

Amphenol Sensors

Delivering Value-Add  Sensors

Propane detection in refrigeration units and heat pumps
SGX Refrigeration gas sensors vs F-Gas Regulations



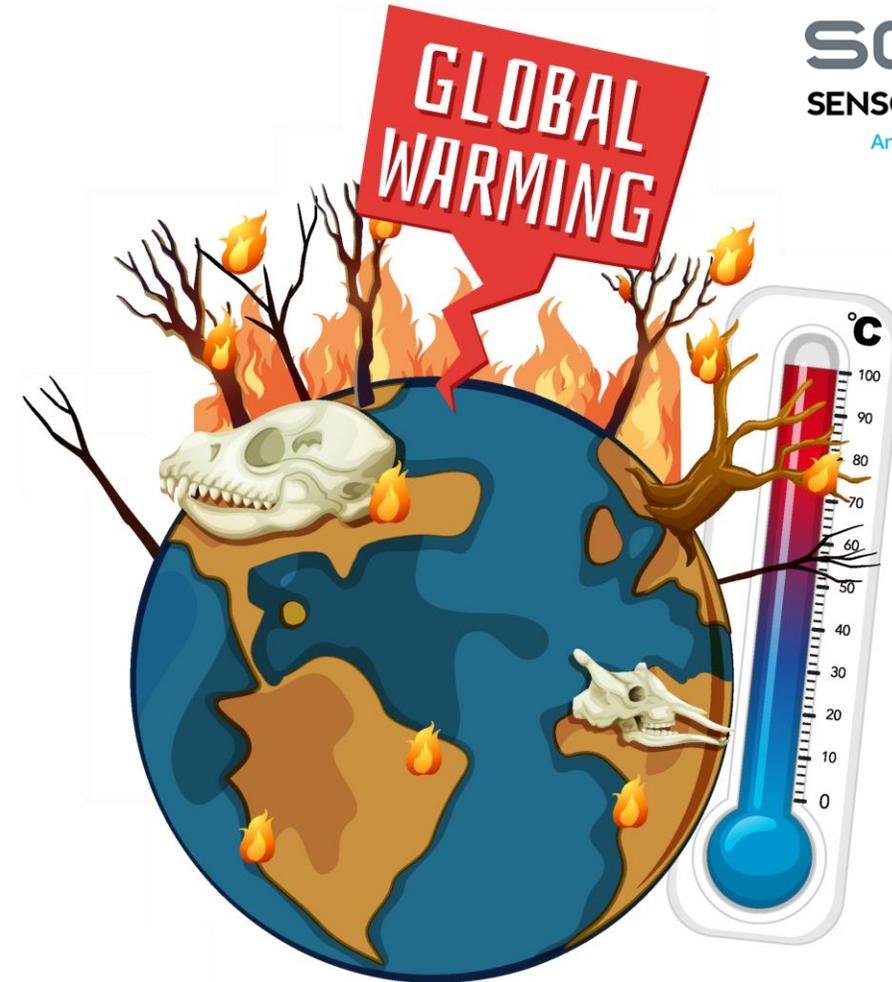


What is the main reasons of Global Warming?



Main reasons of Global Warming

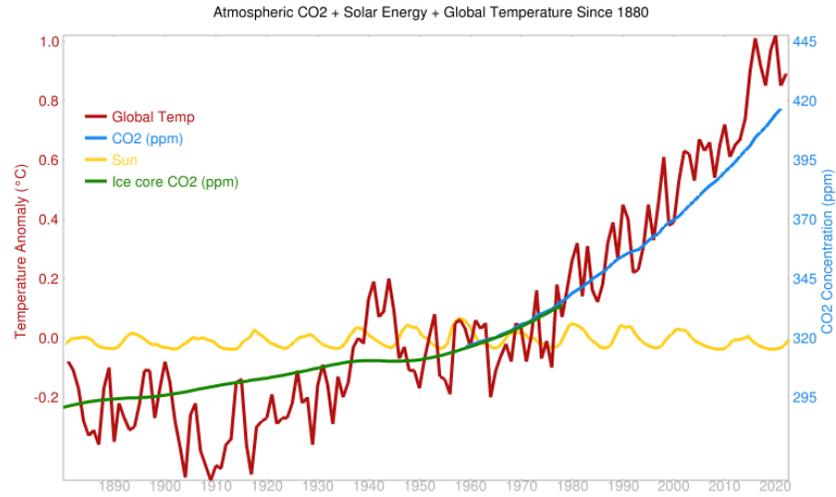
1. Greenhouse gas emissions
2. Burning of fossil fuels
3. Deforestation
4. Agriculture
5. Transportation



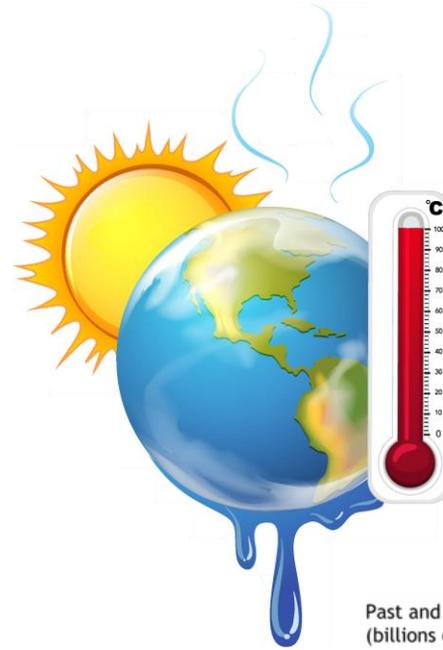
Example:

Atmospheric CO₂ level growth from 320ppm to 420ppm in last 50-70 years

Main reasons of Global Warming



<https://www.co2.earth/global-warming-update>



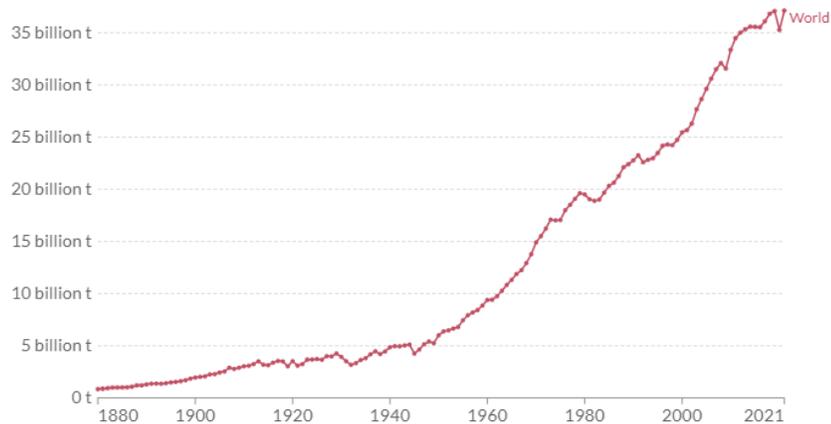
2021 Global Temperatures
+ 1.12 °C
 6th warmest year since 1880

Annual CO₂ emissions

Carbon dioxide (CO₂) emissions from fossil fuels and industry. Land use change is not included.



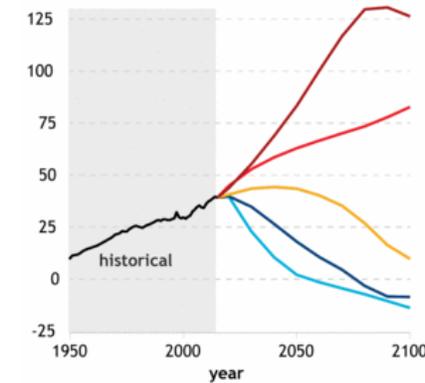
LINEAR LOG + Add country Relative change



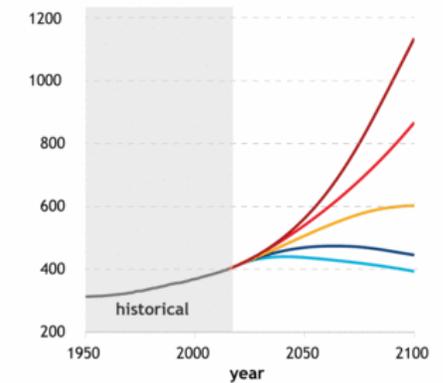
Source: Our World in Data based on the Global Carbon Project (2022) OurWorldInData.org/co2-and-greenhouse-gas-emissions • CC BY

<https://ourworldindata.org/co2-dataset-sources>

Past and future carbon dioxide emissions (billions of tons/year)



Past and future atmospheric carbon dioxide (parts per million)



Socioeconomic pathways
 very high emissions → very low emissions
 SSP5-8.5 SSP3-7.0 SSP2-4.5 SSP1-2.6 SSP1-1.9

NOAA Climate.gov, adapted from IPCC AR6 Technical Summary, Figure TS.4

<https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide>

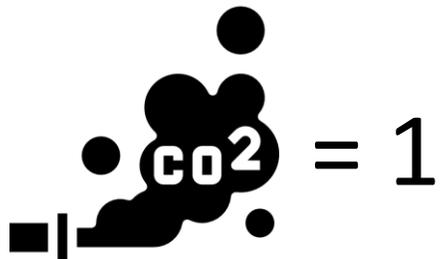
What is Global Warming Potential?



Global Warming Potential, or GWP, is a measure of how destructive a climate pollutant is.

Refrigerants today are often thousands of times more polluting than carbon dioxide (CO₂). The GWP of a gas refers to the total contribution to global warming resulting from the emission of one unit of that gas relative to one unit of the reference gas, CO₂, which is assigned a value of 1. GWPs can also be used to define the impact greenhouse gases will have on global warming over different time periods or time horizons. These are usually 20 years, 100 years, and 500 years. A time horizon of 100 years is used by regulators (e.g., the California Air Resources Board).

The most common refrigerant today, R-22, has a 100-year GWP of 1,810, almost 2,000 times the potency of carbon dioxide, so just one kg of R-22 is nearly as potent as a 2 tons of carbon dioxide. To compare with driving a car, this means that just one 12kg tank of R-22 is more potent if released, than the CO₂ emitted into the atmosphere by driving nearly 7 additional cars each year.

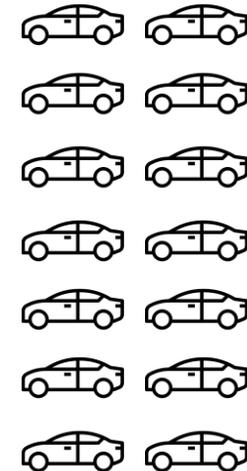


R22 = 1810

R22 = the most common refrigerant today



=



two tanks R22 = annual fuel for 14 cars

Refrigeration system impact into Warming Potential

Amphenol Sensors

Refrigeration systems can hold hundreds to thousands of kilograms, and many of these **leak at the rate of 20% or even more per year** – sometimes much more – the move away from high-GWP refrigerants will slow the pace of the global warming and climate impacts already underway.



