



Les Challenges du Confort Thermique Automobile

Valeo Systèmes Thermiques

Pascale Herman – Marketing Produit

Daniel Neveu – R&D - Innovation

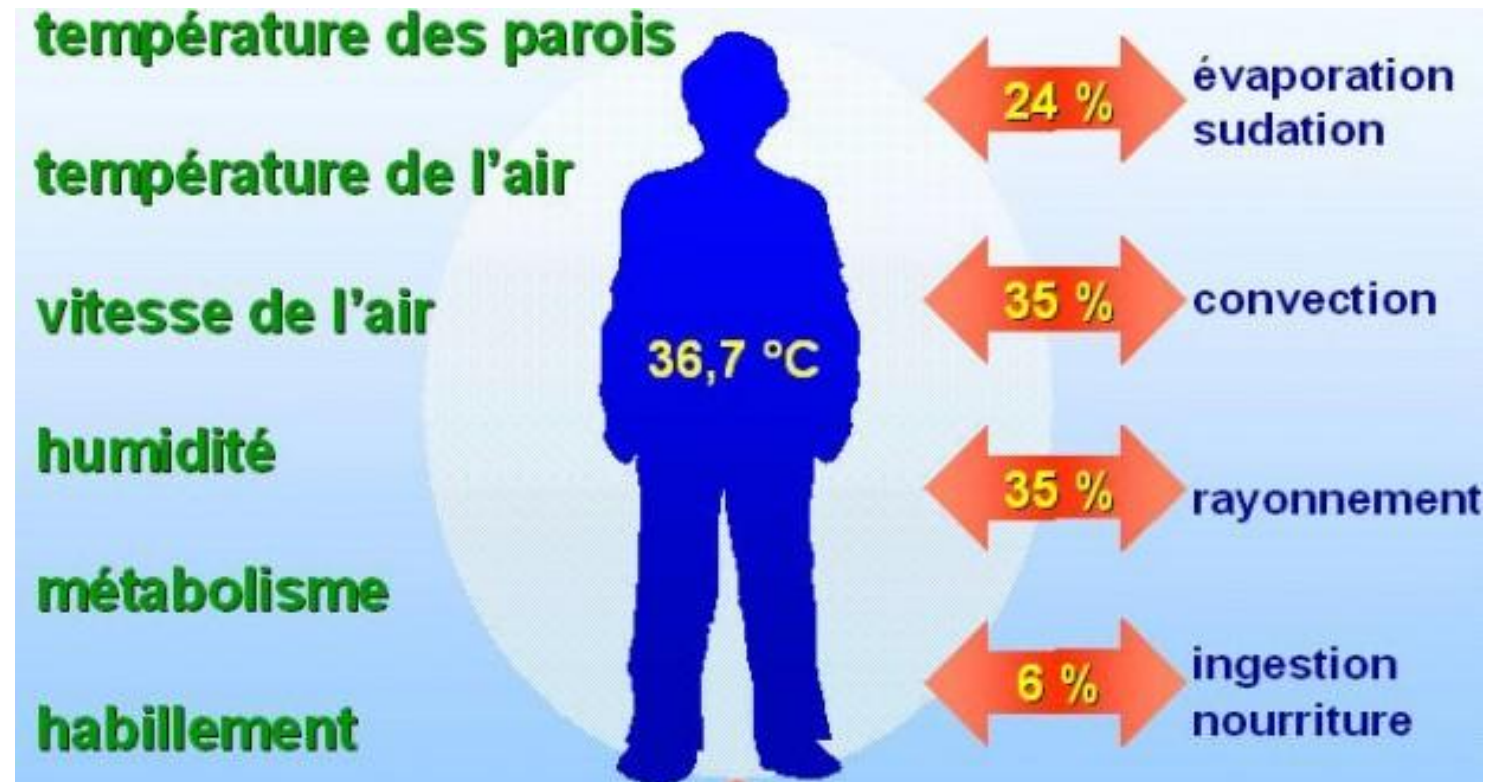
- Thermal comfort principles and physiological needs
- Evolution of the comfort solution in automotive history
- Automotive Market drivers impacting the comfort solutions
 - CO₂ emissions reduction ➡ New refrigerant
 - Pollution issue ➡ Air quality products
 - Car Electrification ➡ Heating deficit / Range ➡ EDC / Heat pumps
- Car of the future
 - Well being / Digitalization ➡ New interior experience

- **Thermal comfort principles and physiological needs**
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Thermal Comfort : *Key Parameters & Mechanisms*



Le confort thermique est défini comme "un état de satisfaction du corps vis-à-vis de l'environnement thermique".



Thermal Comfort : *Do not confuse Thermal Sensation & Thermal Comfort*

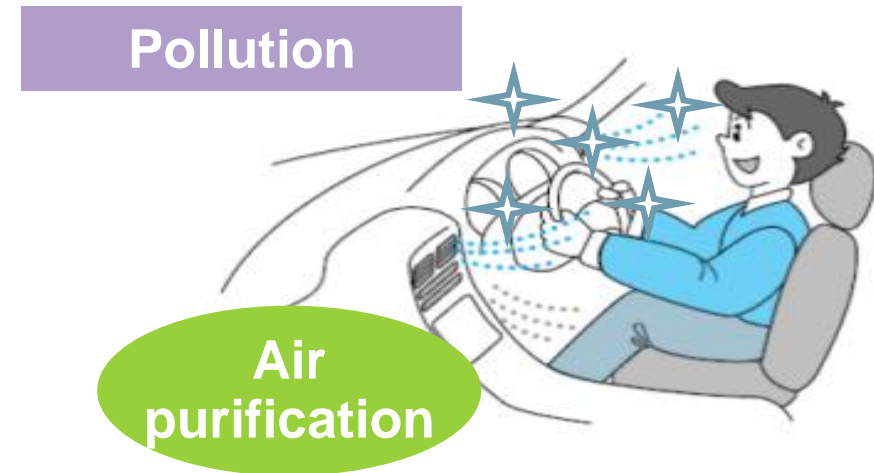
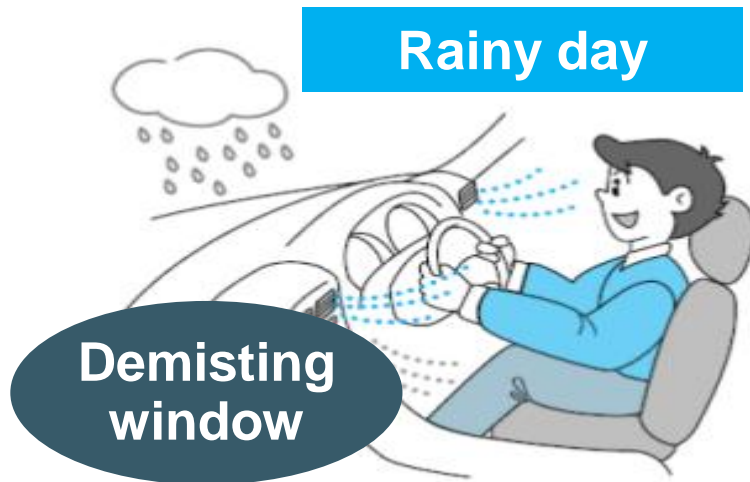
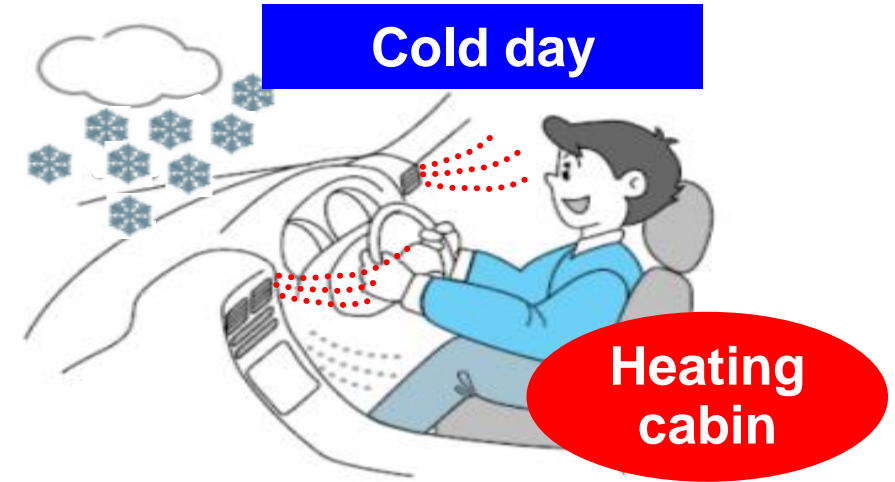
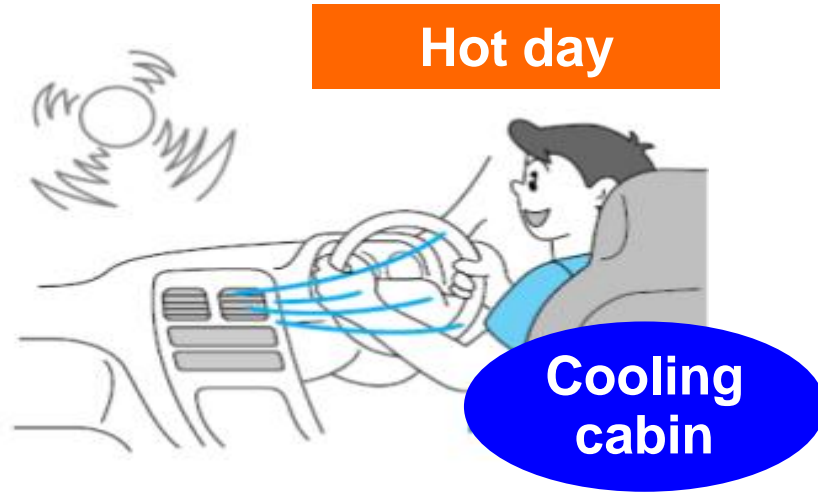


Le confort thermique est défini comme "un état de satisfaction du corps vis-à-vis de l'environnement thermique".



Thermal Sensation : *Physiological*
Thermal Comfort : *Psycho-physiological*
Thermal Neutrality : *No sensation - Global*
Thermal Stimulis : *Local sensation*

Thermal Comfort : *Main functions inside a vehicle*



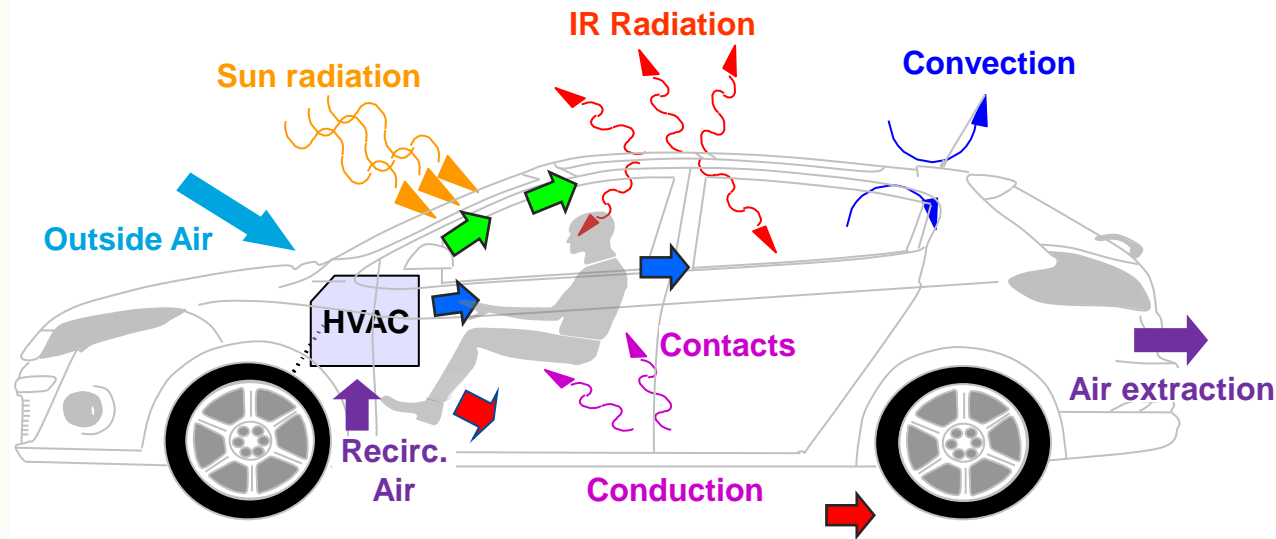
Cabin Thermal Power Balance : *Many exchanges are involved*

