A.1

Making the case for a critical global engineer

1. The global dimension to engineering education
2. Science, technology, innovation and society
3. Technology and basic human needs
4. Professional and international perspectives of engineering: the case of energy
5. Professional ethics and social responsibility of engineers

GDEE | GLOBAL DIMENSION IN ENGINEERING EDUCATION

A.1 Making the case for a critical global engineer

PHOTO: Practical Action.

CHAPTER

1

The global
dimension
to engineering
education

1

CHAPTER 1. The global dimension to engineering education

Citation: Bourn, D. (2014) 'The global dimension to engineering education',
in *Making the case for a critical global engineer*, GDEE (eds.), Global Dimension in Engineering Education, Barcelona.
Available from: http://gdee.eu/index.php/resources.html

1 THE GLOBAL DIMENSION TO ENGINEERING EDUCATION

Douglas Bourn, Director of the Development Education Research Centre, Institute of Education, University of London

EXECUTIVE SUMMARY

This session will address the opportunities and challenges the global dimension presents for engineering education and situate it within the broader debates on the changing role of higher education institutions within the context of a globalised society and skills needs within the twenty first century. It will assess how the engineering education community has responded to global dimension topics and suggest a potential conceptual framework for the Global Engineer that could become the basis for curriculum development in this area. It above all will suggest that the concept of a 'Global Engineer' needs much wider debate and discussion and that a good starting point for academics and students should be to discuss and identify what are the skills needs, the increased knowledge required and the values base within which to contribute to making the world a better place.

LEARNING OUTCOMES

After you actively engage in the learning experiences in this module, you should be able to:

- To visualize the societal and ethical issues within engineering.
- Consolidate a conceptual framework for the Global Engineer.
- To identify what are the skills for a Global Engineer.
- To understand the opportunities and challenges for engineering education.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- Globalisation and engineering.
- Relevance of Social Justice.
- Understanding of Power and Inequality within Development and relationship to engineering.
- Critical thinking, dialogue and transformative learning.

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- What is the relationship of globalization to the skills needs of globalization today and in the foreseeable future?
- To what extent do you think engineering students are generally receptive to discussions around what is meant by the global engineer? How can we promote wider debate of these issues within our department/faculty?
- Identify one example from your own broader learning and experience within engineering that raises issues relevant to the themes raised in this module.
- How would you rank in importance the 4 concepts outlined in this module, global outlook, power and inequality, belief in social justice and critical reflection and dialogue? Give reasons for your answer.

INTRODUCTION

Engineering is a global profession. It could be argued that not only are similar knowledge and skills required wherever you are working around the world, but many engineers may well work in a range of countries and cultures during their career. What has changed, however, over the past two decades has been the increasing recognition of societal and ethical issues within engineering and the direct impact globalisation has had on the profession and the needs of economies around the world.

Societies may be globalised and there may well be common themes and trends around the world, but what such approaches can all too easily ignore is their complex nature, the influence of international policies, the role of economic forces and the differing ways in which cultures and communities respond in these rapidly changing times. Becoming an engineer in today's globalised world therefore means not only learning about differing social, economic and cultural influences but also about how this understanding is formed and the impact it has on an individual's own value base.

GLOBALISATION AND ENGINEERING EDUCATION

As societies have become more socially and culturally complex in response to globalisation and skills needs are in a constant state of change, universities have been forced to adapt and re-think the content of their courses. The student body in many universities around the world is today much more international and diverse than even a decade ago. Above all, universities have been driven into operating like any other institution within capitalist societies by having to compete in a global marketplace (Unterhalter and Carpentier, 2010). One consequence of these changes has been the recognition by many universities that they need to encourage their graduates to see themselves as citizens of a globalised world and that having some form of 'world outlook' could help the students to secure gainful employment (Schattle, 2008; Stearns, 2009).

Universities have also recognised that they need to promote a sense of global social responsibility. The most obvious example of this has been the policies and initiatives at a national and international level within higher education on sustainable development (See Gough and Scott, 2007).

Engineering is a subject that is directly relevant to issues concerning the environment and human development and therefore can (and has in many universities) be one of the leading subjects in demonstrating the economic and social relevance of the discipline (See Bourn and Neal, 2008).

Globalisation has also had an impact on the form and nature of learning. Students can now have instant access to information and knowledge. Universities, by being more culturally diverse, pose issues and questions about the content of courses. These trends have consequences on what, where and how students learn (Beck, 2000, p. 138). Part of the dialectic of globalisation, Beck suggests, is that it replaces 'traditional lecturing societies with dialogic attentiveness and courage to disagree – people beginning to realise transnationalisation of uneventful education and curricula' (Ibid, p. 138).

Beck notes that globalisation has also encouraged the promotion of the knowledge society with a greater focus on qualifications and training but with an emphasis on 'softer skills'. This means areas such as 'ability to work in a team, conflict resolution, understanding of other cultures, integrated thinking and a capacity to handle uncertainties and paradoxes of secondary modernity.' (Beck, 2000, p.137-8).

For engineering education these themes raise important questions about the extent to which degree courses should include elements that address societal issues such as the impact of climate change and global poverty. But it also encourages a re-thinking into how learning takes place and the extent to which problems need to be posed in more open-ended forms rather than in terms of simple solutions and answers.

A traditional response from engineering academics has been that the role of engineering through the use of technology can find solutions to society's problems. This approach assumes there is a solution that can be found and takes no account of the need to understand what the problem is. A particular technological solution to combating global poverty (for example) may well not be the most appropriate response because it does not take account of perspectives and views of the people affected and their own cultures.

Most academic responses to the challenge of globalization within engineering have tended to comment in terms of competencies required to compete in an international market for engineering know-how. This has included knowledge of other languages, developing intercultural skills and working more effectively in teams (Fenner et al, 2005).

What these approaches do not address is the role of engineering within a global economy and what is meant by a 'global engineer'. It is suggested in this chapter that engineering education in the context of a global society therefore needs to be re-thought. Whilst there is a role for considering learning about engineering solutions can be applied around the world, what needs to be considered within degree courses is the process of learning about the relationship of global issues and themes to engineering and the impact this has on the graduate engineer.

RE-THINKING THE CURRICULUM WITHIN HIGHER EDUCATION

Universities around the world have begun to recognise that the impact of globalization is as much pedagogical as it is economic and social and cultural. Through policies under the heading of 'internationalisation', there has been a growing debate and the implementation of policies and practices that have begun to look at processes of learning. A review of these policies by Caruana and Spurling (2007) noted that the changes require 'a shift in thinking and attitudes and that this pedagogy has dimensions that social, cultural, moral and ethical.

Manifestations of these policies and programmes have included sharing of knowledge through mobility of staff and students and a willingness to learn from other nations and cultures and to recognise that there is more than one way of teaching a subject (Knight, 2004).

Within engineering education there are some examples of changes in approaches and curriculum content, notably at University College London and through the involvement of bodies such as Engineers Without Borders. But even where there have been examples of international partnerships between engineering departments, the focus has tended to be more on the rich Northern institution and student body having an 'experience' including volunteering in a poorer country in the Global South.

An area that has provided some opportunities for re-thinking the curriculum has been through sustainable development which is today recognised as an important component of engineering degree courses and wider university policies (see Guerra, 2012).

DEMANDS FROM STUDENTS

Where changes have emerged in universities in terms of re-thinking the content and form of engineering degree courses, there is evidence that students have played an important contribution. This to a large part due to the work of Engineers Without Borders and its groups around the UK and other countries, notably Canada and Australia (Smith, Brown, Blackhall and O'Shea, 2010).

Research with engineering students in Ireland noted that they saw the Global Dimension as not only relevant but would make their course more interesting. As one student stated 'Global engineering being introduced into the curriculum would make active learning more important and therefore the learning of the course more interesting' (Bourn, 2009).

Research in the UK with engineering students found similar evidence:

'Engineers should understand that as a group, they have a large impact on the use of resources, pollution in the environment globally. Engineers who understand this will be more willing to obey new legislation, and create higher quality buildings.

Engineering graduates that support positive world change and have an understanding of the wider impact of their engineering decisions will be able to make more of a difference and will be more motivated in their work.' (Bourn and Sharma, 2008, p.200).

A theme to emerge from research at Northumbria University in the UK was the opportunities these areas created for a range of curriculum approaches and methodologies including lectures and seminars but placements, design modules and closer relation to practical experience. The importance of practical and 'real life experiences' was highlighted as a theme from the dialogue with students. Overall the students involved in the research at Northumbria felt the 'global engineer needed to be a multi-literate all-rounder, who may be multilingual, culturally diverse and aware of different unit applications (Montgomery et al, 2011, p.4).

These demands for changes reflect wider debates within higher education where students are calling for a more relevant curriculum for the needs of a global society that also includes a recognition of the contribution they can play towards a more just and sustainable world.

'Awareness of the world has heightened the curiosity of students about their role in the global society. They travel across the world, absorb news from across the world and communicate with people from across the world. Unless students find themselves roles to play, there is a risk of disenfranchisement or of disillusionment: that they are aware of global issues but do nothing about them.' (Lamb, Roberts, Kentish and Bennett, 2007, p.17).

RESPONSES FROM ACADEMICS

The ways in which university academics have responded to these changing global challenges has varied according to both the nature of the institution, the social and cultural composition of departments and issues these trends pose in terms of academic freedom and concern for wider social change.

Whilst projects such as Engineers Against Poverty's Global Dimension to Engineering Education initiative in the UK showed evidence of innovation and creativity, there was still resistance and difficulty in gaining broader departmental and faculty support. Examples often tended to be led by the enthusiast and only where there was senior management support were courses re-thought. The tendency was for examples that focused on projects and small additional content rather than re-looking at the purpose of the degree course.

This evidence reflects other studies between those academics that questioned a more interdisciplinary approach and wanted to retain a focus on technical skills. Where there was a recognition of the need for broader approaches that included themes such as sustainable development, they tended be covered more in the fourth and final year of degree courses.

There has been recognition of the need for change not only in content but in methods and approaches towards teaching. However, evidence suggests that the obstacle is more to do with a lack of confidence and expertise in differing pedagogical approaches. Role play and simulation models and critical teaching have been referred to as valuable by many academics but as one UK senior engineering academic stated, many still find these approaches as 'challenging' (Bourn and Sharma, 2008).

The same respondent also suggested that, 'we have quite a number of students from Africa and America that are brilliant and the best thing engineering departments can do is to twin the education in academic institutions with partnership with the best universities abroad-both developing and developed countries, or 2 different countries'(Bourn and Sharma, 2008, p.201).

Research undertaken for Engineers Against Poverty suggests that there is a desire by a number of engineering academics to look at learning in their discipline in a different way (Bourn, 2009). Sustainable development has clearly been a major driver, in places such as Plymouth, Queens University Belfast, and Liverpool, for opening up links with other disciplines and issues around social responsibility. At Leeds University there has been close involvement of academic staff from the philosophy department in some engineering courses, looking at questions of ethics and moral dilemmas.

THE GLOBAL ENGINEER

The concept of the Global Engineer has been recognised in recent years in a number of universities around the world and through projects such as that led by Engineers Against Poverty in the UK.

The Global Engineer publication for example noted that the future of engineering is being shaped by global forces which transcend national boundaries, such as the globalisation, rapid technological advances, climate change and inequality (Bourn and Neal, 2008). It shows the relationship of climate change and poverty in terms of habitats, access to water, energy and transport and discusses the key role that engineering can play in addressing these problems. It further suggests that globalisation through economic development, increased tourism and new technology can, through effective use of engineering skills, play a key role in combating global poverty.

These various initiatives have however tended to focus on the following:

- Including greater knowledge and understanding about global issues such as poverty, climate change and impact of globalization
- Recognition of more interdisciplinary approaches and linkages to other degree courses that could help address the themes mentioned above.
- Promotion of projects, including extra curricula activities by students that address relevance of engineering to combating poverty and encouraging sustainable living.

A list of examples of projects from the EWB and EAP UK Research Conference in 2012 shows that the focus of most projects was on supporting people in poorer communities around the world with technological solutions. To their credit, however, several of the examples did address dilemmas and problems including collaborative forms of working, the role of NGOs and how to deal with risk (EAP/EWB, 2012).

BRINGING IN EDUCATION TO BEING A GLOBAL ENGINEER

Central to the themes of this chapter is the need for re-thinking the role and purpose of education within the professional development of an engineer in the context of a global society. This means covering the three elements of any educational approach: knowledge, skills and values. But each of these three areas all pose challenges to what and how the engineer relates their learning to the needs of the wider world. An understanding of the contested nature of the debates in these three areas is also suggested is an important component of developing a framework for a global engineer.

Knowledge of Global Issues

As mentioned earlier, a number of the studies and examples of practice that promote the concept of the 'global engineer' have focused on including increased opportunities for learning about global issues and themes. Globalization as suggested not only leads to ever expanding need and desire for knowledge, it also poses questions about how we learn. Scheunpflug (2011) in relation to learning about the wider world refers to three levels of knowledge:

- Basic knowledge related to data that is accepted around the world and including concepts related to mathematics, literacy and natural sciences.
- Problem solving and knowing how to learn.
- Knowledge that is culturally specific and which might relate to areas such as health, food, lifestyle, attitudes and beliefs (p. 33).

All too often as Scheunpflug notes, education has tended to focus on a linear process of learning, but in the era of globalisation complex problems and issues cannot be easily solved (ibid). She goes on to note that with rapid social change, dealing with uncertainty becomes one of the major challenges of the global society

Andreotti, who has been influenced by postcolonial and poststructuralist ideas, refers to the importance of 'pluralistic knowledge'. She suggests firstly that there is a need for educationalists in whatever context to 'resist instrumental thinking'. Secondly, in response to the challenges of global technologies and skills required today, educationalists need to 'reclaim their role as cultural brokers' by increasing 'their awareness and capacity to analyse and see the world from different perspectives, learning to listen and to negotiate in diverse and complex environments.' Thirdly, Andreotti poses that we should not be imposing on students what to think or offering universal pedagogies. The role of the educator should be to keep 'possibilities open and equip learners to engage critically with each possibility, to listen and to negotiate ethically with others, and to analyse and take responsibility for the implications of their choices.' This requires an understanding of knowledge and identities within transient and changing learning communities (Andreotti, 2010, p. 9-10).

Gilbert (2005) suggests the need to move away from thinking about knowledge as an object to be mastered - a static end-in-itself - to a view of knowledge as a resource, something that people do things with in order to solve real problems.

In terms of knowledge and global engineering, it is important to recognise not only the value of data and information, but also broader content-based knowledge and understanding, as well as its applicability. These could be summarised as:

- The importance of differing perspectives, approaches and critical reflection.
- The global context of the construction and application of knowledge.
- The global relevance of engineering and its potential role in securing change in the world.

It is in this context that the response to the knowledge gap within engineering to global themes identified by Bourn and Neal (2008) should be addressed. This gap was further reflected in research by Mattiussi et al (2013) particularly where the learning included more qualitative than quantitative based approaches - or as one academic commented, 'wishy-washy social science' (p. 5).

What all this means is that merely including additional lecturers (or even courses) aimed at increasing knowledge of global issues is suggested here to be insufficient. Without the relevant skills and values base to go with this knowledge, students could all too easily assume there is only one way of seeing these issues.

Global Skills

Within the debates on skills in a global society there has been recognition that technical skills on their own are insufficient within rapidly changing economies. Themes such as transferable skills, team working, interpersonal skills and the capacity to deal with uncertainty and solve problems are now commonplace within engineering education research. Such generic skills are acknowledged within large companies, for example through workforce requirements of being able to work in a range of complex social and cultural environments, being culturally sensitive and able to communicate with a wide range of customers.

Research by Bourn and Sharma (2008) on engineering companies' perceptions of the value of global skills has reinforced these views. Senior staff from a well-known Japanese automobile manufacturer, for example, emphasised the importance of recruiting engineers who have all-round interpersonal skills, fit into their culture, have an objective focus and an ability to identify and resolve problems quickly. Inter-cultural sensitivity was a key skill for them:

> *"That is key for us because the perception that some people may have is that engineering is not very global. However, sensitivity to different perspectives, nationalities and cultures, languages, locations, time zones and different styles of working in different countries is crucial. This is often lacking in people from the UK. Because we are a Japanese company, this becomes very important for us"* (Ibid, p.202).

There is evidence at least from large international companies that global skills would be seen as linked to having the skills to work in a range of cultural environments, to being adaptable and to being able to recognize broader social needs and agendas. But this should not detract from the context within which employers and policy-makers would see global skills and that is economic competition and working within existing dominant social norms.

There is another dimension to seeing global skills: taking cultural awareness to a further stage and relating it directly to international experience and inter-cultural dialogue. Vitto (2008) refers to the value and importance of these softer skills and the need to be receptive to other cultures as important elements of the development of the engineer.

The 'inter-cultural experience' approach has often taken the form of study visits and exchanges of both staff and students. Whilst these initiatives can help to broaden horizons and give both academics and students differing experiences and perspectives, it is more questionable as to whether they radically change how the learner sees their role and sense of place in the wider world. Rizvi and Lingard (2010) have noted that despite much talk about global interconnectivity and interdependence, 'international contact remains within globally differentiated cultural communities- the west versus the rest (p.175). All too often these exchanges and experiences reproduce dominant notions of cultural superiority. Inter-cultural dialogue is not really dialogue but a form of reproduction of cultural domination.

Only when the exchange and the partnership is part of a broader process of learning and engagement with global issues and questions and addresses questions of power and domination can perhaps such experiences lead to a broader and more questioning global consciousness.

Another lens through which one could see global skills as an approach recognises complexity, critical thinking and is linked closely to a more values-based approach around social justice. Building on the work of Paulo Friere and Giroux (2005) this approach is based on recognition of an approach towards learning that is open, participatory but is also deeply political and recognizant of power. Giroux (2005) talks about critical pedagogy starting not with test scores, but with questions. He states it is also about recognising competing views and vocabularies and the opening up of new forms of knowledge and creative spaces.

This approach to seeing global skills means the following:

- Recognising value of learning about different perspectives and approaches.
- Equipping the learner with the skills to question, critically enquire and reflect upon a range of social, economic and cultural influences.
- Emphasising the importance of positive social engagement and of seeking solutions.

- Recognising the impact of globalisation on people's lives and the need to equip students with the ability to make sense of a rapidly changing world.
- Makes reference to the forces that shape societal and economic change.

These influences can be seen in the following framework for Global Skills:

- An ability to communicate with people from a range of social and cultural backgrounds.
- An ability to work within teams of people from a range of backgrounds and other countries.
- Openness to a range of voices and perspectives from around the world
- Willingness to resolve problems and seek solutions.
- Recognition and understanding of the importance of global forces on people's lives.
- Willingness to play an active role in society at local, national and international level (Bourn, 2008).

This approach towards critical skills builds on the work of Andreotti and De Souza (2008) in posing the need to move from fixed content and skills that conform to a predetermined idea of society to concepts and strategies that address complexity, difference and uncertainty. It also means moving from an approach towards learning that accepts given knowledge to one that questions and moves positions and views. Finally this approach means moving from a universalist and ordered view of the world to one that recognised complex, multifaceted and different means of interpretation (Bourn and Neal, 2008).

The Values of a Global Engineer

Haydon has suggested that 'what determines the way knowledge and skills are used is a person's values and attitudes' (Haydon, 2005). Any forms of learning about issues and themes such as climate change, global poverty and human rights are bound by their very subject matter to raise questions to the learner about their own values base and viewpoints related to these topics. It becomes inevitable that the process of learning about the impact of poverty on communities in particular countries will raise emotional themes such as fairness and justice. These themes are commonplace in the discourses around development education, global learning and global citizenship education.

Inman refers to commitment to justice and equity, empathy with others, respect and caring for ourselves and others, openness and commitment to individual and collective change and commitment to sustainability (Inman, 2005). However, as Tormey (2005) and Tallon (2012) have noted, this emphasis on values can be reduced to discussions on emotions and a sense of empathy.

Within engineering education there has been an uneasy tension about the role and place of values. There are the tensions between professional and societal values and differing values bases around the world that are culturally specific. Mitchell and Baillie (1998) suggest, "Our values are the lens through which we view the world: they stem from our underlying beliefs and assumptions, which are generally neither articulated nor questioned" (p.15). Further they suggest that students as well as professionals need to recognize their own values and perspectives and what influences their point of view when they make judgments.

It is how the engineer understands and reflects the relevance of their own values to their profession that needs to be discussed and debated further. All too often within engineering values are seen purely in terms of workplace themes such as honesty, integrity, security. People and societal needs may well emerge but themes such as social justice, equity and empowerment of people rarely do. Even in discussions on sustainable development, the values are often seen in terms of workplace needs.

It is these wider social values that are also personal values of ethical and social responsibility, a concern and desire to see a more ethical and just world that is the key to being a global engineer.

TOWARDS A PEDAGOGY FOR THE GLOBAL ENGINEER

In taking forward the promotion of the concept of the Global Engineer within engineering departments and faculties within universities, the following elements are suggested as a potential pedagogical approach:

- Promotion of a global outlook and what this means to be an engineer in the twenty first century.
- Understanding of the causes of power and inequality in the world and their relationship to engineering.
- Belief in social justice and a sense of social responsibility and its implications for engineering.
- Commitment to dialogue, critical reflection and recognizing that there are more than perspective on engineering based solutions.

Global Outlook

Learning and understanding about development and global issues within engineering requires an assumption that learning about the wider world is relevant and important to engineering students. This implies a sense of a 'global outlook'. But what does this mean and how could it be interpreted?

A global outlook could be neo-colonialist, even imperialist in nature. It could at a more subtle level start from a position that our own personal viewpoint is the best. Scheunpflug (2011) reviewed how teachers respond to challenges regarding developing a global outlook and noted that it is important to be sensitive to students' tendencies to 'take European superiority for granted' and that teachers need to have a 'sense of how to get students to look through other lenses and perspectives' in order to be able to activate their 'reconceptualisation of these issues' (p.30).

This means that engaging in learning about global development themes may well have to start from demonstrating the value of looking beyond one's own environment. A necessary initial point for any engagement in learning, therefore, must be the process of demonstrating that we live in an interconnected world and that events elsewhere in the world have an impact upon us and that we now live in a 'global village'.

Power and Inequality

There is a tendency within the practice of many bodies engaged in development to see their role in altruistic terms. This results in the emphasis being on volunteering, fundraising or wanting to help the poor. Engineering intervenes within societies often with economic power

and political support. Projects around the world, whether they are roads, dams or introduction of new technologies have often been led by a small elite grouping of powerful companies.

An understanding of what this power means, where it comes from and how it is used must be an essential pre-requisite of the learning of the Global Engineer.

Engineers Against Poverty, in recognition of these issues, see their starting point as power and inequality;

> *The most fundamental issues of development are issues of power. The world is organised in a way that is profoundly unfair and poor people often lack the power necessary to bring about improvements in their own lives. The goal of development therefore should be to empower those who live in poverty to bring about improvements that are meaningful to them[1].*

It is the relationship of power and inequality to the work of engineers that needs opening up for wider debate and discussion.

Belief in Social Justice

There is evidence from the UK and other industrialised countries that a strong driver for the global engineer is the connection with the poverty agenda and the promotion of engineering in terms of social justice (Bourn and Sharma, 2008). In this regard the work and approach of Engineers Against Poverty (EAP) in the UK provides a valuable reference point. EAP sees its role as 'working with industry, government and civil society to fight poverty and promote sustainable development'. It aims to 'influence corporate and public policy and help develop practical solutions aimed at creating jobs, promoting enterprise development and improving education and training'.

