31/12/2012

INTERNATIONAL COMMISSION ON LARGE DAMS

COMMITTEE ON THE ENVIRONMENT

Supplement to the Position Paper on Dams and the Environment

Supplementary Paper 2012

Dams and the Environment from a Global Perspective

December 2012

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Introduction

ICOLD compiled a “Position Paper on Dams and the Environment” in 1995 and issued it in 1997. This Position Paper was addressed to ICOLD members and others associated with dams and was intended to enhance awareness of the environmental issues of dam engineering by defining ICOLD's position on the subject.

When a significant dam project such as the construction of a new dam, the redevelopment of existing dams, or even a change of operation, is planned, executed and operated, it is essential to consider the local and regional environmental issues. However it is also important to appreciate the potential of dams to help address the significant global problems of our time, such as climate change, population increase, food shortages, and the need for increased energy and improved water resources.

This Supplementary Paper summarizes the role of dams in the future in the context of the global environmental changes which have become significant issues in recent years. Global problems such as climate change have impacts on dam safety. Dams can therefore be both affected by global problems and help provide solutions to them. Although, the issue of dam safety in relation to global climate changes is very important, this topic will be addressed by ICOLD in other publications.

Since the original Position Paper was issued it is satisfying to note that a number of advances in water resource development and new approaches to environmental challenges have been generated all over the world.

In 1996, WWC was established in response to increasing concern from the global community about world water issues. The WWC has been granted special consultative status by UNESCO and ECOSOC. Its mission is "to promote awareness, build political commitment and trigger action on critical water issues at all levels, including the highest decision-making level, to facilitate the efficient conservation, protection, development, planning, management and use of water in all its dimensions on an environmentally sustainable basis for the benefit of all life on earth."

In 1996, GWP was founded by WB, UNDP and SIDA to foster IWRM. IWRM is the coordinated development and management of water, land and related resources in order to maximize economic and social welfare without compromising the sustainability of ecosystems and the environment. The GWP's vision is for a water secure world. Its mission is to support the sustainable development and management of water resources at all levels.

In 1998, brokered by WB and IUCN, WCD was established in response to the escalating local and international controversies over large dams. It was mandated to:

- review the development effectiveness of large dams and assessed alternatives for water resources and energy development; and
- develop internationally acceptable criteria, guidelines and standards for the planning, design, appraisal, construction, operation, monitoring and

decommissioning of dams.

In 2000, WCD published its final report, entitled “Dams and Development: a new framework for decision-making”.

In 2001, ICOLD held a symposium named Benefits and Concerns about Dams at the 69th annual meeting at Dresden. In this symposium, WB, ICOLD, government agency such as the United States, Germany, and China showed their positions on the WCD’s report.

In 2004, IEA published “Renewable Energy - Market and Policy Trends in IEA Countries”. This report provides a comprehensive review of renewable energy markets in IEA countries, and renewable energy policies related to research and innovation and to market development strategies. The information is intended to provide a valuable resource for IEA Member governments to assess their renewables options in particular, and to pursue their energy strategies more generally.

In 2004, IHA published “IHA Sustainability Guidelines”. This report was produced to promote greater consideration of environmental, social and economic aspects in the sustainability assessment of new hydro projects and the management and operation of existing power schemes. This was followed in November 2010 by the IHA “Hydropower Sustainability Assessment Protocol”.

, Building upon a decade of major United Nations conferences and summits, world leaders came together in September 2000 in New York to adopt the United Nations Millennium Declaration This declaration committed their nations to a new global partnership to reduce extreme poverty and setting out a series of time-bound targets - with a deadline of 2015 - that have become known as the Millennium Development Goals. These goals provide a framework for the entire international community to work together towards a common end making sure that human development reaches everyone, everywhere. If these goals are achieved, world poverty will be cut by half, tens of millions of lives will be saved, and billions more people will have the opportunity to benefit from the global economy. The eight MDGs are listed below:

Goal 1: Eradicate extreme poverty and hunger

Goal 2: Achieve universal primary education

Goal 3: Promote gender equality and empower women

Goal 4: Reduce child mortality

Goal 5: Improve maternal health

Goal 6: Combat HIV/AIDS, malaria and other diseases

Goal 7: Ensure environmental sustainability

Goal 8: Develop a global partnership for development

In 2007, IPCC published “Climate Change 2007: Synthesis Report”. This Synthesis Report is based on the assessment carried out by the three Working Groups (WGs) of IPCC. It provides an integrated view of climate change as the final part of the IPCC’s AR4.

In 2011, the World Bank updated Operational Policy (OP) 4.01 and Bank Procedure

(BP) 4.01, which had originally been published in 1989. OP/BP 4.01 applies to any Bank-financed or implemented investment loan if there is the potential for that project to result in adverse environmental impacts. It is also designed as a tool to improve project performance and to enhance the quality and sustainability of projects. It does so by providing the guidance that allows borrower decision makers and Bank operational staff to ensure that the project options under consideration are environmentally sound and sustainable.

These developments at the organizational level and the cited publications are only a few examples of global advances in environmentally sound development in general, and of water resources and dam developments in particular, however they demonstrate that by agreeing a set of common goals and working within a sustainable framework individual dam projects can play a meaningful role in improving the everyday lives of millions of people.

Chapter I　Global Issues and Dams

1. Climate Changes

According to the IPCC's AR4, warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750. Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004.

Impacts of global warming are as follows;

(1) The temperature increase

(2) Sea level rise

(3) Increase in drought, heat waves and floods

(4) Biodiversity loss

2. Population Growth

The world population reached 6.8 billion in 2008. It is estimated that the population continues to increase, reaching 7.9 billion in 2025, and possibly 9.3 billion in 2050 though the increasing rate of the world population decreases in the future.

It is anticipated that the rise in population will aggravate food, energy, and water resource pressures. Environmental problems including deforestation and desertification are likely to arise from the requirement to expand the cultivated acreage for food production. These effects are likely to be more strongly felt in the developing countries where the population increase is expected to be greatest.

Thus it will be important to increase the yield of agricultural land to produce more food from that land set aside for cultivation, so as to be able to continue to provide for ongoing environmental requirements.

3. Need for Irrigation

According to the FAO's report (The State of Food Insecurity in the World, 2010), there were 925 million undernourished people in the world in 2010. Among the key causes of hunger are natural disasters, poor agricultural infrastructure and conflict. According to the latest FAO statistics, food and feed crop demand will increase by 1.5 times to three billion tons per annum by 2050 as the population grows and dietary preferences change. Furthermore the growing use of crop biomass for bio-fuels has the potential to trigger further food shortages if not managed carefully.

To meet the food and feed crop demands of the future, it will be essential to expand the productivity amount of arable land, find new and increasingly reliable water resources and improve the efficiency of the world's irrigation systems and agricultural infrastructure.

The provision of well considered irrigation schemes is a proven method of increasing the quantity and value of crops that can be grown. By providing reliable and relatively low cost water at the right time to grow crops on land located in lower rainfall areas it is possible to produce crops that are of high economic value.

For thousands of years irrigation dams have been central to increasing our agricultural outputs. As the world's population grows the role of dams in keeping up with food demands will become increasingly critical.

4. Need for Energy

According to the WEO 2010 (IEA), world primary energy demand has increased by 70% between 1980 (7,229 Mtoe) and 2008 (12,271 Mtoe). The average annual rate of growth is 1.9%. Oil is the dominant fuel in the primary energy mix, with demand at 84 Mb/d in 2009. Demand for coal is 4,736 Mtoe in 2008.

In the New Policies Scenario, which takes account of both existing policies and declared intentions, world primary energy demand is projected to increase by 1.2% per year between 2008 and 2035, reaching 16,750 Mtoe, an increase of 4,500 Mtoe. World demand for coal will increase by around 20%, with almost all of the growth before 2020. The number of people relying on biomass is projected to rise from 2.7 billion today to 2.8 billion in 2030.

Yet there are currently 1.4 billion people in the world who lack access to electricity, some 85% of them in rural areas.

Rising demand for fossil fuels continues to drive up energy-related CO_2 emissions and even in the most environmentally-ambitious interpretation of the Copenhagen Accord, energy-related CO_2 emissions will reach 31.9 Gt in 2020. This means that it will be necessary to limit energy-related emissions to 21.7 Gt in 2035 dramatic emissions cuts after 2020, involving a near-doubling of the annual average CO_2 intensity improvements achieved in the earlier period.

Through hydropower generation dams have an important role, both in the direct generation of electricity and through their ability to generate peak power to stabilize electrical grids. The generation of electricity through renewable sources such as solar, wind and tidal power are an important element in reducing CO_2 emissions yet energy production from these sources rarely coincides with consumer energy demands. Increasingly existing hydropower dams are being operated in new ways to better integrate the outputs from renewable energy sources in the short term. Furthermore the capability of pumped storages to store and release large amounts of electrical energy on demand has led to the development of more and larger pumped storage systems as a means of better storing the energy produced by these large renewable energy schemes.

5. Water Resources

1) Water Distribution

It is estimated that the world contains about 1,400 million km^3 of water with 35 million km^3 (2.5 percent) as freshwater and the rest as saline water. The large amount of freshwater contained in ice caps, glaciers and deep in the ground is not accessible for use.

Freshwater that can be used stems essentially from rainfall over land, generated through the hydrological cycle. The majority of freshwater that can be used exists as groundwater, with only about 0.3 percent of all the freshwater contained in lakes, rivers and the atmosphere (Crops and Drops, FAO, 2002).

Changes in precipitation and temperature will lead to significant changes in runoff and water availability. Runoff is projected with high confidence to increase by 10 to 40% by mid-century at higher latitudes and in some wet tropical areas, including populous areas in East and Southeast Asia, and to decrease by 10 to 30% over some dry regions at mid-latitudes and dry tropics, due to decreases in rainfall and higher rates of evapotranspiration (IPCC, WG1-AR4, 2007).

2) Water Usage

The current total water withdrawal (3,829 km^3) is 8.8 % of the whole renewable water resources (44,659km^3). Around 70% of total water used globally is from surface water and 20% is from groundwater sources. Agriculture is by far the main user of water and. irrigated agriculture accounts for 70% of water withdrawals rising to more than 80% in some regions (UN WATER, Water in a Changing World, 2009).

It is estimated that the world's water withdrawals will increase from 3,800 km^3 a year to 4,200 km^3 between 1995 and 2025, with the amount of water withdrawals for agriculture increasing from 2,500 km^3 to 2,695 km^3, those for industry increasing from 750 km^3 to 800 km^3, and withdrawals for municipal use increasing from 350 km^3 to 500 km^3 (WWC, World Water Vision, 2000).

The water resource is unevenly distributed and securing scarce water resources is particularly important in those regions exposed to a high stress. Furthermore, better use of the available water will be necessary to deal appropriately with the problems associated with the rise in population and the climatic change such as the predicted increase in both municipal and agricultural water demand.

3) Floods and droughts

With global climate change and projected increases in global temperature, scientists generally agree that the hydrologic cycle will intensify and that extremes will become more common.

Although droughts have always been a part of the hydrologic cycle as larger populations become more dependent on water from increasingly variable sources for both their food and water the effects of these droughts may become more intense. Flooding can also have devastating effects, particularly in areas with high population density and without adequate early warning and emergency response systems. During 1992-2001 floods accounted for 43% of recorded disasters and affected more than 1.2 billion people.

Available research suggests a significant future increase in heavy rainfall events in many regions, including some in which the mean rainfall is projected to decrease. Increases in the frequency and severity of floods and droughts are projected to adversely affect sustainable development (UN WATER, Waer in a Changing World, 2009).

Chapter II The Role of Dams in the Future

Security of water supply is a fundamental requirement for a healthy, sustainable society. Civilizations that have been able to harness reliable water supplies have the capacity to thrive and improve their quality of life, whereas the future is simply untenable for those without dependable water. Population growth along with improving incomes and expectations will mean a rise in food, energy, and municipal water requirements. Furthermore, climate change is expected to be associated with an increase of the severity of both droughts and floods. In order to preserve water resources and achieve sustainable development, it is important to adopt the idea of integrated water management at the watershed level.

In this context dams will prove increasingly important in decades to come, in such various domains as ensuring flow, providing flood management, supporting agricultural production, contributing to the supply of energy and water, and fulfilling other needs that advance the life of the communities they support.

1. Flow and Flood Management

As discussed in earlier sections of this paper, seasonal wet and dry periods are expected to become more pronounced in the years to come. Therefore, as well as the importance of storing water in the wet seasons for use in the dry seasons, the use of dams as a means of controlling devastating floods may also prove to be a major benefit.

Droughts affect flow reliability, particularly in arid and semi-arid regions and as global temperatures rise, larger numbers of dams will be constructed to provide security of water supply for agricultural purposes, energy production (hydropower) and for drinking and industrial water (see later sections in this paper for more details on these requirements). As more dams are being constructed across rivers for these purposes, impacts downstream of the dams must be considered. For example, it is important that controlled releases from the reservoirs are maintained to reduce negative effects on the environment such as for wetland habitat.

Flood control remains one of the primary reasons for construction of new dams, and will continue to do so as populations grow. For example, one of the most significant benefits of the construction of the Three Gorges dam in China was the control of seasonal flood water coming from the Yangtze River. The construction of the dam and other flood control measures has reduced the flood risk from a 0.1% probability to a 0.01% probability of occurrence. During the 2010 South China floods, inflows at the Three Gorges Dam reached a peak of 70,000m^3/s, exceeding the peak during the 1998 Yangtze floods. Chinese sources have communicated that the dam reduced the outflow to 40,000m^3/s in discharges downstream, which avoided damage on the scale of the 1998 flood.

Due to population growth, more developments are being built in flood-prone areas and correspondingly, more flood control dams are being constructed to protect these areas. In addition, technological improvements in weather sensing and forecasting as well as in hydrological and hydraulic modeling will support enhanced flood management reservoir operations.

With changing climate conditions, better weather sensing and increasing urbanization, updates and revisions of dam operational procedures and manuals will be required. Reservoir operators in a rainfall catchment area will need to work closer together to ensure timings of flood flow releases do not coincide to exacerbate floods downstream.

There is a rising trend towards construction of un-gated facilities, which reduces miss-management and liability issues. And un-gated facilities reduce the possibilities of pro-active flood management on the basis of hydrological forecasts. Increasingly higher levels of public expectation related to flood management operations must be addressed with provision of well understood and communicated emergency planning and evacuation measures.

2. Agriculture

1) Feeding a Growing Global Population

There are approximately 925 million hungry people in the world and better use of water to improve the productivity of agriculture is essential if we are to deal with this ongoing humanitarian crisis.

Worldwide, agriculture is the largest consumptive usage of water and large dams are the basis of many country's "food bowls". Although the construction of a new dam can cause a loss of agricultural land through impoundment, the benefits of higher production and greater reliability on newly available irrigable land will always outweigh these losses in a well-considered irrigation scheme.

For decades, well planned and executed irrigation schemes have enabled many communities both to increase crop yield and grow much higher value crops, providing an important increase in agricultural income. These schemes have added immense value to what was previously marginal land by feeding growing populations, building local economies and providing greater food security.

2) Patterns of Use

However, as the value of water increases and different crops are grown in response to market demands, patterns of water usage are changing, which can affect reservoir operations. These changes are often small from year to year, but over time the effects on reservoir storage can be profound.

For example some irrigation schemes have operated for almost 50 years on the basis that most, if not all, inflows are released each irrigation season. However in some cases farmer's preference to carry water over between seasons to provide greater water security has led to higher average storage levels, with a consequent increase in the likelihood of spillways operating each year.

The high capital cost of dams and their associated long productive lifespan means that dams designers will need to build flexibility into their designs so that changes to water demands and usage patterns can be accommodated over the life of the structure.

3) Reliability of Irrigation Water

Conversely, as the climate becomes more variable, previously accepted water reliability levels may no longer be applicable. In the future, reservoirs associated with these changed climate conditions will spend more time at much lower levels than historic statistics would suggest.

Additionally increased evaporation losses and ongoing siltation of some storage reservoirs will require regular consideration to confirm reliability levels into the future.

Some wet tropical regions are experiencing increases in rainfall over historic levels which have potentially viable irrigation schemes that have been marginal in the past and will open up further opportunities for a decrease in floods.

3. Energy

Population growth will maintain the pressure to increase the world energy demand in the future. Most of the actual energy supply in the world relies on fossil fuels. The relatively inexpensive conventional fossil fuels are progressively being replaced by more expensive unconventional fossil fuels (oil shales, shale gas, methane hydrate, etc.) pushing the cost of energy upward. Also, fossil fuels have the disadvantage of producing GHG that are known to be related to climatic changes. There is a large consensus in the international community that GHG emissions must be controlled.

The increasing price of energy and the necessity to reduce the emission of greenhouse gases is favorable to the development of renewable sources of energy like wind power, solar energy, tidal energy etc. However, these forms of energy rely on favorable production conditions (wind, daylight, tide etc.) that are not always in phase with energy demand. As these new sources of energy will represent an increasing portion of the energy production portfolio, it will be necessary to provide storage for energy or to modulate energy production from other sources in order to keep in phase with energy consumption.

Energy demand fluctuates greatly during the year due to seasonal changes, but also during the week (weekend versus week days) and on an hourly basis (peak hours versus night hours). To be able to meet these rapid variations of requirement on the distribution network and assure grid stabilization, utility operators rely on equipment that can be put into production in a few minutes with high flexibility. Presently, hydropower plants and gas turbines are the only power production systems that meet these requirements. Among these two, hydropower is a renewable source of energy that generates significantly less GHG than gas turbines.

In addition to its flexibility, hydropower can store the energy produced by other renewable energy sources. For instance, energy production from hydropower plants can be reduced when wind or solar power production is available and hydropower production can be increased when it is not available. Moreover energy of these alternative sources can be stored by pumping if there is an excess of energy on the market. To play this regulating role, there is a need for large storage facilities that can accumulate enough energy to face the daily, weekly and even seasonal demand fluctuations. In order to correspond to energy demand fluctuations, pumping-storage plants are also effective.

In this changing world, it has become more important to maximize power generation and efficiencies at existing hydropower facilities by increasing the capacity of reservoirs when economically, technically and environmentally feasible and to construct new facilities with reservoirs large enough to play fully their role for water management purposes, but also to adjust electricity production to meet consumer demand.

4. Municipal Water

The majority of communities around the globe do not have year round access to sufficient water for their needs. Dams have long been the solution and underpin cities all around the world.

There are many water supply schemes in desert environments that rely on groundwater. Even in these circumstances dams are often an important component of these water supply systems, reducing pressure on groundwater supplies by storing rare rainfall events and providing an opportunity for re-use schemes and recycling of local runoff.

Dams are often important elements in long distance water supply systems, allowing these systems to be built more economically and function more reliably by providing storage capacity close to final users.

Desalination has also become more and more viable to provide water to support societies. In concert with storage dams desalination plants will increasingly provide water for urban growth in some areas. However desalination plants are not well suited to meeting peak flow needs and dams will still play a critical role in storing water to meet peak demands.

5. Other Uses

Along with the primary uses of dams described above, dams and reservoirs can and do provide in many other associated uses and benefits. Infrastructure built to facilitate the building of the dam may be used for other commercial and economic activities providing employment and business opportunities in areas such as tourism, and by providing improved links to the wider world such as better roads, reliable electricity and data connections further opportunities become available...

In the report, Dams and Development (2000), WCD recognized that the major challenge facing the future management of world water resources lies in resolving "competing interests collectively" and finding "ways of sharing water resources equitably and sustainably" to meet social, economic and environmental needs.

All parties with vested interests including the engineers, ecologists, farmers and city dwellers, upstream and downstream nations should have the opportunity to engage in dialogue to ensure competing issues can be resolved. This way it can be ensured that dams are used only when they create a net benefit for all.

1) The environment and habitat creation

Although it is important to carefully consider the negative effects of each dam on the environment an additional use and benefit resulting from construction of a reservoir is the creation of new habitat in which fish and other flora and fauna, including migratory birds, may thrive. For example, four man-made reservoirs located in Eastern France, namely Der Chantecoq, Orient, Amance and Le Temple, are included in a wetland designated in 1991 as of international importance under the Ramsar Convention. Some dams are also now required by legislation to regulate flows for environmental needs. Flows are controlled to carefully manage habitat and ecosystems especially for endangered species recovery programs.

2) Recreational and cultural interest

Whilst dams may not originally be planned for recreational purposes, the reservoirs formed as a result of constructing dams often have large recreational uses. Swimming, boating, water-skiing, bird watching and fishing are just a few of the activities that take place on many reservoirs around the world. Reservoirs often prove to be popular tourist destinations, as places to camp or carry out these water-based activities in a safe, controlled environment. In addition, in some cases, reservoirs are being maintained for their cultural value and historic practices, even when their original use no longer becomes economically viable.

3) Navigation

River navigation can be adversely affected by seasonal rains. As precipitation extremes are becoming more prominent, dams are now being built to maintain more stable water levels. This helps navigation and the movement of goods and people, promoting communication and ensuring the welfare of people along rivers.

Many developed countries still maintain dams and navigation structures that were built over a century ago to facilitate navigation. These structures now provide multiple benefits and even where the original usage is now of low priority these dams still bring in tourist income, support irrigation and underpin both heritage and environmental values.

Reference

Introduction

ICOLD, 1999, Recommendations on Future Mission Strategy of ICOLD

ICOLD, 2001, Benefits and Concerns about Dams

ICOLD, 2006, The role of dams in the XXI Century to achieve a sustainable development target

IEA, 2004, Renewable Energy - Market and Policy Trends in IEA Countries

IHA, 2004, Sustainability Guidelines

WCD, 2000, Dams and Development

1. Climate changes

IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

Rosenzweig, C., G. Casassa, D. J. Karoly, A. Imeson, C. Liu, A. Menzel, S. Rawlins, T. L. Root, B. Seguin, P. Tryjanowski, 2007: Assessment of observed changes and responses in natural and managed systems. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 79-131.

2. Population Growth

Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2006 Revision

Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Urbanization Prospects: The 2007 Revision

Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision

UN WATER, 2006, Water a shared responsibility

3. Need for Irrigation

FAO, 2006, World agriculture: towards 2030/2050
FAO AQUASTAT, 2008
FAO, 2010, The State of Food Insecurity in the World
FAO statistical yearbook 2010
FAOSTAT, 2010
ICOLD, World Register of Dams 2003
ICOLD, The role of dams in the XXI Century to achieve a sustainable development target
IMF Primary Commodity Prices

4. Need for Energy

IEA, Key World Energy Statistics 2010
IEA, WEO 2010

5. Water Resources

FAO, 2002, Crops and Drops
FAO AQUASTAT, 2008
FAO statistical yearbook 2010
IEA, 2006, World Energy Outlook
IGRAC, 2004, Global Groundwater Information System
IPCC, 2007, AR4, Contribution of Working Group I to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change
UN WATER, 2006, Water a Shared Responsibility
UN WATER, 2009, Water in a Changing World
World Bank, World Development Indicators 2007
Water Systems Analysis Group, UNH
WWC, 2000, World Water Vision
WWC, WaterGAP 2.0 - December
http://webworld.unesco.org/water/ihp/db/shiklomanov
http://www.grida.no/publications/vg/water2/page/3289.aspx

Appendices

Appendix A

Some International Associations related to Water Resources Development and Global Environmental Changes

Food and Agriculture Organization of the United Nations (FAO)
Global Water Partnership (GWP)
International Energy Agency (IEA)
International Groundwater Resources Assessment Centre (IGRAC)
International Hydropower Association (IHA)
International Monetary Fund (IMF)
Intergovernmental Panel on Climate Change (IPCC)
United Nations Development Programme (UNDP)
United Nations Educational, Scientific and Cultural Organization (UNESCO)
University of New Hampshire (UNH)
UN Water
Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat
World Bank (WB)
World Commission on Dams (WCD)
World Water Council (WWC)

Appendix B

ICOLD Technical Bulletins related to Environmental Aspects

Bulletin 35 (1980) Dams and the Environment

Bulletin 37 (1981) Dam Projects and Environmental Success

Bulletin 50 (1985) Dams and the Environment - Notes on Regional Influences

Bulletin 65 (1988) Dams and Environment - Cases Histories

Bulletin 66 (1989) Dams and Environment - The Zuiderzee Damming

Bulletin 86 (1992) Dams and Environment - Socio-Economic Impacts

Bulletin 90 (1993) Dams and Environment - Geophysical Impacts

Bulletin 96 (1994) Dams and Environment - Water Quality and Climate

Bulletin 100 (1995) Dams and Environment - Ridracoli: A model achievement

Bulletin 103 (1996) Tailings Dams and Environment - Review and Recommendations

Bulletin 115 (1999) Dealing with reservoir sedimentation

Bulletin 116 (1999) Dams and Fishes Review and Recommendations

Bulletin 124 (2002) Reservoir landslides: investigation and management – Guidelines and case histories

Bulletin 127 (2004) Remote sensing for reservoir water quality management – Examples of initiatives

Bulletin 128 (2004) Management of reservoir water quality – Introduction and recommendations

Bulletin 132 (2008) Shared Rivers: Principles and practices

Appendix C

ICOLD Congresses discussed about Environmental Aspects

1973 The consequences on the environment of building dams (Q.40)

1976 The effects on dams and reservoirs of some environmental factors (Q.47)

1982 Reservoir sedimentation and slope stability - Technical and environmental effects (Q.54)

1988 Reservoirs and the environment - Experience in management and monitoring (Q.60)

1991 Environmental issues in dam projects (Q.64)

1994 Environmental experience gained from reservoirs in operation (Q.69)

1995 Reservoirs in river basin development (Symposium)

1997 Performance of reservoirs (Q.74)

2000 Benefits and Concerns about dams (Q.77)

2001 Benefits and Concerns about dams (Symposium)

2003 Economic evaluation of hydraulic projects including dams (Q.83)

2006 Management of the downstream impacts of dam operation (Q.85)

2009 Dams and Hydropower (Q.88)

2009 Management of siltation in existing and new reservoirs (Q.89)

Appendix D

Global Environmental Changes

1. Climate Changes

1) Global warming

According to the IPCC Fourth Assessment Report (AR4, 2007), warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.

2) Cause of change

According to AR4(2007),global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750.Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. The largest growth in GHG emissions between 1970 and 2004 has come from energy supply, transport and industry, while residential and commercial buildings, forestry (including deforestation) and agriculture sectors have been growing at a lower rate.

It is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica). The observed patterns of warming, including greater warming over land than over the ocean, and their changes over time, are simulated only by models that include anthropogenic forcing.

3) Impacts of global warming

(1) The temperature increase

Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. There is high confidence that natural systems related to snow, ice and frozen ground (including permafrost) are affected. Settlements in mountain regions are at enhanced risk of glacier lake outburst floods and debris flows caused by melting glaciers. Governmental institutions in some places have begun to respond by building dams and drainage works (AR4, 2007).

