Workflow for allocation uncertainty analysis

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NFOGM Hydrocarbon Management Workshop, Stavanger, 01.06.2023

Introduction

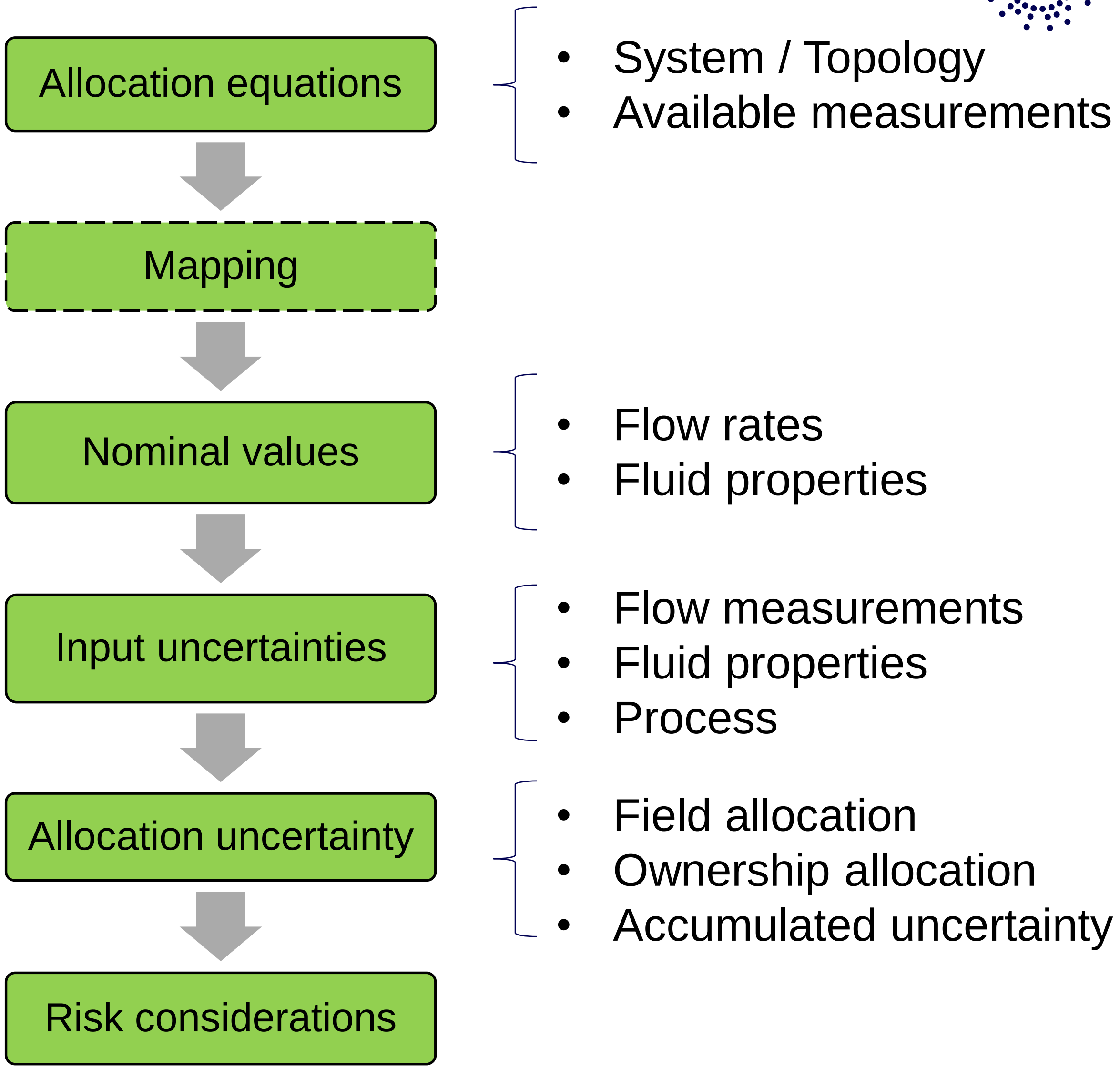
Join Industry Project

Participants: Wintershall Dea, Lundin Energy, DNO and NORCE

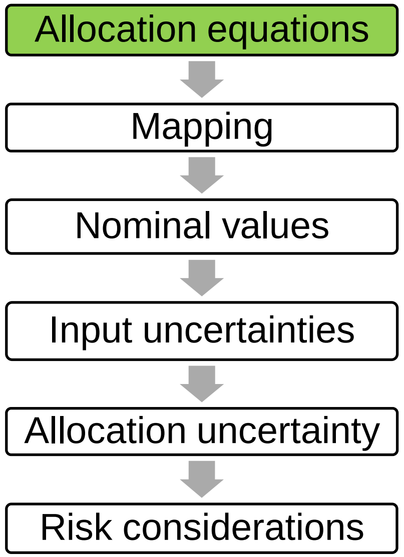
Goal: Foundation for Best practice for Allocation uncertainty and Risk-Cost-Benefit calculations

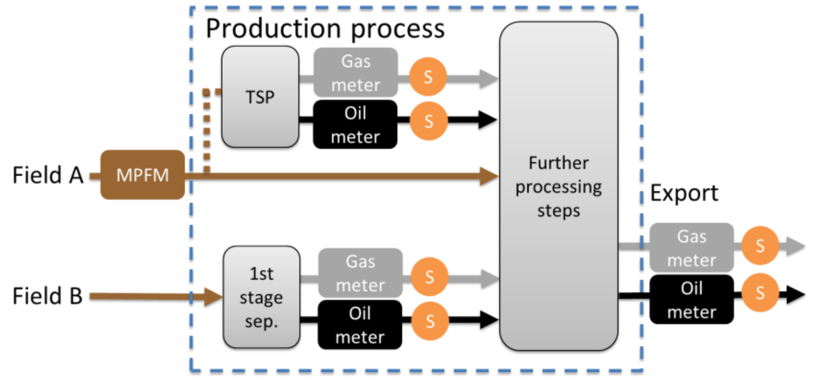
This presentation

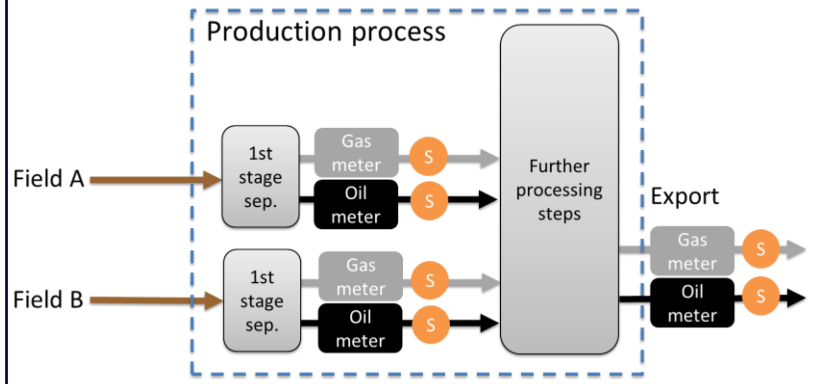
A practical workflow for allocation uncertainty analysis