A belief in social justice will come from a wide range of personal, social and cultural influences. This means recognising that for many people their concern about global poverty is likely to start from a moral position that might be influenced by factors such as personal experience, religion, peer group and family and the media. It is in the process of learning more about social justice themes and issues and the impact this has on the learners' own value systems where development education becomes relevant.

At the other end of the spectrum, one may also find individuals who have been campaigning against global poverty but who have not secured the relationship of the values behind this in

---

[1] www.engineersagainstpoverty.org/about_us/our_development_perspective.cfm

terms of social justice or desire for greater equality to other aspects of their own lives or those of other people.

These beliefs in social justice, wanting the world to be a better place in terms of greater equity and that all peoples should have the opportunity for their voice to be heard and understood leads on to discussions global citizenship and to the relationship between education and social change.

Commitment to dialogue, critical reflection, and listening to different perspective

At one level critical thinking could be reduced to simply looking at different types of information, weighing up evidence and building an argument in order to solve problems. But as Paul suggests, the various definitions of critical thinking imply that it is more than this. In essence, he says, 'critical thinking is thinking about your thinking while you're thinking in order to make your thinking better' Related to this, he states is the importance of self-improvement (Paul, 1995, p.91).

Brookfield refers to critical thinking as about 'hunting assumptions, without trying to assess their accuracy and validity, their fit with life' (Brookfield, 2012, p.7). He is suggesting seeing things from different viewpoints in order to take informed action; that is, 'action that is based on thought and analysis' (ibid, p.13).

In the context of engineering education, the following elements could be seen to incorporating critical thinking:

- Imagining a range of global perspectives – looking at topics and issues through different lenses.
- Looking critically at how engineers perceive other countries and what has influenced our perceptions, particularly from the media.
- Looking at the causes of inequalities.
- Exploring power relations, including questions such as who have power, who is voiceless and who benefits?

Guerra (2012, p.328) in reviewing how engineering has engaged with the debates on sustainable development suggests the importance of moving from broad interpretation of principles and descriptive examples to a common conceptual framework. He suggests that it is central to not only to define, analyse and solve problems but to reflect on the decisions and their consequences.

Pawley (2012), in her reflections on her role as an engineering academic states that it is important to practice critical self-reflection and question who defines engineering problems and who benefits from engineering solutions and social justice.

These examples suggest there are engineering academics beginning to look more critically at their profession. But what is needed is for this critical reflection to be linked up more to the earlier themes around power, social justice and a global outlook in order to provide some coherent framework for pedagogy for the global engineer.

CONCLUSIONS: IMPLICATIONS FOR ENGINEERING EDUCATION

As this chapter has indicated, whilst elements of the themes mentioned above could be seen in a range of initiatives on global issues and sustainability with regard to engineering, what perhaps has not been given sufficient consideration is the implications of promoting a 'global perspective' in terms of the pedagogy (the approach towards learning). This means re-thinking not only the content of courses but also how a topic is taught and how the students themselves will engage with the learning. Examples such as Savagem Vanasupa and Stolk (2007) through their project based approach show elements of the themes mentioned in this chapter.

But whilst scenarios of problems can be valuable with practical research and activity around them, the framework of a global engineer outlined in this chapter suggests going beyond just seeking technical solutions to understanding of the problems.

One web based resource that could provide a valuable tool for looking at issues from differing perspectives and questioning assumptions is the Earth Charter-sponsored resource, titled 'Pictures of Success'. Through the use of photographs, 'Pictures of Success' looks at stories of success that help to combat global poverty and support sustainable development. Examples include how that whilst many people in Ghana have access to a mobile phone, the majority do not have access to clean and hygienic toilets.

Another photographic example looks at the ways in which indigenous communities in many places around the world respect and value their land.

> *"Our ancestors have been living on this land for centuries. Because we were born holding the land, we cannot let go of it, and it cannot let go of us." (Lodu Sikaka, Dongria Kondh leader, India).*

These and other photographic examples provide the opportunity for discussions that can encourage a more critically reflective approach towards addressing problems that need to be tackled, understanding and valuing different perspectives and recognizing that external

factors, be they economic, political or cultural, do play a role in influencing the decisions we make.

The concept of the global engineer as suggested in this chapter is much more than bringing in elements of knowledge about global issues. It is also more than making reference to 'softer skills' such as team work or just respect for other cultures.

Examples such as the 'Pictures of Success' resource provide opportunities for looking at a range of issues that are relevant to engineering, global issues and sustainable development. Starting from real world examples and looking beyond the solution to understand what is problem, how it was formed and who needs to be involved in resolving it are all part of being an effective global engineer.

BIBLIOGRAPHY

Andreotti, V. 2010. Global Education in the 21st Century, two different perspectives on the post of postmodernism. International Journal of Development Education and Global Learning, 2(2), 5-22.

Andreotti, V and De Souza, L.M. 2008. Translating Theory into Practice and Walking Minefields: Lessons from the project 'Through Other Eyes'. International Journal of Development Education and Global Learning. 1(1), 23-36.

Beck, U. 2000. What is Globalisation. Polity Press, Cambridge.

Bourn, D. 2008. Global Skills. Centre for Excellence in Leadership, London.

Bourn, D. 2009. The Global Dimension to Engineering Education. Unpublished paper for Engineers Against Poverty.

Bourn, D and Neal, I. 2008. The Global Engineer. Engineers Against Poverty, London.

Bourn, D. 2009. Global Engineer - Strategies for the Way Forward. Unpublished paper for National University of Ireland, Galway.

Bourn, D & Sharma, N. 2008. Global and Sustainability Perspectives within engineering. The Municipal Engineer. 2008: 199-205

Brookfield, S. 2012. Teaching for Critical Thinking. Josey-Bass, San Francisco.

Caruana, V and Spurling, N. 2007. The Internationalisation of UK Higher Education: a review of selected material, http://www.heacademy.ac.uk/assets/York/documents/ourwork/tla/lit_review_internation alisation_of_uk_he.pdf [Accessed March 3rd, 2014].

Engineers Against Poverty/Engineers Without Borders (EAP/EWB). 2012. Proceedings of the "Changing Course" Global Engineering Education Conference, London.

Fenner R.A., Ainger C.M., Cruickshank H.J. and Guthrie P.M. 2005. Embedding Sustainable Development at Cambridge University Engineering Department. International Journal of Sustainability in Higher Education. 6(3), 229-241.

Gilbert, J. 2005. Catching the Knowledge Wave. New Zealand Council for Educational Research, Wellington.

Giroux, H. 2005. Border Crossings, Routledge, New York.

Gough, S and Scott, W.A.H. 2007. Higher Education and Sustainable Development. Routledge, London.

Guerra, A. 2012. What Are the Common knowledge and Competencies for Education for Sustainable Development and for Engineering Education for Sustainable Development? Proceedings of the SEFI 40th Annual Conference, Thessaloniki, Greece.

Haydon, G. 2005. What kind of values education does development education need? The Development Education Journal. 11(2), 3-5.

Inman, S. 2005. Making Values Central: the Partners in Change Project. The Development Education Journal. 11(2), 25-27.

Knight, J. 2004. Internationalization Remodeled: Definition, Approaches, and Rationales. Journal of Studies in International Education. 8(1), 5-31

Lamb, A., Roberts, E., Kentish, J. & Bennett, C. 2007. Students as Active Global Citizens. Zeitschrift fur internationale Bildungsforschung und Entwicklungspadagogik. 30 Jahrgang, 1, 17-19

Mattiussi, E., Clifford, M., Short, T. 2013. The Global Dimension in the UK Engineering Curriculum: The EWB Challenge. Proceedings from the Engineering Education for Sustainable Development Conference, Cambridge, September 2013, pp. 61.

Mitchell, C.A. & Baillie, C. 1998. On values, role models, and the importance of being me. Proceedings Annual American Society of Engineering Education Conference, Seattle, pp. 3560 – 3570.

Montgomery, C., Penlington, R., Perera, N., Tudor, J. Wilson, A. 2011. Educating the Global Engineer: Staff and student perspectives on embedding sustainable development practices into the engineering curriculum. Higher Education Academy-Engineering Subject Centre, York.

Paul, R. W. 1995. Critical Thinking-How to Prepare Students for a Rapidly Changing World. Foundation for Critical Thinking, Santa Rosa, California.

Pawley, A. 2012. What Counts as Engineering: Towards a Re-definition, in Baillie, C., Pawley, A. and Riley, D. (eds.) Engineering and Social Justice, Purdue University Press, West Lafayette, Indiana, pp. 59-86.

Rizvi, F. and Lingard, B. 2010. Globalizing Education Policy. Routledge, Abingdon.

Savage, R., Vanasupa, L. and Stolk, J. 2007. Collaborative Design Of Project Based Learning Courses: How to Implement a Mode of Learning that Effectively Builds Skills for the Global Engineer. American Society for Engineering Education. http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCoQF jAA&url=http%3A%2F%2Fdigitalcommons.calpoly.edu%2Fcgi%2Fviewcontent.cgi%3F article%3D1002%26context%3Dmate_fac&ei=U6YUU- mgM42V7Aa6n4DACA&usg=AFQjCNFVNlLttPiSbT5JYtTDVlAi- xC35Q&bvm=bv.61965928,d.ZGU&cad=rja [Accessed 3 March 2014].

Schattle, H. 2008. The Practices of Global Citizenship. Rowman and Littlefield, Lanham, Maryland.

Scheunpflug, A. 2011. Global Education and Cross-Cultural Learning: A Challenge for a Research-based Approach to International Teacher Education. International Journal of Development Education and Global Learning. 3(3), pp. 29-44.

Smith, J. ,Brown, L., Blachhall, L., O'Shea, J. 2010. New Partnerships Linking Universities and NGOs on Education for Development Engineering - Case Study From Engineers Without Borders Australia. Proceedings of the Joint International IGIP-SEFI Annual Conference 2010, Slovakia.

Stearns, P. 2009. Educating Global Citizens in Colleges and Universities. Routledge, New York.

Tallon, R. 2012. Emotion and Agency within NGO Development Education: what is at work and what is at stake in the classroom? International Journal of Development Education and Global Learning. 4(2), 5-22

Tormey, R. 2005. The costs of values: questioning the application of the term in development education. The Development Education Journal, 11(2), 9-11.

Underhalter,E. and Carpentier, V. (eds.) 2010. Global Inequalities and Higher Education – whose interests are we serving? Palgrave, London.

Vitto,C. 2008. Cross Cultural 'Soft Skills' and the Global Engineer: Corporate 'Best Practices" and Trainer Methodologies. The Online Journal for Global Engineering Education. 3(1), 1-5.

FURTHER/SUGGESTED MATERIAL

The following websites provide further background material that looks at pedagogical approaches as to how students learn and engage with global themes and issues.

- www.picturesofsuccess.org - This resource was produced for businesses engaged in wanting to promote understanding about global and sustainability issues but can and has been used by teachers, academics and community groups.
- www.throughothereyes.org.uk - An online resource that looks at learning from different perspectives.
- www.deeep.org - European development education website provides valuable background information and links to various sites and presentations.

PHOTO: 'Power up'. A solar panel is being mounted with help from the members of the village. S.Gross.

CHAPTER **2**

Science, technology, innovation and society

2

CHAPTER 2. Science, technology, innovation and society

2 SCIENCE, TECHNOLOGY, INNOVATION AND SOCIETY

Javier Carrasco, Professor of the Department of Industrial Engineering of the Universidad Politécnica de Madrid.

Miguel Ángel Pantoja, ONGAWA - Engineering for Human Development, President of the Board of Directors.

Carlos Mataix, Director of the Technology and Innovation Development Centre of the Universidad Politécnica de Madrid.

EXECUTIVE SUMMARY

This section is intended to provide a broad perspective of the role played by technique, science and technology in the development of humankind. There is already evidence of tensions and issues arising in various human societies due to the continued acceleration of technological progress. This requires a system of global management which not only addresses technology itself, but also its relationship with society, culture, economy and the environment. This section describes the main concepts, actors and interrelations that should be taken into account when governing the particularly complex process of technological change.

LEARNING OUTCOMES

After you actively engage in the learning experiences in this module, you should be able to:

- Provide a broad historic perspective of the evolution of science and technology.
- Identify the social and environmental effects of scientific and technological progress.
- Clarify the main institutional factors that shape the priorities of scientific and technological systems.
- Describe the importance of more inclusive and sustainable pathways for innovation.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- Science, Technology and Society
- Technology and Human Development
- Innovation for Development
- Pathways for sustainability

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- How could science and technology contribute to build a more sustainable society?
- Can we build new pathways to lead innovation towards addressing people's real concerns and supporting the most vulnerable societies?

'Engineers should be thus aware that *becoming* an engineer is not enough to be an engineer'

José Ortega y Gasset, Meditación sobre la Técnica [emphasis added].

HUMAN NEEDS AND ASPIRATIONS

Human evolution on earth has been a long process during which men and women have progressively learned how to meet their survival needs – such as food, shelter or defence from other predators – by using natural resources. At the early stages of this process, such resources were found in their immediate environment and it was relatively easy to adapt them to the intended use.

As human groups started growing in size, in occupied land and in accumulated experience, new needs appeared and, consequently, new materials and ways to transform them were used in order to survive. Gradually, human beings start learning to anticipate future risks and also actions to address them: making an effort now in order to have less problems and increased happiness or comfort in the future. This also means greater self-awareness, including a deeper awareness of one's relationship – present and future – with the environment. The future then appears open to imagination: different mental images of individuals and human groups in different environments, both known or unknown. The issue of decision-making arises, followed by the issue of acting: the future will be shaped by our most utopian ideal and the actions undertaken to achieve this.

Human beings are no longer satisfied with meeting immediate needs, but strive for 'well-being': pleasant sensations including love, recreation, art, spirituality, etc. They have 'aspirations', specifically human needs, and a 'project' guiding their activity, both as individuals and as a human group.

TECHNIQUE AND TECHNICAL DEVELOPMENT

Techniques[1] are enabling. To achieve their aspirations, human beings tend to be very resourceful; employing anything they can to help them meet their goals. Some methods of working, however, require further knowledge: an embedded set of skills to allow the user to

---

[1] For an explanation of the use of the word 'technique' in this context, please see Agazzi, 1998. To summarize: "By technique we usually mean a display of practical abilities that allow one to perform easily and efficiently a given activity…we also use technique as a collective noun, indicating the very wide spectrum of such simple techniques. In some contexts, these are sometimes indicated by the old-fashioned term technics. … . Any such technique is essentially the able application of a certain know-how, which has been constituted through the accumulation and transmission of concrete experiences…without being necessarily accompanied or supported by knowing why such concrete procedures are especially efficacious." (Agazzi, 1998).

employ resources more efficiently. Historically, the term 'artisan' was used to describe individuals within societies who possessed enough skills and knowledge to be able to manipulate resources effectively enough to meet human goals.

From this emerged the process of specializing work, and, perhaps concurrently, the process of managing specialized workers. The management of workers involved defining the results to be attained, articulating the activities undertaken by different people and distributing the outcomes in benefit of all. This how organization originated, with differentiated roles and corresponding hierarchy (for a precise concept of organization, see Ackoff, 1971). More effective modes of organization make possible the growth of human groups. These groups were initially scarce but gradually became larger, developing and shaping complex societies. An increase in size comes hand-in-hand with a larger occupied territory, more contact with other human groups, the discovery new resources, the exchange of products and the spread of skills and techniques.

A focus on European technological history shows that technics and machines from various different cultures were gradually introduced and adapted: the waterwheel, previously used by Egyptians and Sumerians; the windmill from Persia; the compass, gunpowder and paper from China, etc. (Mumford, 1962). In 1440, Gutenberg developed a printing press with mobile type pieces, allowing cheap edition of books and thus quick and spread knowledge diffusion. A peak in the introduction of machines and technical devices is reached in the 16th century with the works of Leonardo da Vinci and his contemporaries. Furthermore, cultural changes were underfoot that would in the future enable further technical development: a new concept of time, a new vision of spatial relationships and the emergence of capitalism in northern Italy – moving from a barter economy supported by local currencies to an economy based on money and international credit , among others (Mumford, 1962).

In this context, the development of machinery, particularly in the textile industry, gave rise to a method of organizing production of major importance: the factory. By the middle of the 18th century, when Europe was full of factories mechanised by hydraulic energy, the so-called 'Industrial Revolution' took off in Great Britain. Based on coal power, poorly paid labour and difficult living conditions, it lasted until the middle of the 19th century. So far, modern science, which could be said to have originated in the 17th century, does not play a major role in technical development.

THE INCEPTION OF MODERN SCIENCE

In parallel to the focus on meeting their needs and aspirations, and the consequent technical development, human beings have tried ever since their origins to create mental images in order to understand things out of reach of immediate experience. This type of knowledge constitutes what is known as religion, philosophy or weltanschauung. Armstrong (2006) analyses four main schools of thought that flourished around 900-200 BC in four separate regions of the world and that still form the basis for modes of current thought: Confucianism and Taoism in China; Hinduism and Buddhism in India; monotheism in Israel; and philosophical rationalism in Greece.

In Europe, the Christian religion, permanently interrelated with a strain of philosophical thought deeply rooted in Greek rationalism, formed to a great extent the philosophical mainstream until the 17th century, when technological development and the evolution of thinking were mature enough to originate what it is currently known as science or modern science (Kuhn, 1962, characterizes this shift as a change of paradigm), which has been so influential in human development up to the present day.

As stated by Russell, 1964, the most relevant elements regarding the emergence of science are the contributions by:

Copernicus (1473-1543), hypothesized that the Sun is in at the centre of the universe and the earth performs a double movement: a daily rotation on its axis and a yearly circuit around the Sun.

Kepler (1571-1630) wrote down the positions of the planets for many years and kept a catalogue of stars. He adopted the heliocentric theory and benefited from fellow astronomer Tycho Brahe's data on planet position which eventually led him to develop laws of planetary motion. The significance of Kepler's work lies in the fact that from observed data he deduced laws concerning the behaviour of Nature. He also overcame the prevailing aesthetic prejudice coming from the Greek school of thought since Pythagoras, introducing thus the possibility of a scientific thinking that is unconstrained from the bonds of traditions, prevailing philosophy or religious beliefs.

Galileo (1564-1642) is considered with Newton to be an important founder of modern science. He described acceleration as a change in velocity, postulating that a body moving freely will continue in the same direction at constant speed unless disturbed and any change in this motion must come from the application of force. This was contradictory with the established ideas by the time that it was natural that celestial bodies run in circles and terrestrial bodies in straight lines, but at a diminishing speed until stopping. Later on, Newton would express this phenomenon as the First Law of Motion or Law of Inertia.

Newton (1642-1727) completed the process initiated by Copernicus, Kepler and Galileo by integrating Galileo's kinematics with Kepler's laws of planetary motion and proving that planets' acceleration towards the Sun is inversely proportional to the square of their distance from it. He defined force as the cause of changes in motion and stated his famous law of universal gravitation. These advances allowed physical sciences to be consolidated as one school of thought.

Descartes (1596-1650): The philosophical contributions of Descartes would eventually help crystallize the impact of Newton's discoveries on the entire system of scientific thinking. He was influenced by new ways of thinking in physics and astronomy and aimed to create a philosophical system ex novo, based on his certainty that he could not be misled about the fact that he was thinking: the famous phrase 'I think, therefore I am' formed the basis of his philosophy. In the second part of his Discourse on the Method, Descartes lays out four rules of thought to guide knowledge. Briefly stated, these are:

- Never to accept anything for true without having known with evidence to be such;
- To divide each of difficulties under examination into as many parts as necessary for its adequate solution;
- To conduct my thoughts step by step, from the simplest objects to the more complex;
- To make enumerations so complete, and reviews so general, as to be assured that nothing was omitted.

Conclusions for Science

As a result of the works carried out by the leading scientists described above, the 17th century left a legacy of certainties and expectations in the scientific field, whose main features were:

- Physical science had been endowed with solid foundations;
- The scientific method had been established as a primary tool available to scientists – the idea that observation provides evidence and enables new theories to be imagined, which can be used to predict phenomena in practice
- The scientific method opened the possibility to develop knowledge in multiple areas of interest for humanity;
- The scientific knowledge developed as a result will allow new techniques and technology to be developed in order to adapt the environment to human needs and aspirations.

TECHNOLOGY AND HUMAN DEVELOPMENT

Science has always been indebted to technics. At the same time, science promoted technics through the increasing accuracy in calculation and its method of acquiring knowledge. This synergy continues today.

Electrical technology is one of the most significant developments within this process of knowledge-sharing between science and technique. Most of inventions and discoveries – the electric battery, accumulator, dynamo, electroscope, etc. – required to support the electricity infrastructure we currently enjoy came about in the first half of the 19th century. Today, access to electricity is considered to be a human right.

Since the 19th century, technological development derived science has been dramatic in its breadth and scope. In fact, it has permeated the human environment so deeply that in order to become aware of how much daily life in industrialized countries is conditioned by technology it is necessary to stand outside of it. The impact of technology on life in developed countries becomes more apparent when considered in parallel to living conditions in the least technologically/economically developed countries.

This thought exercise raises the issue of the relationship between technology and human development. What kind of technology should be developed, in order to facilitate human development? What would be the risks involved in so doing, if any? What would be its purpose of such technology? What kind of human development would it aim to achieve? What type of society would it aim for? To whom would it be directed? Who would be the decision makers?

Unfortunately, there are no simple right or wrong answers to these questions. Different theories can be used to address them in part, but these may add an additional layer of complexity. For example, when considering the question asking what is meant by the term "human development", one can assume that a comprehensive definition of the term would no doubt include references to the economic development of the humans in question. There are, of course, many lenses through which we can view economic systems (liberal, Keynesian, Marxist, humanist, etc.) and each one of these represents a unique direction or pathway towards human development.

Until recently, the success of technology in solving a variety of human problems had raised expectations of unlimited possibilities where science and technology was concerned. Technological advancement became a simple matter of investing the appropriate amount of time, effort and resources. However, the intensive use of the non-renewable natural

resources, particularly of fossil fuels, has led to a collective wake-up call. The first one came following the publication of the Meadows Report (1972) describing on the limits of growth at (then) current consumption levels. Since then, scientific reports and international meetings provide incessant warning that modern lifestyles, technological development and the distribution of wealth should be reoriented.

The weight of evidence against our unstable lifestyles makes it necessary to change the paradigmatic vision of what it means to be a human being on planet Earth. The paradigm that triumphed with the advent of rapid scientific and technological process, beginning in the 17th century brought with it the unrestricted satisfaction of the aspirations of an extra-natural human being through the control and exploitation of nature. It is obvious today that an urgent need exists for a shift in the way we think of ourselves; how we can meet human aspirations in a way that is compatible with sustaining present and future ecosystems ensuring life on this planet.

In contrast to the aforementioned urgent need, the image established in society today and its impacts are described below.

TRADITIONAL VISION OF SCIENCE AND TECHNOLOGY

The main feature of the most widely accepted societal image of science is the commitment to search for the truth. From this stems the following statements about science, also accepted generally without question:

- The scientific method is objective; that is, free from any subjective interference.
- Science is a cumulative process, where new knowledge is added on to the existing base. This development follows its own internal logic.
- Science generates universally valid theories by combining data with logic and reason.
- Scientific knowledge is value-neutral. As the scientific method is objective and logic/reason is systematically applied, results cannot be ethically qualified.
- The only exception to this statement concerns the development or advancement of science, which is considered to be good for humanity, thus receiving a positive general ethical qualification.

