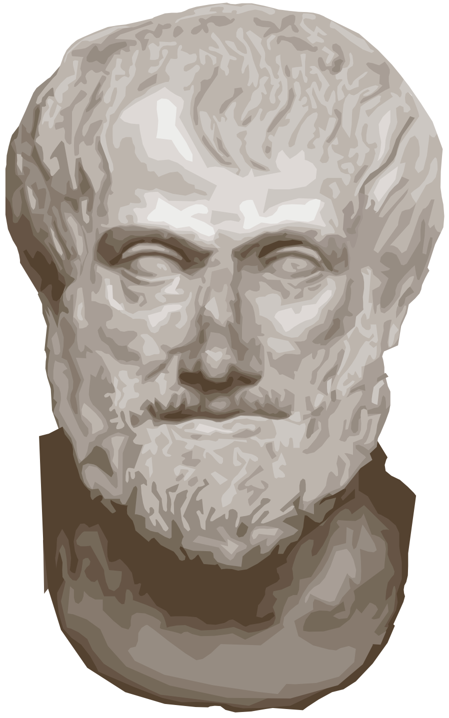
# Allocation for Carbon Capture and Storage (CCS); Requirements, Issues and Considerations

*1st June 2022*

# 5W’s

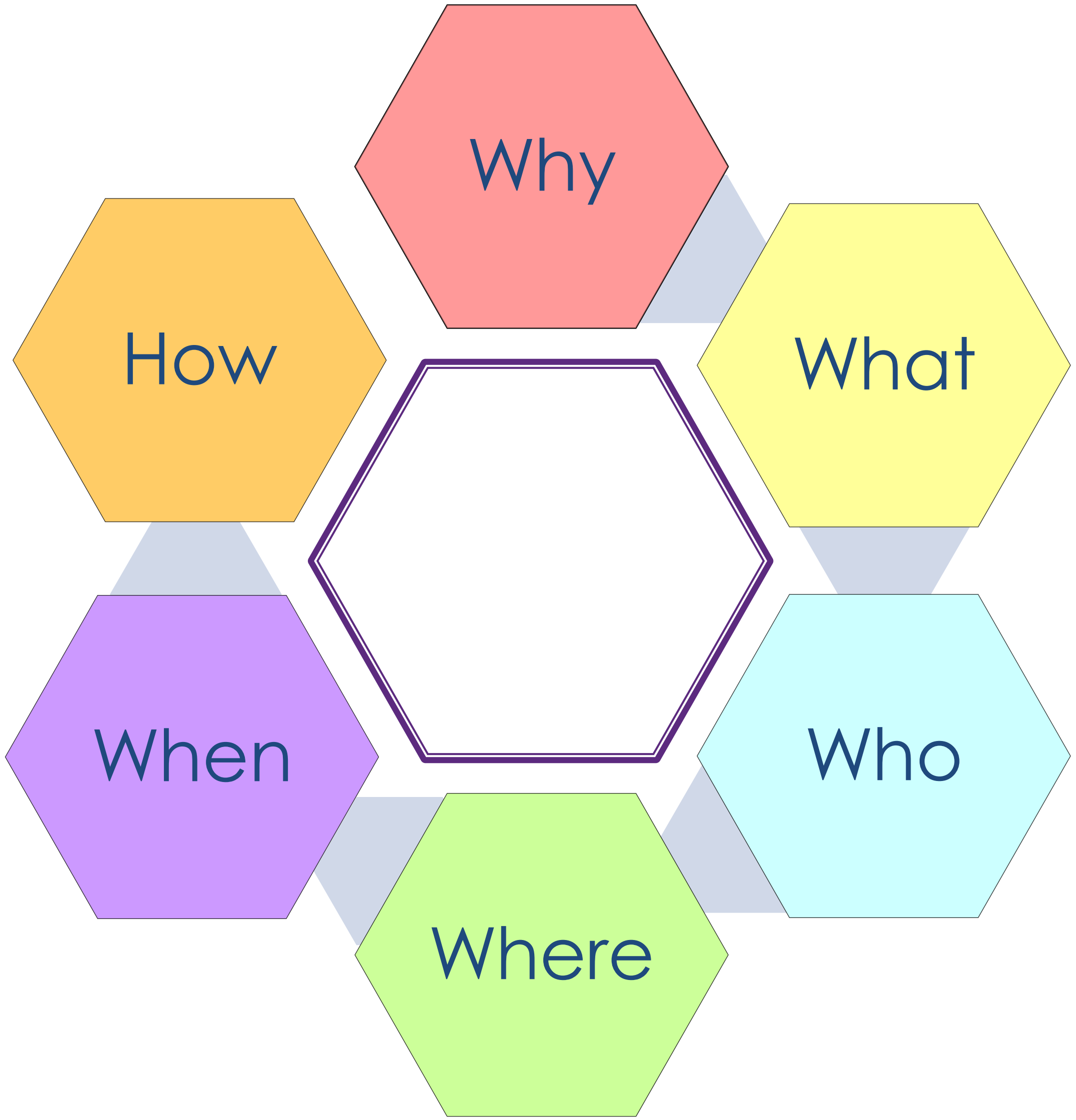

Hermagoras of Temnos
1st century BC

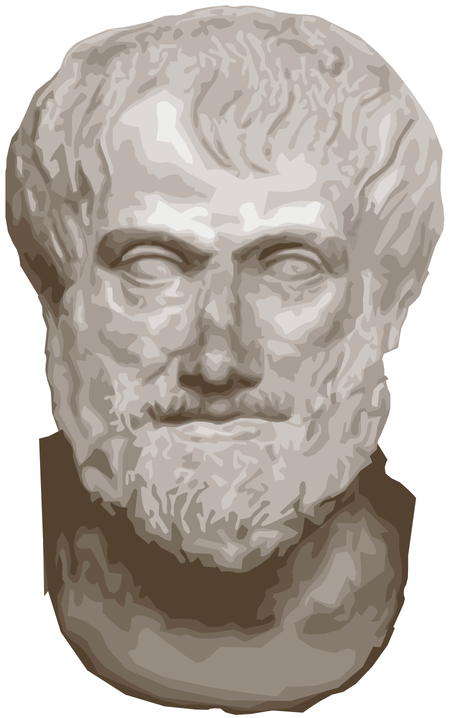




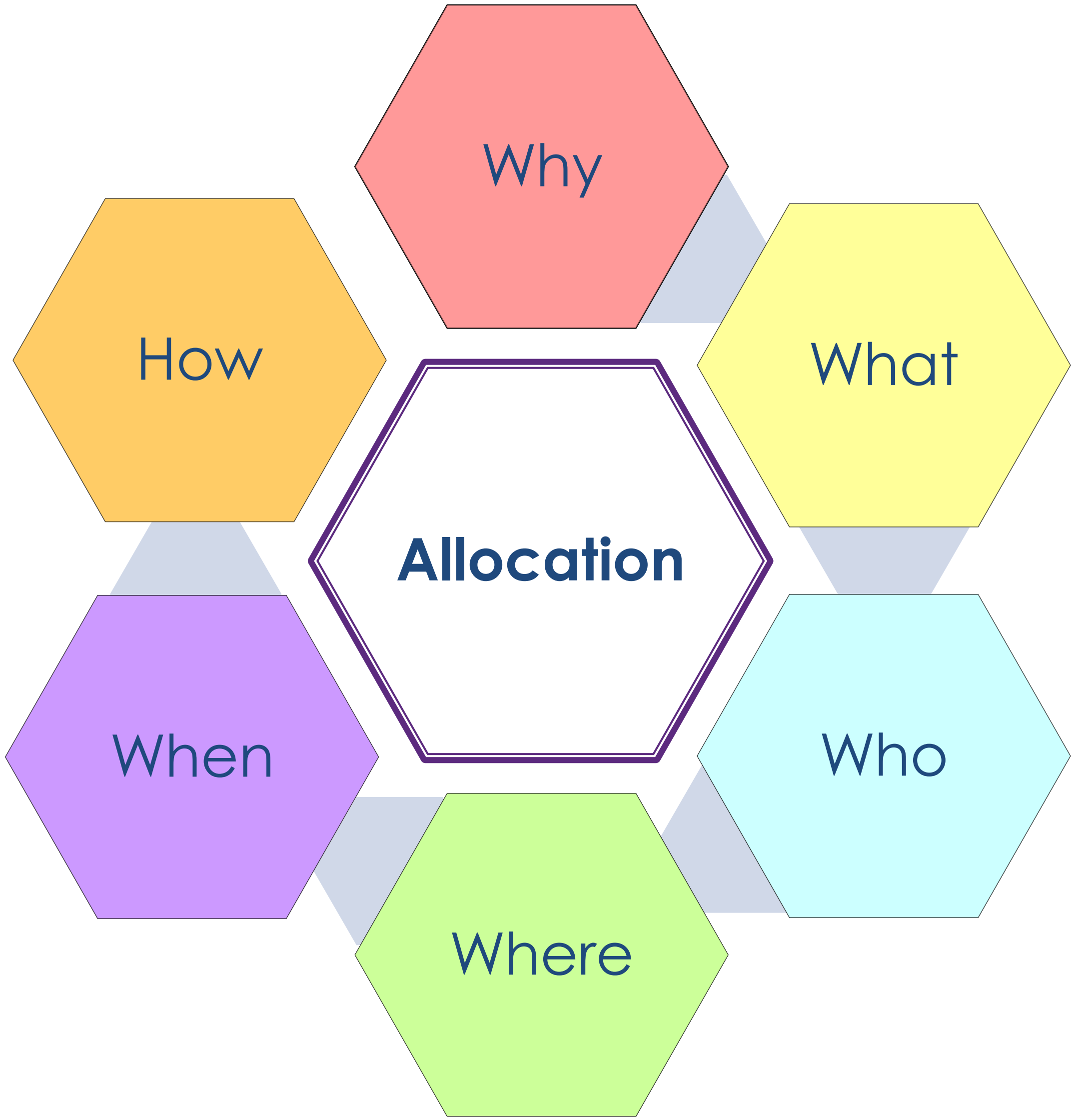
Aristotle
384 – 322 BC

# 5W1H

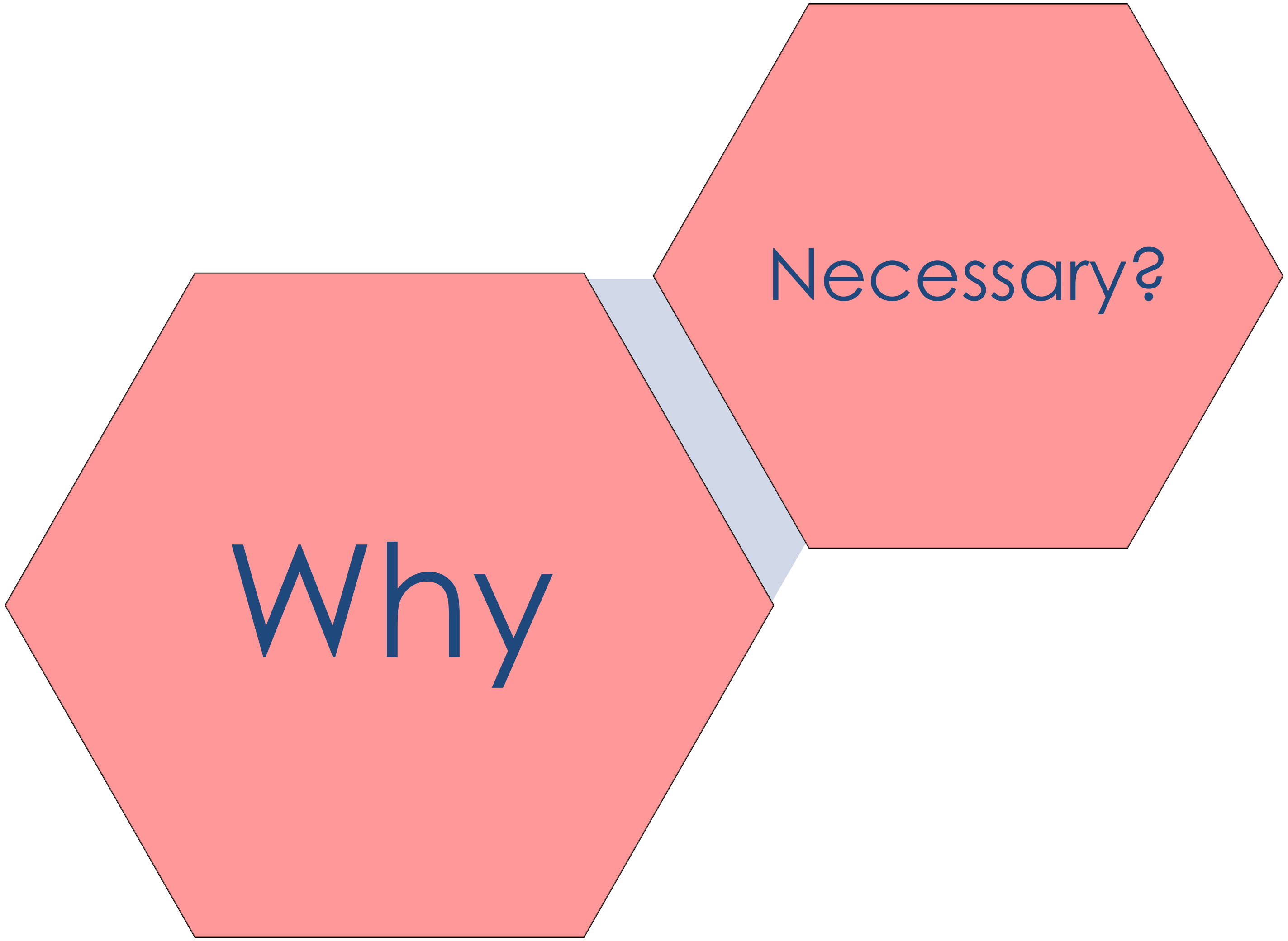
# Why, What, Who, Where, When and How?



# Why?

Why

# Why?






accord (e.s.l)

# Energy Institute HM 96
# Guidelines for the allocation of fluid streams in oil and gas production

and equitable manner.

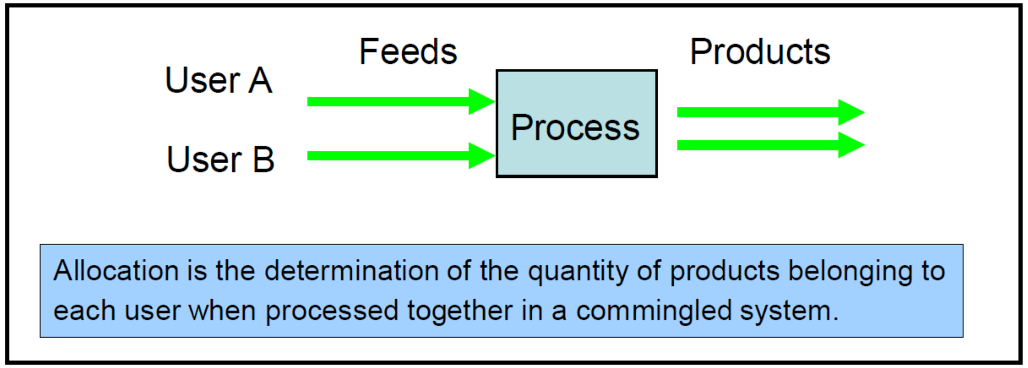



**Figure 1 Definition of allocation**

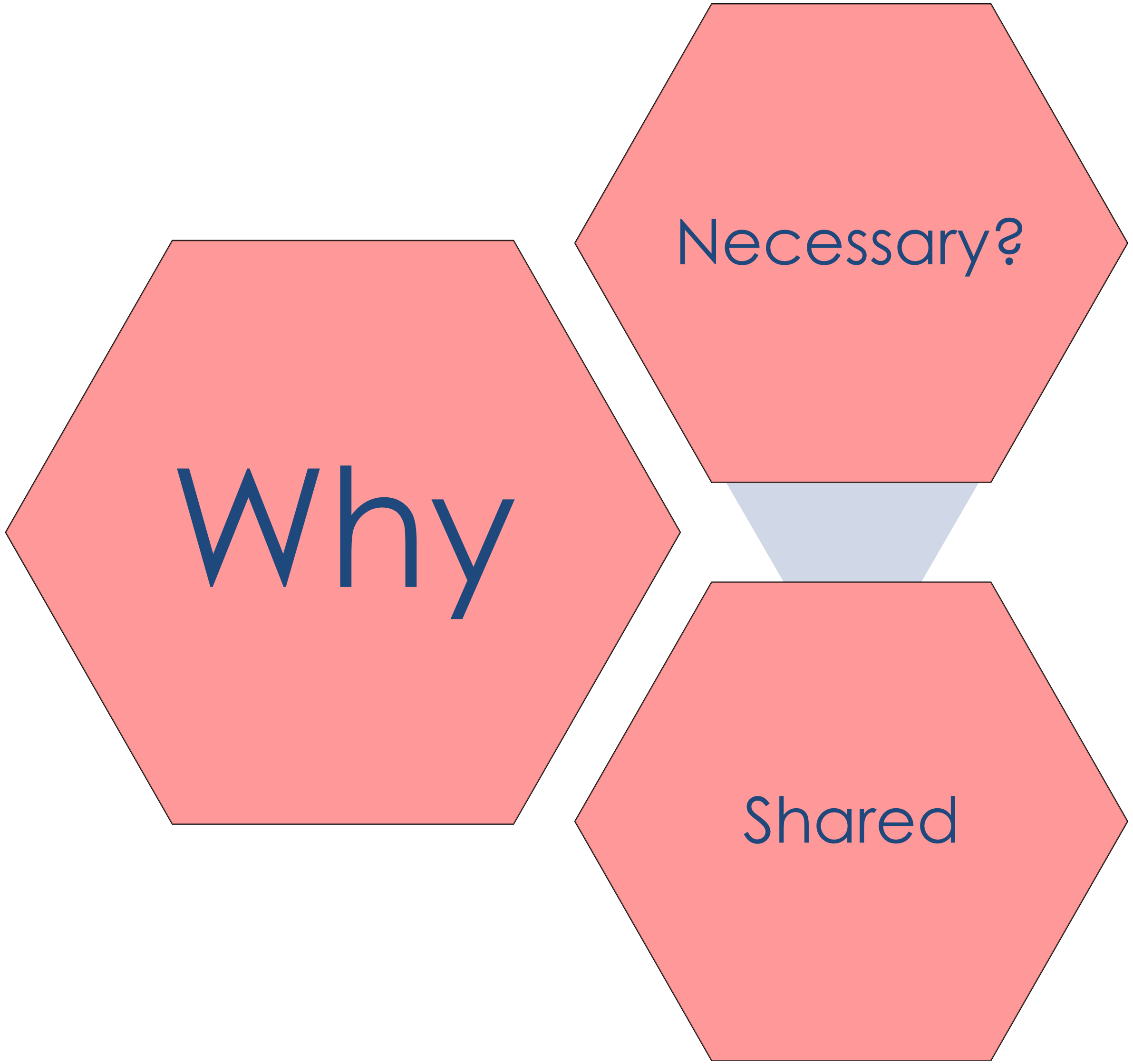
...gh allocation is principally a comm... issue with the me... by the inte...

# Why?

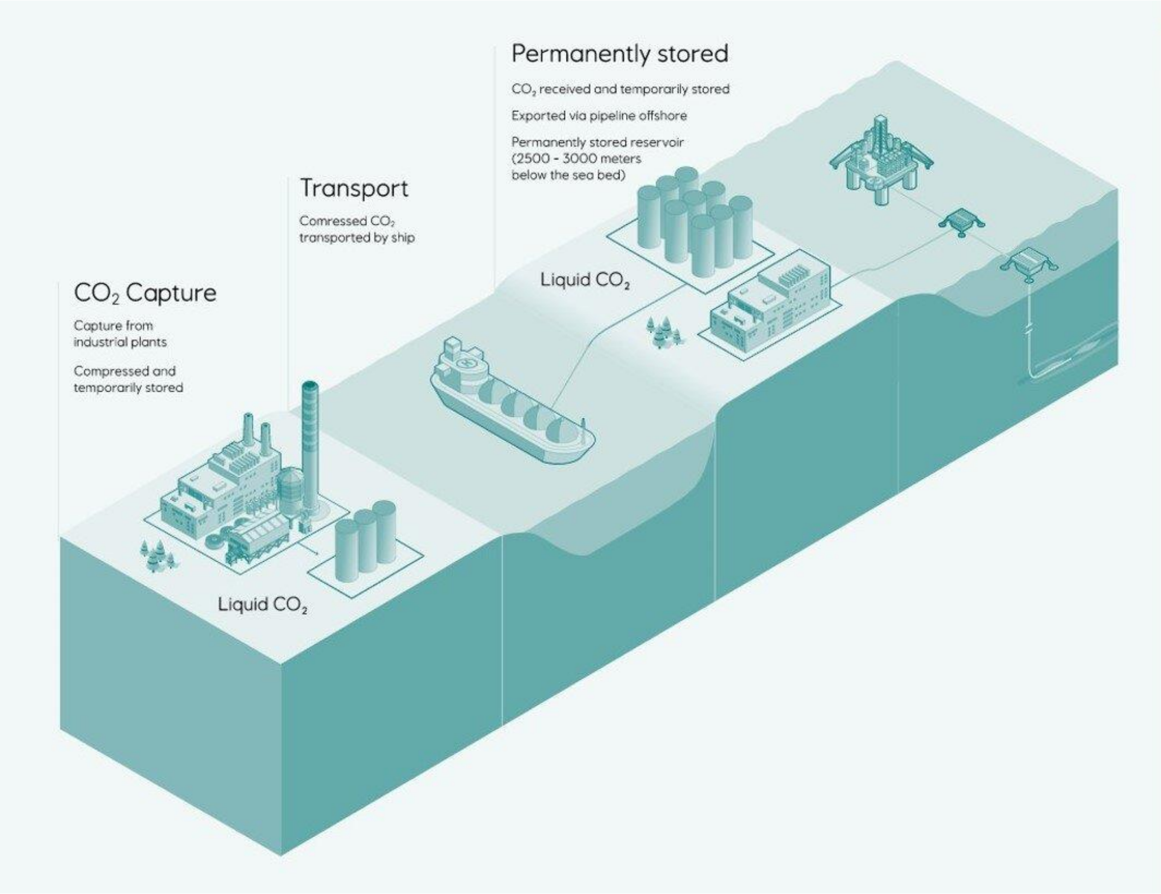
Why

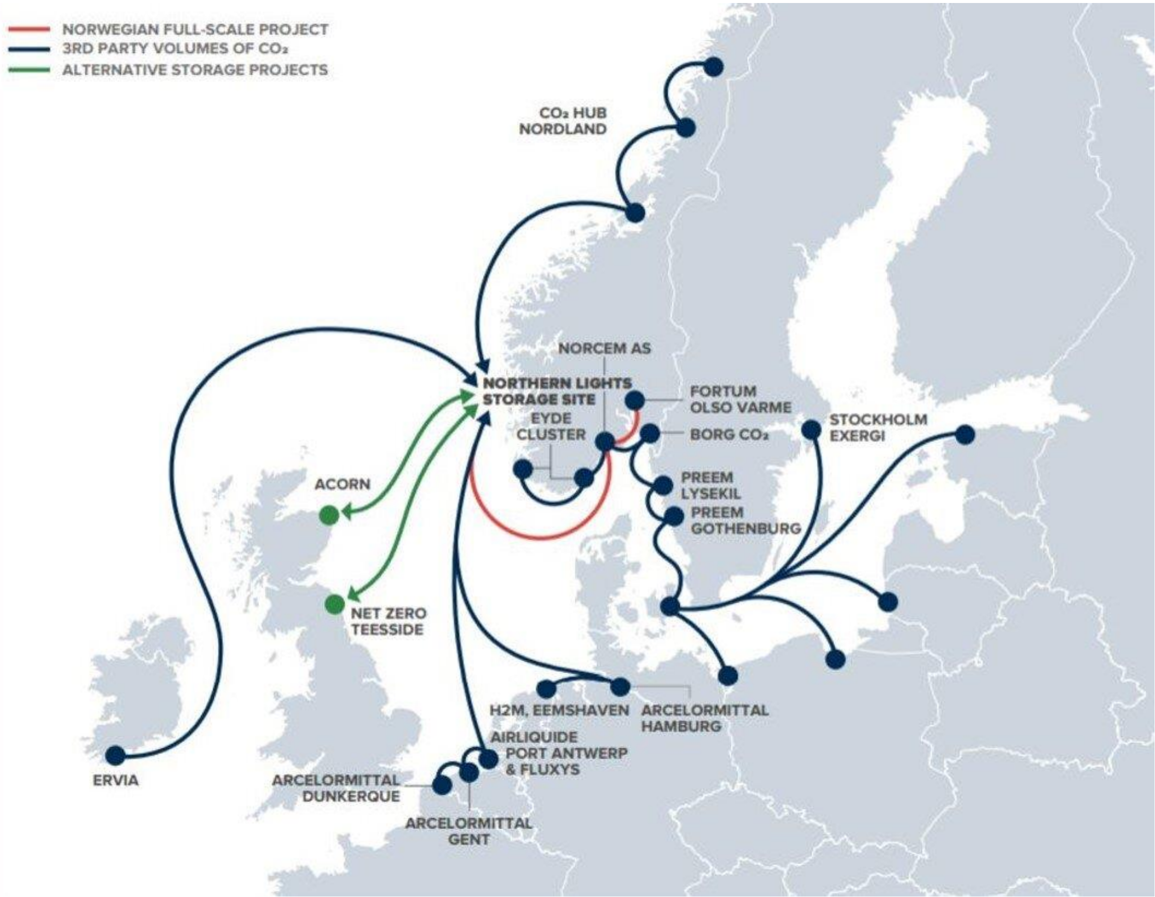
Necessary?

# Why?



# Northern Lights

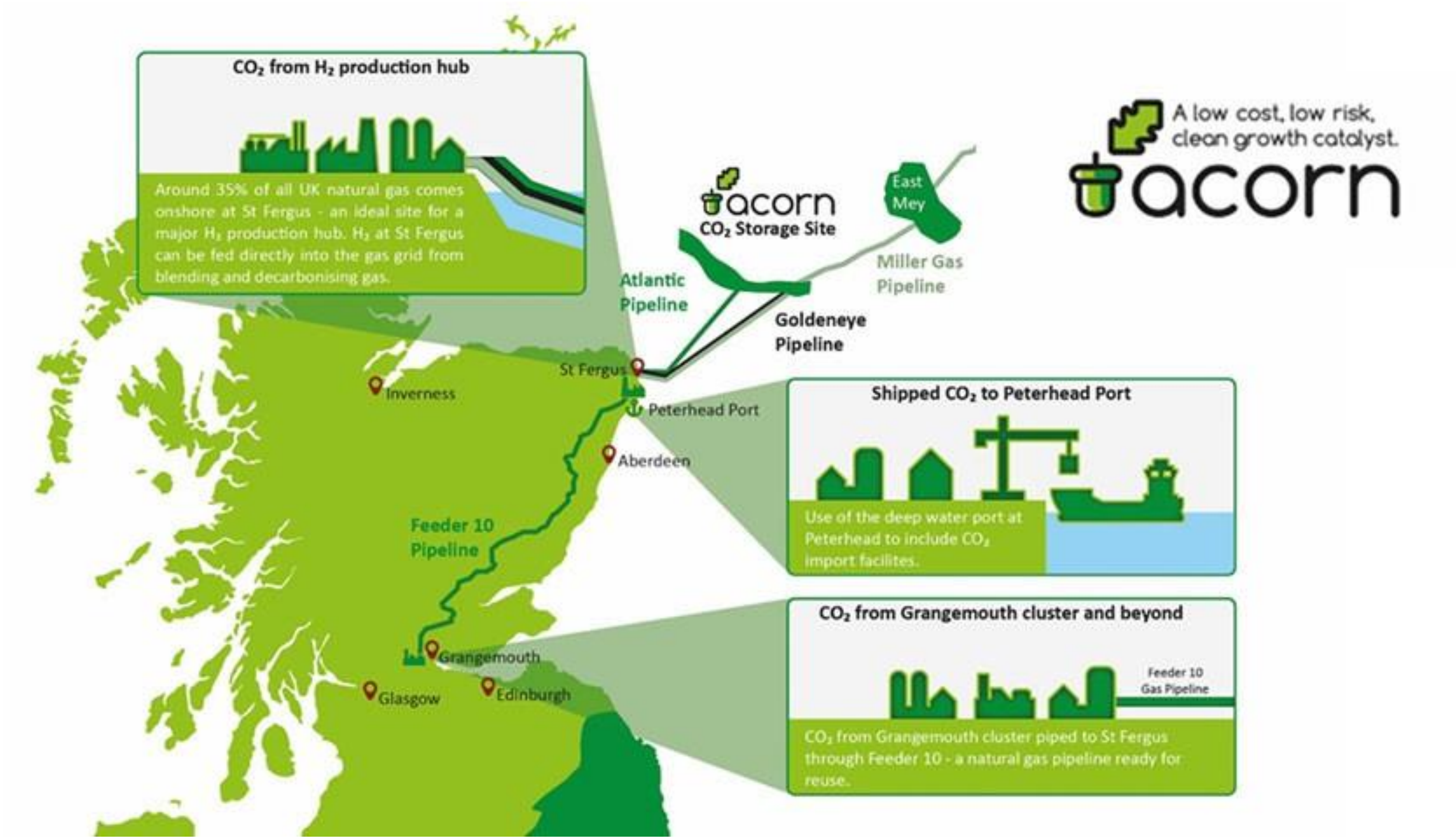




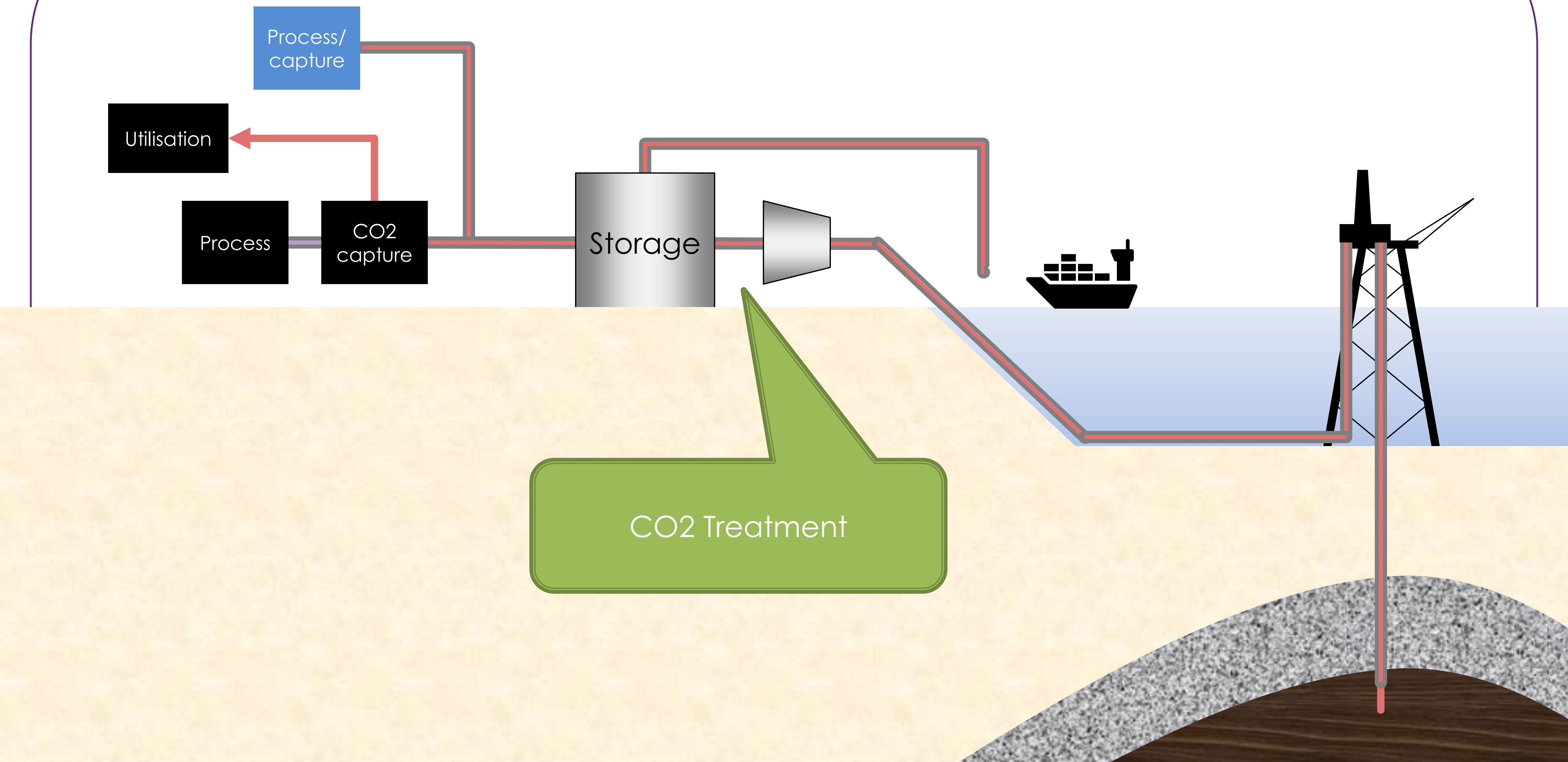

accord (e.s.l)