Refrigeration systems can leak at the rate of 20% or even more per year



The current **F-gas Regulation 517/2014** intends to **reduce the EU's F-gas emissions by two-thirds by 2030** compared with 2014 levels.

Fluorinated gases ('F-gases') are a family of human-made gases used in a range of everyday products as well as industrial applications. The EU is taking regulatory action to control F-gases as part of its policy to combat climate change.

F-gases are often used as substitutes for ozone-depleting substances, because they do not damage the atmospheric ozone layer. However, F-gases are powerful greenhouse gases, with a global warming effect up to 25 000 times greater than carbon dioxide (CO₂).

The emissions of F-gases in the EU doubled from 1990 to 2014 – in contrast to emissions of all other greenhouse gases, which were reduced. However, thanks to **EU legislation on fluorinated gases** F-gas emissions have been falling every year since 2015 ([EEA data](#)).

Important Dates

- China, January 2030 – Reduction of HFC emissions by 60% (no specific regulations known by now)
- China, January 2025 – Reduction of HFC emissions by 25% (no specific regulations known by now)
- Europe, January 2022 – Ban of HFCs with GWP> 150 in **commercial refrigerator** and **freezer devices**
- USA, January 2020 – Ban of HFCs in all MBP applications and stand-alone LBP systems
- Europe, January 2020 – Ban of HFCs with GWP> 150 in mobile room A/C
- Europe, January 2020 – Ban of HFCs with GWP> 2,500 in commercial refrigerator and freezer device
- USA, January 2019 – Ban of HFCs in vending machines and all "MBP" refrigeration systems (<2,200 BTU/h)
- USA, January 2017 – Ban of HFCs in supermarket systems



Refrigeration gases vs F-Gas regulation

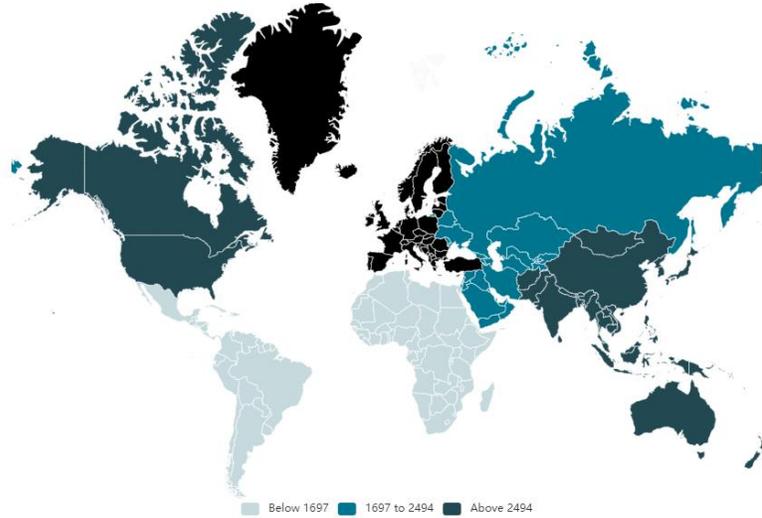


Refrigerant	Category	ODP (R11=1)	Atmospheric life [years]	GWP CO2=1 (100 years)
R11	CFC	1	45	4700
R12	CFC	1	100	10700
R113	CFC	0.8	85	6000
R22	HCFC	0.05	12	1800
R123	HCFC	0.02	1.3	76
R32	HFC	0	4.9	670
R125	HFC	0	29	3450
R134a	HFC	0	14	1400
R290	HC	0	3	3
R600	HC	0	-	4
R717	NH3	0	1	0
R744	CO2	0	100	1
R1234yf	HFO	0	11 days	4
R1234ze	HFO	0	-	6

- ODP** Ozone Depletion Potential
- GWP** Global Warming Potential
- CFC** Chlorofluorocarbon
(used in equipment manufactured before 1995.)
- HCFC** Hydrochlorofluorocarbon
(2nd generation of fluorinated refrigerant gases)
- HFC** Hydrofluorocarbon
(3rd generation of fluorinated refrigerant gases)
- HC** Hydrocarbons
- HFO** Hydrofluro-Olefins
(are considered the 4th generation of fluorinated refrigerant gases)

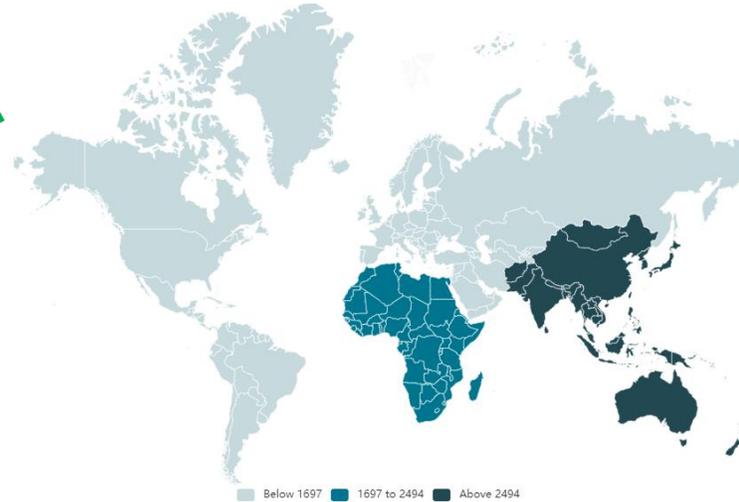


New F-Gas regulation and Impact to CO2 emmission



Unit: MtCO2

Asia-Pacific	18,977
North America	5,078
Europe	3,546
CIS	2,461
Middle-East	2,078
Latin America	1,478
Africa	1,286



