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A.R. van Lienden
P.W. Gerbens-Leenes
A.Y. Hoekstra
Th.H. van der Meer

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Biofuel scenarios in a water perspective: The global blue and green water footprint of road transport in 2030

Value of Water

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BIOFUEL SCENARIOS IN A WATER PERSPECTIVE:

THE GLOBAL BLUE AND GREEN WATER FOOTPRINT OF ROAD TRANSPORT IN 2030

A.R. VAN LIENDEN[1]

P.W. GERBENS-LEENES[1]

A.Y. HOEKSTRA[1,3]

TH.H. VAN DER MEER[2]

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[1] Dept. of Water Engineering and Management, University of Twente, Enschede, The Netherlands
[2] Dept. of Thermal Engineering, University of Twente, Enschede, The Netherlands
[3] Contact author: Arjen Hoekstra, a.y.hoekstra@utwente.nl

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Summary

In the last two centuries, fossil fuels have been our major source of energy. However, issues concerning energy security and the quality of the environment have given an impulse to the development of alternative, renewable fuels. Particularly the transport sector is expected to steadily switch from fossil fuels to a larger fraction of biofuels - liquid transport fuels derived from biomass. Many governments believe that biofuels can replace substantial volumes of crude oil and that they will play a key role in diversifying the sources of energy supply in the coming decades.

The growth of biomass requires water, a scarce resource. The link between water resources and (future) biofuel consumption, however, has not been analyzed in great detail yet. Existing scenarios on the use of water resources usually only consider the changes in food and livestock production, industry and domestic activity. The aim of this research is to assess the change in water use related to the expected increase in the use of biofuels for road transport in 2030, and subsequently evaluate the contribution to potential water scarcity.

The study builds on earlier research on the relation between energy and water and uses the water footprint (WF) methodology to investigate the change in water demand related to a transition to biofuels in road transport. Information about this transition in each country is based on a compilation of different energy scenarios. The study distinguishes between two different bio-energy carriers, bio-ethanol and biodiesel, and assesses the ratio of fuel produced from selected first-generation energy crops per country. For ethanol these crops are sugar cane, sugar beet, sweet sorghum, wheat and maize. For biodiesel they are soybean, rapeseed, jatropha, and oil palm.

The transition to a larger share of biofuels will lead to a larger WF for the global transport sector. It is expected that the global annual biofuel WF will increase more than tenfold, from about 90 km^3/yr today to 970 km^3/yr in 2030. The USA, China and Brazil contribute most, together consuming approximately 54 percent of the global biofuel WF in 2030. In 2030 the blue water share in the global biofuel WF will be 48 percent. In many countries the blue WF of biofuels will have a significant contribution to blue water scarcity.

The research provides a first exploration of potential blue water scarcity in each country resulting from the consumption of internal renewable fresh water resources. On a global level, the blue WF of biofuels is expected to grow to 5.5 percent of the total available blue water for humans in 2030, thus causing extra pressure on fresh water resources. Countries should therefore consider the water factor when investigating the extent to which biofuels can satisfy the future energy demand in the transport sector.

1. Introduction

Humans have used different energy sources throughout time. Peat and wood were the first primary sources of energy for mankind; since ca. 7000 BC they were already used for heating and lighting (Landau, 2005). Later (ca. 600 BC) it was discovered that wind and water power could be converted to do mechanical work, such as pumping up water or milling grains. From 1600 onwards, wood was gradually being replaced by more efficient fossil fuels, which could be used to create movement using the steam engine. Once the dynamo was invented early 1800s, this movement could be converted to electricity, a form of energy that knows copious technical applications. Approximately a quarter of a century ago, it was discovered that nuclear energy could also be used to produce electricity. However, it was soon realized that the use of these forms of energy also has downsides. Events like the oil crisis in 1973, the Chernobyl nuclear disaster in 1986 and ongoing global warming have opened our eyes to the risks of depending on fossil and nuclear fuels (Sørensen, 1991; IPCC, 2008b). This has given an enormous impulse to the development of alternative, renewable fuels. Energy from wind, water, sunlight and biomass is said to be clean and renewable, but production on a large scale also has its complications. According to Sims et al. (2007), a robust mix of energy sources (fossil, renewable and nuclear), combined with improved end-use efficiency, will be required to meet the growing demand for energy services. Energy transitions will continue in the future as we aim to improve our standards of living and productivity.

To gain insight in what the future may look like, scenarios are a useful instrument. There are numerous cases for which scenarios exist, such as the climate, population growth and energy usage. All scenarios are based on assumptions about driving forces and the relations between them. Disagreement on the number of forces and their exact effects results in the construction of several scenarios for the same case. A good example of this can be found in the energy scenarios, for instance regarding the contribution of renewable energy sources. Generally, it is expected that in 2030 biomass will have the largest share of all renewables (IEA, 2006; WEC, 2007; Shell, 2008; IPCC, 2008b). Especially in the transport sector the interest in biofuels[1] is soaring. Many governments believe that biofuels can replace substantial volumes of imported oil with (indigenously produced) renewable fuels and that they will play a key role in diversifying the sources of energy supply in the coming decades (IEA, 2006).

Numerous studies have investigated the potential of bio-energy in the light of land availability, agricultural technology, biodiversity and economical development (Fischer & Schrattenholzer, 2001; Berndes et al., 2003; Hoogwijk et al., 2003; Smeets et al., 2007; Dornburg et al., 2008). Issues about competition between food and energy crops and the carbon dioxide neutrality of bio-energy are already discussed plentiful. But there are very few studies that look at the impact of bio-energy on the water system, whilst the production of biomass is indisputably one of the largest water consumers in the world (Berndes, 2002; Varis, 2007; De Fraiture et al., 2007; Hoekstra & Chapagain, 2008). Research on the water usage of energy crops in several regions already exists (e.g. Gerbens-Leenes et al., 2009a; Dominguez-Faus et al., 2009; Chiu et al., 2009), as does research about regional water systems and the stresses that are exerted on them (IPCC, 2008a; UNESCO, 2006). The link

[1] The term biofuels is used in this report to refer exclusively to liquid fuels derived from biomass that can be used for transport purposes. Some studies use the term more broadly to cover all types of fuels derived from biomass used in different sectors.

between water resources and future biofuel consumption, however, has not been analyzed in great detail yet. Existing scenarios on the use of water resources (e.g. Alcamo et al., 2003) usually only consider the changes in food and livestock production, industry and domestic activity. However, *all* our activities can be associated with the consumption of water. In order to better understand the relation between various commodities that we use and underlying water requirements, the concept of the 'water footprint' (WF) has been introduced (Hoekstra, 2003). The water footprint refers to the direct and indirect water use and is measured over the entire supply chain (Hoekstra et al., 2009). Gerbens-Leenes et al. (2009b) have shown that the WF of energy from biomass is nearly 70 to 700 times larger than that of fossil fuels. Nonetheless, very little attention is paid to this aspect of the fuel transition that is (bound to) taking place. Particularly, as the transport sector is steadily switching from fossil fuel to biofuel, the necessity arises to gain insight in the effects this has on our water resources and hence on the plausibility of some leading energy scenarios.

The objective of this research is to assess the change in WF related to the adoption of biofuels for road transport in 2030, and subsequently evaluate the contribution to potential water scarcity. The study builds on earlier research on the relation between energy and water based on the WF methodology (e.g. Gerbens-Leenes et al., 2009a; Gerbens-Leenes & Hoekstra, 2009).

Two research questions are posed to guide this research in achieving its goals. They will be answered on the basis of six sub-questions, which systematically take into account the key points in this research. The questions will be answered for nearly all regions and countries in the world.

- What is the change in the blue and green WF related to the adoption of biofuels for road transport?
  - Which biofuels will be used for road transport?
  - Which feedstocks will be used to produce these biofuels?
  - How much water will be used for the production of these feedstocks?
- Does the change in the blue WF of biofuels for road transport lead to (increased) blue water scarcity?
  - How much blue water is available for biofuels?
  - Is the available volume of blue water exceeded as a result of the WF of biofuel consumption?
  - Is a country likely to experience blue water scarcity due to the consumption of biofuels?

The answer to the first main question intends to provide information on how a transition to more biofuels in road transport will translate in increased water consumption. The answer to the second main question forms the starting-point for assessing the impact of the WF of biofuels in road transport on our fresh water resources. In this way, the report can play a role in raising awareness on the water scarcity issue, as well as provide insight into options for change. Concepts and terms mentioned in this study are clarified in the glossary in Appendix 1.

2. Water for biofuels

2.1. The rise of biofuels

The current energy consumption of the total human population amounts to roughly 500 EJ per year (= ca. 12000 Mtoe), and it is expected that this will continue to grow in the future (IEA, 2006; WEC, 2007; EREC, 2007; IPCC, 2008c; Shell, 2008; Greenpeace, 2008). This energy is produced from several sources and is used for many different purposes. In the transport sector, for example, most of the energy (95 percent in 2004) comes from oil and this sector alone accounts for about one fifth of the increase in global demand (IEA, 2006). More than 80 percent of all our energy nowadays comes from fossil fuels (coal, oil and natural gas), about 7 percent comes from nuclear sources (uranium) and approximately 13 percent is produced from renewable sources such as biomass, wind and hydropower (IEA, 2006). The dependency on fossil and nuclear fuels has some downsides. First of all, the supply is not infinite and fossil sources in particular are being exhausted quickly. It is expected that reserves of oil will be depleted in approximately 40 years, reserves of natural gas in 70 years and reserves of coal in 210 years (Earthtrends, 2005). Besides this, most of the stocks are situated in unstable regions, which may lead to irregularities in supply to depending nations. Secondly, a large amount of carbon dioxide (ca. 26 gigatons in 2005) is released into the atmosphere when fossil fuels are burned, and the general perception is that this contributes to global warming and all its consequences (IPCC, 2007). Acid rain is another commonly stated environmental problem that is attributed to the use of fossil fuels (UNESCO, 2006; EPA, 2007). Nuclear waste remains dangerous to all living beings for a long time, and moreover a nuclear disaster is catastrophic. Political considerations about energy security, safety, and the quality of the environment can eventually lead to a movement away from fossil and nuclear fuels (IPCC, 2008b). The current contribution of renewable sources is fulfilled by about 80 percent biomass and 16 percent hydropower (IEA, 2006; Varis, 2007). Particularly the share of biomass in the global energy mix is expected to rise sharply (IEA, 2006).

Biomass is defined as all material which is of organic origin, excluding what has been converted to geological formations like fossils (FAO, 2008a). It requires resources such as land, water, nutrients and sunlight to grow and once it has reached the desired size it can be harvested as feedstock for bio-energy (Figure 1). Examples of biomass used for energy production (i.e. feedstock) are wood, straw, (food) crops, manure and organic waste.

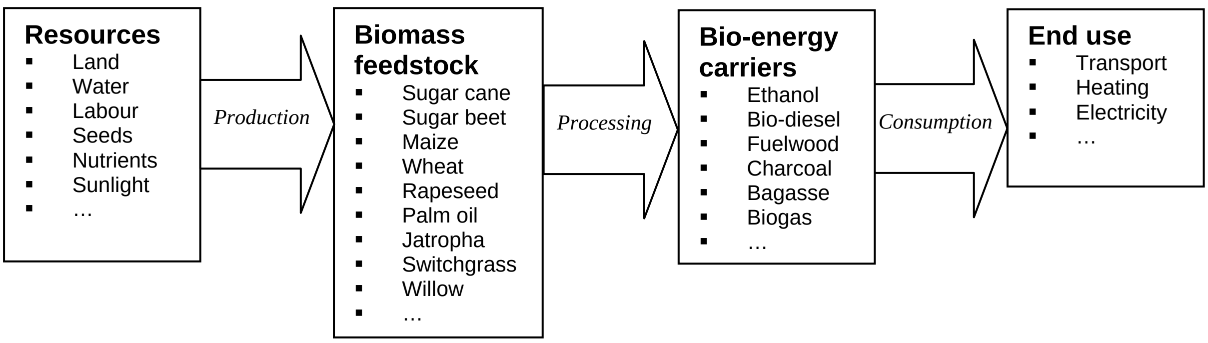

Figure 1: Bio-energy – from resources to end use.

More than 85 percent of all biomass is burnt directly in solid form for cooking, heating and lighting. Biomass feedstock can include agricultural residues, animal manure, wood wastes from forestry and industry, municipal green wastes, sewage sludge, and dedicated energy crops such as short-rotation coppice (eucalyptus, poplar and willow) (IEA, 2007). In developing nations, most biomass is harvested informally and only a small part is commercialized. In developed countries, more modern collection and processing techniques are used. Electricity and heat are produced by co-firing organic waste and wood (residues) in power plants for example (Foster & Mayfield, 2007). However, biomass can also be converted to other energy carriers, such as liquid biofuels. Common biofuels are bio-ethanol and biodiesel. They are used to replace oil-based fuels in the transport sector. Around 80 percent of the energy demand in the transport sector is accounted for by road transport (IEA, 2006). So it is especially in this realm that rising oil prices and the urge to reduce dependency on imported oil motivate countries to heavily invest in the development of biofuels (IEA, 2006; WEC, 2007).

There are several well-established techniques for producing liquid biofuels from agricultural products. Broadly speaking, there are three crop categories that correspond to two forms of liquid biofuel. Bio-ethanol is usually produced from fermentation of so called sugar crops. These are crops that contain a high level of glucose, which by fermentation is metabolized to ethanol and carbon dioxide. This is the easiest, most efficient process, but ethanol can also be produced from the starchy component of cereal crops. In this case, the starch has to be malted first to release the enzymes that can convert it to sugar. Both processes are first-generation conversions, in which the fuel yields are limited by the relative small sugar or starch portions of the plant (FAO, 2008e). Most of the plant consists of cellulosic materials, such as hemicellulose and lignin. These materials can also be converted to ethanol by second-generation conversion processes, but this still faces significant technological challenges and is expensive. Second-generation processes are therefore not expected to become commercially viable before 2030 (IEA, 2006) and are thus not within the scope of this study.

Another type of biofuel is biodiesel, which is obtained from first-generation conversion of oil crops. Typically, the extracted vegetable oil reacts with an alcohol in an esterification reaction to produce alkyl esters of long chain fatty acids and glycerol as a by-product (FAO, 2008e). In warmer countries however, the vegetable oil is less viscous and can be used directly as fuel. The above conversion processes are shown in Figure 2. This report considers only the first-generation production techniques for liquid biofuels, i.e.: (1) fermentation of sugar and starch crops for ethanol, and (2) esterification of oil from oil crops for biodiesel. These routes are shaded in Figure 2.

Currently, liquid biofuels (and biogas) contribute to only 2 percent of total transport fuels worldwide (FAO, 2008b). Around 85 percent of liquid biofuels is in the form of ethanol. The two largest producers are Brazil (from sugar cane) and the United States of America (from maize) and the remainder is primarily made in China, India and the EU (FAO, 2008e). Biodiesel production is mainly situated in the EU (60 percent) and uses rapeseed as dominant feedstock. Other significant biodiesel producers include the United States of America (from soybean), China, India, Indonesia and Malaysia (mostly from palm, coconut and castor oils) (Gerbens-Leenes et al., 2008; FAO, 2008e).

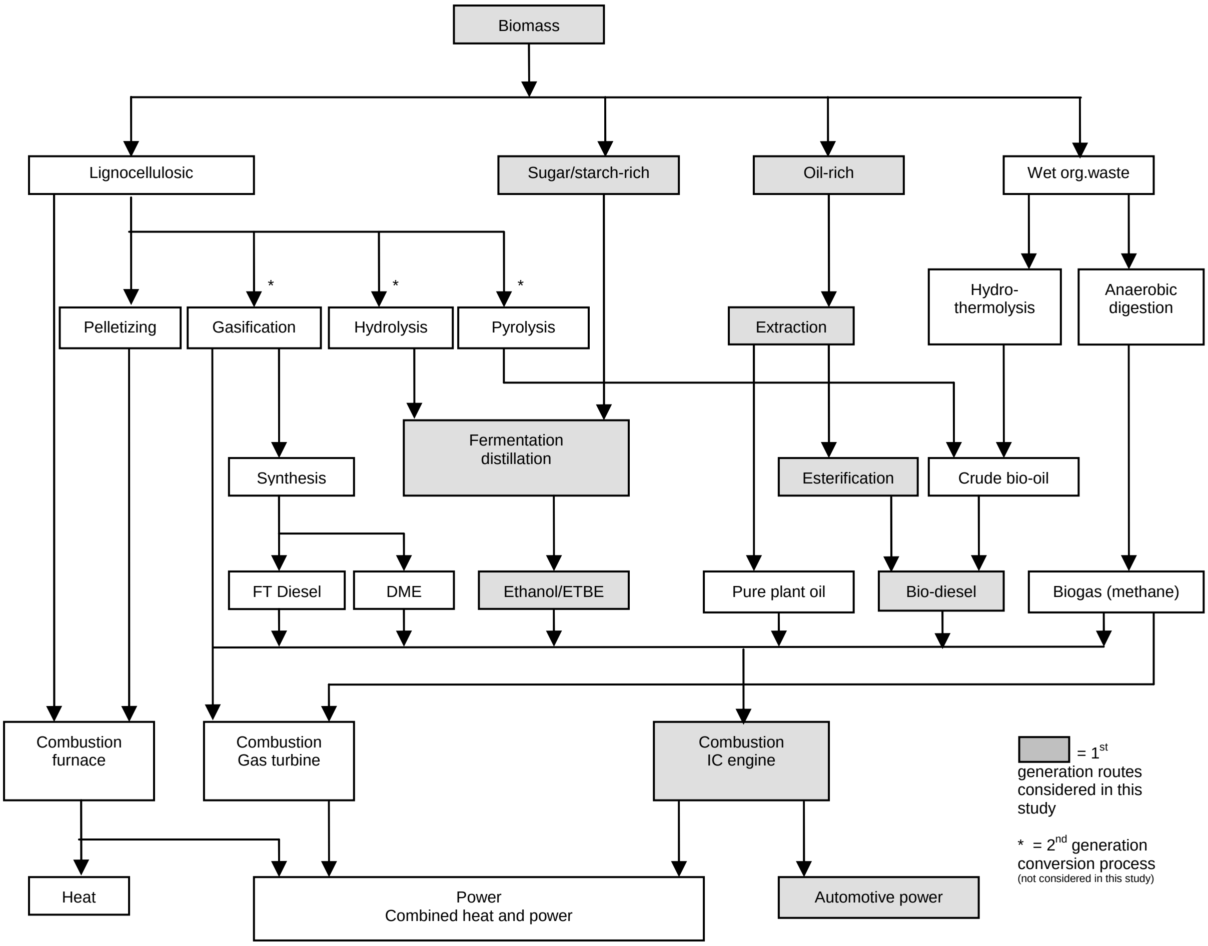

Figure 2: Conversion of biomass to biofuels for automotive power (based on: EUBIA, 2007 and Sielhorst et al., 2008).

