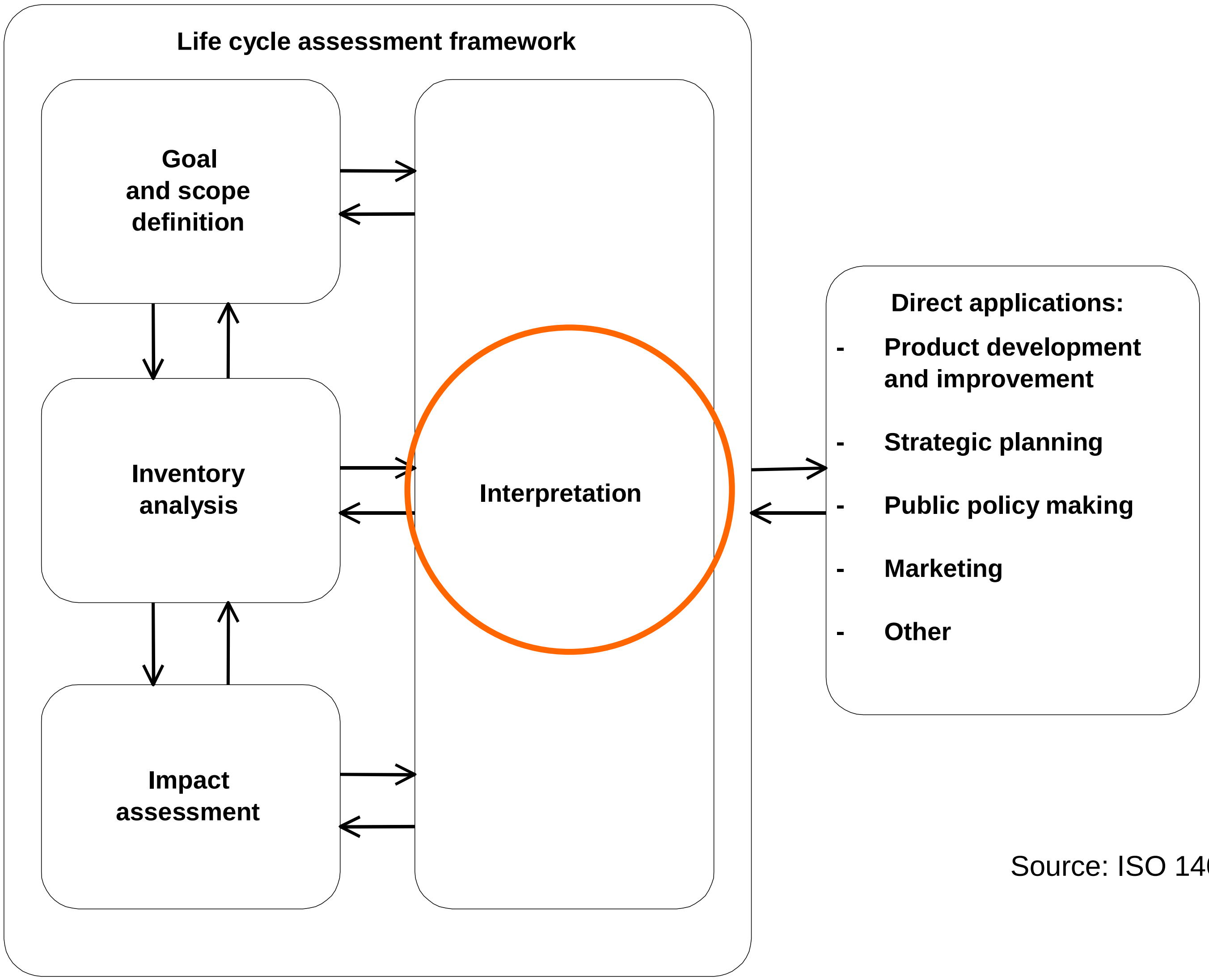
Life Cycle Assessment

A product-oriented method for sustainability analysis

UNEP LCA Training Kit
*Module f – **Interpretation***

ISO 14040 framework



Source: ISO 14040

Life cycle interpretation

- **ISO: Interpretation** is the LCA phase in which the findings of either the inventory analysis or the impact assessment, or both, are combined consistent with the defined goal and scope in order to reach conclusions and recommendations.
  - International Standard ISO 14044 (revises ISO 14043)
  - Interpretation is not the same as a Technical Report.
- **Life cycle interpretation is the fourth and last LCA phase** Life cycle interpretation has no abbreviation like LCI or LCIA.

Contents

Modules b,c,d and e provide necessary background information for this module.