(2) Sea level rise

It is likely that the incidence of extreme high sea level has increased at a broad range of sites worldwide since 1975. Partial loss of ice sheets on polar land and/or the thermal expansion of seawater over very long time scales could imply meters of sea level rise, major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands. Sea-level rise and human development are together contributing to losses of coastal wetlands and mangroves and increasing damage from coastal flooding in many areas (AR4, 2007).

(3) Increase in drought, heat waves and floods

There is now high confidence in the projected increases in droughts, heat waves and floods as well as their adverse impacts. Such increases will occur in many regions and will have mostly adverse impacts, including increased water stress, adverse effects on food production, adverse health effects, increased flood risk and extreme high sea level, and damage to infrastructure.

Climatic changes will also increase exceptional meteorological events such as very heavy rain, flash flooding, hail, tornados, and overall drought durations even if the climatological means evolve slowly (AR4, 2007).

(4) Biodiversity loss

There is also increasing evidence from a wide range of species and communities in terrestrial, in marine and freshwater ecosystems that shows that recent warming is strongly affecting the earth's natural biological systems (AR4, 2007).

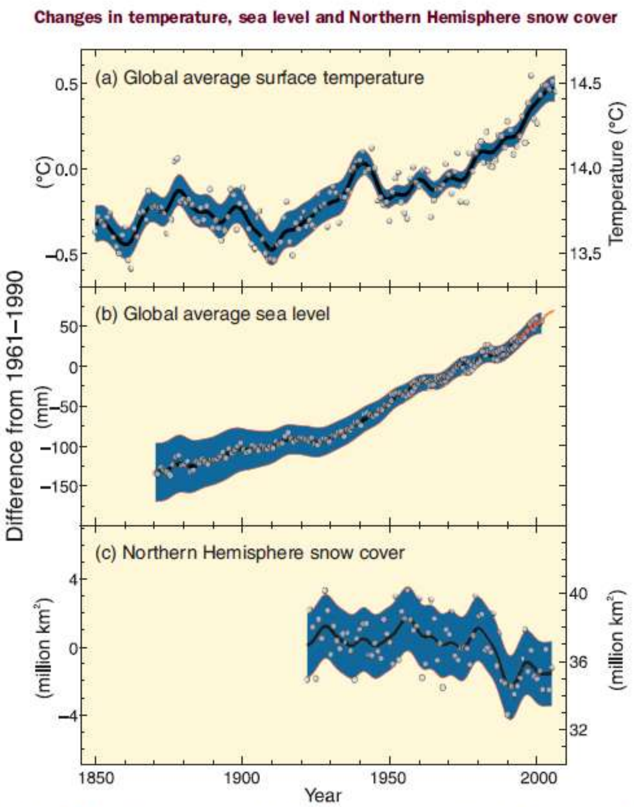


Figure 1.1. Observed changes in (a) global average surface temperature; (b) global average sea level from tide gauge (blue) and satellite (red) data; and (c) Northern Hemisphere snow cover for March-April. All differences are relative to corresponding averages for the period 1961-1990. Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c). {WGI FAQ 3.1 Figure 1, Figure 4.2, Figure 5.13, Figure SPM.3}

Figure 1. Changes in temperature, sea level and Northern Hemisphere snow cover

(Source: WG1-AR4, IPCC, 2007)

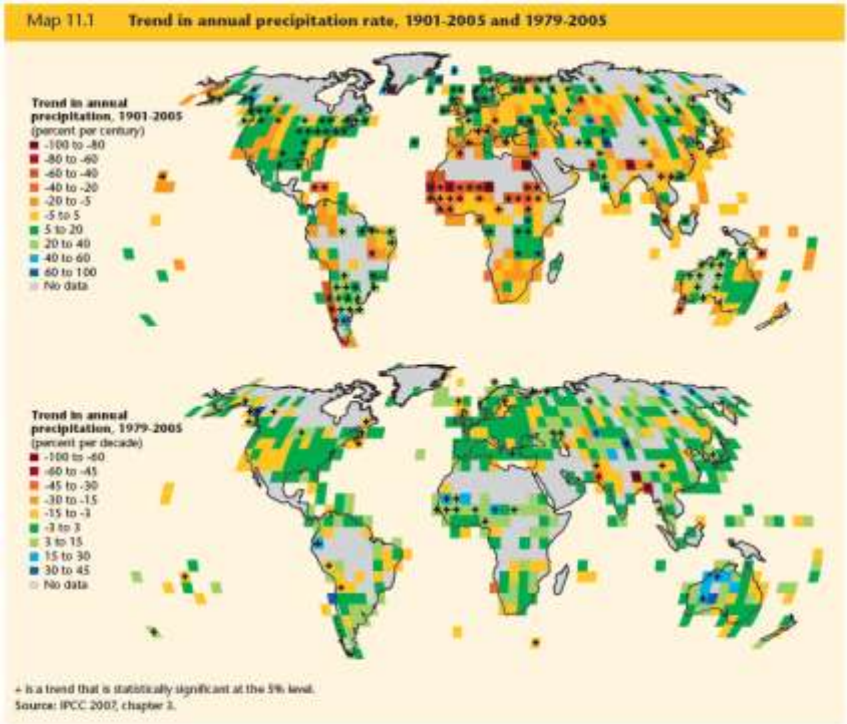


Figure 2. Trend in annual precipitation rate, 1901-2005 and 1979-2005

(Source: Water in a Changing World, UN WATER, 2009)

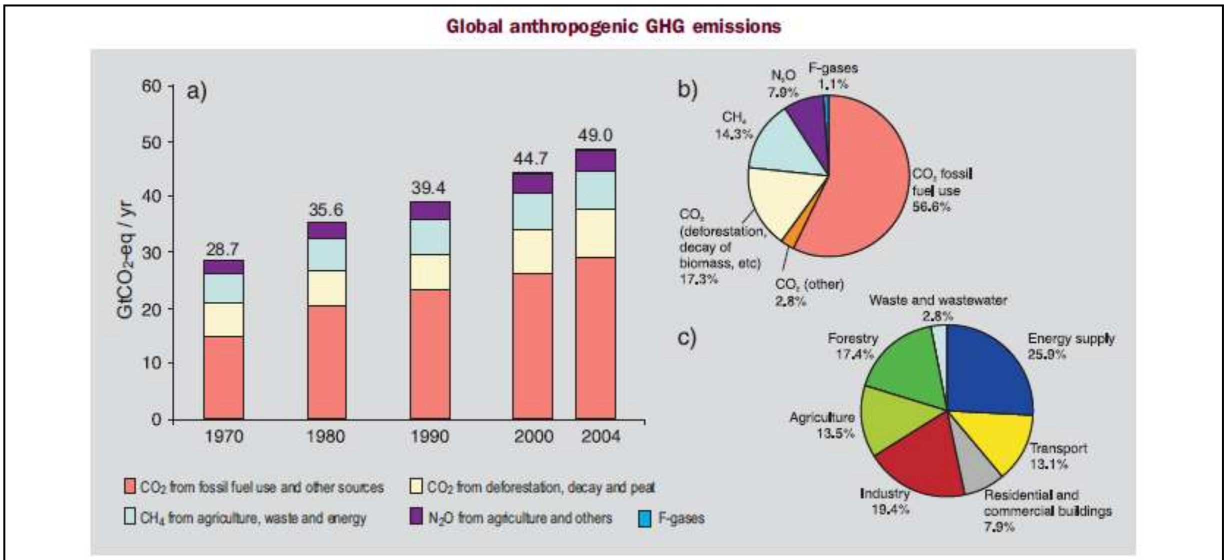


Figure 2.1. (a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.[5] (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO_2-eq. (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO_2-eq. (Forestry includes deforestation.) {WGIII Figures TS.1a, TS.1b, TS.2b}

Figure 3. Global anthropogenic GHG emissions (Source: WG1-AR4, IPCC, 2007)

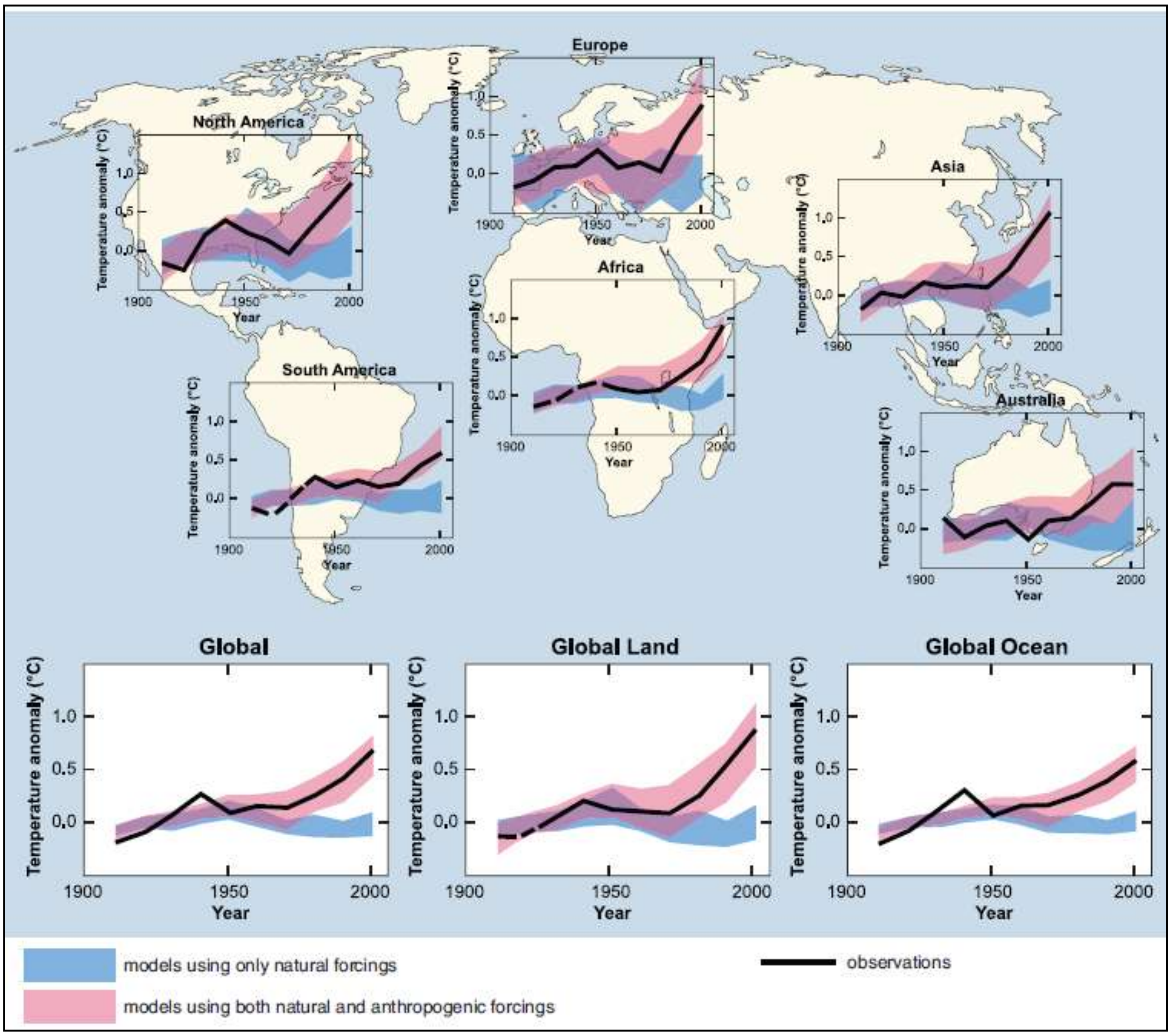


Figure 4. Global and continental temperature change (Source: WG1-AR4, IPCC, 2007)

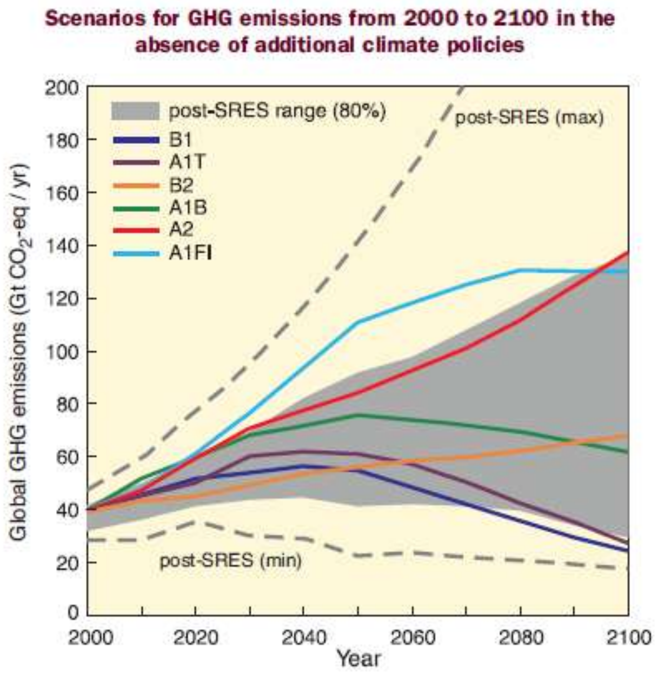


Figure 3.1. Global GHG emissions (in $GtCO_2$-eq per year) in the absence of additional climate policies: six illustrative SRES marker scenarios (coloured lines) and 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases. {WGIII 1.3, 3.2, Figure SPM.4}

Figure 5. Scenarios for GHG emissions from 2000 to 2100 in the absence of additional climate policies (Source: WG1-AR4, IPCC, 2007)

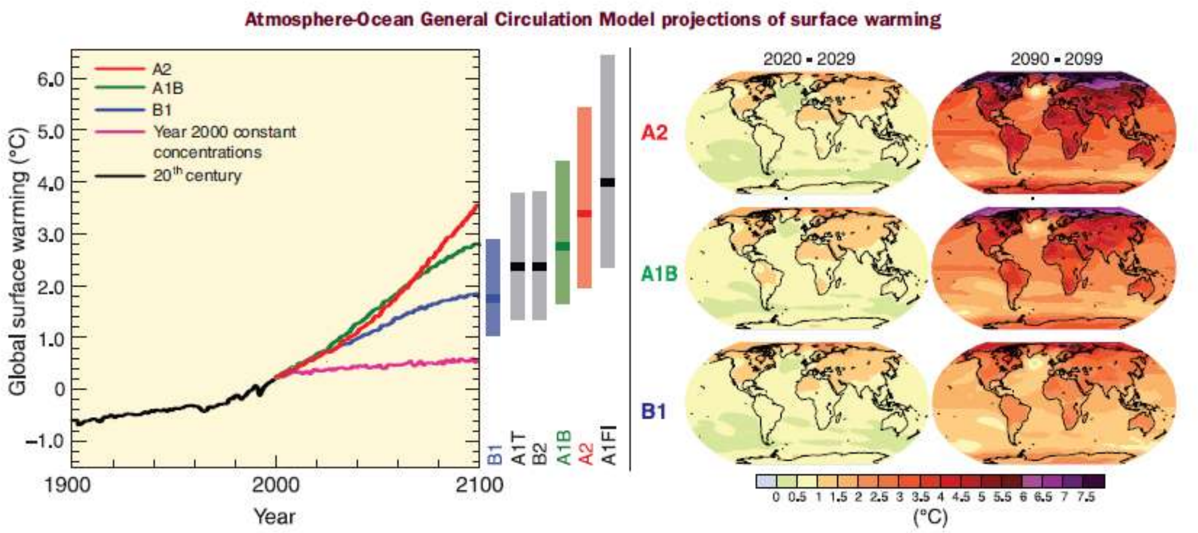
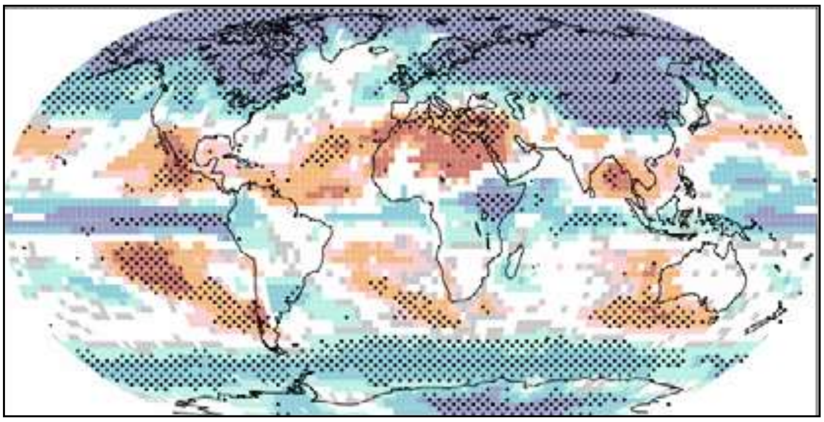


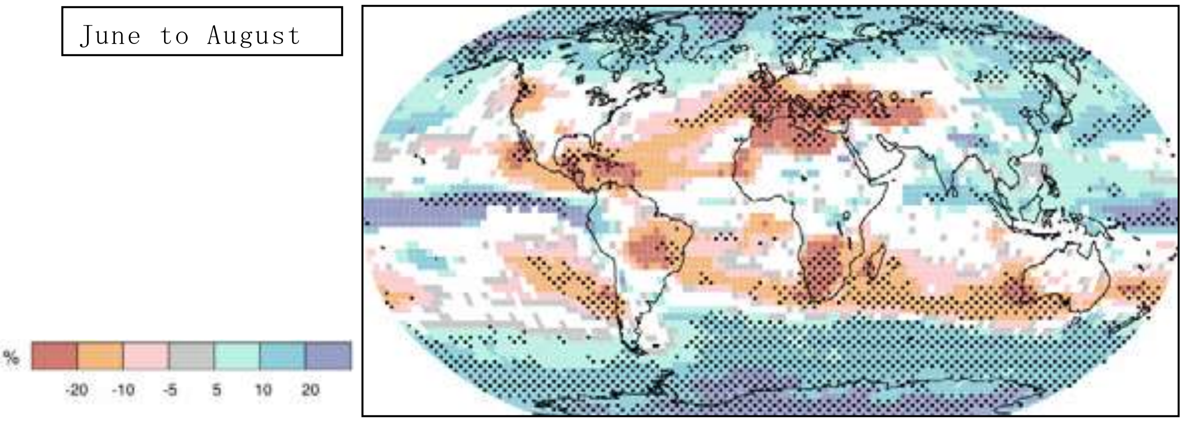
*Figure 3.2. **Left panel:** Solid lines are multi-model global averages of surface warming (relative to 1980-1999) for the SRES scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. The orange line is for the experiment where concentrations were held constant at year 2000 values. The bars in the middle of the figure indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios at 2090-2099 relative to 1980-1999. The assessment of the best estimate and likely ranges in the bars includes the Atmosphere-Ocean General Circulation Models (AOGCMs) in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. **Right panels:** Projected surface temperature changes for the early and late 21st century relative to the period 1980-1999. The panels show the multi-AOGCM average projections for the A2 (top), A1B (middle) and B1 (bottom) SRES scenarios averaged over decades 2020-2029 (left) and 2090-2099 (right). {WGI 10.4, 10.8, Figures 10.28, 10.29, SPM}*

Figure 6. Projections of surface warming (Source: WG1-AR4, IPCC, 2007)

December to February



June to August



SRES scenarios

SRES refers to the scenarios described in the IPCC Special Report on Emissions Scenarios (SRES, 2000). The SRES scenarios are grouped into four scenario families (A1, A2, B1 and B2) that explore alternative development pathways, covering a wide range of demographic, economic and technological driving forces and resulting GHG emissions. The SRES scenarios do not include additional climate policies above current ones. The emissions projections are widely used in the assessments of future climate change, and their underlying assumptions with respect to socio-economic, demographic and technological change serve as inputs to many recent climate change vulnerability and impact assessments.

The A1 storyline assumes a world of very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies. A1 is divided into three groups that describe alternative directions of technological change: fossil intensive (A1FI), non-fossil energy resources (A1T) and a balance across all sources (A1B). B1 describes a convergent world, with the same global population as A1, but with more rapid changes in economic structures toward a service and information economy. B2 describes a world with intermediate population and economic growth, emphasizing local solutions to economic, social, and environmental sustainability. A2 describes a very heterogeneous world with high population growth, slow economic development and slow technological change. No likelihood has been attached to any of the SRES scenarios.

[SRES: Special Report on Emissions Scenarios, IPCC, 2001]

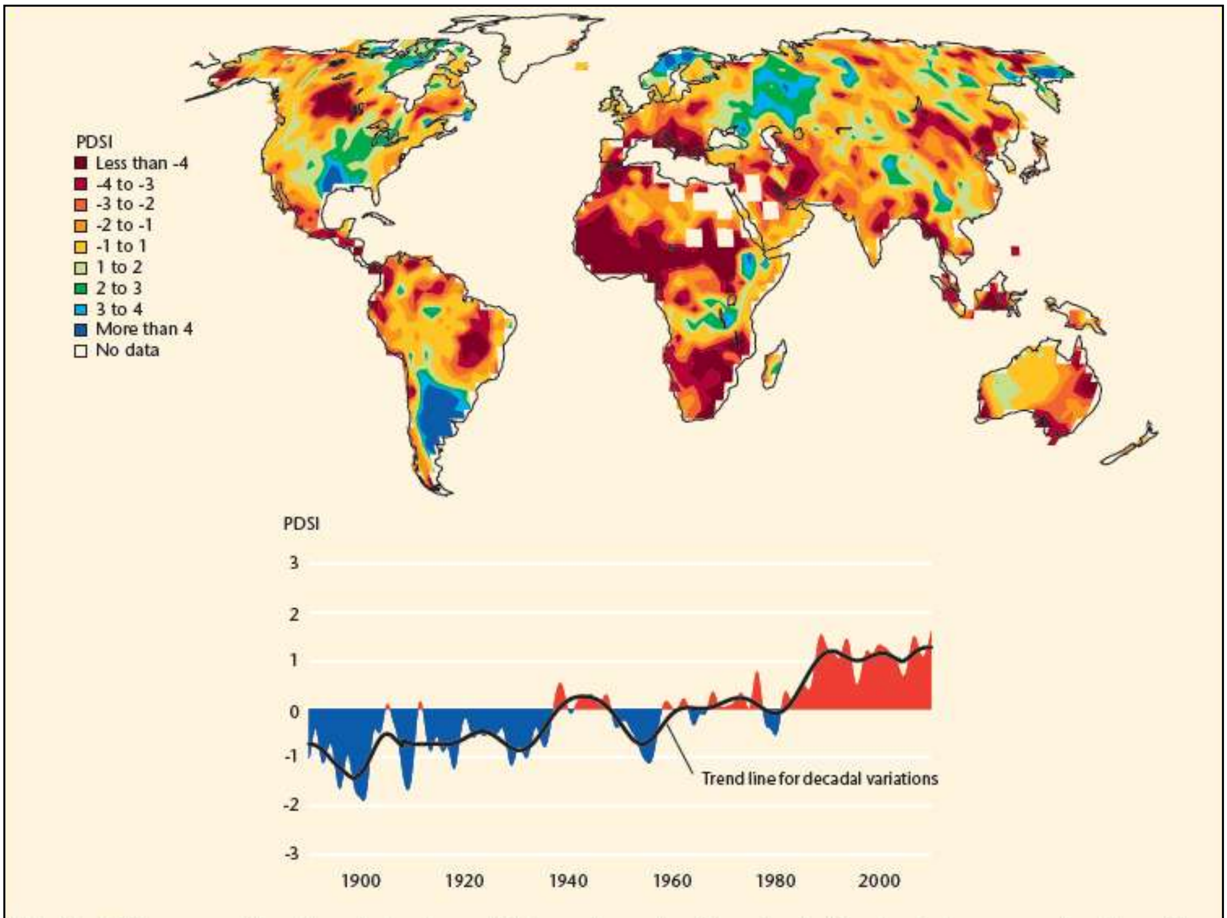
Figure 7. Projected relative changes in precipitation based on SRES A1B scenario

(Source: WG1-AR4, IPCC, 2007)

Table 1. Examples of possible impacts of climate change based on projections to the mid- to late 21st century (Source: WG1-AR4, IPCC, 2007)

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems *{WGII 4.4, 5.4}*	Water resources *{WGII 3.4}*	Human health *{WGII 8.2, 8.4}*	Industry, settlement and society *{WGII 7.4}*
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	*Virtually certain*[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	*Very likely*	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	*Very likely*	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding: pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	*Likely*	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	*Likely*	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migrations; loss of property
Increased incidence of extreme high sea level (excludes tsunamis)[c]	*Likely*[d]	Salinisation of irrigation water, estuaries and fresh-water systems	Decreased fresh-water availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

Notes:
a) See WGI Table 3.7 for further details regarding definitions.
b) Warming of the most extreme days and nights each year.
c) Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
d) In all scenarios, the projected global average sea level at 2100 is higher than in the reference period. The effect of changes in regional weather systems on sea level extremes has not been assessed. *{WGI 10.6}*



Note: The PDSI is a measure of drought severity based on precipitation and temperature information. Positive values imply more severe drought conditions.
Source: Based on IPCC 2007, chapter 3.

Figure 7. Geographic distribution of the trend in the Palmer Drought Severity Index (PDSI) and annual variations in the globally averaged PDSI, 1900-2000

(Source: Water in a Changing World, UN WATER, 2009)

2. Population Growth

1) Current Status

(1) World population

The world population reached 5.0 billion in 1987 and increased up to 6.0 billion in 1997, 12 years later. As of 2008 it has topped 6.8 billion. China has the world's largest population with 1.3 billion people with India, second largest at 1.2 billion. Together the Asia and Africa regions have more than half of world's population and still show a remarkable population growth rate. Most of the world population increase will come from Asia and Africa.

This population growth has led to increased urbanization, water poverty, food prices and as the world's population continues to grow increased conflict and other social and environmental problems can be expected in more regions of the world.

(2) Adequate sanitation facilities available to the population

Within Asia and Africa, from 600 to 850 million people are unable to receive an adequate water supply and it is estimated that from 750 to 980 million people do not have adequate sanitation.

In order to prevent outbreaks of infectious diseases through pollution of existing water resources treatment of human excrement is critical.

2) Outlook

It is estimated that the world's population will continue to increase, although at a declining rate. It is estimated that our population will reach 7.9 billion in 2025, and possibly 9.3 billion in 2050.

