Active-Learning Tool Kit
Sustainable Development

Mike Ashby[1] and Tatiana Vakhitova[2]

[1]Department of Engineering, University of Cambridge
[2]Ansys Academic Development Team

Table of Contents

Part 0. Introduction

What's the idea?

"Sustainability" is not a simple parameter that can be quantified and optimized in an engineering design. Even the simplest proposal for a "sustainable" technological development has many facets. What material and energy resources will it require? What impact will it have on the environment? What regulatory constraints must it observe? Is it socially acceptable and fair? Is it economically viable? Issues of sustainable development are intrinsically complex; their assessment requires acceptance of this complexity and the ability to work with it. Individual facets can be explored in a systematic way but the integration of the facets to give a final assessment requires debate, compromise and reflection.

This Package describes methods and provides a kit of tools to help students explore and form their own judgments about proposals of sustainable technological developments. The 5-step methodology on which it is based has been developed by Granta Design in collaboration with the University of Cambridge, Barcelona (UPC) and the University of Illinois at Urbana Champaign.

The Mind Set

There is no completely "right" answer to questions of sustainable development, a situation unfamiliar to engineering students reared on exact analysis and digital precision. Instead, there is a thoughtful, well-researched response that explores the conflicting economic, legal and social drivers and consequences as well as the environmental legacy. There is a risk that computer-based tools (included in the resources) are seen as engines that can deliver a single metric – an Index of Sustainability, for instance. That is not the intent here. Rather it is to improve the quality of discussion by providing guided access to relevant data.

What will you get from this Tool Kit?

- ✓ Learn about problem-based Sustainability Assessment of technological proposals and the 5-step methodology (for more see "Materials and Sustainable Development" (Ashby 2015);
- ✓ Case Studies, Exercises, PowerPoint Lecture Units, group work templates, and other teaching resources available for educators[1].

What's in the Tool Kit?

Think of this as a Kit of parts for running a project or activity-based course or workshop on the sustainability assessment of proposed technological developments. The parts slot together but can be used in subsets or in isolation. The contents are listed on the cover.

1 The Ansys Academic Development Team has an extensive background in providing teaching resources for College and University teaching of Materials Science and Engineering at the Bachelors and Masters level. For more examples of Ansys Education Resources go to ansys.com/education-resources

Part 1. Assessing proposed sustainable developments

1. What is a "sustainable" development?

What is a "sustainable development"? It has become a buzz-phrase, something warm and comfortable but often meaning little more than "environmentally desirable"; and it has become a favored way of relabeling a current activity to give it the ring of responsibility. We need to do better than that. Here is a short answer: a sustainable development is one that provides needed products or services in ways that reduce the drain on natural resources, is legal, economically viable, acceptable to all stakeholders and equitable both within and between generations.

In slightly more detail: the word "Sustainability" carries three linked associations:

- Environmental sustainability – the preservation of natural capital, meaning clean atmosphere, productive land and water, a vibrant bio-sphere and material and energy resources,
- Economic sustainability – the productive creation of manufactured capital, meaning a financial health, a well-balanced built environment and industrial capacity, and
- Social sustainability – the fostering and support of human and social capital, meaning education, culture, consideration for the present and future generations, the pursuit of health and happiness.

These three essential "Capitals" underpin society as we know it today (Figure 1). Each capital is like a bank balance on which we draw and into which contributions can be made. They are mutually supportive, each dependent on the health of the others.

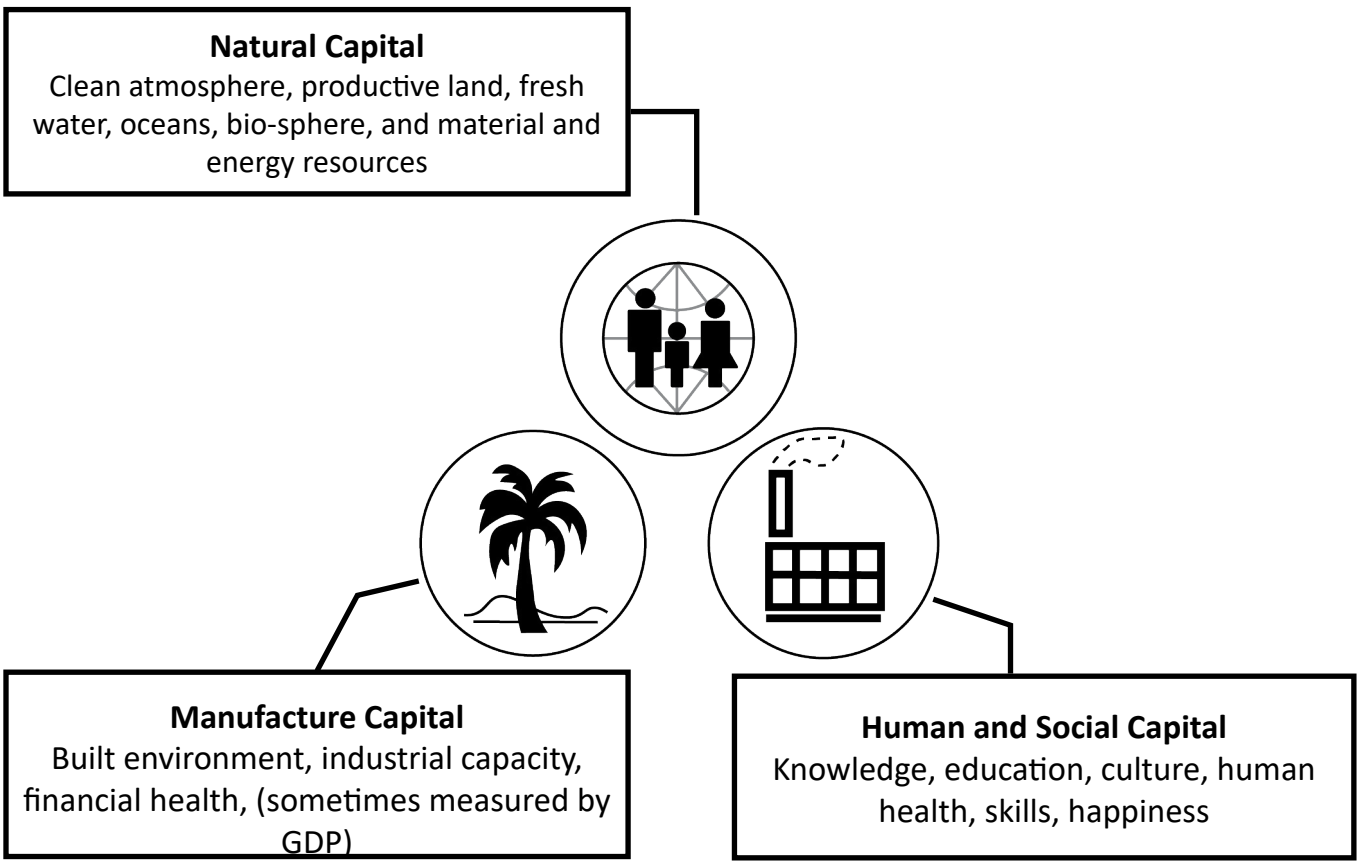


Figure 1: the three capitals

The growth in human population and wealth has increased the demands made on all three. Recognition of the importance of the three capitals has stimulated activities to diminish the undesired impacts of economic growth on them – particularly to diminish resource consumption, emission-release and social and economic inequity. At the same time there are many new proposals for sustainable developments spanning a large spectrum of scientific researches, economic interventions and social engineering projects. Each has a particular motivation. Here are some examples: research on efficient grid-scale energy storage; subsidizing electric cars to reduce the carbon emissions to atmosphere; harvesting electrical energy from waste heat; reclaiming scarce elements from cast-off mobile phones; reducing domestic electricity consumption by phasing out incandescent bulbs. We will refer to them as "proposals" for sustainable development.