# Acorn

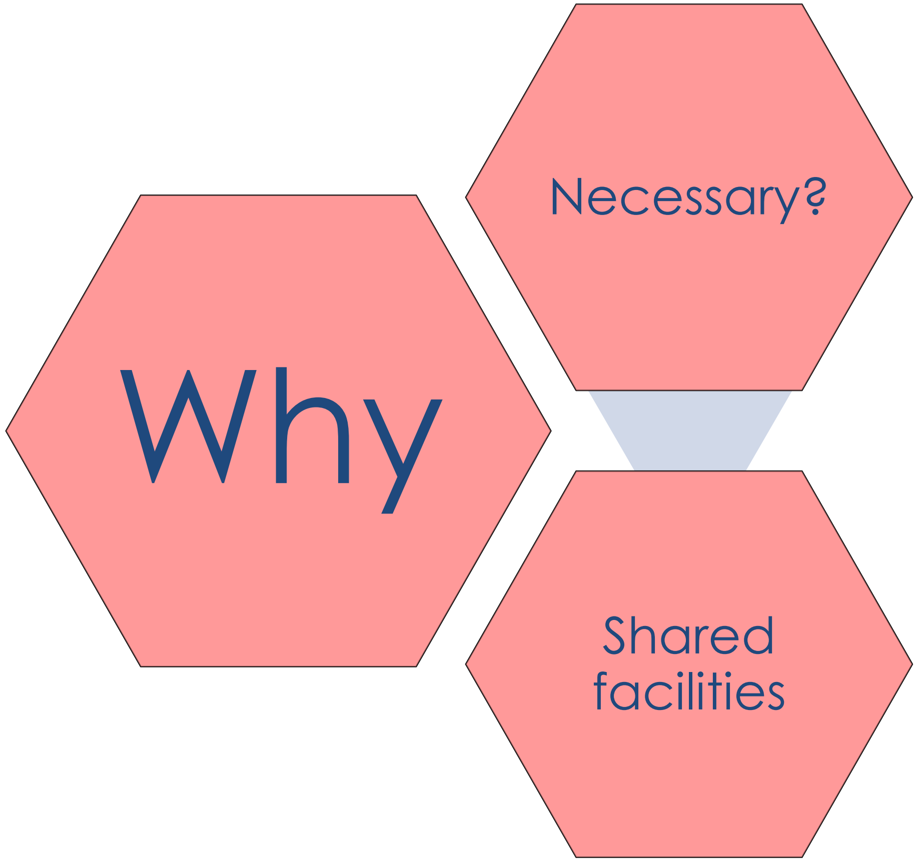


$CO_2$ from $H_2$ production hub
Around 35% of all UK natural gas comes onshore at St Fergus - an ideal site for a major $H_2$ production hub. $H_2$ at St Fergus can be fed directly into the gas grid from blending and decarbonising gas.
acorn
$CO_2$ Storage Site
East Mey
Miller Gas Pipeline
Atlantic Pipeline
Goldeneye Pipeline
St Fergus
Peterhead Port
Inverness
Aberdeen
Feeder 10 Pipeline
Grangemouth
Glasgow
Edinburgh
Shipped $CO_2$ to Peterhead Port
Use of the deep water port at Peterhead to include $CO_2$ import facilites.
$CO_2$ from Grangemouth cluster and beyond
Feeder 10 Gas Pipeline
$CO_2$ from Grangemouth cluster piped to St Fergus through Feeder 10 - a natural gas pipeline ready for reuse.
A low cost, low risk, clean growth catalyst.
acorn

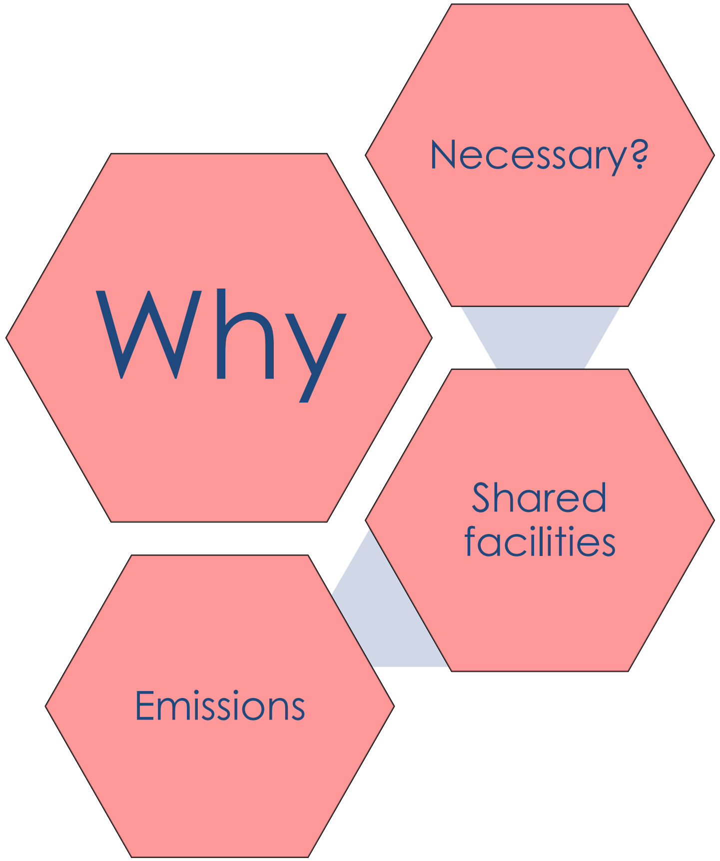
# Shared Facilities



# Why?



# Why?



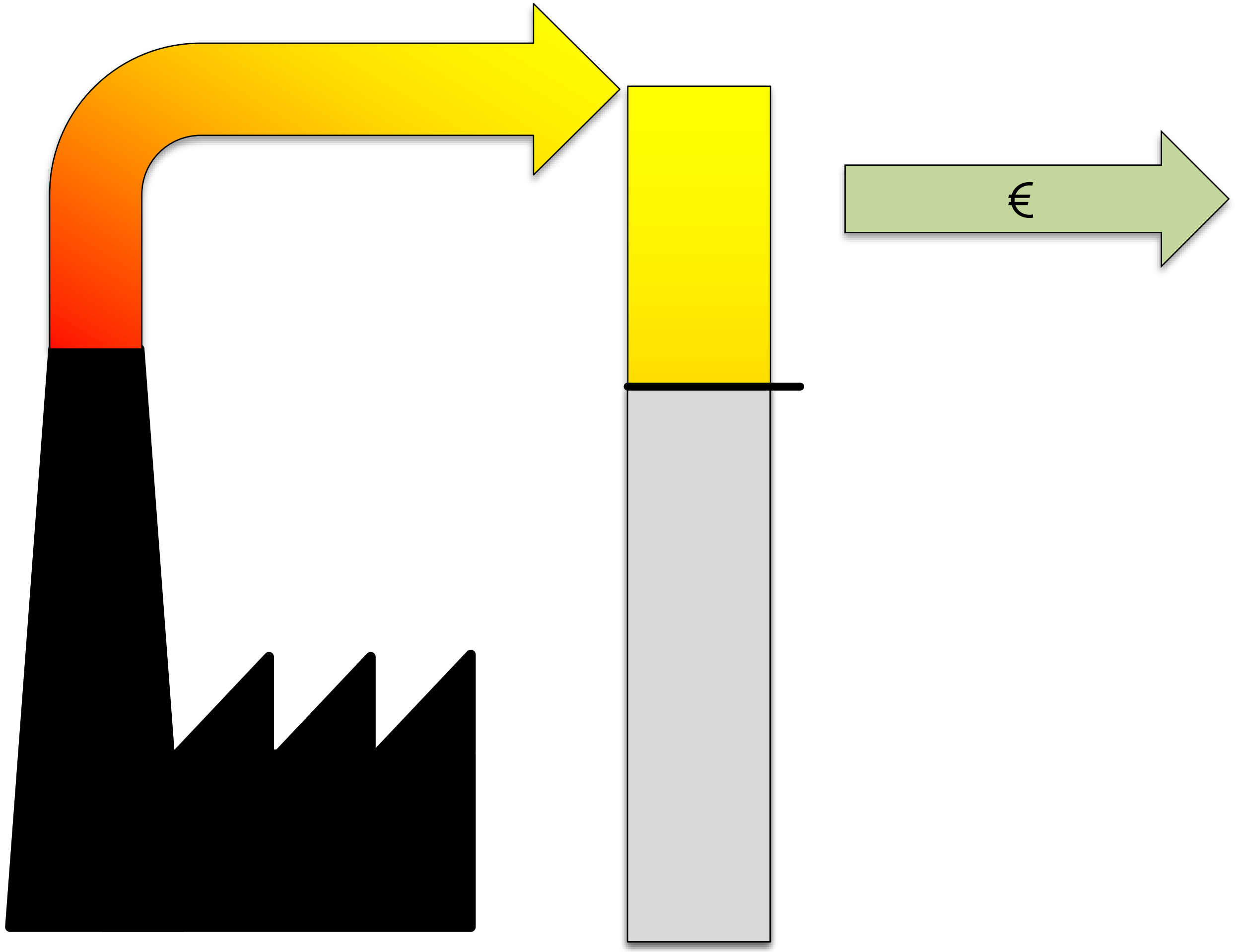
# Emissions Trading Scheme

ETS UK

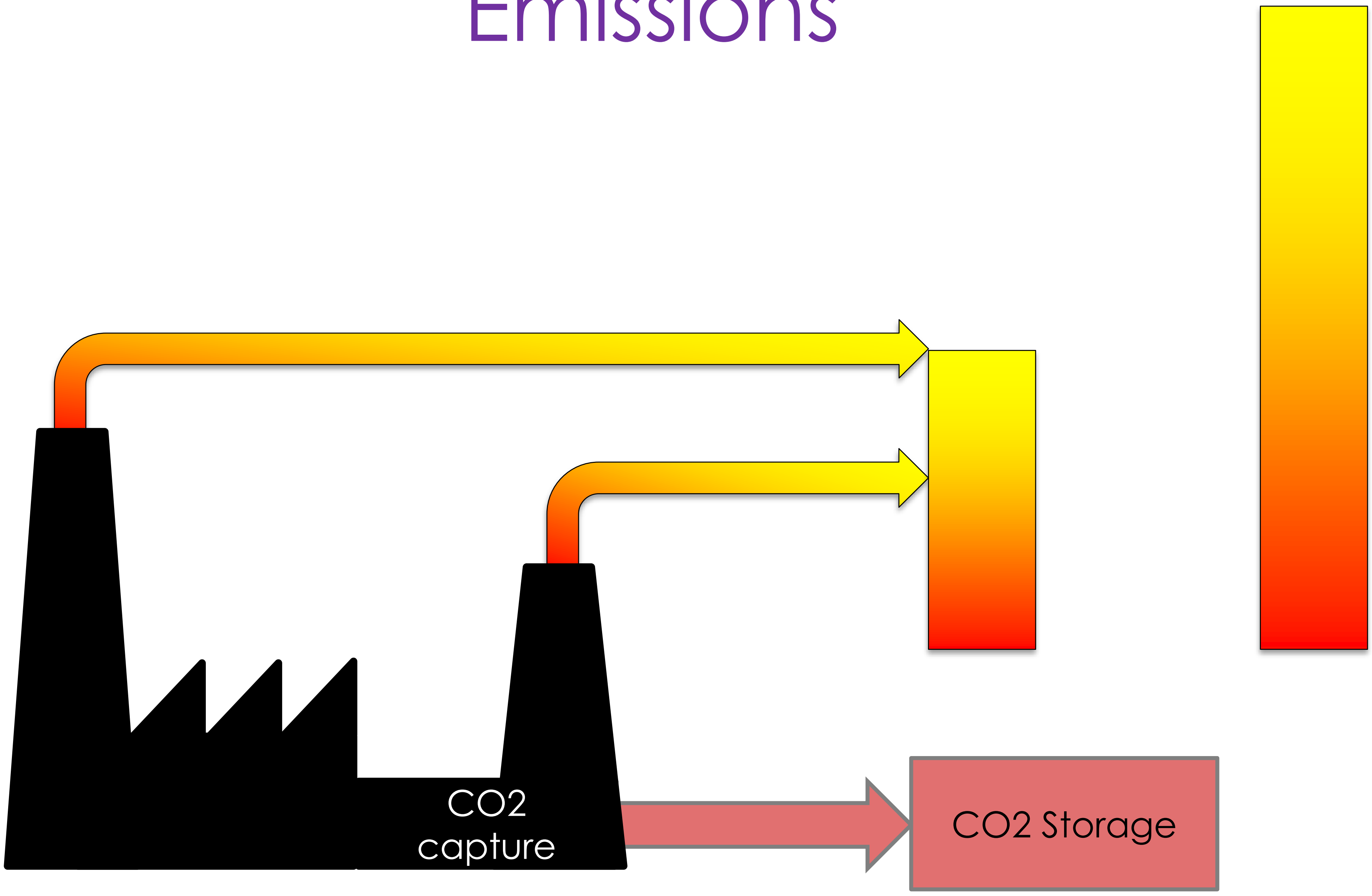

NFOGM 2022 Allocation

accord (e.s.l)

# Emissions




# Emissions



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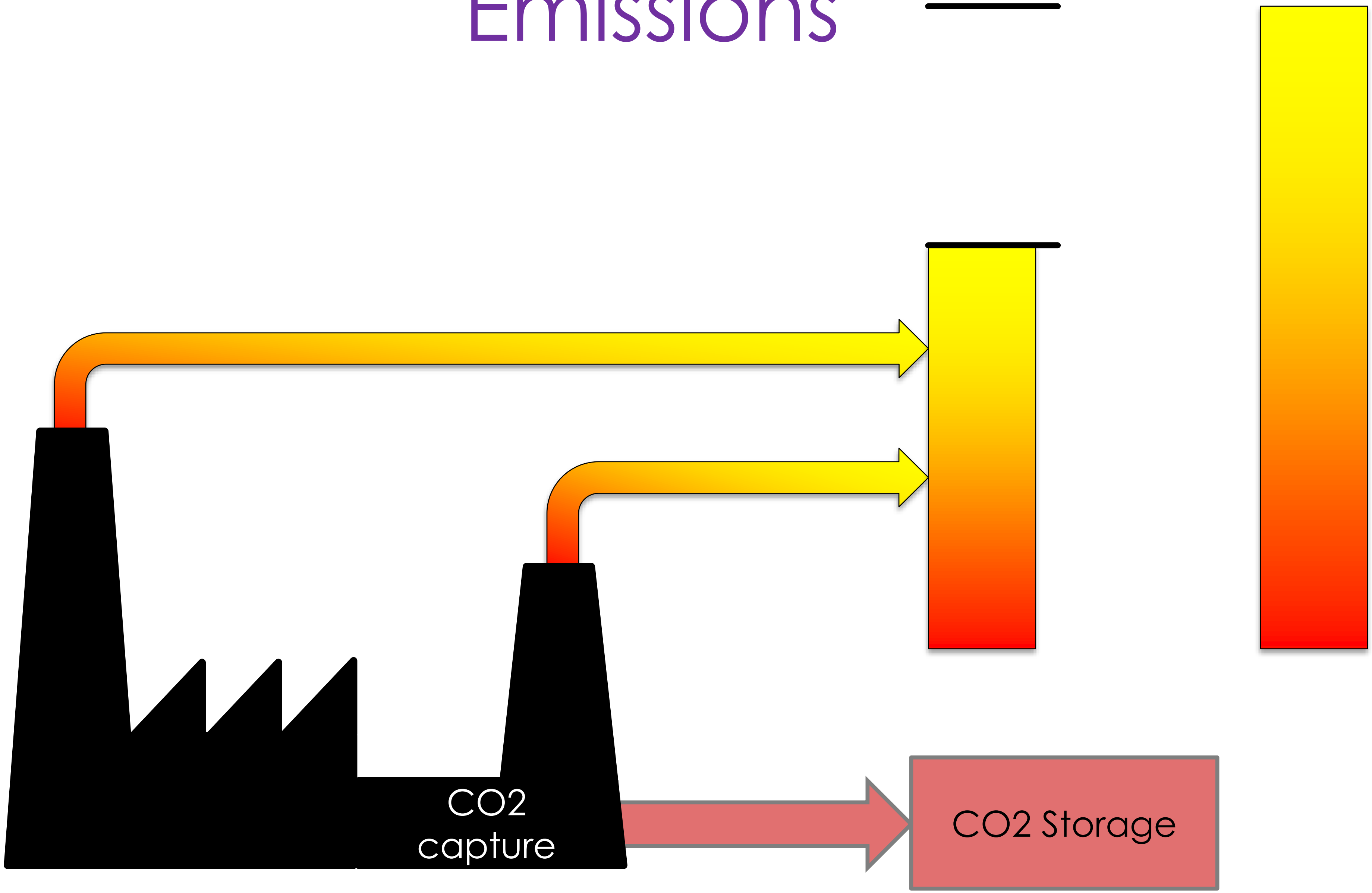
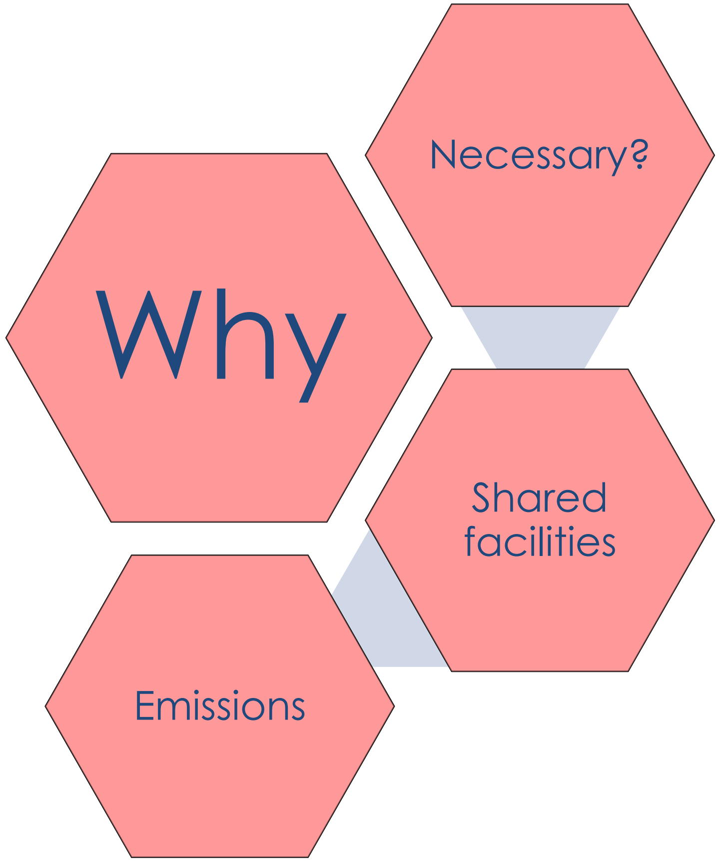


# Emissions




accord (e.s.l)

# Why?



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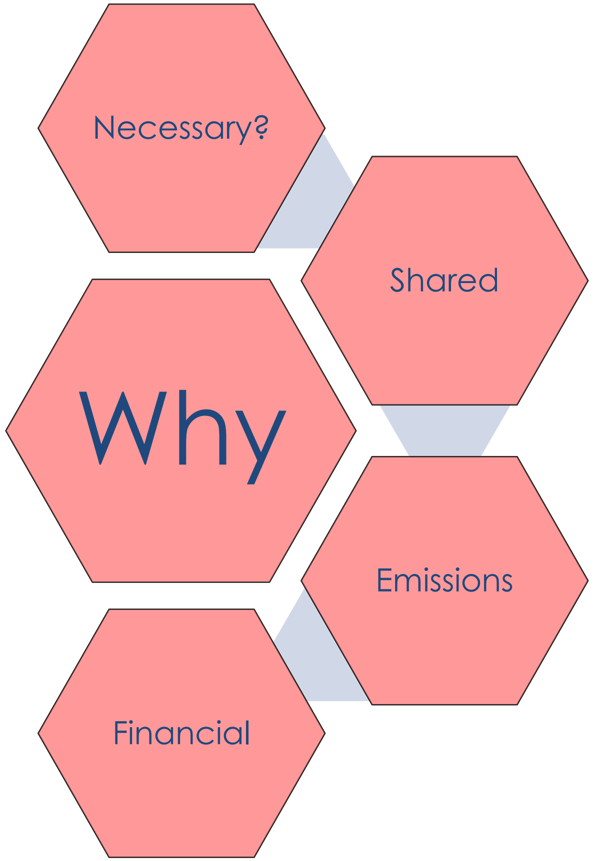
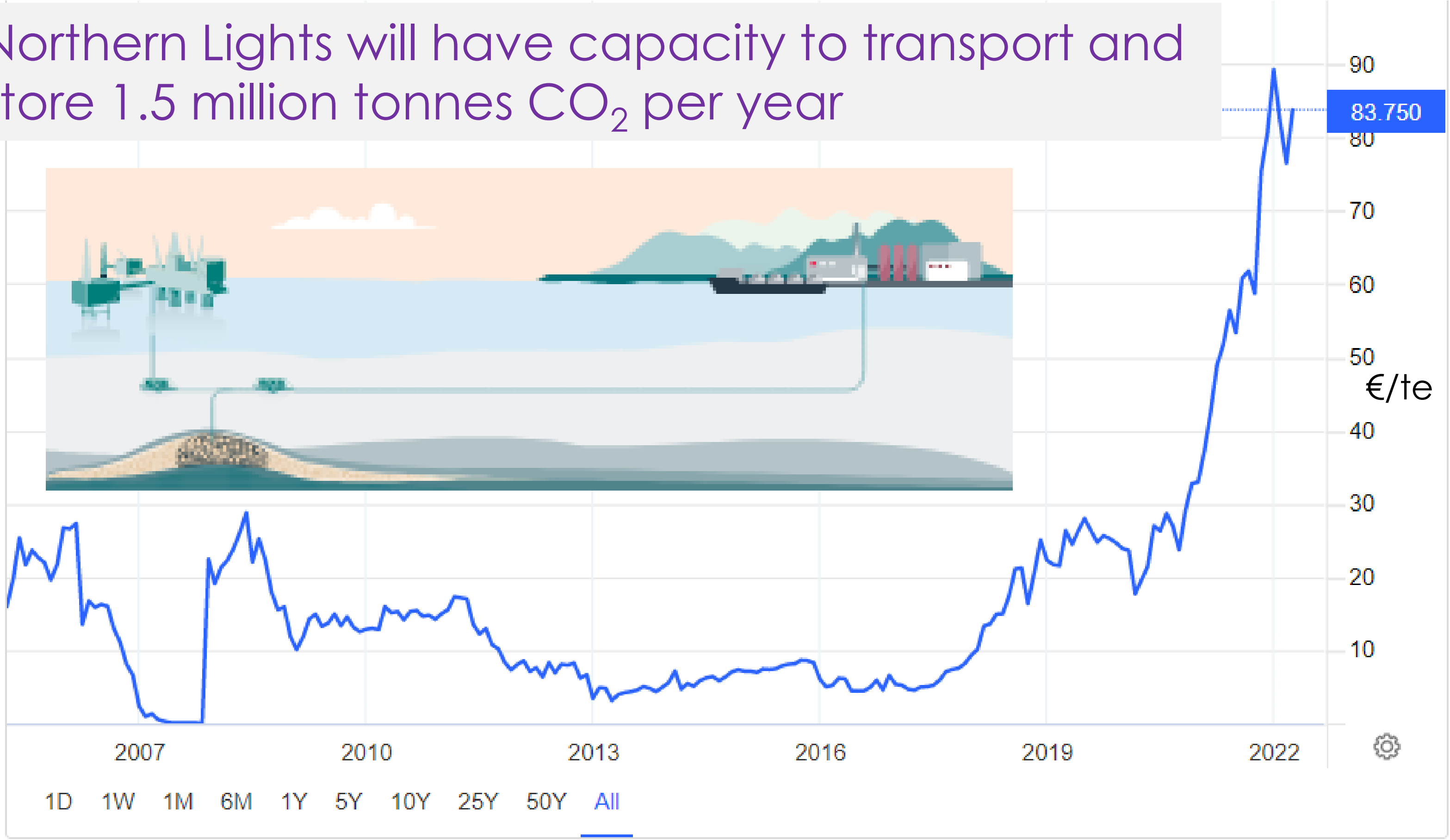


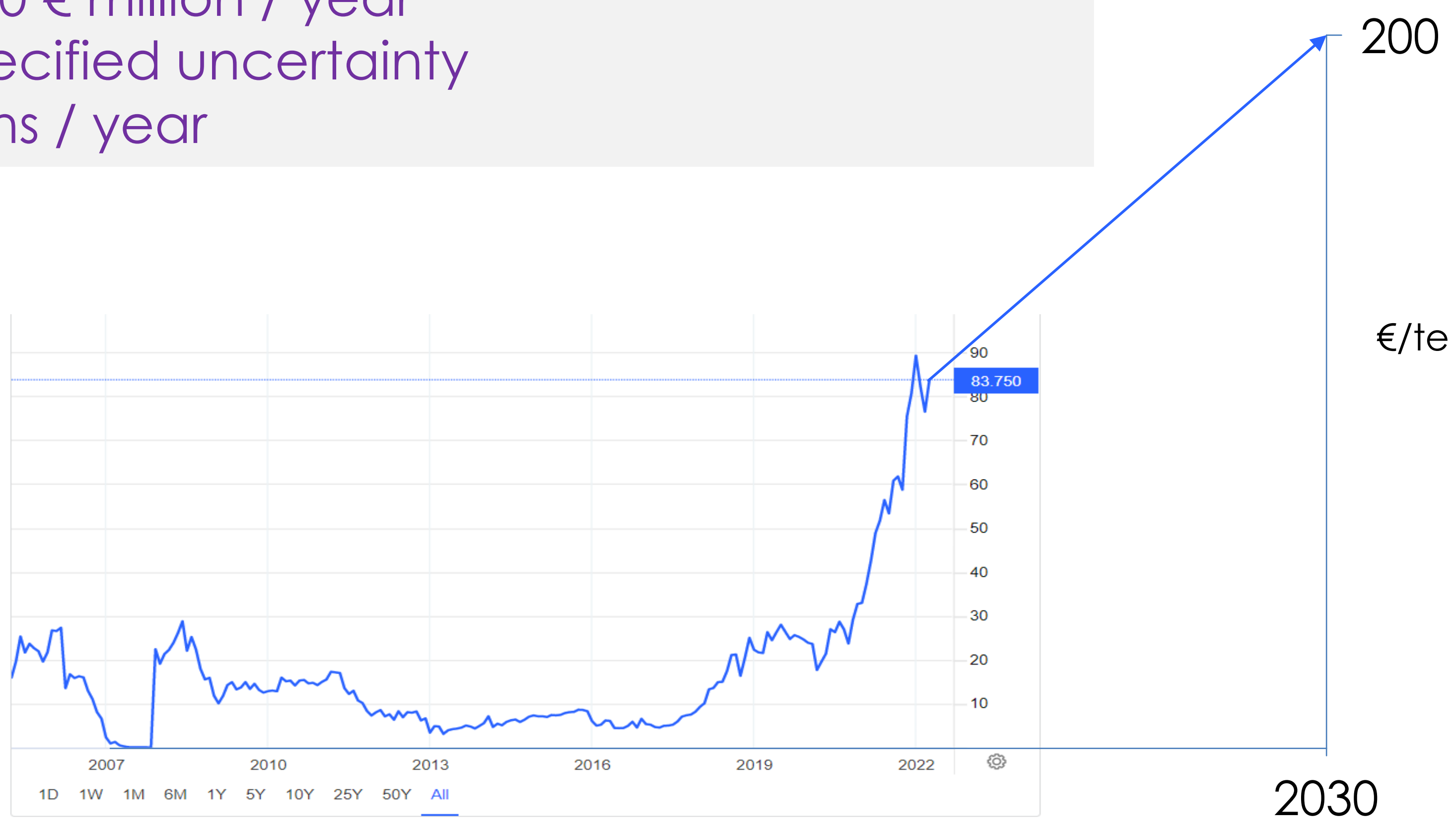
# EU ETS $CO_2$ price €/tonne

Northern Lights will have capacity to transport and store 1.5 million tonnes $CO_2$ per year

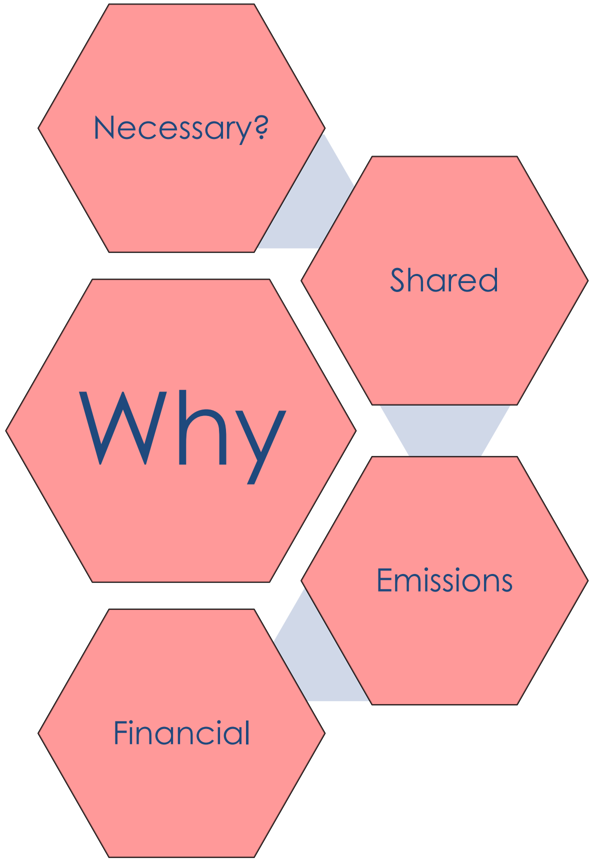


# EU ETS $CO_2$ price €/tonne

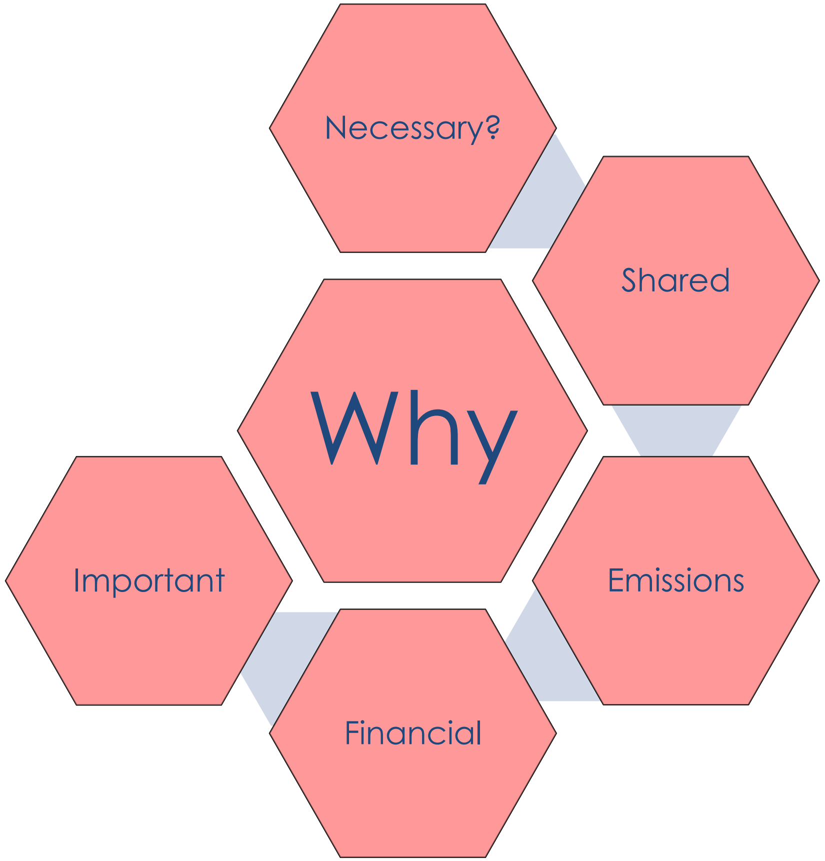
Total stream value of 1.5 million te/yr $CO_2$:
150 to 300 € million / year
±1.5% specified uncertainty
~ € millions / year



