

ENERGY

Benchmarking

Novel carbon capture technologies

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Key elements of this presentation

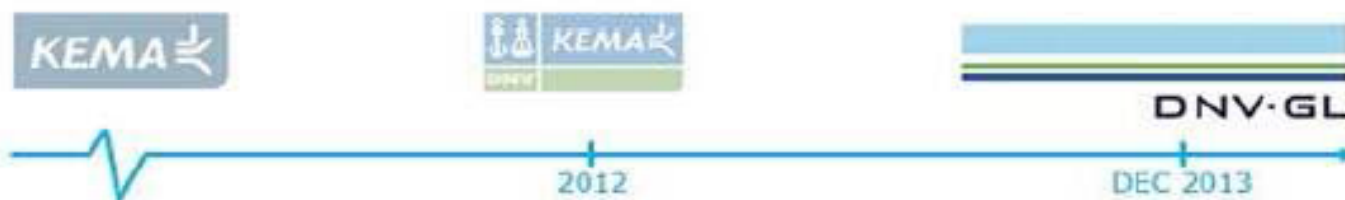
- Benchmarking:
 - Why?
 - How?
- Benchmarking of technologies in early stage of development
- Experiences of DNV GL at the Carbon Capture Mongstad project

DNV GL Energy

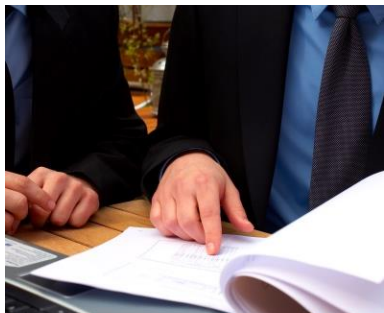
- An Energy Powerhouse uniting the strength of well-known brands: **DNV GL - Energy** combines the strengths and rich heritage of a couple well-known brands in energy, **DNV KEMA**, **GL Garrad Hassan** and **GL Renewables Certification**.



- In energy, our **3,000 experts** help customers throughout the electrical power industry realize efficient, reliable and clean energy, for today and the future.



DNV GL Energy - A Comprehensive Portfolio of Services



Policy



Production



Transmission & distribution



Use

- Power testing, inspections and certification
- Renewables advisory services
- Renewables certification
- Electricity transmission and distribution
- Electricity production
- Smart grids and smart cities
- Energy market and policy design
- Energy management and operations services
- Energy efficiency services
- Software

Benchmarking is part of our Energy Business Decision Support-services



- Benchmarking
- Due Diligence
- Technical Consultancy
- Electricity Market Regulation Consultancy
- Roadmaps Future Energy Systems
- Technology (Development) Assessments
- Electricity Master Planning
- Market Analysis & Modelling Services

Definition Benchmarking (*European Benchmarking code of conduct*):

"Benchmarking is about the process of identifying and learning from best practices in other organizations"

What is benchmarking?

One of the first Benchmarks

The origin of the term **bench mark**, or **benchmark**,

- Chiselled horizontal marks made by [surveyors](#) in stone structures,
- Used to place an angle-iron in to form a “bench” for a levelling rod
- So this levelling rod could be replaced on the exact same level