2.2. Scenarios for the future

What the future will look like in terms of how much energy is consumed and from what sources is hard to say. There are too many uncertainties and many factors are interdependent. Nevertheless, decisions that affect our future energy supply will have to be made now. A tool that can help make those decisions and deal with the dynamics is scenario planning (Wilkinson, 2008; Mason, 2009).

Scenario planning originates from the observation that, given the impossibility of knowing precisely how the future will unfold, a good decision or strategy to adopt is one that plays out well across several possible futures (Wilkinson, 2008). These possible futures are modelled by scenarios, which are basically specially constructed stories that diverge markedly from each other. The possible energy transition paths of a country or region can be portrayed by energy scenarios. Differences in assumptions about driving forces behind these transitions lead to numerous dissimilar scenarios. The literature states roughly five general categories of driving forces: political, economic, societal, technological, and environmental (Nakićenović et al. 1998; Wilkinson, 2008; Mason, 2009). Exploring the nature of the uncertain elements within these forces provides a framework for the scenarios.

There are several independent organizations that have put forward sets of energy scenarios, but individual researchers have also contributed to the large number of scenarios published in the last decade (FAO, 1999). Appendix 3 gives a selection of eighteen global energy scenarios from six leading organizations. Based on the level of detail they contain about the types of biofuel consumed in each region/country, they will be incorporated into this research. The method chapter provides more detail about the selection of a suitable energy scenario for this study.

Foreseeing future energy demand and supply remains notoriously difficult and inexact, but what is evident from examining all these scenarios is that biomass could be a major contributor to future energy supplies especially as a modern fuel in the transport sector. It is expected that virtually all the biofuels consumed in a region will continue to be produced indigenously as a result of protective farm and trade policies (IEA, 2006; Junginger et al., 2008). Junginger et al. (2008) have described a multitude of difficult barriers that currently exist and hamper the development of international bio-energy trade. They include economic, technical, logistical, ecological, social, cognitive, legal, and trade barriers, lack of clear international accounting rules and statistics, and issues regarding land availability, deforestation, energy balances, potential conflicts with food production and local vs. international trade. Nonetheless, they also name some opportunities and explain what strategies could be used to overcome these barriers. Some of these steps are already being taken and the volume of biofuels traded internationally will keep growing, albeit from a small base.

2.3. The link to water

The water system can be seen as a closed cycle (Figure 3). When precipitation falls over land, part of the water flows off as surface runoff to lakes and rivers, part of it seeps into the earth to recharge groundwaters, and part is directly absorbed by vegetation. Subsequently, wind and radiation from the sun result in evapotranspiration. This consists of direct evaporation from the earth's surface and transpiration from plants. This water vapor rises and then condenses in higher, cooler air layers to form clouds from which eventually precipitation will fall again. These processes are all linked in the water balance, which shows that precipitation equals the sum of runoff, evapotranspiration and change in storage (Viessman & Lewis, 2003). The water balance can be used to manage water supplies and predict where there may be shortages. Especially in agricultural practice it can be useful to manage irrigation and drainage issues.

The total volume of water on earth is approximately 1.4 billion km^3, about 35 million km^3 (2.5%) of this is fresh water (Gleick, 1993; UNESCO, 2006). However, about two thirds of this is in form of ice and permanent snow cover, the rest is contained in the ground (30.8%) and in lakes, rivers and swamps (0.3%). The principal sources of water for human use are lakes, rivers, soil moisture and relatively shallow groundwater basins. The usable portion of these sources is only about 200 000 km^3 of water (Gleick, 1993). Nonetheless, a large part of this volume is located in remote areas, or escapes as floodwater (Postel et al., 1996), and part is non-renewable (fossil) groundwater. Efforts to characterize the volume of renewable fresh water actually available to a given nation have been ongoing for several decades. The primary input for many of these estimates is the information database AQUASTAT, which has historically been developed and maintained by the FAO (UNESCO, 2006;

FAO, 2008c). It is based on data related to the quantity of water resources, and uses a water balance approach for each country. The database includes tables of long-term average precipitation, renewable fresh water resources and sector withdrawals, and has become a common reference tool used to estimate each country's fresh water availability. Figure 4 gives an indication of the renewable fresh water resources per country.

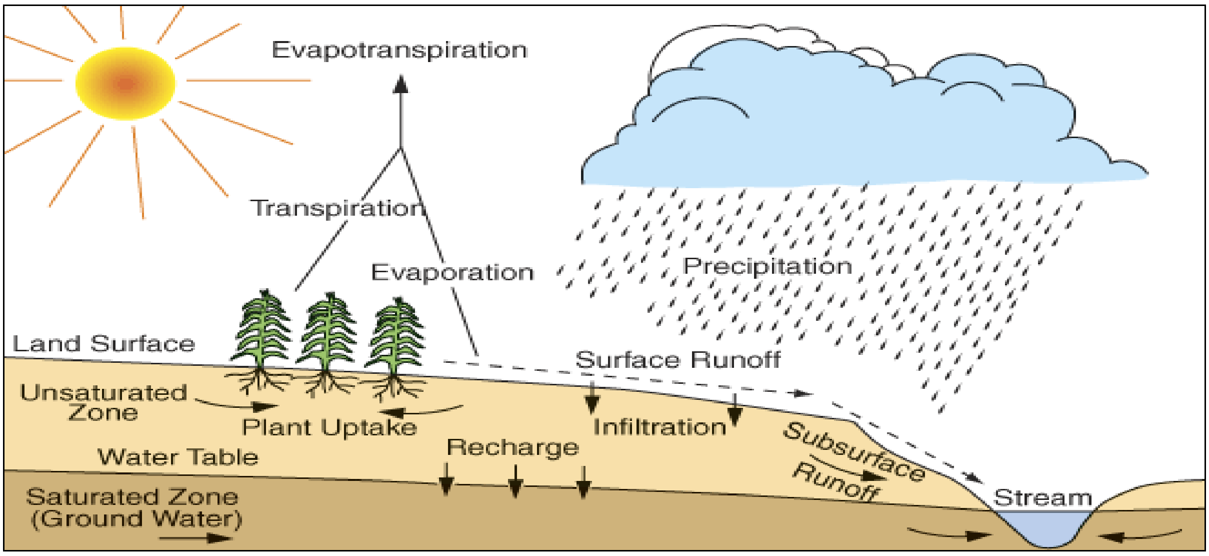

Figure 3: Conceptualization of the water system (RIVM, 2008).

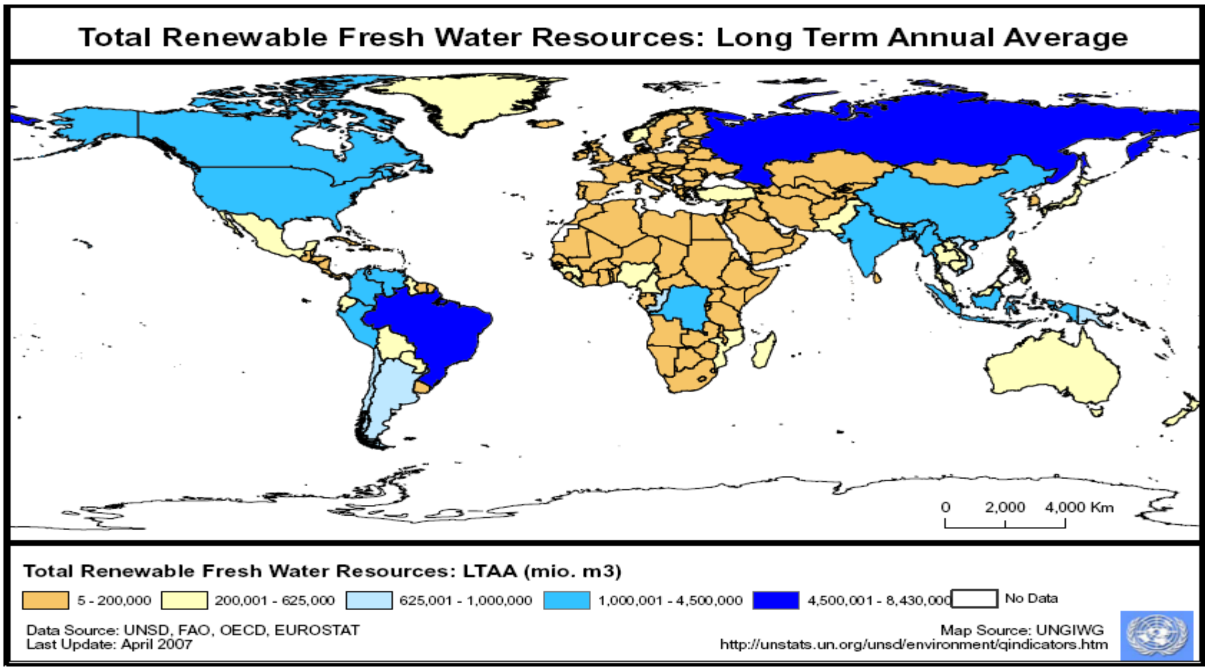

Figure 4: Distribution of fresh water in the world (UN, 2007).

Human activity disrupts the natural water cycle and can upset the balance. Water is used for many purposes and in many regions competition between these uses is not uncommon. The construction of dams in rivers, for example, is done to generate electricity and create a steady supply of water but it constrains the natural flow and affects the environment both upstream and downstream. Furthermore, reservoirs collect a lot of radiation and local evaporation rates may thus increase significantly (Gleick, 1993; UNEP, 2008). Groundwater from aquifers is used for drinking and to irrigate crops but excess pumping can lead to depletion of the storage. Last but not least, the water that is discarded after use is often polluted badly and can have a major impact on the ecosystem. It is thus of utmost importance to regulate human water usage in order to maintain a healthy water system.

The use of fresh water resources can be traced back to different sectors. Globally, about 1 percent of the total renewable fresh water resources is withdrawn for domestic purposes, around 2 percent for industry and 6 percent for agriculture (FAO, 2008c). Besides human use, part of the water should be reserved for ecosystems. This is often termed the Environmental Flow Requirement (EFR). Smakhtin et al. (2004) argued that, worldwide, ecosystems need about 20 to 50 percent of the average, yearly amount of water from rivers to stay in good shape. Hoekstra et al. (2009) suggested a higher precautionary default EFR of 80 percent. If the available water resources are no longer adequate to satisfy all human or ecosystem requirements, this results in increased competition between water users and other demands (UNEP, 2008a). When the amount of water demanded by all users exceeds the water supply in a country, it will suffer from water scarcity and experience water stress. To allow good management of the fresh water resources, a distinction is often made in the ‘type’ of water available for each purpose (Falkenmark, 1997; Hoekstra, 2008). The runoff in rivers, lakes and groundwater aquifers is classified as the blue water supply and the fraction of rainfall that infiltrates through the land surface and forms soil moisture is the green water resource. The green water availability is quantified by the total evapotranspiration over land (minus human-induced evapotranspiration of blue water). The same distinction (i.e. blue, green) is also made in water usage and applies to all products and services we consume, including our energy (Hoekstra & Chapagain, 2008; Gerbens-Leenes et al., 2008).

This is where the energy system and the water system overlap. The consumption of water corresponding to the consumption of energy can be expressed using the water footprint (WF) concept. The WF of energy is the total volume of fresh water that is used to produce the energy carriers consumed by energy services. The WF includes the following three components (Hoekstra et al., 2009):

- Green water footprint: evaporation of rainwater;
- Blue water footprint: evaporation of water withdrawn from aquifers, lakes, rivers or surface reservoirs (e.g. for irrigation purposes);
- Grey water footprint: pollution of water, quantified as the volume of fresh water that is required to assimilate the load of pollutants based on existing ambient water quality standards.

In this study we will not consider the grey water footprint. Table 1 shows the average WF (in cubic meters per Giga Joule) of some primary energy carriers, i.e. sources on which we base our energy production. The WF of bio-energy is nearly 70 to 700 times larger than the WF of energy from fossil fuels. This is because a lot of water is needed to grow the feedstock, so-called energy crops. Hence, the generation of energy from biomass (indirectly) requires water. The WF of bio-energy (in m^3/GJ) is based on: 1) the crop water use (m^3/ha), 2) the crop yield (ton/ha), and 3) the energy content of the crop (GJ/ton).

Table 1: Average WF per unit of energy from some primary energy carriers (Gerbens-Leenes et al., 2009b)

Primary energy carriers	Average water footprint (m^3/GJ)
Wind energy	0.0
Nuclear energy	0.1
Natural gas	0.1
Coal	0.2
Solar thermal energy	0.3
Crude oil	1.1
Hydropower	22.3
Biomass energy (excl. waste)	71.5*

* Average of production in the Netherlands, USA, Brazil, Zimbabwe.

Crop water use depends on the water demand of the crop, precipitation and irrigation. The green crop water use refers to the volume of effective precipitation (retained by the soil and potentially available for crops) that evapotranspirates from the field during crop cultivation. The blue crop water use is the volume of irrigation water that evapotranspirates from the crop field during the growth period. The irrigation requirement is calculated as the difference between crop water requirement and effective precipitation. All in all, the water use of crops can be very different corresponding to the crop type, location, climatic conditions and agricultural practice.

Crop yields also vary between and within countries. Crop yield actually refers to the harvested reproductive or storage organs of a plant that have an economic value when applied for food, feed, or materials production (Gerbens-Leenes et al., 2008). The ratio of the crop yield to the total biomass yield is termed the harvest index (HI). Large differences in HI and crop yield exist between crop locations depending on agricultural practices (Goudriaan et al., 2001). Since the WF (m^3/ton) is calculated by dividing the crop water requirement (m^3/ha) by the crop yield (ton/ha), a lower yield will result in a higher WF.

All plants and trees have a different composition of elements such as carbohydrates, fats, lignins, minerals, organic acids and proteins. Each of these building blocks has its own energy value, which leads to a characteristic energy content for each type of biomass (Gerbens-Leenes et al., 2008). The WF of bio-energy in terms of m^3/GJ depends on the WF of the crop in terms of m^3/ton and the energy content of the crop (GJ/ton).

To conclude, the WF is a concept that allows us to map the impact of human consumption on (global) water resources. The total available fresh water remains constant through the water cycle on a global scale, but availability can vary in space and time. Often, competing uses cannot be fulfilled simultaneously and water scarcity occurs. In any case, water that is used for one purpose (e.g. bio-energy) cannot be used for another. It is thus important to calculate the water use that is related to our consumption pattern.

Since the consumption of bio-energy is on the rise it is essential to properly assess its WF. This chapter has shown us that, in order to do so, we need to know: 1) how much bio-energy is consumed, 2) what bio-energy carriers are used (bio-ethanol and/or biodiesel), 3) which crops are used to produce them, 4) where they are produced and 5) under what circumstances. Each country has its own climate conditions, hydrological system, soil types and agricultural practices, which all have a direct effect on the growth of vegetation and thus influence crop choice and water usage (FAO, 2008d). The approach chosen to analyse this is explained in the next chapter.

3. Method

3.1. Countries included

The IEA (2006) recognises three categories of countries according to their economic development and market structure: OECD, Transition Economies, and Developing Countries. Furthermore, it distinguishes eight geographic regions: North America, Europe, Pacific, Former USSR and Balkans, Developing Asia, Middle East, Africa, and Latin America. This study adopts this categorisation; Figure 5 gives an overview of countries included in this study (see also Appendix 2). This report gives results on both regional and national scale. The explicit geographic scale enables statements about country-specific water related situations and creates a first awareness of potential problems in the future.