# Why?



# Why?

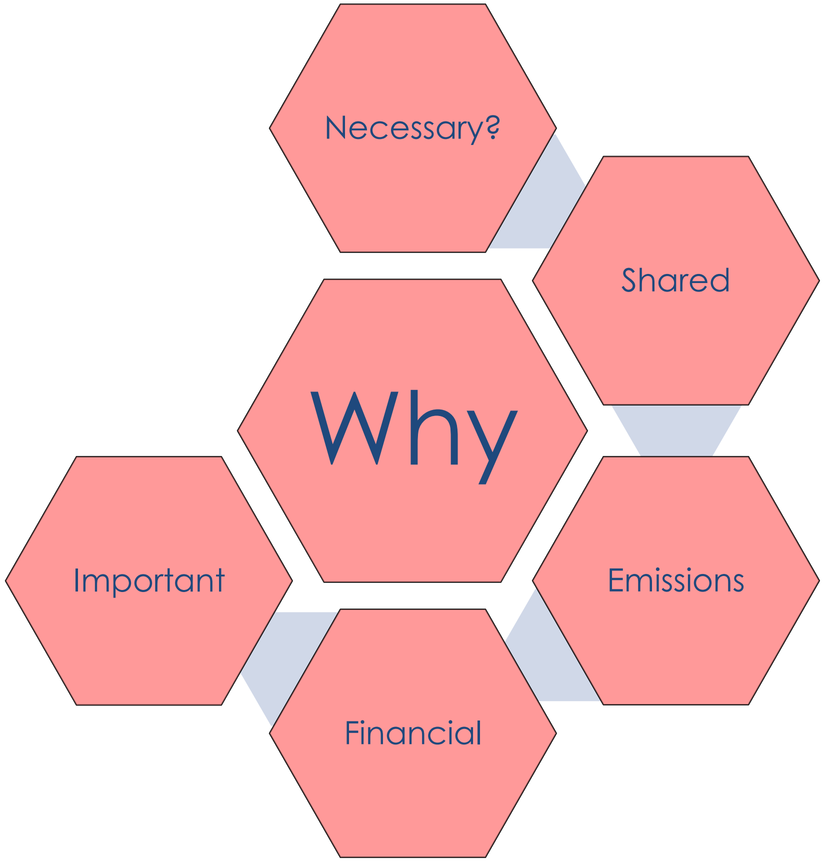


https://www.equinor.com/energy/northern-lights

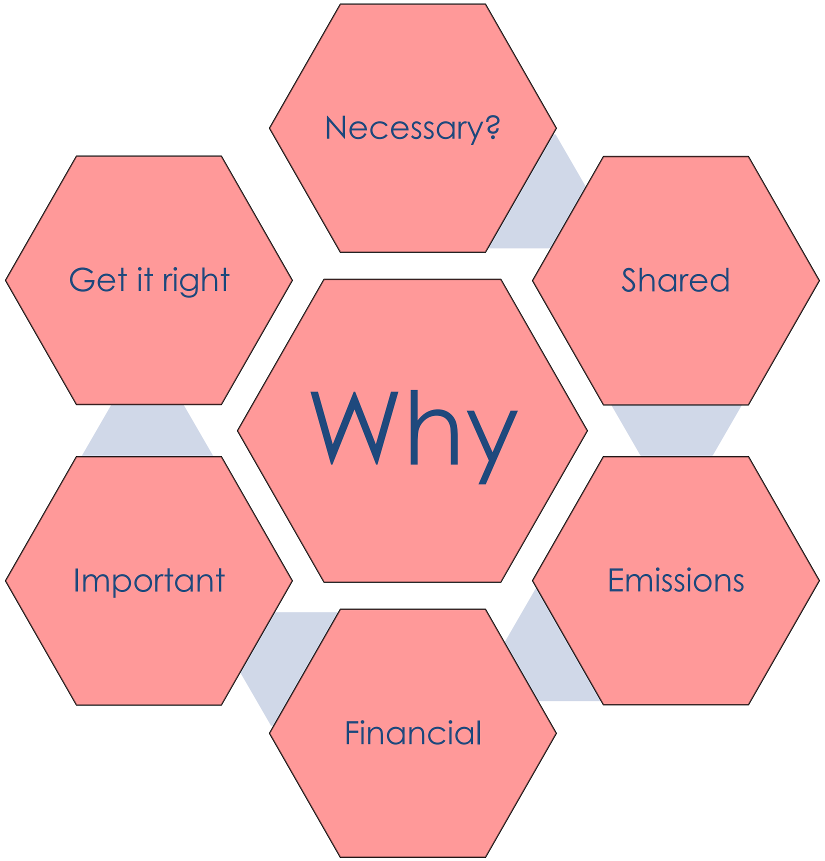
Currently 27 CCS operational sites worldwide

“Many scientists and policymakers argue that this is crucial if the world is to limit temperature rise to under 2°C, the goal of the Paris Agreement. The International Energy Agency states that a tenfold increase in capacity is needed by 2025 to be on track for meeting that target and the Global CCS Institute estimates that 2,500 CCS facilities would need to be in operation by 2040 worldwide, each capturing around 1.5 million tonnes of CO2 per year.”

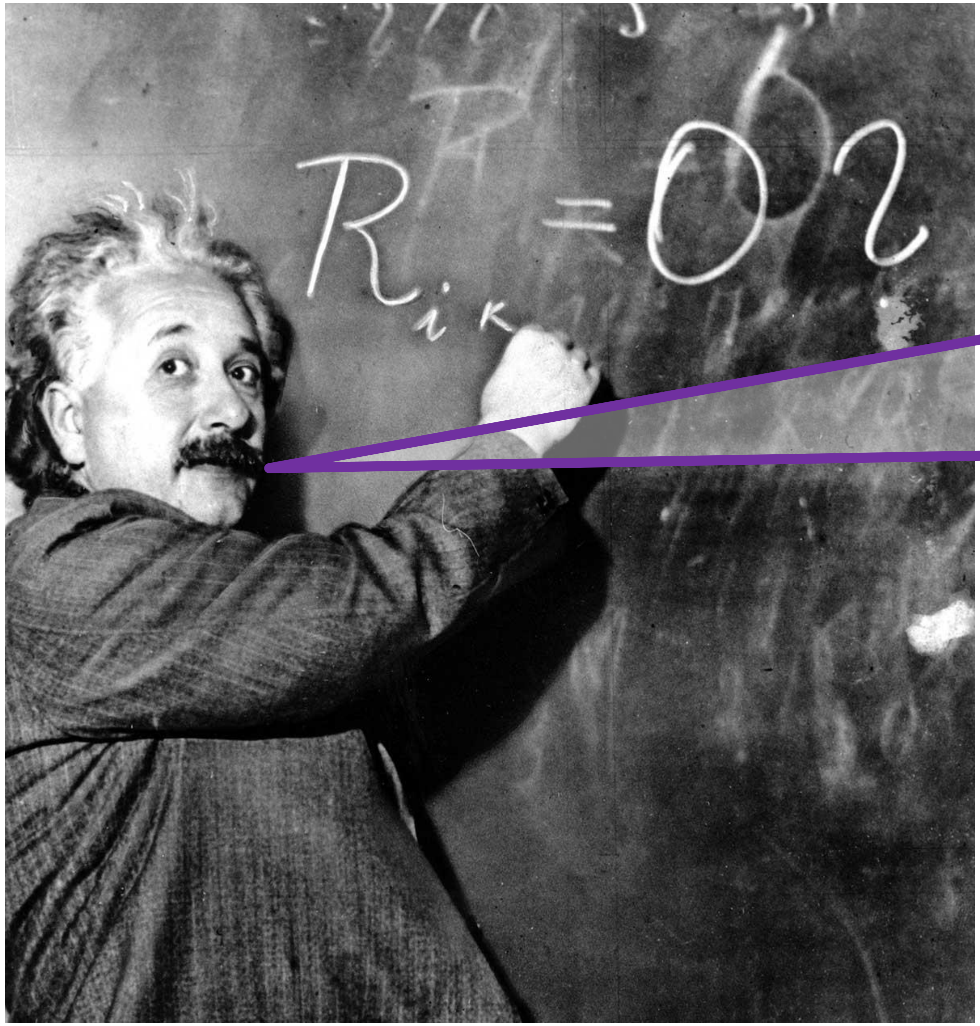
# Why?



# Why?

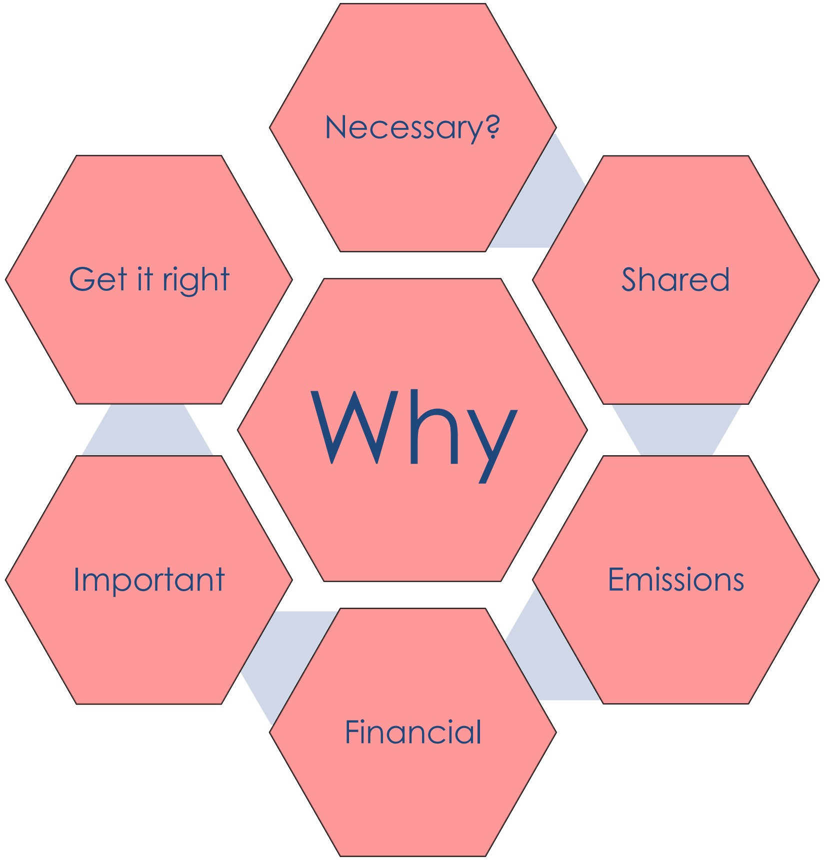

Necessary?
Get it right
Shared
Why
Important
Emissions
Financial

# Keep it simple?



Everything should be made as simple as possible, but not simpler

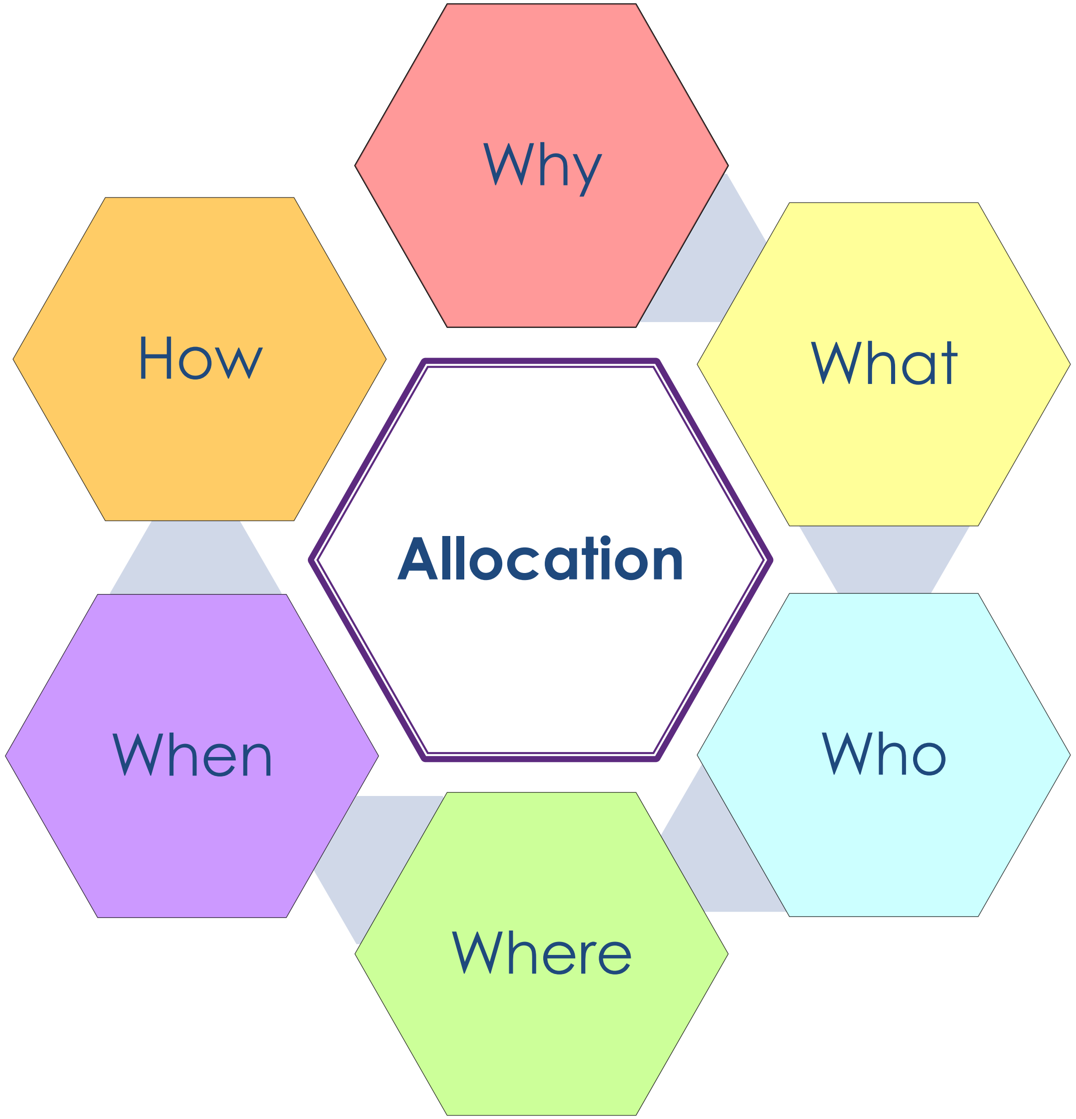
# Why?


Necessary?
Get it right
Shared
Why
Important
Emissions
Financial

# Why?

Why

# Why, What, Who, Where, When and How?

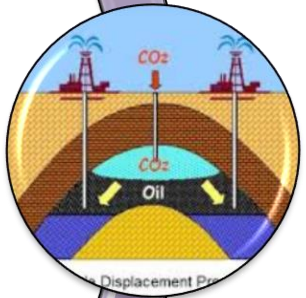


# Why, What, Who, Where, When and How?

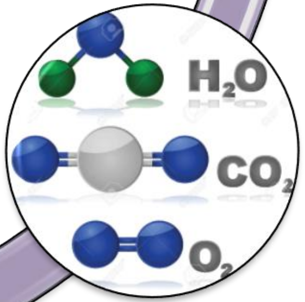
What

# Units/ Basis

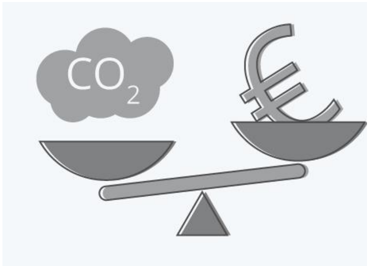

Mass

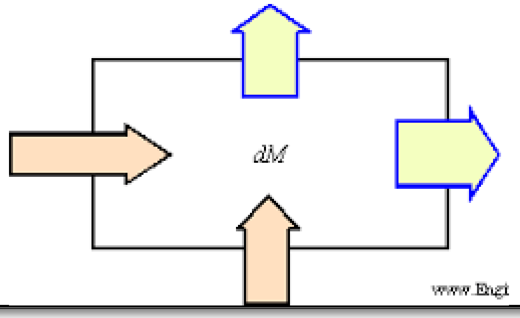


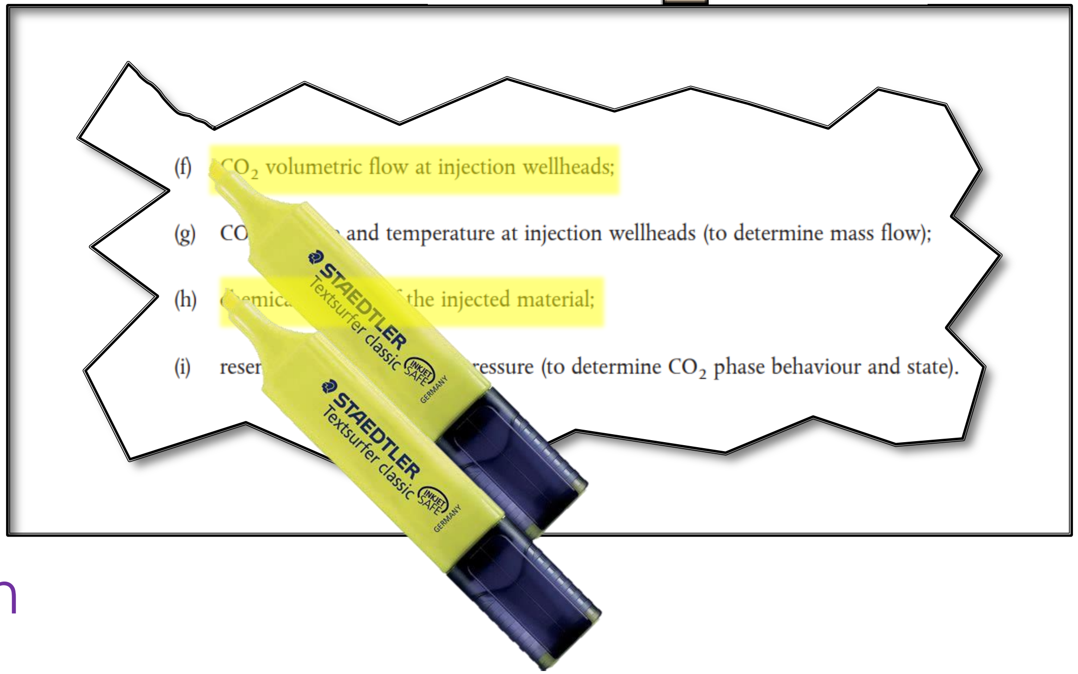

Volume




Composition





(f) $CO_2$ volumetric flow at injection wellheads;

(g) CO … and temperature at injection wellheads (to determine mass flow);

(h) …emica… the injected material;

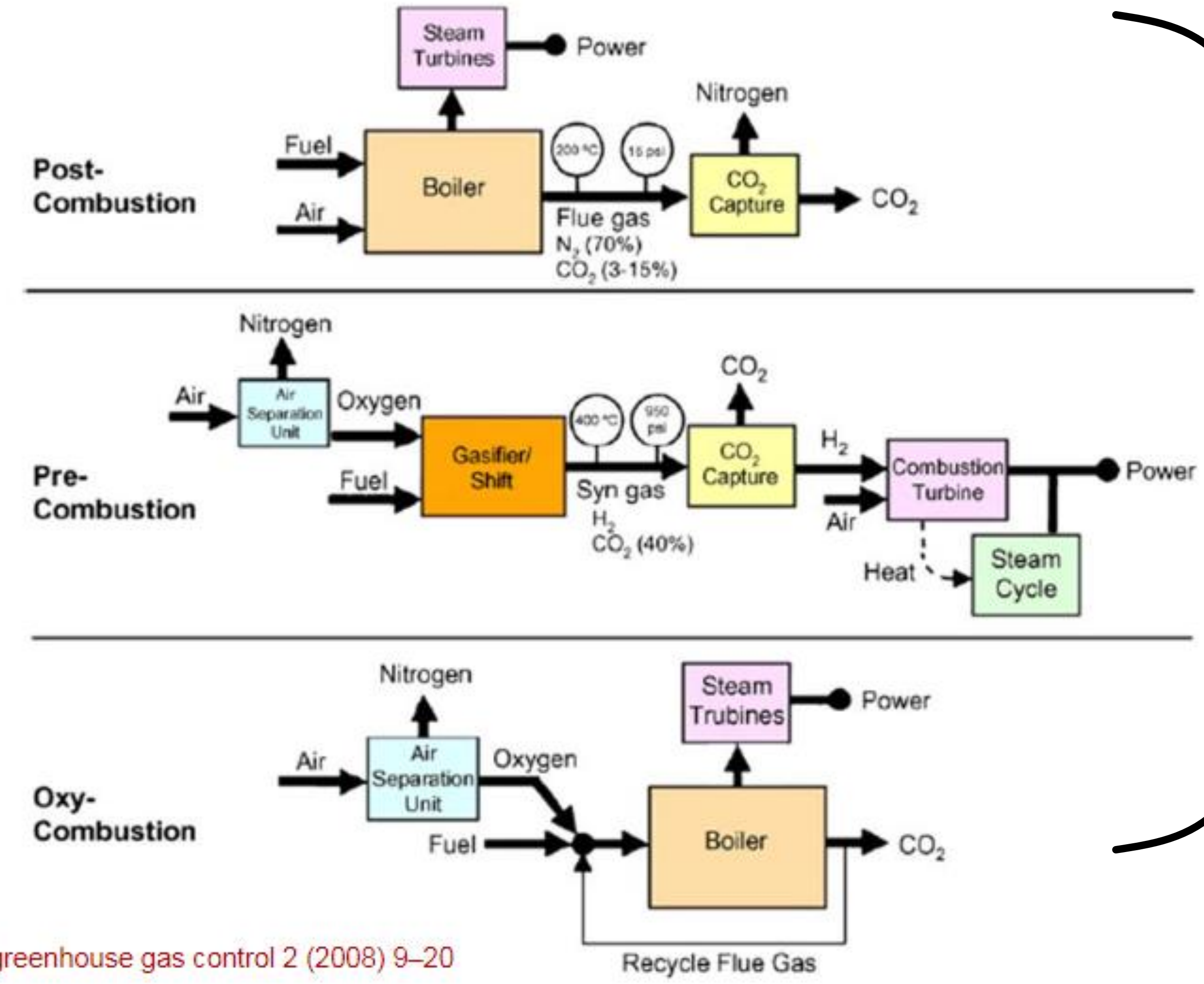
(i) reser… …essure (to determine $CO_2$ phase behaviour and state).





accord (e.s.l)

# $CO_2$ Capture Technologies




Source: International Journal of greenhouse gas control 2 (2008) 9–20

Increased transportation energy requirements

$H_2O$

$O_2$ $CO_2$

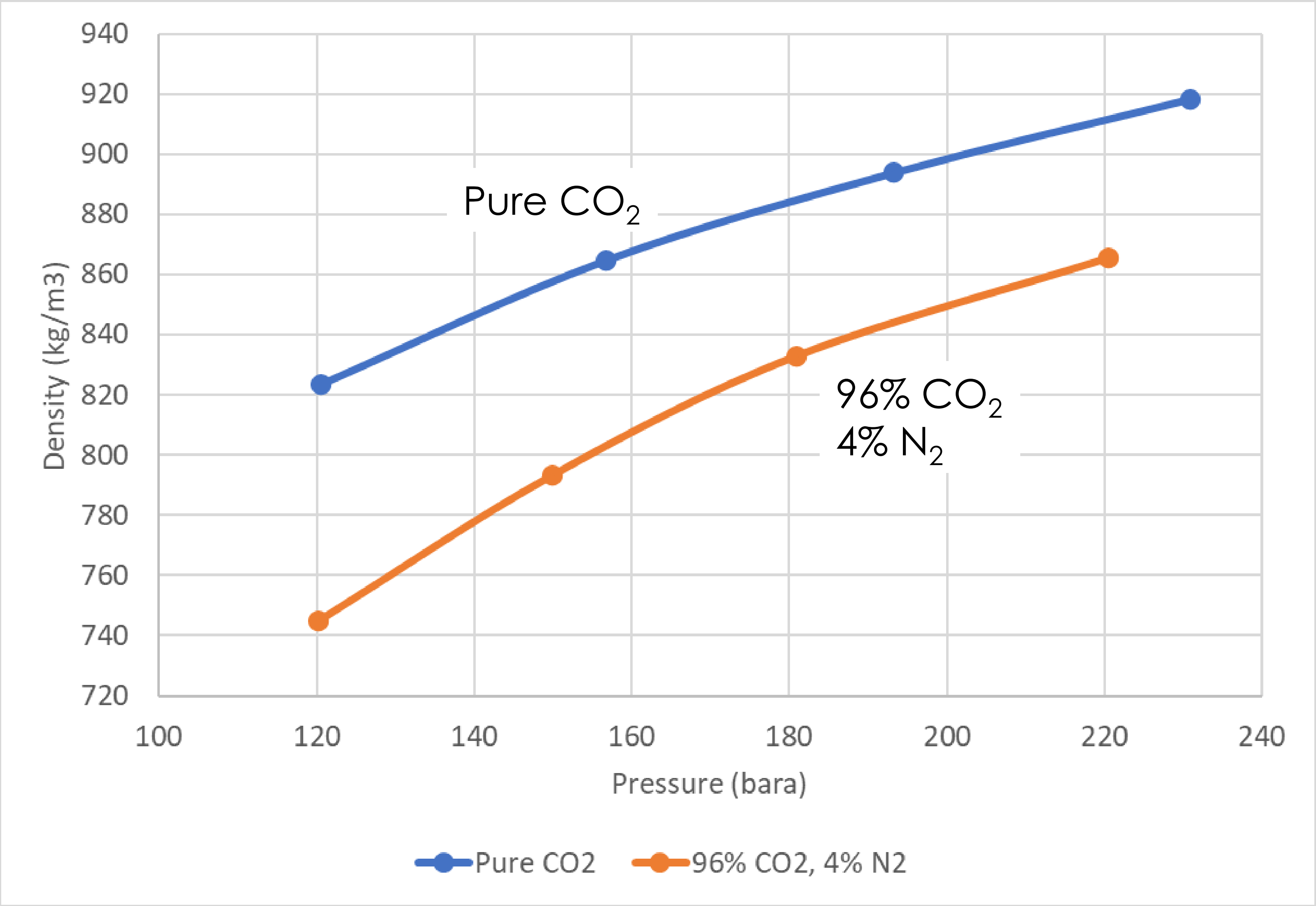
$CH_4$ > 95% ?

$N_2$

...

