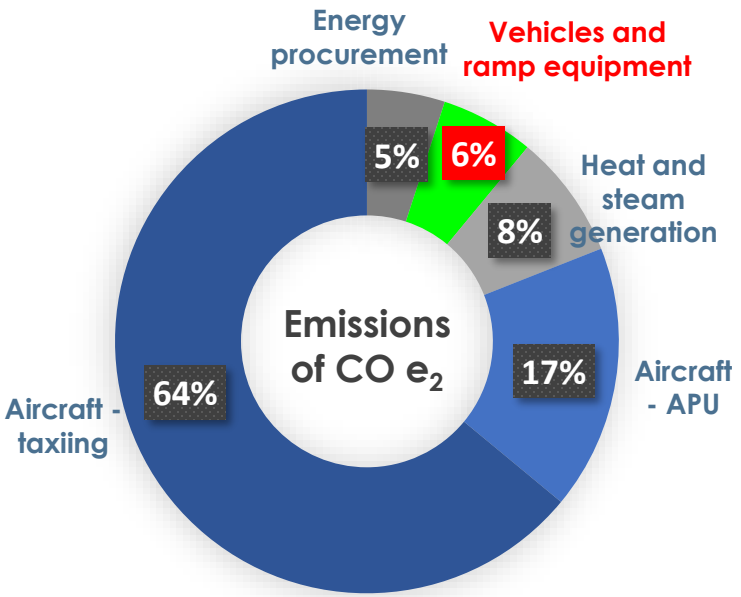
- In **2021,** greenhouse gas emissions from fuel combustion for runway equipment were **16,663 tonnes of CO_2 eq.**

Objectives:

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

Achieving net zero emissions (direct and indirect) by 2050

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



Source: ADEME, 2018, Breakdown of CO_2 equivalent emissions by emission item (11 aerodromes)

CONDITIONS FOR ACHIEVING THESE OBJECTIVES

1. **Support for investment capacity** for the **renewal of** ground handling **fleets** for the **adaptation of** airport **infrastructures**

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

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

3-GOOD PRACTICE

ALTERNATIVE MEANS OF TRANSPORT TO THE APU

ELECTRIC CHARGING INFRASTRUCTURE

ECO-DRIVING

RE-ENGINEERING OF VEHICLES

REGENERATION OF LEAD BATTERIES

ALTERNATIVE MEANS TO APU*

Description

- Reminder of the role of an APU: provides electricity, heating and air conditioning when the aircraft's main engines are shut down (passenger embarkation and disembarkation, cleaning, maintenance, flight preparation, etc). Also required for starting the main engines.
- Fixed alternatives to the APU (to be preferred): 400 Hz cable, PCA (Pre-Conditioned Air). These means 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

- Reduction of fuel consumption, resulting in lower greenhouse gas emissions, local pollutants and costs for airlines and assistants.
- Reduction of aeroplane space in the case of fixed substitutes and noise.

Key success factors

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

Partners involved

- Airports, airlines, ground handlers

* *Auxiliary Power Unit*

ELECTRIC CHARGING INFRASTRUCTURE

Description

- **Solution A**: Installation of a small number of high-density (63A-125A) multi-voltage multi-capacity fast chargers: this type of charger allows different batteries to be charged on the same day and automatically adjusts its rating to the battery according to its state of charge. The charge lasts between 30 minutes and 3 hours. These chargers are particularly suitable for machines requiring high power such as aircraft tractors, loaders or GPUs. For this type of charger, approximately 1 charger for 4 machines can be installed. The prerequisite for this solution is to have the same power available at the airport, as well as the same plug connection standard (Euro CCS2 standard).
- **Solution B**: Installation of a large number of low-current, 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 leaves the possibility to leave the vehicles in charge during the whole period of inactivity (at night for example) for a complete charge 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, approximately 1 charger for 2 machines can be installed. This solution is currently the easiest to implement and the most widespread at airports, but will have limitations for the electrification of the most powerful ramp vehicles (buses, aircraft tractors, etc.).
- **Solution C**: installation of on-board chargers directly on the electric vehicles, which allow the vehicles to be connected to an irregular network (voltage or power variation). The same vehicle 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 an additional cost to add the charger to the price of the machine.