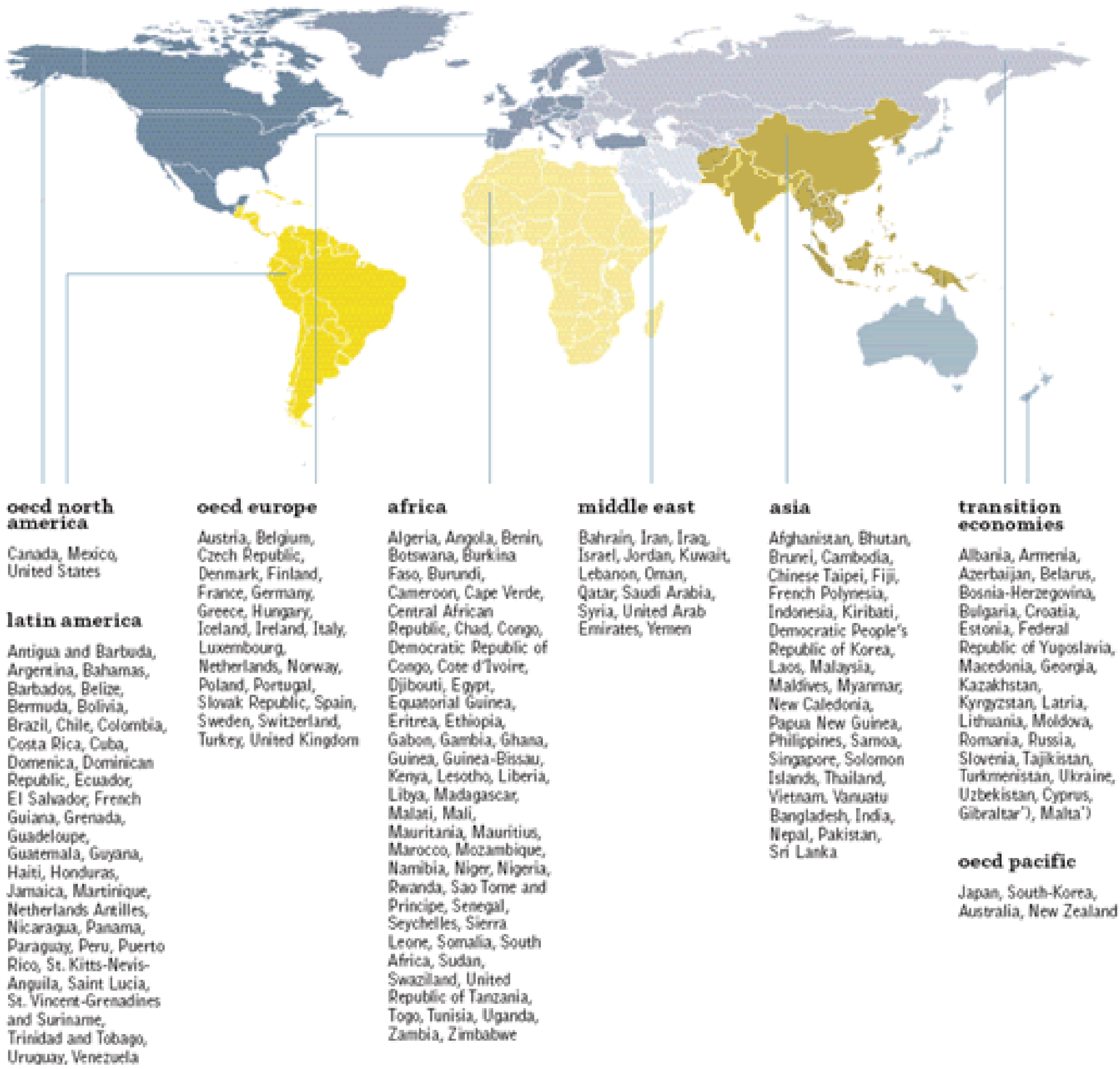

Figure 5: Overview of the countries included in this study.

3.2. Biofuel scenario

A number of global energy scenarios have been reviewed (Appendix 3). For the assessment of the WF of biofuels for road transport, we have selected an energy scenario based on the following criteria: (i) the scenario contains all the necessary data for the calculations, (ii) it is geographically explicit enough and (iii) it is workable (everything is well documented including clarifying background information about fuel types).

The scenarios of the International Energy Agency (IEA, 2006) meet most of these requirements. They contain information on different energy and transport fuel types and provide data about energy use in a large number of regions and some individual countries. The Alternative Policy Scenario (APS) of the IEA comes closest to the average bio-energy share (11 percent) in global energy consumption of all scenarios (see Appendix 3). Developments in the global energy sector between 2006 (scenario release date) and 2009 are reflected well by the APS storyline. For example, the implementation of extra policy plans by many governments concerning energy security, efficiency and carbon dioxide emissions (e.g. the European Union Greenhouse Gas Emission Trading Scheme). For these reasons, we have selected the APS of the IEA as the base scenario for this study.

Where data on individual countries are lacking, the dataset is complemented by data from regional scenarios that share a similar storyline. For individual countries in Europe (EU27) the RSAT-CDM scenario is used (see Appendix 3). This is the European Commission proposal with Clean Development Mechanisms (CDM) and without Renewable Energy Sources (RES) trading (Capros et al, 2008). Key assumptions about policy implementation, technological development and energy efficiency in the region are similar to the ones underlying the Alternative Policy Scenario and trends in energy consumption in all sectors are also alike.

For countries that are not included in one of these scenarios, the study determines the 2030 biofuel consumption either by looking at planned future production capacity (e.g. by private initiatives) or by extrapolation from demand in base-year 2005. In the latter case, the total regional biofuel consumption in 2030, as projected by a scenario, is ascribed to the country according to the share it had in total biofuel consumption in 2005. Consumption data for this year were obtained from the IEA (2009), Eurostat (2009), and USDA FAS (2006) reports on biofuels. Appendix 4 gives the complete dataset on biofuel use in road transport as used in this study.

3.3. Calculation of the biofuel water footprint

This research combines several data sources to assess the WF of biofuel. It analyses the transition to biofuel in the road transport sector per country, distinguishing between two types of biofuels. The study assesses crop feedstock choice for each biofuel per country, and links this to crop water use data, enabling the translation from biofuel consumption to water consumption (i.e. the annual national green and blue WF of biofuel). Subsequently, the blue WF is compared to data about blue water availability. For each country, a balance is made of fresh water resources and uses, enabling the determination of the water volume available for bio-energy. The comparison allows a measure of water scarcity to be established corresponding to the (expected) biofuel consumption. Figure 6 shows the six steps of the method.

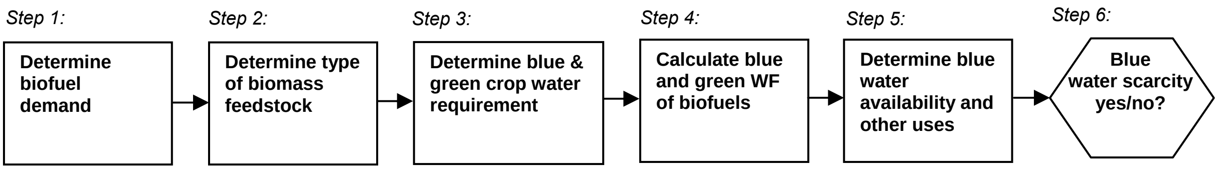

Figure 6: Steps of the research methodology.

3.3.1. Step 1: determine biofuel demand

In the selected energy scenario, bio-energy demand is given for different purposes, such as transport, electricity and heat, and industrial, residential and agricultural services. In this report we will focus on biofuel use in the transport sector, specifically by motorized road vehicles. The appendices of the *World Energy Outlook* (IEA, 2006) provide data about biofuel consumption according to the Alternative Policy Scenario (APS). APS energy balance tables are given for the main regions and some individual countries (USA, Japan, Russia, China, India and Brazil). Energy demand is presented for the years 1990, 2004, 2015, and 2030 and is categorised in sectors. In the transport sector, the demand of biofuels (in energy terms) is stated explicitly. However, the type of biofuel (i.e. biodiesel and/or bio-ethanol) is not specified in these tables. The distinction between bio-ethanol and biodiesel is made in this report based on background information and sector outlooks published by the IEA (2004; 2006), the USDA FAS (2006) and some other sources (see Appendix 4).

The RSAT-CDM scenario (Capros et al., 2008) provides energy balances and indicators for 27 countries in Europe. The balances contain a section for energy demand in transport. In that section energy demand by different transport modes is given for 1990-2030. The modes are: public road transport, private cars and motorcycles, trucks, rail, aviation, and inland navigation. Since this report focuses on road transport, only public road transport, private cars and motorcycles, and trucks are considered. This study assumes that public road transport and trucks run on diesel, and private cars and motorcycles on gasoline. The RSAT-CDM scenario also provides an indicator for the expected share of biofuels in transport diesel and gasoline in each country. Hence, by multiplying the total consumption of diesel and gasoline in 2030 with the projected 2030 biofuel share, the total volume of biodiesel and bio-ethanol demand by each country in 2030 can be estimated.

3.3.2. Step 2: determine type of biomass feedstock

This research considers only the dominant, first-generation feedstocks for each biofuel. For ethanol, these are three sugar crops – sugar cane, sugar beet and sweet sorghum – and two starch crops – maize and wheat. For biodiesel these are four oil crops – rapeseed, soybean, oil palm and jatropha.

Figure 7 gives an overview of the crops and their conversion into biofuels. Data on crop choice per country is based on Dufey (2006), the USDA FAS (2006), the FAO (2009a), Konrad (2006), BioWanze (2008), Breyerová (2007), Kautola et al. (date unknown), SEI (2004), NOVEM (2003), Müllerová & Mikulík (2007), Biofuels Platform (2009), Içöz et al. (2008), Kleindorfer & Öktem (2007), BBN (2008), Min. Agriculture Latvia (2006), NV Consultants (2007), Reuters (2006), ENERO (2005), Vassilieva (date unknown) and Solsten (1991). If information about crop choice in a particular country is not available, this study assumes the country uses the same crops as its neighbours. For bio-ethanol and biodiesel in every country, Appendix 5 gives the ratio of biofuel from each crop to the total biofuel consumption. This research assumes that in 2030 countries still rely on the same (energy) crops they used in base-year 2005 and that they are self-sufficient in their biofuel production.

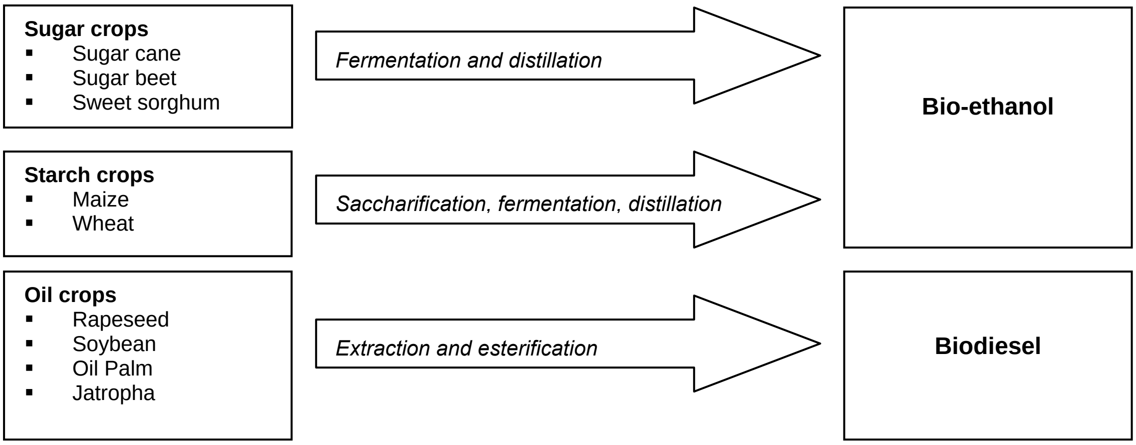

Figure 7: Crops, conversion processes, and final energy carriers considered in this report

3.3.3. Step 3: determine blue and green crop water requirement

For a large number of energy crops, Gerbens-Leenes et al. (2008; 2009a; 2009b) have calculated blue and green crop water requirements (CWRs) . Those studies have used the model CROPWAT 4.3 (FAO, 2007), which is based on the FAO Penman-Monteith method and specific crop coefficients. In those calculations it is assumed that crops are fully satisfied in their water needs by precipitation and/or irrigation. This study derives data on CWRs from Gerbens-Leenes et al. (2008). Furthermore, this report only calculates the blue and green CWR, because existing data on grey water is incomplete and not sufficient for the geographical coverage of this study.

For the countries not covered by Gerbens-Leenes et al. (2008), this study calculates the blue and green CWRs using the same approach. The growing location of crops in a particular country is determined using Agro-MAPS (FAO, 2009c). If no data are available from this source, the crop location is based on the area with most agricultural activity determined by Google Earth aerial images. If unsure, the country capital is chosen. Next, a representative weather station from CLIMWAT 2.0 (FAO, 2009d) is selected in each growing location. Based on the climatic data from the weather station, the planting date of the crops is determined using the report of Chapagain & Hoekstra (2004). Subsequently, the information is loaded into the CROPWAT 4.3 model to obtain values for the green CWR and blue CWR (i.e. irrigation requirement).

In addition, this study calculates the CWR of oil palm (*Elaeis guineensis)*. In Malaysia, Indonesia, Thailand and the Philippines, oil palm is the sole feedstock used for the production of substantial volumes of biodiesel. Palm oil is obtained from the fruit of the oil palm. The fruit contains two oil-rich components: the kernel (nut) and the mesocarp (pulp) that surrounds it. Although both oils are distinct in their chemical and physical properties, they can both be used for fuel (and cooking) (Bora et al., 2003). In commercial plantations the Tenera variety of the oil palm is most commonly used, because of its superior oil yield (Gerritsma & Wessel, 1997; Poku, 2002). Appendix 6 provides information on the composition of the fruit from this plantation crop. It also contains the new oil palm growth profile used in CROPWAT to calculate the water requirements.

3.3.4. Step 4: calculate blue and green WF of biofuel

The WF of a crop in country z (WF_c in m^3/ton) is calculated based on the crop water requirement (CWR in m^3/ha) and crop yield (Y in ton/ha) in the country:

$$WF_c(z) = \frac{CWR(z)}{Y_c(z)}$$

It is hereby assumed that the crop water requirements are actually met. For the WF of biodiesel from oil palm and the WF of biofuels in countries not included in the study of Gerbens-Leenes et al. (2008, 2009a), crop yields are obtained from the report of Chapagain & Hoekstra (2004) and the FAO (2009e). The blue WF of a crop is calculated based on the blue CWR (i.e. irrigation requirement), and the green WF of the crop is calculated as the minimum of the total CWR and effective precipitation. Subsequently, dividing the crop WF by the amount of biofuel (in energy terms) that can be obtained from the sugar, starch or oil fraction of the crop (E_c in GJ/ton), results in the WF per unit energy of biofuel (WF_e in m^3/GJ):

$$WF_e(z) = \frac{WF_c(z)}{E_c}$$

Table 2 shows the energy content of the different crops as assumed in this study. Oil palm has a relatively high biodiesel yield of 16.3 MJ per kilogram of oil palm fruit.

Table 2: Bio-energy provided by energy crops.

Crop	Energy content	
	Bio-ethanol (GJ/ton fresh weight crop)	Biodiesel (GJ/ton fresh weight crop)
Wheat	10.2 [a]	
Maize	10.0 [a]	
Sorghum	10.0 [a]	
Sugar beet	2.6 [a]	
Sugarcane	2.3 [a]	
Soybean	-	6.4 [a]
Rapeseed	-	11.7 [a]
Oil Palm fruit	-	16.3 [b]
Jatropha	-	12.8 [a]

a) Gerbens-Leenes et al., 2009a.

b) Calculated in this study.

The data on WF per unit of bio-energy (m^3/GJ) are coupled with annual biofuel consumption (GJ/yr) and feedstock data (Appendices 4 and 5) to calculate the annual WF of biofuels for road transport in each country z (km^3/yr):

$$WF(z) = \left[\sum_{i=1}^{5} \alpha_i(z) \cdot WF_{e,i}(z) \right] \cdot E(z) + \left[\sum_{j=1}^{4} \beta_j(z) \cdot WF_{e,j}(z) \right] \cdot D(z)$$

where E is the annual ethanol consumption; D the annual biodiesel consumption; α_i the ratio of ethanol from crop i to total ethanol consumption; and β_j the ratio of biodiesel from crop j to total biodiesel consumption. This equation is applied separately for the blue and green water footprint. The numerators i and j refer to the following crops:

i	Bio-ethanol crop
1	Sugar cane
2	Sugar beet
3	Sweet sorghum
4	Maize
5	Wheat

j	Biodiesel crop
1	Rapeseed
2	Soybean
3	Oil Palm
4	Jatropha

3.3.5. Step 5: determine blue water availability and other uses

To calculate the volume of blue water available for the annual blue biofuel WF, a supply and demand balance is created per country using data from AQUASTAT (FAO, 2008c) (see Appendix 8). Internal renewable fresh water resources (IRWR in km^3/yr) indicate the amount of surface runoff and groundwater recharge generated within a country. Flows entering a country from neighbouring countries (i.e. external renewable water resources, ERWR) are excluded to prevent double counting. The volume of blue water available for humans (WA_{blue}) is equal to the IRWR minus the so-called 'environmental flow requirements' (EFR) (see paragraph 2.3). This study uses the precautionary default EFR of 80 percent, as suggested by Hoekstra et al. (2009). Hence, only 20 percent of the IRWR in each country is available for human use.