Reduced $CO_2$ storage capacity

# Density as a Function of Pressure

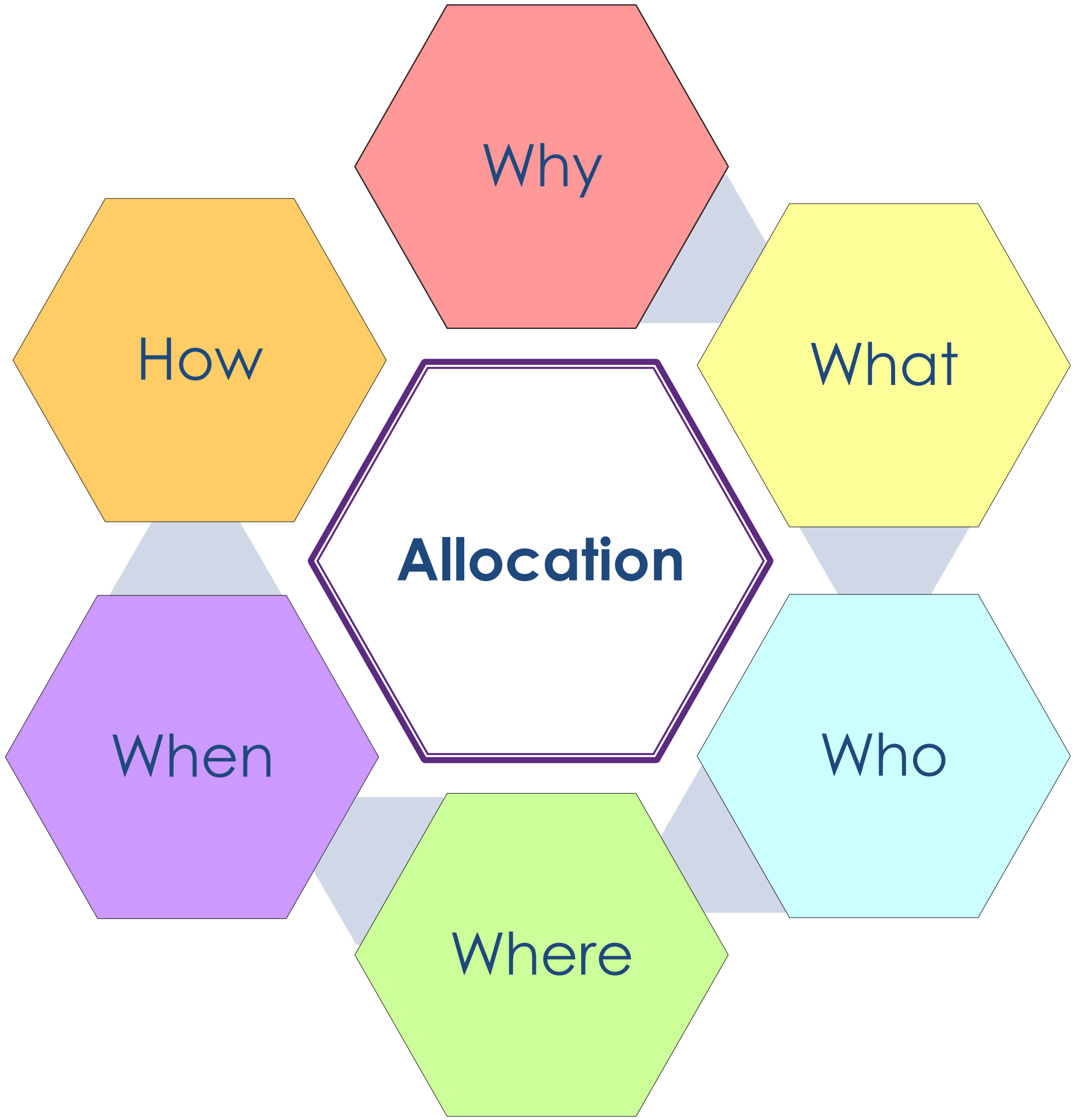



Impact on compression power requirements

# Why, What, Who, Where, When and How?

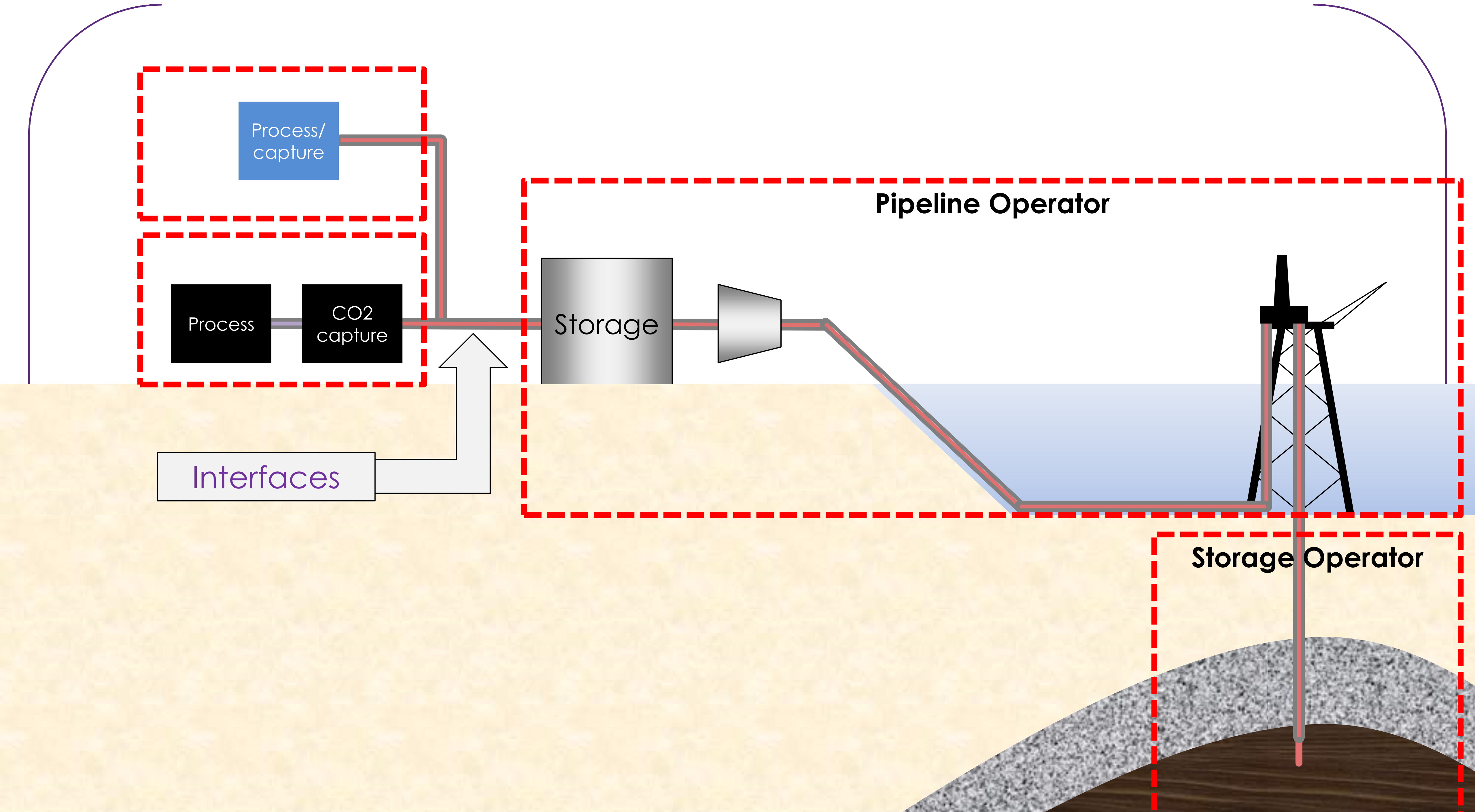
What

# Why, What, Who, Where, When and How?

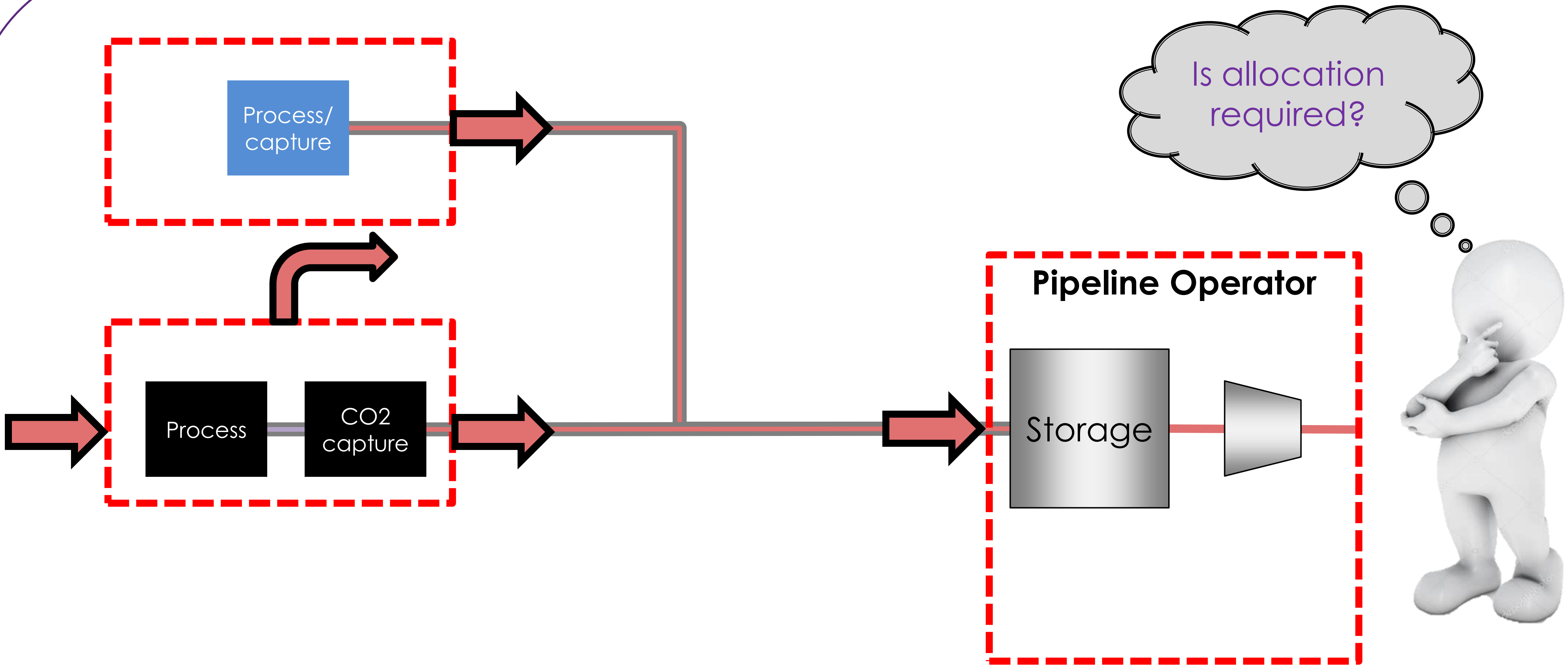


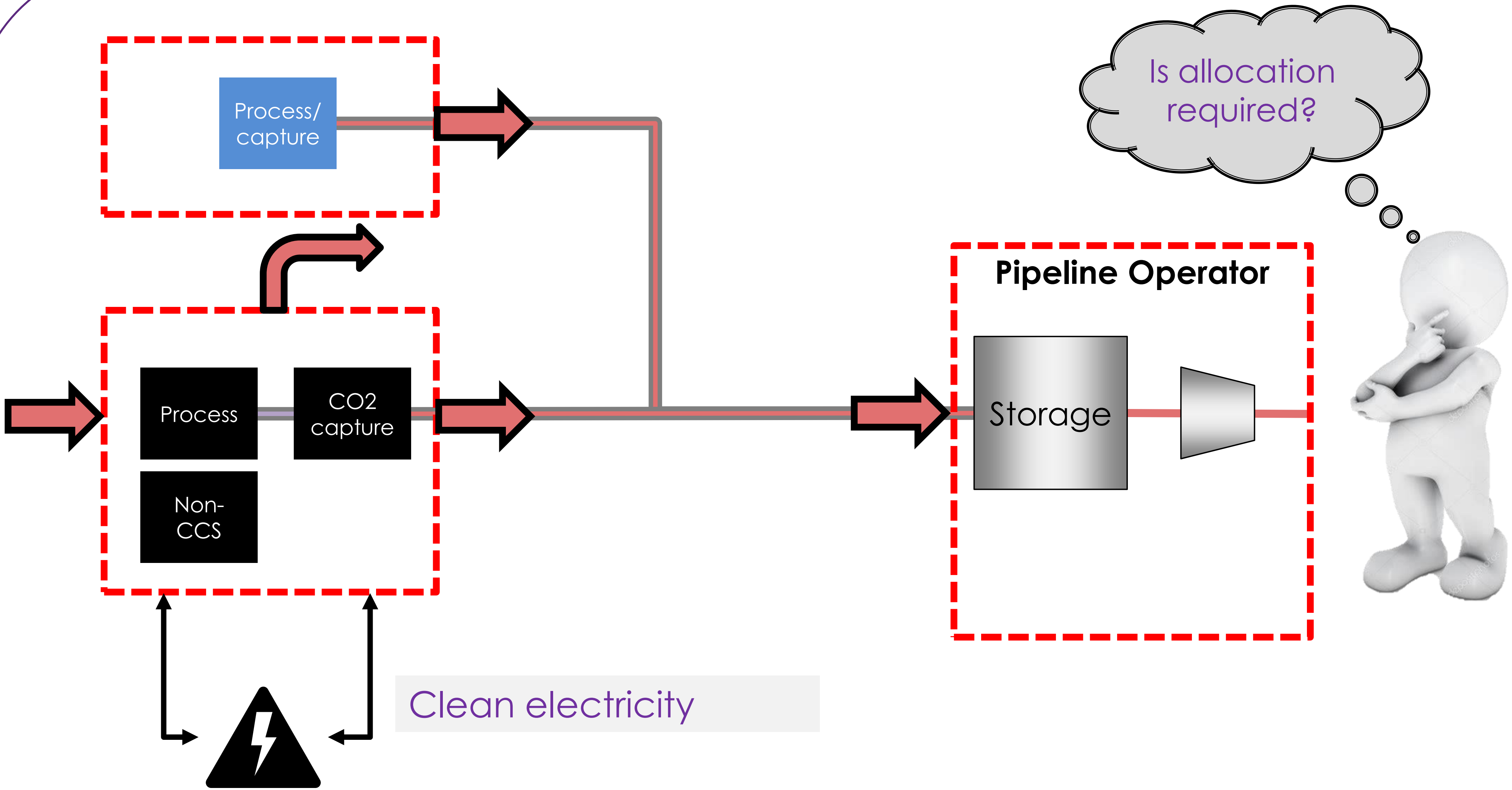
# Why, What, Who, Where, When and How?

Who



Process/
capture
Pipeline Operator
Process
CO2
capture
Storage
Interfaces
Storage Operator

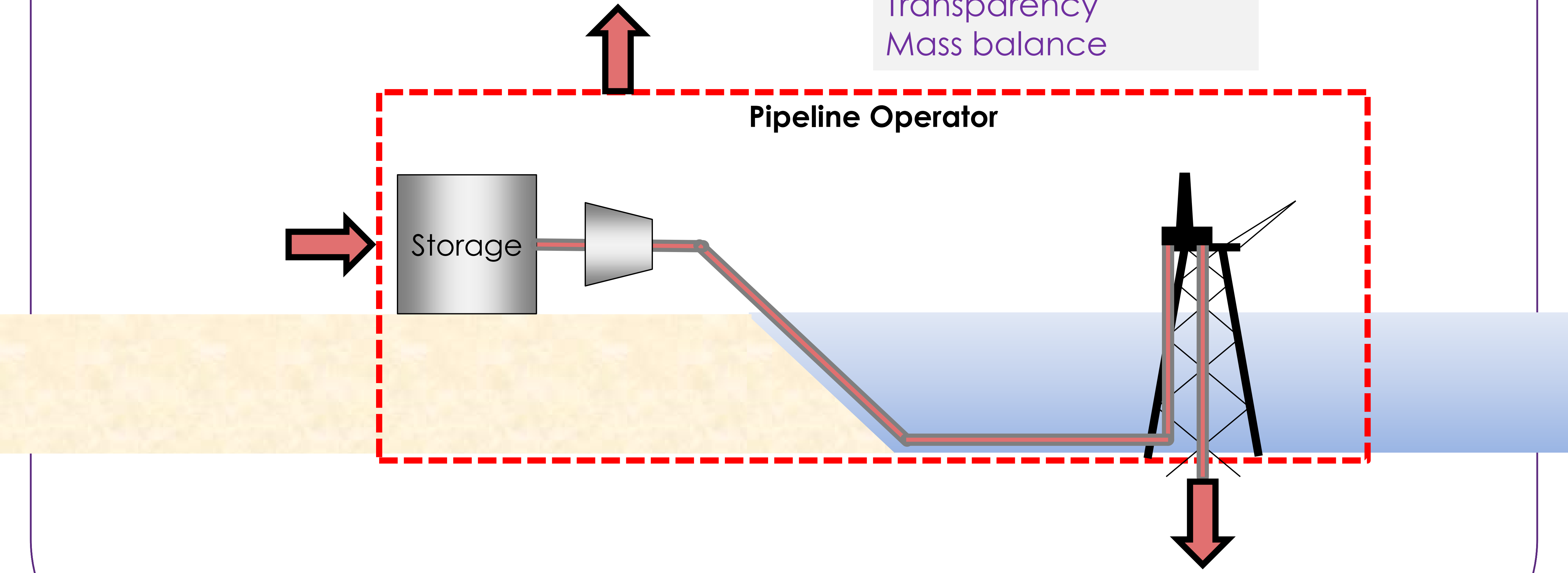

Process/
capture
Process
CO2
capture
Pipeline Operator
Storage
Is allocation
required?


Process/
capture
Process
CO2
capture
Non-
CCS
Clean electricity
Pipeline Operator
Storage
Is allocation
required?



accord (e.s.l)

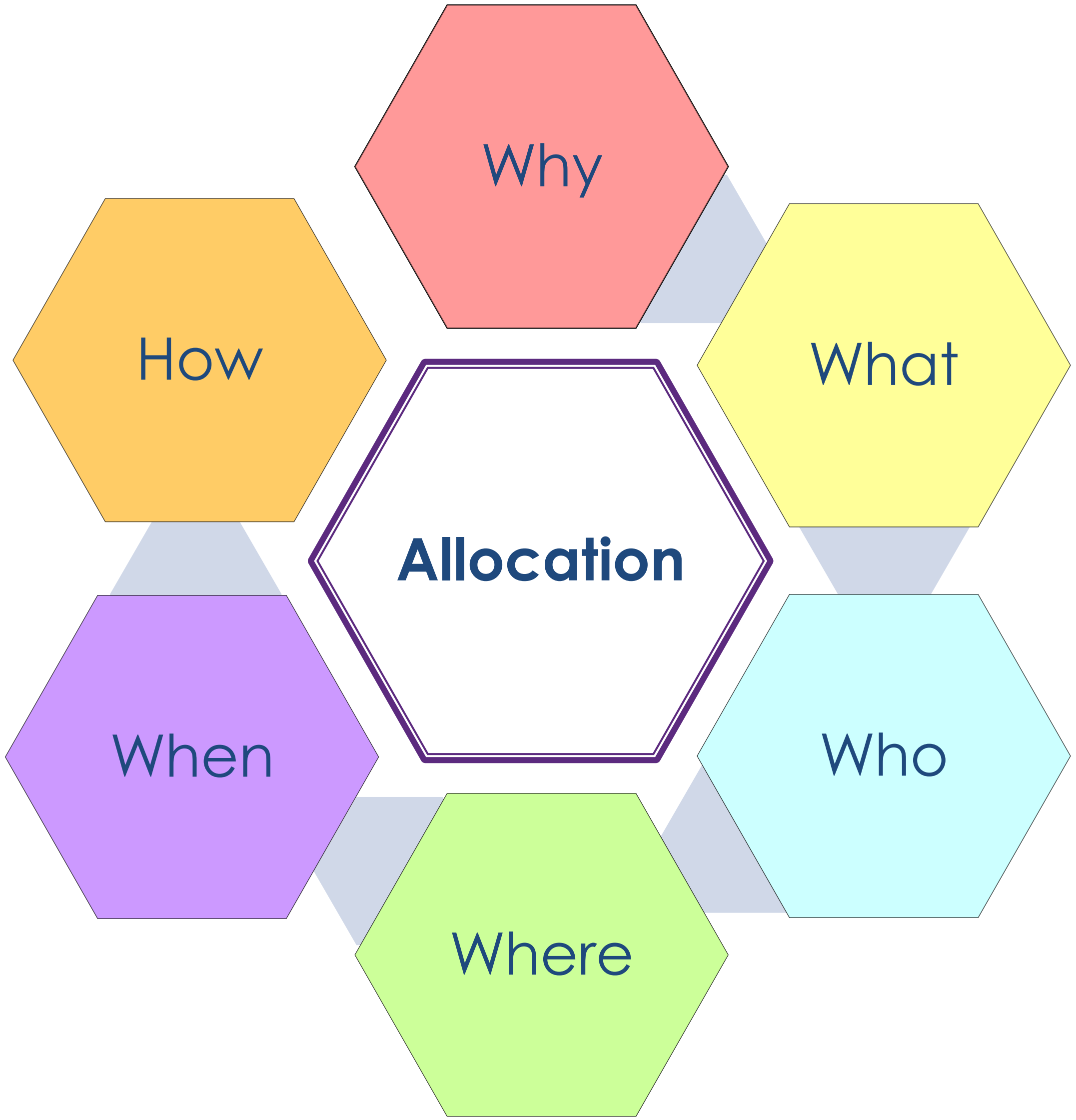
Commercial
Tariff
Power consumption
Transparency
Mass balance



# Why, What, Who, Where, When and How?

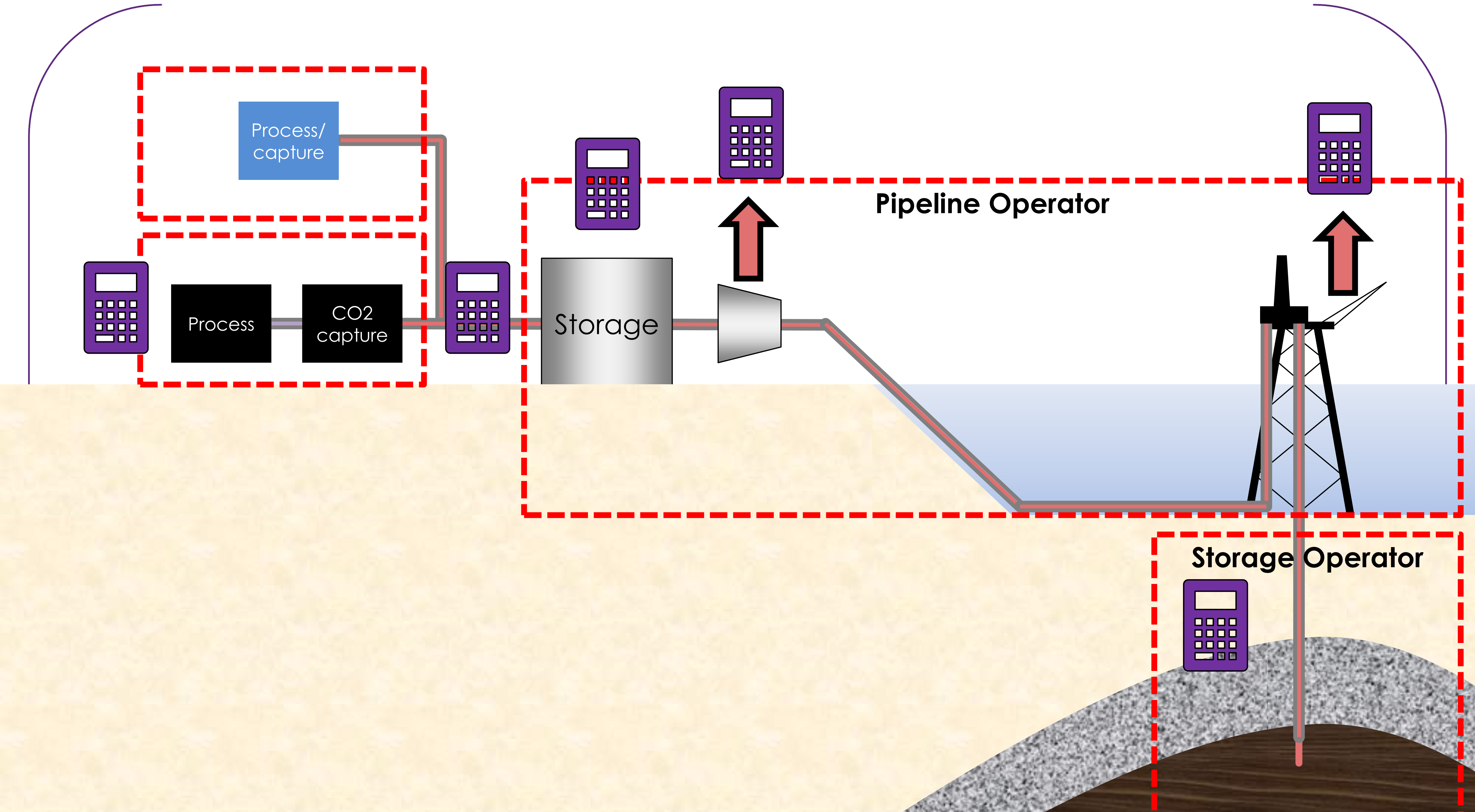
Who

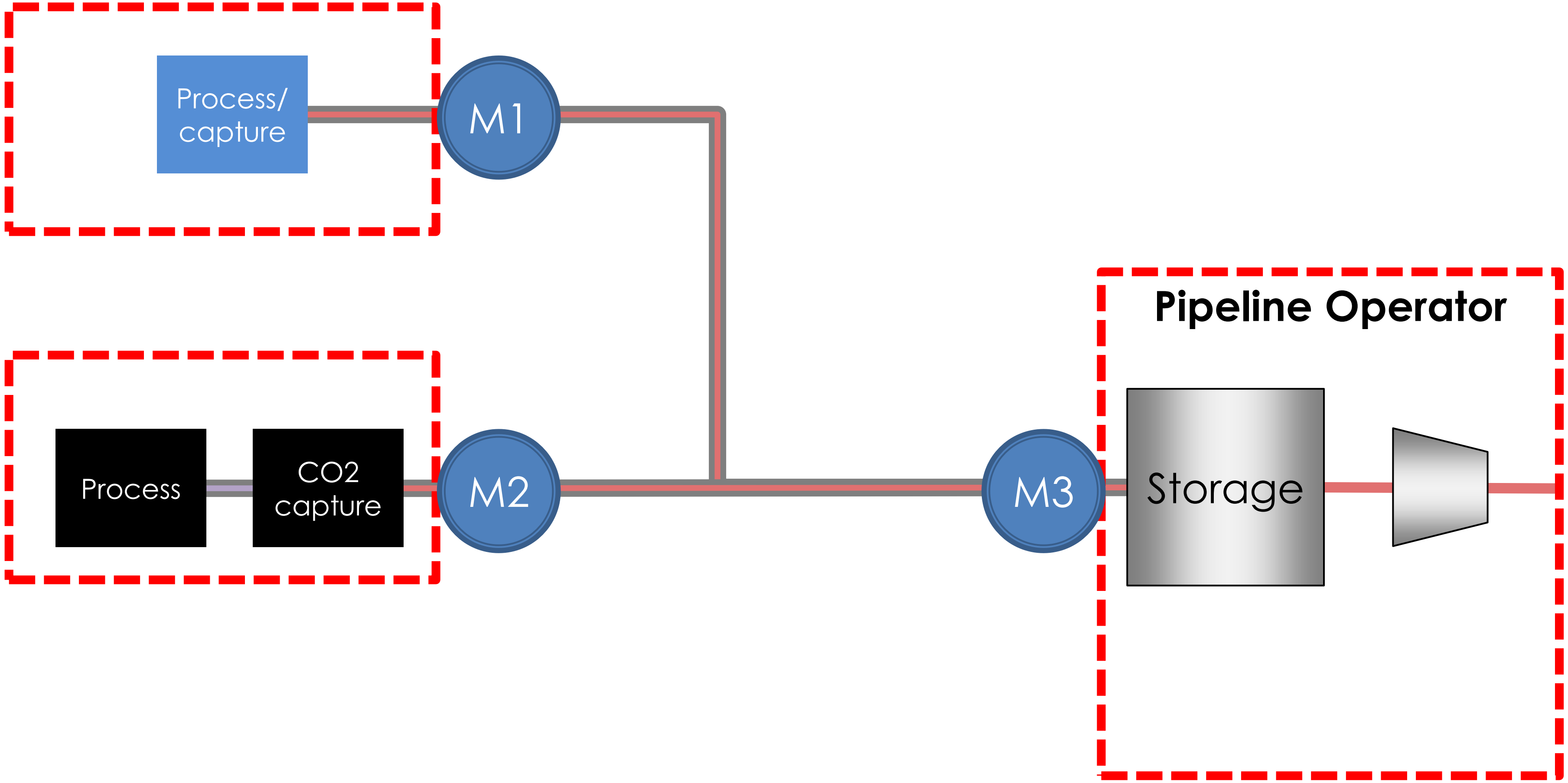
# Why, What, Who, Where, When and How?



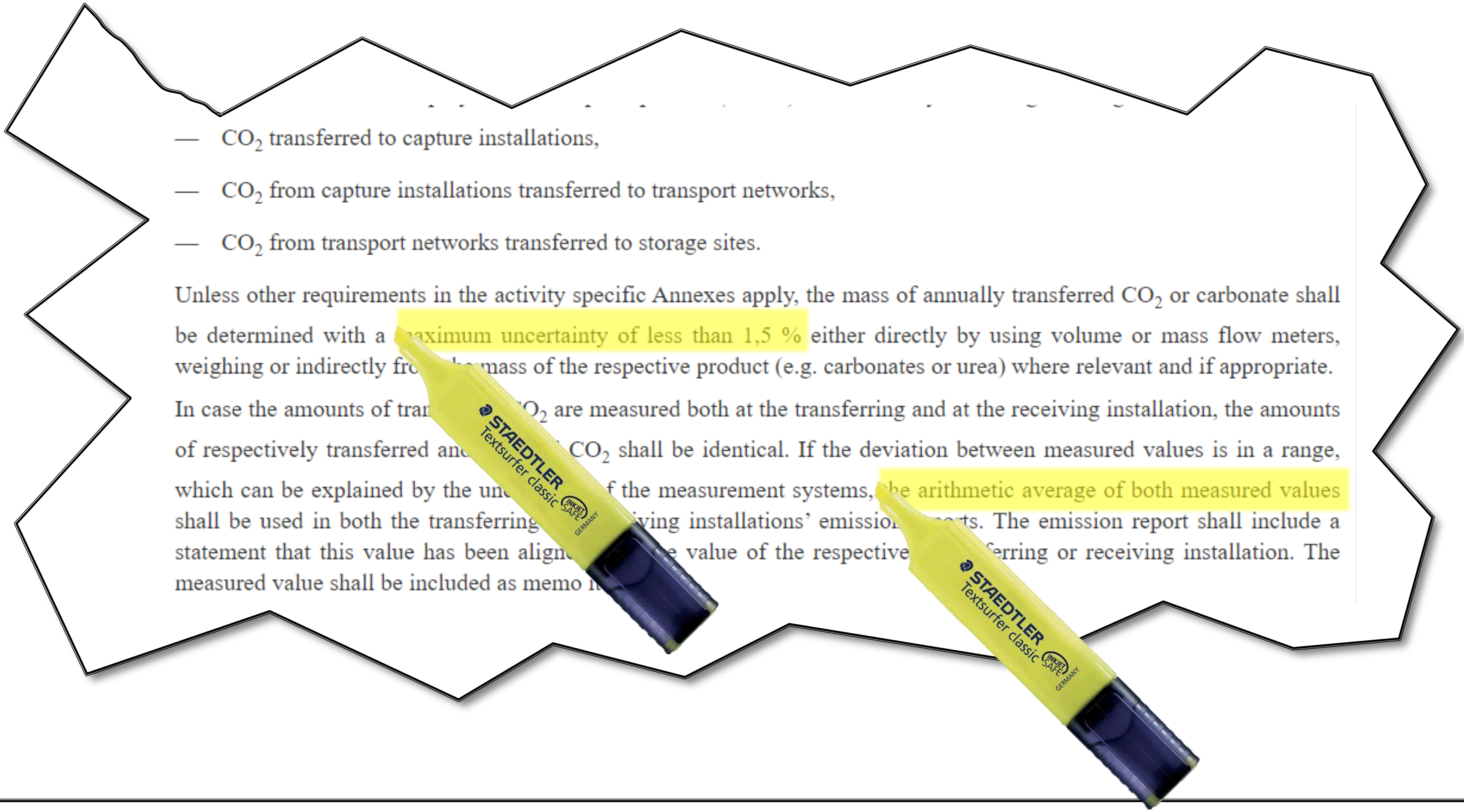
# Why, What, Who, Where, When and How?

Where


Process/
capture
Process
CO2
capture
Storage
Pipeline Operator
Storage Operator


Process/
capture
M1
Process
CO2
capture
M2
M3
Pipeline Operator
Storage

# EU ETS



— $CO_2$ transferred to capture installations,

— $CO_2$ from capture installations transferred to transport networks,

— $CO_2$ from transport networks transferred to storage sites.

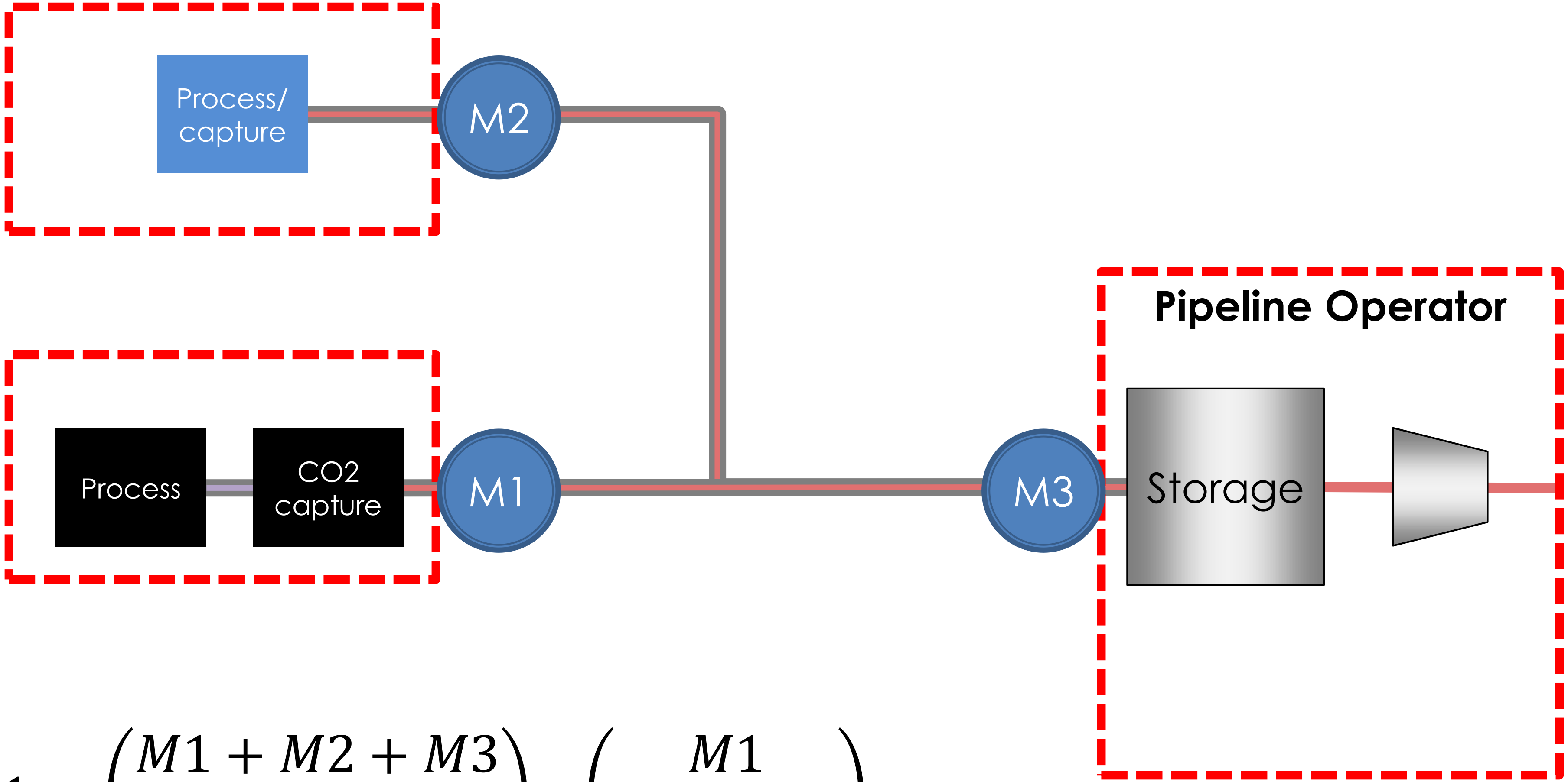
Unless other requirements in the activity specific Annexes apply, the mass of annually transferred $CO_2$ or carbonate shall be determined with a maximum uncertainty of less than 1,5 % either directly by using volume or mass flow meters, weighing or indirectly fro... mass of the respective product (e.g. carbonates or urea) where relevant and if appropriate.