Convection... Gradients

- Air vents closeness :
Quick variation of air Speed & T°
- Variable **Vehicle speed**

Radiation... Anisotropy

- Cold surfaces in winter :
windows, doors...
- Hot surfaces in summer :
dashboard, steering wheel
- **Sun** on head & chest



Conduction... Contacts

- Seat effusivity
- Steering wheel &
Gear shift lever

Small cabin volume

- Variation of **Hygrometry**

Soaking & Inertia

- Cool down / Warm-up

❖ External Exchanges

❖ Outside Air Renewing

❖ Sun load

+ Inertia @ Start

Power calculation

$$HS \cdot (T^\circ_{cab} - T^\circ_{ext})$$

$$QCp \cdot (T^\circ_{cab} - T^\circ_{ext})$$

$$\Phi_s \cdot S_N$$

$$MC_p \cdot dT^\circ/dt \text{ on } 10 \text{ mn}$$

Typical values

$$HS \sim 60 \text{ W/}^\circ\text{C}$$

$$QCp \sim 100 \text{ W/}^\circ\text{C}$$

$$\Phi_s \sim \text{Up to } 1 \text{ kW/m}^2$$

@ +45°C

$$\sim 1.5 \text{ kW}$$

$$0$$

$$\sim 1.5 \text{ kW}$$

@ -20°C

$$\sim 2.5 \text{ kW}$$

$$\sim 4 \text{ kW}$$

$$0$$

Steady Needs:

$$\sim 3 \text{ kW}$$

$$\sim 6.5 \text{ kW}$$

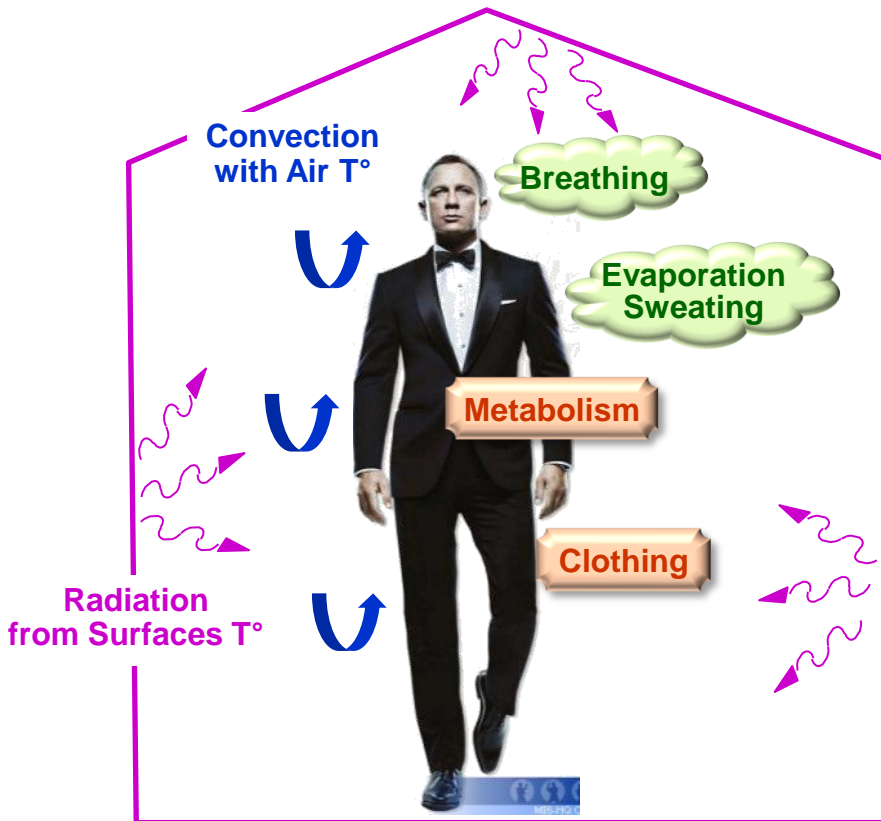
+ Transient Needs :

$$+ 3 \text{ kW}$$

$$+ 3 \text{ kW}$$

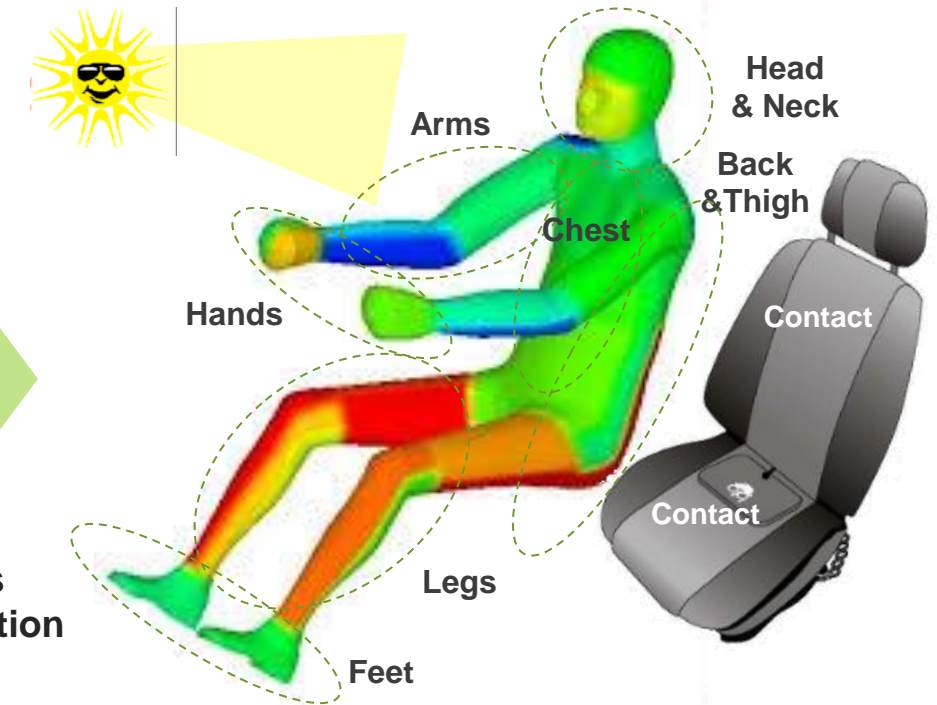
Peak Thermal Power needed for cabin power balance is in a range of 5 to 10 kW - Much higher in winter -

Body Thermal Power balance : *Thermo-Physiological Needs*



A multi-zonal approach is needed in car cabin

Many models are available, but mainly derived from jury tests and giving only indicative correlation



$$PMV = k \cdot [\text{Metabolism} - \text{Respiration Losses} - \text{Skin water Losses} - \text{Convective Heat Exchanges} - \text{Radiative Heat Exchanges}]$$

Fanger Model

$$\text{Heat Exchanges} = f_1 (\text{Skin } T^\circ, \text{ Air Speed \& } T^\circ, \text{ Radiative } T^\circ, \text{ Clothing})$$

$$\text{Mean Skin } T^\circ @ \text{ Comfort} = f_2 (\text{Metabolism})$$

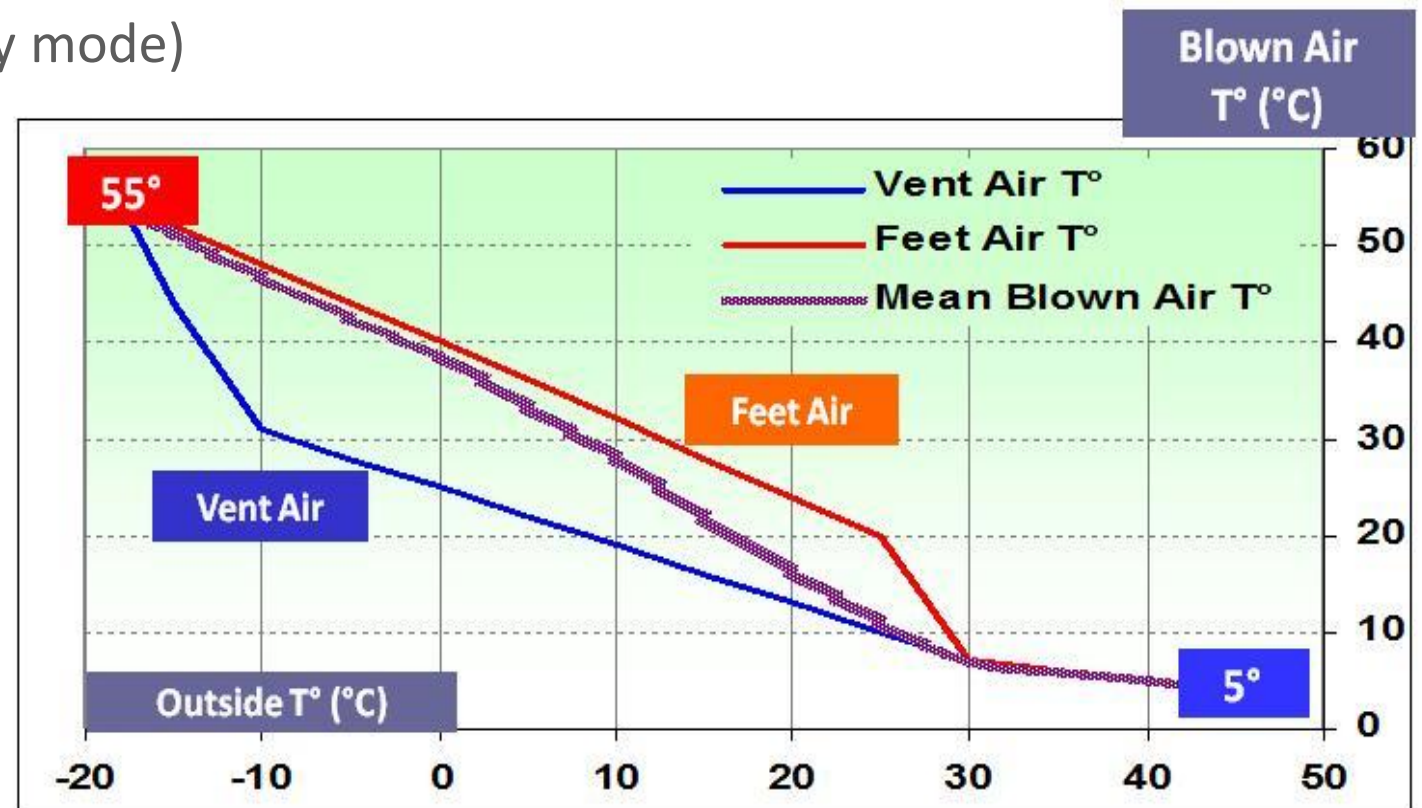
Zhang Model

➔ **Local Skin T° @ Comfort**

According context, Thermal Comfort can be correlated with Thermal Neutrality or Positive Stimulus

Manage Cabin temperature for comfort

- Cabin T° evolution (Warm up / Cool down) until comfort T° Start from outside soaking
- Maintaining the comfort (Steady mode)



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A short story of A/C systems

First Air Conditioning Systems in 1940ies

SMART TECHNOLOGY
FOR SMARTER CARS

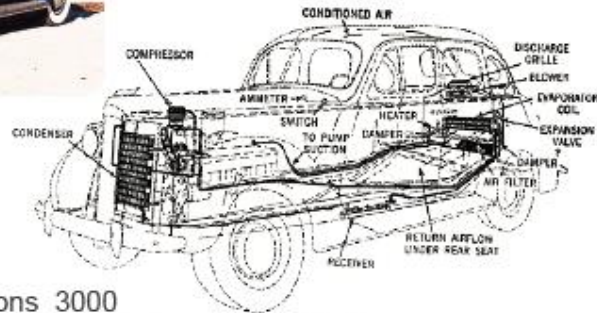
1939

● Première climatisation automobile

A Chicago, dans l'Illinois, le constructeur américain Packard Motors dévoile au public la première voiture équipée de l'air conditionné.