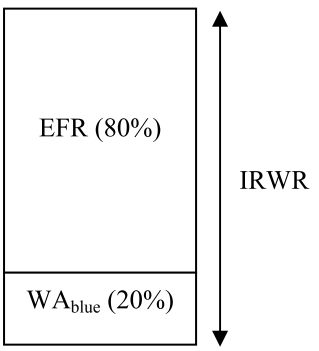

Figure 8: Partitioning of internal renewable fresh water resources (IRWR) into environmental flow requirement (EFR = 80 percent based on Hoekstra et al., 2009) and water available for humans (WA_{blue}).

Future change in water supply is not taken into account in this research. The study derives long-term average IRWR data from AQUASTAT and it is assumed that these will not change significantly in the coming years. It is recognized that climate change may lead to shifts in precipitation patterns around the globe in the long-run, which will directly affect the IRWR, but it was outside the scope of this research to take this into account.

Once the supply side of the balance is completed, the blue water demands for other sectors than biofuels are taken into account. This study derives data on current water withdrawals for industrial, domestic and agricultural purposes from AQUASTAT. Generally, in developed countries the largest withdrawals are for industry and in developing countries for agricultural purposes (FAO, 2008c). It is expected that this will change in the future.

Future changes in (blue) water withdrawals are incorporated in this study based on Alcamo et al. (2003). That study has calculated expected water withdrawals by all sectors for 200 countries in 2025, 2055 and 2075 based on changes in population, economy and technology according to the A2 and B2 IPCC scenarios (see Appendix 3). The B2 scenario emphasizes environmental values and assumes substantially lower emissions in the future, which matches the intentions behind the Alternative Policy Scenario. Climate change was also considered in their numbers (reflected in irrigation requirements), using two different climate models (HadCM3 and ECHAM4). The HadCM3 climate model results in a slightly higher total global irrigation requirement, but regional differences are not very large. This research uses the results from the B2 scenario and the HadCM3 model combination. Linear interpolation between 2025 and 2055 is done to determine the expected water withdrawals for 2030. Appendix 8 shows the current and expected future water balance per country.

3.3.6. Step 6: determine blue water scarcity

This report includes a first global exploration of the water scarcity caused by biofuels in road transport. We limit the study to scarcity of blue water resources because knowledge about green water demands in other sectors and in the environment is poor. Besides, the use of blue water for irrigation is usually a choice explicitly made by governments; the evaluation of blue water scarcity creates awareness and can help to make an informed choice.

Following Hoekstra et al. (2009), the 'blue water scarcity' in country z (WS_{blue}) is defined as the ratio of its total anthropogenic blue water demand (including the blue biofuel WF) (WD_{blue}) to the available blue water resources (WA_{blue}) in the country:

$$WS_{blue}\left(z\right)=\frac{WD_{blue}\left(z\right)}{WA_{blue}\left(z\right)}$$

A blue water scarcity of hundred percent means that the available blue water has been fully consumed; any percentage above indicates excess demand and environmental stress. The contribution of the blue biofuel WF in country z to the country's water scarcity is calculated by the ratio of the blue biofuel WF to the blue withdrawals in the other sectors (i.e. industry, domestic and agriculture).

4. Results

4.1. Changes in biofuel consumption

Although the consumption of both biodiesel and bio-ethanol is expected to increase enormously between 2005 and 2030, Figure 9 shows that the global demand for biodiesel rises more than for bio-ethanol (biodiesel 15×, bio-ethanol 6×). The share of biodiesel in global biofuel consumption doubles from 15 to 30 percent.

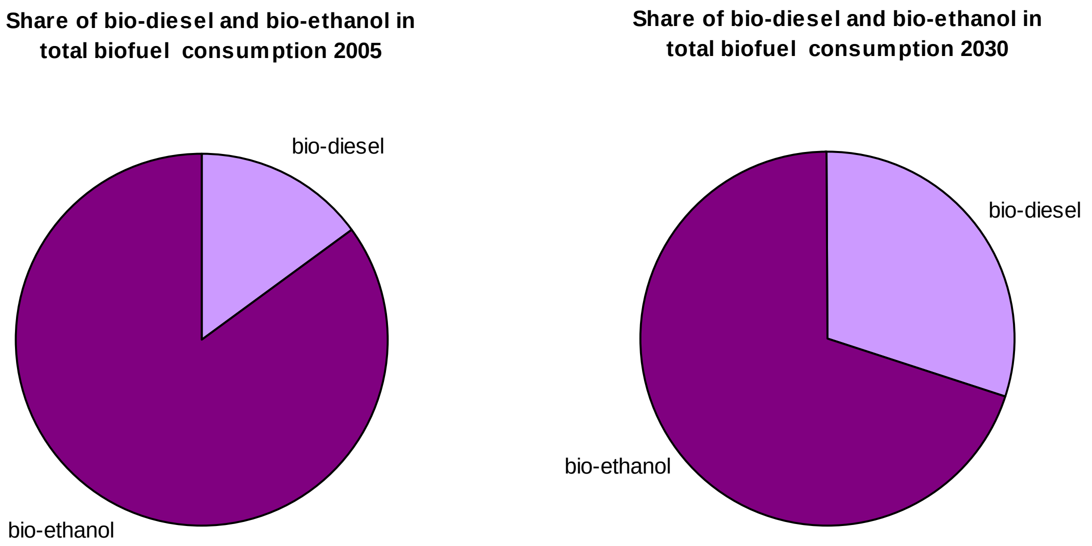

Figure 9: Change in biodiesel and bio-ethanol share in total biofuel consumption between 2005 and 2030.

Figure 10 and Figure 11 show the change in biodiesel and bio-ethanol consumption (in energy terms), respectively, in each world region. In more developed regions, liquid biofuels already form an important constituent in road transport fuels in 2005. Biodiesel consumption is foremost situated in Europe, whilst North-America leads in ethanol demand, followed closely by Latin America. Based on the scenario data in this study, it is expected that these regions continue to be prominent players on the biofuel market as their consumption swiftly increases towards 2030. However, as Developing Asia works hard to reach its targets, both its bio-ethanol and biodiesel consumption increase manifold: 25 and 84 times respectively. In 2030 it is expected that biodiesel consumption in Developing Asia surpasses that of North America, making it the second largest biodiesel consumer in the world. Europe remains the chief biodiesel consumer but also boosts its bio-ethanol production. In 2030 it is expected that bio-ethanol consumption in Europe will overtake that in Latin America, thereby making it the largest bio-ethanol consumer after North America.

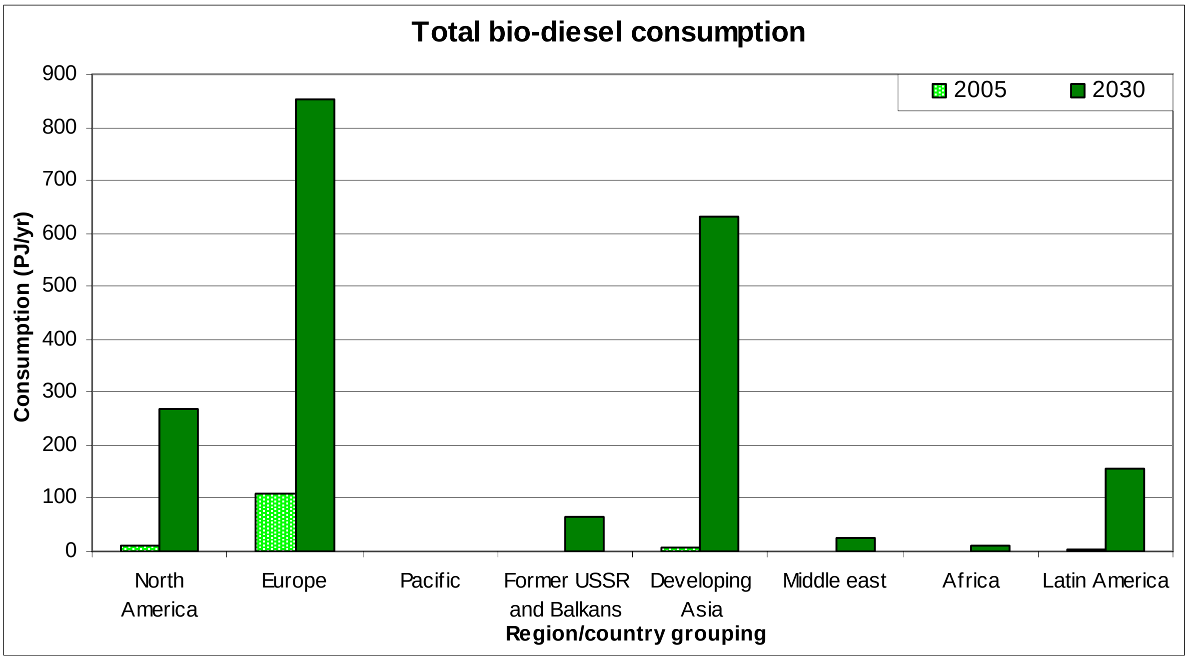

Figure 10: Change in biodiesel consumption between 2005 and 2030 in all regions.

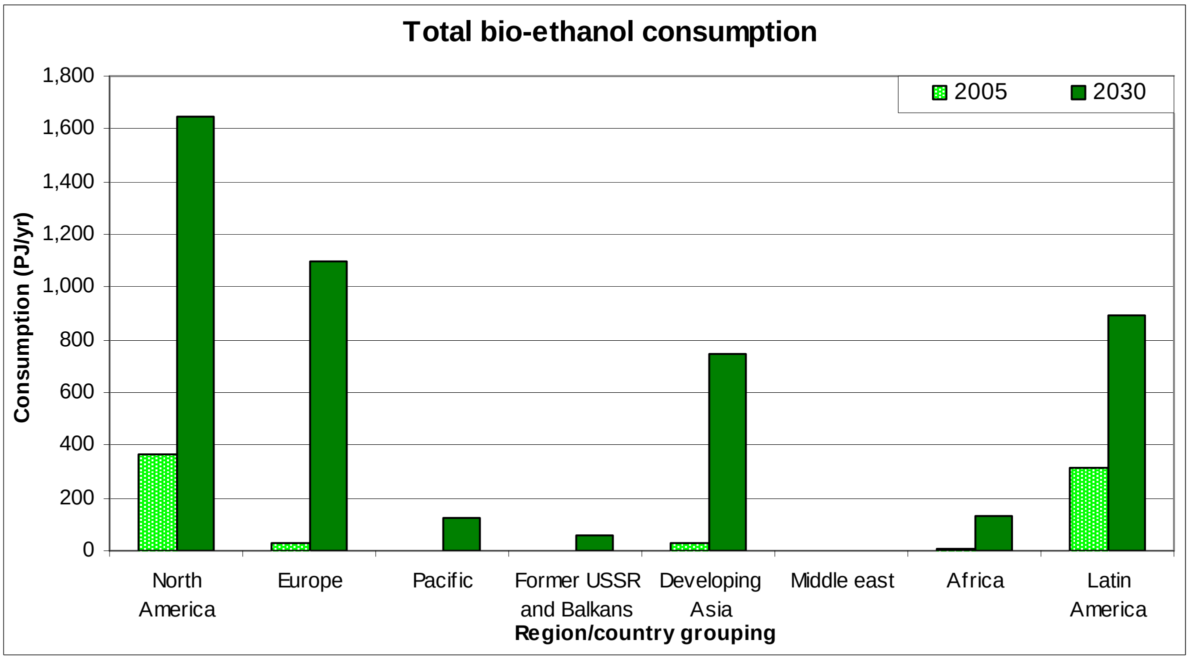

Figure 11: Change in bio-ethanol consumption between 2005 and 2030 in all regions.

Figure 12 and Figure 13 show which individual countries contribute most to the bio-ethanol and biodiesel consumption in 2030. In North America, the USA is the largest consumer of bio-ethanol and biodiesel. In Europe, Germany, Italy, France and the United Kingdom consume the most bio-ethanol (in order), and France, Italy, Germany and Spain the most biodiesel in 2030. Countries in the Pacific region just fall outside the top-ten for both fuels. In Asia, China is the main contributor to ethanol demand and Malaysia is the number one biodiesel consumer. The Middle East consumes very little biofuels. In Africa most bio-ethanol is consumed by

South Africa, and in Latin America Brazil takes the lead in both ethanol and biodiesel consumption. Appendix 4 gives the volume of each biofuel consumed by the remaining countries.

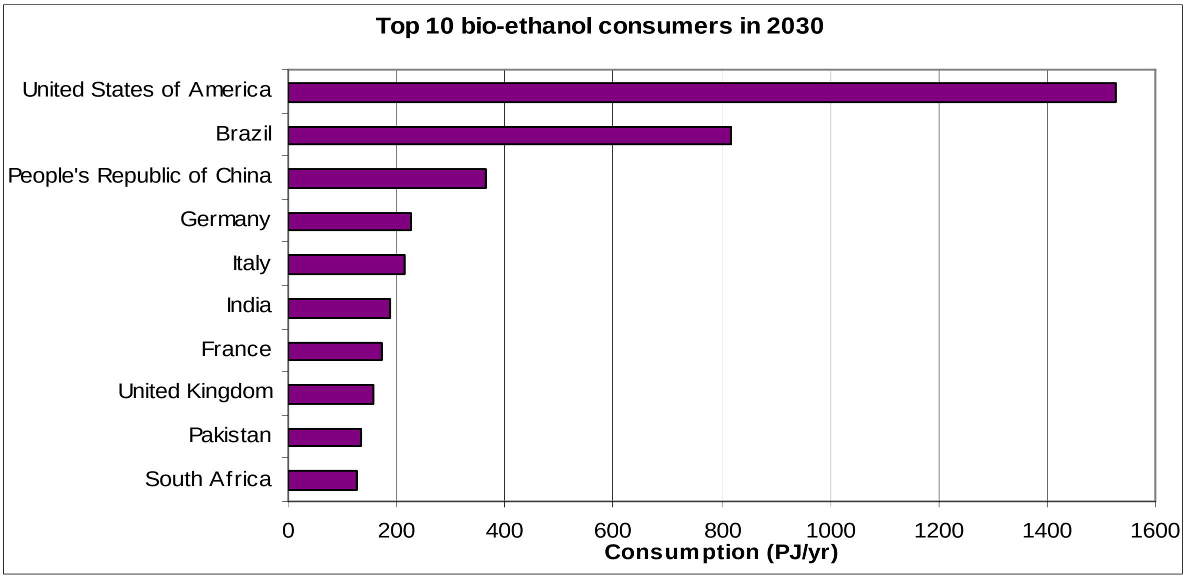

Figure 12: Top-ten of bio-ethanol consumers in 2030.

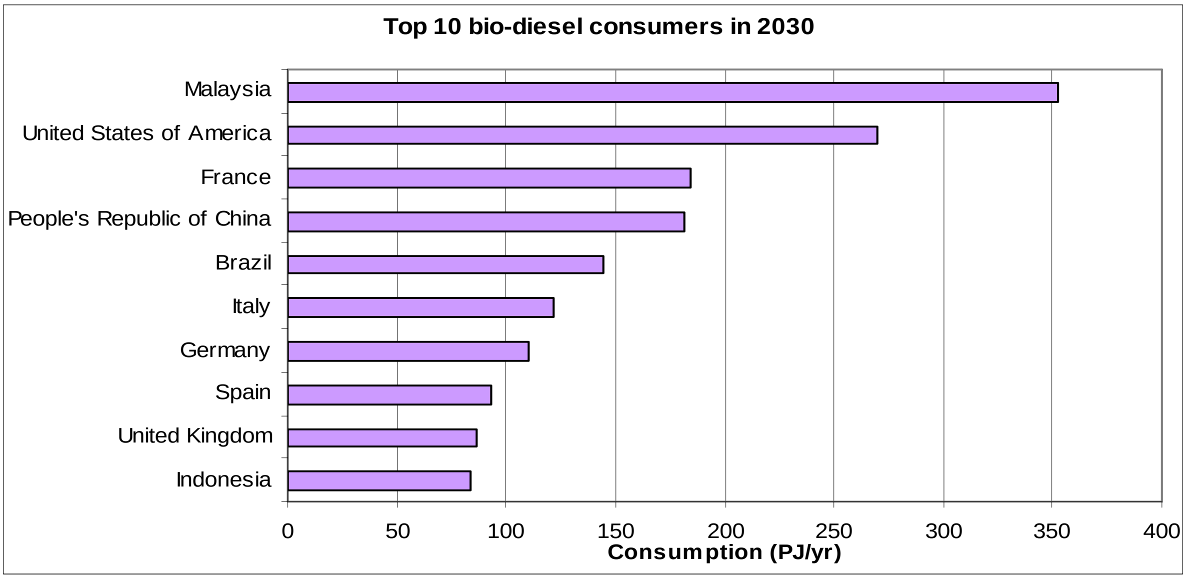

Figure 13: Top-ten of biodiesel consumers in 2030.

The dominant crop feedstocks used to produce these biofuels in each region are presented in Figure 14. The figure only gives a general overview; the crop choice per country is found in Appendix 5. The Americas and Asia use predominantly soybean for the production of biodiesel, whilst in Europe, the Former USSR, and Australia rapeseed is the main feedstock. In the dryer regions of the world, jatropha is commonly used for biodiesel and around the equator (+/-15°) oil palm is usually chosen. For ethanol in Latin America, Africa and Asia, sugar cane is often used, in Europe and the former USSR mainly sugar beet and wheat, and in North America and the Pacific region maize.