Source: Wikipedia



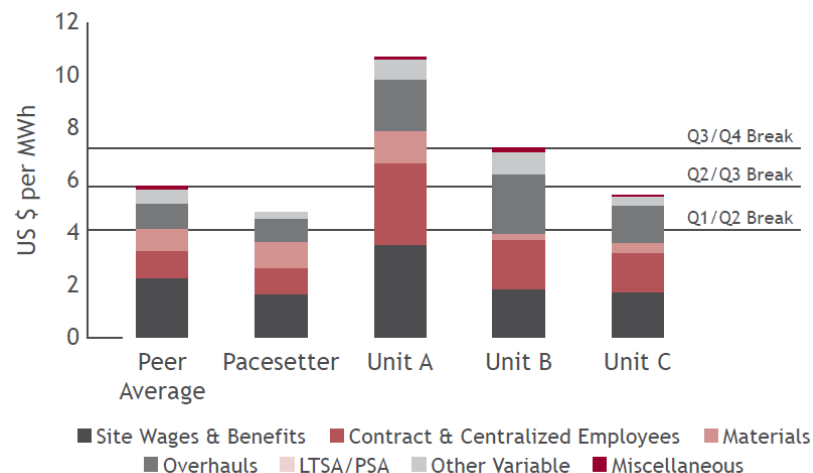
Source: <http://www.waymarking.com>

Goal of benchmarking

Two types of goals

1. Metrics Benchmarking
(to determine (relative)
position in own sector)

Learn where you are, compared to others



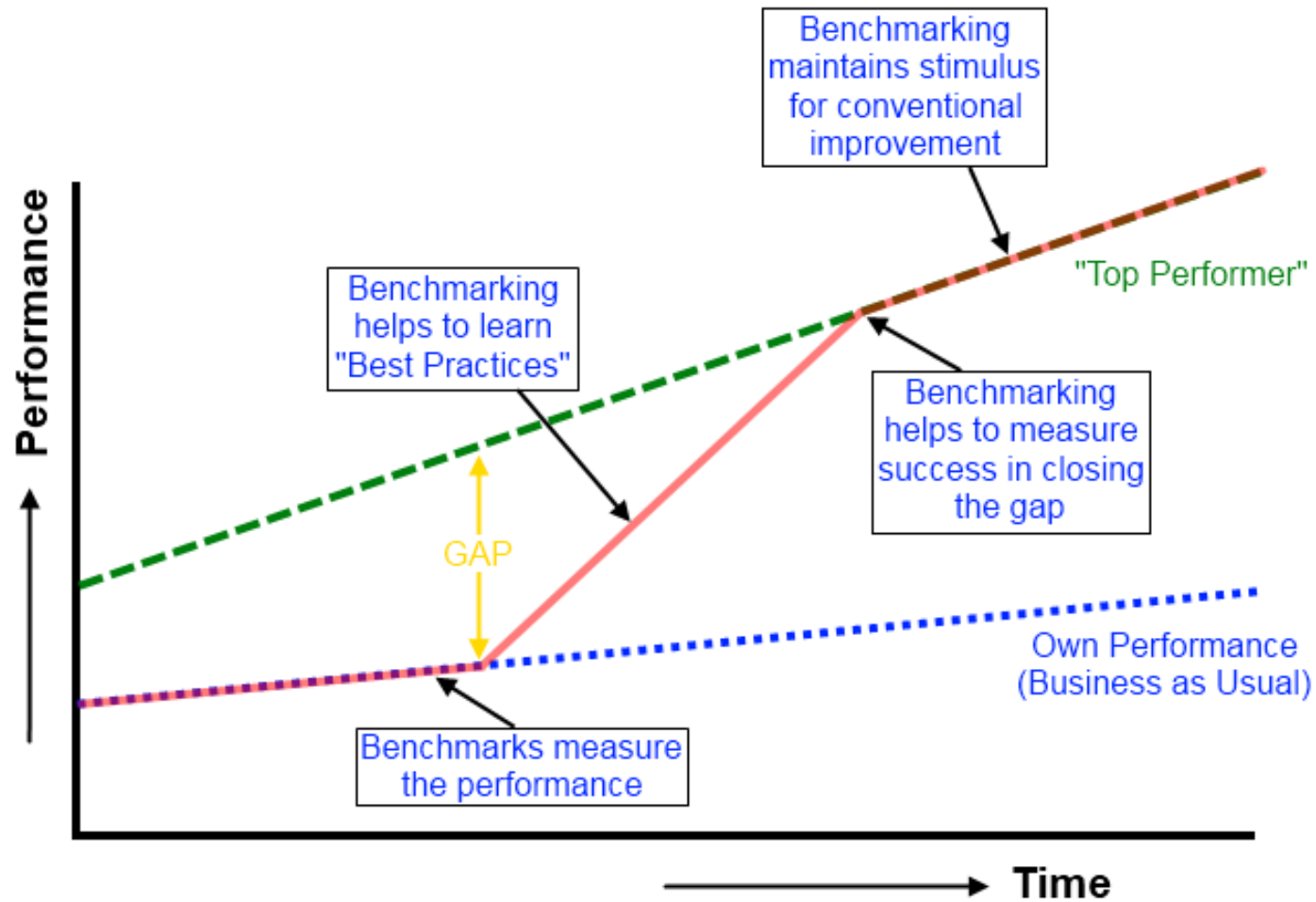
Source: <http://www.solomononline.com>

2. Activity Benchmarking (find & implement 'Best Practices')

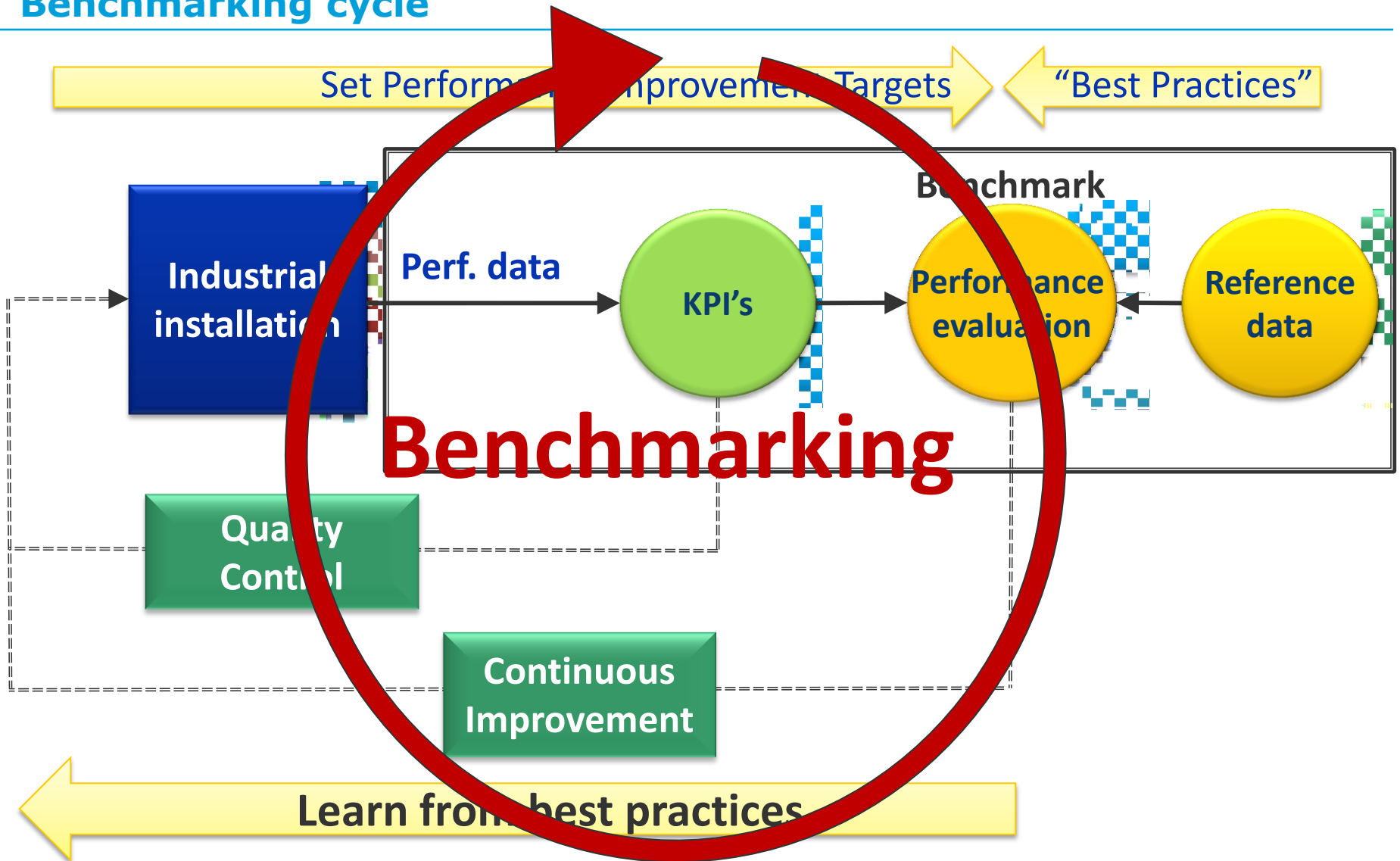
According to the European Benchmarking Code of conduct "Benchmarking is about the process of identifying and **learning** from best practices in other organizations "