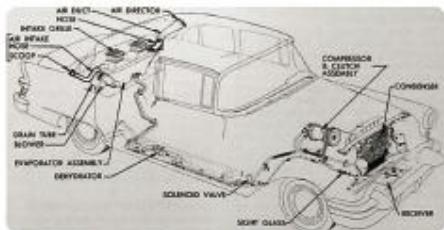


~ 5000 \$ in 2015



Avant la deuxième guerre mondiale, environs 3000 voitures américaines ont été équipées de climatisation.

L'usine Cadillac fera de même à partir de 1941.

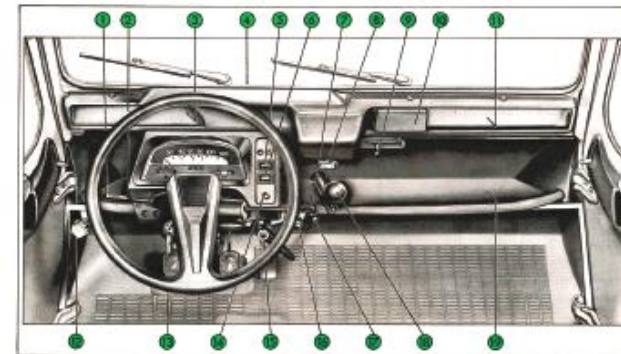


1949

● La Citroën 2CV

Les premiers prototypes datent de 1939, mais la production de la 2CV commence qu'en 1949 avec un modèle unique, u seule couleur disponible et un moteur bicylindre refroidi par air de de 375cm³, dont la cylindrée sera portée à 425 puis 435 et enfin 602 cm³.

Elle a été produite en version berline et utilitaire entre 1949 et 1990 à 5 114 961 exemplaires.



- 3 Bouche d'aération gauche
- 4 Buse de désembuage / dégivrage du pare-brise
- 8 Commande du volet d'aération
- 9 Commande de chauffage
- 11 Bouche aération droite
- 17 Commande répartition d'air pare-brise / plancher
- 20 Echangeur air/air
- 21 Volet de répartition d'air pare-brise / plancher



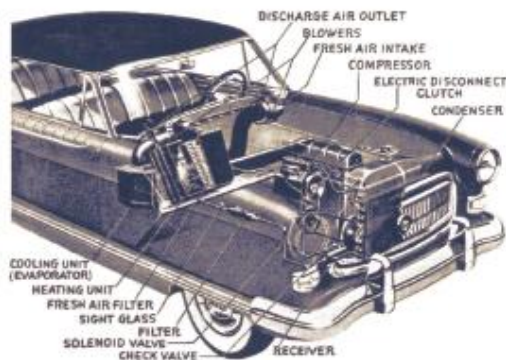
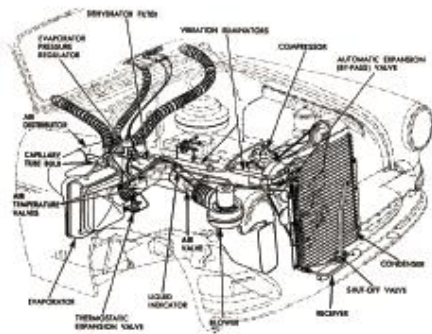
A short story of A/C systems

A/C system as Post-Equipment in USA in 1950ies

SMART TECHNOLOGY
FOR SMARTER CARS

1950

- Développement des premiers systèmes de rafraîchissement, montés en après-vente. Basés sur le principe de l'évaporation naturelle, ils sont populaires en Californie, Arizona, Texas, Nouveau-Mexique et Nevada, où l'air est chaud et sec.



1954



- 1953 - Harrison radiateur, une filiale de General Motors développe un système de climatisation monté dans sa totalité sous le capot moteur
- 1954 - Première climatisation automatique sur les véhicules de Nash Motor avec commande mono-bouton

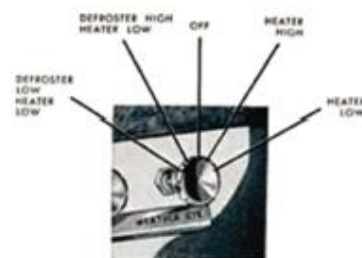


Figure 5



New! Nash Year-'round Air Conditioning Costs Hundreds of Dollars Less!

New year-round air conditioning on the Nash Year-'round Air Conditioning...
1. The new Nash Year-'round Air Conditioning...
2. The new Nash Year-'round Air Conditioning...
3. The new Nash Year-'round Air Conditioning...

Weather Eye Magic

A new way to keep your car cool...
The new Nash Year-'round Air Conditioning...
Nash Year-'round Air Conditioning...
Nash Year-'round Air Conditioning...

A mid-century car...
With next-century features.



in 1960 : 20 % of US cars have Air Conditioning
in 1969 : 54 % of new US cars have Air Conditioning

A short story of A/C systems

First HVAC module for Ventilation & Heating in 1960ies

SMART TECHNOLOGY
FOR SMARTER CARS

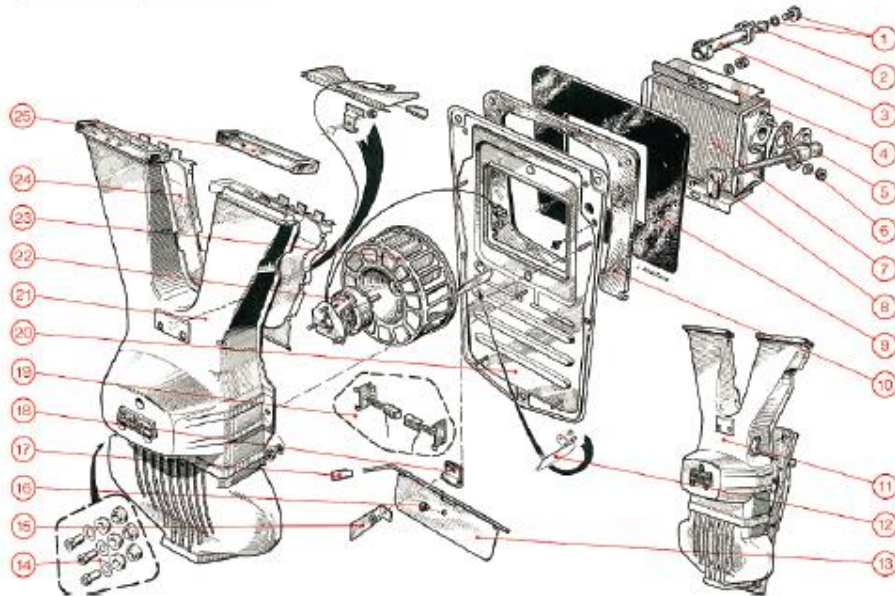
1961

- La 4L, la première traction avant de Renault en réponse à la Citroën 2 CV

Elle fut construite dans l'île Seguin à Boulogne-Billancourt d'août 1961 à fin 1992. Elle reste aujourd'hui la deuxième voiture française la plus vendue avec 8 135 424 d'exemplaires derrière la Peugeot 206.



Chauffage SOFICA



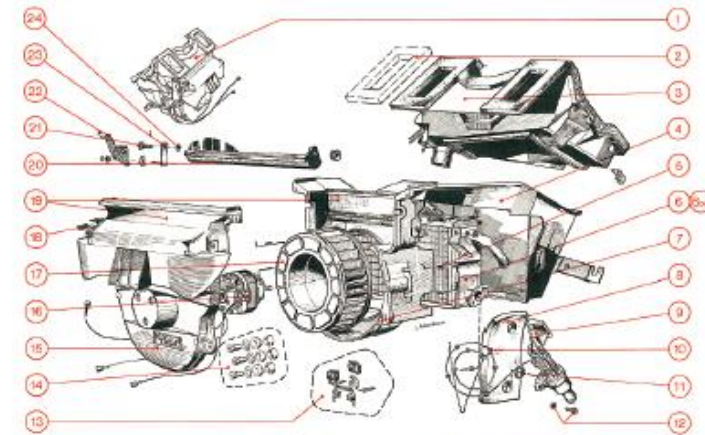
1965

- La 204, la première traction avant de Peugeot

Elle est équipée d'un moteur entièrement en alliage léger, à arbre à cames en tête, de 1 130 cm³ en essence ou 1 255 cm³ en diesel, ce qui en fait le plus petit moteur Diesel de l'époque. Elle est déclinée en berline, break, coupé 2+2 cabriolet 2 places et fourgonnette. Elle a été produite entre 1965 et 1976 à Sochaux à 1 604 296 exemplaires.



Chauffage SOFICA



A short story of A/C systems

First Valeo HVAC with Air Conditioning in 1970^{ies}

SMART TECHNOLOGY
FOR SMARTER CARS

1970

● 1970 - Citroën SM

Destinée à une clientèle aisée et sportive. Il est équipé d'un moteur Maserati V6 de 180cv issu du V8 de la Maserati Indy amputé de 2 cylindres.

Malheureusement, la crise énergétique mettra rapidement un frein à cette sportive gourmande. Elle a été produite à 12 920 exemplaires entre 1970 et 1975.



● Premier groupe de climatisation SOFICA



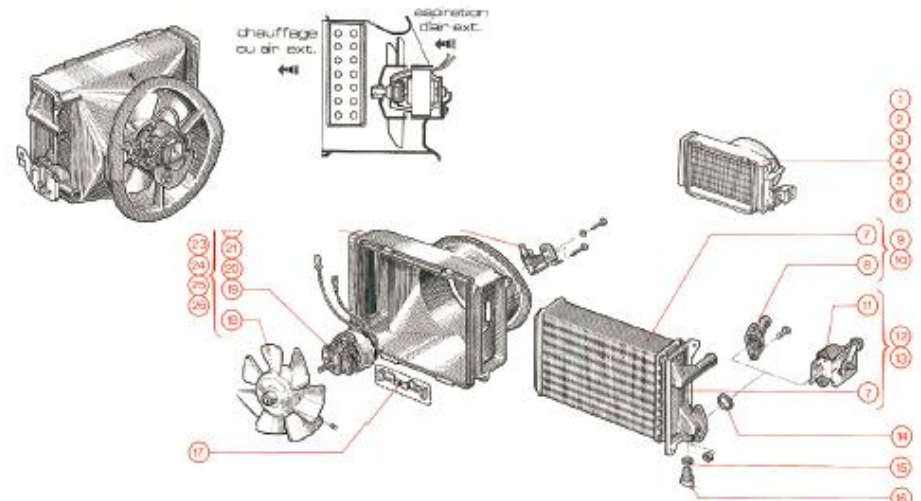
1975

● Volkswagen Polo / Audi 50

La Volkswagen Polo première du nom, produite entre 1975 et 1981, était une petite voiture à trois portes avec hayon, directement dérivée de la mieux équipée Audi 50 lancée en 1974 et dont la production s'arrêtera en 1978. Son nom vient du jeu de polo et devait établir un lien avec le futur nom de Golf chez Volkswagen.



Chauffage SOFICA



A short story of A/C systems

First Valeo HVAC with Automatic A/C in 1980ies

SMART TECHNOLOGY
FOR SMARTER CARS

1989

● Peugeot 605 - 607

Berline haut de gamme de Peugeot pendant 10 ans

Elle a été produite à 250 000 exemplaires entre 1989 et 1999.

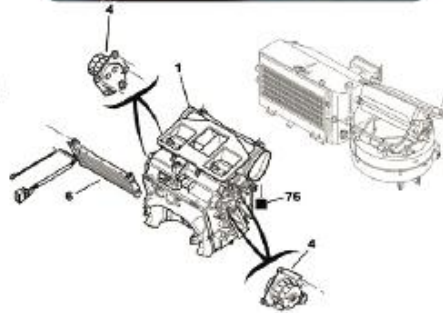
Elle est remplacée par la 607 qui reprend son groupe de climatisation modernisée.

La 607 a été produite à 200 000 exemplaires entre 2000 et 2010.



Climatisation automatique 607 Valeo

Équipé d'un chauffage électrique additionnel CTP et d'actionneurs pas à pas.



1999

1992

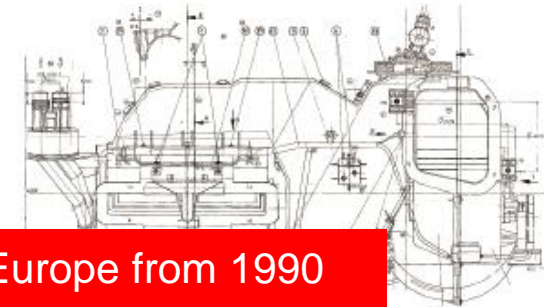
● Renault Safrane

Dernier modèle haut de gamme de Renault avant l'échec de la Vel Satis (2002-2009) et l'abandon de ce segment par le constructeur au Losange.