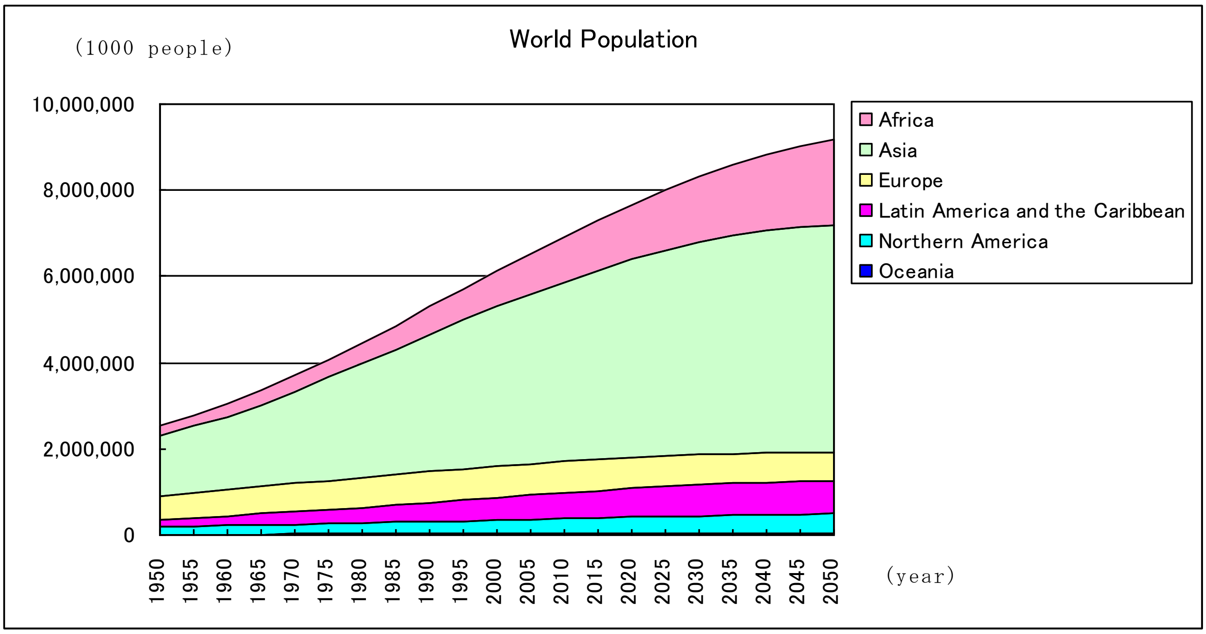
The urban population in Asia and African region is expected to grow to about 3.4 billion people by 2030 (double the number of present). It is also estimated that the population of the Asia region will increase to about 5.2 billion people in 2050. Moreover, it is estimated that the population of the African region becomes 1.8 billion people. Therefore, the population of these two regions will be seven billion people.

In addition, it is forecast that the population will be more urbanized with the city population exceeding six billion people in 2050.

3) Challenges

It is anticipated that this rise in population will aggravate food, energy, and water resource pressures. Environmental problems including deforestation and desertification are likely to arise from the requirement to expand the cultivated acreage for food production. These effects are likely to be more strongly felt in the developing countries where this population increase is expected to be greatest.

Thus it will be important to increase the yield of agricultural land to produce more food from that land set aside for cultivation, so as to be able to continue to provide for ongoing environmental requirements.



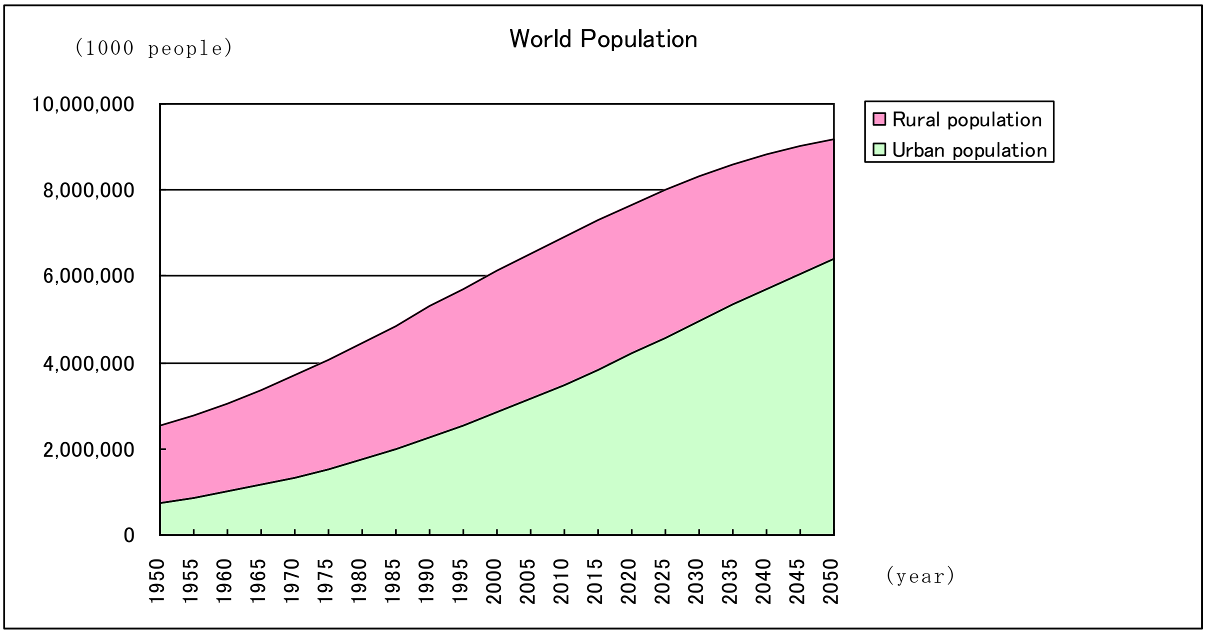
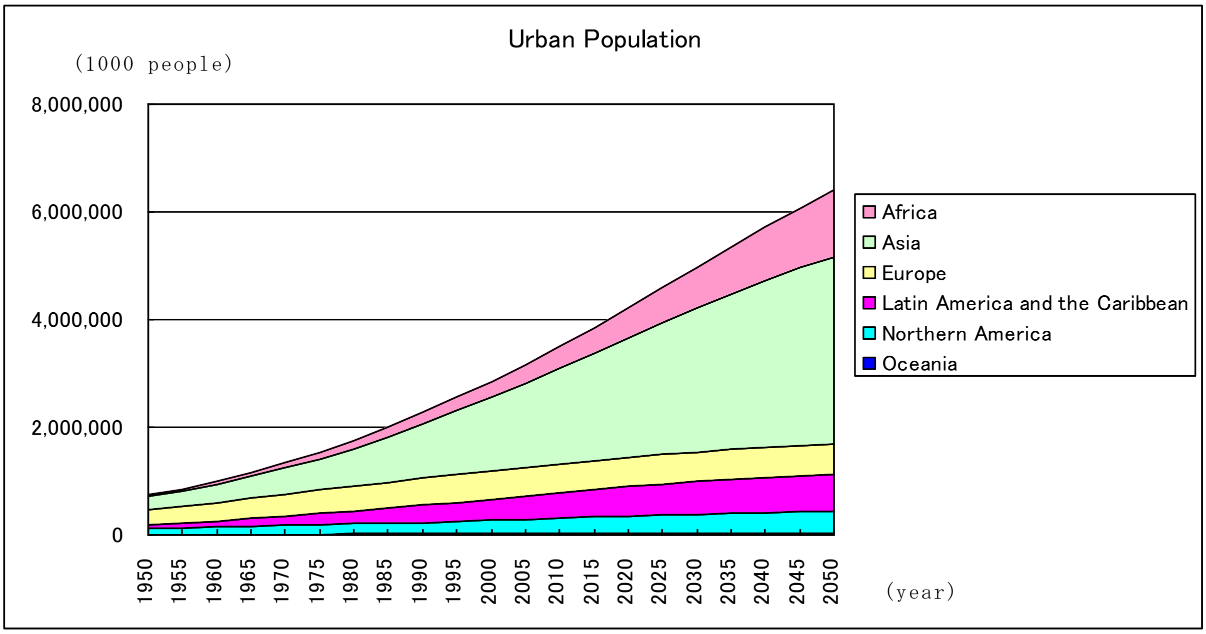


Figure 8. World Population Prospect (Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2007 Revision)



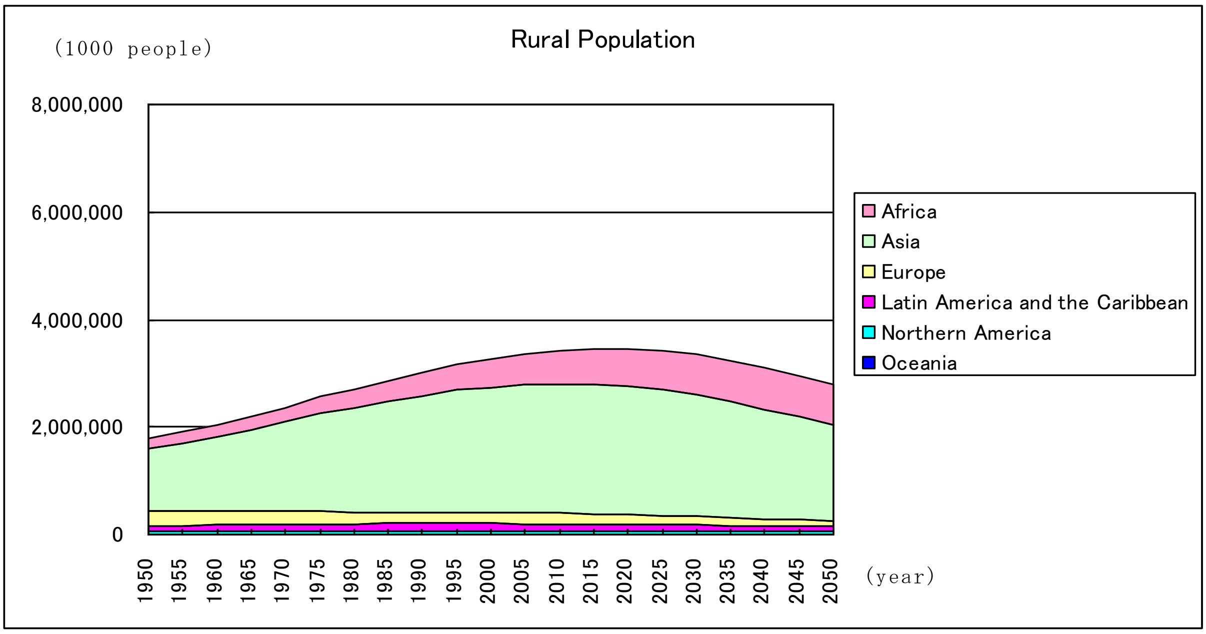


Figure 9. World Population Prospect (Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2007 Revision)

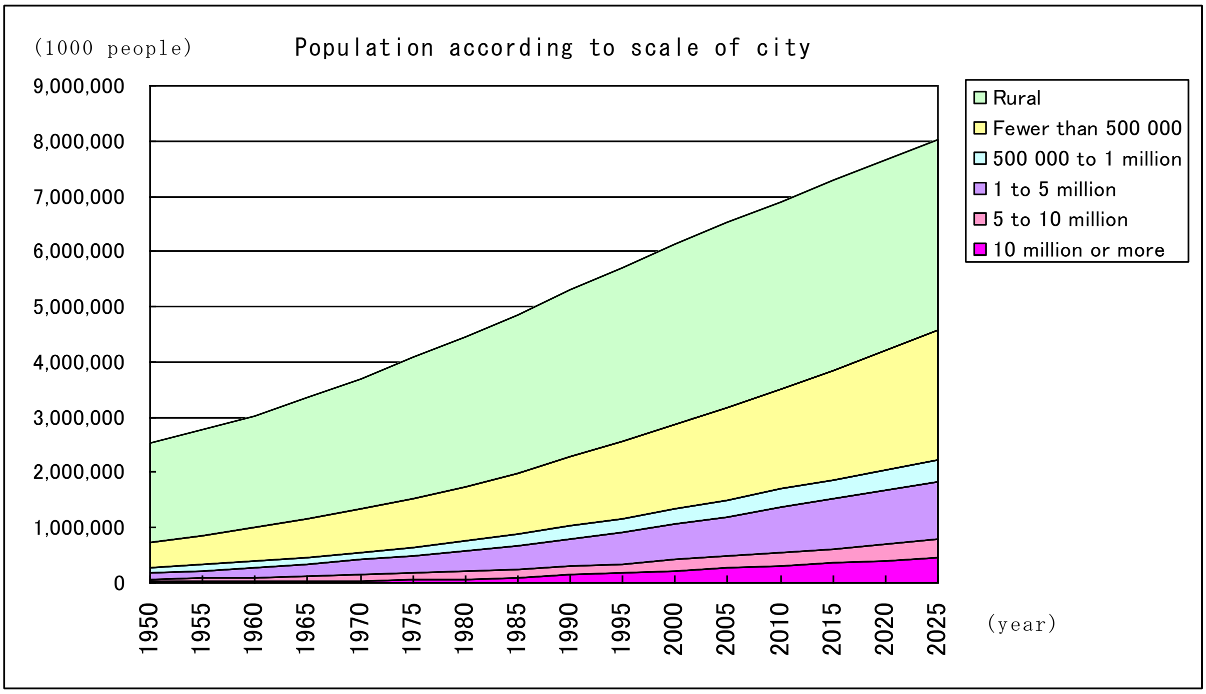


Figure 10. Transition of urban population (Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2007 Revision)

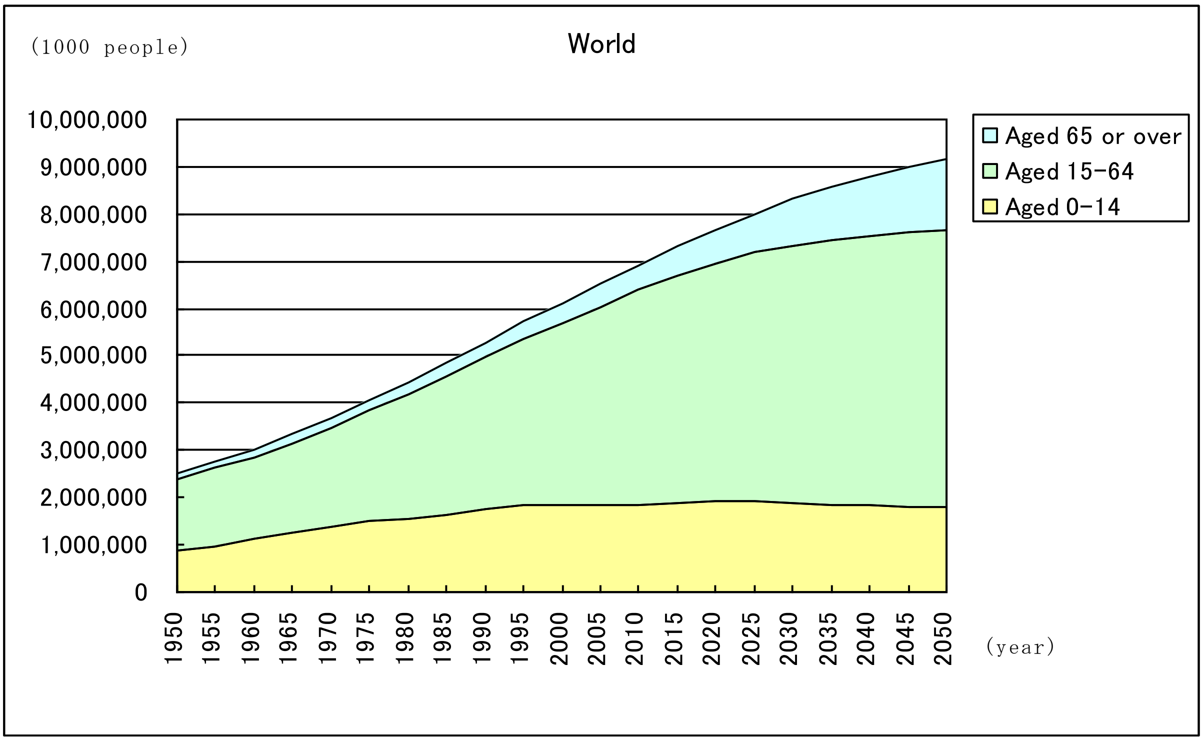


Figure 11. Percentage of population by age group in each country (Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision)

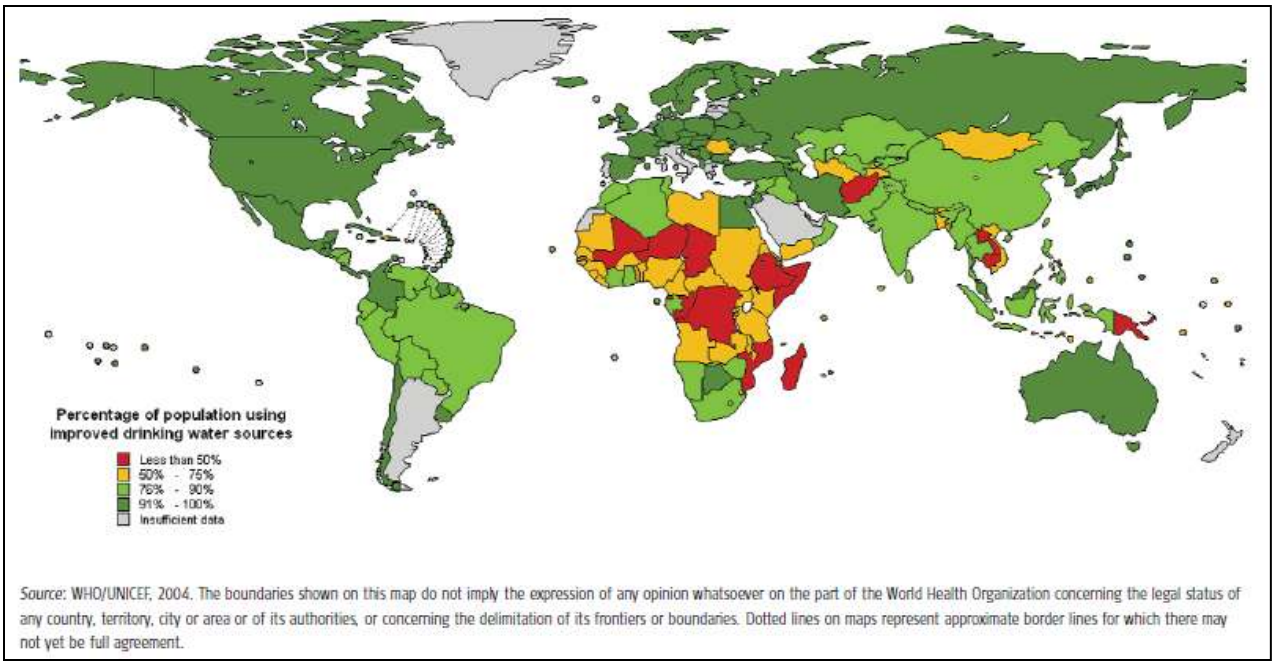


Figure 12. Coverage with improved drinking water sources, 2002

(Source: Water a shared responsibility, UN WATER, 2006)

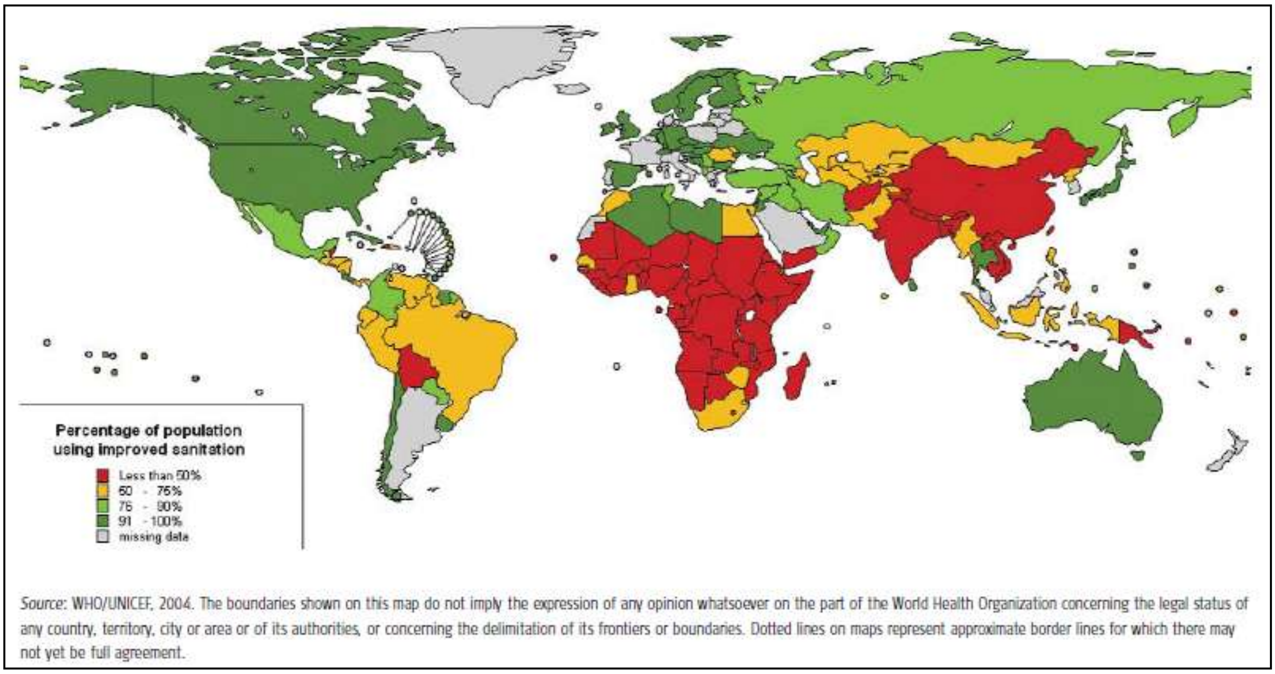


Figure 13. Coverage with improved sanitation, 2002

(Source: Water a shared responsibility, UN WATER, 2006)

3. Need for Irrigation

1) Current Status

According to the FAO’s report (The State of Food Insecurity in the World, 2010), there are approximately 925 million undernourished people in the world. That means one in seven people do not get enough food to be healthy and lead an active life. Among the key causes of hunger are natural disasters, poor agricultural infrastructure and conflict. Recently, natural disasters have pushed more people into hunger. The demand for grain has also suddenly increased as a result of increasing use of grain for both animal feed and bio-fuels

Most of the world’s hungry live in developing countries;

- 578 million in Asia and the Pacific
- 265 million in Sub-Saharan Africa
- 53 million in Latin America and the Caribbean
- 42 million in the Near East and North Africa

2) Outlook

According to the latest FAO statistics, food and feed crop demand will increase by 1.5 times to three billion tons by 2050 as the population grows and dietary preference change. At the present time about 30% of all cultivated lands are being irrigated. However, the food production from the irrigated areas amounts almost to 40 percent of the total crop production. Reservoirs supply 30～40% of all irrigation water. It is estimated that the amount of agricultural water needed to irrigate will increase by 27% in 1995 to 2025.

Furthermore the expanding use of crop biomass for bio-fuels has the potential to cause of food shortages if not managed carefully.

3) Challenges

To meet the food and feed crop demands of the future, it will be essential to expand the amount of arable land, find new and increasingly reliable water resources and improve the efficiency of the world’s irrigation systems and agricultural infrastructure. .

The provision of well-considered irrigation schemes is a proven method of increasing the quantity and value of crops that can be grown. By providing reliable and relatively low cost water at the right time to grow crops on land located in lower rainfall areas it is possible to produce crops that are of high economic value.

For thousands of years irrigation dams have been central to increasing our agricultural outputs. As the world’s population grows the role of dams in keeping up with food demands will become increasingly critical.