Benchmarking is about learning

Goal of activity benchmarking

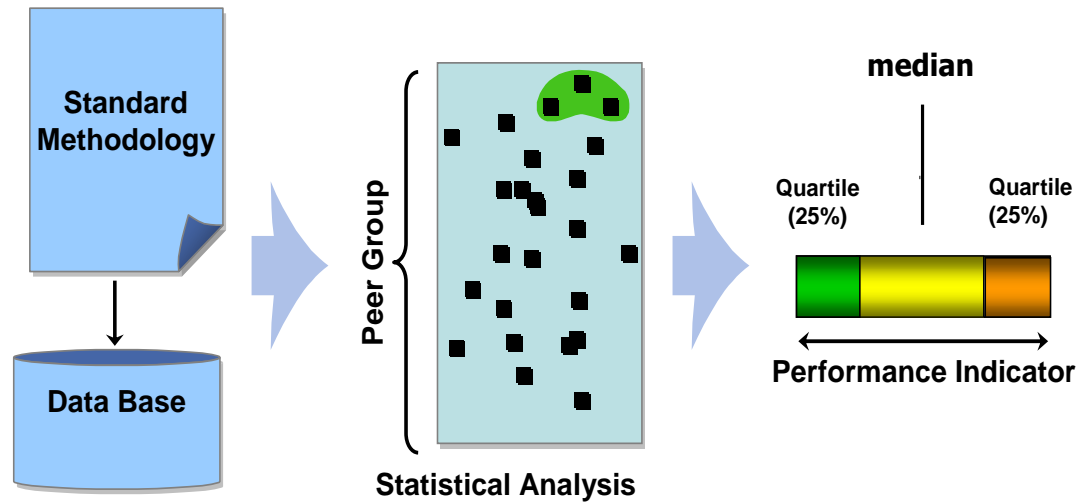


Benchmarking cycle



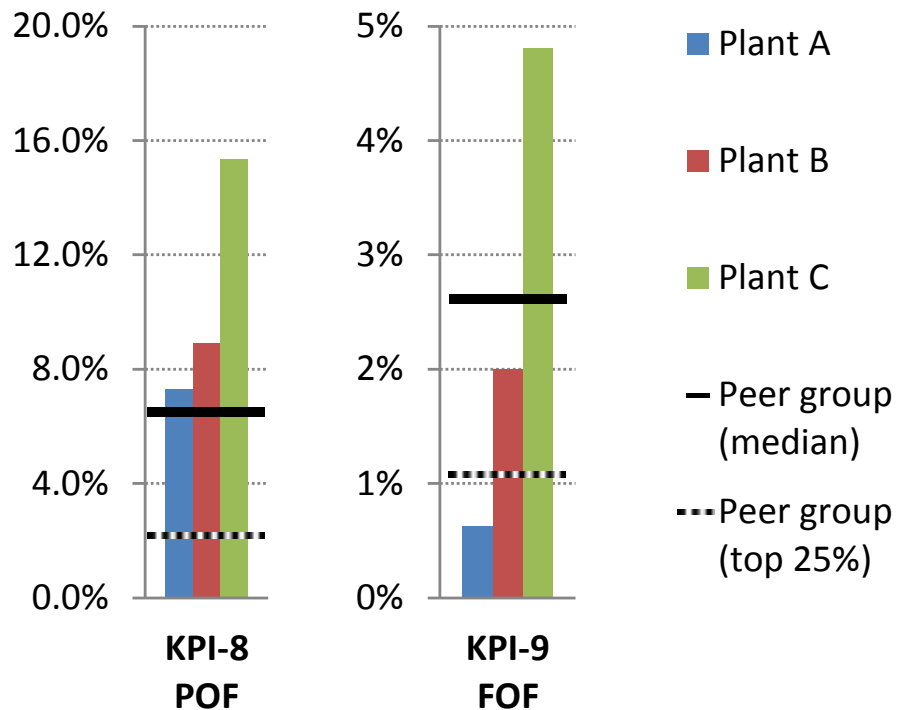
KPI's and reference data explained

- A KPI is
 - a performance measurement
 - defined by a set of values used to measure against
 - based on math that is the same for all situations
 - used to evaluate the success of a particular activity in which it is engaged
- Preferred reference data is obtained from a **peer group**



Example results

Power plant maintenance performance

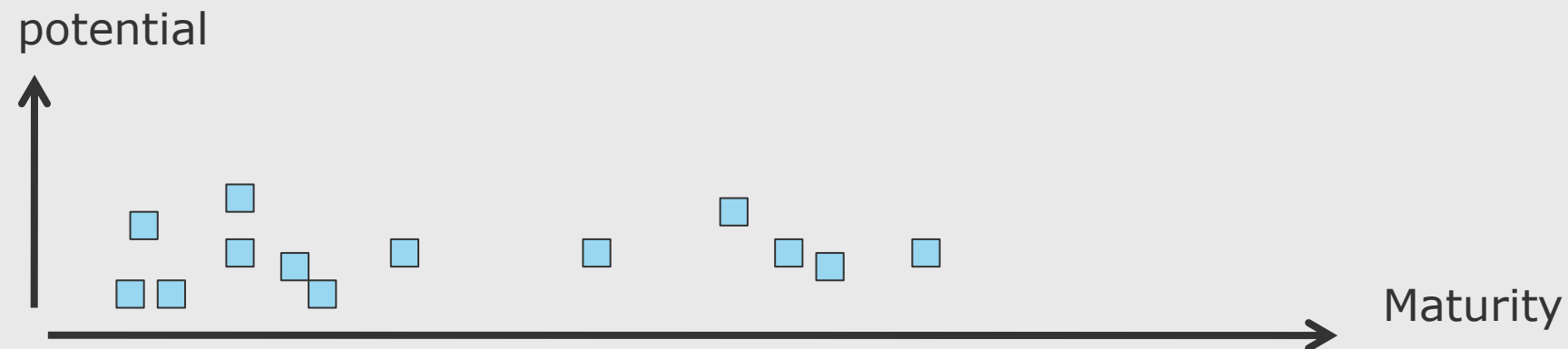


POF = Planned Outage Factor

FOF = Forced Outage Factor

Benchmarking of technologies in early stage of development

Novel Technologies



Different technologies, different potential, different maturity

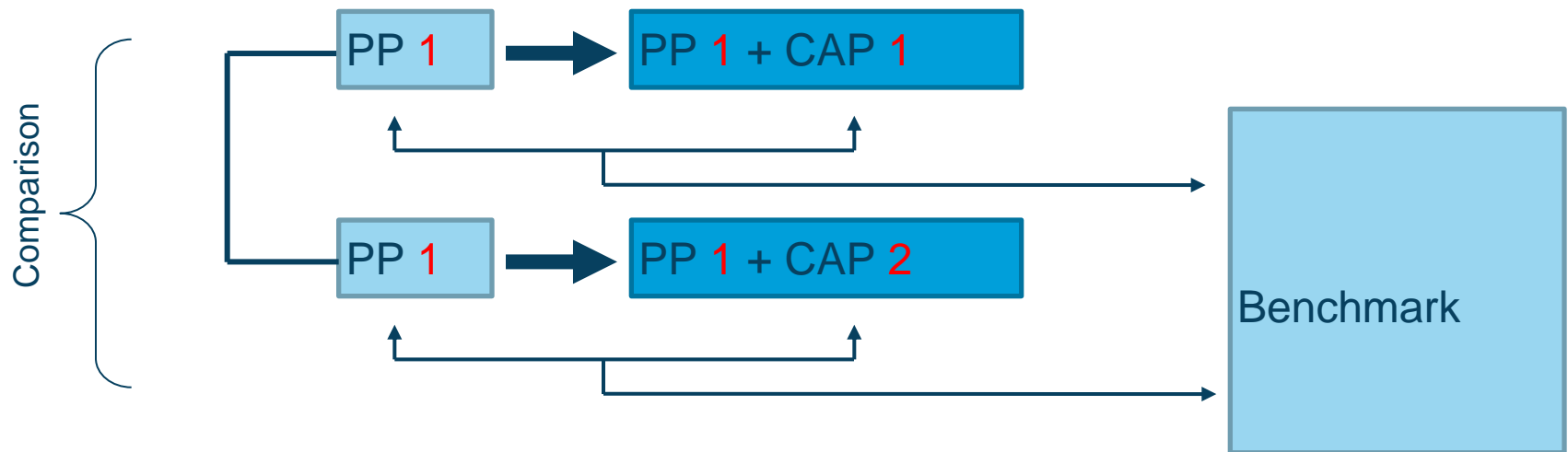
Issues for the benchmarking model

- No reference performance data available -> no peer group
 - Other reference needed?
- Not the same level of maturity (model \neq pilot \neq demo \neq full scale)
 - How to scale for comparison across maturity?
- Scaling means uncertainty
 - What to do with uncertainty?

How to deal with these issues?