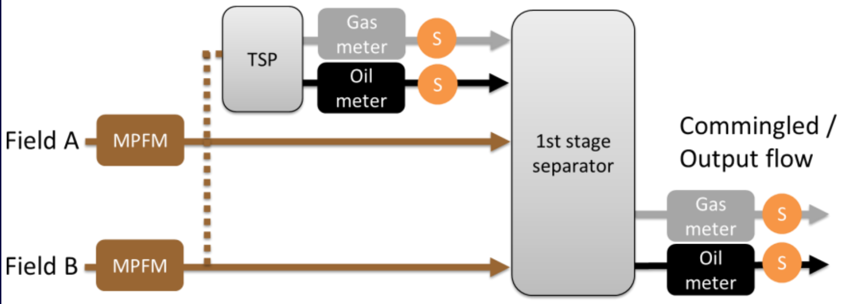


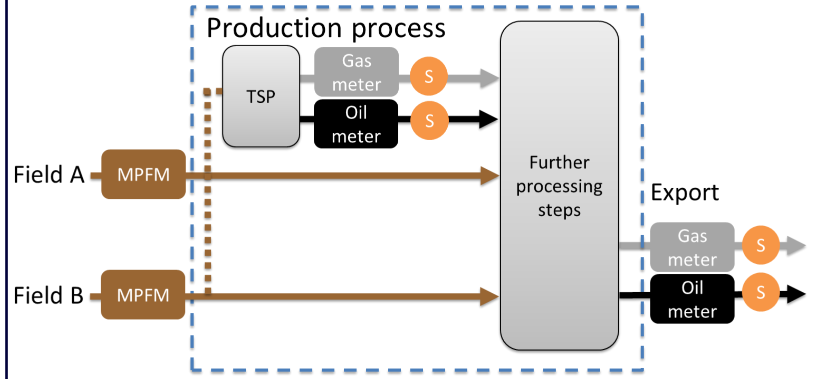
Allocation systems

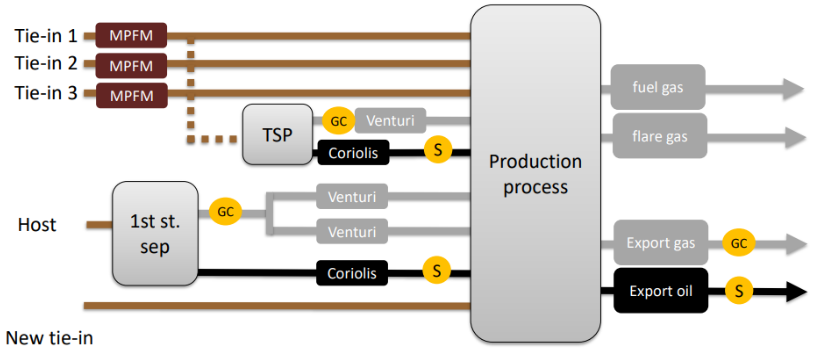


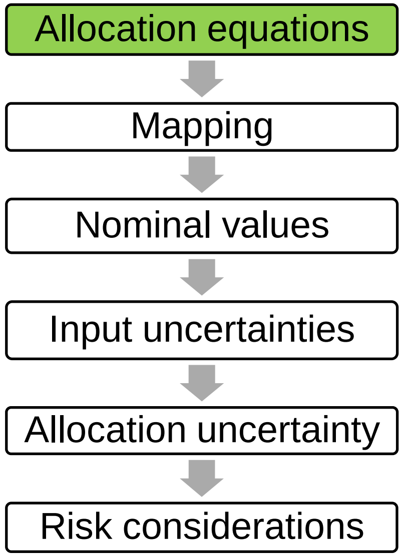






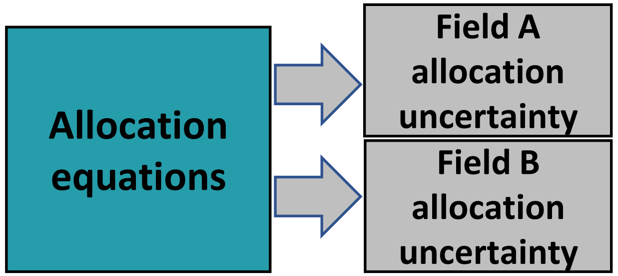


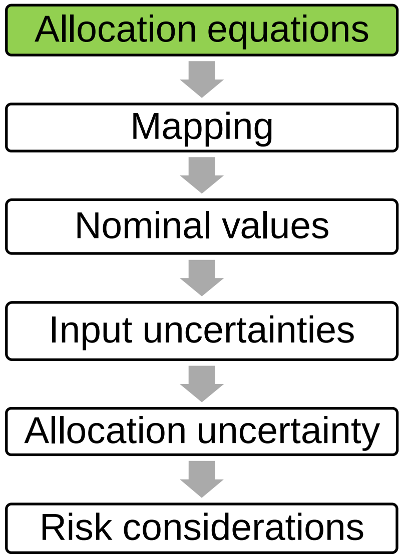




Allocation - method

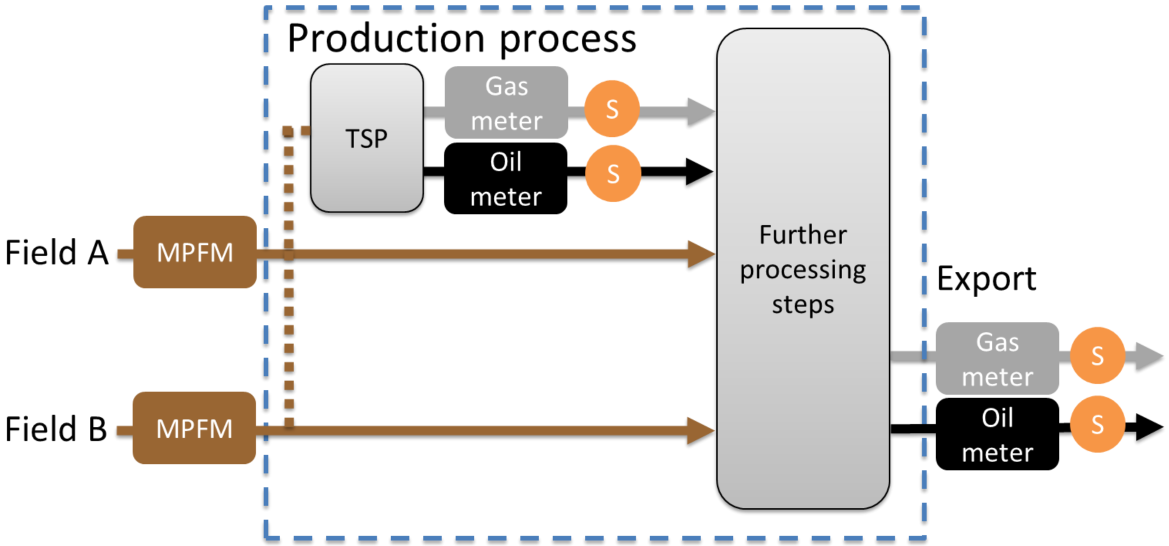
- Pro rata, by-difference or other (e.g. uncertainty-based)
- Single step or mulitstep (with combinations of pro rata and by-difference)
- Separate allocation of gas and oil/condensate
- Component by component or total
- Volumetric, by mass or by energy
- …



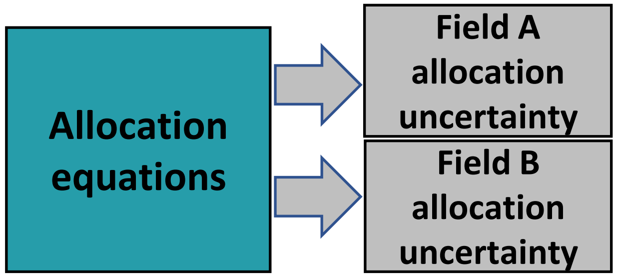


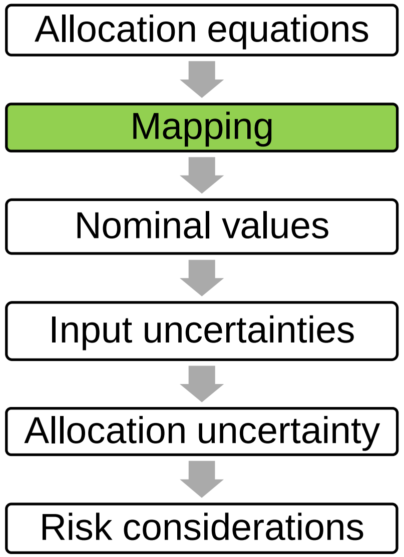
Allocation equation - example

Pro-rata allocation, Hydrocarbon mass



$$m_{HC}^{A,all} = m_{HC}^{export} \cdot \frac{m_{HC}^{A}}{m_{HC}^{A} + m_{HC}^{B}}$$





