

## The Linde Group

*Natural Refrigerants Supply Chain*

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*Linde*

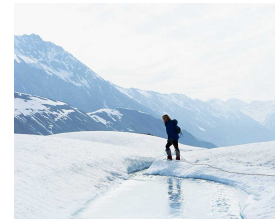
# Natural Refrigerants

Cool by nature



# The Linde Group.

Wide range of products & services



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## Gases

### Air Gases

- Nitrogen
- Oxygen
- Argon
- Rare Gases:  
Krypton, Neon and Xenon

### Other Gases

- Acetylene
- Helium
- Propane
- Carbon Dioxide
- Carbon Monoxide
- Hydrogen

### Specialty Gases

- Pure Gases
- Specialty Gas Mixtures
- Chemical Gases
- **Refrigerant Gases**

### Medical Gases

- Medical Oxygen
- Nitric Oxide (NO)
- Nitrous Oxide (N<sub>2</sub>O)

## Services

### Processes and equipment for use of gases in the most diverse applications

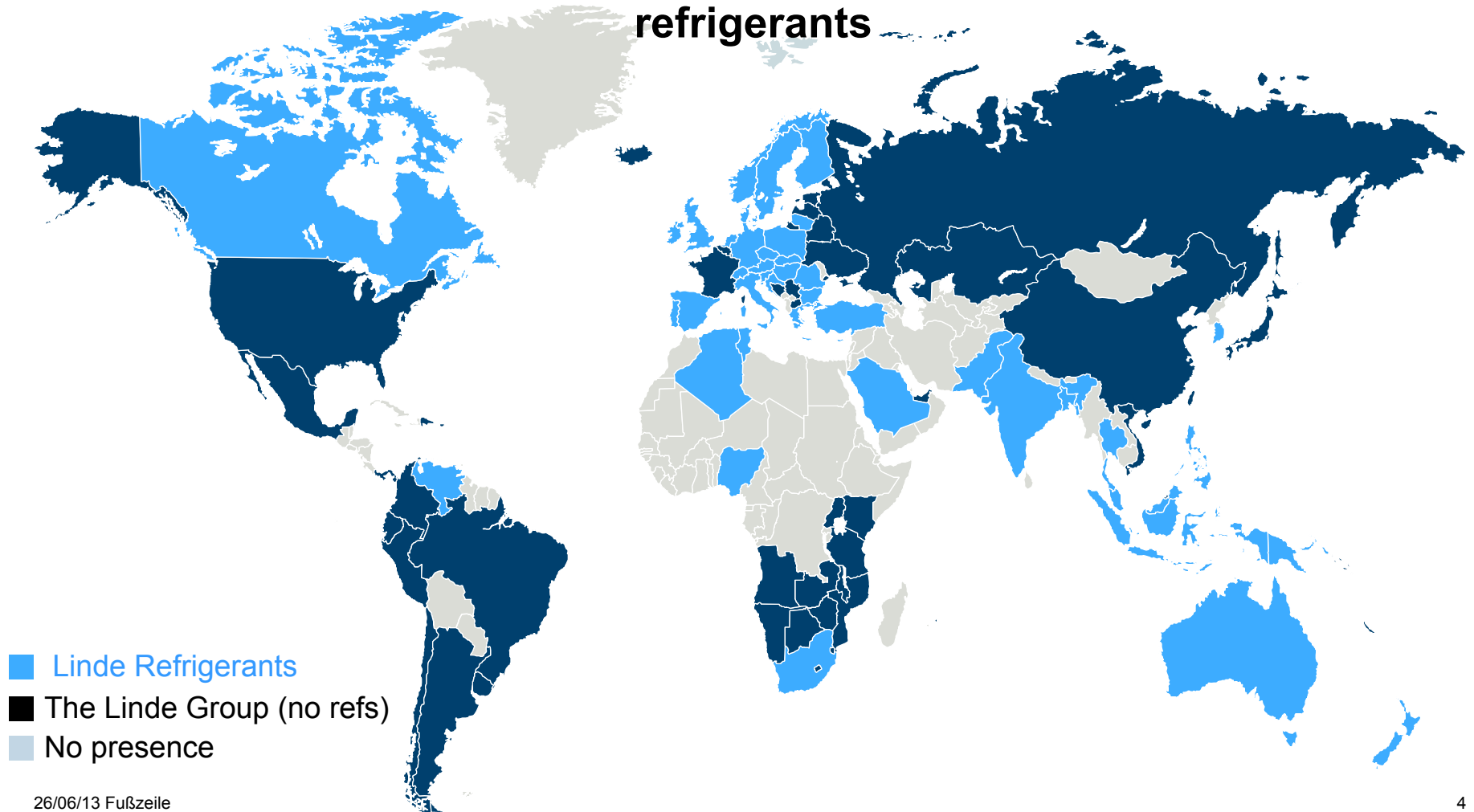
- Chilling, freezing and packaging of food
- Protection and dispensing of beverages
- Heating, melting and treatment of metal
- Welding and cutting in metal fabrication
- Water treatment and environmental protection
- Calibration and testing in laboratories
- Production of chemicals and pharmaceuticals