In case the amounts of tran... $O_2$ are measured both at the transferring and at the receiving installation, the amounts of respectively transferred an... $CO_2$ shall be identical. If the deviation between measured values is in a range, which can be explained by the unc... f the measurement systems, the arithmetic average of both measured values shall be used in both the transferring ...iving installations' emissio... ...ts. The emission report shall include a statement that this value has been align... ...e value of the respective ...erring or receiving installation. The measured value shall be included as memo i...





accord (e.s.l)

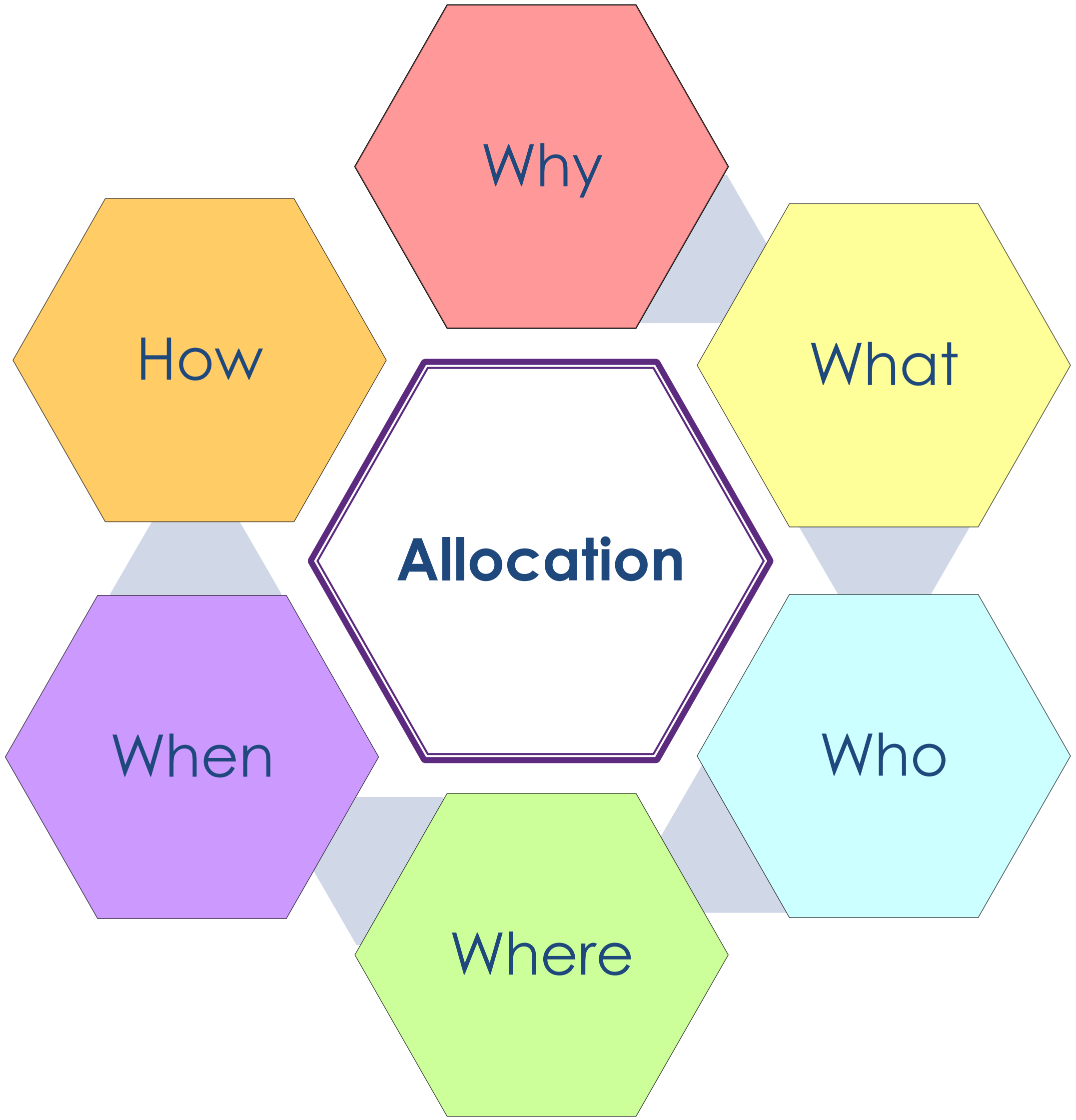



$$A1 = \left(\frac{M1 + M2 + M3}{2}\right) * \left(\frac{M1}{M1 + M2}\right)$$

# Why, What, Who, Where, When and How?

Where

# Why, What, Who, Where, When and How?

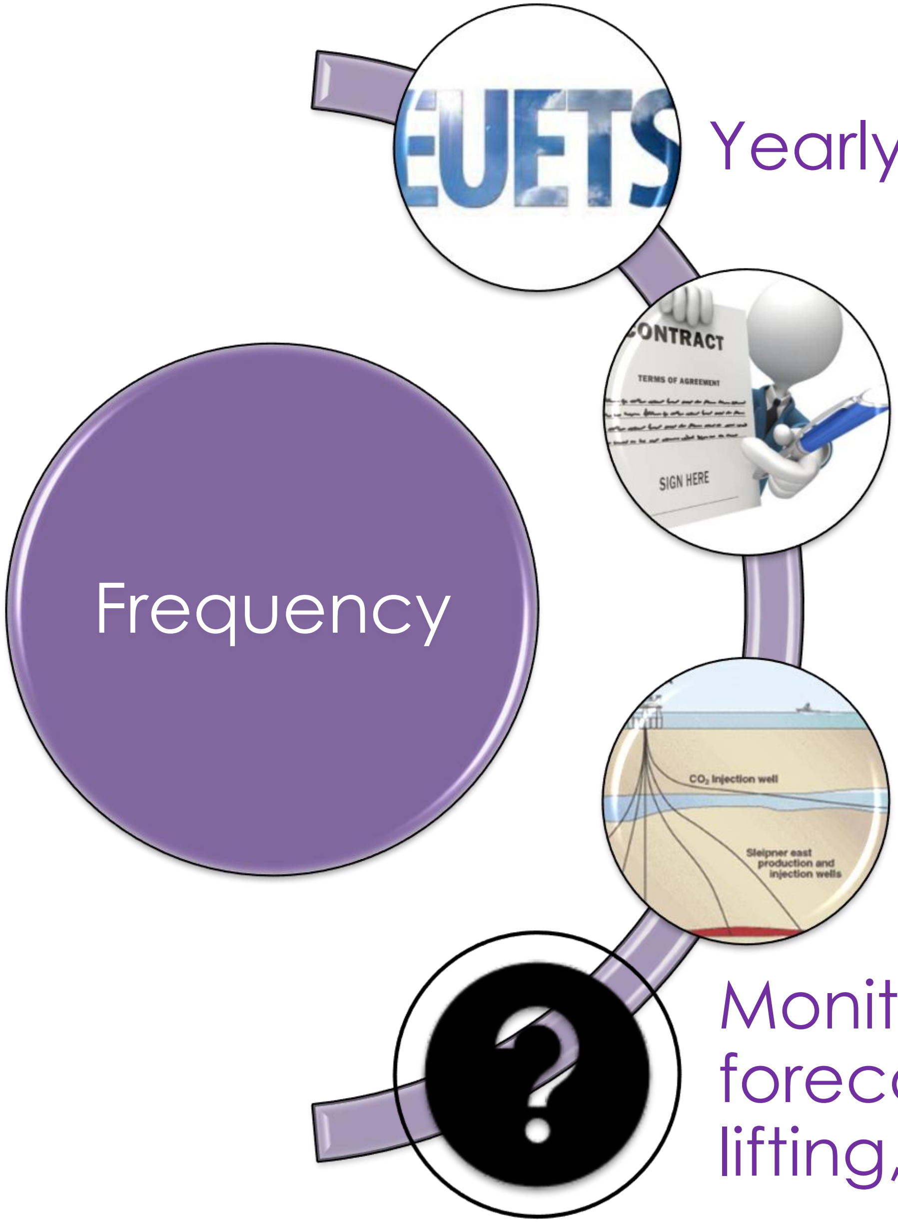





accord (e.s.l)

# Why, What, Who, Where, When and How?

When




Yearly

Monthly

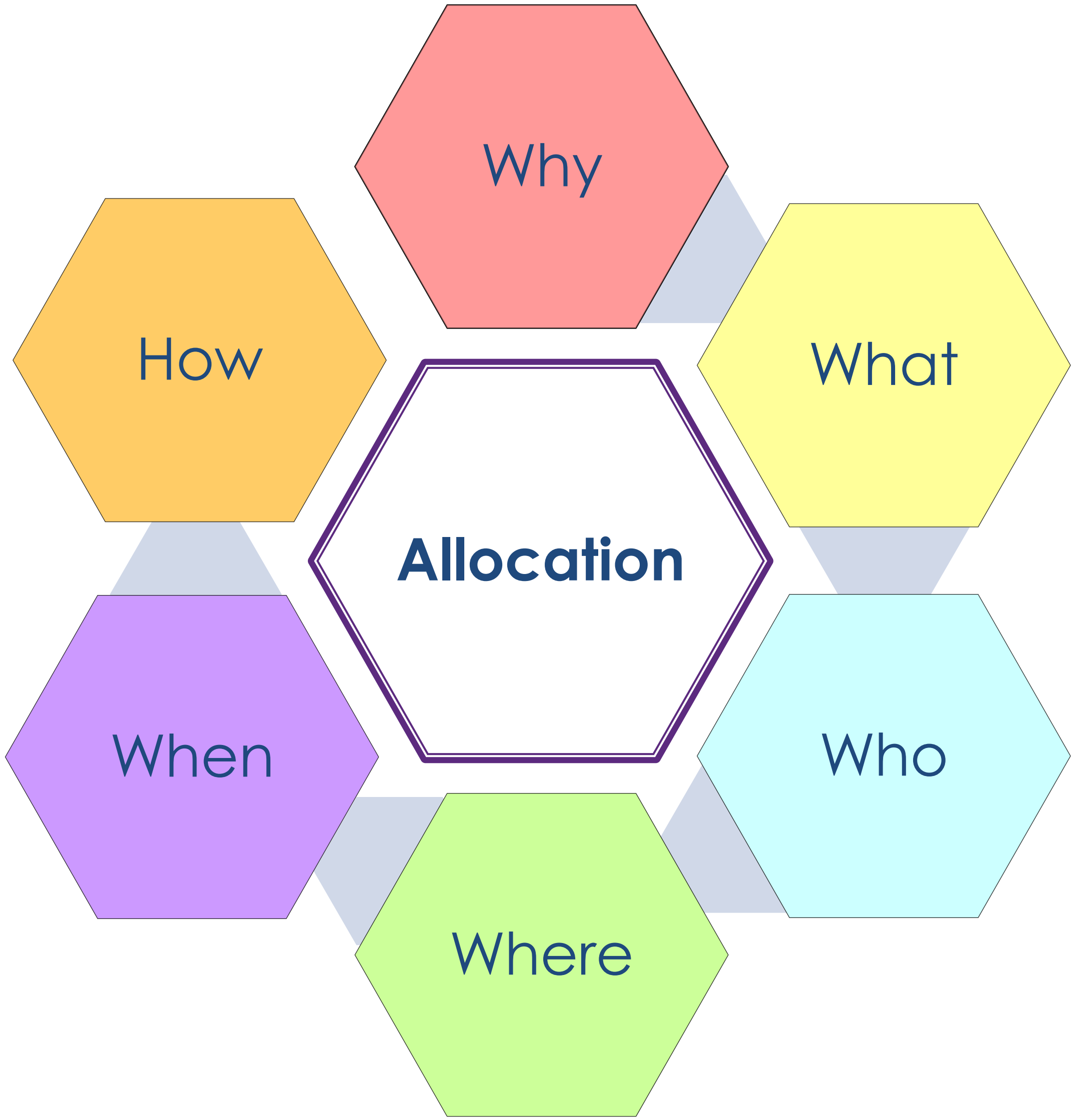
Daily

Monitoring, purity, forecasting, nominations, lifting, trading, capacity

# Why, What, Who, Where, When and How?

When

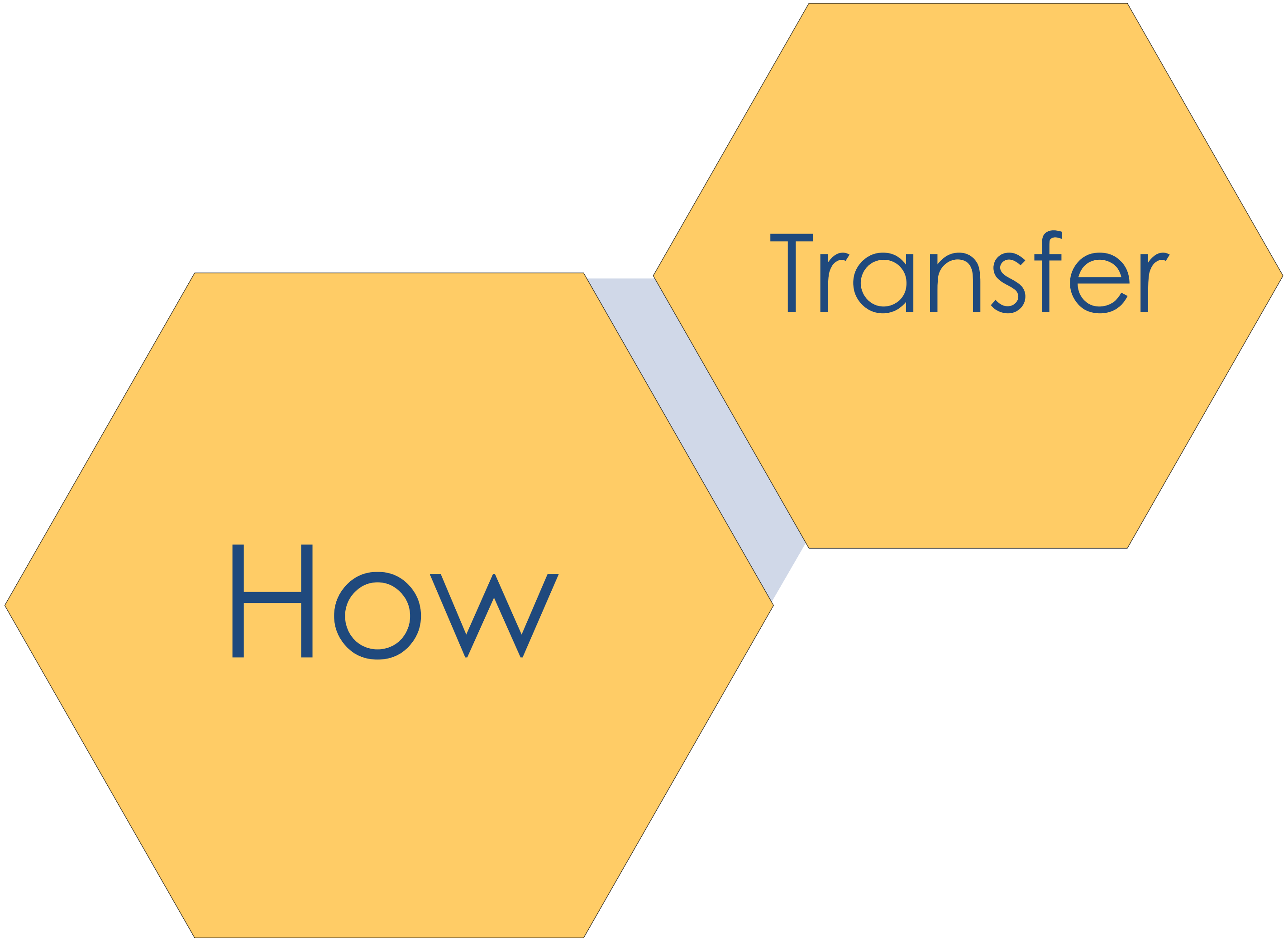
# Why, What, Who, Where, When and How?



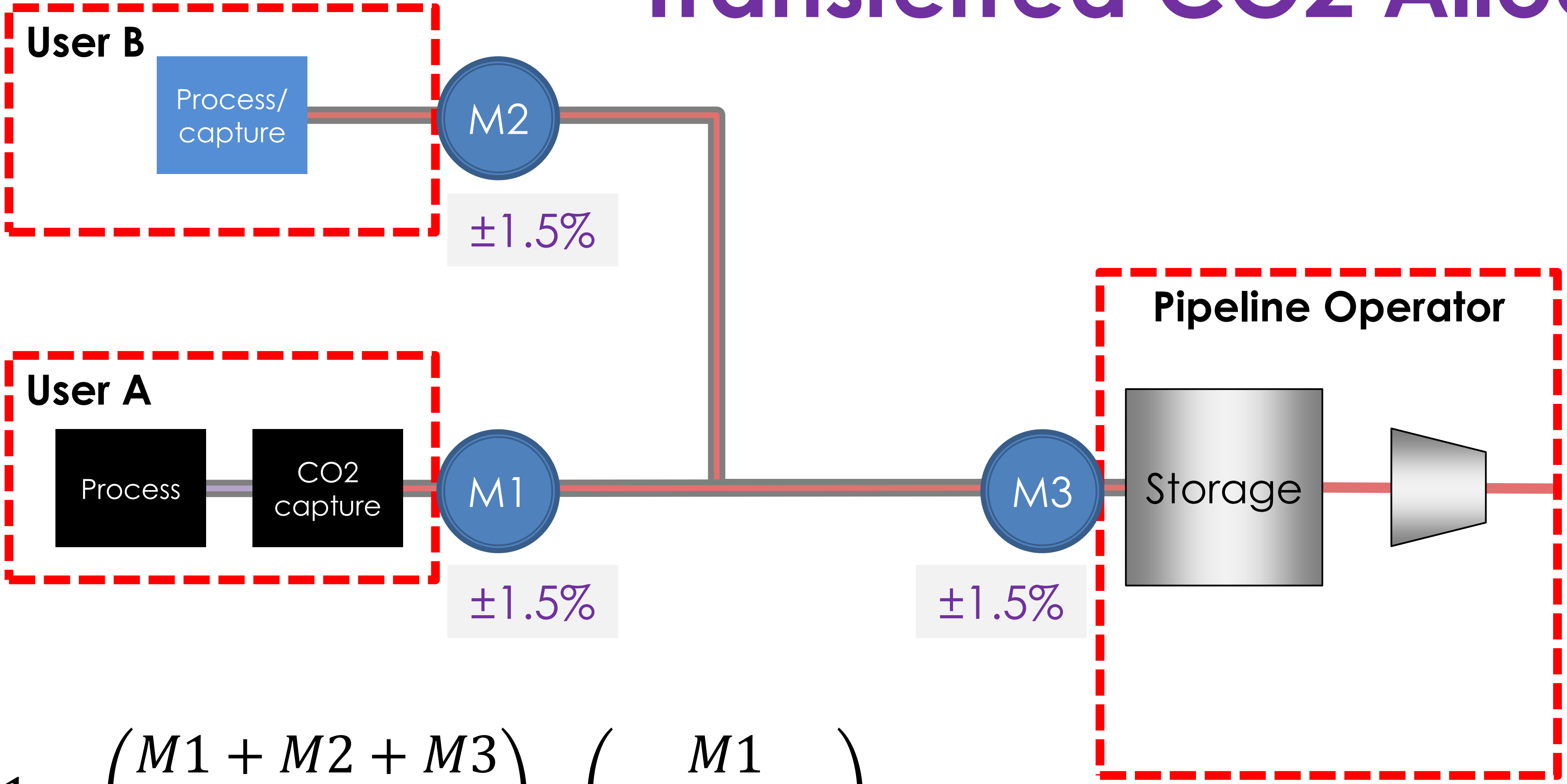
# Why, What, Who, Where, When and How?

How

# Why, What, Who, Where, When and How?



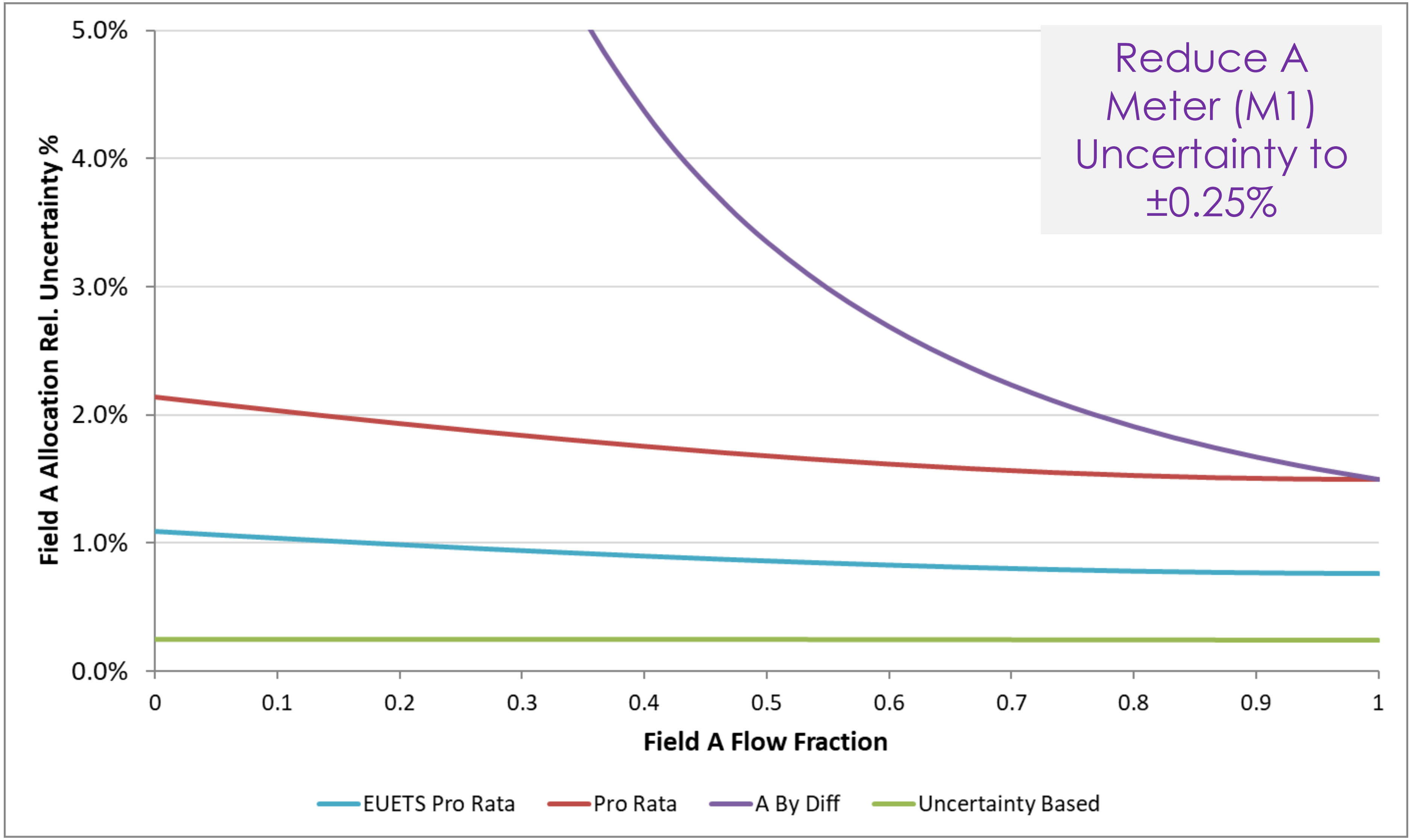
# Transferred CO2 Allocation



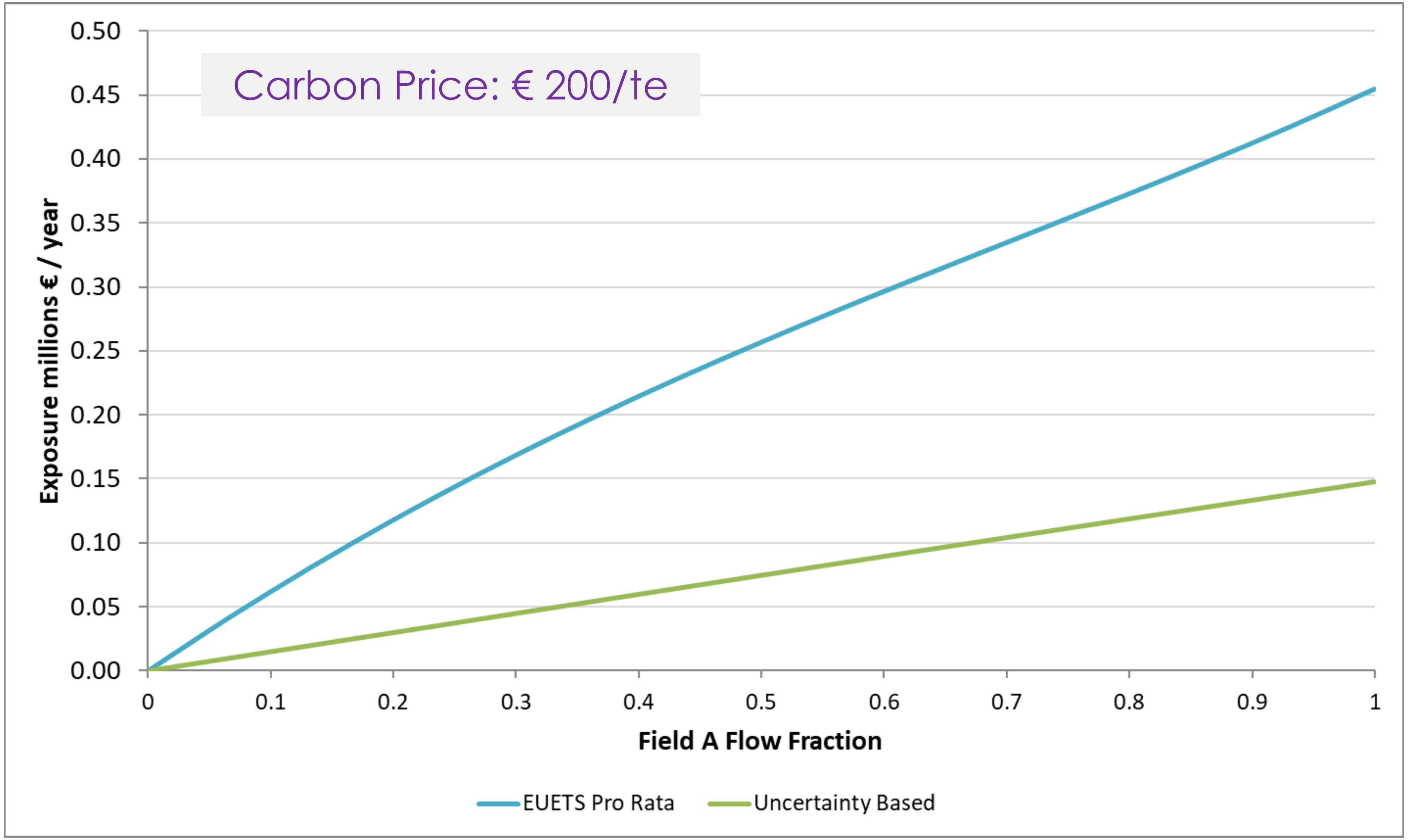

$$A1 = \left(\frac{M1 + M2 + M3}{2}\right) * \left(\frac{M1}{M1 + M2}\right)$$

Pro Rata

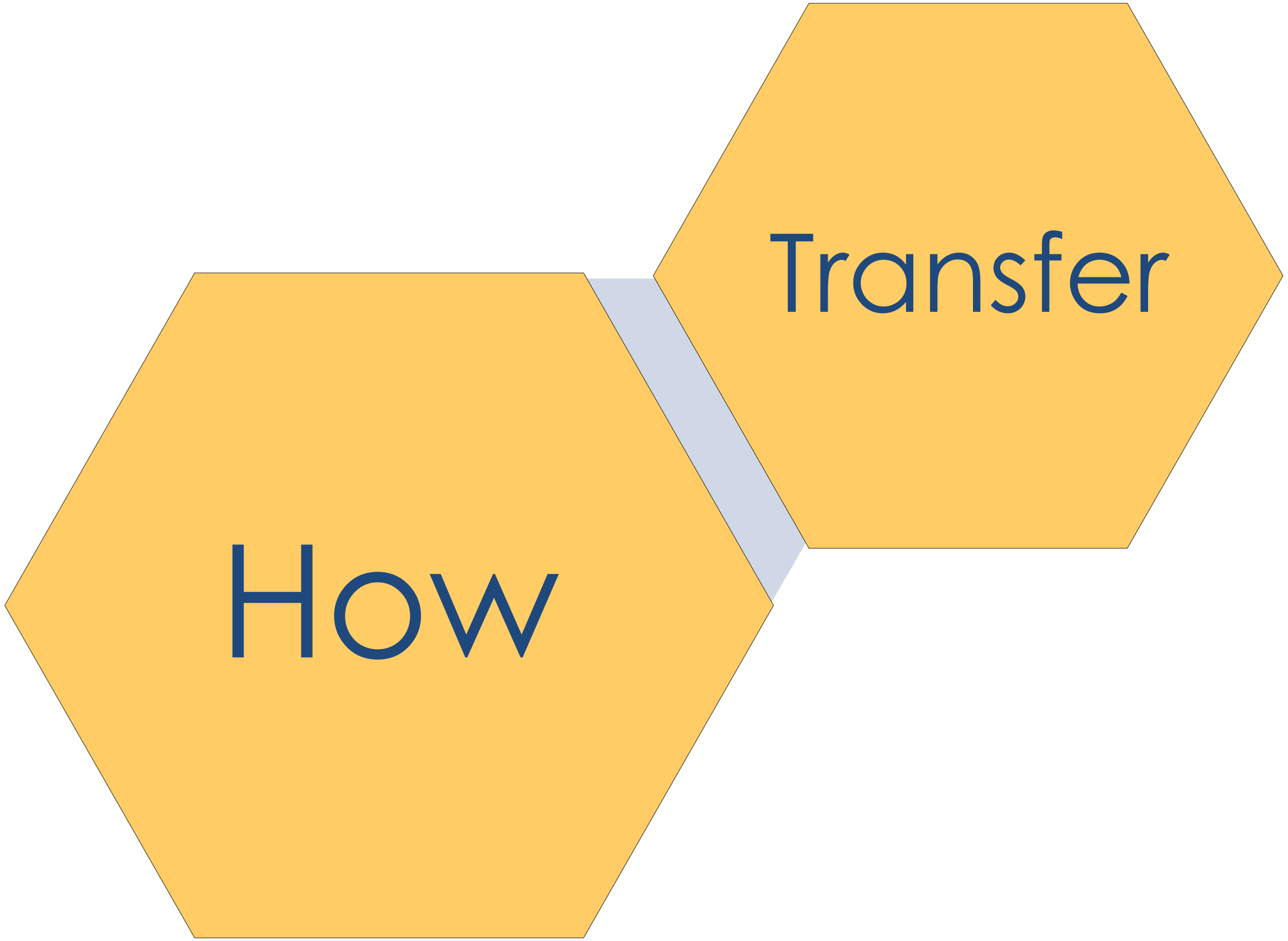
# A Allocation Uncertainty



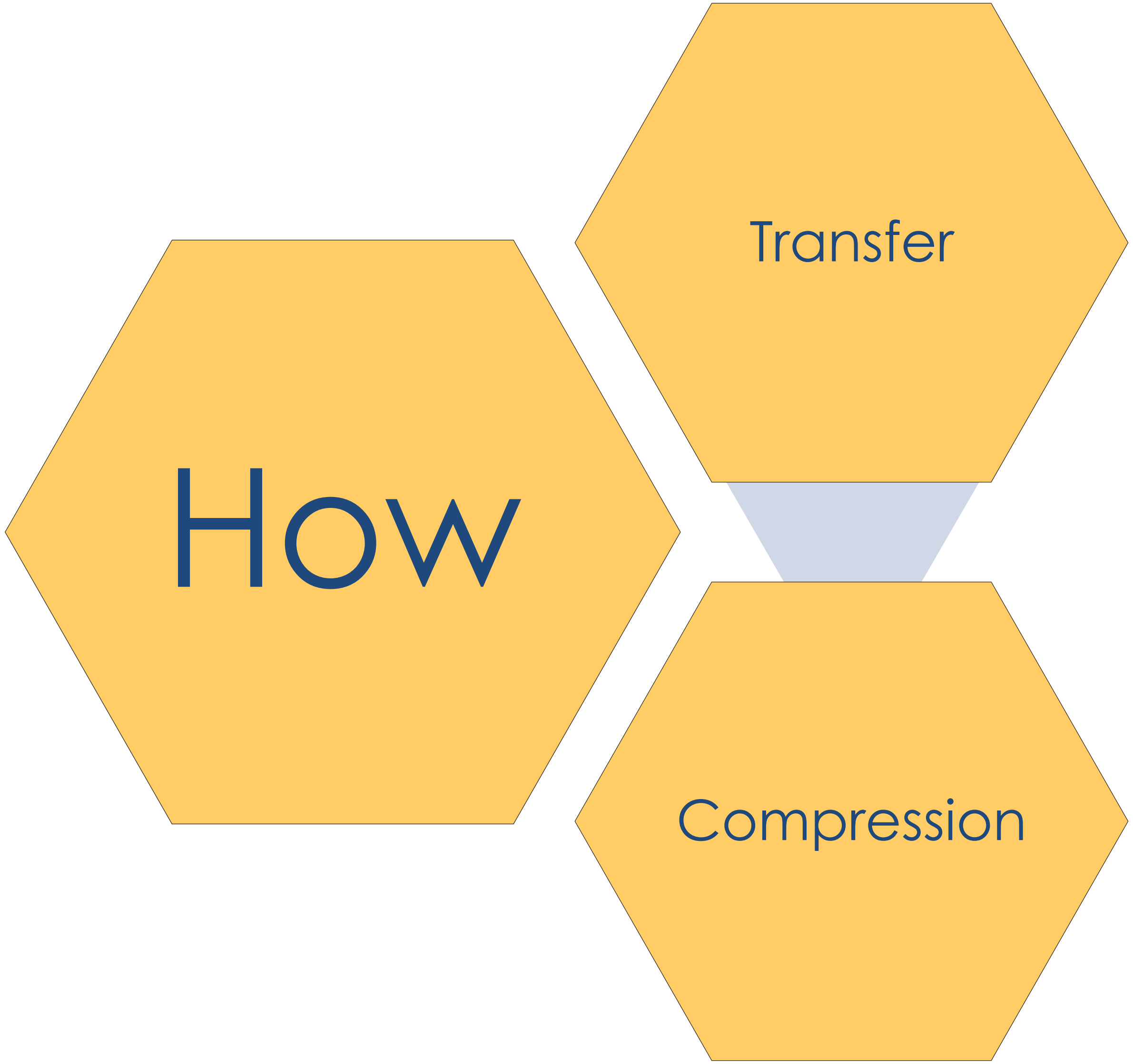
# A Allocation Exposure



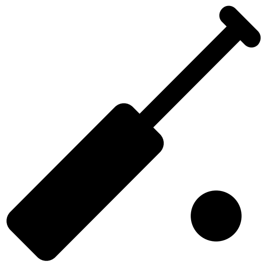
# Why, What, Who, Where, When and How?



