Refrigerants

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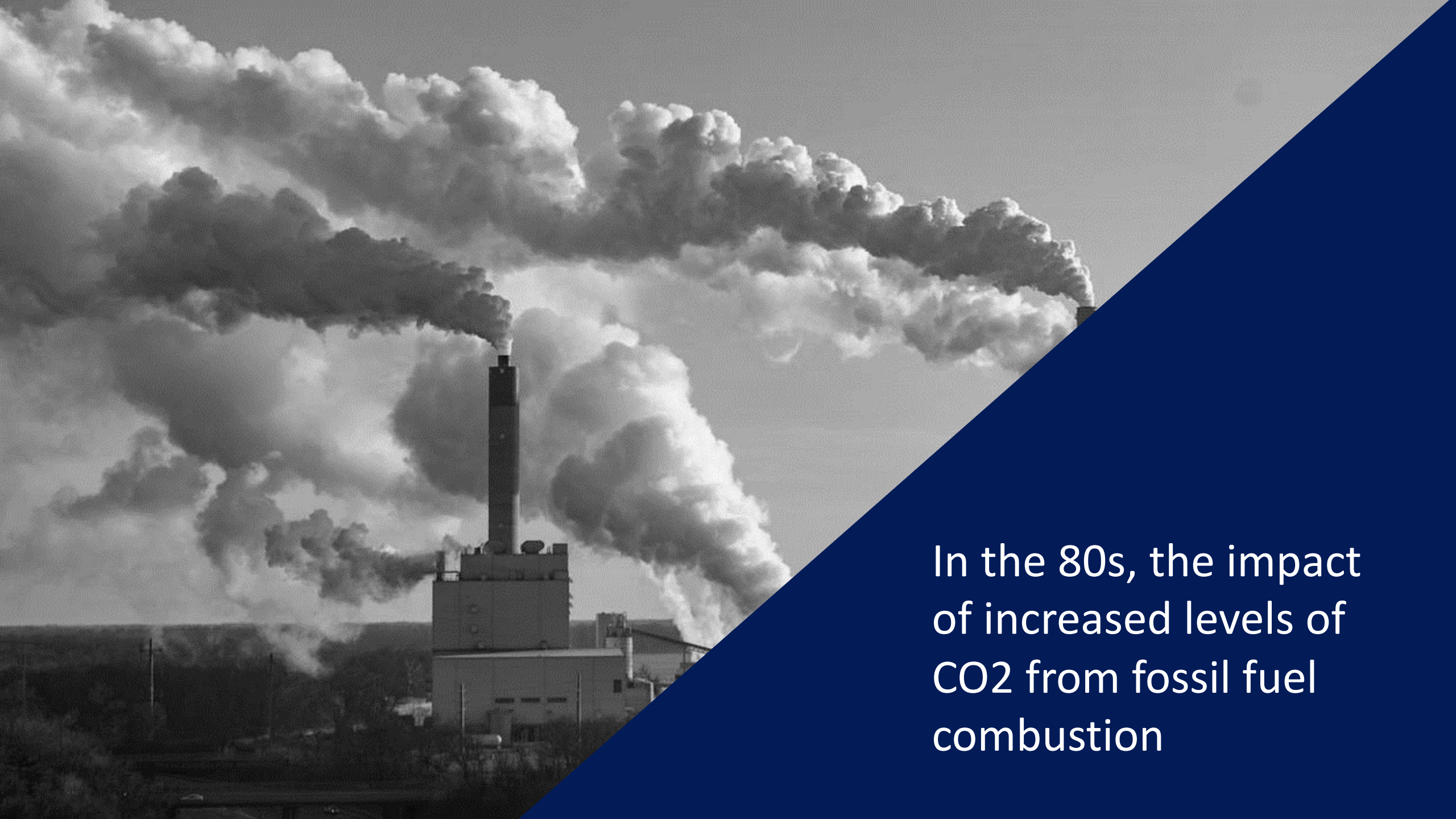
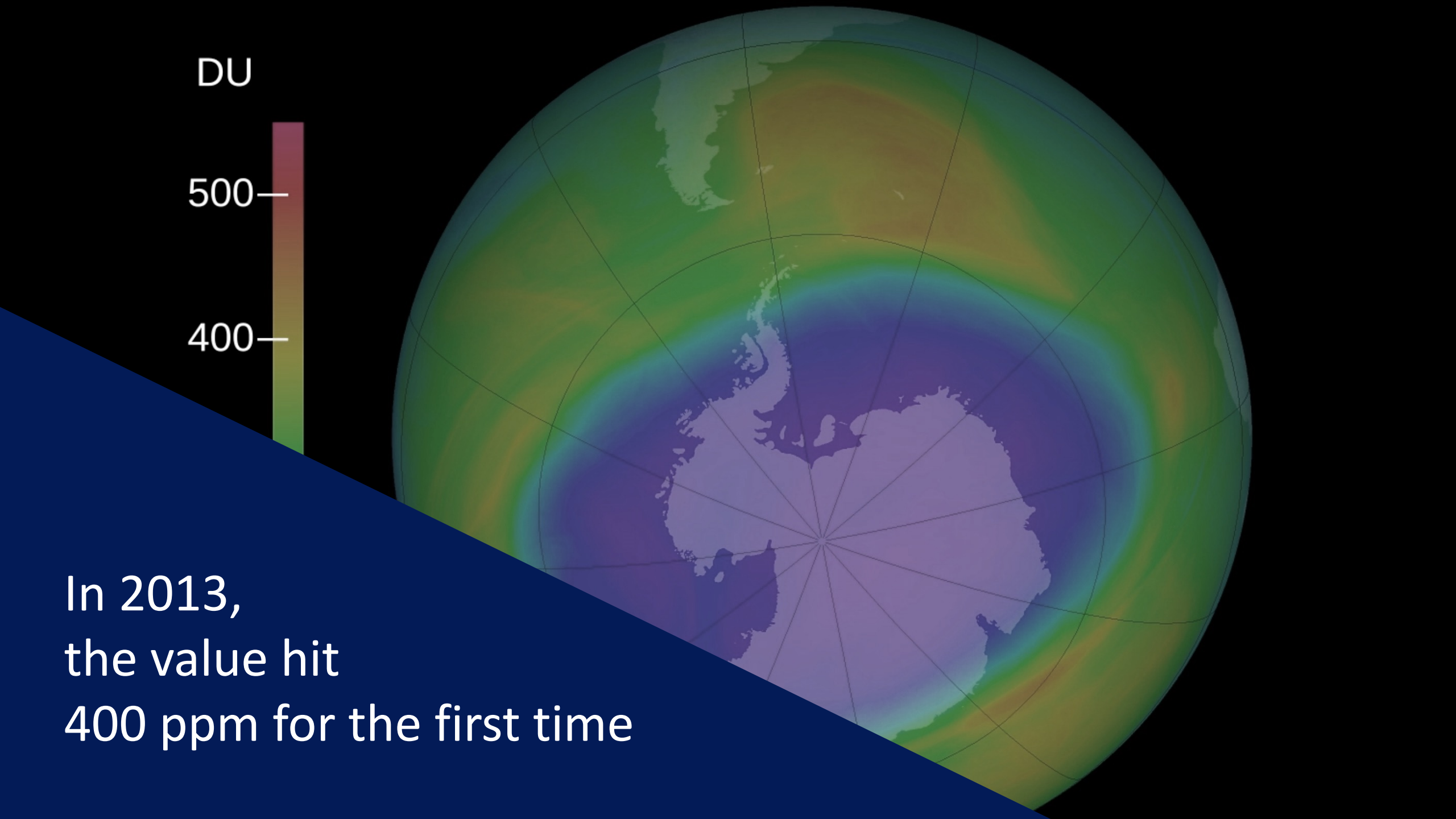
Refrigerants History