# Refrigerant gas & services

Operations & Logistics: Global Coverage



**Refrigerants businesses in more than 40 countries in 5 continents, making The Linde Group one of the largest & most global distributors of refrigerants**



# Natural Refrigerants

## Product Range: Summary



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**Full range of refrigerant products, including a wide range of traditional fluorocarbon refrigerants as well as natural refrigerants.**

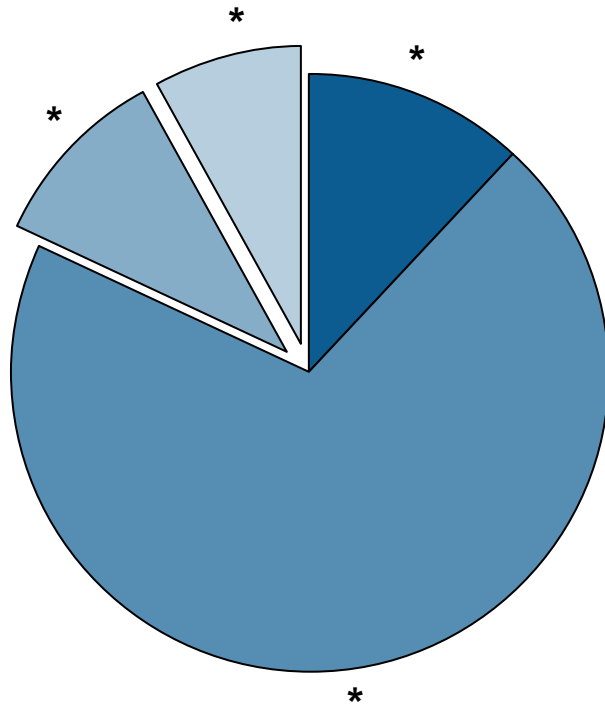
**Wide variety of package sizes including cylinders, drum tanks & road tankers.**

**Linde is also the worlds leading industrial gases company, and therefore can provide other products such as leak detection, cutting & welding gases.**

# Linde Refrigerants: Portfolio



## Sales Revenues

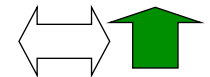


## Growth Rates

HCFCs

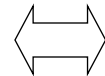


HFCs



Naturals

-R717 Ammonia



-R744 CO2



-HCs



\* Including ethylene

26/06/13 Fußzeile

# Natural Refrigerants

## Product Range



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R717

Ammonia  
(NH<sub>3</sub>)



R744

Carbon Dioxide  
(CO<sub>2</sub>)