- Interpretation in ISO 14044
- Approaches
  - procedural approaches
  - numerical approaches
- Examples of numerical approaches
  - contribution analysis
  - perturbation analysis
  - uncertainty analysis
  - comparative analysis
  - discernability analysis
  - key issue analysis

Interpretation in ISO 14044

- **Identification of significant issues**
- **Evaluation**
  - completeness check
  - sensitivity check
  - consistency check
- **Conclusions, recommendations and reporting**
  - critical review

Interpretation in ISO 14044
Identification of significant issues

- **Objective: to structure the results from LCI or LCIA:**
  - inventory data categories: energy, emissions, waste, …
  - impact categories: resource use, global warming, …
  - essential contributions from life cycle stages: individual unit processes or groups of processes, …

Interpretation in ISO 14044 Checking quality

- **Objective: to establish en enhance the confidence in and the reliability of the results:**
  - **completeness check**
    - to ensure that all relevant information and data are available and complete
  - **sensitivity check**
    - to assess the reliability of the final results and conclusions
  - **consistency check**
    - to determine whether the assumptions, methods and data are consistent with the goal and scope

Interpretation in ISO 14044 Recommendations

- **Objective: to draw conclusions and make recommendations for the intended audience**
- **Import elements:**
  - **transparent reporting**
    - all ISO aspects (phases, steps, data, assumption, choices) can be easily found
    - how to report results
  - **critical review**
    - role and exact form dependent on goal of the study

Categorization of sources of uncertainty

- **Several classifications of uncertainty:**
  - uncertainty and variability
  - reliability and validity
  - model and parameter uncertainty
  - aleatory and epistemic uncertainty

Categorization of approaches to uncertainty

- **Basic concepts**
  - sensitivity: finding intrinsically sensitive parameters or choices
  - uncertainty: estimating consequences of uncertain input data
- **Several techniques/tools are available for each.**

Categorization of approaches to uncertainty

- **Four main paradigms for uncertainty:**
  - 1. the scientific approach (more research, better data)
  - 2. the constructivist approach (stakeholders, agreements)
  - 3. the legal approach (authoritative bodies)
  - 4. the statistical approach (Monte Carlo, confidence intervals)

- **What makes 4 special?**
  - 1, 2, 3 reduce uncertainty
  - 4 incorporates uncertainty

Categorization of approaches to uncertainty

- **Procedural approaches**
  - **discussion of data and results in relation to other sources of information**
    - expert judgment
    - reports on similar products
    - intuition
    - reputation of data suppliers

Categorization of approaches to uncertainty

- **Numerical approaches**
  - **analysis of data and results without reference to other sources of information**
    - contribution analysis
    - sensitivity analysis
    - uncertainty analysis

Contribution analysis

- **Decompose results into contributing elements** (% of total)
- **Can be performed at several levels:**
  - inventory analysis
  - characterisation
  - normalisation
  - weighting
- **Can be performed for different elements:**
  - processes
  - interventions
  - impact categories