Engineering and technology is usually defined as applied science. It follows, therefore, that considerations concerning science also apply to engineering/technology:

- Technology is autonomous, in that only "technological" experts are able to define the direction of technological progress.

- This progress is governed by its own internal rules, which define the alternatives for its development.
- Technology is universal, since it is based on objective knowledge, and therefore may be applied everywhere.
- Due to its value-neutrality, changes produced by technology are partially unavoidable (and thus should be considered as neutral as technology), and partially exogenous, as they depend on how the technology in question is employed.
- This chain of consequences is assumed to be evident:

Better Science ➔ Better Technology ➔ Better Economy ➔ Better Society

Criticism of the Traditional Vision

Since the middle of the 20th century there has been a strong reaction against the established image of science and technology. Beginning in the 1960s, a vigorous critique of this image emerged in academia, especially from the fields of philosophy, history and the sociology of science, which has given weight to a parallel movement from different social sectors. These ideas are slowly arriving in the consciousness of politicians and public institutions.

Academic Criticism

Since the 1960s, a significant body of criticism of the traditional positivist paradigm of science and technology has come from the world of philosophy of science. Its main arguments can be summarized as follows:

- Inductive knowledge is fragile: A finite number of observations cannot form the basis for general statements. Any judgement obtained by induction from experience is therefore of a provisional nature, since experience is always limited.
- Networks of beliefs can fail, bringing down individual hypotheses with them: Hypotheses do not appear independently of each other, but in relation to many others. These take the form of networks of beliefs, which have the potential to fail (or to be proved untrue). For example, many theories in physics in the late 19th century were based on the (ultimately false) hypothesis of 'ether'. These all collapsed when the experiments of Michelson and Morley (1887) (among others) disproved the existence of ether and dismantled the scaffolding on which ether-related hypotheses were constructed.
- The theoretical background of observation: perceptions depend both on impressions and previous knowledge, expectations, prejudices, as well as the

observer's own condition. Whereas data are not dependant on any theoretical contract, theory affects the type and amount of data considered relevant, and thus affects the collection, processing, and interpretation of experimental results/observations.

- Underdetermination: This argument states that, in general, it is always possible to develop an undefined number of theories consistent with the data, but giving mutually incompatible causal explanations.

The above argumentation leads to the assertion of the relative nature of the models justifying theories: given a specific period of time, society and scientific discipline, there may be good reasons for finding some theories preferable to others. This calls into question the concept of science as an absolutely objective, cumulative, neutral, etc. method for creating knowledge and solving problems. Science builds a conceptual world (and, through technology, an environment) from among several potential worlds. The construction of such a world in reality depends on whether or not the significant persons (stakeholders) are convinced after negotiations. Thomas S. Kuhn articulated this idea as the concept of scientific paradigm in his essay The Structure of Scientific Revolutions (Kuhn, 1962).

This does not mean to encourage the adoption of an absolute relativist perspective. Science provides the world with a conventional image, but this does not mean the image is arbitrary. Things may be interpreted in many ways, but not in any way.

The significance of such a conceptual change is that soft facts produced by scientific research are usually the basis for making hard decisions concerning subjects of general concern and with large wide-ranging social impacts. However, scientists, technologists and politicians usually omit these limitations in the public presentation of their works. Indeterminacy, when it cannot be avoided, is presented as incertitude, which can presumably be resolved by improving methods or through greater investment in research.

The distinction between open and closed problems, which can be traced back to Wittgenstein (1921), should be now introduced. In closed problems, answers are obtained by applying a method. Calculating if a road surface may support the transit of certain vehicles is, for instance, a closed problem. In open problems, answers are decided by the application of values. Determining if a highway between two cities should be built is an example of an open problem.

When solving open problems, factual aspects are highly relevant, but it is also essential to show the values at stake. In the above mentioned example, facts such as the size of the affected populations, the geography of the region, available construction technologies and economic costs should all be considered. But the final decision will also be based on values such as the importance of environmental conservation, relative benefits of a collective

transport system versus individual transport, and access of different social groups to the proposed road, among others.

Relativists think that all problems are open problems. Technocrats believe that all problems are closed problems, the most immediate consequence of which is that only experts can discuss and solve problems, as they are the only ones that have the necessary skills and knowledge.

Limitations of Social Constructivism

Social constructivism is a school of thought and research that aims to develop understanding of how science and technology projects are implemented by observing and describing the actors involved, their interactions, the negotiation and decision-making processes, etc. However, these works prove of little value from the point of view of this study, as they don't address the relevant problems raised in this document: how society is influenced by science and technology, and how it controls (or not) the direction of science and technology development.

Social Criticism of Conventional Images of Science and Technology

Since the end of the Second World War, the prevailing spirit of techno-optimism began to decline, especially in occidental societies. This was partly influenced by the 1945 dropping of the atomic bomb on Hiroshima and Nagasaki, which raised awareness among scientists and engineers around the ethical and moral responsibilities concerning their professions. The Russell-Einstein Manifesto in 1955 was a decisive turning point.

Since the late 1950s, however, a number of accidents and abnormal situations within technological systems have raised public alarm and affective public opinion in many countries: explosions in nuclear power plants (England and Soviet Union, 1957), damaging side effects of new medicines (Thalidomide, 1961) (Lenz, 1992), oil spills (southern England, 1967), failures in computer regulatory systems, false red alert in NORAD (United States of America, 1972) (The Nuclear Vault, n.d.), major catastrophes in chemical plants (Bhopal, India, 1984) (Lampierre, 2002), etc.

Many of the incidents deals rely on the capacity of engineers and managers to issue early warnings on associated risks, and thus raise a possible ethical tension between handling the risk in a manner which will benefit society versus in their employers' best interest. Because of this, professional scientific and engineering associations across the world began to take a greater interest in ethical issues affecting their members.

The rise of ecological concern is another social movement which, with others, contributes to change the public image of technology. The publication of Rachel Carson's seminal book Silent Spring (1962) led to a flood of publications on environmental degradation aimed at the general public. The World Wildlife Fund (WWF) was created one year before Silent Spring was published (1961) and the international campaign group Greenpeace in was founded in 1969. Campaigns launched by these organizations do not cover only sectorial issues (such as the protection of endangered species) but also global problems related to the technological systems: concern for the ozone layer (1985) (Maté, 2010), global warming (Rio Summit, 1992), etc.

The Administrative Response

In response to social pressure expressing fear towards uncontrolled technology, a number of university and government bodies were created, including the US Environmental Protection Agency, (1969) and the US Office of Technology Assessment (1972), among others.

It is significant to note that many of the new institutions founded at this time were established in the United States of America. This may be due to the fact that the USA is a large contributor to global scientific research, but may also be related to the vitality of academic and social activism within the country. This leads us to a second relevant observation: that these initiatives mostly occurred in the 1960s and 1970s, feeding off of and into other social movements, such as the Civil Rights movement, the feminist movement, and the Anti-Vietnam war protests.

In the 1980s and 1990s, the political environment in the United States and also in the rest of the world shifted dramatically, moving toward a predominance of so-called neoliberal policies in governance and the economy. During this period, we note few noticeable achievements regarding progress towards greater social control of technology, and those that existed were mostly driven by the UN in the face of US and other countries. Examples of UN sponsored-initiatives include the Montreal Protocol against CFCs (1989), the Kyoto Agreement against Global Warming (1998), and the Earth Summits (1992, 2002).

Despite this apparent slowdown in the forward momentum of the environmental movement, administrative mechanisms such as environment agencies or offices for social evaluation of technology became widespread in industrialised countries and (theoretically) enabled social participation concerning technological development. However, citizens considered that their real capacity to influence key policies irrelevant against economic power such as that which was wielded by governments and corporations during periods of economic neoliberal policies.

And yet, there have been some initiatives in the past few years proving the existence of channels for civic participation in technology policies. There are largely non-institutionalized, non-permanent initiatives, focusing on campaigns for public pressure on governments rather than mechanisms for a social/democratic control of technology. They are limited in effectiveness as decision makers, however, as institutional machinery and direct pressure are required to implement a new, non-technocratic notion of technology.

SCIENCE, TECHNOLOGY, AND SOCIETY TODAY

At this stage, there seems to be no question that the future of humanity will be strongly conditioned by the technology management, particularly its development and implementation. As mentioned above, there are not right or wrong answers to questions surrounding technology management. It is possible, however, to anticipate that the related issues should be analysed under different approaches, following a multidisciplinary methodology. Knowledge from diverse disciplines should be discussed and corroborated.

Technology has been defined above as a technique that is based on scientific knowledge. It is not an isolated process: technology needs to go through a specific process of application to a concrete social reality in order to solve problems or meet human needs. As a result of these processes, some products (goods or services) or processes will be available for certain people or societies within a given geographical area.

This means that one or several social decision-making or implementing actors have somehow predicted the interest (economic, social or environmental) to drive the process of technological development forward and have obtained the means to carry it out. It also implies that the potential recipients of such a technology have decided to use these results and change their behaviour, which ultimately may result in changes in lifestyle with a number of consequences.

The dynamics of this process of continuous change mirrors the dynamics of change in human history. It has been tremendously accelerated in recent decades, and this acceleration will almost certainly increase in the near future.

The main actors in the process of technological development are:

- Governments at different levels: local, regional, national, supranational, global
- Enterprises, particularly financial companies
- NGOs and other civil society organizations
- People, both as users of goods or services and as ultimate power-holders (in democratic societies)

The process of technological development is not always conscious: there are also uncertainties in it, and chance is an ever-present factor. Examples of discoveries resulting from coincidences, or even errors, are well-known. However, this does not mean that the direction of scientific and technological progress should be left up to fate or chance.

Taking the long view of scientific and technological development shows that these have been conditioned by decisions made by a complex network of actors emerging, evolving and acting in accordance with particular power structures highly influential in guiding material resources, creative energy and even values within a society.

An understanding of the complex system surrounding science, technology and innovation is essential to take action in this area, particularly if technology is expected to respond more effectively to current social and environmental challenges.

INNOVATIONS IN HUMAN DEVELOPMENT

As mentioned above, the novel application of new technologies is essential for what is commonly known as 'innovation'. Scientific discoveries provide the development of technologies that may generate new – and better – responses for the specific needs of people or organizations.

In this regard, innovation differs from invention, as innovation requires proof of practical use and produces new technologies or processes that become the preferred choice when compared to other options. The distinction is important because it articulates the transformative nature of innovation: its capacity to change and improve the world.

Innovation has gradually become synonymous with success, either individual or collective. Today, it is continuously repeated, mantra-like, that the well-being of national and regional economies is a direct function of the innovation capacity of their communities and institutions.

However, little is known about how to effectively promote innovation. Radical and rapid social transformations, in particular the possibilities for linkages and exchange of information between people and organizations are modifying the 'ecology' of innovation and rendering it even more difficult to predict innovation processes.

In the search for a more human and sustainable development it is important to consider innovation as a concept beyond products and processes. Changes in how human activities are conceived (paradigm shifts) and in the relationship with people targeted by those activities (position) have a great capacity for transformational change leading towards sustainability. New paradigms are often generated by the combination of some elements that

were initially unconnected. The incorporation of peripheral knowledge, which initially could be considered negligible in a subject's 'core' body of knowledge, may become a trigger for innovation.

Behind every discovery lies a path of experiments and tests, which no doubt include many failures. Admitting errors and learning from them is another feature of the most innovative contexts. Organizations engaged with human development, such as development non-governmental organizations (DNGOs) and international agencies, are well aware of this and some of them already practice learning from failure. Every year, Engineers Without Borders Canada includes in its activities report an exhaustive report on errors (EWB, 2011), which is shared with experts, affiliates and program 'beneficiaries'.

Innovation is not the exclusive domain of experts and technologists anymore. The search for new solutions based on the experience, visions and creativity of local communities may be a powerful source of inspiration for long-lasting and locally adapted transformations. In this regard, pioneering projects concerning the fight against poverty and sustainability are arising. For instance, the Grassroots Innovation (2014) initiative promotes the creation of innovative local networks to drive 'bottom-up' solutions that respond to the situation, interests and values of the concerned communities.

Some of the most influential innovations in the history of development and international cooperation have not resulted from the direct transfer of knowledge from donor countries, but they have emerged in the aid recipient countries. Positive Deviance (2014) is based on the hypothesis that in every community there are certain individuals or groups that develop unique behaviours or strategies leading them to better responses to problems that affect the whole community, using for that the same available resources. This has been useful for finding interesting innovations in the field of child nutrition, for example.

Furthermore, 'reverse innovation' can also provide solutions for donor countries. In a recent article for The Guardian newspaper (Carus, 2012), Thane Kreiner, Director of the Centre for Science, Technology and Society, stated that 'if you can serve the poor profitably, you can disrupt existing markets'.

To conclude this section let us list three aspects ("3 Ds") that can be used as a guide for innovation towards social and environmental sustainability. These 3 Ds are included in the Innovation, Sustainability and Development: A New Manifesto launched in 2010 by the STEPS Centre of the Sussex University (STEPS, n.d.) and summarises some of the ideas outlined above.

- Direction: There are different alternatives for guiding scientific and technologic progress, and this fact requires further attention from politics and form research.

- Distribution: Benefits from each alternative may produce different effects among various social groups. All too often, risks and cost concerning an innovation process are shared, while its benefits are concentrated in a few.
- Diversity: The pathway towards sustainability should be based on wider discussions between cultures and communities, making it easier to identify new alternatives and promoting participation in experimenting and developing them.

CONCLUSIONS

The following conclusions can be stated in summary:

- Human history shows that we are constantly modifying our environment in order to meet needs and aspirations.
- Technique is defined as the skills needed to transform the environment. Technique based on scientific knowledge is known as technology. Technology has expeditiously changed our human environment.
- This rapid societal change due to technological development has produced tensions and problems of social and ecological nature, leading humanity to the urgency of raising relevant questions to lead its future.
- Answers to questions regarding technological development are neither simple nor evident, and they involve different actors. Each of these actors has a different knowledge and power to get involved in the governance and management of this complex phenomenon of key importance for a sustainable human future. Dialogue and a constant quest for consensus between the various stakeholders are required to establish policies and behaviours that properly guide this process.
- Innovation processes are complex. Thus, commitment to innovation is not a simple task and is subject to considerable uncertainty, but this may be balanced with its multiplier effects.

BIBLIOGRAPHY

Ackoff, R. A. 1971. Towards a System of Systems Concepts. Management Science. 17:11.

Agazzi, E. 1998. From Technique to Technology: The Role of Modern Science. Philosophy & Technology, 4:2, pp. 1-9.

Armstrong, K. 2006. The Great Transformation, Alfred A. Knopf, New York.

Carson, R. 1962. The silent spring, 1962. Houghton Mifflin, Boston.

Carus, F. The Guardian, 29 August 2012. Available from: www.guardian.co.uk/sustainable-business/reverse-innovation-social-solutions-home [22 February 2014].

EWB, Failure Report, 2014. Available from: http://legacy.ewb.ca/en/whoweare/accountable/failure.html [20 February 2014].

Grassroots Innovation. Available from: http://grassrootsinnovations.org/about/ [20 February 2014].

Kuhn, T. S. 1962. The Structure of the Scientific Revolutions. 1st ed. University of Chicago Press.

Lampierre, D. and Moro, T. 2002. Five past midnight in Bophal. The Epic Story of the World's Deadliest Industrial Disaster. Warner Books, New York,

Lenz, W., 1992. The History of Thalidomide. Available from: http://www.thalidomide.ca/history-of-thalidomide/ [28 February 2014].

Mainelli, M; Harris, H. 2013. The Price of Fish: A New Approach to Wicked Economics and Better Decisions. Nicholas Brealey Publishing. ISBN: 10: 1857885716

Maté, J., The story of the Ozone campaign. September 24, 2010, Greenpeace.org. Available from: http://www.greenpeace.org/international/en/campaigns/climate-change/solutions/solar_chill/The-story-of-the-Ozone-campaign/ [22 February 2014].

Meadows, D. H.; Meadows, D. L.; Randers, J.; Behrens III, W. W. 1972. The Limits to Growth, Universe Books.

Michelson, A.A. & Morley, E.W. (1887). "On the Relative Motion of the Earth and the Luminiferous Ether". American Journal of Science 34: 333–345.

Mumford, L. 2006. Technics and Civilization. Harcourt, Brace & World, New Cork.

Ortega y Gasset, J. 1961. Meditación de la Técnica, 4ªed. Revista de Occidente, Madrid.

Positive Deviance Initiative. See: http://www.positivedeviance.org/. [23 February 2014].

Russell, B. 1946. History of Western Philosophy, George Allen & Unwin.

STEPS, n.d. A New Manifesto, Blog. Available from: http://steps-centre.org/anewmanifesto/ [22 March 2014].

Stirling, A. 2009. Direction, distribution and diversity! pluralizing progress in innovation, sustainability and development. Working Paper. STEPS Centre. Available from: http://sro.sussex.ac.uk/16081/ [20 March 2014].

The Nuclear Vault, n.d. Available from: http://www2.gwu.edu/~nsarchiv/nukevault/ebb371/ [22 March 2014].

Tidd, J.; Bessant, J. 2009. Managing Innovation Integrating Technological, Market and Organisational Change 4th Edition. Wiley.

UNITED NATIONS DEVELOPMENT PROGRAMME (2001) Human Development Report 2001: Making new technologies work for human development. New York. United Nations Development Programme. Available from: http://hdr.undp.org/reports/global/2001/en/ [20 March 2014].

Russell, B. 1946. History of Western Philosophy, George Allen & Unwin.

Visscher, Jan Teun; Quiroga, Edgar; García, Mariela y Galvis, Gerardo, 1997, "De transferir hacia compartir tecnología", en Transferencia de tecnología en el sector de agua y saneamiento, una experiencia de aprendizaje de Colombia, IRC y CINARA.

Wittgenstein, L. 1922. Tractatus Logico-Philosophicus. 1st edition, ROUTLEDGE & KEGAN PAUL LTD., London.

FURTHER/SUGGESTED MATERIAL

The purpose of this section is to provide different kind of materials, preferably available on-line, in order to help participants to deepen the topics and build critical thinking skills (books, chapters, reports, press articles, PowerPoint presentation with or without integrated voice recording, Prezi presentation with embedded videos, interactive documents, interviews, YouTube/iTunes videos Wikipedia entries, etc.).

Below, you will find the websites of some institutions that are now working on technology and innovation for human development. In each, you can find many inspiring documents, blogs, and projects:

Some academic institutions specialized in research on innovation for sustainability:

- STEPS Centre: http://steps-centre.org/
- Stockholm Resilience Institute: http://www.stockholmresilience.org/
- Centro de Innovación en Tecnologías para el Desarrollo Humano: www.itd.upm.es

Some NGO specialized in technology for development:

- ONGAWA: http://www.ongawa.org/
- Practical Action: http://practicalaction.org/
- EWB: http://www.ewb-international.org/

Innovation programs of multilateral organizations:

- Global Pulse UUNN: http://www.unglobalpulse.org/
- R4D (DFID): http://r4d.dfid.gov.uk/
- OEI: http://www.oei.es/ciencia.php

CHAPTER

3

Technology and basic human needs

A.1 Making the case for a critical global engineer

3

CHAPTER 3. Technology and basic human needs

EDITED BY
Global Dimension in Engineering Education

COORDINATED BY
Agustí Pérez-Foguet and **Enric Velo** *(Universitat Politècnica de Catalunya)*
Manuel Sierra *(Universidad Politécnica de Madrid)*
Alejandra Boni and **Jordi Peris** *(Universitat Politècnica de València)*
Guido Zolezzi *(Università degli Studi di Trento)*
Rhoda Trimingham *(Loughborough University)*

WITH GRATEFUL THANKS TO
Boris Lazzarini *(Universitat Politècnica de Catalunya)*
Jaime Moreno and **Elena López** *(Universidad Politécnica de Madrid)*
Jadicha Sow Paino *(Universitat Politècnica de Valencia)*
Angela Cordeiro and **Gabriella Trombino** *(Università degli Studi di Trento)*
Emily Mattiussi, Sylvia Roberge and **Katie Cresswell-Maynard** *(Engineers Without Borders - UK)*

3 TECHNOLOGY AND BASIC HUMAN NEEDS

Carlos del Cañizo, Professor of the Universidad Politécnica de Madrid.
Leopoldo Antolín, Ángel Fernández, Alba Ramos, ONGAWA – Engineering for Human Development.

EXECUTIVE SUMMARY

This session aims to present the role of technology in meeting basic human needs. It is argued that technology plays a key role in human development, either by directly addressing basic needs (in health, nutrition, education, etc.) or by expanding human capabilities through a cross-cutting role (such as is done by energy services, transport, or telecommunication infrastructures). Therefore we should call for the international community to commit to promoting technologies for human development, by first identifying the barriers that complicate the deployment of technological solutions for the poor, and then developing initiatives to help overcome those barriers. Two key technology sectors are presented, one directly linked to basic needs (water and sanitation), the other to cross-cutting impacts (energy). In the case of water and sanitation, important progress has been achieved worldwide in access to water, but not in providing sanitation services. Technological solutions exist, but must be combined with methodologies to involve people in their management, and their link to hygiene practices. In the case of energy, it is important to pay attention to improved cookstoves due to their impact on health, and to electricity, as modern sources of energy with a broad spectrum of applications. The strengths of renewable energy should be highlighted as an environmentally friendly solution for decentralised energy provision.

LEARNING OUTCOMES

After you actively engage in the learning experiences in this module, you should be able to:

- Visualise the role of technology in international human development.
- Understand the social aspects related to the implementation of technologies for human development.
- List the main trends and challenges of some key technologies.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- Technology for human development.
- Technology serving basic human needs.
- Key technology sectors.
- Water and sanitation.
- Energy services.

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- Is technology serving basic human needs for all?
- What are the main barriers to making technology serve human development and how can they be overcome?
- What are the main challenges and the current status of key technology sectors?

INTRODUCTION

While we can instantly share the latest YouTube videos with hundreds of our friends, over 800 million people still suffer from chronic undernourishment. The annual budget of the CERN research infrastructure that recently enabled scientists to prove the existence of the Higgs Boson is in the range of 1 billion Euros yet more than 2.4 billion people lack sanitation. Is technology really serving basic human needs?

There is no straightforward answer to that question. In fact one can as easily cite counter-examples of technologies applied successfully to reduce poverty: the dissemination of antibiotics or the improvements in agricultural techniques in the last decades, and their impact on large population groups in developing countries, cannot be underestimated.

TECHNOLOGY AND HUMAN DEVELOPMENT

In the year 2000, the United Nations General Assembly established the Millennium Development Goals (MDGs), set for 2015. Of these, eight goals and 18 targets aimed to cut poverty by half, addressing extreme poverty in its various dimensions and promoting gender equality, education and environmental sustainability (see Table 1). On the eve of 2015, following the evaluation of the successes and failures in achieving the MDGs, the debate now revolves around what comes next.