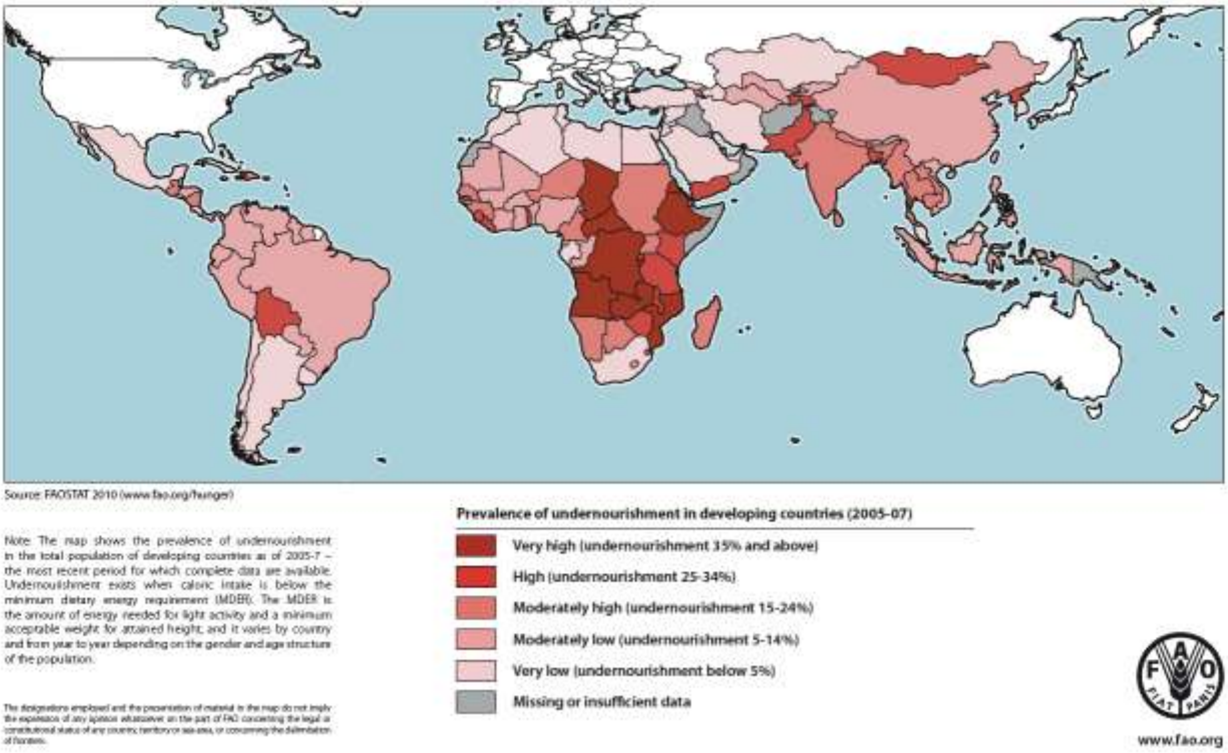


Figure 14. Undernourished population, 2005-2007 (Source: FAOSTAT 2010)

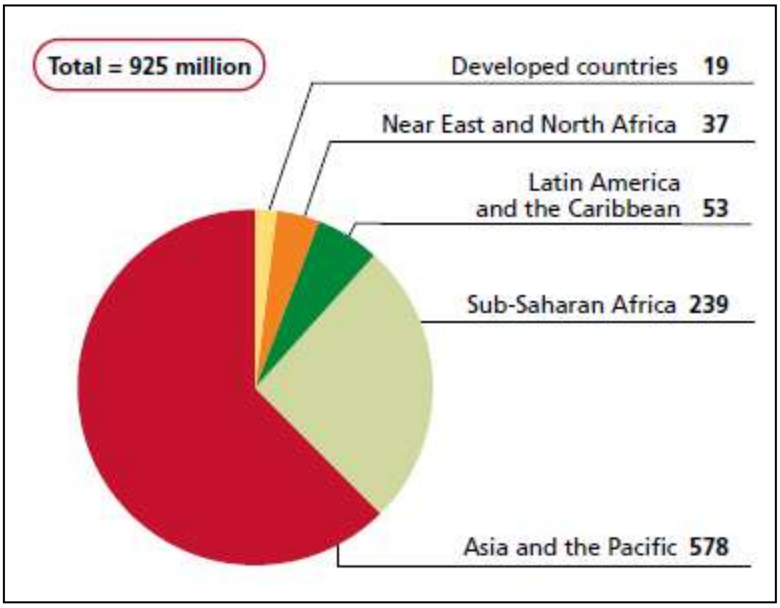


Figure 15. Undernourished population, 2010

(Source: The State of Food Insecurity in the World, FAO, 2010)

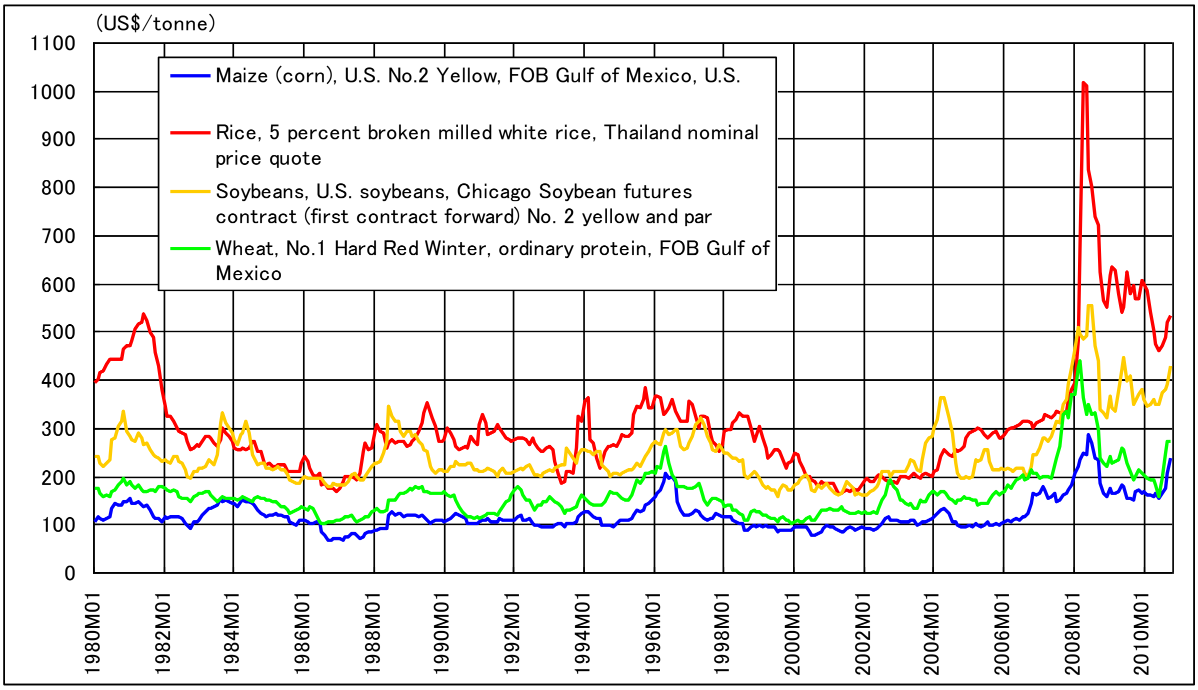


Figure 16. Transition of price of grain (Source: IMF Primary Commodity Prices)

Table 2. Irrigated land, total and share of arable land

(Source : FAO statistical yearbook 2010)

	IRRIGATED LAND (1,000ha)					SHARE IN ARABLE LAND & PERMANENT CROPS (%)				
	1994-1996	1999-2001	2005	2006	2007	1994-1996	1999-2001	2005	2006	2007
World	263,742.9	277,557.7	283,729.1	285,592.5	286,725.5	17.4	18.2	18.3	18.4	18.5
Developed Countries	69,325.3	70,259.3	70,546.1	70,922.6	70,969.5	10.6	11.0	11.2	11.4	11.5
Industrial Countries	42,549.3	44,539.3	45,165.0	45,579.0	45,833.8	11.1	11.6	11.8	12.1	12.3
Transition Countries	26,775.9	25,720.0	25,381.1	25,343.6	25,135.7	10.0	10.2	10.3	10.3	10.3
Developing Countries	194,417.7	207,298.4	213,183.0	214,669.9	215,756.0	22.4	23.3	23.1	23.1	23.1
sub-saharan	5,138.3	5,462.3	5,614.3	5,615.3	5,615.3	3.0	3.0	2.8	2.8	2.8
Latin America and Caribbean	17,972.0	18,514.8	18,589.1	18,599.1	18,599.1	11.4	11.4	11.2	11.1	11.1
Near East / North Africa	27,700.3	29,346.6	31,164.6	31,489.0	31,633.6	27.7	30.2	31.5	32.0	32.4
South Asia	75,218.0	80,663.7	82,793.0	83,108.0	83,278.0	36.9	39.2	40.5	40.6	40.7
East Asia	68,389.0	73,311.0	75,022.0	75,858.5	76,630.0	29.7	30.1	29.7	29.6	29.6

Table 3. Cereal balances, world and major country groups

(Source: World agriculture: towards 2030/2050, FAO, 2006)

	Demand						SSR[a]	Growth rates			
	per capita (kg)		total (million tonnes)				(percent)	(percent p.a.)			
year	food	all uses	food	all uses	production	net trade		period	demand	production	population
	1	2	3	4	5	6	7	8	9	10	11
					World						
1969/71	149	303	547	1114	1118	3	100	**1961-2001**	2.1	2.1	1.8
1979/81	160	325	708	1436	1442	3	100	**1971-2001**	1.7	1.7	1.7
1989/91	171	329	897	1727	1732	4	100	**1981-2001**	1.2	1.2	1.6
1999/01	165	309	1000	1865	1884	3	101	**1991-2001**	0.9	1.1	1.4
2030	165	331	1334	2677	2680	3	100	**1999/01-30**	1.2	1.2	1.0
2050	162	339	1439	3010	3012	3	100	**2030-50**	0.6	0.6	0.5
								1999/01-50	1.0	0.9	0.8
					Developing countries						
1969/71	146	192	381	499	483	-20	97	**1961-2001**	3.1	2.9	2.1
1979/81	162	219	526	711	649	-66	91	**1971-2001**	2.8	2.7	2.0
1989/91	174	238	693	951	868	-89	91	**1981-2001**	2.2	2.2	1.9
1999/01	166	238	784	1125	1026	-112	91	**1991-2001**	1.6	1.6	1.7
2030	166	268	1112	1799	1567	-232	87	**1999/01-30**	1.6	1.4	1.2
2050	163	279	1226	2096	1800	-297	86	**2030-50**	0.8	0.7	0.6
								1999/01-50	1.3	1.1	0.9
					Industrial countries						
1969/71	132	531	96	386	409	21	106	**1961-2001**	1.3	1.8	0.8
1979/81	139	542	110	427	551	111	129	**1971-2001**	1.1	1.2	0.7
1989/91	154	543	130	459	581	130	127	**1981-2001**	1.1	0.8	0.7
1999/01	162	592	147	536	647	114	121	**1991-2001**	1.6	1.4	0.6
2030	159	641	160	643	845	203	132	**1999/01-30**	0.6	0.9	0.3
2050	156	665	159	678	926	248	137	**2030-50**	0.3	0.5	0.1
								1999/01-50	0.5	0.7	0.2
					Transition countries						
1969/71	201	653	70	229	226	2	98	**1961-2001**	0.7	0.5	0.7
1979/81	189	778	72	297	242	-41	81	**1971-2001**	-0.7	-0.6	0.5
1989/91	179	769	74	317	282	-37	89	**1981-2001**	-2.3	-1.4	0.3
1999/01	169	499	69	205	211	2	103	**1991-2001**	-3.7	-2.2	-0.1
2030	164	618	62	235	267	32	113	**1999/01-30**	0.5	0.8	-0.3
2050	158	688	54	236	287	51	121	**2030-50**	0.0	0.4	-0.5
								1999/01-50	0.3	0.6	-0.4

[a] SSR =Self-Sufficiency rate = production/domestic demand (in percent)

Table 4. Wheat, rice and coarse grains: Net trade balances

(Source: World agriculture: towards 2030/2050, FAO, 2006)

	1969/71	1979/81	1989/91	1991/2001	2030	2050
			Developing Countries			
All cereals	-20	-66	-89	-112	-232	-297
Wheat	-25	-49	-59	-63	-127	-163
Rice	-1	-2	0	2	5	6
Coarse grains	6	-16	-30	-51	-110	-139
			Industrial countries			
All cereals	21	111	130	114	203	248
Wheat	24	66	76	66	110	132
Rice	2	3	2	1	-2	-3
Coarse grains	-5	42	52	47	95	118
			Transition countries			
All cereals	2	-41	-37	2	32	51
Wheat	3	-16	-15	2	22	36
Rice	-1	-1	-1	-1	-1	-1
Coarse grains	0	-25	-21	1	11	16
			Memo item: : Developing countries minus developing net exporters*			
All cereals	-30	-85	-106	-144	-295	-380
Wheat	-26	-51	-64	-72	-145	-188
Rice	-1	-5	-6	-9	-16	-20
Coarse grains	-3	-28	-36	-62	-134	-172

* Developing net exporters: those with net cereal exports over 1 million tonnes in 1999/01 (Argentina, Thailand and Viet Nam). India and China, although they met this criterion, are not included in the net exporter category as they are only occasional net exporters and may not be exporters in the future.

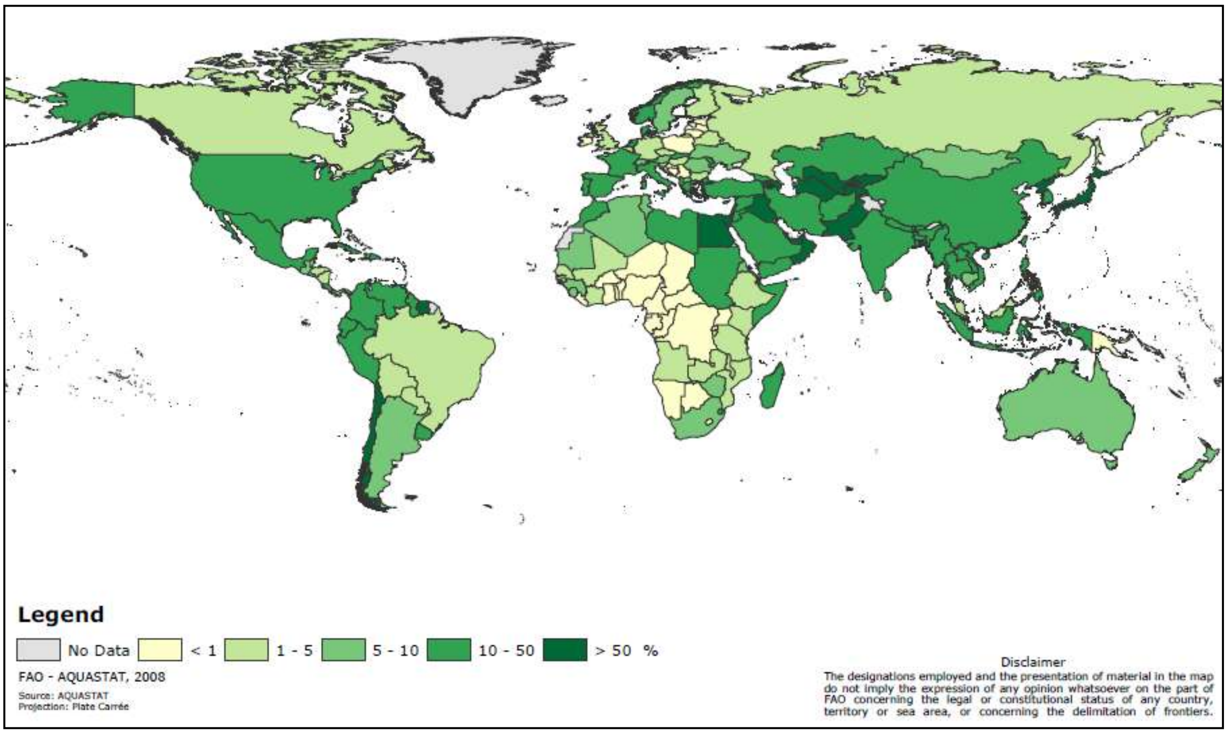


Figure 17. Area equipped for irrigation as percentage of cultivated area, around 2003

(Source: FAO AQUASTAT, 2008)

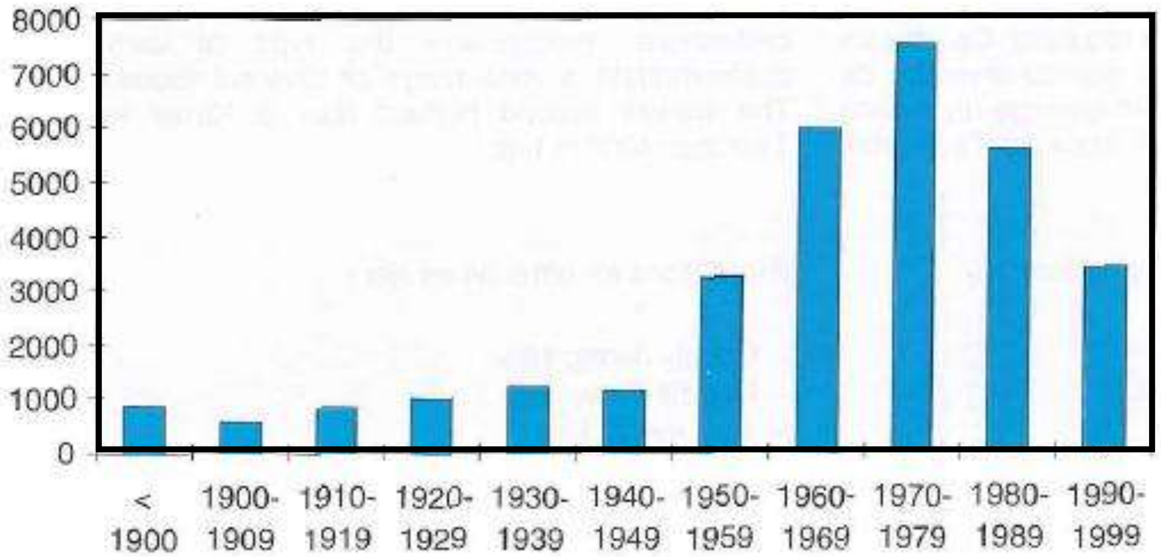


Figure 18. Dams Construction Trend up to 2000

(Source: World Register of Dams, 2003, ICOLD)

4. Need for Energy

1) Current Status

According to the WEO 2010 (IEA), world primary energy demand has increased by 70% between 1980 (7,229 Mtoe) and 2008 (12,271 Mtoe). An average annual rate of growth is 1.9%.

Oil is the dominant fuel in the primary energy mix, with demand is 85 Mb/d in 2008 (84 Mb/d in 2009). Demand for coal is 4,736 Mtoe in 2008.

2) Outlook

According to the WEO 2010 (IEA), in the New Policies Scenario, which takes account of both existing policies and declared intentions, world primary energy demand is projected to increase by 1.2% per year between 2008 and 2035, reaching 16,750 Mtoe, an increase of 4,500 Mtoe, or 36%.

World demand for coal increases by around 20% between 2008 and 2035, with almost all of the growth before 2020. Non-OECD countries share of total demand increases from 66% today to 82% by 2035. China, India and Indonesia account for nearly 90% of the total incremental growth. China remains the world's largest consumer of coal, while India becomes the second-largest around 2030; Indonesia takes fourth position (behind the United States) by 2035.

Global electricity generation grows by 75% over the outlook period, rising from 20,183 TWh in 2008 to 27,400 TWh in 2020, and to 35,300 TWh in 2035. The share of generation from non-hydro renewable energy sources - wind, biomass, solar, geothermal and marine - increases more than five-fold, from 3% in 2008 to 16% by 2035. Electricity production from natural gas maintains a constant percentage of global generation at about 21%; similarly, the shares of hydro and nuclear also stay flat at 16% and 14%, respectively.

Low-carbon technologies increasingly penetrate the electricity mix in the New Policies Scenario. Renewable sources (including hydro) and nuclear power are projected to account for 45% of total global generation by 2035, up from 32% today. A marked shift occurs in OECD countries, where this share reaches 56% by 2035. Non-OECD countries also move towards low-carbon technologies in the power sector, albeit reaching a lower level because of a smaller base at the beginning of the outlook period and less vigorous policy action to mitigate CO_2 emissions. Renewable energy and nuclear power account for 39% of generation there by 2035.

The use of modern renewable energy - including wind, solar, geothermal, marine, modern biomass and hydro - triples over the course of the outlook period, growing from 843 Mtoe in 2008 to just over 2,400 Mtoe in 2035. Its share in total primary energy demand increases from 7% to 14%.

3) Challenges

According to the WEO 2010 (IEA), there are 1.4 billion people in the world that lack access to electricity, some 85% of them in rural areas. Without additional dedicated policies, by 2030 the number of people without access to electricity drops, but only to 1.2 billion and some 15% of the world's population would still lack access, the majority in sub-Saharan Africa.

The number of people relying on biomass for basic cooking needs is projected to rise from 2.7 billion today to 2.8 billion in 2030. Using WHO estimates, linked to IEA's projections of biomass use, it is estimated that household air pollution from the use of biomass in inefficient stoves would lead to over 1.5 million premature deaths per year (over 4,000 per day) in 2030, greater than estimates for premature deaths from malaria, tuberculosis or HIV/AIDS.

To meet the more ambitious target of achieving universal access to modern energy services by 2030, additional investment of $756 billion in 2010-2030, or $36 billion per year, is required. This is less than 3% of the global energy investment projected in the New Policies Scenario to 2030.

In the New Policies Scenario, rising demand for fossil fuels continues to drive up energy-related CO_2 emissions through the projection period. Additional government policies that are assumed to be adopted, including action to implement pledges to reduce greenhouse-gas emissions announced under the Copenhagen Accord and moves to phase out fossil-energy subsidies in certain regions, help to slow the rate of growth in emissions, but do not stop the increase. Global energy-related CO_2 emissions jump by 21% between 2008 and 2035, from 29.3 Gt to35.4 Gt per year.

Even in the most environmentally-ambitious interpretation of the Copenhagen Accord, energy-related CO_2 emissions reach 31.9 Gt in 2020 - a cumulative 17.5 Gt higher from 2008 to 2020 than in the trajectory estimated in the WEO 2009, which assumed more intensive action earlier in the period. This means that it will be necessary to limit energy-related emissions to 21.7 Gt in 2035 dramatic emissions cuts after 2020, involving a near-doubling of the annual average CO_2 intensity improvements achieved in the earlier period.

Through hydropower generation dams have an important role, both in the direct generation of electricity and through their ability to generate peak power to stabilize electrical grids. The generation of electricity through renewable sources such as solar, wind and tidal power are an important element in reducing CO_2 emissions yet energy production from these sources rarely coincides with consumer energy demands. Increasingly existing hydropower dams are being operated in new ways to better integrate the outputs from renewable energy sources in the short term.

Furthermore the capability of pumped storages to store and release large amounts of electrical energy on demand has led to the development of more and larger pumped storage systems as a means of better storing the energy produced by these large renewable energy schemes.

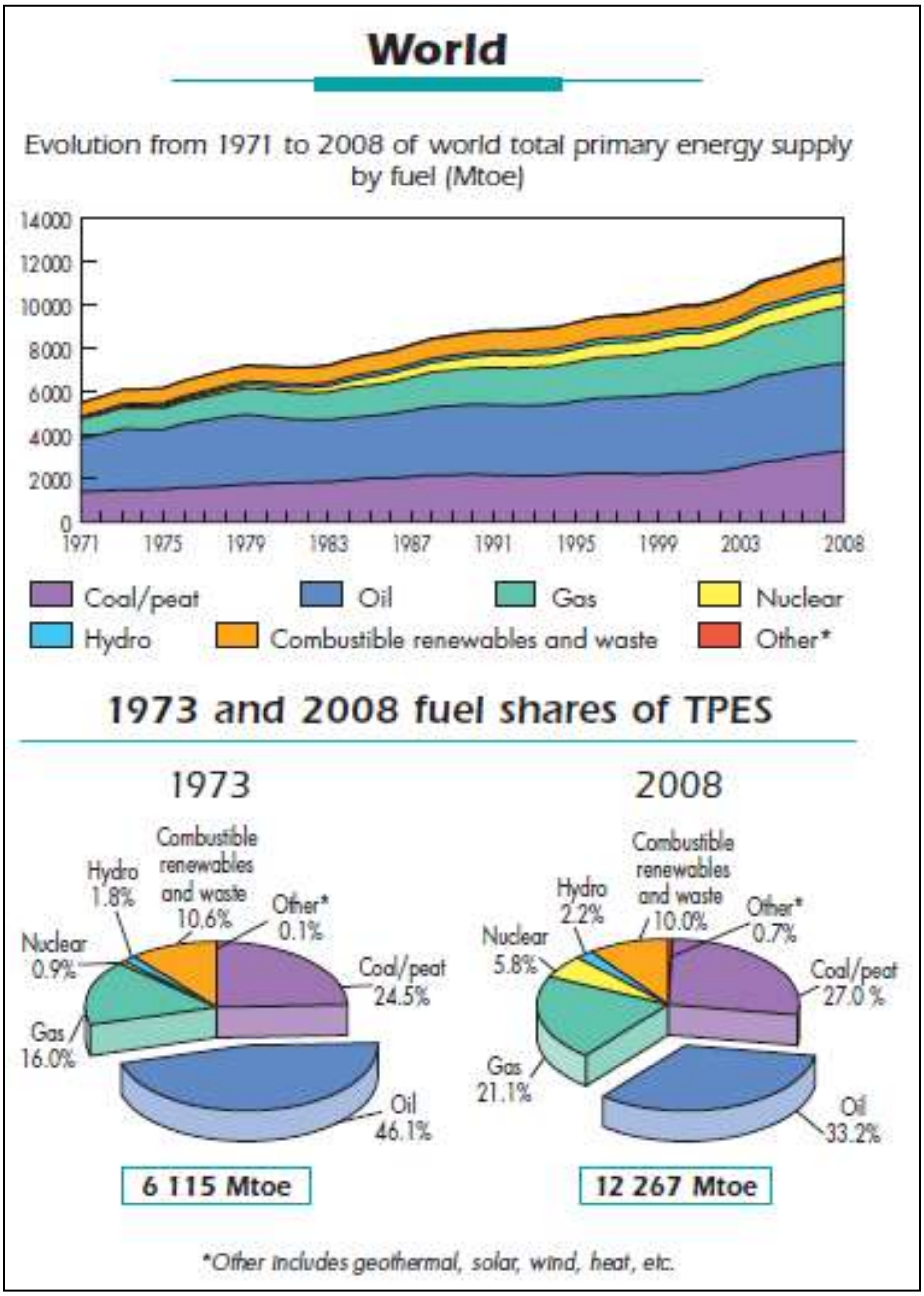


Figure 19. World primary energy supply by fuel

(Source: Key World Energy Statistics 2010, IEA)

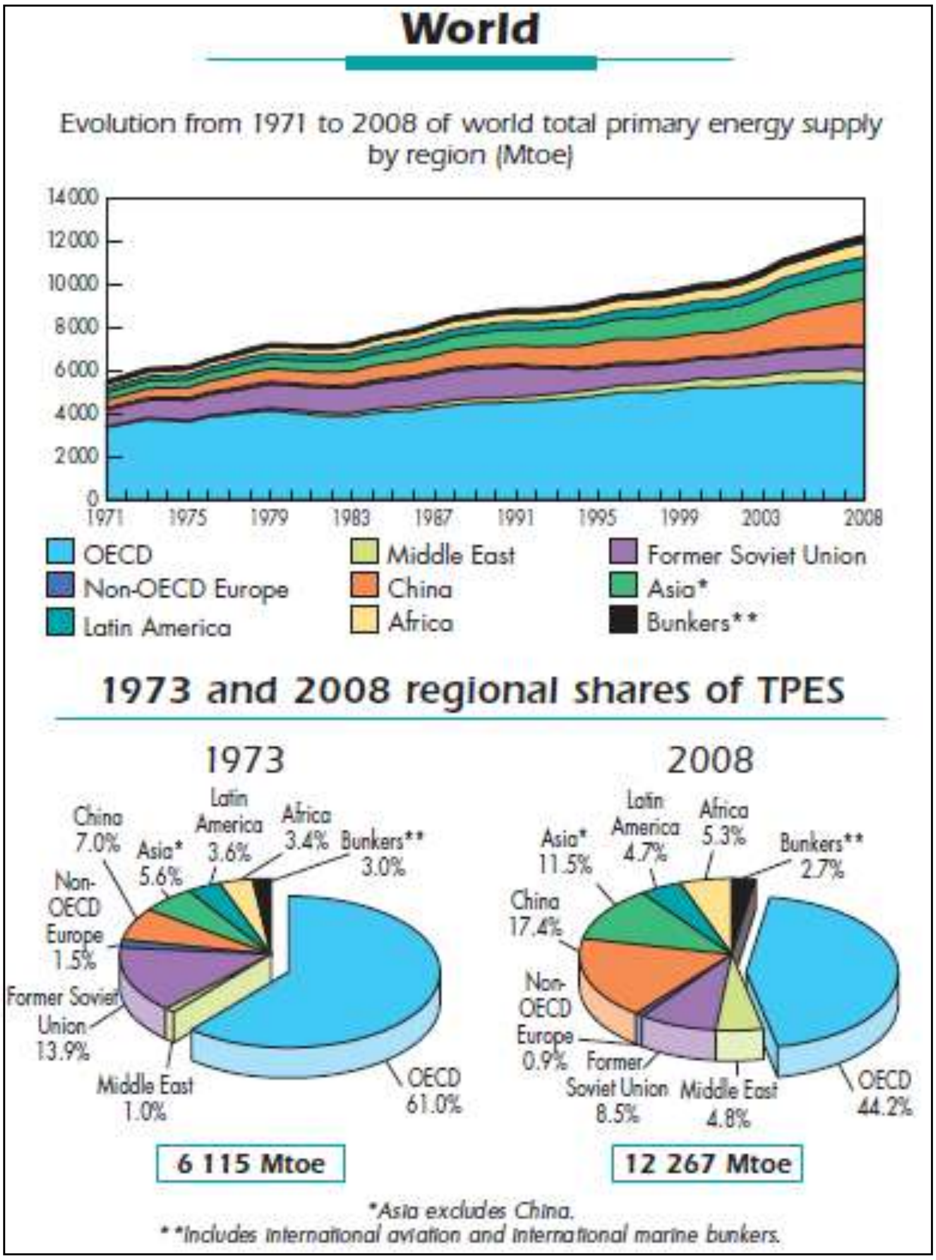
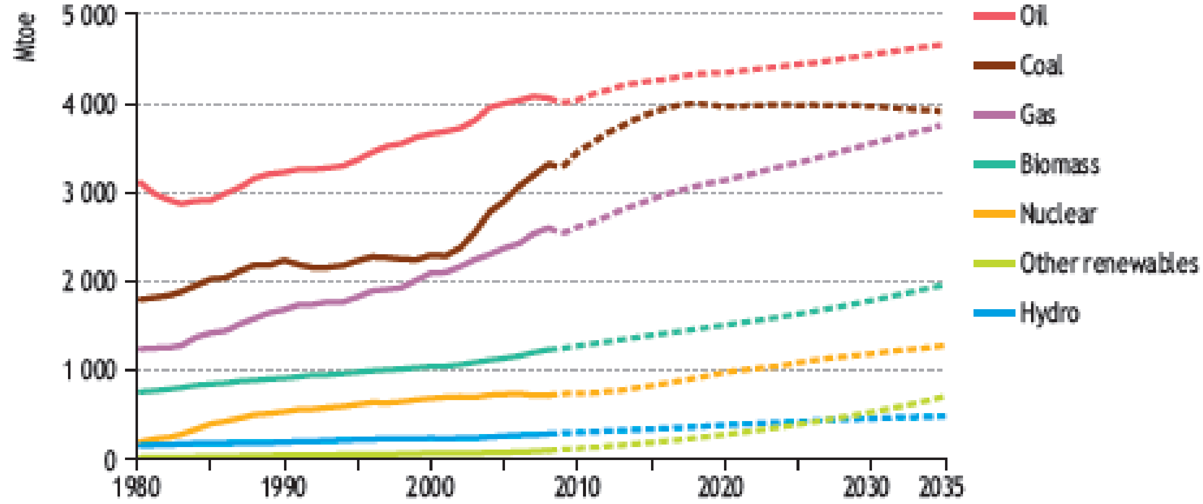


Figure 20. World primary energy supply by region

(Source: Key World Energy Statistics 2010, IEA)



<WEO-2010 New Policies Scenario>

The New Policies Scenario assumes the introduction of new measures (but on a relatively cautious basis) to implement the broad policy commitments that have already been announced, including national pledges to reduce greenhouse-gas emissions and, in certain countries, plans to phase out fossil energy subsidies.