Mapping / 1st step

Measurement uncertainties may be difficult to evaluate

Production profiles are uncertain and subject to change

→ **Mapping in early project phase planning** :

→ Identify and understand relations between production rates, measurement and allocation uncertainties

→ Compare different allocation principles

Method:

1. Set rough but realistic limits for all input parameters and input uncertainties
2. Estimate allocation uncertainties for different combinations
3. Investigate correlations and visualize

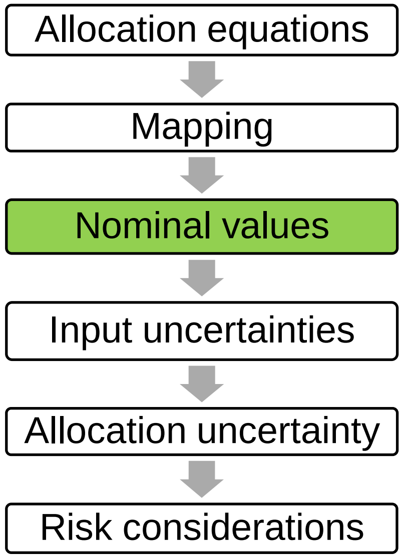
Skålvik A.M., Folgerø, K., Illiano, D. Holstad, M.B. (2022). Simplified sensitivity analysis of uncertainties in common allocation methods – A practical approach. NFOGM Hydrocarbon Management Workshop, Stavanger.

- Allocation equations
- **Mapping**
- Nominal values
- Input uncertainties
- Allocation uncertainty
- Risk considerations

Mapping / 1st step

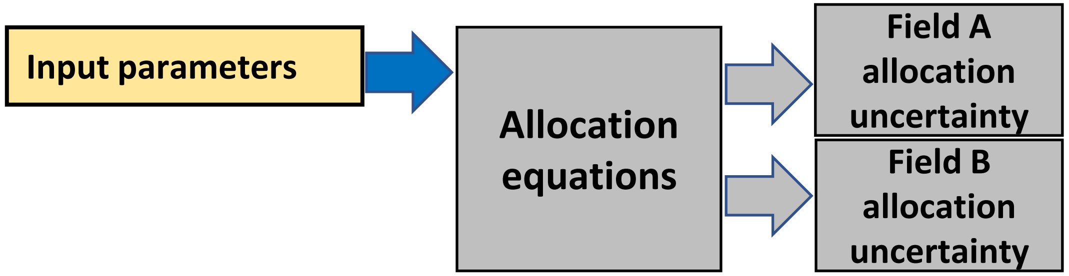
→ **Correlations** between **input** parameters and **allocation uncertainties**

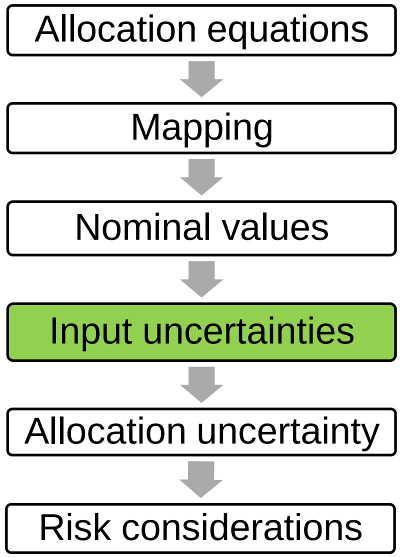
Allocation uncertainties	Field A_ORF	Field A_ORF U	Field A_HC mass fraction A	Field A_HC U*	Field B_ORF	Field B_ORF U	Field B_HC U*	Mix_HC U*
By-difference_Field A_HC	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
By-difference_Field A_Oil	-0,4	0,2	0,0	0,1	0,0	0,0	0,0	0,0
By-difference_Field A_Gas	0,4	0,2	0,0	0,1	0,0	0,0	0,0	0,0
By-difference_Field B_HC	0,0	0,0	0,7	0,2	0,0	0,0	0,0	0,2
By-difference_Field B_Oil	0,1	0,0	0,2	0,0	-0,2	0,0	0,0	0,1
By-difference_Field B_Gas	-0,1	0,0	0,3	0,0	0,3	0,0	0,0	0,1
Pro rata_Field A_HC	0,0	0,0	-0,6	0,3	0,0	0,0	0,3	0,6
Pro rata_Field A_Oil	-0,4	0,1	-0,1	0,0	0,0	0,1	0,0	0,1
Pro rata_Field A_Gas	0,4	0,2	-0,1	0,0	0,0	0,0	0,0	0,1
Pro rata_Field B_HC	0,0	0,0	0,6	0,3	0,0	0,0	0,3	0,6
Pro rata_Field B_Oil	0,0	0,0	0,2	0,0	-0,4	0,2	0,0	0,1
Pro rata_Field B_Gas	0,0	0,0	0,2	0,0	0,4	0,1	0,0	0,1



Input parameters - Nominal values

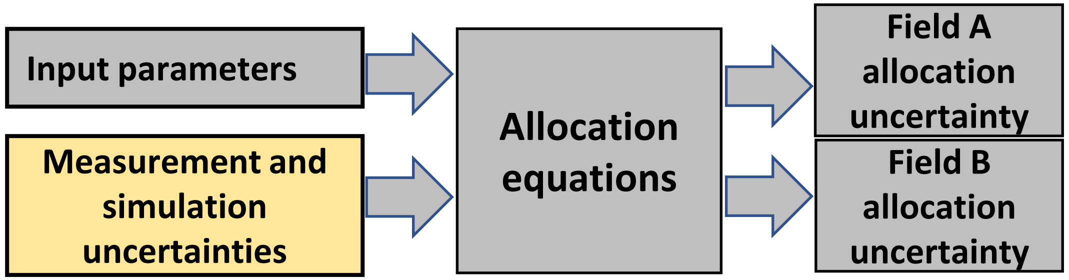
- Production profiles (flow rates) for all involved fields
- Production process (e.g. oil recovery factors / shrinkage factors)
- Fuel and flare gas rates
- Gas injection/lift rates
- Temperature and pressures



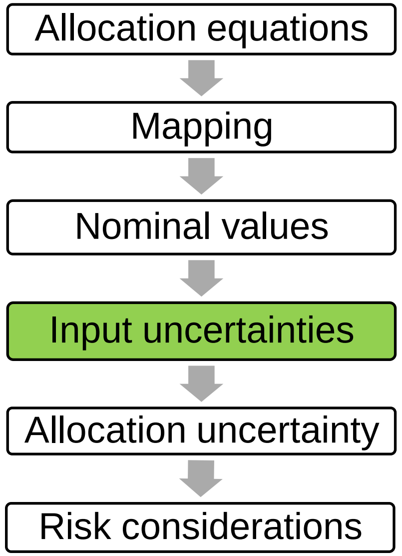


Measurement and simulation uncertainties

- Flow measurement uncertainty
- Composition uncertainty from sampling, handling and analysis
- Process uncertainty (oil recovery or shrinkage factors)



Flow measurement uncertainties

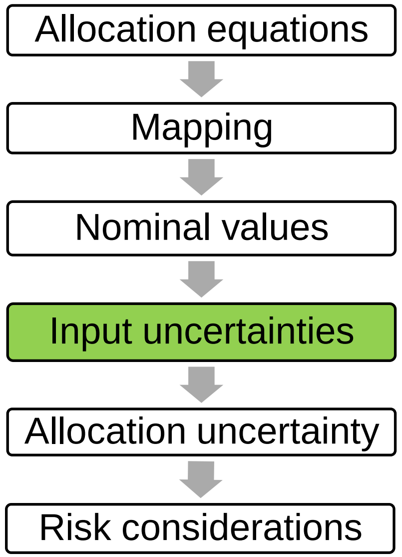


Input separator and export station: Tools and handbooks for uncertainty analysis of single phase flow metering available from nfogm.no/.