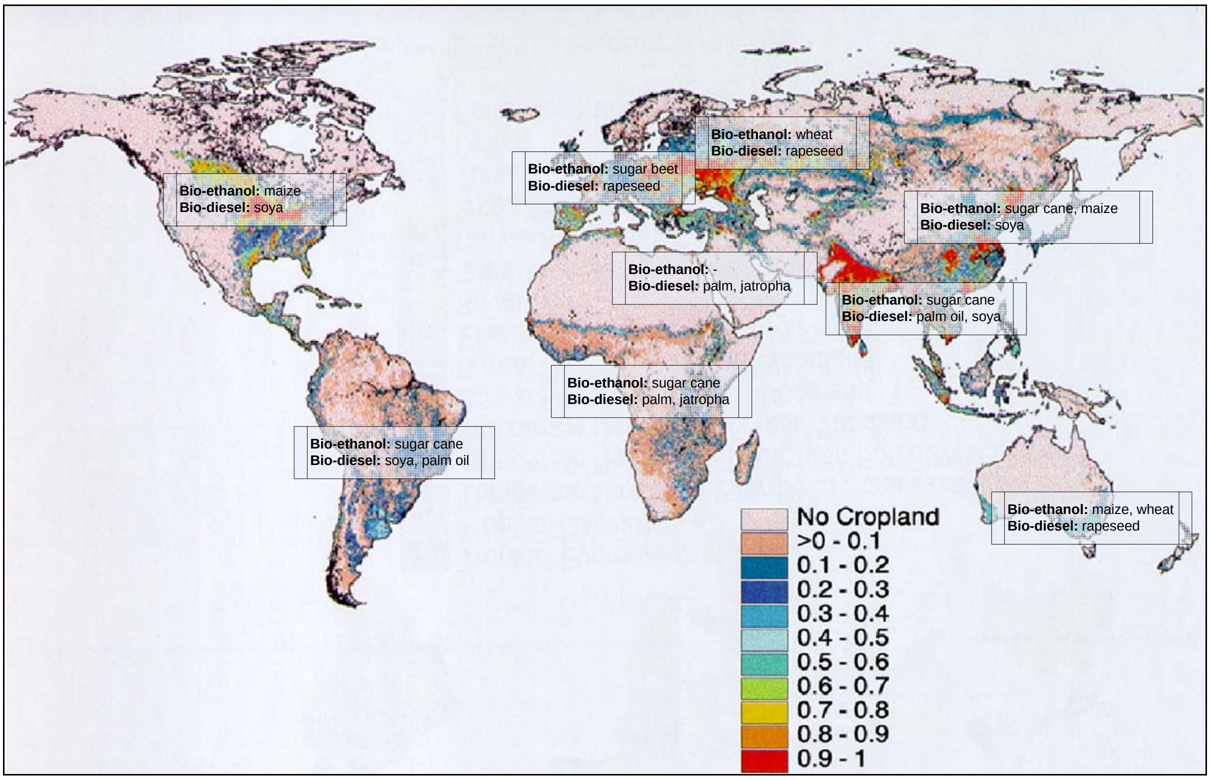

Figure 14: General overview of (likely) biofuel crop choice in different regions of the world.

4.2. The increasing water footprint from biofuel consumption

The increase in biofuel consumption has a direct effect on the water use in a region. Figure 15 and Figure 16 display the change in annual biofuel WF per region. Appendix 7 shows the data per country. A distinction is made between blue and green WF components. The WF increase in all regions can be explained by both the growth of the transport sectors and the higher biofuel share in transport fuels. The order of regions according to their WF size is equivalent to their ranking in biofuel consumption. However, some interesting differences appear when comparing the relative sizes of fuel consumption and WF. For example, biodiesel consumption in Europe and North America constitutes approximately 42 and 13 percent respectively of the world total in 2030. Corresponding WFs, however, represent 31 and 23 percent respectively of the world total biodiesel consumption WF in 2030. In other words, the biodiesel consumption WF of North America is relatively large compared to the one of Europe.

Other noteworthy differences are in the relative magnitudes of the green and blue WF components in each region. Figure 15, for example, shows that North America uses relatively a lot of irrigation (blue water) for its biodiesel crops compared to Europe and Developing Asia. Furthermore, the production of crops for biodiesel in Latin America, the Middle East and Africa depends for the most part on blue water and relatively little on rain water. Figure 16 shows that Developing Asia, Africa and the former USSR and Balkans depend relatively heavily on blue water for their ethanol crops. Globally, the blue WF of biofuels is expected to represent 48 percent (466 km^3/yr) of the total biofuel WF in 2030 (968 km^3/yr). In 2005 its share amounted to 45 percent (42 km^3/yr) of the total WF (93 km^3/yr).

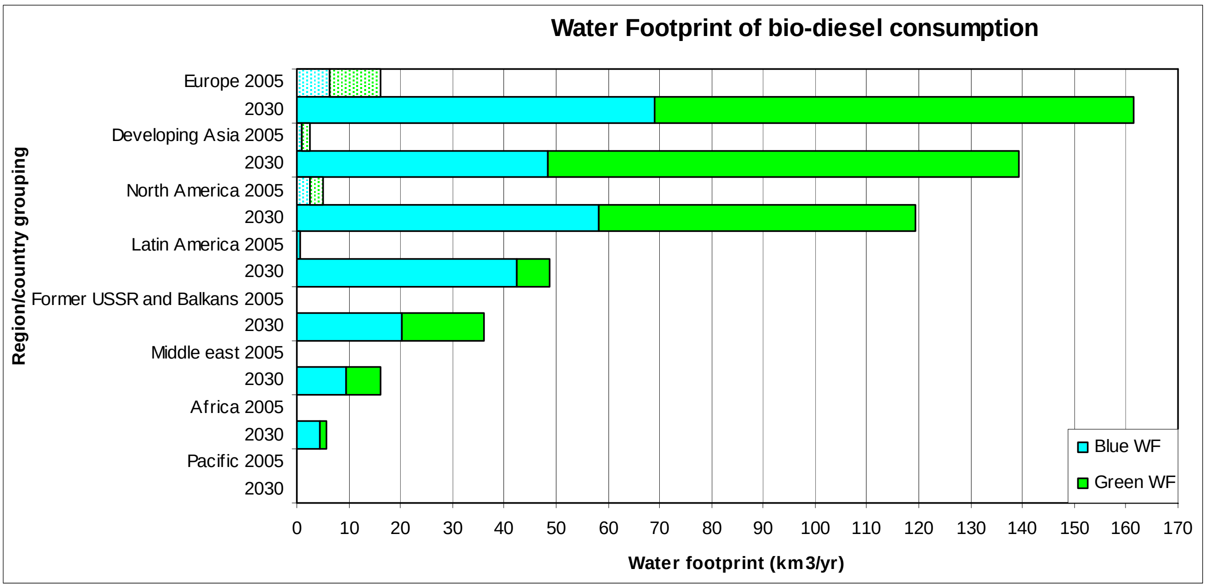

Figure 15: Change in water footprint of biodiesel consumption in road transport between 2005 and 2030.

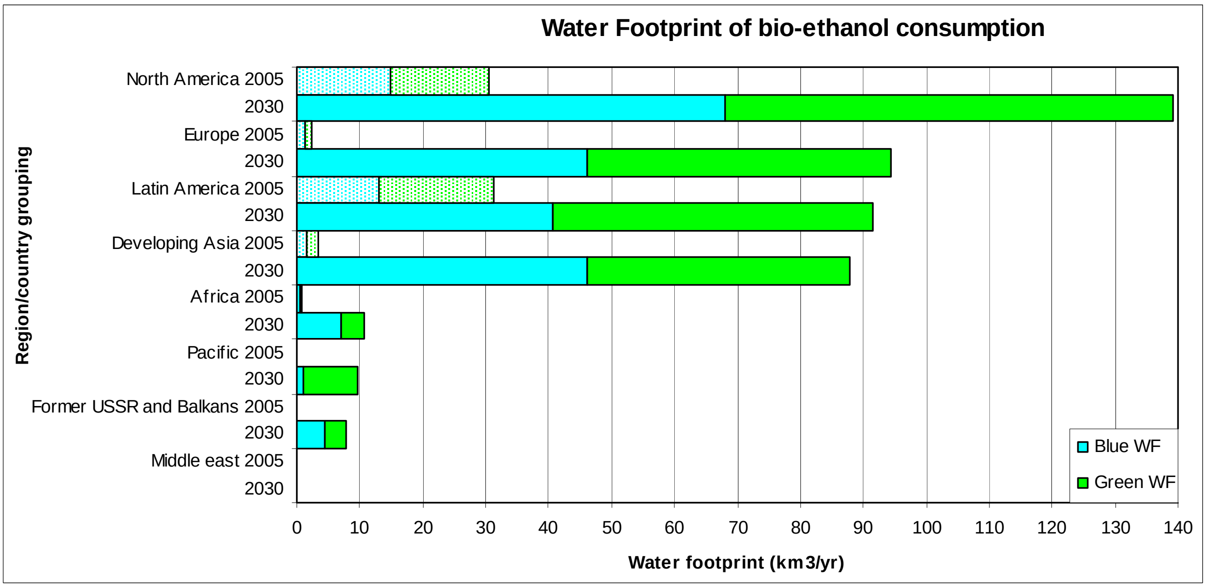

Figure 16: Change in water footprint of bio-ethanol consumption in road transport between 2005 and 2030.

The difference in blue and green contributions to the total biofuel WF also becomes apparent when we look on a national scale. The fact that Figure 17 and Figure 18 show a different ranking of countries according to their 2030 blue and green annual biofuel WFs, means that some countries depend more on green water and others on blue water for their biofuel production. Nonetheless, the USA, China and Brazil are the largest consumers of both blue and green water for their biofuels. Together they will account for approximately 54 percent of the global biofuel WF in 2030.

The differences in annual biofuel WFs can be explained by the crop types that are used to produce the fuel and the conditions they grow in. North America (USA) uses predominantly soybean for the production of biodiesel, whilst Europe uses rapeseed. The WF (per unit of energy) of biodiesel from soybean in North America is much larger than that of rapeseed in Europe, primarily because it requires relatively large amounts of irrigation.

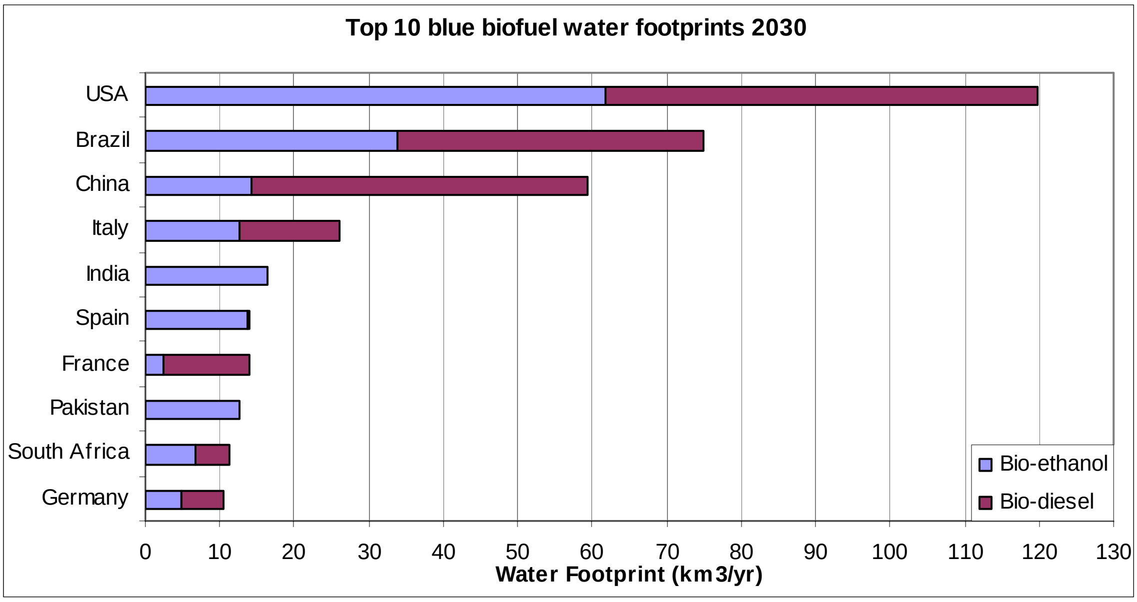

Figure 17: Ranking of countries according to their annual blue biofuel water footprint in 2030.

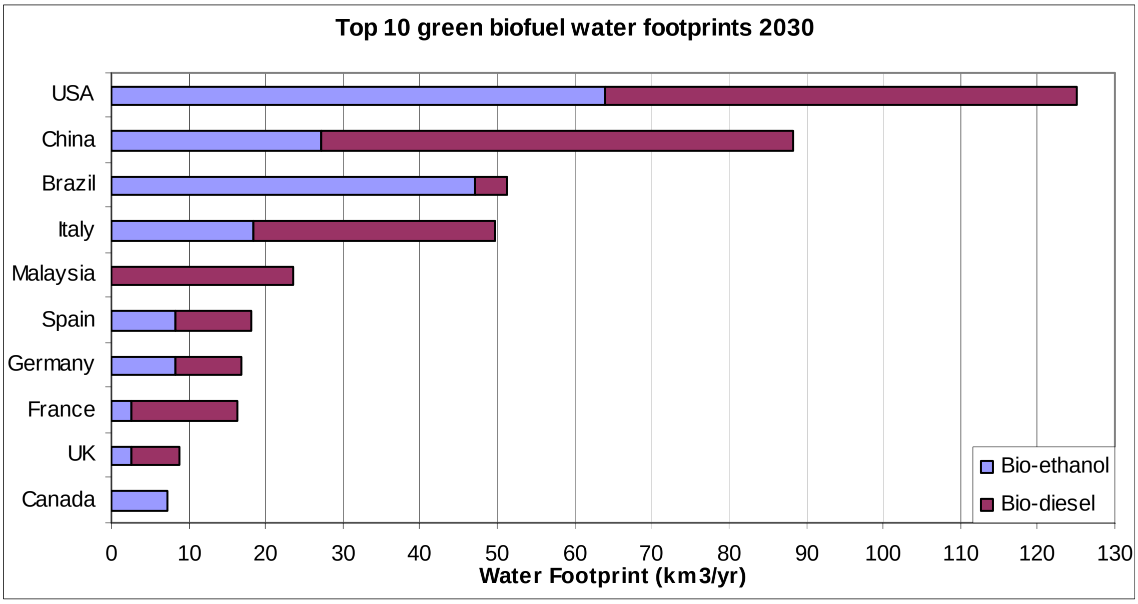

Figure 18: Ranking of countries according to their annual green biofuel water footprint in 2030.

4.3. The effect of biofuels on blue water scarcity

The change in WF of biofuels for transport has a consequence for the water resources in a country. Globally, the blue WF of biofuels is expected to rise from 0.5% of the available blue water in 2005 to 5.5% in 2030. In 2030, the blue WF of biofuels will account for 9% of total blue water demand, compared to 47% by agriculture, 24% by households and 20% by industry. A comparison between national blue water demands and availability in 2030 shows where in the world water scarcity is likely to occur. Table 3 gives a summary of countries which are likely to suffer from blue water scarcity in 2030. For each country it is also shown how much the blue biofuel WF contributes to the potential water scarcity. In Pakistan, for example, blue water demands will likely exceed the available internal blue water resources by about 28 times, causing a high degree of water scarcity. However, the WF of biofuels contributes only 4% to total water demand; the greatest causers of water scarcity in that country are the other sectors, particularly agriculture for food. From the perspective of internal water resources, Egypt will also face immense water scarcity, but it is not expected to consume any biofuels (hence the 0% share). In the United Arab Emirates, South Africa, Malta, Cyprus, Denmark, Portugal and Italy, however, the biofuel WF accounts for the larger part of water scarcity. This could indicate that it is unlikely that these countries will produce their own biofuel as was assumed in this study. The following subparagraphs show a breakdown of the blue water demands and supply in each country per region.

Table 3: Overview of countries which are likely to suffer from blue water scarcity in 2030. It is also shown how much the biofuel WF contributes to the water scarcity.

Country	Blue water scarcity 2030*	Share of blue biofuel WF in blue water scarcity 2030
Bahrain	46008.3%	0.0%
United Arab Emirates	34374.3%	90.7%
Bahamas	25251.3%	0.0%
Egypt	23887.3%	0.0%
Turkmenistan	6610.0%	0.0%
Libya	5732.7%	0.0%
Saudi Arabia	4974.2%	0.0%
Pakistan	2766.4%	4.1%
Mauritania	2742.3%	0.0%
Malta	2411.9%	99.8%
Yemen	1903.9%	0.0%
Uzbekistan	1755.5%	0.0%
Moldova	1741.1%	0.0%
Qatar	1490.9%	0.0%
Jordan	1396.4%	0.0%
Syria	1317.0%	0.0%
Israel	1316.1%	0.0%
Azerbaijan	1077.0%	0.0%
Hungary	902.7%	27.9%
Iraq	664.0%	0.0%
Bulgaria	609.2%	25.1%
Afghanistan	582.3%	0.0%
Tunisia	557.9%	0.0%
Algeria	547.5%	0.0%
Cyprus	468.0%	53.4%
Romania	452.6%	11.9%
Oman	438.4%	0.0%
Iran	419.3%	0.0%
Czech Rep.	397.8%	20.3%
Belgium	394.1%	13.9%
Niger	386.9%	0.0%
Netherlands	386.6%	17.7%
India	383.9%	1.7%
Bangladesh	354.1%	0.0%
Armenia	344.7%	0.0%
South Africa	340.9%	36.8%
Ukraine	340.5%	0.0%
Barbados	334.1%	0.0%
Sudan	324.0%	0.0%
Morocco	304.0%	0.0%
Spain	274.8%	23.0%
Somalia	261.1%	0.0%
Lebanon	253.5%	0.0%
Poland	251.8%	25.2%
Kazakhstan	250.6%	0.0%
Trinidad and Tobago	231.8%	0.0%
Greece	226.5%	38.9%
Slowak Rep.	223.9%	20.2%
Portugal	206.8%	52.5%
Germany	205.5%	23.6%
Kenya	202.0%	0.5%
Rep. Korea	201.7%	0.0%
Turkey	187.8%	4.3%
Denmark	169.4%	33.8%
Eritrea	167.0%	0.0%
Italy	161.8%	44.1%
Macedonia	154.9%	0.0%
France	141.5%	27.6%
Cuba	138.0%	0.0%
China	137.2%	7.7%
Mexico	126.7%	0.0%
UK	120.8%	24.3%
USA	102.6%	20.9%
Lithuania	101.4%	11.1%
Kyrgyzstan	101.4%	0.0%
Vietnam	100.5%	0.0%

* Based on blue water demands relative to available IRWR. For countries with significant ERWR, this can give a distorted result.