Table 1 *Millennium Development Goals and associated targets.*

GOALS	TARGETS
1. To eradicate extreme poverty and hunger	1A: Halve, between 1990 and 2015, the proportion of people living on less than $1.25 a day 1B: Achieve Decent Employment for Women, Men, and Young People 1C: Halve, between 1990 and 2015, the proportion of people who suffer from hunger
2. To achieve universal primary education	2A: By 2015, all children can complete a full course of primary schooling, girls and boys
3. To promote gender equality and empowering women	3A: Eliminate gender disparity in primary and secondary education preferably by 2005, and at all levels by 2015
4. To reduce child mortality rates	4A: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate
5. To improve maternal health	5A: Reduce by three quarters, between 1990 and 2015, the maternal mortality ratio

	5B: Achieve, by 2015, universal access to reproductive health
6. To combat HIV/AIDS, malaria, and other diseases	6A: Have halted by 2015 and begun to reverse the spread of HIV/AIDS 6B: Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it 6C: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases
7. To ensure environmental sustainability	7A: Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources 7B: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss 7C: Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation 7D: By 2020, to have achieved a significant improvement in the lives of at least 100 million slum-dwellers
8. To develop a global partnership for development	8A: Develop further an open, rule-based, predictable, non-discriminatory trading and financial system 8B: Address the Special Needs of the Least Developed Countries (LDCs) 8C: Address the special needs of landlocked developing countries and small island developing States 8D: Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term 8E: In co-operation with pharmaceutical companies, provide access to affordable, essential drugs in developing countries 8F: In co-operation with the private sector, make available the benefits of new technologies, especially information and communications

The point here is not to debate the value or appropriateness of the MDGs; it is to note that if they represent the consensus on what is to be done to reduce poverty and satisfy basic human needs, it seems at first sight that technology (at least, the common understanding of technology) is not often explicitly mentioned in the goals, except for Goal 7 and some of targets in Goal 8. The fact that technology can be a key tool in achieving most of the MDGs, or even a key tool in addressing most of the dimensions of poverty, and hence in satisfying basic human needs, seems to have been overlooked.

The United Nations Development Programme (UNDP) itself commissioned a reflection on the role of technology in human development, and later even linked the fulfilment of the MDGs to technology development in a document that will serve as a guide for this section [UNDP, 2001]. As stated in the UN Millennium Project,

"The key to overcoming the poverty trap is to raise the economy's capital stock—in infrastructure, human capital, and public administration—to the point where the downward spiral ends and self-sustaining economic growth takes over. This requires a "big push" of basic investments between now and 2015 in key infrastructure (roads, electricity, ports, water and sanitation, accessible land for affordable housing, environmental management), human capital (nutrition, disease control, education), and public administration." [Sachs et al, 2005].

How can we describe this key role of technology in human needs satisfaction? Figure 1 sketches the UNDP's vision of how technological changes build human capabilities, and hence improve human development. Some technologies directly impact these human capabilities, such as water facilities that reduce waterborne diseases, or breeding techniques that increase the efficiency of food production. Others influence development indirectly through economic growth and improved productivity: an increase in economic resources can be invested in basic needs such as education or health, or even in the further development of technologies. The link also works in reverse: the development of human capabilities can result in the proposal of innovations and new technologies.

Building human capabilities
To live a long, healthy life
To acquire knowledge and be creative
To enjoy a decent standard of living
To participate in the social, economic and political life of a community

Resources for education, health, communication
Employment

Knowledge Creativity

Advances in medicine, communications, agriculture, energy, manufacturing

Economic growth

Resources for technology development

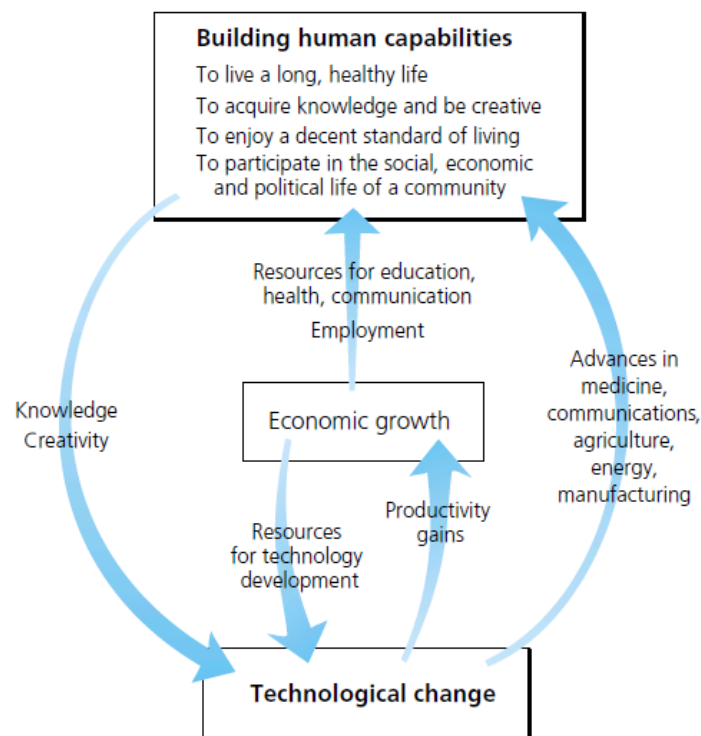Productivity gains

Technological change

Figure 1 *The virtuous circle of technology and human development*

For the purposes of this chapter we define "technology serving basic human needs" as technology directly linked to human capabilities or human development (whereas medicine, communications, agriculture, energy and manufacturing are explicitly mentioned in the

sketch, we could add others such as water, sanitation, housing, etc.) The importance of the indirect link should not be disregarded however; productivity gains in textile manufacturing or in commerce as a result of the introduction of technology can also contribute to human development if the additional economic resources are in turn invested in basic needs, for instance.

Figure 1 shows a virtuous circle, led by a notion of continuous and incremental progress. This cycle however does not seem to be implemented with real success, taking into account the widespread distribution of poverty and the expansion of inequality around the world. For many this may not come as a surprise: technology is no more than a social product, and as such it responds to the demands and priorities of society. And as the dominant tendency has not been to focus on poverty eradication but better satisfy the needs of the wealthy, technology, in general terms, has been at the service of the needs of the wealthy.
Nevertheless there seems to be some political will, supported by statements such as that of the UN Millennium Project cited above, which may serve to focus technology on human development and basic human needs.

Table 2 introduces a tentative list of technology areas to explore. Note that we have omitted the health technology sector (vaccines and other medicines) because we consider it deserves to be dealt with separately.

Table 2 *Classification of main technologies for human development*

AREA	TECHNOLOGY SECTOR
Basic services	Infrastructures for education
General purpose infrastructures	Transport Energy services Information & Communication (ICT)
Production	Agriculture, stockbreeding, fishing Forestry Industry
Multi-sectorial	Environmental protection

Even if these claims were properly addressed, and the political will to prioritise the development of technologies for basic needs extended to the international community, there would remain a number of barriers to making the promises of technology a reality. The UNDP highlights four in its 2001 report:

Different needs in health, agriculture and energy. Many of the technologies necessary in agriculture, health and energy differ significantly in temperate and tropical climates. Many technological solutions developed by industrialised countries address their own context, and cannot be transferred directly from temperate to tropical areas.

Low incomes, weak institutions, scarce infrastructures. Low incomes, low literacy and skill levels, unreliable power supplies, and weak administrative infrastructures all point to a missing solid basis on which to adopt and adapt technologies designed for rich countries.

Global markets, global pricing. In a global market, it is common to establish a similar price for a product in all countries, which may keep the latter out of reach of the poorest nations. A better strategy for a sophisticated technological product (such as a drug for HIV/AIDS) could be to divide the global market into different groups according to their purchasing power. But fears of re-imports and of the negative reaction of those paying more for the same product lead to the maintenance of high global prices.

Weakness of technological capacity. By technological capacity we mean the ability to develop new technologies, or to adapt imported technologies, which may be necessary to address the basic needs of a population. For this technological capacity to exist a country must first develop a solid education system (including higher education levels) and an appropriate environment for research, development and innovation.

To overcome these barriers, important efforts should be made on both the institutional and regulatory fronts. The UNDP lists basic guidelines when designing a roadmap on technology for basic needs:

- Improve basic public infrastructures: water, sanitation, energy, transport and telecommunications.
- Improve the quality of the educational system, specifically in science and technology.
- Network with universities at the regional and global levels.
- Take advantage of the exodus of professionals, mobilising them where they are in favour of the development of the country of origin.
- Strengthen professional competence in the labour market, investing in training.
- Promote technology innovation, designing national policies based on the identification of priority technology sectors, and investing in them.

The UNDP also proposes a number of global initiatives to build technology for human development:

Creating innovative partnerships for research and development, gathering public, university and private efforts. This triple intertwining strategy is at the heart of new approaches to creating technology or taking advantage of existing technologies. But it must be carefully balanced, with each partner focusing on its mandate and comparative advantage.

Managing intellectual property rights. A balance between incentive for innovation and public interest should be reached, to avoid making intellectual property a barrier that prevents widespread benefits from technology advances.

Expanding investments in technologies related to poverty eradication and human development. Because private research tends to be motivated in part by economic benefit, public funding is essential to develop applications the market cannot finance, and policy-makers must take the lead in promoting them, working closely with the industry.

Providing regional and global institutional support. Without international cooperation, many public goods will be undersupplied in national markets or missed altogether. Both regional and global initiatives are necessary.

These reflections on the role of technology for human development, led by the UNDP, have had an impact in international, regional and national policies, and while there is work yet to be done, some forward steps have been taken. In the next section, we will show to what extent this is true by analysing two technology sectors: water and sanitation, followed by energy services. We have chosen them as representative examples of two different types of technologies: those with an immediate impact in health and hence in human development and those with a cross-cutting nature serving a broad spectrum of needs.

TECHNOLOGY SECTOR 1: WATER AND SANITATION

The scope of the problem

Water and sanitation is one of the primary drivers of public health and is crucial to the preservation of human health, especially among children. Water is a basic need: it is used for consumption, basic sanitation, personal hygiene, food production and cleaning.

Water-related diseases are the most common cause of illness and death among the poor of developing countries. The lack of a safe water supply and inadequate sanitation and hygiene are closely related to the presence of diseases like diarrhoea, malaria, schistosomiasis, trachoma, intestinal helmintos, among others. According to the World Health Organisation

(WHO) 1.8 million people die each year from diarrhoeal diseases (including cholera) and 1.3 million people die of malaria, 90 per cent of whom are children under five.

A better management of water resources, safe access to water and sanitation facilities and better hygiene practices reduce morbidity significantly. Access to safe water and sanitation is also fundamental for achieving dignified life, access to education and work opportunities and will also contribute to development and economic growth.

Some of the benefits of safe access to water and sanitation for various age groups include:

- 0 to 4 years: reduced child mortality.
- 5 to 14 years: increased school attendance, enabling children to escape poverty.
- 15 to 59 years: productivity gains.
- Over 60: increased life expectancy.
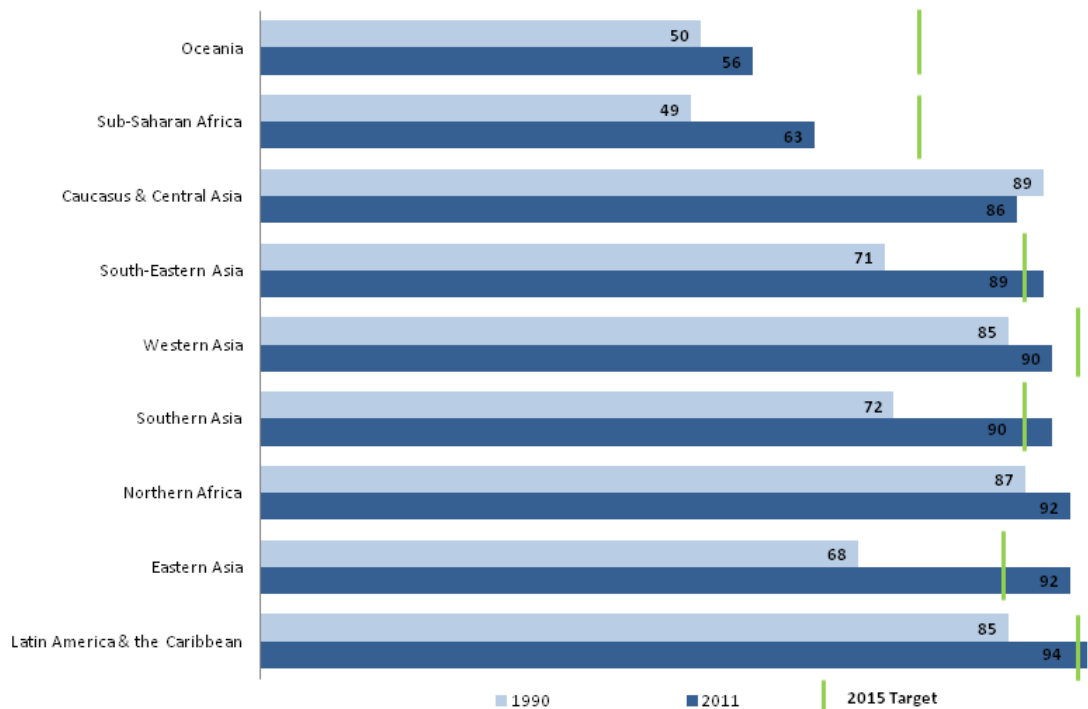
Figure 2 *Percentage of population using an improved water source, 1990 and 2011 [UNDP, 2013]*

Current state of affairs

According to the "Millennium Development Goals Report 2013" [UNDP, 2013], over the past 21 years more than 2.1 billion people gained access to improved drinking water sources. In 1990, 76 per cent of the global population had access to an improved drinking water source; in 2010 the proportion reached 89 per cent. Despite the progress, 768 million people still

drew water from an unimproved source. Figure 2 shows the improvements in water access between 1990 and 2011 in different regions of the world.

Drinking water coverage has increased in all regions except the Caucasus and Central Asia. Sub-Saharan Africa and Oceania are the regions with the least drinking water coverage and 83 per cent of the population without access to an improved drinking water source (636 million) live in rural areas. Figure 3 shows the percentage of the population using improved sources of drinking water in 2011.
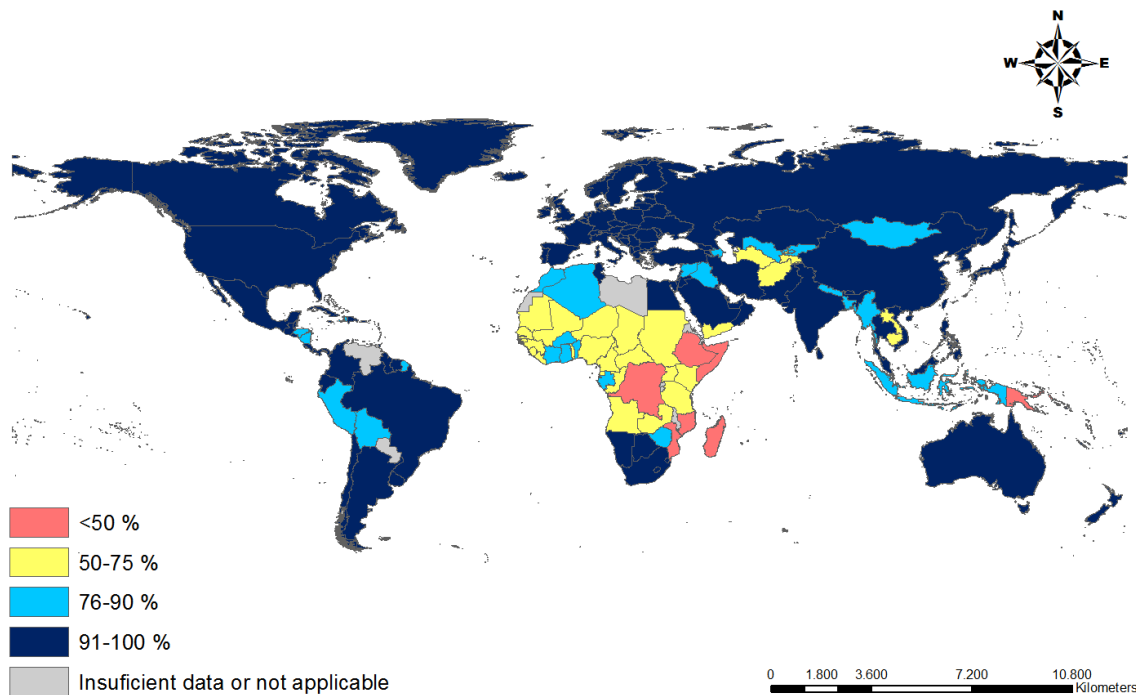
Figure 3 *Percentage of the population using improved sources of drinking water in 2011 [Cañizo et al. 2014].*

Many so-called "improved" drinking water sources are not considered safe due to poor water quality. Therefore the number of people without access to safe drinking water may in fact increase to two to three times the official estimates, with many developing countries currently represented on the map in yellow or blue turning red.

In terms of sanitation more than 2.5 billion people lack improved sanitation facilities, of which one billion continue to practice open defecation. From 1990 to 2011, 1.9 billion people gained access to a latrine, flush toilet or other improved sanitation facility. The greatest progress was made in Eastern Asia, where sanitation coverage has increased from 27 per cent in 1990 to 67 per cent in 2011.

Sub-Saharan Africa and Southern Asia are the regions with the lowest sanitation coverage. In Sub-Saharan Africa, 44 per cent of the population use either shared or unimproved facilities, and an estimated 26 per cent practice open defecation while in Southern Asia, the proportion of the population using shared or unimproved facilities has declined to 18 per cent but open defecation remains the highest of any region (39 per cent).

Figure 4 shows the percentage of population by sanitation practice in 1990 and 2011. Many have improved their sanitation conditions but the improvements are not significant enough to reach the MDG target in sanitation.
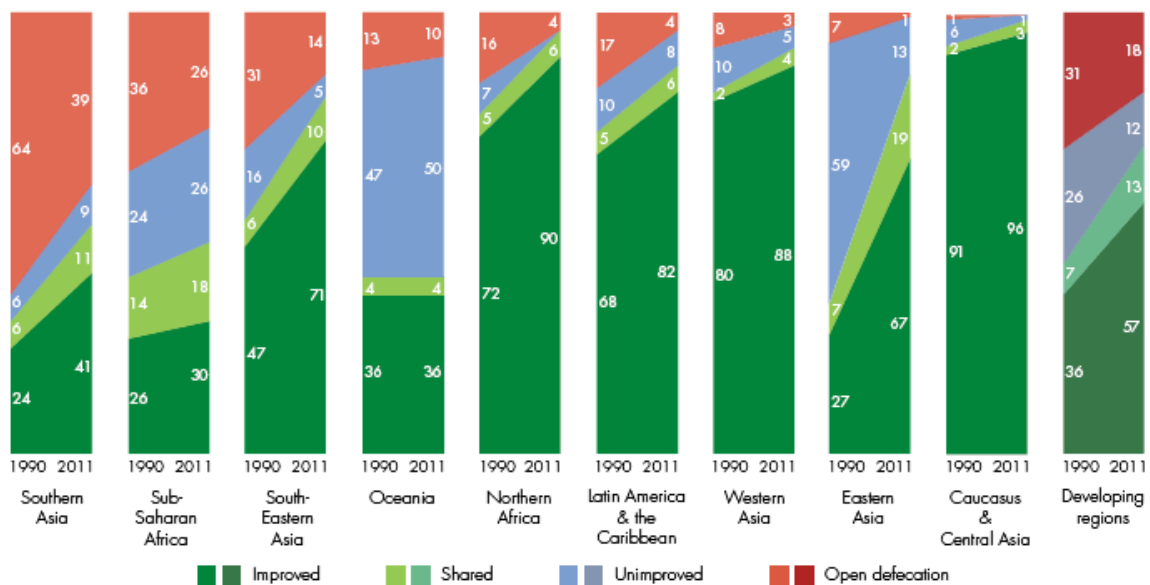

Figure 4 *Percentage of population by sanitation practices [UNDP, 2013]*

Priority interventions and future challenges

The priority interventions focus on the improvement of sanitation practices. No one should practise open defecation and everyone should have access to a sanitation facility at home. With regards to drinking water supply, poor water quality is an important issue to solve. All schools and health centres should have water and sanitation, while also promoting good hygiene.

The 2010 UN General Assembly explicitly recognised the human right to safe water and sanitation and acknowledged that they are essential to the realisation of all human rights. This resolution has changed the approach to water and sanitation projects and has defined the terms of water and sanitation access. The new criteria for good practices related to water and sanitation address five key aspects: availability, quality and safety, acceptability, accessibility and affordability [de Albuquerque et al, 2012].

For the new development aid "post-2015 agenda", the following challenges are being considered:

- Achieving universal access to water and sanitation.
- Water resources protection.
- Risks management: floods and drought prevention.
- Citizen participation in managing water.
- Efficient use of water resources.

Some appropriate technologies and methodologies

The intervention approach for water, sanitation and hygiene (WASH), sketched in Figure 5, combines the implementation of water infrastructure with awareness campaigns of basic hygiene practices, including promoting the construction and use of latrines. The positive impact on health is increased when water projects are coupled with sanitation and hygiene practices education. [Ramos et al, 2013].
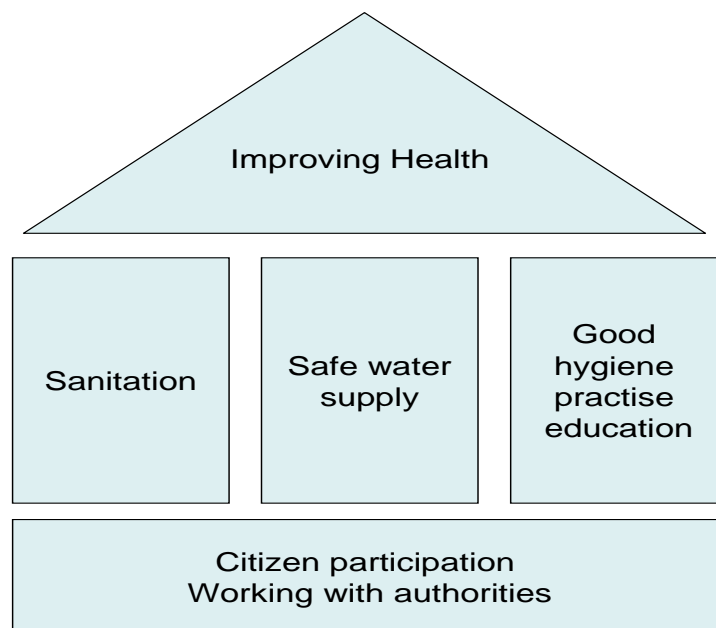

Figure 5 *Intervention model for water, sanitation and hygiene*

Water and sanitation facilities must be functional for a considerable period of time. In order to be sustainable the technologies should:

- Be acceptable to users.
- Be understood by those responsible for their operation and maintenance.
- Be affordable for users (operation and maintenance costs).
- Be locally sourced.

Technologies for water supply

Water resources are collected from rainwater, shallow and deep wells, catchment from rivers and lakes and from springs.

Rainwater. Generally collected from the roofs of houses or community buildings which must be cleaned frequently. The water is stored in a nearby tank.

Groundwater. Sometimes the only option. Groundwater levels do not vary as much as surface water levels do, and is therefore a good option for areas where droughts are frequent. The groundwater catchment requires an initial investment for drilling and well-building, and to implement a pumping system; the latter must be designed according to the users' needs and should be affordable. Rural populations in developing countries are often small, isolated and have limited purchasing power. For this reason they tend to use hand pumps as they are the most cost-effective option. The most common models are rope pumps, suction pumps, drive pumps and ram pumps.

