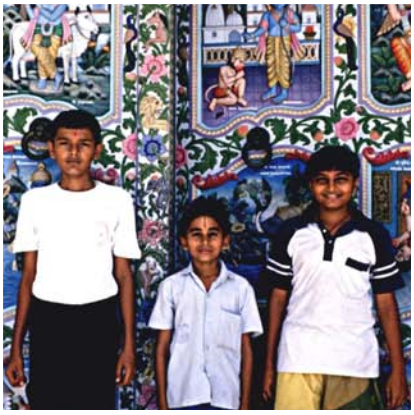
Sustainable Pathways to Attain the Millennium Development Goals

Assessing the Key Role of Water, Energy and Sanitation





SEI STOCKHOLM ENVIRONMENT INSTITUTE

With contributions from the Stockholm International Water Institute

SIWI

Sustainable Pathways to Attain the Millennium Development Goals:

Assessing the Key Role of Water, Energy and Sanitation

Johan Rockström, Göran Nilsson Axberg, Malin Falkenmark, Mats Lannerstad, Arno Rosemarin, Ian Caldwell, Anders Arvidson and Mattias Nordström.

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With contributions from the Stockholm International Water Institute (SIWI)

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Preamble

In the UN Millennium Declaration in 2000 the world's leaders united in a unique commitment to peace, security, development, human rights and fundamental freedom. Eradicating extreme poverty and hunger, and setting world development on an environmentally sustainable pathway are core goals in this endeavour.

The UN Millennium Review Summit in September 2005 will assess the first five years progress and achievements since the Millennium Declaration in attaining the Millennium Development Goals (MDGs). As pointed out by Kofi Annan, UN Secretary General, this meeting is probably even tougher than the Summit in 2000 as, "instead of setting targets, this time leaders must decide how to achieve them". This report by the Stockholm Environment Institute (SEI) sets out to clarify the fundamental and urgent need for environmentally sustainable strategies for goal fulfillment, not only to avoid undermining long-term ability to improve the lives of the world's poorest, but also to tap the opportunities in making the environment work for the MDGs. The report presents environmentally sustainable ways and means to support global, regional and national implementation to attain the Goals. It is submitted as a contribution to the UN Millennium Review Summit in September 2005 of the UN High Level Plenary Meeting of the General Assembly.

Despite significant progress in achieving certain goals in different regions of the world, the predicament for the most poverty-stricken countries remains bleak. Furthermore, there is a growing concern over the insignificant progress on MDG 7 – Ensure Environmental Sustainability - which is a key goal and a prerequisite for overall MDG achievement. First, progress is lacking in the internalization of environmental components in socio-economic development. This is needed to protect valuable ecosystem services, such as biodiversity, fish habitats and pollination. Such services can determine the long-term capacity of human societies to buffer or absorb sudden environmental shocks, such as droughts and floods. Second, the MDG 7 is not an isolated goal in itself, but instead forms an integral goal for all the MDGs. Moreover, there is a growing realization that huge challenges, such as eradicating hunger, will have to be achieved through environmentally sustainable solutions. Instead of, as often has been the case in the past, focusing attention on negative environmental impacts of development investments, it is now urgent to instead focus on how we can make environmental sustainability work for MDG achievement.

This report highlights the importance of the environment in achieving all MDGs. It focuses on three core aspects of goal fulfillment, namely freshwater to eradicate hunger and sustain ecosystems, energy for poverty alleviation and sanitation for poverty alleviation, health improvements and environmental sustainability. The objective is to clarify the large environmental investments required to attain the MDGs, and to identify sustainable solutions where synergies between the environment and development can be achieved for more rapid MDG achievement and to secure long-term sustainability also beyond 2015.

Stockholm Environment Institute, named after the 1972 UN Conference on the Human Environment in Stockholm, is an independent, international research institute specializing in sustainable development and environment issues at local, national, regional and global policy levels. The SEI research programmes aim to clarify the requirements, strategies and policies for a transition to sustainability. SEI along with its predecessor, the Beijer Institute, has been engaged in major environment and development issues for more than a quarter of a century. The Institute seeks to be a leader in the creation of a new field of sustainability science aimed at understanding the fundamental character of interaction between nature and society, and to contribute to the capacities of different societies to build transitions to more sustainable futures.

The project team consisted of Johan Rockström (director, external relations and water and food sub-study), Göran Nilsson Axberg (project manager), Malin Falkenmark (from SIWI) and Mats Lannerstad (both in water and food sub-study), Arno Rosemarin and Ian Caldwell (sustainable sanitation sub-study), and Anders Arvidson and Mattias Nordström (energy sub-study).

This study manifests the growing awareness that environmentally sustainable pathways to improve the lives of the world's poorest and weakest communities are not only urgently needed but achievable, generally cheaper, and offer longer-term and more resilient solutions. This is of fundamental importance in a future where environmental risks and extreme surprise will increase due to global change. The study forms part of a wider context of global partnerships linking environment and development, and has in particular been conducted in consultation with, and as a complement to, the environment and MDG initiative of the Poverty Environment Partnership (PEP). Together with the PEP and other local, regional and international partners in developing and developed countries, we hope this study will contribute to further speed up the definition and realization of sustainable pathways to attain the MDGs.

Stockholm in August, 2005

Johan Rockström

Executive Director

Acknowledgements

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Table of Contents

1. EXECUTIVE SUMMARY

1.1 General 1
1.2 Key messages and main recommendations 3

2. INTRODUCTION

2.1 General 6
2.2 This study 7
2.3 The MDG challenge 8

3. WATER AND FOOD FOR THE MDGS

3.1 Introduction 11
3.2 The Hunger Goal and the 2015 Target 12
3.3 Aspects to consider 13
3.4 Water requirements 17
3.5 Options to meet the water for food challenge 20
3.6 Environmental impacts and trade-offs 28
3.7 Socio-economic impacts 30
3.8 Conclusions and way forward 32
3.9 References 35

4. SUSTAINABLE SANITATION FOR THE MDGS

4.1 Introduction 37
4.2 Estimating the MDG population targets for water and sanitation through to 2015 40
4.3 Estimating the MDG urban and rural household targets for water and sanitation through to 2015 41
4.4 Introducing sustainable sanitation 45
4.5 The financial aspects of introducing ecosan 48
4.6 Determining the amount and commercial value of nitrogen and phosphorus from human excreta 53
4.7 Conclusions and the way forward - A call for innovation 56
4.8 Data sources 59
4.9 References 59

5. ENERGY, THE MDGS AND THE ENVIRONMENT

5.1 Introduction 61
5.2 Global energy sector and the MDGs 73
5.3 Options for meeting growing energy demand 78
5.4 Conclusions and way forward 79
5.5 References 80

6. KEY MESSAGES AND RECOMMENDATIONS

6.1 Key messages 81
6.2 Main recommendations 83

7. APPENDICES

7.1 Appendices to the Water and Food Chapter 86
7.2 Appendices to the Sustainable Sanitation Chapter 90
7.3 Appendices to the Energy and the Environment Chapter 96

1. Executive Summary

1.1 General

The purpose of this study is twofold. First, to manifest the importance of the environment to attain the MDGs. Secondly, to make the case, based on scientific analyses on freshwater, energy and sanitation, where environmentally sustainable management strategies are a prerequisite for long term and resilient improvement of the lives of poor people in the world. This study introduces innovative and sustainable solutions to reduce poverty within the context of the MDGs. We argue that such solutions are required not only to reach the 2015 targets, but also for sustaining the results forming a platform for the continued work to eradicate hunger and poverty in the years to come thereafter.

The study complements the work by the Task Force for Environmental Sustainability of the Millennium Development Project, by showing the new direction investments in water and sanitation needs to take, and supports the ideas put forward by the Poverty and Environment Partnership (PEP) that poverty and environmental issues need to be addressed together. In addition, we argue that environmental sustainability aspects need to be an integral part of all eight MDGs.

The study does not aim to impose additional environmental costs to the implementation of the MDGs. It provides inputs and insights for new and integrated strategies to alleviate hunger, provide energy, sanitation and health that consider the balance between ecosystems and the urgent needs for livelihood improvements, with the objective to assist in making the MDG interventions more resilient and long-lasting, with higher benefits in return.

For example, an environmentally sustainable approach to MDG 7 on water and sanitation would allow for appropriate and affordable small-scale water treatment options and sustainable sanitation systems including ecological sanitation, both helping to meet the MDGs at lower costs than more conventional large-scale systems. In addition significant gains can be reached from the recycling of plant nutrients that ecological sanitation provides, which will improve agricultural yields and save water.

Extensive financial, human and natural resources are required to meet the MDGs. Governments in developing countries are challenged with the need to undertake focused investments in order to facilitate the realization. The UN Millennium Project, in its Practical Plan, states: “In total, we find that (annual) costs of meeting the MDGs in all countries are on the order of $121 billion in 2006, rising to $189 billion in 2015”[1] The additional support to development cooperation per year roughly represents a doubling of official aid flows over year 2000 levels[2].

This should not be compared to the calculations presented in this report. Included cost and investment items are very different and we do not distinguish between donor and within-country funding. Anyhow, the results from the present SEI studies indicate an approximate investment level of USD 107 billion annually during the period 2005 to 2015 to meet the MDG targets related to water and food, sanitation and energy following principles of environmental sustainability in all developing countries. The investments are distributed on the three studied aspects as follows:

- Water and Food: USD 47 billion annually.
- Sustainable Sanitation: USD 15 billion annually.
- Energy and Environment: USD 45 billion annually.

[1] Investing in Development - A Practical Plan to Achieve the Millennium Development Goals, UNDP, 2005
[2] Goals for Development: History, Prospects and Costs, Shantayanan Devarajan, HDNVP, Margaret J. Miller, HDNVP and SRM, Eric V. Swanson, DECDG, April 2002 (http://econ.worldbank.org/files/13269_wps2819.pdf)

The water and food and the sanitation estimates include public, private sector and household investments. The energy part includes public expenses only.

Considering that we cover parts of the MGD targets only, the SEI estimates are somewhat higher than those from the UNDP mainly because a higher level of resilience is being built in, the solutions are longer lasting and there are many positive spin-offs benefiting poor communities. Notably, cost savings and benefits are not deducted from these figures. Additional analyses, including cost-benefit assessments, will likely demonstrate higher economic and financial rates of return for the more sustainable solutions than for the practices and solutions applied in most places today.

Initial analyses from the Water and Food part of this study indicate that the annual investments will increase during the period 2015 to 2030 governed by population growth. Additional investments are needed until year 2050 when the global population is expected not to increase any longer. Thus it is even more important to introduce resilient solutions now in order to be able to cope better later on when the MDG challenge has become even larger.

The estimates include the investments and costs in developing countries only. Necessary investments in developed countries are not included, e.g. for reducing climate change impacts affecting poor people of the World. The greenhouse gas (GHG) emissions have to be addressed on a global level. To reduce negative impacts from climate change on the poor, the mitigation measures should be taken by the affluent population segments of this world, who are responsible for most of the emissions.

The study demonstrates that energy, water, sanitation, health, poverty and hunger are closely linked, stressing the urgent need to integrate environmental sustainability through intelligent energy, freshwater management, land use and sanitation strategies.

The main messages to policy makers for MDG implementation related to water, energy and sanitation are:

- Environmental sustainability needs to be integrated into all the MDGs. Provision of water, energy and sanitation are needed to attain goals on hunger, child mortality, poverty, health, and education. Gender is integral to these domains, and global partnerships are required to manage shared water resources. The MDG 7 is not an isolated goal in itself, but instead forms an integral goal for all the MDGs.
- Environment has to work for the MDGs, where synergies from sustainability investments can speed up achieving the goals, and to sustain the results.
- There are environmentally sustainable solutions and know-how available to attain the MDGs, which will assist in providing long-term livelihood improvements and increased social and ecological resilience, to meet a future with increased risks, including climate change driven shocks, such as droughts and floods.
- Considering the effects of environmentally sustainable solutions, the costs will not be higher.

Freshwater, sanitation and energy are closely linked and fundamental to livelihood improvement and development. There are important untapped synergies between water, agriculture, sanitation, health and energy, in efforts of making the environment work in a sustainable way for the MDGs. Freshwater is required in all biomass production and is key to human health. Sustainable sanitation provides clean water and critical fertilization for food production enabling yield and crop per drop improvements, releasing freshwater pressure from downstream uses. Energy is required in all steps of food production, processing, and marketing, forming a basic necessity to enable a positive spiral of sustainable development. These interactions need to be understood and synergies fully tapped in the quest to attain the MDGs. This is not the case today, and hence:

- New policies are required that link energy, water resources, agriculture, health and sanitation.

1.2 Key messages and main recommendations

Water and Food

There is a very worrying lack of understanding of the freshwater requirements and water investment needs to attain the MDG to eradicate hunger and the target of halving the proportion of undernourished by 2015. This study indicates that a 50 % increase in freshwater use will be required over the coming decade in order to reach the MDG target of halving the proportion of hungry by 2015. In countries experiencing rapid population growth which also face a large under-nourishment challenge, such as India, Kenya and Nigeria, the required increase reaches 100 % until 2015.

The main messages from the Water and Food sub-study are:

- Very considerable and so far underestimated new freshwater allocations are required to attain the MDG hunger target of halving the proportion of under-nourished among the current 800 million under-nourished and in pace with population growth.
- An estimated 2,200 km^3/year of additional freshwater, almost 1.5 times the current global water use in irrigation, may have to be mobilised in agriculture to achieve the hunger 2015 Target.
- Rainfed agriculture will have to carry 85 % of the massive volume of water for food the coming 10 years.
- Crop per drop improvements on the farmers' fields can result in important water savings. We estimate that no less than 350 km^3/year, corresponding to 6 Aswan dams, can be saved per year by 2015 through crop per drop improvements, leaving 1,600 km^3/year of remaining freshwater requirments.
- New investments are needed in small-holder rainfed farming, which will have to bare the heaviest burden in achieving the hunger target. Freshwater is a key prerequisite to attain the MDG on hunger, which is fundamental for poverty alleviation.
- There is an urgent need for agricultural and water policies that promote improved rainwater management, both in-situ systems for rainfall infiltration and water harvesting systems that add new water through supplemental irrigation.
- The large increases in freshwater use for food will result in unprecedented trade-off decisions between freshwater for rainfed agriculture and terrestrial ecosystems and between water for food and downstream needs of water for fish, wetlands and cities.
- A major reduction in encroachment of agricultural land on natural ecosystems is possible, achieved by investing in agricultural water management. We believe that up to 1,000 km^3/year of the remaining 1,600 km^3 of required water for food, can be covered by capturing more rainwater on current agricultural land. This would leave 600 km^3/year to be covered by conversion of 1.2 million km^2 of grasslands and forests during the coming 10 years.
- The MDG 2015 target on hunger addresses less than half of the challenge. Eradicating under-nourishment by 2030 and feeding growing populations will require massive additional volumes of freshwater. Even after crop per drop improvements an additional 3,000 km^3/year will be required by 2030, compared with 2005, to eradicate hunger.
- Freshwater highlights the strong link between MDG 1, the hunger goal, and MDG 7, environmental sustainability and drinking water and sanitation.

The main recommendations from the Water and Food sub-study are:

- The Millennium Development Goals can only be achieved through major investments in freshwater management for food production.
- Develop and implement agricultural and water policies, institutional development and capacity building urgently needed to enable MDG countries to embark on an immediate path towards sustainable and significant upgrading of rainfed agriculture.

- Country plans of action to attain the MDGs should incorporate planning and management strategies to deal with trade-offs between freshwater to sustain food, humans and ecosystems. This is a prerequisite in order to attain MDG 7, where, as shown by the Millennium Ecosystem Assessment, agricultural expansion is one of the key drivers between degradation of ecosystem services.

Sustainable Sanitation

Translating the goal into real numbers of installations by calculating the number of target households reveals that about 95,000 households per day need to be provided sanitation services or about 65 per minute. In total this means 193 million rural households and 256 million urban households by 2015.

The analysis shows that ecological sanitation (ecosan) costs lie within the range from 0.1% to 0.3% of the domestic GDP of the target countries or about a 1/50 of what present health costs are. The challenge is therefore not one of money but one of capacity and policy reform.

The Water and Sanitation Task Force states that open defecators comprise 42% of humanity or 2.6 billion people. Ecological sanitation was assigned the central MDG target. However, there is a high need to further define how and where ecosan feasibly can be applied.

The key messages from the Sanitation sub-study are:

- The task at hand is affordable if appropriate solutions are chosen.
- Sustainable sanitation is a central required component if the MDGs are to provide resilient health and environmental protection on a long-lasting basis.
- Major improvements are required in the institutional and legislative arenas and general public awareness.

The main recommendations from the Sanitation sub-study are:

- Sanitation should be integrated into the water, agricultural and energy systems that communities are built on in order to achieve sustainability and resilience.
- Ecological sanitation should be included in the national MDG action plans.
- To meet the urban sanitation MDG goals, innovation is required at several levels including technology development, policy and institutional capacity and general public awareness.
- Rural sanitation should be put on a faster track than is envisioned by the MDGs because it is both doable with local capacity and equipment and relatively affordable.
- The MDG work should provide for a follow-up to Vision 21 produced by the WSSCC in year 2000 but this time focussing on sustainable sanitation.
- A global programme to build capacity similar to the “Green Revolution” in the 1960s is required on sanitation. In order to do this we suggest the creation of a network of 10-12 centres of expertise in sustainable sanitation in order to provide regional leadership.
- Information and educational programmes, introduction of new policies and regulations and capacity building and training of professionals are needed for sustainable sanitation. It is these areas that should receive significant bi- and multi-lateral assistance in order to mainstream and fast-track sustainable sanitation practices during the next decade.

Energy and the Environment

Increasing the access of poor people to basic energy services (clean fuels for cooking, urban electrification, electrification of social service institutions and mechanical power in communities) will require a substantially accelerated delivery of energy services. Yet, developing countries can ill afford not to increase energy service access to the poor, as that will make it harder to reach the MDG targets.

While expanding and widening energy service access it is crucial to increase energy efficiency world wide. In light of the negligible increase in global energy supply needed to meet the MDGs, the by far most effective way to address global climate change will be interventions where the large emissions occur. This requires a fundamental global change in how we supply and use energy in order to have enough resources and not risk negative environmental impacts that will undermine the chances of living sustainably on this planet.

The key messages from this sub-study are:

- Widened access to basic modern and clean energy services are necessary for almost all MDGs 2015 targets.
- Primary energy requirements to achieve basic levels of energy services compatible with MDG achievement are almost negligible in comparison to the global energy consumption.
- In the short and medium term, increased access to energy services compatible with MDG achievement will reduce local and global environmental impacts even if petroleum based fuels are used.
- Adverse environmental impacts from global unsustainable energy consumption threatens the ability of the poor to move out of poverty.

The main recommendations are:

- Urgently invest in accelerated delivery of energy services to the poor along with strengthening of institutions to absorb and make use of investments compatible with MDG achievement.
- Adopt energy efficiency measures and reduced emissions, not to jeopardise achievement of the MDGs.

2. Introduction

2.1 General

The Millennium Development Goals are internationally agreed targets that aim to make significant inroads to address some of the world's most important development challenges. The MDGs set quantitative targets to be reached by year 2015 for poverty reduction and improvements in health, education, gender equality, the environment and other aspects of human welfare, e.g. for MDG 1 to "halve, between 1990 and 2015, the proportion of people whose income is less than USD 1 a day" and to "halve, between 1990 and 2015, the proportion of people who suffer from hunger". However, the long-term goal is more ambitious; in the case of MDG 1 it is to "eradicate the extreme poverty and hunger".

On the environment (MDG 7) quantitative targets are only set for freshwater supply (to humans) and sanitation, while other targets are essentially qualitative. The Millennium Development Project Task Force on Environmental Sustainability recognises that environmental sustainability is essential to achieve not only MDG 7 but all MDGs. Achieving environmental sustainability requires carefully balancing human development activities while maintaining a stable environment that predictably and regularly provides resources such as freshwater, food, clean air, wood, fisheries, and productive soils and that protect people from floods, droughts, pest infestations, and disease. However, environmental and sustainability aspects are not prioritised in MDG implementation.

Focusing on the key role of Water and Food, Sanitation and Energy, this report deals with environmental sustainability and sustainable pathways to attain the MDGs. The three sub-studies behind this report have strong linkages to all the MDGs, and not only MDG 7. We argue that

- in order to have sustained results from the MDG work, environmental sustainability aspects have to be built into the approaches and solutions from the beginning;
- poverty and environment have to be addressed simultaneously;
- short-term solutions may contribute to attaining the goals in the short run, but will often lead to positions from which we no longer, or only with great difficulties and higher costs, can go back to a sustainable development trajectory;
- applying sustainable solutions from the beginning is most often both appropriate and affordable, providing cost-efficient solutions ;
- environmentally sustainable solutions contribute to building long-term resilience and reducing risks in the future.

Clearly, as the Poverty-Environment Partnership (PEP) points out in preparation for the UN World Summit in September 2005, environmental challenges must be tackled if poverty is to be eliminated. However, a review of 110 country MDG reports found that the environmental dimensions are overlooked by most poverty reduction efforts.

The PEP initiative stresses that "poverty underlies many of the most critical threats facing humanity today", and "the ecosystem services that underpin all life on earth are in a state of collapse with an ever-increasing rate of loss of environmental resources".[1] The PEP group also stresses that there are extensive connections between the poverty and environmental challenges: poverty problems have environmental roots, and vice versa. Generally speaking, poor people are particularly dependent on natural resources, disproportionately affected by environmental degradation and disproportionately vulnerable to environmental hazards. In order to ensure a sustainable future beyond year 2015, with further reduced poverty, the environment-poverty nexus needs to be addressed.

[1] Building Common Ground: Environment for Achieving the MDGs Framework for a Poverty-Environment Partnership (PEP) Initiative. Draft framework document from the PEP Steering Group, May 2005

The UN Millennium Declaration, from which the MDGs are drawn, constitutes a political will and is a milestone towards sustainable development for the World. Many good analyses have been done on ways and means to reach the MDG targets for 2015. However, in our mind, too little effort has been spent defining environmentally sustainable solutions for attaining the goals.

In the presently reported work we do something new, highlighting environment-friendly and sustainable aspects that in essence have not yet been part of the MDG preparatory work. We address key gaps in the MDG discussion and possible solutions particularly in relation to (i) water needed for food production and (ii) sustainable sanitation.

Energy is seen as a key basic element in meeting all the MDGs. Also, energy services enable sustainable solutions related to water and sanitation, but are also central to many of the MDG targets related to social and health issues.

2.2 This study

With this study SEI aims at providing inputs to the September 2005 MDG review meetings of the UN High Level Plenary Meeting of the General Assembly. The objectives of the study project are:

- Develop a framework for assessing environmental implications for meeting the MDGs adopting different alternative development approaches.
- Through an initial assessment for the energy, sanitation and water sectors on environmental impacts of MDG implementation, contribute to making the case that poverty and environmental issues have to be addressed simultaneously.
- Make analysis on possible solutions for MDG implementation and highlight pros and cons applying them on a large scale.
- Participate in the establishment of an international partnership and political commitment to provide recommendations on alternatives approaches and solutions to meeting the MDGs.
- Participate and make comments to other like-minded projects on processes, in particular the PEP process.

This study is not an action plan or an operational plan. Nor is it positioned into a global development agenda. We do believe, however, that the present report will provide enough basis for a re-thinking of the priorities and kind of development aid that is provided by multi- and bilateral donors within the fields of agriculture, water, energy and sanitation. To provide continued decision support, both to developing countries and donors, SEI intends to pursue further analyses to show the dynamics of MDG fulfilment in scenarios, addressing development strategies on global, regional and national levels, climate change effects, global trade in agricultural products, new biotechnologies, and price and availability of input materials such as commercial fertilisers, and much more.

Three coordinated studies are reported in this document. The sub-studies address the following aspects of MDG :

- Water and Food
- Sustainable Sanitation
- Energy and the Environment.

To the extent possible, a common set of data has been used in all three studies, e.g. population data from FAOSTAT 2005 and UN-HABITAT. Another main source is the database of the Joint Monitoring Programme (JMP) of the UNICEF and WHO. The major geographical regions used in the Water and Food and the Sanitation chapters are taken from JMP. The major geographical regions used in the energy chapter are the ones used in the World Energy Outlook 2004. The energy use patterns across the major geographical regions of the world are based on IEA's World Energy Outlook 2004 and 2002. IEA's Reference Scenario as presented in the World Energy Outlook, 2004 has been used to assess the energy service gaps in 2015 and the Global CO_2 emissions projections.

The target population for the MDGs by 2015 is in this study calculated using the percentages and population numbers of those who have and those who do not have. To “have” or to “not have” refers to money, food, health, education and others as required by the MDGs. The number of people who have in 2015 are based on the most recent year (2002) that there is data available. To arrive at the MDG target population by 2015, those who have in 2002 and those who do not have in 2015 are subtracted from the total population in 2015. In Figure 2-1 we illustrate the reasoning in principle.

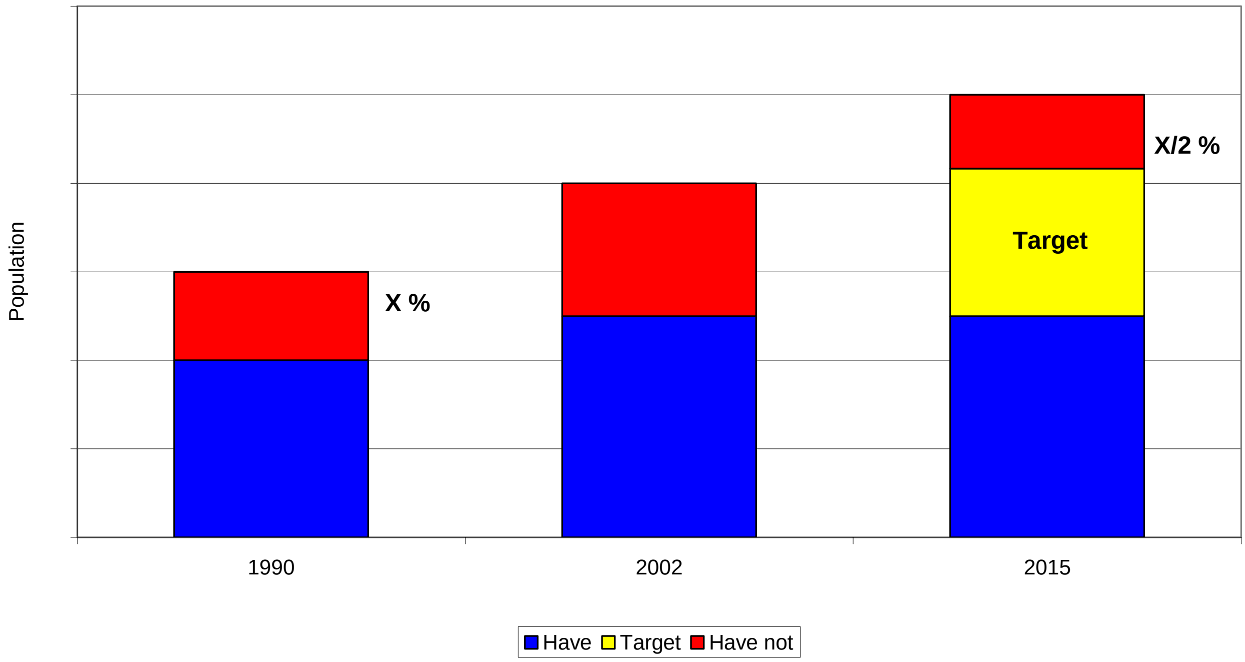


Figure 2-1: MDG Target Population

This report is structured into an Introduction (this chapter), three stand-alone chapters on water and food, sanitation and energy respectively. The key messages and suggested ways forward are presented both in the Executive Summary and in Chapter 6.

2.3 The MDG challenge

The targets

Following the calculation model described in the previous section, the global MDG target population by year 2015 used in this study is:

Water for Food: To reach the MDG 1 2015 Hunger Target in 92 developing countries (see Figure 2-2) it is necessary to:

- Upgrade the diet to full nourishment for 193 million of today’s undernourished people
- Supply full nourishment to a population increase of 893 million people

Sustainable Sanitation: The calculations result in a target population size in the developing countries of 1.75 billion for the MDG target for 2015 on sanitation. In total the target is 95,000 household installations per day between 2003 and 2015.

Energy and the Environment: The targets in number of people, electricity connections and communities to meet a range of MDG targets by year 2015 are shown in Table 2-1:

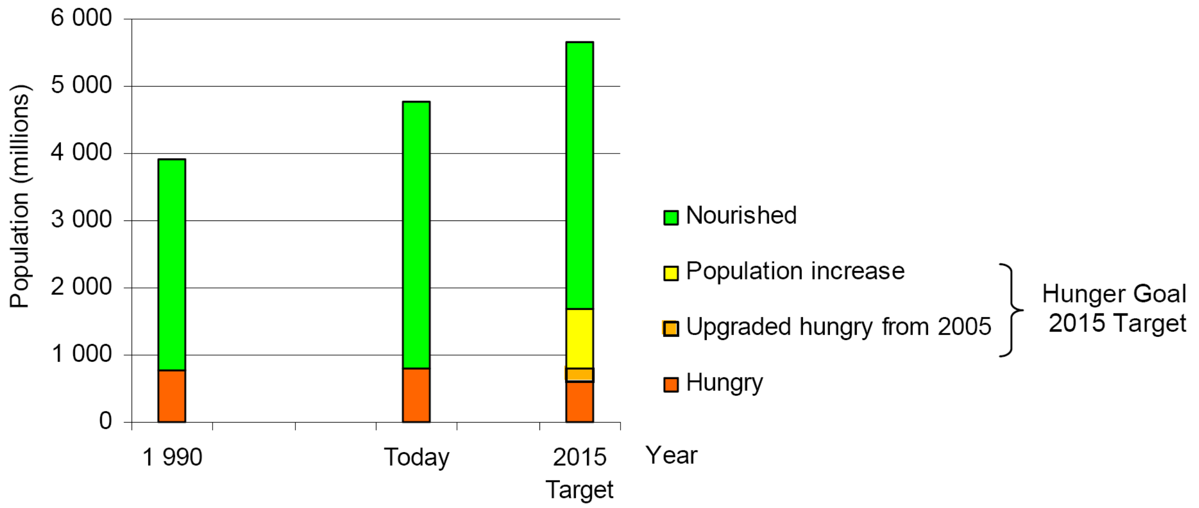


Figure 2-2: MDG Hunger Target in number of people

Table 2-1: Target numbers for Energy

Energy target	Target Size
Goal 1: 100% of the world's urban populations use clean modern fuels for cooking in 2015	303 million people
Goal 2a: Reduce by half, between 2005 and 2015, the proportion of rural households reliant on traditional biomass for cooking	1,122 million people
Goal 2b: Adoption of improved cook stoves and means to reduce air pollution and sustainable biomass production	1,122 million people
All urban populations have electricity access by 2015	304 million people
By 2015, Adequate, clean and efficient energy services to all educational and health facilities	787 thousand connections
By 2015, all communities to have access to mechanised power	1,575 thousand communities

In goes without saying that the task, or the challenge, is enormous.

Urban and rural targets

There is a need to distinguish between the target population in rural and urban areas.

The rapid increase in urbanization in the developing world provides an additional challenge to provide water, sanitation, food and energy services that are both appropriate, gender sensitive and affordable, see Figure 2-3.

Assuming each household is to receive one sanitation installation, the entire target is 450 million households (60:40 urban to rural split). For East Asia this turns out to be 151 million households (70:30). For South Asia it is 112 million households (35:65). For Sub-Saharan Africa it is 80 million (50:50). Beyond the physical challenge of providing 450 million household installations by 2015 a main challenge is the lack of capacity to be innovative and flexible on an institutional and policy level.

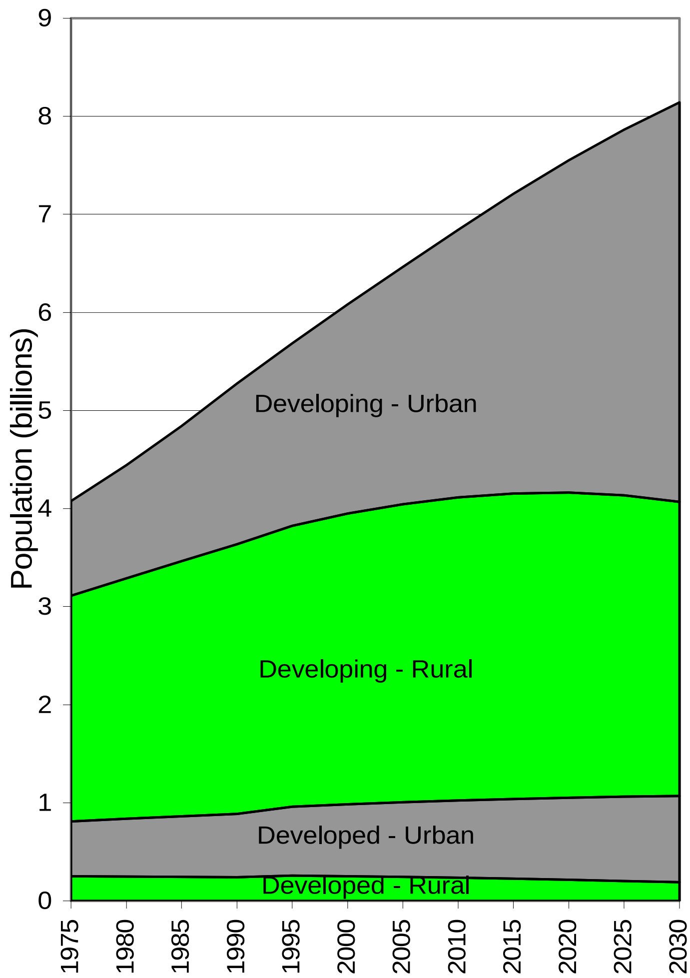


Figure 2-3: Population Dynamics 1975-2030

3. Water and Food for the MDGs

3.1 Introduction

Although there is not yet any universally agreed human right to adequate food, a large number of countries have ratified the human right to food declared in the International Covenant on Economic, Social and Cultural Rights accepted in United Nations in 1966, bringing it into force in 1976. Article 11 states that everyone has the right to an adequate standard of living, including food, clothing and housing. Numerous countries have pressed towards transforming this right from a statement of principle to an enforceable right (FAO, 2004). As of today, the right to food remains a principle, however, not an enforceable right.

Hunger is seen as constituting a crucial element of poverty. This has been eloquently described by the President of Nigeria: *"A hungry person is an angry and dangerous person. It is in all our interest to take away the cause of this anger. There is a saying in my country: when you take hungry out of poverty, poverty is halved. That is why it is crucial we give top priority to ridding ourselves of this blight on development.......In partnership we have the opportunity to conquer these challenges to development in Africa and beyond. We cannot forget that hunger is the voracious handmaiden of poverty. If we do not destroy the one, we will never consign the other to the dustbin of history"*.

Hunger has also a security dimension. As pointed out by Lord John Boyd Orr, Nobel Laureate prior to Normal Borlaug, a champion against hunger and first Director General of FAO: *You can't build peace on empty stomachs"*.

The Millennium Development Goals address poverty in many dimensions. Millennium Development Goal 1 is set to “Eradicate extreme poverty and hunger” and has two targets: Target 1: Halve, between 1990 and 2015, the proportion of people whose income is less than USD 1 a day; Target 2: Halve between, 1990 and 2015, the proportion of people who suffers from hunger.

Target 2 has two indicators for monitoring progress to be measured against baseline data for 1990, the benchmark year for assessing progress in meeting all the Goals:

- The percentage of the human population below the minimum level of dietary energy consumption
- Prevalence of underweight children under five years of age

In this chapter we refer to the hunger component of MDG 1, i.e. to eradicate hunger, as the “*the Hunger Goal*” and the MDG 1 Target 2 as the “*2015 Target*”.

Hunger and under-nutrition are fundamental problems for long-term socioeconomic development since they lead to both physical and cognitive disabilities among those remaining without enough food during childhood. These consequences make prevalence of underweight children especially serious and in fact threaten the future of a country.

Alleviating hunger will basically depend on increased food production which brings water availability to the centre of the problematique. The reason is that water is a fundamental prerequisite of the biomass production because of its direct involvement in the photosynthesis process and therefore for the production of additional food needed to fulfil the Hunger Goal in MDG 1 and its associated 2015 target. The question addressed in this chapter is how much water is needed and how we can appropriate the required water quantities without jeopardizing the long term sustainability of ecosystem services from terrestrial and aquatic ecosystems focused by MDG 7, to ensure environmental sustainability. These services are especially important for the people focused upon in the MDGs, the poor and vulnerable who in many cases live close to and directly depend on support from nature.

A fundamental issue to be aware about is the fact that most of the top and high priority MDG-countries share particular hydroclimatic challenges to master in that they are largely situated in the zone with savanna type climate. This climate is characterised by a whole set of water-related challenges affecting food production.

This chapter analyses the freshwater implications of the food production required for eliminating hunger and under-nutrition in developing countries and reaching the 2015 target. Water requirements are estimated, and the options of meeting those requirements and the environmental trade offs involved are analysed.

3.2 The Hunger Goal and the 2015 Target

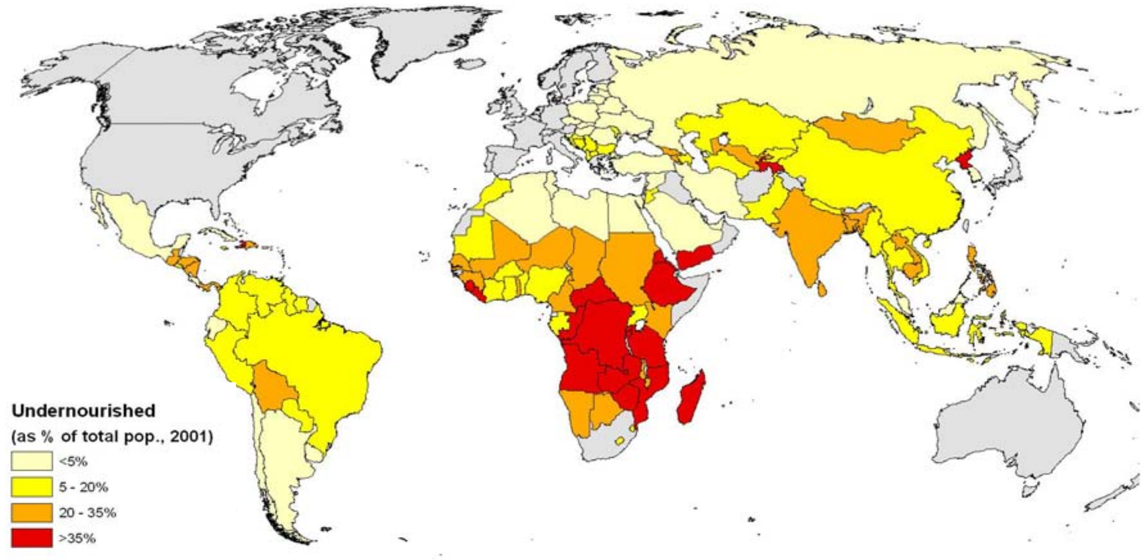


Figure 3-1: Hunger Goal 2015 Target Indicator: Prevalence of undernourished in developing countries, percentage 2001/2002 (UNstat, 2005).

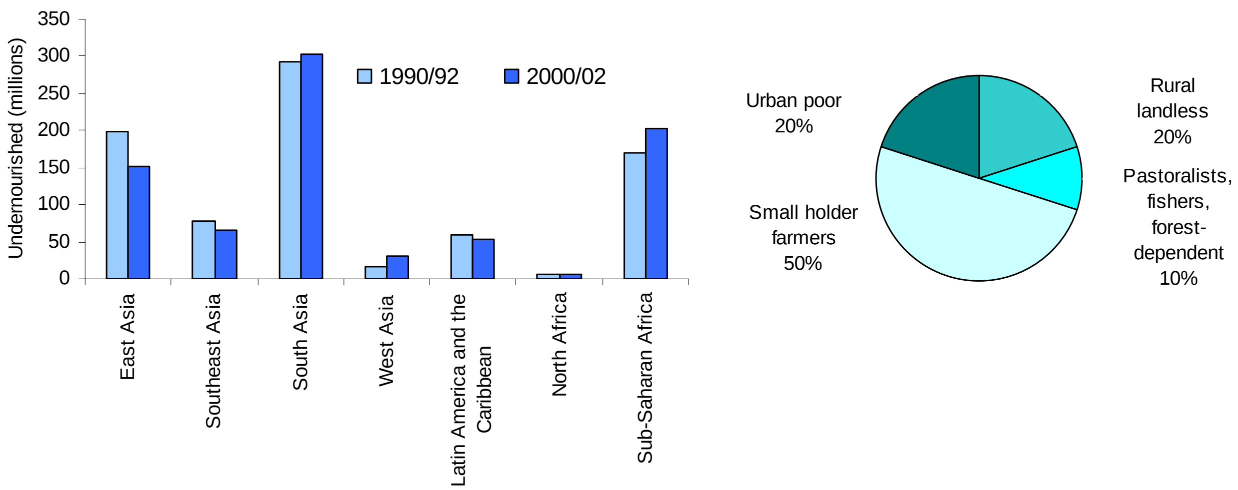


Figure 3-2: Prevalence of undernourished for developing countries in different regions, 1990/92 compared to 2000/02 (left), and clarification of who the undernourished are (right) (FAO, 2004).

Among the altogether 852 million food-insecure people worldwide, 815 million live in developing countries. 80 percent live in rural areas. Most of them are from smallholder farming, about 20 percent are rural landless, ca 10 percent depend on herding, fishing or forest resources, and the rest lives in cities. Figure 3-1 shows the prevalence of undernourished in the developing world and Figure 3-2 the situation in different regions 1990/92 and 2000/02 and the distribution between different population categories.

The Hunger Task Force of the UN Millennium Project identified 313 hunger hot spots in terms of sub-national units where prevalence of underweight children under the age of five is greater or equal to 20 percent. Out of the world's 134 million undernourished preschool children 79 percent are located in these hotspots, mainly in Southern Asia, East Africa and West Africa (see Figure 3-3).

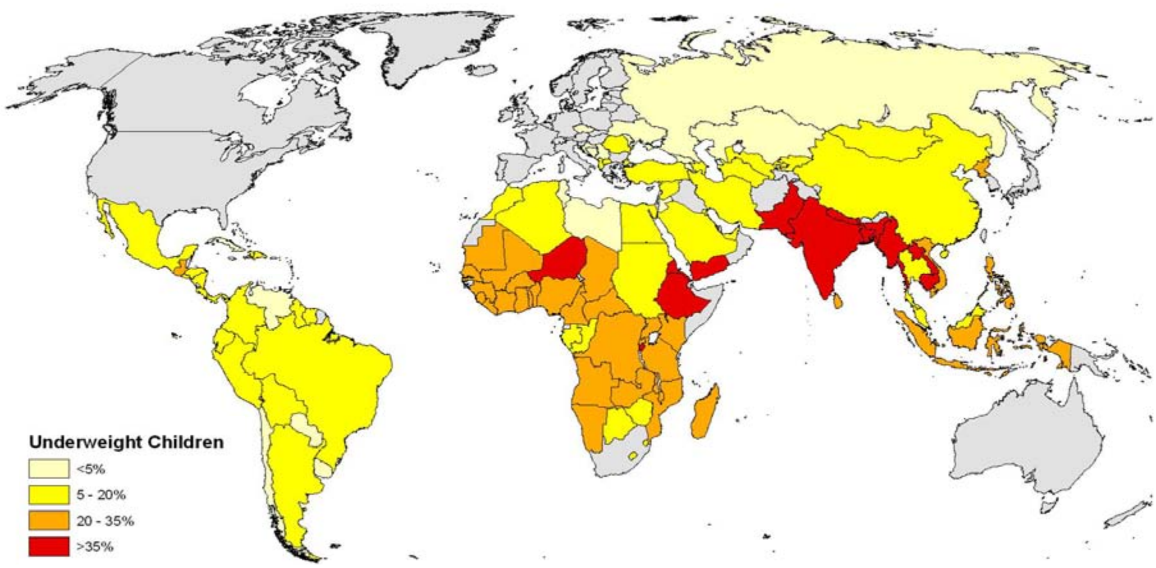


Figure 3-3: Hunger Goal 2015 Target Indicator: Child nutritional status. Moderately and severely underweight children under 5 years of age, percentage most recent data (UNstat, 2005).

Basically, hunger originates from food deprivation, which is measured by three indicators: food availability per person, level of inequality of access to that food, and minimum number of calories required for an average person

Required for nutrition is a certain amount of food, the minimum dietary energy requirement. The Basic Metabolic Rate (BMR) for maintaining the basic functions in the human body amounts to 1,300-1,700 kcal per person and day. For children the diet has to cover also growth requirements. When allowance is made also for light physical activity, the adult requirement increases to 1,720-1,969 kcal per person and day, dependent on the population structure in different developing countries. Population groups where an average individual has an intake below these thresholds are considered undernourished

The implications of the Hunger Goal and its associated 2015 Target is that each country must halve between 1990 and 2015 the proportion of people who suffer from hunger, here understood as under-nutrition. In addition, most of the developing countries will have to secure adequate food also for the additional individuals added through natural population growth during this period, see Figure 2-3. This growth will continue till 2050 before it is expected to stabilise and will in many developing countries add around 25 percent individuals to the population already before the MDG target year 2015.

3.3 Aspects to consider

When calculating the water requirements involved in producing the food needed to alleviate undernourishment in line with the MDG Hunger Goal, a number of factors have to be paid attention to.

3.3.1. Hydroclimate

The first factor to consider is the hydroclimate which defines the preconditions for food production in the MDG countries. Especially striking is the near congruence between the regions where the majority of the hunger-prone countries are located and the arid zone with savanna type climate (see Figure 3-4). Typical for this zone is the considerable water challenges affecting agriculture that have to be overcome:

- seasonal rainfall with intermittent dry spells making the rainfall unreliable
- recurrent drought years

- high evaporative demand so that most of the rainfall evaporates leaving only a limited fraction to form runoff
- often vulnerable soils with low permeability and low water holding capacity which limits the amount of water accessible to the crops.

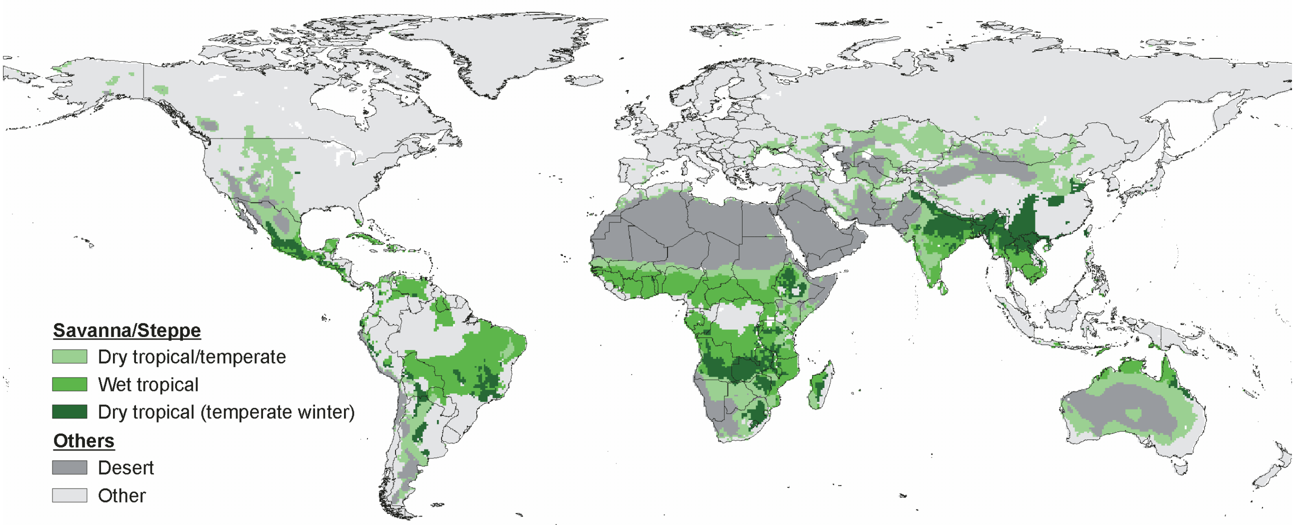


Figure 3-4: The zone with savanna type hydroclimate – the zone with large hunger eradication challenges but also huge potential for additional food production.