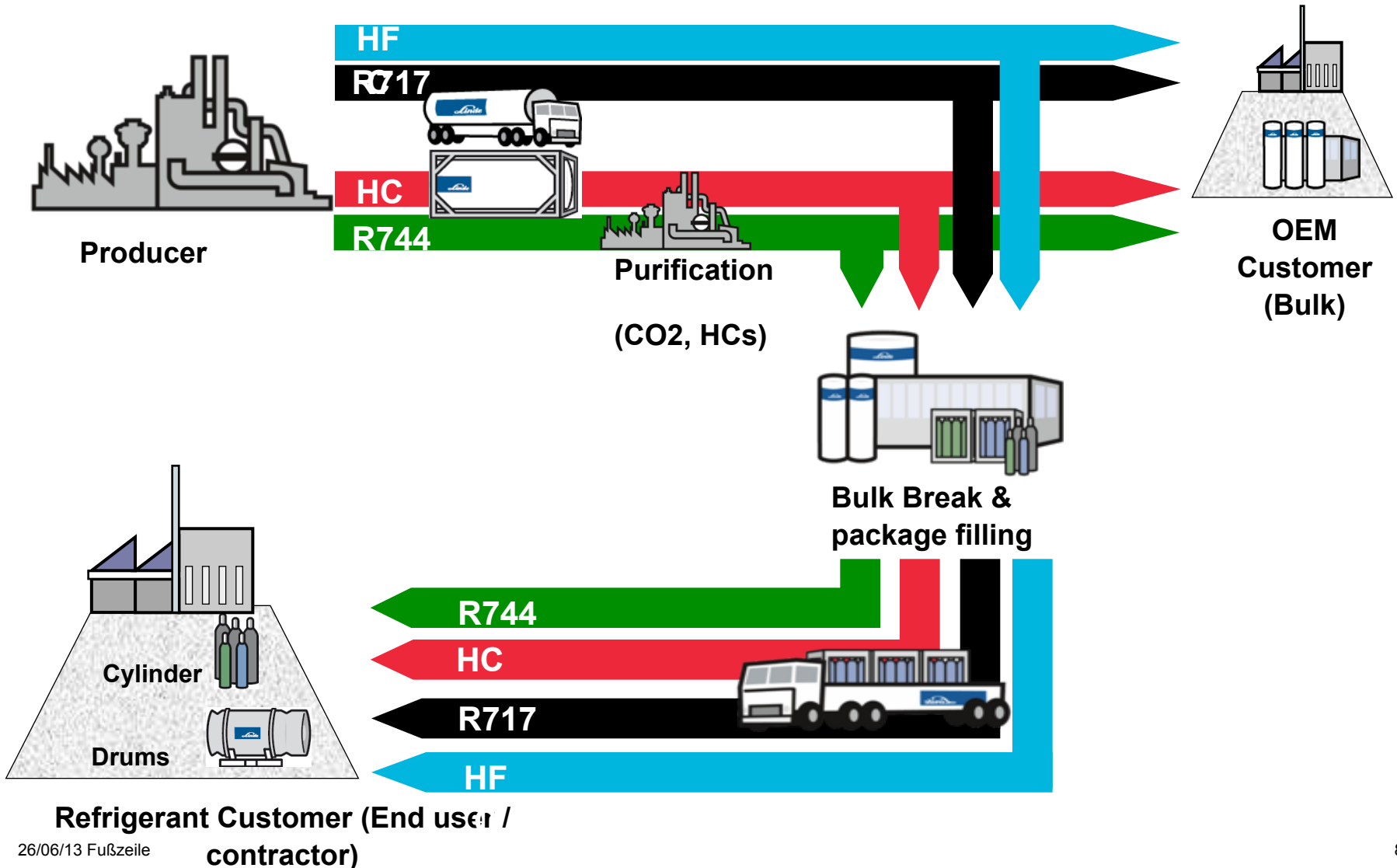
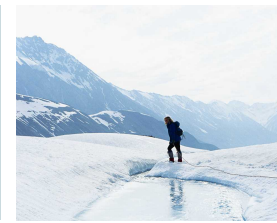
Hydrocarbons

R170 (Ethane)  
R290 (Propane)  
R600a (Isobutane)  
R1150 (Ethene / Ethylene)  
R1270 (Propene / Propylene)



# All Refrigerants have common Supply Chain steps

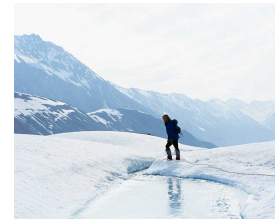
The differences are in the details!