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

Benefits

Reduction of fuel consumption, greenhouse gas emissions and local pollutants for assistants

Key success factors

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

Partners involved

Airports, ground handlers, electricity suppliers

ECO-DRIVING

Description

- Eco-driving module integrated into the training of ramp agents, at the same time as the training on driving machines.
- Training content: speed modulation and obstacle anticipation, smooth driving, encouraging the driver to turn off the ignition when stationary.

Benefits

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

Key success factors

- Frequent involvement and awareness-raising of staff
- Monitoring of consumption and use of machinery and vehicles
- Communication of savings

Partners involved

- Training organisations, ground handlers, airports

RE-MOTORISATION OF GROUND SUPPORT EQUIPMENT

Description

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

Benefits

- Cost reduction compared to a new electric or hydrogen vehicle: only the engine part has to be changed, not the whole vehicle.
- Reductions in greenhouse gas emissions, related to the electrification or conversion to hydrogen of the engine, and emission avoidance in the production of a complete new vehicle.
- Waste reduction: extending the life of an old thermal engine that will be reused rather than scrapped or dismantled.

Key success factors

- Technical feasibility of the retrofit
- Cost of retrofit (conversion + new engine), which should 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 its plates can oxidise.
- The principle of battery regeneration is to send controlled high-power electrical pulses that gradually break down the lead sulphate crystal lattice and increase the life of the batteries by 100% to 250%.

Benefits

- Doubling the life of batteries
- Recovering the original capacity
- Reduce power consumption
- Reducing breakdowns
- Reduce operating costs
- Reducing lead battery recycling waste

Key success factors

- Process reliability
- Speed of processing

Partners involved

Ground handling, battery suppliers, maintenance workshops

4-ANNEXES

DETAILS OF THE FUNCTIONS OF THE RAMP EQUIPMENT

NEW TECHNOLOGIES

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DETAILS OF THE FUNCTIONS OF NON-REGISTERED RAMP EQUIPMENT

Ground Power Unit (GPU)

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

Luggage tractor

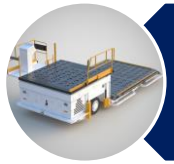
- Carries luggage from the terminal to the aircraft on one or more trolleys

Crew/passenger bus

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

Air Start Unit (ASU)

- Produces a high pressure airflow to assist engine starting in place of the auxiliary power unit (APU)



Lift platform (loader)

- Lifts cargo and containers into the cargo hold of aircraft

Heavy duty freight truck

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

Air conditioning unit (ACU)

- Produces air-conditioned or heated air to power the aircraft in place of 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

Aircraft pushback

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

Forklift truck

- Allows the transport and lifting of small containers or pallets

Truck for People with Reduced Mobility

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

Passenger stairs

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

Catering truck

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

Oleoserver

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

Luggage mat

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

Carrier

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

Tanker

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

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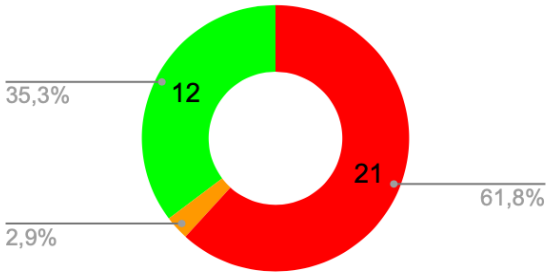
NEW TECHNOLOGIES FOR GSE (1)

The figures quoted are from a study carried out in 2022 by 4 IENAC students from ENAC in the framework of a project proposed by CSAE.

For each family they studied the offer from 16 international manufacturers and looked at the propulsion modes.

