

EPEE Webinar:

A five-step approach to deliver sustainable cooling

Refrigerant and Energy Modelling

Ray Gluckman, January 8th 2020



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specialists in refrigeration and climate change

Agenda

- The importance of refrigerant and energy modelling
- Background to EPEE modelling projects
- Features of latest HFC phase-down models

The importance of refrigerant and energy modelling

- required to support initiatives like *CountOnCooling*
 - to provide good understanding of options create sustainable cooling
- HFC phase-down options
 - what is the optimum rate of HFC use reduction?
- energy efficiency improvements
 - what is the overall potential to improve cooling efficiency?
- what are the key steps that must be undertaken to achieve these objectives?

**Detailed modelling of RACHP sectors is required
to properly understand these issues**

Background to EPEE

HFC Outlook Modelling Projects

Current *HFC Outlook*: a Refrigerants Model

- modelling historic and future use of HFCs
- HFC mitigation scenarios
 - used to assess different measures that reduce HFC use
- key outputs from refrigerants model
 - annual consumption of HFCs [+ other relevant gases] in tonnes CO₂e [+ tonnes]
 - annual demand for HFCs [including pre-charged imports and exports]
 - annual emissions of HFCs
 - number of equipment items
 - gas banks and gas in new equipment
 - gas in retiring equipment, gas recovery, gas reclaim

HFC Mitigation Scenarios based on "Core Actions"



1. Actions for new equipment

- use lower GWP alternatives
- design for less refrigerant charge and low leakage



2. Actions for existing equipment

- leak prevention
- retrofit with low GWP alternatives



3. Use of reclaimed refrigerant

- recovered from equipment at end-of-life
- recovered during retrofit of existing equipment

New *HFC Outlook*: a Refrigerants and Energy Model

- during 2020 we are adding energy modelling to existing *HFC Outlook*
- start point: RACHP stock data from *HFC Outlook* refrigerants model
 - provides a consistent basis for modelling both direct and indirect GHG emissions
- energy mitigation scenarios
 - will used to assess different measures that improve energy efficiency
- key outputs from energy model
 - annual consumption of energy (MWh)
 - annual indirect emissions of CO₂ from energy used
 - annual cost of energy used
 - peak power demand (MW)
- comparison of direct and indirect emissions
 - important feature, only available from a combined energy and refrigerants model

Energy Mitigation Scenarios: also based on “Core Actions”

1. Reduce cooling demand e.g.
 - building design and insulation
 - doors on cabinets
2. High efficiency new equipment
 - many different design opportunities
 - e.g. VSD compressors, micro-channel HX, better system design
3. Improved operation and maintenance
 - better control
 - identifying and fixing maintenance issues
4. Lower carbon electricity supply
5. To reduce peak demand: load shifting

Features of latest *HFC Outlook* Refrigerant Models

Important Model Features

- **Bottom-up model**
 - based on estimates of equipment population / characteristics
 - in 8 main market sectors and around 40 sub-sectors
 - modelling all sectors: RACHP, foams, aerosols etc.
 - including all relevant gases: HCFCs, HFCs, low GWP alternatives
- **Single historical estimates, 2000 to 2018**
- **Multiple forecasts, 2019 to 2050**
 - Mitigation scenarios: actions to phase-down HFCs
 - Economic growth scenarios: to allow for growing markets

Countries Modelled

- EU
- 10 developing countries
 - “Article 5” countries
 - with support from UNEP
- Example outputs in following slides
 - from model for “Country X”
 - data for an Article 5 (developing) country

HFC Outlook: Country X

Compliance View



Regulation Options

HFC Phase Down – Kigali Amendment

Article 5 Group 1

Abatement View

Clear Chart

Reset Chart

- Reported data
- Model – history
- - - Model – forecast
- === Model – phase-down

Compliance Options

Consumption

Gross (before reclaim)