North America

Although North America as a whole does not appear to encounter any water problems, Figure 19 shows that it is likely that the USA and Mexico will suffer from water scarcity in 2030. With a blue WF of biofuels for road transport of 120 km^3/yr added to total blue water demand, the USA exceeds its available blue water resources in 2030. This will undoubtedly lead to extra stress on their water systems. In Mexico, the blue water demand will also surpass the available supply in 2030, resulting in environmental stress. However, this happens even without extra water demands for biofuels. In Canada, water demands are low compared to the available internal renewable water resources and the country is not expected to use a lot of water for biofuels.

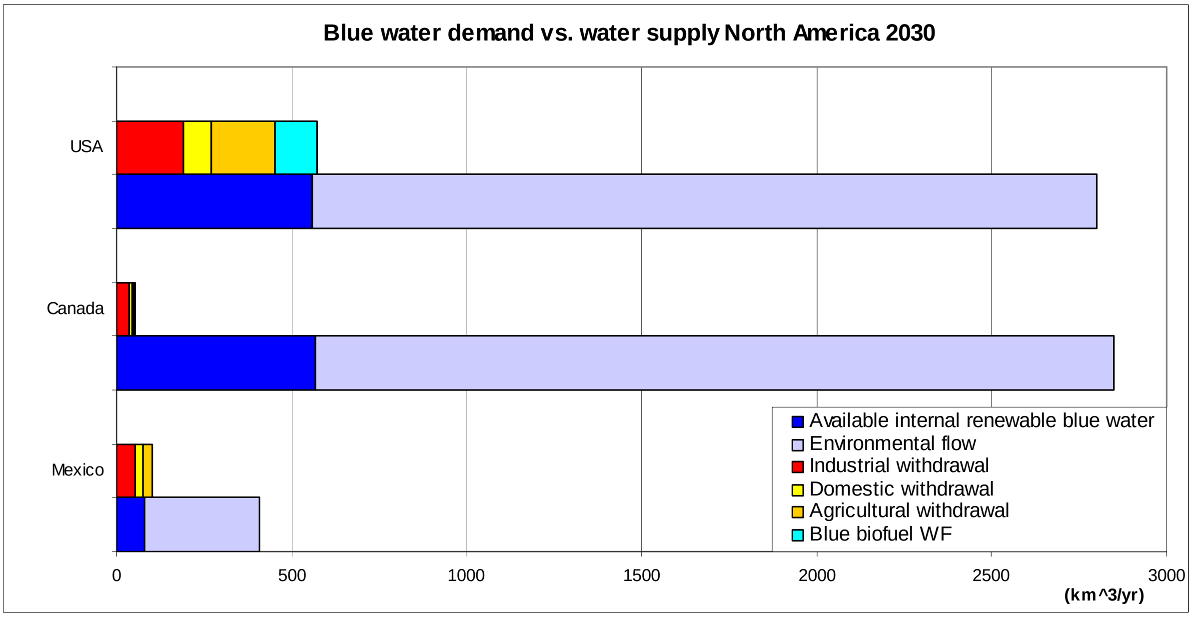

Figure 19: Comparison of blue water demands and available internal renewable blue water resources in North American countries.

4.3.1. Europe

It is expected that the increased consumption of biofuels in Europe will lead to water scarcity in some parts of the region in 2030. Blue water scarcity beyond the threshold of 100% is expected in: Belgium, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, the Netherlands, Poland, Portugal, Slovak Republic, Spain, Turkey and the United Kingdom (see Figure 20). In Denmark, Italy, Portugal and Greece more than a third of the water scarcity is caused by the WF of biofuels for road transport.

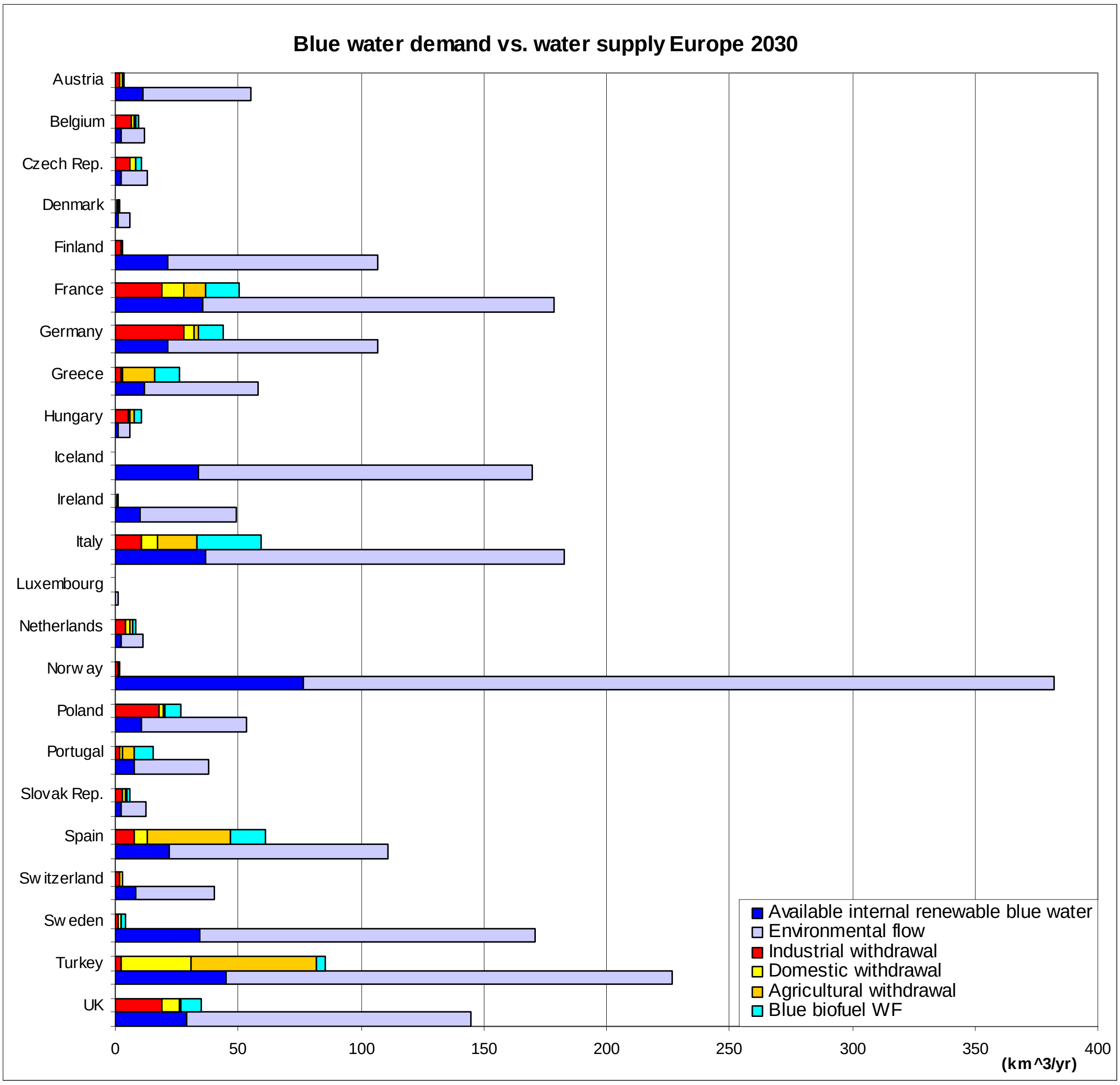

Figure 20: Comparison of blue water demands and available internal renewable blue water resources in European countries.

4.3.2. Pacific

In the Pacific region as a whole there seems to be sufficient water, and total water demand is expected to be relatively low. According to Figure 21, only the Republic of Korea is likely to face blue water scarcity in the future. However, this is not caused by its annual biofuel WF, but by withdrawals in other sectors. Japan and Australia are expected to use some biofuel (bio-ethanol) in 2030, but most of the WF is green (93 and 81% respectively) and the blue component is not visible on the graphing scale. Biomass is not expected to emerge as a major energy source for the transport sector in New Zealand, and will thus not lead to any water problems in that country.

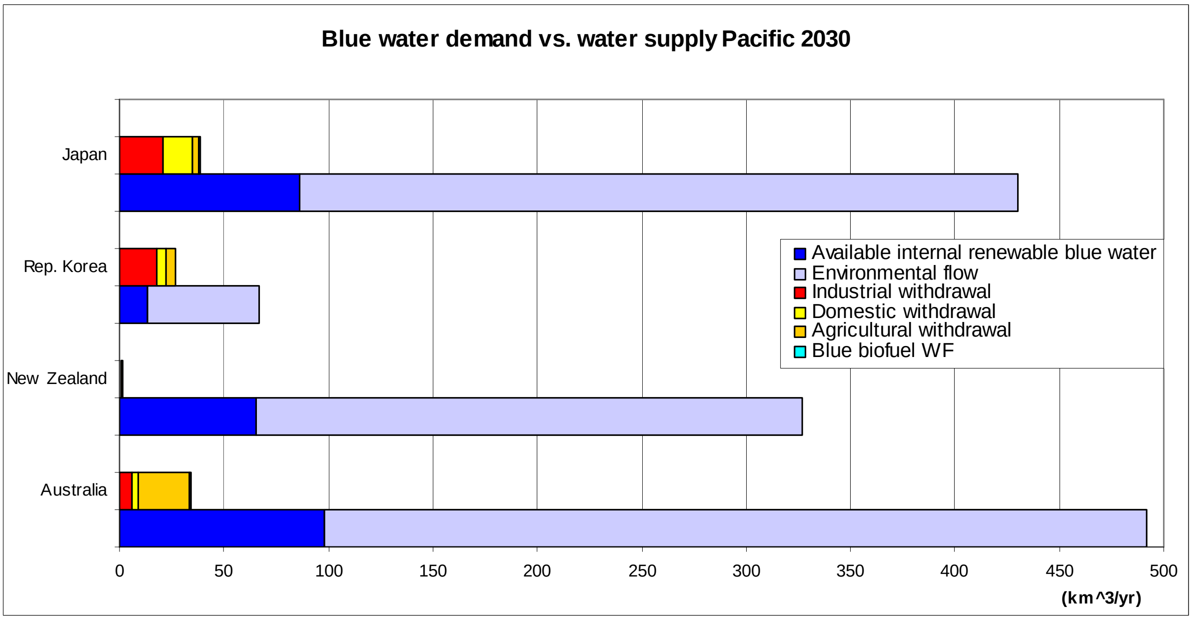

Figure 21: Comparison of blue water demands and available internal renewable blue water resources in Pacific countries.

4.3.3. Former USSR and Balkans

The former USSR and Balkans are classified as transition economies, along with Cyprus, Gibraltar and Malta. Biofuel consumption remains low in these economies. The enormous water availability in Russia is overshadowing the picture of the region as a whole. It is likely that water scarcity will be serious in a number of countries. According to Figure 22, the countries in which blue water demand exceeds available supply are: Armenia, Azerbaijan, Bulgaria, Macedonia, Kazakhstan, Kyrgyzstan, Lithuania, Moldova, Romania, Turkmenistan, Ukraine, Uzbekistan, and Cyprus, but in none of these countries the blue WF of biofuels for road transport is the main causer. Water use in other sectors is more relevant. Nonetheless, in Bulgaria and Romania the consumption of biofuel (especially biodiesel) will contribute to the water scarcity (25 and 12% respectively).

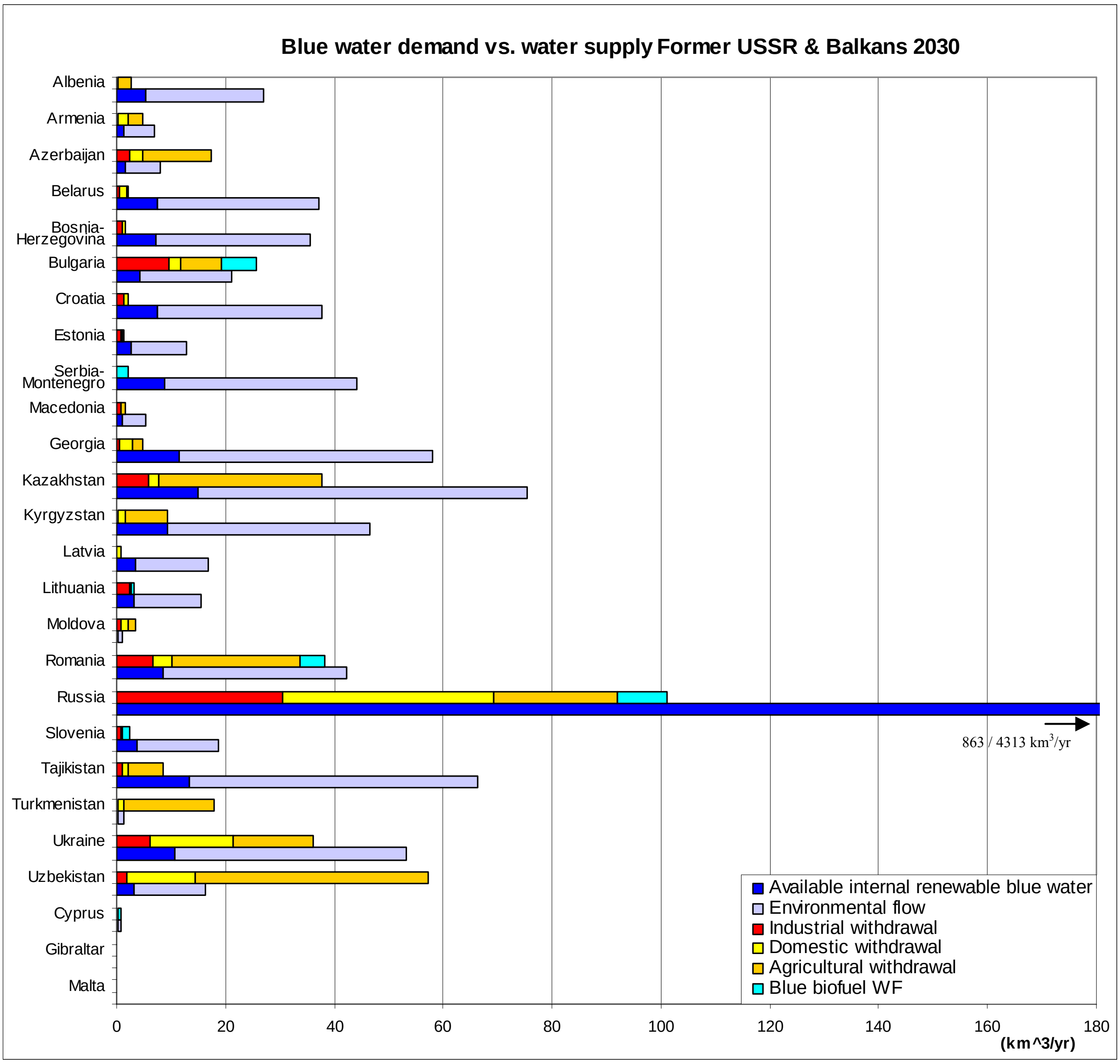

Figure 22: Comparison of blue water demands and available internal renewable blue water resources in Transition Economies.

4.3.4. Developing Asia

It is expected that Developing Asia will face very large water problems in 2030. Afghanistan, Bangladesh, China, India, and Pakistan are the main contributors to those problems (see Figure 23). The enormous blue water demands in these countries are primarily caused by the agricultural sector. Compared to these withdrawals, the annual blue WF of biofuels is relatively small. China and India in particular will have a large blue biofuel WF in comparison to other countries in the world. In 2030 they are expected to rank respectively third and fifth in the world. It is likely that the increased water use for biofuels in road transport will contribute significantly to the water scarcity experienced by those countries.

