Smart Green Campus: How IT can Support Sustainability in Higher Education

Pascal Ravesteyn, Henk Plessius, Joris Mens
HU University of Applied Sciences, Utrecht, The Netherlands
pascal.ravesteijn@hu.nl
henk.plessius@hu.nl
joris.mens@hu.nl

Abstract: Within the Netherlands the interest for sustainability is slowly growing. However, most organizations are still lagging behind in implementing sustainability as part of their strategy and in developing performance indicators to track their progress; not only in profit organizations but in higher education as well, even though sustainability has been on the agenda of the higher educational sector since the 1992 Earth Summit in Rio, progress is slow. Currently most initiatives in higher education in the Netherlands have been made in the greening of IT (e.g. more energy efficient hardware) and in implementing sustainability as a competence in curricula. However if we look at the operations (the day to day processes and activities) of Dutch institutions for higher education we just see minor advances. In order to determine what the best practices are in implementing sustainable processes, We have done research in the Netherlands and based on the results we have developed a framework for the smart campus of tomorrow.

The research approach consisted of a literature study, interviews with experts on sustainability (both in higher education and in other sectors), and in an expert workshop.

Based on our research we propose the concept of a Smart Green Campus that integrates new models of learning, smart sharing of resources and the use of buildings and transport (in relation to different forms of education and energy efficiency).

Flipping-the-classroom, blended learning, e-learning and web lectures are part of the new models of learning that should enable a more time and place independent form of education. With regard to smart sharing of resources we have found best practices on sharing IT-storage capacity among universities, making educational resources freely available, sharing of information on classroom availability and possibilities of traveling together. A Smart Green Campus is (or at least is trying to be) energy neutral and therefore has an energy building management system that continuously monitors the energy performance of buildings on the campus. And the design of the interior of the buildings is better suited to the new forms of education and learning described above. The integrated concept of Smart Green Campus enables less travel to and from the campus. This is important as in the Netherlands about 60% of the CO_2 footprint of a higher educational institute is related to mobility. Furthermore we advise that the campus is in itself an object for study by students and researchers and sustainability should be made an integral part of the attitude of all stakeholders related to the Smart Green Campus.

The Smart Green Campus concept provides a blueprint that Dutch institutions in higher education can use in developing their own sustainability strategy. Best practices are shared and can be implemented across different institutions thereby realizing not only a more sustainable environment but also changing the attitude that students (the professionals of tomorrow) and staff have towards sustainability.

Keywords: Sustainability, Smart Campus, Information Technology, Energy Efficiency

1 Introduction

Over the past years, we have seen increasing attention towards sustainability and ICT in higher education. Internationally, sustainability in higher education has been on the agenda since 1992, when, among other reports, Agenda 21 was published as an outcome of the Earth Summit in Rio de Janeiro (United Nations 1992). In 2012, a new political commitment was expressed towards further development of sustainability during the UN Conference on Sustainable Development, or Rio+20 (United Nations 2012). In this year, the network of student organizations named *Studenten voor Morgen* started ranking Dutch universities by their level of sustainable practices (Studenten voor Morgen 2014). The accompanying award *Sustainabul* was won by the University of Maastricht for their transparent sustainability policies.

European member states have concluded that industrialised nations should join forces to reduce greenhouse gas emissions. In The Netherlands, this imitative has lead to a long-term agreement (LTA) for energy efficiency. Both the educational sector and the IT sector have committed to the LTA for energy efficiency 2001-2020, also known as LTA3, in which a 30% improvement in energy efficiency is envisioned (Rijksdienst voor Ondernemend Nederland 2008). A more elaborate specification for sustainability in higher education was made in the Blueprint for a Green Campus (The Heinz Family Foundation 1995), in which ten practical recommendations were made for improving both the curriculum contents and business operations. For universities, a Greening Universities Toolkit was made available (United Nations Environment Programme 2013). International cooperation with other universities takes place through the International Sustainable Campus Network.

