Lessons learned from industrial field allocation studies

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Introduction / Overview

- Typical workflow in field allocation studies
- Case: Field allocation uncertainty before and after a new tie-in
- Allocation uncertainty over field life time
  → input to risk-cost-benefit analysis
- Key lessons learned

Typical workflow in allocation uncertainty projects

- **Allocation method**: Is this already decided or should project give input to decision?
  - Total hydrocarbon or separate oil and gas phase?
  - Component based or total?
  - Mass or volume or calorific value?
  - Allocation principle (pro-rata, by-difference, phase-split based on simulated ORFs or measurements)
- **System modelling**
  - Metering stations, test separators
  - Gas lift, water injection, gas injection
- **Input data both for host and tie-ins**: What is available and what must be estimated?
  - Metering station uncertainties
  - Production profiles
  - Hydrocarbon or gas & oil composition if allocation is performed on component level
- **Allocation simulation**: Over field lifetime
  - → Risk
  - → Sensitivity to different input parameters
- **Risk-cost-benefit analysis**: Need CAPEX/OPEX estimation from project (operator)

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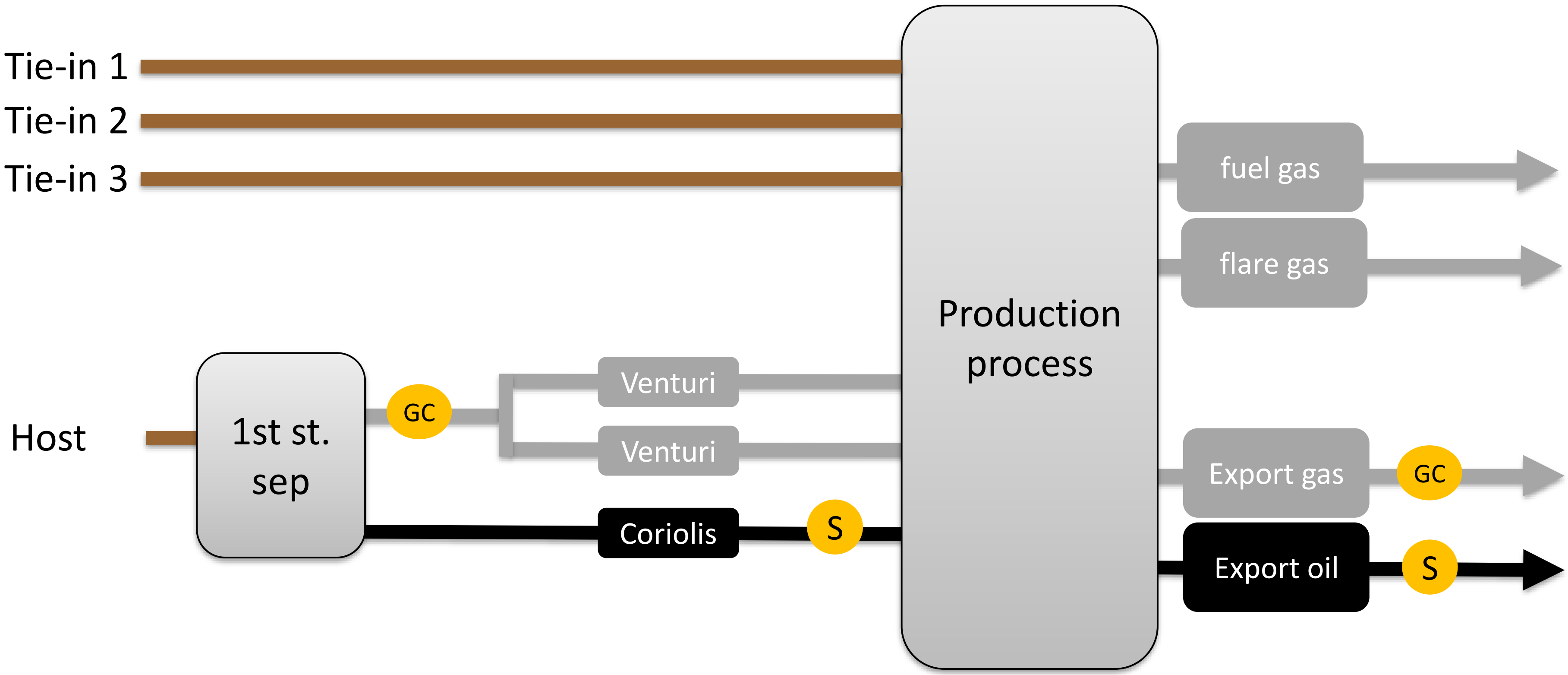
Allocation system – before tie-in