Figure 21. World primary energy demand by fuel in the New Policies Scenario

(Source: WEO 2010, IEA)

Table 5. Primary energy demand by region in the New Policies (Mtoe)

(Source : WEO 2010, IEA)

	1980	2000	2008	2015	2020	2030	2035	2008-2035*
OECD	4 050	5 233	5 421	5 468	5 516	5 578	5 594	0.1%
North America	2 092	2 670	2 731	2 759	2 789	2 836	2 846	0.2%
United States	*1 802*	*2 270*	*2 281*	*2 280*	*2 290*	*2 288*	*2 272*	*-0.0%*
Europe	1 493	1 734	1 820	1 802	1 813	1 826	1 843	0.0%
Pacific	464	829	870	908	914	916	905	0.1%
Japan	*345*	*519*	*496*	*495*	*491*	*482*	*470*	*-0.2%*
Non-OECD	3 003	4 531	6 516	7 952	8 660	10 002	10 690	1.9%
E.Europe/Eurasia	1 242	1 019	1 151	1 207	1 254	1 344	1 386	0.7%
Caspian	*n.a*	*128*	*169*	*205*	*220*	*241*	*247*	*1.4%*
Russia	*n.a*	*620*	*688*	*710*	*735*	*781*	*805*	*0.6%*
Asia	1 067	2 172	3 545	4 609	5 104	6 038	6 540	2.3%
China	*603*	*1 107*	*2 131*	*2 887*	*3 159*	*3 568*	*3 737*	*2.1%*
India	*208*	*459*	*620*	*778*	*904*	*1 204*	*1 405*	*3.1%*
Middle East	128	381	596	735	798	940	1 006	2.0%
Africa	274	502	655	735	781	868	904	1.2%
Latin America	292	456	569	667	723	812	855	1.5%
Brazil	*114*	*185*	*245*	*301*	*336*	*386*	*411*	*1.9%*
World**	7 229	10 031	12 271	13 776	14 556	16 014	16 748	1.2%
European Union	*n.a*	*1 682*	*1 749*	*1 722*	*1 723*	*1 719*	*1 732*	*-0.0%*

* Compound average annual growth rate.
** World includes international marine and aviation bunkers (not included in regional totals).

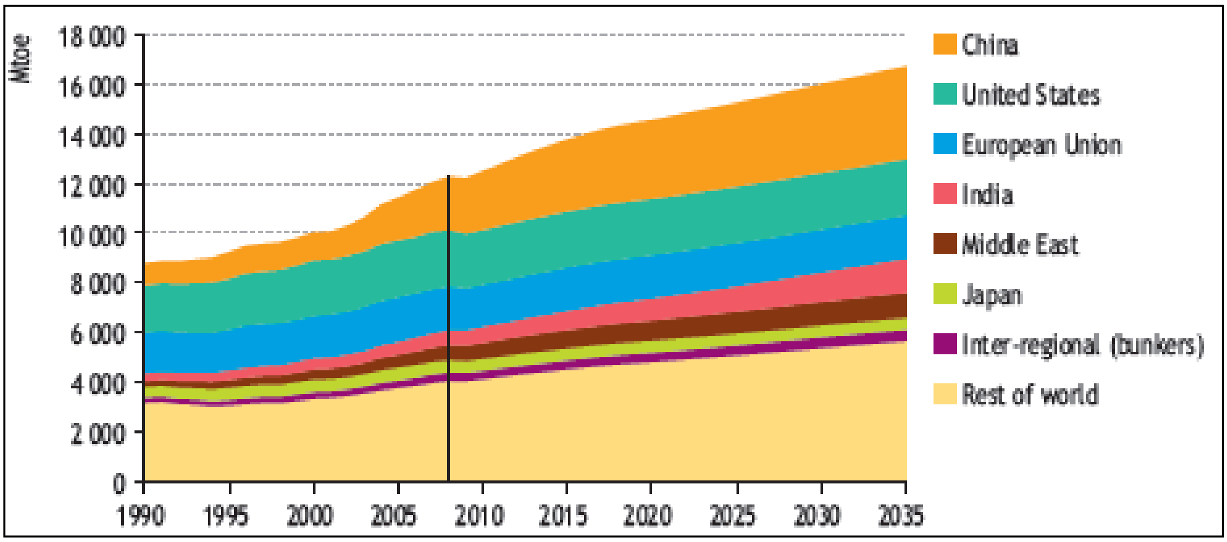


Figure 22. Primary energy demand by region in the New Policies (Mtoe)

(Source : WEO 2010, IEA)

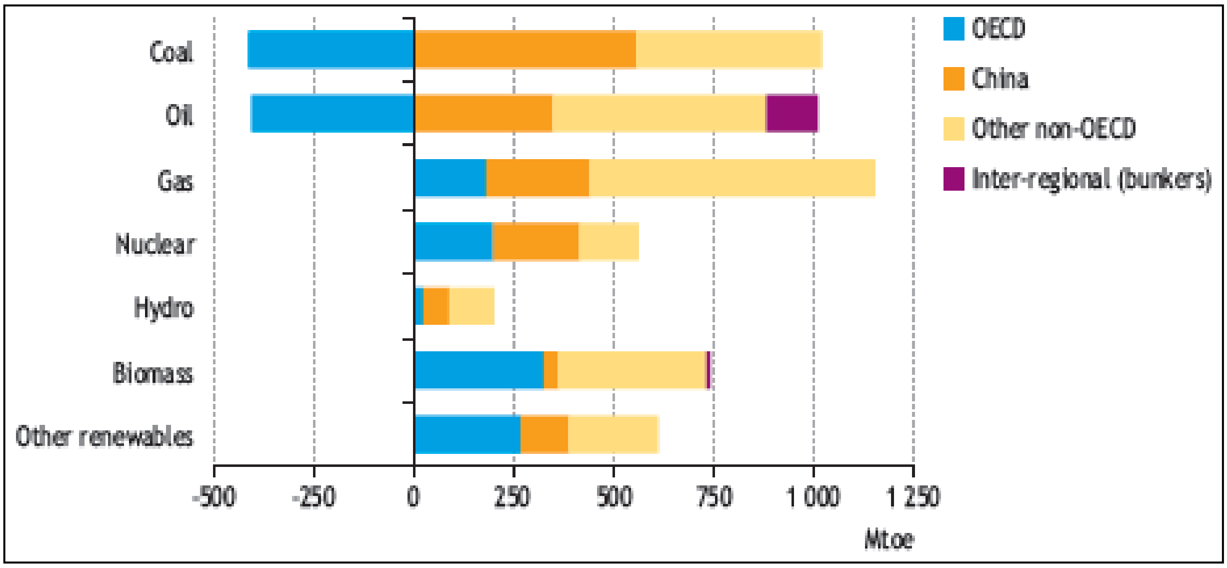


Figure 23. Incremental primary energy demand by fuel and region in the New Policies Scenario, 2008-2035 (Source: WEO 2010, IEA)

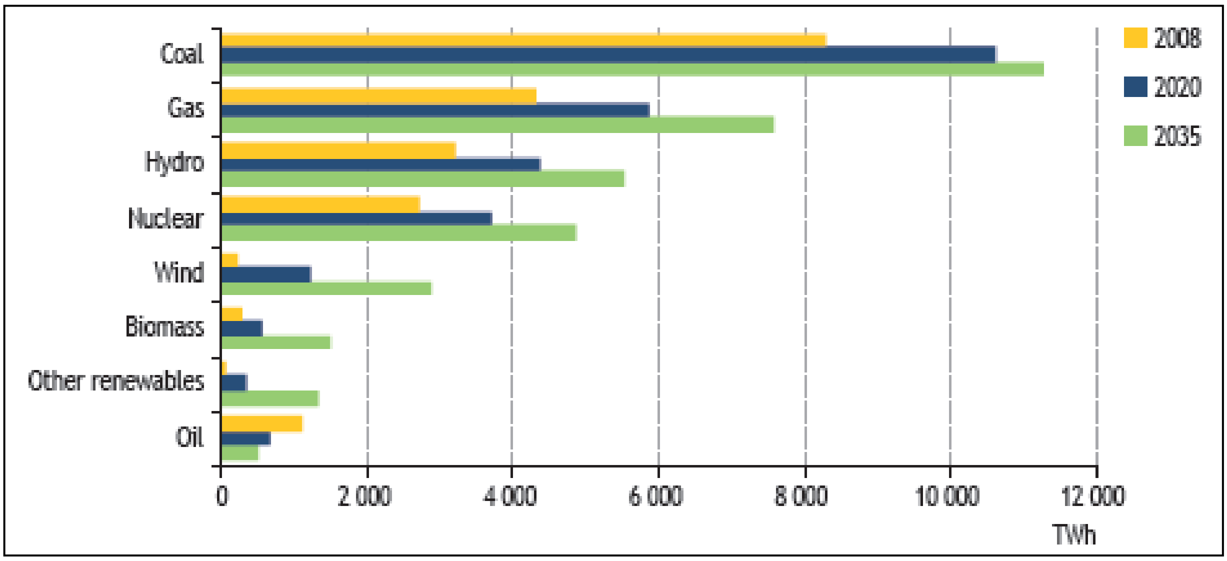


Figure 24. World electricity generation by type in the New Policies Scenario

(Source: WEO 2010, IEA)

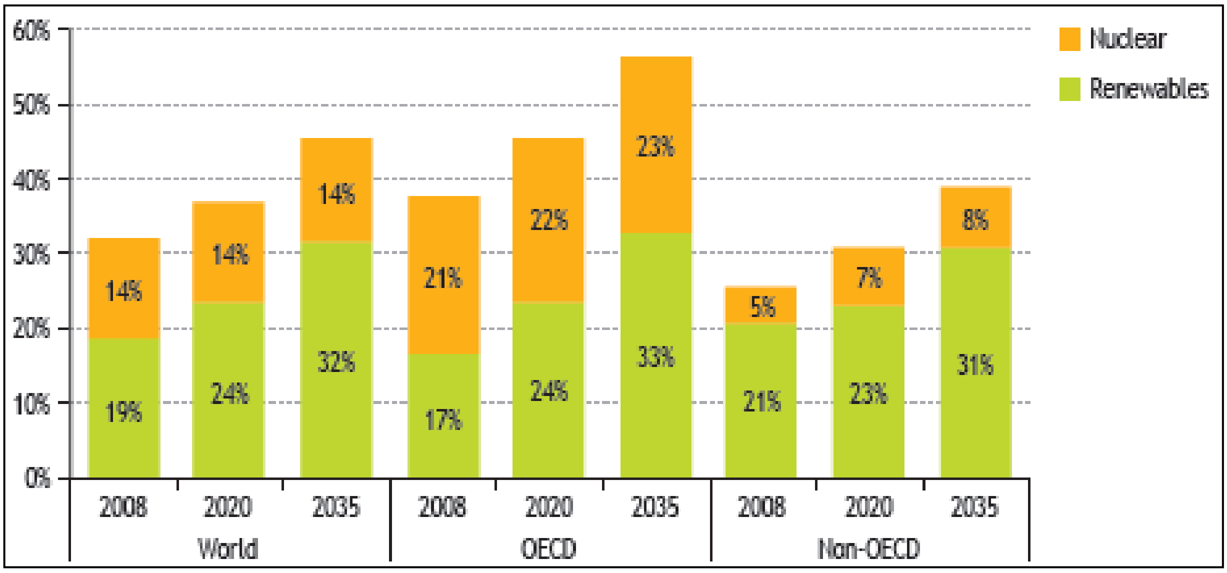


Figure 25. Share of nuclear and renewable energy in total electricity generation by region in the New Policies Scenario (Source: WEO 2010, IEA)

5. Water Resources

1) Water Distribution

(1) Current Status

It is estimated that the world contains about 1,400 million km^3 of water with 35 million km^3 (2.5 percent) as freshwater and the rest as saline water. The large amount of freshwater contained in ice caps, glaciers and deep in the ground is not accessible for use. Freshwater that can be used stems essentially from rainfall over land, generated through the hydrological cycle. The majority of freshwater that can be used exists as groundwater, only about 0.3 percent of all the freshwater is contained in lakes, rivers and atmosphere (Crops and Drops, FAO, 2002).

The average annual precipitation over land amounts to 119,000 km^3, of which some 74,000 km^3 evaporate back into the atmosphere. The remaining 45,000 km^3 flows into lakes, reservoirs and rivers or infiltrate into the ground to replenish the aquifers. Not all of these 45,000 km^3 are accessible for use because some of the water flows into remote rivers and during seasonal floods (Crops and Drops, FAO, 2002) and almost all rivers have minimum environmental flow requirements.

The amount of groundwater recharge is large in the northern part of South America, Central Africa and South-East Asia, and little in North Africa and Central Asia (UN WATER, Water in a Changing World, 2009).

The amount of water resources per inhabitant is poor in North Africa and West Asia (FAO, AQUASTAT, 2008).

(2) Outlook

Changes in precipitation and temperature lead to changes in runoff and water availability. Runoff is projected with high confidence to increase by 10 to 40% by mid-century at higher latitudes and in some wet tropical areas, including populous areas in East and Southeast Asia, and decrease by 10 to 30% over some dry regions at mid-latitudes and dry tropics, due to decreases in rainfall and higher rates of evapotranspiration. There is also high confidence that many semi-arid areas (e.g. the Mediterranean Basin, western United States, South Africa and north-eastern Brazil) will suffer a decrease in water resources due to climate change. Drought-affected areas are projected to increase in extent, with the potential for adverse impacts on multiple sectors, e.g. agriculture, water supply, energy production and health. Regionally, large increases in irrigation water demand as a result of climate changes are projected (IPCC, WG1-AR4, 2007).

The negative impacts of climate change on freshwater systems outweigh its benefits (high confidence). Areas in which runoff is projected to decline face a reduction in the value of the services provided by water resources (very high confidence). The beneficial impacts of increased annual runoff in some areas are likely to be tempered by negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risk (IPCC, WG1-AR4, 2007).

2) Water Usage

(1) Current Status

The current total amount of water withdrawals (3,829 km^3) is 8.8 percent of the whole renewable water resources (44,659km^3). Around 70% of total water used globally is from surface water and 20% is from groundwater sources (renewable or not). Agriculture is by far the main user of water. Irrigated agriculture accounts for 70% of water withdrawals, which can rise to more than 80% in some regions. Although increasing in urbanized economies, industrial (including energy) use accounts for only 20% of total water use and municipal use for about 10%. Water withdrawals for energy generation – hydropower and thermo-cooling – are on the rise, but energy is one of the economic sectors that consumes the least water and returns most of the water withdrawn back to the water system (about 95%) (UN WATER, Water in a Changing World, 2009).

Water withdrawals per person range from 20 m^3 a year in Uganda to more than 5,000 m^3 in Turkmenistan, with a world average of 600 m^3. Water withdrawals are highest in arid and semi-arid areas, where irrigation is most needed for agricultural production, and are lowest in tropical countries (UN WATER, Water in a Changing World, 2009).

The degree of groundwater development (percentage of mean groundwater recharge) is higher in North Africa and West Asia.

(2) Outlook

It is estimated that the world's water withdrawals will increase from 3,800 km^3 a year to 4,200 km^3 between 1995 and 2025. The amount of water withdrawals for agriculture will increase from 2,500 km^3 to 2,695 km^3, for industry from 750 km^3 to 800 km^3, for municipal use from 350 km^3 to 500 km^3. Also it is estimated that the world's water use will increase from 2,100 km^3 to 2,300 km^3 (WWC, World Water Vision, 2000).

3) Floods and droughts

With global climate change and projected increases in global temperature, scientists generally agree that the hydrologic cycle will intensify and that extremes will become more common.

Although droughts have always been a part of the hydrologic cycle as larger populations become more dependent on water from increasingly variable sources for both their food and water the effects of these droughts may become more intense.

Flooding can also have devastating effects, particularly in areas with high population density and without adequate early warning and emergency response systems, such as Central America, Central Europe, West Asia, East Asia and South-East Asia. During 1992-2001 floods accounted for 43% of recorded disasters and affected more than 1.2 billion people.

Available research suggests a significant future increase in heavy rainfall events in many regions, including some in which the mean rainfall is projected to decrease. Increases in the frequency and severity of floods and droughts are projected to adversely affect sustainable development (UN WATER, Water in a Changing World, 2009).

4) Challenges

(1) Current Problems

The water resource is unevenly distributed. Securing the water resource is important in the region exposed to a high stress. It is necessary to construct appropriate water withdrawal equipment in the region where the quantity of water withdrawn per person is a little compared with the amount of the water resource. And it is necessary to secure the water resource in the region where water depends on underground water, because underground water is drying up.

(2) Future Problems

It is necessary to deal appropriately with the following problems which will occur along with the rise in population and the climatic change.

- Increase of municipal water demand (population growth and urbanization, improvement of life level)
- Increase of agricultural water demand (the rise in foods demand, and grain demand for fodder)
- Increases in the frequency and severity of floods and droughts

Table 6. World water distribution

(Source : Crops and Drops, FAO, 2002)

		Water volume (million km³)	Percent of freshwater	Percent of total water
Total water		**1 386**		**100.00**
Freshwater		**35**	**100.0**	**2.53**
Glaciers and ice caps	24.4		69.7	1.76
Groundwater	10.5		30.0	0.76
Lakes, rivers, atmosphere	0.1		0.3	0.01
Saline water		**1 351**		**97.47**

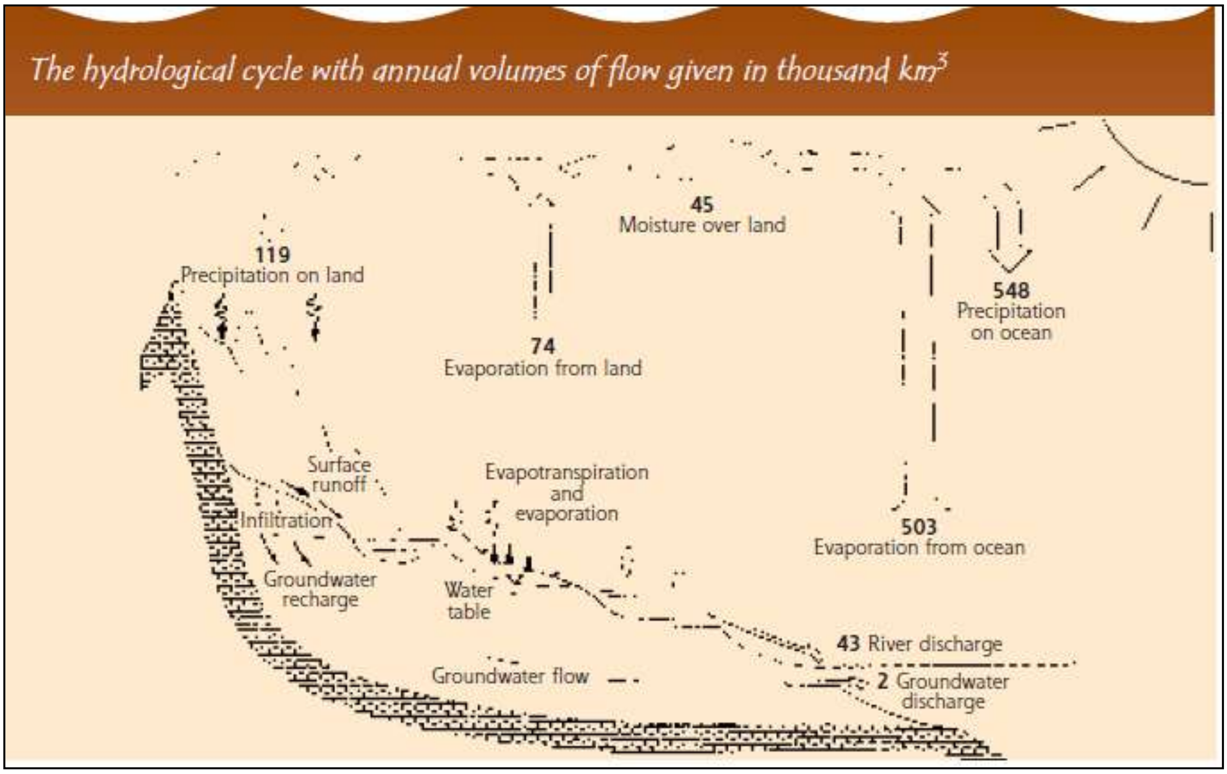


Figure 26. The hydrological cycle with annual volumes of flow

(Source : Crops and Drops, FAO, 2002)

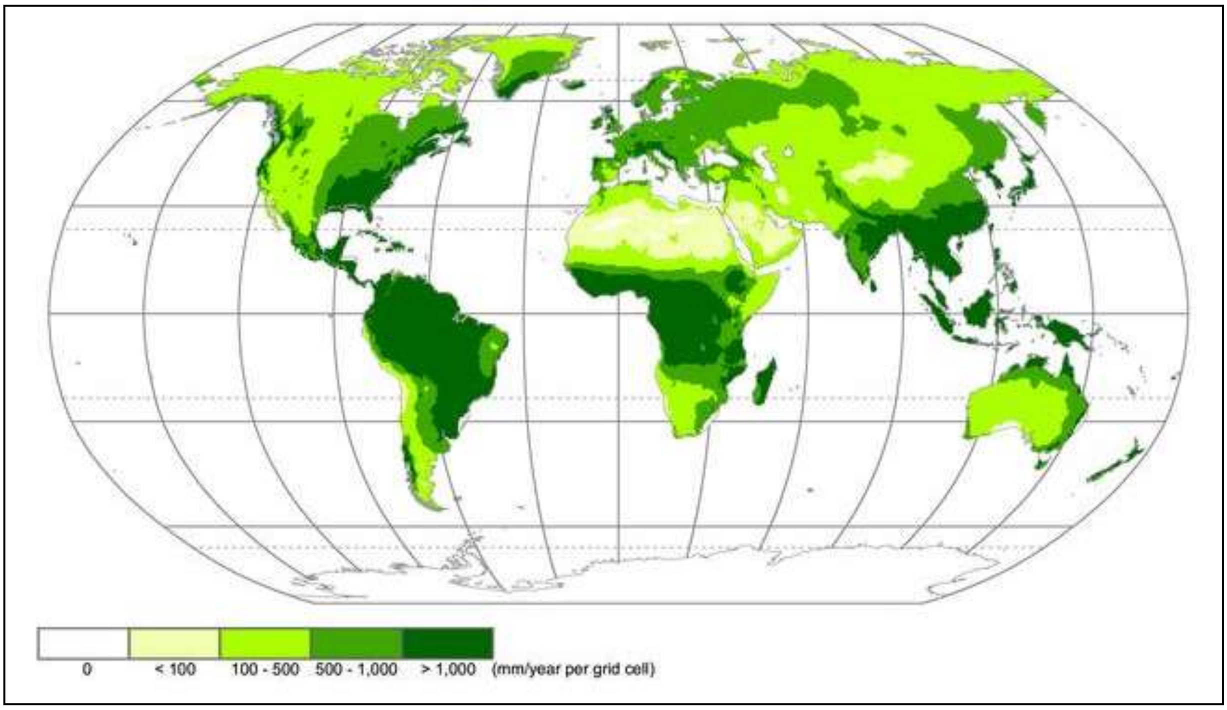


Figure 27. Annual Precipitation (Source : Water Systems Analysis Group, UNH)