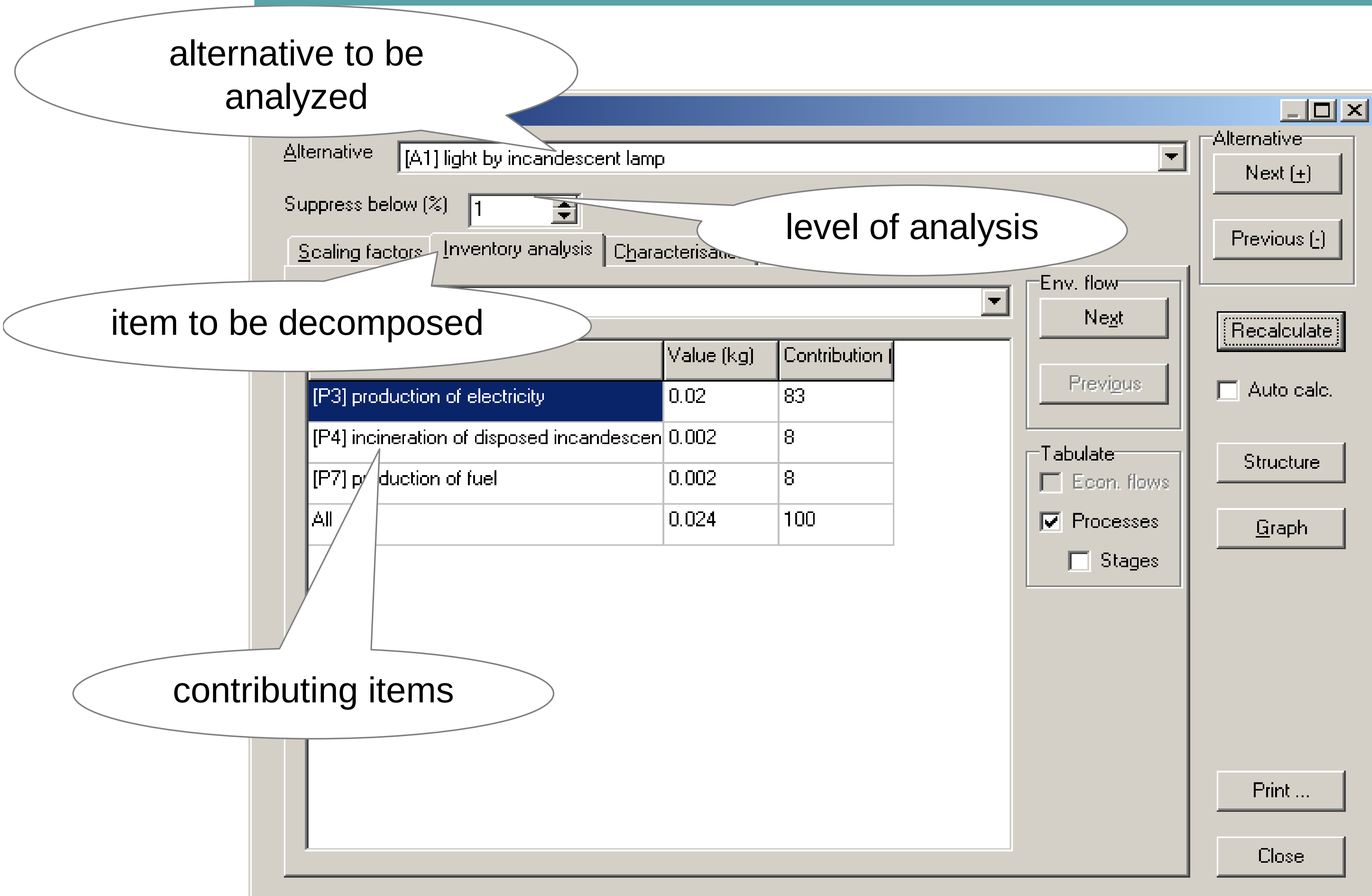
Contribution analysis

- **Purposes**
  - **application-oriented:**
    - results of contribution analysis may provide opportunities for redesign, prevention strategies, etc.
  - **analysis-oriented:**
    - precise knowledge of data is more important for highest contributors, than for those that hardly contribute
    - testing results against what one would intuitively expect

Contribution analysis

- **Restrictions:**
  - ‘false negatives’ due to underestimated or missing flows cannot be identified with contribution analysis
  - results only indicate direct contributions of item analyzed
  - problems with “negative contributions”

Contribution analysis



Perturbation analysis

- **Also known as marginal analysis or sensitivity analysis**
- **Investigate inherently unstable elements**
  - change data/factor with 1%, and determine how much a result is changed
- **Multiplier: extent to which perturbation of certain input parameter propagates into certain output result**
  - if an increase of 1% of an input parameter leads to an increase of 2% of an output result, multiplier 2
  - if output result decreases by 2%, multiplier is -2
  - multipliers restricted to marginally small changes