Surface Water. The catchment area should be in a non-seasonal spring, one that maintain the flow throughout the year. The spring must also be adequately protected from potential pollution sources.

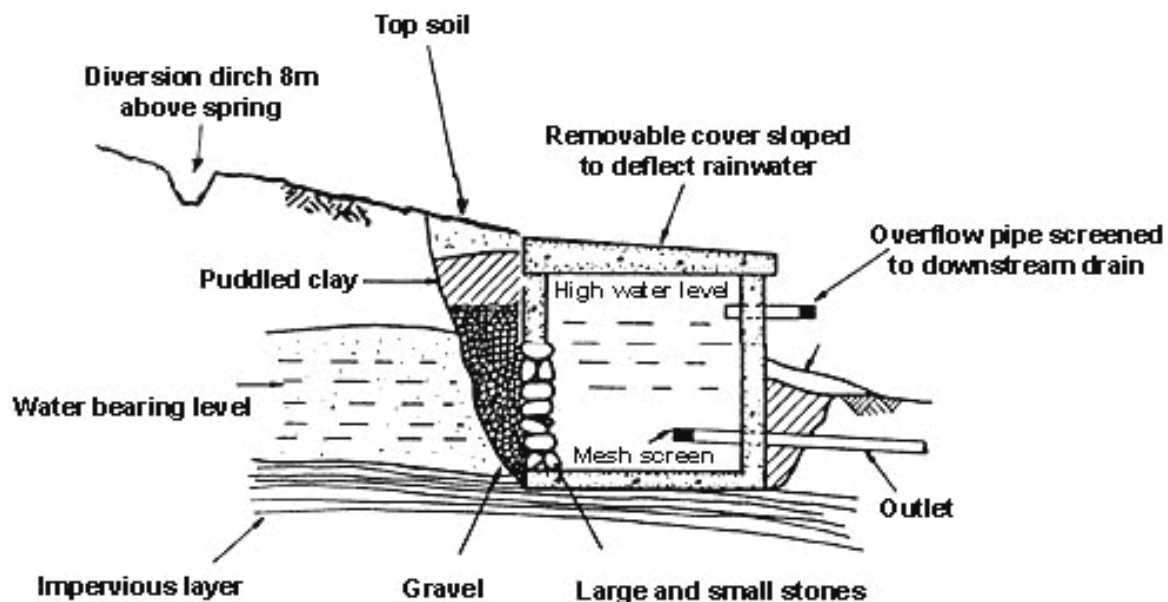Figure 6 shows a diagram of the technical characteristics of a spring catchment.

Figure 6 *Cross-section of a spring tank*

Technologies for basic sanitation

In rural and marginal urban areas, basic sanitation is usually provided by latrines. The Ventilated Improved Pit Latrine is the most used technology (see Figure 7 below). It differs from traditional latrines by its long vent pipe which prevents the entrance of insects and the exit of bad odours. The action of wind blowing over the top of the vent pipe creates an up-draught of air, which flows up the pipe. The air circulates in the pipe and through the hole in the cover slab, preventing the unpleasant odour from escaping. The vent pipe is covered with a fine gauge mesh to prevent the entrance of insects. The interior of the latrine superstructure requires a permanent superstructure with a roof.
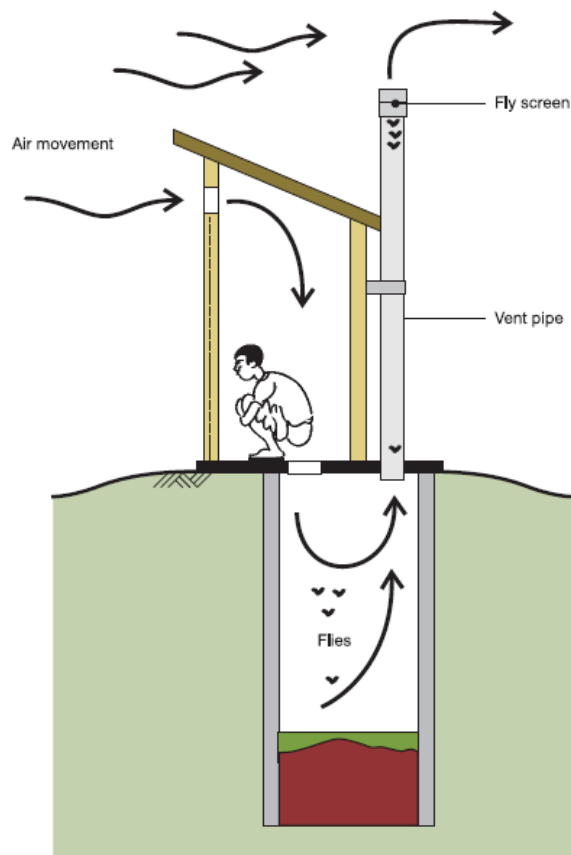
Figure 7 *Ventilated Improved Pit Latrine*

Methodologies for hygiene promotion

In order to improve hygiene practices, to educate and to promote proper hygiene behaviour, various participatory methods can be considered [Peal et al, 2012], [Gibbs et al, 2002].

Participatory Hygiene and Sanitation Transformation (PHAST) is a participatory learning methodology seeking to help communities improve hygiene behaviours, reduce diarrhoeal diseases and encourage effective community management of water and sanitation services. This methodology establishes participatory activities to be developed within the community.

Community Health Clubs (CHC) are free voluntary, community-based organisations formed to provide a forum for information and good practice relating to improving family health. They vary in size and composition from 40 to 200 people, men, women and children of all educational levels, and are facilitated by a health worker trained in participatory health promotion activities.

WASH in Schools aims to provide children with an effective and healthy learning environment and change the hygiene behaviour of school children.
Child-to-Child is an approach to health promotion and community development led by children. It is based on the belief that children can be actively involved in their communities and in solving community problems.

Summary

In conclusion, the international community has agreed that access to water and sanitation is a human right, and we can say that in the context of the MDGs important progress has been made in the access to water. The same is not true however of providing sanitation services. Technological solutions exist, but emphasis should be placed on the intervention approach, linking water and sanitation with hygiene practices, and promoting the participation of all stakeholders in the process.

TECHNOLOGY SECTOR 2: ENERGY

Current state of affairs

Approximately 22 per cent of the world's population (1.5 billion) has no access to electricity. Additionally, natural biomass (wood, charcoal and animal or agricultural waste) is the only source of energy of nearly 40 per cent of the world population (2.7 billion). Over 95 per cent of those in this latter group live in Sub-Saharan Africa or in developing regions of Asia, as shown in Figures 8 and 9.
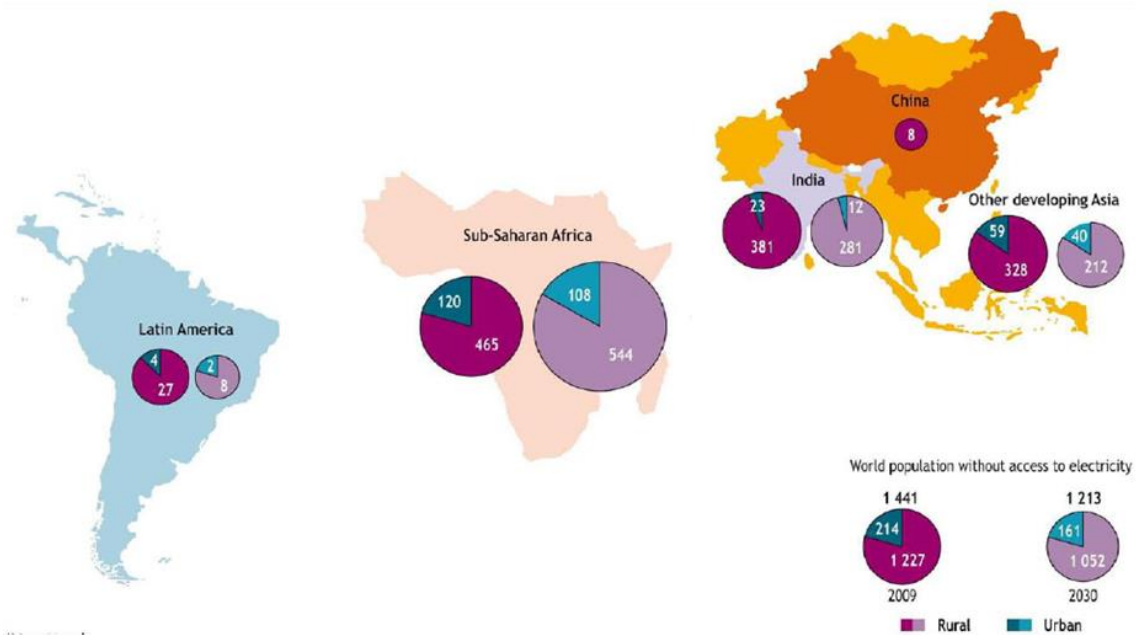
Figure 8 *World population lacking access to electricity [IEA 2010]*
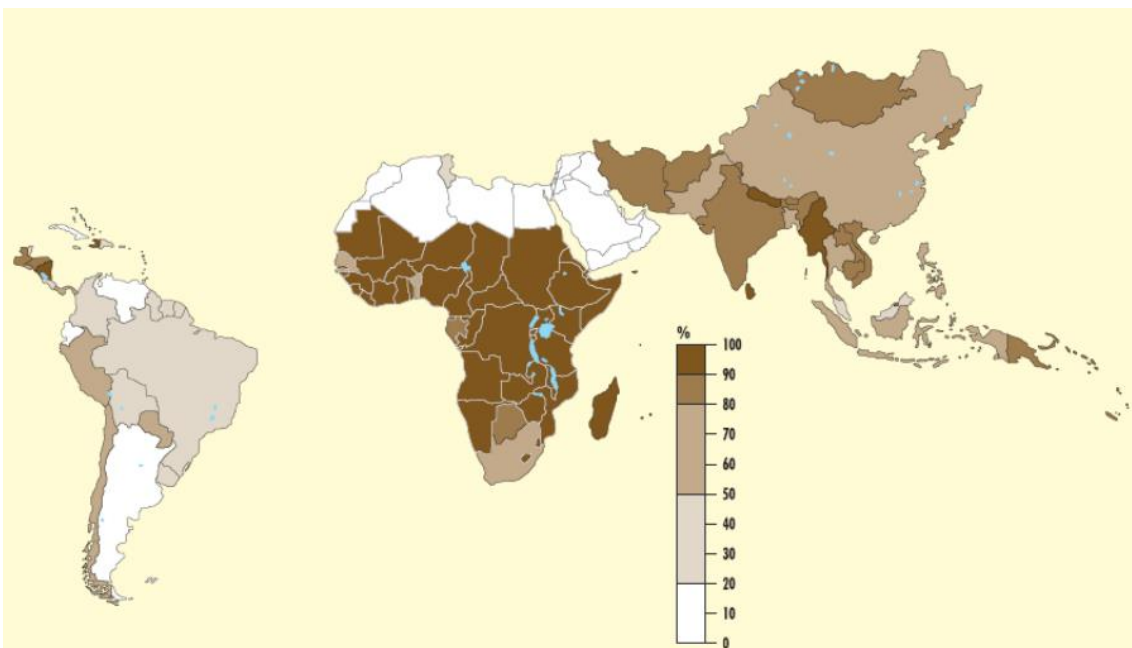
Figure 9 *Percentage of population dependent on natural biomass [IEA 2006]*

There is strong evidence to suggest that access to modern energy sources, especially electricity, is essential to overcoming poverty [UNDP, 2005]; Figure 10 indicates that countries where the electricity consumption per capita is lower also rate lower on the Human Development Index (HDI). There is solid evidence that having access to electricity and not relying on biomass as a unique energy source decreases the prevalence of respiratory diseases and gender inequalities. For example Figure 11 shows the impact of household air

pollution (mainly due to reliance on biomass) on premature annual death rates compared with other major diseases.
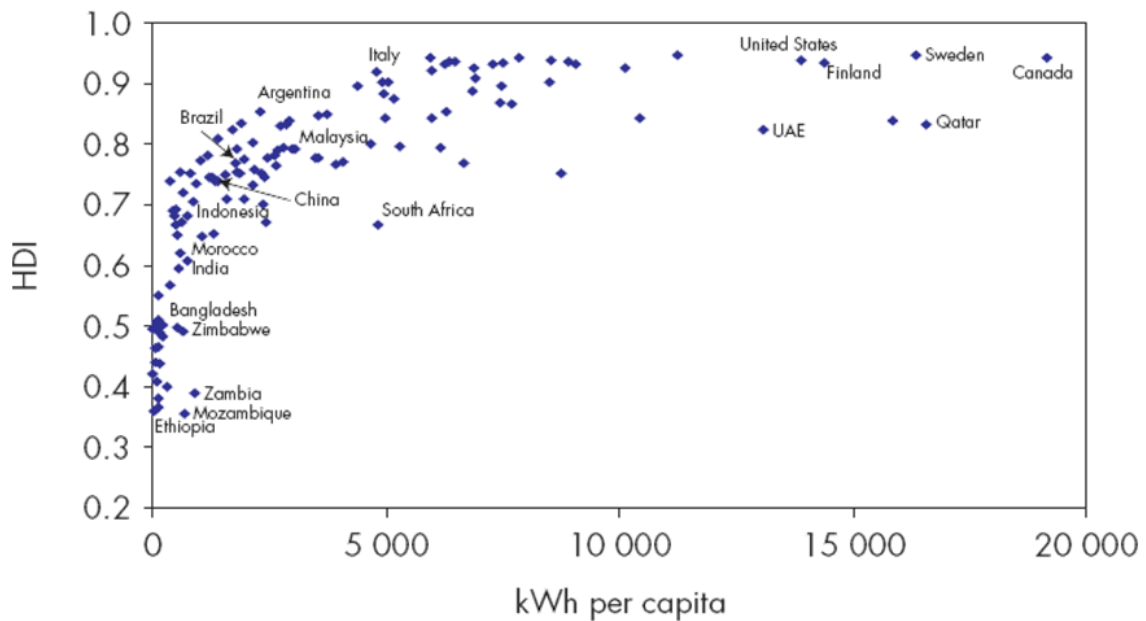
Figure 10 *Relation between Human Development Index (HDI) and annual electricity use per capita [IEA 2004]*
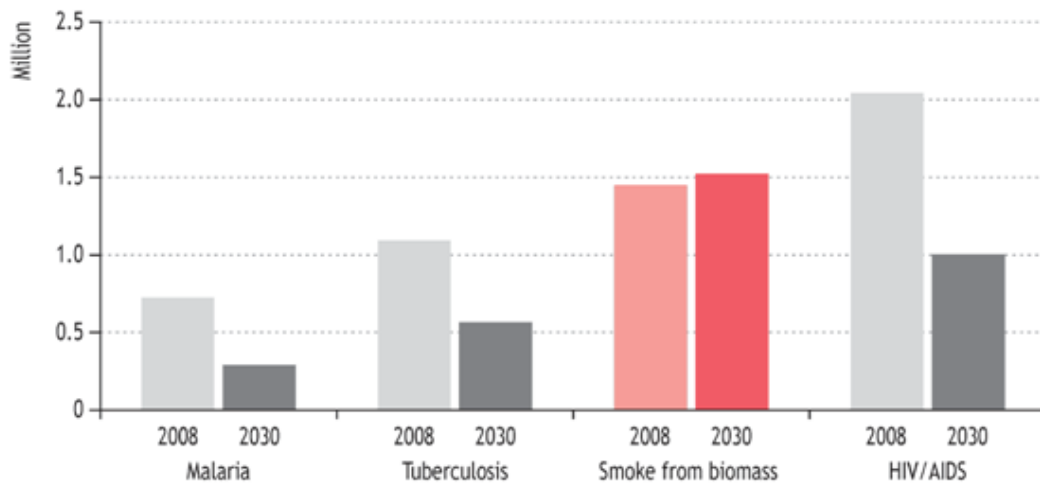
Figure 11 *Premature annual deaths from household air pollution and other diseases in 2008, and WHO projections for 2030 [IEA 2010]*

The UNDP considers an electricity consumption of 0.5 kWh/day per capita necessary for a decent life. This figure is around 0.22 kWh/day in the poorest countries, while in the richest countries this number is one hundred times higher: 22 kWh/day.

Reducing such inequality is not so much a technical or economic issue, but a political one. Universal access to electricity would be reached by 2030 with only an additional 3 per cent of the global energy investments planned until then. In this respect, it is also critical to address the sustainability of the energy sources: renewable energies are essential to addressing this challenge and combatting climate change [IEA 2013].

Priority interventions

The MDGs should inspire the priorities in the field of energy. Priority should be given to community, social and productive uses, and always consider appropriate technologies.

Taking electricity as an example, the following are considered priorities:

- Health facilities: lighting, refrigeration of vaccines and drugs, etc.
- Educational and training facilities: similar to the above but with some specificities for the use of computers, projectors, video or media.
- Telecommunications facilities: telephone, radio and television, telemedicine to communicate with large health centres, access to e-mail and internet.
- Pumping water facilities: supply drinking water and water for agriculture or livestock.
- Production facilities: small agro-industries for processing agricultural, livestock or fish from the area, electro-mechanical workshops and others.
- Home electrification can be considered if economic conditions permit it.

Technology options

The best appropriate technology will depend on the specific characteristics of each site. Used widely until recently, solutions such as diesel generators are being replaced nowadays with renewable energies. They have proven to be a reliable mean of developing lower income countries, especially in rural areas far from the national electricity grid.

In cases where the grid extension is unaffordable, an isolated systems solution often appears. It will consist of either single (isolated systems) or multiple (isolated hybrid systems) energy sources, and will require an energy storage system (battery). A common problem of these systems is the need for a larger initial investment.

Appropriate, renewable energy sources technologies are preferable if:

- They are modular projects, adjustable to family and community levels.
- Their technology and maintenance is relatively simple.
- They have a positive impact on the environment.

- There are no fuel cost and supply problems.

The energy sources considered for isolated rural areas, apart from coal, liquid fuels and natural gas, are listed below. A deeper review of rural applications of renewable energies, in this case for electrification, can be found in [Rolland, 2011].

Biomass options. Development agencies promote "improved stoves" or efficient wood stoves, instead of open fires inside the dwelling, because they release smoke through a chimney, therefore improving the health of users, and also because they prevent deforestation by significantly reducing (between 40 and 70 per cent) the consumption of firewood. The cost benefit ratio is extremely high.

Liquid biofuels (biodiesel and bioethanol) also have great potential, but special care must be taken to avoid their production negatively affecting the food security of lower income communities. Charcoal has been used extensively in the past but tends to be decreasingly popular. Biogas production is booming, especially in small farms, via biodigestors.

Solar energy options. Photovoltaic (PV) solar panels allow direct production of electricity and are being installed more and more widely. PV power can only be produced during the day however, requiring the installation of a battery for consumptions at night, for example for lighting. Off-grid PV systems offer a user-friendly and cost-effective electricity solution to cover the electricity needs of single households (Solar Home System), public buildings or commercial units. Solar thermal energy can be used for water heating, while solar cookers can only be used effectively with sufficient radiation.

Small wind energy options. Small wind energy is converted to electricity through wind turbines. A fairly simple technology when compared to the complexity of the high power wind turbines, it can be manufactured locally. Small wind turbines supply electric power between 100 W and 100 kW. Electricity production will vary depending on the area's wind patterns. A common difficulty is the lack of wind data for the proper sizing of the wind turbine.

Mini- and micro-hydro stations. A mini- or micro-hydro station is a relatively complicated project requiring significant investment, but one that can produce an important amount of electric energy if a sufficient waterfall is available nearby. There also exist special turbines to take advantage of large river streams.

Implementing appropriate technologies

Improved stoves. From the 1970s the number of improved stoves worldwide has greatly increased. The progress is remarkable in countries like China (185 million rural households had improved their biomass and coal stoves in 1998), India, Vietnam, Latin American countries (with programmes such as 'For a Smokeless Peru' aiming to install 0.5 million

improved stoves between 2009 and 2011), and others. In Africa, despite the efforts of various NGOs, there has not been significant progress in this sector.

The UN Foundation recently created the Global Alliance for Clean Cookstoves, aiming to install 100 million clean and efficient stoves by 2020. This number is still very low and the Alliance seeks to promote public-private partnerships to further enhance smaller and larger scale projects.

Solar Home Systems (SHS) are already 30 years old and are the symbol of PV stand-alone systems. It is probably the most known and frequently installed type of renewable energy systems around the world. The global photovoltaic industry continues to invest in new solutions and components improvement. A stand-alone PV system can be defined as an off-grid-system with one or several solar PV modules and various appliances serving an independent user. The number of SHS currently in use is difficult to estimate, but is likely to be in the several tens of million.

Small wind energy. Wind energy production has increased dramatically worldwide since 2000. In Europe, the average annual growth in the last 17 years (1995-2011) was 15.6 per cent. It covered over 6 per cent of the annual electricity demand in 2011 (16 per cent in Spain).

In developing countries it has experienced a slower growth but NGOs such as the Intermediate Technological Development Group, Practical Action or the Alliance for Rural Electrification (ARE) strongly support small wind energy as an appropriate technology. For instance, ARE is conducting an information campaign (Small Wind Campaign) with the aim of promoting the deployment of the technology, especially for personal consumption in small and remote communities.

CONCLUSIONS

As the UNDP has highlighted in its "Making New Technologies Work for Human Development" report, "there is a specific need of technologies to satisfy the needs of the poor" [UNDP 2001].

The role of technology in satisfying basic human needs is crucial. There are direct applications that promote health, education and an expansion of human capacities, and indirect routes through which technology benefits human development. As a social product, technology serves the priorities of a society, so it is urgent that we first drive the international community's attention to promoting technologies for human development. The barriers that complicate technology deployment must be identified, and initiatives decisively undertaken to overcome them. Water and sanitation, as a representative technology sector which

directly impacts human development, and energy, a representative technology of a more cross-cutting nature, have been shown to be key aspects in human development. In the case of water and sanitation, the link to hygiene and the need to involve stakeholders in interventions is crucial. In the case of energy, the benefits of renewable energies are clear for the provision of electricity in a decentralised and environmentally friendly manner.

BIBLIOGRAPHY

de Albuquerque et al, 2012. On the right track: Good practices in realising the rights to water and sanitation. Entidade Reguladora dos Serviços de Águas e Resíduos, Lisbon.

Gibbs et al., 2002. Child-to-Child: A Practical Guide. Southwark Primary Care Trust, London.

INTERNATIONAL ENERGY AGENCY (2006) World Energy Outlook 2006. International Energy Agency. Paris.

INTERNATIONAL ENERGY AGENCY (2010) World Energy Outlook 2010. International Energy Agency. Paris.

INTERNATIONAL ENERGY AGENCY (2013) World Energy Outlook 2013. International Energy Agency. Paris.

Peal, A. et al., 2010. Hygiene and sanitation software: An overview of approaches. Water Supply and Sanitation Collaborative Council, Geneva.

Ramos et al., 2013. Introducción a la Tecnología para el Desarrollo Humano. ONGAWA, Madrid.

Rolland, S., 2011. Rural electrification with renewable energy: Technologies, quality standards and business models. Alliance for Rural Electrification, Brussels.

