CGE Webinar Series
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Monte Carlo approach to uncertainty analyses in forestry and GHG accounting

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On behalf of:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
of the Federal Republic of Germany

Goals of the presentation

1. Understand what is the Monte Carlo approach
2. Learn the steps to carry out Monte Carlo approach for emissions estimates and uncertainty analyses
3. Understand the implications of applying Monte Carlo approach

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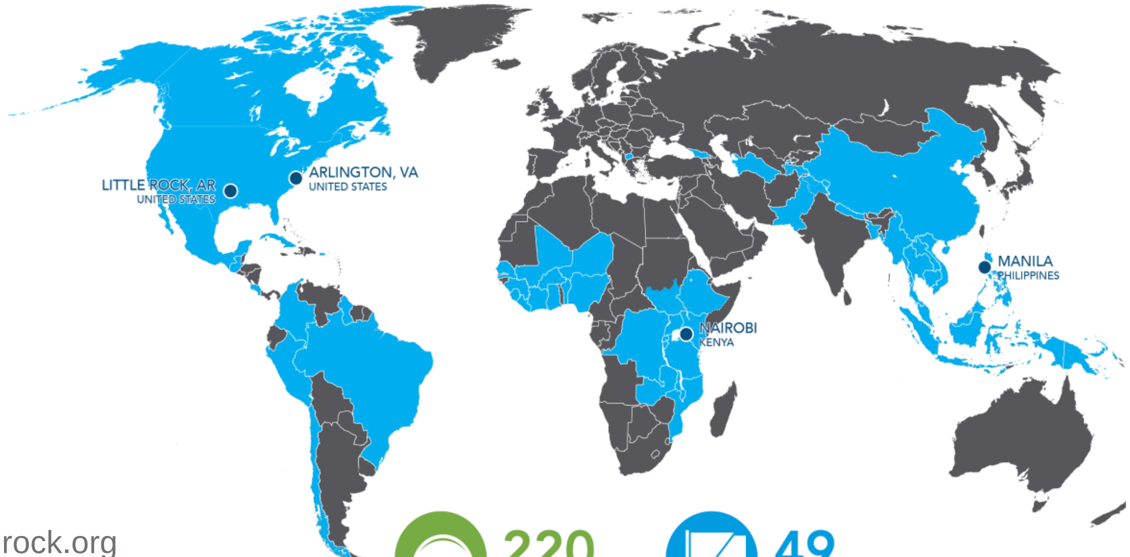

220 PROJECTS

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About the guidance document

- Builds upon the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
- Assumes understanding of descriptive statistics and experience in the application of basic statistics
- Examples provided are focused on the forestry sector but is applicable to other sectors
- Examples of excel-based software

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Uncertainty analyses

Three steps in any uncertainty analysis

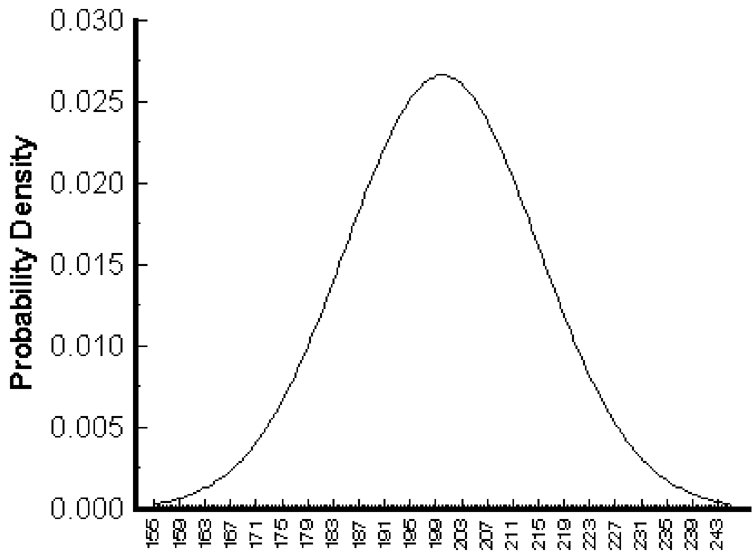
1. Identify the sources of uncertainty in the emission estimate
2. Quantify the different sources of uncertainty, whenever possible
3. Combine the different uncertainties to come up with a final uncertainty value
   - IPCC Approach 1: Propagation of Error
   - **IPCC Approach 2: Monte Carlo Simulations**