Elle a été produite à 310 000 exemplaires entre 1992 et 2002.



Climatisation Valeo



Ramp-up of A/C systems in Europe from 1990
In 2003 : 75% of new cars with A/C



A short story of A/C systems

Extended ranges of HVAC along 1990^{ies} and XXI^{ies}

SMART TECHNOLOGY
FOR SMARTER CARS

1996

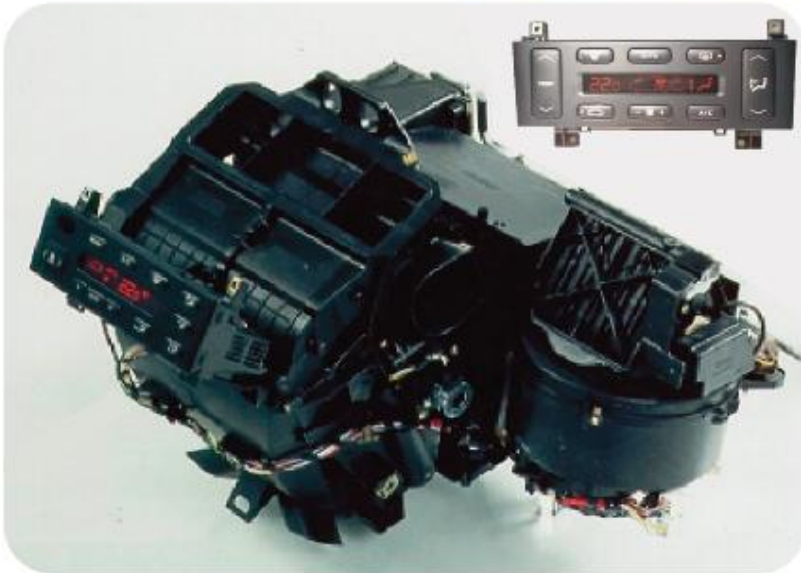
● Peugeot 406

Deuxième modèle PSA a étrenné l'architecture multiplexée VAN (concurrent du CAN Bosch)

Elle a été produite à 1 667 364 exemplaires entre 1996 et 2004.



Climatisation automatique Valeo



2004

● Renault / Dacia Logan

Renault lance, en 1998, l'étude d'un projet de véhicule familial, moderne, robuste et fiable commercialisé, en prix d'entrée, à 5 000 euros. Personne n'y croit sauf le patron de Renault.

La Logan et variante en version 5 portes Sandero produite à partir de 2007 a été produite à plus de 2 millions d'exemplaires.



Climatisation Valeo

Version dépouillée pour réduire les coûts, produite dans une nouvelle usine à Mioveni aux portes de Dacia, puis en Russie

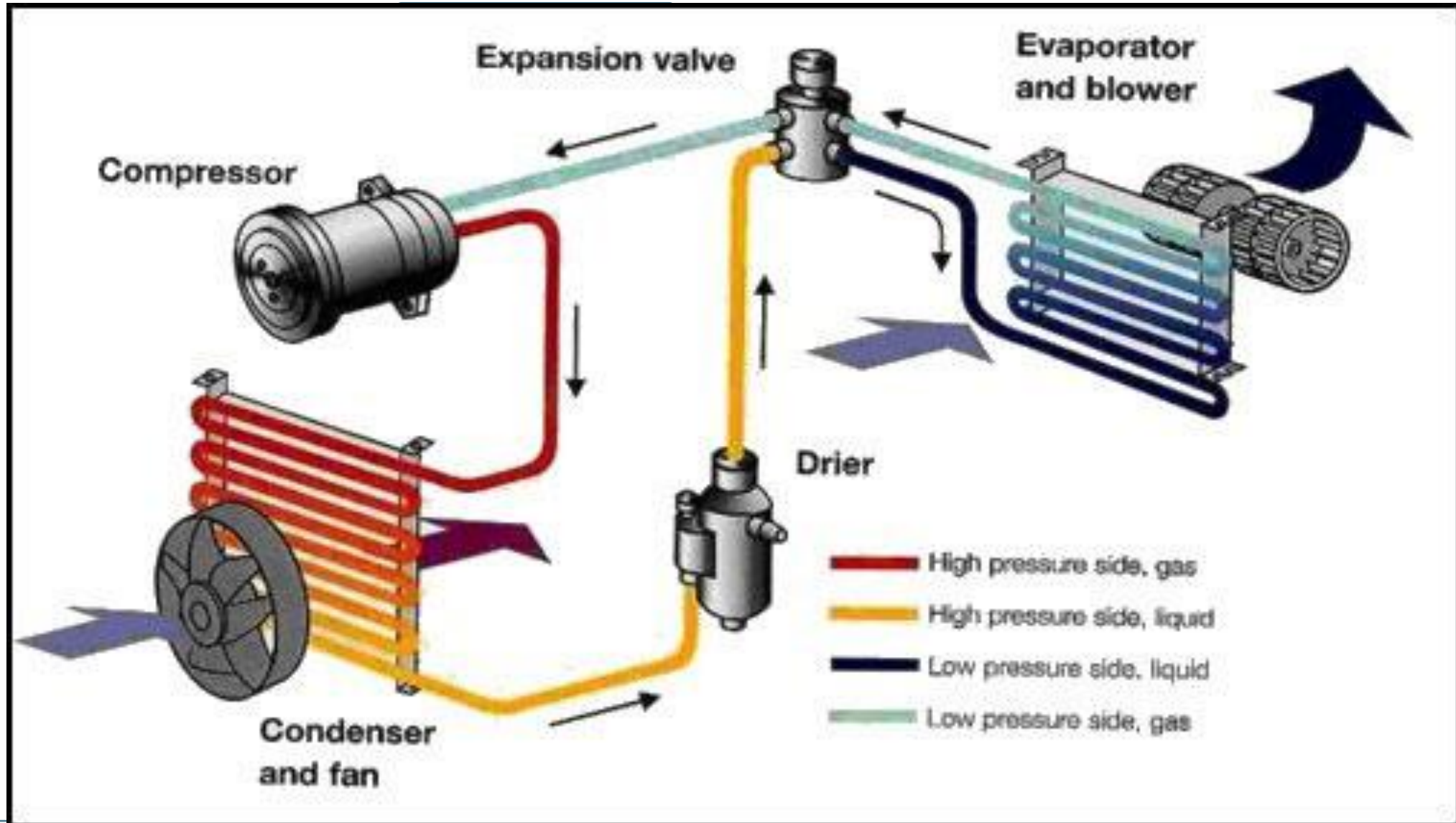
Designing a modern and reliable car at a break

in 2020 : > 90% of European cars with A/C

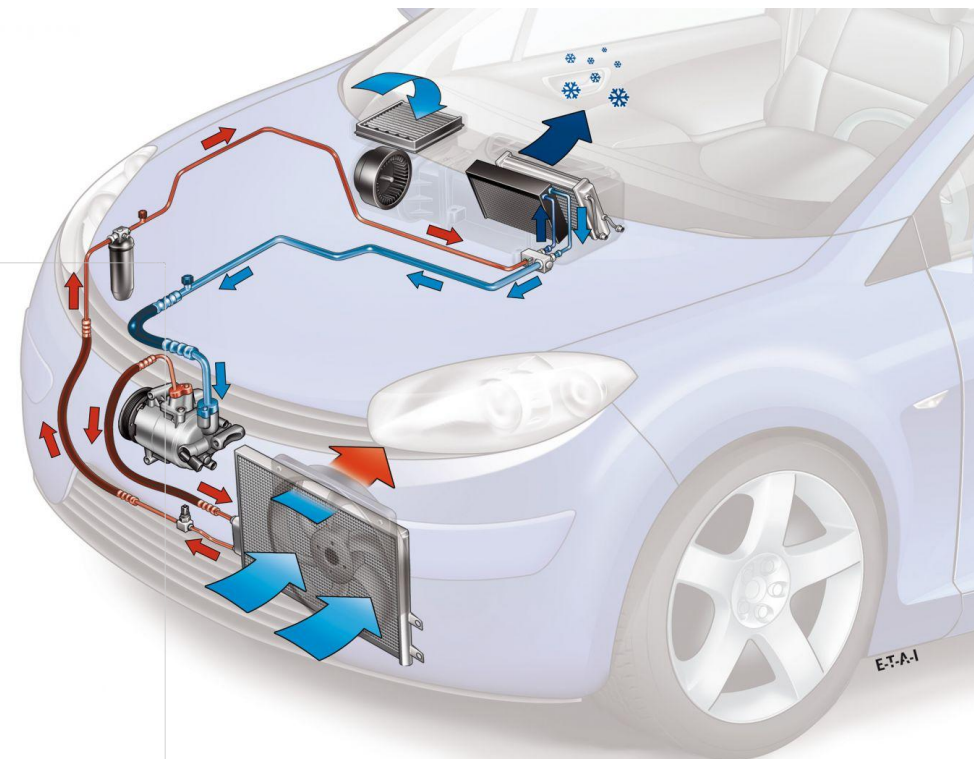
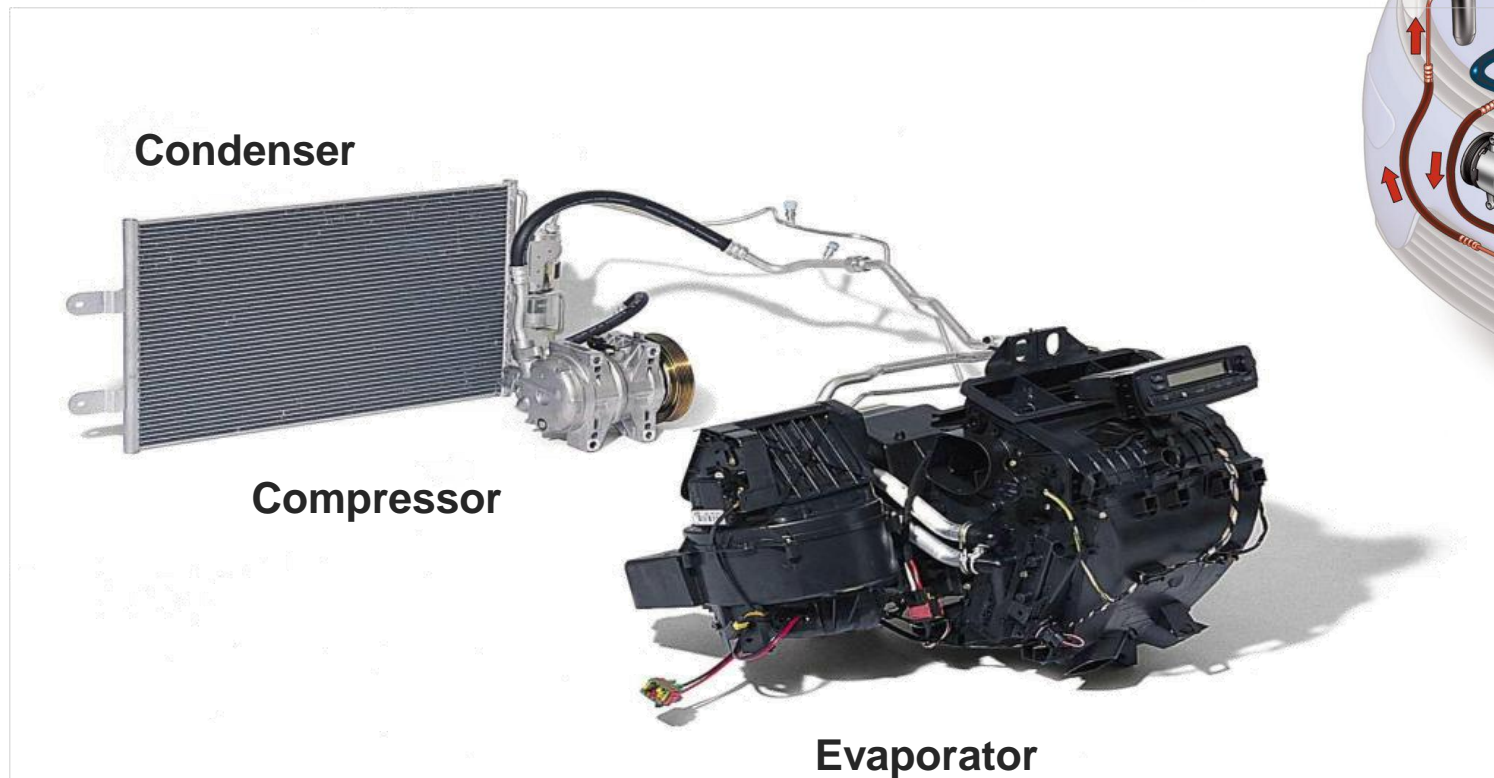
Lucien Schaefer
Renault Chairman and CEO