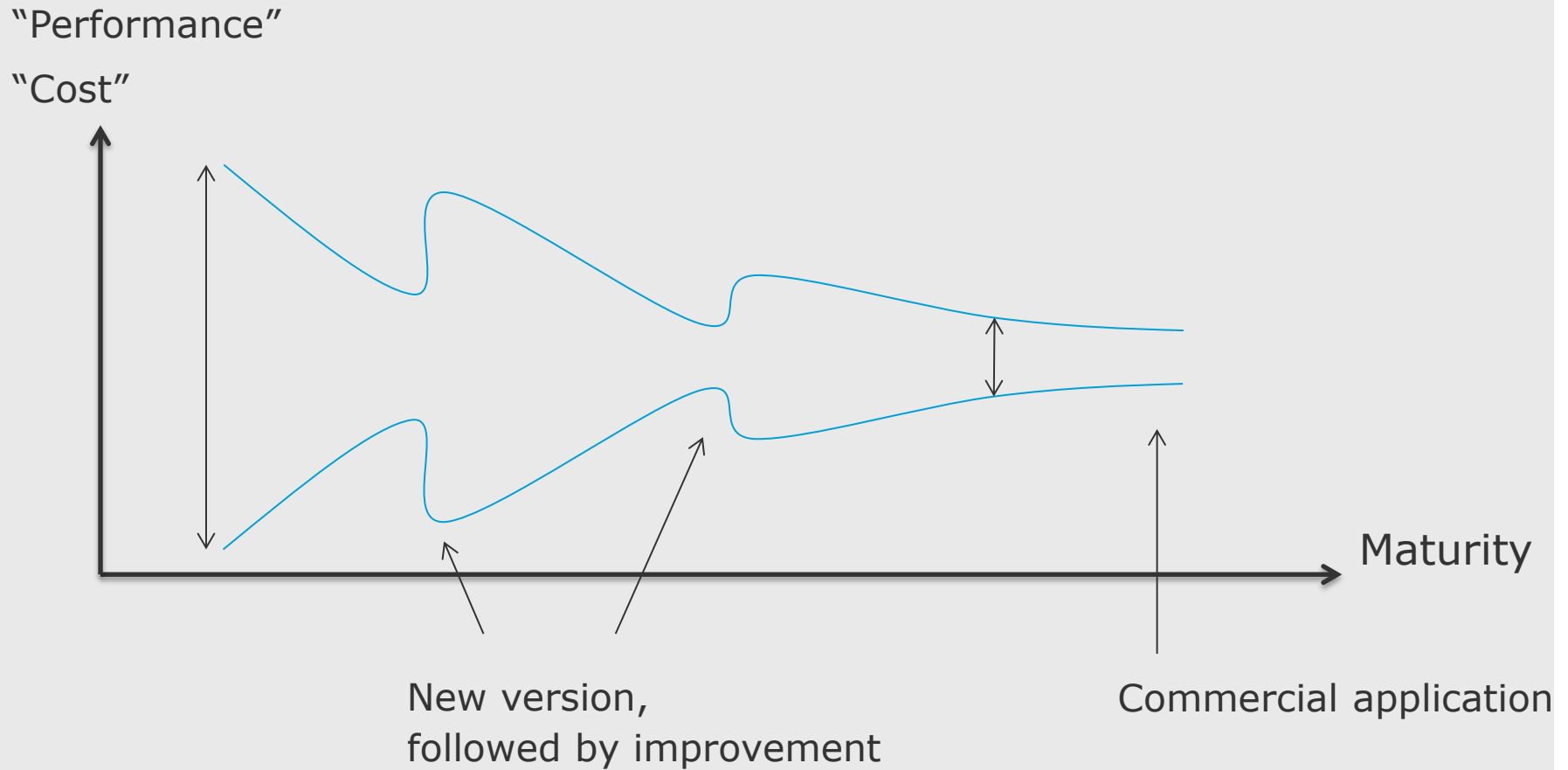
Reference

- When a peer group doesn't exist one could use a well defined reference plant.