3.3.2. Population categories

The second factor is the different population categories that will have to be kept in mind. The task of halving hunger till 2015 will involve additional food supply both for the people to be upgraded according to the 2015 Target and properly provide the additional individuals following the population increase. In comparison, producing the food needed to feed the additional population is often a larger task than producing the amount needed to upgrade the diet for the actually undernourished. Visualised in Figure 3-5, The Hunger Goal 2015

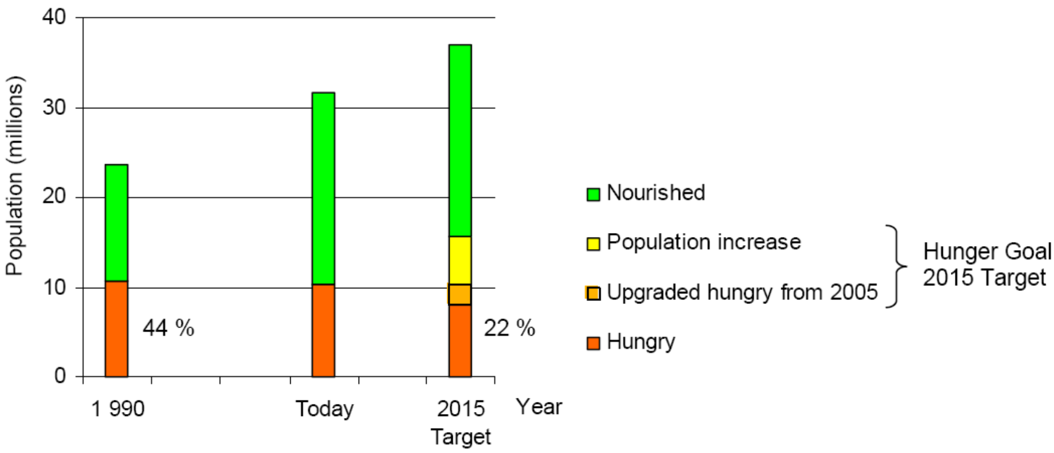


Figure 3-5: Population categories to fulfill the Hunger Goal Target 2015. Data and projections for Kenya given as an example.

Target states that it is the percentage of hungry in 1990 that should be halved by 2015. In 1990 44 percent, or 10.7 million, of the Kenyan population were characterized as undernourished and by 2015 the halved target percentage is 22 percent, at that time equal to 8 million. The global Hunger Goal 2015 Target estimated for 92 developing countries amounts to 192 million undernourished that need to get an upgraded diet and a staggering 893 million additional people whom will require full nourishment (Figure 2-3).

3.3.3. Dietary energy supply levels

The third factor is the dietary energy supply levels to be considered adequate. While the average diet supply in kcal per day and person in the industrialised world is today close to 3,500 kcal per person and day it is in the developing world around 2,500 kcal per person and day, averaging over the whole population including the undernourished. A rule of thumb indicates that a supply in the range 2,700-3,200 kcal per person and day is adequate for most countries to satisfy basic food needs for all (Seckler & Amarasinghe, 2004).

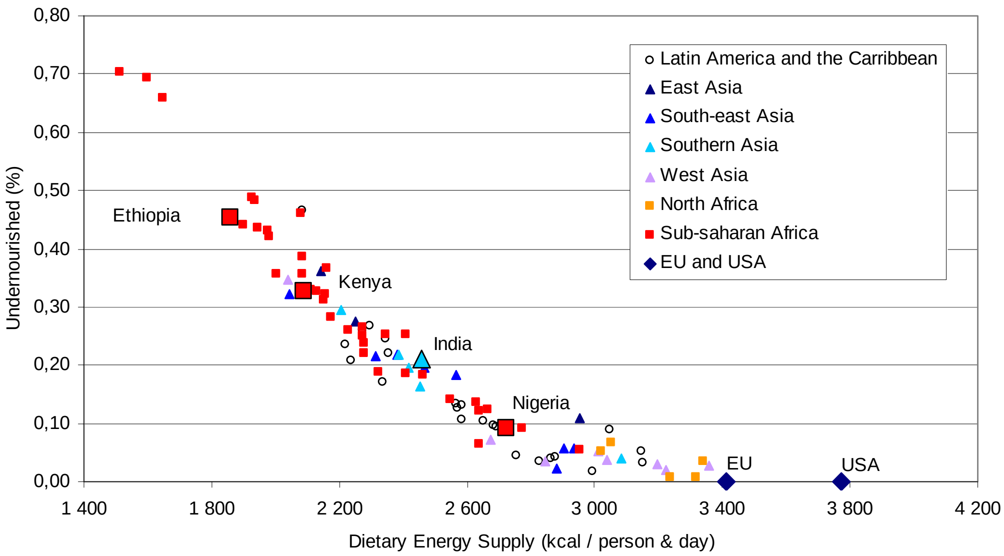


Figure 3-6: The figure shows that the percentage undernourished approaches zero when the average diet supply has reached 3000 kcal per person and day (data FAOstat and UNstat, 2005).

Figure 3-6 shows that the percentage undernourished tends to decrease towards zero only when the average diet has reached some 3,000 kcal per person and day. This is the average calorie level projected by FAO to be reached in developing countries by 2030 (FAO, 2003). In our study, this is taken as the desirable national average calorie level supply to be strived at when eradicating hunger.

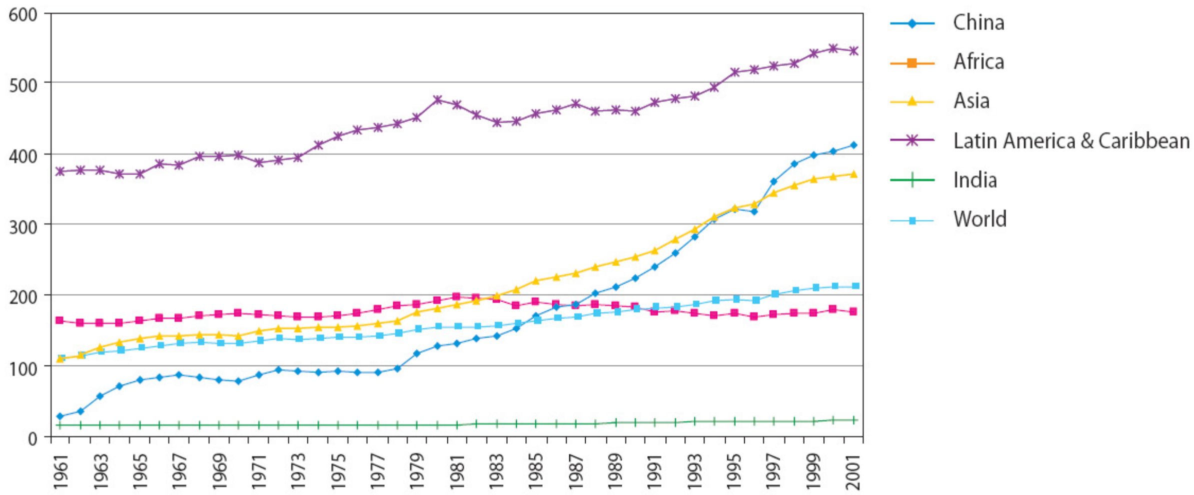


Figure 3-7: Calories per capita met by meat products. Countries tend to increase the meat component of their diets as development proceeds (graph from Molden and Fraiture, 2004).

There is in most developing countries also a protein deficit which has to be mitigated by incorporating an increased amount of protein in the diet. As shown in Figure 3-7 countries tend to increase the meat component of their diets as development proceeds. In the United States and Europe meat consumption has stabilized at around 25 to 30 percent of total calorie intake, whereas in African countries it constitutes of less than 10 percent. In Asia, meat consumption took off in the late 70s, quadrupling to nearly 15 percent of total calorie intake in 2001, and it is still rising. Much of the increase comes from China. India remains largely vegetarian, because of cultural and religious reasons. It is reasonable to assume that production of feedstuffs will have to increase dramatically by 2025 (Seckler & Amarasinghe, 2004). The meat component in this study pays attention to experienced tendencies in the development process. This trend is probably further strengthened by the influence the coming decades by the influence of urbanization on people's preferred diets. Calculations in this study therefore assume 20 percent meat in the diet (600 kcal per person and day).

3.3.4. Water implications

The fourth factor to pay attention to is the consumptive water use, i.e. the water evaporated in the photosynthesis process in producing different food items. Without freshwater, no food! In general terms, there is a strong correlation between freshwater use and food production, both for vegetal and animal foods. More food requires more water. This is explained by the role of water in biomass production, where plant growth is directly linked to root water uptake and transpiration of water from leaves to the atmosphere.

The study assumes that the amount of water consumed in producing the equivalent to 1,000 kcal vegetal food amounts to 0.5 cubic meters and the amount consumed in producing 1,000 kcal of animal protein 4 cubic meters (Falkenmark & Rockstöm 2004). Much more water is required for producing animal food since only part of the vegetal energy consumed by animals is transformed into meat. Most of the energy is lost as heat during the life time of the animal. Consequently there is low energy transformation efficiency in transforming grain into meat. A vegetal and animal protein balanced diet of 3,000 kcal per person and day will therefore demand a freshwater quantity of around 1,300 m^3 per person and year. This is 70 times more than the so-called basic water need, seen as necessary for drinking and household purpose.

The outcome of these assumptions is that to produce an adequate amount of food for each million of additional individuals, an additional 1.3 cubic kilometres of freshwater must be appropriated. To upgrade the diet for 1 million presently undernourished will demand about half this quantity, and to lift the diet to the desired level for one million of the rest of the population today would only demand one tenth of that amount.

3.3.5. Time

Finally, the time factor involved in achieving the Hunger Goal and its associate 2015 Target has to be paid attention to. In the estimations of the water implications of hunger alleviation it has been assumed that the number of hungry will be halved till 2015 and abolished completely by 2030. The process of increasing food requirements will however have to continue since the population will continue to grow. Therefore the estimates in this paper cover the time period till 2050 when the population probably will have reached or be close to a stabilised situation.

3.3.6. The analysis

The approach proceeds in three steps: (i) Assessing the amount of water required to produce the food needed - this calculation is based on the water productivity as practised in the developing world today. This first calculation gives so-called *overall water requirements*; (ii) for the following period of eradicating the hunger completely, special attention will be paid to the gains possible by *productivity increases* (a crop-per-drop maximization), i.e. reducing non-productive water losses in terms of evaporation from irrigation canals and moist soil between the plants. The water productivity improvement deemed realistic will be assessed, arriving at what is referred to as *remaining water requirements*. (iii) The study then goes on to analyse where to find the water needed: how much can be contributed by expanded *irrigation*, by efforts to capture more of local rainfall, and how much remains to be contributed by *expanding into forests and grasslands*, involving environmental trade offs.

The study in other words analyses what the options are of finding the water needed to cover the over-all water requirements:

- by crop per drop maximization through water productivity increase, basically minimization of wasteful evaporation losses
- by capturing more rainwater locally, e.g. increasing infiltration

- by additional irrigation with liquid/blue water
- by appropriation of water now consumed by natural terrestrial ecosystems, i.e. horizontal expansion

3.4 Water requirements

3.4.1. Food water requirements

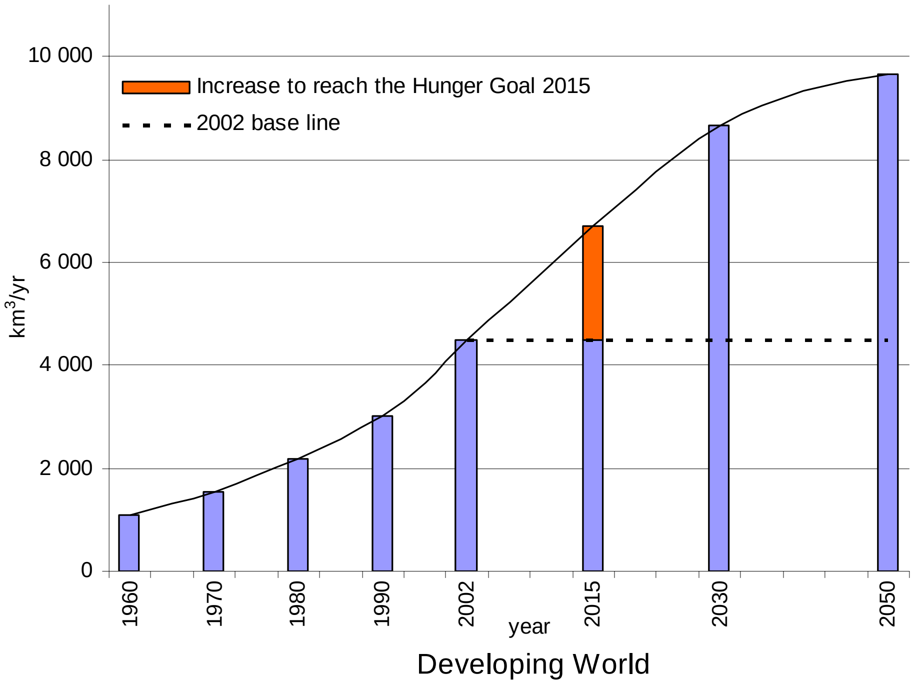


Figure 3-8: Over-all water requirements for food production in 92 developing countries to fulfill the Hunger Goal 2015 Target and to eradicate hunger 2030 and 2050.

The amounts of freshwater consumed in food production in developing countries is shown in Figure 3-8. To reach the Hunger Goal 2015 Target with halved undernourishment by 2015 the freshwater requirements will increase from 4,500 km^3 to 6,700 km^3. The study in other words shows that the evaporation involved in food production must increase by 2,200 km^3 or 49 percent during the coming decade. In comparison the volume equals the outflow from an additional 39 new High Aswan Dams (outflow average 1970-80). For some regions the increase is even higher and Southern Asia (mainly India) and sub-Saharan Africa stand out as the areas facing the largest challenges with increases of 92 respectively 135 percent by 2015. With the assumption that the Hunger Goal is reached by 2030 and all the people in developing countries get full nourishment the freshwater requirements increase even further. By 2030 the estimated increase is 4160 km^3 and by 2050 as much as 5160 km^3, relative increases compared to today of 93 and 115 percent. Once again sub-Saharan Africa faces the largest increases with a staggering 300 percent by 2030 and even further increase of 400 percent by 2050.

Figure 3-9 shows the relative increase from today to reach the Hunger Goal target by 2015 in the 92 developing countries considered in this study. Many of the countries facing increases of more than 80 or 120 percent are found in the Savanna zone.

A separate study has been performed for a set of individual developing countries, picked out from different positions from the under-nutrition diagram (see Figure 3-10). India, Kenya and Nigeria represent different undernourishment prevalence and nutrition levels and thus face different future challenges. A combination of population increase, reduction (and finally eradication) of undernourishment, diet increase and diet composition improvement results in large consumptive water use increases.

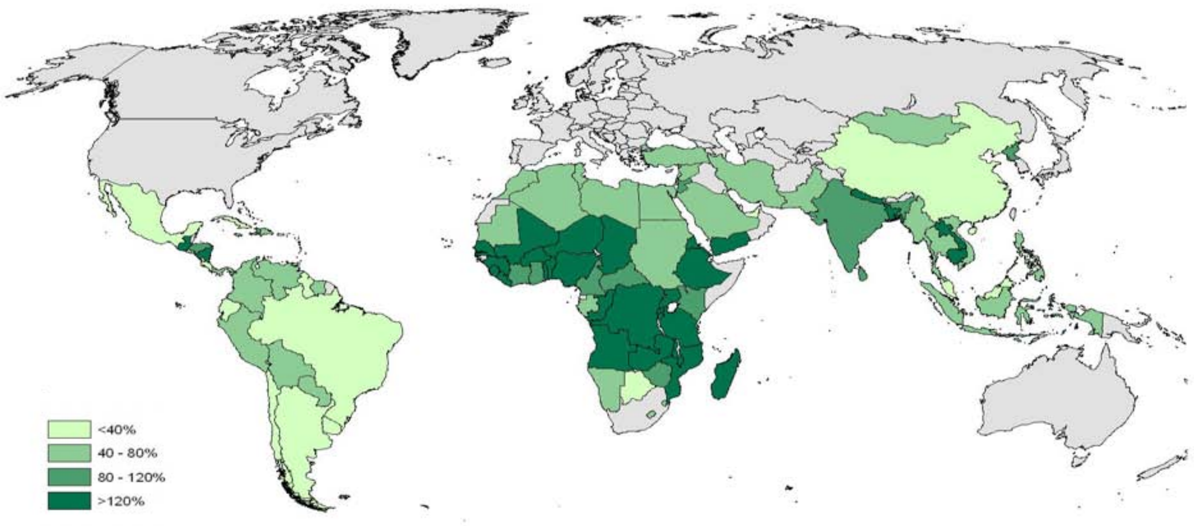


Figure 3-9: The freshwater challenge of the Hunger Goal 2015 Target. The map shows the percentage increase in consumptive water use for food production by 2015 compared to today.

By 2015 India has to increase from today's volume of 700 to 1,400 km^3/year, a 100 percent increase in ten years. Total eradication of hunger in India requires according to our estimates around 1,860 km^3/year by 2030 and more than 2,000 km^3/year by 2050, increases by 160 and 180 percent compared to today. Kenya displays the same pattern with similar percentage increase that requires an additional 20 km^3 /year by 2015 and increases of around 32 and 36 km^3 by 2030 and 2050. Projections for Nigeria on the other hand exhibit a more steep increase pattern. This is mainly explained by the rapid population increase, a 115 percent increase from 120 million today up to almost 260 millions by 2050. Population increases in India and Kenya the coming 35 years are more modest and is only around 40 percent. Freshwater requirements for future food production in Nigeria thus increase dramatically from around 70 km^3/year today to about 160 km^3 by 2015 and 270 versus 340 km^3/year by 2030 and 2050. These freshwater quantities represent increases of 120 percent by 2015, 270 percent by 2030 and around 360 percent by 2050 compared to today.

In our calculation we have used a standard diet with a 20 percent meat calorie composition for all countries by 2030 and by 2015 a gradual increase from today. Since animal calories require eight times more water compared to agricultural production of vegetal calories this has particular implications on the water requirement approximations for countries where animal protein levels according FAO statistics are very low, like India and Nigeria. The estimates therefore might be higher than present consumption pattern indicates. As seen in Figure 3-7 there is a general trend towards higher and higher animal protein intake. Increased purchasing power and the strong urbanization trend, with a global conformation of diet preferences, will probably increase this trend even stronger the coming decades.

3.4.2. Ecosystem water requirements

A fundamental question is what water is available to meet these rapidly growing food water requirements. First of all it has to be made clear that food production will have to compete for water with natural ecosystems; rain fed agriculture with terrestrial ecosystems and irrigation with aquatic ecosystems.

Thus, MDG 1 and MDG 7 will in other words have to share the same precipitation. This is visualised in Figure 3-11 which shows how the precipitation over 92 developing countries is partitioned into:

- the consumptive water use by rainfed ecosystems (besides agro ecosystems, savanna and grasslands, forests, wetlands)
- the remainder generating liquid blue water in aquifers and rivers, used by humans and aquatic ecosystems.

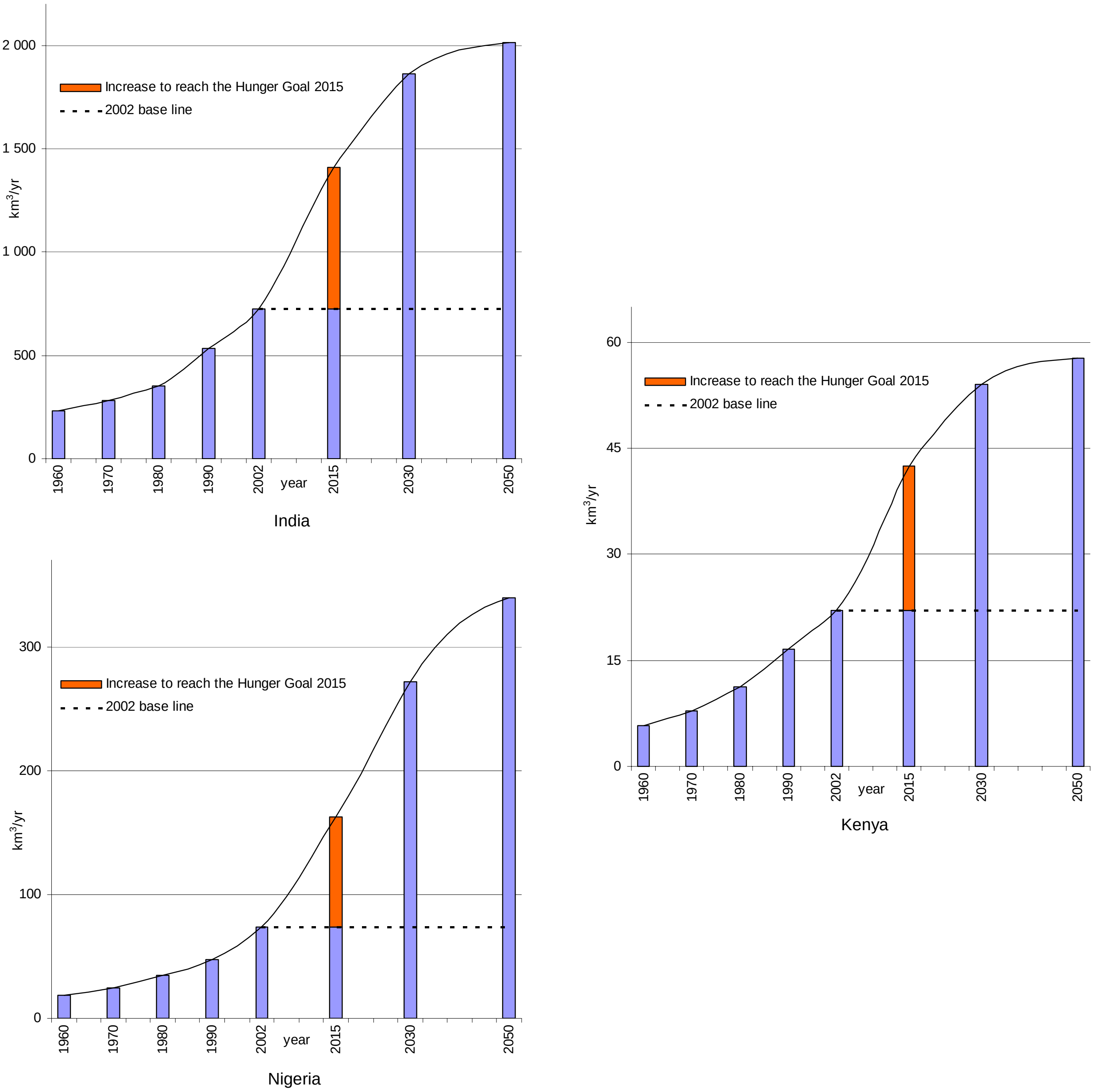


Figure 3-10: Water requirements in 3 developing countries: India (top left), Kenya (middle right) and Nigeria (bottom left).

Only a very limited portion of the blue water is currently withdrawn for societal water uses (domestic, industrial and agricultural use, mainly irrigation). Two thirds of this water goes to consumptive (evaporating) water use while the remaining third forms return flow to the hydrological system, available for downstream reuse.

Figure 3-12 shows this situation in the three country cases. There is plenty of green water/soil moisture available and the croplands are presently consuming only limited portions of available green water:

India	9.4 percent
Kenya	5.8 percent
Nigeria	6.6 percent

The maps in Figure 3-12 indicate where such expansion potential might be considered after due consideration of the environmental trade-offs involved. The figure also clarifies the huge hydrological differences in terms of runoff generation within the country:

India	35 percent
Kenya	5.7 percent
Nigeria	21 percent

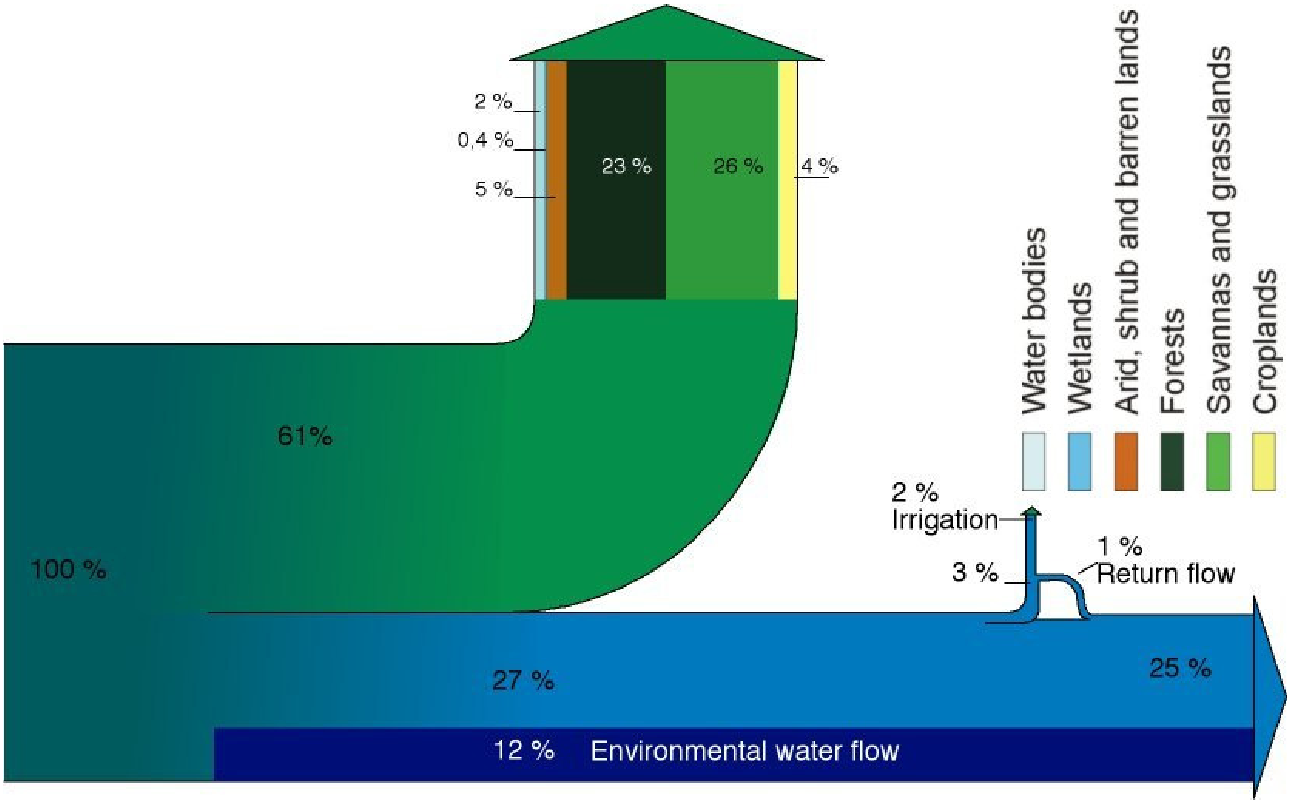


Figure 3-11: Water flows in 92 developing countries. Rainwater partitioning into green water feeding terrestrial ecosystems and blue water, withdrawn for societal uses and constituting habitat for aquatic ecosystems.

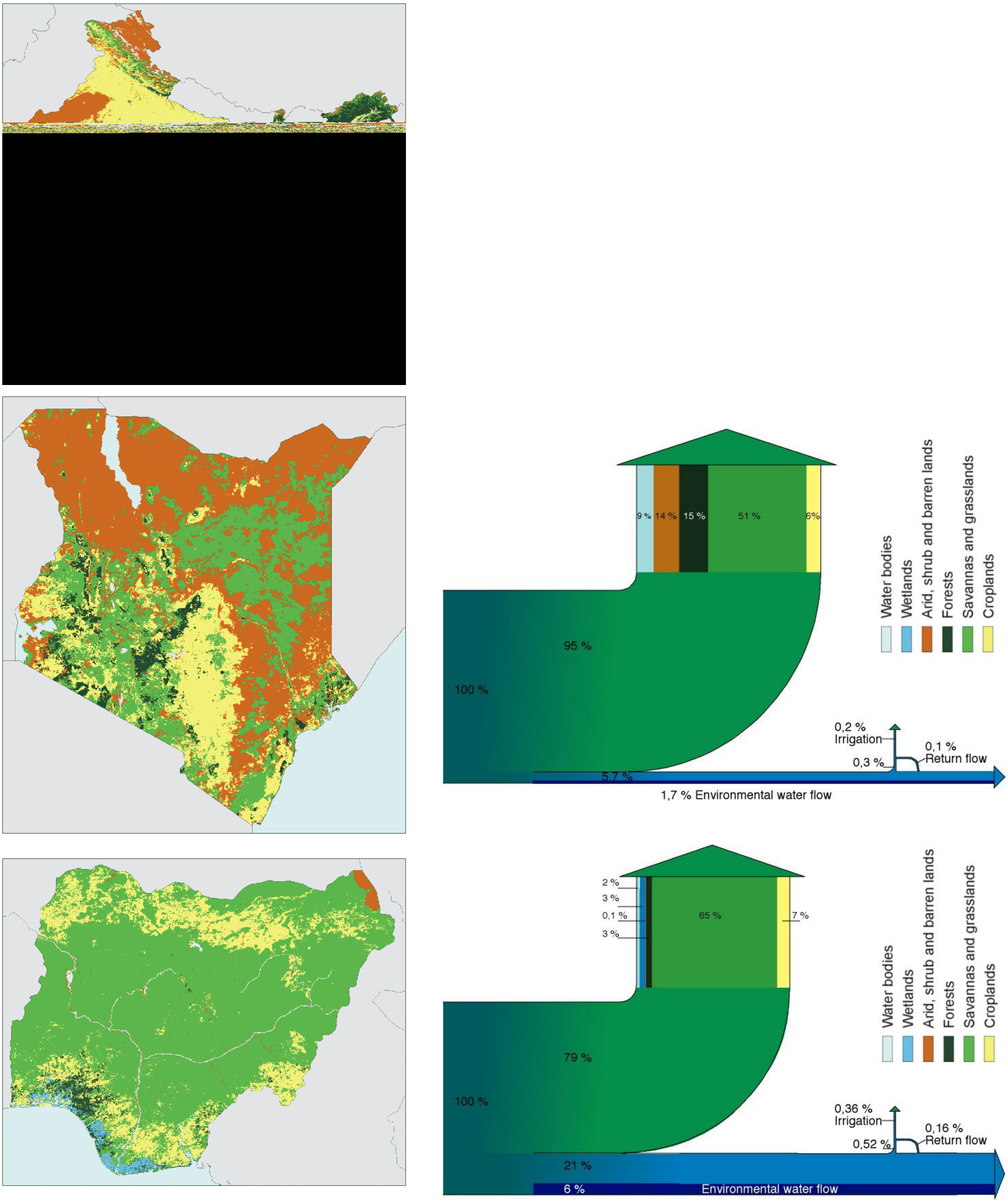
3.5 Options to meet the water for food challenge

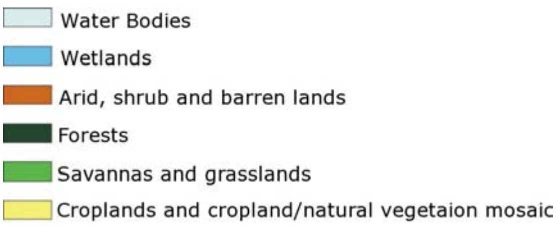
The analysis so far indicates a major freshwater challenge to meet the Hunger Goal 2015. *An increase of 2,200 km^3/year of consumptive water use in agriculture is required between now and 2015*. By 2030, 4165 km^3/year more water use in agriculture is required compared to today, to eradicate hunger, a figure which reaches 5,160 km^3/year by 2050. This is a major environmental challenge, where agriculture, already the world's largest consumer of blue water, *will have to increase its water consumption by 49 percent by 2015, and 115 percent by 2050*.

The overarching question in this section is to assess whether it is possible to mobilize the huge additional freshwater requirements for food. How can the additional water needs be met in order to achieve the Hunger Goal and the 2015 Target? This question is sub-divided in two parts (i) from where will the additional freshwater be taken, and (ii) what options are there to reduce the required freshwater volumes through efficiency improvements in water management?

3.5.1. Blue contribution through irrigation

The freshwater challenge to meet rapidly growing food requirements will necessitate a wide focus on developing both blue water dependent irrigated agriculture and green water dependent rainfed agriculture. Until recently, the political solution to meet growing freshwater needs for food production was predominantly to expand irrigation by investing in new dams and infrastructure. This has resulted in large over-appropriation of rivers and groundwater. At least 25 percent of the world's river basins are already today hydrologically closed, i.e., water withdrawals predominantly for irrigation, already today exceeds sustainable levels Figure 3-13.





Note: The yellow area on the maps represents both "croplands" and "cropland/natural vegetation mosaic", i.e. land surface. The yellow segment of the green arrow only visualizes the quantity of freshwater vapour flow from rainfed crops. The yellow segment and the irrigation arrow together represent an estimate of the freshwater use in food production in each country.

Figure 3-12: Land cover maps and rainwater partitioning diagrams for India (top), Kenya (middle) and Nigeria (bottom).

Figure 3-13 highlights the need to safeguard blue water for aquatic life, so called environmental water flows, and indicates the limited opportunities to expand irrigation (Smakhtin et al., 2004). Furthermore, as pointed out by the World Commission on Dams, the high risks of negative social side-effects associated with large scale water resource development, necessitates a careful approach to dam growth (WCD, 2000). However, irrigation plays and will continue to play a very important role in feeding the world. Globally, irrigated agriculture covers 20 percent of the agricultural land, and produces approximately 30 percent of the world's food. Large opportunities for sustainable irrigation expansion still remain, particularly in sub-Saharan Africa where more than 95 percent of the agriculture is rainfed. In this analysis we have adopted the most optimistic outlooks on irrigation expansion (FAO Aquastat, 2005).

There are furthermore good opportunities to improve efficiency of water use in irrigation. Here we have assumed that 70 percent of applied irrigation water is consumed in growing crops, while 30 percent is return flow available for downstream use (Shiklomanov and Rodda, 2003).

Based on these projections and assumptions, we assess that irrigation water can contribute an additional 270 km^3/year by 2015. This corresponds to a 19 percent increase compared to the 1,400 km^3/year used in 2002.

For the period between 2015 – 2050, we assume an irrigation expansion in pace with population growth (Seckler et al., 1998). This gives an additional blue water contribution of 520 km^3/year by 2030 and 725 km^3/year by 2050, compared to 2002.

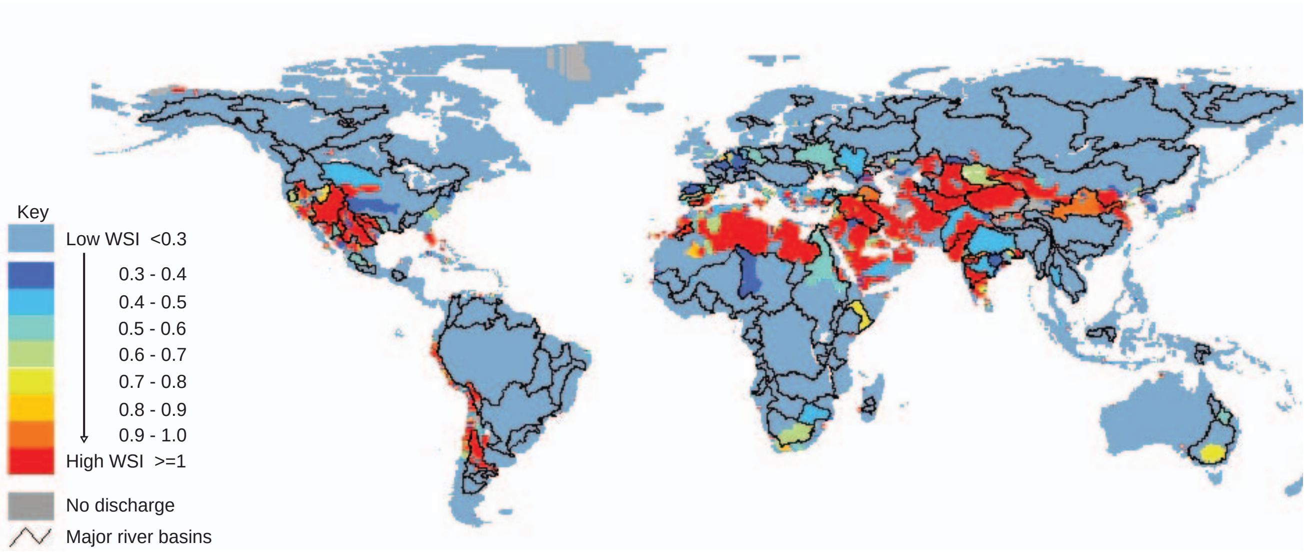


Figure 3-13: Over-appropriation of blue water in rivers jeopardizes MDG 7. In yellow and red areas current withdrawals are too large to satisfy environmental water flow requirements (map from Smakhtin et al., 2004).

3.5.2. Green water contribution

The conclusion is, despite the fact that irrigation will continue to play an important role in food production, that the bulk of the food water requirements will have to originate from green water in rainfed agriculture (Figure 3-14).

As seen in Figure 3-14, after reduction of the potential irrigation increase there remains a very large additional freshwater requirement which amounts to an additional 1,940 km^3/year of green water to meet the 2015 Target. To lift diets to 3,000 kcal per person and year for the remaining half of the world's undernourished people and provide the additional population on the same level by 2030 will require another staggering 3,645 km^3/year. By 2050, the additional population growth will lift this green water requirement to 4,430 km^3/year.

Where will this huge volume of freshwater come from? For the timeframe 2005-2015 the additional water requirement is of the same magnitude as today's total global consumptive water use in irrigation. What options are there to reduce the trade-offs with other water uses by improving productivity?

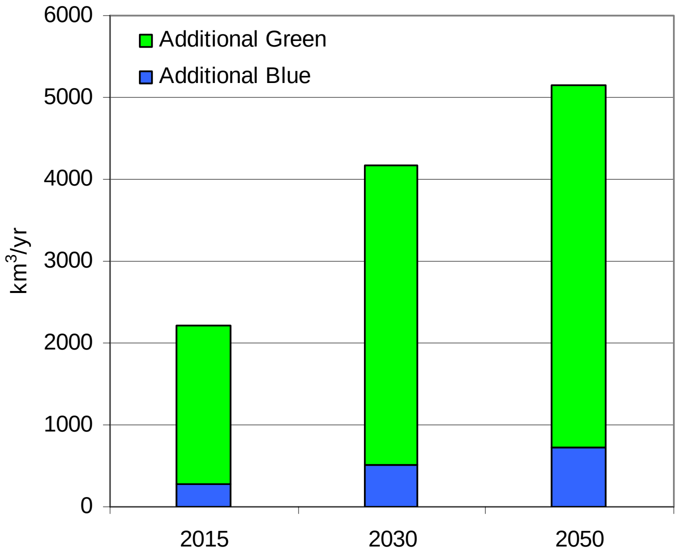


Figure 3-14: Additional freshwater requirements to achieve the Hunger Goal and 2015 Target, and possible blue water contribution from irrigation development (blue).

3.5.3. Water productivity impacts on freshwater requirements

It is clear from this analysis that large investments will be required to upgrade rainfed agriculture. As just indicated, large increased use of freshwater to produce food, may result in trade-offs with other terrestrial and aquatic ecosystems that depend on freshwater. The large amounts of "new" water for food, means that there is a large risk for competition between MDG 1 on halving undernourishment and MDG 7 on environmental sustainability. It has to be remembered that freshwater is finite and non-substitutable, and just as food production, all other ecosystem functions and services, require large amounts of water, both blue and green.

It is therefore crucial to explore options of improving the water productivity of food production, or, in the words of Kofi Annan, UN Secretary General, in his Millennium Report (UN, 2000): *"We need a blue revolution in agriculture that focuses on increasing productivity per unit water – 'crop per drop'"*. This is an important statement, acknowledging the fact that humankind is facing a global freshwater challenge which is closely linked to food security, and that there is a certain degree of freedom, to produce more food with less water.

The increased freshwater requirement to meet the Hunger Goal 2015 Target is a strong manifest of the environmental prerequisite to attain the MDGs. The 1,940 km^3/year of additional freshwater to attain the 2015 Target, translates to the large increased growth of all crop (cereals, legumes, vegetables, tubers, and fruit) and animal feeds (fodder and cereal feed). No less than a new Green Revolution is required to feed growing populations in developing countries. Food production has to grow faster than during the Green Revolution in the 1960s and 70s, which lifted large parts of Asia out of an eminent food crisis. Now, yields need to more than double over the coming 25 years. A difference compared to the 1st green revolution is the realization that long-term solutions require an environmentally sustainable revolution, or "Green-Green Revolution" (Conway, 1997).

We are actually facing a Triple Green Revolution, where production must more than double over one generation (Falkenmark and Rockström, 2004). This must be achieved in an environmentally sustainable way and will depend largely on mobilizing green water in rainfed agriculture. Moreover it concerns primarily resource poor communities in water scarcity prone agro-ecosystem regions – the MDG hot-spot countries. The deepest poverty, 95 percent of population growth and most of the undernourishment all coincide in the MDG hot-spot regions. They are concentrated in the savanna climate region, subject to recurrent droughts and dry spells and high rainfall variability.

Yield levels of staple foods in these regions (primarily maize, millets, and sorghum) are generally low, on average between 1.5 – 2 tons/ha. Estimates indicate that these will have to increase to between 3.5 – 4 tons/ha by 2030 in order to keep pace with requirements (Falkenmark and Rockström, 2004; FAO, 2003). Even in water scarce semi-arid savanna regions there are no immediate freshwater limitations on the farmers field to achieve this doubling of agricultural productivity, i.e. there is enough local rainfall to support such production levels (Rockström and Falkenmark, 2000).

Box 3-1: Crop per drop improvements.

What are the implications for freshwater use of producing more food? Conventionally, the assumption is that there is a linear relationship between biomass growth and consumptive water use (as evaporation and transpiration, i.e., as vapour or so-called green water flow), i.e., that every new unit food requires a new unit of consumptive water, e.g., if 1 ton of food consumes 1500 m^3, 2 tons consume 3,000 m^3. This would suggest only small options to improve the amount of “crop per drop” in line with Kofi Annan’s Millennium Development speech. As a matter of fact, this linear relationship is not correct. Instead, there is a strongly dynamic relationship between food growth and water use, which is explained by the fact that green water flow consists of both water which does not contribute to food growth (evaporation) and water flow that directly contributes to food growth, namely transpiration. This means that improvements in agricultural productivity, through yield increase, can shift the balance between non-productive evaporation and productive transpiration, in favour of the productive flow. This we call vapour shift. Vapour shift is particularly important in the MDG hotspot countries which predominantly are in the savanna zone, as the dry and hot climate results in a very thirsty atsmosphere and thus high non-productive vapour flows. Actually, in a country like Namibia, 85 percent of the rainfall can consist of non-productive evaporation flow, while the proportion for savannas in general in African smallholder farms amount to 40-60 percent of rainfall (Rockström, 1999).

Improvements in agricultural productivity can contribute to improve the water productivity, by shifting relatively more freshwater from non-productive (evaporation, and from a farmers perspective also surface runoff and drainage) to productive flows (plant transpiration). The result is that with improved yields, more crop is produced per unit freshwater consumed (as evapotranspiration) (Figure A).

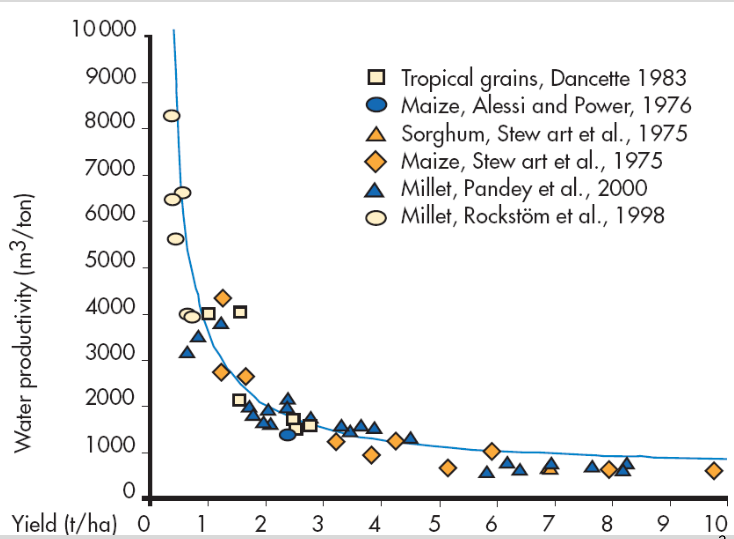


Figure A: Crop per drop improvements of upgrading rainfed farming systems. Water productivity (m^3 of green water flow per ton of grain) improvement for common staple grain foods in savanna farming systems in Africa with growth in yields (after Rockström, 2003)

Improved management of land and water can thus very significantly improve the amount of crop per drop. As seen from Figure A the most substantive crop per drop improvements are achieved when raising yields in currently poorly performing farming systems, i.e., the potential of saving water is highest in the MDG hot spot countries where large portion of the current water balance is lost as non-productive water. E.g., for a poor farmer producing food at typical yields of 1 t/ha, this crop requires some 3,500 m^3 of freshwater to produce (3.5 tons of water, or 3,5 million litres). When doubling the yield, through improved soil, water and crop management, the farmer would produce 2 tons of food per hectare consuming 2,000 m^3/ton, i.e. a relative crop per drop improvement of 1,500 m^3, or 1.5 million liters). It is important to note though, that while the relative crop per drop improvement is substantial, more food always means more water – in this case producing 1 ton consumes 3,500 m^3 of freshwater, while the upgraded systems producing 2 tons consumes 4,000 m^3. However, the improved system, does not consume twice as much water, 7,000 m^3, which would be the case if every new ton of food was produced with the same water productivity. Here the relative improvement is from 7,000 m^3 (with no crop per drop improvement) to 4,000 m^3, i.e. a relative saving of 3,000 m^3.

3.5.4. Know-how already exists

Furthermore, a vast amount of research shows that know-how, technologies and management systems, appropriate and adaptable to local rural communities, exist and can be successfully adapted and adopted if the right investments, capacity building efforts, policies, and legal frameworks are in place. For example, as shown by Pretty and Hine (2001) in a review of agricultural development projects around the world, there is generally a more than 100 percent productivity improvement potential in rainfed agriculture (compared to only 10 percent potential in irrigated systems). Integrated approaches to soil and water management, with a particular focus on supplemental irrigation (to bridge dry spells) and soil fertility management, are key strategies in doubling yield levels in African savanna farming (Barron et al., 2004; Rockström, 2003). Similar water harvesting strategies, both adding supplemental water to crops and practices that conserve moisture by maximizing rainfall infiltration in soils, are practiced and further developed successfully among farmers around the world (Reij et al., 1996; Proceeding Blomfontein; Timsina and Connor, 2001; Zhu and Li, 2004; CSE India). A forthcoming research review shows that yields among poor farmers in Ethiopia, Kenya, Tanzania and Zambia can more than double by abandoning conventional ploughing in favour of different forms of minimum and conservation tillage systems (Rockström et al. forthcoming). Important advancements are being made on developing less water dependent "aerobic" rice systems (Bouman et al., 2005), and research on biotechnology and plant genetics indicate promising opportunities of developing robust food crop varieties for tropical farming systems (Toenniessen et al., 2003).

The conclusion is, supported by the ongoing global Comprehensive Assessment on Water Management in Agriculture, that affordable and appropriate technologies and management practices do exist to substantially increase yields levels in developing countries (Molden, 2004). This is important, as we are in many regions coming to the limits of sustainable expansion of agricultural area (Leach, 1995).

3.5.5. Implications of the crop per drop improvements

Our projections so far of the *over all* water requirements to attain the Hunger Goal (Section 3.4.1) did not consider crop per drop improvements possible in more efficient farming systems. Based on the dynamic crop per drop relations in Figure A in Box 3-1, productivity in staple grain production in the MDG countries can be raised from today's 1.5 – 2 t/ha to 3.4 – 4 t/ha by 2030-50. This corresponds to a productivity improvement from current 1,800 m^3/ton to 1,200 m^3/ton, i.e. a relative saving of 600 m^3 per ton of grain produced. If we assume the same relative improvement in production of all food stuffs in a diet (for both plant and animal food), the current dietary water requirement of 1,300 m^3 per person and year, which was used as an estimate of freshwater to attain 3,000 kcal per person and day, will reduce to 1,000 m^3 per person and year. This means in other words that in 2050, an adequate diet of 3,000 kcal per person and day, will require "only" 1,000 m^3 of freshwater to generate per person and year, instead of the current 1,300 m^3.