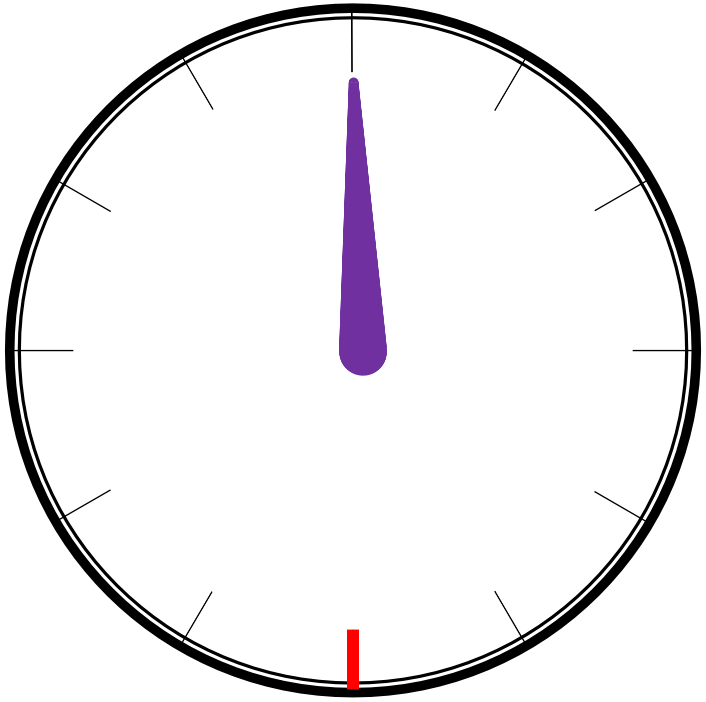
# Why, What, Who, Where, When and How?



# Bat and Ball Problem

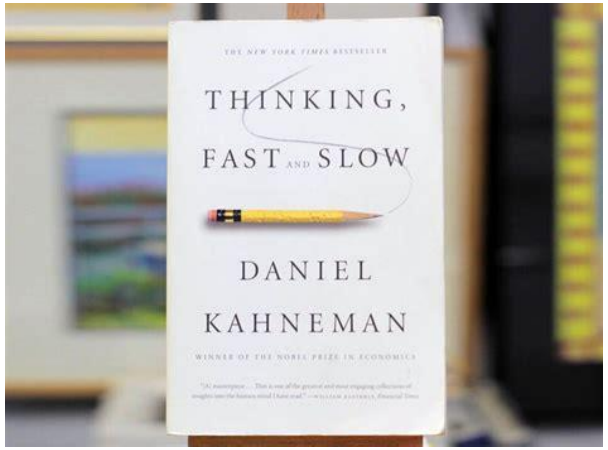


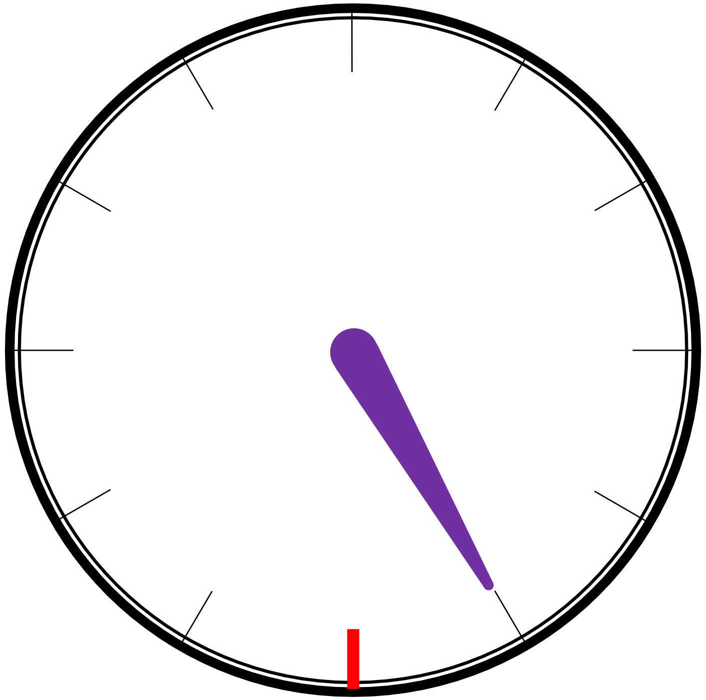
- Bat and a ball together cost € 1.10
- The bat cost one euro more than the ball
- How much does the ball cost?
- 10 cents?
- 5 cents

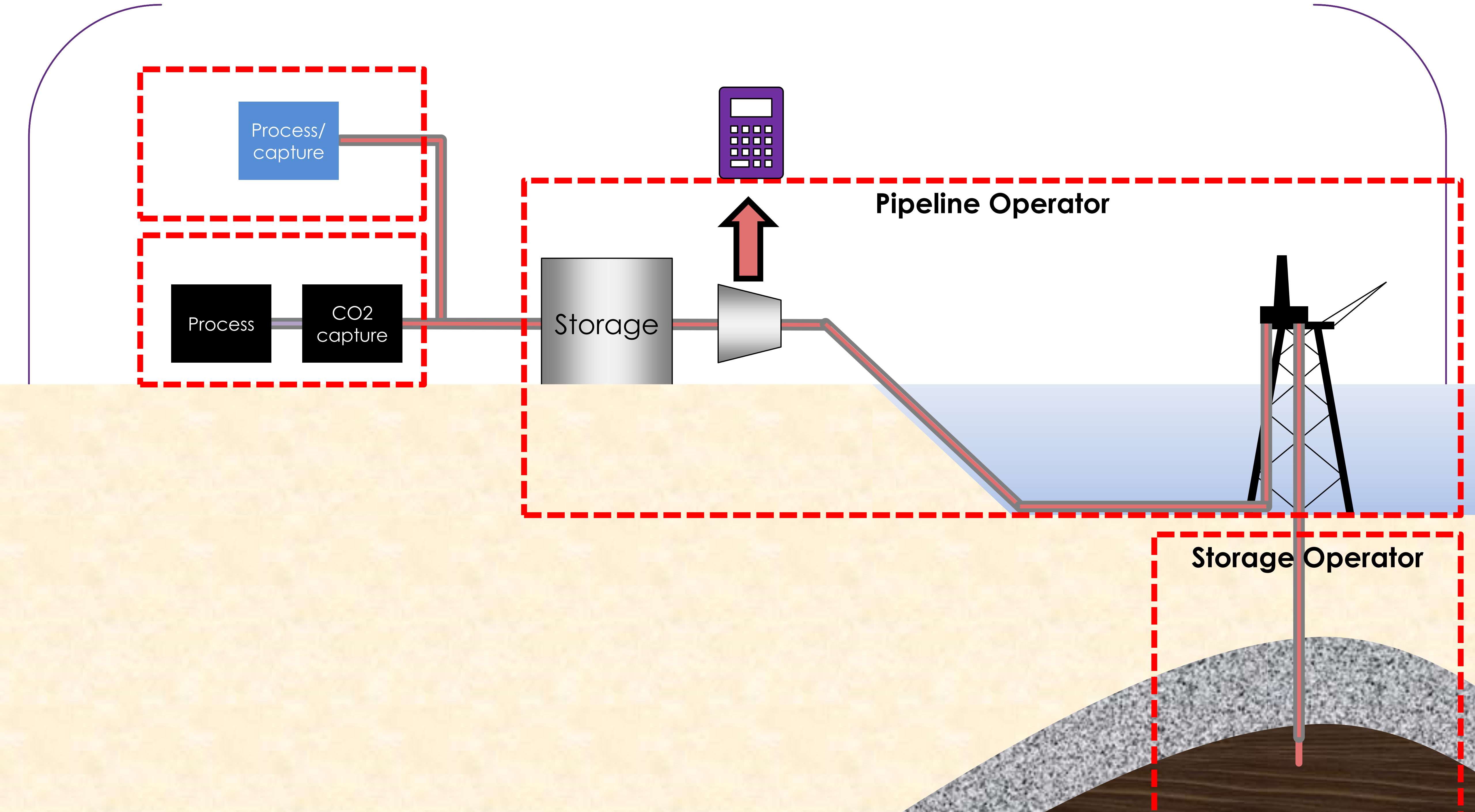


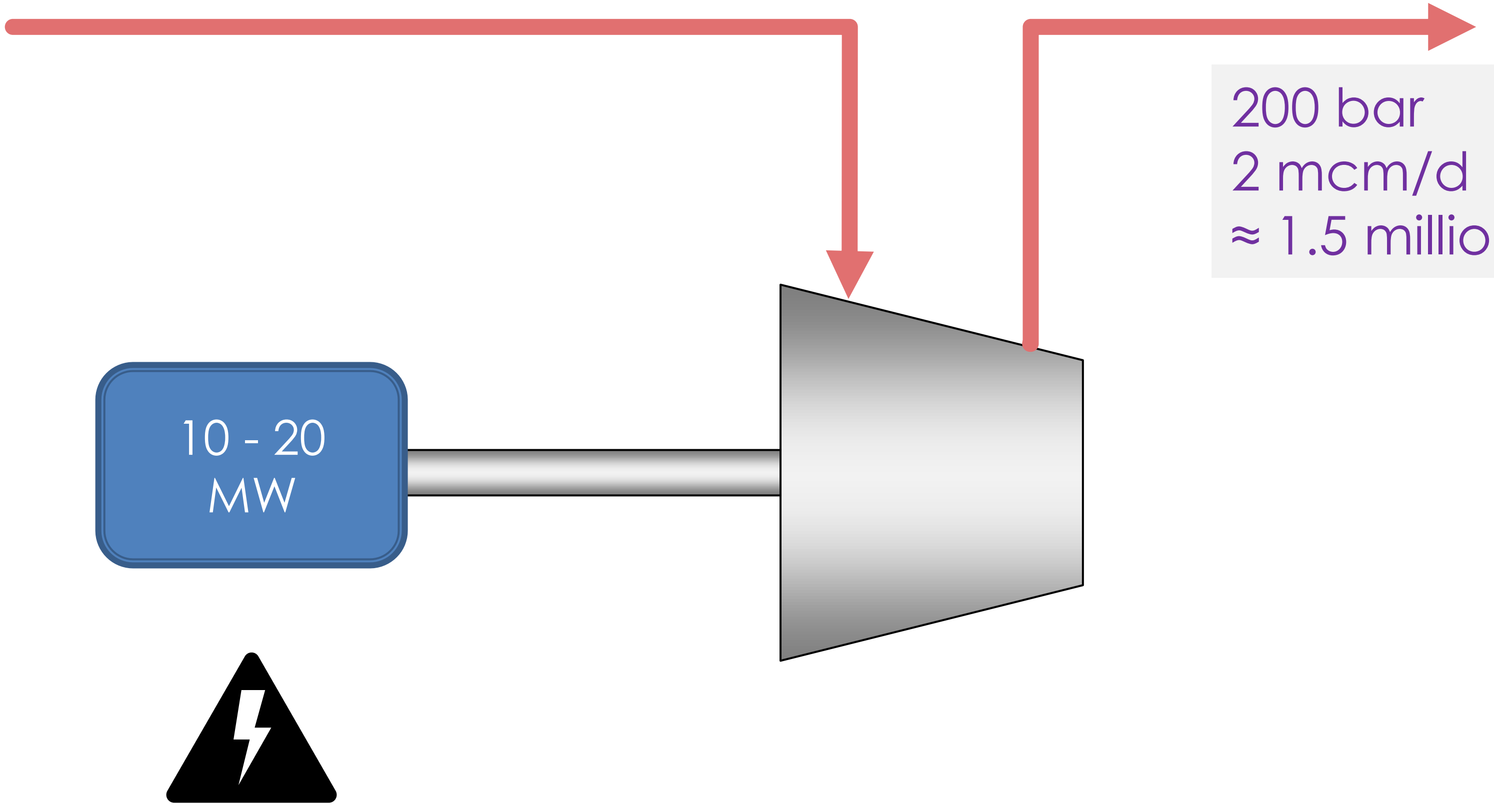
# Bat and Ball Problem

- Bat and a ball together cost € 1.10
- The bat cost one euro
- How much does the ball cost?
- 10 cents?



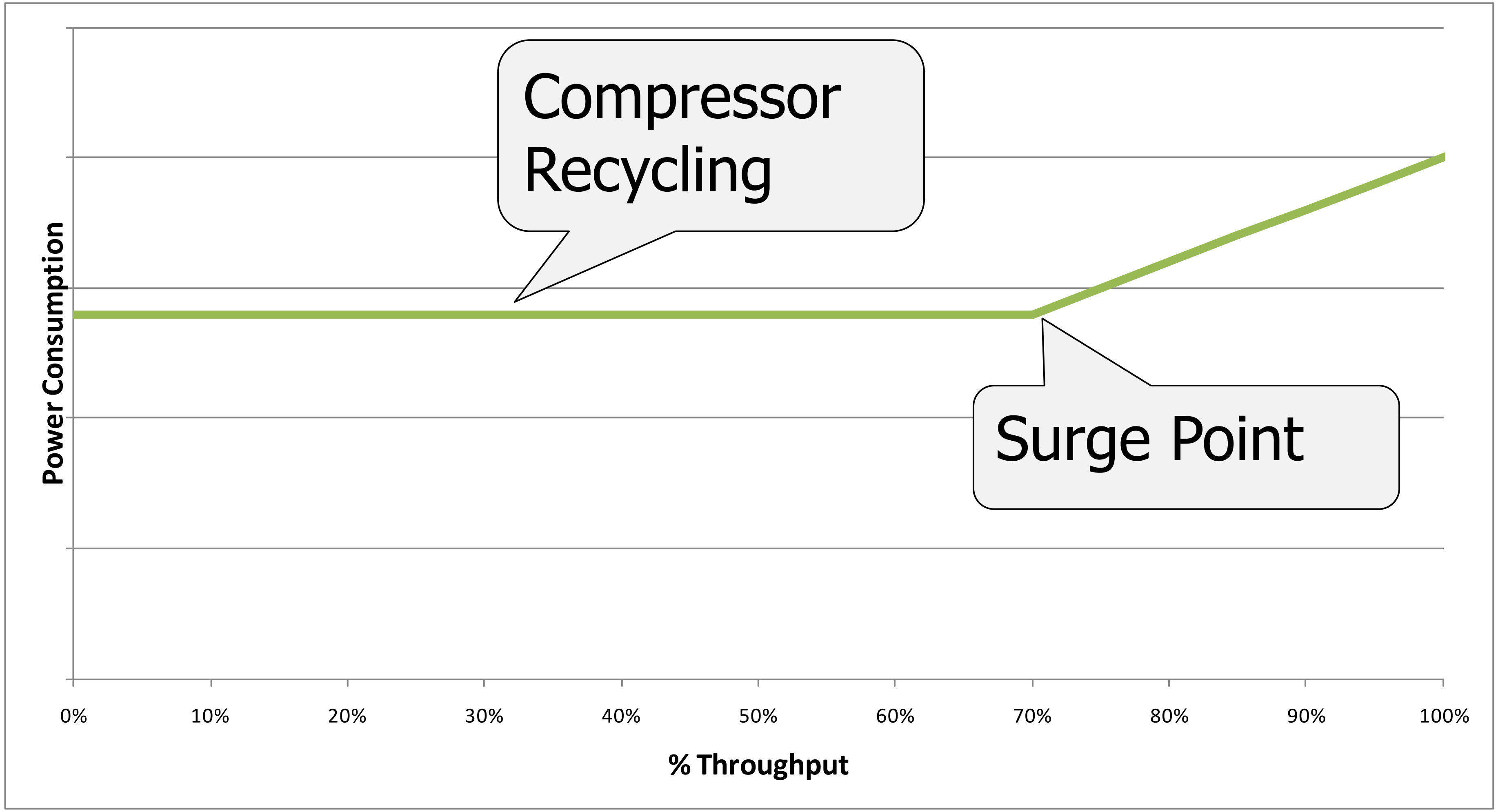

Process/
capture
Process
CO2
capture
Storage
Pipeline Operator
Storage Operator



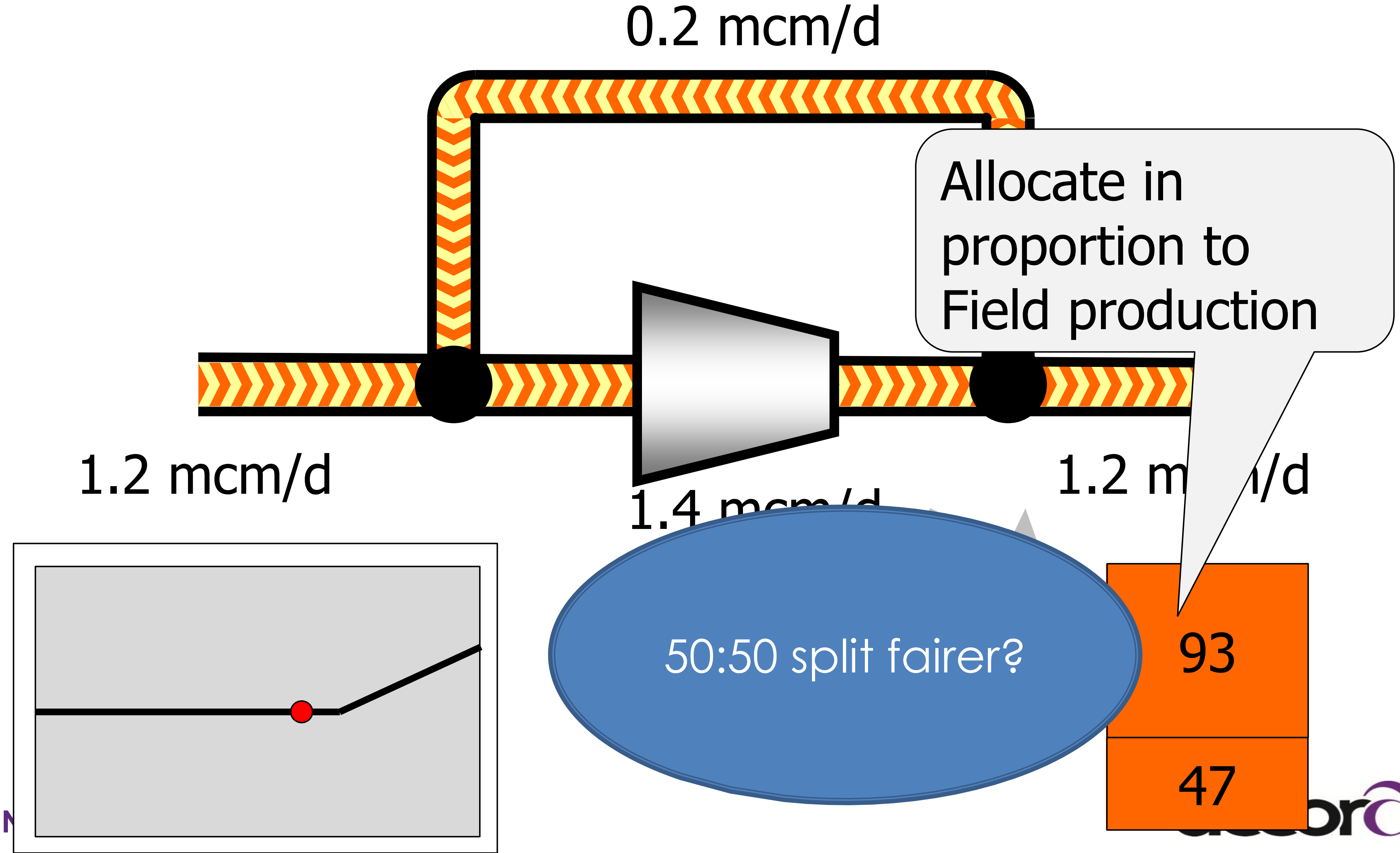

200 bar
2 mcm/d
≈ 1.5 million te/y $CO_2$

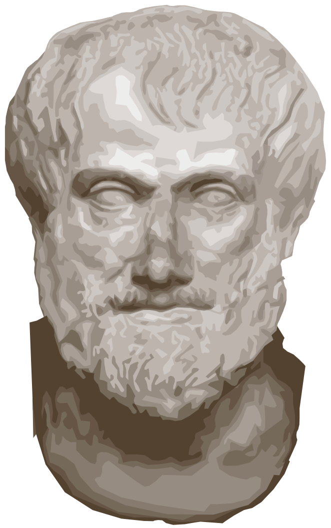
200 t/d CO2e
~40,000 €/d
~16 million €/y

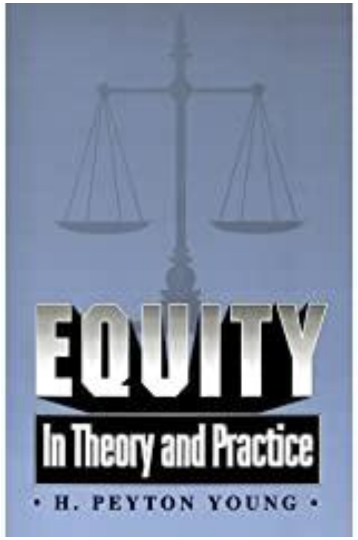
# Compressor Power Consumption

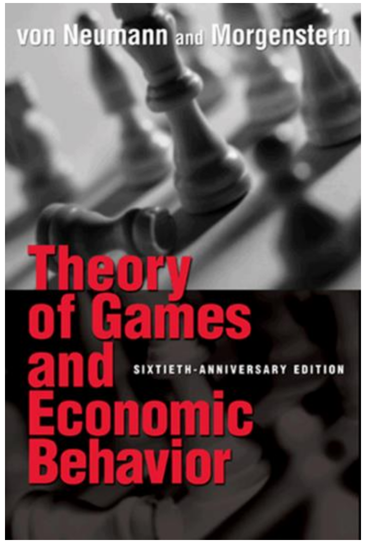


**User A 0.8 mcm/d**
**User B 0.4 mcm/d**








Pro rata appears arbitrary to some extent

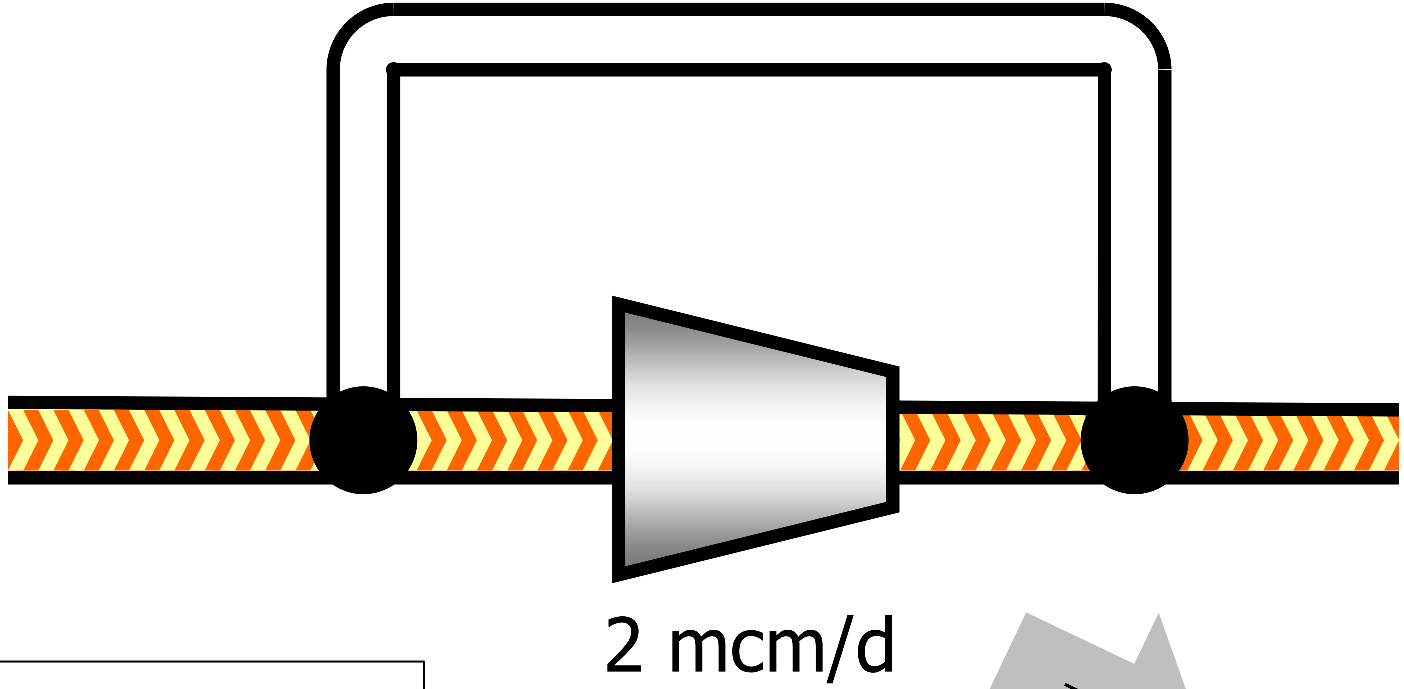
**Game Theory**

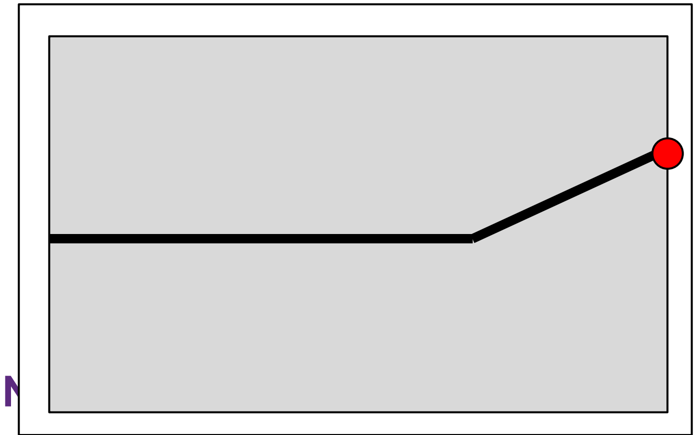
Define some properties wish the allocation to have

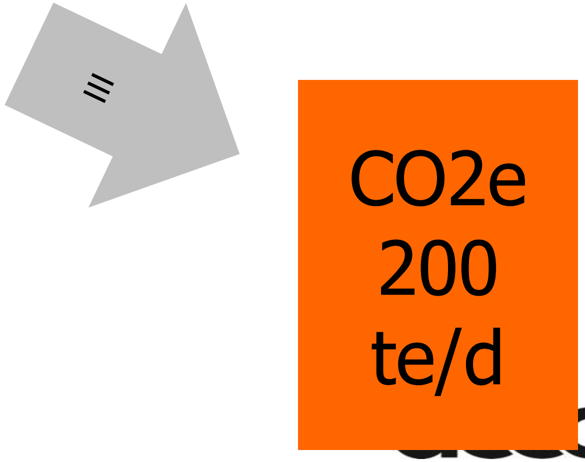


accord (e.s.l)