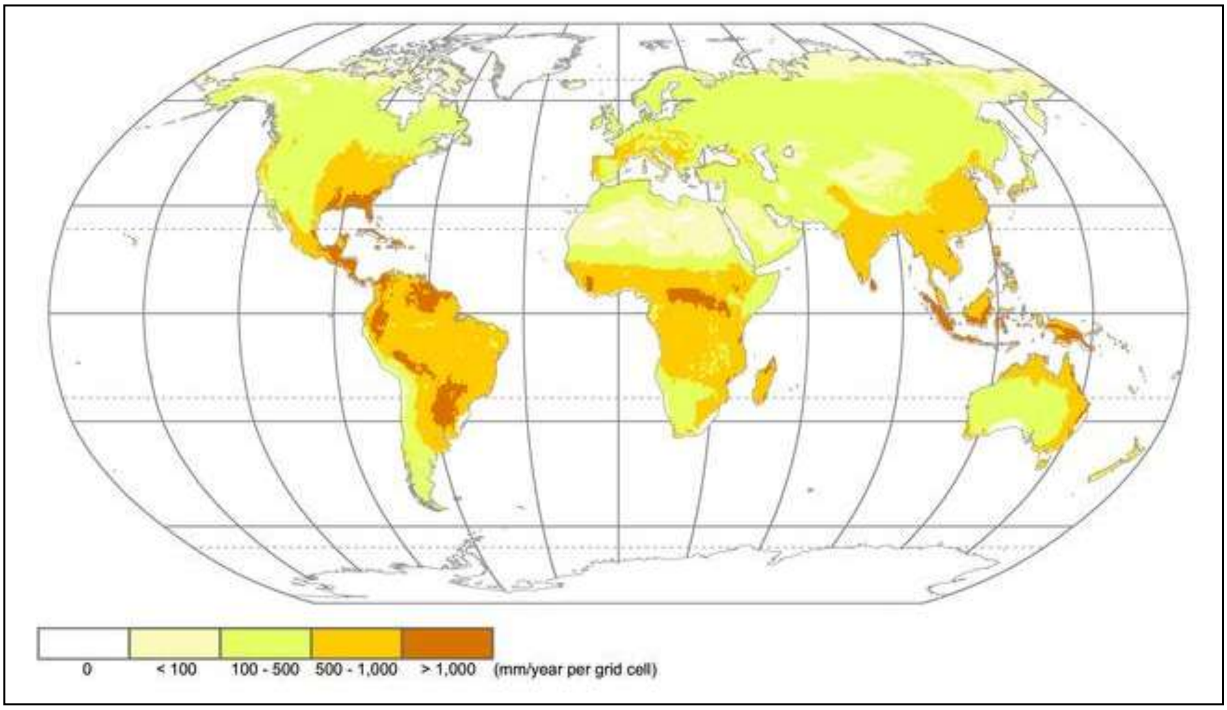


Figure 28. Annual Evapotranspiration (Source : Water Systems Analysis Group, UNH)

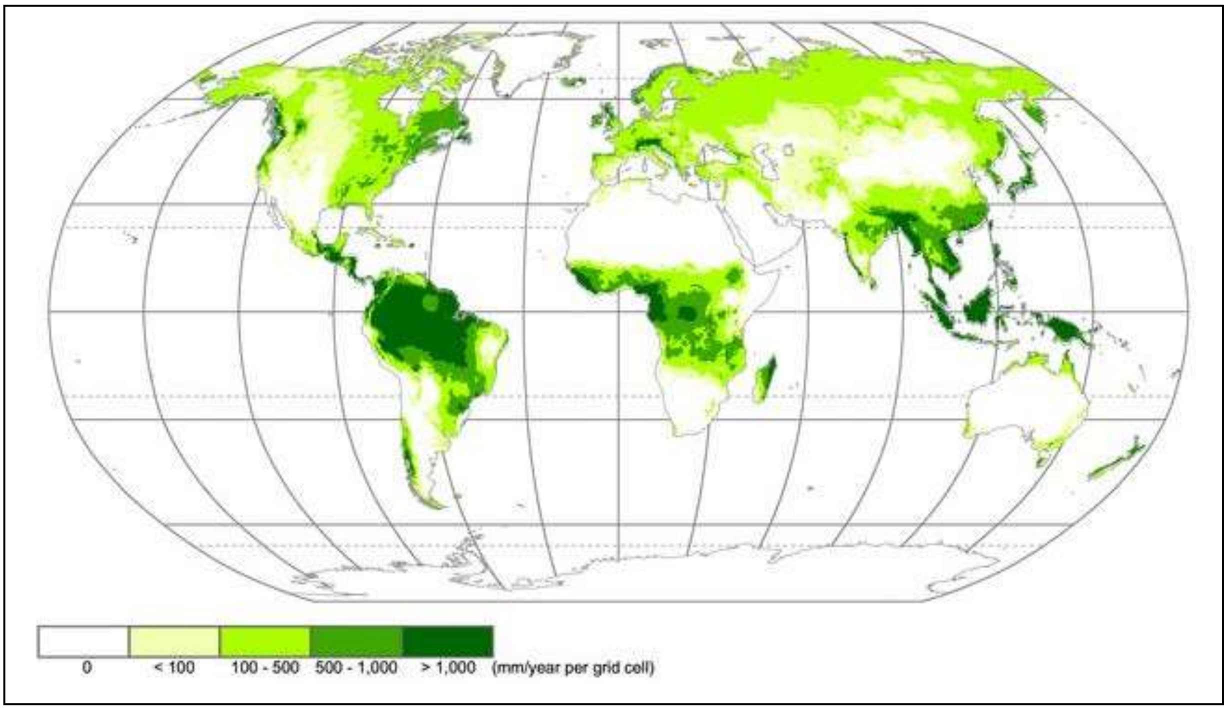


Figure 29. Annual Runoff (Source : Water Systems Analysis Group,UNH)

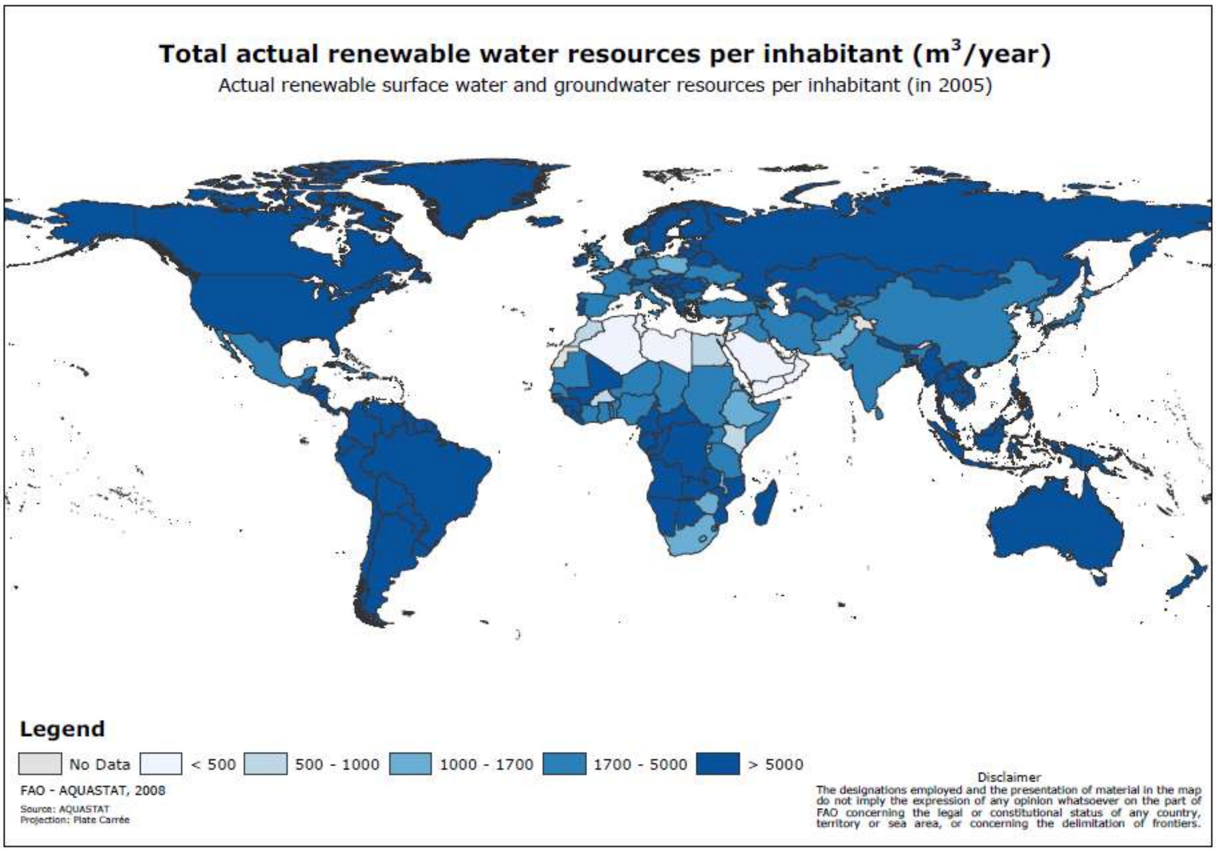


Figure 30. Total actual renewable water resources per inhabitant, 2005

(Source : FAO AQUASTAT, 2008)

Table 7. Water resources and withdrawal, 2000

(source : Water in a Changing World, UN WATER, 2009)

(Cubic kilometres per year unless otherwise indicated)

Region	Renewable water resources	Total water withdrawals	Water withdrawals: Agriculture Amount	Agriculture Percent	Industry Amount	Industry Percent	Domestic (urban) Amount	Domestic (urban) Percent	Withdrawals as percent of renewable resources
Africa	3,936	217	186	86	9	4	22	10	5.5
Asia	11,594	2,378	1,936	81	270	11	172	7	20.5
Latin America	13,477	252	178	71	26	10	47	19	1.9
Caribbean	93	13	9	69	1	8	3	23	14.0
North America	6,253	525	203	39	252	48	70	13	8.4
Oceania	1,703	26	18	73	3	12	5	19	1.5
Europe	6,603	418	132	32	223	53	63	15	6.3
World	43,659	3,829	2,663	70	784	20	382	10	8.8

Source: Based on Comprehensive Assessment of Water Management in Agriculture 2007.

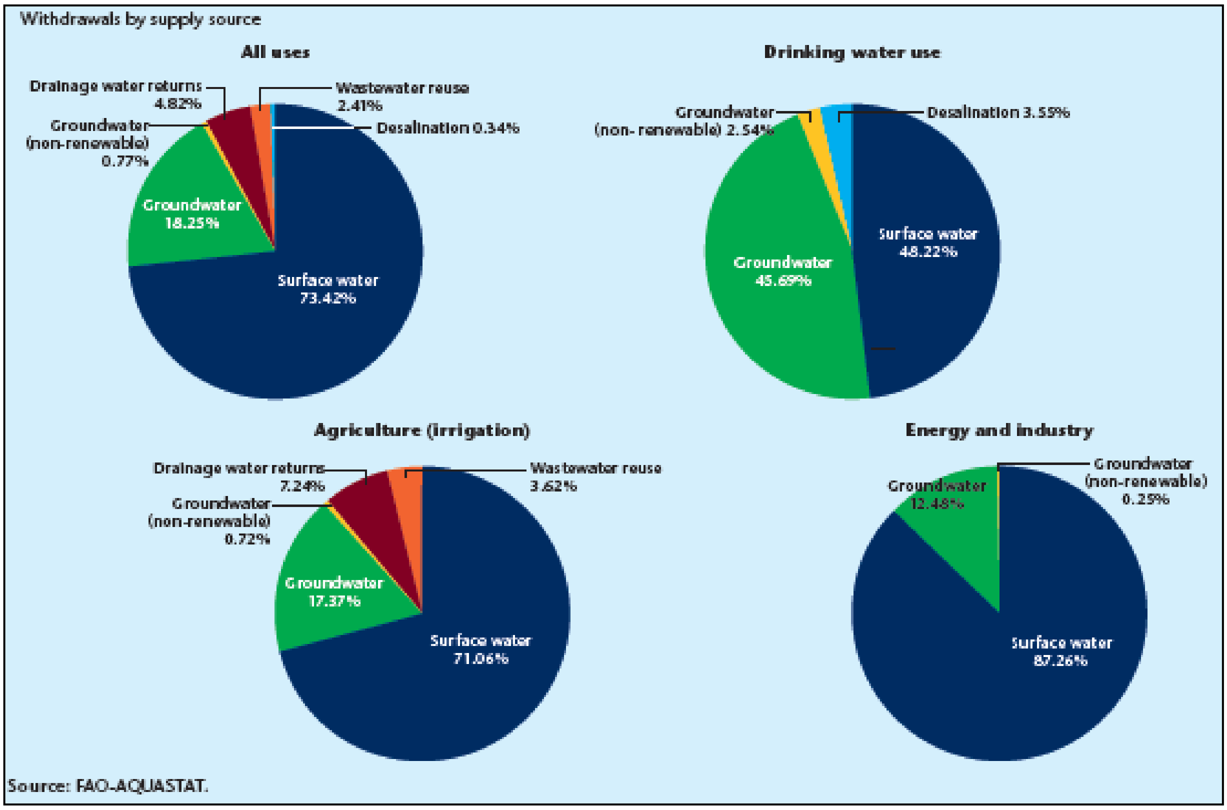


Figure 31. Sources of water use globally and for major sectors

(Source : Water in a Changing World, UN WATER, 2009)

Table 8. Estimates of renewable water supplies, access to renewable supplies and population served by freshwater, 2000

(Source : Water in a Changing World, UN WATER, 2009)

Indicator	Asia	Eastern Europe, the Caucasus and Central Asia	Latin America	Middle East and North Africa	Sub-Saharan Africa	OECD	Global total
Area (millions of square kilometres)	20.9	21.9	20.7	11.8	24.3	33.8	133.0
Total precipitation (thousands of cubic kilometres a year)	21.6	9.2	30.6	1.8	19.9	22.4	106.0
Evaporative returns to atmosphere (percent of precipitation)	55	27	27	86	78	64	63
Total renewable water supply (blue water flows; thousands of cubic kilometres a year) [% of global runoff]	9.8 [25]	4.0 [10]	13.2 [33]	0.25 [1]	4.4 [11]	8.1 [20]	39.6 [100]
Renewable water supply (blue water flows accessible to humans; thousands of cubic kilometres a year) [percent of total renewable water supply]	9.3 [95]	1.8 [45]	8.7 [66]	0.24 [96]	4.1 [93]	5.6 [69]	29.7 [75]

Note: Means computed based on methods in Vörösmarty, Leveque, and Revenga (2005). Estimates are based on climate data for 1950-96, computed using estimates of population living downstream of renewable supplies in 2000.

Source: Fekete, Vörösmarty, and Grabs 2002.

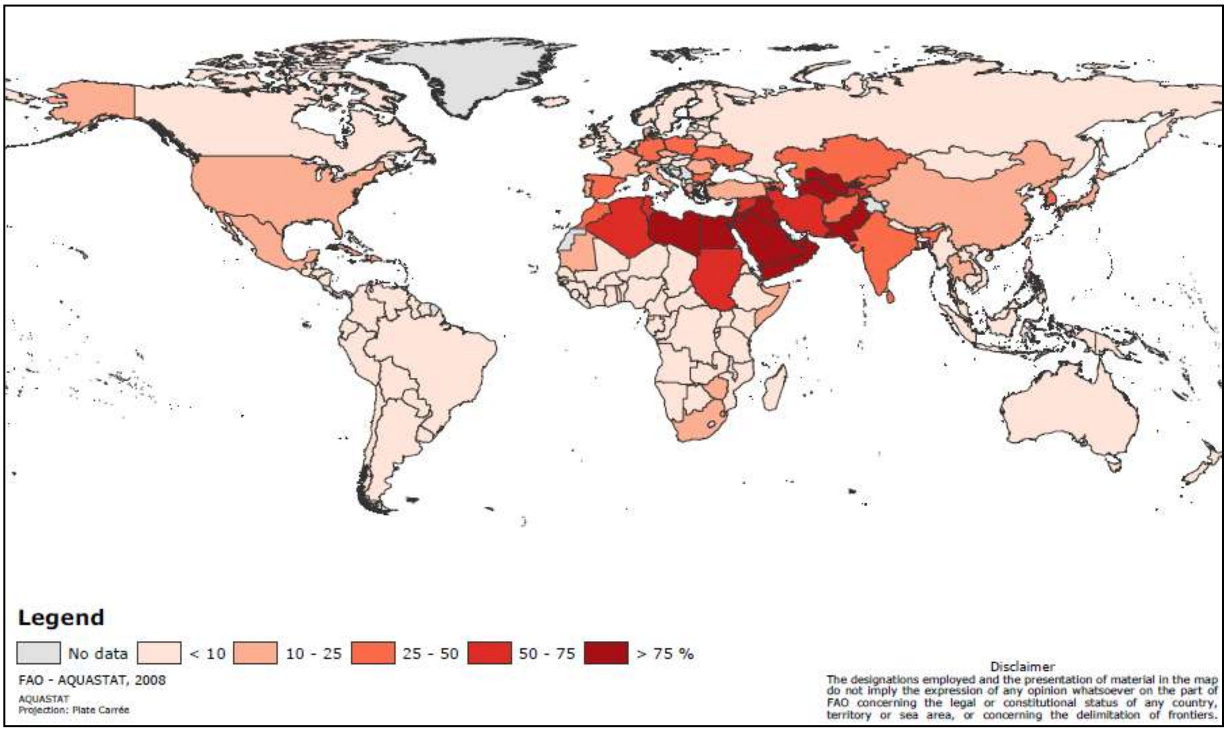


Figure 32. Proportion of renewable water resources withdrawn, around 2001

(Source : FAO AQUASTAT, 2008)

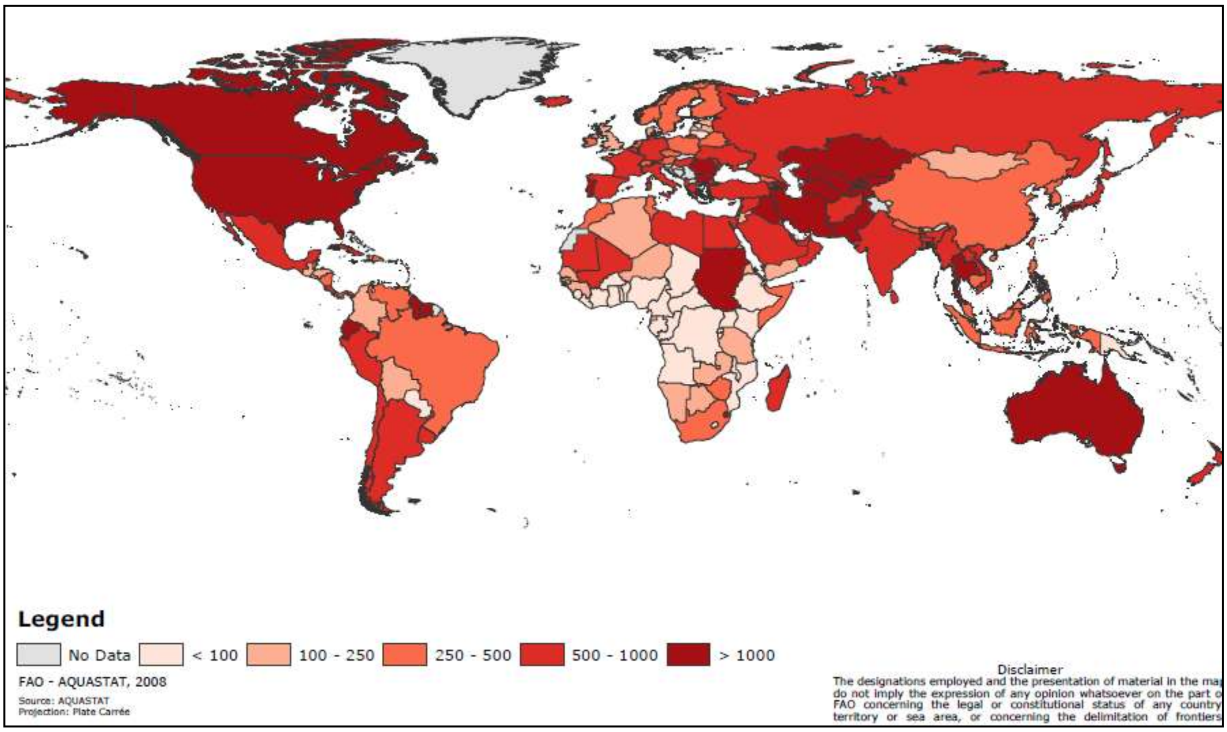


Figure 32. Water withdrawal per inhabitant, around 2001

(Source : FAO AQUASTAT, 2008)

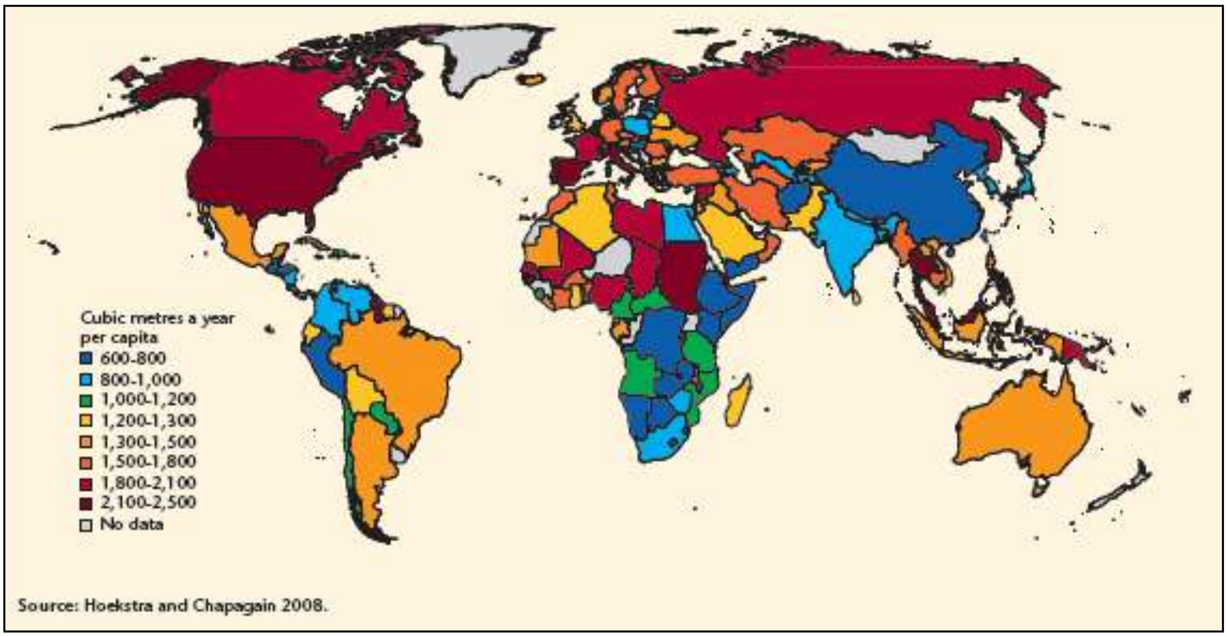


Figure 33. Average national water footprint per capita, 1997-2001

(Source : Water in a Changing World, UN WATER, 2009)

Table 9. Virtual Water and Water Footprint

(Source : Water a shared responsibility, UN WATER, 2006)

International virtual water flows

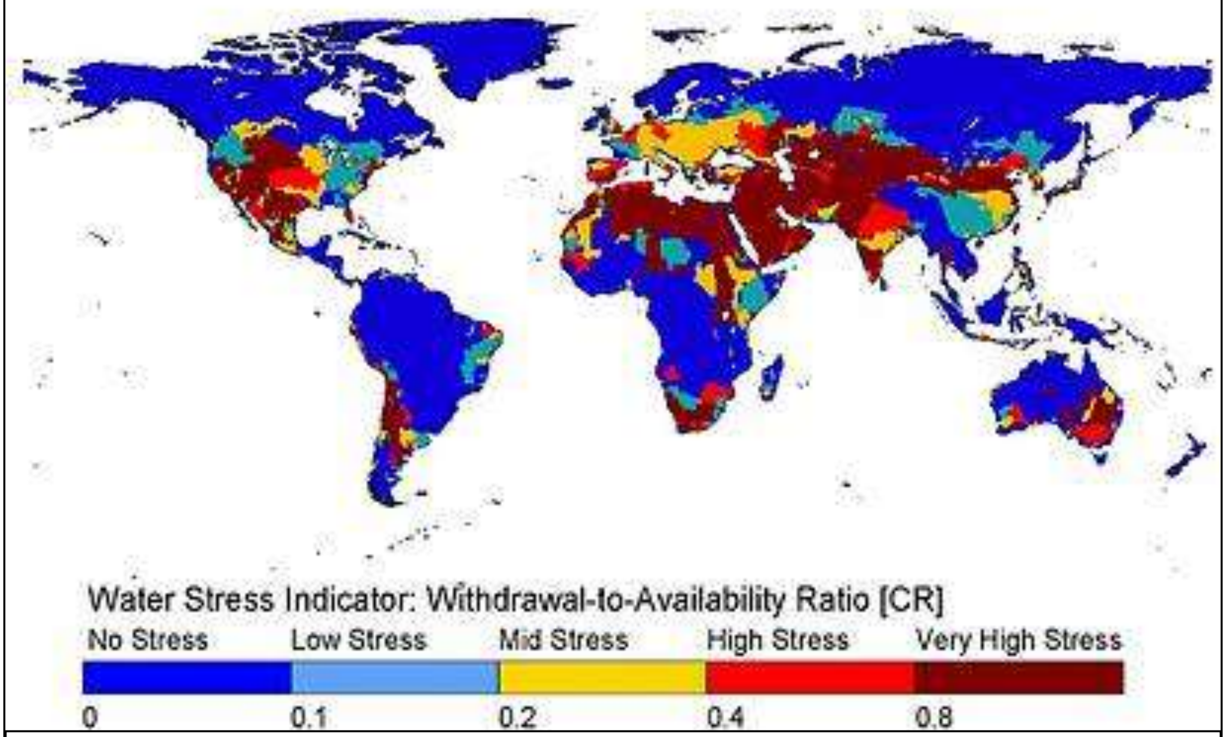
The International trade of commodities implies flows of virtual water over large distances, where virtual water should be understood as the volume of water required to produce a commodity. Virtual water flows between nations can be estimated from statistics on international product trade and estimates of the virtual water content of products. The global volume of virtual water flows related to the international trade in commodities is 1.6 trillion m^3/yr. About 80 percent of these virtual water flows relate to the trade in agricultural products, while the remainder is related to industrial product trade. An estimated 16 percent of global water use is not for producing domestically consumed products, but rather products for export. With the increasing globalization of trade, global water inter-dependencies and overseas externalities are likely to increase. At the same time, the liberalization of trade creates opportunities to increase global water use efficiency (see **Chapter 12**).

Globally, water is saved if agricultural products are traded from regions with high water productivity to those with low water productivity. At present, if importing countries produced all imported agricultural products domestically, they would require 1.6 trillion m^3 of water per year; however, the products are being produced with only 1.2 trillion m^3/yr in the exporting countries, saving global water resources by 352 billion m^3/yr.