# R717 - Ammonia

R717



## •Production

- Conversion methane / LPG into Hydrogen, reaction with Nitrogen.
- A local product, many producers & widely available
- Long existing supply chains (not a new product!!)

## •Applications

- >80% used for Fertiliser production (mostly “captive” & quite low quality)
- <10% is “traded” and of higher quality.
  - Refrigerant application - R717 - accounts for ~2% of NH<sub>3</sub> production
  - Other key applications – Explosives, Heat Treatment, De-NOX, Water treatment etc.

## •Challenges:

- Characteristics: Managing Toxicity and flammability
- Purity: In some geographies local NH<sub>3</sub> purity may be lower than R717 recommended purity. If customer needs higher specifications, no simple solution -purification & import only economically viable in certain cases

# R744 – CO<sub>2</sub>

R744



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## •Production:

- Various production routes – mostly “capture and purification” of “waste” streams
- Linde is a market leader globally in CO<sub>2</sub> with >100 product capture & purification plants
- CO<sub>2</sub> is a local product & is widely available
- Packaged R744 needs & specifications different – cylinder fleet should be separate to other grades e.g. “Industrial” or “food”.

## •Applications:

- Common applications include Food & beverage (carbonation, freezing), Chemical Synthesis, Metallurgy, Lasers, Agriculture etc.
- The volume of CO<sub>2</sub> used as R744 is very small (<1%)

## . Challenges:

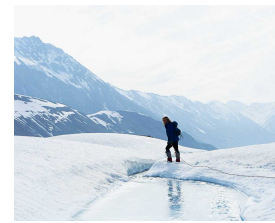
- Low volume product in many markets ( < 1 bpdpa )
- Purity: In some geographies local CO<sub>2</sub> purity may be lower than R744 recommended purity - no simple solution - purification & import expensive.

Linde CO<sub>2</sub>  
Production Capacity

R744 Demand

# Linde's Global CO<sub>2</sub> Plant Network

>100 production sources



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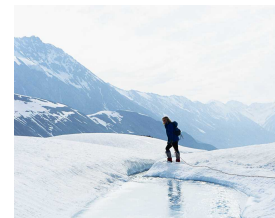


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Source: Linde operations database

# Hydrocarbons

Hydrocarbons



## •Production:

- Multiple different products – Propane, Butane, Isobutane, Ethane, Ethene.....
- Mostly a by product of natural gas processing & petroleum refining
- Most product demand is relatively low quality

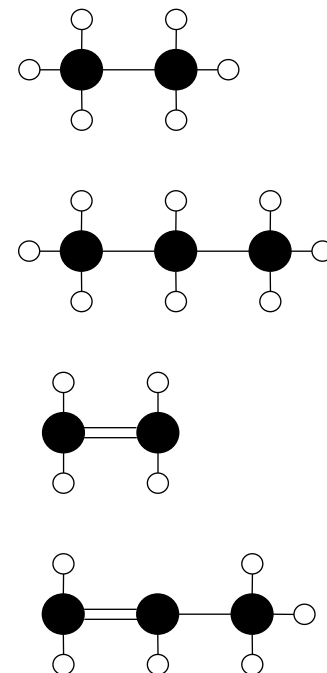
## •Applications:

- Vast majority of produced Hydrocarbons for captive use in petrochemical synthesis or as natural gas. (LPG)
- Higher purity product: Refrigerant, propellant, blowing applications.
- The volume used for these applications is very small.