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

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



34 different models available on the market, including :

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

Power/Use

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

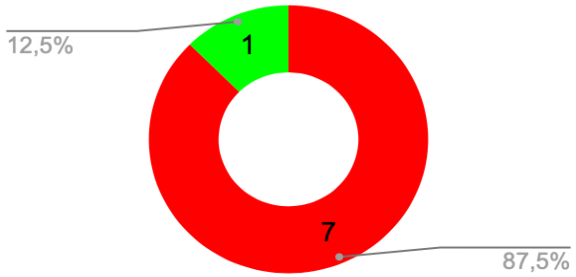
Future developments

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

NEW TECHNOLOGIES FOR GSE (2)

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

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



8 different models available on the market including :

- 87.5% (7 models) of thermals
- 12.5% (1 model) electric (compressed air system and electric compressor)
- No hybrid, hydrogen (fuel cell) or battery electric

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

Power/Use

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

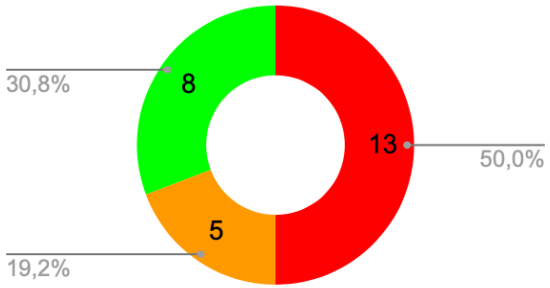
Future developments

- Thermal HVO (transition)
- Thermal H_2

NEW TECHNOLOGIES FOR GSE (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 available on the market including :

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

Power/Use

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

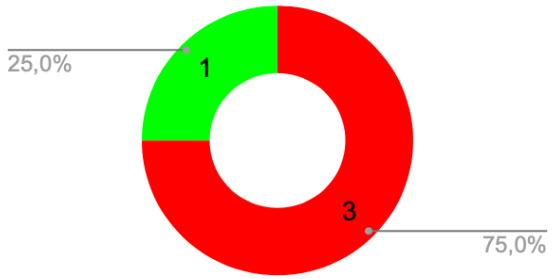
Future developments

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

NEW TECHNOLOGIES FOR GSE (4)

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

Cargo tractors 20t and 30t



4 different models available on the market including :

- 75% (3 models) of thermals
- 25% (1 model) of electric battery
- No hybrids
- hydrogen (fuel cell test conducted)

Power/Use

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

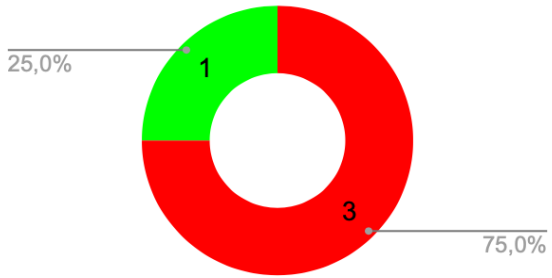
Future developments:

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

NEW TECHNOLOGIES FOR GSE (5)

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

20t runway tractors



4 different models available on the market including :

- 75% (3 models) of thermals
- 25% (1 model) of electric
- No hybrids, hydrogen or solar energy

Power/Use

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

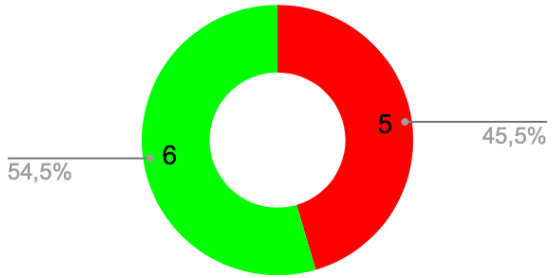
Future developments:

- Thermal HVO (transition)
- Battery electric
- lithium

NEW TECHNOLOGIES FOR GSE (6)

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

20t luggage tractors



11 different models are available 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/Use