Sachs et al., 2005. Investing in Development: A Practical Plan to Achieve the Millennium Development Goals. United Nations Development Programme, New York.

UNITED NATIONS DEVELOPMENT PROGRAMME (2001) Human Development Report 2001: Making new technologies work for human development. New York. United Nations Development Programme.

UNITED NATIONS DEVELOPMENT PROGRAMME (2005) Energizing the Millennium Development Goals: A guide to energy's role in reducing poverty. New York. United Nations Development Programme.

UNITED NATIONS DEVELOPMENT PROGRAMME (2013) The Millennium Development Goals Report 2013. New York. United Nations Development Programme.

FURTHER/SUGGESTED MATERIAL

Practical Action provides a number of short and interesting videos on examples of appropriate technologies of various categories: energy, food, water and sanitation, construction, etc. These help to visualise the concept of "appropriate technology": http://practicalaction.org/video/

- The website of ONGAWA (in Spanish) contains several sources related to the water, ICT, energy and agriculture sectors http://www.ongawa.org/area-de-trabajo/

- The Royal Spanish Academy of Engineering recently published (in Spanish) a meritorious work on Technologies for Human Development of Isolated Communities http://www.raing.es/es/publicaciones/libros/tecnolog%C3%AD-para-el-desarrollo-humano-de-las-comunidades-rurales-aisladas

In particular, some interesting materials in water, sanitation and hygiene:

- The Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) - 2012 Report. http://www.unwater.org/publications/publications-detail/en/c/204405/

- Gender Mainstreaming in Water and Sanitation in African Cities (UNHABITAT) (Video) http://www.unhabitat.org/video.asp?cid=8732&catid=7&typeid=60&subMenuId=0

- Sanitation: A human rights imperative. http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=2927

- On the Right Track: Good practices in realising the rights to water and sanitation. Office of the High Commissioner for Human Rights http://www.ohchr.org/Documents/Issues/Water/BookonGoodPractices_en.pdf

- Post-2015 WASH targets and indicators. A review from a Human Rights Perspective. ONGAWA
- http://www.ongawa.org/wp-content/uploads/2013/12/WASH-Human-Rights-post-20152.pdf

- Manual on Hygiene Promotion, UNICEF http://www.unicef.org/wash/files/hman.pdf

For the energy sector, some suggestions:

- Poor people energy outlook 2013. Practical Action.
  http://practicalaction.org/ppeo2013
- Evidence of Benefits for Poor People of Increased Renewable Electricity
  Capacity: Literature Review. Institute of Development Studies.
- http://www.ids.ac.uk/publication/the-evidence-of-benefits-for-poor-people-of-
  increased-renewable-electricity-capacity-literature-review

PHOTO: Spanish students in a computer training course in Cusco, Peru. ONGAWA.

CHAPTER

4

Professional and international perspectives of engineering: the case of energy

A.1   Making the case for a critical global engineer

4

CHAPTER 4. Professional and international perspectives of engineering: the case of energy

EDITED BY
Global Dimension in Engineering Education

COORDINATED BY
Agustí Pérez-Foguet and **Enric Velo** *(Universitat Politècnica de Catalunya)*
Manuel Sierra *(Universidad Politécnica de Madrid)*
Alejandra Boni and **Jordi Peris** *(Universitat Politècnica de València)*
Guido Zolezzi *(Università degli Studi di Trento)*
Rhoda Trimingham *(Loughborough University)*

WITH GRATEFUL THANKS TO
Boris Lazzarini *(Universitat Politècnica de Catalunya)*
Jaime Moreno and **Elena López** *(Universidad Politécnica de Madrid)*
Jadicha Sow Paino *(Universitat Politècnica de Valencia)*
Angela Cordeiro and **Gabriella Trombino** *(Università degli Studi di Trento)*
Emily Mattiussi, Sylvia Roberge and **Katie Cresswell-Maynard** *(Engineers Without Borders - UK)*

4 PROFESSIONAL AND INTERNATIONAL PERSPECTIVES OF ENGINEERING: THE CASE OF ENERGY

Emanuela Colombo, Lorenzo Mattarolo, Alessandro Manzato, Francesco Romeo
Politecnico di Milano, UNESCO Chair in Energy for Sustainable Development.
Riccardo Mereu, Tomaso Amati, Engineering Without Borders Milan.

EXECUTIVE SUMMARY

The discovery of how to use and manage the open fire dates back to a few hundred thousand years ago and represents the first manifestation of energy at the service of mankind. Thanks to the ability to control fire, heat and light became available on demand and a wider range of food from plants and animals could be preserved and consumed, thus reducing the urgency to procure food on a daily basis. Later on, with the development of agriculture, direct solar energy contributed another important element to local development. Similarly, the domestication of animals allowed for additional energy to be used for farming and land transport. Thanks to the increasing capacity to manage natural energy sources, humans began working with metals, ceramics or glass while also developing writing, literature, science and arts.

Thus, energy and human development have always been linked in two interconnected ways:

- The availability of energy allowed human beings to extend their life and increase its quality, by saving time for activities other than subsistence.
- The consequent socio-cultural development allowed the discovery of new energy sources, processes and technologies for a more efficient use of energy.

These linkages became increasingly obvious with the first and second industrial revolutions, when the energy scenario shifted from low power to power-intensive systems, and more recently with the production of energy from controlled nuclear fission. It was only in the second half of the 20th century that increasing concerns about climate change drew attention towards renewable energy.

Nowadays, the opportunity to overcome the development divide strongly depends on energy access and availability. Access to energy can concretely contribute to reducing poverty by:

- Reducing the amount of time women spend on domestic tasks.
- Enabling access to educational media and communications in schools and at home.
- Mitigating the impact of indoor air pollution on women and children.
- Allowing access to better medical facilities for maternal care.
- Enhancing income-generating activities.

In this scenario, the contribution of engineering in international energy cooperation can be seen as part of an interdependent frame, where the main objective is the provision of energy access to enhance local development. Engineering professionals interact with other stakeholders to define and implement tailored actions and bring innovative solutions and appropriate technologies, while promoting local capacity and creating a sense of ownership within local communities. Engineers' knowledge, skills and competences must therefore be adapted and tailored to this framework.

Addressing the issue raised by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) Sustainable Engineering Initiative (Lozano and Lozano 2013) (UNESCO), some engineering schools have been pioneers in incorporating sustainability science into their curriculum. The challenge of supporting sustainable development has become a mission also for the Politecnico di Milano, in line with the international aims.

LEARNING OUTCOMES

After you actively engage in the learning experiences in this module, you should be able to:

- Identify the challenges of current international cooperation together with the relevance of energy access in the global development.
- Understand why the energy sector is by default a multidisciplinary frame of action.
- Understand the role of engineers in a multi-stakeholder, multi-objective frame.
- Define the transversal competences, skills and attitude required to operate in the sustainable development field.
- Identify features of appropriate solutions and capacity-building activities.
- Understand the role of academia in preparing these new professional figures.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- Sustainable development
- Access to energy
- Energy for sustainable development
- Role of engineers
- Multi-stakeholder approach
- Appropriate technology
- Capacity building

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session.

- What are the challenges of international cooperation and how does energy contribute to sustainable development?
- What are the main challenges of the energy sector in relation to sustainable development?
- What is the role of energy engineering in the development cooperation context?
- What skills and attitude are required of the new generation of engineers?
- What are the characteristics of an appropriate solution and how can the process of capacity building being promoted?
- What is the contribution of academia in preparing new professionals?

INTRODUCTION

Energy represents one of the pillars of sustainability. Today the role of university and engineering education within sustainable development is often debated at the international level. Indeed the current claim of society for a sustainable growth and therefore for a more equitable distribution of energy, water and food, represents today a big challenge which cannot be overcome without the proactive role of academia. Hence, at the global level, a number of international initiatives have been launched to activate the scientific community.

The launch of the United Nations Sustainable Development Solutions Network (SDSN) by the UN Secretary-General in 2012 represents an institutional recognition of the role of science and education (UN SDSN). SDSN aims at accelerating joint learning and helps to overcome the compartmentalization of technical and political work by promoting integrated approaches to the interconnected economic, social, and environmental challenges faced by the whole world. A more specific initiative devoted to the universities is the Academic Impact promoting a network of High Education Institutions (HEIs), which, together with the United Nations, promotes ten universally accepted principles in the areas of human rights, literacy, sustainability and conflict resolution and acknowledges the role of higher education in economic and social development. These initiatives contribute to underline the central role of education as a pillar of socioeconomic development, foundation for world peace and long-lasting engine for facing the many global challenges, including sustainable energy strategies.

ENERGY CHALLENGE AND THE SUSTAINABLE DEVELOPMENT GOALS

Energy challenges vary at the global level and therefore strategies must be tailored to the specific context in which they are to be applied. Moreover, when looking for durable and long-term energy solutions that aim to enhance capabilities and promote integration and acceptability within the local context, strategies must be developed to include the three main dimensions of sustainability: economic, social and environmental.

Energy and economy have always been interrelated. As shown in Figure 1, in all high-income countries the Total Primary Energy Supply (TPES) per capita (toe) is above 2 toe per capita, while the remaining countries are mostly below this threshold. The correlation results are more evident and distribution less scattered at low Gross National Income (GNI), where developing countries are located.
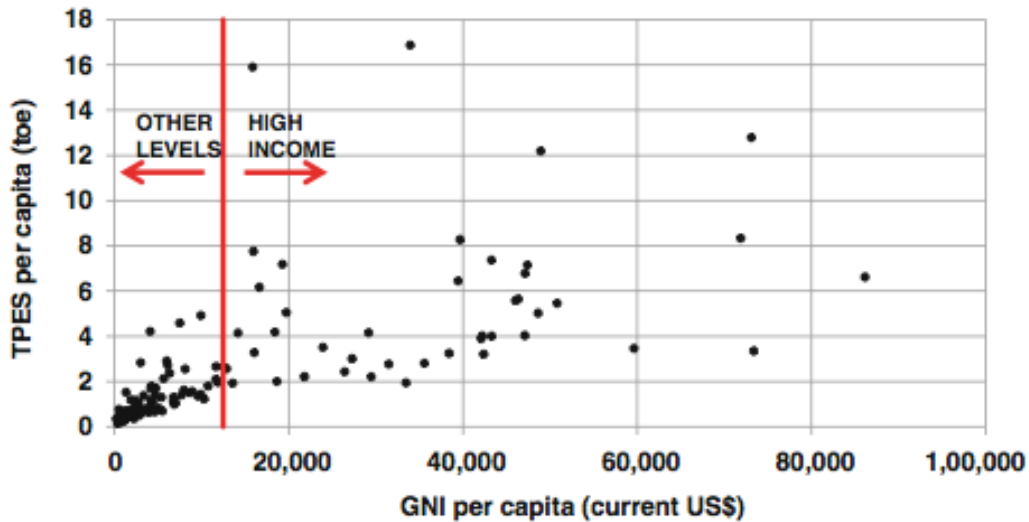
Figure 1 *World Countries Distribution according to GNI per capita and TPES per capita (World Bank 2012)*

As far as the social dimension is concerned, more than 1.4 million deaths per year (more than malaria and tuberculosis) are related to the effects of breathing smoke from three-stone fires and the number is expected to increase in 2030 to the point of overcoming deaths from HIV/AIDS (Fat 2008) (Mehta et al. 2004). Traditional fuel usage also leads to considerations of the "burden" of biomass and raises a problem of equity, since low energy availability limits development and increases disparities between classes. In rural areas women and children are generally in charge of fuel collection: a real drudgery, one which exposes them to health hazards and various risks (Victor 2005). Furthermore, this activity prevents children from accessing education and being involved in income-generating activities, thus having an important social impact. Figure 2 shows the correlation between per capita electric energy consumption and the rate of enrolment to secondary schools for several countries, thus demonstrating how energy availability is related to the opportunities for local people to achieve a higher level of education.

Figure 2 *Energy consumption versus secondary school enrolment (Colombo et al. 2014)*

The promotion of energy usage must also take into consideration the ecosystem and potential environmental damage in order to guarantee environmental sustainability. For instance, although renewable energy technologies are generally perceived as more sustainable compared with non-renewable sources due to their reduced environmental impact and bene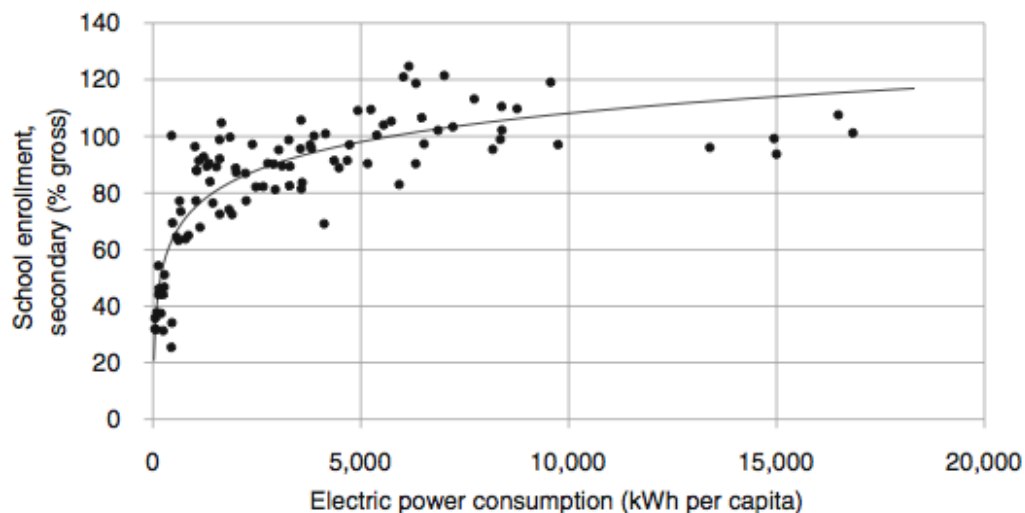fits to local development (Burguillo et al. 2008), they can also have negative effects and therefore careful planning to address possible environmental impacts throughout their life cycle is essential. The use of fossil and traditional energy sources in developing countries may also impact global biodiversity, where ecosystems are affected by an unregulated exploitation. Therefore an energy mix, strongly leaning towards the use of traditional and renewable resources, is necessary in order to reduce pollution, land degradation and deforestation.

For these reasons, and also because energy is considered a key means of providing services essential to local development, worldwide interest in the energy challenge and sustainable energy strategies is progressively increasing (Colombo et al. 2014). Access to modern energy facilitates water purification, food security and cleaner means of cooking and heating, as well as supports adequate healthcare, education, work and Information and Communication Technologies (ICTs). For instance, mainly in rural areas of developing countries, modern forms of energy reduce the amount of time women spend on domestic tasks, enable access to educational media and communications in schools and at home, mitigates the impacts of indoor air pollution, allows access to better medical facilities for maternal care and enhances income-generating activities.

However, energy is still not available to all: almost 1.3 billion people today live without access to electricity and 2.6 billion people rely on traditional biomass such as three-stones firewood for cooking and lighting (IEA 2013). For many of these persons, especially those who live in rural areas of developing countries, the key issue is access either in term of quality (i.e. access to modern fuels) and quantity (i.e. access to proper amounts of energy resources). The poor access indeed leads to health and environmental consequences due to traditional energy habits and lack of alternative solutions, but also to development hurdling and economic losses for manufacturing processes and basic services which require reliable and affordable energy supplies.

International organisations have devised indicators to assess the possible link between energy and development with a comprehensive approach that goes beyond the single economic perspective: the Human Development Index (HDI) (UNDP 2010) and the Energy Development Index (EDI) (IEA 2012), whose correlation is evident especially for low and medium income countries, as shown in **Error! No s'ha trobat l'origen de la referència.**. In light of this close relation, the need to improve access to clean, efficient, affordable and reliable modern energy services has become more clear both from economic, social and environmental viewpoints. Indeed, building enterprises and creating new jobs, improving health and education, and providing basic needs such as food and water in a sustainable manner require a balanced energy mix that is suited to the economic, social, and resource conditions of each context.
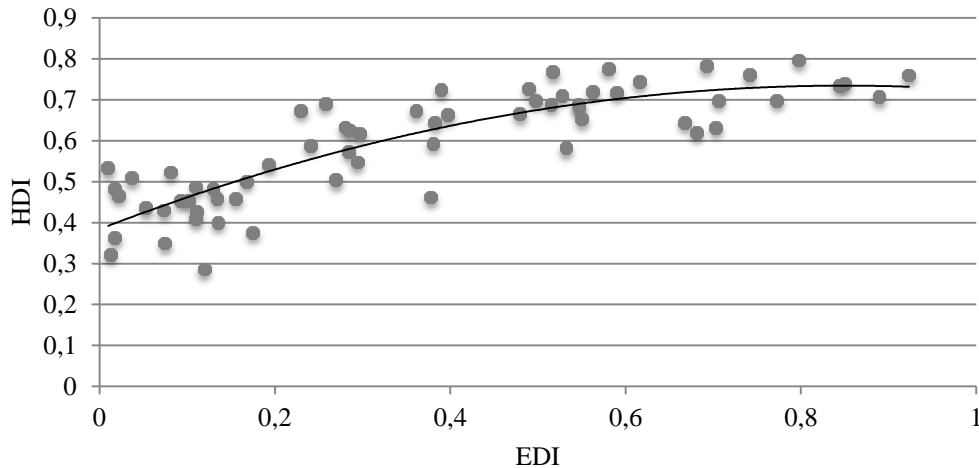
Figure 3 *HDI-EDI for medium and low HDI countries. Authors' elaboration based on UNDP (UNDP 2010) and IEA (IEA 2012) data.*

Although the issue of access to energy is central for international cooperation in developing countries (Brew-Hammond 2010), new evidences of energy poverty are also appearing in Europe and in other industrialized regions, underlining how the energy challenge has become a global concern (Bouzarovski et al. 2012). It has been estimated that 50 million of Europeans are affected by "fuel poverty", and this is mainly due to the shift to liberalized markets that were formerly strictly regulated and the current financial crisis. Within the context of development, the United Nations Conference on Sustainable Development held in Rio de Janeiro in 2012 resulted in an agreement by the Member States to launch a set of Sustainable Development Goals (SDGs), in order to overcome the limitations of the Millennium Development Goals (MDGs) that did not include global challenges specifically related to the energy issue (UN). SDGs are intended to advance sustainable development as a further component to the economic, social and environmental dimensions, while also tackling other pressing challenges at global level to include developing, developed and emerging economies.

In order to support these objectives, the United Nations Secretary General has launched the Sustainable Energy for All (SE4All) initiative (UN), which aims to ensure universal access to modern energy services, doubling the rate of improvement in energy efficiency and doubling the share of renewable energy in the global energy mix by 2030. Within this new paradigm, SE4All aims at fostering green economies as central element for the sustainable development, capable of taking into account human physical, emotional and social needs, while equity becomes an essential element to manage resources distribution.

Therefore, in order to guarantee both a reliable energy provision in high-income economies and a tool by which to alleviate poverty in developing countries, integrating sustainable energy strategies into national policies and guiding international cooperation actions focusing on the energy challenge is therefore truly urgent and represents the direction suggested by the international community.

THE CONTRIBUTION OF ENGINEERS

In the definition and implementation of sustainable energy strategies, the role of engineers has become more complex as they now face new and interdisciplinary challenges, in a wider and more international context.

As depicted in Figure 4, the contribution of engineering in international energy cooperation may be seen as part of an interdependent frame, where the main objective is the provision of energy access to enhance local development in a specific local context. Engineering professionals interact with other stakeholders to define and implement tailored actions in order to bring innovative solutions and appropriate technologies. In such a frame, the commitment should also focus on promoting skills transfer and capacity building, and fostering ownership within communities. Engineers' knowledge, competences and skills be adapted and tailored to make the former work properly within this frame.

The following paragraphs will provide an overview of all these aspects. Some examples will then demonstrate how these issues have been tackled within Politecnico di Milano and by Engineering Without Borders – Milan in some implemented projects.
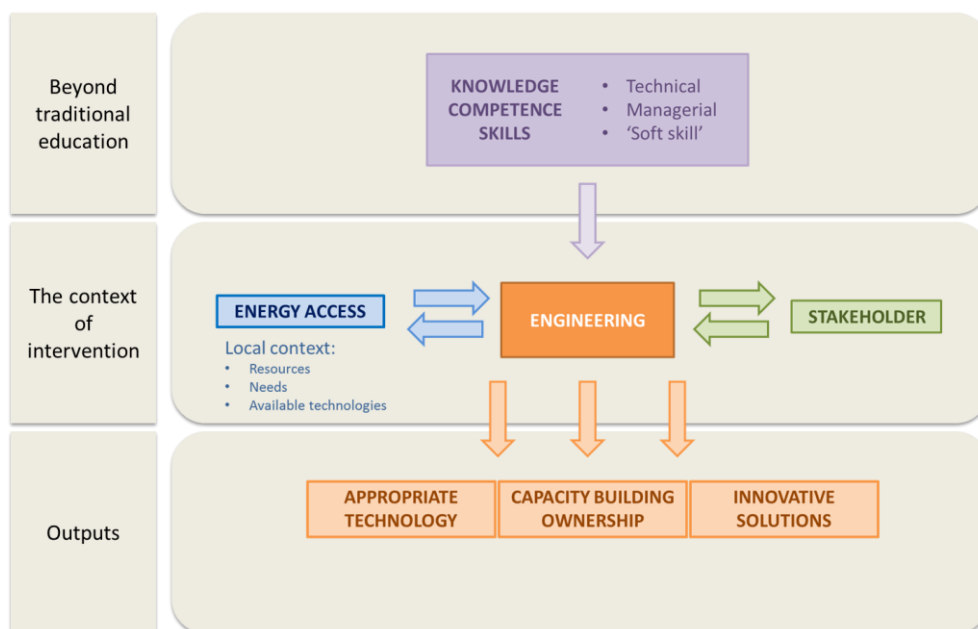

Figure 4 *Perspective and role of engineering in fostering sustainable development*

THE CONTEXT OF INTERVENTION

As shown in Figure 4, in order to promote effective and inclusive development of which energy represents a fundamental requisite, engineers should consider both the local context where the intervention is called for and the interaction with the other stakeholders.

With regards to the local context, a first analysis of the overall context is necessary in order to make the new interventions consistent with the available means and capacities, and to provide an adequate coupling between local energy sources (solar, wind, biomass or water) and needs. This means taking into consideration target communities' needs and expectations while preserving their health and environment. One must also consider the technologies available in the field to ensure they are consistent with the technical capabilities and opportunities already present.

Various stakeholders are involved in these processes contributes with their own expertise. From a technical perspective, research and implementation of innovative solutions to promote efficiency and clean energy are the domain of scientists and technical professionals such as engineers. From a political viewpoint, policy makers and institutional actors are the ones engaged with the promotion of new norms, laws and regulation, which must go hand in hand with technical specifications. The social dimension pertains to the role of civil society and its responsibilities. In this articulated and multi-sectorial framework, engineers must interact within a complex frame, combining their skills in a multi-disciplinary and multi-stakeholder approach.

Engineers should then apply their research attitude towards and knowledge of energy systems to international partnerships, by interacting with different perspectives and cultures, thus increasing their global knowledge. As students, they may profit from networking, based on relationships established by universities with international organisation, NGOs and private actors, and by carrying out field projects in developing countries.