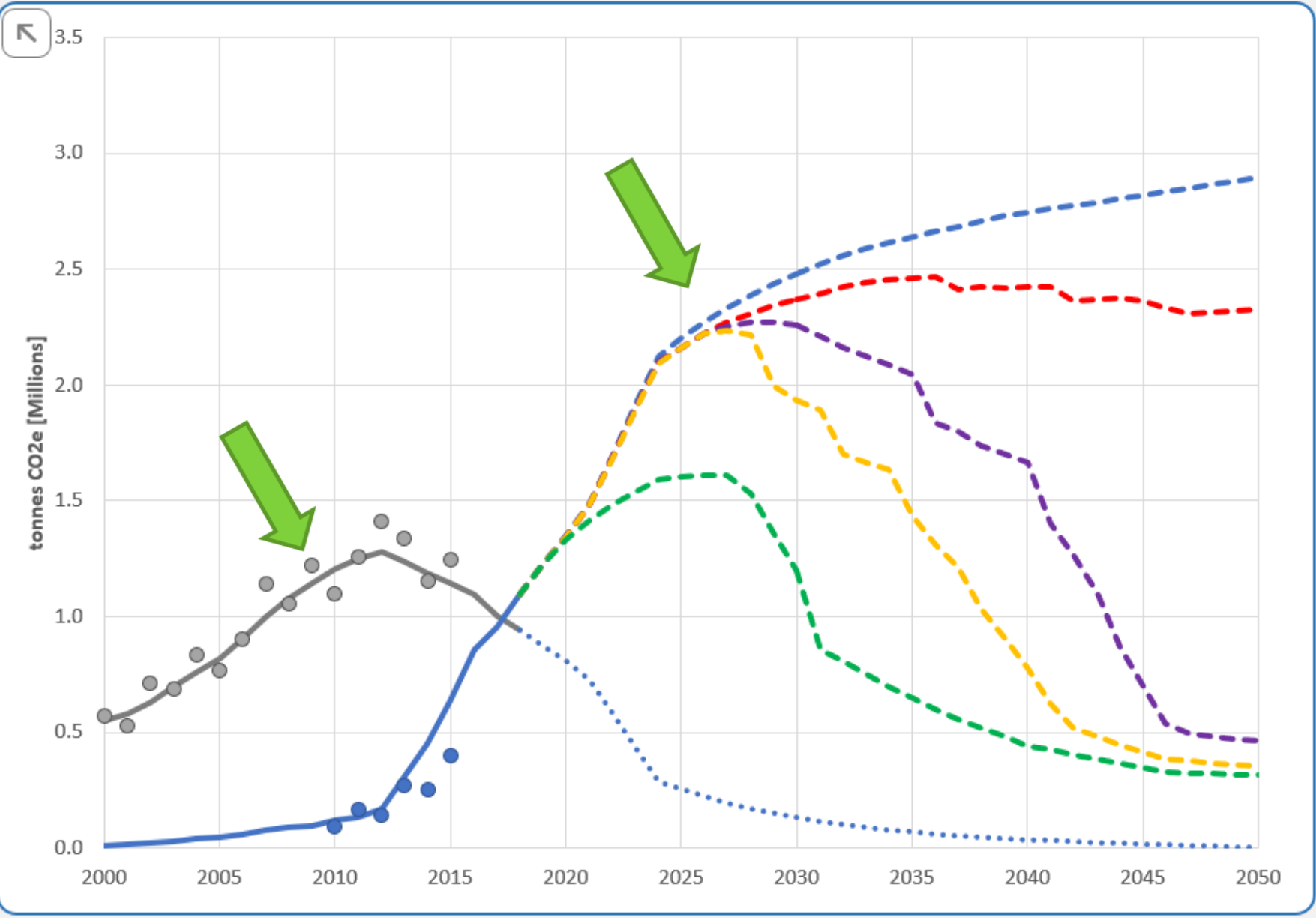
Scenario Options

Mid growth

Standard Scenarios

No Action	Unregulated	Just Compliant	Faster Action	Best Possible
HFC	HFC	HFC	HFC	HFC

Reported - history	X	X				
Modelled - history	X	X				
HCFC Forecast	X					
HFC Forecast	X	X	X	X	X	
Baseline Contribution						
Baseline Total						
Phase-down						



HFC Outlook: Country X

Compliance View



Regulation Options

HFC Phase Down – Kigali Amendment

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Compliance Options

Consumption

Gross (before reclaim)

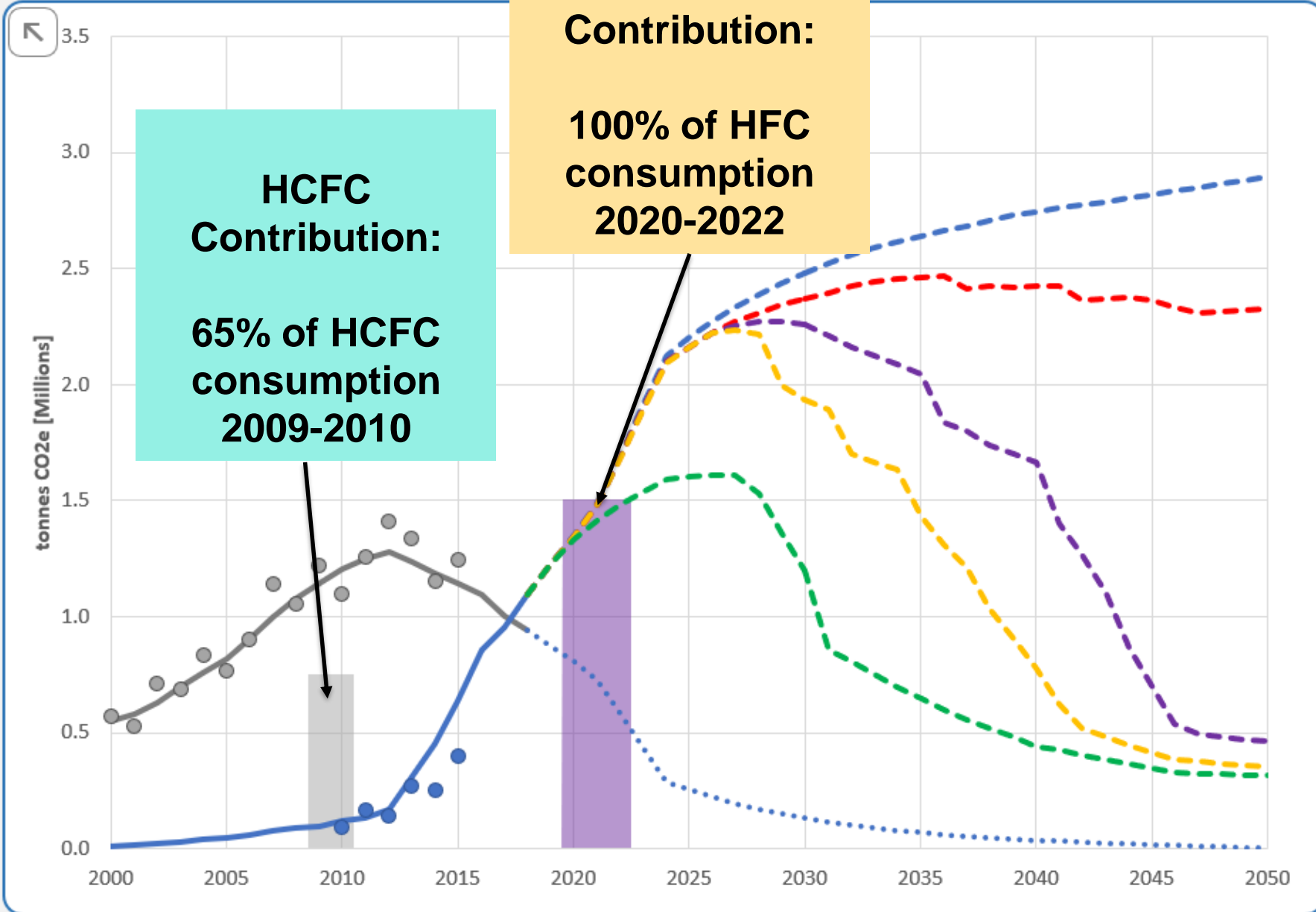
Scenario Options

Mid growth

Standard Scenarios

No Action	Unregulated	Just Compliant	Faster Action	Best Possible
HCFC	HFC	HFC	HFC	HFC

Reported - history	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Modelled - history	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
HCFC Forecast	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
HFC Forecast	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Baseline Contribution	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Baseline Total	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Phase-down	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



HFC Outlook: Country X



Regulation Options

HFC Phase Down – Kigali Amendment

Article 5 Group 1

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- Model – phase-down

Compliance Options

Consumption

Gross (before reclaim)