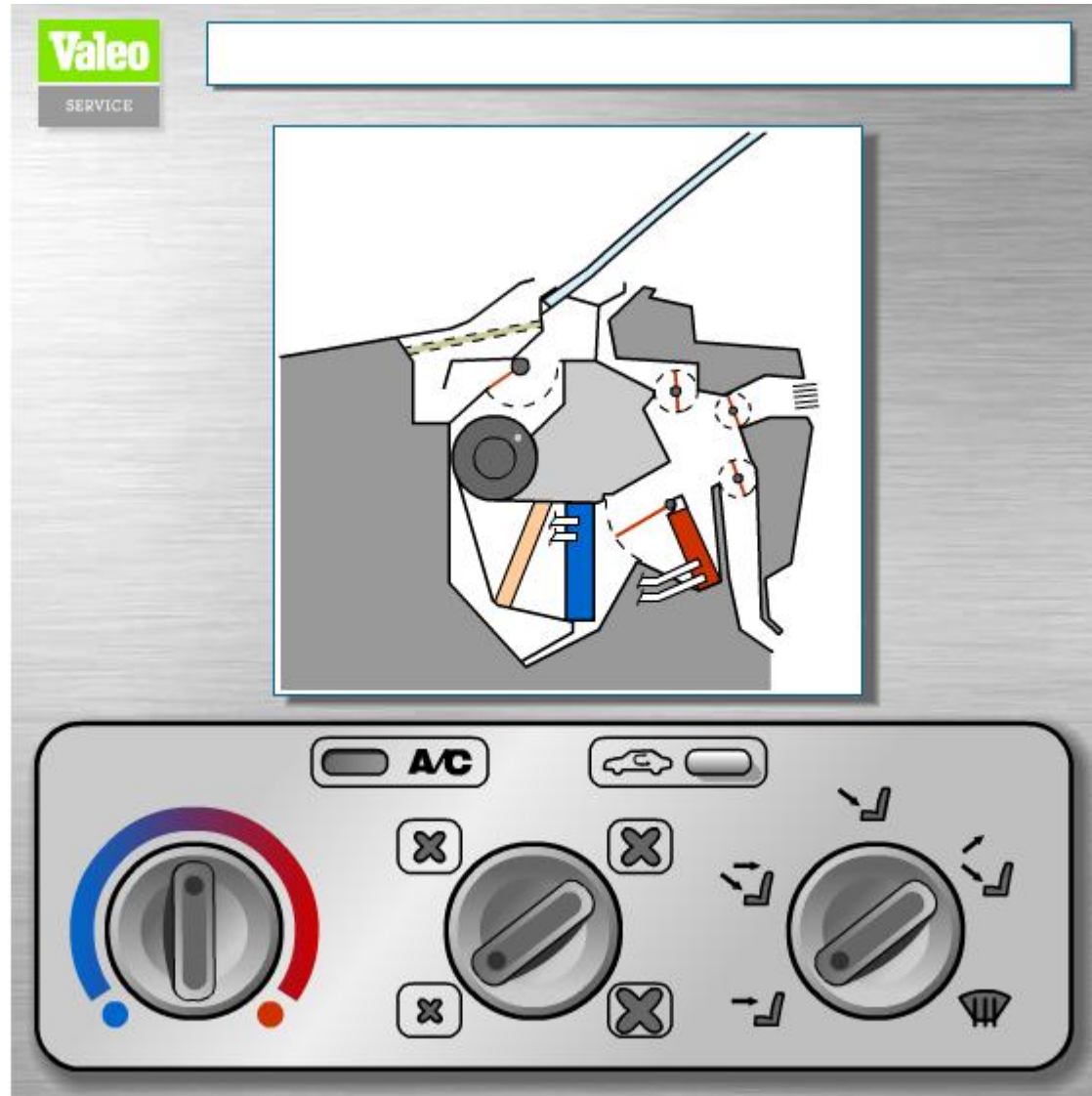


Air conditioning system

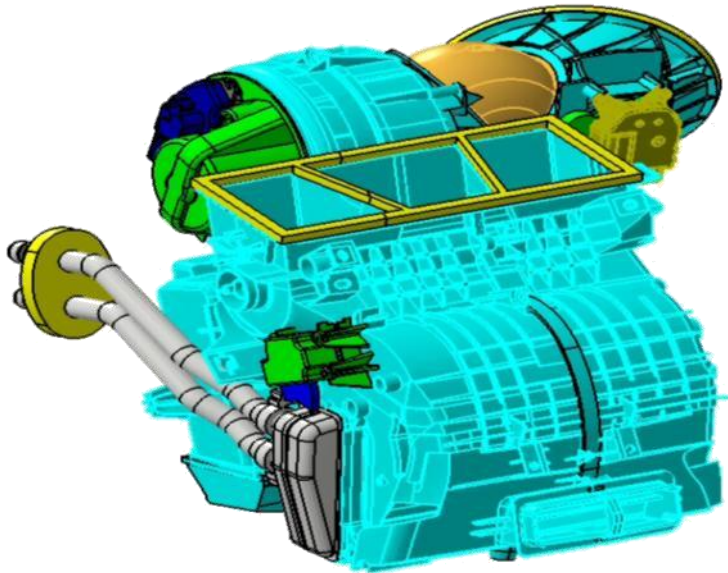


Air conditioning system

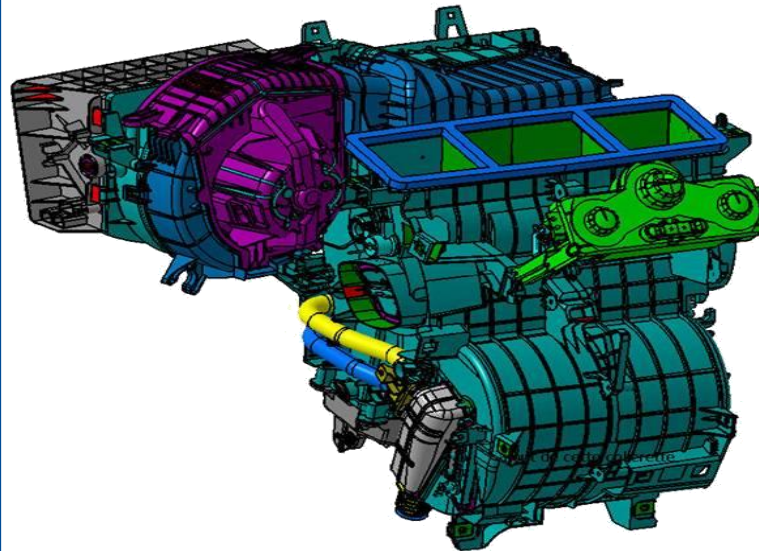




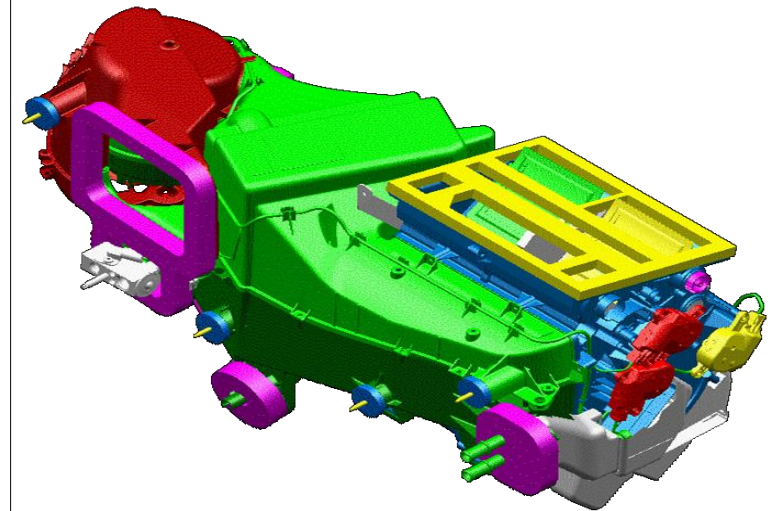
Centered HVAC unit



**Centered HVAC unit
with lateral blower**



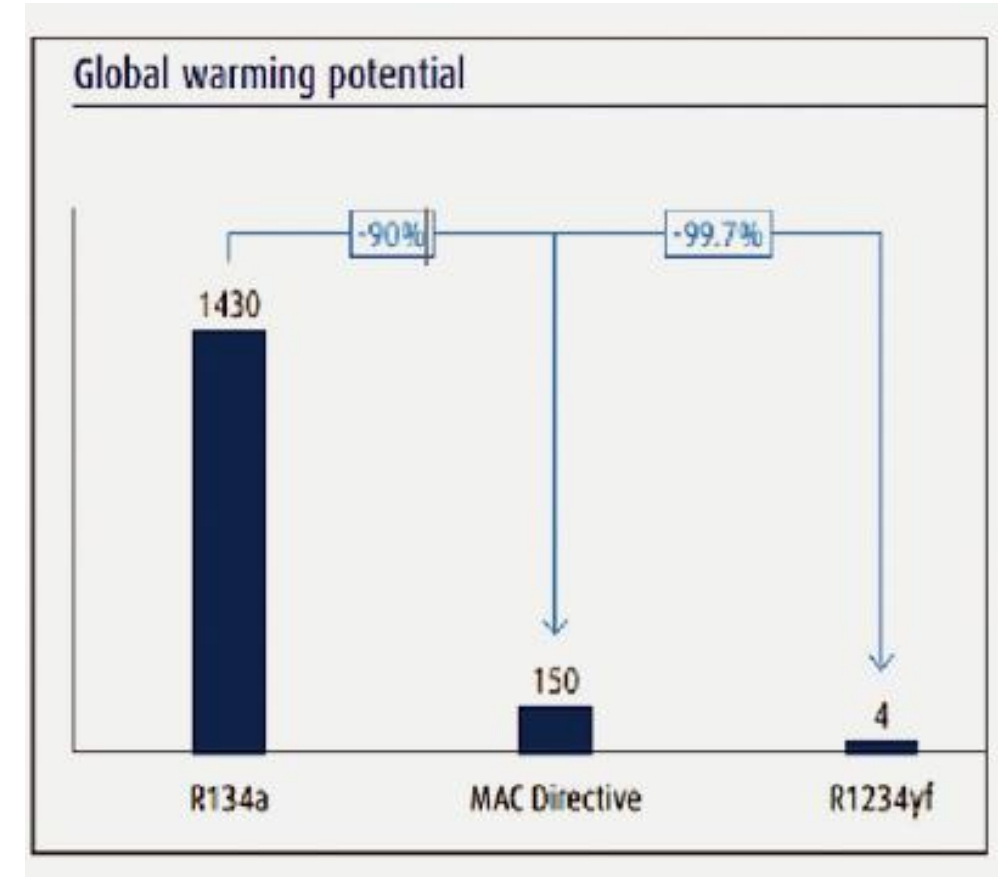
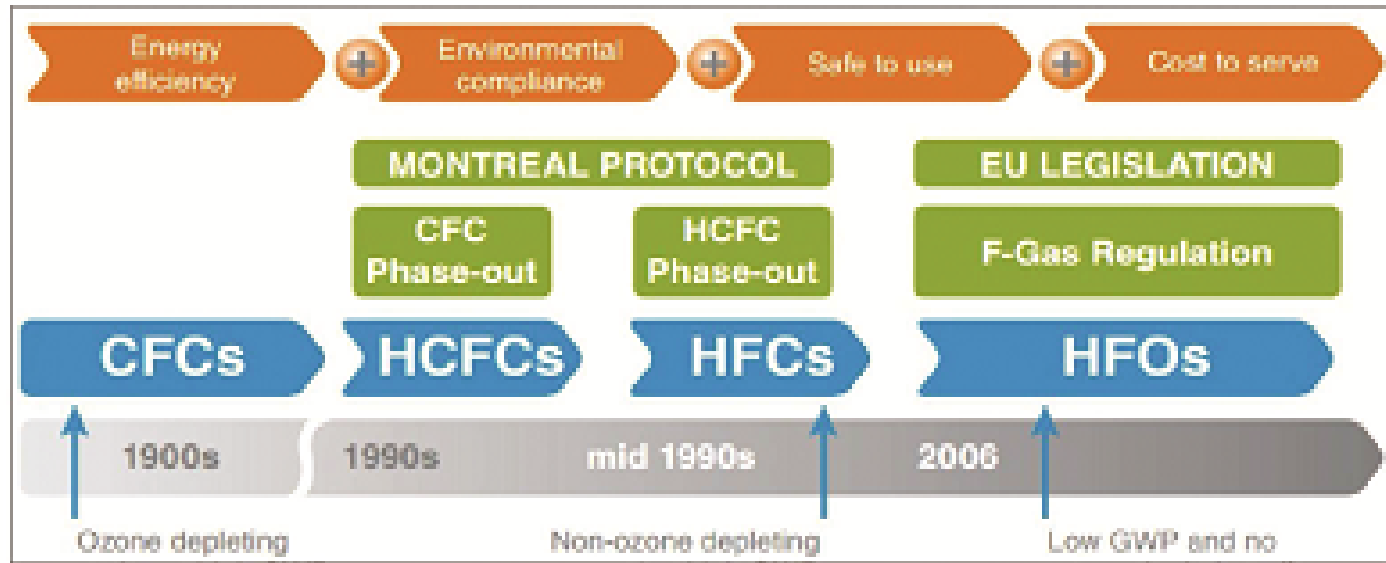
Half centered HVAC unit