BEYOND TRADITIONAL EDUCATION

In this frame of intervention, due to the complexity and multidisciplinary nature of the access to energy issue, a transversal set of knowledge, competence and skills is required (Figure 4). Technical competences are necessary to design, manufacture and adapt new technologies and to install, operate and maintain energy systems. In addition, managerial capabilities are necessary to properly run the daily activities, to plan operations and to manage the business.

Besides these specific requirements, other transversal skills are necessary, especially in the international cooperation context where many different players (NGOs, community-based organisations private sector, government agencies and individual end users) interact. A facilitator attitude, together with communication and learning skills are essential for coordinating

negotiations, promoting public participation and building consensus between stakeholders and target communities.

Indeed, engineering companies operating in the global context are increasingly recruiting for highly specialized technical skills supported by a set of soft skills (interpersonal skills, teamwork, communication skills, etc.) which represent added value in the modern and complex context of global development. Hence, energy issues and conversion technologies must be tackled with a wide approach that goes beyond the sole technical and engineering aspects, with a multidisciplinary and comprehensive perspective. Themes such as climate change, Life Cycle Analysis (LCA), environmental impact and political and legislation frameworks are necessary to grasp interconnections when analysing technologies within the sustainable development paradigm.

THE NEED FOR AN INTEGRATED MANAGEMENT

Despite widespread acknowledgment that energy, together with other resources such as water and food, represents a nexus essential to meeting basic human needs and improving income-generating activities and livelihoods, it has emerged that there is a lack of an integrated management model of resources available to engineers to achieve these goals. As a result, various governmental structures adopt separate policies for each resource, for two reasons:

Different ministries and administrative entities are usually responsible for energy, water and agriculture. As a result, global coherence cannot be attained and decisions by one ministry or department can conflict with the objectives of others;
Analytical tools and conceptual models able to manage the overall nexus are still limited. Analysis of individual systems such as energy and water systems are undertaken routinely but they focus on only one resource, thus neglecting their interconnection with and effects on others, and simulating unsustainable scenarios in the long run (Sovacool 2012).
Concerning the lack of an integrated management model, different strategies must still be promoted to properly face the nexus, such as:

- Decision support tools at the nexus level
- Supporting system thinking within the policy-making process
- Increasing the number of interdisciplinary experts in all three areas
- Analysing solutions with a comprehensive perspective aimed at sustainable development

The International Atomic Energy Agency has suggested the adoption of different policies for diverse resources (IAEA 2009), an integrated analysis tool addressing all relevant aspects (climate change, land, energy, water) to allow a multi-resource and interlinked representation, useful also to perform analyses in developing countries. Such a tool would facilitate decision-making and support the achievement of the future SDGs, and be one in which engineers provide an effective

transversal contribution to promote appropriate technologies, capacity building and innovative solutions (Figure 4).

APPROPRIATE TECHNOLOGY

Acquiring all these diversified skills allows engineers to better engage the global and dynamic issues of sustainable energy technologies, ensuring an effective process from resources to services and productive usages, to sustainable and equitable growth mainly in low and middle-income economies. In order to be successful and result in durable benefits over time, energy technologies' design and management must take into account several techno-socio-economic aspects proper to the local context (Brent et al. 2010).

When identifying new energy solutions, engineers should promote multilateral collaboration and knowledge sharing with other stakeholders by adopting and using skills apparently far from the technical sector, in order to identify the most appropriate solution through a comprehensive and multidisciplinary approach. The energy solution implemented may not be state of the art but it must be reliable and affordable, suitable and scalable and able to meet local needs with the available resources. Thus, tailored to the local context, a technology must be replicable, addressing one or more real immediate needs; it must also be easy to understand, install, maintain and dispose of to empowerment the local people and increase their sense of ownership. Working with this perspective in developing countries does not always mean to operate with low sophistication: in some cases the most appropriate technology may coincide with the most sophisticated one, but in others the most suitable way to act may require a smaller technology input, rather giving more important roles to the technicians' transversal skills.

The concept of appropriate technology was originally intended as a mere technology transfer, strongly characterised by a top-down approach. As a consequence, the technology was not always adapted to local resources nor based on local skills and fostering capacity development. Only in the last decades has the definition of appropriate technology stressed the importance of local resources and local human capital to overturn the consolidated approach. In this way, locals have started to operate not only as mere recipients of the implemented solutions, but rather as responsible owners of the technology.

CAPACITY BUILDING AND OWNERSHIP

In the current global framework, it is widely acknowledged that developing countries must acquire knowledge, skills and competences to design or redesign, produce, market, install, operate and maintain sustainable energy technologies. As stated by Sovacool, the main topics to be addressed are:

- Renewable energy technologies, which require specific skills at the local level.
- Training, necessary to having the required workforce (vocational to higher education).
- Research and innovation capacities, to be developed within academia.

Education pathways, both in developed and developing countries, must be designed and implemented according to local needs and to be taught both inside (formal) and outside (vocational) the education system. For instance, in developing rural areas capacity building may be delivered through specific training courses carried out at the community level. Community-based organisations and self-help groups (SHGs) can play an important role in empowering the community and making it responsible for managing public goods, as suggested by Reddy et al. or by Adkins et al. Moreover, when capacity building occurs within local communities and companies, other benefits may arise: policies and strategies can be better assessed, local acceptance is easier to gain and local technical reliance is more prompt.

The coordination between the education system and the national and local energy institutions, along with the contribution of the private sector and civil society, are essential to facilitate capacity building. They also play a part in clarifying the needs for training and research, thereby contributing to the reduction of the gap between academia and local communities (society and enterprises) which is still very deep in many developing countries.

The role of academic cooperation therefore becomes increasingly relevant, since it could allow, through for instance the establishment of effective North-South and South-South partnerships, for the strengthening of Research and Development (R&D) activities in energy technologies both at national and regional levels.

INNOVATIVE SOLUTIONS

In this context, innovation becomes central not only as a key driver for enabling growth but also fosters the creative attitude towards new business models, making the local contexts very receptive (Agbemabiese 2012). The World Bank states that developing and developed countries must innovate in order to ensure the well-being of their population through creative and effective solutions (World Bank 2010).

Two relevant innovation issues in developing countries are the intensification of globalisation and the intensive continuing technological change. These two drivers represent both a challenge and an opportunity which can be faced through knowledge development and the modernisation of traditional activities. The major obstacles to these challenges are poorly constructed innovation systems of limited interest to the research community, university systems weakly connected to local realities, lack of technological support services and poor national innovation programmes.

To overcome these obstacles, universities (as the source of new knowledge) and industries (as the users of knowledge) can play an especially crucial role in creating innovations and can function as tools for regional development.

THE CASE OF POLITECNICO DI MILANO

In promoting innovation, universities (especially the technical ones) play a key role. On the other hand, as highlighted by UNESCO, the lack of engineers who operate with transversal competences and with global attitudes is becoming increasingly evident. In a rapidly changing world two key elements have recently assumed more importance: the need to enrich the academic background of future professionals with new contents and the relevance of scientific research and innovation for global development.

The challenge of supporting sustainable development has become a mission at Politecnico di Milano, through specific activities in the Department of Energy under the UNESCO Chair in Energy for Sustainable Development, established in March 2012. Its research activities focus mainly on distributed generation, strategies for improving access to energy but also methodologies for evaluating the impact of energy projects on local development. The vision of the Chair is to contribute to the shift toward more sustainable and equitable energy systems in order to meet the needs of global development.

The Chair also aims to foster international university partnerships with developing and emerging countries, supporting capacity building and upgrading of higher education institutions (HEIs) in the target countries, promoting joint research and staff exchange focused on sustainability, innovative technologies and modern renewable energies.

Three project proposals have received the grant by the European Commission and are now on-going: two in Egypt under the TEMPUS programme and another in Kenya, Tanzania and Ethiopia under the EDULINK programme. The three projects aim to upgrade the local higher education systems on sustainable development and sustainable energy strategies while promoting North-South and South-South cooperation. The main objective is to create a new generation of business and social entrepreneurs with the right skills to start green businesses up, launch innovative ventures and products, and put in place public policy and social innovation.

The Chair also conducts advisory activities and joint projects with NGOs and private companies active in the energy sector at the national and international level. In this technological cooperation, the role of the Chair focuses on research and is oriented towards capacity building, innovative solutions and methodologies for promoting penetration of sustainable energy technologies.

The Chair has consequently promoted a new track in "energy for development" within the Master of Science in Energy Engineering. The track aims to combine fundamental knowledge of engineering

with a holistic approach to address global problems with integrated perspectives, to assess economic, environmental and social impact of technological solutions and sustainable energy strategies. Studies in this track aim to train a professional figure with a broad knowledge in technical and scientific fields, able to operate in the energy sector at a multi-scale level, including the development of specific technologies and energy analyses within various scenarios and areas.

The course "Engineering and Cooperation for Development" for example has been delivered within this MSc. and introduces students to the themes of development and cooperation as well as to the role of scientific research and technology within the field, improving the academic background of future professionals with contents related to scientific research and innovation for global development.

The course proposes to meet two educational goals: first, to provide the specific cognitive and methodological tools of cooperation and development in order to increase a student's ability to face the social challenges particularly affecting the critical economies; secondly, to couple the engineering vision with the set of human factors and ethical principles necessary for students to develop the instruments and values to generate innovation and development in different contexts. The lectures provide a reminder of the methodological approaches for technology-related cooperation projects and inspired by the criteria of sustainability, and address in detail the following topics: context analysis, participatory and sustainable design tools, the appropriate technologies for energy and resource management, the financial mechanisms and models for the evaluation of technical cooperation projects and finally human rights and ethics, distribution of resources and equity.

Another course, this one in the MSc. in Environmental Engineering and entitled "Energy for Sustainable Development", aims to provide environmental engineering students with adequate technical and general knowledge of the energy challenge in the global economy, showing the link between energy and sustainable development. An overview of the current global energy situation is presented in term of overall and specific indicators for high income, middle income and low income countries, with the link between energy and the socio-economic development clearly outlined. This will prepare students to better understand the technological modules in which the operating principles, performance analysis, costs, environmental and social impacts of the main energy technologies for energy conversion are studied. All the energy resources are analysed in detail and two major global issues are discussed: the problem of access to energy in developing countries and the needs to look for a more sustainable energy mix for all. In class, participatory discussions are used to develop the students' critical abilities, based on quantitative and scientific evaluation.

In 2012 Politecnico di Milano launched, jointly with Fondazione Politecnico di Milano, an academic responsibility programme: Polisocial programme. The programme aims to enrich training opportunities with new content and to promote scientific research and innovation for development.

A prerequisite to living and working in an international context is the capacity to understand and cooperate with different cultures, traditions, experiences, environments and economies. As evidenced by a 2011 survey in collaboration with Assolombarda, a North Italian entrepreneurial association, engineering companies operating in the global context look for highly specialised technical skills and also for a set of additional soft skills such as interpersonal and communication skills, teamwork and leadership.

To meet this need, pilot programmes consisting of multi-disciplinary teams combining students, faculty members and civil society players have been implemented. The projects cover different social needs and urgencies: accessibility of public spaces for people with disabilities, renewal of farms as places of historical roots, identification of spaces for social dialogue in prisons, communication strategies for temporary housing, technologies for communication between immigrants or refugees and their communities of origin and IT systems for social inclusion.

In this context, projects on renewable energy technologies to mitigate environmental impact and increase social inclusion are required. Scientific research plays a key role in development when technology and innovation meet ethics and social responsibility. For these reasons, Polisocial promotes internships, MSc. theses and joint research projects in developing countries and encourages communication and knowledge dissemination. The majority of the resulting research projects aim to promote sustainable development of local communities and focuses on capacity building, knowledge sharing and technological cooperation.

CASE STUDIES FROM ENGINEERING WITHOUT BORDERS MILAN

Engineering Without Borders Milan (Ingegneria Senza Frontiere - Milano, ISF-MI) is a non-profit organisation established in 2004, whose mission is based on education, technology transfer and dissemination of sustainable development principles. The following case studies, in which ISF-MI played a significant role, will help demonstrate the material previously discussed, with some concrete and operative considerations. Each example will refer to the framework shown in Figure 4, focusing on some specific aspects.

How to define appropriate technologies for productive activities: the case of the Médina Training Centre (Senegal)

The project Centro di Formazione Médina (CdF Médina) or Médina Training Centre, based in the Médina in Dakar (Senegal), seeks to improve the living, health and economic conditions of weavers working in the fair trade sphere, students at the CdF Médina, and the community in which they operate, through a qualifying training scheme and real support for the development of sustainable economic activities. The CdF Médina is part of a wider Senegalese textile chain that has shown a growing effort in enhancing national productivity through the promotion of organic

cotton and the rediscovery of traditional weaving and dyeing techniques. The project involves qualified partners and stakeholders in fair trade, textile craftsmanship, local non-governmental organisations and ISF-MI for the technological transfer and training. ISF-MI's mandate was to identify, evaluate and install a suitable energy provision solution. This mandate has been tackled through the study, development and use of appropriate technologies capable of satisfying the environmental, economic and social sustainability requirements.

The first step was to conduct an analysis of the local context (at the centre in Figure 4), noting the need for electricity and heating for the centre and determining the types of technology necessary and how to properly introduce them. Different resources and technologies were considered and studied to guarantee the satisfactions of the Centre's needs with positive social, economic and environmental impacts. Several theses and specialist degrees were subsequently developed with the staff of the Department of Energy of Politecnico di Milano, leading to a preliminary design for the most appropriate system with, as a starting point, the local context and the partners' needs.

The need for hot water for textile production (dye fixing) and for domestic use (showers, cooking), resulted in the design of a do-it-yourself system of solar heating panels as an alternative to biomass (wood) and gas used in both rural and urban settings. This solution offers environmental, economic and social advantages over traditional methods: it eliminates the production of CO2 and the cost and inconvenience of obtaining wood and gas. Moreover, the choice of the do-it-yourself technique over a commercial solution is followed maximises the positive impacts of the activity, effectively exploiting the local resources, creating local value through the training of local personnel and constituting a potential market opportunity for a business activity within the Médina.

The introduction of the solar heating system led to a participatory process involving in the construction, installation and maintenance, members of the CdF and Médina craftsmen interested in the technology, therefore allowing for skills transfers. The craftsmen were thus able to put into practice their advanced capabilities for a new innovative solution.

Hence, the do-it-yourself construction technique proposed in the project represents a valid example of appropriate technology, (Outputs in Figure 4) where every dimension of sustainability is taken into account. This approach guarantees at the same time environmental (increasing the reuse and recycling of waste materials), economic (investing in a local market where there is a constantly growing demand) and social sustainability (recognising the value of and enhancing local skills, and guaranteeing independence from external subsidies). The value of the potential of local resources is recognised and local skills lie at the core of the project itself.

Green energies dissemination: multi-stakeholder and multi-disciplinary approach to maximize the goal in rural areas (Albania)

This project involves the design and construction of pilot plants for the transfer of technologies and competences, the dissemination and promotion of the use of renewable energy sources in agriculture, agri-food and agri-tourism in northern Albania, and the creation and development of a help desk at the Centre for Technology Transfer in Agriculture (CTTA) of Shkoder. The project also aims to improve the efficiency of agricultural activities through the innovative use of renewable energy, ensuring energy independence and sustainability of agricultural activities.

The lack of income for farmers and tourism initiatives in rural areas and the need, at the same time, for the supply of energy in remote areas of northern Albania were some of the reasons Green Energy Park (GEP) was created, providing concrete examples of and information on the most appropriate technologies currently available. The creation of GEP started in 2012 and it is currently developing through feasibility studies and the implementation of pilot plants.

For the success of this project, the involvement of different stakeholders was an indispensable prerequisite. The promoter of the project is the CTTA, which ensures the institutional commitment and the results' dissemination. CeLIM, an Italian NGO working in Albania since 1998, has identified the local stakeholders, the agricultural activities mainly developed in Albania and the most promising for the future of the northern area. The technical part of designing the technologies, from the evaluation of energy needs to the selected activities, is covered by Engineering Without Borders – Milano. The evaluation of energy needs and resources available was realised with the participation of local stakeholders and CeLIM to take into account the social and economic impact of each technically available solution.

Engineers from ISF-MI provided tailored energy and technological solutions. Their design included a sustainable management of resources facet to guarantee the solutions were sustainable and replicable. For instance, biomass technology solutions were designed with the whole production process, from the initial resources to the outflow and wastes, taken into consideration.

One of the most important outcomes of this project has been the creation of an effective network through which knowledge and best practices could be shared. To this end a help desk at the CTTA was created, where private citizens, enterprises and associations can consult with local staff and collect information and selected material. In addition, individuals who have adopted the technologies and public bodies working in the field of education and technology transfer have joined the desk with the aim of promoting and spreading the awareness about renewable energy resources.

CONCLUSIONS

The importance of access to energy and the need for a sustainable development paradigm require broad competences and a comprehensive and multi-disciplinary approach.

In the energy field, technical skills are essential, but must be coupled with the human factor and the interdependence logic. More specifically, new engineers must be trained to take into account the social, economic and environmental context in which they operate and their respective evolution. Due to their high technical capabilities and problem solving skills, they are essential players in innovating solutions. Filling this gap yields significant benefits, by adapting professional development to the new global context while creating a new ethic of responsibility in each individual.

In order to tackle these challenges, the roles of academia and other stakeholders is relevant. Different approaches and solutions may be used. The case of Politecnico di Milano and projects by Engineering Without Borders – Milan represent concrete examples where engineers came to be essential figures capable of making a difference in the complex frame of intervention in the field of energy access.

BIBLIOGRAPHY

Adkins, E., Modi, V., Oppelstrup, K., 2012. Rural household energy consumption in the millennium villages in Sub-Saharan Africa. Energy for Sustainable Development, 16, 3, 249-259.

Agbemabiese, L., Nkomo, J., Sokona, Y., 2012. Enabling innovations in energy access: An African perspective. Energy Policy, 47, 38-47.

Balachandra, P., Nathan, H.S.K., Reddy, B.S., 2009. Universalization of access to modern energy services in Indian households: Economic and policy analysis. Energy Policy, 37, 11, 4645-4657.

Bologna, S., Colombo, E., Masera, D., 2014. Renewable Energy for Unleashing Sustainable Development. Springer International Publishing, Cham.

Bouzarovski, S., Petrova, S., Sarlamanov, R., 2012. Energy poverty policies in the EU: A critical perspective. Energy policy, 49, 76-82.

Brent, A.C., Rogers, E.A., 2010. Renewable rural electrification: sustainability assessment of mini-hybrid off-grid technological systems in the African context. Renewable Energy, 35, 57-265.

Brew-Hammond, A., 2010. Energy access in Africa: Challenges ahead. Energy Policy. 38, 5, 2291-2301.

Burguillo, M., Del Rio, P., Assessing the impact of renewable energy deployment on local sustainability: Towards a theoretical framework. Renewable and Sustainable Energy Reviews, 12, 5, 1325-1344.

International Atomic Energy Agency (2009). Seeking sustainable climate land energy and water (CLEW) strategies. Vienna, International Atomic Energy Agency.

INTERNATIONAL ENERGY AGENCY (2012). World Energy Outlook 2012. Paris, International Energy Agency.

INTERNATIONAL ENERGY AGENCY (2013). World Energy Outlook 2013. Paris, International Energy Agency.

Lozano, F.J., Lozano, R. (2014). Developing the curriculum for a new Bachelor's degree in Engineering for Sustainable Development. Journal of Cleaner Production, 64, 136-146.

MaeusezahlFeuz, M., Mehta, S., Smith, K.R., (2004). Indoor air pollution from household use of solid fuels in: Ezzati, M., Lopez, A., Roders, A. (Eds.), Comparative Quantification of Health Risks, Global and Regional Burden of Disease Attributable to Selected Major Risk Factors. World Health Organization, Geneva, pp. 1435-1494.

Sovacool, B.K., (2012). The political economy of energy poverty: A review of key challenges. Energy for Sustainable Development, 16, 3, 272-282.

UNITED NATIONS. Sustainable Development Solutions Network website. Available from: <unsdsn.org> (16 February 2014).

UNITED NATIONS. Sustainable Development Knowledge Platform website. Available from: <http://sustainabledevelopment.un.org> (16 February 2014).

UNITED NATIONS. Sustainable Energy for All website. Available from: http://www.se4all.org (16 February 2014).

UNITED NATIONS DEVELOPMENT PROGRAMME (2010). Human Development Report 2010: 20th Anniversary Edition. New York, United Nations Development Programme.

UNITED NATIONS ECONOMIC, SCIENTIFIC AND CULTURAL ORGANIZATION. Sustainable Engineering website. Available from: <http://www.unesco.org/new/en/natural-sciences/science-technology/engineering/sustainable-engineering/> (16 February 2014).

Victor, D., (2005) The Effects of Power Sector Reform on Energy Services for the Poor. New York, United Nations.

WORLD BANK (2010). Innovation policy: A guide for developing countries. Washington DC. The International Bank for Reconstruction and Development.

WORLD BANK (2012). World Development Indicators 2012. Washington, World Bank.

WORLD HEALTH ORGANIZATION (2008). The global burden of disease: 2004 update. Geneva, World Health Organization.

FURTHER/SUGGESTED MATERIAL

- World Bank data (www.worldbank.org): Data, indicators, The Little Green Data Book.

- International Energy Agency Data (www.iea.org): Key Statistics, World Energy Outlook, Key World Energy Statistics.

- United Nation Development Program (UNDP) Data (www.beta.undp.org): The Energy Access Situation in Developing Countries, Human Development Report.

- World Energy Council (WEC) data (www.worldenergy.org): Survey of Energy Resources.

PHOTO: 'Construction Collaboration'.
Working to construct a double-storey bamboo house
for a family in Dinajpur, Bangladesh. J. Ashbridge

CHAPTER

5

Professional ethics and social responsibility of engineers

5

CHAPTER 5. Professional ethics and social responsibility of engineers

5 PROFESSIONAL ETHICS AND SOCIAL RESPONSIBILITY OF ENGINEERS

J. Félix Lozano, Professor at the Universitat Politècnica de València.

EXECUTIVE SUMMARY

This session aims to present and assess the ethical values and social responsibilities concerning professional engineers.

The first part will focus on the relevance of ethics in the practice of engineering from a theoretical and practical perspective, with particular attention to the ethical challenges faced by engineers in their daily work (corruption, safety, whistle-blowing, information ownership, etc.).

The second part will look more closely at some processes aimed at increasing ethical and social responsibility (code of ethics, ethical auditing, sustainability reports, etc.).

LEARNING OUTCOMES

After you actively engage in the learning experiences in this module, you should be able to:

- Become aware of the ethical aspects of engineering.
- Be able to identify and apply professional ethical values and duties.
- be able to critically assess the most commonly used ethical business processes (e.g. ethical codes, ethical auditing, etc.) specifically targeted at engineering

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- Ethics, professional values and responsibility of professional engineers
- Critical issues in engineering ethics (safety, information ownership, whistle-blowing, etc.)
- Professional ethical codes and corporate responsibility reports, etc.

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- Why is professional ethics necessary in engineering?
- What does it mean to be a responsible professional?
- What are the key ethical issues in the practice of engineering?
- How could corporate and engineering responsibility be developed?

INTRODUCTION

The Challenger explosion (1986), the Exxon Valdez accident in Alaska (1989), the gas leak in Bophal, India (1984) or the case of Shell in Nigeria (1995) are some examples that immediate spring to mind when talking about ethics in engineering. These were dramatic cases which resulted in grave environmental damages and the loss of thousands of human lives. They are practical examples of the importance of ethical professional behavior and the need for corporate social responsibility.