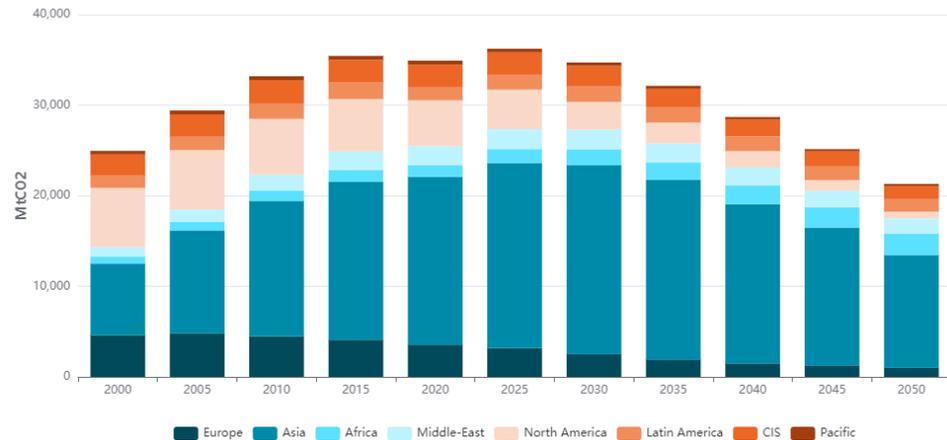
Unit: MtCO2

Asia-Pacific	12,684
Africa	2,347
Middle-East	1,670
CIS	1,469
Latin America	1,377
Europe	986
North America	764

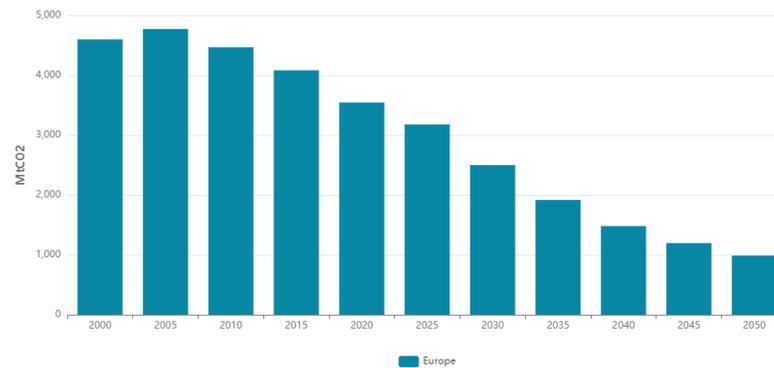
CO2 emmission in 2020

CO2 emmission plan (forecast) in 2050

World



Europe





Thanks to implementation of new F-Gas regulations refrigeration systems are switched to use new „**friendly for environment**” gases like **R32, R454B, R454C, R1234, R290**

We see higher and higher approach to use **R290 (propane)** in many different refrigeration's systems.



GWP
R22= 1810

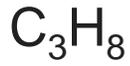


GWP
R32= 675



GWP
R290= 3

Propane



GWP R290= <4



Propane gas is a great solution as a refrigeration gas to reduce CO2 emission. GWP is reduced from 1810 for most common R22 into just 4

R290 is a **refrigerant**-grade propane **used on** a wide range of commercial **refrigeration** and air conditioning units. A highly pure propane, it has a low environmental impact and nominal global warming potential (GWP), meaning it possesses no qualities that can destroy the ozone layer.

R290 (Propane) is **refrigerant** grade propane, used as an alternative to R404A and R407 series **refrigerants** in new refrigeration and air conditioning systems. **R290** (Propane) is a Hydrocarbon and although highly flammable it is an efficient **refrigerant** that has a **low Global Warming Potential (GWP)**

Advantages of R290:

- Zero ozone depletion potential
- Very low global warming potential (<4)*
- Excellent thermodynamic properties leading to high energy efficiency
- Good compatibility with system components
- Low charges allowing smaller heat exchangers and piping dimensions

This gas is flammable and explosive so require gas leak detection for safe applications.



R290 has similar thermodynamic properties to R22, although certain characteristics such as capacity and working pressures are lower. Even so, it has excellent thermo-physical properties, and its thermal efficiency is good for most conditions, including high ambient temperatures, where the discharge temperature is low.

R290 gas is affected by the F-Gas regulation in Europe, but it is not a refrigerant destined to die, like F-gases or HFCs. Its limitation is rather on safety and use aspects due to being a highly flammable substance.



R290 Regulation

Currently the regulations applicable to **R290 or propane gas** are:

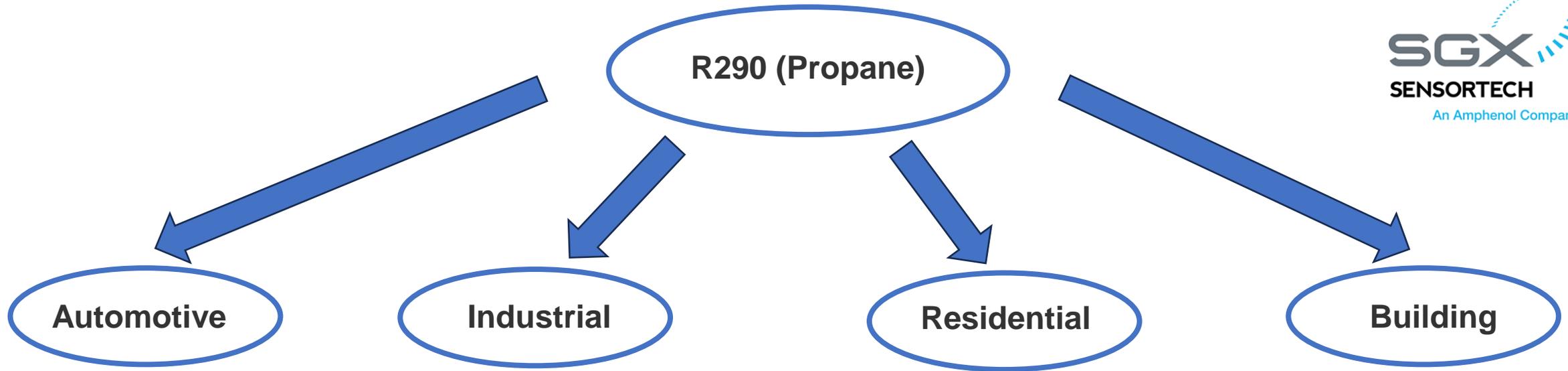
- Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases. “F-Gas Regulation”.
- European Standard (EU) EN-378:2017, concerning refrigerant charge limitations in outdoor installations, or engine room.
- Royal Decree 138/2011, of 4 February, approving the safety regulations for refrigeration installations and their complementary technical instructions.
- Royal Decree 1042/2013, of 27 December, approving the Regulation on the Tax on Fluorinated Greenhouse Gases.
- Law 6/2018, of 3 July, on the General State Budget for 2018.
- Article 85 (amendment of the previous regulation).
- Royal Decree 115/2017, of 17 February. Regulating the marketing and handling of fluorinated gases and equipment based on them, as well as the certification of professionals who use them and establishing the technical requirements for installations that carry out activities that emit fluorinated gases.



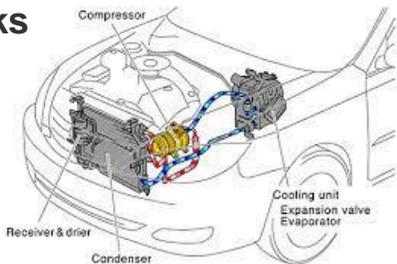
Detection technologies:

- **Thermal Conductivity** – for detection of gases with good thermal conductivity (much better than air). Used for detection of high concentrations but have low sensitivity for small leakages, not selective to one gas.
- **Catalytic sensors** – used for flammable gases, good to detect low concentrations, used in 0-LEL range (Lower Explosion Limit), Short lifetime for refrigeration systems, not selective to one gas.
- **Metal Oxide Sensors (Semiconductor Metal Oxide)** – detect very low concentration, detection is relative not absolute, longer lifetime, good to use as indicator of changes in gas concentrations, not selective to one gas.
- **NDIR** - Nondispersive infrared – good technology for selective detection of one gas (or very narrow group of gases), long lifetime, sensors build in ATEX housing.

Where propane will be used



- Personal cars air conditioning
- Transport Refrigeration
- Personal cars air conditioning
- City transportation (bus, tram)
- Trains
- Trucks



- Cold Storage
- Gas leak control manufacturers
- Commercial refrigeration
- Vending machines



- Air conditioning, Chillers
- Tumble/cloth dryers
- Water heaters



- Air to Water heat-pumps
- Office air conditioning





Heat-pumps

1. Heating systems

EU market: 1M heat pumps per year in the year 2021
 forecast – 4M heat pumps per year by 2030

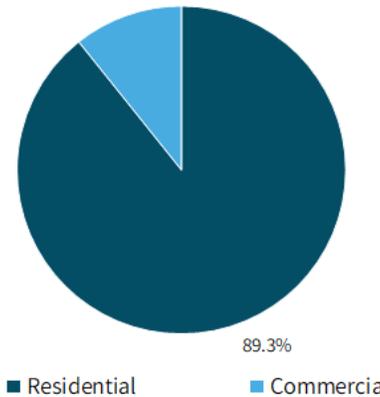
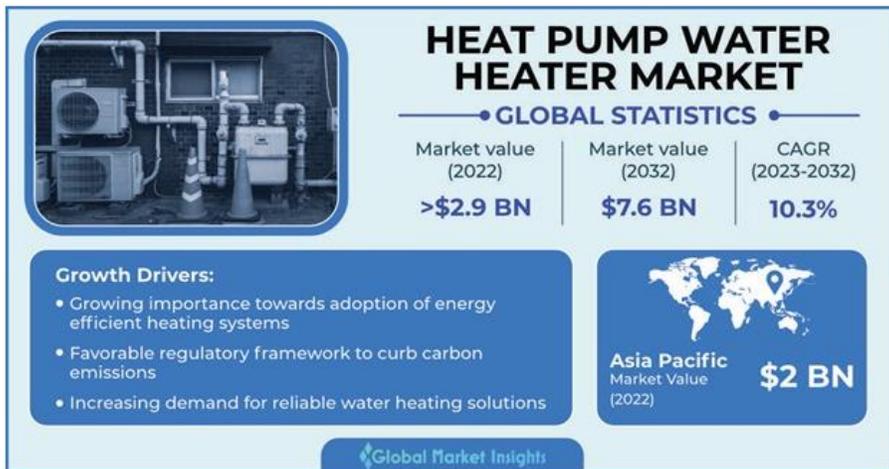
2. Dryers

EU market: 4M dryers per year – domestic tumble dryers
 30k – commercial market

https://iea-etsap.org/E-TechDS/PDF/R09_Dryers_FINAL_GSOK.pdf

3. Heat pump water heaters

Heat Pump Water Heater Market Revenue Share, By Application, 2022



Confidential

Major manufacturers operating across the industry:

- include A.O.
- Smith
- Bradford White Corporation
- USA, DAIKIN INDUSTRIES, Ltd.
- Stiebel Eltron, Inc.
- SAMSUNG
- LG Electronics
- Hubbell Heaters
- Vaillant Group International GmbH
- Trane
- Nyle Systems
- Rheem Manufacturing Company
- Vaughn Thermal Corporation
- American Water Heaters
- Lync, State Industries.