This article describes a 5-step method for analyzing a proposed sustainable development. The method are described in Section 3 and illustrated by a running case study (blue boxes) that shows how the steps work but should not otherwise be taken seriously (serious case studies are available separately).

Any such proposal impinges in one way or another on the three capitals. The capitals are introduced at the very start because they provide the set of values against which we will judge the merits or failings of a proposed development. Sustainable developments are not simple – there are environmental aspects, there are aspects relating to material and energy resources, and there are legal, economic and social dimensions – and they are often presented in ways that favor the case made by the proposer or are biased towards the views of the opponents; in short, they are multidimensional, complex and, often, poorly defined. So we start with a brief description of a strategy for dealing with complex systems.

2. Dealing with complex systems.

It is natural to feel uncomfortable when confronted with problems that are multi-dimensional, interactive and poorly defined. The answer is to have a framework for critical thinking that recognizes the complexity and the interdependence and allows you to work with them.

One approach is to split the problem into layers (Figure 2). The bottom layer, the starting point, is a statement of the problem. Problems have a context: the circumstances that surround them. Why and how has the problem arisen? Who is involved? What outcomes would be desirable? What consequences might they have? These form the second layer. Given the answers to these questions, factual information about the problem and its context can be researched in a systematic, value-independent way. Technical, economic and legal aspects, for instance, lend themselves to objective research. No implications are sought here; the facts are simply assembled while suspending all judgment. The facts are stored on the third layer.

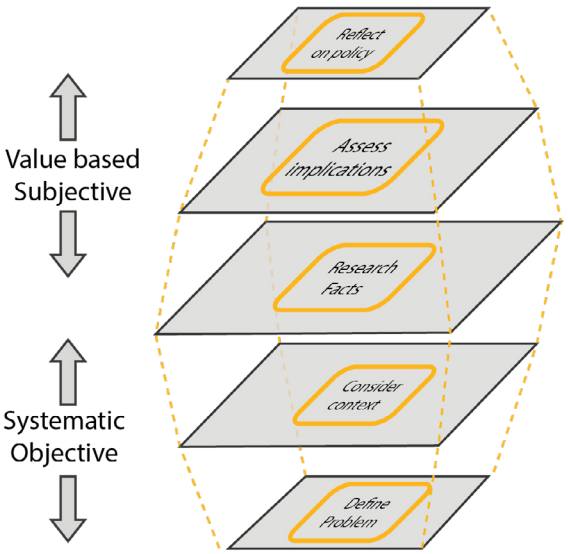


Figure 2: Layering as a way of thinking about complex problems

Complex problems would not be complex if systematic research alone could solve them. The complexity arises when trying to compare things that are measured in different units or are not "measured" at all: personal judgments, culture or belief-dependent values. To move from the third layer to the fourth,

that of value-based assessment, may require recognition of diverse views, only resolvable by discussion, debate and compromise to reach a mutually acceptable position.

The final step is one of reflection. What conclusions for strategy or action can be drawn from the debate? It is possible that any solution to the problem will leave some of the parties involved dissatisfied. Are there ways to involve them in ways that reduce the dissatisfaction?

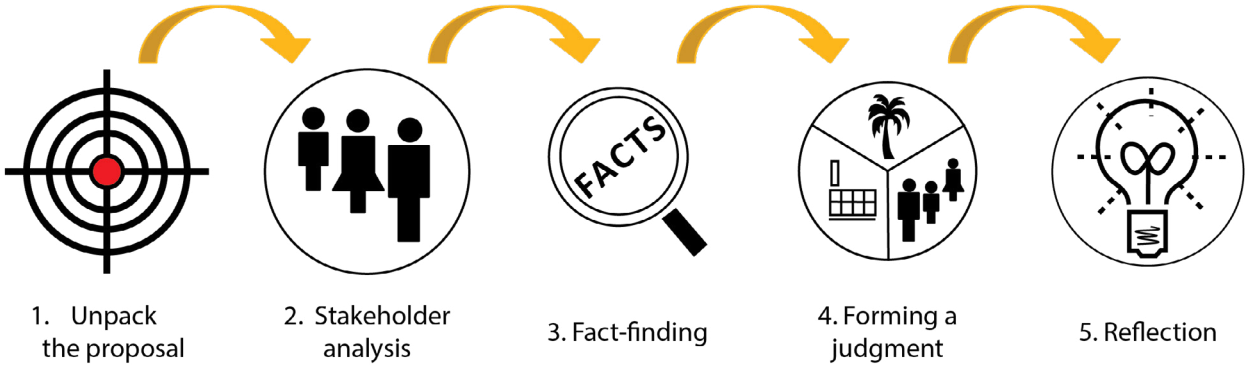
This layer-based approach clearly separates the objective, fact-based aspects of the problem from the more difficult value-based aspects. It allows thinking about interaction within each layer, followed by interaction *between* layers. Broadly speaking the lower layers inform the ones above, so that the approach has a sequence and a direction (from bottom to top). That is not to say that it is linear – thinking about any one layer may require further clarification of the layers below. But it does give a framework.

Let's now see how it might play out in analyzing a proposal of sustainable development.

3. Assessing proposals of sustainable development: the method

Here (Figure 3) is a five-step strategy for assessing a design or project (an proposal) that claims to contribute to sustainable development. Each step is a layer. Handouts with check-lists and templates guide the implementation. The strategy is illustrated with a running example that shows how the steps work but is not otherwise to be taken seriously.

Figure 3: the five-step method



Step 1: Problem definition – unpacking the proposal.

Any proposal of sustainability has an underlying motive that we will call its Objective. If the proposal is going to make a difference it must act on a scale that is significant in comparison with that of the problem itself. Thus, legislation requiring supermarkets to provide only bio-degradable plastic bags (with the aim of reducing "plastic pollution) will make a difference only if plastic bags from supermarkets constitute a significant fraction of all plastic bags. Similarly, a proposal has a time scale. Insisting on bio-degradable bags within 12 months presupposes that the supply chain for the bio-degradable film used to make them can cope with the resulting demand within that time. It is not possible to judge the viability of the proposal without knowing how large it will be and how soon it should happen; and if comparison is to be made with alternatives we need to identify a functional unit (Table 1). We identify step 1 with the target-icon.

Table 1: Unpacking the proposal

Questions	**Facts that are sought**
Objective?	What's the motive? What should the project achieve?
Size scale?	What's the scope? How many? How much? How extensive?
Time scale?	At what future date should the objective be achieved?
Functional unit?	What is the unit on which the assessment will be based?