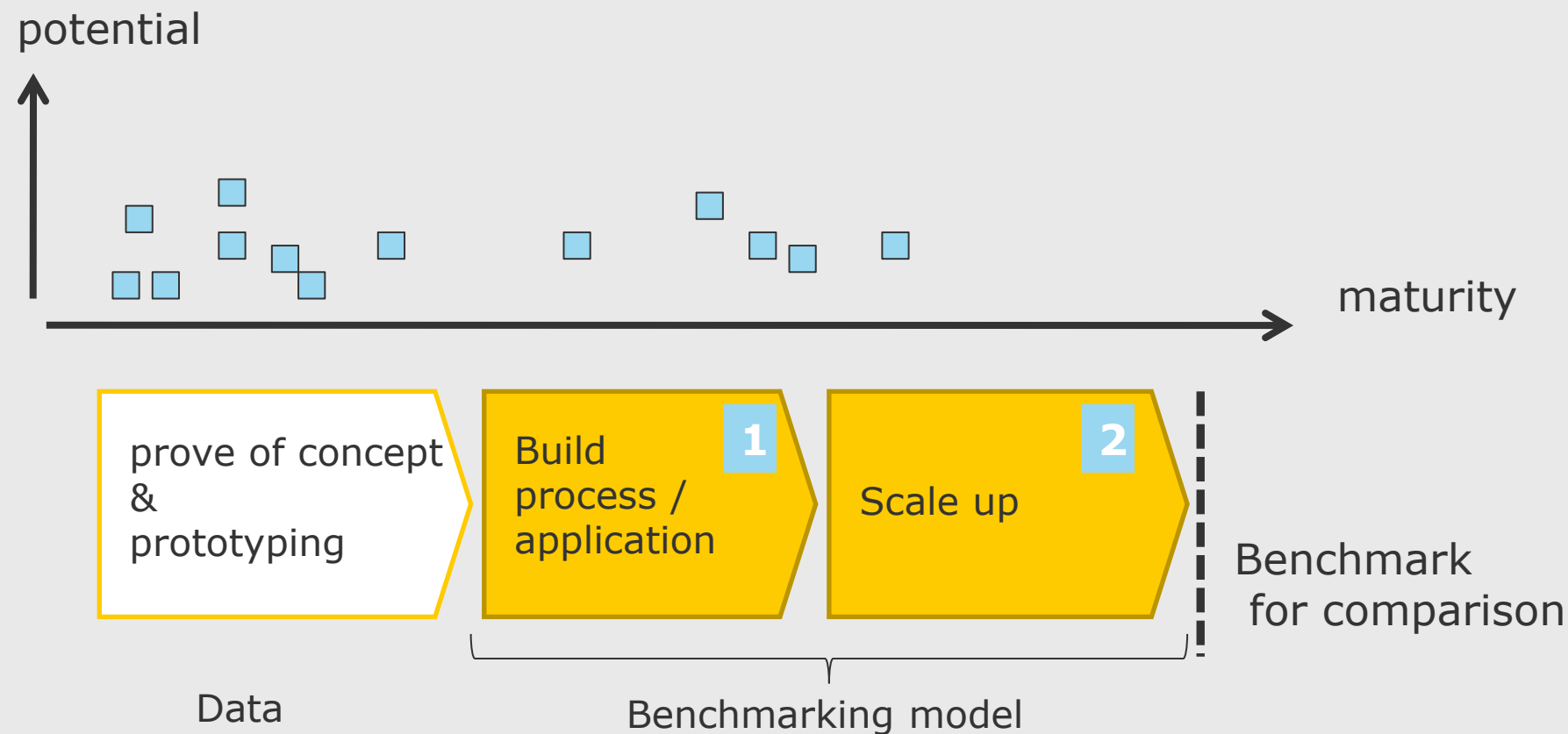


1. Reference plant
2. Plant to be benchmarked

Uncertainty

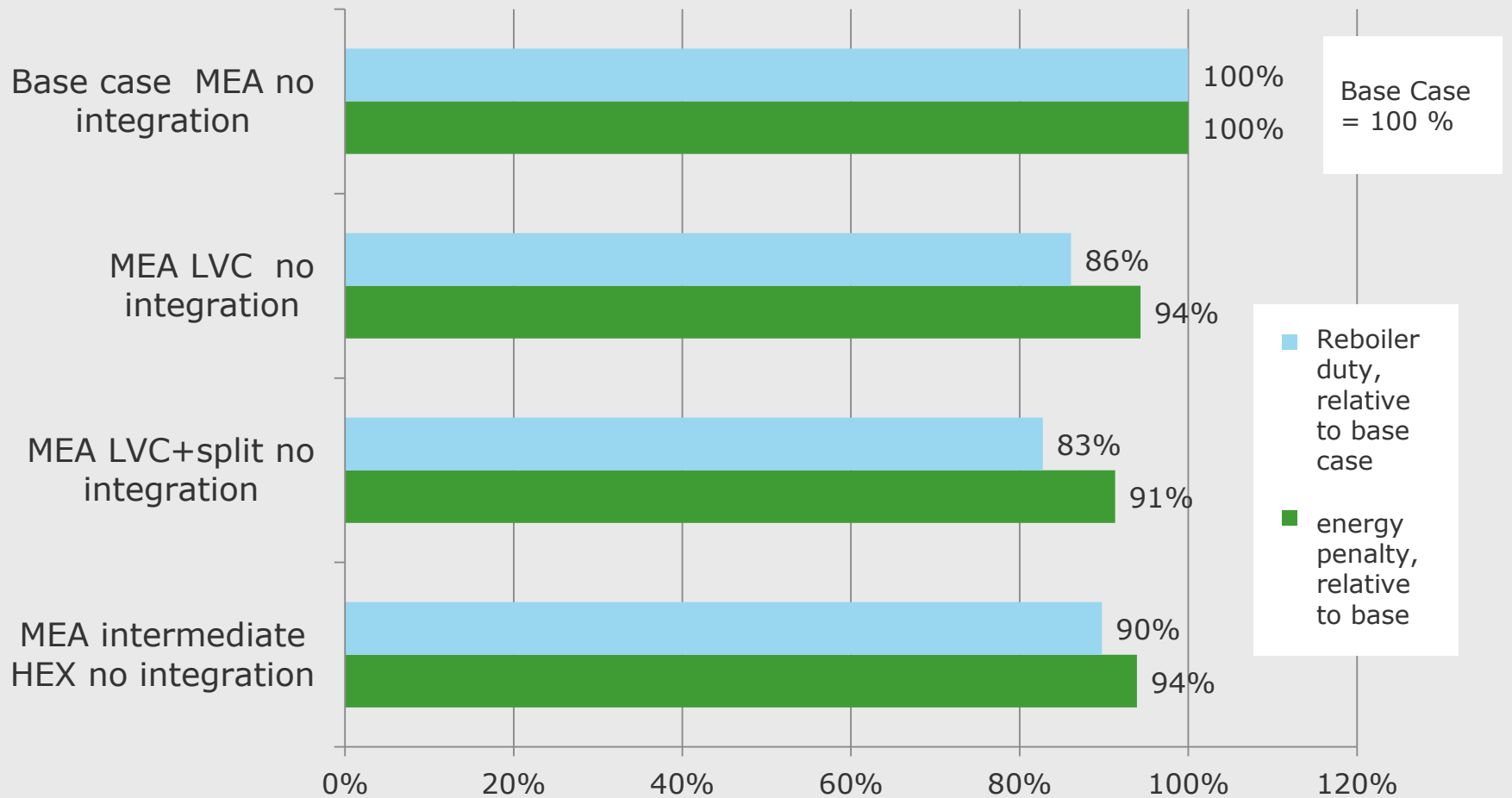


Benchmarking model



Concept of benchmarking: bringing performance indicators to one (artificial) level for comparison, generally executed by an independent 3rd party

Example results: ROAD 250 MW_e DEMO - design alternatives



Net Electrical output and reboiler duty compared: illustrative of the need to have a model to bring all inputs to the same level of comparison. source: de Miguel Mercader et al, IJGGC, 2013

Let's take a side-step - Example use of TRL Carbon Capture Mongstad (CCM)

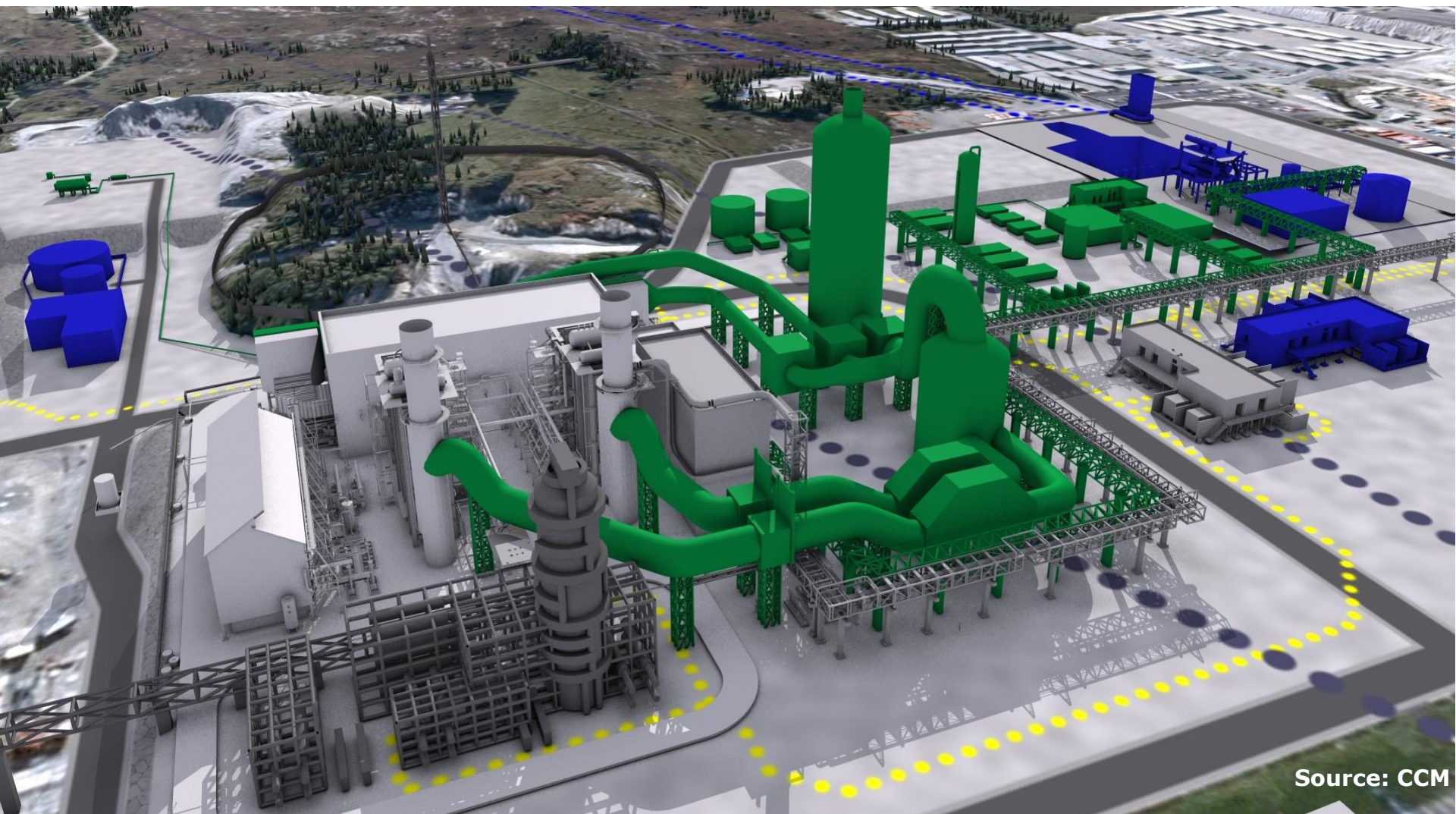
New gas fired CHP plant at Mongstad Refinery (2010)