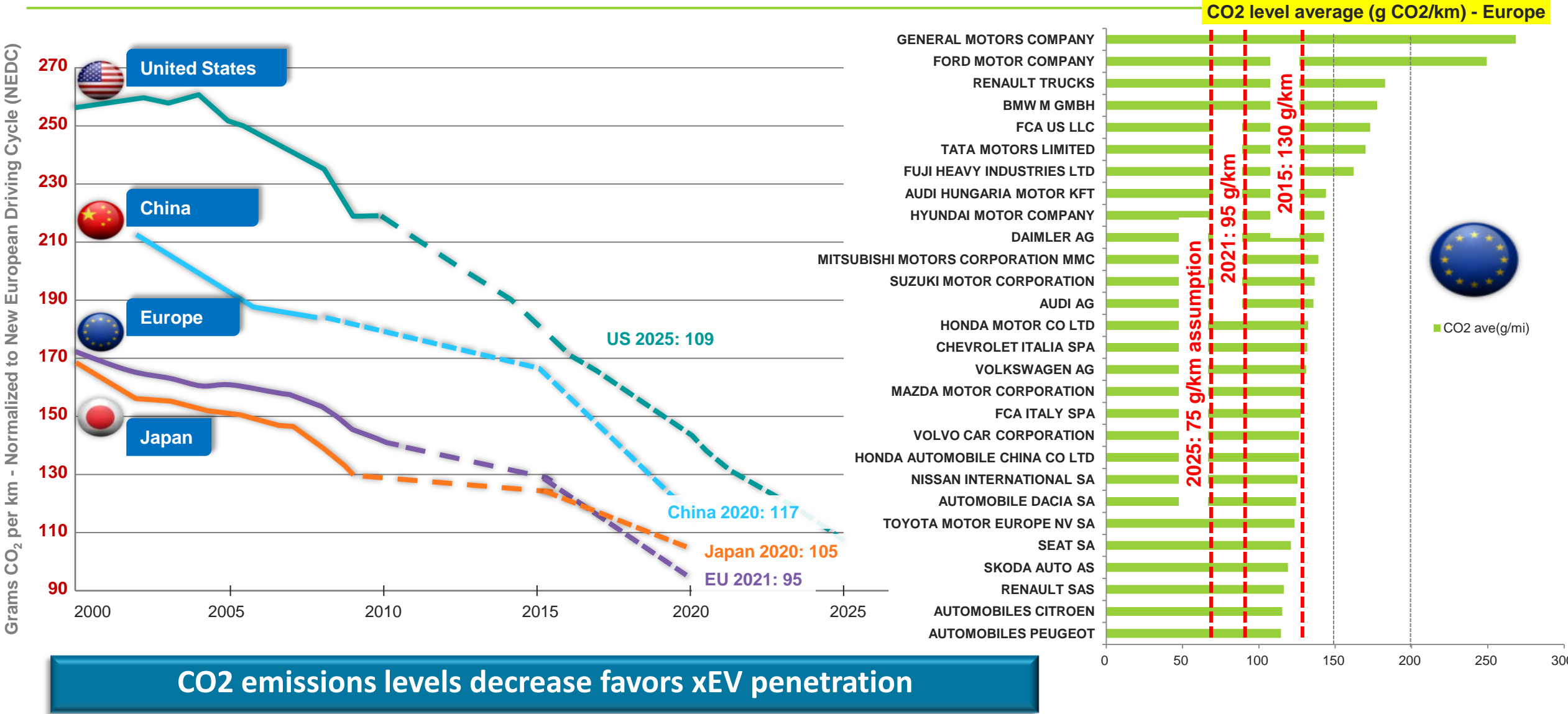
The final solution will depends on the allocated packaging space,
the performance level, and the required functionality's

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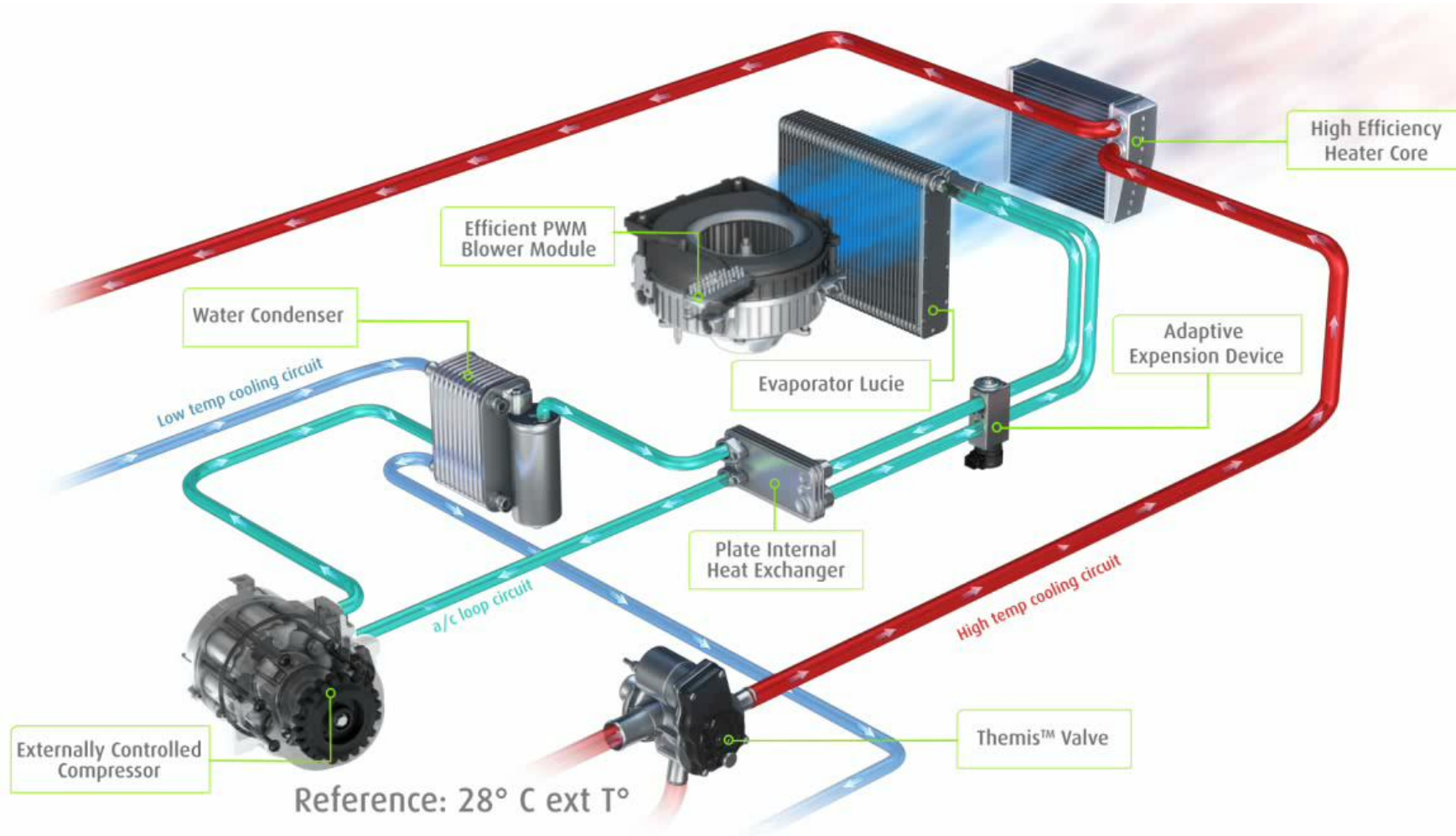
Ozone impact : R12 -> R134a -> 1234yf -> R744



Regulation : CO₂ emissions levels put pressure on all OEMs

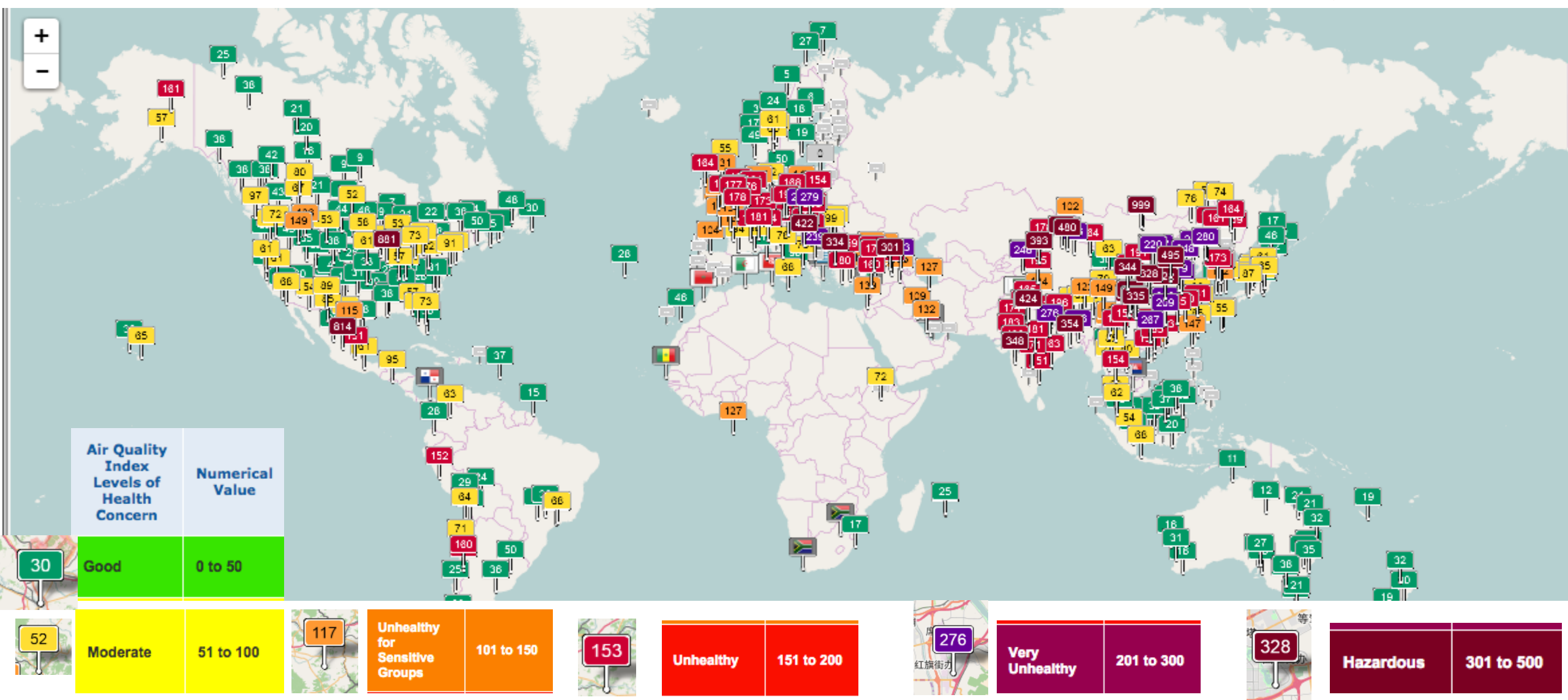


A/C System Efficiency



A/C system for ICE

Air Pollution is a worldwide issue ...