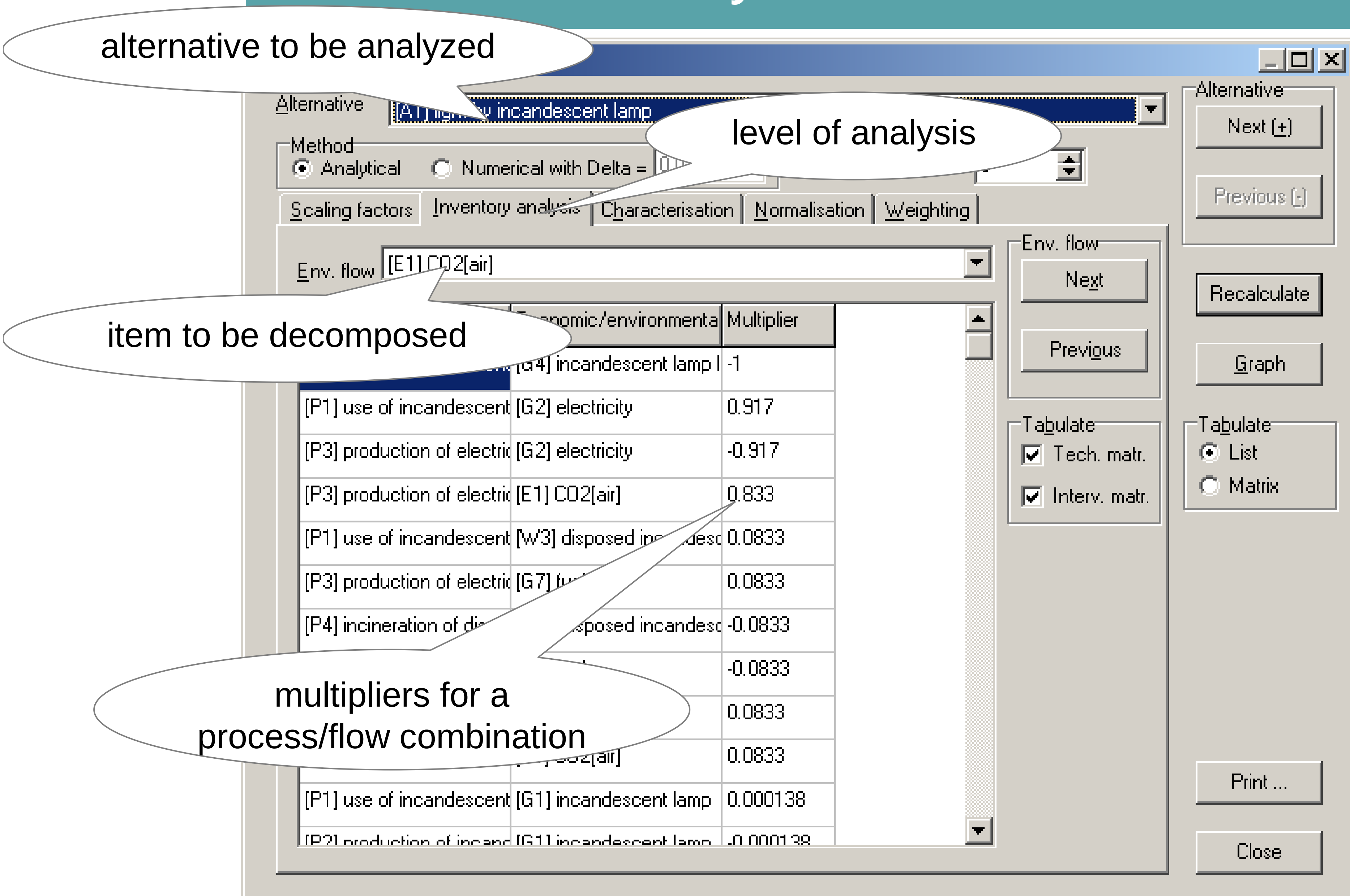
Perturbation analysis

- **Can be performed at several levels:**
  - inventory analysis
  - characterisation
  - normalisation
  - Weighting
- **Can be performed for different elements:**
  - process data/ allocation factors
  - characterisation/ normalisation/ weighting factors
- **No specification of parameter uncertainties needed**
- **Contrary to contribution analysis, perturbation analysis covers both economic and environmental flows**

Perturbation analysis

- **Purposes:**
  - application oriented: results of perturbation analysis may provide opportunities for redesign, prevention strategies, etc.
  - analysis oriented: precise knowledge of data is more important for highest contributors, than for those that hardly contribute
- **Restrictions:**
  - time-consuming for numerical solutions; analytical solutions very fast

Perturbation analysis

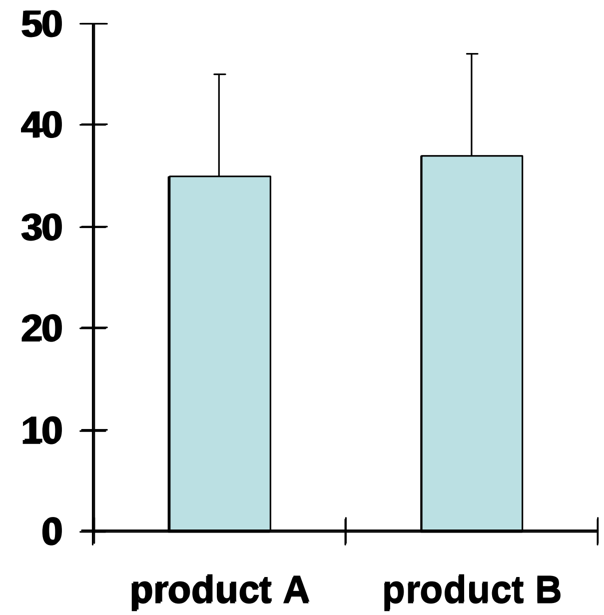


Uncertainty analysis

- **Systematic study of propagation of input uncertainties into output uncertainties**
- **Several techniques:**
  - **numerical treatment**
    - parameter variation
    - Monte Carlo analysis
    - other (fuzzy sets, Bayesian statistics, ...)
  - **analytical treatment**

Uncertainty analysis

- **Purposes**
  - **To provide an understanding of the uncertainty of the LCA results**
    - specific output result, like ‘120 kg CO2’ would then become something like ‘120 kg CO2 with standard deviation of 10 kg’
    - comparison of product alternatives on basis of merely results without uncertainties can lead to erroneous conclusions.

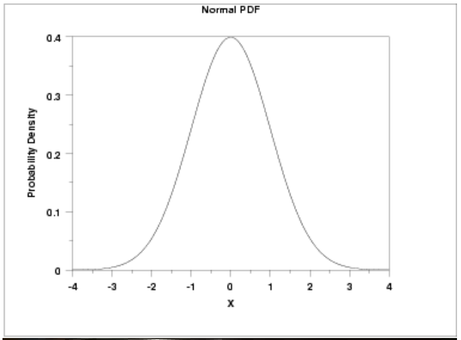


Uncertainty analysis

- **Parameter variation**
  - define different sets of parameters (scenarios)

Uncertainty analysis

- **Monte Carlo simulations:**
  - consider every input parameter as a stochastic variable with a specified probability distribution
  - construct the LCA-model with one particular realization of every stochastic parameter
  - calculate the LCA-results with this particular realization
  - repeat this for a large number of realizations
  - investigate statistical properties of the sample of LCA-results



N = 10,000

Uncertainty analysis

- **Analytical treatment:**
  - formulas for error propagation
  - e.g., if $z = f(x,y)$ then $(\sigma_z)^2 = \left(\frac{\partial f}{\partial x}\right)^2 (\sigma_x)^2 + \left(\frac{\partial f}{\partial y}\right)^2 (\sigma_y)^2$
  - LCA: if $\mathbf{g} = \mathbf{B}\mathbf{A}^{-1}\mathbf{f}$ then $\frac{\partial g_k}{\partial a_{ij}} = -\left(\mathbf{B}\mathbf{A}^{-1}\right)_{ki}\left(\mathbf{A}^{-1}\mathbf{f}\right)_j$