We need a size scale and timing for this and any such analysis. As in this example, the original statement of a proposal is often vague about these, yet they are always there. If they are not explicit, we will infer sensible default values from the context.

The first step, then, is to *clarify the Objective* and *its size scale and timing*.

Step 2: Identify stakeholders and their concerns.

Stakeholders are individuals, groups or organizations that are in any way affected by the proposal. Some, like the originators of the proposal in question, wish to see it succeed. Others may have reservations or voice outright opposition. It is important to identify the stakeholders and their concerns, identified by the stakeholder-icon. If the concerns are not addressed the proposal will face obstacles and may fail to gain acceptance. If this happens the proposal is not sustainable.

How are stakeholders identified? A simple check-list, like that in Table 2 acts as a prompt. The National Press can provide background: controversial proposals (building land-based wind farms, for instance, or fracking for shale gas) cause stakeholders to express their concerns through Editorials, News and Business reports, Letters to the Editor, Commentaries in the Press, on radio and television, blogs, Facebook and Twitter. Ultimately, however, stakeholder concerns are best identified by face-to-face meetings, phone interviews or questionnaires.

Table 2: possible stakeholders

Local or national government	Suppliers	Customers, existing and potential
Owners	The public or local community	Lobbyists and interest-groups
Employees	Trade unions	Investors, shareholders
Health and planning authorities	The Press, radio and television	Managers, colleagues, or team
Alliance partners	Business partners	The scientific community

Stakeholders differ in their level of interest and the influence or power that they can exert. Figure 4 is a diagram with Stakeholder Interest and Influence as axes. The likely behavior of a particular stakeholder depends, to some extent, on the position they occupy on this diagram. Once positioned, it is possible to reflect on the mutual influence or dependence of the stakeholders, shown here by arrows.

The second step, then, is to *identify the stakeholders and their concerns* – they set the context in which the assessment is carried out.

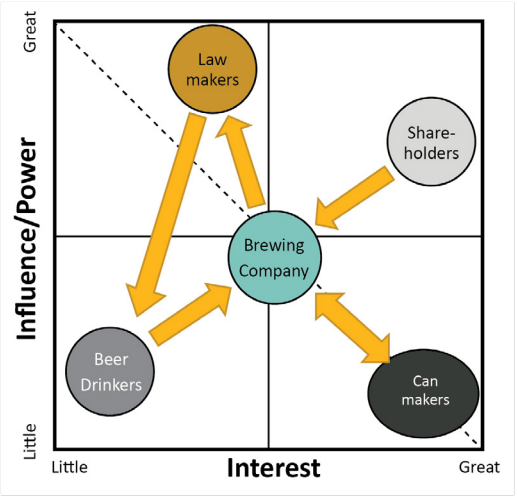
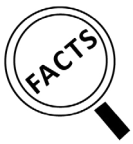


Figure 4: The stakeholder diagram for the CEO of the Beneficial Brewer, with paths of influence

Step 3: Fact finding.

To get further we need facts and facts need research. What sort of facts?



- Facts about the proposal and the resources needed to make it happen. What environmental impact will it have? Are there regulations with which is must comply? Is it fair and equitable? What will it cost?
- Facts that relate to the stakeholder's concerns. Are the concerns justified? What information is needed to confirm or refute them?
- Facts relating to essential infrastructure. What products or services will have to be in place to support the proposal if it goes ahead?

Each of these questions can be researched in an objective way using generally-available sources: books, databases, interviews and the Internet, guided by check-lists. The step is identified by the Sherlock Holmes icon.

What facts would be helpful to the CEO of Beneficial Brewing? They are best listed under six headings shown in the six segments of Figure 5.

- **Materials.** Is the supply-chain secure? Is a supplier of steel cans available? Have they the spare capacity to provide 500 million cans per year?
- **Energy.** The shareholders believe that steel cans require less energy than aluminum cans. Is this true? What are the values? If the change was made, how much energy would the company save in a year? What is this as a fraction of the total energy used by the company? Is it significant?
- **Environment.** What are the relative environmental impacts of the two sorts of can? Does one have a lower carbon footprint than the other? Is one recycled more effectively than the other?
- **Regulation**. What regulations bear on the use and recycling of cans? Is it the same for steel and aluminum? Are there any other legal or regulatory constraints?
- **Society.** Are steel cans acceptable to drinkers of Beneficial Beer? Would the lower embodied energy of the cans be seen as a demonstration of environmental responsibility?
- **Economics.** Do steel cans cost less than aluminum cans? What is the cost of re-equipping to cope with the change from steel and of aluminum? What are the benefits? Do they justify the cost?