Air quality: Pollution as the world's largest single environmental health risk



36%
OF DEATHS FROM
LUNG CANCER



34%
OF DEATHS FROM
STROKE



27%
OF DEATHS FROM
HEART DISEASE

The invisible killer:

According to the World Health Organization, it is now considered "the world's largest single environmental health risk," with more than three million people dying every year as a result. This is **more than twice the number of people that die in vehicle accidents** each year.

A worldwide issue:

Air pollution is a major public health problem. The World Health Organization (WHO) found that **92% of the population** breathes air with unhealthy levels of pollutants.



A priority in China:

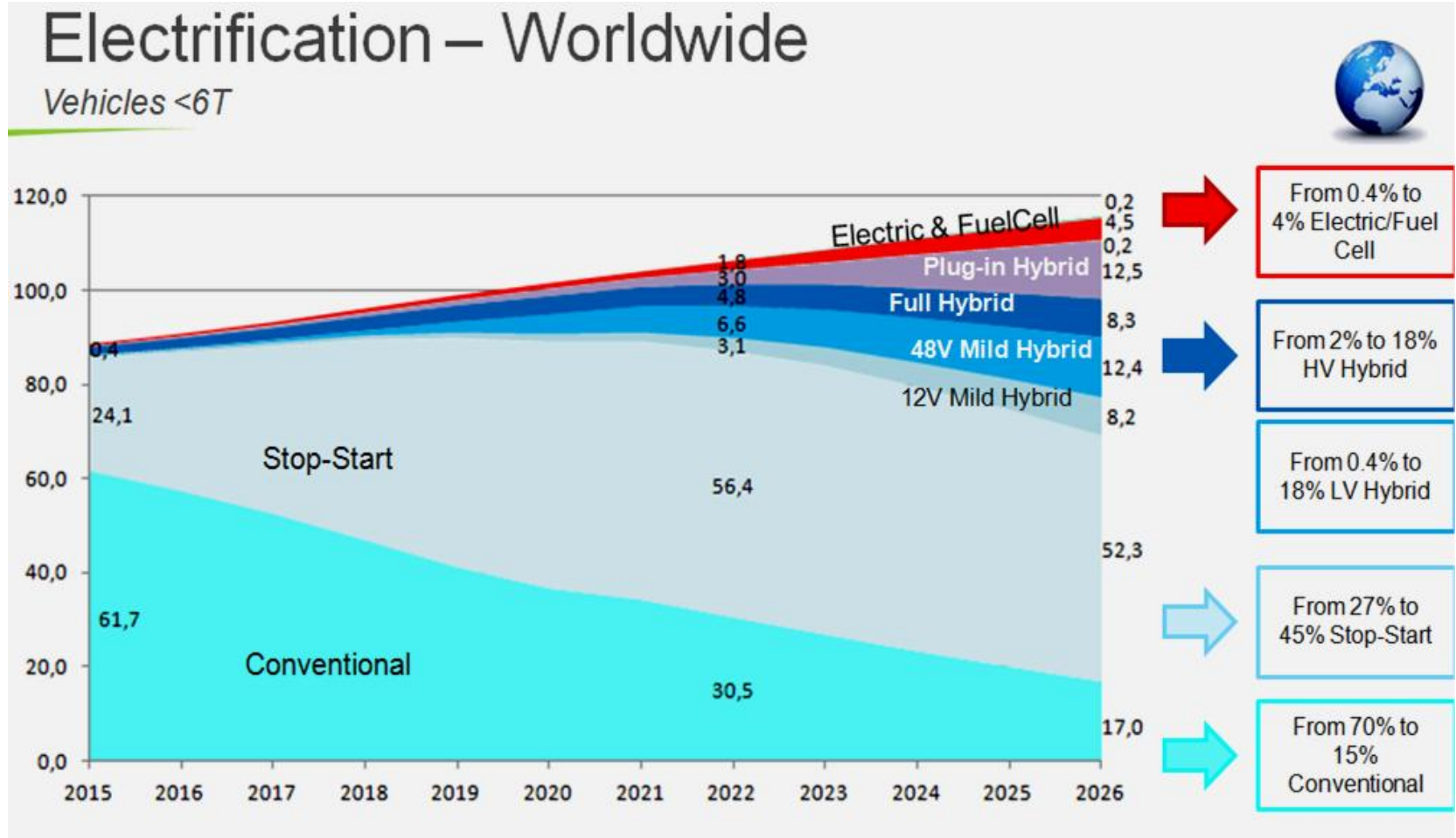
Almost **50% of respondents** in China rated the quality of the air in the area where they live as quite poor/poor/very poor (Europe 25% - USA 17%)
3 out of 4 Chinese seek access to relevant information within their personal living environment

Full Air quality system





Comfort and max.range
Battery life time



Electrification : Impact on the EV range

According Reference User Scenario

Urban / Periurban trips

- 15 mn @ 25 km/h
- Driving Elec. Pw ~ 3.5 kW
- 25% of time in « Convergence »

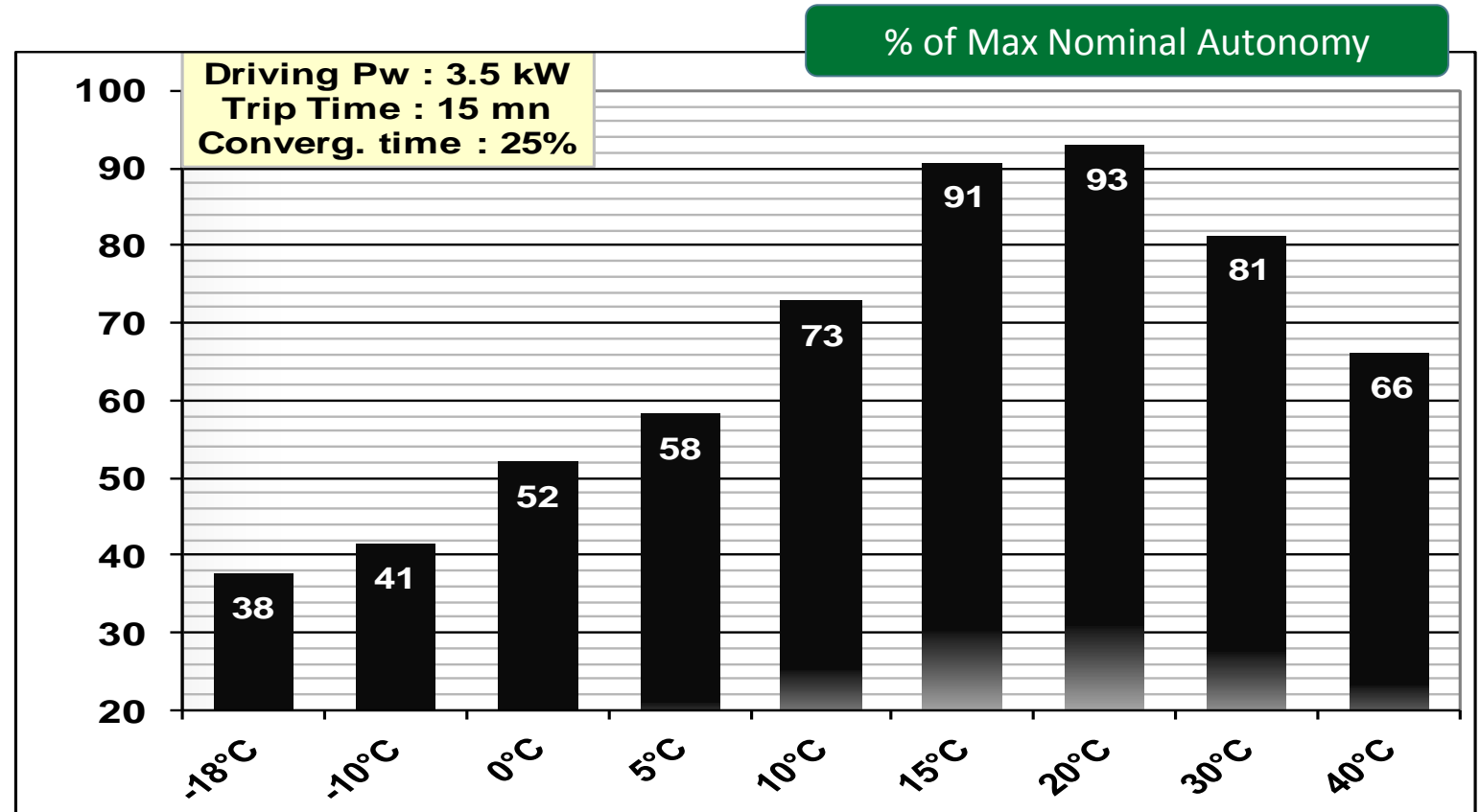
Electrified AC system

- Electrical compressor
- Electrical Water heater

Comfort Strategy :

- No dehumidification
- $T^{\circ} \text{ amb} < 30^{\circ}\text{C}$: 25% Recirc rate
- $T^{\circ} \text{ amb} \geq 30^{\circ}\text{C}$: 40 kg/h Fresh Air

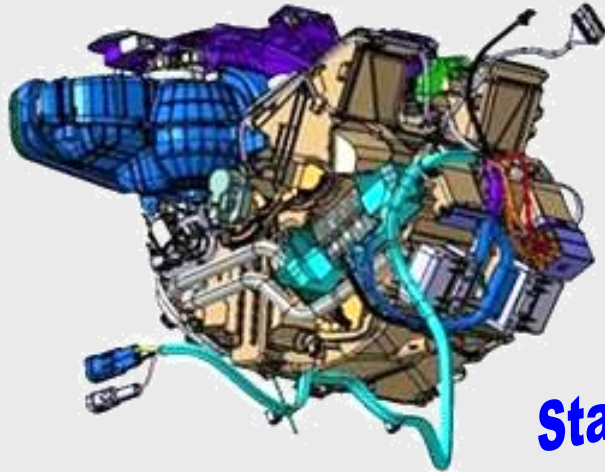
European Climate occurrence profile



Additional Electrical Auxiliary Pw : + 100 W
brings - 5 km in urban cycle (vs. 140 km)

Air Renewing Control

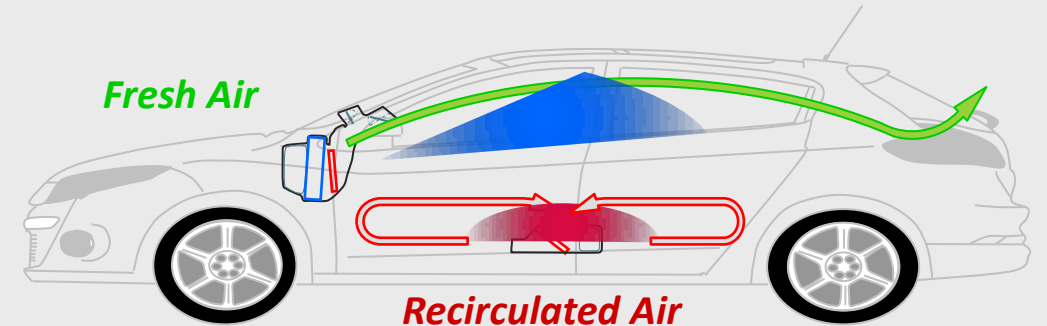
- Dry fresh air is pulsed through the upper zone
- Heated recirculated air is used for lower zone



Standard HVAC

- HVAC with new air inlet and actuator
- Humidity or Mist sensor
- ➔ Accurate control of fresh air
- ➔ Adjust air renewing according misting risk
- ➔ High sensitivity to operating profile