Multiphase Flow Meter (MPFM) uncertainty: depends among others on calibration frequency, flow stability, flow meter repeteability, sampling position and analysis uncertainty, reference uncertainty.

- e.g. K. Folgerø, E. L. Soldal, J. Kocbach, K.-E. Frøysa, K. Kleppe, E. Åbro, (2013), *Uncertainty analysis of multiphase flow meters used for allocation measurements: Field experiments and future challenges*, NSFMW 2013

Composition uncertainty from sampling, handling and analysis



There is today no established methodology for uncertainty evaluation of composition, based on samples from non-stabilized and possibly phase-contaminated single phase sampling

Some presentations from NFOGM Teamdag/Fagdag by O. Øiestad, 2023, H. Nilsen, 2023 and C. Nilsson, 2021 decribe the sampling, handling and analysis process, without explicitly discussing uncertainties.

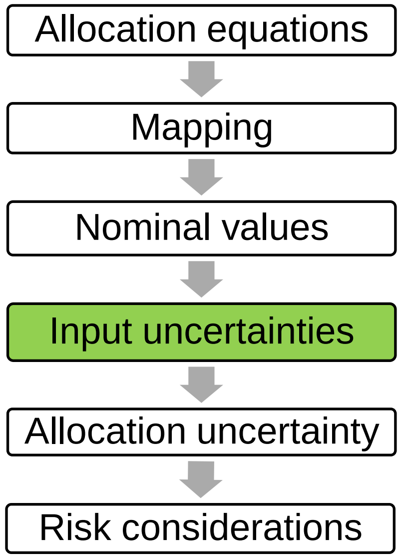
The use of repeatability requirements from ASTM-standards is proposed in:

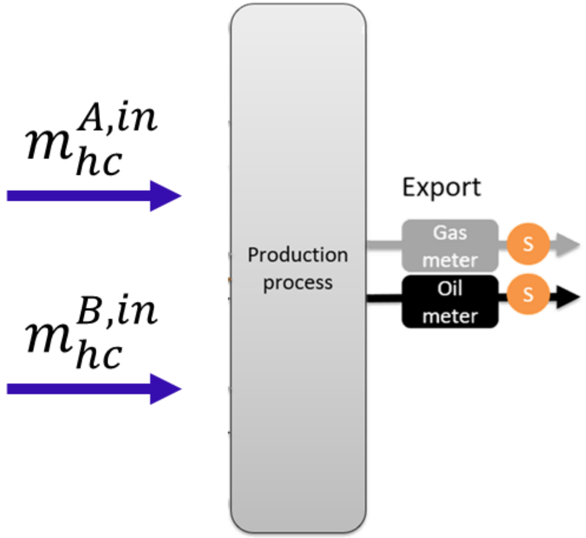
Folgerø, K., Haukalid, K., Skålvik, A. M., Helsør, T., Holstad, M. B., Syre, B., Maudal, K. Å., Johnsen, A., Westgaard, E. (2021). *Influence of fluid compositions and process parameters on allocation uncertainties*, North Sea Flow Measurement Workshop, Tønsberg, Norway

And a planned paper will describe a method for estimating oil sample recombination uncertainties:

Skålvik, A. M., Folgerø, K., Haukalid, K.,Bjørk, R. N., Illiano, D. (2023, in preparation). *Measurement uncertainty of non-stabilized oil sample compositional analysis evaluated using Monte Carlo methodology*, Global Flow Measurement Workshop, Tønsberg, Norway

Process uncertainty – Oil Recovery or shrinkage factors



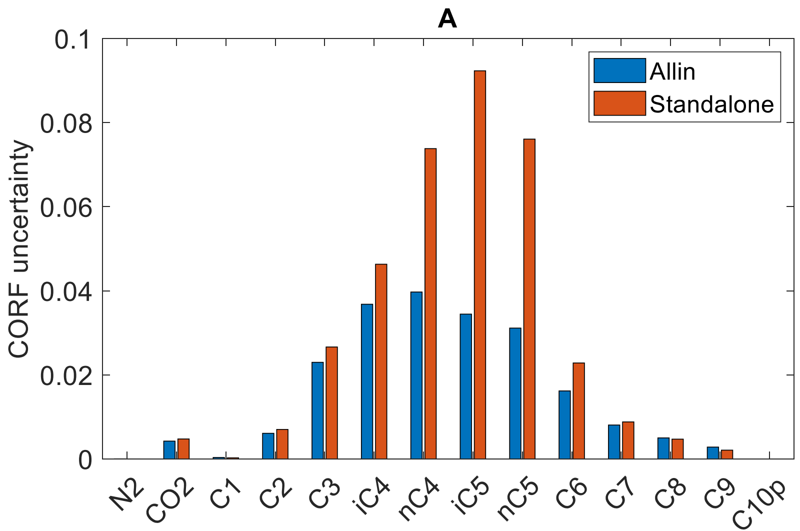


$$m_{oil}^{A} = ORF^{A} \cdot m_{HC}^{A}$$

Uncertainties in ORF or shrinkage factors depend on:

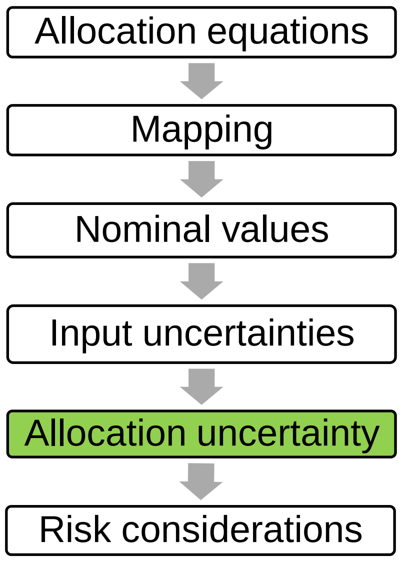
- **Flow rate ratios and variations** for all input producer
- **Temperature** and **pressure** conditions/variations
- **Variation in fluid compositions** for all input producers.

Uncertainties can be estimated through Monte Carlo simulations on process models.