Scenario Options

Mid growth

Standard Scenarios

No Action

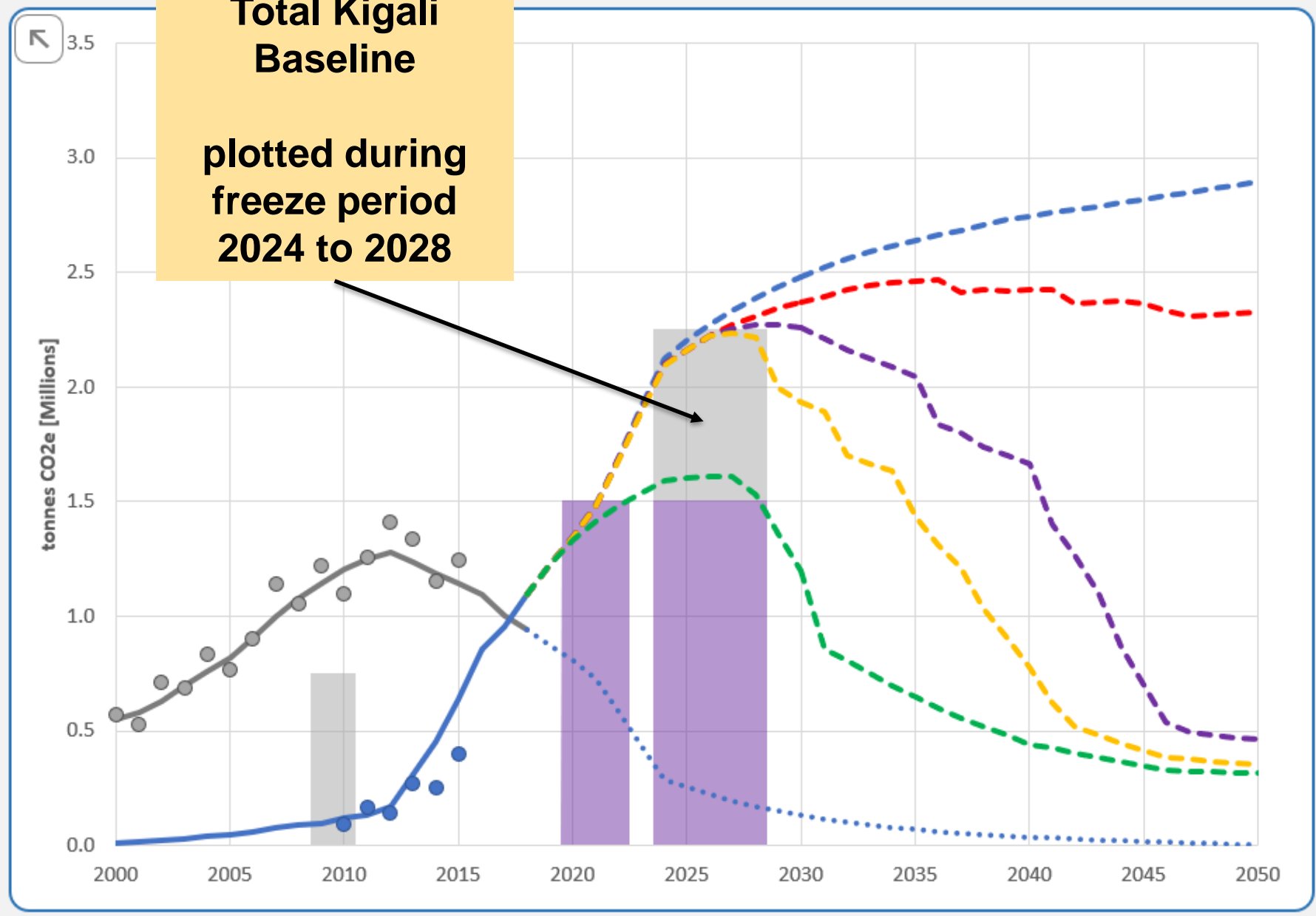
Unregulated

Just Compliant

Faster Action

Best Possible

	HCFC	HFC	HFC	HFC	HFC	HFC
Reported - history	X	X				
Modelled - history	X	X				
HCFC Forecast	X					
HFC Forecast	X	X	X	X	X	X
Baseline Contribution	X		X			
Baseline Total			X			
Phase-down						



HFC Outlook: Country X

Compliance View



Regulation Options

HFC Phase Down – Kigali Amendment

Article 5 Group 1

Abatement View

Clear Chart

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- Reported data
- Model – history
- - - Model – forecast
- === Model – phase-down

Compliance Options

Consumption

Gross (before reclaim)

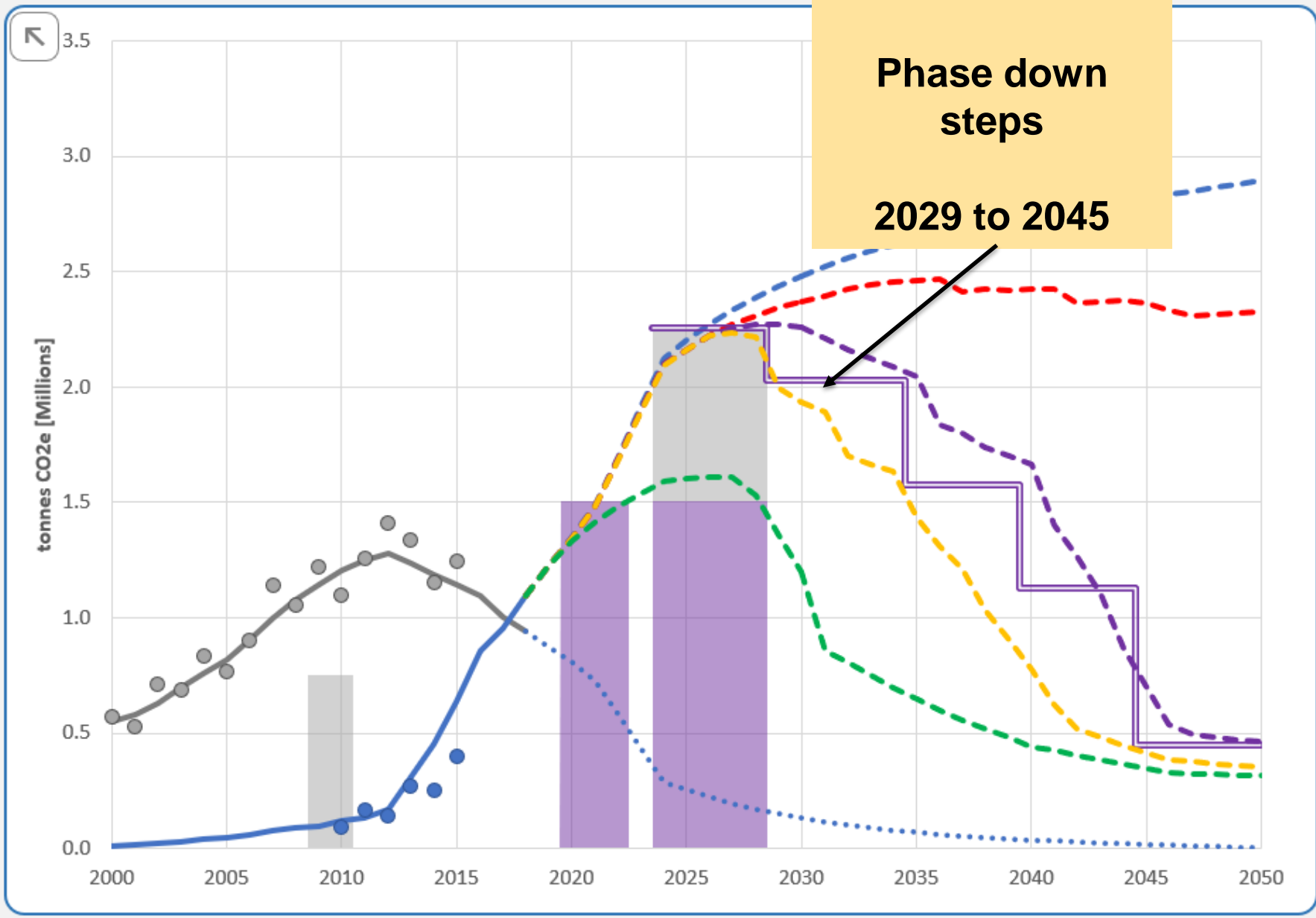
Scenario Options

Mid growth

Standard Scenarios

No Action	Unregulated	Just Compliant	Faster Action	Best Possible	
HCFC	HFC	HFC	HFC	HFC	HFC