Most common gas used in cars air conditioning system is R134a

R134a GWP (100yr) is 1400

Gas need to be replaced by:

- R1234yf
- R290 (propane)
- R744 (CO2)
- R717 (ammonia)
- R600a (isobutane)

R290 efficiency vs R1234yf:

Improvement by 30% of volumetric efficiency

Improvement by 15% of compressor efficiency

Price of R290: one 750ml bottle (370g) price is 15eur

Price of 740g = 30Eur

(but we need 30% less then R1234yf -> $600g \times 0,7 = 420g$)

$420g \times 0,04Eur/g = 17eur/car$

Price of R1234yf

950g bottle cost 150eur

$600g \times 0,157eur/g = 95eur/car$

R290 vs R1234yf -> $95eur - 17eur = 78eur$ saving in gas cost

Sensor life-time

Approx car milage over 10years:

300 000km

30 000km/year

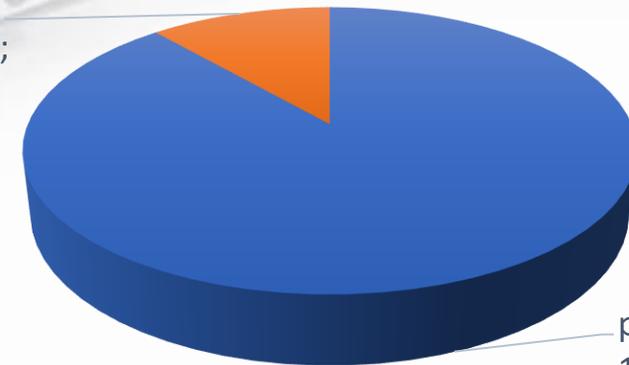
Avg car speed 30km/h

$30\ 000km/30km/h = 1000h$ use in year

$365 \times 24h = 8760h - 1000h = 7760h$ when car is not used

77 600h over 10 years and 116 400h during over 15 years

drive;
15000;
11%



parking;
116400;
89%

■ parking ■ drive

Winson



ZRT510

R454B



MH-Z1542B

R32 (also probably R290)



AM4205

A2L gas, such as R32, R454A, R454B, R454C, or A3 hydrocarbon like propane R290.

DYNAMENT

INFRARED GAS SENSORS
A PST BRAND



Axiom

R32, R454B, R454C, R290, and R744



MPS

R-32, R-454b blends, R-1234yf, (A1) R744 as well as (A3) R290 and R600

sensience

A2L GAS SENSOR



NevadaNano Technology
R32 and R454 blends

SGX

SENSORTECH
An Amphenol Company

Sensata

Technologies



Resonix™ RGD Series

R32, R454A, R454B, R454, R455 and R1234yf

R290 NDIR sensor in development

Competition – full list



LP	Company	Model	Construction	Detectable Gas	Detection Rnge	Detection Principal	Size	Lifespan	Output Signal	Connection type	Picture	Datasheet
1	Winsen	ZRT510	Module	R454B	0-50% LFL	NDIR	75.4x57x21.5 mm	15years	RS485	Connector		Datasheet
2	Winsen	MH-Z1542B	Module	R32 (also probably R290)	0-50% LFL	NDIR	32.9x22.3x11.9mm	15years	UART	9 pins		Datasheet
3	Winsen	ZP211	PCBA - module	R290	? Alarm at 2000ppm	semiconductor	25x34x14.1mm	?? (long life-time) probably 5years	PWM	5 pins terminal		Datasheet
4	Winsen	ZP201	PCBA - module	R32	? Alarm at 5000ppm	semiconductor	25x34x14.1mm	?? (long life-time) probably 5years	PWM	6 pins terminal		Datasheet
5	Winsen	MH-441D	4 series sensor	R32, R454B, R410A, R134A	0-5% VOL	NDIR	Ø20x22.4mm	15years	UART	5 pins		Datasheet
6	Winsen	MH-441D-454B	4 series sensor	R454B	0-5% VOL	NDIR	Ø20x22.4mm	15years	UART	5 pins		Datasheet
7	Winsen	MP510C	Sensor	R32, R134a, R410a, R290	100-1000ppm	Semiconductor	φ9.05x12.5	?? (long life-time) probably 5years	Analog	2 pins		Datasheet
8	Cubic	AM4205	Module	R32, R454A, R454B, R454C, R290	0-100% LFL	NDIR	76.8x59.2x19.5mm	15years	RS485+Modbus / Analog output optional	Connector		Datasheet
9	NevadaNano	MPS	Module	R-32, R-454b blends, R-1234yf, (A1) R744 as well as (A3) R290 and R600	??	Molecular Property Spectrometer		15years		5 pins		Datasheet
10	Dynament	Axiom	Module	R32, R454B, R454C, R290, and R744	R32 0-15% volume R454B 0-12% volume R454C 0-15% volume R290 0-2% volume R744 0-5% volume R744 0-500 ppm	NDIR	76x48x20mm	10 years	RS485 Modbus output	USB-C connector		Datasheet
11	Nissha	FIS5084-01NC	Module	R32, R454B, R1234yf	1,000~10,000ppm	Semiconductor		15years	Analog	5pins terminal		Datasheet
12	Nissha	FIS5084-01C1	Module	R32, R454B, R1234yf	1,000~10,000ppm	Semiconductor		15years	Analog	5pins terminal		Datasheet
13	Sensair	Sunlight HC-R	Module	R32, R454A, R454B and R454C 1	0~50% LFL	NDIR	34 x 21 x 12mm	15years	UART, I2C	4pins		Datasheet
14	N.E.T.	IRNET-P-32	Sensor	R290, R32, R452b, R-454b	0-100% LEL	NDIR	φ31,5x16,8mm	>5years	MODBUS protocol communication, Compatible UART P2P protocol	5pins		Datasheet
15	N.E.T.	IREF-LITE	Sensor	R1234yf, R1234ze, R134a, R32, R404a, R407c, R410a	0-100% LFL	NDIR	φ31,5x16,8mm	>5years	MODBUS protocol communication	5pins		Datasheet
16	Figaro	FCM2630-C01	PCBA - module	R32	0-10000ppm	Semiconductor	25 x 25 x 16mm		Analog	5pins connector		Datasheet
17	Figaro	FCM2630-E00	PCBA - module	R32	0-10000ppm	Semiconductor	25 x 34 x 16mm		Analog	5pins connector		Datasheet
18	Sensata	Resonix	Module	R32, R454 series and R455 series, R1234yf	0-100% LFL	Acoustic ?	50 x 80 x 18 mm	15 years	RS485 Modbus RTU	Wire		Datasheet