Conditions for applying propagation of error vs Monte Carlo (as presented in 2006 IPCC guidelines)

- Propagation of Error
  - Small uncertainty
  - Normal (Gaussian) distribution
  - Simple equations
  - No correlations between data
  - Same uncertainty for different years of the inventory
- Monte Carlo
  - Small or large uncertainty
  - Any distribution
  - Simple or complex equations
  - Data can be correlated or not
  - Uncertainties can vary between years

Key concept to understanding the Monte Carlo approach

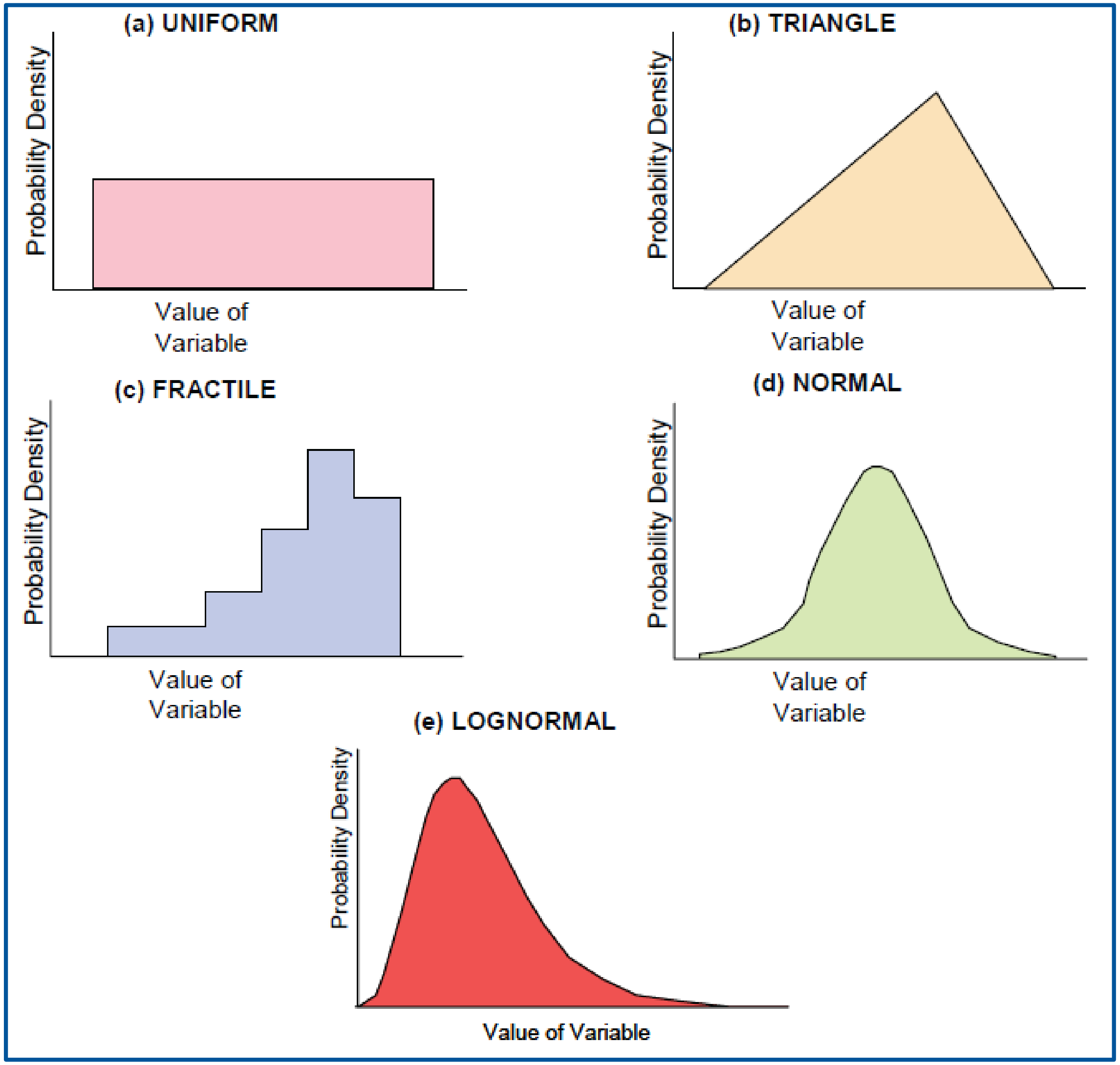
- **Probability density functions (PDFs)** (which describe the likelihood of possible values)



http://www.engineeredsoftware.com/lmar/density.htm

To do Monte Carlo simulations, the analyst needs to identify the PDFs of the input data (emission factors and activity data)