To achieve the objectives stated in LTA3, institutions should not only improve the sustainability of their business operations. They should also work on the evolution of this topic within their research and educational activities. The use of information and communication technologies (ICT) offers the opportunity to organize processes and activities in a more efficient and effective manner, thereby preventing waste of resources.

This paper identifies a number of potentially interesting opportunities for sustainability in higher education, which will be referred to as the Smart Green Campus. These opportunities take into account the research and educational activities as the core activities of higher education, which can serve as a driving force for sustainability improvement. The Smart Green Campus concept encompasses four themes: Smart Learning and Smart Sharing in the field of education and research and Smart Buildings and Smart Transport in the operations of universities.

The goal of this study is to gather input from various educational institutions and organisations in order to provide a Smart Green Campus framework that will meet the needs of higher education and society at large in the years to come.

2 Theoretical Background

The Oxford English Dictionary defines sustainability as being 'able to be maintained at a certain rate or level'. Sustainability can be applied to different systems, such as social, economic or biological systems. According to Brown et al. (1987), most definitions of sustainability in different domains state that human survival is the goal of sustainability, while disregarding sustainability of the biosphere without the existence of humans. Gatto (1995) identifies distinct definitions of sustainability for biological, ecological and economical systems and argues that these definitions are flawed, because they imply sustained development when in fact continuous population or economical growth is not feasible. Gatto (1995) argues that biological systems are sensitive to fluctuations, and are therefore inherently unsustainable in the sense that there is no continuous development. These fluctuations are in fact necessary to maintain ecosystem diversity (Gatto 1995). As continuous growth is infeasible, compromises must be made by controlling or limiting growth so that quality of living can be maintained while exercising equitable resource use (Brown et al. 1987).

In the context of higher education, Wals and Jickling (2002) argue that we should not limit ourselves to one particular definition of or one approach to sustainability. Educators play a central role in constantly seeking new standards for sustainability in education in order to make a contribution to

environmental improvement. A case study of two different universities found that sustainability in higher education requires a comprehensive approach (Clugston & Calder 1999). A university will have to rethink its role in society and needs to improve in all areas, as an institution cannot achieve sustainability when improving only some areas and neglecting others. Clugston and Calder (1999) identify the institutionalization of sustainability as the key indicator for success. This is achieved through official policy, budgeting or permanent staff positions. Sustainability should be incentivized through favourable pricing schemes and subsidies, so that ecological efficiency leads to cost savings. The lack of monetary incentives is one of the main obstacles to improving sustainability (Clugston & Calder 1999).

Shriberg (2002) also identifies the reputation of an institution as primarily important for the ascendance of sustainability initiatives. A link is found between successful sustainability practices and the willingness of the institution to exert a sustainable image, supported by a progressive and liberal orientation, a collegial atmosphere and collaborative structures rather than top-down processes. Transformational leadership was not found to correlate to sustainability as strongly as a pervasive collaborative environment. Brinkhurst et al. (2011) also underscore this statement by finding that sustainability efforts should be neither 'top-down' nor 'bottom-up', but should be performed by the organisational 'middle', namely faculty and staff. Staff needs to be encouraged and provided permission to take on sustainability projects, for example by providing the role of greening officer to faculty members.

Wright (2002) discusses the prevalence of sustainability declarations such as the Talloires declaration and the Halifax declaration, which are signed by universities to state their commitment to sustainability issues. It remains to be seen whether signing these declarations truly leads to change or if it is merely a matter of public relations. Wright proposes that there is a gap in knowledge for the effective implementation of such a declaration.

In regards to students' perception of sustainability, a recent study between two universities by Emanuel & Adams (2011) found that there is sufficient awareness for sustainability among students. However, there is a difference in the level of commitment expressed in participating in sustainable practices. This appears to be caused by the level of commitment that is found in the community where the campus is located.

In prior research in this field many different factors relating to sustainability practices in higher education were studied. Building on previous research and trying to put theory into practice, the proposed Smart Green Campus framework will take into account these different factors as well as the needs of stakeholders in the internal and external environment.