First invented by James Harrison in 1856

In 1987 the Montreal Protocol was finalized to help protect the ozone layer



In the 80s, the impact of increased levels of CO2 from fossil fuel combustion



In 2013,
the value hit
400 ppm for the first time

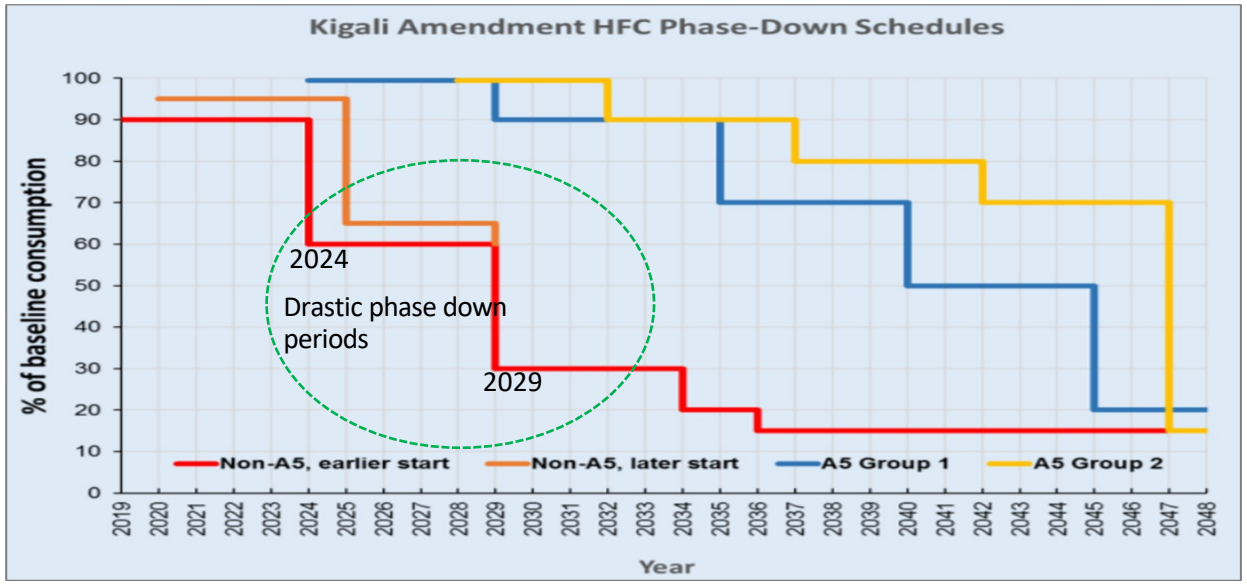
If we hit 1500 ppm, we will see a new geographic era, where climate is very different

In 2015,
the Paris Agreement recognized the urgency of the problem, and was signed by more than 180 countries

An amendment was made in Kigali to limit HFC emissions

Montreal Agreement with Kigali Amendment will accelerate refrigerant change

The AIM Act gives authority to the EPA to phase down HFC refrigerants in the US



With planned Kigali Amendment phase down of HFCs, we can hold the rise to 0.06° C or .1° F

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Refrigerant Comparisons scales

Ether

Alcohol

Ammonia

CO2

R12

R22

R410a

Life Cycle Climate Performance

The total greenhouse gas emissions due to the operation of an air conditioner or heat pump are the direct emissions of refrigerant and the indirect emissions due to energy use.

DIRECT EMISSIONS

Related to the type and amount of refrigerant used in a unit.

Countermeasure is use refrigerant with low Global Warming Potential and reduce refrigerant quantity in the units

INDIRECT EMISSIONS

Related to emissions of the construction process and largest part to equipment energy use.

Countermeasures are to reduced emission of production process and improve equipment efficiency to reduce energy consumption.