Air Stratification



Splitted HVAC

- ➔ Decoupling of Cabin T° and Humidity control
- ➔ Down to 20% of renewing air :
 - without impacting front & rear comfort
 - without increasing misting risk

NEW CABIN TREATMENT & COMFORT STRATEGY

New Glazing Technology



1 Electrical Windshield

- ➔ Drop demisting & defrosting power

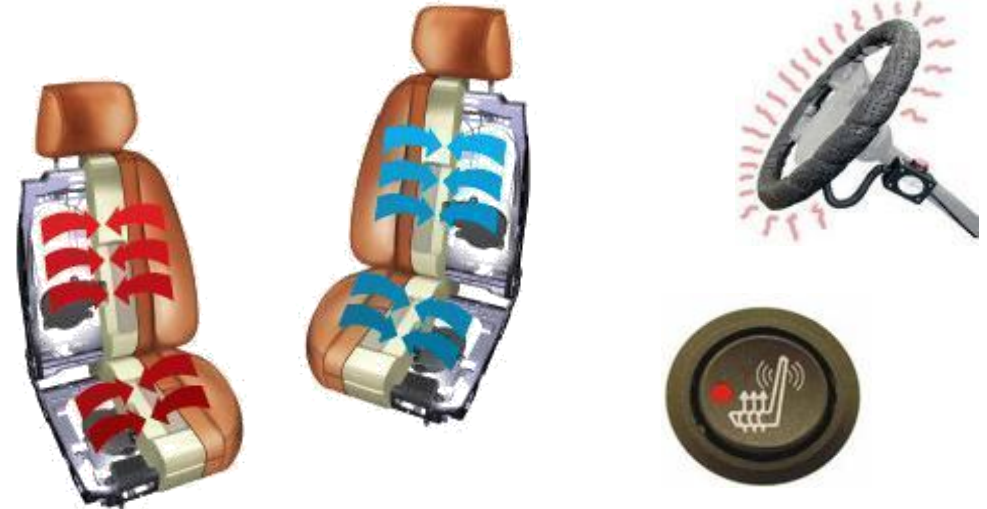
2 Low Emissivity coating

- ➔ Drop inner cabin infrared radiation

3 Anti-Mist hydrophilic coating

- ➔ Drop air renewing without misting

Local Comfort



■ Heating & Cooling seat + Heating steering wheel

- ➔ Drop the power needs during convergence

> Up to - 8°C in Winter (- 4.0°C measured at 5°C)
> Up to + 2°C in Summer (+0.5°C measured at 30°C)

■ Individualization of air distribution

- ➔ Adjust the air flow-rate to passengers

Added value / Added cost to balance

Heat Pump Architecture

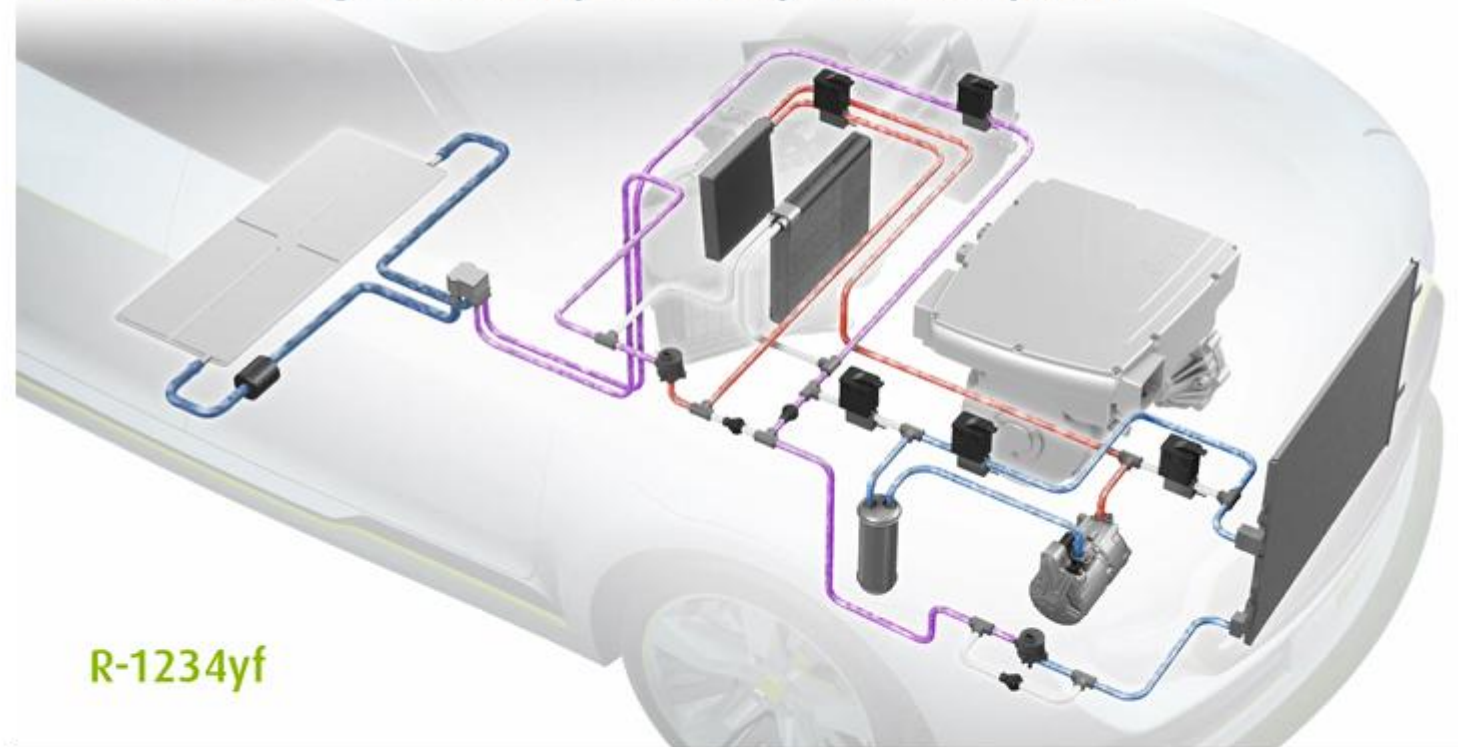
3 discussions are still of concern
to select architecture & technology :

- ❖ **Direct** or **Indirect** HP !
- ❖ **Ambient** or **Recovery** HP !
- ❖ **Chemical** or **CO₂** refrigerant !

depending on a balance between

- [Perfs x Robustness] / [Integration x Cost]
- Usage profile [BEV vs PHEV]

Cabin Heating: Heat Pump & Battery Thermal System



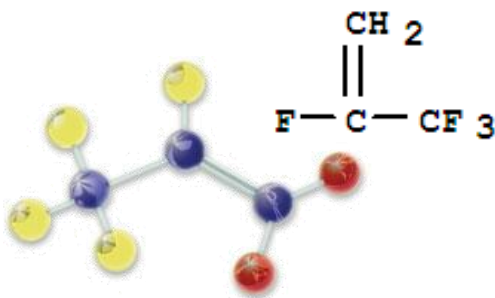
R-1234yf

Heat Pump Architecture

CHEMICAL OR NATURAL REFRIGERANT ?

R1234yf Heat Pump

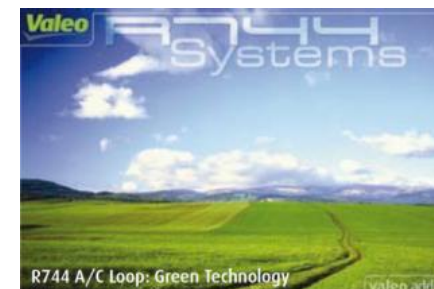
■ Use R1234yf as chemical refrigerant



- ➔ GWP = 4 - “R” classified
- ➔ Agreed as new European standard for MAC
- ➔ Easy switch from current technology
- ➔ Poor Heating efficiency at very low temperature
 $COP < 1.5$ for $T^{\circ} amb < -10^{\circ}C$
- ➔ Additional high power heater for low T°
- ➔ **Flammability & Cost still of concern**

R744 / CO₂ Heat Pump

■ Use CO₂ as natural refrigerant



- ➔ GWP = 1
- ➔ High heating power & efficiency with quick response on all temperature range
 $COP > 2$ for $T^{\circ} amb = -18^{\circ}C$
- ➔ Higher cooling efficiency below 30°
- ➔ Lower cooling efficiency above 35°
- ➔ **High operating pressure & leakage sensitive**
 - New component technology → Invest & Cost
 - Reliability & Maintainability of concern

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 - **Well being / Digitalization ➡ New interior experience**

4 Disruptive Automotive Trends impact comfort & well-Being inside the cabin

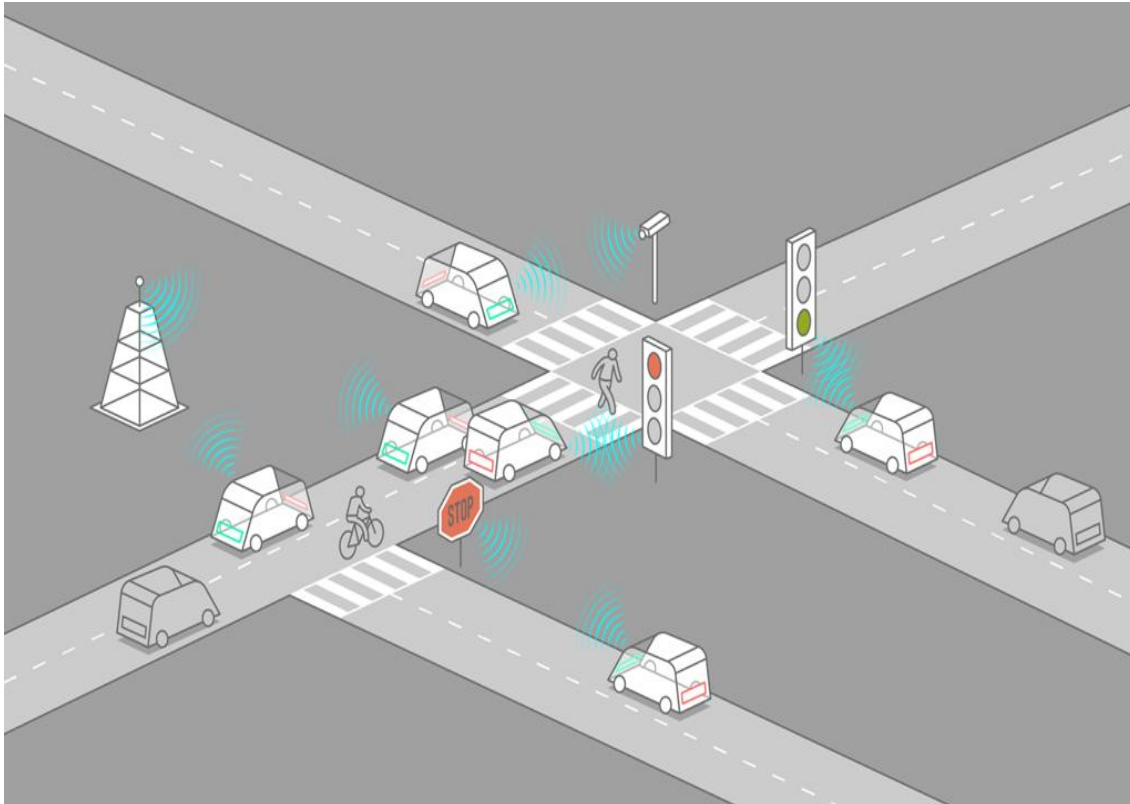


New usages, functions & services are emerging along new mobility expectations & experiences

Unique Interior Experience



**V2X for more safety, better traffic flow
and better fuel efficiency**



Car as a personal mobile living space

Differentiation



**Unique
Interior experience**

User centric functions



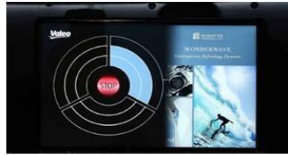
Adaptive ambiance



See



Breathe



Feel



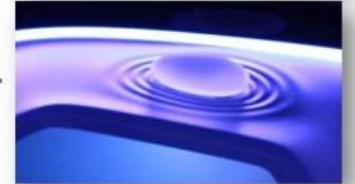
Healthy journey



Activation



Perception



Information



Safe drive



Detection



Stimuli activation



Thank you for your attention