From 2006 IPCC Guidelines



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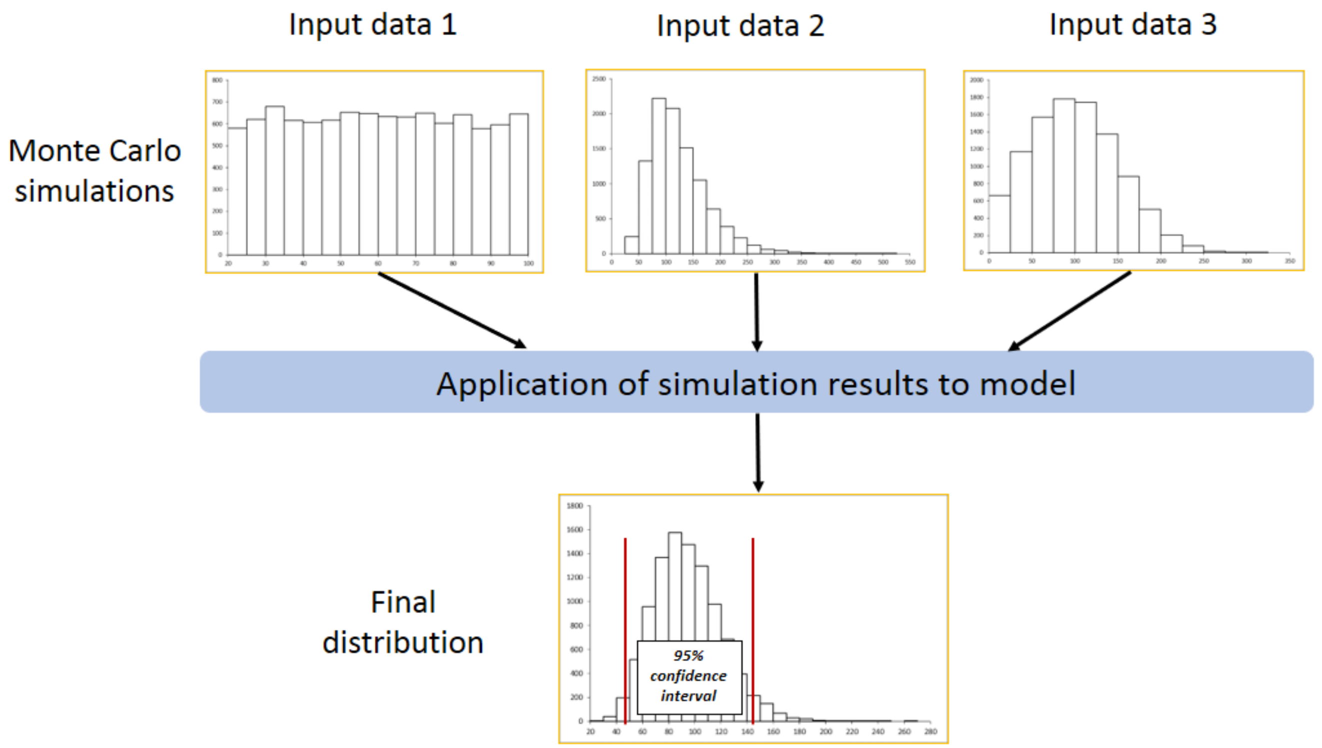
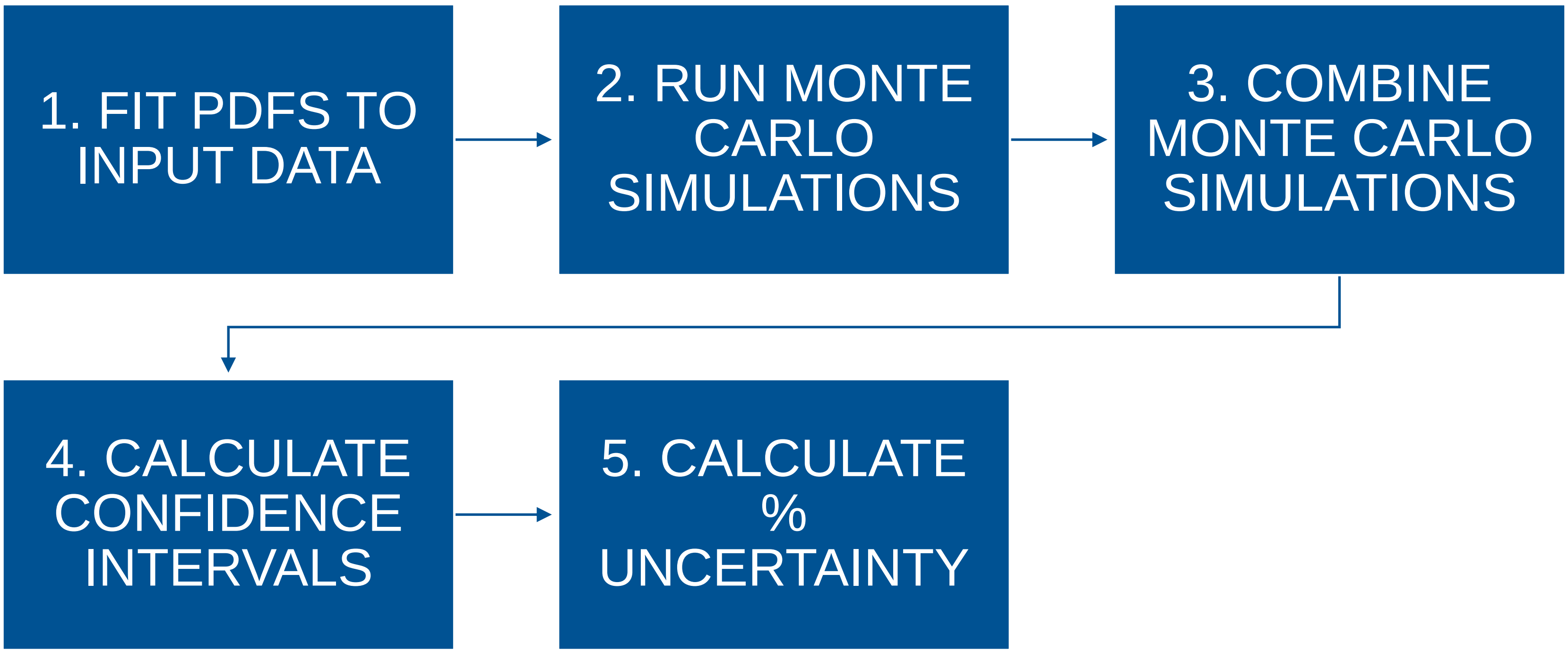
Monte Carlo approach: what is it?