The sum of direct and indirect emission result in the Life Cycle Climate Performance (LCCP)

DIRECT EMISSIONS + **INDIRECT EMISSIONS** = **LIFE CYCLE CLIMATE PERFORMANCE (LCCP)***

- **Refrigerant GWP**
- **End of life impact**

- **Production process**
- **Equipment energy usage**
- **End of life impact**

**Indirect Emissions* make up more than 89% of a systems *Lifetime Emissions*

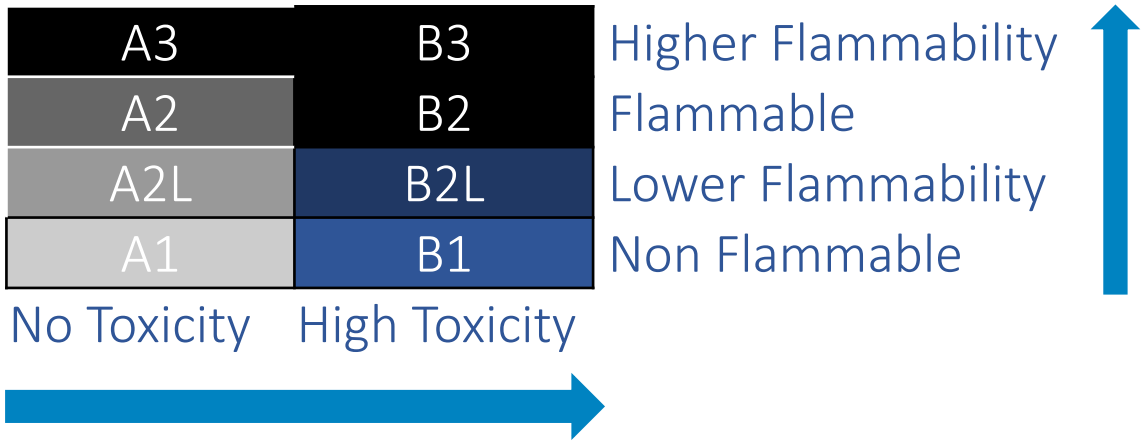
Direct Emissions

Direct emissions are directly related to refrigerant Global Warming Potential (GWP).

For application with SCROLL compressors the reference refrigerant is R410A with GWP = 2088

When evaluating alternative refrigerant, it is important to consider not only the GWP but also characteristic as flammability, toxicity and efficiency.

Refrigerants are categorized based on toxicity and flammability.
This is an alphanumeric system, where letters A and B denote lower toxicity and higher toxicity respectively, and the numeral 1 denotes no flame propagation, 2L denotes lower flammability, 2 denotes flammable and 3 denotes higher flammability.



R410A is classified A1 meaning:
non toxic and non flammable

Indirect Emissions

Indirect emissions are related to equipment efficiency.
Minimum values for efficiency indexes based on seasonal or annual operation for comfort and process application, respectively.

COMFORT COOLING

SEER

Seasonal energy efficiency ratio

COMFORT HEATING

HSPF

Heating seasonal performance factor

SCOP

Seasonal coefficient of performance

HIGH TEMPERATURE PROCESS

SEPR

Seasonal energy performance ratio

Select an alternative to R410A

The alternative to R410A should have following characteristics:

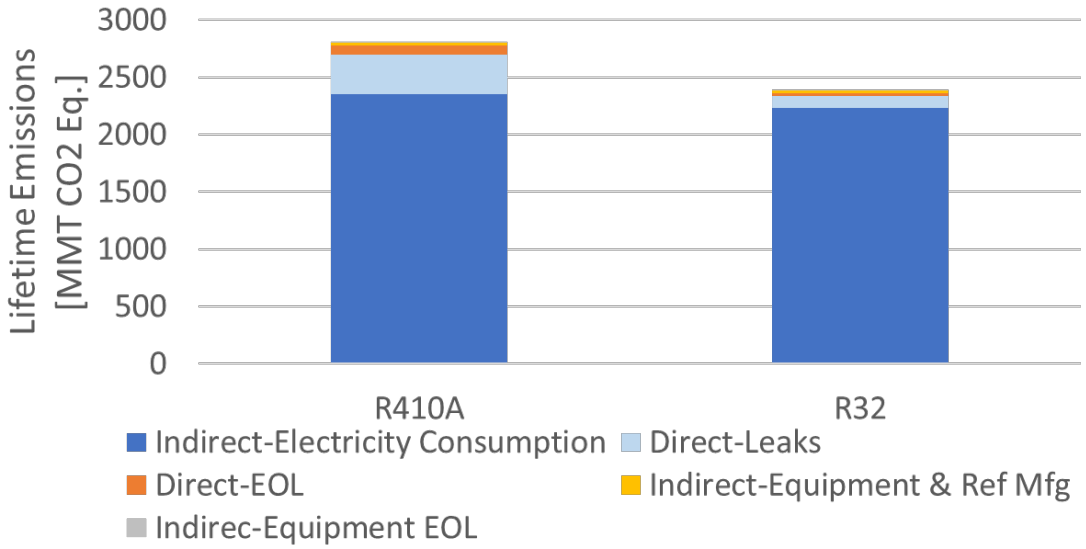
- low GWP
- be applicable without restrictions
- high efficiency of the refrigerant cycle
- easy to handle

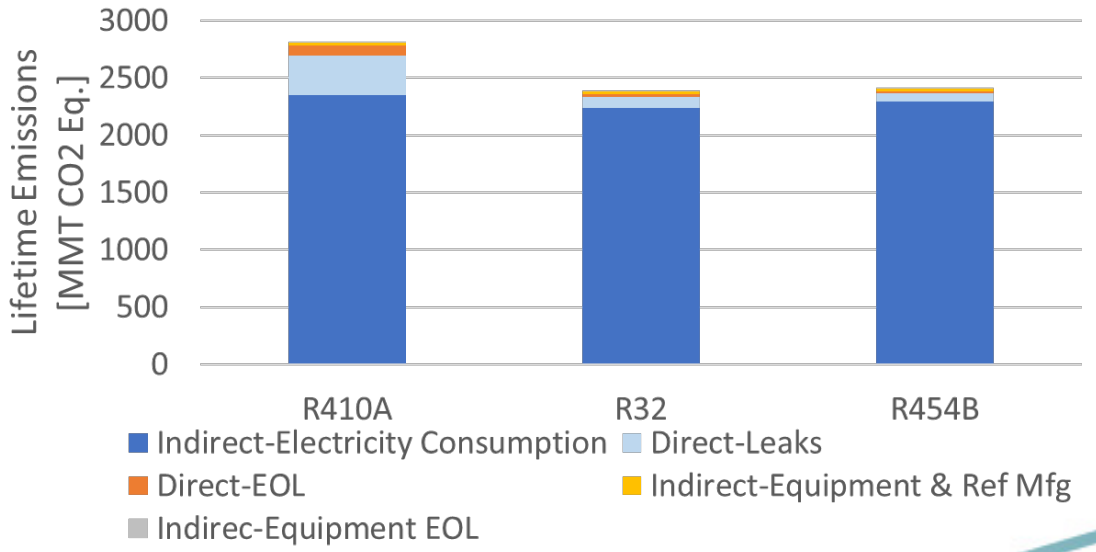
There are different alternatives each one with pros and cons on the market, the most relevant are:

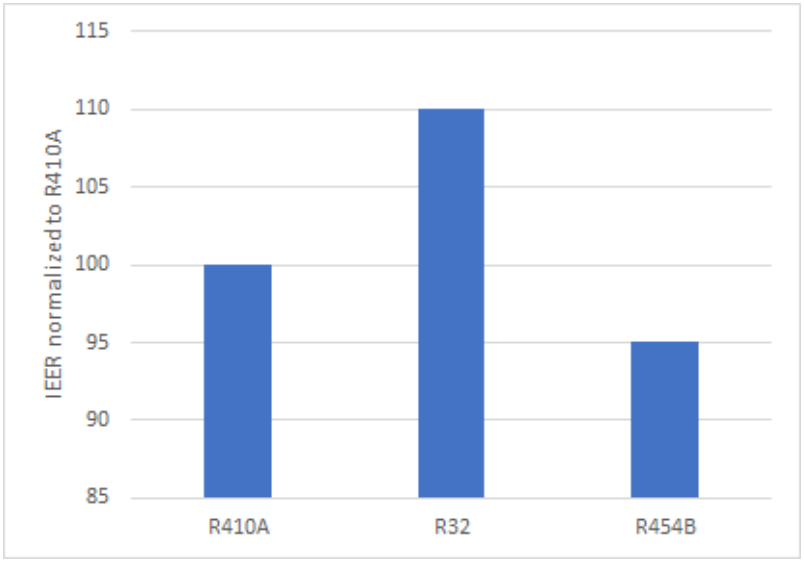
R32, R454B, R466A

The best solution is the one representing the best compromise between GWP, efficiency and applicability

Let's show you a real-world example model to compare lifetime CO2 equivalent emissions / LCCP for R410A and R32 systems. This residential model took advantage of the improved efficiency of R32 for cooling and heat pumps across all of the USA.







CO_2 eq. Emissions mostly from electricity consumption

R-32 Excellent Efficiency and Capacity; Better than R-410A and R454B

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Select an alternative to R410A

There are three leading replacement options for R410A

	R410A (reference)	R32	R454B	R466A
Global Warming Potential	2088	675	466	733
Composition	50% R32+50% R125	100% R32	68,9% R32+31,1% R1234yf	49% R32+11,5% R125+39,5% R1311
Classification	A1	A2L	A2L	A1
Temperature Glide	Yes (< 0,1K)	NO	Yes (≈ 1K)	Yes (≈ 1,5K)
System efficiency	100%	≈107%	≈102%	≈100%
System capacity	100%	≈110%	≈97%	≈95%
Refrigerant Charge	100%	60%	90%	126%
Direct Emissions [kg CO_2-eq.]*	1879	496 (73,6% ↓)	346 (81,6% ↓)	660 (64,8% ↓)
Indirect Emissions [kg CO_2-eq.]*	15384	14419 (6,3% ↓)	14662 (4,7% ↓)	15117 (1,7% ↓)
Total Emissions [kg CO_2-eq.]*	17263	14916 (13,6% ↓)	15008 (13,1% ↓)	15776 (8,6% ↓)

*Comparison is made using the Life Cycle Climate Performance (LCCP) metric, measured in kg-CO2.eq. LCCP analysis was performed using a high efficiency HP (24+ SEER), using performance gains claimed by respective refrigerant manufacturer, for a residential sized (9000 Btu/h cooling capacity), installed in Houston, TX climate zone, with an assumed annual leakage rate of 4% and end of life refrigerant leakage of 15% with a 15-year lifetime. The heating COP and SEER were adjusted based on refrigerant characteristics and performance. The physical system size, trim charge requirements and capacity were kept consistent to ensure a like-to-like comparison.