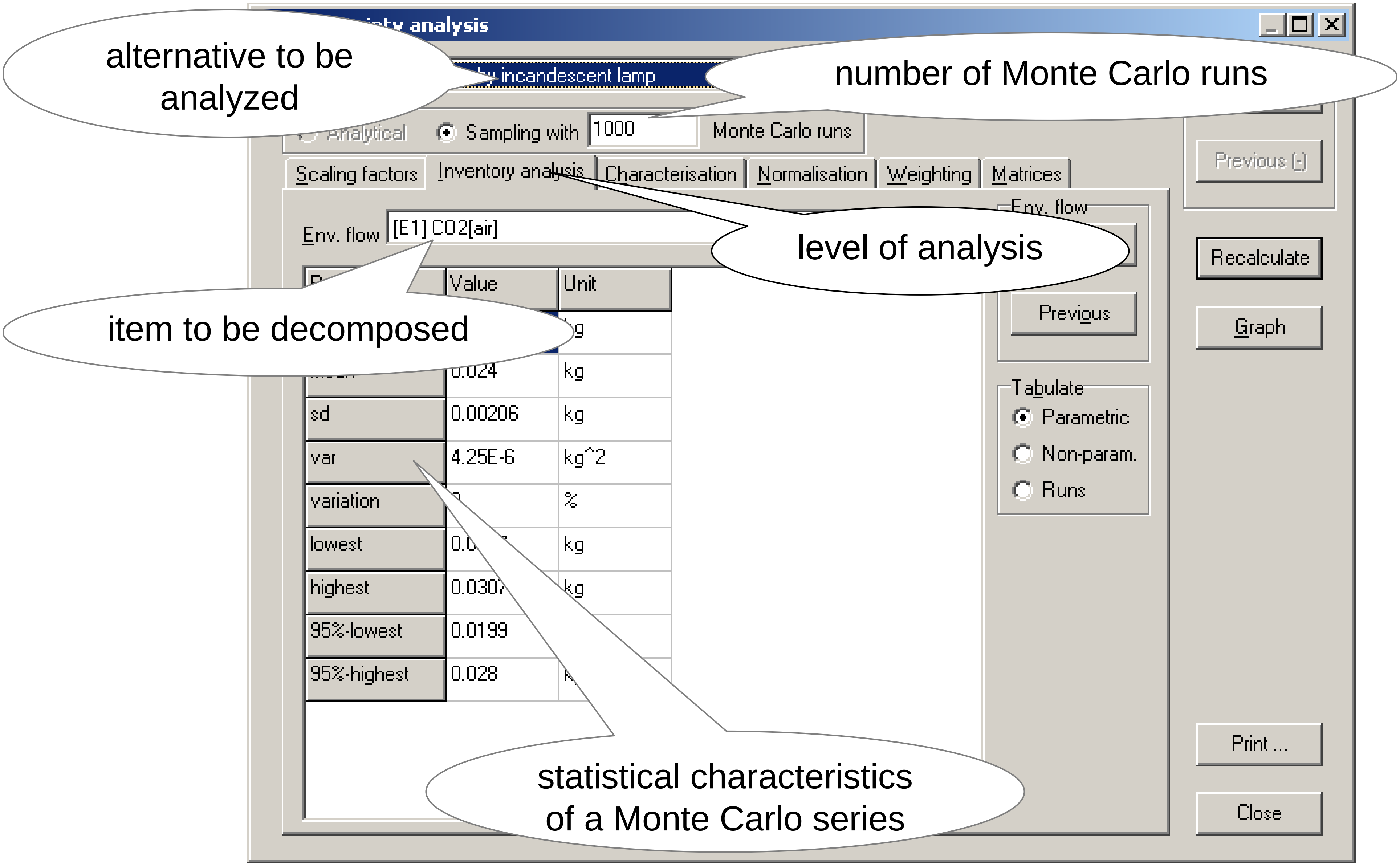
Uncertainty analysis

- **Needed:**
  - specification of uncertainty (e.g., probability distributions)
  - appropriate software with Monte Carlo techniques and/or matrix formulae
- **Will result into probabilistic statements**
  - standard deviations
  - confidence intervals
  - partly overlapping histograms
  - statements about discernability of products
- **All input data in LCA may be treated as stochastic variables; can be performed at all levels**

Uncertainty analysis

- **Restrictions**
  - **Time-consuming analysis**
  - **Uncertainty analysis presumes that uncertainty parameters are available for all input parameters**
    - quantitative and not qualitative (no DQI)
    - most LCA-databases do not contain standard deviations