Professional responsibility is an essential element in the training of engineers, and it should enhance their capacity for moral judgment and civic courage. This is the aim of this chapter: to present the implications of ethics in the practice of engineering, to identify the most common ethical issues and to become acquainted with some of the already existing business processes for developing professional and corporate responsibility.

ENGINEERING ETHICS AND CORPORATE SOCIAL RESPONSIBILITY

To think seriously about professional and corporate ethics requires clarification on the concept of 'ethics' and 'responsibility'.

Encompassing more than twenty centuries of history, the word 'ethics' (*ethos*) has different and diverse meanings, This definition presented by Dewey and Tufts is most suitable for the field of engineering: '*Ethics aims to give a systematic account of our judgment about conduct, in so far as these estimate it from the standpoint of right or wrong, good or bad.*' (Dewey and Tufts, 1908).

Three essential features may be drawn from this definition significant for the professional practice of engineering: first, the field of ethics needs to make well-reasoned judgments about human behaviour. In other words, there are criteria and arguments to determine whether a given conduct or decision is ethically correct. The second implication, similar to the first, is that ethics is comprised of practical, action-and-decision- oriented knowledge, not merely theoretical. Finally, this type of judgement or reasoning takes into account the moral dimension of human actions and decisions. Thus, assessing actions in terms of good/bad or fair/unfair places respect for principles of behaviour as main benchmark.

Discussion about the concept of ethics and its implications is obviously wider and much more comprehensive but for the purposes of this paper we can understand ethics to be a type of knowledge providing criteria and arguments to guide our actions and decision in all areas of daily life.

Engineering ethics could be defined as follows: '*the analysis of moral cases and decisions faced by individuals and organizations in the field of engineering; and also the study of issues related to moral ideals, nature, politics and relations of individuals and corporations involved in technological activities.*' (Martin/Schinzinger, 1996, p. 2).

The concepts of professional responsibility and corporate social responsibility for companies and/or organizations have emerged in connection with the idea of professional ethics. In the field of technology, responsibility is defined as: '*… [being] ready and able to respond to someone for something...responsible for something (action, task, assignment) and to someone (individual or institution).*' (Lenk, 1987, p.115).

Responsibility has two specific features: willingness and capability. Willingness implies that a professional has an inclination or readiness to be accountable for actions and decisions made. Capability is a factor of responsibility as well, as it is not possible to make someone accountable for something that he or she is not able to do or avoid.

Knowledge, resources and authority are constraining factors related to capability. In other words, people with greater knowledge on a particular topic are more able to understand a certain phenomenon and to act on it (e.g., more is expected from a chemical engineer than from a chemical company worker). People with more resources (physical, economic, etc.) are best qualified to influence future events (e.g. a large multinational company has more responsibility in the fight against corruption than a small repair shop with 5 employees). Finally, a person with more authority also bears greater responsibility (e.g. a company chief executive officer has greater responsibility than its employees).

The idea of responsibility is presented here from the point of view of the individual, and applied to the specific context of engineering professionals. However, the concept and philosophy of responsibility for companies and organizations, in the form of corporate social responsibility or CSR policies, has also spread over the last years. CSR is conceived as 'a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis.' (EU, 2001). Ultimately, it is a question of economic growth and social and environmental protection going hand in hand. It is worth noting in this definition the voluntary nature of CSR and its aim to complement laws already in force. These initiatives do not replace legal regulations on environmental or social issues, but they reinforce them. Thus, where minimum conditions are non-existent or insufficient, efforts should focus on creating them.

This definition shows six important features of CSR and current recommendations for how CSR policies should be implemented:

- *Volunteer basis.* The option in favour of integrating social and environmental concerns is voluntary in the sense that it is no legally enforced and that it should go beyond current laws.
- *Integration.* CSR initiatives should be integrated in a company's daily activities, in all business areas and levels. It involves doing things in a different way rather than simply doing more things or 'add-ons'. Instead of being solely about social action, meaning developing social projects using company money as seed funding, CSR initiatives should be integrated directly into processes dictating *how* profit is generated and *how* daily activities are undertaken.
- *Consistency.* CSR initiatives should be sustained over time. There are two reasons for CSR to be a long-term project: first, credibility, since a company that is not coherent in its CSR initiatives will lose public confidence, and secondly because implementing CSR requires time.
- *Transparency and accountability.* Organizations choosing to assume their responsibilities towards society must be willing to act quickly and efficiently in providing truthful information on their actions and decisions related to the key issues for their various stakeholders.
- *Dialogue.* The core of CSR is to understand companies as actors within society and as institutions that should be legitimated by their contribution to satisfying people´s needs and demands.. Contrary to the idea of businesses as independent or even opposed to society and in fight against it, responsible companies should be willing to engage in dialogue with stakeholders.

CSR impacts can be divided into two separate categories: internal and external. Internally, CSR impacts are implemented by internal management, and tend to deal particularly with human resources (working conditions, continuous training, facilities for groups at risk of social exclusion, respect for privacy, etc.); safety and occupational health (prevention measures, sanitation conditions, level of accidents, etc.), and ecological impacts and natural resources (energy consumption, water consumption, waste management, etc.). The external dimension of CSR focuses on reporting on companies' impact on local communities, treatment of suppliers and clients, respect for human rights, and recognition of global biodiversity and environment issues.

Promoting corporate social responsibility demands a global and comprehensive approach addressing all the above-mentioned aspects.

ETHICAL ISSUES IN ENGINEERING ETHICS: CORRUPTION AND CONFLICT OF INTEREST, WHISTLE-BLOWING, AND CONFIDENTIALITY AND INFORMATION OWNERSHIP

Engineering professionals have to confront numerous ethical challenges within their day-to-day work, but only the three will be addressed below: corruption and conflict of interest, whistle-blowing, and information ownership

Corruption

Corruption describes any organized, interdependent system of activities in which a person is either not performing duties he or she was originally intended to, or using privileges in an improper way to the detriment of the common good. In organizations, particularly in public organizations, (OECD, 2009) it refers to the practice of using the purposes and means of the organization for the economic profit, or other benefit, of managers, executives, or individual stakeholdres. *Transparency International*, an independent body engaged in the study of corruption, describes it as the abuse of entrusted power for private gain (Transparency International, 2008: 2).

There are different types of corruption:

- *Bribery*, which consists of offering something to someone in exchange for economic profit or other illegitimate privileges.
- *Extortion*, or exerting pressure on someone to act in a certain way through threats or other illegitimate means.
- *Trading in influence*, which occurs when a person uses his or her power to facilitate advantageous positions to close individuals or organizations. This may involve personal relationships used to exchange favours and other kind of benefits.
- *Fraud*, or lying or tampering with information for personal benefit in the performance of duties.
- *Embezzlement*, which is a type of fraud committed by stealing or allowing a third party to steal money or assets entrusted to them. Embezzlement refers only to the use of money for purposes other than those stipulated.

A conflict of interest occurs when an economic, professional or personal interest may endanger the engineer's objectivity and his or her commitment to good professional practice, loyalty and proper use of the company's assets. According to Martin and Schinzinger '*professional conflicts of interest are situations where professionals have an interest which if pursued might keep them from meeting their obligations to their employers or clients.*' (Martin and Schinzinger, 1996, p. 216). For example, conflict of interest appears when an

engineer holds any economic interest in competitors, clients or suppliers of the company they work for.

Both corruption and conflict of interest involve an adjustment of professionals' loyalties and priorities, and they also imply a violation of the implicit agreements between them and the company or clients. Factors engendering such situations can include:

- Information shortfalls and lack of transparency in decision making.
- Situations of strong convergence between opportunities and incentives, making it very easy to commit irregularities and make a good profit from them.
- Legislative gaps and poor functioning of audit institutions.
- Lack of social recognition of honesty: when people consider acceptable some level of corruption.

In the fight against corruption, different approaches and strategies should be employed simultaneously. Some approaches aim to encourage integrity awareness so that professionals are able to identify corruption situations. These approaches usually include training on ethics and professional responsibility, as well as ethical and codes of professional duty. Other approaches target organizations and their institutional context, seeking to establish a regulatory system with sanctions and incentives so that it is easier to resist corruption or to avoid situations of conflict of interest.

Whistle-blowing

Whistle-blowing is the act of disclosure by a person involved in an organization undertaking any alleged dishonest or illegal activity that would pose a significant risk to society. As a prime example, whistle-blowing would have been an appropriate mechanism in the case of the Challenger explosion in 1986 (see Whitbeck, 1998, p. 133-145 for further discussion). It is the act of reporting to relevant people any suspected offences, irregularities and legal or moral corruption committed by an organization. Here, 'relevant people' refers to those in a position that enables them to ensure an effective response to that situation.

Several aspects of whistleblowing can be drawn from this definition:

- The complaint should be made publically.
- The purpose of making the complaint should be to avoid a risk to society.
- The person reporting should show evidence of the threat arising from the company's behaviour.
- The reported action may be either immoral or illegal (or both).

A baseline should be observed in order to ensure that a whistle-blowing act truly constitutes an ethical decision:

- The whistleblower's purpose is to safeguard the security and well-being of society.
- There is clear evidence of bad practice and the serious risk involved.
- Other complaint channels within the organization have been tried without good results.
- It is reasonably expected that the complaint would prevent damage which could result from the action going forward.

When, in such a situation, professionals respond by denouncing the act and in so doing, may potentially place their career on the line, they are showing a moral courage and ethical consciousness.

Confidentiality and information ownership

Over the past several years, issues related to confidentiality and information ownership have become some of the most serious and discussed ethical topics. Through information technologies, huge amounts of information can be collected, stored, classified and transported in real-time. While this is clearly an advantage, it does not come without risk.

Confidentiality is the obligation to respect the private information of an individual or organization, and it means not to disclose information outside one's scope of competence or if it could cause damage to a person or organization. Sensitive company and client information (economic or technical data, client information, technology, etc.) is routinely accessed by employees for perfectly legitimate, work-related reasons, so most companies establish clauses and adopt measures to keep this information from their competitors.

Some types of information and knowledge are protected by patent and copyright laws, but there are other forms of information and knowledge which are more difficult to secure, such as the implicit knowledge produced developed by professionals through their work experience in a particular company. Many companies impose very strict confidentiality clauses on their employees, including in some cases a prohibition to work in the same sector for a number of years after leaving the company.

There are two key questions regarding ethical information management: who has obtained that information and by what means, and what is the purpose of collecting and employing the information? The first question provides guidance to establish the information and knowledge that can be disclosed outside of the workplace. The second question helps to identify when the use of certain information is legitimate or not. The issue of confidentiality in

the context of a potential of conflict of interest between the company and wider social good arises from the analysis of this second question.

Confidentiality is a *prima facie* obligation but not an absolute one. In principle, respect for confidentiality is a duty whenever it does not clash with a more compelling reason for sharing information. The obligation to respect the private information concerning a person or an organization loses much of its relevance when:

- The moral purpose justifying the breach of confidentiality is realistic and possible.
- Breaching confidentiality is the only possible way to reach a legitimate aim.
- The rule of confidentiality is broken in the least damaging way.
- Any harmful impacts of the breach of confidentiality are minimized.

The essence of confidentiality is to keep professional secrecy, be trustworthy and not to disclose information concerning other persons or organizations without their consent.

PROCESSES FOR DEVELOPING RESPONSIBILITY IN ENGINEERING: ETHICAL CODES AND ETHICAL AUDITING

Ethical and deontological codes constitute a conventional way of realizing the connection existing between ethics and professional activities.

Ethical and deontological codes

A code of professional ethics may be considered as a collective recognition of the individual professionals' responsibility. When formulated clearly and concisely, a code may be a critical factor in creating an environment favourable for ethical conduct to be the norm. 'A code of ethics for engineers should be a concise statement of general rules, preferably positive, for professional conduct.' (Unger, 1994, p. 107).

The main function performed by a code is to serve as a guide for conduct in specific situations. A code should be employed mainly to inspire, encourage and support ethical professionals and to provide the basis for proceedings against misconduct. As opposed to criminal codes, ethical codes should stress positive aspects and commit to ideal models of professional conduct, rather than simply listing forbidden behaviours. According to Hans Lenk (1987), all codes present two key types of rules in this regard: prohibitions, and guidelines. They should both go hand in hand to produce a document clearly stating the dividing line between what is allowed and what is not, and point to the highest level of professional excellence. Above all, codes should not be interpreted as a step-by-step

manual for ethical behaviour, but rather a framework of how to approach situations of potential ethical tension.

It is nevertheless necessary to bear in mind that the ethical requirement underpinning deontological codes and any other self-regulatory instrument is responsibility. The concept of responsibility –as mentioned above– is the key for professional behaviour.

Ethical audits and guides for CSR Management

Social audits are becoming a key element for enhancing the contribution of businesses to social good. Ethical and social audits are emerging over the last several years as a multi-purpose tool: they are a both critical mechanism to meet the need for transparency and a tool for managing organizations in complex economic, cultural and social contexts.

Social Accountability 8000

Social Accountability 8000 (SA 8000) certification, developed by Social Accountability International (SAI) has made a considerable contribution to the development of ethical audits. SA8000 is a standard, auditable and certifiable by independent experts, that requires companies to assure compliance with a series of occupational-related requirements. SA 8000 is based on the Universal Declaration of Human Rights, International Labour Organization (ILO) statements on labour rights and UNESCO statements on the Rights of the Child (SAI 2014).

The purpose of these standards is to ensure decent and basic working conditions around the world. For this reason, they contain identical criteria irrespective of the context they are employed in, and are specifically targeted at companies operating in disadvantaged and weak contexts from a socioeconomic, political and legal perspective.

SA8000 assessments of working conditions focus on 9 essential areas:

- *Child labour.* According to SA 8000, companies should not use or support child labour, which refers to any work carried out by school children or children under the age of 15. There are also standards for young workers, between 15 and 18 years old, establishing a maximum limit of 8 hours and never at night or in hazardous conditions. If companies find out child labour is taking place within their operations, they should provide support in resolving the situation.
- *Forced and compulsory labour.* Workers should be free to terminate their employment and also to leave the work centre after concluding their workday. Payment of 'deposits' or withholding of identity documents are prohibited.

- *Safety and health.* This is one of the most comprehensive and detailed areas of SA8000 criteria. It refers to the right to a safe and healthy work environment for workers. In this spirit, companies should implement the basic mechanisms regarding safety and accident prevention. Sanitary work environments and access to drinking water, as well as protection for new and expectant mothers, are included as measurable criteria for SA 8000.
- *Freedom of Association and Right to Collective Bargaining* means that all persons are entitled to form and join trade unions, and to associate in order to bargain collectively their working conditions. Companies should also ensure protection for workers' representatives and free communication among them.
- *Discrimination.* Companies should not allow any kind of discrimination in labour hiring, access and remuneration. This non-discrimination standard includes the duty to respect religious, cultural or any other kind of such practices, and to take measures to avoid any threatening, abusive or denigrating behaviour inside the company.
- *Disciplinary measures.* Companies must treat all personnel with dignity and respect. No corporal punishment, verbal abuse or coercion to workers is allowed.
- *Working hours.* Normal workweek should not exceed 48 hours, including at least one day off. Overtime is exceptional, voluntary and not longer than 12 hours per week.
- *Remuneration.* Companies should ensure that salaries comply with legal or sector standards and that they are sufficient to meet the basic needs of the personnel.
- *Management system.* It refers to all measures to be developed by companies in order to integrate and effectively meet the above mentioned requirements, and it includes: production and written publication of the working conditions in the company, participation of worker's representatives in SA8000 monitoring, periodic review of the standard, assessment of suppliers and subcontractors, and participation in discussions with all stakeholders.

ISO 26000

The International Organization for Standardization (ISO) is well known worldwide for its technical standards regarding quality, safety and other areas of business activity. After many years of working with experts from more than 90 countries, ISO 26000, "Guidelines for Social Responsibility" was launched in 2011 (ISO 2010).

This standard is intended to provide guidance on implementing business social responsibility as a way to make a positive and effective contribution to sustainable development. It should

be noted that, unlike other ISO standards, ISO 26000 is not a certifiable or external evaluation, but instead provides 'guidance to users'.

According to ISO 26000, social responsibility is 'the willingness of organizations to incorporate social and environmental considerations in their decision-making and be accountable for the impacts of their decisions and activities on society and the environment.' (ISO 26000, 2010, p. 3.3.1). Starting from this definition, the standard is structured around the following seven principles:

- *Accountability* involves explanations of the company's on society, economy and the environment, as well as submitting themselves to scrutiny and responding to it. Admitting mistakes, developing appropriate measures to repair them and implementing prevention measures to avoid future impacts are the essential features of accountability.
- *Transparency* means to 'disclose in a clear, accurate and complete manner and to a reasonable and sufficient degree, policies, decisions and activities for which they are responsible' (ISO 26000, 2010, p.4.3). In other words, stakeholders should have easy and truthful access to information on decisions affecting them.
- *Ethical behaviour.* This principle may be materialised by actively promoting organizational behaviours based on the values of honesty, equity and integrity. For this, there are several core activities, including identification and statement of the essential values and principles; prevention or resolution of conflict of interest; and establishment and maintenance of internal monitoring and control mechanisms.
- *Respect for stakeholder interests*, including owners, partners and clients as well as other groups interested on the progress of the organization. Respect for stakeholders involves identifying the different groups, recognizing and respecting their interests, and considering their capacities to call attention to their concerns.
- *Respect for the rule of law* as a mandatory and undeniable principle that requires knowing the applicable law and its enforcement even if the authorities in charge of its implementation are not effective.
- *Respect for international norms of behaviour*, defined as behaviours arising under customary international law, generally recognized principles of international law or intergovernmental agreements, universally or almost universally recognised
- *Respect for human rights* is an inevitable condition for any responsible company, requiring human rights to be protected in all cultures, countries and situations, not only by not directly violating them, but also of not benefiting from its violation by others.

These principles for developing corporate social responsibility are general guidelines for the right behaviour in the business world. And they are especially relevant in seven key areas or subjects, where they should be implemented: organizational governance, human rights, labour practices, the environment, fair operating practices, consumer issues, and community involvement and development. For each of these key subjects, organizations should identify and address every issue affecting their decisions and practices.

According to ISO 26000, the effective development of corporate social responsibility involves a real integration of the above mentioned principles and subjects into every activity of the company. Obviously, the implementation of the guidelines will depend on the physical and business environment as well as the type or size of company, but this standard recommends a certain number of actions which are valid for all companies, including due diligence in identifying negative impacts, assessments on relevance and importance of the issues, and assessment of sphere of influence of organizations. Finally, ISO 26000 also takes into account and regulates the issue of communication on corporate social responsibility as an element for companies to increase their credibility.

CONCLUSION

This chapter has briefly presented the importance of the ethical aspects and responsibility of engineering. It found that:

- Ethical responsibility is a core element in the practice of engineering. The power generated by wielding scientific and technical knowledge involves a great responsibility since it may profoundly affect the life of many people.
- Ethical challenges are common and may be intense in engineering, and they cannot be addressed mechanically. Personal reflection and the capacity for moral judgment by professionals, as well as the implementation of responsible structures and organizational cultures, are essential to address them successfully.
- Processes and instruments to promote professional integrity and organizational responsibility in the field of business have been place for many years. The most widely recognised and used among them are ethical and deontological codes, as well as ethical auditing.

Finally, it should be recalled that professional ethical training is essential for the practice of responsible engineering. Engineering students should be aware of the ethical impact of their work and of the need for respecting principles of justice and promoting ethical values in their professional activity. Only in this way will they contribute positively to a more just world and to sustainable human development.

BIBLIOGRAPHY

European Union (EU). 2001. Green paper - Promoting a European framework for corporate social responsibility. Available from: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52001DC0366:EN:HTML>. [February 2014]

ISO. 2010. ISO 260000 – Social Responsibility. Available from: <http://www.iso.org/iso/home/standards/iso26000.htm.> [April 2014]

Lenk, H. 1997. Einführung in die angewante Ethik. Kohlhammer, Stuttgart.

Lozano, J. F. 2006. Developing an ethical code for Engineers: the discursive approach. Science and Engineering Ethics, 12, 245-256.

Lozano, J. F. 2011. Qué es la ética de la empresa. Edit. Proteus, Barcelona

Martin, M.W., Schinzinger, R. 1996. Ethics in Engineering, McGraw- Hill, New York.

OECD 2009. OECD Convention on Combating Bribery of Foreign Public Officials in International Business Transactions. Available from: http://www.oecd.org/corruption/oecdantibriberyconvention.htm [March 2014]

Raufflet, E.; Lozano, J. F.; Barrera, E.; García, C. 2012. Responsabilidad Social empresarial. Ed. Pearson, Mexico-Madrid.

Social Accountability International (SAI). 2014. SA8000 Standard. Available from: <http://www.sa-intl.org/index.cfm?fuseaction=Page.ViewPage&PageID=937> [April 2014]

Scholossberger, E. 1993. The ethical Engineer. Temple University, Philadelphia.

Transparency International. 2008. Bribery Payers index. Available from: http://www.transparency.org/whatwedo/pub/bribe_payers_index_2008 [March 2014)]

Unger, S. H. 1994. Controlling technology: Ethics and the responsible Engineer. John Wiley and Sons, New York.

Whitbeck, C. 1998. Ethics in Engineering practice and research. Cambridge University Press, Cambridge.
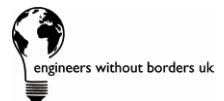
FURTHER/SUGGESTED MATERIAL

- Transparency International
  http://www.transparency.org/
- Online Ethics Center for Engineers and Research
  http://www.onlineethics.org/
- Roger Boisjoly. The Challenger case.
  http://www.onlineethics.org/Topics/ProfPractice/Exemplars/BehavingWell/RB-intro.aspx
- Lampierre, D. and Moro, T. 2002. Five past midnight in Bophal. The Epic Story of the World's Deadliest Industrial Disaster. Warner Books, New York,
- Bohpal disaster (BBC)
  http://www.youtube.com/watch?v=rJg19W8x_Ls
- National Institute for Engineering Ethics
  http://www.niee.org/murdoughCenter/index.php
- Global Reporting Initiative
  https://www.globalreporting.org/Pages/default.aspx
- Shell in Nigeria
  http://www.youtube.com/watch?v=htF5XElMyGI
  http://www.youtube.com/watch?v=bq2TBOHWFRc
- Markkula Center for Applied Ethics
  http://www.scu.edu/ethics/practicing/focusareas/cases.cfm

GDEE | GLOBAL DIMENSION IN ENGINEERING EDUCATION

http://www.gdee.eu

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

United Nations Educational, Scientific and Cultural Organization | uniTwin | UNIVERSITY OF TRENTO - Italy | UNESCO Chair in Engineering for Human and Sustainable Development

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

CAMPUS DE EXCELENCIA INTERNACIONAL
POLITÉCNICA "Ingeniamos el futuro"

Loughborough University

ONGAWA
INGENIERÍA PARA EL DESARROLLO HUMANO

Centro per la Formazione alla Solidarietà Internazionale | Training Centre for International Cooperation

PRACTICAL ACTION
Technology challenging poverty

engineers without borders uk

This project is funded by

MINISTERIO DE ASUNTOS EXTERIORES Y DE COOPERACIÓN | aecid