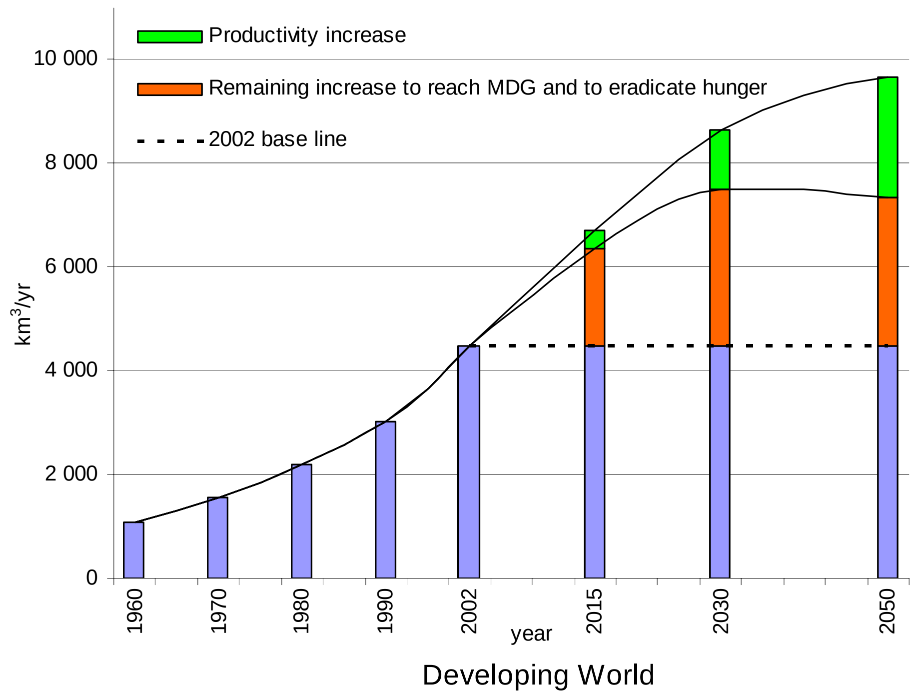


Figure 3-15: Freshwater requirements to attain the 2015 Target, and requirements for 2030 and 2050, indicating possible water savings thanks to crop per drop improvements.

Figure 3-15 shows the substantial contributions of these "crop per drop" improvements for MDG countries to reduce the water for food requirements. By 2015, water savings of 350 km^3/year can be attained, which is a 16 percent reduction of freshwater requirements compared to the previous scenario with no crop per drop improvements (shown in green in Figure 3-15). The water savings by 2030 and 2050 are even larger, potentially reaching 1,150 km^3/year and 2,300 km^3/year, respectively, which correspond to a crop per drop saving of 28 percent and 45 percent, compared to the static scenario.

The total remaining additional freshwater requirements after considering crop per drop improvements are thereby estimated to 1,850 km^3/year to achieve the 2015 Target, to 3,015 km^3/year to eradicate undernourishment by 2030 and to 2,850 km^3/year to keep pace with population growth by 2050 (shown in red in Figure 3-15). Even these reduced quantities involve huge challenges for many countries. The 2015 Target alone, will require the mobilization of almost twice as much freshwater as the current global freshwater use irrigation (1,450 km^3/year). Irrigation may contribute up to 270 km^3/year, or 14 percent of this challenge, which leaves, even after considering crop per drop increase through higher agricultural productivity on existing crop land, 1580 km^3/year or rounded 1600 km^3/year of new green water required to attain the Hunger Goal 2015 Target.

In summary, thus huge volumes of additional freshwater will be required to attain the Hunger Goal 2015 Target, which even after considering crop per drop improvements in agriculture amounts to staggering 1,850 km^3/year. Irrigation can contribute with 270 km^3/year of these, leaving approximately 1,600 km^3/year unaccounted for. This freshwater can only come from three different sources: (1) Capturing additional local rain, (2) horizontal expansion of agriculture, i.e., trade-offs with ecosystems, (3) imports of food, i.e. virtual water, from elsewhere, (4) changes in diets, i.e. lower kcal intake and/or more vegetarian diets.

The most likely scenario is a combination of these three, where trade-offs with ecosystems will be unavoidable given the limitations of poor countries, generally strongly agrarian dependant economies, to generate the purchasing power to solve food deficits through imports alone. The past 50 years are characterized by strong horizontal expansion of agricultural land use, a still ongoing process in many developing countries. The consequences of taking freshwater from terrestrial and aquatic ecosystems, i.e. impacts on MDG 7, are discussed in the next section.

3.5.6. Country level implications

The implications of crop per drop improvements at national level are shown in Figure 3-16 As can be seen from these figures, the trend in the previous scenarios prevail, with Nigeria experiencing growing freshwater requirements until 2050, while India and Kenya experience a gradual decline given that they earlier (in 2030) attain full diets. The net additional freshwater use for food to attain the 2015 Target in India amounts to 460 km^3/year. India reduces its freshwater needs by 64 km^3/year, which corresponds to more than one Aswan Dam. By 2050 India has reduced its water for food requirements by a massive 460 km^3/year. As India requires 1/3rd of the total additional water for food requirement to attain the Hunger Goal, crop per drop improvements are imperative. Kenya can save 2 km^3/year while Nigeria saves 8 km^3/year by 2015 through water productivity improvements. These are important reductions at national level, corresponding, for Nigeria, to at least 10 substantive large dam constructions.

The implications of crop per drop improvements on overall country level freshwater requirements will differ between countries depending on population growth and food requirements. As seen from Figure 3-16, the freshwater requirement will decline between 2030-2050 for India and Kenya, while it continues to increase in Nigeria. The reason is that water savings from crop per drop improvements in India and Kenya are predicted to exceed freshwater demand from populations projected to grow at a slower pace.

3.5.7. Horizontal expansion

Over the past decades, much of the food production increase in many African countries originates from expansion of crop land, and not from improved productivity. Even though sub-Saharan Africa, as opposed to Latin America and Asia, still has regions where agricultural land can expand further, there is a growing realization of the need to primarily focus on producing more on existing land. The Millennium Ecosystem Assessment (MA) concluded that humans have changed ecosystems more rapidly and extensively over the past 50 years than in any time in human history, and that agricultural land use change is the dominant factor behind this change, which has degraded 60 percent of critical ecosystem services (Millennium Ecosystem Assessment, 2004).

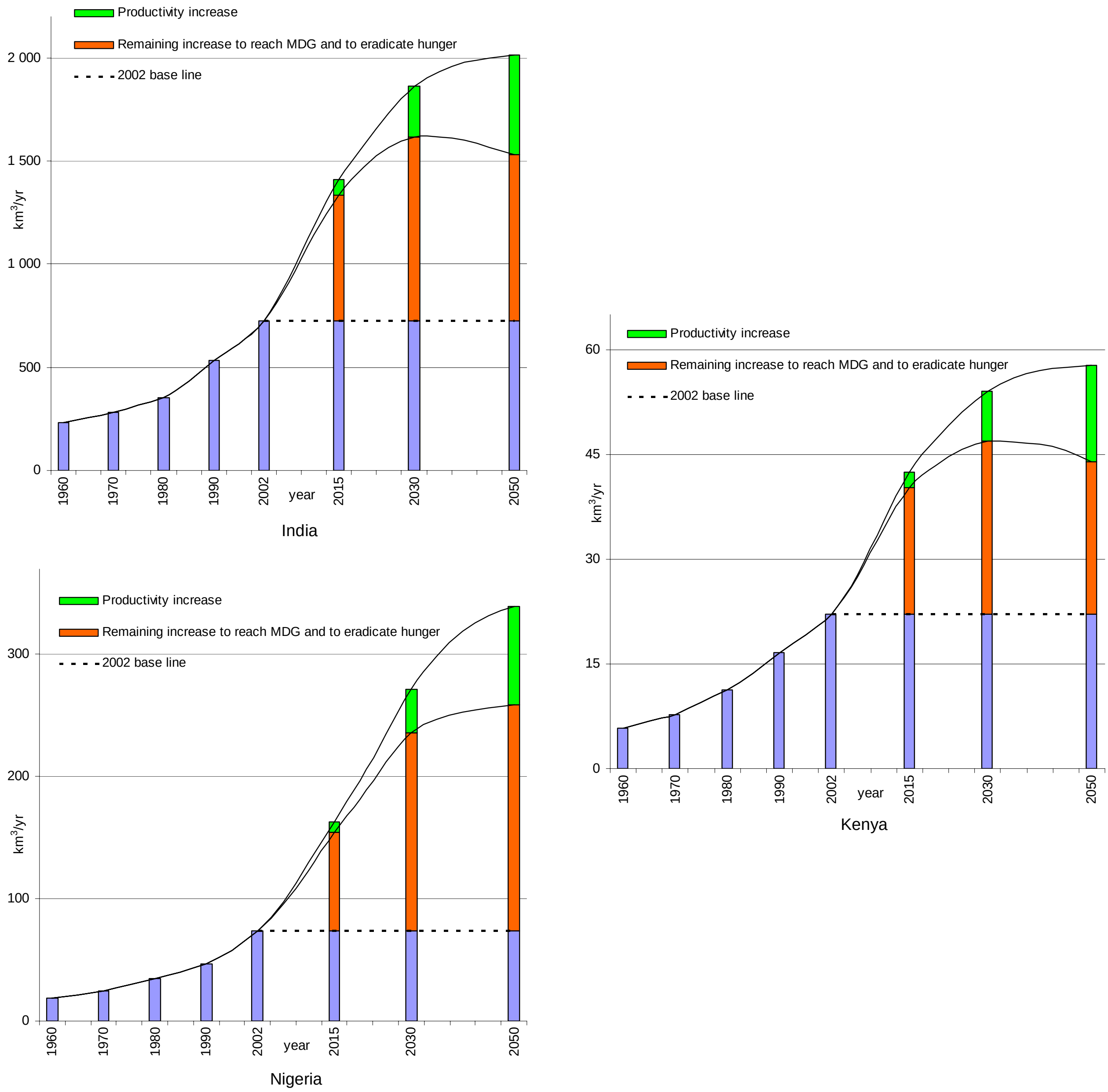


Figure 3-16: Freshwater requirements for India, Kenya and Nigeria, to attain the Hunger Goal and the 2015 Target, and requirements for 2030 and 2050, including possible water savings thanks to crop per drop improvements. India (top left), Kenya (middle right) and Nigeria (bottom left).

As shown above the remaining 1,600 km^3/year of water to attain the 2015 Target will have to come from upgraded rainfed agriculture, on current or expanded croplands. This is where the Hunger Goal and environmental sustainability goal, MDG 1 and 7, closely interlinks. Increased freshwater consumption for food production will reduce water availability for other ecosystems. This can be done either by horizontal expansion of agriculture, i.e. agriculture moves into what is currently forests, savannas, grasslands, and wetlands, or by capturing more local rainfall on current cropland. The result may reduce runoff generation, leaving less blue water in rivers and groundwater, for downstream use.

The remaining challenge of finding 1,600 km^3/year of "new" freshwater to halve hunger, addresses both these trade-off options. Following the historic trend of horizontal expansion of agriculture, the risk is high that the increased freshwater requirement will be met by an accelerated pace of conversion of land to agriculture. If the total additional freshwater requirement of 1600 km^3/yr is to be met from land use conversion, another 3 million km^2 would have to be put under agriculture over the next 10 years, a pace which is almost three times faster than the expansion of agricultural area over the past 50 years (of roughly 1 million km^2 per decade). This would seriously increase the pace of degradation of ecosystem services from terrestrial ecosystems.

If instead investments are made to improve rainwater management in agriculture, to enable a significant increase in productivity (i.e., improve yield levels), this could reduce the need for horizontal expansion. Here we make a first approximation of how much of the additional required water consumption (1600 km^3/yr) which could be met on current cropland. This is made by estimating the potential of increasing rainwater capturing on current croplands. Over the next 10 years, we estimate that yields will increase on average from 2 t/ha to 2.5 t/ha which, as we highlighted earlier can improve water productivity, and for the MDG time step give a crop per drop improvement from 1,800 m^3/ton to 1,600 m^3/ton.

Even though this is a substantial crop per drop improvement, it still results in an absolute increase in freshwater use from 3,600 m^3/ha to produce 2 tons/ha of food, to 4,000 m^3/ha to produce 2.5 tons/ha in the year 2015. More food always means more water. If attributed to the total agricultural land area in the MDG countries, this translates to approximately 1,000 km^3/year by making even better use of rainwater. This is an optimistic analysis, given that a prerequisite for success is that (1) this water is available on current land, which in savanna regions would correspond to essentially using all rainfall available to produce food, i.e., no contribution to river and groundwater recharge, and (2) that the downstream corresponding reduction in blue water flow (from the increased green water flow) is acceptable from an ecosystem and human perspective.

The remaining 600 km^3/year (deducting 1,000 km^3/year from 1,600 km^3/year of total new green water) is an indication of the necessary horizontal expansion after major investments in upgrading productivity on current agricultural land, or trade-off with other ecosystems. *This translates to a potential need to convert 1.2 million km^2 of forests, savannas, wetlands and grassland, to agricultural land. This is a major challenge, as it amounts to a 13 percent increase of current cropland in developing countries, or a 4 percent increase of total agricultural area (including crop land and permanent pastures).*

The horizontal expansion estimated here corresponds to the rate of agricultural expansion over the past 50 years, and leads to the disturbing conclusion, that the historic rate of expansion, which the Millennium Ecosystem Assessment considered highly unsustainable causing major degradation of ecosystem services, may have to continue even after considering productivity improvement on current cropland.

Attaining the Hunger Goal 2015 Target will thus entail difficult decisions on trade-offs with other ecosystems, thereby closely connecting MDG 1 and MDG 7. As much as 1600 km^3/yr, or at best only 600 km^3/year, may have to be shifted already during the coming ten years from ecosystems to agriculture.

3.6 Environmental impacts and trade-offs

The massive amounts of water that will have to be evaporated to produce the food required for meeting the Hunger Goal, as illustrated in Figure 3-15, will evidently involve environmental tradeoffs. This chapter has shown the massive amounts of water will have to be evaporated to produce the food required for meeting the Hunger Goal, first the target of halving the number of hungry till 2025, and then of alleviating developing world undernourishment till 2050. Making these amounts of water accessible either from the blue water available in rivers and aquifers or from the green water (soil moisture) available on arable lands, now under a cover of grasslands or forests, will evidently have to involve environmental tradeoffs

3.6.1. Environmental sustainability implications, MDG 7

The trade-offs involved in shifting the 600 km^3/year just arrived at in Section 3.5.7 from terrestrial ecosystems to agricultural have to be analysed from the aspect of MDG 7, where the goal is to secure environmental sustainability. This means in practical terms to avoid an undermining of the resource base for humans and vital ecosystems by protection of resilience and to secure long term functioning of these systems, so that they continue to produce for society vital ecological services.

But MDG 7 is involved also in other ways in the efforts towards achieving the Hunger Goal, because of other side effects on terrestrial and aquatic ecosystems surrounding agricultural lands. Different sets of environmental impacts have to be paid attention to in this connection:

- impacts of measures taken for productivity increase
- impacts of increased irrigation
- impacts of land cover change for cropland expansion
- impacts of pollution from increased use of fertilizers and pesticides (not further discussed here)

The large scale productivity increase will evidently have positive impacts in terms better protecting the cropland from erosion, water logging and salinization. The suggested development might however also have possible negative impacts downstream, with reduced runoff following rainwater harvesting and dry spell damage protective irrigation.

Expanded large scale irrigation always means effects in terms of reduced runoff and therefore further depletion of stream flow with effects on aquatic ecosystems

Land cover change on currently non-cropped arable land, i.e. turning natural grasslands or forests into croplands, will most probably involve some unavoidable water balance change influencing groundwater recharge and runoff, and therefore wetlands and aquatic ecosystems

These different effects indicates that in securing eradication of hunger and undernourishment it will be unavoidable to address a set of environmental trade offs between water for producing more food and blue water now left in rivers and aquifers, and green water under terrestrial ecosystems. *Guiding principles will have to be developed by proper attention to the necessity to secure resilience and the biodiversity necessary for that resilience.*

3.6.2. Trade-offs against natural ecosystems

It may be useful to try to quantify the trade offs involved in trying to reach food self sufficiency in the developing world and in the country cases analysed closer in this chapter to get an idea of the degree of stress that will have to be coped with in the next few decades.

A first comparison of the net food water requirements (after productivity increase) with water resources available, blue as well as green, is shown in Figure 3-17. The different water resource components are:

- blue, indicated by the runoff formation, how much is currently consumed in irrigation, the 30 percent indicating the minimum amount ("environmental flow" to remain unappropriated for the aquatic ecosystems)
- green , indicated as the natural soil moisture under different land covers: the usable part under today's croplands, grasslands, forests, and the non-usable part (under arid lands, urban and industrial lands, settlements etc)

Figure 3-17 gives a first water-balance-based characterization of the situation, which evidently differs a lot between different countries. The column designated “Today” represents the total precipitation, 100 percent, for each country and visualises how the freshwater is “used” for each country under present land and water use situation. All the categories above the red line “use” the naturally infiltrated rainfall, soil moisture, as their freshwater resource – *green water*. For the three categories below the red line it is the runoff that constitutes the resource – *blue water*. For the all categories above the red line and “irrigated crops” the freshwater after use returns to the atmosphere as a vapour flow, i.e. a consumptive water use. After use by the categories “unappropriated” and “environmental flow reserve” the water ends as an outflow to the oceans.

India depends to a considerable degree on irrigation. Although several rivers are already over-appropriated, the country scale data suggest that a certain potential remains in terms of blue water reserve. There is however a clear need to expand rainfed agriculture by using green water from savanna, grasslands or forests. The green water needs for increased food production might be met without large expansion into savanna, grasslands or forests. Nigeria finally, seems from this country scale perspective to have a certain potential for irrigated agriculture although marginal irrigation at the moment. When comparing the total length of the blue and yellow columns (total estimated consumptive water use for food production) for "2015 MDG", "2030" and "2050" with the blue part below the red line on the "Today" column it is however clear that even if every single drop in all the three countries is turned into food production the nation runoff will not be enough.

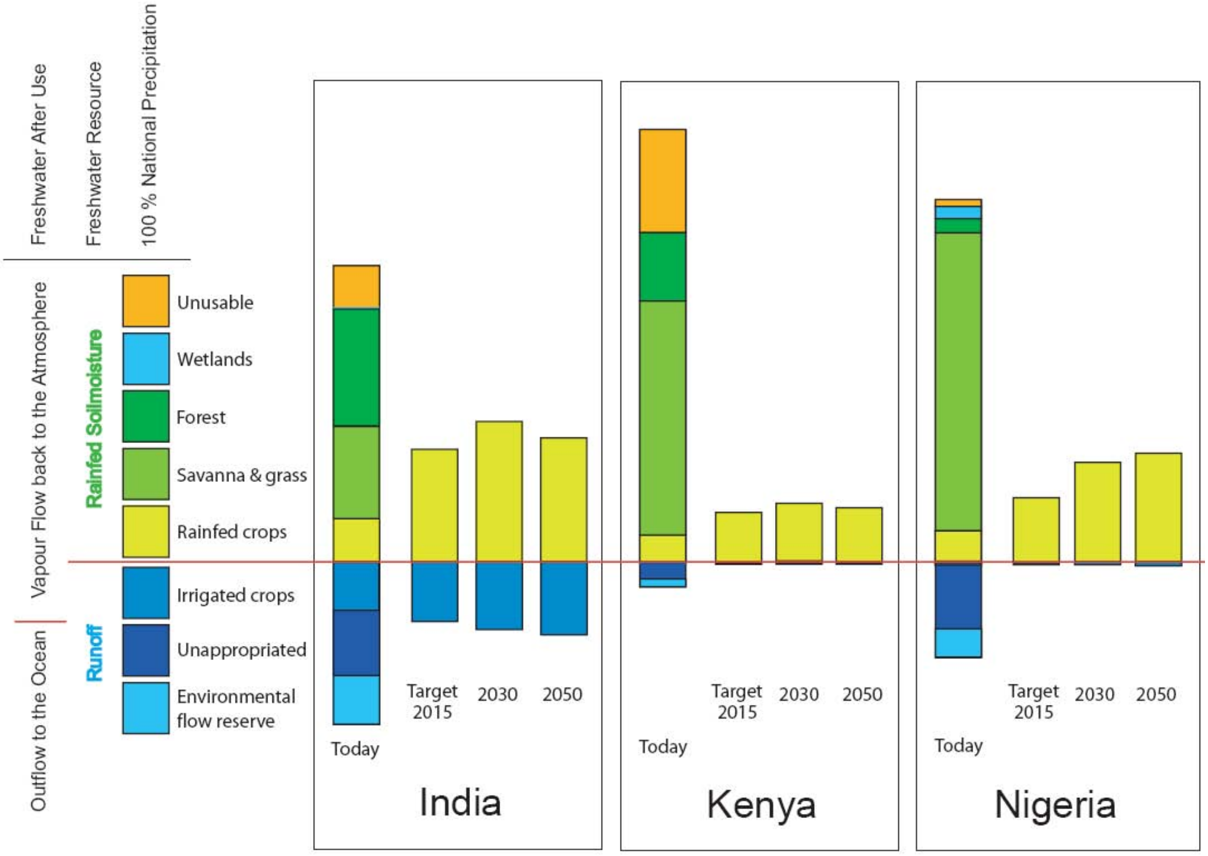


Figure 3-17: Current use of green as opposed to blue water resources, "Today" compared to future food water requirements, "2015 Target", "2030" and "2050".

3.7 Socio-economic impacts

As shown in this report, meeting the Hunger Goal 2015 Target, which in itself is closely linked to attaining the MDG goal on poverty, will require large redirections of freshwater, 1,600 km^3/year, from ecosystems and downstream human use (e.g., urban areas), to produce food. Our estimates indicate that 600 km^3/year of these may have to originate from horizontal expansion of agricultural land use, while the remaining 1,000 km^3/year would be increased use of water on current crop land, which may reduce the amount of blue water in rivers and groundwater. The additional 1,600 km^3/year has already considered major crop per drop improvements in agriculture achieved by investing in integrated land, water and crop management in order to double yields by 2030, as well as increased blue water use, where water development in irrigation may contribute with up to 270 km^3/year. The new water use of 1,600 km^3/year will thus occur in rainfed agriculture.

These water developments; (i) to expand irrigation, (ii) to provide water to enable increase of yields and with attention to crop per drop increase on current agricultural lands, and (iii) to deal with trade-offs with ecosystem and other human use of water, are a prerequisite to attain the 2015 Target. Of these water developments, only the first, irrigation expansion, is normally considered when discussing water needs to produce more food for a growing world. There has been much focus on how to halve the number of malnourished, but little understanding of the environmental factors behind the goal, where freshwater plays the most fundamental role.

A stronger focus is imperative on how to manage land and water resources to enable large enough increases in food production. Also, the strong current freshwater focus on blue water developments for irrigation, has to be balanced with new policies and investments on how to upgrade rainfed agriculture, which will, by far, provide the bulk of food to attain the MDG on food. Moreover, 70 percent of the poor people live in rural areas, and are predominantly smallholder farmers depending on rainfed agriculture for their livelihoods. These are the people in focus of the MDGs. We thus need to see a redirection of agricultural and water policies in favour of upgrading rainfed.

Here we make a rough estimate of the direct investment and recurrent costs to achieve the required water developments in both irrigated and rainfed agriculture. The key redirection of focus is on water investments in rainfed agriculture to enable resource poor smallholder farmers to capture more rainfall and redirect it to the crop in order to double yields over the coming 25 years. This is an absolute necessity in order to half the number of undernourished and, on the longer term, eradicate hunger all together. Table 3-1 describes the assumptions on costs to enable this process.

We have considered infrastructure investments in dams for conventional irrigation, development of rural roads (IWMI, 2000), agricultural research (IWMI, 2000; Millennium Taskforce on Hunger, 2004), extension and capacity building (Millennium Taskforce on Hunger, 2004; ODI, 2000), and management investments and running costs on land, water and crop management (Stocking and Abel, 1992; Fox et al., 2003; Pollak, 2004; Kedderman, 1992).

As our analysis shows there is an urgent need to redirect focus towards the large water investments required in rainfed agriculture *(85 percent of the freshwater to meet the MDG on hunger will derive from rainfed agriculture)*. There is a major policy and knowledge gap that needs to be filled rapidly, in order to enable extension services and other service providing agencies to provide required know-how to farmers on how to raise the amount of water available to produce food in rainfed agriculture. Furthermore, there is a strong realization that new methods of extension are required, as pointed out by Sachs et al.(2004), which more strongly consider adaptive management and participatory approaches, such as farmer field schools and action research based extension.

Unfortunately the starting point is bleak. Government funding for extension in many developing countries was reduced throughout the 1980s despite growing numbers of people depending on agriculture for their livelihoods. In Africa spending on agricultural extension fell by 50 percent during the 1980s, affecting both quantity and quality. According the FAO, only two out of three farmers in Africa and three out of four farmers in Asia had no contact with extension services in the mid 1990s (FAO, 1996).

As seen from Table 3-1 the costs directly related to food production have bee translated to USD per m^3 of freshwater made available for consumption in biomass growth (USD/1,000 m^3). The estimated water related investment requirements to halve hunger by 2015 amount to 47 Billion USD per year. This amount equals about 25 percent to the UN Millennium Project estimate of 190 billion USD/year in 2015 required to succeed with the implementation of the MDG plans of action. This suggest an underestimation in the UN Millennium Development Project estimates of the investments needed in smallholder water management, particularly in terms of capacity building to enable farmers to adapt and adopt appropriate water resource management systems, such as water harvesting, drip irrigation, pumps, wells etc.. However, it should be recognised that these figures are not directly comparable, as our estimates include total investment needs in upgrading rainfed and irrigated agriculture, i.e., both external and internal investments needs. It can be expected that a large portion of the investment costs will be carried by the farmers and domestic budgets. In perspective though the investment requirements to half hunger are not excessive if set against current agreed ODA commitments or per capita costs. Currently (2002 figures) ODA amounts to 0.23 percent of combined national income of donor countries, which leaves a shortfall of 120 billion USD/year, in relation to the 2002 Monterrey Consensus of the International Conference on Financing for Development where developed countries agreed to makes serious efforts to achieve the target of 0.7 percent of GDP.

As seen in Figure 3-18, the estimated annual costs to achieve the goal of eradicating hunger, will require increased investments over the period following after 2015, with a peak in 2030 of 67 billion USD per year, when we assume that hunger is eradicated. By 2050, lower pace of population growth and water productivity improvements will reduce and stabilise the annual costs to maintain adequate nourishment for the world's 9-10 billion people at a cost of approximately 58 billion USD/year.

Table 3-1: Estimated annual investment and running costs in water resource-related management to enable achievement of the Hunger Goal and the associated 2015 Target.

Sector	Used in present study	Range min	Range max		Source
Irrigation Development	75.0	55.0	85.0	USD/1,000m^3	1
Upgrading Rainfed: In-situ soil and water management	7.0	5.0	10.0	USD/1,000m^3	2,3
Upgrading Rainfed: Small-scale water management	4.0	2.0	30.0	USD/1,000m^3	4,5
Agriculture Research	3.0	2.0	10.0	USD/1,000m^3	1,6
Extension Services	2.0	0.5	5.0	USD/1,000m^3	6,7

1. IWMI, 2000. 2. Stocking and Abel, 1992. 3. Keddeman, 1992 . 4. Fox et al., 2004. 5. Pollak, 2004. 6. UN Millennium Task Force on Hunger, 2004. 7. ODI, 2000

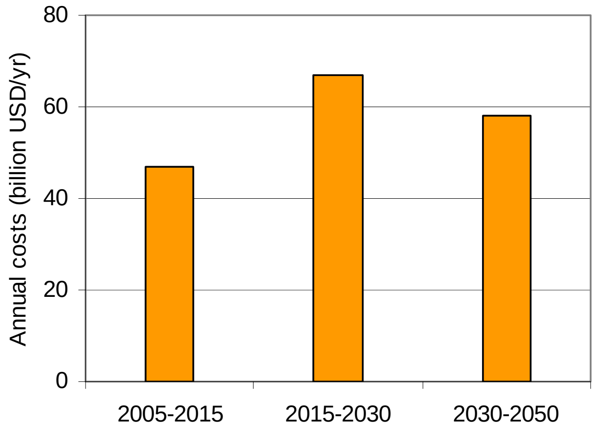


Figure 3-18: Estimated annual investment and running costs for water resource related management (including, apart from the sectors in Table 3-1, investments in rural roads)

3.8 Conclusions and way forward

The Millennium Development Goal 1 state eradication of extreme poverty and hunger, and the 2015 target aim to reach half-way by 2015. MDG 7 sets out to reach the poverty and hunger targets as well as all other MDGs in an environmentally sustainable way. To halve the prevalence of hunger by 2015, *the Hunger Goal 2015 Target*, the 10 year challenge is to lift 193 million undernourished people to adequate diets and to assure full diet supply to an additional population of 893 million.

Here we have highlighted not only the critical role of freshwater to attain the Hunger Goal 2015 Target, but also shown that environmentally sustainable freshwater strategies, in both irrigated and rainfed agriculture can enhance chances of actually halving the number of hunger on Earth by 2015. This can be done in a way that minimises trade-offs with other essential ecosystem services, such as biodiversity, forest products, and fish production. Wise water investments over the coming 10 years are critical, and a prerequisite for MDG success, especially if long-term solutions are sought for, which are not undermined by short term success. In many regions the productivity increase success of the Green Revolution is dependent on unsustainable groundwater pumping, with e.g. groundwater levels in India declining with several meters per year due to over-draft. Intensive ploughing and mono-culture cropping contribute to soil erosion and land degradation. Poor irrigation management has e.g. resulted in large scale salinization problems in Egypt, India and Australia, and environmental disaster in the Aral Sea basin.

Importantly, this chapter clarifies the climatic predicament behind the hunger goal. The poorest countries subject to the largest hunger challenge – the MDG hot-spot countries - also tend to be situated in regions subject to extreme rainfall variability in hot tropical regions with recurrent water scarcity. These countries are located in the world's savanna and steppe hydroclimate zones, where freshwater plays a fundamental role in determining the livelihoods of poor people. This is especially relevant for many MDG hot-spot countries with agriculture dependent economies and with a large portion of their populations directly relying on rainfall for their livelihoods, in sub-Saharan Africa often more than 60 percent.

The analysis indicates that meeting the 2015 Target will require massive additional volumes of freshwater to produce food, 50 percent more water consumed in agriculture compared with today, for improved diets among malnourished in poor developing countries. This is a huge increase, for a sector which already today is the world's by far largest consumer of freshwater in rivers, groundwater and lakes.

For countries hosting large portions of undernourished people and which still experience rapid population growth the increase in freshwater to attain the 2015 Target is even larger. *For India, Kenya and Nigeria, an 100 percent increase of freshwater will be needed to halve the proportion of hungry by 2015.*

To attain a balanced diet today of 3,000 kcal per person and day, containing 20 percent animal products, requires with current water productivity 1,300 m^3 per person and year to produce. Table 3-2 summarizes the freshwater requirements to achieve the Hunger Goal and associated 2015 Target. The table further assesses the possible origins and trade-offs of the freshwater challenge. To halve the proportion of undernourished to meet the 2015 Target an additional 2,200 km^3/year would be required assuming current crop per drop levels. This is 1 ½ times as large as the current global use of water in irrigation.

Still, beyond 2015 half of the Hunger Goal remains. By 2030 a staggering 3,645 km^3/year would be required to address the remaining part of the world's undernourished people and supply full diet to the additional population increase, all with a diet of 3,000 kcal per person and year. Further population growth lifts the additional requirement to 4,430 km^3/year of additional green water requirement by 2050. This shows that, despite the risks of investing in short term solutions with long-term trade-offs, the needs are immense and urgent. Major contributions will be required from both water development for irrigation and unprecedented investments in upgrading rainfed agriculture.

Table 3-2: Summary of freshwater requirements to achieve the Hunger Goal and the 2015 Target, and assessment of possible origins and trade-offs of remaining freshwater challenge (rounded figures).

Component of freshwater requirement		Consumptive water use (km^3/year)			
		Present	2015	2030	2050
Present Crop per Drop	Overall required	4,500	6,700	8,665	9,660
	Additional required		2,200	4,165	5,160
	% increase 2005-2015		49	93	115
After Improved Crop per Drop	Overall required	4,500	6,350	7,510	7,350
	Water saving		350	1,155	2,310
	Additional required		1,850	3,010	2,850
	% increase 2005-2015		41	67	63
Possible Blue contribution (irrigation)	Overall required	1,415	1,685	1,935	2,140
	Additional required		270	520	725
	% increase 2005-2015		19	37	51
Remaining Green water requirement (rainfed)	Overall required		1,600		
	% increase 2005-2015		36		
Capturing more local rain on current land	Reduction downstream blue water availability		1,000		
Horizontal expansion	Trade-offs with terrestrial ecosystems		600		

Investments in irrigation, where blue water from rivers, lakes and groundwater is withdrawn to produce food, are thus required. According to our optimistic outlook an increase of 270 km^3/year, or a 12 percent increase, of consumptive water use could be achieved over the coming 10 years. Blue water contribution would continue to increase, adding altogether 520 km^3/year by 2030 and 725 km^3/year by 2050, a 25 percent increase over the next 45 years. This leaves an additional 1,940 km^3/year of freshwater to produce food over the next 10 years.

Luckily, there is a window of opportunity to reduce the freshwater requirements through crop per drop improvements, i.e. by improving water productivity in agriculture. This is possible, and there is ample evidence that we have the know-how required to double and even triple yield levels even in water scarcity prone savanna regions, the hot-spot region in terms of MDG achievement. Integrated land, water and crop management, new tillage systems, water harvesting, supplemental irrigation and a particular focus on soil fertility and diversification of production systems, are particularly important. Our analysis suggests that crop per drop improvements could reduce the water requirement to generate diets from 1,300 m^3/person/year to 1,000 m^3/person/year by 2050 (by doubling yields over this period). This would, until 2015, correspond to a water saving of 350 km^3/year, i.e., reduce the actual water requirement to halve hunger to 1600 km^3/year. This is a large crop per drop saving, corresponding to 6 Aswan dams, but still the "unaccounted" remaining freshwater exceeds today's global irrigation water use of some 1,500 km^3/year.

This freshwater, 1,600 km^3/year of "new" freshwater by 2015, which will rise to 2,500 km^3/year by 2030 and stabilise at 2,100 km^3/year by 2050, will essentially have to originate from expansion and hopefully from upgrading of rainfed agriculture.

The Hunger Goal is thus also a freshwater goal. Behind each well-fed human being hides large volumes of freshwater to enable the production of her diet. Not only will massive volumes of new freshwater have to be mobilised, until now there is a very limited understanding of this huge environmental predicament to attain the hunger goal. Water policy remains blue water focused, on irrigation development, which is important, but will as we have seen, will only contribute with a small portion of the goal to eradicate hunger. *In total 85 percent of freshwater to meet the Hunger Goal will originate from rainfed agriculture.*

The conclusion is that large and rapid shifts in water and agricultural policies are required, in favour of investments in technologies, management and human capacities to provide water for upgrading of rainfed farming. From an MDG perspective this is crucial, as 70 percent of the world's poor still live in rural areas. Only a few countries in the world have agricultural policies that in an explicit way promote water harvesting, and water resource management for rainfed farming. Large investments are needed now, and a first estimate indicates that *47 billion USD per year is required by 2015 to enable the release of 1,600 km^3/year in rainfed farming, 270 km^3/year in irrigation development and 350 km^3/year of crop per drop savings.*

From an ecosystem perspective it is clear that horizontal expansion of agriculture to cover the full additional requirement of 1600 km^3/yr would increase the pace of ecosystem degradation and have severe consequence on ecosystem services. This large trade-off with ecosystems will most likely not be accepted, even though past trends suggest that horizontal expansion has been the major source of food production increase in developing countries. This analysis clearly highlights the urgent need for water investments in rainfed agriculture to reduce horizontal expansion. If this were to succeed, a first approximation indicates that out of the 1,600 km^3/year of new green water flow required by 2015, around 1000 km^3/year could originate from increased water use on current agricultural land through yield increase by making better use of local rain. The remaining 600 km^3/year correspond to the necessary expansion of agriculture into forests, grasslands, savannas and wetlands. This horizontal expansion of rainfed agriculture corresponds to an increase over the next 10 years of 1.2 million km^2 or a 4 percent increase in total agricultural land area (both crops and grazing). Such a scenario confirms the development over the past 50 years, where the expansion of agricultural land use (of some 1 million km^2 per decade) has been the dominant driver behind loss of ecosystem services from deforestation and loss of wetlands, savannas and grasslands. This analysis thus indicates that the fear for continued horizontal expansion expressed by the Millennium Ecosystem Assessment, may be difficult to avoid. This will cause difficult trade-off decisions between ecosystem services generated in agriculture and other terrestrial biomes.

The fact that more food will require appropriation of freshwater currently consumed by other ecosystems, such as forests, grasslands and wetlands, is clearly shown in the analysis of freshwater requirement to sustain terrestrial and aquatic ecosystems, the backbone of MDG 7. This report clarifies that there are no free freshwater lunches, instead even though crop per drop improvements (which result in no trade-offs) are considered, the large required increase in food production will result in environmental trade-offs. As shown in this study, 21 percent of all rain falling in developing countries is consumed to sustain forests, 23 percent to sustain ecosystem services in savannas and grasslands, while only 4,8 percent is used to sustain food production.

In this analysis we have only focused on actual freshwater requirements to attain the 2015 Target and to eradicate hunger by 2030. We have carried out the country level analysis on the assumption that food production will primarily occur within the country, i.e., we have not considered import of food, or virtual water trade. As seen from Figure 3-19, most MDG hot-spot countries currently depend to varying degree on food imports, with the arid North African and Middle East countries most heavily dependent on imports. As seen from the figure, the poorest countries oscillate around the zero dependence on imports/exports. This is a reflection of the low purchasing power of these societies and the importance of the local agricultural sector. We assume this importance will prevail over the next 10 years. Moreover, it is worth reminding of the low overall importance of food trade for food security, where only 5 – 10 % of world food production is traded on the world market. This food is moreover predominantly produced in North America, Europe and in Australia, and consumed in arid countries in North Africa and the Middle East. The MDG hot-spot countries largely remain local markets, with food self-sufficiency, often as an active local policy priority, or as a consequence of weak local and agriculture dependent economies. However, it is clear that countries facing major food related water stress and are approaching the limit of its potentially available green and blue water resource for food production, as e.g. India, might have to rely on food imports to balance their food needs. For most countries in sub-Saharan Africa though, there is room within the national green and blue water resource to upgrade agriculture to meet future food needs.

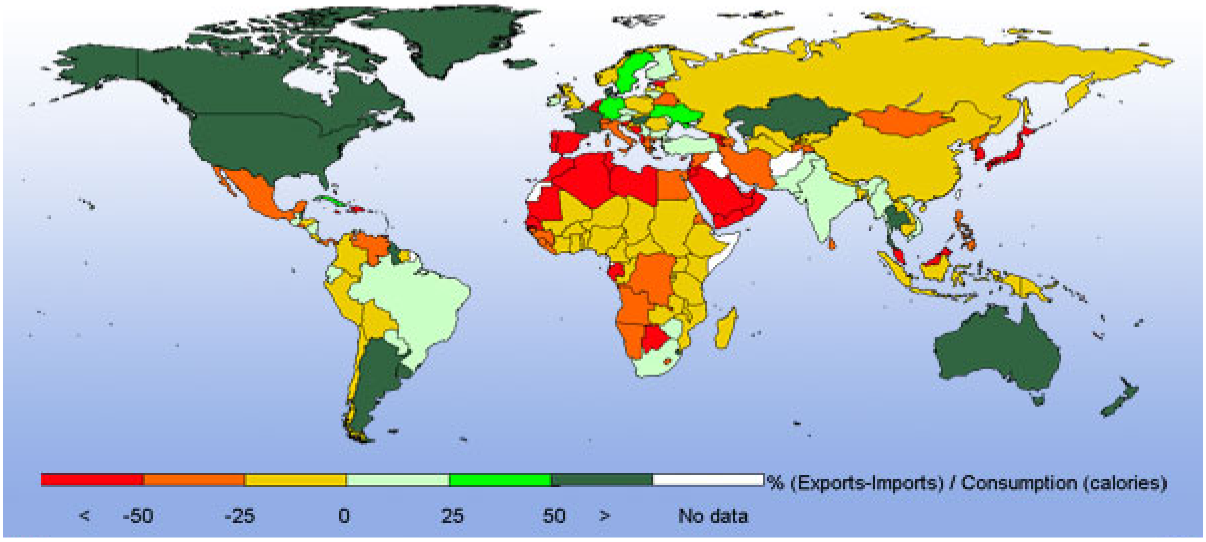


Figure 3-19: Global net trade in calories (map from FAO, 2005)

Children and women are most sensitive to under-nourishment, and have to lowest resilience to cope with large fluctuations in access to food caused by fluctuations in rainfall. Droughts and floods cause major food driven social disasters, such as the current food disaster in Niger, where 3 million people are at the brink of starvation. In the poorest countries most food is produced by smallholder farmers in rainfed agriculture. Investments in water management in these communities, which would stabilise food production over time, would benefit all people, and in particular give women and children a chance to avoid water driven hunger shocks.

Urbanization is a rapid trend in developing countries. Already by 2015 more than 50 percent of the population in developing countries are predicted to live in urban areas. This will probably speed up the current trend of increased meat based diets, which from a water perspective is important, as meat based foods consume at least eight times more freshwater than plant based foods.

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4. Sustainable Sanitation for the MDGs

4.1 Introduction

The Joint Monitoring Programme (JMP) of the WHO and UNICEF reported in 2004 that the number of people lacking basic sanitation services rose from 2.1 billion in 2001 to 2.6 billion by 2004. It is common knowledge that improved sanitation has a direct positive effect in reducing diarrhoea morbidity (Fewtrell et al 2005). Still, progress in improving sanitation for almost half the world's population remains slow and diarrhoea from unsafe water, sanitation and lack of hygiene causes 1.8 million deaths per year, 90% of which are children under 5 years of age (SIWI, 2005). A direct relationship exists between child mortality and access to sanitation Figure 4-1.

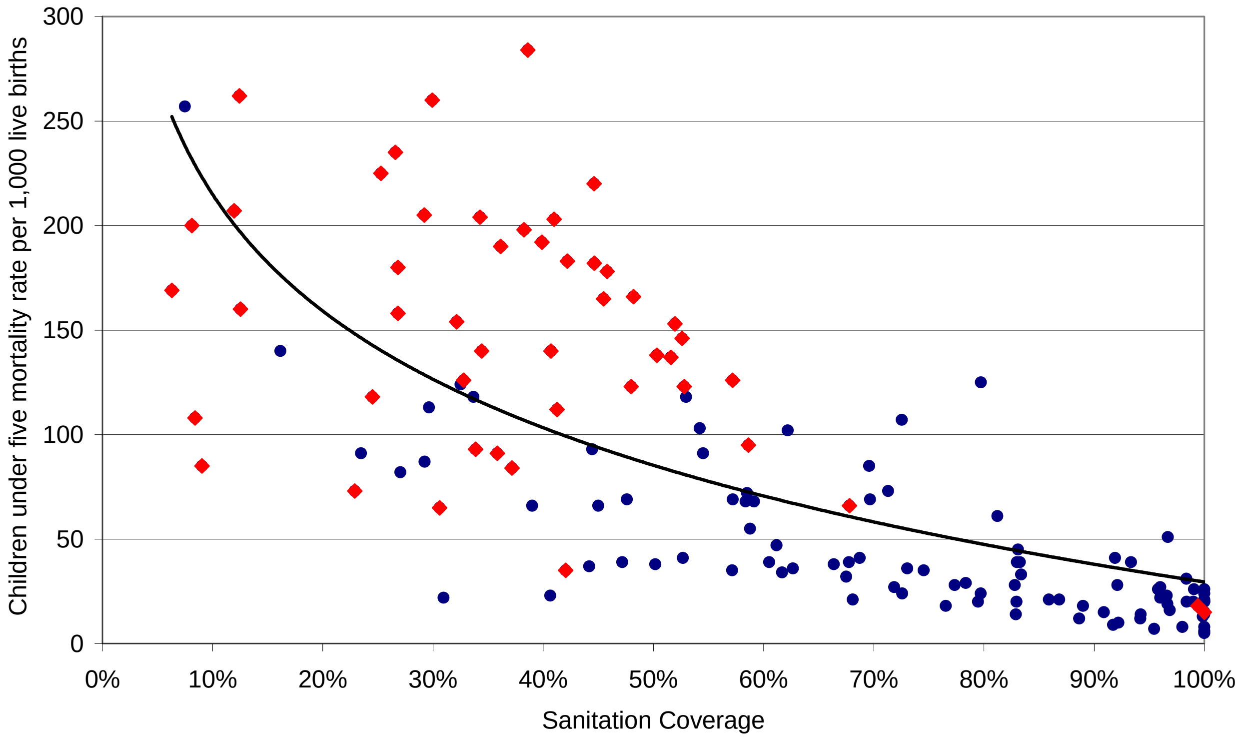

Figure 4-1: Child Mortality versus Sanitation Coverage for Developing Countries (Sub-Saharan Africa as red diamonds) (UN millennium indicators)

The prime objective of this chapter is to flag alternative approaches to sanitation taking into account the need to protect the environment and human health and to allow for recycling of the nutrients derived from human excreta. Achieving the MDG for sanitation (i.e. to halve the proportion of the world's population in 1990 lacking basic sanitation services by the year 2015) using conventional approaches would provide multiple positive spin-offs (Hutton and Haller, 2004). These, further clarified by SIWI (2005), include time savings due to closer sanitation facilities, productive and educational time gain due to less illness from diarrhoea, and health sector and patient savings due to less treatment for diarrhoeal diseases. These result in relatively high benefit to cost ratios averaging 5.5 for all targeted regions (8.9 for Sub-Saharan Africa). Of particular note, these significant benefits result from a mere 10% reduction in global diarrhoeal occurrence. However, to reach this and even more, within the MDG time frame, innovation focussing on sustainability is badly needed within the water and sanitation sector and should be central to the MDG strategy as laid out by the MDG Task Force on Water and Sanitation (UN Millennium Project**,** 2005). Conventional approaches to sanitation, even if successfully applied to the MDG target populations, do not address the present situation for those today that receive poor standard sanitation services. This is a major source of health and environmental problems. Also, the existing conventional approaches to sanitation might not always be appropriate to the context of the MDG target population for a variety of reasons. Thus there is a need for a new look at sanitation using some principles of sustainability.

Sustainable sanitation encompasses in general the following criteria (Winblad and Simpson-Hébert, 2004):

- Disease prevention: the sanitation system must be capable of destroying or isolating faecal pathogens
- Environmental protection: the sanitation system must prevent pollution and conserve valuable water resources
- Nutrient recycling: the sanitation system should return nutrients to the soil.
- Affordability: the sanitation system must be accessible to the world's poorest people.
- Acceptability: the sanitation system must be aesthetically inoffensive and consistent with cultural and social values including gender equality
- Simplicity: the sanitation system must be robust enough to be easily maintained with the limitations of the local technical capacity, institutional framework and economic resources.

Other more detailed criteria for what is sustainable sanitation exist in the literature (Bracken et al. 2005). A detailed assessment of the elements required in gender equality within the water and sanitation sector including empowerment of women is provided in the SEI report by Kjellén and Bernstein (2004).

Recently the WHO (2005) has approved new health guidelines for the reuse of human excreta and greywater which will help promote the further development of ecological sanitation. These will be published by the end of 2005.

Ecological sanitation (ecosan) solutions, if introduced, would provide a series of additional benefits to those using conventional approaches. These include:

- permanent installations (conventional pit latrines last 5-10 years and then are often abandoned),
- prevention of downstream ground and surface contamination by both nutrients (eg nitrate) and pathogens (ecosan systems provide a high level of pathogen kill-off),
- improvements over leaky septic tanks and sewage systems,
- lower cost latrines in urban areas not requiring large-bore sewage pipe collectors and large treatment plants,
- savings of domestic water (especially important in drought-prone regions),
- alternatives to pit latrines in areas of high water tables and flooding,
- recycling of nutrients derived from human excreta for local agriculture (especially important in regions with poor soil fertility and poverty)

Ecological sanitation has the capacity to meet all the above requirements and play an essential role in achieving the MDGs. Ecosan emphasises the aspect of source separation in order to allow for containment, sanitization and reuse of excreta following treatment. This is applied to urine, faeces, greywater and household organic wastes. The objective is to protect human health and the environment while reducing the use of water in sanitation systems and recycling nutrients to help reduce the need for artificial fertilizers in agriculture. Ecosan represents a conceptual shift in the relationship between people and the environment and it is built on the necessary link between people and soil. The conceptual model of ecological sanitation is shown in Figure 4-2. Ecosan is a closed-loop system, closing the nutrient and water cycles.

Ecosan does not consist of a single solution, a "one-size fits all" sanitation system. Instead, ecosan represents a wide range of options, appropriate for both poor and rich livelihoods, and rural and urban populations. In addition to protecting human health and the environment, it addresses a wide range of cultural needs such as indoor and outdoor installations, anal cleansing by using paper or water, and provides practical solutions to deal with odour arising from urine and faeces.