Uncertainty analysis



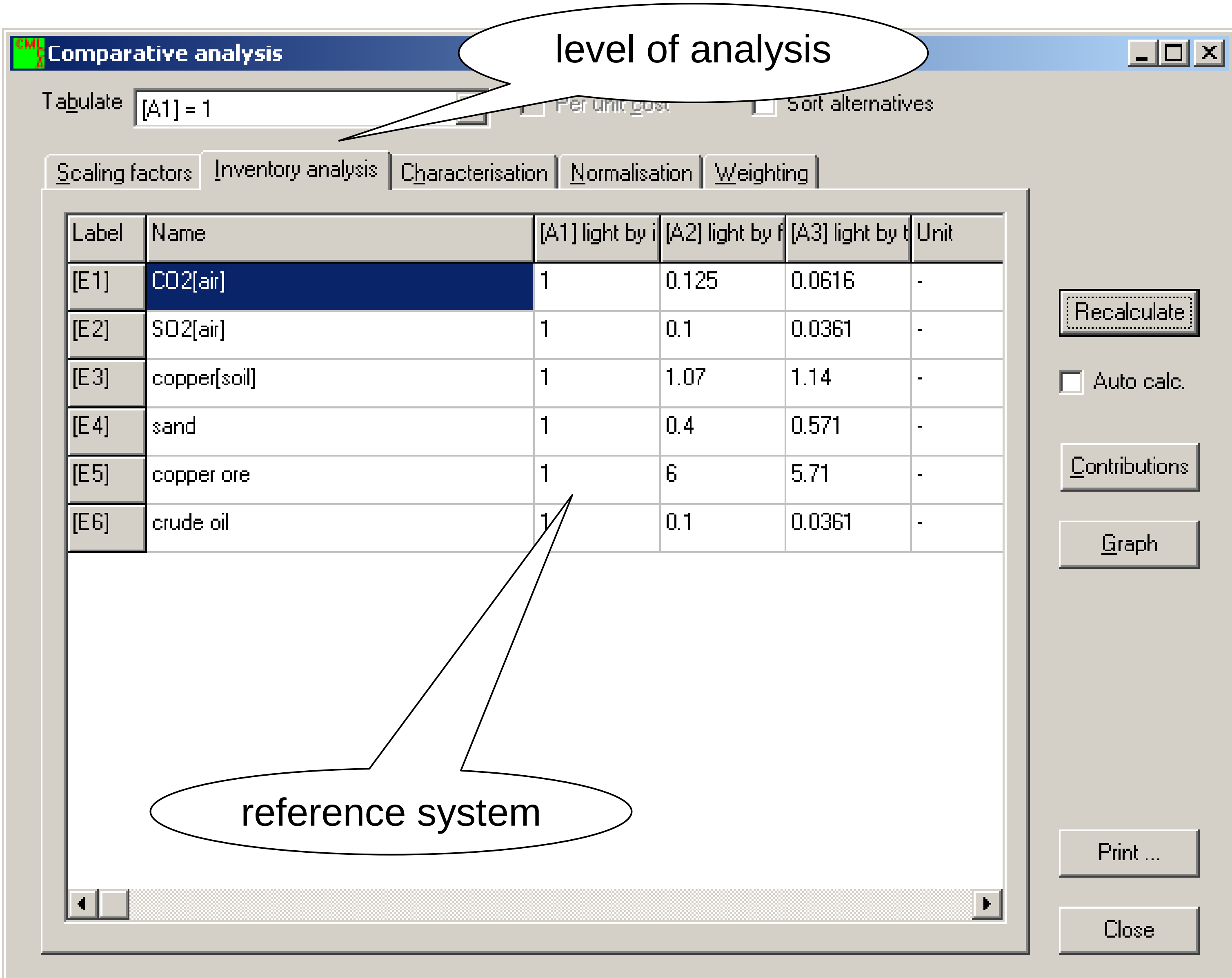
Comparative analysis

- **Systematic place to list the LCA results for different product alternatives simultaneously**
- **Can be performed at several levels**
  - inventory analysis
  - characterisation
  - normalisation
  - weighting

Comparative analysis

- **Purposes:**
  - to provide presentations of results on the basis of which different product alternatives can easily be compared
- **Restrictions:**
  - comparative analysis is seductively simple
  - dangerous, because it may easily induce claims without a proper analysis of robustness of these claims with respect to influence of uncertainties

Comparative analysis

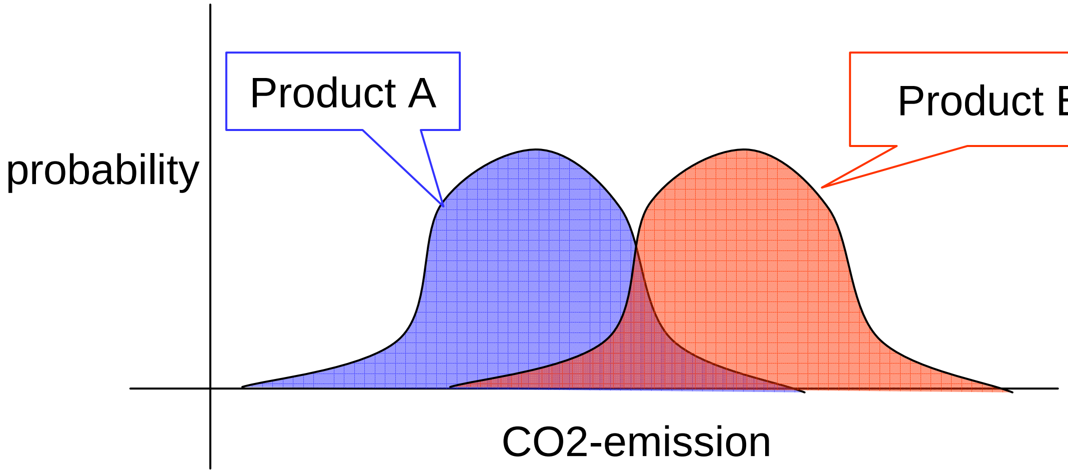


Discernability analysis

- **Special form of uncertainty analysis, i.e. combination of comparative and uncertainty analysis:**
  - one Monte Carlo realization to calculate results for all product alternatives simultaneously, ranking if A is better than B or not
- **Approach effectively comes down to counting number of times that first product alternative has higher score and number of times this is not the case**
- **Can be performed at several levels**
  - inventory analysis
  - characterisation
  - normalisation
  - weighting