Reported - history	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			
Modelled - history	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			
HCFC Forecast	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
HFC Forecast	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Baseline Contribution	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Baseline Total	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Phase-down	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



Standard Scenarios

Mitigation Scenarios

- No Action
- Unregulated
- Just Compliant
- Faster Action
- Best Possible

Growth Scenarios

- Low
- Mid
- High

3 Growth Scenarios

- Table View
- Custom Views

Display Options

- Scenario
- Output
- Main Sector
- Sub-Sector
- Gas Type
- Gas

Units: tonnes CO₂e

Other Options

5 Mitigation Scenarios

Market Selector

Gas Selector

Main Market Sector: All

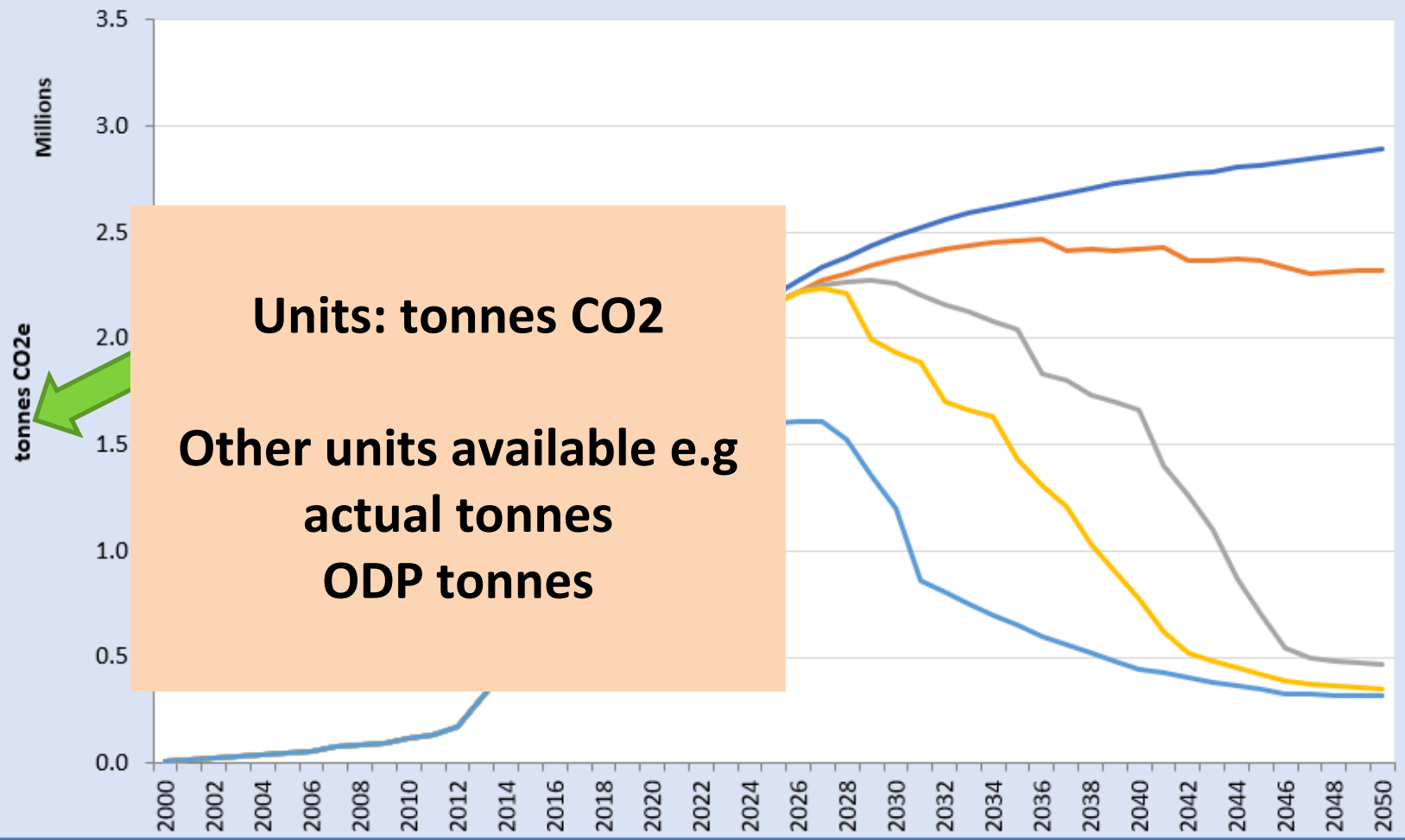
Market Sub-Sector: All

Mitigation Scenario: See legend

Growth Scenario: See legend

Gas Type: HFC

Gas: All



Units: tonnes CO₂

Other units available e.g
actual tonnes
ODP tonnes

- No Action - Mid
- Unregulated - Mid
- Just Compliant - Mid
- Faster Action - Mid
- Best Possible - Mid

Standard Scenarios

Mitigation Scenarios

- No Action
- Unregulated
- Just Compliant
- Faster Action
- Best Possible

Growth Scenarios

Low Mid High

Custom Scenarios

Output Selector [Filter icon]

Market Selector [Dropdown arrow]

Gas Selector [Filter icon]

Output Type: Gas Consumption (Montreal Protocol definition)