3 Research Approach

The foundation of our research is based on the theory for design and action that states it “is about the principles of form and function, methods, and justificatory theoretical knowledge that are used in the development of IS.” (Gregor 2006, p.628)

As we are not developing an entirely new theory but propose a framework for the Smart Green Campus we can use design science theory that puts the notion of the development of an artifact central as is explained by Hevner, et al. (2004): “The design-science paradigm seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artefacts.” (Hevner et al. 2004, p.75). Both descriptive and prescriptive research elements are present (Hevner et al. 2004; March & Smith 1995). The descriptive part (knowledge-producing activity) aims to understand, explain and predict why certain phenomena are occurring, while the prescriptive approach (knowledge-using activity) is meant to provide results that improve the performance in relation to the business need, which in our research is a more sustainable campus.

As stated above the objective of this paper is to develop a framework for the Smart Green Campus concept, which can be used as a blueprint that institutions in Dutch higher education can use in developing their own sustainability strategy. Hereto a mixed method research approach was chosen that fits the theory of design science. The research process (Figure 1) consisted of a literature study, interviews with experts on sustainability (both in higher education and in other sectors), and an expert workshop.

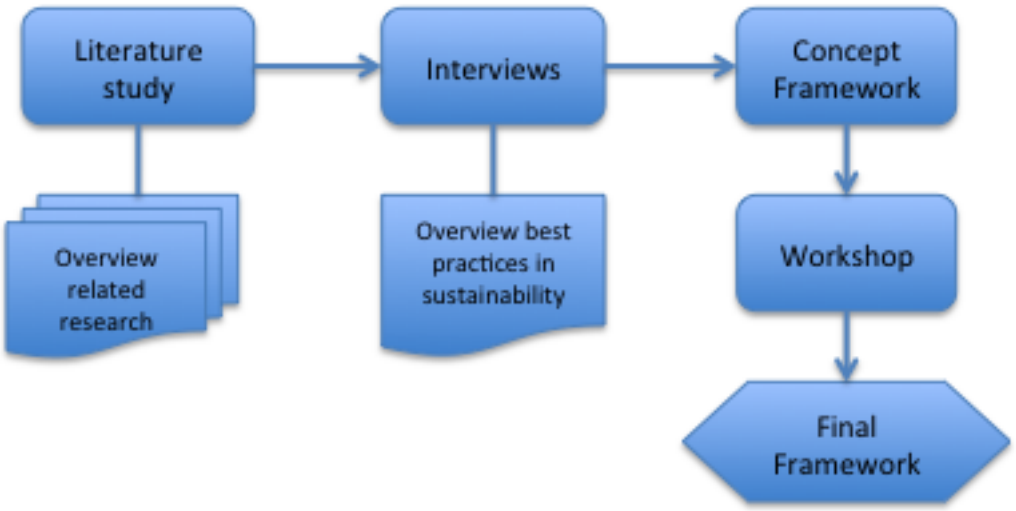

Figure 1: research process

The literature study is based on a two-step approach. First the researchers independently searched relevant databases (provided by the University library) and scholar Google using keywords such as *sustainability*, *higher education*, *(Green) IT*, *energy efficiency*. Papers that were retrieved were subsequently discussed in a group meeting and if relevant stored for this research. The second step consisted of acquiring all Energy Efficiency Plans (EEPs) of all Dutch Higher Educational institutions. Each institution needs to write such a plan, which has a three-year time span, as part of the LTA agreements. In an EEP the plans for energy reduction are described, the goals that need to be met and how more green energy is going to be used. All EEPs were studied to determine if there are best practices in reducing energy use.

The next step in our research process consisted of interviewing 8 persons in 7 interview sessions (see Table 1). The interviews were open interviews in which we asked the participants three questions: 1) describe your role in your organisation? 2) What best practices for sustainability in Dutch higher education do you know and can you describe these? And 3) Do you think that IT can be used to enable sustainability? If so please explain.