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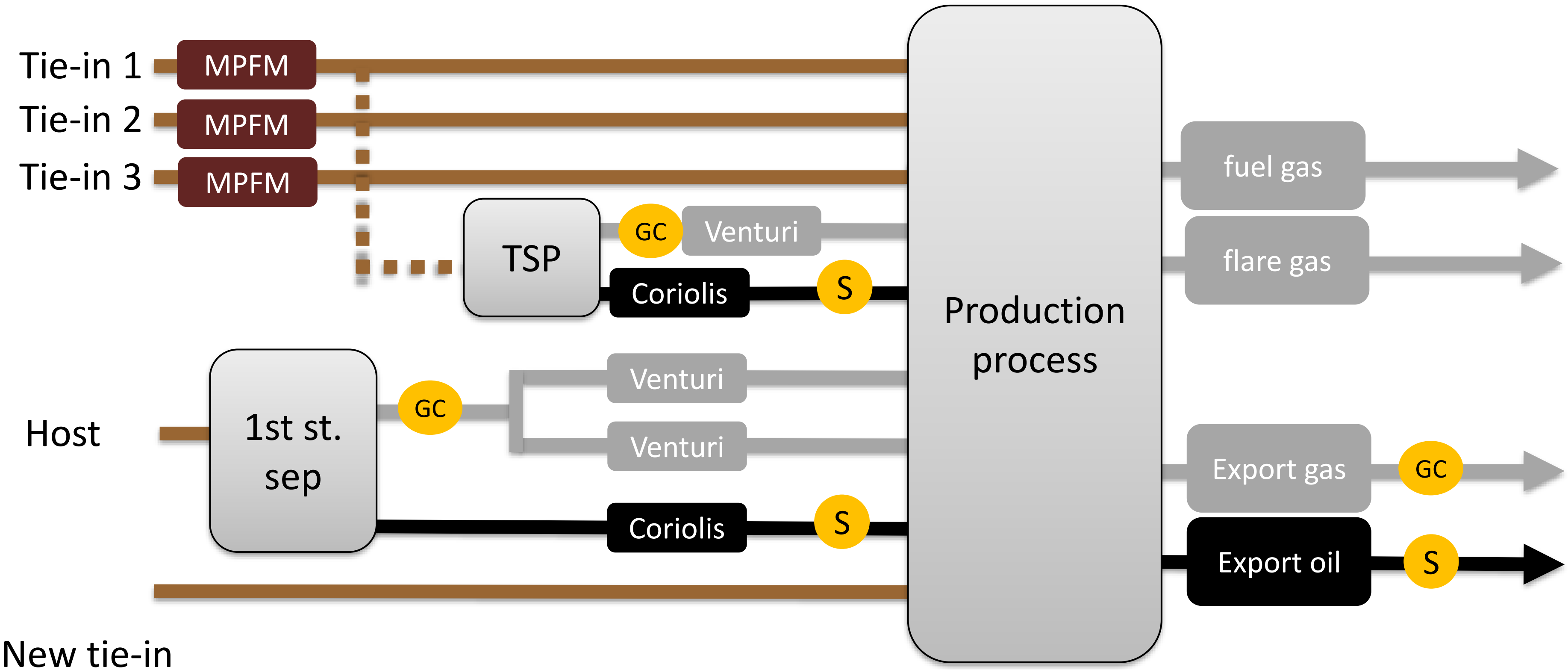
Allocation system – after tie-in



Input: Metering station uncertainties - QUANTITY

- **Host metering station:** Assumed in line with NPD requirements (a detailed uncertainty analysis was outside project scope).
- **Existing tie-ins:** Topside multiphase flow meters (MPFM) to be installed, with regular calibration against test separator (TSP).
- **New tie-in:** Allocated by-difference, no measurements

Input: Metering station uncertainties - QUALITY

Gas composition:

Uncertainties based on NORSOK I-106, annex F, but take into account additional uncertainty related to sample representativity

Oil composition

Uncertainty related to sample representativity and handling
Analysis uncertainties according to Intertek WL reports

- **Host**: More frequent and higher quality of sampling → lower uncertainties
- **Old tie-ins:** Only sporadic and lower quality of sampling and input to and update of PVT-simulation → higher uncertainties

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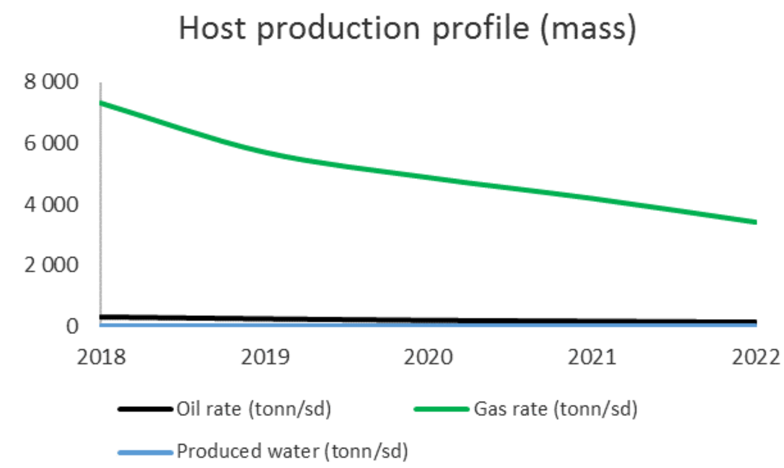
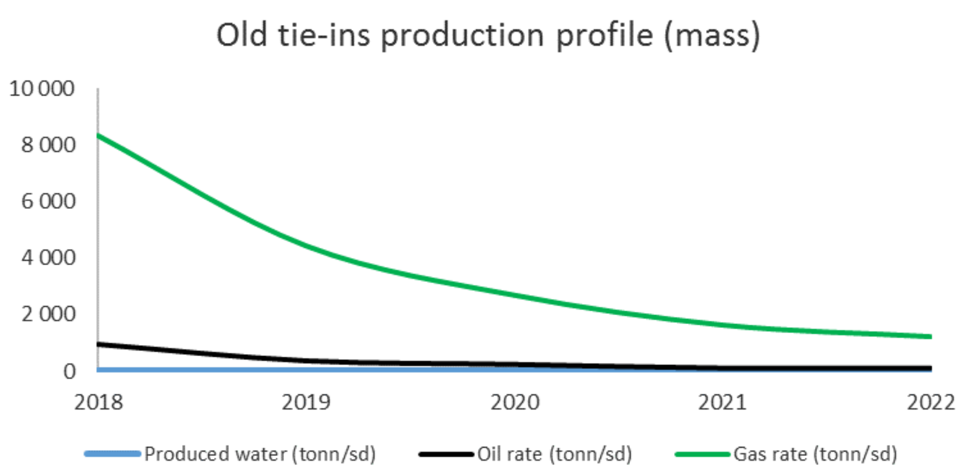
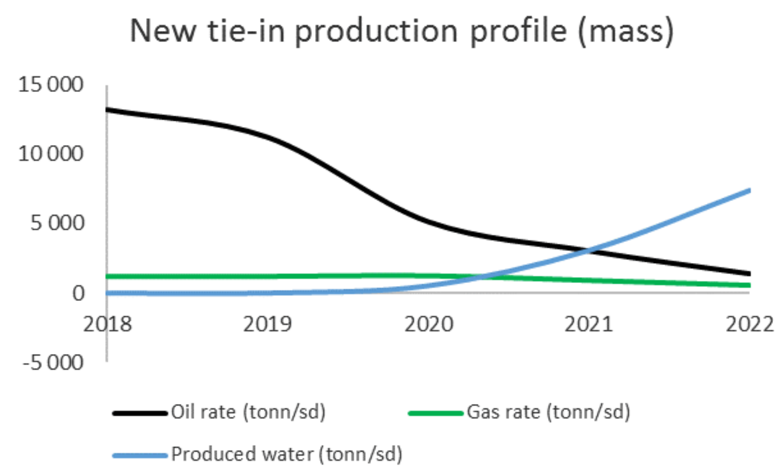
Input: Production profiles