CCM Agreement

- CHP plant may be operated on the condition that CO₂ is captured and stored
- Max. capacity 1.3 Mton/yr
- Start-up foreseen in 2020
- Only amine based and ammonium carbonate based technologies considered



Typical post-combustion CO₂ capture plant



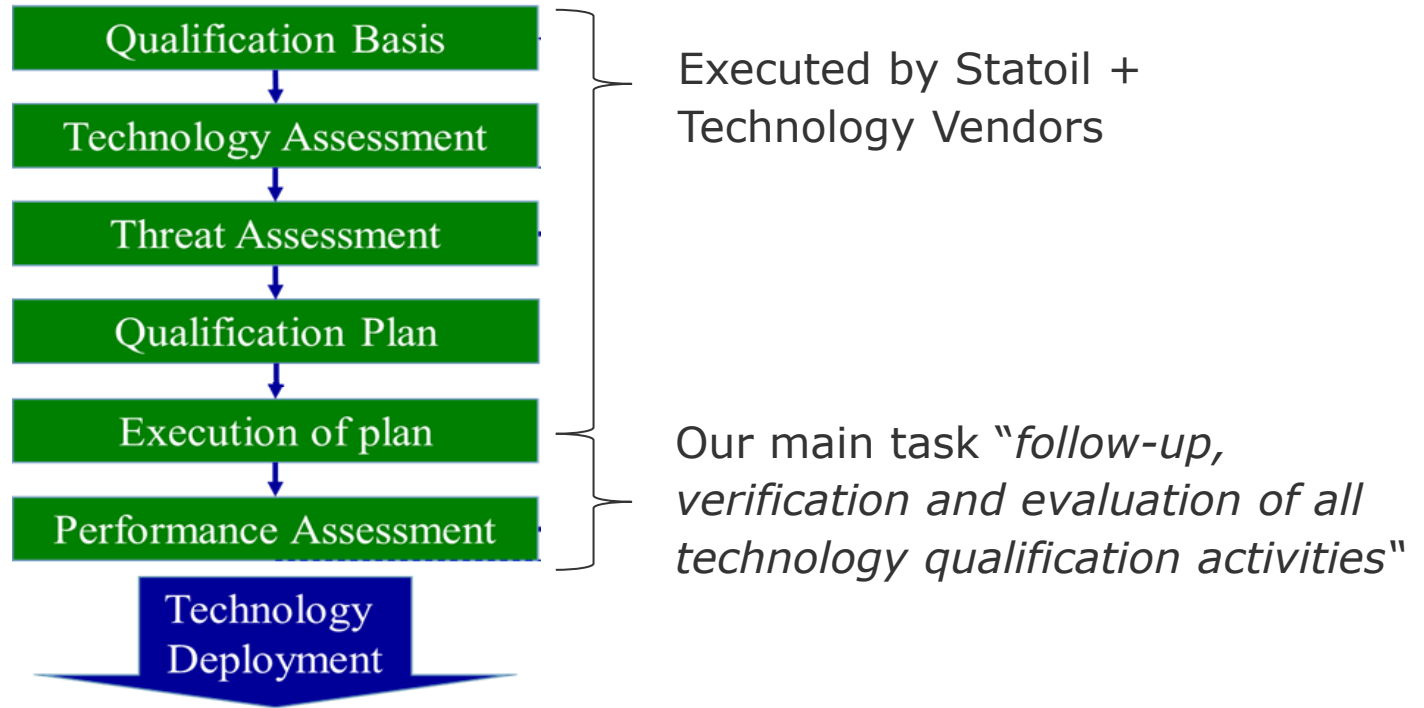
Source: CCM

Participating Technology Vendors

1. Huaneng CERI Powerspan
 - Proprietary amine based ECO₂ solvent
2. Siemens
 - Proprietary amino acid salt based AAS solvent
3. Aker Clean Carbon (ACC)
 - Proprietary amine based S-21 solvent
4. Mitsubishi Heavy Industries (MHI)
 - Proprietary amine based KS-1 solvent
5. Alstom
 - Ammonium carbonate solvent



Technology qualification process



Goals:

- **Prove capture plant is TRL 4***
- Energy performance meet minimum requirements
- Emissions meet minimum requirements