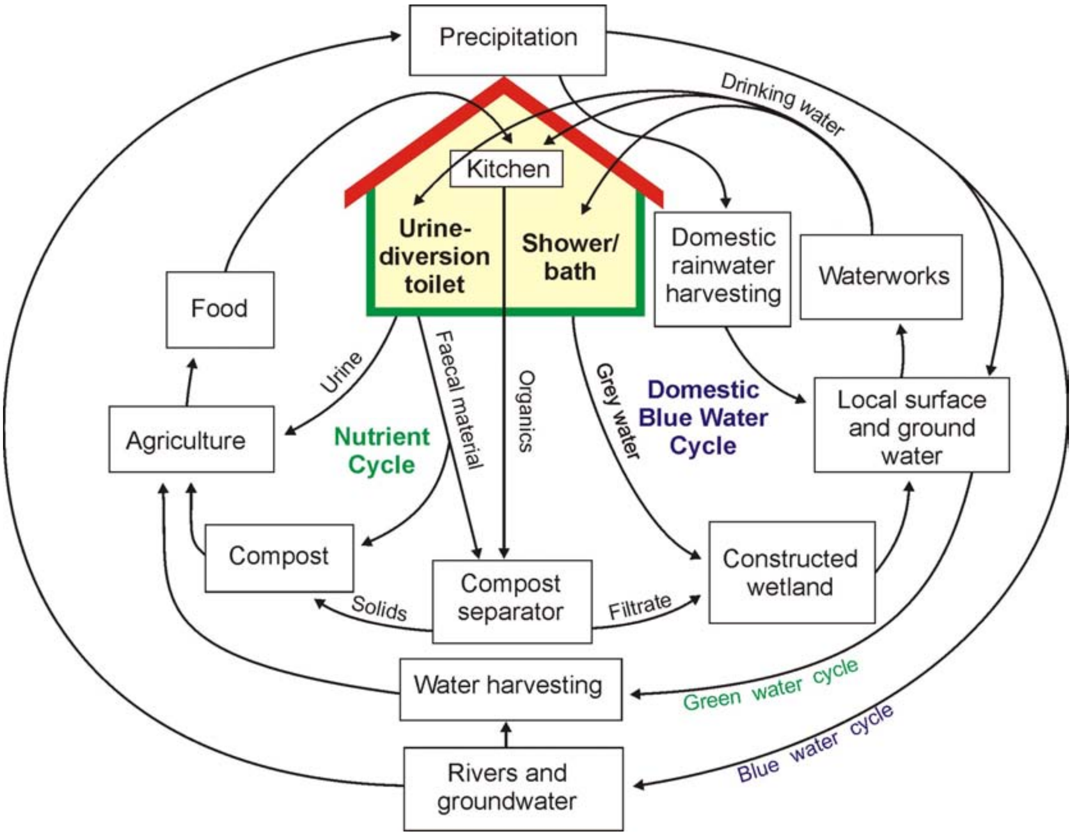

Figure 4-2: Complete household ecosan and eco-water use (Modified from Oldenbrg, M. [Otterwaser])

In this chapter, we make a deeper analysis of the MDG water and sanitation target population, providing an assessment of the number of target households for both urban and rural populations through to 2015. We also discuss financial aspects of achieving the MDGs utilizing ecosan systems compared to conventional systems. Also the economic value of nitrogen and phosphorus from human excreta is assessed for the MDG target population. The steps we went through are listed as follows:

- The MDG target population for water and sanitation through to 2015 was estimated for the nine global regions involved
- These data were transformed into the number of MDG target households both urban and rural for the nine regions
- Ecological sanitation was introduced and applied to the target households providing cost estimates for the nine regions, both urban and rural
- An analysis was done of the potential yearly amount of nitrogen and phosphorus that could be recycled form the MDG target population for the nine regions
- An additional scatter diagram analysis was carried out describing the relationship between fertilizer utilised and capacity for recycling of N and P for each country of the world
- Recommendations were introduced whereby present water and sanitation practices can be made more sustainable

This study does not examine alternative methods of extracting, storing and managing domestic water resources, but emphasises essentially the sanitation aspects. Water is of course central to human hygiene and within the context of sanitation; the wastewater generated from domestic uses is a central aspect of ecological sanitation. Ecosan attempts to reduce the use of water in toilets in order to simplify the task of treatment and to conserve and protect this essential resource for drinking, hygiene, food production and recreation.

4.2 Estimating the MDG population targets for water and sanitation through to 2015

In 2002, 2.6 billion people lacked basic sanitation (WHO and UNICEF, 2004). Of these, 0.6 billion were in urban areas and 2.0 billion in rural areas. Also, as of 2001, 0.9 billion people live in urban slums, up from 0.7 billion in 1990 (UN-HABITAT), and thus will be a key target group of those without sanitation. As we near 2015 the size of the target will increase and the relative split between urban and rural will also increase significantly due to urbanization and urban population growth.

Table 4-1: MDG Target populations to 2015, # of persons in millions that will require coverage (FAO, JMP)

UN Region	Urban sanitation target population	Rural sanitation target population	Urban water target population	Rural water target population
East Asia	247.9	147.8	254.2	14.2
Eurasia	7.5	16.2	4.7	9.7
Latin America & Caribbean	114.8	25.2	97.4	7.9
North Africa	27.6	17.8	27.8	13.8
Oceania	0.8	2.7	0.8	2.9
South-East Asia	89.7	60.6	105.2	31.9
Southern Asia	189.5	380.9	171.2	132.3
Sub-Saharan Africa	158.4	199.4	146.9	147.9
West Asia	44.5	22.8	43.6	16.8
Total	880.6	873.5	851.9	377.4
Combined totals		1,754		1,229

The following describes the calculation of the number of people targeted to receive water and sanitation coverage to meet the MDGs by 2015. The target population estimates are based on JMP (WHO & UNICEF, 2004) country data on water and sanitation coverage from 1990 and 2002 and FAO country population projections for 2015. The target population estimate is the projected total population for 2015 minus the population already covered by water and sanitation services in 2002 and minus the population not yet to be served by 2015. The population not yet to be served by 2015 is one-half of the percentage not covered in 1990 (or 2002 if 1990 data are not available) multiplied by the projected population for 2015. **This results in a target population size in the developing countries of 1.75 billion for the MDG on sanitation and 1.23 billion for the MDG on domestic water** (Table 4-1). These estimates are somewhat lower than those provided by the MDG Task Force (UN Millennium Project, 2005) (2.1 and 1.6 billion respectively).

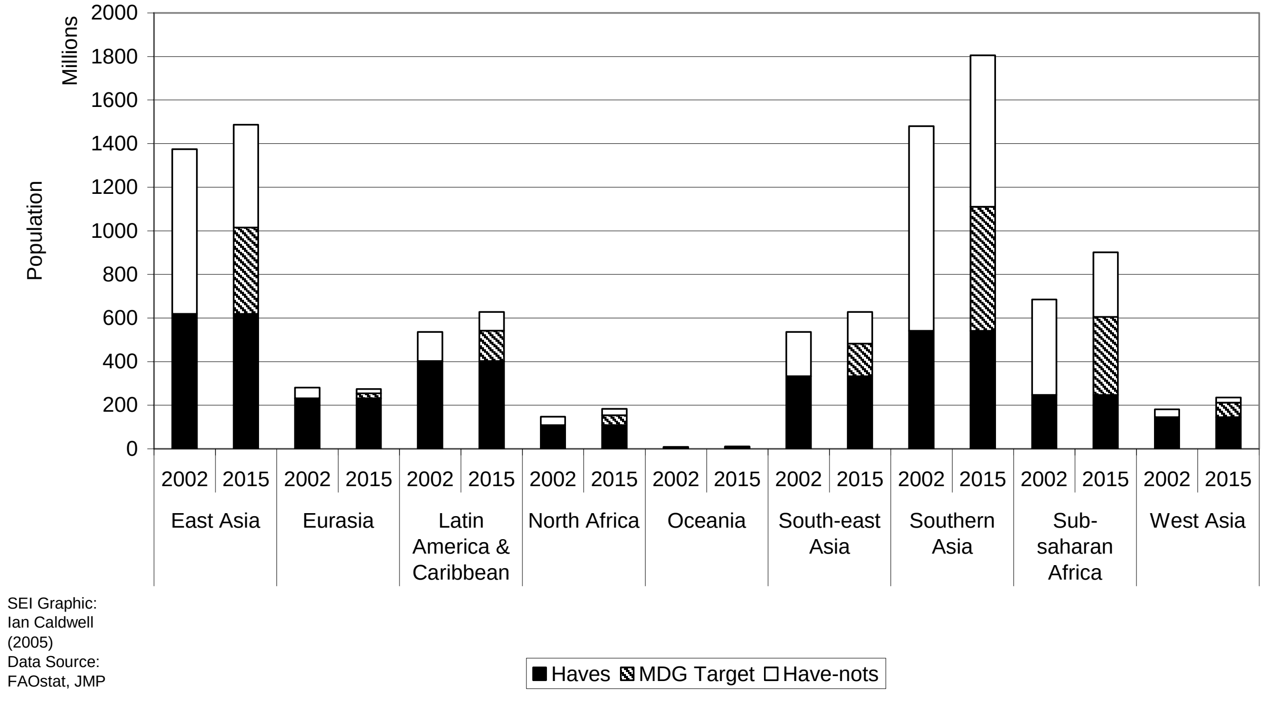

Figure 4-3: Sanitation Coverage in 2002 and 2015: The Haves, the MDG Target, and the Have-Nots

For the sanitation target (Figure 4-3), Southern Asia dominates at almost 600 million (dominantly rural), followed by 400 million for East Asia (dominantly urban) and 350 million for Sub-Sahara Africa (rural and urban). Latin America and the Caribbean (LAC) and South-East Asia come in at about 150 million each (dominantly urban). This is followed by Western Asia at 66 million (dominantly urban), North Africa at 45 million (dominantly urban) and Eurasia (mainly Russia) at 25 million (dominantly rural). For a more detailed view of which countries lie in the various UN regions see Figure 4-7.

Figure 4-4 indicates the size of the MDG water target population for the various world regions taking into account population growth between 2002 and 2015. The targets for East Asia (mainly China), Southern Asia (mainly India) and Sub-Saharan Africa dominate at around at 250-300 million people in each of these regions. This is followed by South-East Asia which is about 135 million and LAC which is about 105 million.

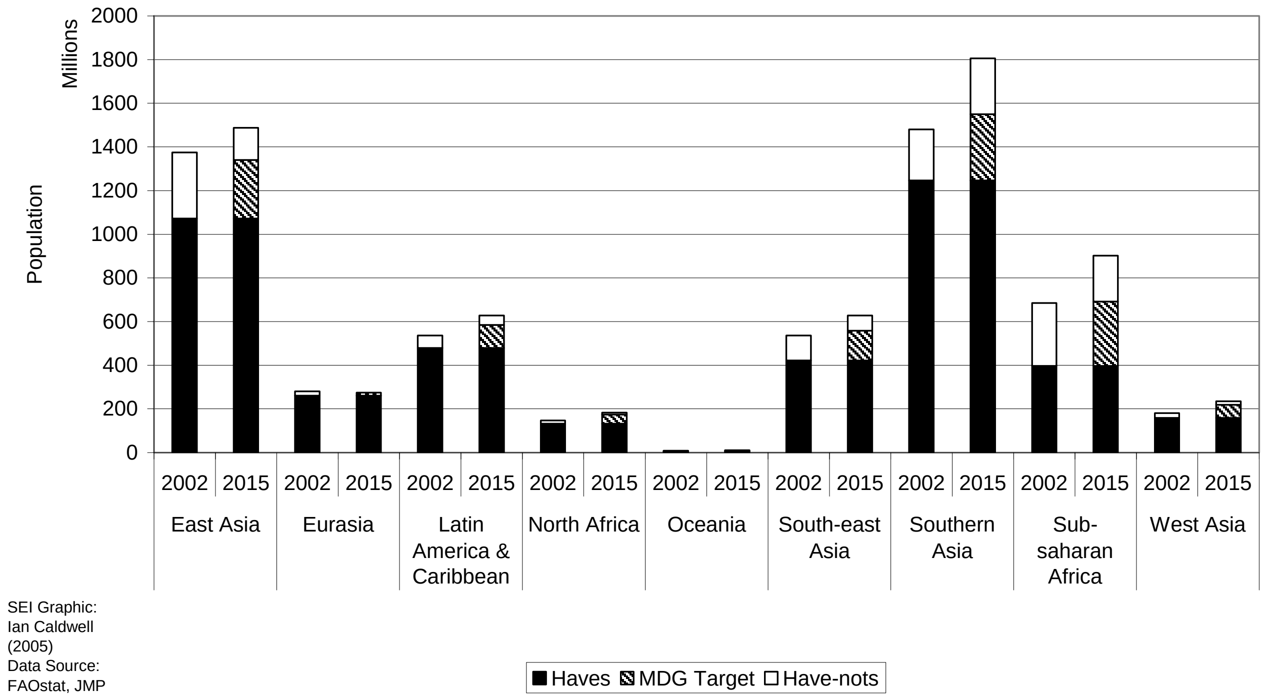

Figure 4-4: Water Coverage in 2002 and 2015: The Haves, the MDG Target, and the Have-Nots

4.3 Estimating the MDG urban and rural household targets for water and sanitation through to 2015

The coverage in improved water and sanitation differs significantly between rural and urban areas. The UN MDG plan does not specify how the target should be applied to rural and urban areas. It does identify the size of the urban and rural targets but the designation of relative priority is primarily an issue to be decided by each signing country. For this study, the estimated MDG target population to receive services in urban and rural areas has been based on the current urban-rural proportional need. For the target population and the household size, the number of households to be served were calculated. For the purpose of this study it has been assumed that each household is to receive one toilet or sanitation installation.

What becomes apparent in carrying out the urban-rural analysis for the period to 2015 is the dramatic trend towards urbanization (Rosemarin, 2005). When the MDGs were first drafted, the decision to go ahead was based on 1990 population statistics which showed that the MDGs for water and sanitation were primarily a rural-centred activity. But by 2015 the urban households requiring sanitation and water services are in fact much larger (Table 4-2). It is in only Southern Asia and Eurasia where the rural household numbers still dominate the sanitation target.

Table 4-2: Households (in millions) to receive improved sanitation and water services during the period 2003 to 2015 (UN-HABITAT, JMP, FAO)

	Sanitation		Water Supply	
UN Region	**Urban**	**Rural**	**Urban**	**Rural**
East Asia	108.3	43.3	111.5	4.2
Eurasia	1.9	4.1	1.1	1.8
Latin America &the Caribbean	31.5	7.5	26.6	2.1
North Africa	6.3	3.2	6.3	2.5
Oceania	0.3	0.4	0.3	0.4
South-East Asia	18.2	19.4	21.7	9.3
Southern Asia	38.8	72.7	34.5	24.2
Sub-Saharan Africa	42.0	38.2	38.9	27.9
West Asia	8 4	4.6	8.1	2.9
TOTALS	255.6	193.3	249.1	75.2
		448.9		324.3

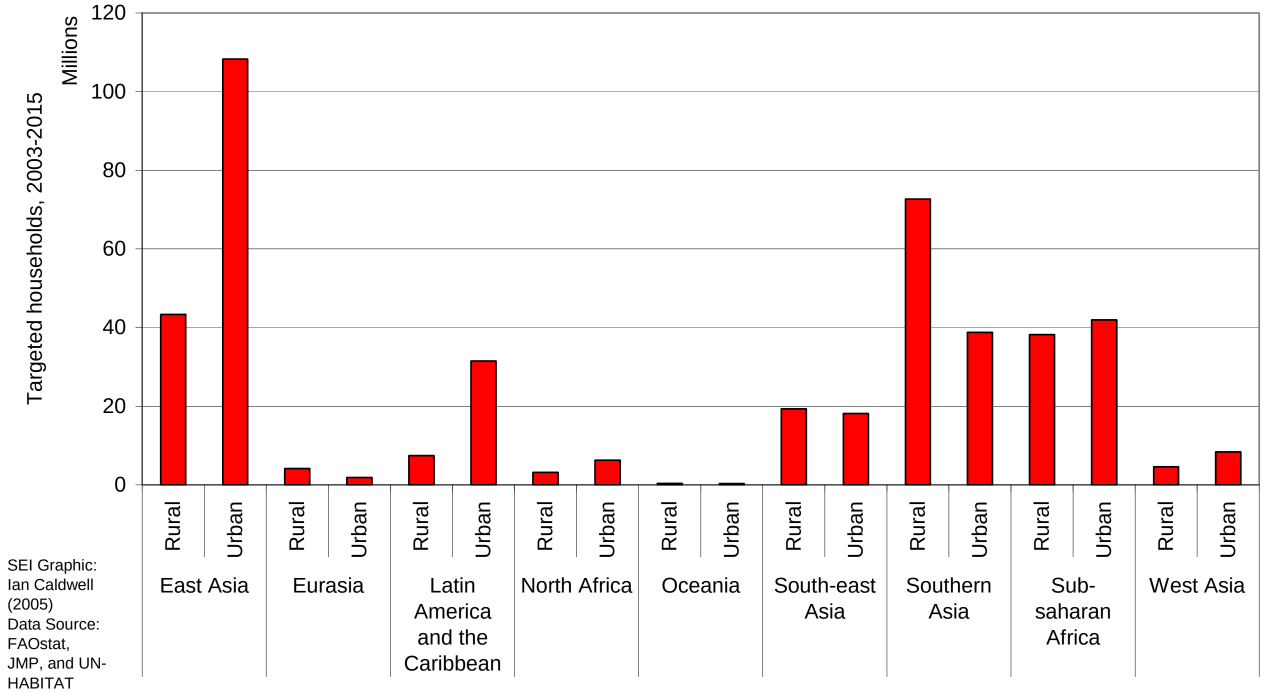

Figure 4-5: Number of MDG Sanitation Target Households (through 2015)

Globally, the average number of people in a household varies, from below two per household in some developed countries to 6 and above in African countries. There are also differences in household sizes between rural and urban areas. The UN-HABITAT "Compendium of Human Settlements Statistics" (2001 and 1995) list numbers of households by populations, from which an average number of people per household can be calculated. Since the UN-HABITAT does not cover every country, regional averages were generated and applied to other countries in the region. In some cases, number of living quarters was listed instead of households, and it was assumed that a living quarter represented one household for the purposes of water and sanitation services. It was also necessary to adjust these data on the rural and urban household numbers to fit 2015 rural and urban population predictions. In the calculations of number of households to be covered, the different household sizes for rural and urban areas were accounted for. It was assumed that these household sizes would remain constant between 2003 and 2015. Table 4-2 and Figure 4-5 and Figure 4-6 show the regional totals for number of households targeted to receive improved sanitation and water services by 2015, by urban and rural areas.

The data represent the remaining target sizes for the MDGs calculated from January 2003 to December 2015. It is interesting to note that about 95,000 households per day need to be provided sanitation services or about 65 per minute. For water services a similar calculation results in about 70,000 households per day or about 50 per minute. This is the MDG water and sanitation challenge expressed in a more simplified fashion (Figure 4-7).

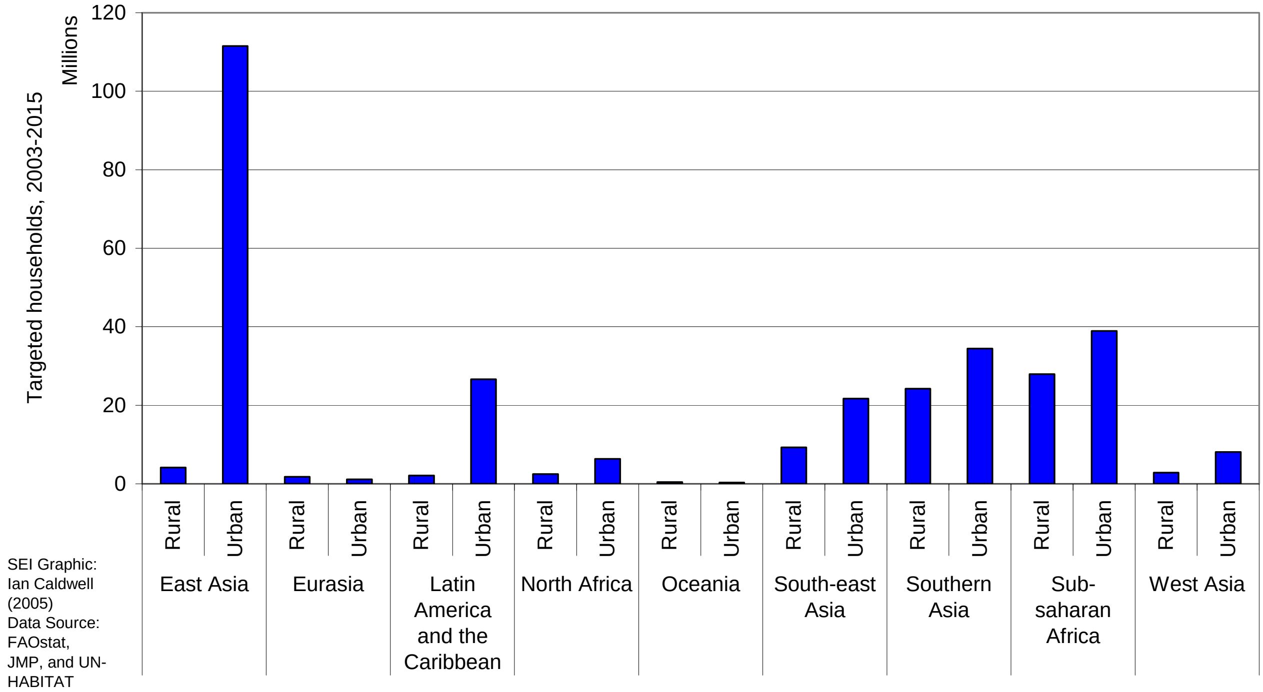

Figure 4-6: Number of MDG Water Target Households (through 2015)

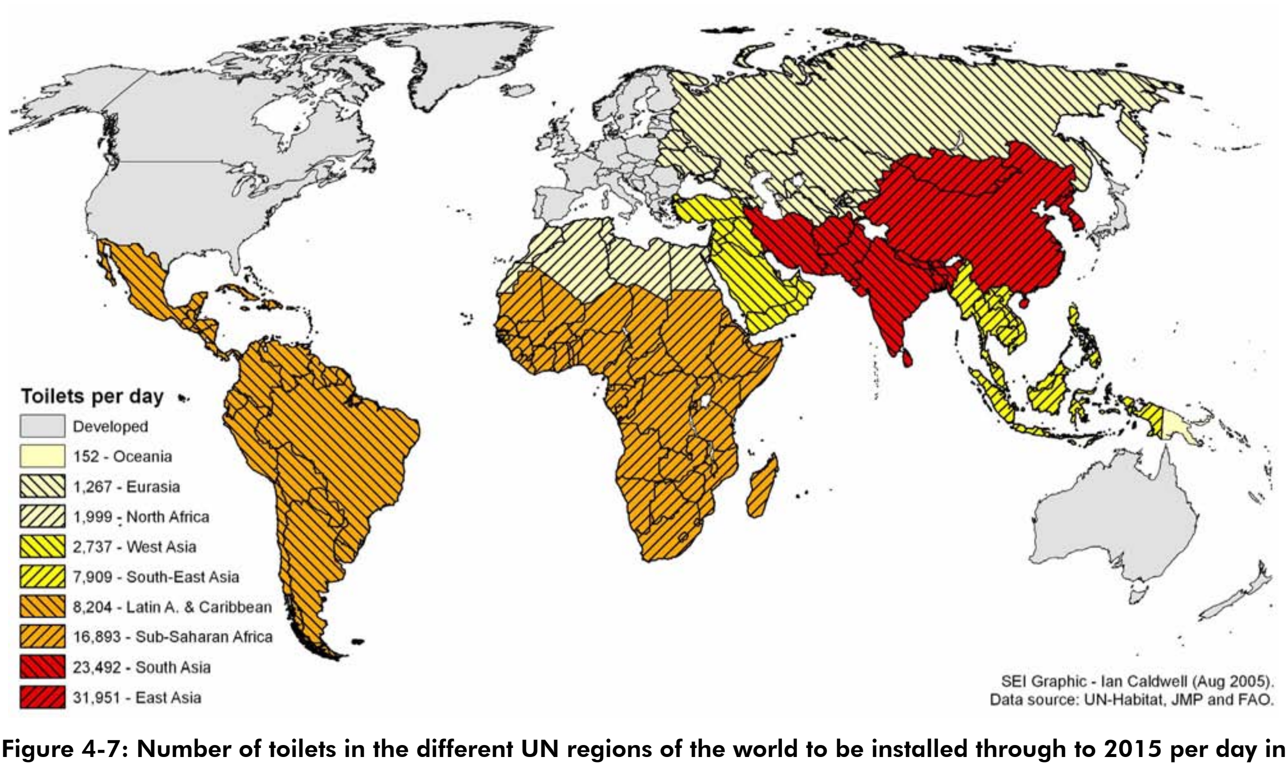

Figure 4-7: Number of toilets in the different UN regions of the world to be installed through to 2015 per day in order to meet the MDGs.

In East Asia (dominated by China) the MDG household target for water and sanitation is predominantly urban. The largest single regional goal (112 million households (hh)) is to supply water to the cities of East Asia which are growing rapidly in size and number. This is followed very closely by the urban sanitation target of 108 million hh in the same region. The rural target for sanitation in East Asia is still significant running at 43 million hh although less than half the urban target. The urban challenge is large for LAC (Latin America and the Caribbean) with 32 and 27 million hh requiring sanitation and water services. In Southern Asia (dominated by India) the rural target for sanitation is larger than the urban one (73 vs 39 million hh) but the opposite is true for the water requirement (35 vs 24 million hh, urban and rural, respectively). For South-East Asia, the sanitation target is about the same for urban and rural areas (18 and 19 million, respectively) while the urban water requirement is much higher (22 and 9 million hh, respectively). The sanitation target for Sub-Saharan Africa becomes more urban than rural over this period to 2015 (42 and 38 million, respectively). A similar trend is found for water service requirements (39 and 28 million, respectively). The large general differences between urban and rural requirements for sanitation and water services is striking and it appears that no general "watsan" approach can be taken to meet the MDGs.

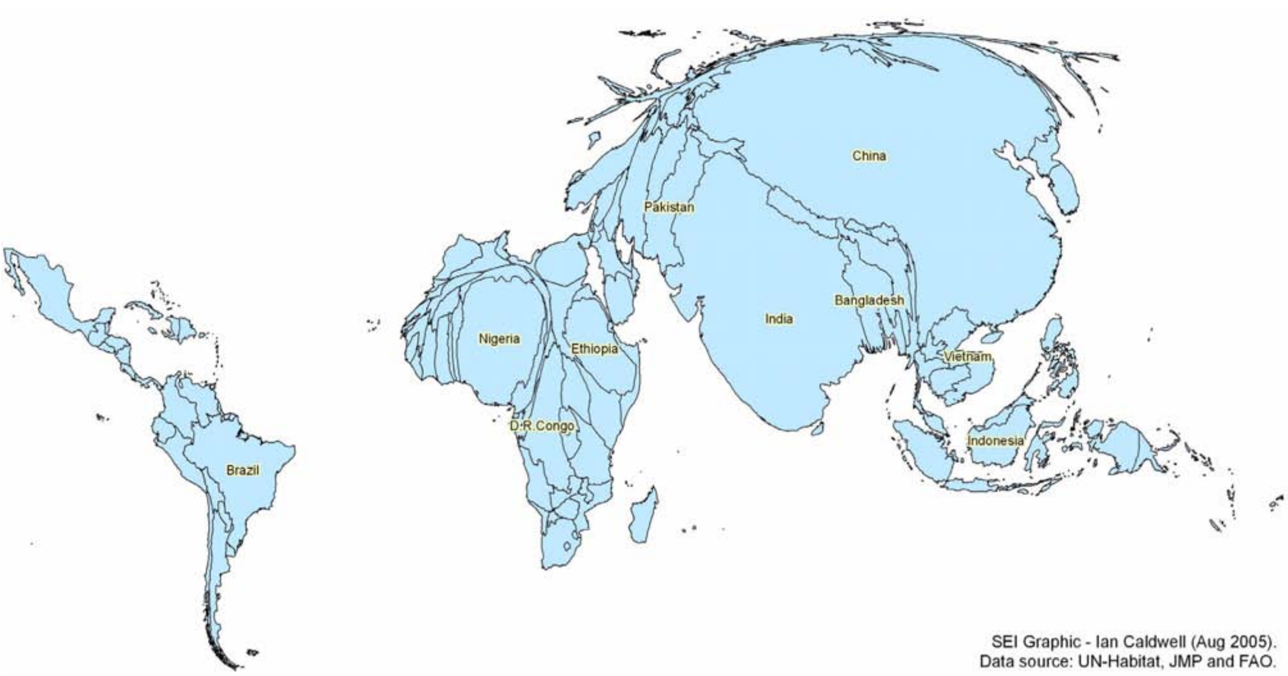

Figure 4-8: Map showing the relative size of the MDG sanitation target for each country based on the number of installations required through to 2015.

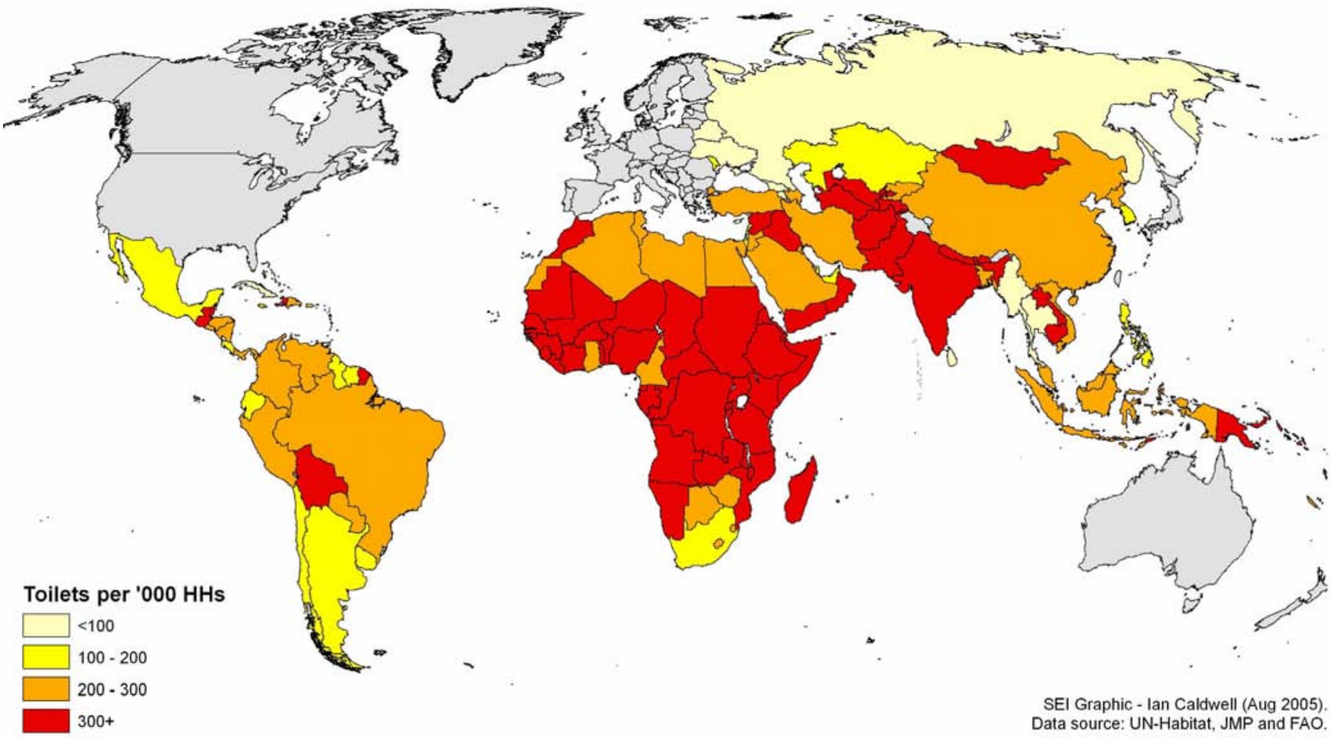

Figure 4-9: Number of toilets per thousand households to be installed through to 2015 to meet the MDGs

Figure 4-8 illustrates the vastly different size of the absolute MDG requirements for the various target countries. In general this is governed by the relative population size of the country. In particular the Asian countries and China and India in particular become enhanced using this projection. The same is true for Sub-

Sahara Africa, especially for Nigeria, Ethiopia and D.R Congo. In contrast Figure 4-9 provides a relative measure of the needs in terms of number of toilets required per 1,000 households. Here the high requirement countries (in RED) are seen dominated by those in Sub-Saharan Africa and Southern Asia as well as some Middle Eastern, Southeast Asian, East Asian and Latin American countries. The medium level countries (in ORANGE) such as China, those in Northern Africa and the Middle East and those in northern South America are also seen.

4.4 Introducing sustainable sanitation

The MDGs aim to provide basic improved sanitation to those lacking coverage. This includes installation of pit latrines, VIPs, pour-flush latrines, septic tank latrines, and public sewer connections with or without wastewater treatment (UN Millennium Project**,** 2005). This study aims to flag some of the recently developed ecological sanitation approaches with the ambition that they can also join the “sanitation ladder” of choices in the attempt to achieve the MDGs. A comprehensive description of ecological sanitation is provided in Winblad and Simpson-Hébert, 2004. The attempt here is to provide a brief look at these new opportunities and at the same time provide insight into some of the limitations of conventional sanitation.

4.4.1. The need for safe sanitation

Pathogens found in human excreta, if ingested, can result in a variety of illnesses, including diarrhoea leading to malnutrition. If left untreated these illnesses can result in poor growth, iron deficiency (anaemia), vitamin A deficiency, and leave the body’s immune system weakened and susceptible to more serious infections. Not all pathogens and parasites result in death, but the resulting malnutrition creates persistent poor health and a predisposition to disease and death from other causes. The heavy toll of these were mentioned in the introduction to this chapter.

4.4.2. The limitations of conventional sanitation

Conventional sanitation is currently offered by two approaches: pitsan (pit toilets) or flushsan (flush toilets). Although conventional sewage systems transport excreta away from the toilet user, they usually neither contain nor sanitize, often releasing pathogens and nutrients into the downstream environment. This is considered the “linear pathogen flow” (Winblad and Simpson-Hébert, 2004). These systems mix faeces, urine, flush water and toilet paper with grey water, storm water and industrial effluents, usually overtaxing the design capacity of the treatment plants, if such a facility exists, as very few communities in the world are able to afford fully functional sewage systems. Simply put, many flushsan systems contaminate the environment with pathogens and/or nutrients – indicating they are neither appropriate nor sustainable for many settings in the world. Far more common than flush sanitation is the pit toilet, primarily because it is inexpensive and requires little or no infrastructure. This method fails to contain and sanitize excreta since pathogens and nutrients often seep into the groundwater. Deep pit latrines also fail to recycle since the excreta are located too deep for plants to make use of the nutrients. Pits are prone to periodic flooding, causing them to spill their contents. In general, pits are smelly, are often infested with flies, and in most parts of the world are poorly maintained and continue to be a source of disease and pollution.

4.4.3. Ecosan defined

Ecological sanitation can be viewed as a three-step process dealing with human excreta: containment, sanitization and recycling. The objective is to protect human health and the environment while reducing the use of water in sanitation systems and recycling nutrients to help enable sustainable production of food. Ecosan represents a conceptual shift in the relationship between people and the environment; it is built on the necessary link between people and soil. An essential step in the process of sanitation is the containment of pathogens that can cause disease. Human faeces contain bacteria, viruses and parasites and can spread disease. Without containment and sanitization, a vicious circle develops where the pathogens in excreta are released back into the environment, re-infect people through consumption of contaminated water and food, and are then multiplied and excreted again, only to begin the cycle over. Ecological sanitation systems are designed around containment and provide many ways of rendering human excreta innocuous, two of which are storage and thermophilic composting. Usually drying materials, like wood ash, lime and soil, are added to cover the fresh excreta. Ash and lime increase pH which acts as an additional toxic factor to pathogens if the pH can be raised to over 9.5. The less moisture the better, and in most situations it is better to divert the urine and treat it separately. Figure 4-10 shows a dry, double-vault urine-diversion toilet, a model being used in China, India, Vietnam and Mexico. It takes an average family 6 months to fill one of the vaults. Then the second vault is used. The first vault is emptied following an additional 6 months of sanitization and the material is taken to a soil compost. Urine is never mixed in this toilet but continuously diverted into a separate container and later used in diluted form as plant fertilizer. The dry ecotoilet, if properly managed, meets necessary health and environmental protection criteria (Stenström, 2002; Schönning and Stenström, 2004). It also saves water and prevents water pollution. Properly operated, it produces no smell, does not attract flies and is an affordable solution inside and outside of dwellings throughout the world.

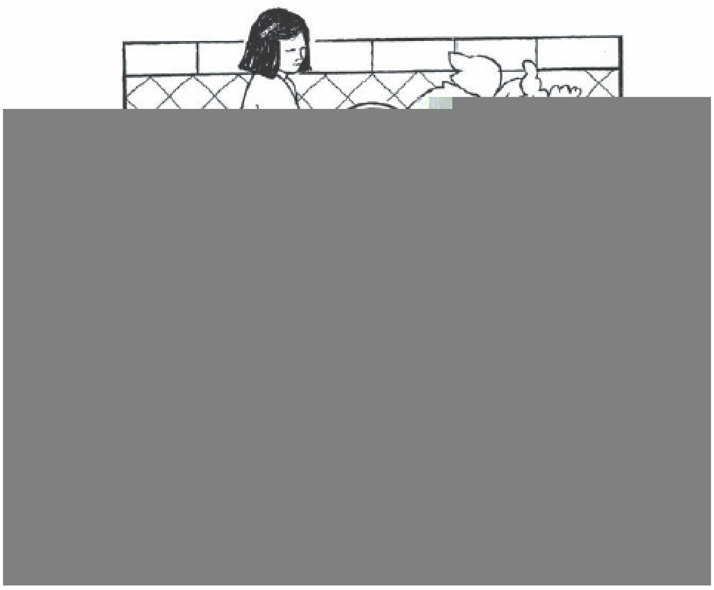

Figure 4-10: Double-vault urine-diverting dry ecotoilet used in China, Vietnam, Mexico & India (SARAR; Lin Jiang)

Figure 4-11: Fossa alterna soil-composting pit latrine. (Aquamor)

Soil-composting toilets are constructed using shallow, reinforced pits where soil and ash are added after each use. Toilets such as the Fossa Alterna (Figure 4-11) and Arbour Loo (Morgan, 2005) have been successfully tested in Mozambique and Zimbabwe. The Fossa Alterna uses two alternating pits with a similar frequency of alternation as the double-vault dry toilet (i.e. 6 months to fill and an additional 6 months to sanitize). Once sanitized and composted, the contents are removed and used in agriculture. The Arbour Loo produces a composted product – humus – an excellent soil conditioner. In addition, it is important to recover and reuse these nutrients (Figure 4-12) toward sustainable ecosystems to reduce the drain on natural reserves and enable sustainable food production. Some countries and cultures have been recycling human excreta for agricultural purposes for thousands of years, especially in China and Southeast Asia, but often excreta have not been properly sanitized therefore propagating disease. By implementing ecosan, we can safely recycle nutrients without risking people's health and polluting the environment.

The ecosan approach to sanitation has the advantage of allowing for simple use of human excreta for cultivation purposes, which might entail improved food security and important financial input to the MDG target households. Success stories in ecosan pilot projects with agricultural applications as the key driving interest are to be found e.g. in Niassa Province of Mozambique and Malawi (Water Aid) and in several countries in West Africa where CREPA has been active (Morgan, 2005; Klutse and Ahlgren, 2005).

Ecosan is based on the fact that humans produce rather limited amounts of fecal material (ca 50 L per person/year) and if the urine is diverted (500 L per person/year) a relatively cheap system can be developed. It is the greywater produced by households that is the truly voluminous task in sanitation (from 20 to 250 L per person/day). By keeping these fractions separate, the greywater can be treated at relatively low cost. This must be compared to the problems arising when faeces, urine, greywater and often storm water are mixed in sewage systems requiring enormous collector systems and treatment plants.

Figure 4-12: A crop of spinach four weeks after planting, using processed excreta from one family, using a Fossa alterna, Zimbabwe. (Aquamor)

Figure 4-13: Straight-drop dry urine-diverting toilet in multi-story apartments in Dong Sheng, Inner Mongolia, Northern China including illustrations of the porcelain toilet and fecal bin (SEI)

Urban ecosan requires innovative approaches and very little development has occurred in this area. Of interest, however, is the large pilot project in Dong Sheng District of Erdos (Inner Mongolia), in Northern China where straight drop, dry urine-diverting toilets are being installed in new multi-story apartment buildings following the success of a similar approach taken in Stockholm, Sweden (the so-called Gebers, housing complex). Figure 4-13 shows a cross-section of one of the buildings in Dong Sheng (about 700 apartments will be completed in 2005) including the high standard porcelain toilet and fecal bin collector.

4.4.4. Some recommendations to improve present sanitation practices in order to make them more sustainable

In order to provide some insight into what can be done in the short-term to improve present sanitation practices the following list was generated:

- Pit latrines could be modified to be soil-composting latrines, thus requiring some wall reinforcement, made shallow (max 1-1.5 m) and maintained using daily soil additions; the pits would be periodically closed and covered with soil in order to allow for sanitization and composting prior to emptying and reuse in agriculture.
- Simple urinals with separate collector systems could be installed instead of using toilets and pit latrines for urination
- Flush toilets could be modified to use less water.
- Greywater could be source-separated from the blackwater from toilets thus simplifying its treatment and providing opportunities for reuse.
- Blackwater from toilets could be held in conservancy tanks instead of open septic tanks and cess pits and then emptied and transported to biogas fermentors; alternatively the toilets could be connected to biogas fermentors.
- Cess (or drainage) pits e.g. from pour-flush toilets could be equipped with a safety zone of additional filter material to prevent contamination of ground water.
- Toilets and especially any new toilets could be equipped with urine diversion in order to reduce primarily the nitrogen load to the environment.
- Above ground dry toilets with urine diversion could be installed in dry areas lacking water, rocky areas where pits are expensive to dig and areas with high water tables and flooding.

4.5 The financial aspects of introducing ecosan

Table 4-3 presents the “sanitation ladder” originally produced by van de Guchte and Vanderweerd (UNEP, 2004) and published by the MDG Task Force (UN Millennium Project, 2005) but this time with the alternatives for ecological sanitation included. The ecosan data are based mainly on pilot projects varying in size and should be seen at this point in time an indication of cost. The largest ecosan programmes are in China where one million dry vault installations plus around 10 million biogas toilets exist. Significant numbers are also seen in Vietnam, South Africa and El Salvador. Otherwise most other projects are limited in size.

It is interesting to note that ecosan alternatives cost much less than conventional solutions especially at the lower end of the ladder. For ecosan, the quality of the treatment, degree of containment, level of protection of the environment and ability to produce recyclable nutrient products remains high throughout whether it is a soil composting shallow pit in the open (the minimum solution to improve sanitation for open defecators) or a porcelain urine-diverting pedestal toilet in a multi-story apartment building in an urban setting. Urban ecosan is more expensive than rural ecosan mainly because of the expense of greywater treatment where decentralised small-bore pipe systems are required using novel treatment systems such as biofilm vertical filters, pond systems, horizontal macrophyte rootzones, often called constructed wetlands, but traditional anaerobic and aerobic techniques can be used as well. Also additional costs are for transportation of the various products to local ecostations for composting and storage as well as to agricultural sites for recycling. But even with these costs included, high-end urban ecosan is very competitive costing less than the high-end conventional sewage systems with treatment plants. In the case of the large project in Dong Sheng, in Inner Mongolia, Northern China, the cost for ecosan is being incorporated into the housing cost, providing considerable savings compared to the standard cost of installing sewers commonly supported by municipal government funds.

Table 4-3: Sanitation Cost Ladder for Conventional and Ecological Sanitation Methods (includes initial capital cost and O&M for the first year of operation)

	Conventional Sanitation (sourced from UN Millennium Project, 2005; original source UNEP, 2004)		**Ecological Sanitation (various sources see below)**	
	Method	**Estimated cost per person (USD) incl. operation and maintenance**	**Estimated actual initial capital cost per person (USD) and household incl. operation and maintenance (hh size is 4.5 unless otherwise given)**	**Method**
Mainly urban	Tertiary wastewater treatment	**800**	**340** (1190 per hh) (China, hh size 3.5)* (source: Dong Sheng EcoSanRes Programme))	Urine-diverting high standard porcelain dry toilet (indoor and multi-story); piped urine system, dry fecal collection and composting, decentralized piped grey water treated using septic tank, and aeration treatment; local collection and transportation costs included
	Sewer connection and secondary wastewater treatment	**450**	**330** (1500 per hh) (Sarawak)* (source: Mamit et al, 2005)	Conventional indoor toilet with sealed conservancy tank, black water collection by truck; local biogas digester; decentralized piped greywater treated using septic tank and vertical biofilm filter technique
	Connection to conventional sewer (assumed without treatment)	**300**	**150** (675 per hh) (estimated)	Indoor dry single-vault urine-diverting pedestal toilet; decentralized piped greywater treatment using constructed wetland; local transportation included
Mainly peri-urban	Sewer connection with local labour (assumed without treatment)	**175**	**88** (400 per hh) (South Africa) **25** (110 per hh) (Mexico, El Salvador, India, South Africa, Zimbabwe) (source: Morgan, 2005)	Dry single- or double-vault urine-diverting squatting pan or pedestal toilet with permanent upper housing structure; greywater treatment using on site infiltration pit; transportation assumed as local labour
	Septic tank latrine	**160**	**12** (55 per hh) (source: Lin Jiang, Nanning, Guangxi, China) **8** (35 per hh) (West Africa) (source: Klutse & Ahlgren, 2005)	Dry single or double-vault urine-diverting squatting pan or pedestal toilet (LASF or Skyloo) with permanent upper housing structure; greywater treatment and disposal onsite; local recycling
Mainly rural	Pour-flush latrine	**70**		
	Ventilated improved pit latrine	**65**	**8** (40 per hh) (Zimbabwe, Mozambique) (source Morgan, 2005)	Soil composting pit with cement slab and simple upper housing structure (Arborloo or Fossa Alterna); grey water treatment and disposal onsite; local recycling
	Simple pit latrine	**45**		
	Improved traditional practice	**10**	**3** (10 per hh) (estimated)	soil composting shallow open pit; soil added after each use

*initial cost calculations based on ongoing large-scale pilot projects

Figure 4-14 illustrates the relationship between the MDG requirement as number of toilets per thousand households and the GDP per capita for each country. The poor countries have a high specific requirement for sanitation while the more affluent countries have a lower specific requirement. The GDP per capita statistic is also an expression of "ability to pay" so this diagram is useful to group the various countries in a possible economic model based on need and capacity for domestic financing. In order to estimate the household capacity to pay, GDP per household was calculated using the data on household sizes for each UN region. Also 1% of the household GDP for the targeted households was chosen as an appropriate minimum level of domestic spending on sanitation (Table 4-4).

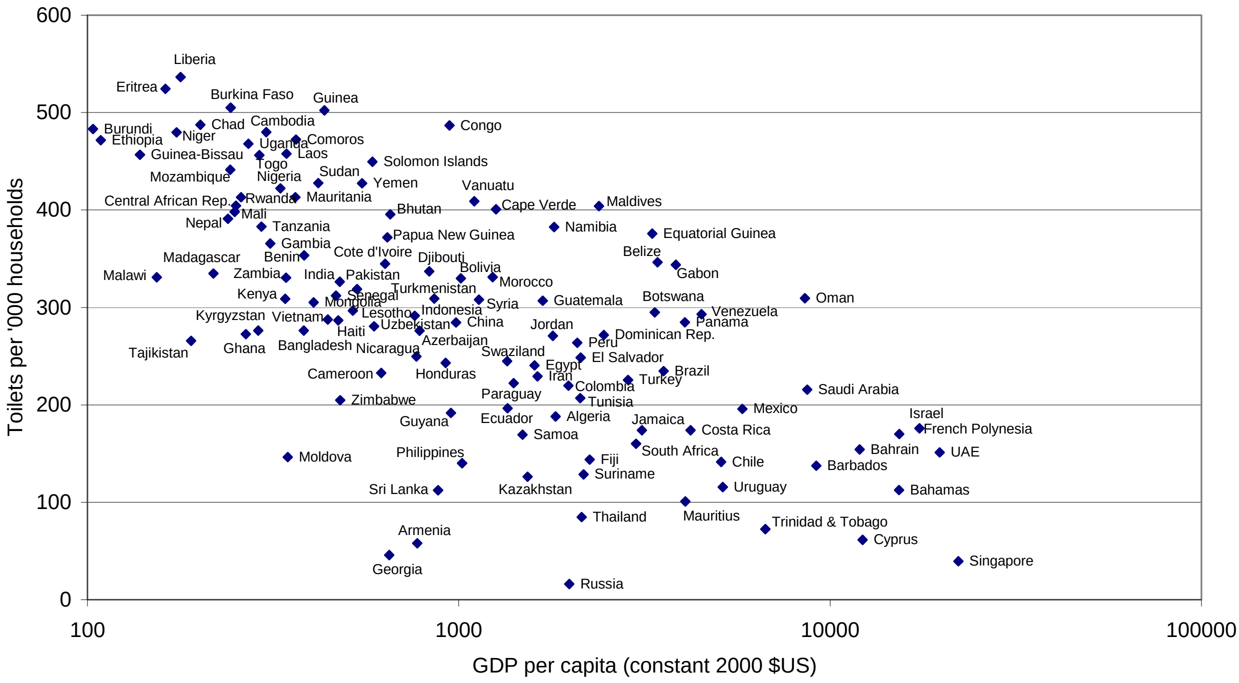

Figure 4-14: MDG Sanitation Target 2015: Toilets per '000 households versus GDP per capita

These estimates were used to rank the UN regions in ascending order (Table 4-5). Using this ranking, an appropriate range of ecosan methods from the cost ladder was chosen and a unit cost was generated for each region for both urban and rural households. These are shown in Table 4-5.