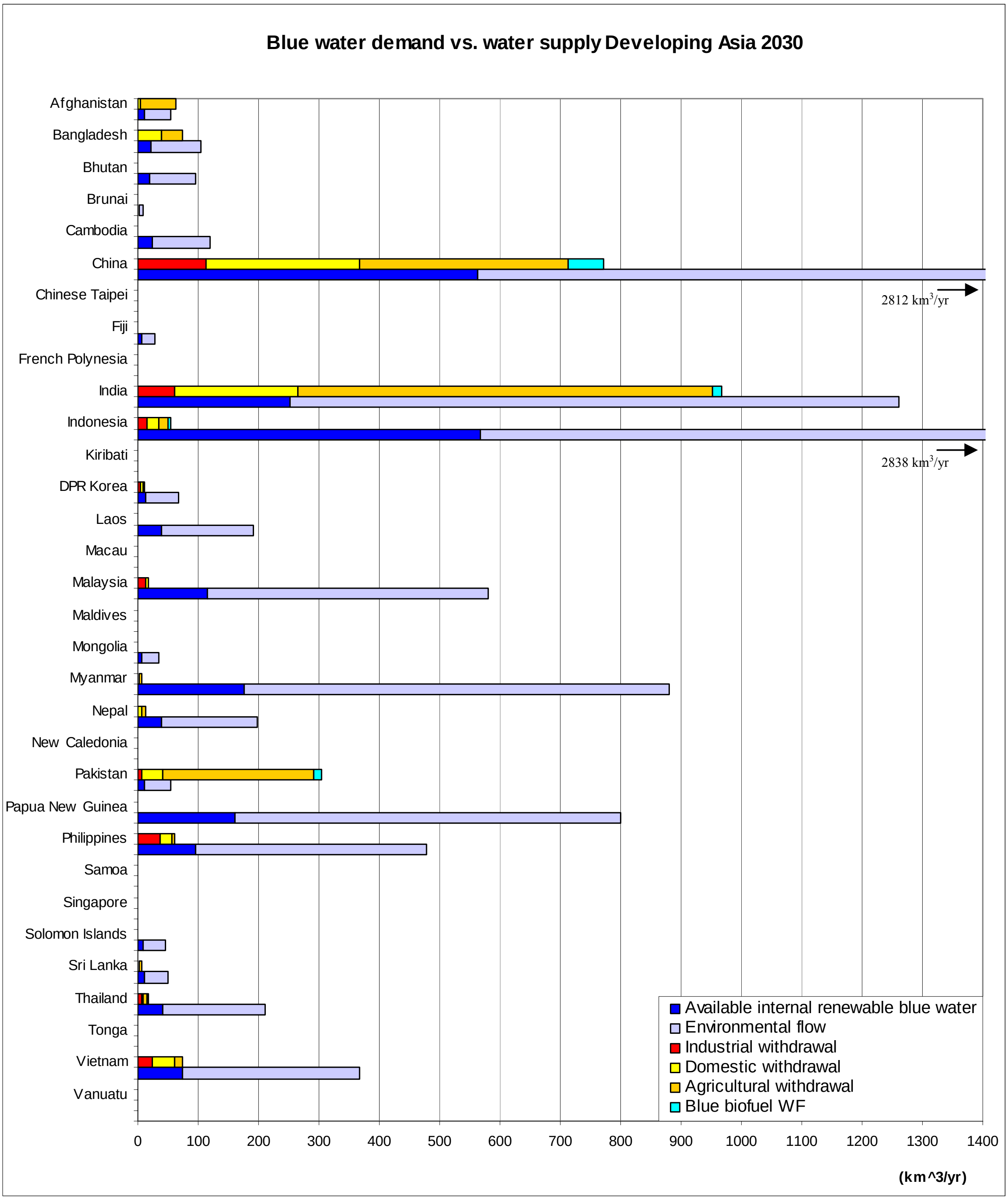

Figure 23: Comparison of blue water demands and available internal renewable blue water resources in Developing Asian countries.

4.3.5. Middle East

According to scenario projections, the Middle Eastern region will run into a serious water problem. Already in 2005 most countries in the region face water scarcity even without the consumption of biofuels. Many countries have very little renewable fresh water resources to start off with, and in most cases the water that is available is used for other purposes. The reason that water use in countries such as Saudi Arabia, Syria and the UAE is so much larger than water supply, is because these countries are mining fossil ground water. The extraction rate is often many times larger than the recharge rate and it is thus only a short-term solution. In the near future, the United Arab Emirates are planning to exploit biofuel to some extent. They have some projects lined up for the production of biodiesel and there is research in progress on jatropha as a potential feedstock. These developments are expected to lead to (increased) water scarcity in that nation (see Figure 24).

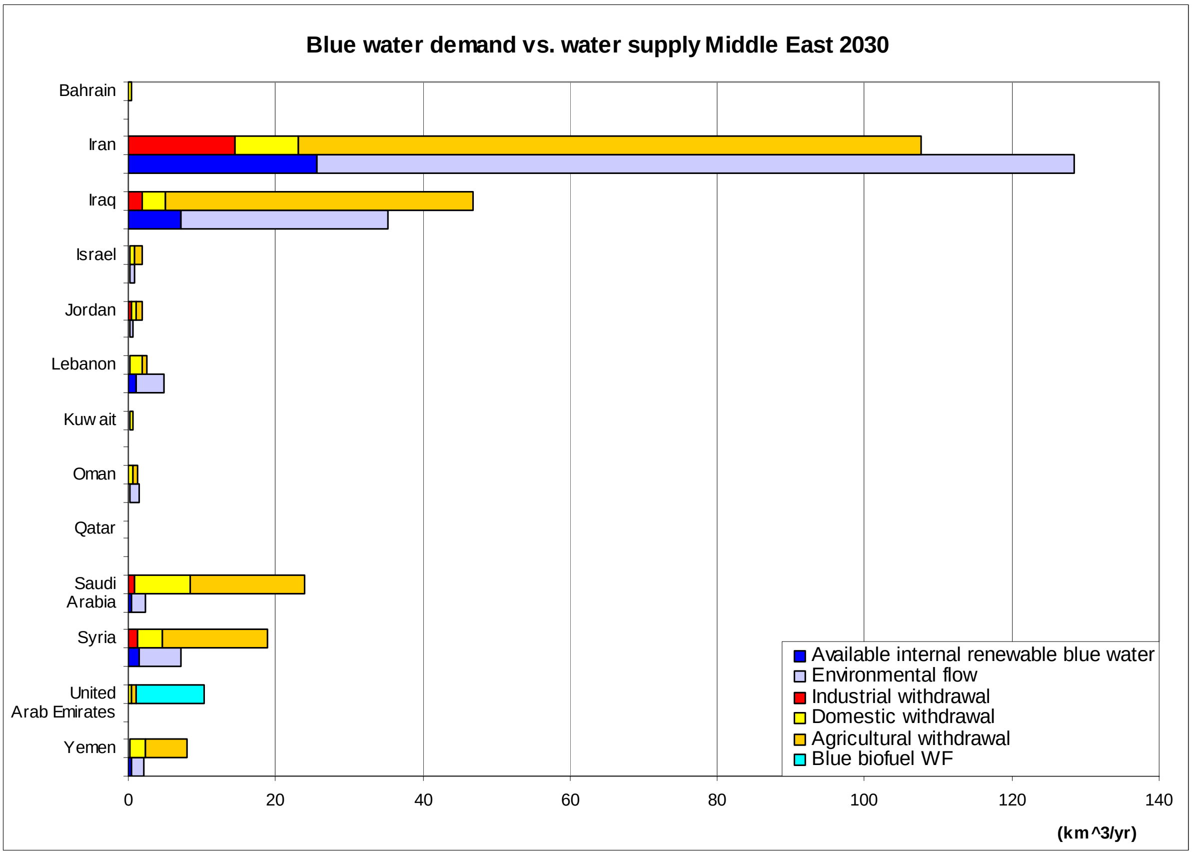

Figure 24: Comparison of blue water demands and available internal renewable blue water resources in Middle Eastern countries.

4.3.6. Africa

Most African countries are not expected to face increased blue water scarcity due to biofuel consumption, because it is not likely that they will produce large volumes of liquid biofuels in the future and use irrigated crops to do so. Algeria, Egypt, Eritrea, Kenya, Libya, Mauritania, Morocco, Niger, Somalia, Sudan, and Tunisia are expected to face blue water scarcity. In the case of Egypt, water demands that are so much larger than internal water supply is possible due to inflow of the Nile from neighbouring countries. Water scarcity in these countries is not caused by extra water demands from biofuels for road transport (see Figure 25). Only in South Africa a significant amount of bio-ethanol is expected to be produced, using a combination of partially irrigated sugar beet and sugar cane. There will also likely be some consumption of biodiesel, produced from soybean and jatropha. In this country the biofuel WF contributes nearly 37% to total blue water withdrawals, and is thus one of the main causers of water scarcity in 2030.

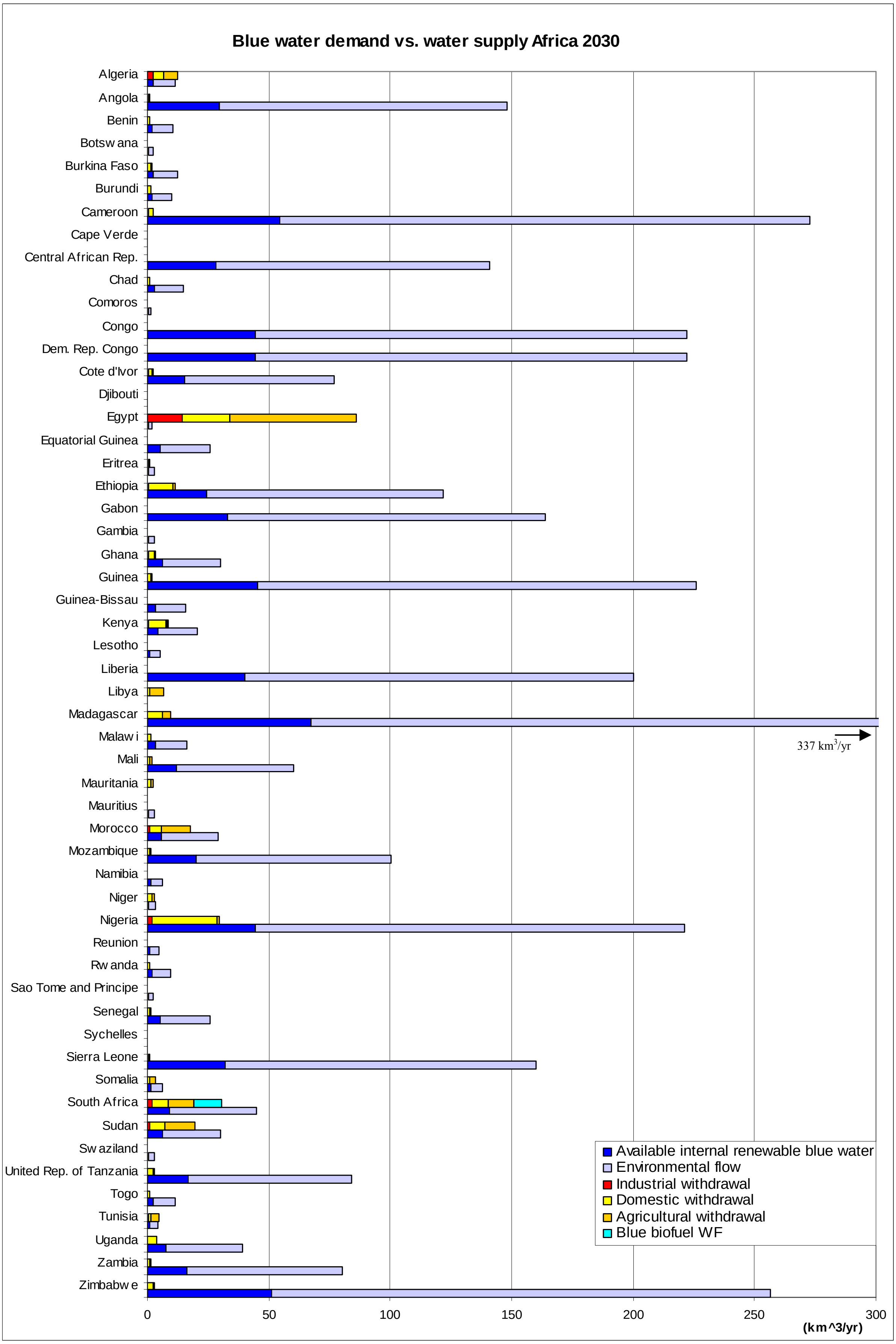

Figure 25: Comparison of blue water demands and available internal renewable blue water resources in African countries.

4.3.7. Latin America

Latin America is not expected to suffer from blue water scarcity in the future. The region has a third of the available renewable blue water resources in the world (2630 km^3/yr) and uses only 16 percent of the total resources in 2030. However, 34 percent of the regional blue water demand can be attributed to the production of biofuels in 2030. Brazil, in particular, has a relatively large blue biofuel WF in 2030 (ranking second in the world). Although the country is expected to produce nearly six times more bio-ethanol than biodiesel, 55 percent of the blue biofuel WF is caused by the production of biodiesel. The reason is that Brazilian ethanol is produced from sugar cane, which is based only 40 percent on blue water, whilst Brazilian biodiesel is produced using soybean based 95 percent on blue water. Nonetheless, Brazil has access to plenty of blue water resources, thus causing no water scarcity on a national level. The Bahamas, Barbados, Cuba, and Trinidad and Tobago will experience water scarcity as they use more IRWR than they have available in 2030, but this is not caused by biofuel production (see Figure 26).

The above paragraphs have shown the consequence of the adoption of biofuels on the water resources across the globe. The competition for available IRWR between blue water users will lead to blue water scarcity in many countries, especially in Europe, Developing Asia and the Middle East. In many European countries the biofuel WF will contribute significantly to water scarcity, but also in the United Arab Emirates and South Africa the biofuel WF will take a large share. In most other countries over-consumption of water in other sectors appears to be the main cause for water scarcity. Although these results are meaningful, they need to be interpreted with some caution. In the next chapter some issues are discussed that will help to understand the full significance.

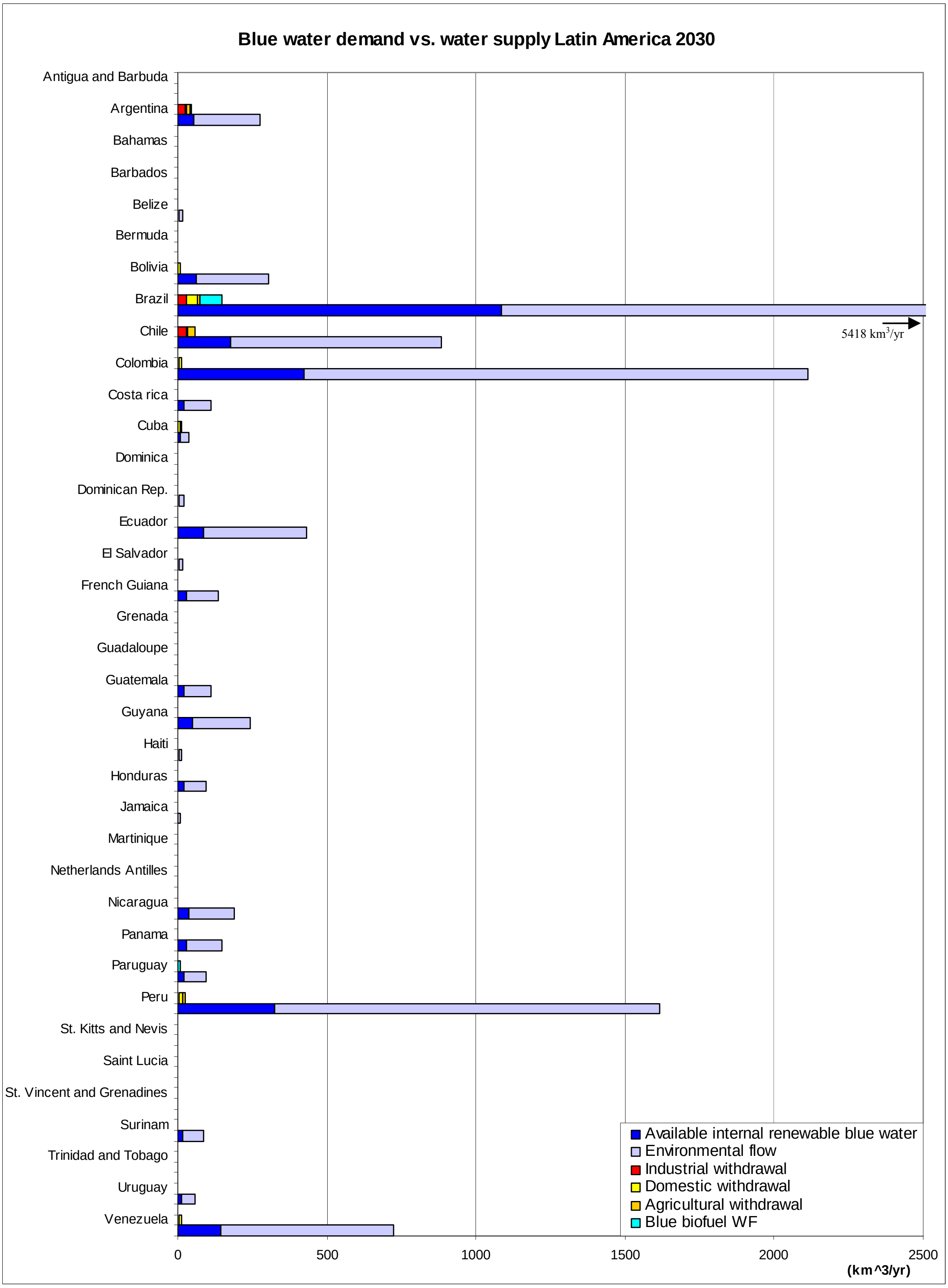

Figure 26: Comparison of blue water demands and available internal renewable blue water resources in Latin American countries.