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Input: Compositions

	HC composition (wt %)									
	N2	CO2	C1	C2	C3	iC4	nC4	iC5	nC5	C6+
New tie-in	1,0	1,0	10,0	2,0	2,0	1,0	1,0	1,0	1,0	80,0
Host	2,0	3,0	50,0	20,0	20,0	1,0	1,0	1,0	1,0	1,0
Older tie-ins	2,0	4,0	50,0	15,0	15,0	1,0	1,0	1,0	1,0	10,0

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Framework used for field- and ownership allocation calculation:

- Modular
- ISO-GUM compliant
- Numeric Monte Carlo method

References:

- *Systematic bias in pro rata allocation schemes, ,* Ranveig Nygaard Bjørk, Astrid Marie Skålvik, Armin Pobitzer, 35th International North Sea Flow Measurement Workshop 2017, October 24 – 26, Tønsberg, Norway.

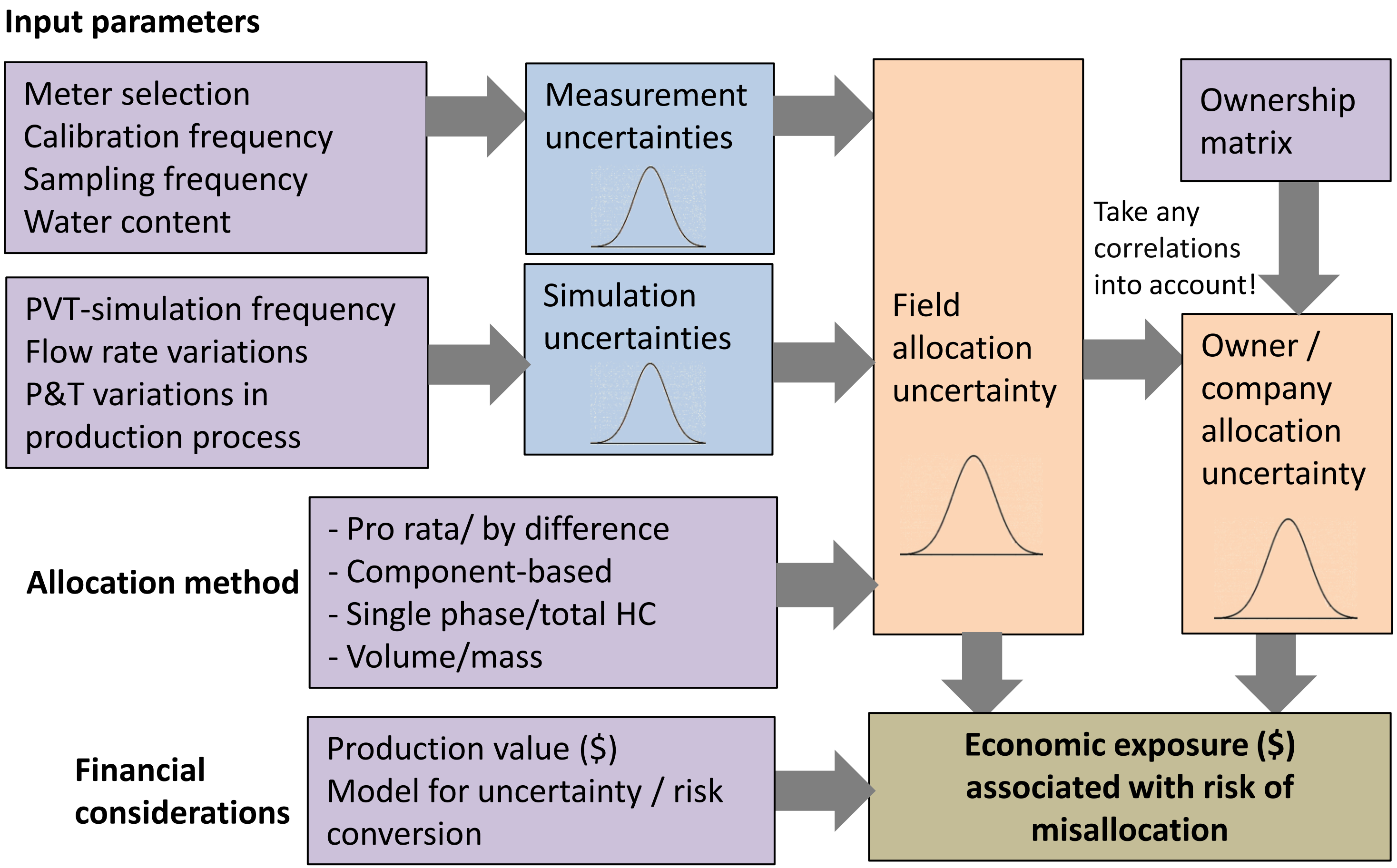
- *Cost saving metering station maintenance for allocation systems,* Ranveig Nygaard Bjørk, Astrid Marie Skålvik, Armin Pobitzer, Camilla Sætre, European Flow Measurement Workshop 2017, Noorwijk, Netherlands