Output Sub-Type: All

Main Market Sector: All

Market Sub-Sector: All

Mitigation Scenario: See legend

Growth Scenario: See legend

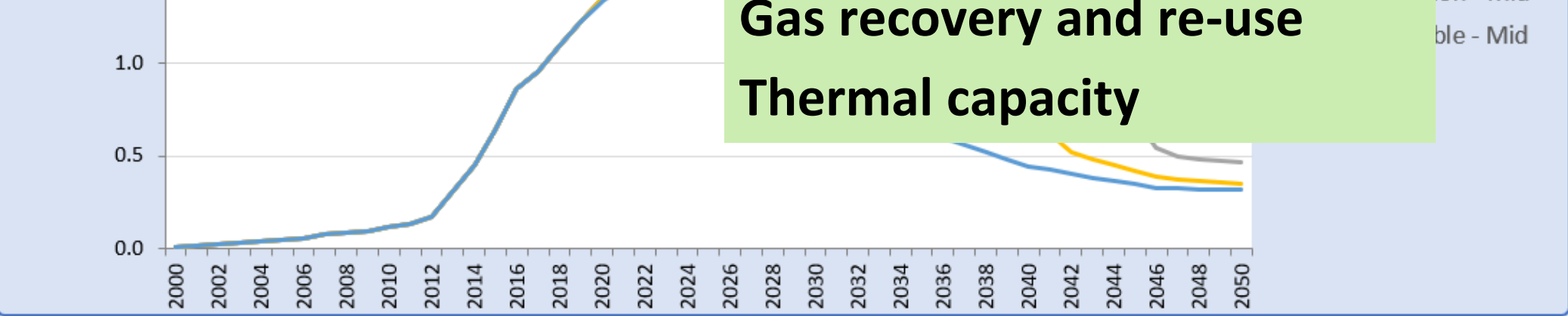
Gas Type: HFC

Gas: All

Output Type: Gas Consumption
(Montreal Protocol definition)

Several other outputs available:

- Gas Consumption
- Gas Demand
- Gas Emissions
- Gas Banks
- Number of equipment items
- Gas recovery and re-use
- Thermal capacity



HFC Outlook: Country X

Consumption View



Standard Scenarios

Mitigation Scenarios

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- Best Possible

Growth Scenarios

- Low
- Mid
- High

Custom Scenarios

Output Selector

Output Type: Gas Consumption (Montreal Protocol definition)

Output Sub-Type: All

Main Market Sector: All

Market Sub-Sector: All

Market Selector

Gas Selector

Mitigation Scenario: See legend

Growth Scenario: See legend

Gas Type: HFC

Gas: All

Viewing Options

Time Series | Single Year

Table View | Custom Views

Display Options

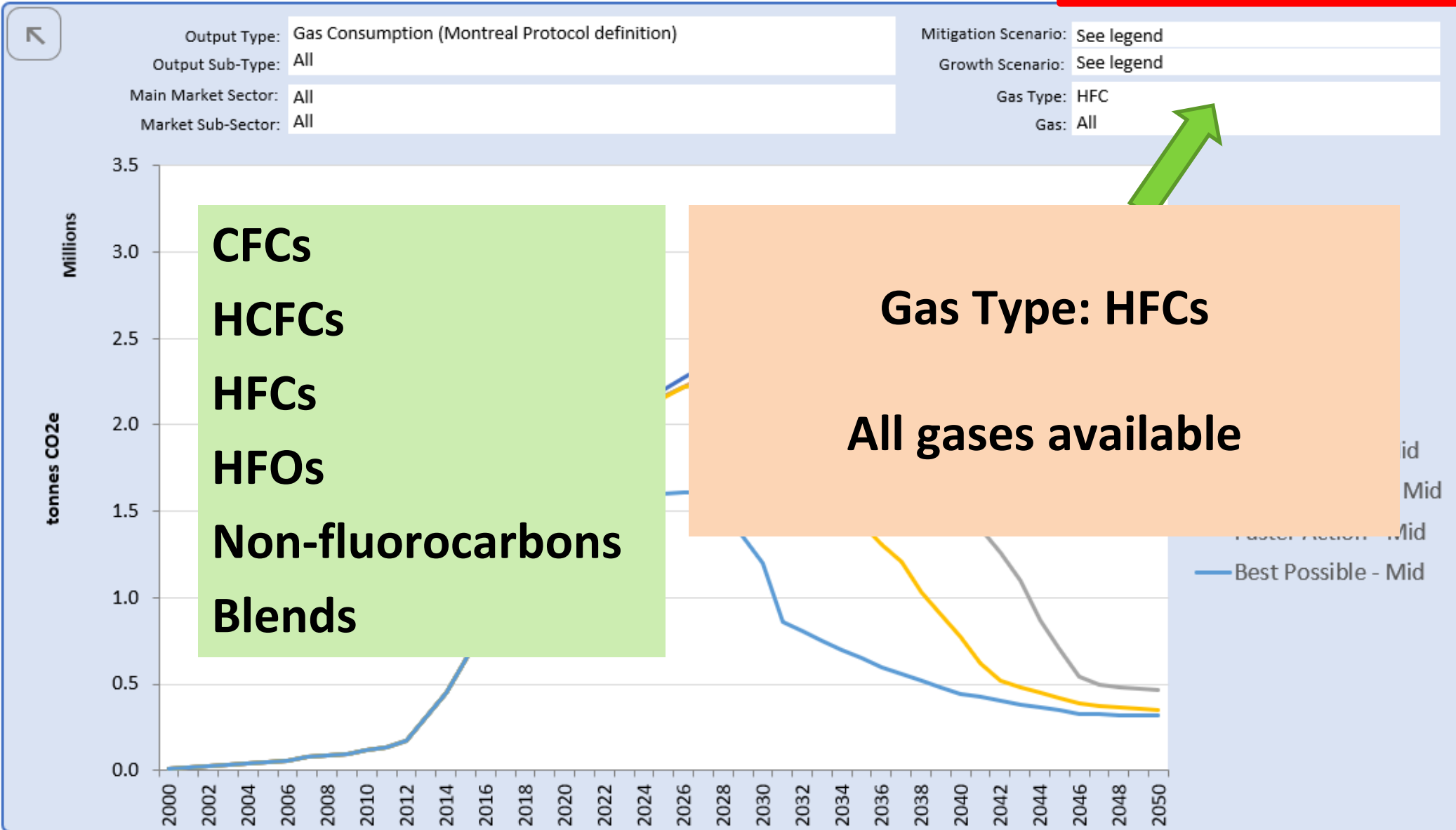
Scenario | Output

Main Sector | Sub-Sector

Gas Type | Gas

Units: tonnes CO2e

Other Options



Market Selector:

11 main sectors and 40 sub-sectors used to define markets:

Market Selector

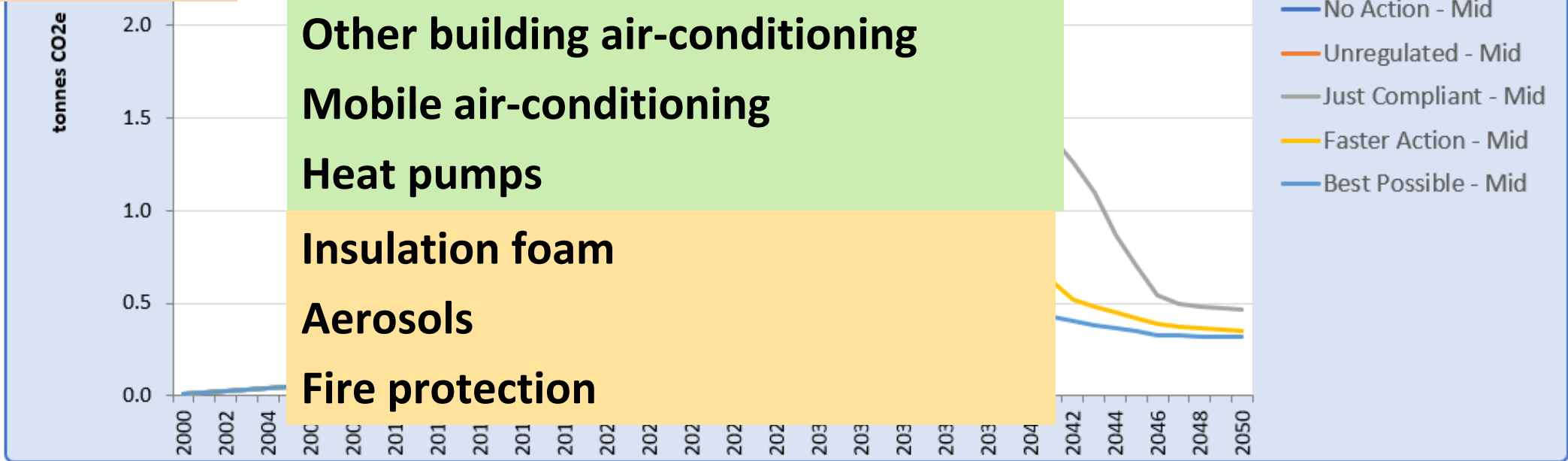
Gas Selector

Residential refrigeration
 Commercial refrigeration
 Industrial refrigeration
 Transport refrigeration

Residential air-conditioning
 Other building air-conditioning
 Mobile air-conditioning
 Heat pumps

Insulation foam
 Aerosols
 Fire protection

Mitigation Scenario: See legend
 Growth Scenario: See legend
 Gas Type: HFC
 Gas: All



Viewing Options

Time Series (selected) | Single Year
 Table View | Custom Views

Display Options

Scenario (selected) | Output
 Main Sector | Sub-Sector
 Gas Type | Gas

Units: tonnes CO2e ▲

Other Options ▼

Standard Scenarios

Mitigation Scenarios

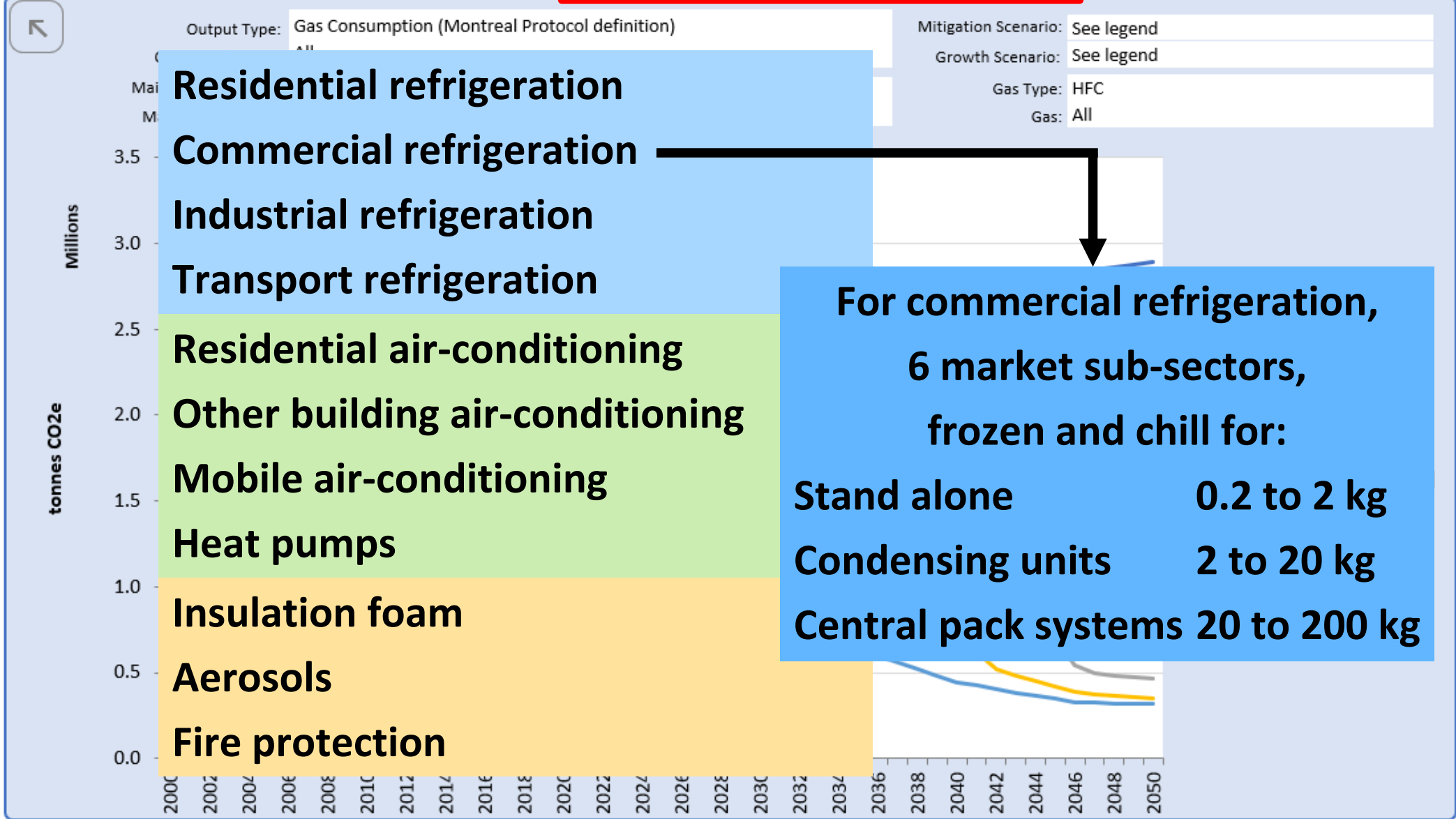
- No Action
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- Faster Action
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Growth Scenarios

- Low
- Mid
- High

Custom Scenarios

Output Selector ▼ **Market Selector** ▼ Gas Selector ▼



For commercial refrigeration, 6 market sub-sectors, frozen and chill for:

Stand alone	0.2 to 2 kg
Condensing units	2 to 20 kg
Central pack systems	20 to 200 kg

Standard Scenarios

Mitigation Scenarios

- No Action
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Growth Scenarios