More details in: Folgerø, K., Haukalid, K., Skålvik, A. M., Helsør, T., Holstad, M. B., Syre, B., Maudal, K. Å., Johnsen, A., Westgaard, E. (2021). *Influence of fluid compositions and process parameters on allocation uncertainties*, North Sea Flow Measurement Workshop, Tønsberg, Norway

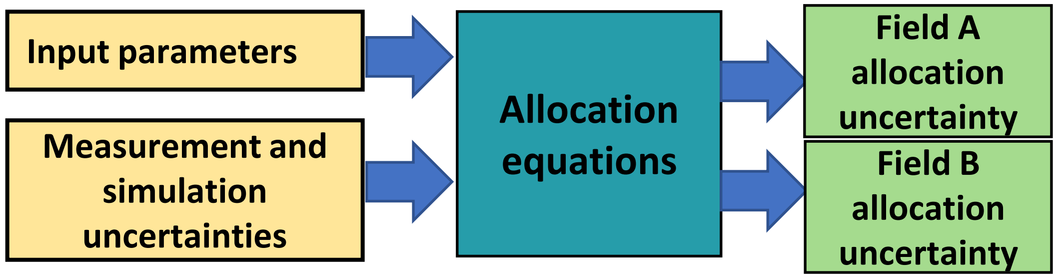
Another relevant paper: Stockton, P., Martin, J. (2014). *Process Simulation Uncertainties*, North Sea Flow Measurement Workshop, St. Andrews, Scotland



Allocation uncertainty estimation

Depending on complexity, the uncertainty can be calculated

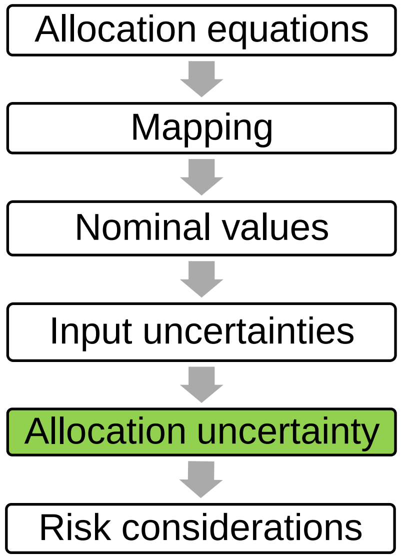
- Analytically
- Monte Carlo simulation



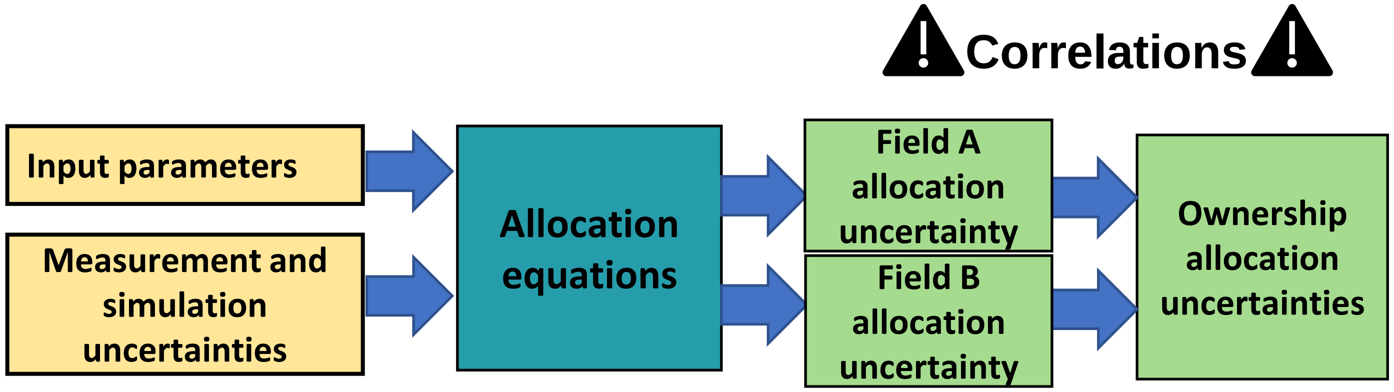
Can be carried out according to ISO GUM

$$u_c^2(y) = \sum_{i=1}^{N} \left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) + 2 \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{\partial f}{\partial x_i} \frac{\partial f}{\partial x_j} r(x_i, x_j) u(x_i) u(x_j)$$

ISO/IEC Guide 98-3:2008, "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)," ISO/IEC, Geneva, 2008. Available from BIPM

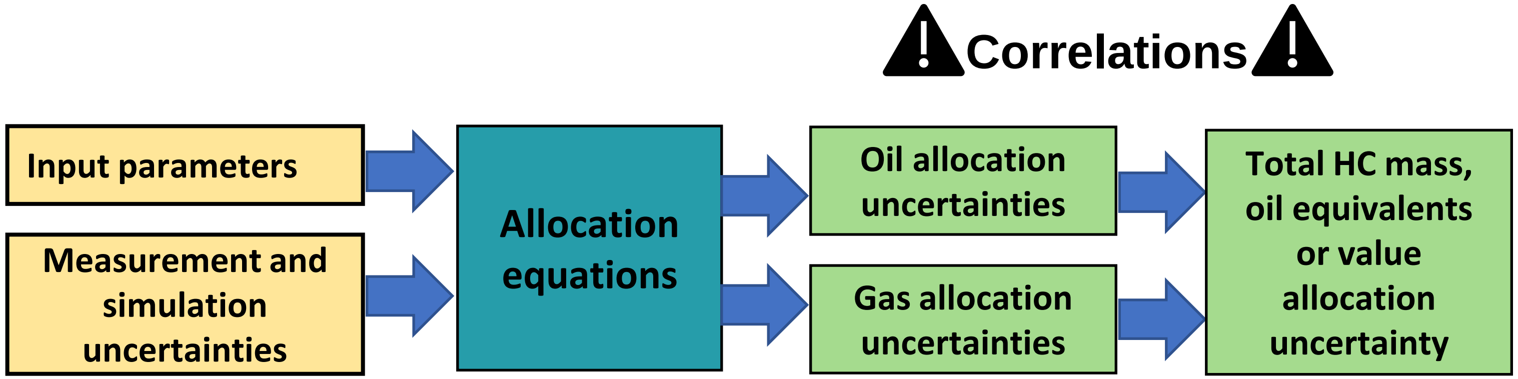


Ownership allocation uncertainties - based on ownership matrix



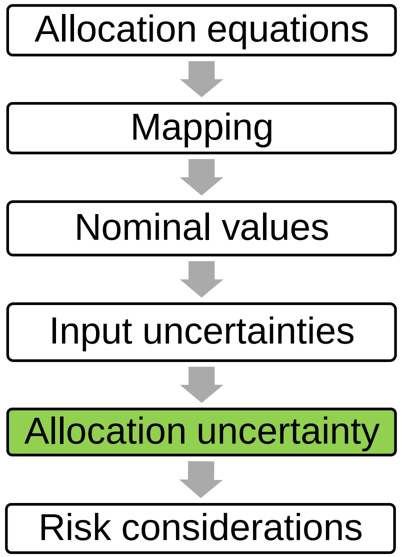
Skålvik A.M., Bjørk R. N. (2016). Uncertainty related to ownership allocation – NFOGM Hydrocarbon Management Workshop, Stavanger