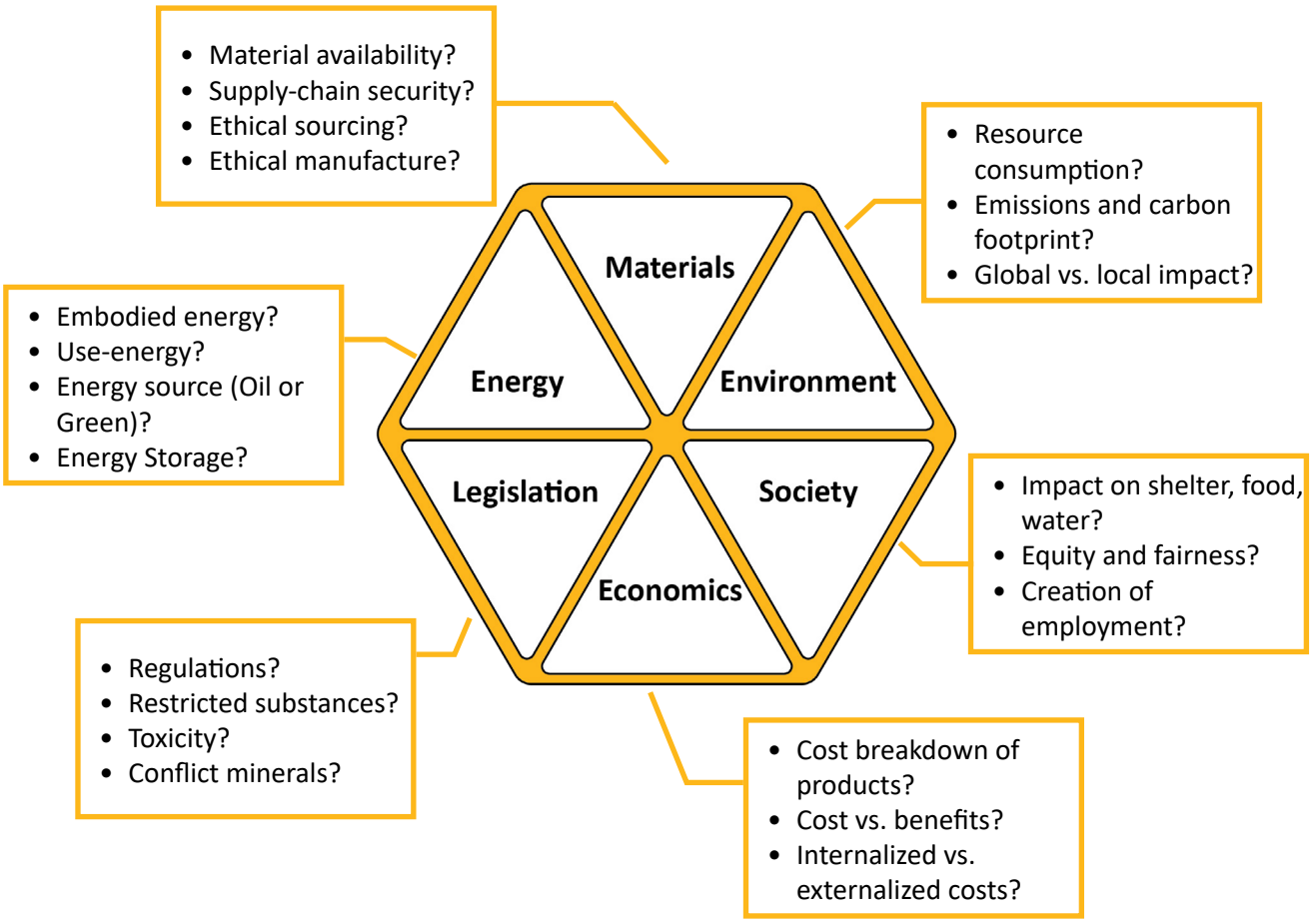


Figure 5: the six major sectors that are involved in most articulations of sustainable development

Step 4: Forming a judgment.

The fourth step is one of drawing together the facts from Step 3 to form a balanced judgment. To do this we need value-criteria by which the impact of the facts can be assessed. The value criteria are provided by the three Capitals (Figure 6) identified by the icon shown here.

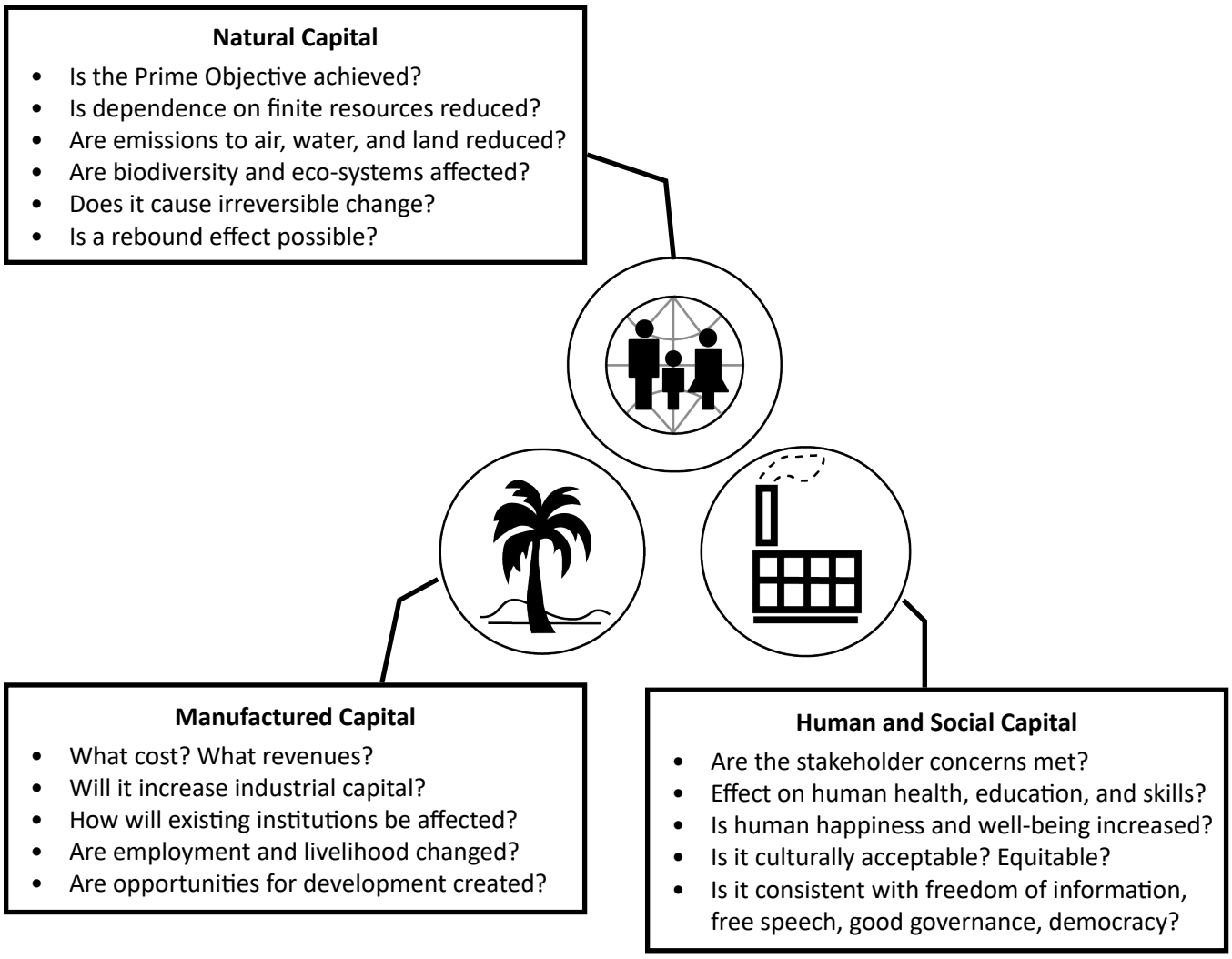


Figure 6: Synthesis – debating the impact of the facts on the three capitals. Check-lists help with this and the other steps.

It is here that values, culture, beliefs and ethics enter more strongly. Think of each Capital as representing the world-view associated with a particular set of values. An environmentalist might argue that the impact on natural capital ranked most highly: after all, the natural environment is the support system of all life. Humanists might see the sharing of knowledge, understanding, reason, humanity and happiness as the central pillars of a civilized society and feel that any impact on human capital was unacceptable. To an economist, economic stability and growth of manufactured capital could seem to be the first priority, arguing that these provide the resources needed to protect the environment, enable innovation and support a vibrant society. Each of these groups recognizes the cases made by the others; indeed they have many concerns in common. But their final judgment will be influenced by their underlying beliefs and values, cultural, religious and political. It is no surprise that one set of facts can be interpreted in more than one way. A balanced view is best formed by debating the facts from the perspective of each of each of these value-sets in turn, seeking to identify what is of value and what is unacceptable to each.

All this must be accepted. The important things to retain:

- Respect for the facts
- Respect for alternative interpretations of the facts
- Respect for the value of compromise reached by reasoned debate.

Step four, the Synthesis step, is the most difficult one. Check-lists, provided separately, help with it.

Step 5: Reflection.

The fifth and last step is that of reflection on alternatives. Is the Objective achievable? Is its influence on a scale that makes a significant difference? Do the benefits to the three capitals outweigh the negative impacts? Can the analysis suggest a new, more productive, way of achieving the initial Objective? This final step is identified by the illumination icon.

4. Assembling the layers

The layers are stacked in Figure 7 in the ascending sequence:

- Proposal statement
- Stakeholder and their concerns
- Fact-finding
- Synthesis: interpretation of the facts
- Reflection.

The lower layers inform the ones above. As explained earlier, the layer-based approach clearly separates the objective, fact-based aspects of the problem that can be explored in a systematic, scientific way from the more difficult value-based aspects. It encourages thinking about interaction within each layer, and gives a logical path to explore the interaction between layers.