The water footprint

The water footprint shows the extent and locations of water use in relation to consumption. The water footprint of a country is defined as the volume of water needed for the production of the goods and services consumed by the inhabitants of the country. The internal water footprint is the volume of water used from domestic water resources, whereas the external water footprint is the water used in other countries. Water footprints of individuals or nations can be estimated by multiplying the volumes of goods consumed by their respective water requirement. The US appears to have an average water footprint of 2,480 cubic metres per capita per year (m^3/cap/yr), while China has an average footprint of 700 m^3/cap/yr. The global average water footprint is 1,240 m^3/cap/yr. The four major factors that determine the water footprint of a country are volume of consumption (related to the gross national income); consumption patterns (e.g. high versus low meat consumption); climate (growth conditions); and agricultural practice (water use efficiency).

Sources: Chapagain and Hoekstra, 2004; Chapagain, et al., 2005.



Water stress results from an imbalance between water use and water resources. The water stress indicator in this map measures the proportion of water withdrawal with respect to total renewable resources. It is a criticality ratio, which implies that water stress depends on the variability of resources. Water stress causes deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.) The value of this criticality ratio that indicates high water stress is based on expert judgment and experience (Alcamo and others, 1999). It ranges between 20 % for basins with highly variable runoff and 60 % for temperate zone basins. In this map, we take an overall value of 40 % to indicate high water stress. We see that the situation is heterogeneous over the world.

Figure 34. Water Stress Indicator (Source : WaterGAP 2.0 - December, WWC)

Table 10. Renewable water use in the World Water Vision

(Source : World Water Vision, WWC, 2000)

In our Vision the water for irrigated agriculture is drastically limited, with 40% more food produced (partly from rainfed agriculture) consuming only 9% more water for irrigation. Industrial use goes down in developed countries, but the decline is more than offset by increases in the developing world. Municipal use goes up sharply in developing countries, to provide a minimum amount for all, and down in the developed world. Recycling and increased productivity lower the ratio of water withdrawn to water consumed for all uses.

User	Cubic kilometres 1995[a]	Cubic kilometres 2025[b]	Percentage increase 1995–2025	Notes
Agriculture				
Withdrawal	2,500	2,650	6	Food production increases 40%, but much higher water productivity limits increase in harvested irrigated area to 20% and increase in net irrigated area to 5–10%.
Consumption	1,750	1,900	9	
Industry				
Withdrawal	750	800[c]	7	Major increase in developing countries is partly offset by major reduction in developed countries.
Consumption	75	100	33	
Municipalities				
Withdrawal	350	500[d]	43	Major increase and universal access in developing countries; stabilisation and decrease in developed countries.
Consumption	50	100	100	
Reservoirs (evaporation)	200	220	10	
Total				
Withdrawal	3,800	4,200	10	
Consumption	2,100	2,300	10	
Groundwater overconsumption	200[e]	0		Increased recharge of aquifers makes groundwater use sustainable.

Note: Totals are rounded.

a. The 1995 uses are provided for reference. These data are based on Shiklomanov (1999), rounded off.

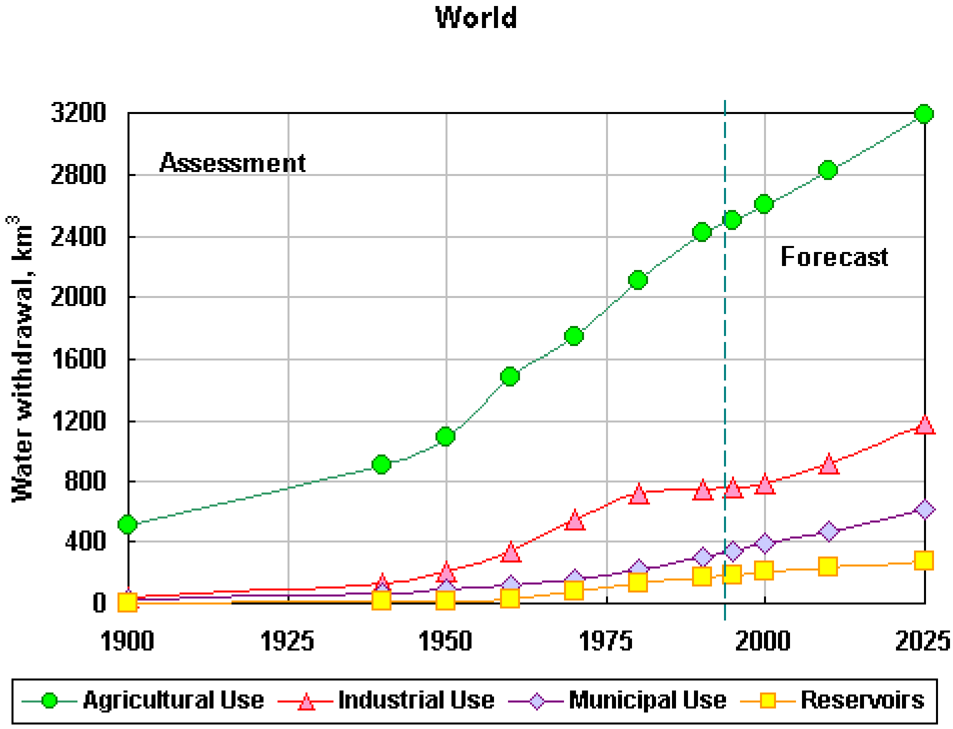
b. World Water Vision staff estimates.

c. For industry it is recognised that developing countries need a major expansion in industrial water use. For the roughly 2 billion people in cities in developing countries that need livelihoods (both the current poor plus the increase in population) an average of 200 liters a person per day is used. This means a 400 cubic kilometre increase in diversions for industry in developing countries. At the same time, diversions for industry in developed countries can be drastically reduced. Better management and reduced losses lower the ratio of water withdrawn to water consumed.

d. Residential water use of poor people in developing countries needs to be drastically increased. Residential use in developed countries stabilises and is reduced.

e. Postel (1999).

Source: Shiklomanov 1999; World Water Vision staff; Postel 1999.



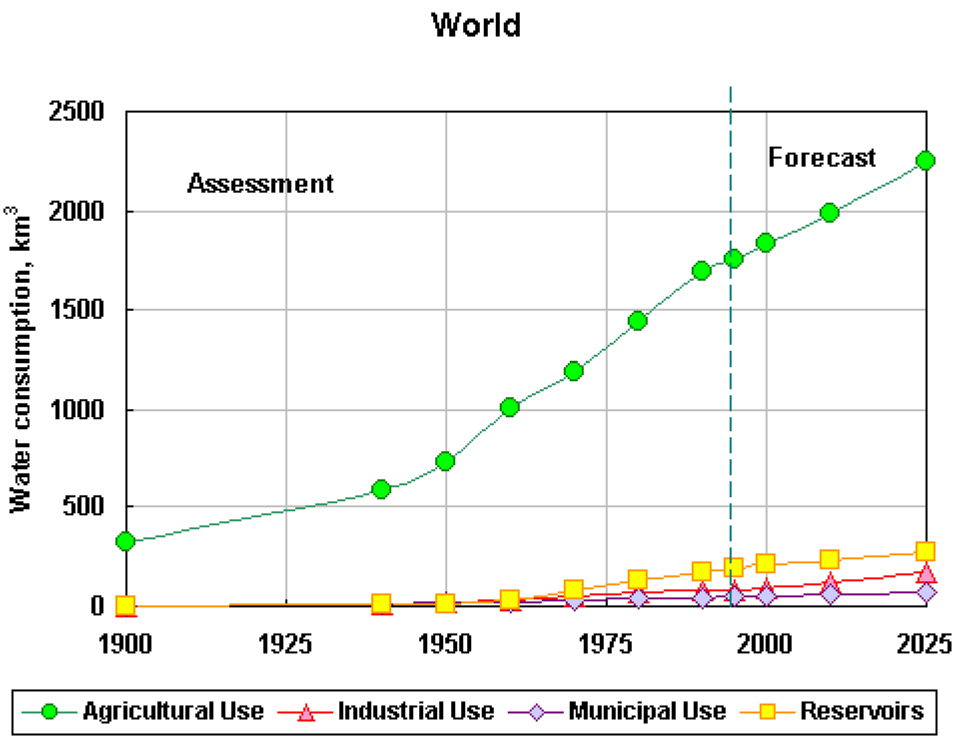


Figure 35. Dynamics of water use in the world by kind of economic activity

(Source : http://webworld.unesco.org/water/ihp/db/shiklomanov)

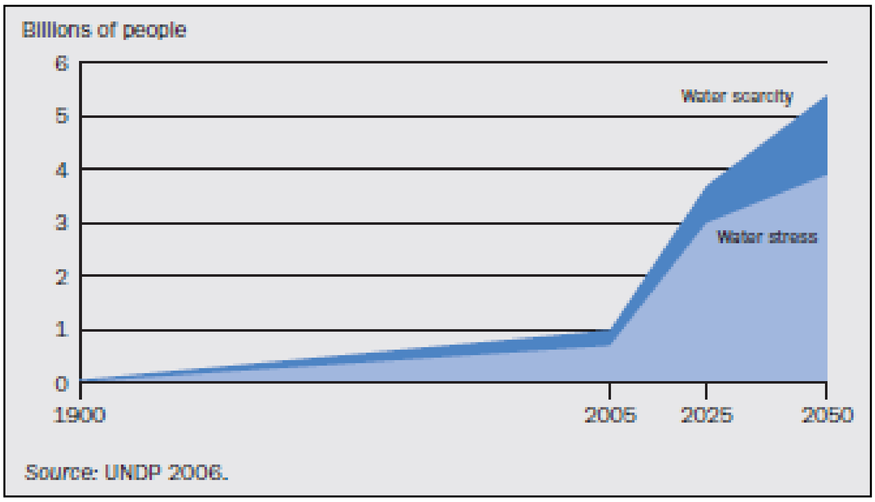
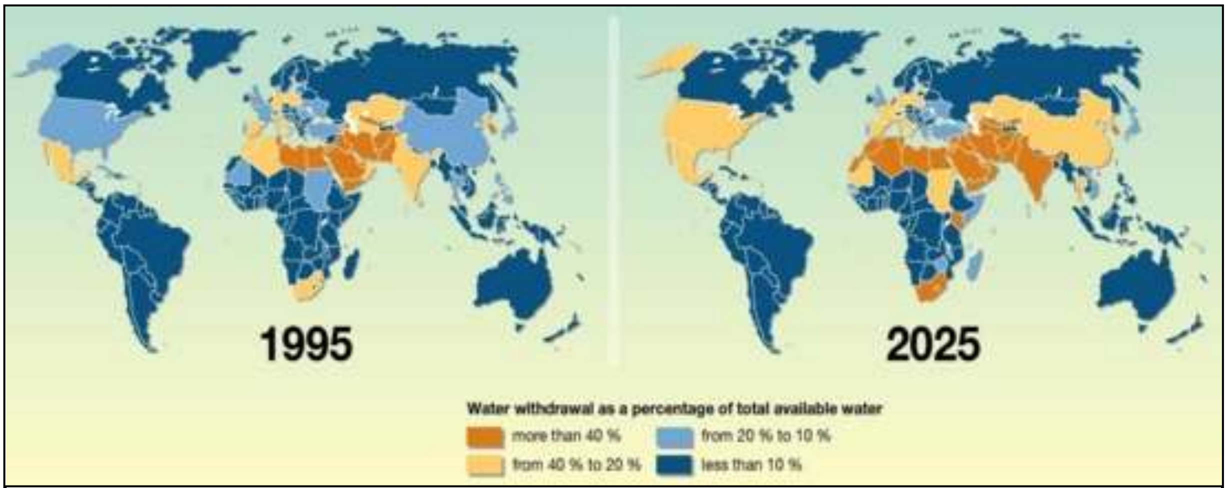


Figure 36. More people will experience water scarcity and water stress

(Source : World Development Indicators 2007,World Bank)



According to Population Action International, based upon the UN Medium Population Projections of 1998, more than 2.8 billion people in 48 countries will face water stress, or scarcity conditions by 2025. Of these countries, 40 are in West Asia, North Africa or sub-Saharan Africa. Over the next two decades, population increases and growing demands are projected to push all the West Asian countries into water scarcity conditions. By 2050, the number of countries facing water stress or scarcity could rise to 54, with a combined population of four billion people - about 40% of the projected global population of 9.4 billion (Gardner-Outlaw and Engleman, 1997; UNFPA, 1997).

Figure 37. Increased global water stress

(Source : http://www.grida.no/publications/vg/water2/page/3289.aspx)

Table 11. Virtual water content of selected products

(Source : Water a Shared Responsibility, UN WATER, 2006)

Product	Litres of water per kilo of crop
Wheat	1, 150
Rice	2, 656
Maize	450
Potatoes	160
Soybeans	2, 300
Beef	15, 977
Pork	5, 906
Poultry	2, 828
Eggs	4, 657
Milk	865
Cheese	5, 288

Note: Virtual water is the total amount of water used in the production and processing of a given product.

Source: Adapted from Hoekstra, 2003.

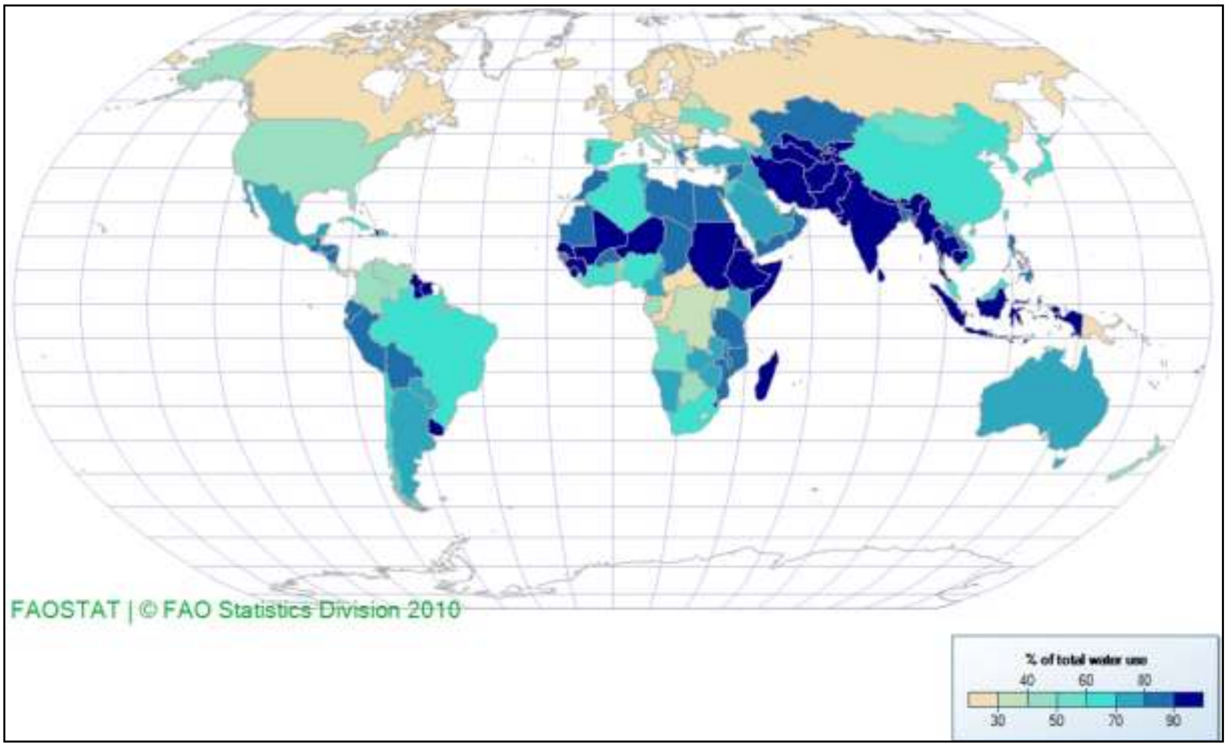


Figure 38. Share of agriculture in water use, 1998-2007

(Source : FAO statistical yearbook 2010)

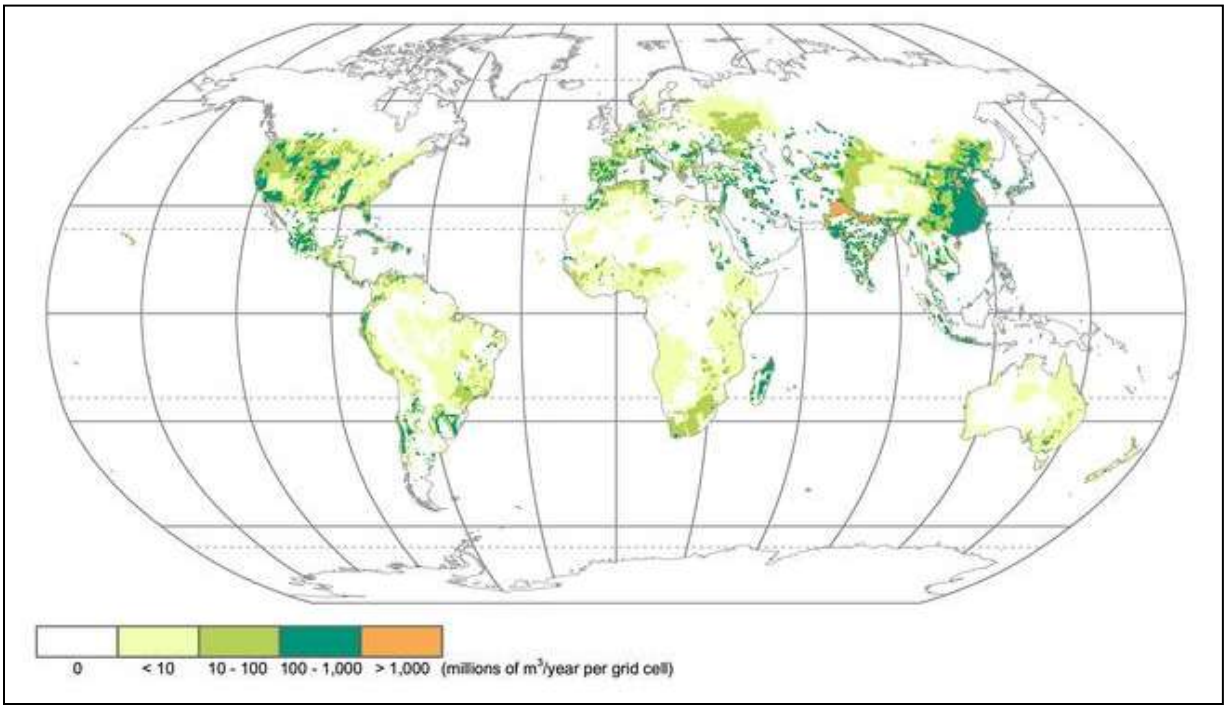


Figure 39. Irrigation Water Withdrawals, 2000

(Source : Water Systems Analysis Group, UNH)

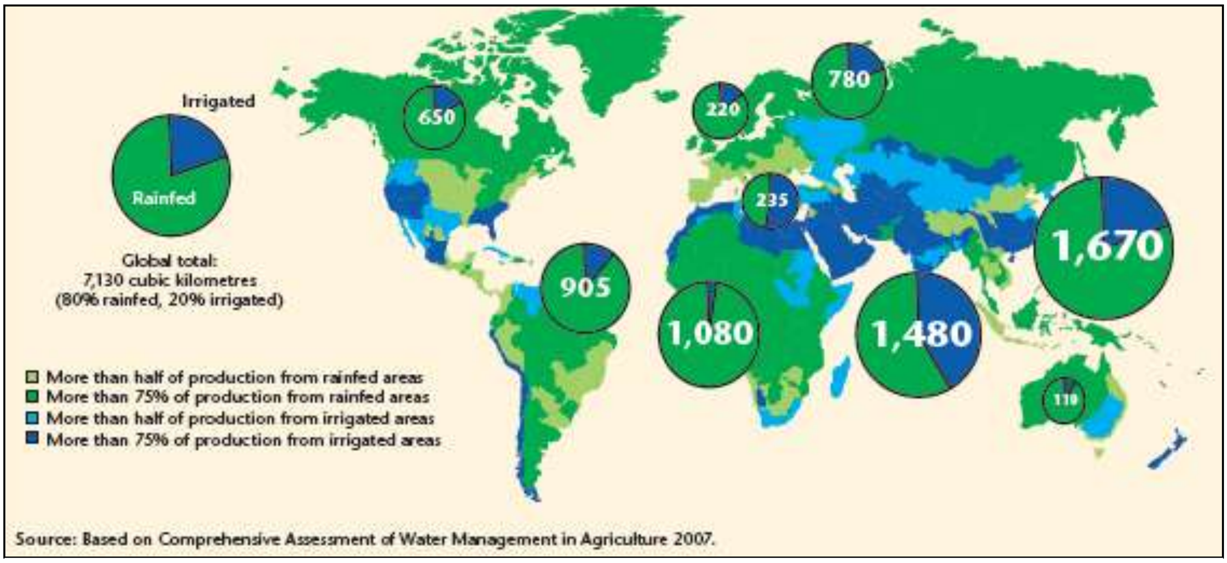


Figure 40. Relative Importance of Rainfed and Irrigated Agriculture

(Source : Water in a Changing World, UN WATER, 2009)

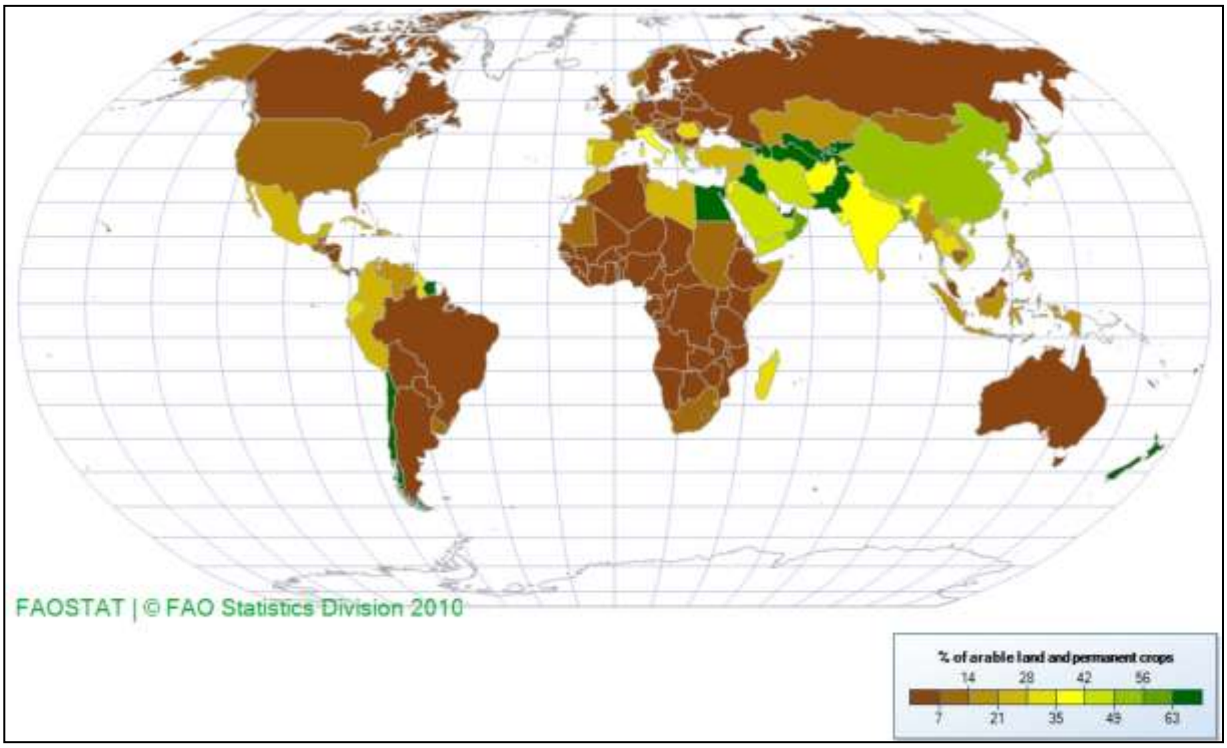


Figure 41. Share of Irrigated Land in Arable Land and Permanent Crops, 2008

(Source : FAO statistical yearbook 2010)

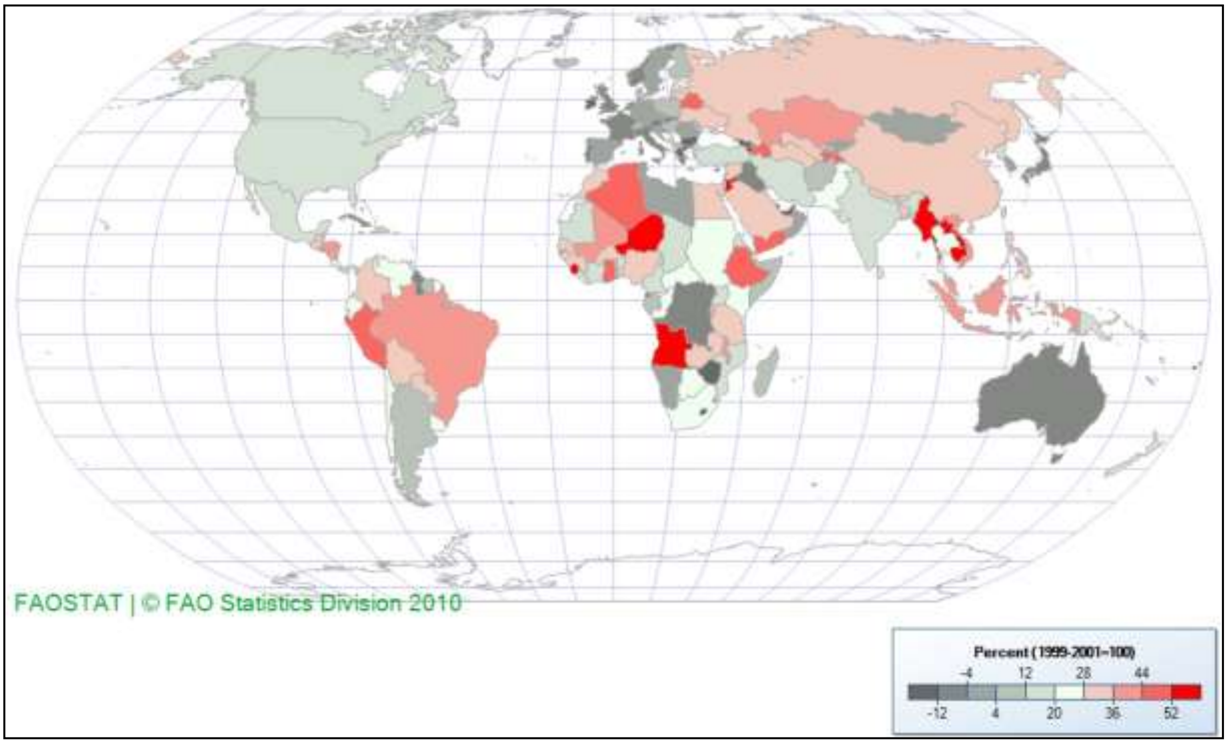


Figure 42. Growth of agricultural production, 1999-2009

(Source : FAO statistical yearbook 2010)