Combined allocation uncertainties - total HC, oil equivalents or value

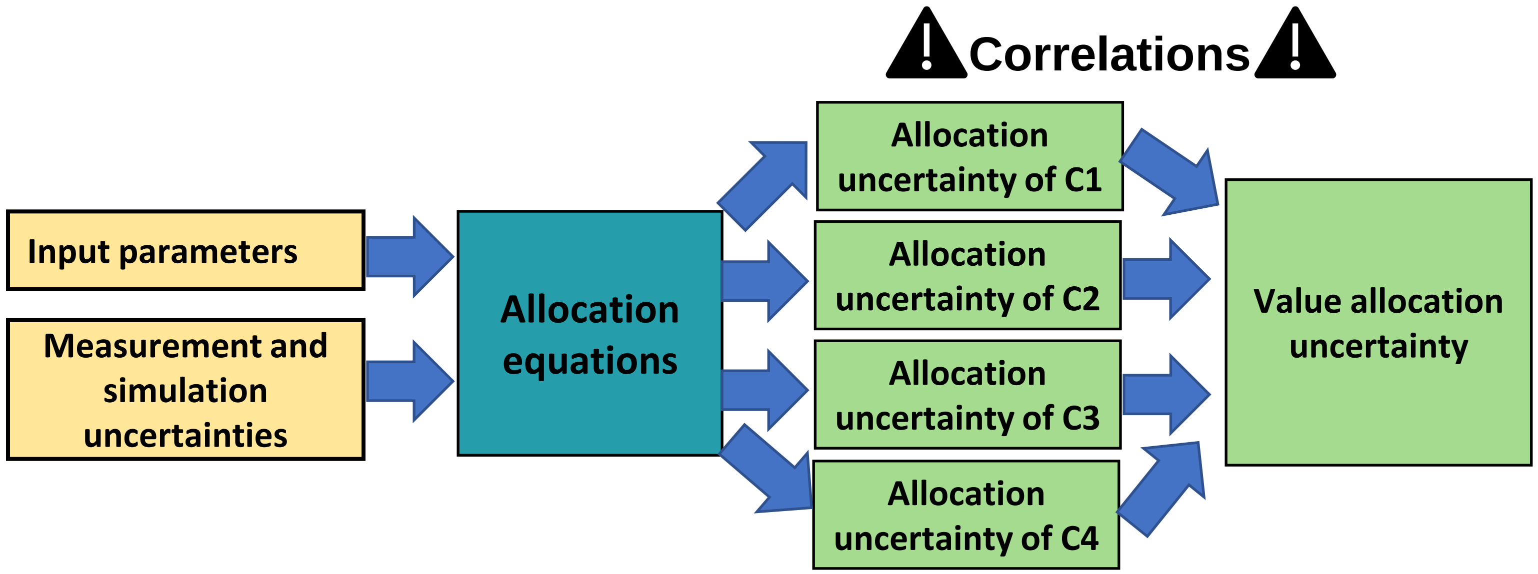


If one allocates oil and gas **separately**, then **combine** these allocated quantities to find **total hydrocarbon** mass or multiplied by price to find allocated values:

→ one must **take into account the correlation between allocated oil and gas**



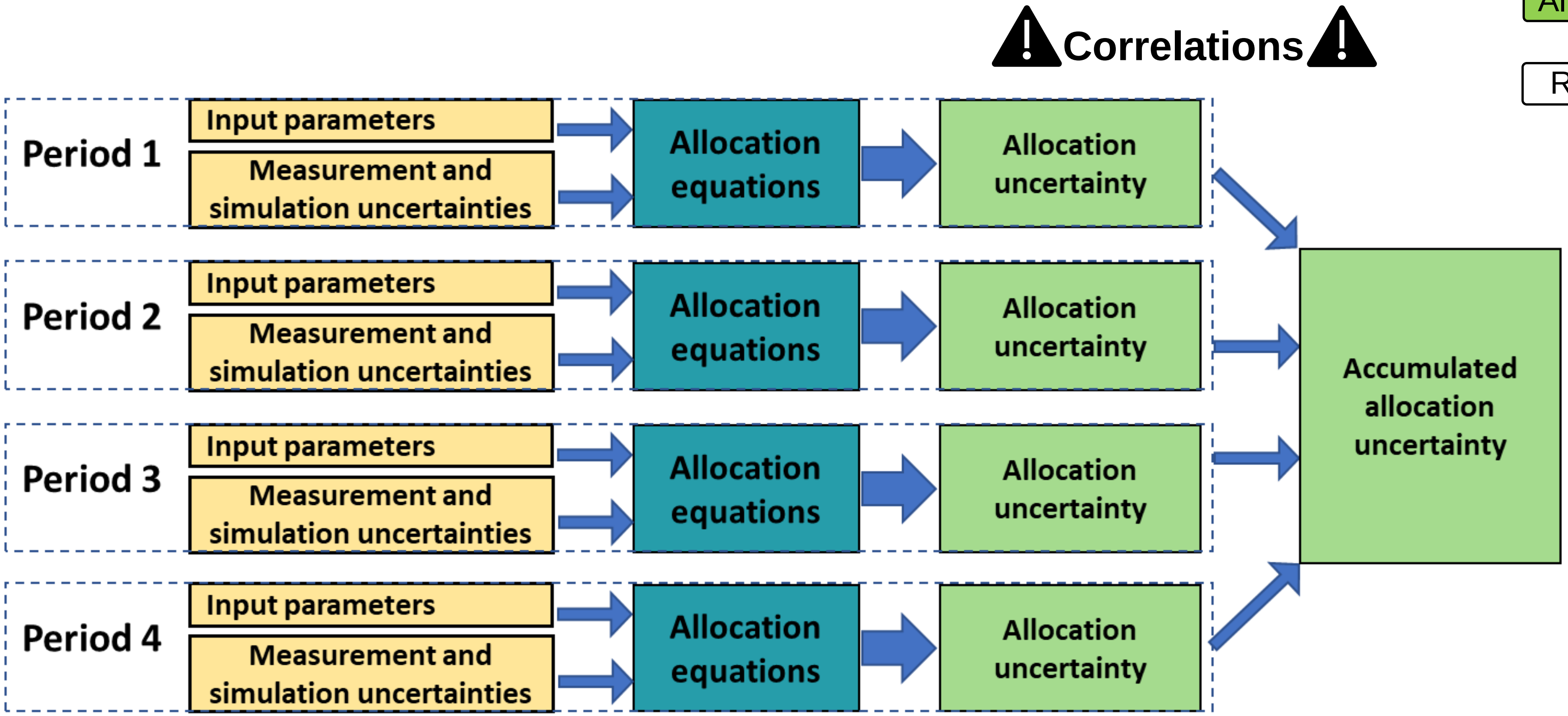
Combined allocation uncertainties - value allocation based on components

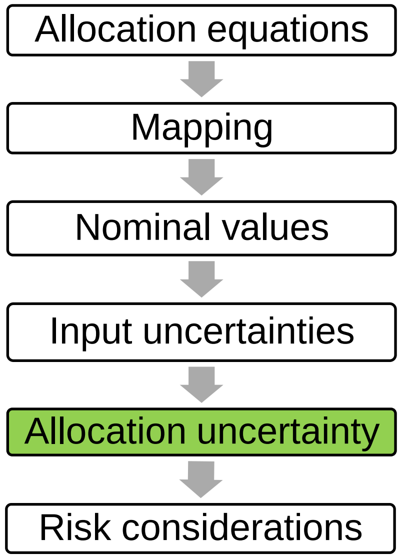


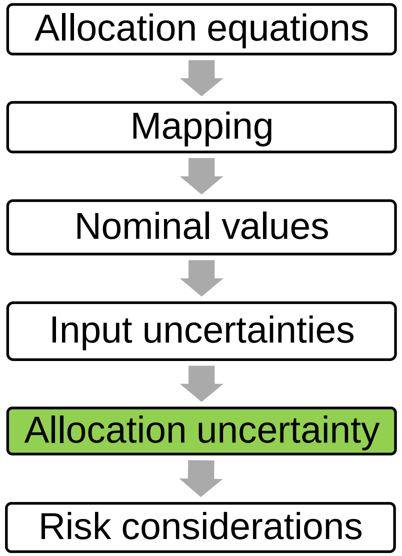
Simlarly, if one allocates component by component **separately**, then **combine** these allocated quantities to find total hydrocarbon mass or multiplied by price to find **allocated values**:

→ one must **take into account the correlation between component allocated quantities**