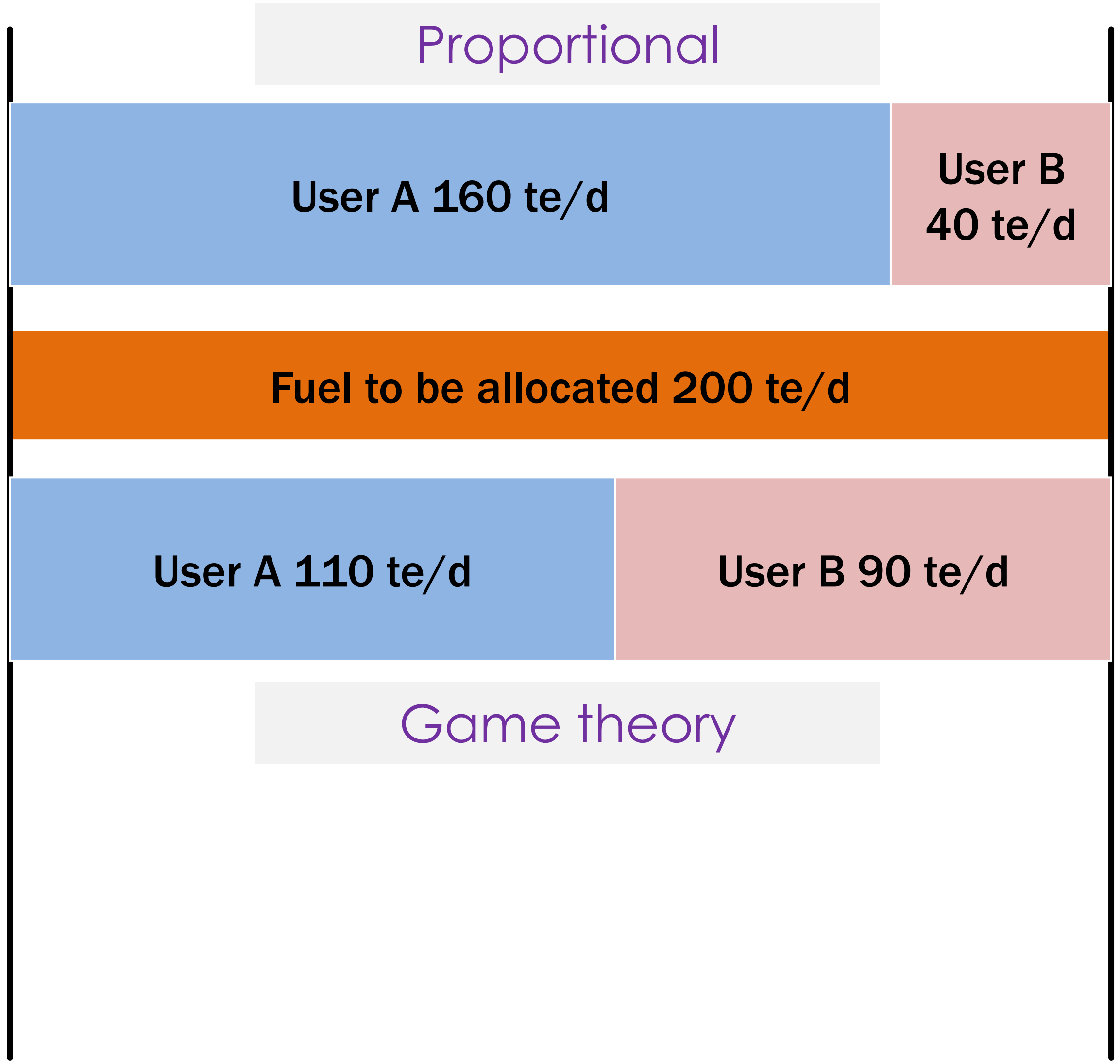
**User A 1.6 mcm/d**
**User B 0.4 mcm/d**



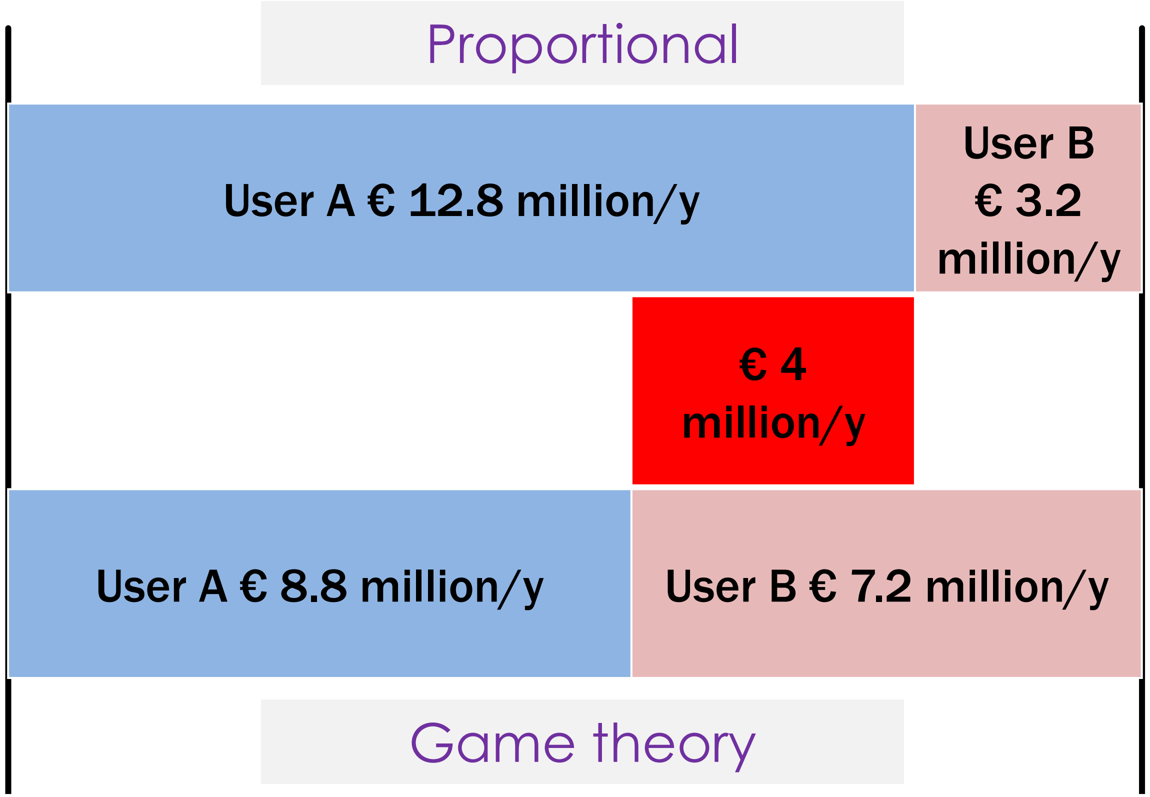





# Allocation


Proportional
User A 160 te/d
User B
40 te/d
Fuel to be allocated 200 te/d
User A 110 te/d
User B 90 te/d
Game theory

# Allocation Value

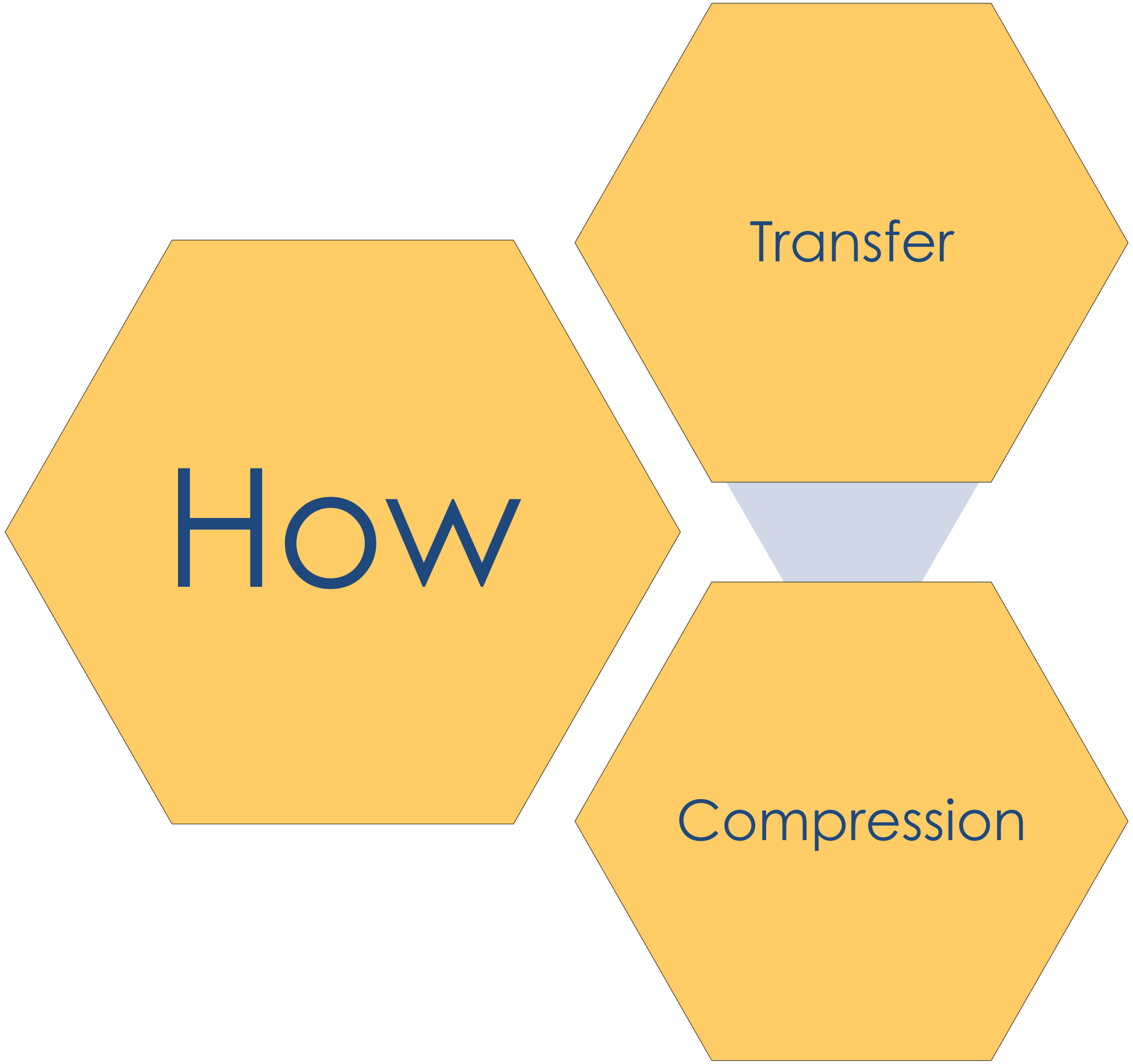



28th International North Sea Flow Measurement Workshop
26th – 29th October 2010

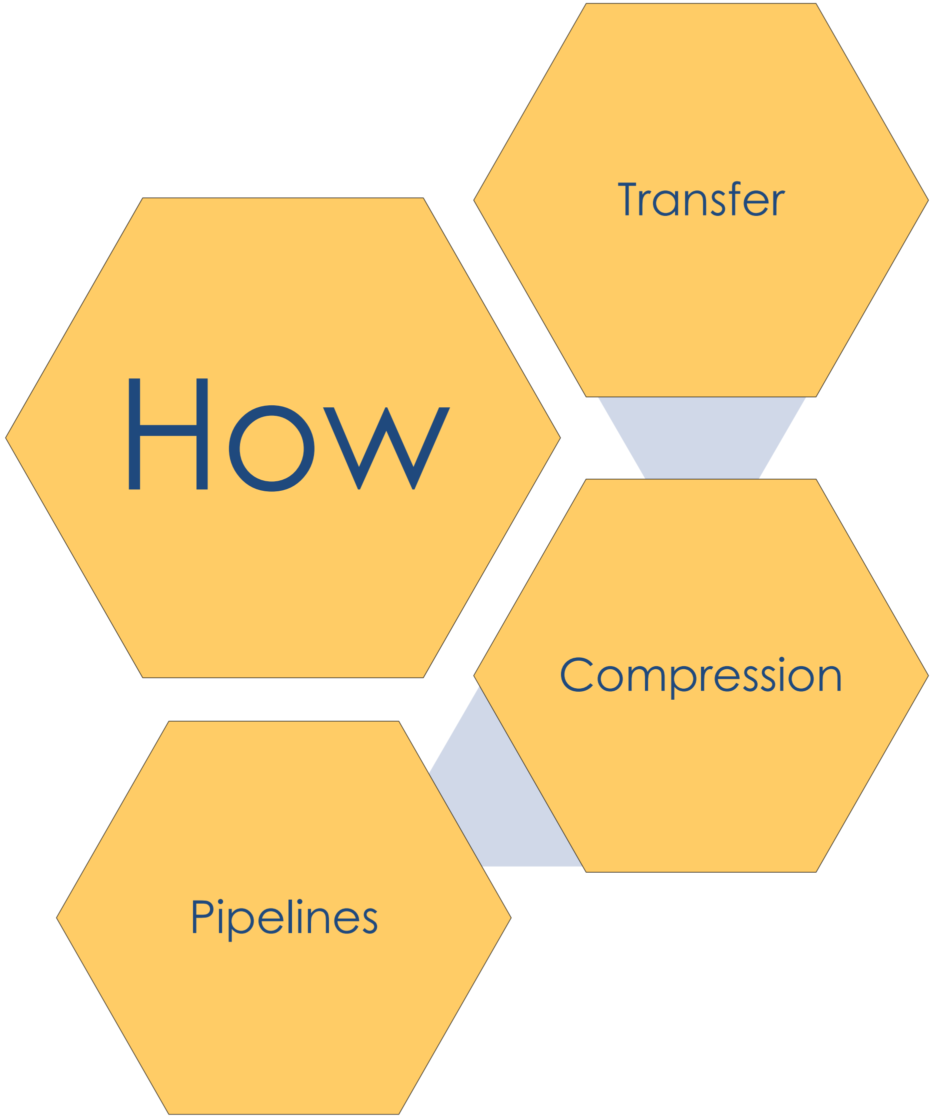
**Equitability, Allocation and Game Theory**

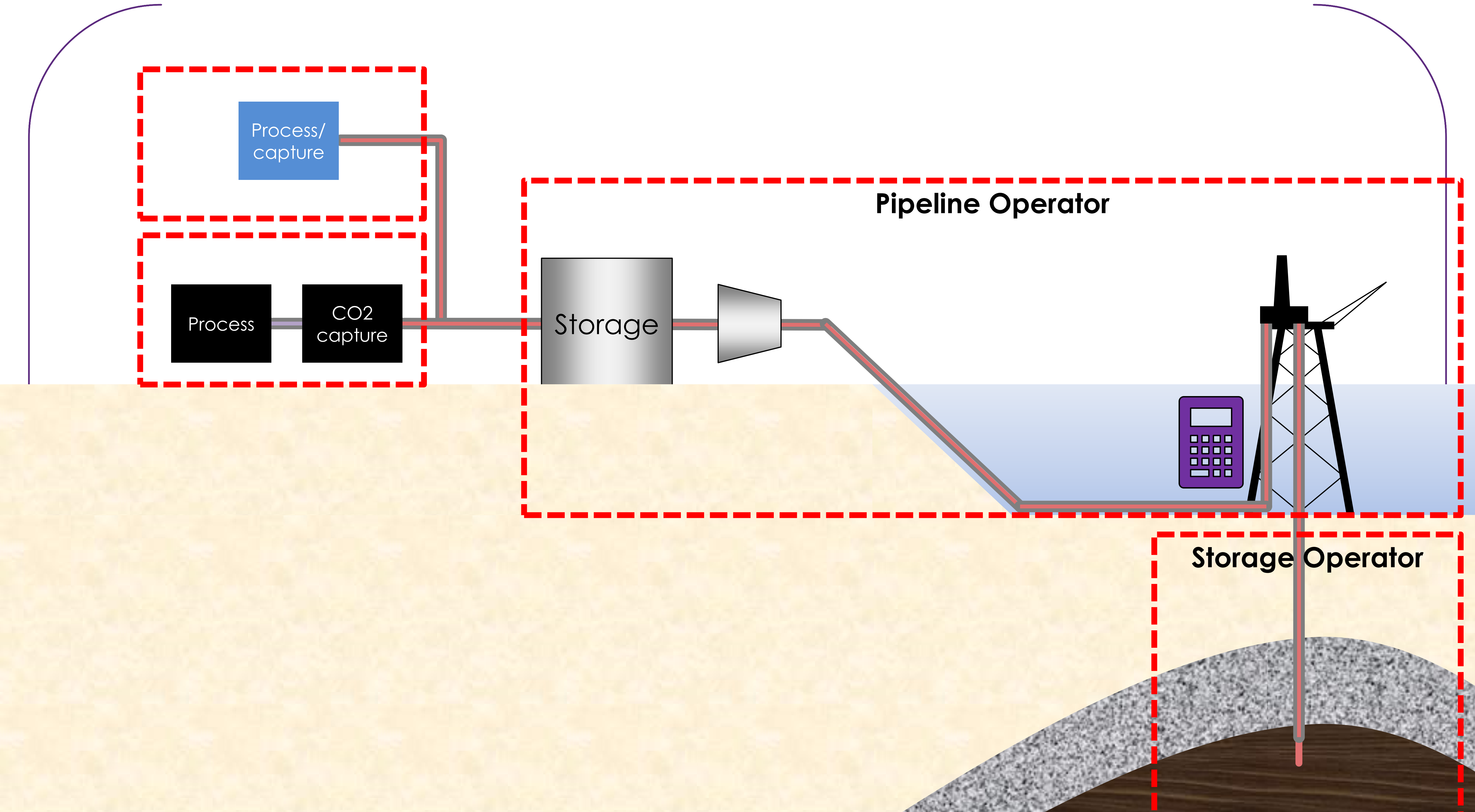
**Phil Stockton, Accord Energy Solutions Ltd**
**Allan Wilson, Smith Rea Energy Ltd**