-*Kvalitet for olje og gass og innvirkningen på allokering,* Astrid Marie Skålvik, NFOGM Temadag 2017, Stavanger, Norway

-*Analysis of field and ownership allocation uncertainty in complex multi-field configurations*, Ranveig Nygaard Bjørk, Astrid Marie Skålvik, Armin Pobitzer, Eivind Nag Mosland, Camilla Sætre, Kjell-Eivind Frøysa, North Sea Flow Measurement Workshop 2016, St. Andrews, Scotland.

-*Allocation system setup optimization in a cost-benefit perspective,* Armin Pobitzer, Astrid Marie Skålvik, Ranveig Nygaard Bjørk, Journal of Petroleum Science and Engineering, 2016

Field allocation uncertainty analysis - Method



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Results: Field measured and allocated relative uncertainties

Host measured and allocated relative uncertainties (confidence level 95 %)

Year	N2	CO2	C1	C2	C3	iC4	nC4	iC5	nC5	C6+
2018-2022	1,0 %	1,0 %	1,6 %	1,0 %	0,9 %	0,9 %	0,8 %	0,8 %	0,8 %	1,4 %

Old tie-ins measured and allocated uncertainties (rel.exp, conf.level 95 %)

Year	N2	CO2	C1	C2	C3	iC4	nC4	iC5	nC5	C6+
2018-2022	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %

New tie-in allocated relative uncertainties (confidence level 95 %)

Year	N2	CO2	C1	C2	C3	iC4	nC4	iC5	nC5	C6+
2018	14 %	8 %	36 %	54 %	53 %	7 %	7 %	7 %	7 %	2 %
2019	9 %	5 %	22 %	33 %	33 %	5 %	5 %	4 %	4 %	2 %
2020	11 %	7 %	27 %	40 %	40 %	5 %	5 %	5 %	5 %	2 %
2021	11 %	8 %	27 %	41 %	40 %	5 %	5 %	5 %	5 %	2 %
2022	17 %	12 %	43 %	64 %	53 %	8 %	8 %	8 %	8 %	2 %

	HC composition (wt %)									
	N2	CO2	C1	C2	C3	iC4	nC4	iC5	nC5	C6+
New tie-in	1,0	1,0	10,0	2,0	2,0	1,0	1,0	1,0	1,0	80,0
Host	2,0	3,0	50,0	20,0	20,0	1,0	1,0	1,0	1,0	1,0
Older tie-ins	2,0	4,0	50,0	15,0	15,0	1,0	1,0	1,0	1,0	10,0

Analytical expression of tie-in allocation uncertainties

$$M_{i,by\ diff} = M_{i,exp} - M_{i,meas} = M_{exp}\, c_{i,exp} - M_{meas} c_{i,meas}$$

$$\left(\frac{u\left(M_{i,by\ diff}\right)}{M_{i,by\ diff}}\right)^2$$

$$= \left(\frac{M_{i,exp}}{M_{i,exp} - M_{i,meas}}\right)^2 \left(\left(\frac{u\left(M_{exp}\right)}{M_{exp}}\right)^2 + \left(\frac{u\left(c_{i,exp}\right)}{c_{i,exp}}\right)^2\right)$$

$$+ \left(\frac{M_{i,meas}}{M_{i,exp} - M_{i,meas}}\right)^2 \left(\left(\frac{u\left(M_{meas}\right)}{M_{meas}}\right)^2 + \left(\frac{u\left(c_{i,meas}\right)}{c_{i,meas}}\right)^2\right)$$