Table 4-4: GDP, household size and calculation of 1% GDP per household for the 9 UN regions of the world

UN Region	GDP/cap (2003 USD)	Household size	GDP per hh	1% of GDP per hh
East Asia	$1,486	2.73	$4,063	$41
Eurasia	$2,016	2.25	$4,536	$45
Latin America & Caribbean	$3,393	3.53	$11,967	$120
North Africa	$1,582	4.80	$7,595	$76
Oceania	$1,554	4.78	$7,433	$74
South-East Asia	$1,364	3.81	$5,200	$52
Southern Asia	$599	5.08	$3,046	$30
Sub-Saharan Africa	$625	4.29	$2,685	$27
West Asia	$4,906	4.95	$24,281	$243

Table 4-5: Ecosan household unit costs for the UN Regions (includes initial capital expenditure and O&M for year one of operation)

UN region	Urban household unit cost (USD)	Rural household unit cost (USD)
Sub-Saharan Africa	$350	$35
Southern Asia	$440	$40
East Asia	$650	$50
Eurasia	$725	$55
South-East Asia	$800	$60
Oceania	$875	$65
North Africa	$900	$65
Latin America & Caribbean	$1,000	$70
West Asia	$1,200	$80

The unit cost data were then applied to the number of MDG targeted households over the period between 2003 and 2015 and calculated on an annual basis for urban (Figure 4-15) and rural (Figure 4-16) areas for each global region. The assumption is that each targeted household should receive one ecosan toilet installation during this period. The assumption is also made that the quality of health and environmental protection should be the same in both urban and rural settings and that urban includes densely populated centres where sewage systems would normally be proposed and peri-urban areas where high standard sanitation would normally be neglected.

4.5.1. The sanitation challenge will become primarily an urban one

As can be seen the urban costs exceed those for rural areas by about 20-fold. The total *annual* global cost to meet the MDG target between 2003 and 2015 for urban areas using ecosan solutions is about USD13 billion and that for rural is about USD 0.7 billion. *One can immediately see that to achieve acceptable safety and environmental standards in the target regions, the sanitation challenge is clearly an urban one over the next decade and beyond. It can be reasoned, therefore, that waterborne sanitation in sewage systems as an MDG solution for the cities of the developing world is not competitive and has a tenuous future merely on the basis of defending the finances that it requires, let alone the negative health and environmental impacts usually due to poor management.* The use of septic tanks and pour-flush toilets with cess pits in urban and mainly peri-urban settings is probably where most of the urban financing will end up. But if ecosan alternatives are chosen, they can provide safer systems at less cost and at the same time save on limited water resources and provide access to sustainable fertilizers. The limited water resources available to many of the MDG cities should be used first to ensure adequate human hygiene and not for the transportation and discharge of poorly treated urine and fecal material.

4.5.2. The urban sanitation challenge will become acute for China

Regionally speaking, the annual cost burden for urban sanitation is highest for East Asia, LAC and Southern Asia, followed by Sub-Saharan Africa, South-East Asia, West Asia, North Africa and Eurasia. The challenge to provide urban sanitation is largest in East Asia (China) with an estimated cost of USD 5.4 billion per year. China's urban challenge is larger than any other nation since the average household size is low compared to the rest of the world. The cost burden for Southern Asia (mainly India) is less than a third at USD 1.3 billion per year. The rural statistics show a very different distribution where Southern Asia dominates at USD 223 million per year followed by East Asia at USD 167 million, Sub-Saharan Africa at about USD 100 million, and South-East Asia at USD 90 million. Introducing ecosan globally to rural communities is therefore both doable and affordable.

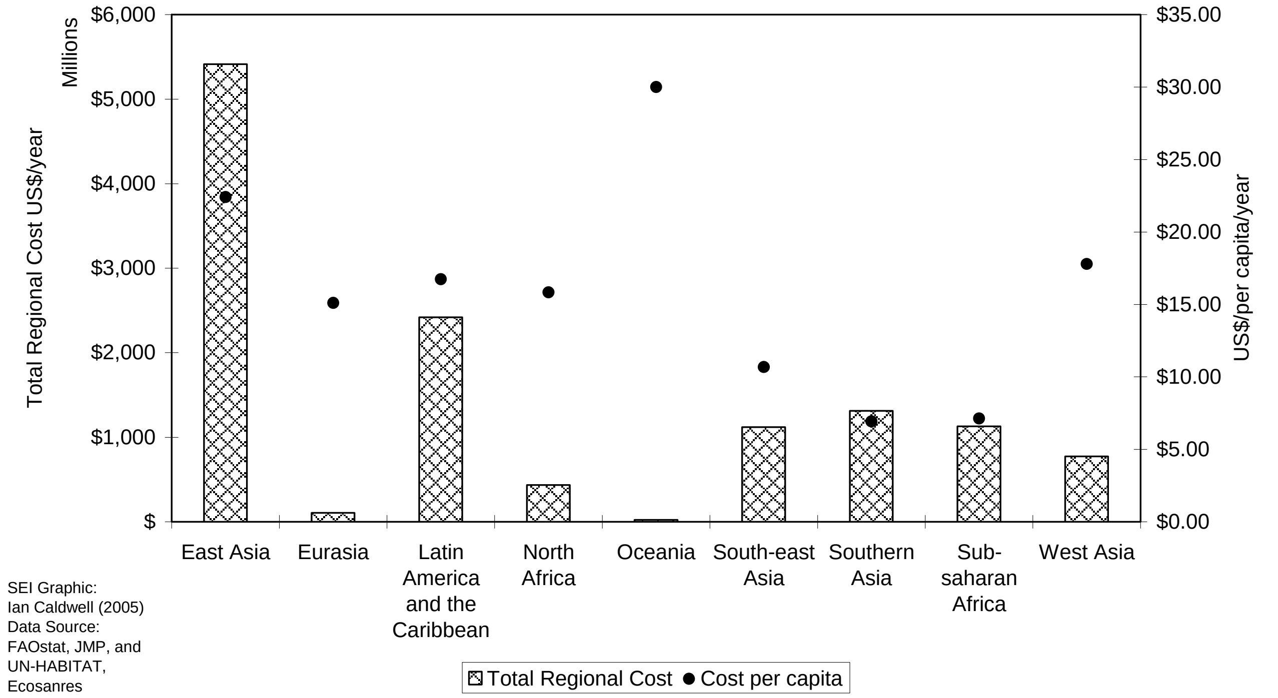

Figure 4-15: Annual Cost for Urban Ecosan (2003-2015)

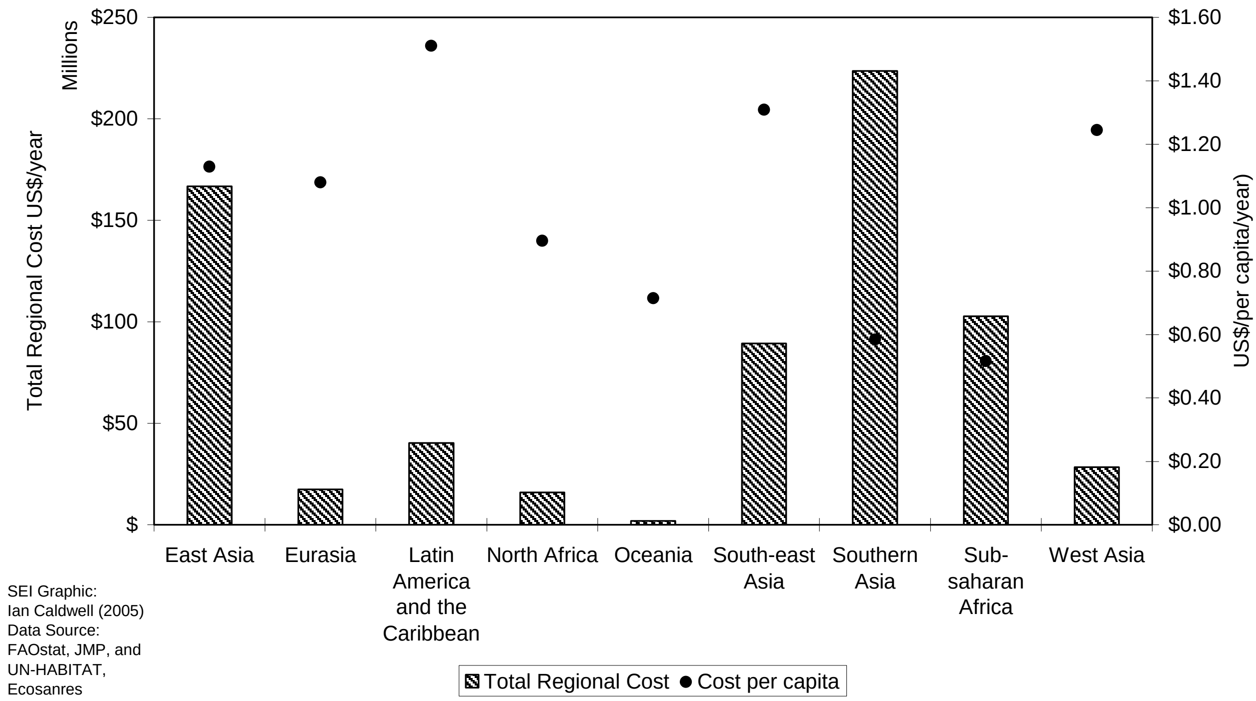

Figure 4-16: Annual Cost for Rural Ecosan (2003-2015)

In terms of annual cost per capita, rural ecosan ranges from USD 0.5 to USD 1.5 averaging out at USD 1.0 (Figure 4-16). Urban ecosan ranges from USD 7 to USD 30 per capita per year averaging at USD 16 (Figure 4-15). The cost for urban ecosan is much higher than rural areas since greywater needs to be collected and treated using decentralised treatment facilities (although these cost only a fraction of what sewage treatment plants cost).

4.5.3. In General Ecological Sanitation is Affordable

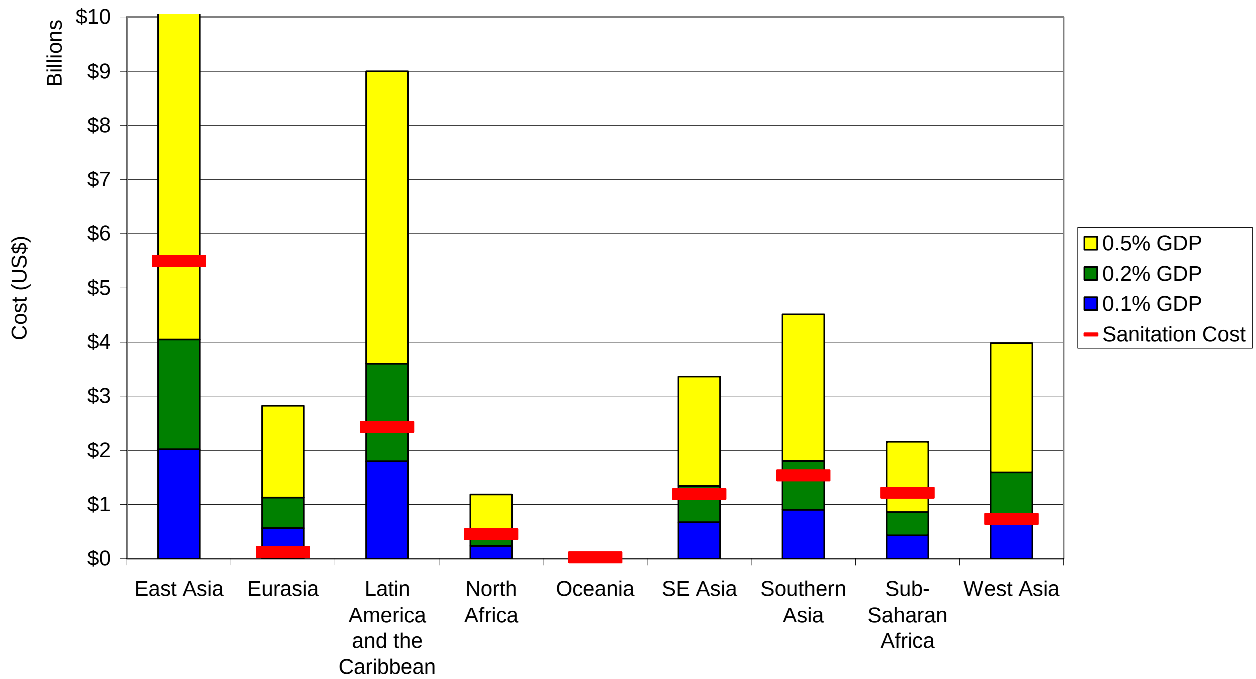

Figure 4-17: Annual cost for ecological sanitation as percent of regional GDP

As can be seen in Figure 4-17 the total regional annual costs for ecosan between 2003 and 2015 would require less than 0.2% of the domestic GDP for each UN region. It is only in East Asia and Sub-Saharan Africa where the cost edges over 0.2%. In Eurasia, Oceania and West Asia it would cost 0.1% or less. These levels when compared to other expenses such as health or military are therefore well within the domestic limits of affordability. That is, there should be sufficient financing available at the regional level to cover the MDG requirement. Global public expenditures on health care were 5.8% of the GDP and those for military were 2.4% (World Bank Group).

4.6 Determining the amount and commercial value of nitrogen and phosphorus from human excreta

4.6.1. Nitrogen and Phosphorus calculations

To calculate the amount and value of N and P from human excreta, the following estimates were required: MDG target population by 2015, N and P amounts per person per day based on food protein consumption, cost of N and P by country in local currency, and currency conversion rates to USD. The size of the MDG target population is taken from the above calculations, and can be kept as rural/urban or combined. The N and P amounts from human excreta are calculated using Equations 1 and 2 below (Jönsson et al, 2004). N and P are both in grams per day per person. It is assumed the 100% of the P in the excreta is available for recycling. However, only the N from urine (85% of the total excretion), is assumed to be available for recycling, since the N in faeces is lost in dessication and composting.

Equation 1: N = 0.13 * Total food protein

Equation 2: P = 0.011 * (Total food protein + vegetal food protein)

Data for daily protein intake per person by country are derived from the FAO statistical database. To get the total amount of N and P per year for a country for the MDG target population, the amount of N and P per person per day was multiplied by the target population to give the total amount per day, and then by 365 to give the total amount per year. This final amount in grams was changed to metric tonnes, and N was multiplied by 85% to account for the loss of N.

The cost of N and P are also from the FAO database, based on using single-superphosphate (SSP) and urea. This value was available in local currency amounts, so a currency conversion table based on historical exchange rates between the local currency and the USD was used to convert all values into USD. This currency conversion table is based on www.oanda.com and CIA factbook currency data. For both SSP and urea, FAO gives the amounts in nutrient equivalents, P_2O_5 and N. For P_2O_5, P is roughly 44%, and all P_2O_5 amounts have been adjusted accordingly to P. Prices for both SSP and urea were available for only 38 countries, with incomplete data for 1999-2002. Thus, if the 2002 value was not available the preceding year's value was used instead. For those countries without price data, regional averages were used. For example, only six Sub-Saharan African countries had price data, and the average price for SSP and urea was used for the rest of the Sub-Saharan African countries. The price of elemental N and P, in USD per metric ton, was then multiplied by the amount of N and P per country per year, to give a final amount in USD of the value of the nutrients N and P for the excreta from the MDG target population.

Table 4-6: Annual regional totals of potential recycled nitrogen (N) and phosphorus (P) from human excreta based on the MDG target population between 2003 and 2015 (FAO, Oanda)

UN Region	N value (2002 USD)	P value (2002 USD)	N & P value (2002 USD)	Value per capita
East Asia	$498,507,056	$129,016,745	$627,523,801	$1.61
Eurasia	$34,842,184	$24,686,699	$59,528,883	$2.57
Latin America & Caribbean	$231,855,476	$104,743,489	$336,598,965	$1.97
North Africa	$69,236,560	$32,032,645	$101,269,205	$2.23
Oceania	$1,813,614	$1,659,769	$3,473,384	$5.50
South-East Asia	$142,002,772	$85,600,913	$227,603,685	$0.41
South Asia	$363,172,097	$240,706,441	$603,878,538	$3.50
Sub-Saharan Africa	$459,234,709	$334,123,468	$793,358,177	$2.27
West Asia	$79,485,178	$78,340,470	$157,825,648	$2.95
Totals	$1,880,149,646	$1,030,910,639	$2,911,060,285	$1.65

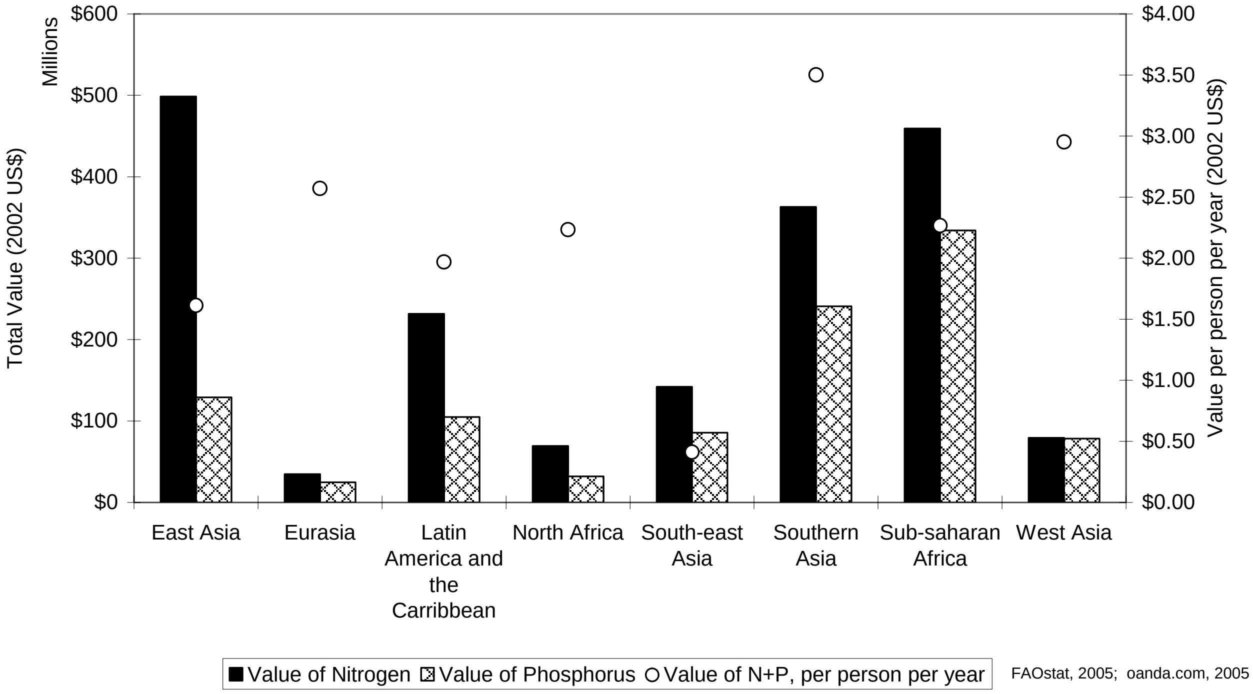

Figure 4-18: Annual Value of Potential Recycled Nitrogen and Phosphorus from Excreta for the MDG Target Populations through to 2015

Table 4-6 and Figure 4-18 therefore provide a picture of the potential economic value of recycled N and P from the targeted MDG population produced in one year. It is interesting to note that the value per capita can cover the costs of providing ecosan to the rural population. That is ecosan could "pay for itself" just by recycling nitrogen and phosphorus in rural populations. Also, the value for Southern Asia at USD 3.5 per capita/year could make a major contribution to the cost of ecosan in the peri-urban areas and slums as well where the cost is USD 10 per capita/year. Also of interest is the relatively high financial value of phosphorus that ecosan could provide in Sub-Saharan Africa and Southern Asia since P costs more in these regions than elsewhere.

4.6.2. Balancing Nitrogen and Phosphorus

The ratio was calculated between the amount of nitrogen and phosphorus available for recycling from human excreta and the amount of nitrogen and phosphorus in chemical fertilizer that is utilized. By comparing the per capita utilization and per capita recycling potential, countries can be evaluated on the sustainability of their nutrient flows. The annual fertilizer utilized per capita is based on FAO (2005) fertilizer consumption, food consumption, and population data for 2002. FAO reports fertilizers in tonnes of N and P_2O_5, so the phosphorus component is multiplied by 43.64% (the elemental proportion of P by weight in P_2O_5) to get the amount of pure P. These N and P amounts are then divided by the total population to generate the per capita rate of utilization. The potential amount of N and P available for recycling is based on Equation 1 and Equation 2, using the amount of protein eaten. Figures 6.2 and 6.3 show the ratio between N and P fertilizer utilized and the potential N and P available for recycling. The horizontal line denotes the amount of N or P that should be available based on a 3,000 kcal/day diet (MDG target) and using US FDA recommended daily allowances for phosphorus (1,000mg) and protein (50 g) (US FDA, 1999). These latter values are for a 2,000 kcal/day diet, and were both increased by 50%, to 1,500mg P and 75g protein in order to meet the 3,000 kcal/day diet. The vertical curved line represents a one to one balance between utilization and potential for recycling; a country on or near this line can meet its current fertilizer needs by using ecosan.

Another factor that proves important in Figure 4-19 and Figure 4-20 show whether a country is a net importer or exporter of food. Developed countries (eg EU, US and Canada) that have subsidized agriculture producing large exports, use much more fertilizer than the inhabitants consume domestically. Excess fertilizer use is also an indication of high meat consumption since the fertilizer nutrients are not being directly consumed by humans but via animals. It can also be caused by the fact that not all fertilizer is being used on crops but some on non-edibles like fibre or biofuels. Undernourished countries that cannot produce enough food domestically and are forced to import, use less fertilizer than the amount they could recycle via ecosan (lower left part of the diagrams). The category to the lower right of the figures is yet another situation where the population is undernourished but there is plentiful use of fertilizer due to inefficient agricultural practices or inadequate food distribution to the poor population. Inefficient use of fertilizer causes excessive nutrient runoff, eutrophication, and contamination of drinking water resources

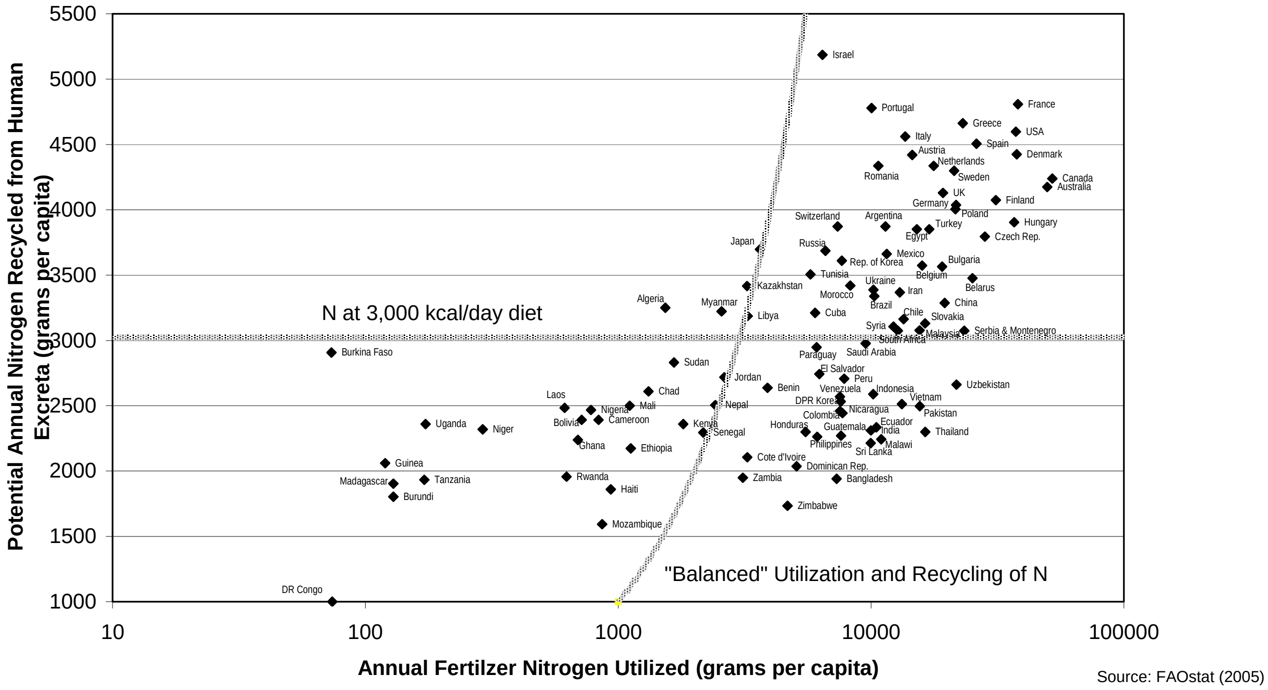

Figure 4-19: Nitrogen Utilized and Potential Recycled, 2002 (countries with population greater than five million)

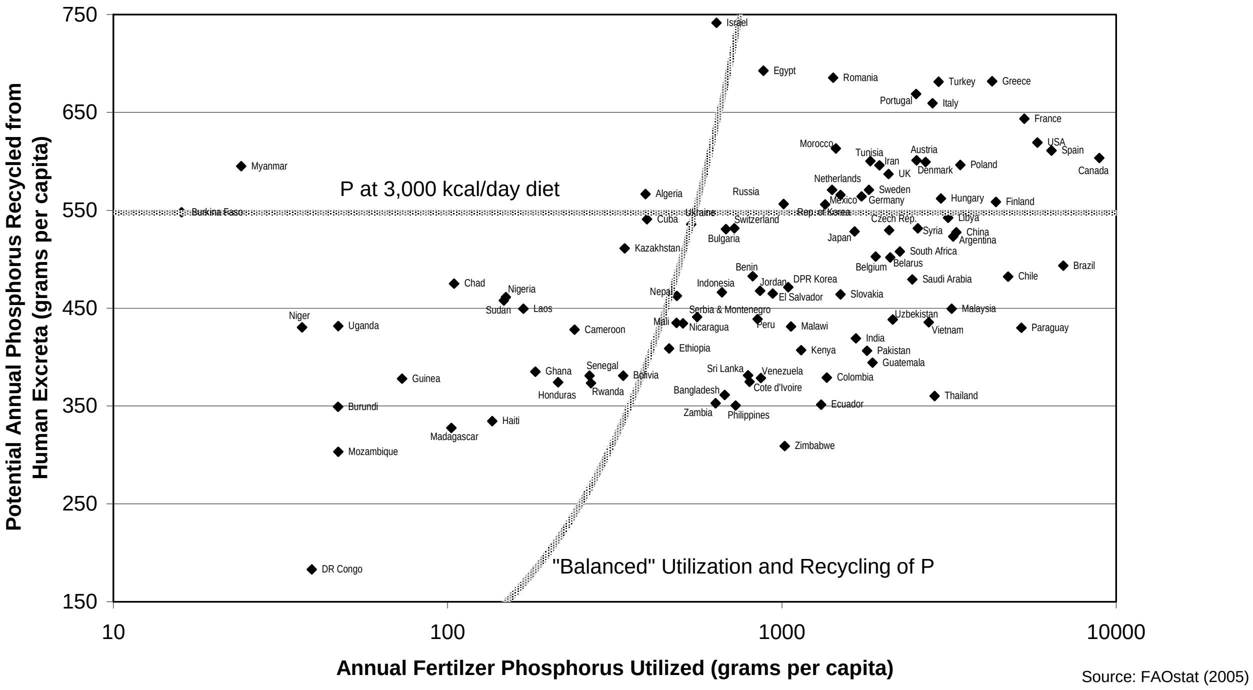

Figure 4-20: Phosphorus Utilized and Potential Recycled, 2002 (countries with population greater than five million)

Figure 4-21 shows the aggregated regional ratios of potential recycled nutrients against chemical fertilizer nutrients utilized. Of great significance is the situation for Sub-Saharan Africa. Here again this shows the great potential that ecosan could have in providing nitrogen and phosphorus self-sufficiency in this region. Also worth noting is the relatively high ratio of phosphorus that could be recycled compared to nitrogen. This will become more and more important as the world phosphate resources dwindle. The US cheap reserves will be depleted in 30 years and most other producing countries except for China, Morocco, South Africa and Jordan will deplete their cheap reserves within 20 to 40 years (USGS, 2005).

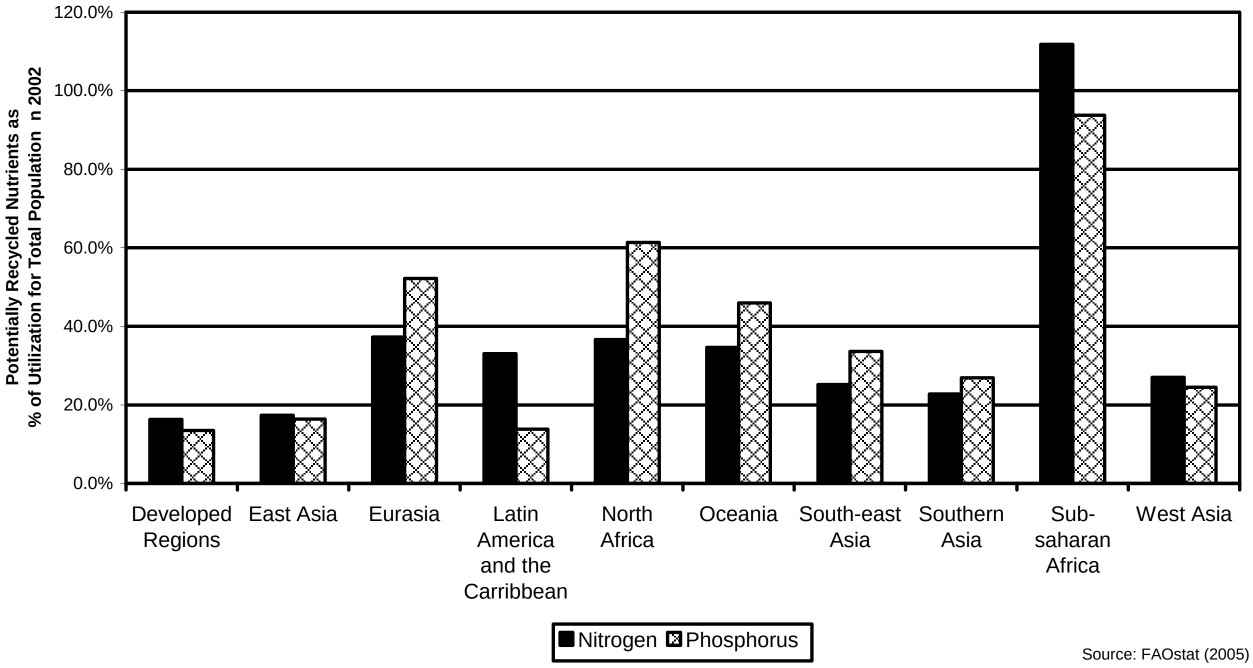

Figure 4-21: Potential Recycled Nutrients as % of Currently Utilized Chemical Fertilizer Nutrients

4.6.3. A note on potassium

Potassium was not included in these calculations since the data on excretion of potassium from humans is highly variable depending on the intake of various foodstuffs. In general it can be stated that human urine contains about twice the amount of potassium than phosphorus and human faeces contain about equal amounts of K and P. Also in NPK fertilizer mixtures K amounts to about 25-30% of the cost. Including potassium would further enhance the positive impact of recycling of nutrients from human excreta and remains a subject for follow-up research.

4.7 Conclusions and the way forward - A call for innovation

The financial and institutional challenges surrounding the MDGs for water and sanitation were well expressed at 8th Special session of the UN Governing Council/Global Ministerial Environmental Forum in Jeju, Korea, in 2004 (UNEP, 2004). This was a call for financial commitment and more effective allocation of resources in order to reduce the poverty and health problems caused by lack of water and sanitation services. It was also a call for a systems approach to go beyond the conventional view restricted to “taps and toilets”. Plus it addressed the deterioration of the aquatic environment due to nutrient discharges causing eutrophication, fish habitat destruction and losses in biodiversity. In order to provide universal coverage by 2025, Vision 21 in 2000 (WSSCC, 2000) called for an increased allocation of external moneys for water and sanitation to the order of USD 9 billion per year to complement the present level of domestic spending of 10-25 billion per year. Vision 21 also called for innovation including ecological sanitation and community-lead initiatives. But this appeal to action five years ago did not result in significant increases in the necessary external allocations (Winpenney, 2003).

No where in the Camdessus Report (Winpenney, 2003) is there a reference to the need for innovative change within the sector. Innovation is, however, introduced as an action element by the MDG Water and Sanitation Task Force (UN Millennium Project, 2005). Composting toilets are mentioned once as a possible innovative technology. And ecological sanitation is stated once in a table as the recommended approach to deal with open defecation. But the report neglects to include any details on ecological sanitation. *The MDG Task Force states that open defecators comprise 42% of humanity or 2.6 billion people. Assigning ecological sanitation* *the central MDG target while not including it in the report, seems like unfinished business worthy of significant follow-up.*

Although the MDG target to 2015 for improved sanitation services is mammoth in size (1.75 billion people), the task at hand is affordable if appropriate solutions are chosen. The real challenge however is one of building capacity to provide such services, especially in the urban areas of the developing world which are growing much faster than the rural areas. *Translating the goal into real numbers of installations by calculating the number of target households reveals that about 95,000 households per day need to be provided sanitation services or about 65 per minute. In total this means 193 million rural households and 256 million urban households by 2015.*

The urban challenge for East Asia (108 million households) is particularly acute where the rate of urbanization is fast and the size of households relatively small. The East Asia urban target for water supply is just as large (112 million hh). For South Asia, the challenge is first rural (73 million hh) and then urban (40 million hh). For Sub-Saharan Africa it is both an urban (42 million hh) and rural (39 million hh) challenge. The urban challenge is relatively large for Latin America and the Caribbean (32 million hh). In Southeast Asia the urban and rural challenge is about equal (at about 20 million hh in each case). *Strategies for providing sanitation services to urban areas cannot be the same for those for rural areas. The urban MDG for sanitation will most probably not be reached unless significant innovation is introduced. On the other hand rural sanitation could be put on a faster track than is required by the MDGs because it is doable with local capacity and equipment and is relatively affordable.*

What is required at this point in time is a new look at the options for rural and urban sanitation. The future of sanitation in dense urban areas is one of source-separation and solid waste systems used to collect the valuable urine, faeces and kitchen organic waste fractions. It also involves decentralised greywater collection and treatment systems that allow for reuse for various purposes. The choices for rural sanitation are even wider depending on the circumstances and level of affordability. In general, ecological sanitation is less expensive and much more resilient than conventional approaches from a socio-ecological point of view. The calculations in this report were provided as an indication of what ecological sanitation approaches would cost. *The data show that ecosan costs lie within the range of 0.1 and 0.3 % of the domestic GDP of the target countries or about a 50th of what present health costs are. The challenge is therefore not one of money but one of capacity and policy reform.*

Urban sanitation requires new innovative approaches if the MDGs are to be met. In the developing world there is an acute need to develop appropriate and affordable systems that can be adapted to the needs of communities providing services to the old and young, women and men, rich and poor. These include source-separation and the use of solid waste collection systems. Ecological sanitation has much to offer in terms of providing services for urine and fecal collection, for decentralised greywater collection and treatment and urban ecostations whereby materials are sanitised and made available for recycling (Jenssen et al., 2004). But to achieve such a mammoth transformation requires institutional changes and capacity building at a large scale. *A global programme to build capacity similar to the "Green Revolution" in the 1960s is thus required. In order to do this a network of 10-12 centres of expertise in sustainable sanitation are required in order to provide regional leadership. Each node institution would be responsible for developing a capacity building programme creating extension services, training and R&D in target countries.*

Much can be done to improve present and future sanitation systems:

- Pit latrines could be modified to be soil-composting latrines, thus requiring some wall reinforcement, made shallow (max 1-1.5 m) and maintained using daily soil additions; the pits would be periodically closed and covered with soil in order to allow for sanitization and composting prior to emptying and reuse in agriculture.
- Simple urinals with separate collector systems could be installed instead of using toilets and pit latrines for urination
- Flush toilets could be modified to use less water.
- Greywater could be source-separated from the blackwater from toilets thus simplifying its treatment and providing opportunities for reuse.

- Blackwater from toilets could be held in conservancy tanks instead of open septic tanks and cess pits and then emptied and transported to biogas fermentors; alternatively the toilets could be connected to biogas fermentors.
- Cess (or drainage) pits e.g. from pour-flush toilets could be equipped with a safety zone of additional filter material to prevent contamination of ground water.
- Toilets and especially any new toilets could be equipped with urine diversion in order to reduce primarily the nitrogen load to the environment.
- Above ground dry toilets with urine diversion could be installed in dry areas lacking water, rocky areas where pits are expensive to dig and areas with high water tables and flooding.

In addition to providing sound sanitation services that can protect human health and the environment, ecosan could replace a significant percentage of the chemical fertilizer used in agriculture (the entire requirement for Sub-Saharan Africa). But for this to occur, policy and legislative changes are required whereby the high value products are legally defined and provide a niche in the socio-ecological system. An investigation showing what sort of work is required in terms of regulatory frameworks is provided by Johansson and Kvarnström (2005). The recently approved WHO (2005) guidelines on reuse of human excreta and greywater soon to be published will provide further impetus towards this development.

In order to instil an urgently needed paradigm shift in the general approach we have taken to sanitation, in order to better protect drinking water resources and human health and to promote the recycling of nutrients, major improvements are required in the institutional, legislative and general public awareness. *This means information and educational programmes, introduction of new policies and regulations, and capacity building and training of professionals. It is these areas that should receive significant bi- and multi-lateral assistance in order to mainstream and fast-track sustainable sanitation practices during the next decade.*

In addition, a vision and dialogue are required in order to create genuine public interest and concern. Without this, sanitation will not become a top priority. Attempts were made with the global policy exercise "Vision 21" prior to the World Water Forum in the Hague in 2000 (WSSCC, 2000). This effort helped put water and sanitation on the global agenda but major efforts towards sustainable sanitation have still to come. *This report therefore recommends that the MDG work should provide for a follow-up to Vision 21 focussing on sustainable sanitation.*

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5. Energy, the MDGs and the Environment

5.1 Introduction

At the World Summit on Sustainable Development in Johannesburg in 2002, all Member States of the United Nations agreed that access to affordable modern forms of energy is a prerequisite for reaching each of the Millennium Development Goals. Box 5-1 shows some ways that energy can help achieve the MDGs.

Box 5-1: Energy and the Millennium Development Goals

Energy and the MDGs
Energy services can play a variety of direct and indirect roles in helping to achieve several MDGs (WEA, 2004):
To halve extreme poverty: Access to energy services facilitates economic development – micro-enterprise, livelihood activities beyond daylight hours, locally owned businesses that create employment – and assist in bridging the digital divide.
To reduce hunger and improve access to safe drinking water: Energy service can improve access to pumped drinking water and provide fuel for cooking the 95% of stable foods that need cooking before they can be eaten.
To reduce child and maternal mortality, and to reduce diseases: Energy is a key component of a functioning health system, contributing for example, to lighting operating theatres, refrigerating vaccines and other medicines, sterilizing equipment, and providing transport to health clinics.
To achieve universal primary education, and to promote gender equality and empowerment of women: Energy services reduce the time spend by women and children (especially girls) on basic survival activities (gathering firewood, fetching water, cooking, etc.; lighting permits home study, increases security, and enables the use of educational media and communications in schools, including information and communication technologies.

To ensure environmental sustainability: Improved energy efficiency and use of cleaner alternatives can help to achieve sustainable use of natural resources, as well as reduce emissions, which protects the local and global environment.

Source: DFID, 2002 in UNDP, 2004, p. 34.

Access to modern forms of energy affects all aspects of development - social, economic, and environmental - including livelihoods, access to water, agricultural productivity, health, population levels, education, and gender-related issues. It is a key prerequisite for providing income generating activities. With about one billion people living on less than USD 1/day opportunities for income generating activities are critical to poverty reduction.

Presently about 2.4 billion people lack access to clean fuels for cooking and approximately 1.6 billion people lack access to electricity. By 2015 the situation will not look much different unless concerted actions are taken to at least bring basic levels of energy services to the world's poor.

There are two main energy-related challenges with regard to meeting the MDGs. The first is the expansion of access to energy services that is needed to realize the MDGs. The second challenge relates to the vast environmental and public health impacts of the global energy sector as it expands to meet the demands of growing economies and rising affluence. These impacts, including pollution, climate change, and habitat degradation, undermine the very livelihoods of the world's poor. They not only jeopardize strides made toward meeting the MDGs, but they obstruct progress toward poverty reduction in general. This is because poor communities vitally depend on healthy environmental resources for their livelihoods, and moreover they are most vulnerable to environmental degradation. Poverty can therefore only be effectively addressed if the current trend toward increasing environmental deterioration is confronted. The ability, cost, and likelihood of achieving MDGs therefore strongly depends not just on the interventions targeted specifically at achieving the MDGs, but on the broader global development policies and their environmental implications.

In this study, we discuss both challenges - the scale of direct MDG-related energy demands, and also the impact on poverty reduction efforts of environmental threats related to global energy expansion.

With regard to the scale of the energy demands, it is well-understood that improved access to modern energy services is a critical input for reducing poverty and meeting the Millennium Development Goals. An effective energy sector that can fulfil the demand for energy services is a prerequisite for economic and social development which in turn is a prerequisite for sustainable poverty reduction. In the absence of specific targets for access to energy services stipulated as part of the Millennium Declaration, a few initiatives have been taken to set targets for what type of energy services are needed to support the achievement of the Millennium Development Goals. In this study, we base our discussion on an “MDG Energy Vision” that was developed and used as part of the Millennium Development Project (Modi, 2005).

The targets of the MDG Energy Vision are that by 2015:

- 100% of the world’s urban populations and 50% of the world’s rural population use modern liquid and gaseous fuels for cooking
- 50% of the world’s rural population use improved biomass stoves
- 100% of the biomass used for cooking is produced in a sustainable way
- 100% of the world’s urban populations have a basic electricity supply to meet lighting and communication needs
- 100% of the world’s health facilities and schools have electricity supply and use modern liquid and gaseous fuels to meet cooking and heating needs.
- 100% of all communities have access to mechanised power

Achieving the MDG Energy Vision will require a substantially accelerated delivery of energy services to the poor people of the world. Still, we are not talking about a lot of energy. The total amount is only equal to about 900 TWh annually, comparable to the amount of energy Sweden consumes in 18 months. The total annual financing needed to achieve the MDG Energy Vision is about 45 Billion USD. This is slightly more than 10% of what OECD countries in 1999 spent on agricultural sector subsidies.

Achieving the MDG Energy Vision will have important positive environmental impacts at the local, regional and global level. Annually, 1.6 million deaths of especially women and children will be avoided by eliminating indoor air pollution. Global greenhouse gas emissions will be reduced as a result of switching away from traditional biomass fuels to modern liquid and gaseous fuels even if they are petroleum based (i.e. kerosene and liquefied petroleum gas).

Will achieving the MDG Energy Vision mean that the world will be free of energy poverty? No, far from it - the MDG Energy Vision is only a starting point and will only have put the countries on the right trajectory for further development. Much more is needed to reach “satisfactory” levels of human and societal welfare. In this endeavour it is important to be aware of the dangers of technology lock-in the development of national energy sectors. While this is not too difficult to avoid in the provision of basic services for the poorest it is absolutely necessary to think about when designing large infrastructure programmes, such as power plants and grid-based system with long lifetimes.

The achievement of the MDG Energy Vision will also be intricately connected to the development of the rest of the energy sector over the next 10 years. As the energy sector expands, it is likely to contribute to economic and social development, which will help reduce poverty levels around the world. However, the positive benefits of this expansion may be dampened by some of the negative environmental impacts of an expanded energy sector. These negative impacts have the potential to make it harder for development to occur, and may inhibit poverty reduction. Climate change in particular threatens to undermine society’s very capacity to meet basic needs for food, health and shelter. It is therefore crucial to increase energy efficiency and transition toward sustainable energy sources world wide.

While the energy-related demands of the MDGs would contribute to energy sector growth, this study demonstrates that the incremental energy requirements of meeting the MDGs would be negligible in comparison to the global energy demand projections. In light of the negligible contribution to global energy supply needed to meet the MDGs, the by far most effective way to address the energy sector’s environmental impacts – such as global climate change – will be interventions where the large emissions occurs. This requires a fundamental global change in how we supply and use energy in order to have enough resources and not risk negative environmental impacts that will undermine the chances of living sustainably on this planet. In order not to jeopardise the achievement of the MDGs, it is necessary that industrialised countries reduce greenhouse gas emissions and other energy sector impacts significantly.

5.1.1. The MDG Energy Vision Targets

Several initiatives have been made to quantify and set targets for what type and what quantities of energy services are needed to support the achievement of the Millennium Development Goals. Common to all these is the identification of reduced reliance on traditional biomass and increased access to electricity services.

The International Energy Agency (IEA) estimates that in order to half the population living on less than one dollar a day the number of people without electricity needs to be brought down to about 1 billion from today's 1.6 billion people. Almost all of these will be in South Asia and Sub-Saharan Africa. By 2015, electrification rates will be close to 100% in all other regions. According to IEA estimates the additional investment needed to bring electricity to these 600 million people will be about USD 200 billion, which is equal to 10% of the total cumulative investment in the electricity sector in developing countries expected to occur between 2003 and 2015.

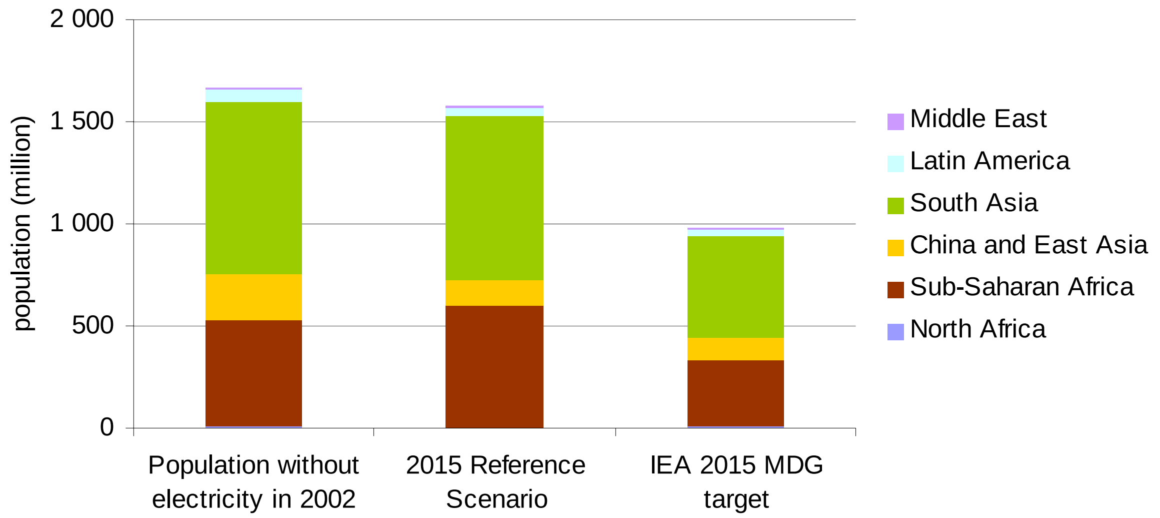


Figure 5-1: MDG Target Population

IEA also recognises that to achieve the Millennium Development Goals a substantial reduction in the use of traditional biomass for cooking and heating is needed. In IEA's reference scenario, the number of people relying almost entirely on traditional biomass for cooking and heating will increase slightly from 2.4 billion in 2002 to over 2.55 billion in 2015. IEA's analysis suggests that to meet the poverty reduction target, the number would need to be reduced to fewer than 1.85 billion people. To accomplish this, new measures to extend the use of modern cooking and heating fuels to more than 700 million people from 2002 to 2015 are needed.