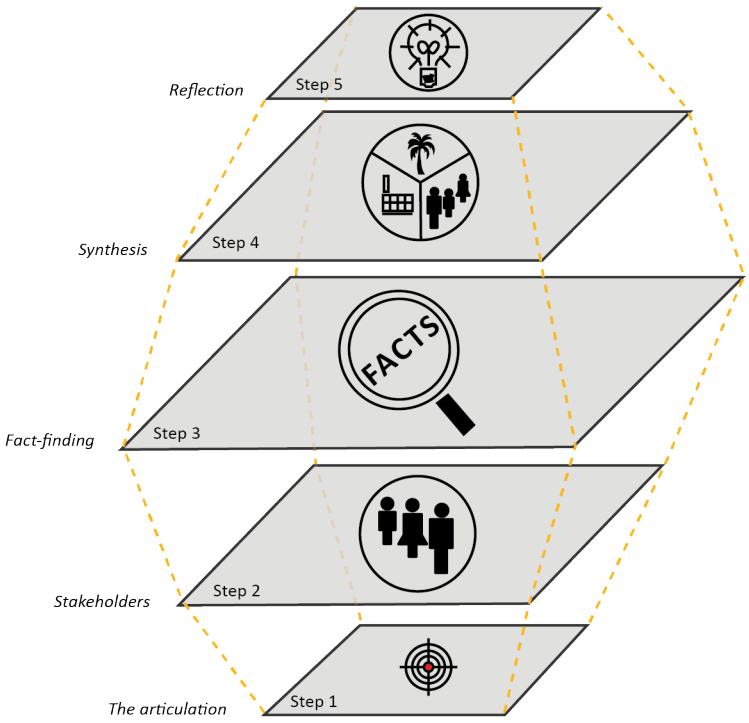


Figure 7: the layered approach to analyzing an articulation of sustainable development

5. Summary and Conclusions

There is no completely “right” answer to questions of sustainability development; instead there is a thoughtful, well-researched response that recognizes the many conflicting facets and seeks the most productive compromise. The layer-based approach described here provides a framework for doing this. The method is designed to help teachers introduce students to sustainability analysis in a simple, progressive way.

6. Further Reading relating to the method

Ashby M.F., Ferrer-Balas, D. and Segalas Coral, J. (2015) “Materials and Sustainable Development” Butterworth-Heinemann Ltd , Oxford. ISBN-10: 0081001762 ISBN-13: 978-0081001769

Kioupi, Vasiliki & Vakhitova, Tatiana & Whalen, Katherine. (2021). Active learning as enabler of sustainability learning outcomes: Capturing the perceptions of learners during a materials education workshop. MRS Energy & Sustainability. 9. 10.1557/s43581-021-00019-3.

Whalen, Katherine & Vakhitova, Tatiana. (2018). How to approach experiential learning for sustainable development in materials education?. 10.13140/RG.2.2.21093.86241.

Part 2. The Ansys Granta EduPack Sustainability Database

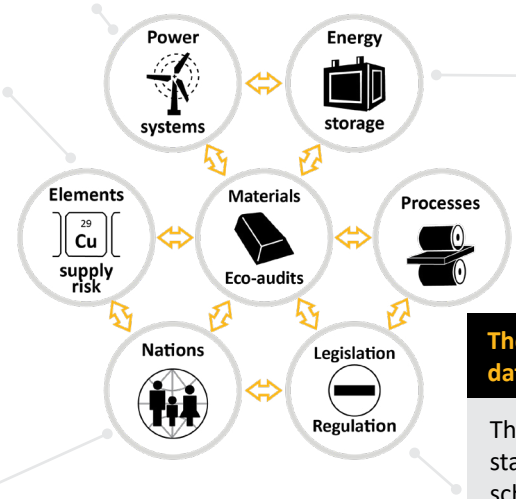
There are two Granta EduPack Sustainability databases, the first ("Level 2") providing an introduction, the second ("Level 3") allowing more advanced projects. Both are fact-finding tools to introduce students to the complexity of decision-making for sustainability and the role of materials in it. They help contextualize the role of materials and expand competences in critical thinking about complex issues (including resource use, legal barriers, ethical considerations, societal concerns, etc). At the heart of the database is a data-table for Materials that includes environmental properties such as carbon footprint, embodied energy, water use and durability. The Materials data-table is linked to further data-tables, as illustrated in Figure 8. Links connect records in different data-tables that are in some way related. For example, records for copper and its alloys in the Materials data-table are linked to copper in the Elements data-table, to the nations from which copper is sourced, to the processes that can shape, join or finish copper and to power-generating and energy storage systems that use it. Environmental restrictions in the Legislation database are linked to the nations that have enacted them and the materials affected by them. The different databases allow students to explore material criticality, geopolitical risk, legislative and social aspects relevant to materials and the sources from which they are drawn. Further, the Sustainability Database has an enhanced Eco Audit Tool, which helps to assess environmental performance of products at the design stage, providing quick estimates of the energy and carbon load of a product at each stage of its life as well as associated costs.

Elements data-table

The building blocks of all Materials are the elements of the Periodic Table. The Elements data-table has records for all 118 elements. In them you find the usual atomic-level properties (atomic weight, crystal structure, thermal, electrical, magnetic and nuclear properties). You also find data relevant to issues of sustainability: countries of origin with annual production, criticality status, embodied energy and carbon and water footprints, and principal uses and substitutes.

The Power Systems data-table

This data-table provides facts about power-generation systems in a consistent set of units. *(only available in the Level 3 database)*



The Energy Storage Systems data-table

Energy storage is of central importance in two important sectors, storing excess energy, and storing energy in a portable form for transportation.
This data-table contains facts about energy storage systems in a consistent set of units. *(only available in the Level 3 database)*

The Nations of the World data-table

The Nations data-table contains information for the 210 Nations of the World. Figure 2 shows an extract from a typical record. It opens with a map and flag. This is followed by data for geography and population, indicators of wealth, well-being, economic development and respect for law and human rights. Each field-name is linked to an attribute-note explaining its relevance and source.

The Legislation and Regulation data-table

This data-table summarizes legislation, standards, and taxation and incentive schemes that might influence the use and disposal of products and materials. These include European Directives and Regulations, US TSCA laws and Acts of Congress, environmental taxes and subsidies and international agreements and protocols. It is important to keep legalities in mind: projects that fail to conform to legally binding legislation are not sustainable.

Figure 8: Data-tables and links within the Sustainability Database

Part 3. Sustainability Case Studies

We have collected a set of case studies focused on sustainability topics. They can be found on the Ansys Education Resources website and cover subjects such as energy, built environment, electric vehicles and appliances.

For this particular exercise, we recommend focusing on one resource, the Biopolymers Case Study.

Part 4. Instructors experience

The use of the method in a Workshop format

The 5-step methodology, accompanying case studies, templates, and the Granta EduPack Sustainability database is now used in workshops and incorporated into teaching at a number of leading Universities including TU Delft, Universitat Politècnica de València, Universitat politecnica de Catalunya, University of Illinois at Urbana-Champaign, and the University of Cambridge. This Tool Kit is based on feedback from instructors involve in teaching sustainability concepts to students at both undergraduate and graduate levels and on their experience in using the Granta EduPack Sustainability database.