Repeated simulations of random values within the PDFs of the input data. Simulations then applied to the model to calculate the final estimate and its uncertainty.



Steps to carry out the Monte Carlo approach for uncertainty analyses



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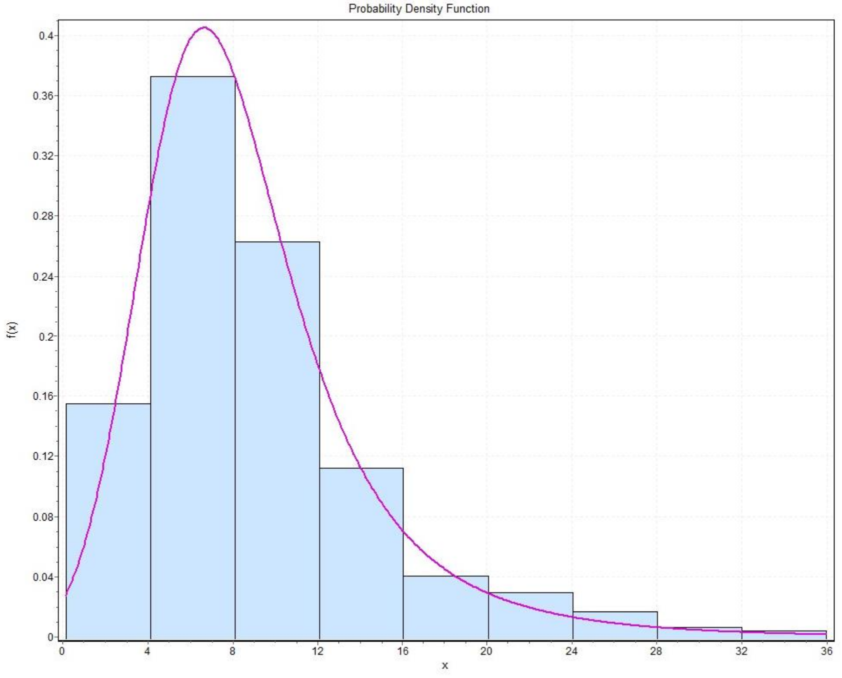
Step 1. Fit Distributions of Input Data to Probability Density Functions

- Identify the PDFs that have a good fit with of the different data distributions.
  - When original dataset is available, perform goodness-of-fit tests
    - Software: Easyfit and XLSTAT



  - When original dataset is unavailable, rely on understanding of underlying data and available metrics

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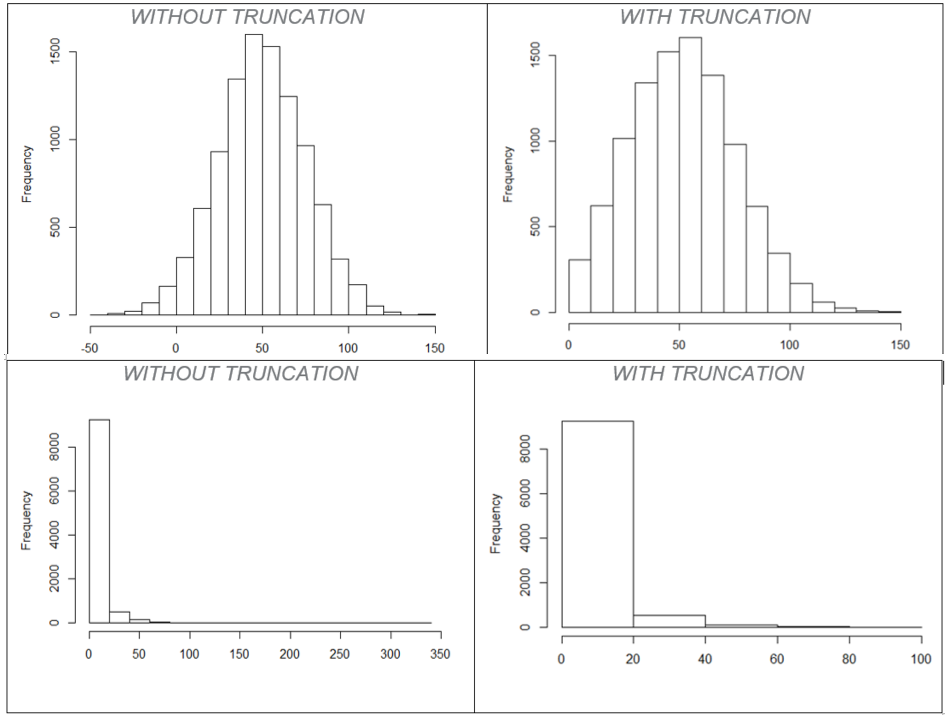
Step 2. Running Monte Carlo simulations

- Selected software apply algorithms to generate random values based on the PDF of the data
- Considerations
  - Selection of software. Examples: XLSTAT and Simvoi
  - Numbers of simulations
  - Truncation of fitted distribution