McKinsey & Company has also made an assessment of the energy requirements necessary to support achievement of the MDGs. A "Parallel Energy MDG" was outlined as follows:

- Reduce by half, between 2005 and 2015, the proportion of urban and rural households without access to adequate lighting;
- Reduce by half, between 2005 and 2015, the proportion of urban and rural households reliant on cooking methods that are not MDG-compatible; and
- By 2015, provide adequate, clean and efficient energy services to all educational and health facilities".

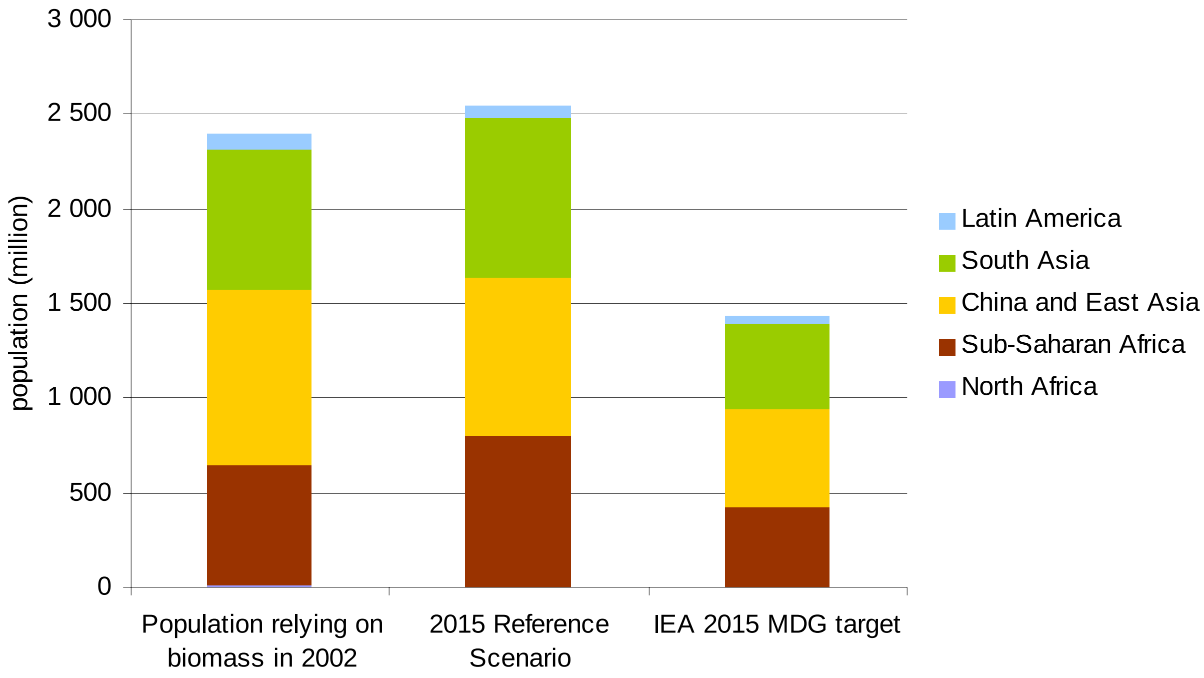


Figure 5-2: MDG Target Population

The Millennium Development Project elaborated on the Parallel Energy MDG used by McKinsey and Company and defined a set of targets to be achieved by all countries by the year 2015, namely:

- Enable the use of modern fuels for 50% of those who at present use traditional biomass for cooking. Support efforts to develop and adopt the use of improved cook-stoves, means to reduce indoor air pollution and measures to increase sustainable biomass production.
- Access to reliable modern energy services for all urban and peri-urban poor
- Electricity for all schools, clinics, hospitals and community centres
- Access to mechanised power within the community for all communities

Common to all these MDG related energy targets is the focus on radical change in traditional biomass use as well as increased electrification levels. Based on the essence of the targets set up by the IEA, the Millennium Project and the McKinsey & Company report we have in this study elaborated on the implications of fulfilling five goals as part of the an MDG Energy Vision, two of them relating to energy services for cooking and three relating to electricity and mechanical power.

Table 5-1: Targets to achieve by 2015 to realise the MDG Energy Vision used in this study.

Cooking		
Target 1	By 2015, replace all traditional biomass fuels for cooking with modern fuels within **urban** households.	
Target 2	Reduce by half, between 2005 and 2015, the proportion of **rural** households reliant on traditional biomass for cooking and for the remaining adoption of improved cook stoves and means to reduce air pollution as well as practices for sustainable biomass production.	
	Target 2a	Reduce by half, between 2005 and 2015, the proportion or rural households reliant on traditional biomass for cooking with modern fuels
	Target 2b	By 2015 improved cook stoves and means to reduce air pollution to be adopted by households reliant on traditional biomass for cooking
	Target 2c	By 2015, biomass used in improved cook stoves to be produced in a sustainable way
Electricity and mechanised power		
Target 3	By 2015, electricity supply to all urban and peri-urban households	
Target 4	By 2015, provide adequate, clean and efficient energy services to all educational and health facilities	
Target 5	By 2015, all communities to have access to mechanised power	

The aim of the MDG Energy Vision is not to ensure equality of access to energy services across all populations, but rather to ensure that all populations have access to basic forms of energy service. For urban populations and institutions, this means access to electric lighting and cook stoves that use modern fuels. For rural populations, it means increasing the access to modern fuels, and ensuring that the traditional biomass used for cooking is produced in a sustainable way and used in improved stoves. It also means ensuring that all communities have access to mechanised power, to help them perform basic tasks like water pumping and agricultural food processing.

In this study we have calculated the target groups across the major geographical regions of the world, calculated the energy needs for each of the targets, and calculated the investment needs for each of the goals as well as the direct CO_2 emissions for each of the targets. The calculations in this study are based on statistics and other information from the Millennium Development Project, IEA, UN FAO, UNDP as well as national experiences in developing countries.

The population data comes from FAO, the major geographical regions used in the study are the ones used in the World Energy Outlook 2004, the energy use patterns across the major geographical regions of the world are based on IEA's World Energy Outlook 2004 and 2002, IEA's Reference Scenario as presented in the World Energy Outlook, 2004 has been used to assess the energy service gaps in 2015 and the Global CO_2 emissions projections.

5.1.2. Target groups for the MDG Energy Vision

The target groups for the MDG Energy Vision are found mainly in Africa and Asia, in both rural and urban areas. With only a minor effect on total world energy consumption, achieving these goals can have a significant effect on reducing poverty and promoting development in these populations. Not only will access to these energy services improve lifestyles and income earning potential in these areas, the technologies and fuels used to meet these goals will benefit the environment as well, both locally and globally. Local air quality will be improved through the increased use of modern fuels, and overall emissions will be reduced by the movement away from biomass incompletely combusted in inefficient stoves.

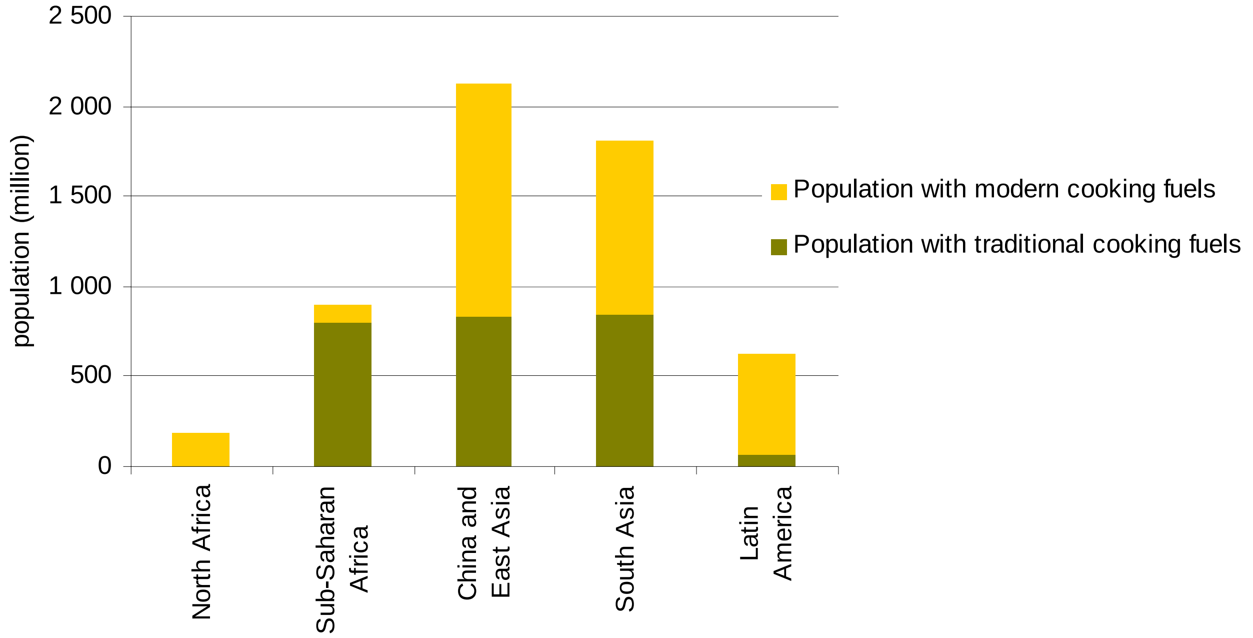


Figure 5-3: Modern and traditional cooking fuels across the world regions in 2015

Targets 1 and 2 relating to cooking

By 2015 about 2.5 billion people in developing countries will rely on traditional biomass fuels to meet their cooking and heating needs. At the same time (see Figure 5-3) almost all of the populations in North Africa and in Latin America will have switched away from traditional biomass fuels, whereas in Asia, slightly less than half of the population will still be relying on traditional cooking fuels. In Sub-Saharan Africa a large majority of the population will still be heavily reliant on traditional cooking fuels in 2015 unless major actions are taken.

The targets of the MDG Energy Vision relating to cooking fuels are to replace all traditional biomass fuel use within urban areas with modern fuels and to replace half of the use of traditional biomass fuels in rural areas with modern fuels. Furthermore, the vision is for the remaining rural population to have adopted improved cook stoves with significantly lower levels of indoor air pollution as well as application of practices for sustainable biomass production. The total challenge of meeting the targets related to cooking fuels is illustrated in Figure 5-4.

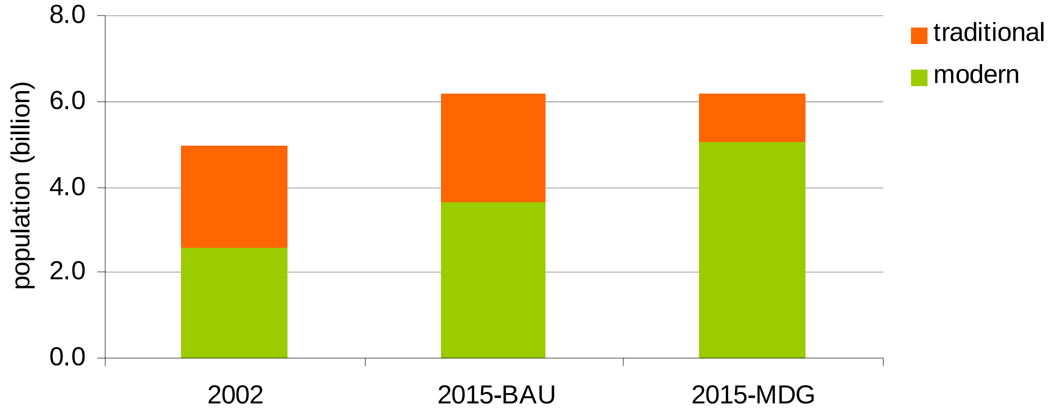


Figure 5-4: Fuels used for cooking in 2002, in 2015 with a business as usual scenario and with the MDG Energy Vision

Targets 3, 4 and 5 relating to electricity and mechanical power

By 2015 the absolute number of non-electrified will be about the same as today. As is illustrated in Figure 5-5 the bulk of the non-electrified will be found in Sub-Saharan Africa and in South Asia.

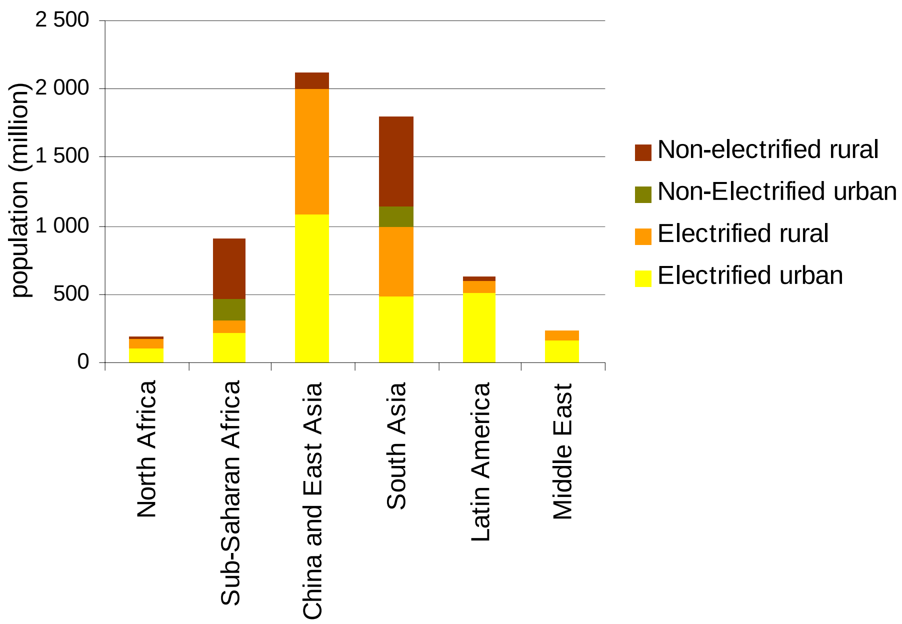


Figure 5-5: Electrified and non electrified urban and rural populations in 2015

To achieve the MDG Energy Vision all urban populations and all schools and health facilities should have access to electricity by 2015. This gives a total deficit of about 300 million people as compared to a business as usual scenario as is illustrated in Figure 5-6. According to IEA estimates a further 570 million people need to get access to electricity to achieve the MDGs.

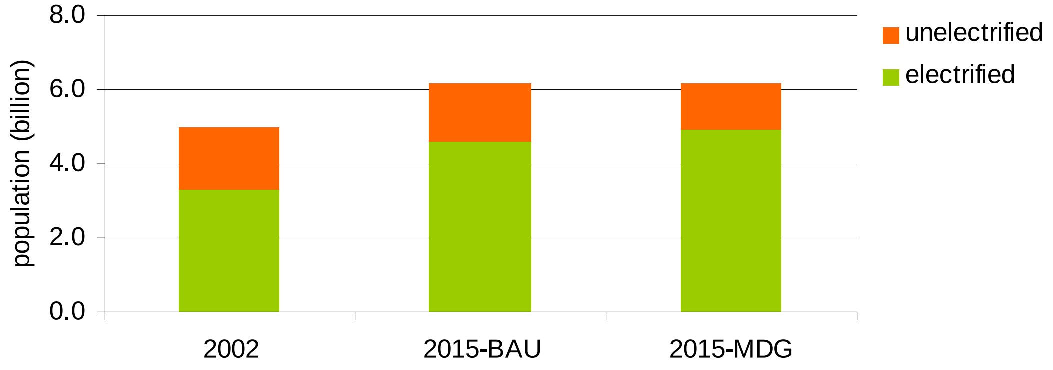


Figure 5-6: Electrification levels in 2002, in 2015 based on a business as usual scenario and with the MDG Energy Vision

We have calculated the target groups for the MDG Energy Vision and will in the following chapters look at each of the targets.

Target 1: 100% of the world's urban populations use clean modern fuels for cooking in 2015

By 2015, most of the urban populations across the world regions except for the Sub-Saharan African and China and East Asian regions will have access to modern cooking fuels (see Figure 5-7). To achieve the first target of the MDG Energy Vision, about 300 million people living in urban areas need to get access to modern clean (gaseous or liquid) fuels for cooking. 270 million of these live in Sub-Saharan Africa and 33 million in China and East Asia.

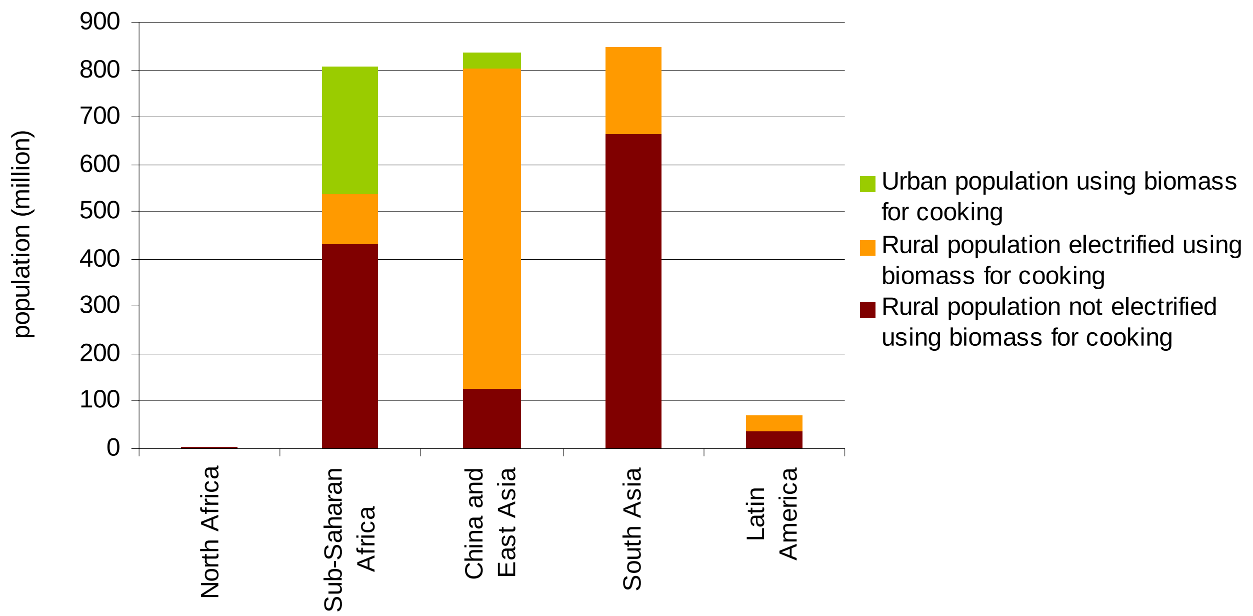


Figure 5-7 Assumptions about population relying on biomass for cooking and heating in 2015

Target 2: Reduce by half, between 2005 and 2015, the proportion of rural households reliant on traditional biomass for cooking and for the remaining adoption of improved cook stoves and means to reduce air pollution as well as practices for sustainable biomass production

The MDG Energy Vision targets the replacement of 50% of the reliance on traditional biomass in rural areas with modern fuels and the introduction of improved cook stoves for the remaining population as well as the introduction of sustainable biomass production methods for the fuels used in the improved cook stoves. Target 2 can be subdivided into three specific target groups that are presented in Table 5-2.

Table 5-2: Target groups in 2015

Region	Rural population relying on biomass (millions of people)	Target 2a	Target 2b	Target 2b
North Africa	3	1.5	1.5	1.5
Sub-Saharan Africa	532	266	266	266
China and East Asia	796	398	398	398
South Asia	844	422	422	422
Latin America	68	34	34	34

Target 3: All urban populations have electricity access by 2015

By 2015 it is likely that electrification of all urban populations has been achieved except in Sub-Saharan Africa and South Asia where still about 300 million urban residents will lack electricity access (see Figure 5-8). These are the target group for target 3 which numbers are presented in Table 5-3.

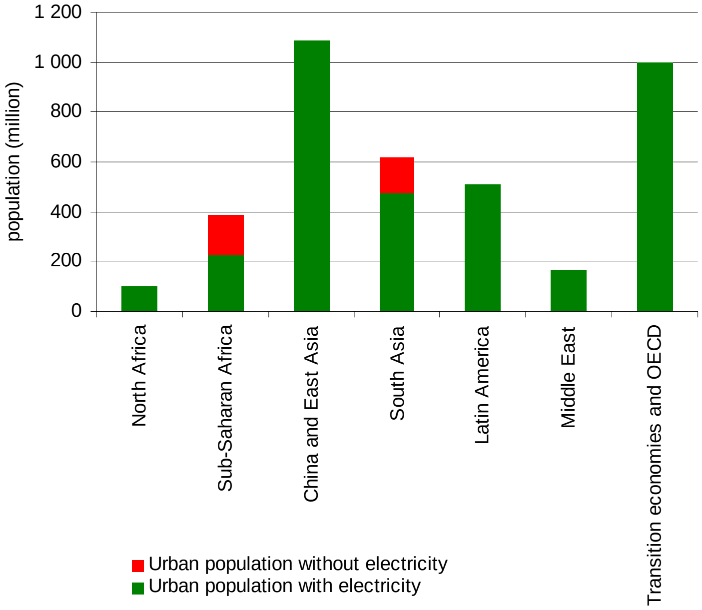


Figure 5-8: Urban populations with and without electricity across the world's regions in 2015

Region	Target 3: Urban population without electricity (million)
Sub-Saharan Africa	162
South Asia	142

Table 5-3: Target population (million), the urban population without access to electricity by 2015.

Target 4: By 2015, Adequate, clean and efficient energy services to all educational and health facilities

By 2015, almost 800,000 schools and health facilities will still not have access to electricity supply. The number of supply points that have to be made across the world's regions to achieve the 4th target are presented in Table 5-4 and in Figure 5-9.

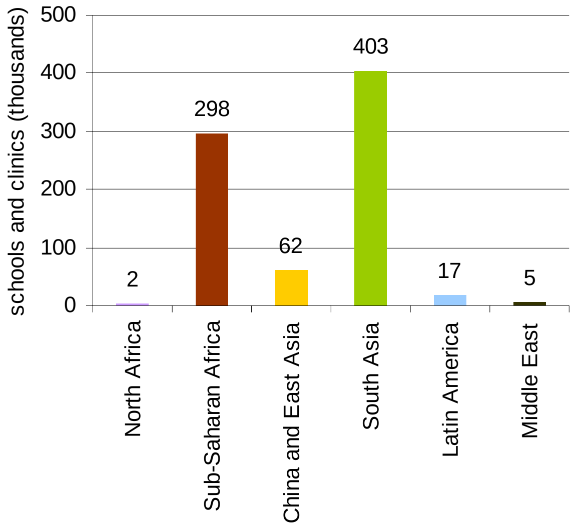


Figure 5-9: Number of schools and clinics to be electrified across the world's regions, thousands

Region	Target 4: Number of schools and clinics to get access to electricity
North Africa	2,000
Sub-Saharan Africa	298,000
China and East Asia	62,000
South Asia	403,000
Latin America	17,000
Middle East	5,000
Developing countries	787,000

Table 5-4: Number of schools and clinics to be electrified across the world's regions by 2015

Target 5: By 2015, all communities to have access to mechanised power

By 2015, almost 1.6 million communities will still not have access to electricity supply. The numbers of communities that have to be supplied with mechanical power across the world's regions to achieve the 5th target are presented in Table 5-5 and in Figure 5-9.

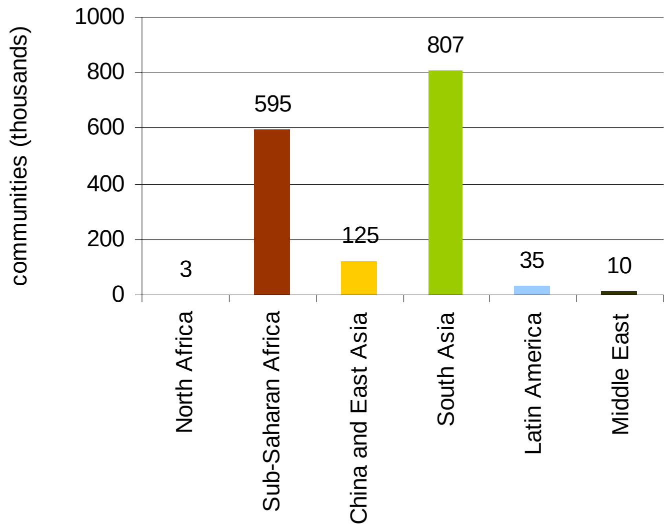


Figure 5-10: Number of communities to get access to mechanical power

Region	Target 5: Number of communities to get access to mechanical power
North Africa	3,000
Sub-Saharan Africa	595,000
China and East Asia	125,000
South Asia	807,000
Latin America	35,000
Middle East	10,000
Developing countries	1,575,000

Table 5-5: Number of communities to be provided with basic mechanical power

Summary of the target population

Table 5-6 provides a summary of the target groups for the MDG Energy Vision. It shows that for North Africa, Latin America and the Middle East the challenge is not as big as for the other regions. It points at the urgency of addressing access to cleaner fuels and improved cook stoves in Sub-Saharan Africa, China and East Asia and in South Asia; it points to the major challenge of increasing urban access to modern cooking fuels in especially Sub-Saharan Africa and in China and East Asia; and for the huge need to increase electricity access in Sub-Saharan Africa and in South Asia.

Table 5-6: Summary of populations and electricity connections concerned to achieve the MDG Energy Vision targets

Targets	North Africa	Sub-Saharan Africa	China and East Asia	South Asia	Latin America	Middle East	Comments
1.	0	270	33	0	0	0	Million people
2a.	1.5	266	398	422	34	0	Million people
2b	1.5	266	398	422	34	0	Million people
2c	1.5	266	398	422	34	0	Million people
3.	0	162	0	142	0	0	Million people
4.	1.6	298	62	403	17	5	Thousand connections
5.	3	595	125	807	35	10	Thousand communities

5.1.3. Energy needed to meet the MDG Energy Vision

In this study we have calculated the required energy to meet the MDG Energy Vision based on some basic minimum levels of energy consumption presented in Table 5-7 (Modi, 2005 and UNDP, 2000). Included in the table is also the community access to mechanical power based on the experience from application of the multifunctional platform in West Africa[1].

Table 5-7: Minimum levels of annual energy consumption

Annual consumption per	Lighting/electrification	Cooking
Household	75 kWh	1 GJ useful energy
School	2,000 kWh	7,000 kg LPG
Hospital	50,000 kWh	10,000 kg LPG
Clinic	8,000 kWh	1,000 kg LPG
Health post	2,000 kWh	400 kg LPG
Community mechanical power	10 horsepower diesel engine	

The total required level of commercial energy consumption to meet the MDG Energy Vision is about 900 TWh equivalent of energy (see Table 5-8), most of it in the form of cooking energy, in this study represented by LPG (Liquefied Petroleum Gas). LPG is not the only modern cooking fuel; all available modern and clean liquid or gaseous cooking fuels should be considered in meeting the targets. Other modern cooking fuels that should be part of a menu of cooking fuels to meet the targets are for example biogas, producer gas, natural gas and DME stoves. Secondly, diesel represents about 5% of the total required energy consumption to meet the MDG Energy Vision. In the future it is envisioned that liquid bio fuels can be used instead of diesel.

Table 5-8: Summary of annual commercial energy needs to meet targets 1-5

For all the targets		TWh equi-valent	Current annual consumption in Sweden (2005) (for comparison purposes)	Current annual consumption globally (2005) (for comparison purposes)
Amount of LPG needed	65 million tons	824		
Amount of Electricity needed	31 TWh	31		
Amount of diesel needed	5 million m^3	45		
Total		900	600	130,000

Improving the rural energy situation will require a concerted effort over a long period of time, and will involve a variety technologies as development continues. Due to costs and availability, the best long-term solutions may not be feasible in the near term, but steps can be made toward these long-term solutions. These intermediate steps, though they do not represent final solution, do represent an improvement over the current situation.

[1] The multifunctional platform is built around a simple diesel engine, than can power various tools, such as a cereal mill, husker, alternator, battery charger, pump, welding and carpentry equipment, etc. It can also generate electricity and be used to distribute water. The 10 Horsepower diesel engine is typically run for 1500 hours per year and consumes about 2 litres of diesel per hour.

5.1.4. Cost of meeting the MDG Energy Vision

The total annual required public financing of meeting the MDG Energy Vision will be about USD 45 billion. The calculations are based on a complete subsidy of the investment and recurrent fuel/electricity cost for public institutions (schools and health facilities) while private and commercial end-users pay a substantive share of the cost[1]. The calculation does not include necessary investments in institutional capacity building and administration related to the implementation of the MDG Energy Vision. The largest per capita public financing needed is for Sub-Saharan Africa (USD 18) followed by South Asia (USD 9). The amount of public financing needed gives a direct indication of where the energy poverty is the most severe. Consequently North Africa and the Middle East will only require about USD 0.3 per capita public financing to meet the MDG Energy Vision (see Table 5-9).

Table 5-9: Summary of annual public financing needed to achieve the MDG Energy Vision (in Billion USD)

	Targets								
Region	**1**	**2a**	**2b**	**2c**	**3**	**4**	**5**	**Total per region**	**Per capita public financing need in USD**
North Africa	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.06	0.3
Sub-Saharan Africa	4.43	4.36	0.67	0.67	1.62	4.02	0.62	16.38	18
China and East Asia	0.54	6.53	1.00	1.00	0.00	0.84	0.13	10.03	5
South Asia	0.00	6.92	1.06	1.06	1.42	5.45	0.85	16.74	9
Latin America	0.00	0.56	0.09	0.09	0.00	0.23	0.04	1.00	2
Middle East	0.00	0.00	0.00	0.00	0.00	0.07	0.01	0.08	0.3
Total	4.97	18.39	2.80	2.80	3.04	10.63	1.65	44.29	

5.1.5. Environmental impacts of meeting the MDG Energy Vision

Global environmental impacts of meeting the MDG Energy Vision

The greenhouse gas emissions resulting directly from the energy consumed as part of the MDG Energy Vision will represent about 0.7% of the global CO_2 emissions in 2015. The largest share of this comes from LPG. The amount of emissions will be about the same for other petroleum fuels such as kerosene.

What this figure does not include is the reduced total greenhouse gas emissions (CO_2, gaseous hydrocarbons etc) that can be expected to occur from replacing traditional biomass fuels with liquid and gaseous petroleum fuels. Several studies suggest that a shift to fossil fuels for cooking will result in reductions of greenhouse gas emissions in the order of 1 – 10% (Smith, 2000; Bailis, 2005; Johansson et al, 2005). Taking these considerations into account, the actual impacts of meeting the MDG Energy Vision will have a positive global environmental impact by reducing greenhouse gas emissions.

Table 5-10: CO_2 emissions caused by meeting the MDG Energy Vision

	Energy for all the targets	**CO_2 emission factors (kg/ton, m^3 and MWh)**	**CO_2 emissions million tons**
Amount of LPG needed	65 million tons	2,996 kg/ton	194
Amount of Electricity needed	31 TWh	100 kg/MWh	3
Amount of diesel needed	5 million m^3	2,940 kg/m^3	14
Total			210
Global CO_2 emissions 2002			23,579
Global CO_2 emission in 2015			30,521

Regional and local environmental impacts

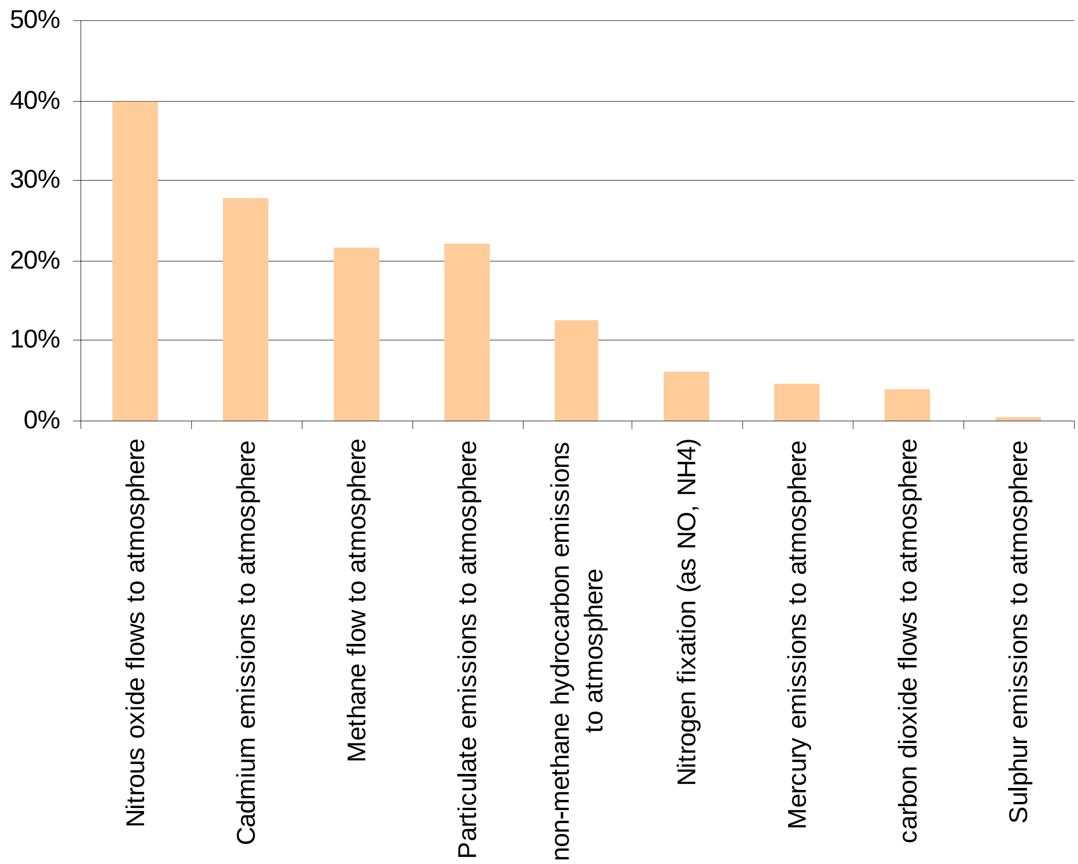
The regional and local environmental impacts of meeting the MDG Energy Vision are to the largest degree related to the change in fuels used for cooking. There will also be impacts arising from the use of diesel fuel

[1] See annex for assumptions behind the cost estimates

in the communities with mechanised power and from the fuels used to generate the additional electricity to meet the electricity loads from urban households and from social service institutions. However, in relation to the cooking needs, the environmental impact from this will be small.

Based on a switch from traditional biomass, to liquid and gaseous petroleum fuels and improved stoves with chimneys to reduce indoor air pollution, the environmental impacts at the global, regional, local and household level will be important, in a positive way.

Starting from the household level, the impacts of realising the MDG Energy Vision (with modern fuel stoves for all urban end-users and for half of the rural end-users, and improved stoves for the rest of rural end-users), will primarily be related to reductions of indoor air pollution. Indoor air pollution, primarily caused by incomplete combustion of solid fuels such as firewood, charcoal, dung cakes and to some extent, coal in countries such as China and South Africa, can lead to infectious respiratory disease such as acute respiratory infections and tuberculosis; chronic respiratory diseases such as chronic bronchitis and lung cancer; and adverse pregnancy outcomes such as still birth and low-weight babies born to women exposed during pregnancy. Combustion of bio fuels emits pollutants that currently cause over 1.6 million deaths globally (Ezzati et al, 2002 in Bailis, 2005). The global impacts of indoor air pollution could be 2 million deaths per year, with women and children particularly affected (UNDP, 2000). Petroleum based liquid and gaseous fuels produce substantially less health-damaging pollution than many of the solid biomass fuels (Smith et al, 2000). An LPG stove can reduce indoor air pollution with up to 90% and an improved chimney stove with up to 80% (Warwick and Doig, 2004).



Source: Adopted from UNDP, 2004, p. 41.

Figure 5-11: Share of the global energy sector's atmospheric emissions resulting from traditional energy supply

Poor air quality resulting from solid fuel use for cooking and heating has significant environmental impacts not only at the household level. Particulate matter (which is emitted directly and formed in the air as the result of emissions of gaseous precursors in the form of oxides of sulphur and nitrogen) and hydrocarbons are growing concerns world wide (UNDP, 2004). Traditional energy supply is causing a substantial share of the energy sector's emissions of harmful pollutants. This is particularly so for nitrous oxide, cadmium, methane as well as non-methane hydrocarbon and particulate emissions to the atmosphere (see Figure 5-11)

At a local and regional level, the reduced environmental impacts of burning of traditional bio fuels are likely to have positive regional environmental and health impacts on reduced acidification, reduced cadmium releases to the atmosphere and reduction of particulate emissions that contribute to the formation of the "Brown Clouds". The Brown Cloud is a cloud of haze and smog that is almost permanently suspended over part of Asia and is considered to be one of the most serious manifestations of the urban air pollution in recent times.

Table 5-11 presents some of the major Health and Environment Impacts of Selected Energy-Related Air Pollutants some of which are partly caused by traditional biomass fuel use.

Table 5-11: Health and Environment Impacts of Selected Energy-Related Air Pollutants

Pollutant	Source	Health and environment impact
Particulate matter	Incomplete combustion of solid fuels	Suspended particulates affect the lungs. Small particles are likely to be most damaging (penetrate deep into the lungs and tend to be more chemically active).
	Diesel vehicles	Particulates from diesel engines are potentially carcinogenic. Can cause allergies, asthma and chronic bronchitis.
Carbon monoxide (CO)	Combustion –primarily from motor vehicles and industrial processes. Burning of refuse, cooking fuels and heating	Weakens the blood's capacity to transport oxygen to cells Affects the cardiovascular, nervous and pulmonary systems. Contributes to (ground level) ozone formation.
Sulphur oxides (SO, SO_2)	Burning of fossil fuel (coal and petroleum) Burning wood	Aggravates respiratory diseases. Increases risk of cardiovascular disease. Contributes to acidification of water and soils.
Nitrogen oxides (NO, NO_x, NO_2)	Burning of fossil fuel (coal, oil, natural gas)	Damages human lungs, certain plants, as well as physical structures. Can increase susceptibility to contracting viral diseases. Contributes to acidification.
Lead	Vehicle emissions (leaded gasoline)	Can cause impairments in intellectual functioning, kidney damage, infertility, miscarriage and hypertension. Especially hazardous for young children.
Ozone (O_3) (at ground level)	Secondary pollutant resulting from chemical reaction between nitrogen oxides and organic compounds in the presence of solar radiation.	The principal component of dense smog. Irritates eyes, nasal congestion, and reduction of lung function. Can also decrease resistance to infections. Harms vegetation.

Source: SEI, 1999b

5.2 Global energy sector and the MDGs

Achieving the MDG Energy Vision will not happen in isolation – energy sectors at the national, regional and global levels are constantly evolving. According to IEA projections, the global energy consumption will have increased by 15% between 2005 and 2015. The increase is expected to be largest in the developing world.

Energy is undoubtedly critical to human development generally and the reduction of poverty in particular. It is essential to the provision of basic services needed by poor people, their communities and their private enterprises, as well as to the broad economic growth necessary for sustainable poverty reduction (SEI, 1999a).

An energy sector that is able to deliver needed energy service can be an effective means of reducing poverty. Much depends, however, on both the organisation of the energy sector, and the energy systems built up, as well as the context within which the energy sector delivers its services. If the priorities of the poor lie elsewhere, providing them with energy services will not be the best means of reducing their poverty. If the benefits of economic growth are captured by a small minority, energy services which contributes to that growth till not be an effective means of reducing poverty. If energy sector investments impose heavy environmental burdens on low-income dwellers (including potential displacement) interventions are far less likely to reduce poverty (SEI, 1999a).

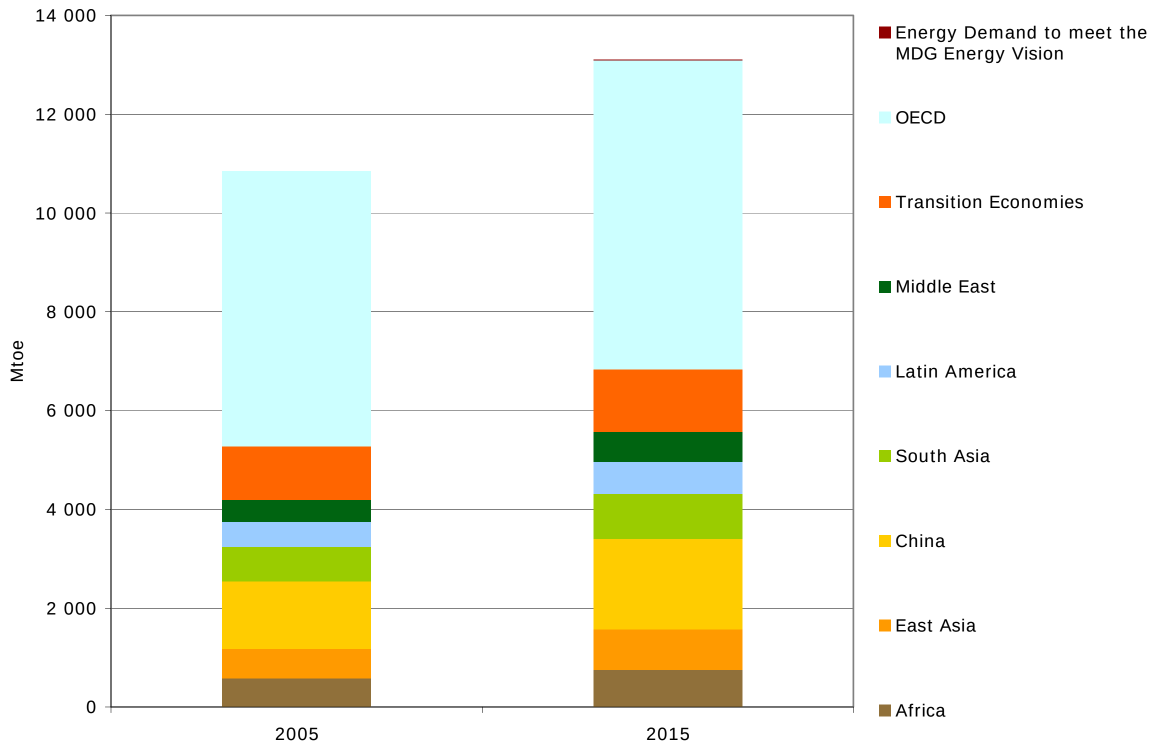


Figure 5-12: Energy Demand 2005 and 2015 in Mtoe

The positive aspects of the scenario pictured in Figure 5-12 is that is likely to contribute to economic and social development for a lot of people who have just passed the poverty line and are earning more than USD 2 a day thus reducing the risk of people falling back into poverty.

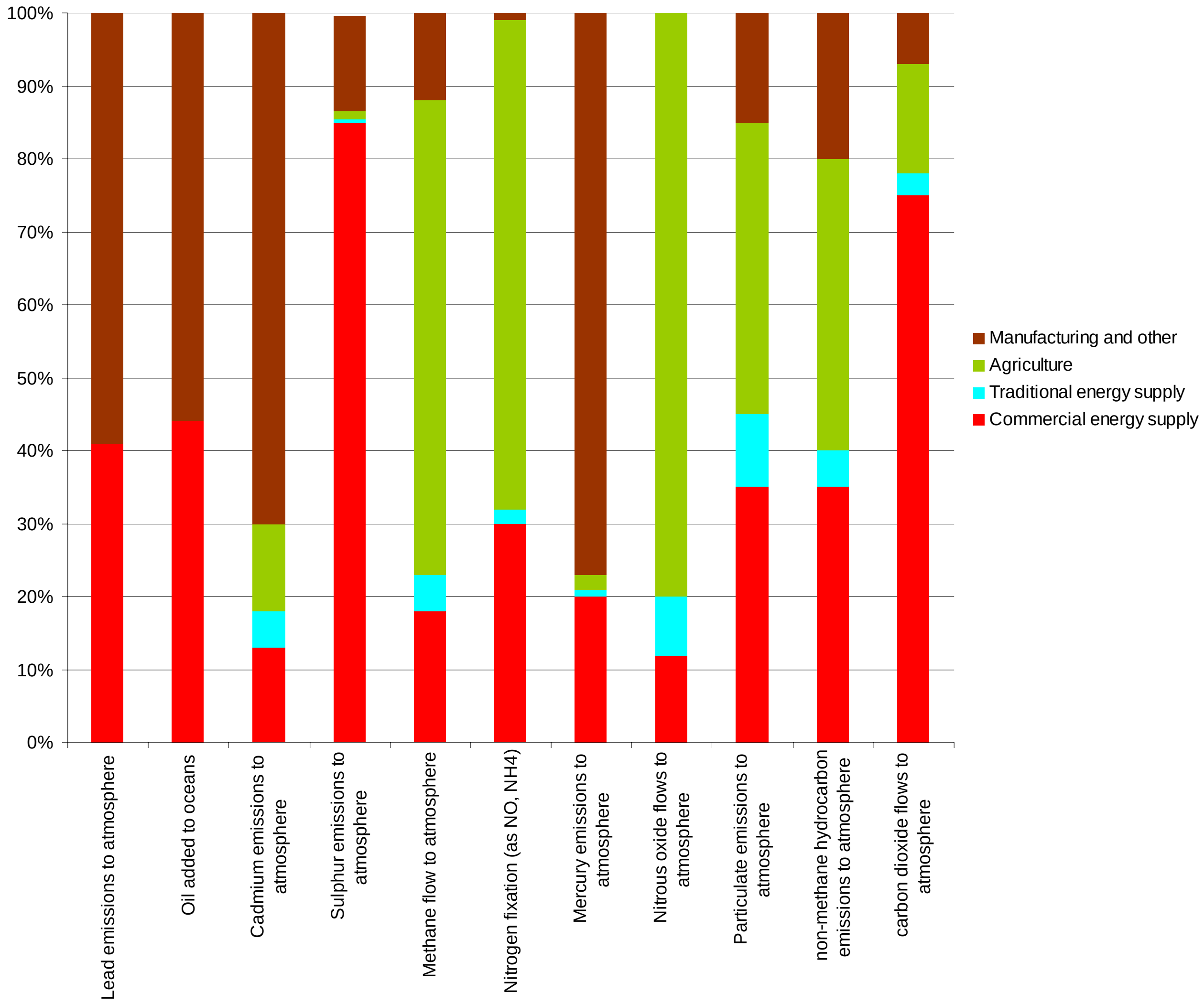
The possible negative aspects of this scenario, if the energy sector develops as it has for the past decades, is that some negative environmental impacts will make it harder to achieve economic and social development and poverty reduction. The development could therefore counteract the objectives of reducing poverty, especially for the poor who are more vulnerable to environmental stresses than the rich - who have more coping strategies to make use of.

The extraction, processing and use of fossil fuels are associated with land degradation and conversion, pollution of water bodies, local and regional air pollution, emissions of heavy metals, and climate change leading to adverse effects on human health and ecological systems. The most significant environmental concerns with respect to nuclear power and large hydropower are reactor safety and radioactive waste management, and damage to terrestrial and aquatic ecological systems and their biodiversity, respectively. In general, renewable energy technologies have positive effects on local and regional air pollution compared to fossil fuels, but may have negative effects on biodiversity, depending upon site selection and management practices (Watson, 2004). Figure 5-13 provides an overview of the emissions due to human activities caused by different sectors.

5.2.1. Traditional energy

Poor air quality resulting from solid fuels use for cooking and heating has significant health and environmental impacts at the household, local, regional and global levels. It is associated with increased illness and premature death. About 1.6 million premature deaths per year – disproportionately women and children – are estimated to occur from exposure to indoor air pollution caused by incomplete burning of solid fuels in poorly ventilated spaces.

Particulate matter (which is both emitted directly and formed in the air as the result of the emissions of gaseous precursors in the form of sulphur and nitrogen oxides) and hydrocarbons is a world wide concern, as it causes regional brown clouds and contributes to global warming. Furthermore, sulphur and nitrogen oxides also cause acidification of soil and water which reducing the productivity of fisheries and agriculture. The combustion condition in small cooking fires and stoves are such that a significant amount of unburned hydrocarbons, including methane, is emitted to the atmosphere. These greenhouse gases are estimated to correspond to several percents of the world's total greenhouse gas emissions.



Source: UNDP, 2004

Figure 5-13: Emissions due to human activities by sector

Desertification in the Sahel and elsewhere in Sub-Saharan Africa has links to fuel demand. But it has been difficult to separate out the influence of all the relevant factors, including climate change, intensification of grazing, land use shifts, and fuel harvesting. Nevertheless, as with deforestation, there are some poor areas where harvesting of wood and brush plays an important role.

5.2.2. Commercial energy

Fossil fuel combustion is problematic on several levels. The main pollutants emitted in the combustion of fossil fuels are sulphur and nitrogen oxides, carbon mono- and dioxide and suspended particulates. Harmful ground level ozone is formed as a secondary pollutant from interactions between hydrocarbons, nitrogen oxides and sunlight.

Energy related emissions from fossil fuel combustion, including that of the transport sector, are major contributors to urban air pollution which is thought to be responsible for about 800,000 deaths annually around the world. Precursors of acid deposition from fuel combustion can be precipitated thousands of kilometres from their point of origin – often crossing national boundaries. The resulting acidification is causing significant damage to natural systems, crops, and human-made structures, and can over time alter the composition and function of entire ecosystems. In many regions, acidification has diminished the productivity of forests, fisheries and farmlands.