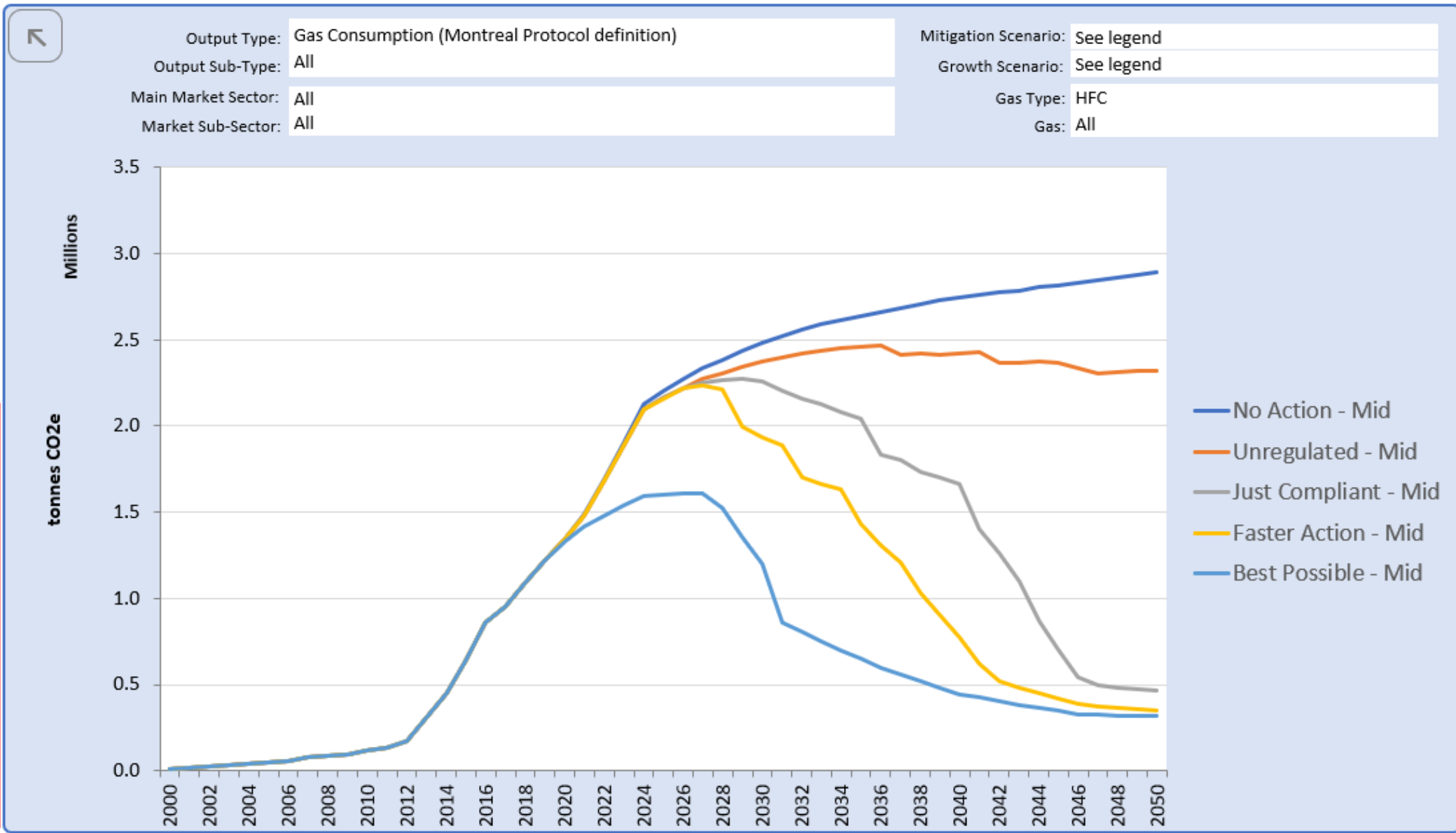
- Low
- Mid
- High

Custom Scenarios

Output Selector

Market Selector

Gas Selector



Viewing Options

- Time Series
- Single Year
- Table View
- Custom Views

Display Options

- Scenario
- Output
- Main Sector
- Sub-Sector
- Gas Type
- Gas

Units: tonnes CO2e

Other Options



Standard Scenarios

Mitigation Scenarios

- No Action
- Unregulated
- Just Compliant**
- Faster Action
- Best Possible

Growth Scenarios

- Low
- Mid**
- High

Custom Scenarios

Viewing Options

- Time Series**
- Single Year
- Table View
- Custom Views

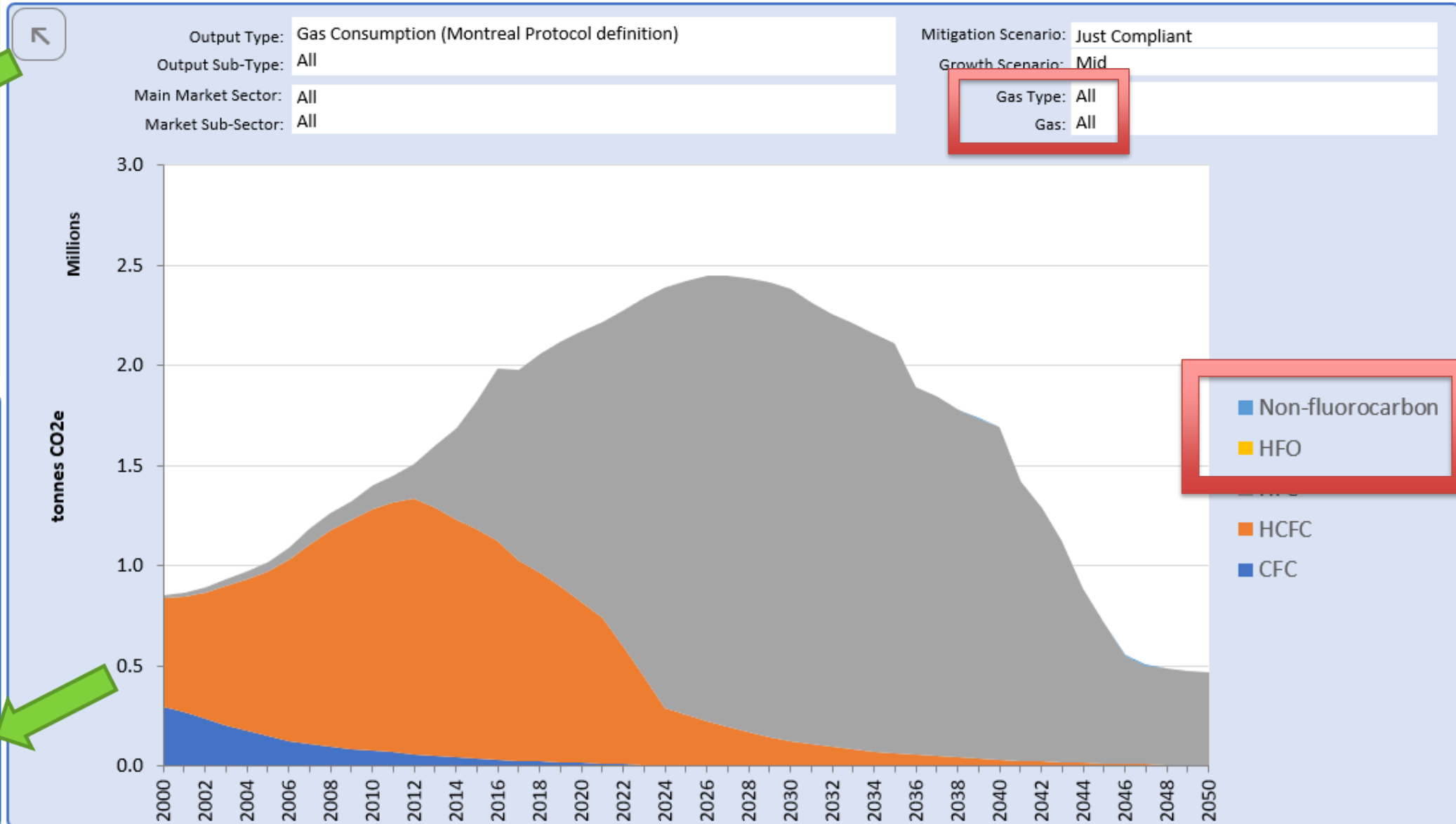
Display Options

- Scenario
- Output
- Main Sector
- Sub-Sector
- Gas Type**
- Gas

Units: tonnes CO2e

Other Options

Output Selector **Market Selector** **Gas Selector**





Standard Scenarios

Mitigation Scenarios

No Action

Unregulated

Just Compliant

Faster Action

Best Possible

Growth Scenarios

Low

Mid

High

Custom Scenarios

Viewing Options

Time Series

Single Year

Table View

Custom Views

Display Options

Scenario

Output