The format of a standard workshop (Figure 9) illustrates one approach. The methodology can be compressed into a 2 hour Workshop or (preferably) expanded to form a week or term-long project based exercise. The approach supports group work and enables group discussion.

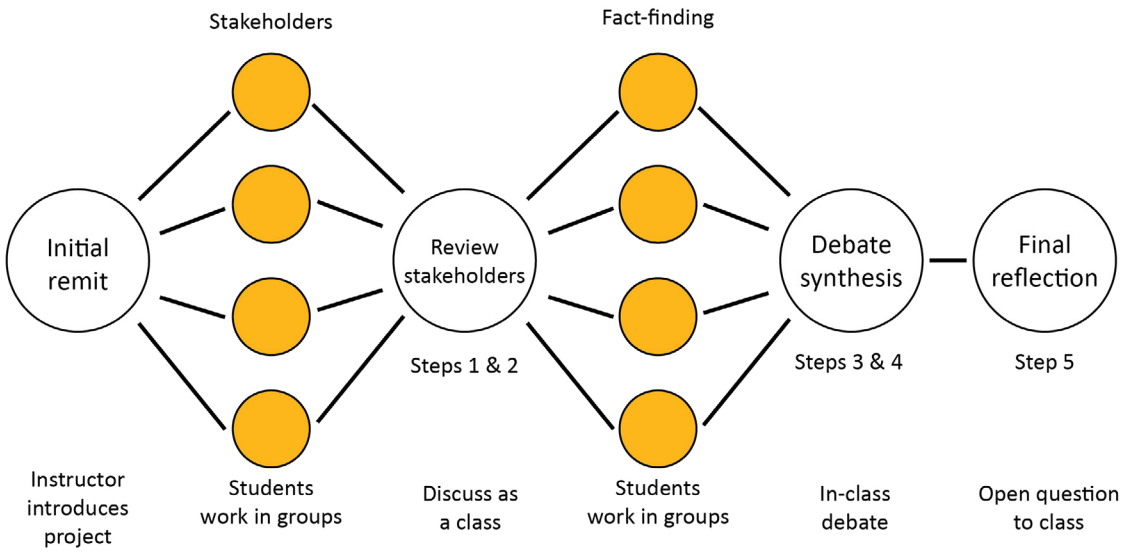


Figure 9: example of a workshop process.

Experience of Ansys Employee Usage

We have had experience of using this method in 2, 3 or 5-hour workshops. A typical agenda is reproduced below (Figure 10). The teaching experience is greatly enhanced if participants are given preparatory reading – we ask participants in short Workshops to read the short paper "Assessing proposed Sustainable Developments" that appears as Part 1 of this Tool Kit before they come. Students in week or term-long

projects are given a 30 minute introduction to the Granta EduPack followed by an introduction to the method with a worked example before they start their project. The use of Templates helps to guide the discussion in groups and manage the time. The Handouts help with initial problems with unfamiliar contexts. This best practice is illustrated in Figure 11.

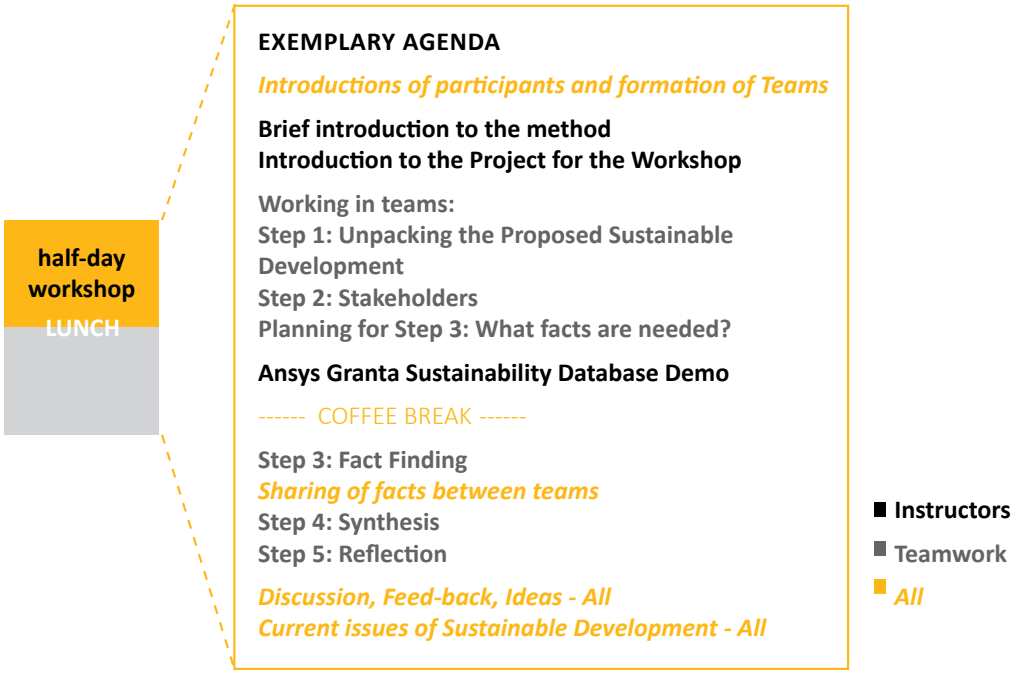
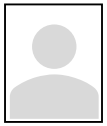


Figure 10: exemplary workshop agenda based on Ansys instructors' experience

Academic Instructor Experience:



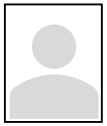
Bas Flipsen
TU Delft
Industrial Design Engineering

Name of course:
Master Teaching for Industrial Design Engineers
Number of students:
15 groups * 5 people = 75 students.
Background of students:
Industrial design ~ 80% and other engineering bachelor courses (e.g. mechanical engineering and aeronautics).

Format of course:
- Flipped classroom, Peer-to-peer reviews, inspired by Materials and Sustainability (Ashby 2015).
- 5 months in total, workshop every 3-4 weeks, 4 hours each with 3 mentors; ***peer-reviews every 2 weeks***
- ***Final presentations in groups: 20 slides, 6.5 minutes*** per group and a video-recorded message, include process and outcomes.

Feedback:
- Methodology best suited for 1st and 2d year students, who would be guided by the method
- Hard to set-up a prime-objective and differentiate it from an articulation
- Students felt uncomfortable finding a "negative" impact as a conclusion and admitting their difficulties in following the method
- Key challenge was in identification of the main issues from a materials' perspective.
- They need support with identifying key factors to focus on.

Discussion:
Ansys's Response:
- New hand-outs have been prepared to help introduce the key concepts to students. The ToolbKit with templates, extensive worked case studies and power point presentations would be of help.
- Focus on added value, links. If a "small" product – focus on key part/material, supply-chain etc.
- Introduce micro-projects to start the discussion and address the key concepts as a first task.

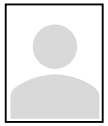


Javier Orozco Messana
Polytechnic University of Valencia
Building engineering

Name of course:
Technology and Application of Non-Traditional Materials
Number of students:
10 - 20
Background of students:
Bachelor students in their final year (4th year) studying towards a Degree in building engineering.