Discernability analysis

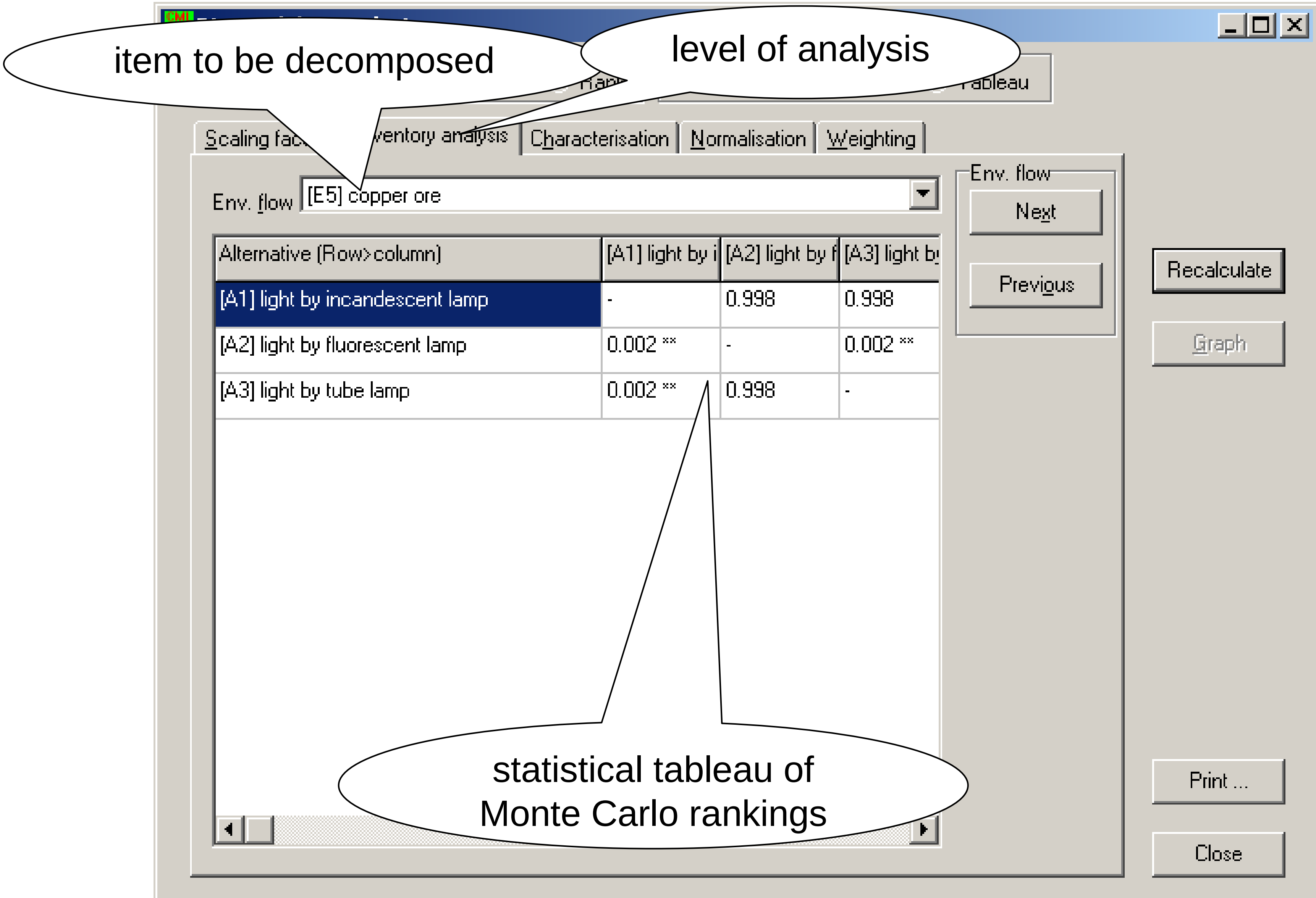
- **Purposes:**
  - **To test if product A is statistically discernible from product B**
  - **To rank product alternatives in statistically sound way, rather than in form of point estimates**, e.g.
    - 'product A is significantly better than product B'
    - 'there is 95% chance that product A is better than product B’



Discernability analysis

- **Restrictions:**
  - **discernability analysis ignores distance between scores of product alternatives; it only uses smaller-larger dichotomy**
  - **as discernability analysis is special form of uncertainty analysis; the same restrictions apply:**
    - time-consuming
    - requires specification of many uncertainty parameters