Main Sector

Sub-Sector

Gas Type

Gas

Units: tonnes

Other Options

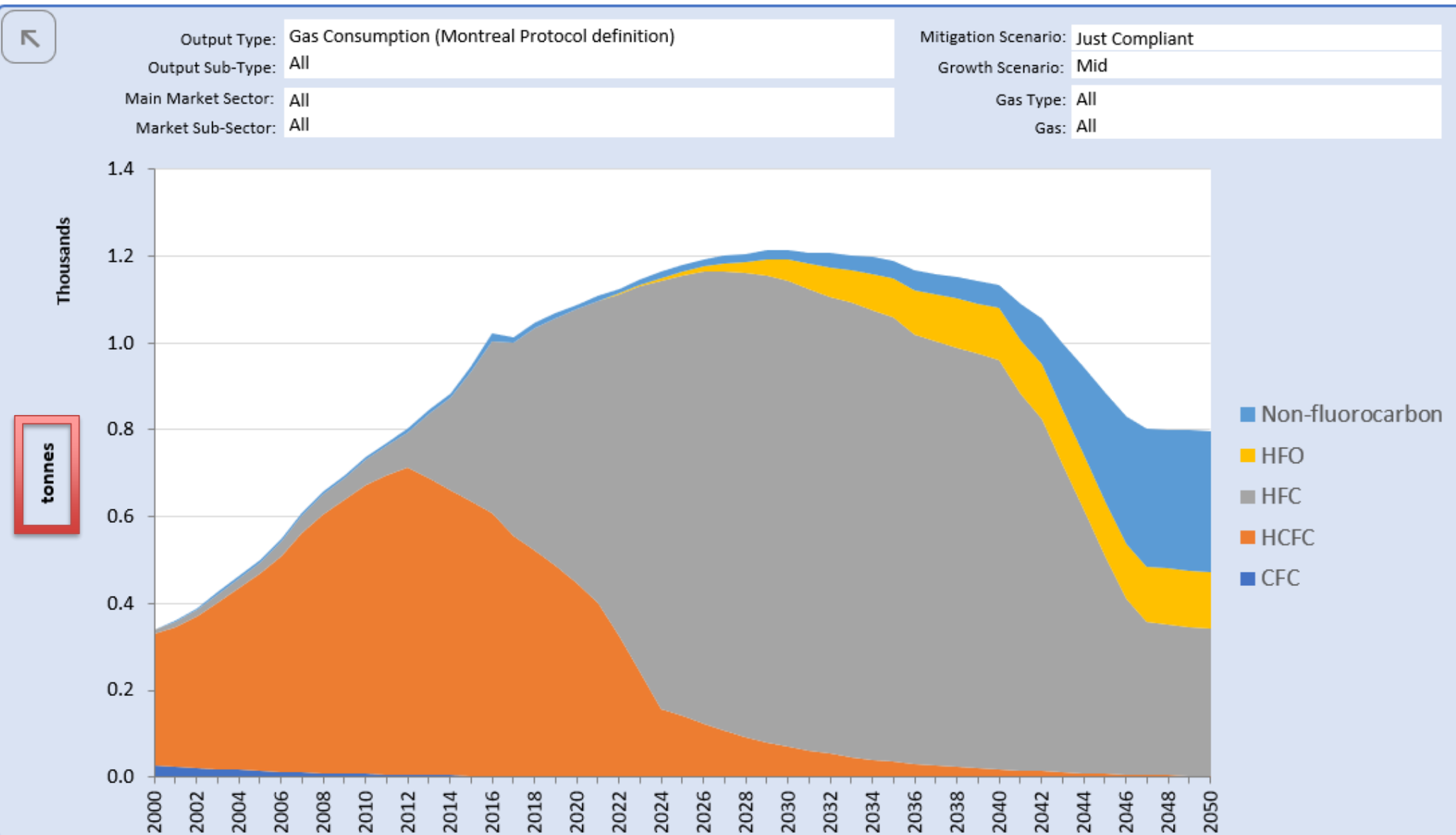
Output Selector



Market Selector



Gas Selector



Concluding Comments

- modelling of RACHP sectors important
 - to support policy development for sustainable cooling
- *HFC Outlook* Refrigerants Model
 - assesses use of refrigerants
 - compliance with HFC phase-down legislation
 - direct GHG emissions
- *HFC Outlook* Energy Model
 - uses same stock data as refrigerants model
 - assesses energy use and potential for reduction
 - indirect GHG emissions
- comparison of direct and indirect emissions is crucial
 - total GHG emissions dominated by energy related indirect emissions

Contact Details

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Information Sheets about EU F-Gas Regulation:

www.gluckmanconsulting.com/f-gas-information-sheets/

Fact Sheets about low GWP alternatives to HFCs:

www.gluckmanconsulting.com/low-gwp-alternatives-to-hfcs/

Fact Sheets about Kigali Amendment:

www.gluckmanconsulting.com/kigali-amendment/