No.	Role	Organisation
1	Social Innovation Manager	Microsoft Netherlands
2	Program Manager	GreenIT Amsterdam
3	Assistant Professor	TU Delft
4	Manager service unit IT	HAN University of Applied Sciences
5	Senior consultant sustainable development	HAN University of Applied Sciences
6	Manager Sustainability	ICT Office
7	Board member	Studenten voor morgen
8	Initiator	An Innovative Truth

Table 1: Overview of interview respondents

Based on our findings from the literature study and the interviews we constructed a first version of a framework for a Smart Green Campus. To validate and enhance the framework an expert workshop was organized. The workshop consisted of a 20-minute presentation of our research process and subsequently the proposed framework. The 20 experts that participated (amongst them numbers 6 and 7 from the interviewees) were asked in an open discussion to provide feedback on the framework. Two researchers were present, one of who moderated the discussion and wrote down notes on a whiteboard while the other made research notes. After the workshop we were also provided with the notes of a participant from another university. Based on the outcome of the workshop the framework was adapted. This version has been sent by e-mail to five of the workshop participants for further feedback and validation. The final framework, which is introduced in the next section, is constructed based on a synthesis of all input provided during the research.

4 Results

In the preceding sections we have used the concept of Smart Green Campus in two ways. On the one hand it is used as a container for the greening of higher education by means of IT. In this context the question arises: what is inside this container and how may that be represented in a universal framework? On the other hand the concept of Smart Green Campus is used as a focal point for all efforts that should lead to an environmental neutral university, which raises the question how this goal may be reached most effectively. In this paragraph we will first identify what we understand when using the term Smart Green Campus, followed by a short discussion of how it may be reached and the role of the framework.

The focus of higher education is on learning (both in education and in research) and sharing (of knowledge). While these are immaterial in nature, they have counterparts in the real world: books, lab equipment, PowerPoint's, etcetera. In order to support these primary goals, universities have built an infrastructure, essentially consisting of meeting places and transport possibilities to and from these places. These places and ways of transport are by their very nature physical, but have acquired virtual counterparts in the worldwide IT infrastructure.

So, a Smart Green Campus can be expressed in four themes: Learning, Sharing, Buildings and Transport, where all of these themes may be material as well as immaterial. Moreover, the ubiquitous presence of IT has accelerated the transition from material to immaterial and in this way IT has contributed to a greener campus by giving rise to Smart Learning, Smart Sharing, Smart Buildings and Smart Transport. In the remainder of this section we will examine these four themes and give examples of how they can be used to enable sustainability at university campuses.

Smart Learning and Smart Sharing

With Smart Learning we allude to the digitization of (higher) education. Some examples are the introduction of eLearning, blended learning and MOOCs, multiple on-line open courses. All these new learning models aim to make learning a process that can take place anytime, anywhere. A second common denominator in all these new ways of shaping the educational process is the use of IT as a means to diminish physical contact time. And it is not only knowledge that is propagated through the use of eLearning tools, but by using simulations it is possible to practice skills as well. As a result, the use of IT as a means to diminish physical contact time has a substantial effect on the need for meeting places (i.e. buildings) and transport.

An example of how a digital learning environment may be followed by the redesign of a course can be found in the authors' experience with a minor program, the minor Virtual and Social Networks given at the University of Applied Sciences Utrecht (Ravesteyn & Kohler 2013). In this course the average contact time of 300 hours in a semester has been reduced by 50% by consequently using digital possibilities and the sharing of information throughout the student group by means of groupware tools. This example shows the importance of smart sharing as well: where email was discouraged, discussions were held in groups and not on a one-to-one base, ensuring a much faster exchange rate of information.

In research, there is a growing trend in free sharing of research data and results as well: Open Access (Corrado 2005; Verschraegen & Schiltz 2007). Benefits according toe Corrado are lower costs, greater accessibility, and better prospects for long-term preservation of scholarly works, but we think Open Access contributes to sustainability principles as well and so we add it to our Smart Green Campus concepts.