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

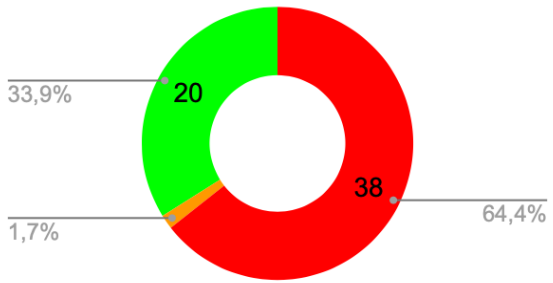
Future developments:

- Battery electric
- Lead or lithium

NEW TECHNOLOGIES FOR GSE (7)

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

Aircraft tractors with bar: small, medium and large



59 different models available 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/Use

Idle and rated power operation	800h/year to 1200h/year
75 to 150 kW	Short and regular use several times a day

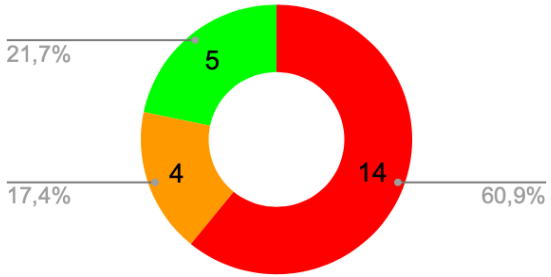
Future developments:

- Thermal HVO (transition)
- Electric lithium battery small push
- Thermal H_2 big push

NEW TECHNOLOGIES FOR GSE (8)

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

Aircraft tractors without bar



23 different models available on the market including :

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

Power/Use

Idle and rated power operation	800h/year to 1200h/year
75 to 150 kW	Short and regular use several times a day

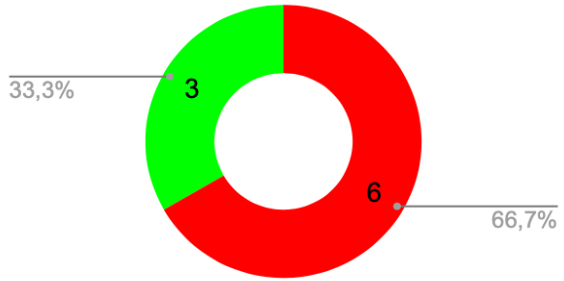
Future developments:

- Thermal HVO (transition)
- Electric lithium battery small push
- Thermal H_2 big push

NEW TECHNOLOGIES FOR GSE (9)

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

Baggage carpets



9 different models available on the market including :

- 66.7% (6 models) of thermals
- 33.3% (3 models) electric
- No hybrids, hydrogen or solar energy

Power/Use

Idle and rated power operation	800h/year to 1200h/year
35 kW	Short and regular use several times a day

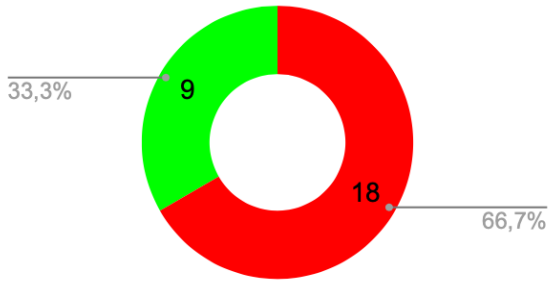
Future developments

- Thermal HVO (transition)
- Battery electric

NEW TECHNOLOGIES FOR GSE (10)

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

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



27 different models available on the market, including :

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

Power/Use

Idle and rated power operation	800h/year to 1200h/year
50 kW to 150kW	Short and regular use several times a day

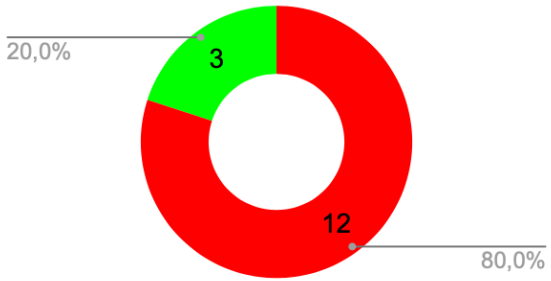
Future developments

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

NEW TECHNOLOGIES FOR GSE (11)