Format of course:
- Industrial case studies, Method and Questions from the book Materials and Sustainability. (Ashby 2015)
- 5 months in total
- Use of 5-step method, where possible
- Preselected cases are related to refurbishment of different real buildings. Projects are provided by various stakeholders, including data on all materials quantities for specific applications and relevant software models.
- The format of the course is first to acquire knowledge on the subject and then to collect data – make interviews/surveys with stakeholders from city council, building companies etc.
- Students perform materials selection, apply building standards, collect opinions from public and city council, analyze the impact looking at energy consumption and analyze different scenarios by using alternative materials and quantities, considering energy and price
- ***Final presentation: technical design exploring new possibilities, affecting performance of buildings, evaluate tools and make impact assessment of non-technical steps.***

Feedback:
- The key to the successful outcome is that prepared cases are specific enough and have sufficient details to help students to frame the solution.
- Difficulty in finding the data and perform evaluation looking at a case as a whole.
- For the lecturer it is in preparing/finding the case, so students can use it comfortably, having all needed numbers, access to stakeholders and knowing procedures.

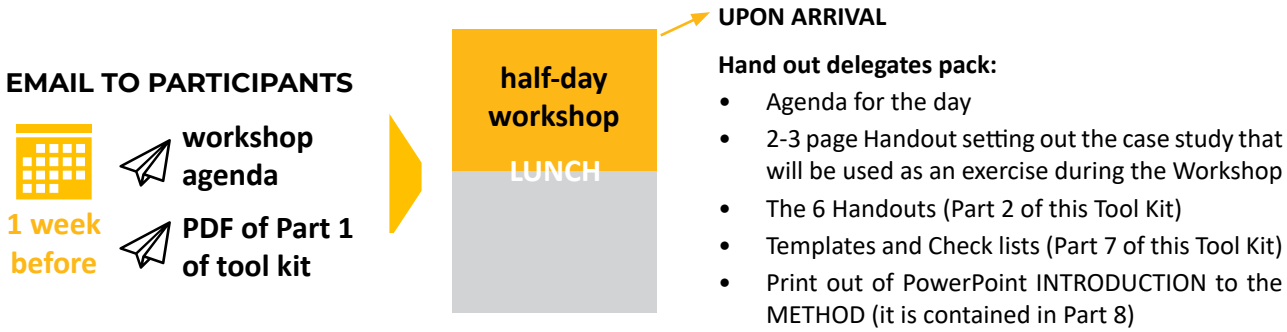


Annie Chimphango
Stellenbosch University
Department of Chemical Engineering

Name of course:
Environmental Engineering
Number of students: > 350
Background of students:
4th Year students from Mechanical and Mechatronics Engineering, Electrical and Electronics Engineering, Industrial Engineering, in some cases non-engineering disciplines e.g. Agricultural Sciences
Format of course:
- **Duration**: 6 weeks (4 weeks dedicated to sustainability analysis, eco-design and environmental impact assessment)
- **Application of 5-step method:**
  Students are given a case study on a topic that is of local importance/interest or that relates to current affairs in the country, on selected proposed interventions to the issue, and are then requested to perform the 5-step methodology in 1.5 weeks for assignments (partial steps, where they are expected to apply sustainability concepts in a 2h-exam based on a given case study). Students are given individual assignments but are encouraged to engage with peers. The case study includes claims and students are asked to verify these, using EduPack and sometimes case-specific additional resources.
- **Learning Objectives & Outcomes:**
  Help students contextualize sustainable development based on: local conditions, national priorities, field specialization; Encourage critical thinking, a systematic and holistic approach in analyzing technologies or processes claimed to be sustainable; To motivate students to think beyond their field of expertise and seek both technical and non-technical solutions to developmental problems; To increase students' understanding and appreciation of the complexities and the trade-offs that are unavoidable when considering the interplay among the three capitals.

Feedback:
The 5-step sustainability analysis is an eye-opener. Some technologies that are thought to be sustainable may be more damaging to the environment. The students found the fact-finding stage to be useful and exciting. In particular, the use of the eco-audit tool and the plotting of bubble charts were the highlights of the process. However, some students found the synthesis step (step 4) to be challenging because of the need to consider all information from the previous steps.

FORMAT USED BY ANSYS INSTRUCTORS



OUR TIPS

- It can be useful to think of a specific geographical location in which the proposed sustainable development is to be applied (e.g. electric buses in London) because it is easier to explore stakeholders on a local rather than a global scale.
- Students need guidance in setting priorities for the fact-finding stage. Before starting this phase it is helpful to list the facts needed to understand the proposal itself and those needed to understand stakeholder concerns, then assign time to explore them systematically. The clearer is the link between stakeholders' needs and the facts-finding stage, the easier the synthesis and the reflection will be.
- It is helpful to prompt students to consider cross-impacts (e.g. reduced emissions, but at higher cost, or an unacceptable reduction in performance); while they are exploring the articulation and the stakeholders.

Figure 11: workshop format and best practice based on Ansys instructors' experience

Part 5: Templates and Checklists for 5-Step Method

The next five pages are template pages that can be shared with students as handouts for each of the steps of the methodology. They include useful figures from this tool kit document in a more easily shareable format.

- Step 1: Unpacking the proposal
- Step 2: Stakeholder analysis
- Step 3: Fact-finding
- Step 4: Forming a judgment
- Step 5: Reflection

Please remember to follow proper reference protocols as described on the last page of this document when sharing.

Step 1: Unpacking the Proposal

Objective: .....

Size scale: .....

Time scale: .....

Now

Anticipated resource needs: .....

Anticipated energy needs: .....

Anticipated eco-impact: .....

To research in fact-finding step

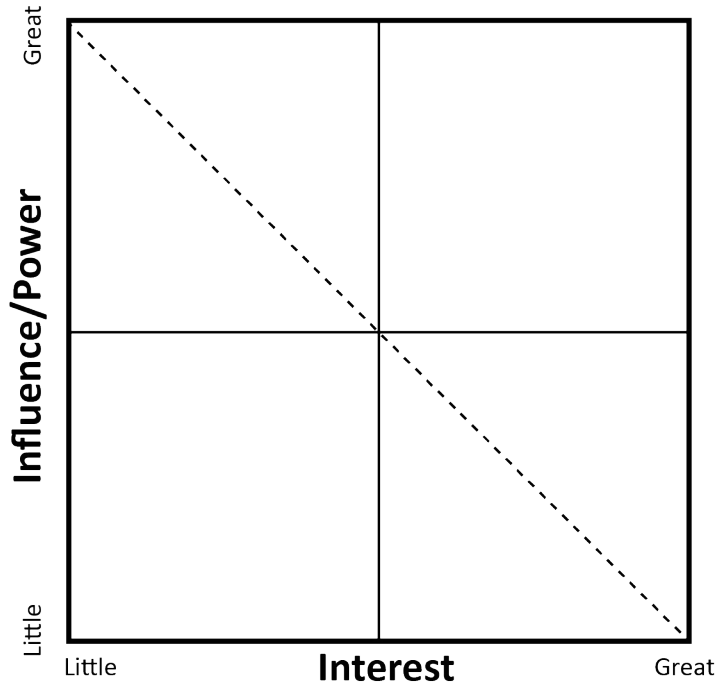
Step 2: Stakeholders and their Concerns

The questions:

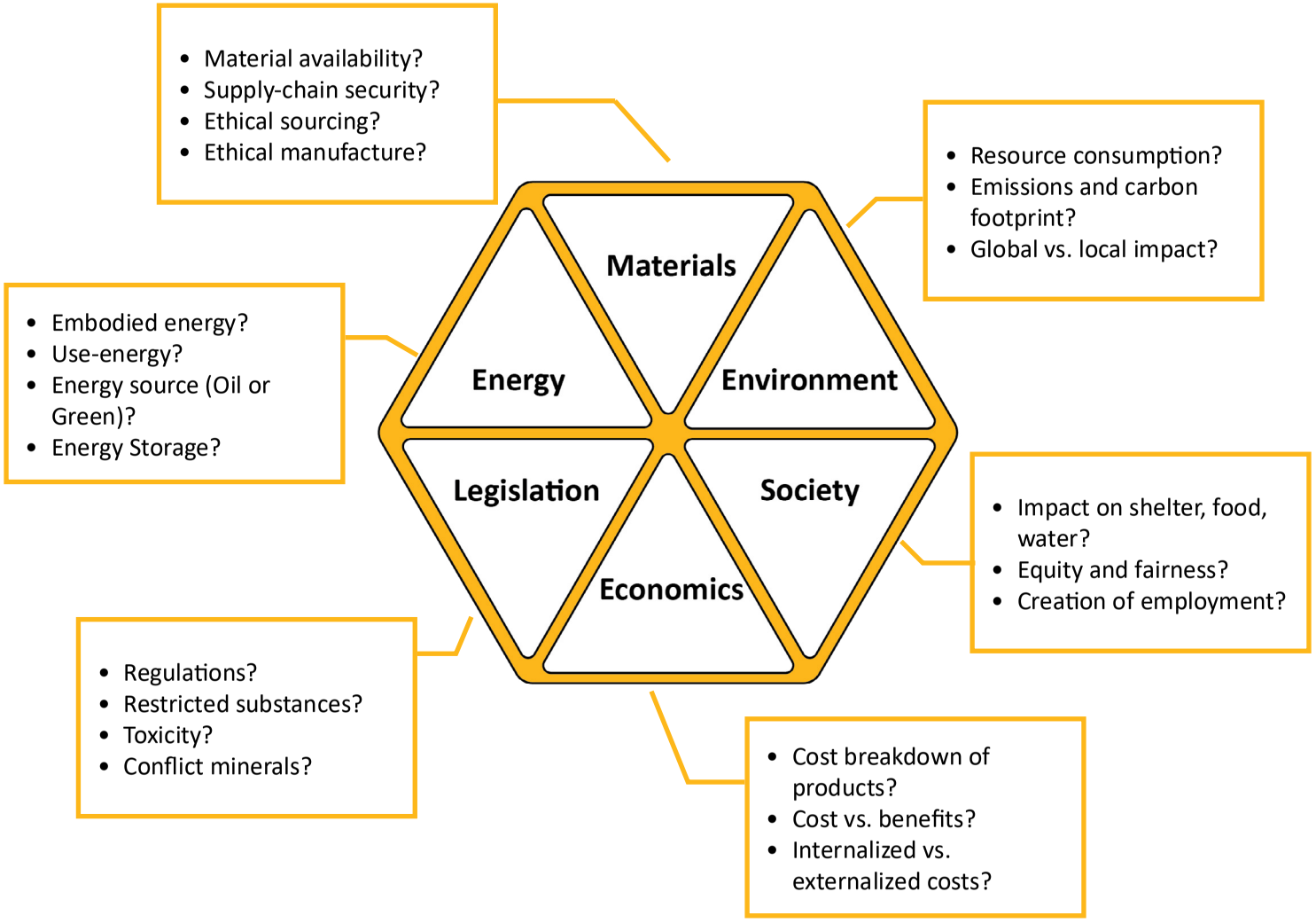
- Who are they?
- What are their concerns?
- What power do they have?

Check list:

- Government
- NGOs
- The public
- Local communities
- Religious groups
- Owners
- Investors
- Manufacturers
- Suppliers
- Employees
- Trade Unions
- Customers
- Lobbyists
- National Press



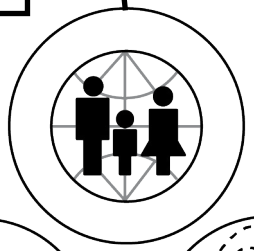
Step 3: Fact-finding

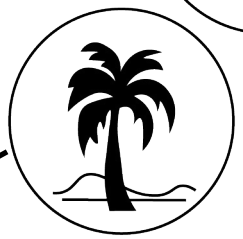


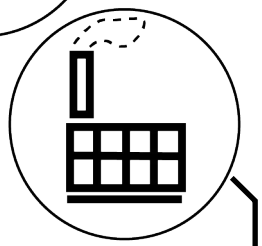
Step 4: Forming a judgment- checklists

Natural Capital

- Is the Prime Objective achieved?
- Is dependence on finite resources reduced?
- Are emissions to air, water, and land reduced?
- Are biodiversity and eco-systems affected?
- Does it cause irreversible change?
- Is a rebound effect possible?







Manufactured Capital

- What cost? What revenues?
- Will it increase industrial capital?
- How will existing institutions be affected?
- Are employment and livelihood changed?
- Are opportunities for development created?

Human and Social Capital

- Are the stakeholder concerns met?
- Effect on human health, education, and skills?
- Is human happiness and well-being increased?
- Is it culturally acceptable? Equitable?
- Is it consistent with freedom of information, free speech, good governance, democracy?

Step 5: Reflection prompts

Reflection on the initial remit

Moderating over-ambition

- Was the initial remit (the objective and scale) well thought out?
- Should the initial remit be modified to enable the objective to be met with less co-lateral damage?
- Is either the proposed size-scale or time-scale unrealistic?

Reflection on long vs. short-term gain

"No gain without pain"

- Do the long-term benefits outweigh the short-term sacrifices?
- What infrastructure is lacking that will be needed for long-term gain?

Reflection on radically different ways to meet objective

Invoking disruptive technologies

- Could the objective be met but a totally different route?
- Technical solutions?
- Invoking constraining legislation?
- Changing social behavior?

Use and Reproduction

The content used in this resource may only be used or reproduced for teaching purposes; and any commercial use is strictly prohibited.

Document Information

This document is part of a set of teaching resources to help introduce students to materials, processes and rational selections.

Ansys Education Resources

To access more undergraduate education resources, including lecture presentations with notes, exercises with worked solutions, microprojects, real life examples and more, visit www.ansys.com/education-resources.

ANSYS, Inc.
Southepointe
2600 Ansys Drive
Canonsburg, PA 15317
U.S.A.
724.746.3304
ansysinfo@ansys.com

If you've ever seen a rocket launch, flown on an airplane, driven a car, used a computer, touched a mobile device, crossed a bridge or put on wearable technology, chances are you've used a product where Ansys software played a critical role in its creation. Ansys is the global leader in engineering simulation. We help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the most complex design challenges and engineer products limited only by imagination.

visit **www.ansys.com** for more information