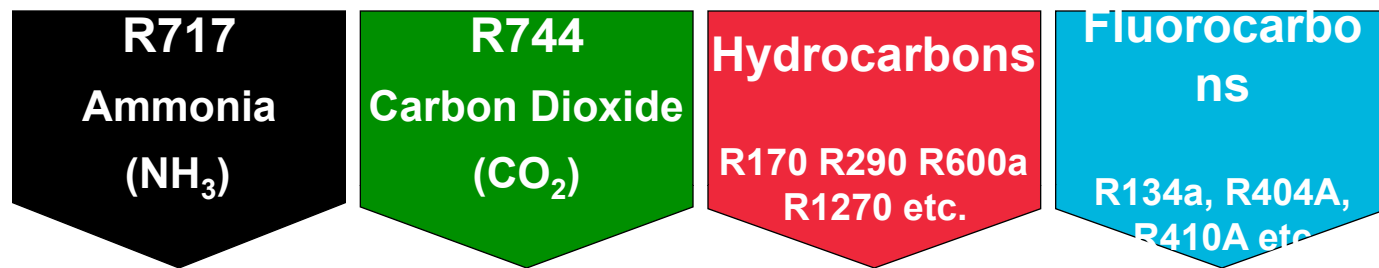
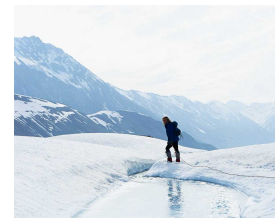
## •Challenges:

- Finding sources!: Few sources of many products & even fewer purification companies
- Managing Introduction: Low volume product in many markets

- Characteristics: Managing high flammability



# Naturals & Fluorocarbon Refrigerants



**Refrigerant Grades:  
Local vs global supply  
chain**

**LOCAL**

**LOCAL**

**REGIONAL /  
GLOBAL**

**REGIONAL /  
GLOBAL**

**Refrigerant demand as  
% overall production**

**SMALL**

**SMALL**

**SMALL (HIGHER  
FOR HIGH  
PURITIES)**

**LARGE**

**Supplier numbers?**

**MANY**

**SOME**

**FEW**

**FEW**

**Ability to patent / add  
value?**

**LOW**

**LOW/MED**

**LOW/MED**

**LOW/HIGH**

# Major Supply Chain Differences North America



**HFC,s in NA very few producers.....**

**Producers, Perform R&D, Patent, Produce, Promote, Package Distribute and Sell the products as refrigerants**

**Complete vertically integrated supply chain controlled end to end by producer**

**High Value add, and high selling price....**

**Naturals, In NA produced in BULK as commodity by various local producers**

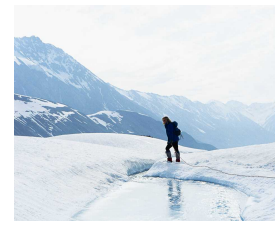
**Not Patented, Not promoted, Not packaged by producers,**

**Sold as bulk low purity commodities to other sectors**

**Rarely packaged promoted or distributed as refrigerants**

**But.....**

# Major Supply Chain Differences North America - Solutions



***All readily available and sold as specialty gases by industrial / specialty gas companies under different names***

**R744      CO2//“Coleman”//Grade 4.0//”Bone dry”//Medical Grade**  
**R290      “UHP Propane”//“Scientific”//Grade 4.0//”Instrument grade”**  
**R717      Anhydrous Ammonia //“Metallurgical Grade//Grade 4.0**  
**NH3**

***Just be sure to specify the purity & moisture content you require, in most cases, R290//10ppm R717//35ppm// R744//10 ppm (5ppm IUCGIT)***

# Natural Refrigerants – Challenges...



- **Producers are not leading development of products**

- Volumes “tiny” versus other uses of same gas
- Low margin – limited / no patent opportunity, substantial competition

- **Natural Refrigerants – a minor portion of demand and so we are at the mercy of other influences**

- Ammonia production costs, purity & availability driven by fertiliser use.
- Hydrocarbons – oil/energy
- CO<sub>2</sub> – freezing / beverage etc.

- **Finding a source of some products can be troublesome**

- Very fragmented supply situation
- Hydrocarbons
- Ammonia at correct / consistent quality

- **Biggest demand for Naturals is with OEMs...**

- OEMs often will source directly from manufacturers & offer low margins
- Service industry small at present

- **Demand patterns peaky / messy**

- Shortage to excess in 12 months.....
- Startup versus ongoing

- **Current demand can be small. Often requests are not worth the effort....**

- “One 10kg cylinder of R290 for Guatemala please”

- **Managing risk**

- Flammability / toxicity – in our supply chain, but most critically with our customers & their customers....



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# Cascade CO2 and HC System



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