*According to Statoil WR-1622

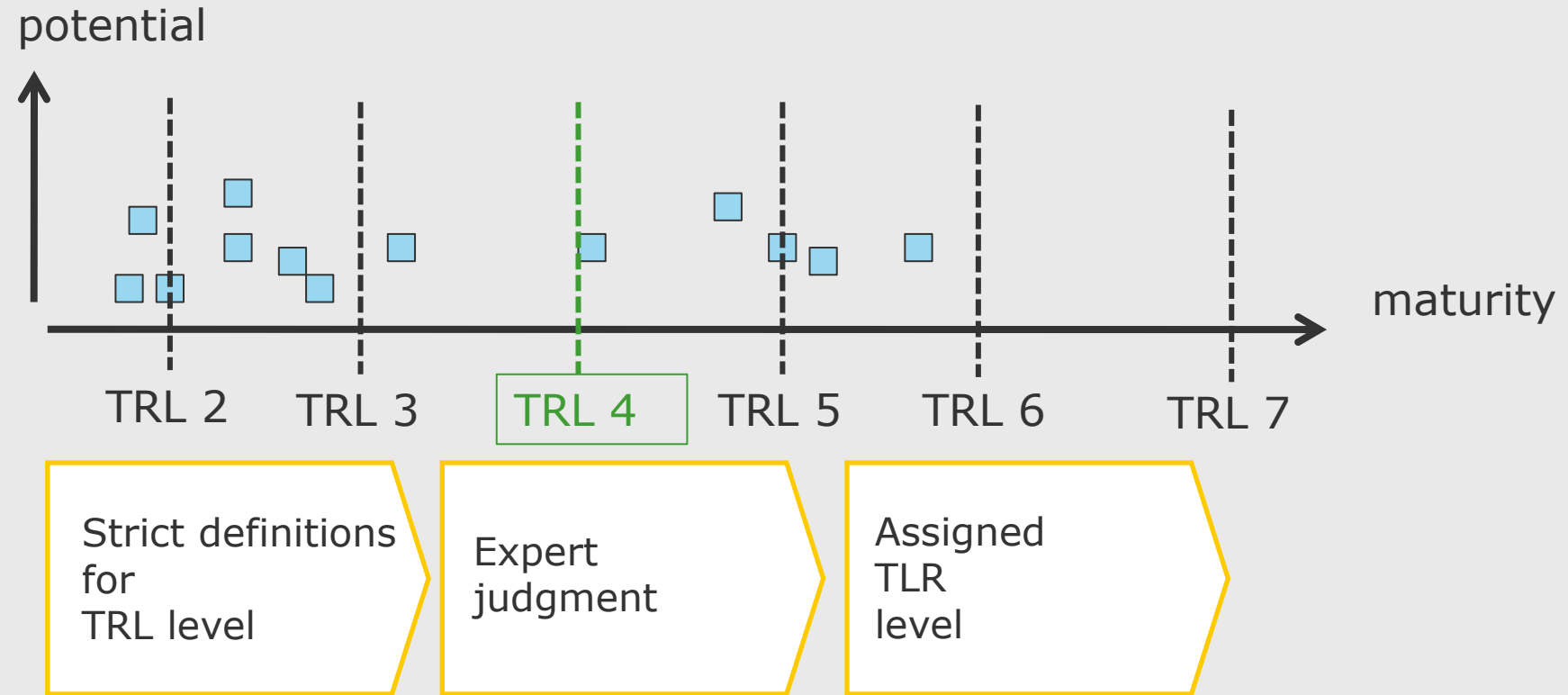
Technology Readiness Level goal

TRL 4: Representative of full scale prototype (or production unit) built and put through a qualification test program in (simulated or actual) intended environment

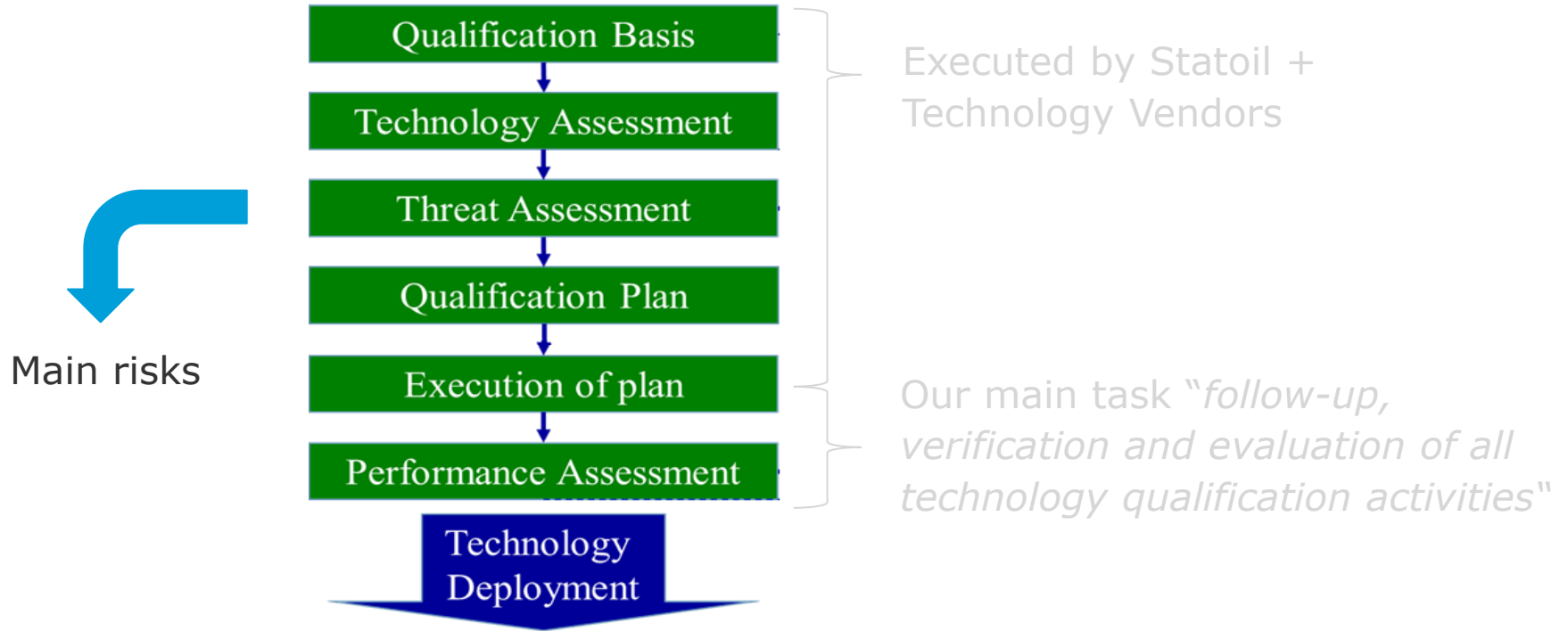
Technology Readiness Level (Statoil WR-1622)

Level	Development stage
TRL 0	Unproven Idea
TRL 1	Analytically Proven Concept
TRL 2	Physically Proven Concept
TRL 3	Prototype Tested
TRL 4	Environment Tested
TRL 5	System Integration Tested
TRL 6	System Installed
TRL 7	Proven Technology

Technology Readiness Levels



Technology qualification process



Goals:

- **Prove capture plant is TRL 4***
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*According to Statoil WR-1622

Main development risks identified

- Scale-up of absorber (and stripper)



(Diameter 0.5 m)