Best compromise

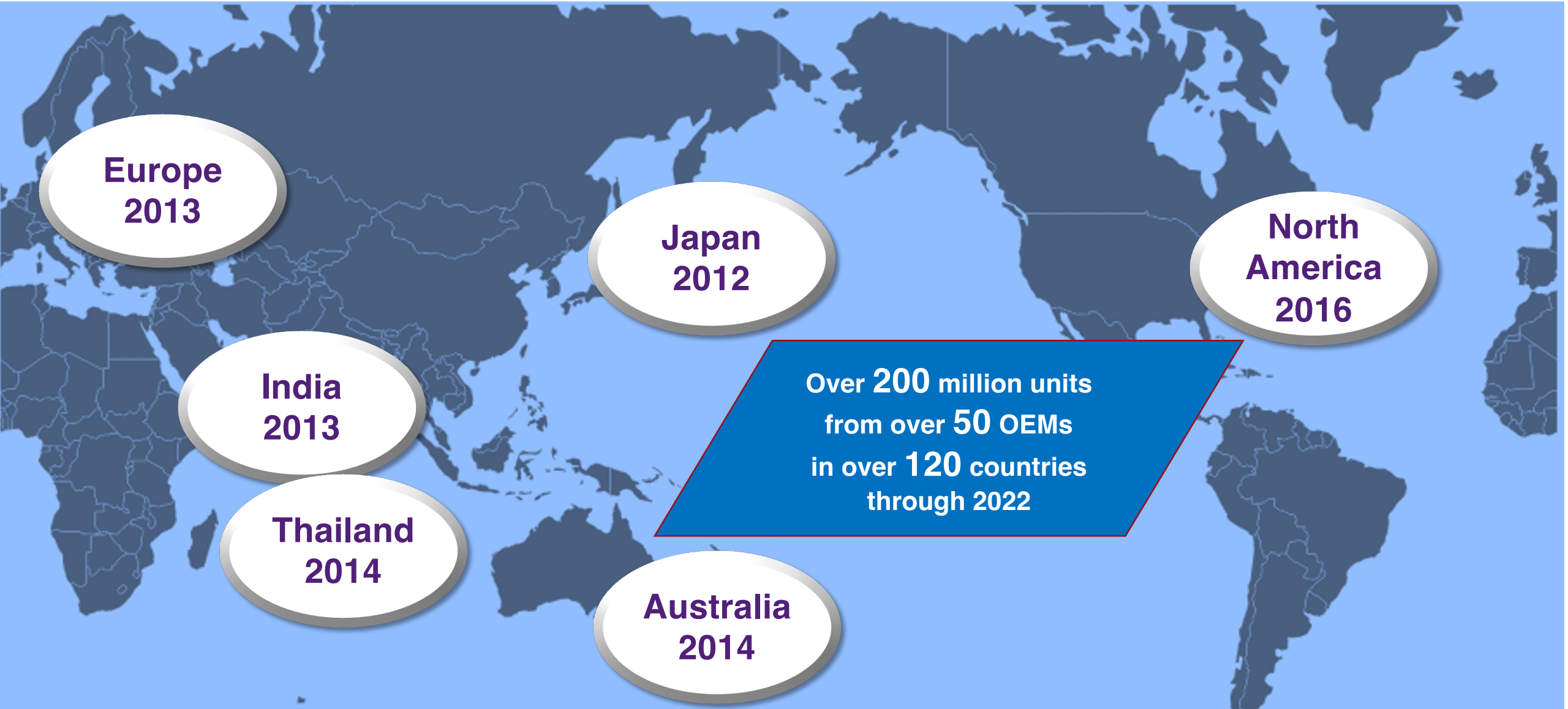
Based on LCCP analysis the best refrigerant is R32. The largest impact on Life Cycle Climate Performance is from the indirect emissions, so the refrigerant with highest efficiency is the best choice

R32 is a single component refrigerant, so is simpler to handle than most blends. Single component refrigerants do not have a temperature glide; refrigerant charging can be performed in liquid or gas phase even with an upright cylinder; there is no negative performance impact due to composition change; it can be easily reclaimed, recycled, and after reused and its production cannot be restricted by patents, as is the case for many newer low GWP blends.

Even if classified as mildly flammable R32 does not require any additional requirement for installation and operation of unit installed outdoor.

So, considering the different factors R32 is the best Low GWP alternative for R410A

R-32 is a Trusted Commodity Used Globally



What is happening in North America?