While sharing may be difficult for the physical infrastructure (and most universities will find it undesirable as well), it is quite feasible for the IT infrastructure where cloud services are becoming quite common. The use of these specialized suppliers of IT services (like data storage, software-as-a-service, etcetera) has a positive effect on energy usage as the example of Groningen University shows. In this university a new datacenter not only services the university, but other educational institutes as well. In this datacenter various energy saving measures - feasible by the scale of the new datacenter - have been introduced, resulting in a substantial decrease (almost 50%) in energy usage (SURFnet 2011).

Smart Buildings and Smart Transport

By using smart ways of learning and sharing, the need for a physical infrastructure diminishes. But physical contact will always be necessary, both in education as in research. So it is important that buildings will become (at least) energy-neutral.

In many universities, buildings are used quite ineffectively. Some hours they are overpopulated with students, while on other hours (and in holidays), the same buildings are almost empty. Smart energy management, which anticipates on the actual attendance, may help control these fluctuations as seen from an energy perspective. A good example is the SEECE Center of Excellence in the HAN University of Applied Sciences (Hogeschool van Arnhem en Nijmegen 2014) where research is done on how to optimize the supply and demand for energy throughout the day.

Where the need for physical contact diminishes, so does the need for physical buildings. But, as explained before, physical contact will always be necessary and with it, transport.

There are many developments in transport nowadays. Probably one of the most promising is the development of electrical powered transport. The batteries used by these cars may play an important role in the 'smart grid' for the storage of solar energy. For example the University of Delft researches the possibilities of these smart grids (Delft University of Technology 2014).

The Smart Green Campus Framework

In the preceding sections, we have focused on the four themes constituting a Smart Green Campus. To make explicit the contribution of these themes, separate and in combination, to the greening of a campus, we compare these themes with the traditional triple P-criteria of People, Planet and Profit (Elkington 1998). This (influential) political-societal driven model is based on the idea that economical, ecological and social aspects should be integrated in order to make economic activities sustainable as well.

The combination of our four themes with the triple P-criteria creates the Smart Green Campus Framework of figure 2.

	People	**Planet**	**Profit**
Learning	Digital learning environment		
Sharing	Open Access		Shared datacenters
Buildings		Energy management	
Transport		Smart grids	

Figure 2: The Smart Green Campus Framework

In this framework, the measures taken by the university may be plotted which gives a view on the resulting sustainability of the campus in one glance. As an example, we have plotted the various examples given in the preceding sections, in the framework of figure 2.

Smart Green Campus as a goal

In the preceding sections, we have shown various examples of the four main themes of a Smart Green Campus and integrated these themes in a framework. But how to effect changes towards a smarter and greener campus? From what we have outlined before, we may conclude that universities have to move to virtual environments and the remaining physical assets should be made as sustainable as possible.

In order to move in the desired direction, actors are necessary. For a university, three kinds of actors come naturally: students, employees and ‘outsiders’, by which we mean anyone who is in some way involved with the university, but not as a student or an employee. Examples are the government, researchers from other universities, but suppliers as well. Everyone involved should be included in making the campus greener. Specifically students could play an important role, by using the campus as a Living Lab, as the following case shows: “Walking is already one of the greenest forms of transportation but one researcher at Louisiana Tech University thought it could be made even more eco-friendly — so he designed a shoe that converts the wearer’s footsteps into electricity. The Piezo power shoe contains a small generator in its sole that can charge batteries or power small electronics. Bet your Nikes can’t do that” (Yoneda 2010).

5 Conclusion

In this research we have used literature study, interviews and an expert workshop to gather best practises on sustainability from various Dutch educational institutions and organisations. These were subsequently analysed in order to provide a Smart Green Campus framework that can be used by higher educational institutes to develop an integrated sustainability strategy for their campus.