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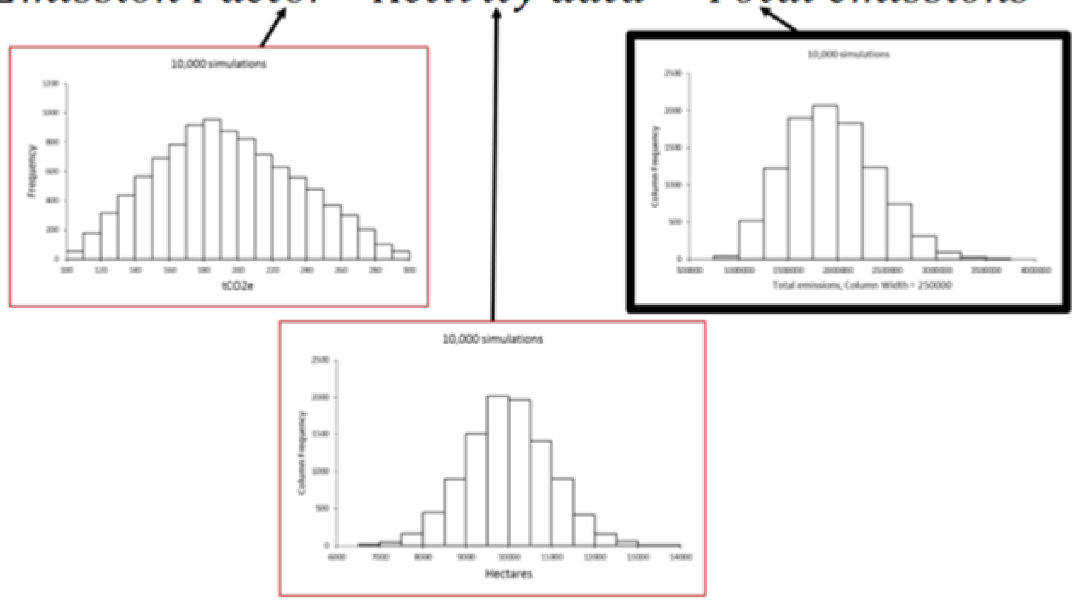
Step 3. Combining simulations

$$Emission\ Factor * Activity\ data = Total\ emissions$$



Monte Carlo simulation #	Emission factor (tCO_2e)	Activity data (Hectares)	Total emissions (Emission factor * Activity data)
1	163.13	9,951.46	1,623,412.40
2	242.66	10,836.08	2,629,464.37
…	…	…	…
10,000	240.95	8,280.32	1,995,104.00

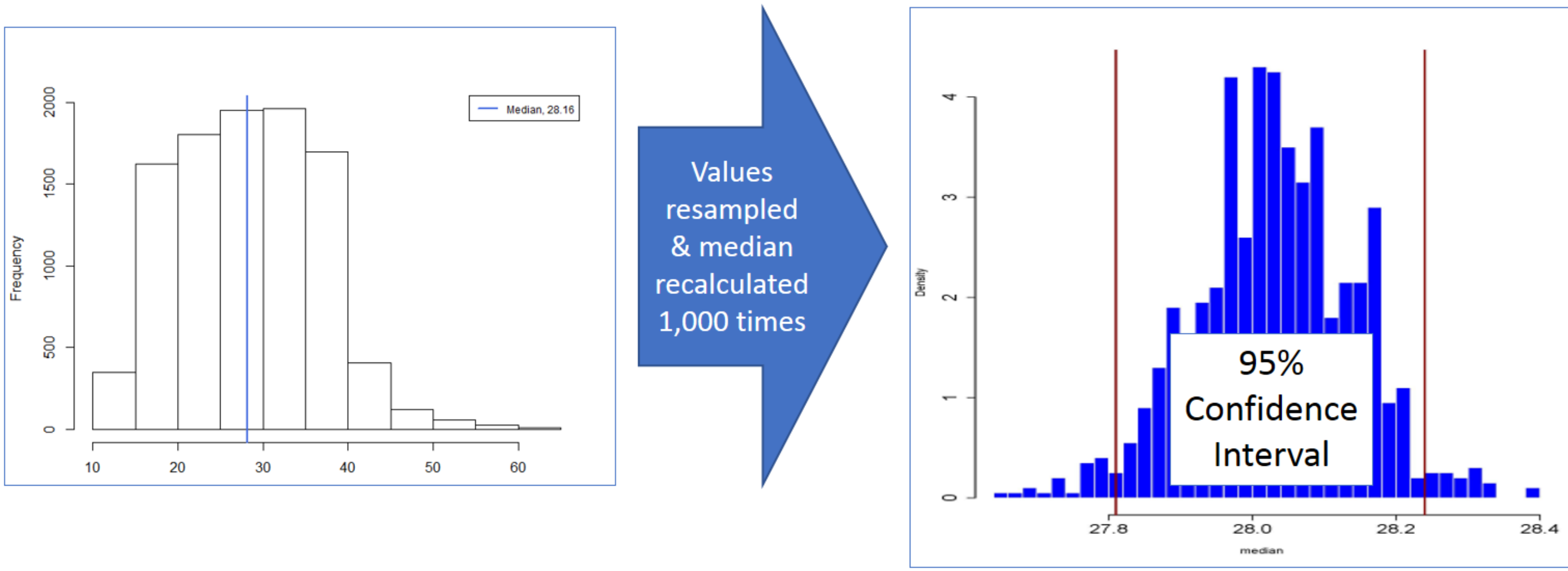
Steps 4 and 5. Calculating confidence intervals and percent uncertainty