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

Freight forwarders



15 different models available on the market, including :

- 80% (12 models) of thermals
- 20% (3 models) electric

Power/Use

Idle and rated power operation	800h/year to 1200h/year
50 kW to 100kW	Short and regular use several times a day

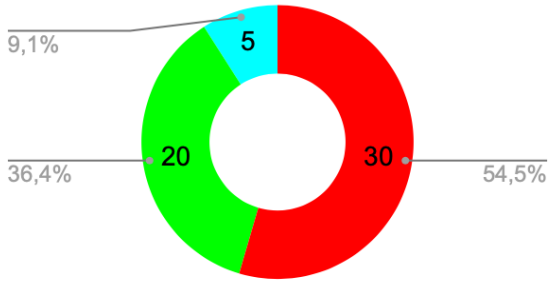
Future developments

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

NEW TECHNOLOGIES FOR GSE (12)

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

Passenger stairs



55 different models available on the market, including :

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

Power/Use	
Idle and rated power operation	200h/year to 600h/year
20 kW to 35kW	Short and regular use several times a day

Future developments

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

NEW TECHNOLOGIES FOR GSE (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 functionality
- Electric batteries

Power/Use	
Idle and rated power operation	100h/year to 300h/year
75 kW to 150kW	Short, non-regular uses several times a day 6 months/year

Future developments

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

NEW TECHNOLOGIES FOR GSE (14)

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

Trucks for the transport of people with reduced mobility

Various models are available on the market, including :

- Thermal (industrial and commercial chassis)
- Battery operated electrics (industrial chassis)

Power/Use	
Idle and rated power operation	1000h/year to 1500h/year
50 kW to 100kW	Short and regular use several times a day

Future developments

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

NEW TECHNOLOGIES FOR GSE (15)

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

Catering and armoured car trucks

Various models are available on the market, including :

- Thermal (commercial chassis)
- Ongoing studies on commercial electric chassis

Power/Use	
Idle and rated power operation	1000h/year to 1500h/year
100 kW to 150kW	Short and regular use several times a day

Future developments

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

NEW TECHNOLOGIES FOR GSE (16)

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

Pallet cargo trucks

Alternative solution:

Cargo tractor with pallet carriers

CF sheet cargo tractors

Various models are available on the market, including :

- Thermal (commercial chassis), electric tri-pallet
- Ongoing studies on commercial electric chassis

Power/Use	
Idle and rated power operation 100 kW to 150kW	1000h/year to 1500h/year Short and regular use several times a day

Future developments

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

csae

NEW TECHNOLOGIES FOR GSE (17)

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

Aircraft Service Trucks (Drinking Water and Toilet Emptying)

Various models are available on the market, including :

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

Power/Use

Idle and rated power operation	1000h/year to 1500h/year
50 kW to 100kW	Short and regular use several times a day

Future developments

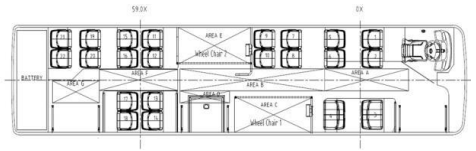
- Thermal HVO (transition)
- Electric batteries
- Thermal H_2

csae

NEW TECHNOLOGIES FOR GSE (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)
- Electrics (commercial and industrial chassis) (lithium batteries from 120kWh to 400kWh)

Power/Use

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

Future developments

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

NEW TECHNOLOGIES FOR GSE (19)

Beyond the apparatuses described above, others not included in the study deserve attention:

- **De-icers**: the first electric versions are coming 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 truck**: To date there are no other trucks than the classic diesel trucks

NEW TECHNOLOGIES FOR GSE (20)

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

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

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

Version	Date	Nature of the review
1.0	23/03/2023	Creation