The proposed framework is a matrix that consists of four themes 1) Learning, 2) Sharing, 3) Buildings and 4) Transport, which are combined with the traditional triple P-criteria of People, Planet and Profit. The cells of the matrix should be filled with different sustainability initiatives and thus functions as a guide to university administrators and faculty in proposing measures that can be taken by the university on the path to a Smart Green Campus.

It is important to realize that the change towards a smarter and greener campus can only be made possible if the relevant actors (students, faculty and external stakeholders) work together. Therefore sustainability efforts should be neither 'top-down' nor 'bottom-up', but should be performed by the organisational 'middle' (i.e. staff and students) with strong management support.

Based on this research we have found that although there are many sustainability initiatives in the Dutch higher educational environment, most seem to be disconnected from an overall vision and strategy. The framework proposed in this paper can help in aligning existing initiatives and projects as well as developing a clear overall path to the Smart Green Campus.

6 Discussion & Further Research

In our opinion the proposed framework should be usable in any country by any institute in higher education. However it is good to realize that this research stems from a Dutch perspective on higher education and sustainability and therefore could have a bias. As such it is necessary to gather best practices in other countries and test the usability of the framework.

Also we need to mention that the framework is focused on enabling the university processes, both primary (teaching and research) as secondary (e.g. administrative processes), to be more sustainable. The framework does not provide any guidance or help with implementing sustainability competences in curricula. Further research might provide extensions to our framework to also incorporate this aspect of sustainability.

Finally it should be clear that this is an exploratory research on which the proposed framework is developed. The validity of the framework can only be determined by actual use by higher educational institutions. Therefore we propose to perform several case studies at institutions that adopt the framework in the development of a strategy and portfolio of sustainable initiatives towards a Smart Green Campus.

References

Brinkhurst, M. et al., 2011. Achieving campus sustainability: top-down, bottom-up, or neither? *International Journal of Sustainability in Higher Education*, 12(4), pp.338–354. Available at: http://www.emeraldinsight.com/10.1108/14676371111168269 [Accessed May 28, 2014].

Brown, B.J. et al., 1987. Global sustainability: Toward definition. *Environmental Management*, 11(6), pp.713–719. Available at: http://link.springer.com/10.1007/BF01867238.

Clugston, R. & Calder, W., 1999. Critical dimensions of sustainability in higher education. *Sustainability and university life*. Available at: http://www.ulsf.org/pdf/Critical_dimensions_SHE.pdf [Accessed June 7, 2014].

Corrado, E., 2005. The importance of open access, open source, and open standards for libraries. *Issues in science and technology librarianship*, (42), pp.1–7. Available at: http://is.muni.cz/www/4209/ICMLG-13-Proceedings.pdf#page=289 [Accessed June 10, 2014].

Delft University of Technology, 2014. Smart Grids: Fresh light on the energy network of the future.

Elkington, J., 1998. Partnerships fromcannibals with forks: The triple bottom line of 21st-century business. *Environmental Quality Management*, 8(1), pp.37–51. Available at: http://doi.wiley.com/10.1002/tqem.3310080106 [Accessed May 27, 2014].

Emanuel, R. & Adams, J.N., 2011. College students' perceptions of campus sustainability. *International Journal of Sustainability in Higher Education*, 12(1), pp.79–92. Available at: http://www.emeraldinsight.com/10.1108/14676371111098320 [Accessed June 7, 2014].

Gatto, M., 1995. Sustainability: is it a well defined concept? *Ecological applications*, 54(6), pp.1681–1682. Available at: http://www.ncbi.nlm.nih.gov/pubmed/24911909 [Accessed June 10, 2014].

Gregor, S., 2006. The Nature of Theory in Information Systems. *MIS Quarterly*, 30(3), pp.611–642.

Hevner, A. et al., 2004. Design science in information systems research. *MIS quarterly*, 28(1), pp.75–105. Available at: http://www.springerlink.com/index/pdf/10.1007/s11576-006-0028-8 [Accessed June 10, 2014].