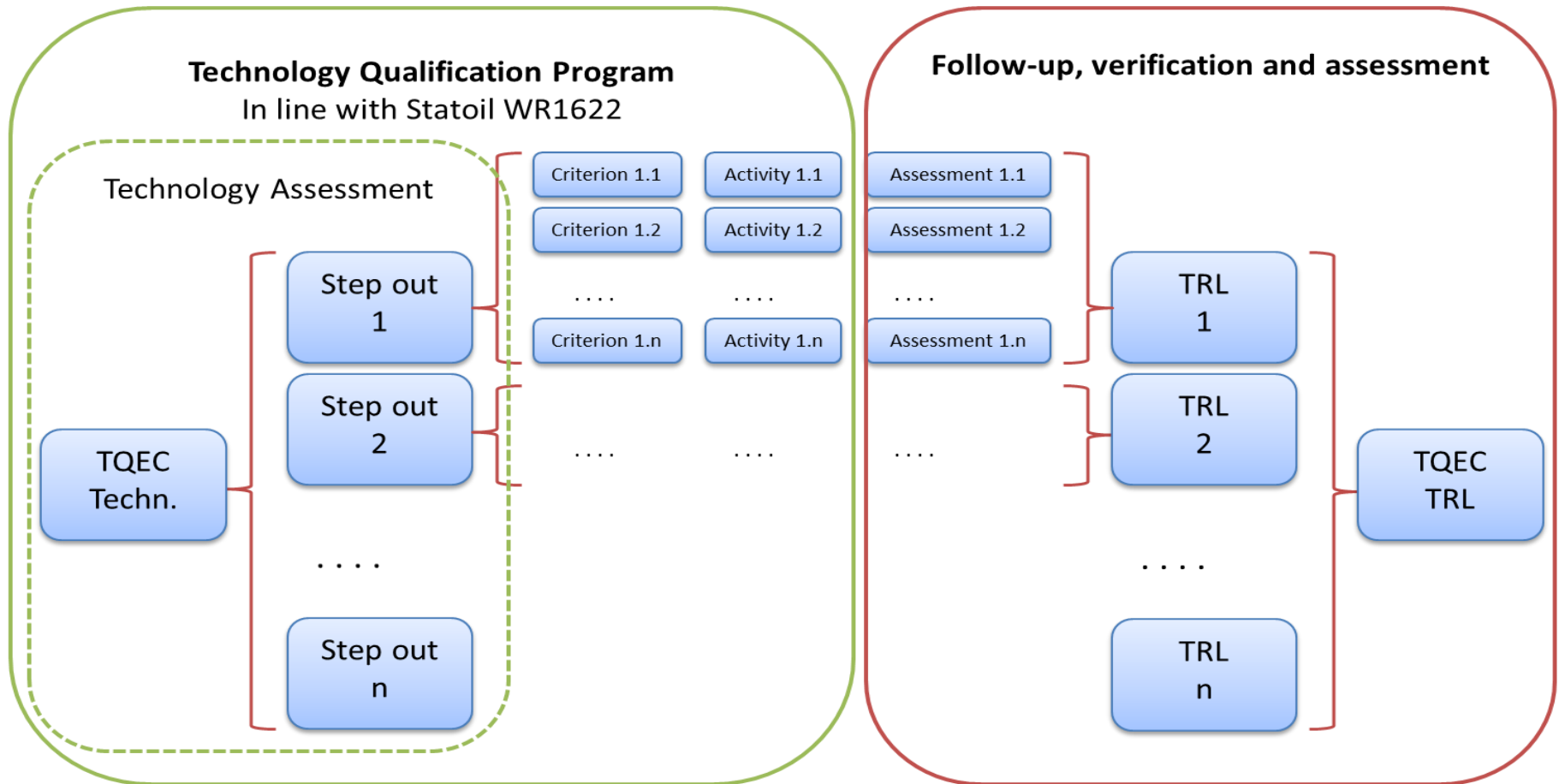


(Diameter ~20 m)

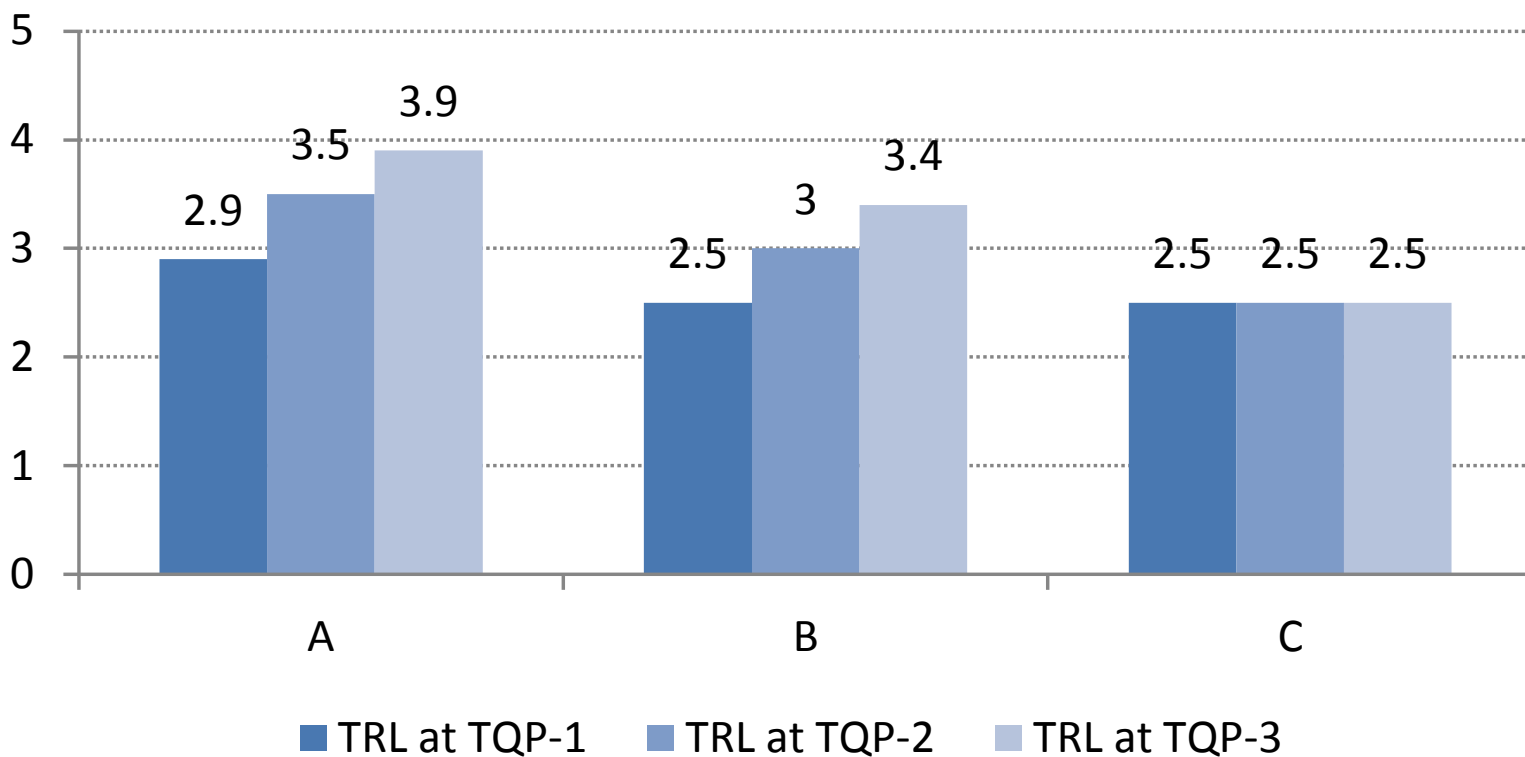
- Severe solvent degradation
 - O_2 and NO_x in flue gas
- H&E aspects
 - Carcinogenic nitrosamines and nitramines
 - Amines and other degradation products
 - Waste (water)
 - NH_3

TRL assessed per technology step out category

- Example step out A: (design and scale-up of) Absorber



TRL assessment of technology vendors on three project phases



Because of confidentiality reasons, these numbers are not corresponding to the actual outcome of the CCM project



TRL 4 ?

Thanks

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