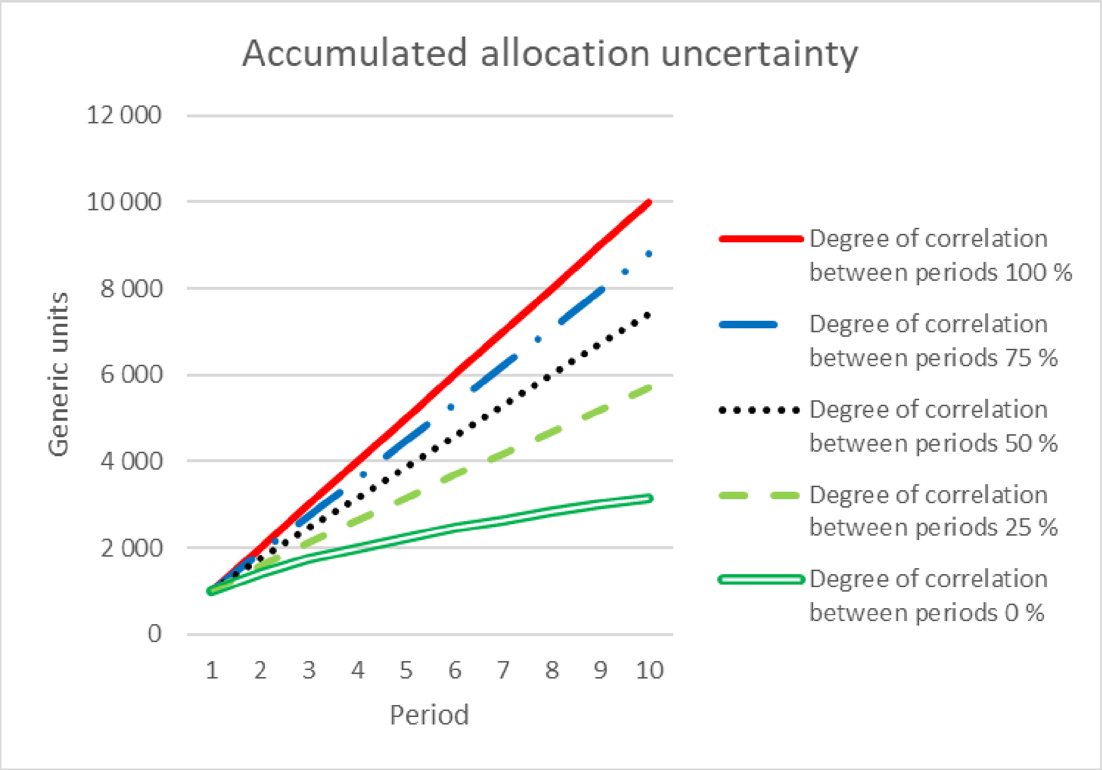
Accumulated allocation uncertainty - over time







Accumulated allocation uncertainty - over time



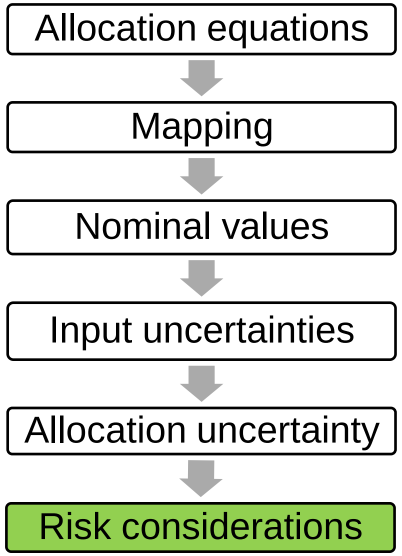
$$(u(M_{accumulated}))^2 = (1-r)\cdot\left(u\left(M_{accumulated}^{if\ all\ \mathbf{uncorr}}\right)\right)^2 + r\cdot u\left(M_{accumulated}^{if\ all\ \mathbf{corr}}\right)^2$$

$$\left(u\left(M_{accumulated}^{if\ all\ \mathbf{uncorr}}\right)\right)^2 = \sum_N \left[u(M_{period})^2\right]$$

$$u\left(M_{accumulated}^{if\ all\ \mathbf{corr}}\right) = \sum_N u(M_{period})$$

Derived from the general expression for combining correlated uncertainties found in ISO GUM

ISO/IEC Guide 98-3:2008, "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)," ISO/IEC, Geneva, 2008.



Risk associated with allocation uncertainty

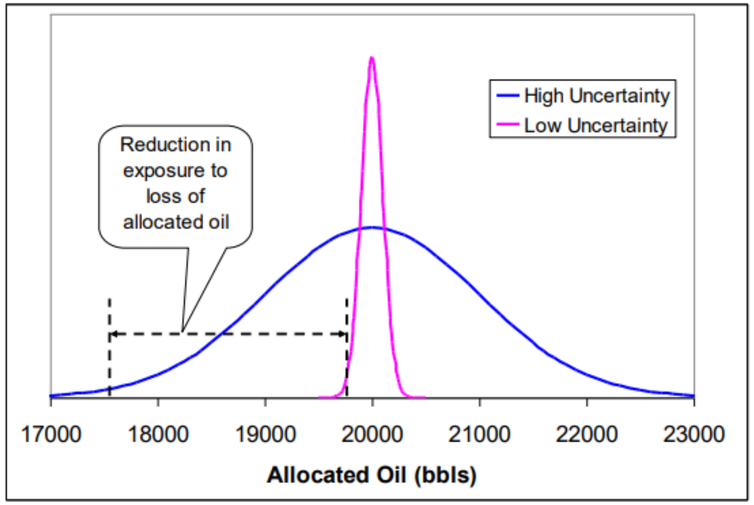
Background: Stockton's excellent paper *Cost Benefit Analyses in the Design of Allocation Systems* at NSFMW 2009

- Integrated Risked Exposure Approach
- Allocation Uncertainty Approach
- *«There is no right or wrong method because the approach adopted depends on attitude to risk aversion»*

Table 3 – Cost Benefit Analysis Comparison of Field B Allocation Quality Meter

Cost Benefit Analysis		
Meter Cost Saving	$	$5,000,000
Increase in Loss Exposure at 95% Conf Level	$	$80,642,744
Increase in Loss Exposure integrated	$	$16,085,900

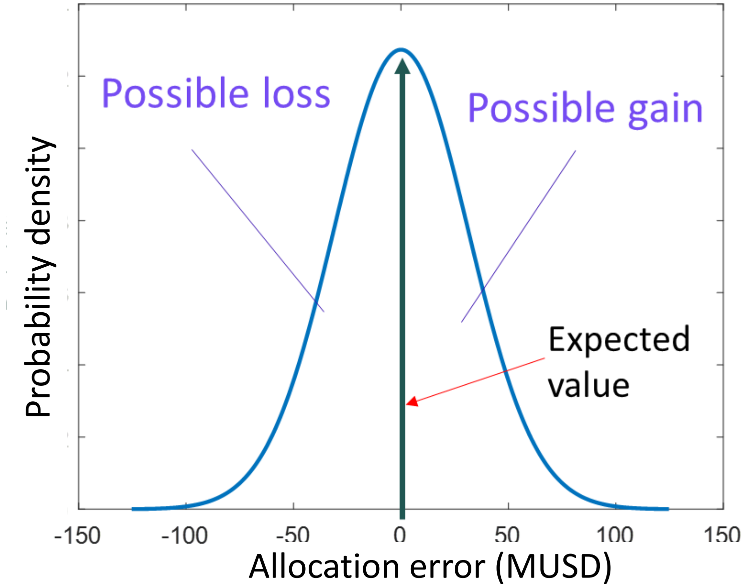
Figure 7 – Reduction in Loss Exposure Based on Allocation Uncertainty