Discernability analysis



Key issue analysis

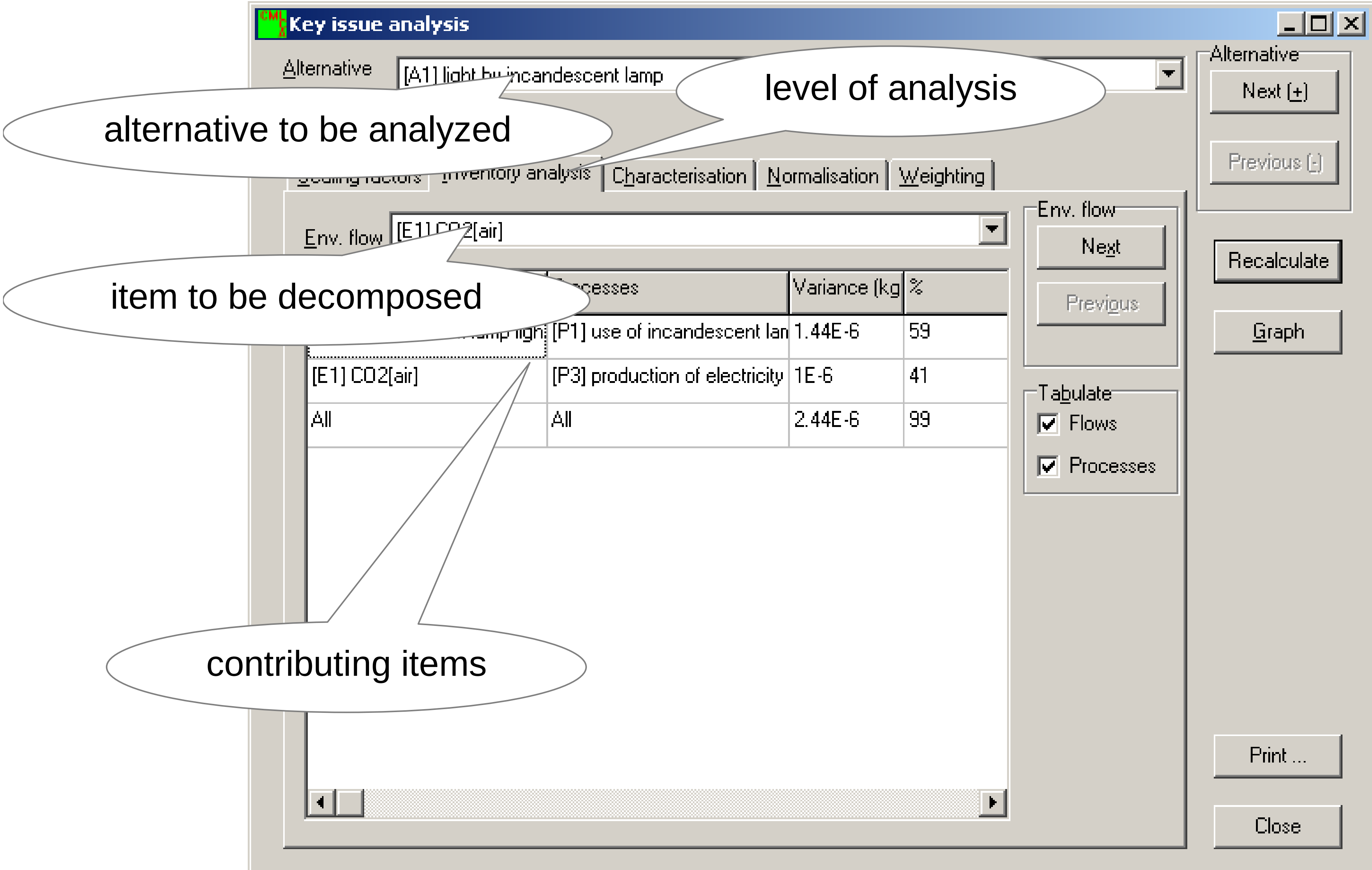
- **Combination of uncertainty analysis and contribution analysis**
  - **What is the composition of the uncertainty in the results?**
  - **based on rule of addition of variances**

$$(\sigma_z)^2 = \left(\frac{\partial f}{\partial x}\right)^2 (\sigma_x)^2 + \left(\frac{\partial f}{\partial y}\right)^2 (\sigma_y)^2$$

Key issue analysis

- **Purposes:**
  - **to focus attention on improved data collection**
    - “key issues for further investigation”
    - remember: LCA is an iterative process!
- **Restrictions:**
  - same as for uncertainty analysis
  - no problem of negative contributions

Key issue analysis



Numerical Approach Summary

	One product alternative	*Several product alternatives*
Without uncertainty data	**Contribution analysis** **Perturbation analysis**	**Comparative analysis**
With uncertainty data	**Uncertainty analysis** **Key issue analysis**	**Discernability analysis**

The future of interpretation

- **Numerical approaches are in their infancy.**
- **Many more numerical approaches are possible.**
- **Dilemma:**
  - need to improve LCA-software so that uncertainty estimates of input parameters can be handled
  - need to add uncertainty estimates to LCA-databases
  - most current LCA software cannot deal with them, lowering priority for collecting such data

Present practice

- **Use common sense and - if available - data indicators to identify data quality issues**
- **Use numerical approaches in interpretation to identify contributors for which data quality is particularly important**
- **Know limitations of LCA as tool and of study at stake** (with respect to system boundaries, lacking inventory data, lacking impact categories and data, etc.)
- **Use common sense to formulate appropriate conclusions and recommendations taking notice of possibilities and limitations of LCA tool and of the study at stake**

You may wish to review segments of this module.

- **Interpretation in ISO 14044**
- **Approaches**
  - **procedural approaches**
  - **numerical approaches**
- **Examples of numerical approaches**
  - **contribution analysis**
  - **perturbation analysis**
  - **uncertainty analysis**
  - **comparative analysis**
  - **discernability analysis**
  - **key issue analysis**

The remaining modules cover these topics:

Module	contents
g	Allocation in LCA
h	LCA mathematics
i	LCIA mathematics
j	Life cycle costing
k	Uncertainty in LCA
l	Carbon footprint