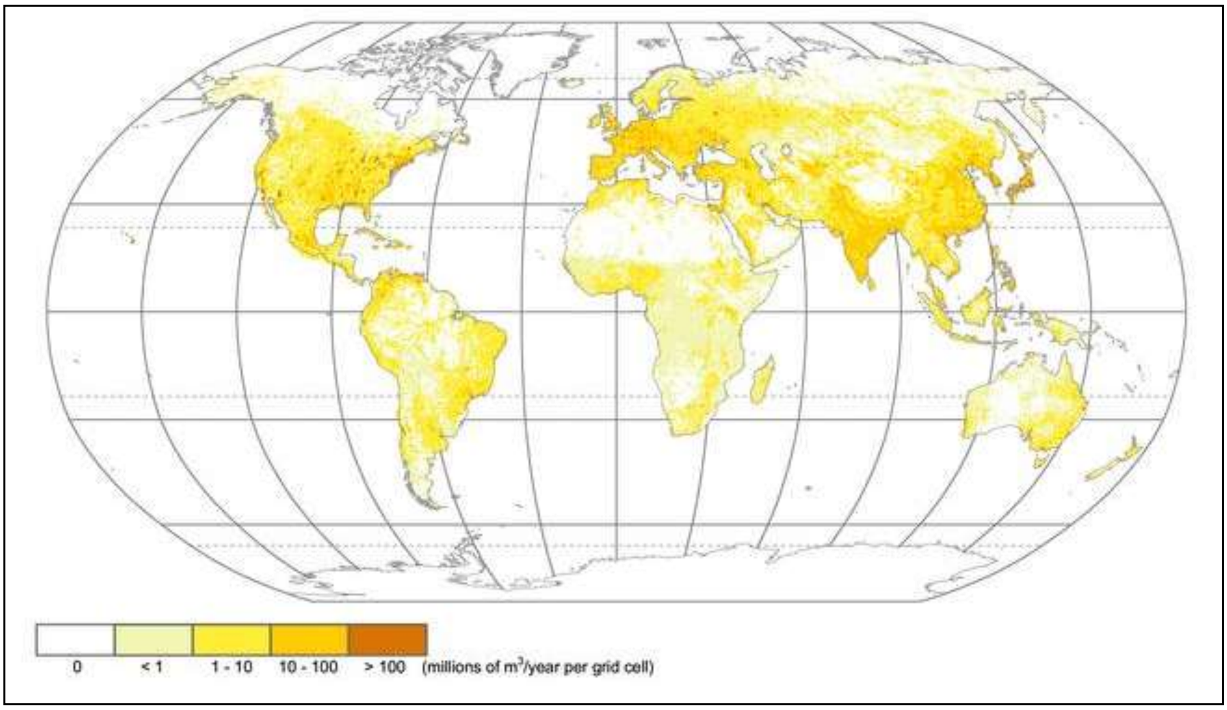


Figure 43. Domestic Water Use, 2000 (Source : Water Systems Analysis Group, UNH)

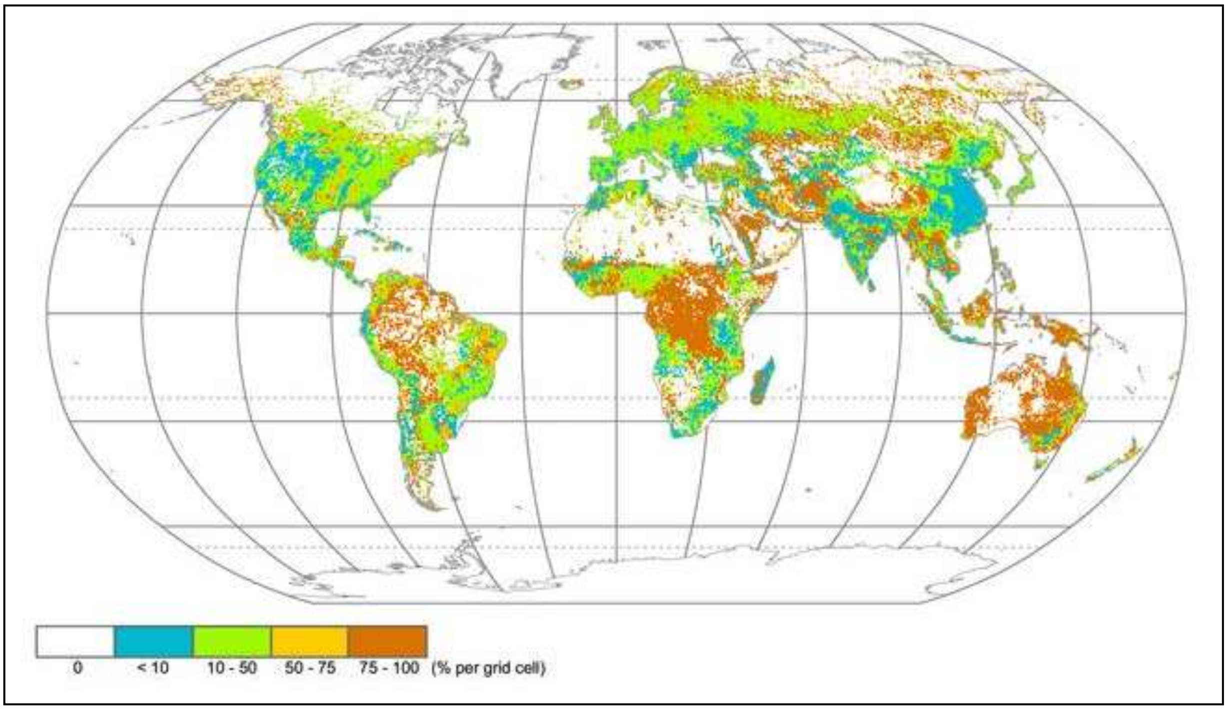


Figure 44. Ratio of Domestic to Total Water Use, 2000

(Source : Water Systems Analysis Group, UNH)

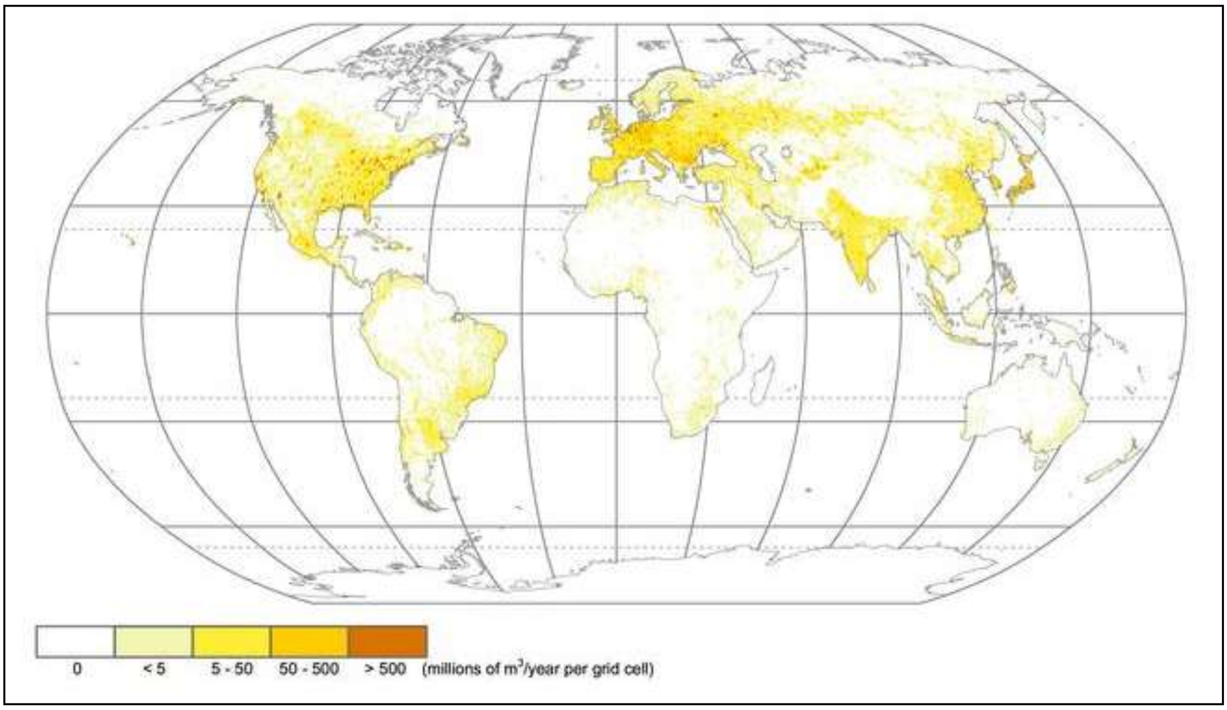


Figure 45. Industrial Water Use, 2000 (Source : Water Systems Analysis Group, UNH)

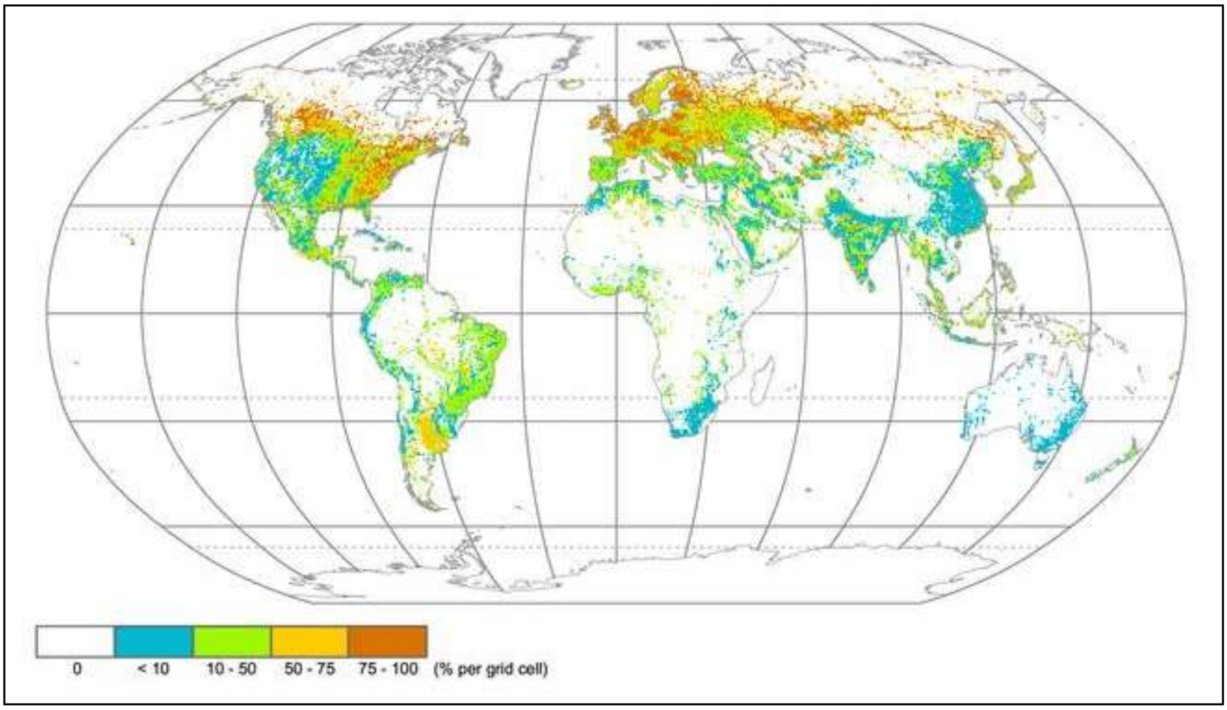


Figure 46. Ratio of Industrial to Total Water Use, 2000

(Source : Water Systems Analysis Group, UNH)

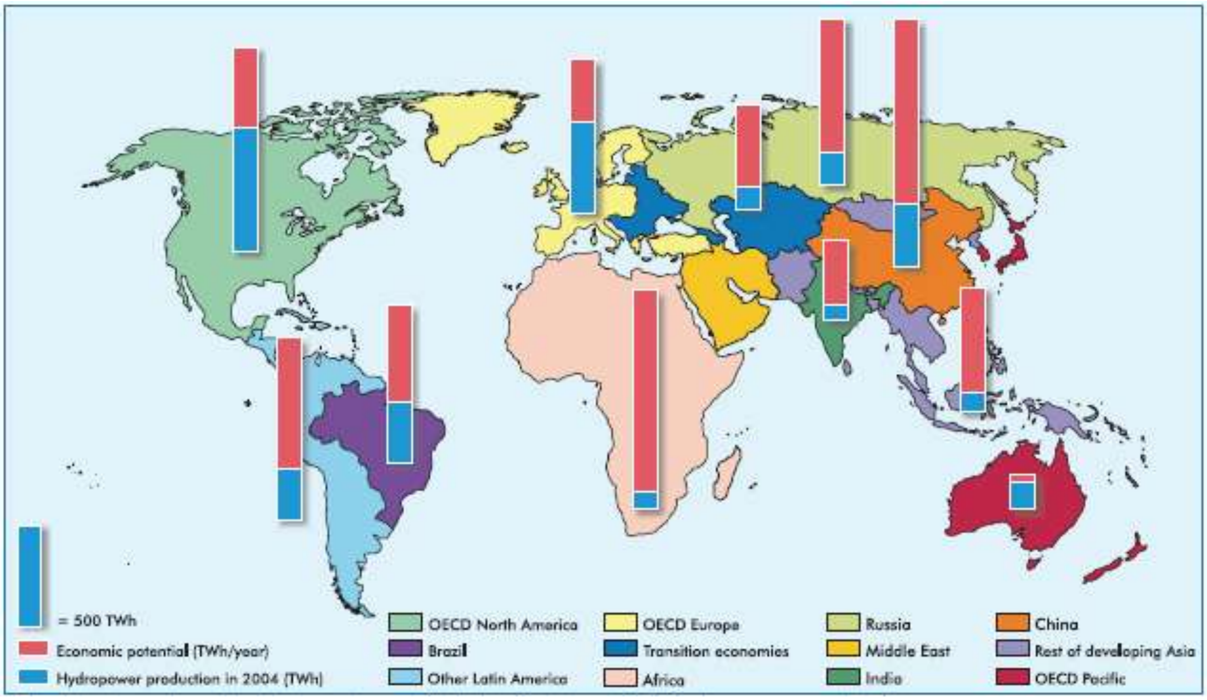


Figure 47. World Potential and Current Hydropower Production, 2004

(Source : WEO 2006, IEA)

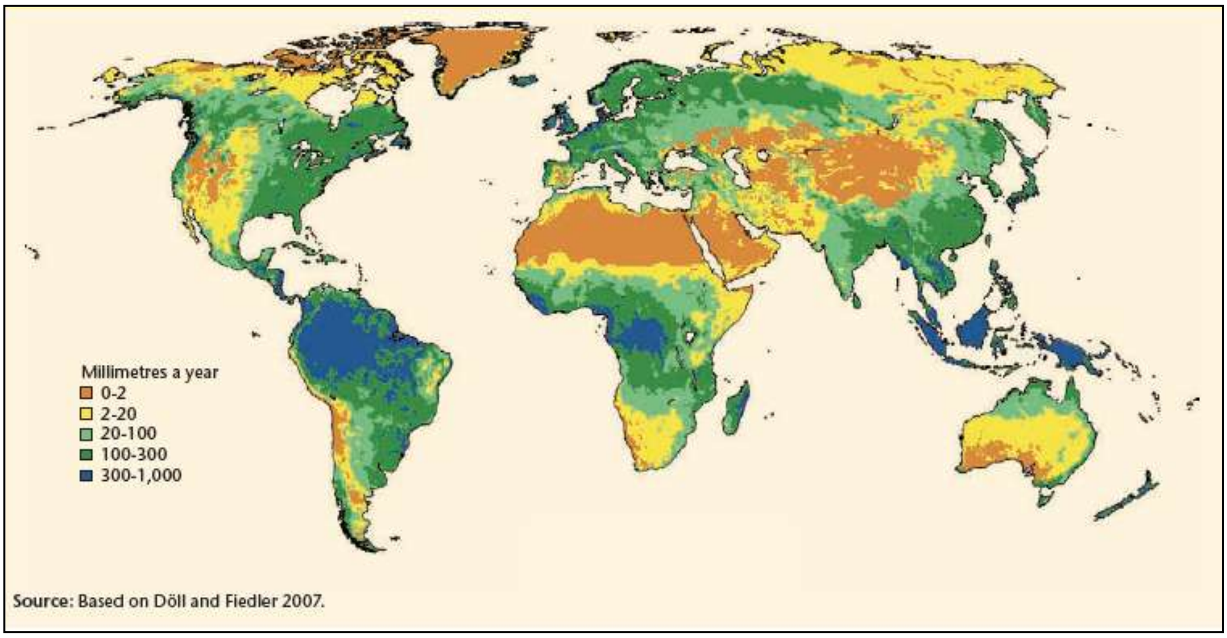


Figure 48. Patterns of long-term average diffuse groundwater recharge, 1961-90

(Source : Water in a Changing World, UN WATER, 2009)

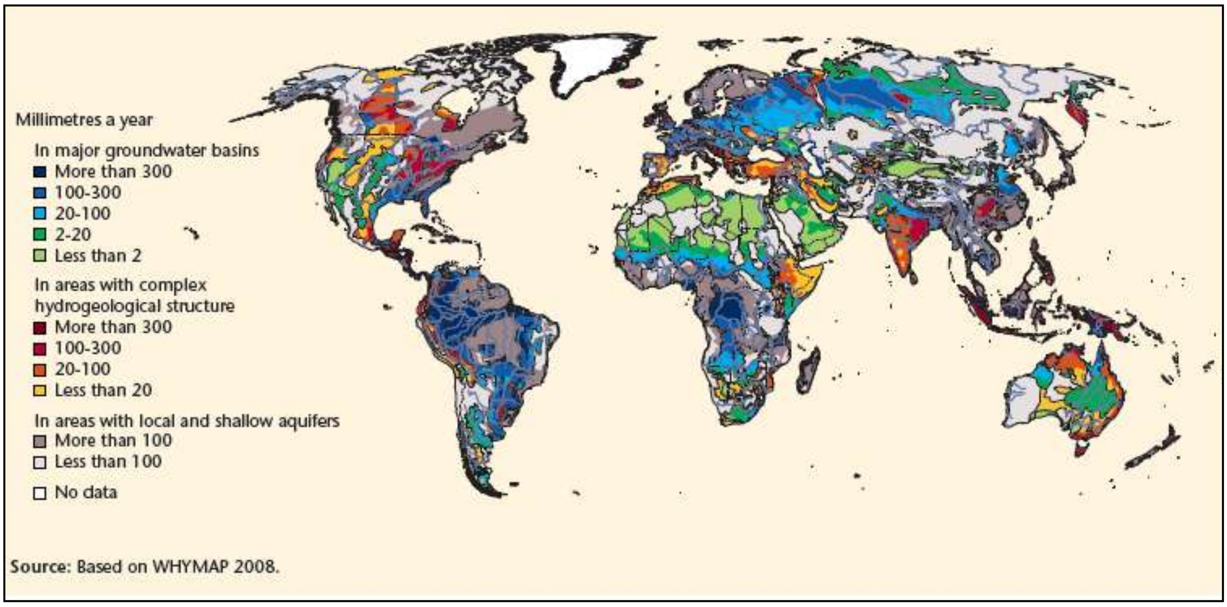


Figure 49. Global groundwater recharge, most recent year available

(Source : Water in a Changing World, UN WATER, 2009)

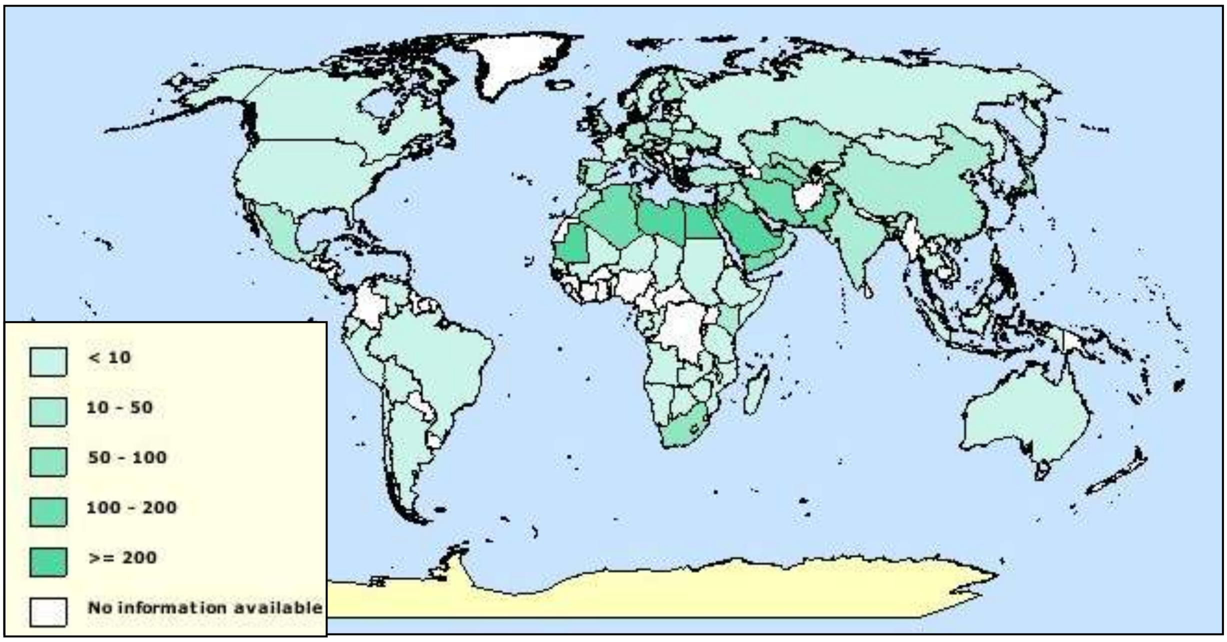


Figure 50. Degree of groundwater development (percentage of mean groundwater recharge) (Source : Global Groundwater Information System, IGRAC, 2004)

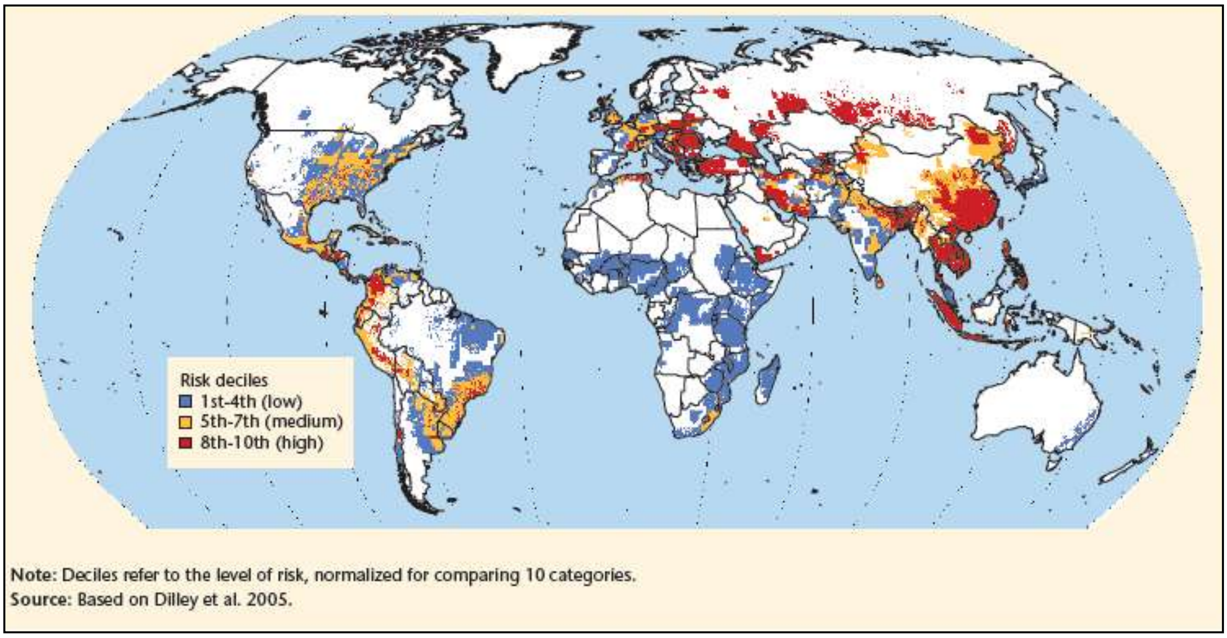


Figure 51. Impact of flood losses (comparative losses based on national GDP) (Source : Water in a Changing World, UN WATER, 2009)

Appendix E

Abbreviations

AIDS	Acquired Immune Deficiency Syndrome
AR4	Fourth Assessment Report
CO2	Carbon Dioxide
ECOSOC	United Nations Economic and Social Council
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gases
Gt	Gigatonnes
GWP	Global Water Partnership
HIV	Human Immunodeficiency Virus
ICOLD	International Commission on Large Dams
IEA	International Energy Agency
IGRAC	International Groundwater Resources Assessment Centre
IHA	International Hydropower Association
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resource Management
Mb/d	Million barrels per day
MDGs	Millennium Development Goals
Mtoe	Million tons of oil equivalent
OECD	Organization for Economic Co-operation and Development
SIDA	Swedish International Development Cooperation Agency
TWh	TeraWatt-hours
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNH	University of New Hampshire
WB	World Bank
WCD	World Commission on Dams
WEO	World Energy Outlook
WFP	World Food Programme
WHO	World Health Organization
WWC	World Water Council

Appendix F

The background of the Supplementary Paper

2004, the annual meeting in Seoul

New terms of reference;

Revise and update the Position Paper on Dams and the Environment

Leader France

Members Austria, Japan, New Zealand, Norway, Slovenia, Sweden

2008, the annual meeting in Sofia

The draft of the new Position Paper had been prepared and was discussed. It was agreed that the new paper would take the form of a supplement to the existing Position Paper, duly addressing emerging issues for the 21st Century.

2009, the annual meeting in Brasilia

It was agreed that the draft of Supplementary Paper would be prepared by Japan mainly.

2011, the annual meeting in Lucerne

The draft of Supplementary Paper was prepared.