- North American HVAC manufacturers are planning to user-32 and R-454B
  - Ductless/VRV partners/suppliers are using R-32
    - ***Mitsubishi/Gree/Midea/Toshiba/Hitachi/LG/Samsung/Etc.***
- Over 120 countries are predominantly R-32
- More than 50 OEMs worldwide are providing R-32 products
- Over 200 million R-32 system are already installed worldwide
  - R-454B is in it infancy

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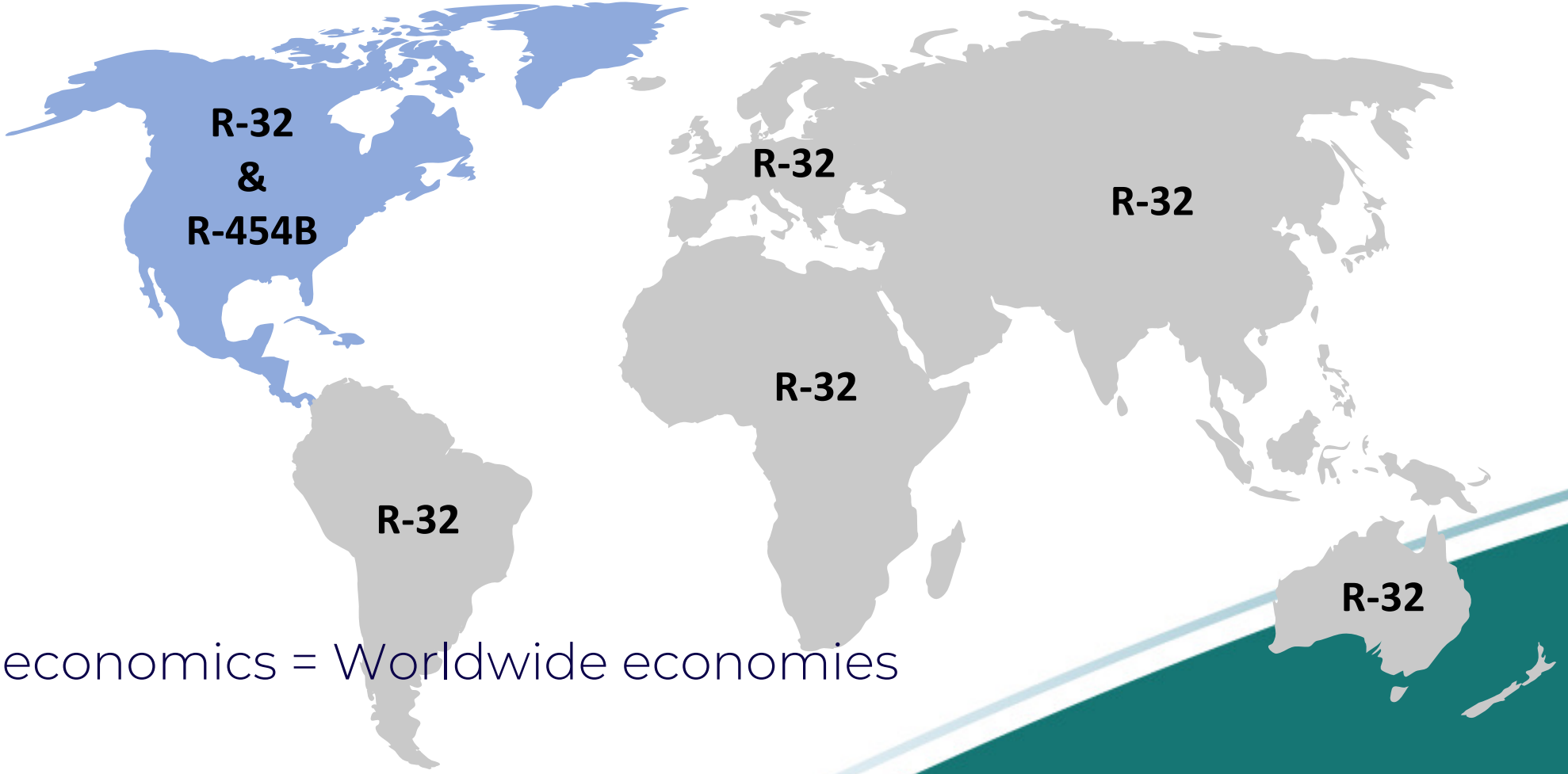
What is happening globally?



› Simple economics = Worldwide economies of scale

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Questions?

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