Results: Tie-in allocated mass and absolute allocation uncertainties

New tie-in allocated mass (generic units)

Year	N2	CO2	C1	C2	C3	iC4	nC4	iC5	nC5	C6+
2018	144	144	1444	289	289	144	144	144	144	11552
2019	125	125	1246	249	249	125	125	125	125	9963
2020	64	64	641	128	128	64	64	64	64	5126
2021	40	40	396	79	79	40	40	40	40	3165
2022	19	19	195	39	39	19	19	19	19	1557

New tie-in allocated absolute uncertainties (confidence level 95 %), mass, generic units

Year	N2	CO2	C1	C2	C3	iC4	nC4	iC5	nC5	C6+
2018	21	11	513	155	153	10	10	10	10	243
2019	11	7	272	82	81	6	6	6	6	189
2020	7	4	171	51	51	3	3	3	3	103
2021	4	3	108	32	32	2	2	2	2	63
2022	3	2	83	25	21	2	2	2	2	33

Lessons learned – allocation per component of HC mass of different qualtiy streams

When allocation is performed per component of HC mass and the HC compositions of the measured and non-measured flows are very different, then:

If new tie-in is allocated <u>by-difference</u>:

- Host mHC_i allocation uncertainties remain unchanged as measurement is used directly for allocation
- A by-difference allocation uncertainty is expected to be dominated by the export station uncertainties

If the new tie-in is measured (MPFM) and allocated <u>pro-rata</u>:

- The host and older tie-ins allocation uncertainties for mHC_i are expected to increase as a high MPFM and sampling uncertainty of the new tie-in will «contaminate» the more accurate measurements
- Requires a MPFM metering solution with a low uncertainty and close follow-up, combined with representative sampling.

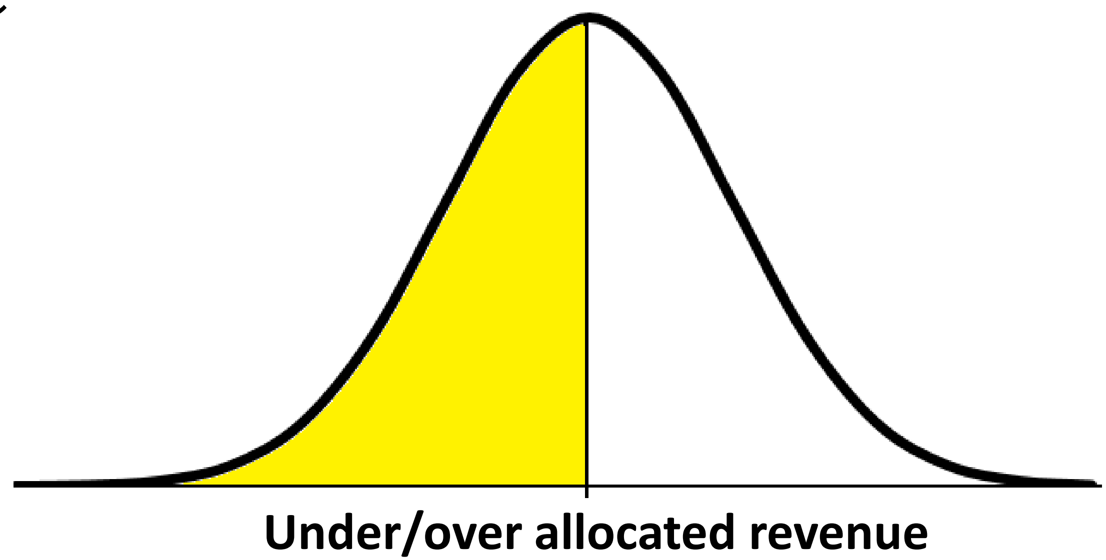
Risk of loss due to misallocation – Background / Theory

Statistical expected loss (Stockton, 2009):

$$Exposure\ to\ lost\ revenue, R = \int_{-\infty}^{0} (probablility\ \cdot misallocation)$$

$$R \approx 0.2 \cdot U^{*} \cdot\ Q\ \cdot\ V$$

R: exposure to lost revenue due to allocation uncertainty
Q: Allocated quantity
U:* relative expanded uncertainty
V: value per unit