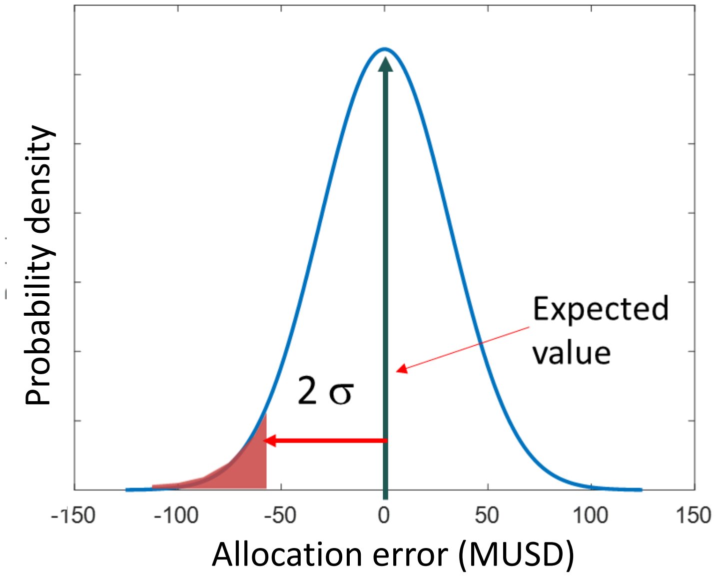
Stockton, P. (2009). *Cost Benefit Analyses in the Design of Allocation Systems*, North Sea Flow Measurement Workshop, Tønsberg, Norway

Allocation equations
→ Mapping
→ Nominal values
→ Input uncertainties
→ Allocation uncertainty
→ **Risk considerations**

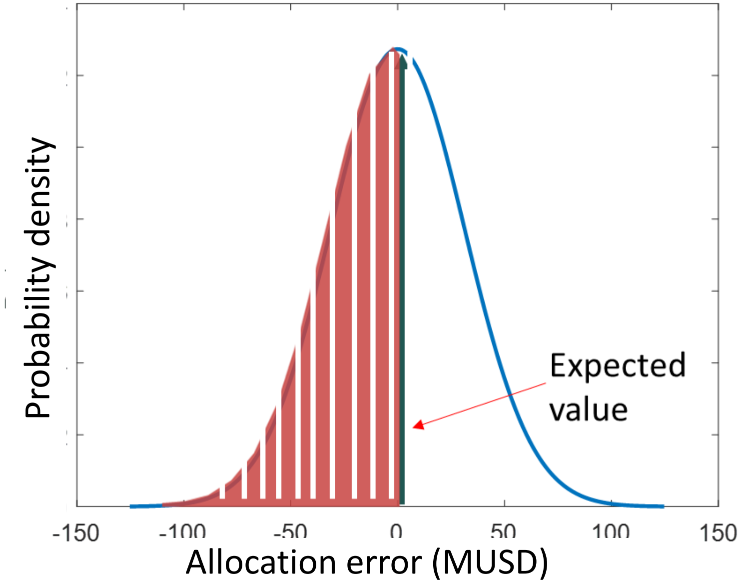
Risk associated with allocation uncertainty



50 % probability for loss
50% probability for gain



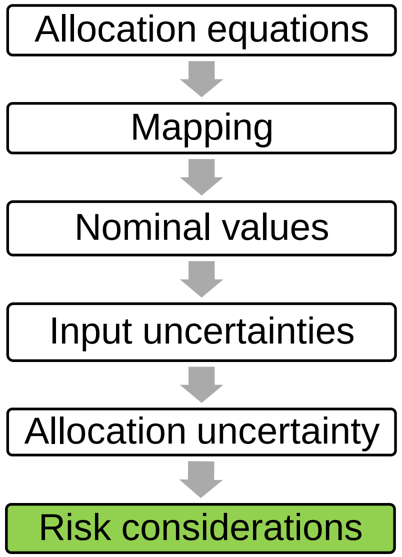
2.5 % probability that the loss is larger than 60 MUSD (2σ)

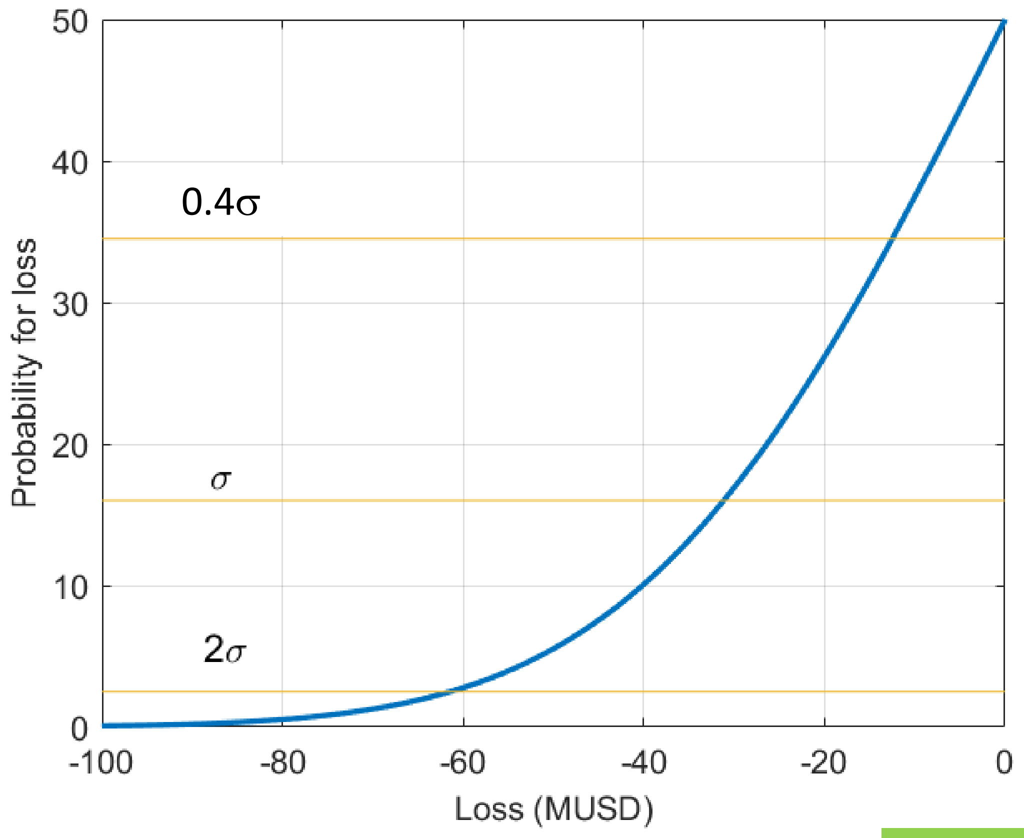


Risk = Loss · Probability

Integrated risk = Σ (risk for loss) $\approx 0.2 \cdot U \cdot value \approx 12$ MUSD

Risk associated with allocation unertainty





50 % probability for loss

16 % probability that the loss is larger than 30 MUSD (σ)

2.5 % probability that the loss is larger than 60 MUSD (2σ)

36 % probability that the loss is larger than 12 MUSD (0.4σ), same as for integrated risked exposure

→ Risk exposure should be stated with description of reference method or corresponding coverage factor/confidence level

Way forward

- **Composition uncertainties** from sampling, analysis and simulation are more and more important as it becomes more common to allocate on component level

  → we need a method for estimating these uncertainties

- **Correlation** between allocated quantities for different **periods** important when considering **accumulated** allocation uncertainites

  → we need a method for estimating this correlation

Correlations

- The final result from all allocation calculations is the **allocated value**

  → oil, gass or component allocation uncertainties propagate **through value calculations.** For simpler value estimations this propagation can be straight-forward, but for more complex value estimations more studies are required.

Thank you.

Questions?
Comments?

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