Hogeschool van Arnhem en Nijmegen, 2014. SEECE, Sustainable Electrical Energy Centre of Expertise. Available at: http://specials.han.nl/sites/seece/ [Accessed June 10, 2014].

March, S.T. & Smith, G.F., 1995. Design and natural science research on information technology. *Decision Support Systems*, 15(4), pp.251–266. Available at: http://linkinghub.elsevier.com/retrieve/pii/0167923694000412 [Accessed May 23, 2014].

Ravesteyn, P. & Kohler, A., 2013. The Future of Learning and the Educational Process. In V. Ribiere & L. Worasinchai, eds. *Proceedings of the International Conference on Management, Leadership and Governance*. Bangkok: Bangkok University, pp. 274–281. Available at: http://is.muni.cz/www/4209/ICMLG-13-Proceedings.pdf#page=289 [Accessed June 10, 2014].

Rijksdienst voor Ondernemend Nederland, 2008. *LTA3 Long-term agreement on energy efficiency 2001 - 2020*, Available at: https://www.rvo.nl/sites/default/files/bijlagen/LTA3 convenanttekst - 13 juni 2008.pdf.

Shriberg, M., 2002. Sustainability in US higher education: organizational factors influencing campus environmental performance and leadership. Available at: http://promiseofplace.org/research_attachments/Shriberg2002SustainabilityinHigherEdu.pdf [Accessed June 7, 2014].

Studenten voor Morgen, 2014. What is the SustainaBul? Available at: http://www.studentenvoormorgen.nl/en/sustainabul-2/what-is-the-sustainabul/ [Accessed June 7, 2014].

SURFnet, 2011. *Best Practice: ICT-scan helpt RUG verduurzamen*, Available at: http://www.surf.nl/binaries/content/assets/surf/nl/kennisbank/2011/bestpractie_201111_duurzaamheid_rug.pdf.

The Heinz Family Foundation, 1995. *Blueprint for a Green Campus*, Available at: http://www.ithaca.edu/sustainability/docs/crr/blueprintgreencamp.pdf.

United Nations, 1992. *Agenda 21*, United Nations. Available at: http://rioplus20education.info/wp-content/uploads/2012/02/Agenda21.pdf.

United Nations, 2012. *The future we want*, Available at: https://rio20.un.org/sites/rio20.un.org/files/a-conf.216l-1_english.pdf.pdf.

United Nations Environment Programme, 2013. *Greening Universities Toolkit*, UNEP Publishing Board. Available at: http://www.unep.org/training/docs/Greening_University_Toolkit.pdf.

Verschraegen, G. & Schiltz, M., 2007. Knowledge as a Global Public Good: The Role and Importance of Open Access La connaissance en tant que bien public: le rôle et l'importance d'accès publique El conocimiento como un bien público global: el papel y la importancia del acceso libre. *Societies Without Borders*, 2(2), pp.157–174. Available at: http://booksandjournals.brillonline.com/content/journals/10.1163/187219107x203540 [Accessed June 10, 2014].

Wals, A.E.J. & Jickling, B., 2002. "Sustainability" in higher education: From doublethink and newspeak to critical thinking and meaningful learning. *International Journal of Sustainability in Higher Education*, 3(3), pp.221–232. Available at: http://www.emeraldinsight.com/10.1108/14676370210434688 [Accessed June 1, 2014].

Wright, T., 2002. Definitions and frameworks for environmental sustainability in higher education. *Higher Education Policy*, 15(2), pp.105–120. Available at: http://www.palgrave-journals.com/doifinder/10.1016/S0952-8733(02)00002-8 [Accessed June 7, 2014].

Yoneda, Y., 2010. 6 Inspiring Examples of Groundbreaking Green Technology. *Inhabitat*. Available at: http://inhabitat.com/6-inspiring-examples-of-groundbreaking-green-technology/ [Accessed June 10, 2014].