Risk of loss due to misallocation – Method

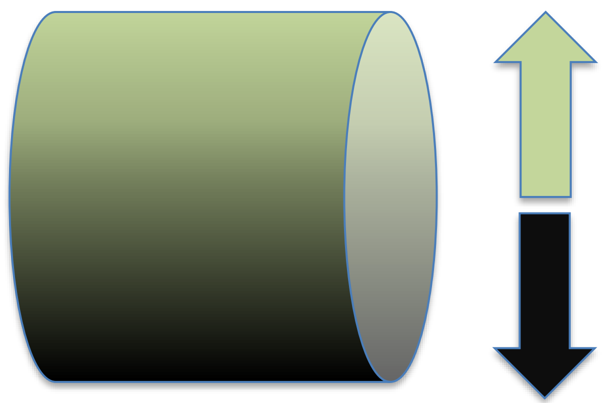
In the case of allocation of oil and gas volume:

$$R \approx 0.2 \cdot U^*_{gas} \cdot Q_{gas} \cdot \; V_{gas} + 0.2 \cdot U^*_{oil} \cdot Q_{oil} \cdot \; V_{oil}$$

Production allocation

Value distribution

Hydrocarbon mass
per component



Gas volume

Oil volume

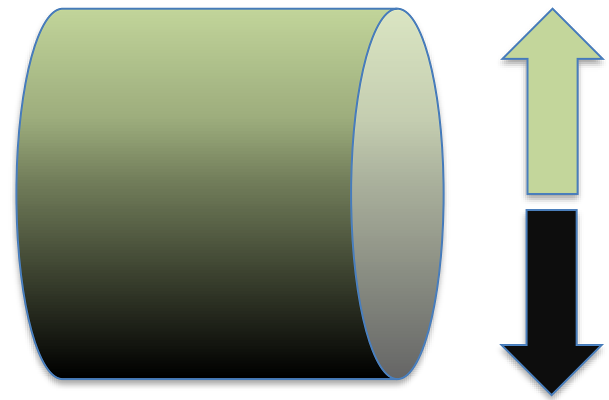
→ The uncertainties in Oil Recovery Factors (ORFs) and product densities must be taken into account in order to calculate risk related to misallocation

Oil Recovery Factors - ORF

$$ORF = \frac{m_{oil}}{m_{HC}}$$

Field oil mass **after** processing, at fiscal export conditions

Field hydrocarbon mass



$$ORF_i = \frac{m_{oil,i}}{m_{HC},i}$$

Uncertainties estimated based on a previous sensitivity study on a PVT-simulation software together with assumed variation in process conditions, flow rates, compositions.

- **Host**: More frequent and higher quality of sampling and input to PVT-simulation → lower uncertainties
- **Old tie-ins:** Only sporadic input to and update of PVT-simulation → higher uncertainties

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Risk of loss due to misallocation – Example calculation

Year	Allocated VOil (Sm3/day)	U* Allocated VOil	Allocated VGas (Sm3/day)	U* Allocated VGas
2018	14	1,8	3069	6,1
2019	12	1,8	2647	6,4
2020	6	1,9	1362	11,4
2021	4	2,0	841	17,6
2022	2	2,3	413	34,3

Year	Allocated [USD]
Total	**327 884 698**
2018	120 773 273
2019	104 152 692
2020	53 559 166
2021	33 125 619
2022	16 273 948

Year	Allocation risk of loss [USD]
Total	**6 200 392**
2018	1 451 320
2019	1 312 878
2020	1 200 211
2021	1 143 100
2022	1 092 883

Oil price: 80 USD/barrel
Gas price: 4 USD/MMBTU

Risk of loss due to misallocation

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- Quality matters!

- As metering uncertainties and production profiles for both host and tie-in(s) are vital input to the analysis, it is an advantage if host and tie-in(s) can cooperate or share data

- In order to assess the risk of misallocation, the uncertainty analysis must be carried out on the exact calculations that are applied to distribute income


Thank you
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Cox kommunikasjonsbyrå / Statoil - Statoil ASA