INIR – Integrated InfraRed sensors (digital)



The Integrated IR (INIR) sensor has been designed with the latest technology, using a microcontroller with an ARM7 core and via software design the necessary techniques have been implemented to increase the reliability of the device therefore minimize the probability of faults.

The INIR is a user-friendly digital Gas Sensor, which is designed to use the latest SGX Sensortech's Infrared technology.



SGX NDIR Sensors designed for refrigeration systems:

INIR2-PR2.1% (R290)

INIR2-R32

INIR2-BU1.8% (R600)

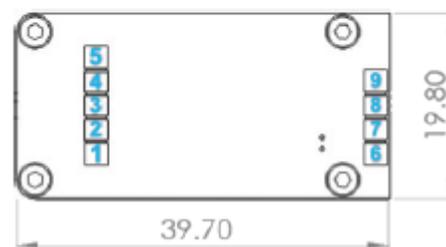
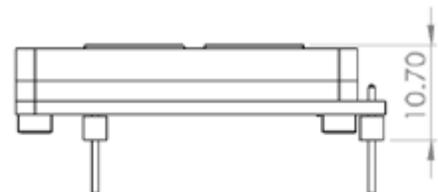
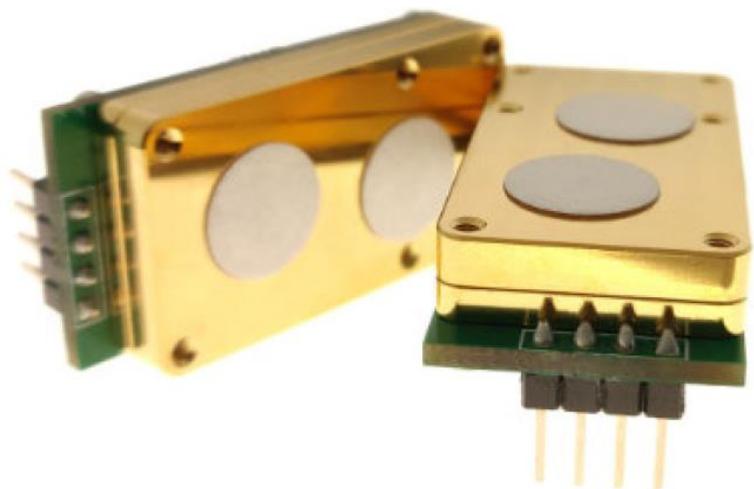


INIR – Integrated InfraRed sensors (digital)

The INIR is a user-friendly digital Gas Sensor, which is designed to use the latest SGX Sensortech's Infrared technology.



F-gas Regulation
Kigali Amendment



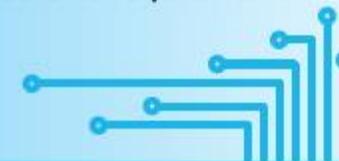
SGX NDIR4 Sensors designed for refrigeration systems:

INIR4-R290

INIR4-R32

Features

- **Factory calibrated** for up to 2.1% Propane
- Linear approximation for 100% of range
- **High Resolution** up to 50 ppm
- **Detectivity Level** at 200ppm
- **Temperature compensated**
- Serial port communication
- PWM output
- 0V/2.8V Alarm output
- **Dual channel operation**
- **Full Faults Diagnostics & Error Generation**
- **Typical Low power** consumption < 100mW (Average) in measurement mode, <30mW in standby mode.
- **Evaluation Kit** available including **PC software** for easy testing and calibration functions
- Meets UL 60335-2-40 / IEC 60079-29-1 / IEC60335-2-40 requirements



Additional versions of INIR sensor (digital NDIR sensor)

INIR5-R290 – economic version of INIR2 sensor with plastic gold-plated housing and Series 4 (ø20mm housing)

INIR6-R290 – INIR4 sensor in series 4 plastic gold-plated housing (ø20mm)

INIR7-R290 – plastic housing with connector (easy to mount by screws and easy to connect by wire)



INIR5-R290



INIR6-R290



INIR7-R290

Longer term solutions

- low power sensor
- low-cost sensor for low price applications like fridge or portable chillers (MOX based sensor)

R290, R32, R600:

Category	SGX Partnumber	Gas Type	Description
Infra Red	INIR2-BU1.8	Butane (R600)	Integrated Infra Red - gen2 - Butane - 0-1.8%(EX-d) - R600
Infra Red	INIR2-PR2.1	R290 (Propane)	Integrated Infra Red - gen2 - Propane - 0-2.1%(EX-d) - R290
Infra Red	INIR2-R32	R32 (Difluormethane)	Integrated Infra Red - gen2 - refrigeration gases - R32 - 100%LEL (EX-d)
Infra Red	INIR4-R32	R32 (Difluormethane)	Low profile InfraRed - gen4 - R32 Refrigerant gas sensor
Infra Red	INIR4-R290	R290 (Propane)	Low profile InfraRed - gen4 - R290 Refrigerant gas sensor
Infra Red	INIR-BU1.8%	Butane	Integrated Infra Red - Butane - 0-1.8%(EX-d)
Infra Red	INIR-RF-R290	R290	Integrated Infra Red - refrigeration gases - R290 - 100%LEL (EX-d)
Infra Red	INIR-RF-R32	R32	Integrated Infra Red - refrigeration gases - R32 - 100%LEL (EX-d)
Infra Red	INIR-RF-R600	R600	Integrated Infra Red - refrigeration gases - R600 - 100%LEL (EX-d)

Ammonia:

Category	SGX Partnumber	Gas Type	Description
Catalytic	VQ41TSB	Ammonia	Ammonia Pellistor Pair, 2V/100mA
Catalytic	VQ547TS	Ammonia	VQ47 Ammonia Sensor, VQ500 head for portable applications
Electrochemical	SGX-4NH3-100	Ammonia	4 Series Ammonia sensor - 100ppm
Electrochemical	SGX-4NH3-1000	Ammonia	4 Series Ammonia sensor - 1000ppm
Electrochemical	SGX-4NH3-300	Ammonia	4 Series Ammonia sensor - 300ppm
Electrochemical	SGX-7NH3-100	Ammonia	7 Series Ammonia sensor - 100ppm
Electrochemical	SGX-7NH3-1000	Ammonia	7 Series Ammonia sensor - 1000ppm
Electrochemical Module 4-series	SGX-NH3-1000-MOD	Ammonia	4 Series Ammonia Sensor Module - 1000ppm
Metal Oxide	MICS-5914	Ammonia	SMD Ammonia Sensor - range 100-10,000 ppb
Solid Polymer 1-series	PS1-NH3-100	Ammonia	Ammonia 100ppm
Solid Polymer 4-series	PS4-NH3-100	Ammonia	Ammonia 100ppm
Solid Polymer Module 1-series	PS1-NH3-100-MOD	Ammonia	Ammonia 100ppm
Solid Polymer Probes	NH3-500-Probe	Ammonia	Ammonia probe for Animal Farming

CO2:

Category	SGX Partnumber	Gas Type	Description
Infra Red	INIR2-CD100	Carbon Dioxide	Integrated Infra Red - gen2 - Carbon Dioxide - 0-100%(Ex-d)
Infra Red	INIR2-CD5	Carbon Dioxide	Integrated Infra Red - gen2 - Carbon Dioxide - 0-5%(Ex-d)
Infra Red	INIR-CD5%	Carbon Dioxide	Integrated Infra Red - Carbon Dioxide - 0-5%(Ex-d)

Methane:

Category	SGX Partnumber	Gas Type	Description
Infra Red	INIR2-ME100	Methane	Integrated Infra Red - gen2 - Methane - 0-100%(EX-d)
Infra Red	INIR2-ME5	Methane	Integrated Infra Red - gen2 - Methane - 0-5%(EX-d)
Infra Red	INIR-ME100%	Methane	Integrated Infra Red - Methane - 0-100%(EX-d)
Infra Red	INIR-ME5%	Methane	Integrated Infra Red - Methane - 0-5%(EX-d)
MEMS Pellistor	NGM-1	Methane	Natural Gas module
MEMS Pellistor	NGM-WIFI	Methane	Natural Gas module with WiFi
Thermal Conductivity	VQ546M	Methane	VQ46 Pellistor, VQ500 Head
Thermal Conductivity	VQ546MR	Methane	VQ46 Pellistor, VQ500 Head, +ve Output



R290 market will grow within next 3-5 years very fast.

„Old” gases are harmful for environment and will be blocked quite quickly with new standards.

There are of course new blends available but taking into consideration safety, cost and effectiveness Propane should be taken as most common gas used in new refrigeration systems.

- ❑ **CO2** is safe but require high pressures (100bar) and n high temperature is not effective.
- ❑ **R1234yf** have low GWP and is low flammable but when it’s burning its very toxic. Creating HF gas and COF2 (Carbonyl Fluoride) which is even more toxic than HF. It’s aslo expensive.
- ❑ **NH3** – GWP is zero but is also very toxic
- ❑ **R32** is good but GWP is still too high and will be blocked in the future.

To be successful in this market we need:

- **Release new easy to use and not expensive sensor (like INIR7-R290).**
- **UL certification.**
- **Build well know brand and this require good marketing and product management**

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BLD1 - BATTERY LEAKAGE DETECTION SENSOR (H2)

BLD1 is a Battery Failure Detection sensor that measures H₂ concentration when different battery leakage occur through CAN communication.

The module has to be placed in the battery enclosure allowing to sense H₂ gas generated during a failure mode.

BLD1 solution allow Battery Management System (BMS) to monitor the safe operation of the battery and send an **earlier signal** during a thermal runaway warning to give time to passengers to leave the vehicle safely.

DATASHEETS APPLICATION NOTES CERTIFICATIONS