Fossil fuel combustion produces more carbon dioxide than any other human activity. Current CO_2 emissions trends, if not mitigated, will lead to more than a doubling of atmospheric concentrations before 2070, relative to pre-industrialisation levels. IPCC concludes in its Third Assessment Report that global mean surface temperature has increased by 0.6 degrees Celsius during the last two centuries due to human activities.

Other forms of energy supply pose problems as well. There is widespread concern about a range of issues associated with nuclear power, particularly its links to proliferation of nuclear weapons and the safe disposal of radioactive waste.

Table 5-12: Impacts of large dams

Insult caused by dam	Impact seen	Severity of impact	Example of impact
Changes in the thermal properties of release water	Thermal pollution often results in species diversity reduction, species extinction, and productivity changes in the reservoir.	Diversity, biomass, distribution, and density of fish stocks can be affected, disrupting breeding cycles.	Productivity levels in the surface waters of new reservoirs often increase before long-term decline occurs. China's Three Gorges Dam may be the final critical factor driving to extinction the Yangtze River Dolphin.
Changes in the chemical properties of release water	Deterioration of downstream ecosystem caused by inability to process the increased dissolved minerals	Depends on the sensitivity of the affected ecosystem (tropical ecosystems are especially sensitive)	Enhanced algae growth in the reservoir consumes the oxygen in the epilimnion and as it decays the mass sinks to the already oxygen deficient hypolimnion, where decay processes reduce the oxygen concentration even further, resulting in acid conditions at lower levels and the dissolution of minerals from the reservoir bed.
Changes in the flow rate and timing of release water	Erosion increases downstream of dam. Settling of sediments in the reservoir causes high sediment loads to be picked up in the area immediately below the dam.	Erosion of natural riverbeds can disturb the nurseries and spawning of many aquatic organisms, disturbing theirs breeding cycles.	Changes in the downstream river morphology and ecosystem productivity.
Changes in the sediment load of the river	High trap efficiencies of dams prevent the natural processes of sediments and associated nutrients refreshing downstream soils.	Effects often noticed most severely in high-productivity areas downstream from the dam that no longer receives annual fertilization.	Before the Aswan High Dam was constructed, the Nile carried about 124 million tonnes of sediment to the sea each year, depositing nearly 10 million tonnes on the floodplain and the delta. Today 98 percent of the sediment remains behind the dam, resulting in a drop in soil productivity and depth, among other serious changes to Egypt's floodplain agriculture.
Changes in the dynamics of downstream riverbeds	Increased likelihood of lower water tables, which can create problems in areas near the dam where groundwater is a major source.	Reduced access to potable water is a huge problem in many developing countries.	Within nine years of the closure opening of the Hoover Dam, 110 million cubic metres of material had been washed away from the first 145 kilometres of riverbed below the dam.
Changes in the coastal area morphology	The loss of sediment in the rivers flowing through deltas and into the sea often results in a gradual process of delta and coastal degradation.	Financially expensive for many areas where there is a large population living near the coastal zone.	Over the past 80 years dams have reduced by four-fifths the sediment reaching the coast of southern California. This has reduced the beach cover at the base of cliffs along the shorelines, causing cliffs to collapse.

Source: UNDP, 2000

Large scale hydro power development can have adverse environmental impacts, and cause human displacement. Often, poor groups bear most of the burden. When a large hydro power plant is constructed it will typically be poor rural dwellers that are displaced or at increased risk from vector borne diseases, even if it is affluent urban dwellers and industrial consumers who receive the bulk of the electricity (SEI, 1999a). Table 5-12 presents an overview of the possible environmental implications caused by large dams.

5.2.3. Global climate change

Observed changes in the global climate have already affected many parts of the world. There have been changes in species distributions, population sizes, the timing of reproduction or migration events, and an increase in the frequency of pest and disease outbreaks. Many coral reefs have undergone major, although often partially reversible, bleaching episodes and polar ice caps have deceased in size.

In some regions in Africa the combination of regional climate change and anthropogenic stresses has led to decreased cereal crop production since 1970. Changes in fish populations have been linked to large scale climate oscillations, e.g., El-Nino events that have impacted fisheries off the coast of South America and Africa, and decadal oscillations in the Pacific have impacted fisheries off of the west coast of North America. Climate change is projected to disproportionally affect the world's poor, of which 70 percent live in rural areas and are directly dependant on soils, water and weather for their subsistence. Millions of people in West Africa experience almost annual famines related to declining precipitation in the Sahel region. Unusually frequent droughts and sudden floods in Eastern and Southern Africa affects farmers. Sea level rise in Bangladesh puts millions of people in lowlands at risks. In Asia temperature rise can reduce rice harvests, the world's most important staple food, by 15%.

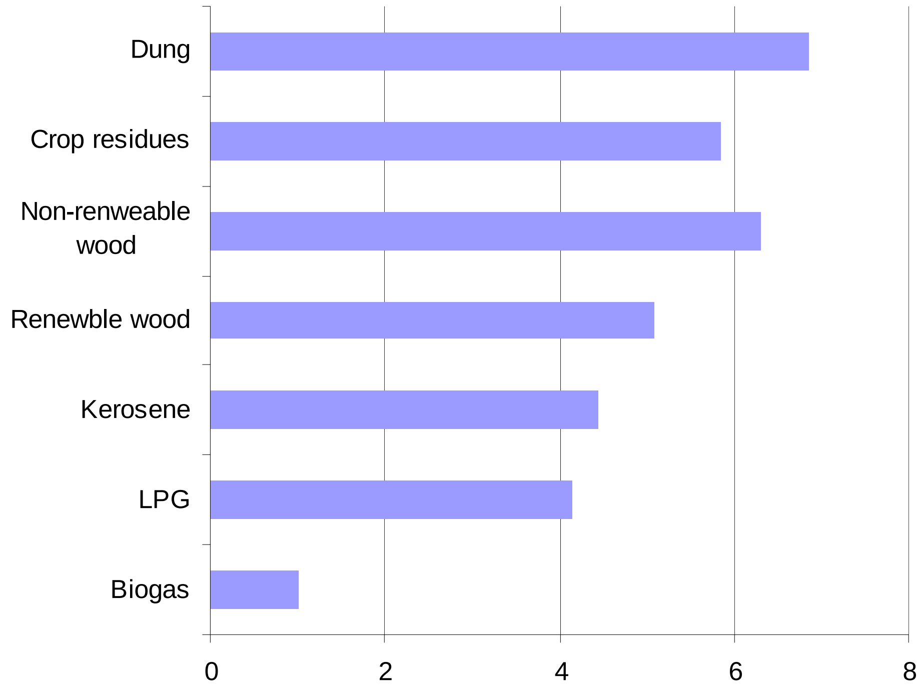


Figure 5-14: Grams of carbon per megajoule delivered (UNDP, 2000; Smith, 2000)

Greenhouse gas emissions from several of the most important household cooking fuels in developing countries as shown in Figure 5-14 (converted to carbon equivalents) below also contribute to climate change. Solid biomass fuels, even though renewable, can have larger greenhouse gas emissions per meal than fossil fuels because of significant emissions of non-carbon dioxide greenhouse gases. These relationships have several important policy implications:

- Even if renewably harvested, many biomass fuel cycles are not greenhouse gas neutral because of the substantial emission of incomplete combustion by-products. These other pollutants are not sequestered in the carbon cycle, like CO_2 is, and thus constitute a net contribution to climate change.

Substitution of biomass with fossil fuels can therefore be recommended to reduce net green house gas emissions in certain situations.

- In order for biomass fuel cycles to be greenhouse gas neutral, they must be renewably farmed and harvested, as well as have close to 100 percent combustion efficiency (which most small scale applications do not in their current configurations).

  Improved biomass stoves should thus be designed to reduce combustion inefficiency.

Stoves using biogas have by far the least net greenhouse gas emission per unit of useful energy, only about 10 percent of those for LPG. A complete comparison would however require evaluation of greenhouse gas emissions over the entire fuel cycle for example including methane leaking from biogas digesters and releases from oil refineries making kerosene.

5.3 Options for meeting growing energy demand

Although the scope of environmental problems related to energy systems may seem overwhelming, numerous strategies could simultaneously benefit the environment (at several levels), the economy, and human wellbeing. The projected impacts outlined in this study are based on a business as usual reference scenario. Fortunately, policy options and technological alternatives are available that can dramatically reduce the negative impacts from the energy sector. Realising sustainable futures will require much greater reliance on some combination of higher energy efficiencies, renewable resources and advanced energy technologies. A prerequisite for achieving an energy future compatible with sustainable development objectives is finding ways to accelerate progress for new technologies, from research and development to demonstration deployment and diffusion - a responsibility which lies heavily on developed countries.

Table 5-13: Selected near-, medium- and long-term energy supply options

Energy source or task	Present	Near term	Medium term	Long term
Fuel	Wood, charcoal, dung, crop residues	Natural gas, LPG, producer gas, biogas	Syngas, DME	Biomass-derived DME with electricity co-product
Source Electricity	Grid or no electricity	Natural gas combined cycles, biomass based generation using gasifiers coupled to internal combustion engines, photovoltaic, small wind, small hydroelectric for applications remote from grids	Biomass based generation using gasifiers coupled to micro-turbines and integrated gasifiers combined cycles, mini grids involving various combinations of photovoltaic, wind, small hydroelectric, batteries	Grid connected photovoltaic and solar thermal, biomass-based generation sing gasifiers coupled to fuel cells and fuel cell/turbine hybrids
Cogeneration (combined heat and power)		Internal combustion engines turbines	Micro turbines and integrated gasifiers combined cycles	Fuel cells, fuel cell/turbine hybrids
Task Cooking	Woodstoves	Improved woodstoves, LPG stoves, biogas	Producer gas, natural gas and DME stoves	Electric stoves, catalytic burners
Lighting	Oil and kerosene lamps	Electric lights	Fluorescent and compact fluorescent lams	Improved fluorescent and compact fluorescent lights
Motive power	Human- and animal powered devises	Internal combustion engines, electric motors	Bio-fuelled prime movers, improved motors	Fuel cells
Process heat	Wood, biomass	Electrical furnaces, cogeneration, producer gas, NG/solar thermal furnaces	Induction furnaces, biomass/solar thermal furnaces	Solar thermal furnaces with heat storage

Source: UNDP 2000

Meeting the MDG Energy Vision will include replacing solid fuels for cooking with gaseous or liquid fuels would have significant environmental benefits at the local community, regional and global scales, with added benefits for health and productivity (UNDP, 2004). There is a wide menu of different types of energy forms and technologies that can be used in the near, medium and long term to expand energy services in developing countries. Figure 5-13 presents options for an energy system that evolves from being based on a large share of non-renewable and traditional energy sources to one that is to a significant degree based on energy efficient technologies and modern renewable energy sources.

5.4 Conclusions and way forward

In light of the targets set up to achieve the MDGs, the implementation of the MDG Energy Vision is absolutely necessary, and a prerequisite for achieving the MDGs. Reaching the poor, their communities and social service institutions with basic levels of modern cooking technologies and fuels, electricity and mechanical power will have positive environmental impacts at the local, regional and global levels, even if fossil fuels are used to a large extent.

Strikingly, the primary energy requirements for implementation the MDG Energy Vision are small, almost negligible as compared to the projected global energy sector growth during the same period. Moreover, achieving the MDG Energy Vision will actually have positive environmental impacts at the local, regional and global levels, even if modern fossil fuels are used to a large extent. Reduced indoor air pollution would lead to a decrease in the estimated 1.6 million deaths per year from respiratory related diseases. A shift from low-efficiency traditional fuels will reduce the energy sector emissions of particulates; nitrogen oxides etc, and reduce greenhouse gas emissions, even if converting to petroleum based gaseous and liquid fuels.

In developing countries that have committed to the MDGs, there is a need to further integrate poverty reduction strategies with energy strategies. Developing countries can ill afford not to increase energy service access to the poor, as this will make it harder to reach the MDG targets. On the national level, this means that energy sector planning will have to include strong components on social factors such as valuation of energy poverty and energy access, environmental factors such as emission impacts on humans and ecosystems. Furthermore, a redirection of parts of energy sector investments into effective measures to reduce energy poverty will mean that new actors will have to be empowered to take an active part in energy sector planning.

On the global level there are adverse environmental impacts of the increasing energy consumption world wide due to growing economies and rising affluence, including pollution and climate change. These impacts are likely to have serious negative consequences on the ability of the poor to move out of poverty. Climate change in particular threatens to disrupt the food production systems, and the poor are also the most vulnerable to adverse climatic effects such as floods and hurricanes. Achieving the Millennium Development Goals – and addressing poverty generally – is thus a truly global responsibility, as the environmental impacts of the energy sector is mainly caused by activities carried out by and for the more affluent shares of the world's population.

In developed countries committed to support the MDGs and a global transition to a sustainable energy sector, there is a need for focused research and investments into energy efficiency and development and dissemination of renewable energy technologies. Even though this will be done from a national or regional perspective based on trade/export competitiveness, agricultural sector support and environmental benefits it will also benefit developing countries as primary energy demand will shift from fossil based fuels to renewable fuels, and technologies will become widely available.

Thankfully, the impacts of the foreseen global energy sector expansion are not inevitable. The projected impacts reported in this study have been based on a "business-as-usual" reference case, but – as amply demonstrated by major studies (IPCC SRES, 2001; IEA, 2004) – policy options and technological alternatives are available to us that can dramatically reduce the impacts from the energy sector. Transitioning to a more sustainable energy system globally is not only necessary for attaining global poverty reduction goals, but it is also possible.

Briefly, processes already happening will have to be strengthened and accelerated in order to reach the MDG energy targets on time, while at the same making a global energy transition.

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6. Key Messages and Recommendations

6.1 Key messages

Water and Food

The main messages from the Water and Food sub-study are:

- Attaining the MDG Hunger Goal in pace with population growth will require very considerable and so far underestimated new freshwater allocations.

An estimated 1940 km^3/year of additional freshwater, a volume larger than current global water use in irrigation, will have to be mobilised in rainfed agriculture to reach the MDG Hunger Target 2015. There is a very worrying lack of understanding of the freshwater requirements and water investment needs to attain the MDG to eradicate hunger and the target of halving the proportion of undernourished by 2015. This study indicates that a 50 % increase in freshwater use will be required over the coming decade. In countries experiencing rapid population growth and which face a large under-nourishment challenge, such as India, Kenya and Nigeria, the required increase reaches 100 % until 2015.

- Freshwater is a key prerequisite to attain the MDG on hunger, which is fundamental also for poverty alleviation. New investments are needed in small-holder rainfed farming, which will have to bare the heaviest burden in achieving the hunger target.

Both irrigation and rainfed agriculture will have to make major contributions to the hunger goal. However, irrigation will only be able to contribute up to 15 % of freshwater requirements by 2015. The remaining 85 % will have to come from investments in upgrading rainfed agriculture.

- The MDG 2015 Target on hunger addresses less than half of the challenge.
- Eradicating under-nourishment by 2030 and feeding growing populations will require massive additional volumes of freshwater. An additional 3000 km^3/year, compared with 2005, is required, even after crop per drop improvements, in order to eradicate hunger by 2030.
- Crop per drop improvements, where investments in integrated land, water and crop management improves yield levels in farmers' fields, can result in important water savings.

We estimate that no less than 350 km^3/year, corresponding to 6 Aswan dams, can be saved per year by 2015 through crop per drop improvements, leaving 1600 km^3/year of remaining freshwater for hunger reduction.

As shown in this study, the hunger goal is intimately linked with freshwater management. Freshwater sustains all terrestrial and aquatic ecosystems, which generate key ecosystem services for environmental sustainability.

- We believe that up to 1000 km^3/year of the remaining 1600 km^3 of required water for food, might be captured on current agricultural land, by adopting improved rainwater management. This is a major reduction in encroachment of agricultural land on natural ecosystems, achieved by investing in agricultural water management.

In the past, the solution has been to expand agriculture into new land, resulting in disastrous degradation of natural ecosystems, through deforestation and land conversion. This trend needs to change, which will require better use of local rainfall through sustainable water resource management strategies on small farms and watersheds.

- There is an urgent need for agricultural and water policies that promote improved rainwater management, both in-situ systems for rainfall infiltration and water harvesting systems that add new water through supplemental irrigation.

Technologies, and approaches for adaptive management and adoption of appropriate management practices are available. Key to success is investments in capacity building, diversification of production, and putting in place conducive policies that promote water management in rainfed farming.

- The hunger goal is closely linked to MDG 7 on environmental sustainability. Producing more food to halve hunger will result in trade-off decisions with freshwater and land supporting ecosystems.

An increase of 1000 km^3/year of freshwater use on current agricultural land, would result in serious downstream trade-offs with aquatic ecosystems and human use of water in urban coastal areas. The remaining unaccounted 600 km^3/year will have to come from expansion of agricultural land, and corresponds in a first approximation to 1.2 million km^2 of new agricultural land by 2015, or an increase of agricultural land by 4 %.

Sustainable Sanitation

Translating the sanitation goal into real numbers of installations by calculating the number of target households reveals that about 95,000 households per day need to be provided sanitation services or about 65 per minute. In total this means 193 million rural and 256 million urban households by year 2015.

In light of this, the main messages from the Sanitation sub-study are:

- The task at hand is affordable if appropriate solutions are chosen.

Although the MDG target to 2015 for improved sanitation services is mammoth in size (1.75 billion people), the real challenge however is one of building capacity to provide such services especially in the urban areas of the developing world which are growing much faster than the rural areas. Strategies for providing sanitation services to urban areas cannot be the same for those for rural areas. The urban MDG for sanitation will most probably not be reached unless significant innovation is introduced. On the other hand rural sanitation could be put on a faster track than is required by the MDGs because it is both doable with local capacity and equipment and relatively affordable.

- Sustainable sanitation is a central required component if the MDGs are to provide resilient health and environmental protection on a long-lasting basis.

We see a need to instil an urgently needed paradigm shift in order to better protect drinking water resources and human health and to promote the recycling of nutrients.

- Major improvements are required in the institutional and legislative arenas and general public awareness.

This means information and educational programmes, introduction of new policies and regulations and capacity building and training of professionals. It is these areas that should receive significant bi- and multi-lateral assistance in order to mainstream and fast-track sustainable sanitation practices during the next decade.

- Ecological sanitation (ecosan) should be included in the choices made available within the national MDG action plans.
- With relatively small investments, there are several ways to improve present and future sanitation systems by making small changes to present technology, making use of soil-composting and urine diversion and by adapting technology to dry areas, high water tables, flooding zones and rocky areas.

Ecosan provides new opportunities to rural, peri-urban and urban communities that want to install locally appropriate, gender sensitive and affordable sanitation systems. Ecological sanitation has the added advantage of being able to recycle water and nutrients using affordable onsite or decentralised treatment facilities. It can replace a significant proportion of the chemical fertilizer being used for domestic agriculture (the entire requirement for Sub-Sahara Africa).

Energy and the Environment

The main messages from the Energy sub-study are:

- Widened access to basic modern and clean energy services are necessary if the MDGs are to be achieved.

Access to modern forms of energy affects all aspects of development - social, economic, and environmental - including livelihoods, access to water, agricultural productivity, health, population levels, education, and gender-related issues. It is key to providing income generating activities. Opportunities for income generating activities among the about one billion people living on less than USD 1/day are critical to poverty reduction.

In light of the targets set up to achieve the MDGs, it is absolutely necessary to significantly reduce the number of people reliant on traditional biomass fuels for cooking and heating, to provide access to basic electricity services for urban populations and social service institutions with electricity and facilitating access to mechanical power in communities. Among others, this will allow for income generating activities that will contribute significantly to attaining the MDGs.

- Primary energy requirements to achieve basic levels of energy services compatible with MDG achievement are almost negligible in comparison to the global energy consumption.
- In the short and medium term, increased access to energy services compatible with MDG achievement will reduce local and global environmental impacts even if petroleum based fuels are used.

Reaching the poor, their communities and social service institutions with basic levels of gaseous and liquid cooking fuels, electricity and mechanical power will have positive environmental impacts at the local, regional and global levels, even if modern fossil fuels are used to a large extent. Reduced indoor air pollution would lead to a significant decrease in the estimated 1.6 million deaths per year from respiratory related diseases. Because of incomplete combustion, a shift from low-efficiency traditional fuels will reduce the energy sector emissions of particulates; nitrogen oxides etc, and reduce greenhouse gas emissions, even if converting to petroleum based gaseous and liquid fuels.

- Adverse environmental impacts from global unsustainable energy consumption threatens the ability of the poor to move out of poverty.

On a global level, adverse environmental impacts from unsustainable energy consumption threatens the ability of the poor to move out of poverty. Shifting to a sustainable global energy system is thus a truly global responsibility, as climate change is mainly caused by activities carried out by and for the affluent shares of the world's population.

6.2 Main recommendations

Water and Food

The main recommendations from the Water and Food sub-study are:

- The Millennium Development Goals can only be achieved through major investments in freshwater management for food production.

These investments need to be consolidated in the sector of current focus – irrigation development, and widen into innovative new investments in freshwater management to upgrade rainfed agriculture.

- New agricultural and water policies, institutional development and capacity building are urgently needed.

MDG countries have to embark on an immediate path towards sustainable and significant upgrading of rainfed agriculture which will require massive volumes of freshwater, in a sector that will have to carry 85 % of the water for food load the coming 10 years

- It is critical that country plans of action to attain the MDGs incorporate planning and management strategies to deal with trade-offs between freshwater to sustain food, humans and ecosystems.

This is a prerequisite in order to attain MDG 7, where, as shown by the Millennium Ecosystem Assessment, agricultural expansion is one of the key drivers between degradation of ecosystem services.

- There is an immediate need to realise the strong freshwater links between different millennium development goals: particularly MDG 1, poverty and hunger, and MDG 7, environmental sustainability.

Large increases in freshwater use for food, will result in unprecedented trade-off decisions between freshwater to support terrestrial ecosystems and between water for food and downstream needs of water for fish, wetlands and cities.

A particular focus is required in an area which so far has received very little attention, namely the large green water flows required to sustain terrestrial ecosystems, which generate key ecosystem services, e.g., biodiversity, and biomass growth in forests and grasslands

Sustainable Sanitation

The main recommendations from the Sanitation sub-study are:

- Sanitation should be integrated into the water, agricultural and energy systems that communities are built on in order to achieve sustainability and resilience.

Educational and awareness-raising programmes, introduction of new policies and regulations and capacity building and training of professionals should receive significant bi- and multi-lateral assistance in order to mainstream and fast-track sustainable sanitation practices during the next decade.

- Ecological sanitation should be included in the national MDG action plans.

Ecological sanitation provides new opportunities to provide affordable, resilient and sustainable sanitation solutions to rural, peri-urban and urban communities.

- To meet the urban sanitation MDG goals, innovation is required at several levels including technology development, policy and institutional capacity and general public awareness.

Major efforts are required to inject new thinking into how urban communities should deal with sanitation, including decentralised treatment systems and urban ecostations to collect, treat and recycle source-separated fractions eg urine, faeces, kitchen organics and greywater.

- Rural sanitation could be put on a faster track than is envisioned by the MDGs because it is both doable with local capacity and equipment and relatively affordable.

Energy and the Environment

The main recommendations from the Energy sub-study are:

- Investments in accelerated delivery of energy services to the poor is urgently needed, along with strengthening of institutions to absorb and make use of investments compatible with MDG achievement, is urgently needed.

Increasing the poor’s access to basic energy services (clean fuels for cooking, urban electrification, electrification of social service institutions and mechanical power in communities) will require a substantially accelerated delivery of energy services to the poor people of the world, yet developing countries can ill afford not to increase energy service access to the poor, as this will make it harder, or even impossible, to reach the MDG targets.

On the national level, this means that energy sector planning will have to include strong components on social factors such as valuation of energy poverty and energy access, environmental factors such as emission impacts on humans and ecosystems. Furthermore, a redirection of parts of energy sector investments into effective measures to reduce energy poverty will mean that new actors will have to be empowered to take an active part in energy sector planning.

- Adoption of energy efficiency measures and reduced emissions globally are important not to jeopardise achievement of the MDGs.

While expanding and widening energy service access it is crucial to increase energy efficiency world wide. In light of the negligible increase in global energy supply needed to meet the MDGs, the by far most effective way to address negative global climate change effects on the poor will be interventions where the large emissions occur. This requires a fundamental global change in how we supply and use energy, primarily in developed countries, in order to have enough resources and not risk negative environmental impacts that will undermine the chances of living sustainably on this planet.

There is a need for focused research and investments into energy efficiency and development and dissemination of renewable energy technologies. Even though this will be done from a national or regional perspective based on trade/export competitiveness, agricultural sector support and environmental benefits it will also benefit developing countries as primary energy demand will shift from fossil based fuels to renewable fuels, and technologies will become widely available.

Follow-up Research

- Establish and implement a comprehensive framework for continuous monitoring and analyses of environmental dimensions of the MDG process.
- Continue the presently reported work, possibly adding analytical work on national, regional (possibly Sub-Saharan Africa) and global level, possibly within the air quality, biotechnology, climate change, chemicals, energy, sanitation and water sectors, all with a focus to analyse and demonstrate the feasibility of using sustainable solutions in MDG implementation. .
- As a policy support tool for MDG implementation 2005-2015, develop a scenarios framework to enable forward looking analyses of alternative solutions, approaches and technologies to attain the MDGs and provide concrete outputs that facilitate decision making at a national level for how the MDG targets can be met while minimising the negative environmental impacts. This set of activities would also address MDG 8: Partnerships.

7. Appendices

7.1 Appendices to the Water and Food Chapter

Regions: EA = East Asia, EURA = Eurasia, LAC = Latin America and the Caribbean, NAC = North Africa, OC = Oceania, SA = South Asia, SEA = South-East Asia, SSAF = Sub-Saharan Africa, WA = West Asia
(The water requirement for food production is based upon present productivity and after productivity increases)

Region	Country	Target population increase that need full nourishment 2002-2015	Target population that need upgraded diet 2002-2015	Water requirement 2002 (km^3/yr)	Water requirement Hunger Goal 2015 Target (km^3/yr)	% Increase 2002-2015	Water requirement 2030 (km^3/yr)
EA	China	108,397,000	77,469,030	1,729.72	1,836.86	6.2%	1971.16
EA	D.P.R. Korea	1,165,000	1,526,025	12.80	26.37	106.1%	32.82
EA	Mongolia	492,000	251,023	3.97	5.85	47.3%	7.23
LAC	Argentina	5,469,000	244,896	64.14	73.22	14.2%	82.30
LAC	Bolivia	2,186,000	392,483	7.52	13.25	76.2%	17.44
LAC	Brazil	25,713,000	6,163,227	249.52	273.81	9.7%	309.28
LAC	Chile	2,406,000	360,609	20.40	24.22	18.7%	27.80
LAC	Colombia	8,664,000	1,647,692	43.55	65.63	50.7%	79.95
LAC	Costa Rica	936,000	37,435	5.16	6.53	26.6%	7.73
LAC	Cuba	254,000	377,253	12.05	14.82	23.0%	14.90
LAC	Dominican Rep.	1,505,000	571,039	7.51	12.37	64.6%	14.84
LAC	Ecuador	2,345,000	239,678	14.66	19.54	33.3%	22.78
LAC	El Salvador	1,145,000	165,519	5.82	9.62	65.3%	11.57
LAC	Guatemala	4,161,000	137,681	8.02	19.81	147.1%	27.60
LAC	Guyana	0	73,423	0.80	0.95	19.1%	0.91
LAC	Haiti	1,476,000	1,422,627	4.65	9.30	99.8%	14.58
LAC	Honduras	1,981,000	143,569	5.85	10.83	85.0%	14.08
LAC	Jamaica	350,000	127,402	2.61	3.77	44.6%	4.44
LAC	Mexico	17,653,000	1,364,238	138.15	155.28	12.4%	175.54
LAC	Nicaragua	1,692,000	124,069	3.46	7.86	127.1%	11.73
LAC	Panama	726,000	119,895	3.40	5.29	55.9%	6.61
LAC	Paraguay	1,913,000	92,530	6.85	10.27	49.8%	13.81
LAC	Peru	5,198,000	2,588,162	24.05	37.20	54.7%	48.84
LAC	Suriname	39,000	22,522	0.40	0.60	48.7%	0.64
LAC	Uruguay	292,000	83,497	5.39	6.12	13.6%	6.67
LAC	Venezuela	5,963,000	499,862	23.89	39.87	66.9%	48.61
NAF	Algeria	6,876,000	340,070	29.22	49.24	68.5%	57.97
NAF	Egypt	19,489,000	516,720	65.91	108.65	64.8%	143.37
NAF	Libya	1,441,000	6,653	5.70	9.03	58.4%	10.67
NAF	Morocco	6,424,000	406,784	25.73	43.86	70.5%	55.85
NAF	Tunisia	1,388,000	23,599	10.05	14.57	45.0%	16.23
SEA	Cambodia	4,611,000	373,134	8.54	20.73	142.7%	30.95
SEA	Indonesia	33,297,000	5,307,805	149.86	266.86	78.1%	364.72
SEA	Laos	1,753,000	174,833	3.49	7.97	128.5%	12.20
SEA	Malaysia	5,598,000	98,782	28.57	38.59	35.1%	46.24
SEA	Myanmar	6,910,000	1,283,138	34.93	60.22	72.4%	80.56
SEA	Philippines	17,758,000	3,720,651	71.52	118.31	65.4%	149.53
SEA	Thailand	7,392,000	5,615,105	51.45	84.28	63.8%	99.11
SEA	Vietnam	14,464,000	6,138,887	69.34	113.77	64.1%	142.40
SA	Bangladesh	37,619,000	7,476,637	70.35	168.99	140.2%	289.50
SA	India	196,802,000	60,017,134	724.93	1,411.36	94.7%	1861.38
SA	Iran	13,352,000	617,275	63.75	104.23	63.5%	124.10
SA	Nepal	7,402,000	620,626	16.04	35.43	120.8%	53.53
SA	Pakistan	54,554,000	2,815,893	150.02	253.45	68.9%	356.88
SA	Sri Lanka	1,730,000	1,882,146	12.31	22.67	84.2%	28.47
SSAF	Angola	6,084,000	0	7.99	19.96	149.7%	37.56
SSAF	Benin	2,535,000	52,184	3.99	9.36	134.6%	15.89

Water requirement 2050 (km³/yr)	Water requirement Hunger Goal 2015 - after productivity increases (km³/yr)	% Increase 2002-2015	Water requirement 2030 after productivity increases (km³/yr)	Water requirement 2050 after productivity increases (km³/yr)	Blue Water contribution 2002 (km³/yr)	Green Water contribution 2002 (km³/yr)	Blue Water contribution 2015 (km³/yr)	Green Water contribution 2015 (km³/yr)
1897.34	1,739.32	0.6%	1,709.47	1,443.94	298.80	1,430.93	323.67	1,415.65
32.81	24.97	95.1%	28.46	24.97	3.47	9.33	3.65	21.32
7.81	5.54	39.5%	6.27	5.94	0.16	3.81	0.19	5.35
89.40	69.33	8.1%	71.38	68.04	15.06	49.07	17.23	52.10
20.69	12.54	66.8%	15.13	15.75	0.81	6.71	1.02	11.53
324.69	259.27	3.9%	268.22	247.10	25.64	223.88	29.38	229.88
29.85	22.93	12.4%	24.11	22.71	5.58	14.82	6.44	16.49
88.68	62.15	42.7%	69.33	67.49	3.44	40.10	4.13	58.02
8.57	6.19	19.8%	6.70	6.52	1.00	4.16	1.23	4.96
13.24	14.03	16.4%	12.92	10.07	3.95	8.10	4.04	10.00
15.61	11.71	55.9%	12.87	11.88	1.57	5.94	1.84	9.87
24.60	18.50	26.2%	19.75	18.72	9.77	4.88	11.56	6.94
12.87	9.11	56.5%	10.03	9.79	0.53	5.29	0.63	8.48
34.38	18.75	134.0%	23.93	26.17	1.13	6.89	1.52	17.24
0.67	0.90	12.8%	0.79	0.51	1.12	0.00	1.12	-0.22
16.33	8.81	89.2%	12.64	12.43	0.65	4.00	0.77	8.04
16.60	10.25	75.2%	12.21	12.63	0.48	5.37	0.62	9.63
4.82	3.57	36.9%	3.85	3.67	0.14	2.47	0.16	3.41
184.26	147.03	6.4%	152.23	140.23	42.24	95.91	49.55	97.48
14.28	7.44	115.0%	10.18	10.87	0.76	2.71	1.00	6.45
7.52	5.01	47.6%	5.73	5.72	0.16	3.23	0.20	4.81
16.91	9.72	41.9%	11.97	12.87	0.25	6.61	0.33	9.40
54.01	35.22	46.4%	42.36	41.11	11.49	12.56	13.73	21.50
0.60	0.56	40.8%	0.56	0.46	0.43	0.00	0.47	0.09
6.96	5.80	7.6%	5.79	5.30	2.12	3.27	2.30	3.49
54.84	37.75	58.0%	42.15	41.73	2.78	21.11	3.44	34.32
63.95	46.62	59.5%	50.28	48.67	2.76	26.47	3.36	43.26
167.41	102.88	56.1%	124.34	127.41	41.30	24.61	52.72	50.16
12.15	8.55	49.9%	9.26	9.25	2.48	3.22	3.14	5.41
61.84	41.53	61.4%	48.44	47.06	7.71	18.02	9.35	32.18
16.93	13.80	37.3%	14.07	12.89	1.52	8.54	1.73	12.06
38.85	19.63	129.8%	26.84	29.57	2.80	5.74	3.73	15.89
386.05	252.69	68.6%	316.30	293.80	52.92	96.94	61.04	191.66
15.04	7.54	116.3%	10.58	11.45	1.89	1.60	2.49	5.06
51.97	36.54	27.9%	40.10	39.55	3.92	24.65	4.84	31.71
84.74	57.02	63.2%	69.86	64.49	22.85	12.08	26.08	30.94
166.83	112.03	56.6%	129.68	126.97	14.77	56.75	18.11	93.92
101.28	79.80	55.1%	85.95	77.08	57.93	0.00	64.81	14.99
154.65	107.73	55.4%	123.50	117.69	34.03	35.30	40.17	67.56
334.54	160.02	127.5%	251.07	254.60	53.45	16.90	67.43	92.59
2012.31	1,336.41	84.4%	1,614.27	1,531.44	390.87	334.06	464.17	872.25
138.61	98.70	54.8%	107.62	105.49	46.36	17.39	55.45	43.24
66.76	33.54	109.1%	46.43	50.81	6.87	9.17	8.94	24.60
458.19	239.99	60.0%	309.50	348.70	113.86	36.16	155.29	84.70
27.82	21.47	74.4%	24.69	21.17	8.40	3.91	9.17	12.30
56.67	18.90	136.4%	32.58	43.13	0.15	7.85	0.21	18.68
20.50	8.86	122.1%	13.78	15.60	0.04	3.95	0.06	8.81

Region	Country	Target population increase that need full nourishment 2002-2015	Target population that need upgraded diet 2002-2015	Water requirement 2002 (km^3/yr)	Water requirement Hunger Goal 2015 Target (km^3/yr)	% Increase 2002-2015	Water requirement 2030 (km^3/yr)
SSAF	Botswana	0	123,373	1.57	2.13	35.3%	2.05
SSAF	Burkina Faso	5,938,000	0	7.51	19.22	155.9%	36.67
SSAF	Burundi	3,232,000	381,919	2.27	8.40	269.6%	17.94
SSAF	Cameroon	3,131,000	861,248	9.13	19.42	112.7%	28.59
SSAF	Central African Rep.	767,000	360,233	2.34	5.12	118.8%	7.19
SSAF	Chad	3,790,000	0	4.71	11.80	150.3%	23.29
SSAF	Congo	1,582,000	0	2.05	5.06	147.3%	9.93
SSAF	Cote d'Ivoire	3,472,000	528,078	10.10	20.35	101.6%	30.56
SSAF	D.R. Congo	22,959,000	524,802	17.25	67.61	291.9%	140.58
SSAF	Eritrea	1,923,000	0	1.52	5.44	257.5%	10.44
SSAF	Ethiopia	24,884,000	0	31.40	84.66	169.6%	167.17
SSAF	Gabon	339,000	15,965	1.19	2.10	77.2%	2.69
SSAF	Gambia	463,000	9,899	0.80	1.98	146.6%	3.07
SSAF	Ghana	5,888,000	930,413	13.14	25.76	96.1%	42.90
SSAF	Guinea	2,874,000	283,220	4.60	10.52	128.7%	19.61
SSAF	Kenya	5,324,000	2,598,353	22.08	42.43	92.2%	54.06
SSAF	Lesotho	0	125,527	1.13	1.78	57.4%	2.04
SSAF	Liberia	1,474,000	0	1.35	4.37	223.4%	8.97
SSAF	Madagascar	7,084,000	104,250	10.29	27.78	170.0%	43.97
SSAF	Malawi	3,294,000	1,045,650	5.56	13.18	137.1%	26.06
SSAF	Mali	6,363,000	0	8.37	22.52	169.2%	38.86
SSAF	Mauritania	1,181,000	12,994	3.16	5.05	59.9%	7.20
SSAF	Mauritius	130,000	24,943	1.30	1.73	32.7%	1.89
SSAF	Mozambique	4,000,000	1,692,753	8.14	17.98	120.8%	34.98
SSAF	Namibia	235,000	124,941	1.72	2.64	52.8%	3.18
SSAF	Niger	6,773,000	0	6.09	17.99	195.6%	39.86
SSAF	Nigeria	40,815,000	1,033,545	73.50	162.96	121.7%	271.60
SSAF	Rwanda	2,293,000	526,578	3.79	9.49	150.6%	17.68
SSAF	Senegal	3,304,000	224,894	6.70	15.64	133.3%	22.24
SSAF	Sierra Leone	1,635,000	411,042	2.14	5.88	175.4%	10.78
SSAF	Sudan	8,552,000	1,508,140	32.42	51.24	58.1%	67.08
SSAF	Swaziland	6,000	46,642	0.88	1.36	54.8%	1.34
SSAF	Togo	1,550,000	119,550	2.54	6.03	136.8%	10.67
SSAF	Uganda	14,331,000	0	15.76	42.59	170.2%	84.03
SSAF	U. Rep. Tanzania	9,633,000	1,483,280	18.85	47.72	153.1%	74.77
SSAF	Zambia	1,972,000	1,002,477	5.05	12.05	138.5%	20.00
SSAF	Zimbabwe	196,000	1,925,737	7.01	13.77	96.4%	16.78
WA	Jordan	1,653,000	0	4.27	8.85	107.2%	11.36
WA	Kuwait	909,000	93,175	2.98	4.17	39.9%	5.52
WA	Lebanon	611,000	16,648	4.59	5.49	19.6%	6.17
WA	Saudi Arabia	9,208,000	31,109	23.93	42.52	77.7%	56.76
WA	Syria	5,637,000	81,306	18.80	29.83	58.6%	37.78
WA	Turkey	11,832,000	290,897	71.67	105.79	47.6%	120.78
WA	U.A.E.	651,000	15,087	4.46	5.02	12.6%	5.73
WA	Yemen	11,362,000	0	10.72	32.99	207.7%	66.47

	Regional Totals						
EA	East Asia	110,054,000	79,246,078	1,746	1,869	7.0%	2,011
LAC	Latin America & Carribbean	92,067,000	16,999,309	658	820	24.7%	963
NAF	North Africa	35,618,000	1,293,826	137	225	65.0%	284
SEA	South-east Asia	91,783,000	22,712,334	418	711	70.2%	926
SA	Southern Asia	311,459,000	73,429,710	1,037	1,996	92.4%	2,714
SSAF	sub-Saharan Africa	210,006,000	18,082,631	359	845	135.1%	1,454
WA	West Asia	41,863,000	528,221	141	235	65.9%	311
	TOTALS	892,850,000	212,292,110	4,497	6,701	49.0%	8,662

Water requirement 2050 (km^3/yr)	Water requirement Hunger Goal 2015 - after productivity increases (km^3/yr)	% Increase 2002-2015	Water requirement 2030 after productivity increases (km^3/yr)	Water requirement 2050 after productivity increases (km^3/yr)	Blue Water contribution 2002 (km^3/yr)	Green Water contribution 2002 (km^3/yr)	Blue Water contribution 2015 (km^3/yr)	Green Water contribution 2015 (km^3/yr)
1.81	2.02	28.1%	1.78	1.38	0.06	1.52	0.05	1.96
55.68	18.20	142.3%	31.80	42.37	0.48	7.03	0.71	17.49
25.57	7.95	250.0%	15.56	19.46	0.16	2.12	0.23	7.72
32.78	18.39	101.4%	24.80	24.95	0.51	8.62	0.61	17.78
8.62	4.85	107.2%	6.24	6.56	0.00	2.34	0.00	4.85
33.32	11.17	137.0%	20.20	25.36	0.13	4.58	0.19	10.98
13.98	4.79	134.2%	8.61	10.64	0.00	2.04	0.00	4.79
36.23	19.27	90.9%	26.50	27.57	0.42	9.68	0.51	18.76
199.26	64.02	271.1%	121.92	151.64	0.08	17.18	0.11	63.91
13.85	5.15	238.6%	9.05	10.54	0.39	1.14	0.57	4.58
224.68	80.17	155.3%	144.97	170.99	3.64	27.76	4.96	75.21
3.27	1.99	67.8%	2.33	2.49	0.04	1.15	0.04	1.95
3.82	1.87	133.5%	2.66	2.91	0.01	0.79	0.02	1.85
51.97	24.39	85.7%	37.20	39.55	0.46	12.68	0.59	23.81
25.74	9.96	116.5%	17.00	19.59	0.95	3.65	1.28	8.68
57.79	40.18	82.0%	46.88	43.98	0.71	21.37	0.83	39.35
1.81	1.68	49.1%	1.77	1.38	0.01	1.12	0.01	1.68
12.90	4.13	206.2%	7.78	9.82	0.04	1.31	0.06	4.07
60.83	26.31	155.6%	38.13	46.29	10.02	0.27	14.21	12.09
34.10	12.48	124.5%	22.60	25.95	0.57	4.99	0.72	11.76
60.44	21.33	154.9%	33.70	46.00	4.13	4.24	6.21	15.11
9.85	4.78	51.4%	6.25	7.50	1.05	2.11	1.49	3.29
1.92	1.64	25.7%	1.64	1.46	0.34	0.96	0.38	1.26
41.10	17.03	109.1%	30.33	31.28	0.39	7.76	0.47	16.56
3.49	2.50	44.7%	2.76	2.65	0.15	1.58	0.17	2.33
69.69	17.03	179.9%	34.57	53.04	1.46	4.63	2.31	14.72
339.64	154.30	109.9%	235.54	258.48	3.86	69.65	5.16	149.14
22.30	8.98	137.3%	15.33	16.97	0.07	3.71	0.09	8.89
28.37	14.81	120.9%	19.29	21.59	1.45	5.26	1.93	12.88
13.59	5.57	160.8%	9.35	10.34	0.25	1.89	0.33	5.24
79.84	48.52	49.7%	58.17	60.76	25.25	7.17	31.82	16.71
1.25	1.29	46.6%	1.16	0.95	0.70	0.17	0.71	0.58
13.15	5.71	124.3%	9.25	10.01	0.05	2.49	0.07	5.64
135.67	40.33	155.9%	72.88	103.25	0.08	15.68	0.13	40.20
90.81	45.19	139.7%	64.84	69.11	3.24	15.61	4.10	41.08
24.35	11.41	125.8%	17.35	18.53	0.92	4.13	1.09	10.32
16.63	13.04	86.0%	14.56	12.66	2.32	4.69	2.36	10.68
13.34	8.38	96.2%	9.85	10.15	0.53	3.74	0.70	7.69
6.47	3.95	32.5%	4.78	4.93	0.16	2.82	0.22	3.73
6.50	5.20	13.3%	5.35	4.95	0.64	3.95	0.75	4.45
71.93	40.26	68.3%	49.22	54.74	10.79	13.13	15.02	25.24
44.90	28.24	50.2%	32.76	34.17	13.25	5.55	17.55	10.70
128.46	100.17	39.8%	104.75	97.76	19.50	52.17	22.78	77.39
5.80	4.75	6.6%	4.97	4.42	1.10	3.36	1.34	3.41
110.88	31.24	191.3%	57.64	84.39	4.42	6.30	7.03	24.21

1,938	1,770	1.3%	1,744	1,475	302	1,444	328	1,442
1,040	777	18.1%	835	792	131	527	153	624
322	213	56.2%	246	245	56	81	70	143
999	673	61.1%	803	761	191	227	221	452
3,038	1,890	82.2%	2,354	2,312	620	418	760	1,130
1,927	800	122.6%	1,261	1,467	65	295	85	715
388	222	57.1%	269	295	50	91	65	157
9,654	6,345	41.1%	7,512	7,347	1,415	3,082	1,682	4,663

7.2 Appendices to the Sustainable Sanitation Chapter

Regions: EA = East Asia, EURA = Eurasia, LAC = Latin America and the Caribbean, NAC = North Africa, OC = Oceania, SA = South Asia, SEA = South-East Asia, SSAF = Sub-Saharan Africa, WA = West Asia
(Source: JMP, 2004; FAOstat, 2005; SEI, 2005)

Region	Country	Urban Population 2002	Rural Population 2002	Urban Population 2015	Rural Population 2015	Urban Sanitation % 2002	Rural Sanitation % 2002
EA	China	494,215,000	808,094,000	702,738,000	707,967,000	69%	29%
EA	DPR Korea	13,699,000	8,842,000	15,586,000	8,120,000	58%	60%
EA	Mongolia	1,440,000	1,119,000	1,817,000	1,234,000	75%	37%
EA	Republic of Korea	37,871,000	9,559,000	41,236,000	8,436,000	69%	29%
EURA	Armenia	1,965,000	1,107,000	1,901,000	1,062,000	96%	61%
EURA	Azerbaijan	4,153,000	4,144,000	4,851,000	4,599,000	73%	36%
EURA	Belarus	6,994,000	2,946,000	7,088,000	2,339,000	92%	65%
EURA	Georgia	2,702,000	2,475,000	2,438,000	2,286,000	96%	69%
EURA	Kazakhstan	8,537,000	6,931,000	8,916,000	6,412,000	87%	52%
EURA	Kyrgyzstan	1,718,000	3,349,000	2,103,000	3,846,000	75%	51%
EURA	Moldova	1,948,000	2,322,000	2,104,000	2,102,000	86%	52%
EURA	Russian Federation	105,449,000	38,633,000	99,144,000	34,285,000	93%	70%
EURA	Tajikistan	1,539,000	4,656,000	1,770,000	5,482,000	71%	47%
EURA	Turkmenistan	2,164,000	2,630,000	2,911,000	2,909,000	77%	50%
EURA	Ukraine	32,783,000	16,118,000	30,575,000	13,793,000	100%	97%
EURA	Uzbekistan	9,474,000	16,231,000	11,379,000	19,339,000	73%	48%
LAC	Anguilla	12,000	0	14,000	0	99%	99%
LAC	Antigua & Barbuda	27,000	45,000	33,000	43,000	98%	94%
LAC	Argentina	34,154,000	3,826,000	40,053,000	3,397,000	87%	47%
LAC	Aruba	45,000	52,000	54,000	69,000	85%	44%
LAC	Bahamas	277,000	33,000	321,000	29,000	100%	100%
LAC	Barbados	138,000	132,000	165,000	114,000	99%	100%
LAC	Belize	121,000	130,000	163,000	152,000	71%	25%
LAC	Bolivia	5,434,000	3,211,000	7,475,000	3,357,000	58%	23%
LAC	Brazil	145,199,000	31,058,000	178,485,000	23,485,000	83%	35%
LAC	British Virgin Islands	13,000	8,000	18,000	7,000	100%	100%
LAC	Cayman Islands	39,000	0	55,000	0	85%	44%
LAC	Chile	13,529,000	2,084,000	16,250,000	1,769,000	96%	64%
LAC	Colombia	33,062,000	10,465,000	42,433,000	9,757,000	96%	54%
LAC	Costa Rica	2,465,000	1,630,000	3,363,000	1,668,000	89%	97%
LAC	Cuba	8,495,000	2,776,000	9,002,000	2,522,000	99%	95%
LAC	Dominica	56,000	22,000	61,000	19,000	86%	75%
LAC	Dominican Republic	5,082,000	3,534,000	6,541,000	3,579,000	67%	43%
LAC	Ecuador	7,846,000	4,964,000	10,237,000	4,918,000	80%	59%
LAC	El Salvador	3,828,000	2,587,000	4,854,000	2,705,000	78%	40%
LAC	Falkland Islands	3,000	1,000	3,000	0	85%	44%
LAC	French Guiana	131,000	43,000	178,000	52,000	85%	57%
LAC	Grenada	32,000	48,000	38,000	39,000	96%	97%
LAC	Guadeloupe	433,000	3,000	470,000	1,000	64%	61%
LAC	Guatemala	5,531,000	6,505,000	8,409,000	7,788,000	72%	52%
LAC	Guyana	284,000	480,000	337,000	425,000	86%	60%
LAC	Haiti	3,024,000	5,194,000	4,408,000	5,286,000	52%	23%
LAC	Honduras	3,065,000	3,716,000	4,492,000	4,269,000	89%	52%
LAC	Jamaica	1,369,000	1,258,000	1,614,000	1,364,000	90%	68%
LAC	Martinique	372,000	18,000	401,000	11,000	85%	44%
LAC	Mexico	76,655,000	25,310,000	94,240,000	25,378,000	90%	39%
LAC	Montserrat	0	3,000	1,000	3,000	96%	96%
LAC	Netherlands Antilles	152,000	67,000	176,000	65,000	85%	44%
LAC	Nicaragua	3,040,000	2,295,000	4,415,000	2,612,000	78%	51%
LAC	Panama	1,740,000	1,324,000	2,339,000	1,451,000	89%	51%
LAC	Paraguay	3,246,000	2,494,000	4,924,000	2,729,000	94%	58%
LAC	Peru	19,680,000	7,087,000	24,943,000	7,022,000	72%	33%