- Confidence intervals
  1. For normal distributions
     - Same method as in propagation of error approach
     - Sample size = number of simulations
  2. For non-normal distributions
     - Different methods. One common method known as "*bootstrapping*"
- Percent uncertainty
  - Same as in propagation of error approach

Bootstrapping to calculate confidence intervals

Distribution calculated with Monte Carlo approach

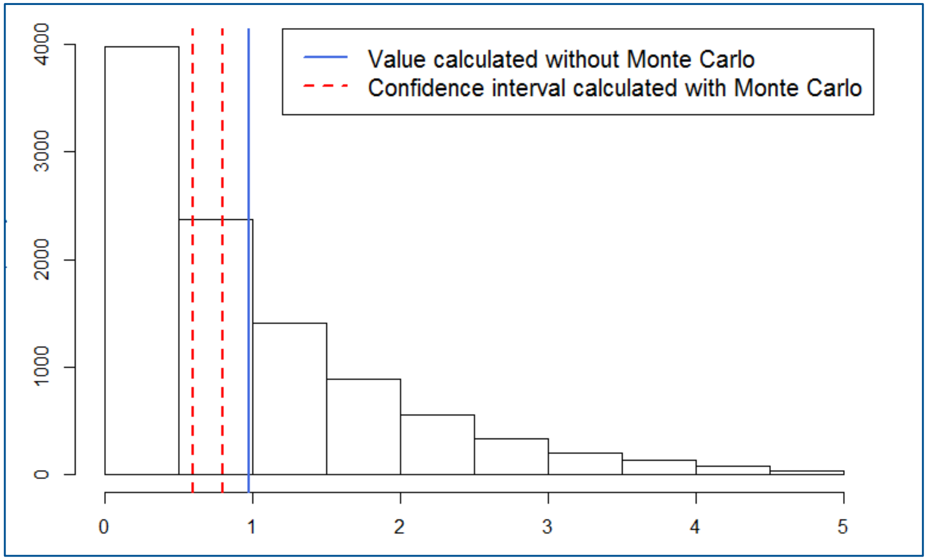
Bootstrapped distribution of medians



- Calculate CI of bootstrapped distribution: difference between 2.5th percentile and 97.5th percentile (for 95% CI)
- Can be performed in Excel add-on XLSTAT

Application of Monte Carlo to emissions estimates AND uncertainty analyses

1. More accurate estimates of final emissions
2. When Monte Carlo is *only* applied to the uncertainty analysis, potential incongruencies between the confidence interval and the final estimate



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Discussion on Monte Carlo application to uncertainty analyses

- Estimation of uncertainty under more flexible conditions
- Produce low uncertainty values:
  - High number of simulations produce robust, stable results *but* inevitably lead to small confidence intervals
  - Implications: may underestimate uncertainty *especially* if not also applied to estimate emissions.

Final thoughts on the Monte Carlo approach

- Because in many GHG accounting contexts there is large uncertainty, non-normal distributions, etc., the use of the Monte Carlo analyses must become more common.

- Challenges to wide scale adoption
  - Lack of reasonably priced, thorough, and accessible software available to run the approach from start to finish
  - Lack of clarity in international guidance on how to apply the Monte Carlo

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THANK YOU

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