# Why, What, Who, Where, When and How?

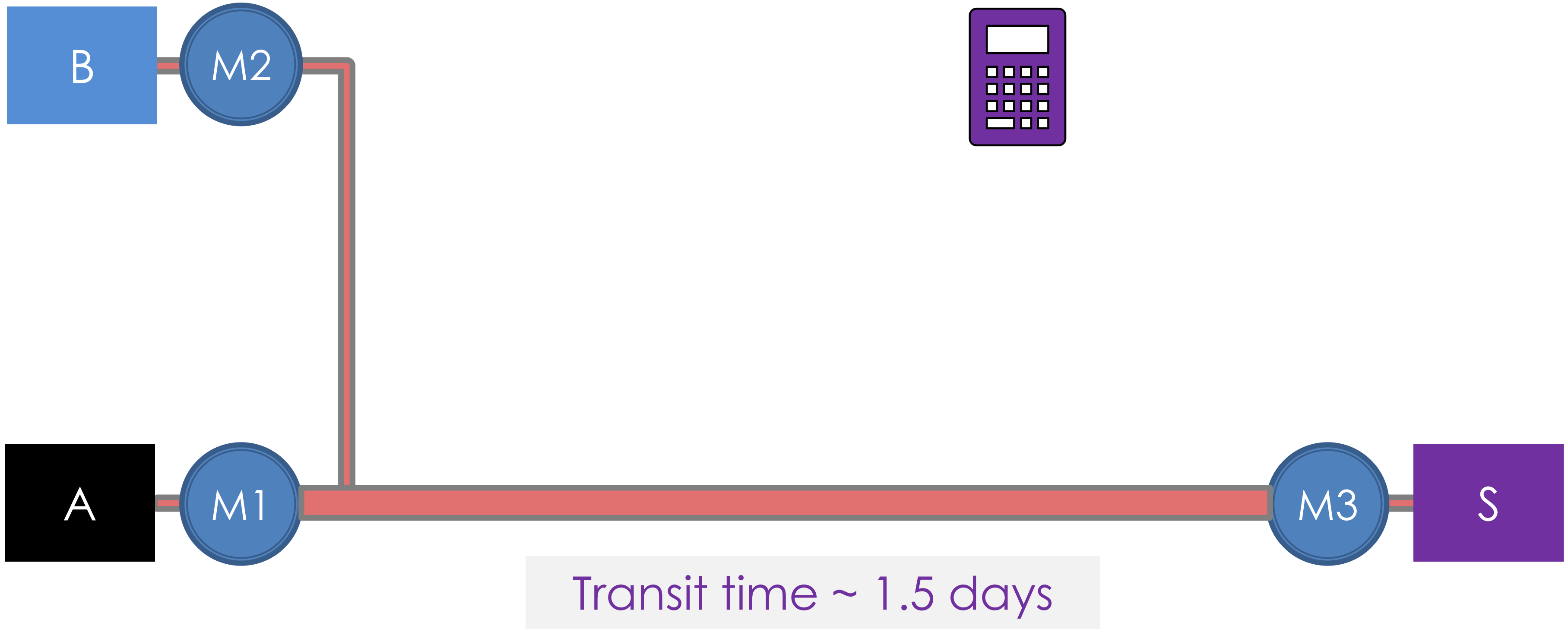


# Why, What, Who, Where, When and How?

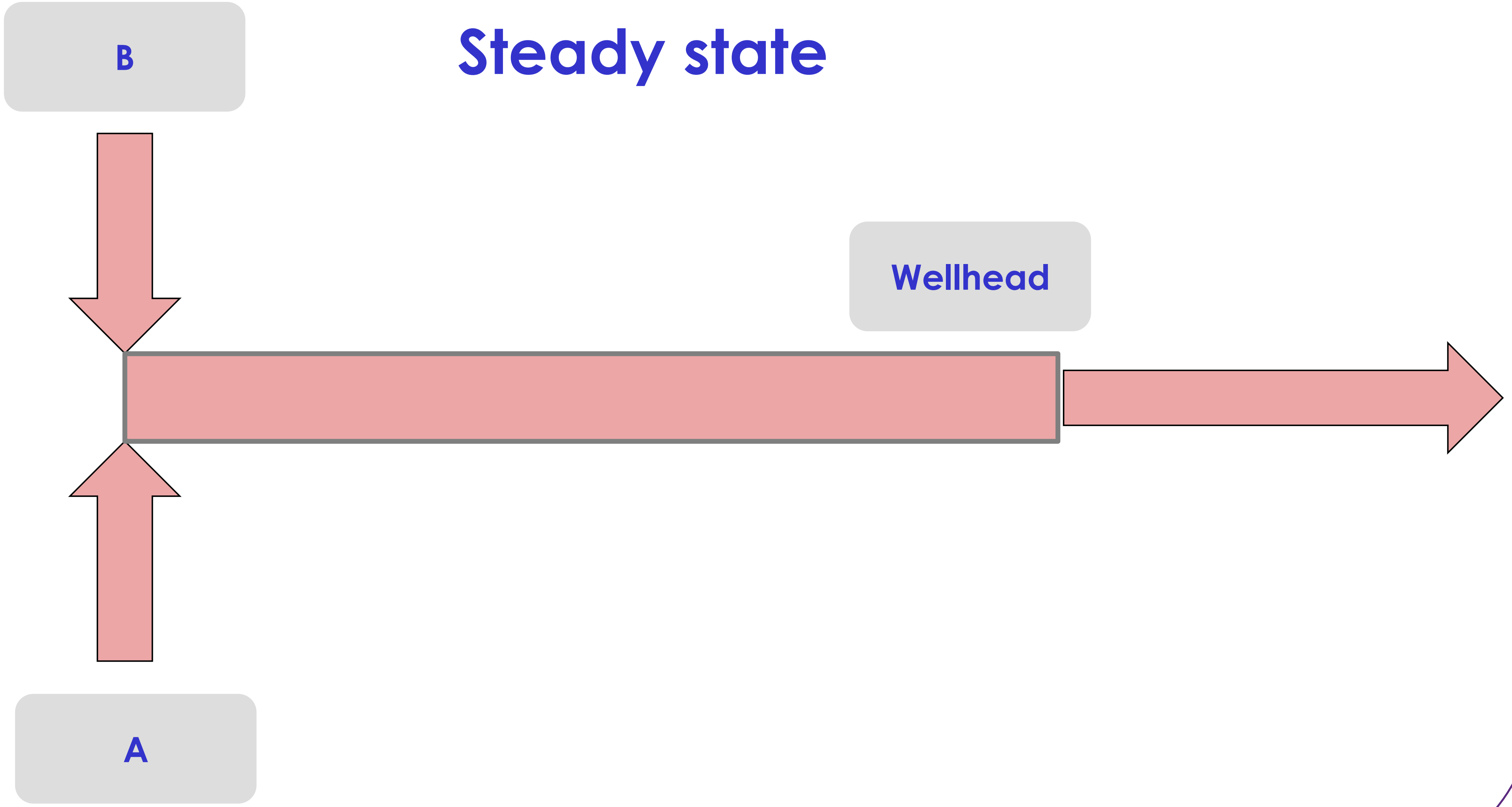



Process/
capture
Process
CO2
capture
Pipeline Operator
Storage
Storage Operator

# Allocation at Wellhead



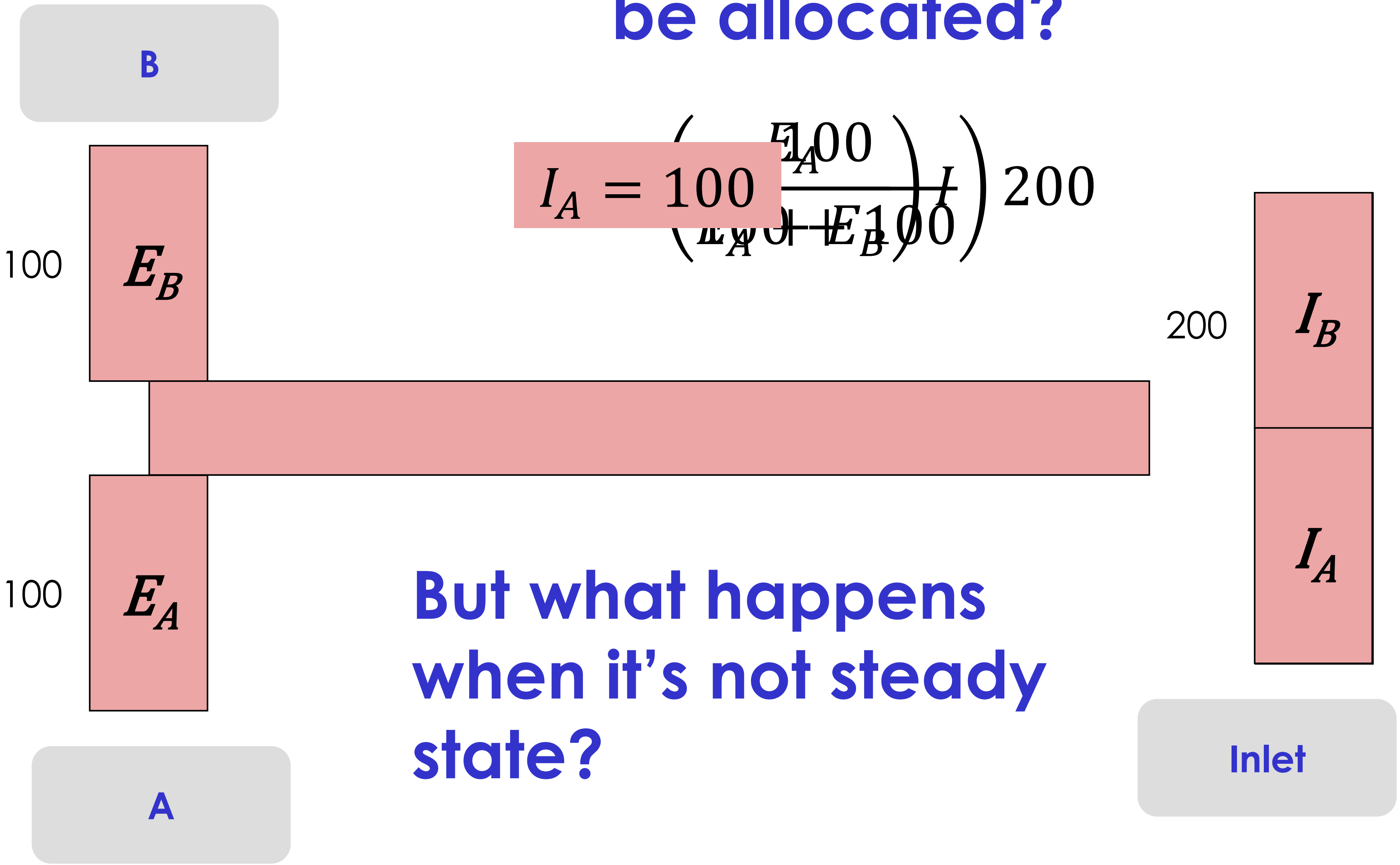
# Steady state



# How should the inlet be allocated?

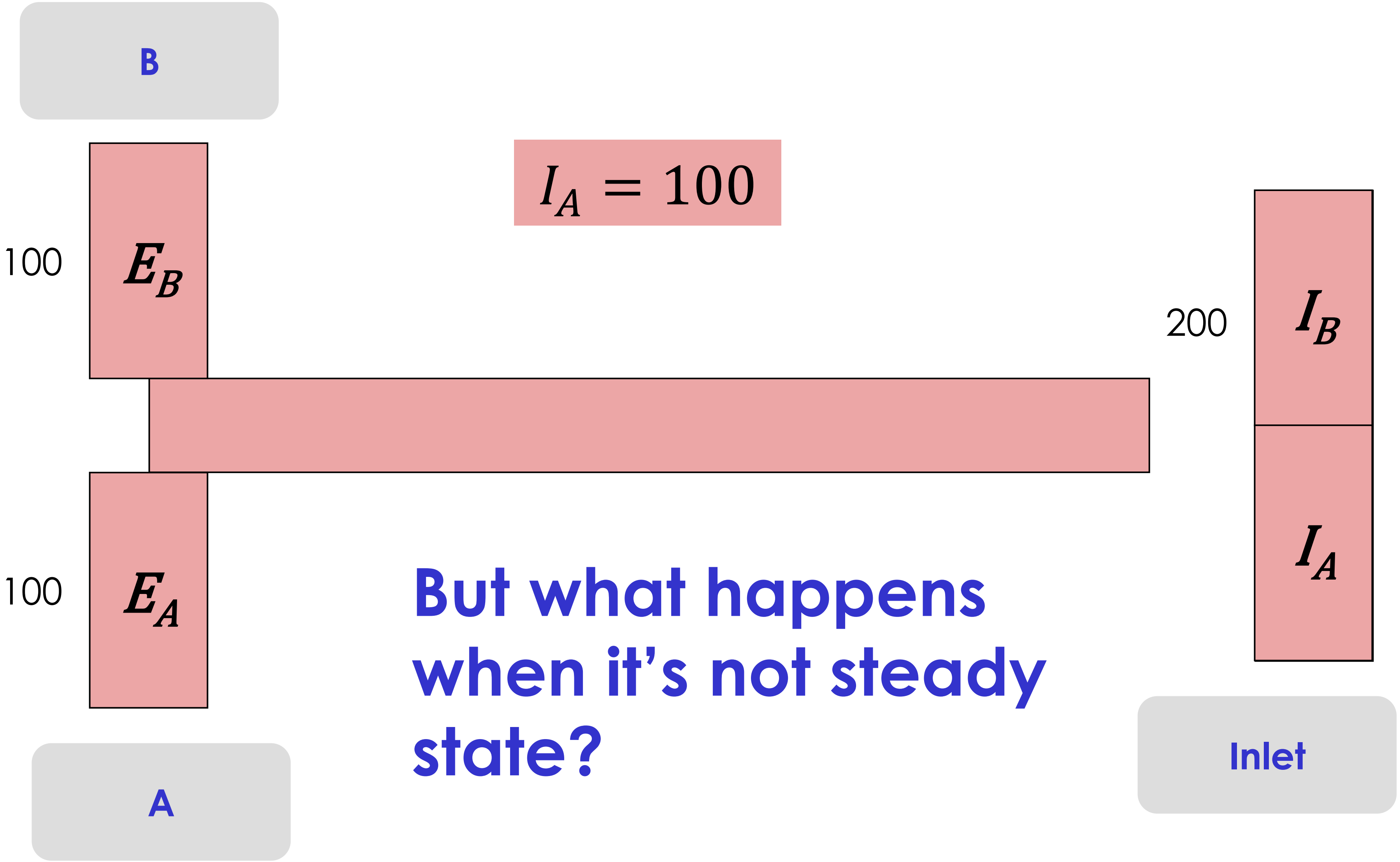
$$I_A = 100$$

$$\left(\frac{E_A}{E_A+E_B}\right) I = \left(\frac{100}{100+100}\right) 200$$

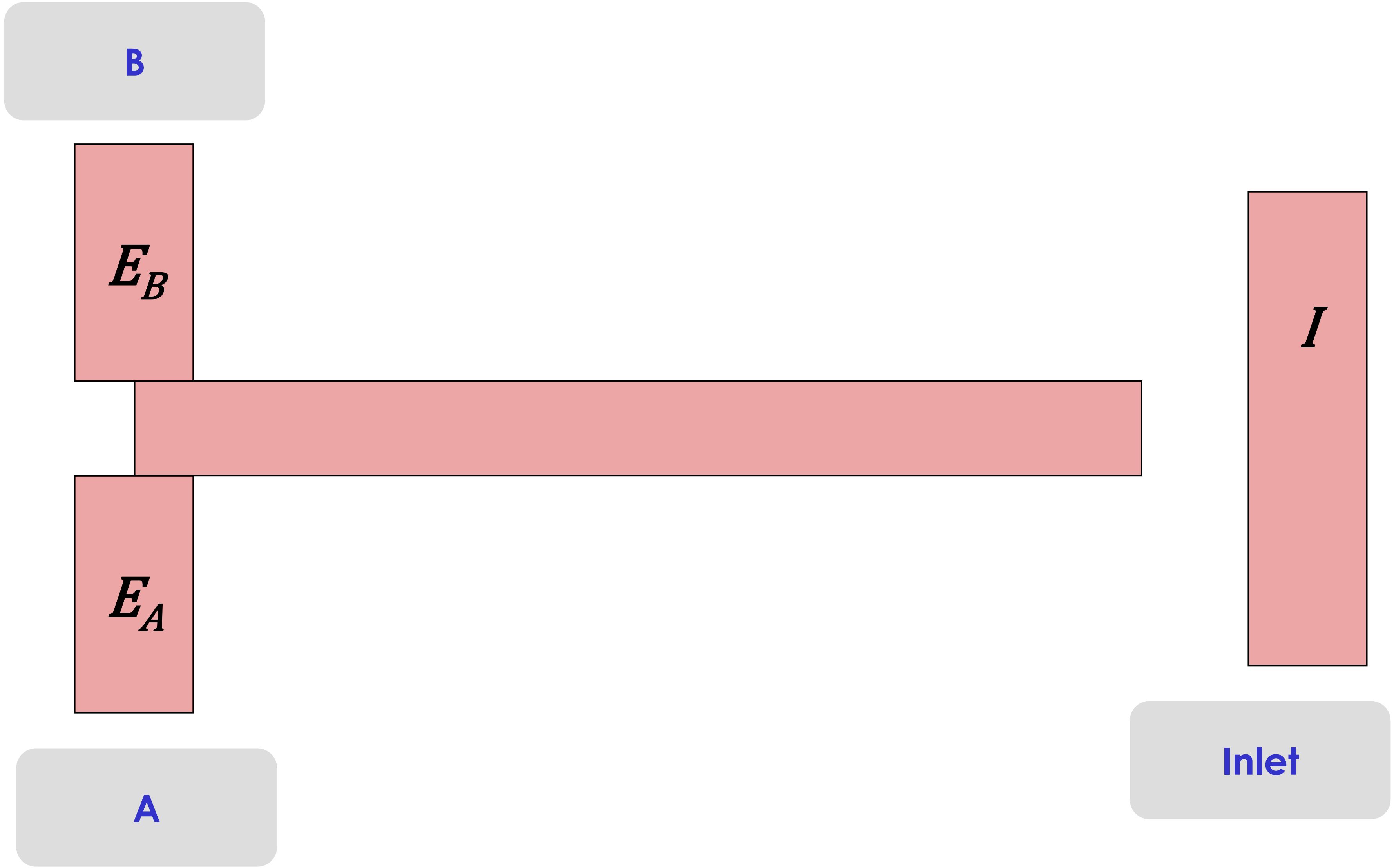



## But what happens when it's not steady state?

# Keep it simple!



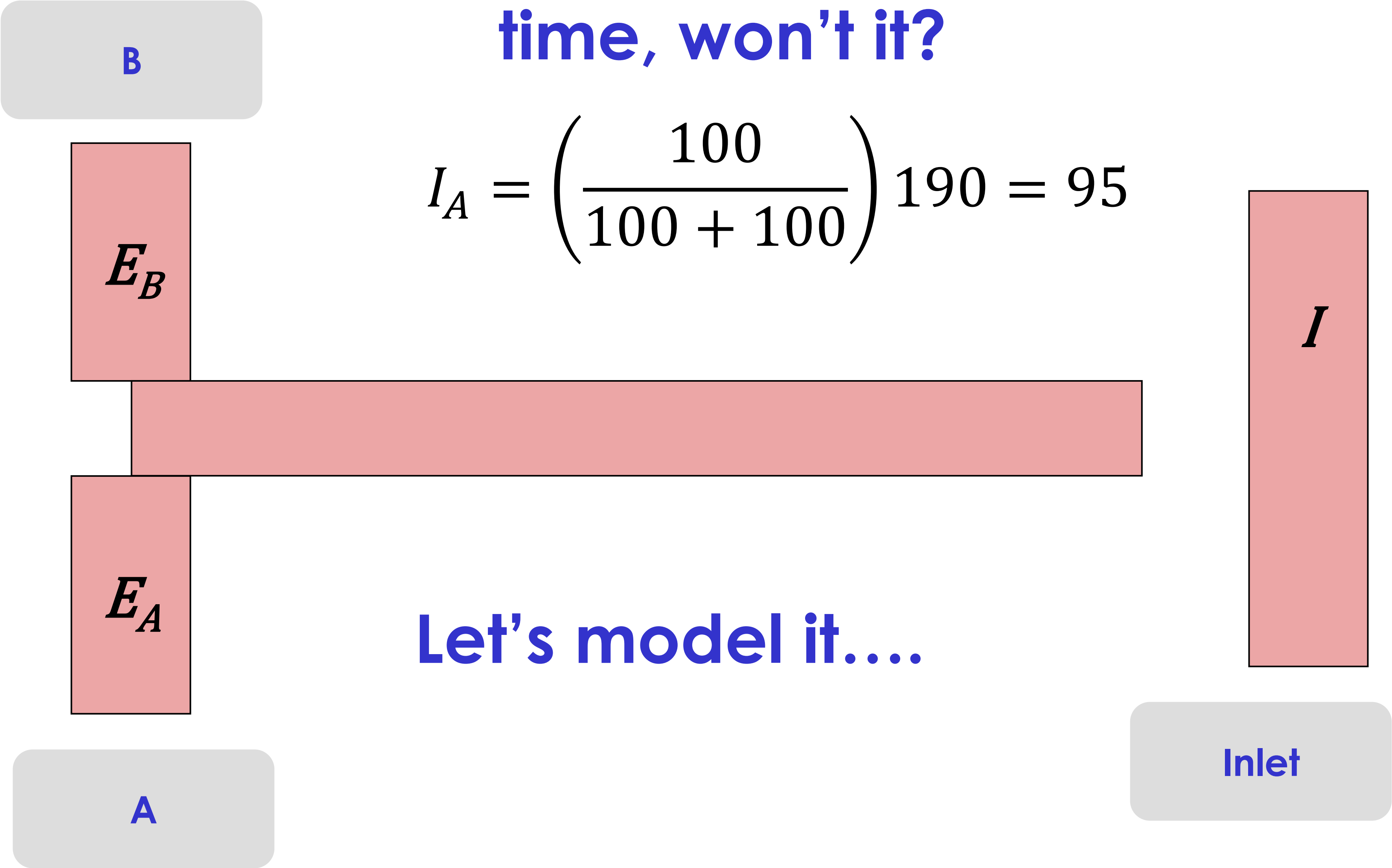

**But what happens when it's not steady state?**



B
$E_B$
$E_A$
A
$I$
Inlet

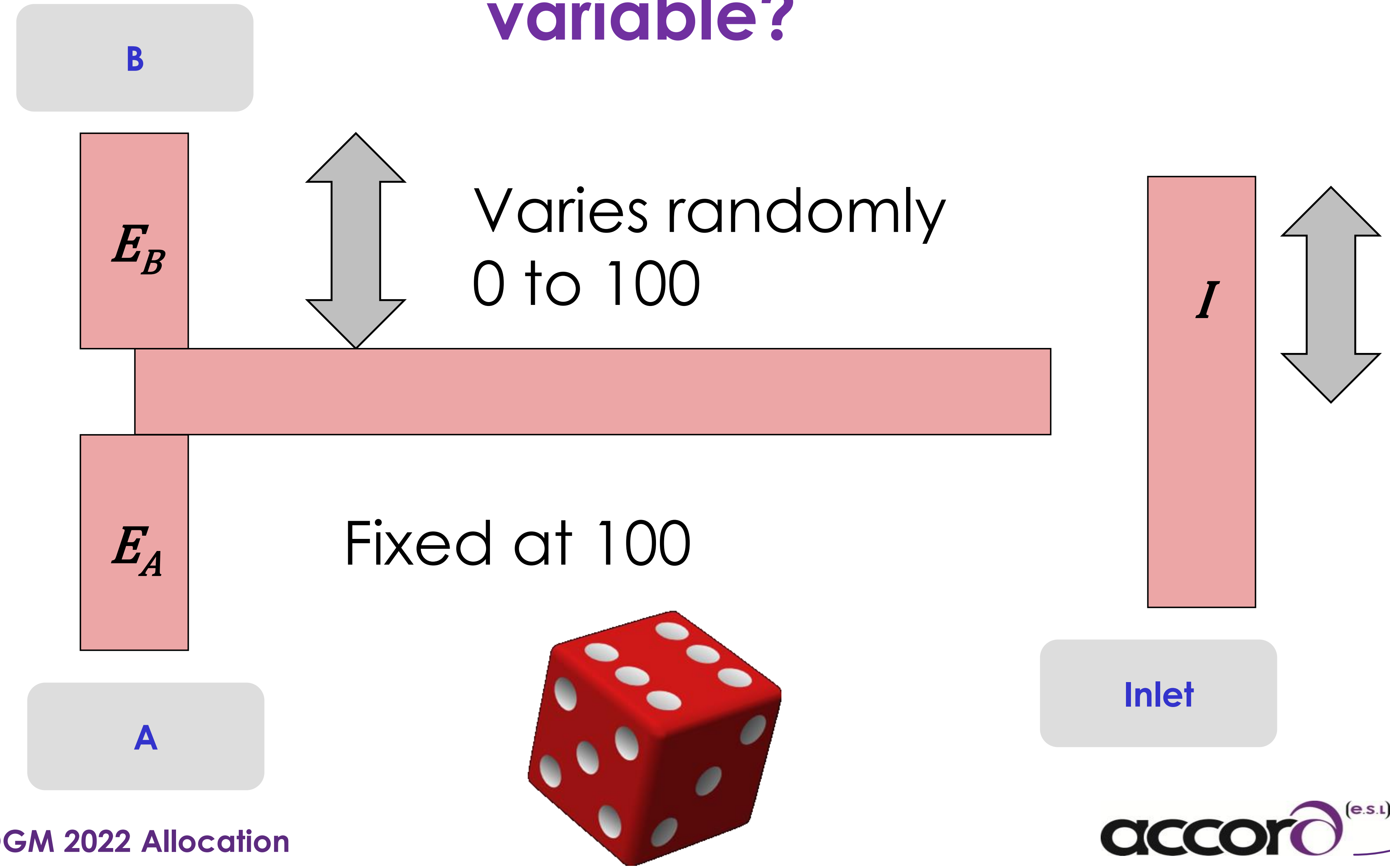
# It will even out over time, won't it?

$$I_A = \left(\frac{100}{100+100}\right)190 = 95$$

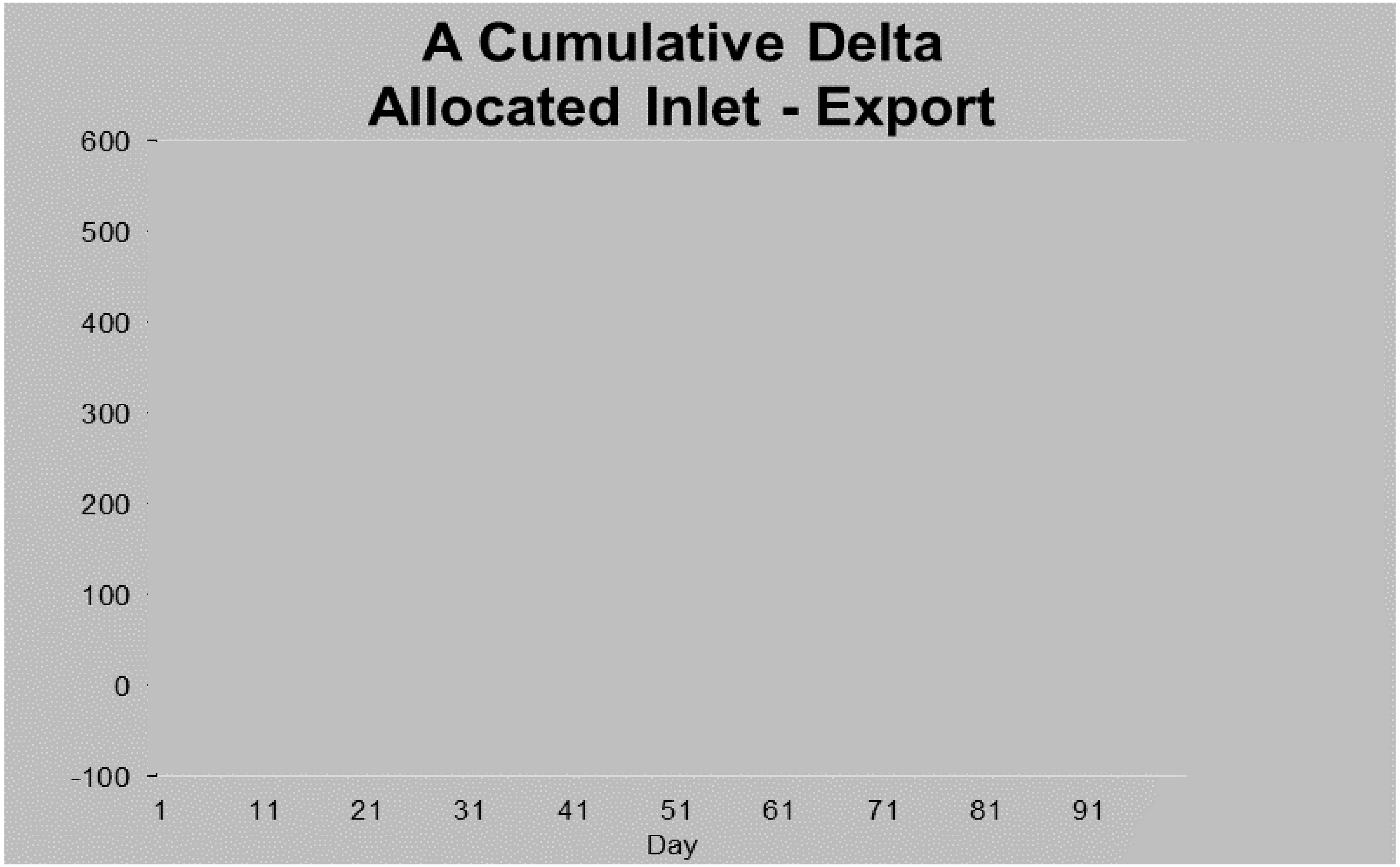



Let's model it….

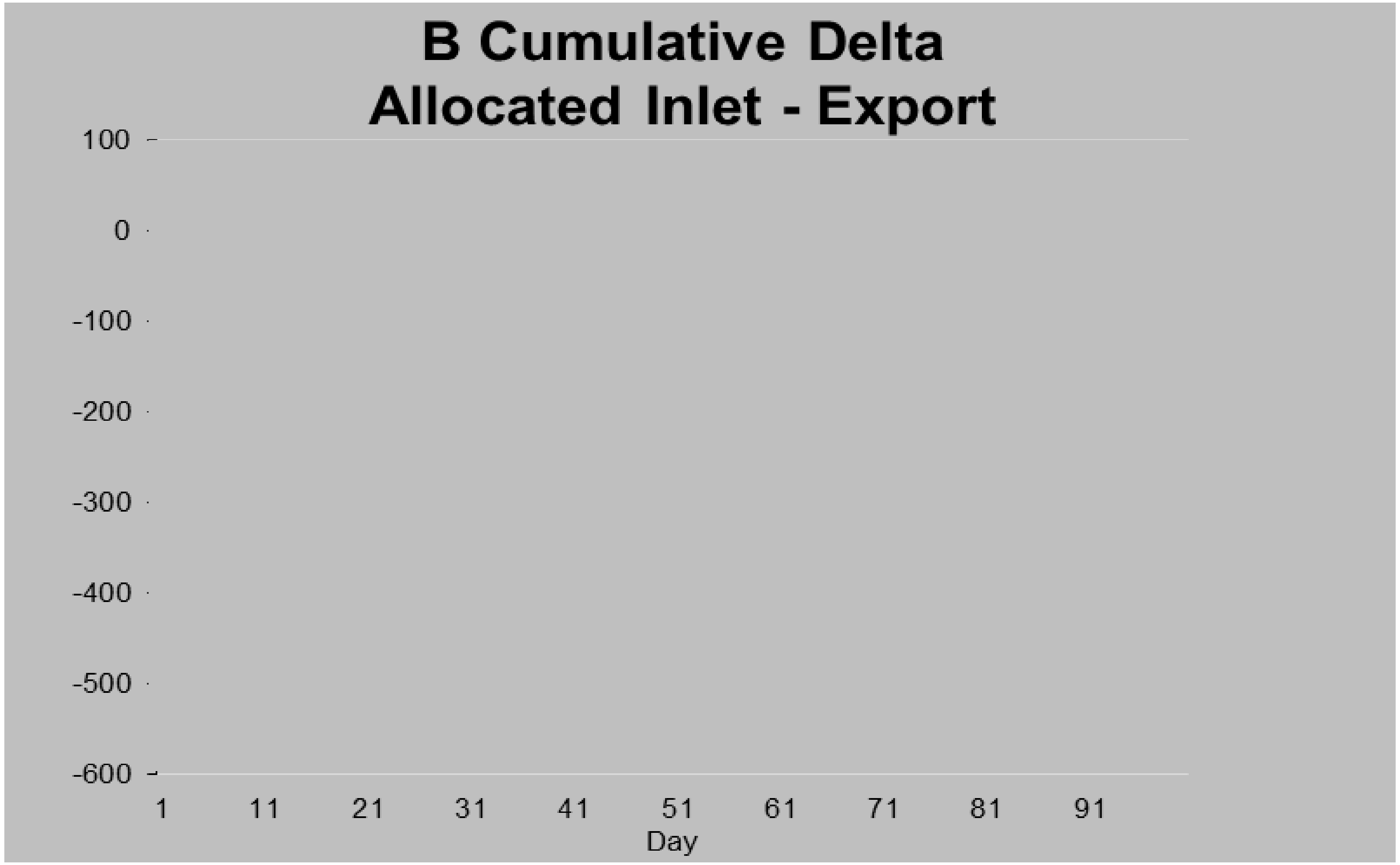
# What happens if one flow is more variable?



# Field B Varying 0 to 100/day
# Field A Constant at 100/day

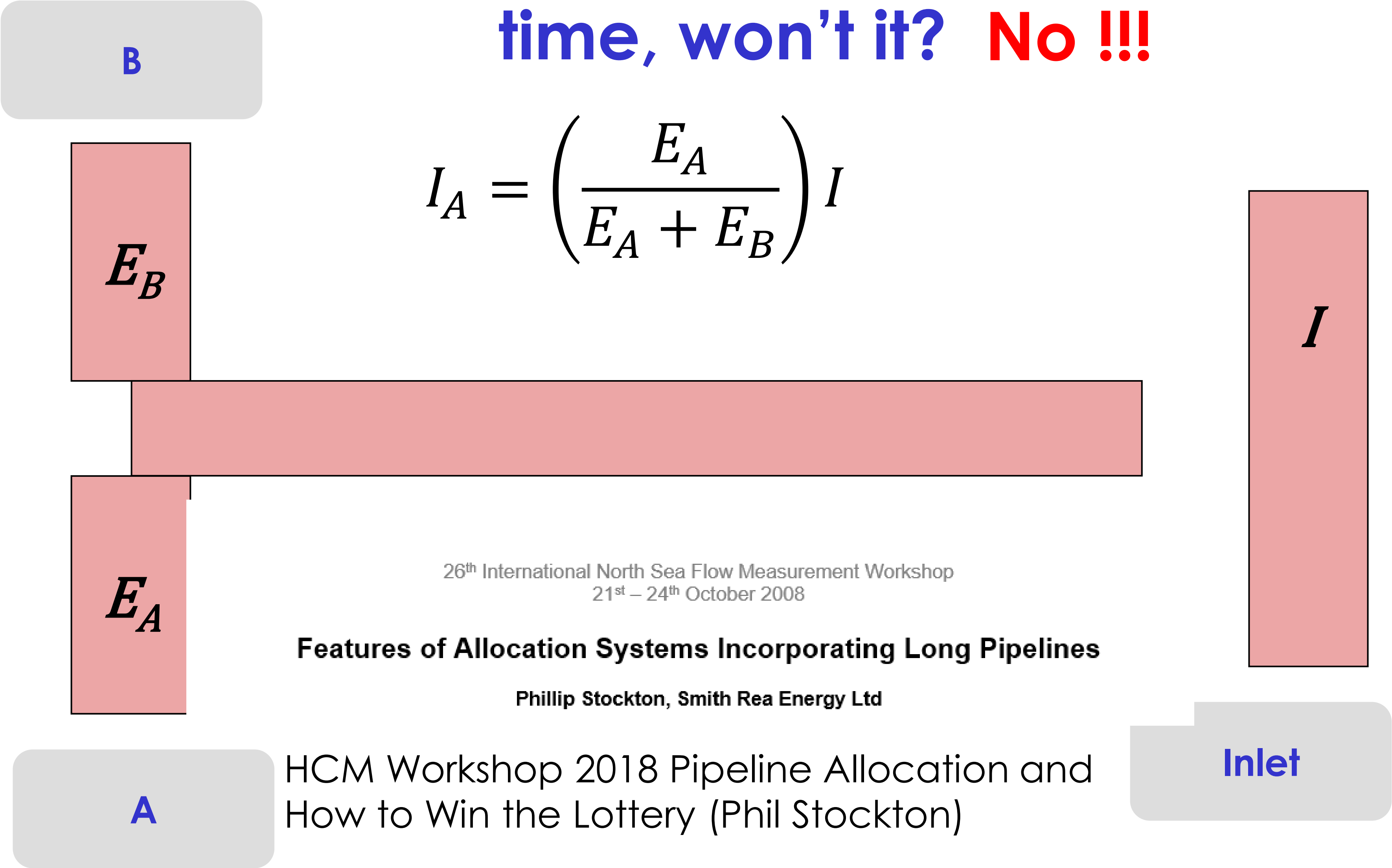


# Field B Varying 0 to 100/day
# Field A Constant at 100/day



# It will even out over time, won't it? No !!!

$$I_A = \left(\frac{E_A}{E_A + E_B}\right) I$$



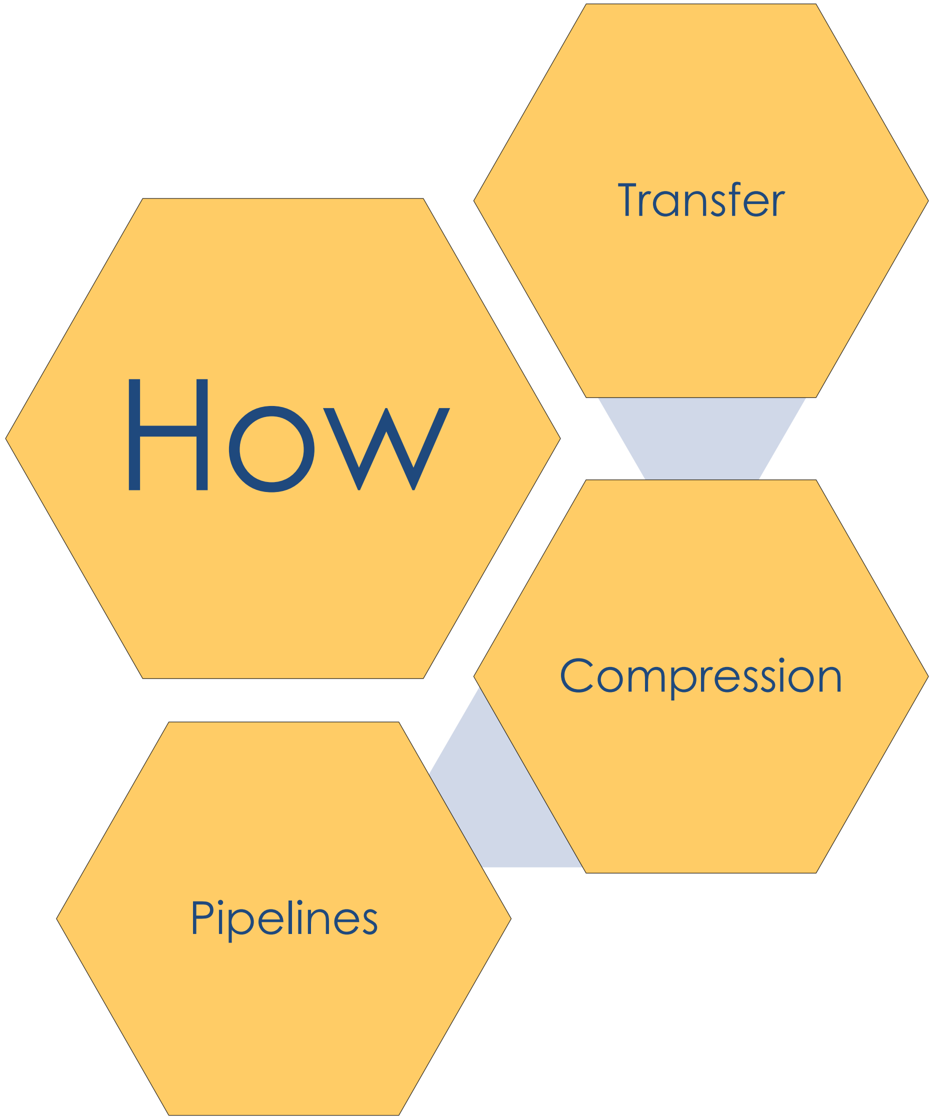

26th International North Sea Flow Measurement Workshop
21st – 24th October 2008

**Features of Allocation Systems Incorporating Long Pipelines**

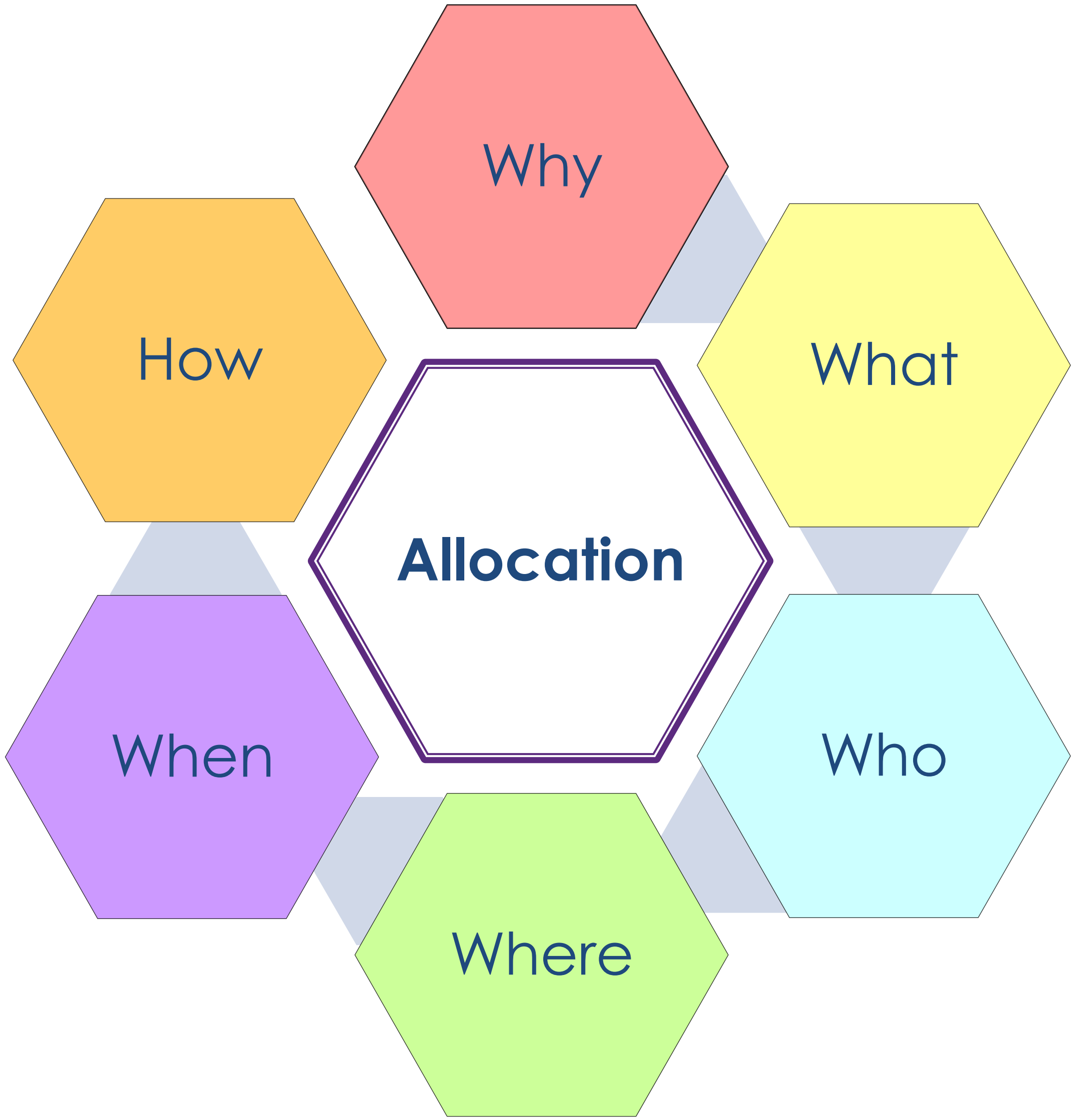
**Phillip Stockton, Smith Rea Energy Ltd**

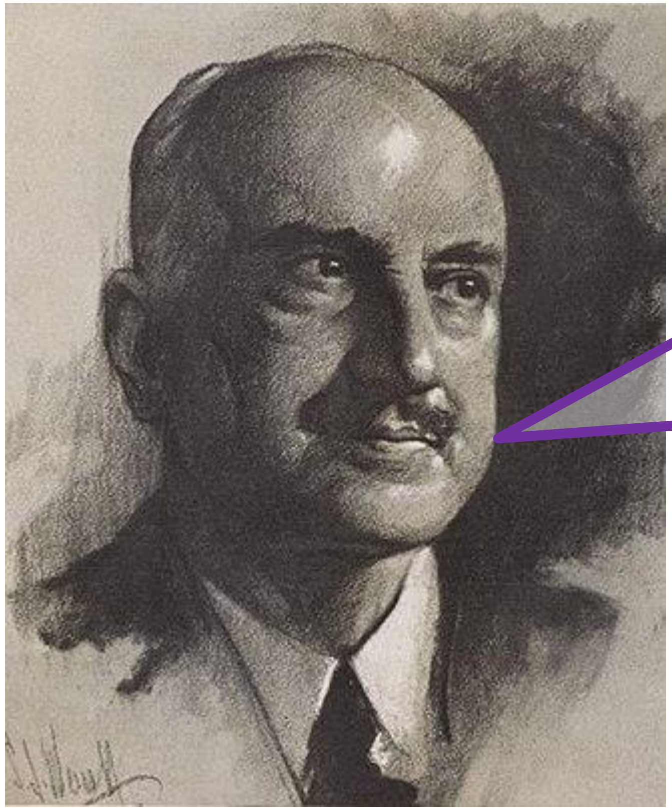
HCM Workshop 2018 Pipeline Allocation and How to Win the Lottery (Phil Stockton)

# Why, What, Who, Where, When and How?



# Why, What, Who, Where, When and How?






George Santayana