Urban Water % 2002	Rural Water % 2002	Urban Sanitation Target Population	Rural Sanitation Target Population	Urban Water Target Population	Rural Water Target Population	Urban Sanitation Target Households	Rural Sanitation Target Households	Urban Water Target Households	Rural Water Target Households
92%	68%	235,236,810	144,415,085	248,060,200	13,329,845	103,598,920	42,284,853	109,246,375	3,902,989
100%	100%	4,367,520	1,190,800	1,887,000	0	1,792,925	333,079	774,638	0
87%	30%	509,875	431,260	446,095	466,400	143,113	82,478	125,211	89,198
97%	71%	7,753,730	1,731,389	3,882,590	425,890	2,734,089	640,657	1,369,063	157,590
99%	80%	0	179,640	0	70,200	0	36,598	0	14,302
95%	59%	1,164,425	1,635,480	420,550	981,295	258,986	289,494	93,537	173,698
100%	100%	383,061	26,727	94,000	0	142,447	7,910	34,955	0
90%	61%	0	223,920	0	330,480	0	63,317	0	93,449
96%	72%	909,270	1,269,000	542,160	524,000	447,599	497,149	266,885	205,285
98%	66%	551,625	1,195,740	398,330	981,840	115,585	199,398	83,464	163,729
97%	88%	281,440	390,080	182,880	0	106,410	117,376	69,145	0
99%	88%	0	2,099,150	0	0	0	1,401,176	0	0
93%	47%	420,660	1,840,950	276,780	1,840,950	96,988	337,800	63,815	337,800
93%	54%	909,955	866,750	796,595	819,730	125,538	95,165	109,899	90,003
100%	94%	0	0	0	0	0	0	0	0
97%	84%	2,926,815	6,519,980	2,018,535	4,157,840	604,718	1,072,094	417,055	683,682
60%	60%	2,050	0	4,000	0	581	0	1,134	0
95%	89%	6,210	0	6,525	585	1,737	0	1,825	168
97%	73%	7,735,575	698,575	6,322,825	145,425	2,485,059	204,811	2,031,212	42,636
100%	100%	11,052	23,878	9,000	17,000	3,092	6,840	2,518	4,869
98%	86%	44,000	0	46,330	0	10,163	0	10,701	0
100%	100%	27,555	0	27,000	0	9,781	0	9,584	0
100%	82%	53,455	62,500	42,000	31,720	12,750	15,264	10,018	7,747
95%	68%	2,417,155	1,158,175	1,976,325	300,700	512,973	250,694	419,419	65,088
96%	58%	41,906,180	5,216,925	32,846,985	187,235	12,692,107	1,700,321	9,948,352	61,024
98%	98%	5,000	0	5,080	0	1,408	0	1,431	0
96%	70%	17,039	0	15,627	0	4,831	0	4,430	0
100%	59%	2,530,910	10,680	2,558,500	88,345	840,501	3,130	849,664	25,892
99%	71%	9,632,655	1,764,220	9,277,290	1,253,580	2,505,569	365,911	2,413,134	260,001
100%	92%	984,185	61,880	898,000	101,680	262,694	28,542	239,690	46,900
95%	78%	546,940	0	706,700	79,300	245,588	0	317,324	32,289
100%	90%	8,570	125	5,000	0	2,416	36	1,410	0
98%	85%	1,827,860	860,415	1,462,525	74,040	533,737	257,240	427,059	22,136
92%	77%	2,578,205	415,480	2,046,165	0	807,107	135,619	640,552	0
91%	68%	1,140,060	764,025	1,079,280	229,015	390,160	267,713	369,359	80,246
96%	70%	191	0	18	0	54	0	5	0
88%	71%	53,300	16,310	52,040	13,930	16,747	2,910	16,352	2,485
97%	93%	6,520	0	6,390	0	1,826	0	1,790	0
98%	93%	108,280	0	40,960	0	41,153	0	15,567	0
99%	92%	3,207,375	1,874,300	2,428,770	596,260	482,258	343,581	365,188	109,301
83%	83%	69,170	52,000	72,635	0	18,633	14,342	19,566	0
91%	59%	1,226,600	1,739,110	1,149,240	715,030	290,156	421,214	271,856	173,181
99%	82%	1,247,570	863,875	1,210,590	752,290	294,911	189,235	286,170	164,792
98%	87%	260,850	263,040	248,170	174,060	55,699	39,989	52,992	26,461
96%	70%	50,059	0	30,170	0	18,700	0	11,271	0
97%	72%	17,711,300	5,355,900	15,172,650	1,317,860	3,999,410	2,236,982	3,426,155	550,426
100%	100%	980	60	1,000	0	273	17	279	0
96%	70%	31,509	14,520	24,014	5,139	11,691	5,516	8,910	1,952
93%	65%	1,249,100	488,170	1,411,200	362,770	265,253	93,345	299,675	69,367
99%	79%	661,755	420,265	604,705	252,685	183,689	104,775	167,853	62,996
100%	62%	1,158,780	545,650	1,185,600	445,890	318,116	132,810	325,479	108,528
87%	66%	6,782,520	1,698,940	6,324,820	308,200	1,669,580	431,159	1,556,913	78,215

Region	Country	Urban Population 2002	Rural Population 2002	Urban Population 2015	Rural Population 2015	Urban Sanitation % 2002	Rural Sanitation % 2002
LAC	Puerto Rico	3,735,000	125,000	4,007,000	37,000	85%	44%
LAC	Saint Kitts & Nevis	14,000	28,000	13,000	27,000	96%	96%
LAC	Saint Lucia	44,000	104,000	59,000	102,000	89%	89%
LAC	Saint Vincent & Grenadines	68,000	51,000	87,000	40,000	96%	96%
LAC	Suriname	326,000	106,000	384,000	87,000	99%	76%
LAC	Trinidad & Tobago	974,000	324,000	1,070,000	272,000	100%	100%
LAC	Turks & Caicos Islands	9,000	11,000	16,000	14,000	98%	94%
LAC	U. S. Virgin Island	103,000	7,000	117,000	5,000	85%	44%
LAC	Uruguay	3,133,000	258,000	3,476,000	207,000	95%	85%
LAC	Venezuela	22,049,000	3,177,000	28,069,000	3,120,000	71%	48%
NAF	Algeria	18,194,000	13,072,000	24,913,000	13,229,000	99%	82%
NAF	Egypt	29,623,000	40,884,000	40,401,000	49,595,000	84%	56%
NAF	Libya	4,682,000	763,000	6,127,000	759,000	97%	96%
NAF	Morocco	17,069,000	13,003,000	23,640,000	12,856,000	83%	31%
NAF	Tunisia	6,151,000	3,578,000	7,571,000	3,545,000	90%	62%
NAF	Western Sahara	281,000	20,000	384,000	18,000	89%	57%
OC	American Samoa	54,000	6,000	75,000	5,000	84%	46%
OC	Cook Islands	12,000	6,000	15,000	3,000	100%	100%
OC	Fiji	424,000	406,000	552,000	366,000	99%	98%
OC	French Polynesia	126,000	115,000	153,000	134,000	99%	97%
OC	Guam	150,000	11,000	182,000	9,000	99%	98%
OC	Kiribati	40,000	47,000	63,000	39,000	59%	22%
OC	Marshall Islands	34,000	18,000	42,000	18,000	93%	59%
OC	Nauru	13,000	0	17,000	0	84%	46%
OC	New Caledonia	137,000	87,000	180,000	98,000	84%	46%
OC	Niue	1,000	1,000	1,000	1,000	100%	100%
OC	N. Mariana Islands	71,000	5,000	113,000	4,000	94%	96%
OC	Palau	14,000	6,000	18,000	8,000	96%	52%
OC	Papua New Guinea	739,000	4,848,000	1,038,000	6,131,000	67%	41%
OC	Samoa	39,000	137,000	50,000	153,000	100%	100%
OC	Solomon Islands	75,000	388,000	134,000	509,000	98%	18%
OC	Tokelau	0	2,000	0	2,000	74%	74%
OC	Tonga	34,000	69,000	44,000	71,000	98%	96%
OC	Tuvalu	6,000	5,000	8,000	4,000	92%	83%
OC	Vanuatu	47,000	160,000	79,000	196,000	78%	42%
SA	Afghanistan	5,205,000	17,725,000	10,831,000	24,641,000	16%	5%
SA	Bangladesh	34,352,000	109,456,000	53,619,000	127,809,000	75%	39%
SA	Bhutan	180,000	2,010,000	385,000	2,658,000	65%	70%
SA	India	294,846,000	754,703,000	401,898,000	844,452,000	58%	18%
SA	Iran	44,874,000	23,197,000	60,143,000	21,279,000	86%	78%
SA	Maldives	88,000	221,000	157,000	290,000	100%	42%
SA	Nepal	3,614,000	20,994,000	6,547,000	25,464,000	68%	20%
SA	Pakistan	50,549,000	99,362,000	80,858,000	123,607,000	92%	35%
SA	Sri Lanka	3,982,000	14,927,000	4,653,000	15,987,000	98%	89%
SEA	Brunei Darussalam	264,000	86,000	375,000	78,000	80%	49%
SEA	Cambodia	2,502,000	11,307,000	4,814,000	13,608,000	53%	8%
SEA	Indonesia	96,666,000	120,465,000	144,622,000	105,806,000	71%	38%
SEA	Laos	1,115,000	4,414,000	1,992,000	5,290,000	61%	14%
SEA	Malaysia	15,278,000	8,687,000	20,998,000	8,565,000	94%	98%
SEA	Myanmar	14,124,000	34,728,000	20,960,000	34,802,000	96%	63%
SEA	Philippines	47,315,000	31,265,000	66,658,000	29,680,000	81%	61%
SEA	Singapore	4,183,000	0	4,707,000	0	100%	100%
SEA	Thailand	19,630,000	42,564,000	25,571,000	44,014,000	97%	100%
SEA	Timor-Leste	53,000	686,000	101,000	959,000	65%	30%
SEA	Vietnam	20,276,000	60,003,000	30,732,000	64,011,000	84%	26%
SSAF	Angola	4,593,000	8,591,000	8,654,000	10,614,000	56%	16%
SSAF	Benin	2,872,000	3,687,000	4,860,000	4,233,000	58%	12%
SSAF	Botswana	899,000	871,000	985,000	727,000	57%	25%
SSAF	Burkina Faso	2,197,000	10,427,000	4,310,000	14,251,000	45%	5%
SSAF	Burundi	628,000	5,974,000	1,438,000	8,397,000	47%	35%
SSAF	Cameroon	7,963,000	7,766,000	11,295,000	7,565,000	63%	33%

Urban Water % 2002	Rural Water % 2002	Urban Sanitation Target Population	Rural Sanitation Target Population	Urban Water Target Population	Rural Water Target Population	Urban Sanitation Target Households	Rural Sanitation Target Households	Urban Water Target Households	Rural Water Target Households
99%	99%	0	0	0	0	0	0	0	0
98%	98%	16,595	3,830	15,290	0	4,664	1,102	4,297	0
93%	93%	19,980	0	20,715	0	5,622	0	5,829	0
98%	73%	59,340	0	60,680	0	16,181	0	16,546	0
92%	88%	96,000	0	136,470	0	25,273	0	35,927	0
100%	100%	7,020	3,240	7,000	3,000	1,903	899	1,897	833
96%	70%	19,292	300	14,096	0	5,464	87	3,992	0
98%	93%	412,750	0	370,900	0	136,286	0	122,468	0
85%	70%	8,344,205	783,840	7,222,175	428,100	2,104,944	216,359	1,821,896	118,166
92%	80%	6,776,375	922,480	8,049,955	2,242,240	1,313,702	162,980	1,560,605	396,149
100%	97%	9,457,530	12,317,410	10,171,985	7,953,720	2,618,951	2,145,898	2,816,796	1,385,670
72%	68%	1,493,555	11,340	1,898,180	118,720	228,167	1,374	289,981	14,389
99%	56%	7,936,130	4,196,910	6,032,490	2,874,560	1,643,966	792,302	1,249,628	542,666
94%	60%	1,845,825	387,215	1,524,075	636,025	474,110	82,724	391,467	135,879
96%	84%	103,666	1,837	105,645	0	21,737	351	22,152	0
91%	39%	23,330	920	22,877	1,151	3,374	1,082	3,309	1,354
98%	88%	3,000	0	3,165	0	756	0	798	0
91%	39%	129,480	0	144,198	97,166	29,696	0	33,072	21,344
100%	100%	27,495	20,440	27,000	19,000	10,743	2,017	10,549	1,875
100%	100%	32,590	0	32,000	0	4,642	0	4,558	0
77%	53%	18,295	13,255	24,640	1,025	5,357	980	7,214	76
80%	95%	7,860	2,970	13,750	630	2,119	202	3,706	43
91%	39%	4,649	0	4,494	0	972	0	940	0
91%	39%	49,767	32,238	48,169	34,475	12,330	9,343	11,934	9,992
100%	100%	0	0	0	0	0	0	0	0
98%	97%	37,785	0	42,290	0	8,108	0	9,075	0
79%	94%	2,040	3,040	4,330	2,320	554	208	1,176	159
88%	32%	371,600	2,334,675	325,400	2,495,100	210,779	334,426	184,574	357,406
91%	88%	11,000	14,470	14,260	24,025	6,329	2,103	8,205	3,491
94%	65%	59,160	230,470	59,480	167,725	26,590	26,159	26,734	19,037
89%	89%	0	0	0	180	0	0	0	38
100%	100%	10,240	3,340	10,000	2,000	1,550	818	1,513	490
94%	92%	1,800	0	2,040	0	501	0	568	0
85%	52%	33,650	71,960	36,285	66,740	12,832	6,930	13,837	6,427
19%	11%	5,449,180	12,050,275	5,455,495	11,726,005	1,139,266	2,305,535	1,140,587	2,243,493
82%	72%	20,080,245	28,246,155	20,892,745	28,551,240	4,073,960	5,244,302	4,238,803	5,300,945
86%	60%	200,625	852,300	203,250	920,400	41,800	162,503	42,347	175,488
96%	82%	116,346,390	290,601,720	94,731,960	60,927,400	24,264,975	58,024,861	19,757,112	12,165,461
98%	83%	17,341,350	844,650	15,565,050	216,775	5,294,845	226,514	4,752,486	58,134
99%	78%	69,000	113,080	69,880	116,170	7,656	18,942	7,754	19,460
93%	82%	2,845,550	9,424,440	2,989,570	4,047,360	637,561	1,932,376	669,829	829,866
95%	87%	26,671,410	38,769,465	30,815,000	23,565,290	3,231,978	4,762,421	3,734,088	2,894,748
99%	72%	494,725	0	501,435	2,202,030	102,138	0	103,523	522,908
91%	70%	101,654	11,302	117,503	3,748	13,205	2,795	15,263	927
58%	29%	2,356,650	6,443,760	2,351,900	5,498,130	266,892	1,389,240	266,354	1,185,367
89%	69%	51,403,400	27,229,440	52,804,380	2,582,010	10,268,518	10,355,046	10,548,383	981,909
66%	38%	923,410	2,397,340	917,460	1,972,780	121,028	598,163	120,249	492,231
96%	94%	6,006,740	0	5,911,160	142,270	1,495,678	0	1,471,879	29,476
95%	74%	1,008,160	0	4,712,600	0	238,669	0	1,115,647	0
90%	77%	16,001,120	2,594,750	21,741,470	2,934,750	3,109,287	959,850	4,224,734	1,085,623
100%	100%	524,000	0	524,000	0	85,496	0	85,496	0
95%	80%	5,890,625	0	5,260,385	5,121,260	1,162,627	0	1,038,237	1,735,680
73%	51%	48,875	417,550	48,675	374,185	7,052	114,697	7,024	102,785
93%	67%	5,402,520	21,525,600	10,799,700	13,247,175	1,402,609	5,939,479	2,803,832	3,655,244
70%	40%	4,437,660	4,940,770	1,587,870	3,993,400	1,179,662	1,017,717	422,103	822,574
79%	60%	1,517,540	1,695,225	1,886,420	1,047,210	287,405	331,424	357,267	204,734
100%	90%	280,495	222,085	86,000	0	86,775	53,238	26,605	0
82%	44%	2,179,200	7,174,190	1,711,110	5,031,545	259,792	838,786	203,989	588,274
90%	78%	725,820	3,954,940	844,040	2,351,775	226,208	955,099	263,053	567,942
84%	41%	3,059,235	1,484,495	3,307,155	1,808,840	1,033,303	388,528	1,117,042	473,417
86%	73%	149,180	81,835	133,680	25,945	40,714	17,306	36,483	5,487

Region	Country	Urban Population 2002	Rural Population 2002	Urban Population 2015	Rural Population 2015	Urban Sanitation % 2002	Rural Sanitation % 2002
SSAF	Cape Verde	249,000	205,000	374,000	203,000	61%	19%
SSAF	Central African Rep.	1,618,000	2,201,000	2,305,000	2,281,000	47%	12%
SSAF	Chad	2,047,000	6,301,000	3,778,000	8,359,000	30%	1%
SSAF	Comoros	257,000	490,000	448,000	594,000	38%	15%
SSAF	Congo	1,937,000	1,696,000	3,091,000	2,124,000	14%	2%
SSAF	Cote d'Ivoire	7,268,000	9,097,000	10,117,000	9,720,000	61%	23%
SSAF	Djibouti	577,000	116,000	735,000	104,000	55%	27%
SSAF	DR Congo	15,867,000	35,334,000	29,473,000	44,687,000	43%	23%
SSAF	Equatorial Guinea	227,000	254,000	385,000	277,000	60%	46%
SSAF	Eritrea	776,000	3,215,000	1,568,000	4,346,000	34%	3%
SSAF	Ethiopia	10,582,000	58,379,000	18,567,000	75,278,000	19%	4%
SSAF	Gabon	1,089,000	217,000	1,467,000	179,000	37%	30%
SSAF	Gambia	363,000	1,025,000	514,000	1,336,000	72%	46%
SSAF	Ghana	9,228,000	11,243,000	13,479,000	12,880,000	74%	46%
SSAF	Guinea	2,870,000	5,489,000	4,968,000	6,265,000	25%	6%
SSAF	Guinea-Bissau	480,000	969,000	916,000	1,188,000	57%	23%
SSAF	Kenya	12,083,000	19,457,000	19,088,000	17,776,000	56%	43%
SSAF	Lesotho	321,000	1,479,000	360,000	1,352,000	61%	32%
SSAF	Liberia	1,511,000	1,729,000	2,548,000	2,164,000	49%	7%
SSAF	Madagascar	4,443,000	12,474,000	7,373,000	16,626,000	49%	27%
SSAF	Malawi	1,879,000	9,992,000	3,360,000	11,805,000	66%	42%
SSAF	Mali	3,984,000	8,638,000	7,769,000	11,218,000	59%	38%
SSAF	Mauritania	1,694,000	1,114,000	2,945,000	1,043,000	64%	9%
SSAF	Mauritius	523,000	687,000	633,000	707,000	100%	99%
SSAF	Mozambique	6,419,000	12,118,000	10,928,000	11,609,000	51%	14%
SSAF	Namibia	626,000	1,335,000	873,000	1,323,000	66%	14%
SSAF	Niger	2,495,000	9,049,000	5,434,000	12,883,000	43%	4%
SSAF	Nigeria	55,448,000	65,463,000	89,758,000	71,968,000	48%	30%
SSAF	Reunion	677,000	68,000	818,000	44,000	55%	26%
SSAF	Rwanda	1,372,000	6,901,000	4,281,000	6,284,000	56%	38%
SSAF	Sao Tome & Principe	59,000	98,000	85,000	126,000	32%	20%
SSAF	Senegal	4,817,000	5,038,000	7,614,000	5,545,000	70%	34%
SSAF	Seychelles	40,000	40,000	47,000	41,000	100%	100%
SSAF	Sierra Leone	1,781,000	2,983,000	3,043,000	3,355,000	53%	30%
SSAF	Somalia	3,240,000	6,240,000	6,514,000	8,749,000	47%	14%
SSAF	South Africa	25,362,000	19,397,000	27,770,000	16,496,000	86%	44%
SSAF	Sudan	12,489,000	20,389,000	20,417,000	21,013,000	50%	24%
SSAF	Swaziland	250,000	819,000	291,000	785,000	78%	44%
SSAF	Togo	1,665,000	3,136,000	2,751,000	3,600,000	71%	15%
SSAF	Uganda	3,037,000	21,967,000	5,591,000	33,744,000	53%	39%
SSAF	U. Rep. of Tanzania	12,491,000	23,785,000	21,506,000	24,403,000	54%	41%
SSAF	Zambia	3,758,000	6,940,000	5,169,000	7,500,000	68%	32%
SSAF	Zimbabwe	4,420,000	8,415,000	5,391,000	7,640,000	69%	51%
WA	Bahrain	638,000	71,000	823,000	77,000	100%	100%
WA	Cyprus	549,000	247,000	617,000	244,000	100%	100%
WA	Iraq	16,549,000	7,961,000	22,847,000	11,379,000	95%	48%
WA	Israel	5,789,000	515,000	7,178,000	594,000	100%	100%
WA	Jordan	4,207,000	1,122,000	5,664,000	1,318,000	94%	85%
WA	Kuwait	2,360,000	83,000	3,249,000	102,000	95%	51%
WA	Lebanon	3,147,000	449,000	3,789,000	418,000	100%	87%
WA	Oman	2,125,000	644,000	3,229,000	678,000	97%	61%
WA	Qatar	552,000	49,000	666,000	45,000	100%	100%
WA	Saudi Arabia	20,464,000	3,056,000	29,825,000	2,903,000	100%	100%
WA	Syria	8,706,000	8,675,000	12,066,000	10,952,000	97%	56%
WA	Turkey	46,161,000	24,158,000	59,055,000	23,095,000	94%	62%
WA	U.A.E.	2,493,000	444,000	3,128,000	459,000	100%	100%
WA	Yemen	4,873,000	14,442,000	9,610,000	21,067,000	76%	14%

Urban Water % 2002	Rural Water % 2002	Urban Sanitation Target Population	Rural Sanitation Target Population	Urban Water Target Population	Rural Water Target Population	Urban Sanitation Target Households	Rural Sanitation Target Households	Urban Water Target Households	Rural Water Target Households
96%	70%	485,165	0	284,484	0	171,373	0	100,488	0
93%	61%	760,840	1,081,670	454,510	197,065	210,552	231,947	125,779	42,257
40%	32%	1,784,930	4,158,285	1,920,250	2,706,515	271,522	490,147	292,106	319,023
90%	96%	218,180	271,020	214,460	79,050	38,434	36,994	37,779	10,790
72%	17%	1,490,690	1,049,320	1,263,620	954,220	393,352	231,389	333,435	210,418
98%	74%	3,255,440	3,545,290	1,679,150	1,335,820	799,069	674,304	412,159	254,069
82%	67%	252,275	34,720	195,710	9,120	59,080	6,300	45,833	1,655
83%	29%	16,166,130	14,886,985	15,124,470	17,459,080	4,695,015	3,350,168	4,392,493	3,928,992
45%	42%	171,800	85,370	176,975	89,990	50,425	19,416	51,944	20,467
72%	54%	880,800	2,141,740	695,680	1,219,180	226,286	426,360	178,727	242,704
81%	11%	8,572,610	36,056,620	8,138,880	37,239,550	2,171,757	7,078,023	2,061,877	7,310,236
95%	47%	601,965	51,250	395,775	29,575	172,450	11,377	113,381	6,565
95%	77%	180,680	503,780	156,300	393,110	46,099	51,606	39,879	40,270
93%	68%	3,550,110	3,651,020	3,886,035	1,113,160	1,037,177	907,104	1,135,318	276,567
78%	38%	2,437,180	3,210,385	1,984,200	2,049,080	404,189	412,555	329,065	263,320
79%	49%	445,460	507,750	440,620	410,250	47,540	41,989	47,024	33,926
89%	46%	7,454,080	4,076,690	7,475,170	2,604,180	2,669,552	1,131,308	2,677,105	722,677
88%	74%	93,990	419,040	55,920	81,780	38,314	132,112	22,795	25,783
72%	52%	1,285,270	1,220,650	1,268,980	550,800	246,417	181,341	243,294	81,828
75%	34%	2,431,055	5,610,060	3,377,180	6,316,350	609,924	1,090,630	847,297	1,227,937
96%	62%	1,313,460	3,712,710	1,388,160	1,714,310	138,196	395,480	146,056	182,609
76%	35%	3,476,190	4,121,440	2,798,910	4,212,310	494,645	635,781	398,271	649,799
63%	45%	844,815	556,830	685,055	317,455	119,974	61,274	97,286	34,933
100%	100%	110,000	23,335	110,000	20,000	27,662	5,704	27,662	4,889
76%	24%	4,976,950	4,920,610	4,738,200	4,289,260	886,802	679,378	844,261	592,209
98%	72%	320,160	527,520	255,155	0	66,287	84,631	52,828	0
80%	36%	2,595,100	6,208,370	2,405,540	5,438,385	276,207	619,072	256,031	542,293
72%	49%	40,703,460	28,219,820	39,962,060	15,781,850	13,832,154	7,430,903	13,580,206	4,155,710
82%	45%	254,742	9,631	183,775	0	82,809	239	59,740	0
92%	69%	2,421,025	1,650,740	2,761,900	171,250	795,606	420,346	907,626	43,607
89%	73%	37,220	56,000	27,815	37,450	10,061	11,729	7,519	7,844
90%	54%	2,414,740	1,697,255	2,898,000	1,438,230	267,421	191,546	320,939	162,313
100%	75%	7,000	1,000	7,000	5,875	1,821	202	1,821	1,184
75%	46%	1,383,965	1,285,850	1,326,875	1,076,970	365,469	263,115	350,393	220,373
32%	27%	3,264,990	4,113,330	3,262,440	3,870,815	541,327	528,445	540,904	497,289
98%	73%	3,875,930	3,177,480	2,776,390	0	1,924,364	1,203,970	1,378,452	0
78%	64%	9,374,505	8,344,830	9,144,305	3,446,245	1,177,071	811,896	1,148,167	335,297
87%	42%	63,990	204,840	54,585	213,370	29,815	73,955	25,433	77,034
80%	36%	1,169,955	1,761,600	1,157,655	1,337,040	334,482	390,247	330,966	296,194
87%	52%	2,695,460	15,222,390	2,361,755	12,197,960	532,753	2,331,334	466,797	1,868,138
92%	62%	9,491,890	7,940,325	7,756,150	749,205	1,871,362	1,213,032	1,529,154	114,455
90%	36%	1,683,140	2,504,200	1,424,970	2,264,100	356,079	410,510	301,461	371,151
100%	74%	1,505,595	1,056,350	944,045	228,700	541,823	313,023	339,736	67,770
100%	100%	185,000	6,000	185,000	6,000	26,279	864	26,279	864
100%	100%	68,000	0	68,000	0	14,154	0	14,154	0
97%	50%	6,554,275	4,599,180	6,451,765	4,553,750	708,825	504,486	697,739	499,503
100%	100%	1,389,000	79,000	1,389,000	79,000	396,889	24,867	396,889	24,867
91%	91%	1,624,460	265,450	1,835,630	237,670	250,921	40,304	283,539	36,086
95%	73%	930,991	37,332	906,414	23,233	110,804	4,507	107,879	2,805
100%	100%	642,000	200	642,000	0	129,536	41	129,536	0
81%	72%	1,119,315	152,950	1,200,995	119,400	162,324	22,498	174,169	17,563
100%	100%	114,000	0	114,000	0	19,383	0	19,383	0
97%	63%	9,361,000	0	9,527,545	440,665	1,236,348	0	1,258,344	59,031
94%	64%	3,440,190	3,684,560	3,520,380	3,428,640	654,754	595,659	670,016	554,286
96%	87%	14,482,560	4,306,365	12,378,240	0	3,670,573	1,369,131	3,137,238	0
95%	73%	635,000	15,000	662,501	52,743	179,886	4,310	187,677	15,154
74%	68%	3,936,470	9,670,305	4,754,680	7,875,720	819,376	2,041,601	989,687	1,662,727

7.3 Appendices to the Energy and the Environment Chapter

Table 7-1: Importance of energy to achieve MDG 1

IMPORTANCE OF ENERGY TO ACHIEVING THE GOAL		
Goal	**Directly contributes**	**Indirectly contributes**
1. Extreme poverty and hunger		
To halve, between 1990 and 2015, the proportion of the world's people whose income is less than one dollar a day	Access to reliable energy services enables enterprise development	Modern energy supplies are necessary for economic growth, supply must be pro-poor in design, and inclusive of the rights of people in the design of their basic services
	Lighting permits income generation beyond daylight hours	Efficient energy systems reduce costs, help create sustainable businesses/jobs and economies and underpin the social fabric of a region
	Increased productivity from being able to use machinery	Privatization of energy services can help free up government funds for social welfare investment
	Local energy supplies can often be provided by small scale, locally owned businesses creating employment in local energy service provision and maintenance fuel crops, etc.	Clean, efficient fuels reduce the large share of household income spent on cooking, lighting and keeping warm (equity issue – poor people pay proportionately more for basic services)
To halve, between 1990 and 2015, the proportion of people who suffer from hunger.	The majority (95%) of staple foods need cooking before they can be eaten and need water for cooking.	Energy for irrigation helps increase food production and access to nutrition. Clean water helps improve health. Increased health and nutrition open up opportunities for employment and income generation.
	Improving productivity throughout the food chain (in tilling, planting, harvesting, processing, transport etc.)	Chemical fertilizers are a form of captured energy, particularly ammonia-based ones where natural gas is the feedstock – indirect use of gas increases crop yields
	Reduction of post harvest losses through better preservation (for example, drying and smoking) also through chilling/freezing	

Source: DFID

Table 7-2: Importance of energy to achieve MDG 2

IMPORTANCE OF ENERGY TO ACHIEVING THE GOAL		
Goal	**Directly contributes**	**Indirectly contributes**
2. Universal primary education		
To ensure that, by 2015, children everywhere will be able to complete a full course of primary schooling.	Energy can help create a more child friendly environment (access to clean water, sanitation, lighting and space heating/cooling) thus improving attendance at school and reducing drop out rates.	Access to energy provides the opportunity to use equipment for teaching(overhead projector, computer, printer, photocopier, science equipment)
	Availability of modern energy services frees children's and especially, girls' time from helping with survival activities (gathering firewood, fetching water); lighting permits home study	Modern energy systems and efficient building design reduces heating/cooling costs and thus school fees, enabling poorer families greater access to education
	Lighting in schools allows evening classes and helps retain teachers, especially if their accommodation has electricity	
	Electricity enables access to educational media and communications (ICTs) in schools and at home that increase education opportunities and allow distance learning	

Source: DFID

Table 7-3: Importance of energy to achieve MDG 3

IMPORTANCE OF ENERGY TO ACHIEVING THE GOAL		
Goal	**Directly contributes**	**Indirectly contributes**
3. Gender equality and women's empowerment		
Ensuring that girls and boys have equal access to primary and secondary education, preferably by 2005, and to all levels of education no later than 2015.	Availability of modern energy services frees girls' and young women's time from survival activities (gathering firewood, fetching water, cooking inefficiently, crop processing by hand, manual farming work)	Lighting in schools allows evening classes and helps retain teachers especially if their accommodation has electricity.
	Good quality lighting permits home study Electricity enables access to educational media and communications (ICTs) in schools and at home that increase education opportunities and allows distance learning	Street lighting improves women's safety
		Reliable energy services offer scope for women's enterprises

Source: DFID

Table 7-4: Importance of energy to achieve MDG 4

IMPORTANCE OF ENERGY TO ACHIEVING THE GOAL		
Goal	**Directly contributes**	**Indirectly contributes**
4. Child mortality		
To reduce by two-thirds, between1990 and 2015, the death rate for children under the age of five years	Indoor air pollution contributes to respiratory infections that account for up to 20% of the 11 million deaths in children each year (WHO 2000, based on 1999 data)	Provision of nutritious cooked food, space heating and boiled water contribute towards better health
	Gathering and preparing traditional fuels exposes young children to health risks and reduces time spent on child care	Electricity enables pumped clean water and purification
	Modern energy can be safer (fewer burns, accidents and house fires)	Cold chain provision allows access to vaccinations

Source: DFID

Table 7-5: Importance of energy to achieve MDG 5

IMPORTANCE OF ENERGY TO ACHIEVING THE GOAL		
Goal	**Directly contributes**	**Indirectly contributes**
5. Maternal health		
▪ To reduce by three-quarters, between 1990 and 2015, the rate of maternal mortality.	Energy services are needed to provide access to better medical facilities for maternal care, including medicine refrigeration, equipment sterilization and operating theatres	Excessive workload and heavy manual labour (carrying heavy loads of fuelwood and water) may affect a pregnant woman's general health and well-being.
		Energy can help produce and distribute sex education literature and contraceptives
		ICTs for long distance learning and 'distance medicine' requires a power supply
		Provision of nutritious cooked food, space heating and boiled water contribute towards better health and all need energy

Source: DFID

Table 7-6: Importance of energy to achieve MDG 6

IMPORTANCE OF ENERGY TO ACHIEVING THE GOAL		
Goal	**Directly contributes**	**Indirectly contributes**
6. HIV/AIDS, malaria and other major diseases		
By 2015, to have halted and begun to reverse - the spread of HIV/AIDS: - the scourge of malaria - the scourge of other major diseases that afflict humanity	Electricity in health centres enables night availability, helps retain qualified staff and allows equipment use(for example, sterilization, medicine refrigeration)	Energy is needed to develop, manufacture and distribute drugs, medicines and vaccinations
	Energy for refrigeration allows vaccination and medicine storage for the prevention and treatment of diseases and infections	Electricity enables access to health education media through ICTs
	Safe disposal of used hypodermic syringes by incineration prevents re-use and the potential further spread of HIV/AIDS	

Source: DFID

Table 7-7: Importance of energy to achieve MDG 7

IMPORTANCE OF ENERGY TO ACHIEVING THE GOAL		
Goal	**Directly contributes**	**Indirectly contributes**
7. Environmental sustainability		
■ To stop the unsustainable exploitation of natural resources; and ■To halve, between 1990 and 2015 the proportion drinking water of people who are unable to reach or to afford safe	Increased agricultural productivity is enabled through the use of machinery and irrigation, which in turn reduces the need to expand quantity of land under cultivation, reducing pressure on ecosystem conversion	Clean energy production can encourage better natural resource management, including improved water quality
	Energy can be used to purify water or pump clean ground water locally, reducing time spent collecting it and reducing drudgery.	National sustainability aided by greater use of indigenous renewable energy sources instead of imported fossil fuels as economy grows
	Traditional fuel use contributes to erosion, reduced soil fertility and desertification: this can become more sustainable through substitution, improved efficiency and energy crops	Rural energy services enable non-farm-based enterprise and processing of non-timber forest products
	Using cleaner, more efficient fuels will reduce greenhouse gas emissions, which are a major contributor to climate change	Efficient use of energy helps to reduce local pollution and improve conditions for poor people

Source: DFID

Table 7-8: Population across the studied regions

Region	Urban 2002	Urban 2015	Rural 2002	Rural 2015	Total 2002	Total 2015
North Africa	76,000	103,036	71,320	80,002	147,319	183,039
Sub-Saharan Africa	241,471	386,084	443,298	515,407	684,765	901,496
China and East Asia	770,678	1,085,713	1,148,228	1,040,414	1,918,901	2,126,127
South Asia	437,690	619,091	1,042,595	1,186,187	1,480,287	1,805,280
Latin America	409,034	508,263	126,594	119,996	535,626	628,260
Middle East	121,043	165,720	62,918	74,617	183,960	240,340
Transition Economies and OECD	934,256	998,663	350,607	325,032	1,284,863	1,323,702

Source: FAOstat - http://faostat.fao.org

Table 7-9: Non electrified urban population rates 2002 and 2015

Region	Urban non-electrification rate for 2002	Projected urban non-electrification rate for 2015	IEA MDG Target urban non-electrification rate for 2015
North Africa	1.20%	0%	0.60%
Sub-Saharan Africa	48.50%	42%	24.25%
China and East Asia	4.00%	0%	2.00%
South Asia	30.60%	23%	15.30%
Latin America	2.30%	0%	1.15%
Middle East	0.90%	0%	0.45%
Transition economies and OECD	0.00%	0%	0.00%
World	9.30%	7%	4.65%

Table 7-10: Non electrified rural population rates 2002 and 2015

Region	Rural non-electrification rate for 2002	Projected rural non-electrification rate for 2015	IEA MDG Target rural non-electrification rate for 2015
North Africa	12.10%	4.00%	6.05%
Sub-Saharan Africa	91.60%	84.00%	45.80%
China and East Asia	16.90%	12.00%	8.45%
South Asia	67.50%	56.00%	33.75%
Latin America	38.60%	29.00%	19.30%
Middle East	22.40%	13.00%	11.20%
Transition economies and OECD	1.80%	0.00%	0.90%
World	41.80%	38.00%	20.90%

Table 7-11: Population relying on biomass by 2015

Region	Population relying on biomass by 2015 (in millions of people)
North Africa	3
Sub-Saharan Africa	802
China and East Asia	829
South Asia	844
Latin America	68
Total developing Countries	2,549

Source: World Energy Outlook 2004, page 348

Table 7-12: Target group for Goal 1: All urban populations have modern cooking fuels

Region	Urban population relying on traditional biomass for cooking and heating
Sub-Saharan Africa	270,258,800
China and East Asia	32,571,390

Table 7-13: Amount of LPG needed to meet goal 1

Region	Population (million)	annual LPG consumption per capita (kg)	Annual LPG consumption (million tons)
Sub-Saharan Africa	270	41	11
China and East Asia	33	41	1
Total			12

Table 7-14: Amount of LPG to meet goal 2a

Region	Population (million)	annual LPG consumption per capita (kg)	Annual LPG consumption (million tons)
North Africa	1.5	41	0
Sub-Saharan Africa	266	41	11
China and East Asia	398	41	16
South Asia	422	41	17
Latin America	34	41	1
Total			46

Table 7-15: Amount of electricity needed to meet target 3

Region	Population (million)	Annual kWh consumption per capita	Total annual TWh consumption
Sub-Saharan Africa	162	75	12
South Asia	142	75	11
Total			23

Table 7-16: Amount of LPG needed to meet goal 1

Region	Population (million)	annual LPG consumption per capita (kg)	Annual LPG consumption (million tons)
Sub-Saharan Africa	270	41	11
China and East Asia	33	41	1
Total			12

Table 7-17: Amount of LPG to meet goal 2a

Region	Population (million)	annual LPG consumption per capita (kg)	Annual LPG consumption (million tons)
North Africa	1.5	41	0
Sub-Saharan Africa	266	41	11
China and East Asia	398	41	16
South Asia	422	41	17
Latin America	34	41	1
Total			46

Table 7-18: Amount of electricity needed to meet goal 3

Region	Population (million)	Annual kWh consumption per capita	Total annual TWh consumption
Sub-Saharan Africa	162	75	12
South Asia	142	75	11
Total			23[1]

Table 7-19: Amount of electricity and LPG needed to meet target 4

Region	Number of schools and heath facilities	Annual TWh electricity consumption[2]	Annual LPG consumption (million tons)[3]
North Africa	1,600	0.02	0.01
Sub-Saharan Africa	297,549	2.98	2.38
China and East Asia	62,425	0.62	0.50
South Asia	403,328	4.03	3.23
Latin America	17,399	0.17	0.14
Middle East	4,850	0.05	0.04
Total		7.87	6.30

Table 7-20: Amount of diesel needed to meet target 5

Region	Number of communities	Annual diesel consumption (million litres)
North Africa	3,200	9
Sub-Saharan Africa	595,097	1,738
China and East Asia	124,850	365
South Asia	806,656	2,355
Latin America	34,799	102
Middle East	9,700	28
Developing countries	1,574,302	4,597

[1] 23 TWh of electricity consumption is about equivalent to the electricity consumed in Sweden over 2 months.
[2] Based on assumption of 10,000 annual kWh electricity consumption per school and health facility
[3] Based on assumption of annual LPG consumption of 8,000 kg per schools and health facility.

Table 7-21: CO_2 emissions of meeting the MDG Energy Vision

For all the targets			Equivalent TWh	Carbon dioxide emission factors (kg/ton, m^3 and MWh)	Unit	CO_2 emissions million tons
Amount of LPG needed	65	million tons	824	2,996	kg/ton	194
Amount of Electricity needed	31	TWh	31	100	kg/MWh	3
Amount of diesel needed	5	million m^3	45	2,940	kg/m^3	14
Total			900			210
Sweden's total annual energy consumption			600			
Swedens CO_2 emissions 2003						50
The Global CO_2 emissions in 2002						23,579
The Global CO_2 emissions in 2015						30,521

Table 7-22: Environmental insults due to human activities, by sector

Insult	Commercial energy supply	Traditional energy supply	Agriculture	Manufacturing and other
Lead emissions to atmosphere	41%	-	-	59%
Oil added to oceans	44%	-	-	56%
Cadmium emissions to atmosphere	13%	5%	12%	70%
Sulphur emissions to atmosphere	85%	0.5%	1%	13%
Methane flow to atmosphere	18%	5%	65%	12%
Nitrogen fixation (as NO, NH4)	30%	2%	67%	1%
Mercury emissions to atmosphere	20%	1%	2%	77%
Nitrous oxide flows to atmosphere	12%	8%	80%	0%
Particulate emissions to atmosphere	35%	10%	40%	15%
non-methane hydrocarbon emissions to atmosphere	35%	5%	40%	20%
carbon dioxide flows to atmosphere	75%	3%	15%	7%

Source: WEA, Overview: 2004 Update

Table 7-23: World Energy Consumption in Million toe

Region	2002	2005	2010	2015	2020	2005 2015 increase %	Share of World Energy Consump-tion 2005	Share of World Energy Consump-tion 2015
OECD	5,346	5,572	5,970	6,253	6,550	12%	51%	48%
Transition Economies	1,030	1,086	1,186	1,269	1,358	17%	10%	10%
Middle East	407	447	524	603	695	35%	4%	5%
Latin America	465	504	575	655	746	30%	5%	5%
South Asia	644	698	797	903	1,024	30%	6%	7%
China	1,242	1,373	1,622	1,833	2,072	34%	13%	14%
East Asia	533	594	712	825	955	39%	5%	6%
Africa	534	578	660	750	852	30%	5%	6%
Energy Demand to meet the MDG Energy Vision				18.06				0.14%
Total	10,201	10,852	12,046	13,092	14,252	21%		

Source: IEA 2004

Table 7-24: Assumptions used in the calculations of the cost of achieving the MDG Energy Vision

Item	Calculated cost per unit	Unit	Comments
LPG	0.40 USD/	kg	The total assumed cost for LPG is 0.75 USD per kg where 0.40 USD is the fuel cost and 0.35 USD is for transport, filling and distribution. The cost for implementing a replacement of traditional biomass with LPG is based on the need for subsidies from Brazilian experience.
Improved stoves	125 USD/	stove	The calculations are based on an assumed average size of households of 5 persons
Sustainable biomass production	10 USD/	ton	Figures stated in Modi 2005
Electrification of schools and health facilities	50,000 USD/	Connection	Average assumed cost to connect one school and one health facility for every 2000 people
Electricity consumption in schools and health facilities	0.23 USD/	kWh	
LPG consumption in schools and health facilities	0.75 USD/	Kg	All the fuel costs are covered by public financing
Community power	0.12 USD/	KWh	The total assumed cost for community mechanical power is 0.23 USD/KWh which includes capital cost, fuel cost and maintenance parts. It does not include the staff costs for maintenance. It is assumed that the community pays for 50% of 0.23 USD/kWh. It is assumed that on average the community power is powered 4 hours per day.

Source: SEI 2005

Table 7-25: Regional definitions used in the energy chapter

East Asia	South Asia	Middle East	North Africa
Bhutan	Afghanistan	Bahrain	Algeria
Brunei	Bangladesh	Iran	Tunisia
Chinese Taipei	India	Iraq	Morocco
Fiji	Nepal	Israel	Egypt
French Polynesia	Pakistan	Jordan	Libya
Indonesia	Sri Lanka	Kuwait	
Kiribati		Lebanon	
D.P.R. Korea		Oman	
Malaysia		Qatar	
Maldives		Saudi Arabia	
Myanmar		Syria	
New Caledonia		U.A.E.	
Papua New Guinea		Yemen	
The Philippines			
Samoa	China refers to the People's Republic of China & Hong Kong		
Singapore			
Salomon Islands			
Thailand			
Vietnam			
Vanuatu			

Table 7-25 (continued)

Latin America	Sub-Saharan Africa	Transition economies	OECD
Antigua & Barbuda	Angola	Albania	Austria
Argentina	Benin	Armenia	Belgium
Bahamas	Botswana	Azerbaijan	Czech Republic
Barbados	Burkina Faso	Belarus	Denmark
Belize	Burindi	Bosnia-Herzegovina	Finland
Bermuda	Cameroon	Bulgaria	France
Bolivia	Cape Verde	Croatia	Germany
Brazil	Central African Republic	Estonia	Greece
Chile	Chad	Fed. Rep. of Yugoslavia	Hungary
Colombia	Congo	F.Y.R. Macedonia	Iceland
Costa Rica	D.R. Congo	Georgia	Irelend
Cuba	Cote d'Ivoire	Kazakhstan	Italy
Dominica	Djibouti	Kyrgyztan	Luxembourg
Dominican Republic	Equatorial Gunea	Latvia	Netherlands
Ecuador	Eritrea	Lithuania	Norway
El Salvador	Ethiopia	Moldova	Poland
French Guiana	Gabon	Romania	Portugal
Grenada	Gambia	Russia	Spain
Guadeloupe	Ghana	Slovak Republic	Sweden
Guatemala	Guinea	Slovenia	Switzerland
Guyana	Guinea-Bissau	Tajikistan	Turkey
Haïti	Kenya	Turkmenistan	United Kingdom
Honduras	Lesotho	Ukraine	United States
Jamaica	Liberia	Uzbekistan	Canada
Martinique	Madagascar	Cyprus	Mexico
Netherland's Antilles	Malawi	Gibraltar	Japan
Nicaragua	Mali	Malta	Korea
Panama	Mauritania		Australia
Paraguay	Mauritsius		New Zealand
Peru	Mozambique		
St Kitts-Nevis-Anguilla	Nambibia		
Saint Lucia	Niger		
St Vincent-Grenadines & Suriname	Nigeria		
Trinidad & Tobago	Rwanda		
Uruguay	Sao Tome & Principe		
Venezuela	Senegal		
	Seychelles		
	Sierra Leone		
	Somaila		
	South Africa		
	Sudan		
	Swaziland		
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	Togo		
	Uganda		
	Zambia		
	Zimbabwe		

The Stockholm Environment Institute (SEI)

SEI is an independent, international research institute specializing in sustainable development and environment issues. It works at local, national, regional and global policy levels. The SEI research programmes aim to clarify the requirements, strategies and policies for a transition to sustainability. These goals are linked to the principles advocated in Agenda 21 and the Conventions such as Climate Change, Ozone Layer Protection and Biological Diversity. SEI along with its predecessor, the Beijer Institute, has been engaged in major environment and development issues for a quarter of a century.

Mission

SEI's mission is to support decision-making and induce change towards sustainable development around the world by providing integrative knowledge that bridges science and policy in the field of environment and development.

The SEI mission developed from the insights gained at the 1972 UN Conference on the Human Environment in Stockholm (after which the Institute derives its name), the work of the (Brundtland) World Commission for Environment and Development and the 1992 UN Conference on Environment and Development. The Institute was established in 1989 following an initiative by the Swedish Government to develop an international environment/development research organisation.

The SEI programmes:

Implementing Sustainability

Atmospheric Environments

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