5. Discussion

5.1. Uncertainty of the results

It has to be realised that the results presented in the previous chapter are based on compiled scenario data. The base scenario used was the Alternative Policy Scenario from the International Energy Agency (2006), which was supplemented by similar region-specific scenarios/targets and extrapolated historic data. The fact remains that these results are merely based on a particular view of the future. Although this is a reasonable, established projection, it does not mean that the future will actually unfold this way. These results should merely be used to get an idea of what the consequences might be if we will follow the storyline of the scenarios. It should also be noted that the scenarios used in this research reflect an average biofuel transition. Some of the other scenarios examined in this study (e.g. Greenpeace [r]evolution and EREC AIP) are much 'greener' and project a much larger contribution of biofuels. Using those numbers will undoubtedly result in even greater consequences for the water resources.

The same goes for the data used for the water balance. Future water withdrawals are based on one particular combination of a scenario and climate model, and although these are obtained from reliable, renowned sources (IPCC, 2000; Alcamo et al., 2003), they remain just one interpretation of the future. Furthermore, no account is taken of possible changes in temperature and precipitation due to climate change. The study could have used a hydrological scenario, but used long-term average precipitation figures from the past instead. It has to be recognized that this choice has an effect on the determination of the fresh water supply in a country.

Besides this, spatial and temporal variability in water supply are not reflected in the water availability data. Both temporal and spatial average supply and demand data are used in this research. Extreme rainfall events or periods, like the monsoon in some tropic countries, are not taken into account, neither are microclimates within some countries. It is possible that the timing of water supply may not exactly coincide with water demand, which means that the full potential available fresh water can not be used. Furthermore, only the water resources generated within a country are considered, not the external flows. For these reasons, actual water availability in a particular location may deviate from the figures presented in this study.

The statements about blue water scarcity are also particularly sensitive to the amount of flow allocated to the environment. This study assumes a precautionary default EFR of 80 percent for all countries, representing a threshold for potential concern. The actual EFR in a particular country may be different. A further limitation in this research is that we did not analyse the green water scarcity. No data were found on green EFR and determination of future green water demands by other sectors involved too much complexity. It should nonetheless be realized that the green WF of biofuels will also have a significant impact on the water system. Moreover, this study has excluded the grey WF of biofuels, i.e. the amount of water that is needed to assimilate pollution to an accepted standard. The reason is that the available data were not satisfactory for global coverage. In the study of Gerbens-Leenes and Hoekstra (2009), the grey WF bio-ethanol was calculated on a smaller scale and it was found that the grey WF generally constitutes a minor part of the total WF, on average about 10 percent. Thus, the WF of biofuels could be about 10 percent higher than presented in this report.

Another point for discussion is the assumption that the blue water used for agriculture as taken from FAO (2008c) and Alcamo et al. (2003) is solely applied for the production of crops for food, feed and seed. According to the FAO food balance sheets, the quantity of crop used for other purposes besides food, feed and seed (e.g. biofuels) is relatively small. In the United States of America for example, the amount of maize used for other purposes, mainly bio-ethanol, constitutes only 3 percent of the total domestic maize production (FAO, 2009b). We assume that the agricultural water demand projections for 2030 based on Alcamo et al. (2003) exclude the increase of water use in agriculture for producing biofuels.

It also has to be noted that the annual biofuel WFs calculated in this research are based on a biofuel WF database that has its weaknesses. To begin with, the study integrates data from several sources, each adding a degree of uncertainty. Biofuel WF numbers from Gerbens-Leenes et al. (2008), for example, are based on the assumption that crop water use is equal to crop water requirements. In other words, shortages are always compensated through irrigation and crops grow in ideal water conditions. In reality this may not be the case, leading to an overestimation of the crop water use. Furthermore, only one weather station in one particular growing location was used per country. Climatic conditions may differ if another growing location and weather station are chosen and this will influence crop water use numbers. Some inaccuracy is also introduced by using regional WF averages for several countries and assuming crop types used based on neighbouring countries.

Finally, the actual biofuel WFs might deviate from the results in this research, because changes in crop choice, production techniques, and crop technology are not taken into account. For example, if second-generation conversion processes break through sooner, then a greater fraction of the crop can be used for the production of biofuels, thus leading to a lower biofuel WF (in m^3/GJ). Likewise, new crop varieties or new agricultural technology may make it possible to get the same yields with less irrigation, or higher yields using the same amount of water. Switching to more water-efficient crops will also have an effect on the WF, but it can be argued that this is unlikely to occur because often farmers do not easily give up their traditional practice. Moreover, countries may choose to use waste oils or fish oil to produce biodiesel, or adopt biogas for transport. These developments will all have an effect on the annual WF of biofuels.

5.2. Suggestions for further research

This study is primarily intended as a first exploration of the consequence of a transition to biofuels in road transport on the biofuel WF in a country. It provides insight in what could happen to the water balance in a country if it were to follow a particular energy scenario. However, considering the scope of this research, various assumptions have been made regarding several parameters in the calculations. It is suggested here that a sensitivity test is done regarding the effect of changes in these parameters on the results. For example, only first-generation conversion processes are considered in the results. It would be interesting to see what effect the (early) commercial breakthrough of second-generation technology would have on the WF of biofuels. By merely using the sugar and starch parts of the crop in first-generation conversion to ethanol, only a maximum efficiency of about 30 percent can be obtained. If, however, the whole crop could be used to produce biofuel, efficiency would probably approach 59 percent, the same order of magnitude as the production of electricity from biomass (Gerbens-Leenes et al., 2008). A comparison of energy content of ethanol crops in first and second-generation conversion is shown in Table 4. It can be seen that in most cases more than twice as much energy can be obtained from the same amount of crop, which improves the water efficiency of biofuels. This supports the statement of the IEA (2006) that the contribution of biofuels hinges on new technology.

Table 4: Comparison of ethanol energy content of crops by 1st and 2nd generation conversion.

Crop	MJ ethanol / kg fresh crop	
	First generation	Second generation
Sugar beet	2.6	3.4
Sugar cane	2.3	5.0
Maize	10.0	22.0
Wheat	10.2	23.2
Sorghum	10.0	23.2

Source: Gerbens-Leenes et al. (2008).

The impact of switching to different crops also deserves some attention, not only to more water-efficient (food) crops, currently considered in this study, but also to grasses or woody biomass. This becomes interesting as soon as second-generation conversion technology becomes available.

Regarding technological change, it was pointed out that the agricultural technology is considered stable over time for the computations in this research. It is assumed that current sowing, irrigation and harvesting practices are still applicable in 2030, whereas in reality developments in the agricultural business are not on halt. For example, increased crop yields can be realized by applying more nutrients or using more advanced harvesting machines. OECD countries already achieve larger yields by applying these methods, but developing nations could follow if returns on energy crops are high enough. The effect of such developments on the WF should therefore also get some attention.

Another interesting development that could be investigated is trade in biomass or biofuels. For this research it was assumed that all biofuels consumed in a nation are produced domestically. However, there are indications of increasing trade in biofuels and feedstock. Japan, for example, has limited possibilities for growing its own biomass for biofuels and has therefore recently signed an import pact with Brazil (IEA, 2004). This means that (extra) water is used in Brazil to produce biofuels for Japan, possibly leading to more stress on the Brazilian water system. So trade could have a significant effect on the annual biofuel WF of nations, and it is suggested that this is taken into account in further research.

In addition, the geographic resolution could be made finer. It would be interesting to zoom in even further and compare the locations of energy crop growth to the places where water is found, using GIS software for example. This would allow more precise statements about water scarcity in local water systems and allow better intervention.

Last but not least, the research could be expanded to include more bio-energy carriers and/or transport modes. The consumption of bio-electricity and heat could be included for example. It was already mentioned that more than 85 percent of all biomass is used in solid state for cooking, heating, lighting and co-generation. This undoubtedly has an enormous WF associated with it, but the determination of feedstock (i.e. round wood, wood residues, organic waste, etc.), yields and water use is expected to be far more complex. It is suggested here to investigate this in future research on the topic. Inclusion of other transport modes, such as rail, aviation and shipping, should also be considered. Especially aviation is a climate-intensive form of transport and is currently the fastest growing source of transport greenhouse gas emissions (T&E, 2009). Extensive testing of so-called biojet fuel is already being performed and many activities are currently being undertaken to increase the implementation of alternative jet fuels for aviation (IATA, 2008). These developments will affect future biofuel demand and the WF and thus deserve some attention.

6. Conclusion

Energy scenarios project an absolute increase in biofuel consumption in the future. Based on the scenario dataset used in this research, the share of biodiesel in global biofuel consumption will increase from 15 to 30 percent. Europe and North America continue to play an important role, but towards 2030 Developing Asia catches up and becomes the second largest biodiesel consumer in the world. Individual countries that contribute most to global biodiesel consumption in 2030 are Malaysia, the USA and France. The top-three ethanol consuming regions are North America, Europe and Latin America in 2030. The individual countries that will consume most bio-ethanol are the USA, Brazil and China.

The transition to biofuels requires that more energy crops will be grown. Depending on the location, different crops are chosen. For biodiesel, North America and northern Asia predominantly use soybean. Palm oil is used in the tropical regions of Latin America and southern Asia. Europe, the former USSR and Balkans, and the Pacific region rely on rapeseed. In the dryer regions of the world jatropha is commonly chosen. For ethanol in Latin America, Africa and Asia sugar cane is often used, in Europe and the former USSR mainly sugar beet and wheat, and in North America and the Pacific region maize.

The production of these crops involves large fresh water demands. Crops use precipitation stored in the soil (green water) and irrigation water (blue water), quantified by their evapotranspiration. Depending on the location and growing conditions, the crop water requirements and yields vary significantly, resulting in different biofuel water footprints (WF) per country.

Overall, the transition to biofuels will lead to a larger WF for the global transport sector. It is expected that the global annual biofuel WF will increase more than tenfold, from about 90 km^3/yr in 2005 to 970 km^3/yr in 2030. The USA, China and Brazil contribute most, together consuming approximately 54 percent of the global biofuel WF in 2030. The blue WF of biofuels is expected to represent 48 percent of the total biofuel WF in 2030. In 2005 its share amounted to 45 percent. The share of the blue WF of biofuels in total blue water demand will be 9 percent in 2030, compared to 47 percent by agriculture, 24 percent by households and 20 percent by industry.

The research also provides a first exploration of potential blue water scarcity in each country resulting from overconsumption of internal renewable fresh water resources. In the United Arab Emirates and Malta water scarcity will almost entirely be caused by the biofuel WF in 2030. In Cyprus, Portugal and Italy over half of the blue water withdrawals will be for biofuels, and in South Africa, Greece, Denmark more than a third. This could indicate that it is unlikely that these countries will produce their own biofuels, as was assumed in this study. Other countries in which the blue biofuel WF will contribute to water scarcity are: Hungary, France, Poland, Bulgaria, the UK, Germany, Spain, the USA, Czech Republic, Slovak Republic, the Netherlands, Belgium, Romania, Lithuania, China, Turkey, Pakistan, India, and Kenya (in order of magnitude). On a global level, the blue biofuel WF is expected to grow to 5.5 percent of the total available blue water for humans in 2030, thus causing extra pressure on our fresh water resources.

Hence, biofuel scenarios should not only be analysed in the context of land availability, food production, biodiversity and the carbon dioxide balance, they also need to be looked at in a water perspective. This study shows the repercussion of extensive biofuel consumption on our fresh water resources. It advocates that countries should consider the water factor thoroughly when investigating the extent to which biofuels can satisfy the future energy demand in the transport sector. Energy transitions will only improve our standards of living and productivity if all impacts are taken into account.

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Appendix 1: Glossary

Biodiesel – Biodiesel is a liquid biofuel made from the transesterification (a chemical process which removes glycerin from oil) of vegetable oils. It can be used to replace normal diesel in motorised vehicles for example.

Bio-electricity and heat – This is electricity and heat produced by combustion of solid biomass. Wood (e.g. eucalyptus, pine and poplar) from productive plantations or organic waste is often used in co-generation.

Bio-energy – Bio-energy is the collective name for all energy from energy carriers that are directly or indirectly obtained from organic material (i.e. biomass). Biomass can be converted to energy in several ways: thermo-chemical, biological, physical or chemical.

Bio-ethanol – Bio-ethanol is a liquid biofuel obtained by fermentation of the sugar and starch part of crops (first generation), or by enzyme saccarification (and fermentation) of the cellulosic crop parts (second generation). The latter process is not yet commercially viable today. Bio-ethanol can be used to (partially) replace gasoline in motorised vehicles.

Blue water – Fresh surface and groundwater, i.e. the water in freshwater lakes, rivers and aquifers.

Blue water availability – Runoff (through groundwater and rivers) minus environmental flow requirements. Blue water availability typically varies within the year and from year to year as well.

Blue water footprint – The volume of surface and groundwater consumed as a result of the production of a good or service. Consumption refers to the volume of freshwater used and then evaporated or incorporated into a product. It also includes water abstracted from surface or groundwater in a catchment and returned to another catchment or the sea. It is the amount of water abstracted from ground- or surface water that does not return to the catchment from which it was withdrawn.

Blue water scarcity – The ratio of blue water footprint to blue water availability. Blue water scarcity varies within the year and from year to year.

Crop water requirement – The total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield.

Crop yield – Weight of harvested crop per unit of harvested area.

Energy carrier – An energy carrier is a substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes (ISO 13600). Oil, coal, gas, uranium, but also dammed or flowing water, sunlight and wind are energy carriers. They contain energy in different forms, which can be converted into a usable energy form if required (ENS, 2008). Primary energy carriers are energy carriers directly derived from a natural source without any conversion (e.g. biomass), while secondary energy carriers (e.g. biofuels, bio-electricity) are the product of a conversion process (Gerbens-Leenes et al., 2008).

Energy crop – An energy crop is a crop that is specially grown for energy purposes. The most important product worldwide is wood (for heat and electricity), but crops are also grown for liquid biofuels (ethanol and biodiesel). Examples of the latter are: sugar cane, sugar beet, maize, potato, wheat, rapeseed and soybean (FAO, 2008e).

Energy scenario – Scenarios are images of alternative futures, they are neither predictions nor forecasts. A scenario is an outline or model of an expected or supposed sequence of events (transition), it is a plausible description of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces (e.g. GDP, rate of technology changes, prices) (IPCC, 1996). Energy scenarios provide a framework for exploring future energy perspectives

Environmental flow requirements (EFR) – The quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.

Evapotranspiration – Evaporation from the soil and soil surface where crops are grown, including the transpiration of water that actually passes crops.

Green water – The precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. Eventually, this part of precipitation evaporates or transpires through plants. Green water can be made productive for crop growth (but not all green water can be taken up by crops, because there will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth).

Green water availability – The evapotranspiration of rainwater from land minus evapotranspiration from land reserved for natural vegetation and minus evapotranspiration from land that cannot be made productive.

Green water footprint – Volume of rainwater consumed during the production process. This is particularly relevant for agricultural and forestry products (products based on crops or wood), where it refers to the total rainwater evapotranspiration (from fields and plantations) plus the water incorporated into the harvested crop or wood.

Grey water footprint – The grey water footprint of a product is an indicator of freshwater pollution that can be associated with the production of a product over its full supply chain. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards. It is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards.

Internal renewable water resources (IRWR) – Long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation. Double counting of surface water and groundwater resources is avoided by deducting the overlap from the sum of the surface water and groundwater resources.

Water footprint (WF) – The water footprint is an indicator of freshwater use that looks at both direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business. Water use is measured in terms of water volumes consumed (evaporated) and/or polluted per unit of time. A water footprint can be calculated for a particular product, for any well-defined group of consumers (e.g. an individual, family, village, city, province, state or nation) or producers (e.g. a public organization, private enterprise or economic sector). The water footprint is a geographically explicit indicator, not only showing volumes of water use and pollution, but also the locations.

Water footprint of a product – The water footprint of a product (a commodity, good or service) is the total volume of freshwater used to produce the product, summed over the various steps of the production chain. The water footprint of a product refers not only to the total volume of water used; it also refers to where and when the water is used.

Appendix 2: Regions and countries

OECD	**Transition Economies**	**Developing Countries**		
North America	**Former USSR and Balkans**	**Developing Asia**	**Africa**	**Latin America**
United States of America	*Albenia*	*Afghanistan*	*Algeria*	*Antigua and Barbuda*
Canada	*Armenia*	*Bangladesh*	*Angola*	*Argentina*
Mexico	*Azerbaijan*	*Bhutan*	*Benin*	*Bahamas*
Europe	*Belarus*	*Brunai*	*Botswana*	*Barbados*
Austria	*Bosnia-Herzegovina*	*Cambodia*	*Burkina Faso*	*Belize*
Belgium	*Bulgaria*	*China*	*Burundi*	*Bermuda*
Czech Republic	*Croatia*	*Chinese*	*Cameroon*	*Bolivia*
Denmark	*Estonia*	*Taipei*	*Cape Verde*	*Brazil*
Finland	*Serbia-Montenegro*	*Fiji*	*Central African Republic*	*Chile*
France	*former Yugoslav Republic of Macedonia*	*French Polynesia*	*Chad*	*Colombia*
Germany	*Georgia*	*India*	*Comoros*	*Costa rica*
Greece	*Kazakhstan*	*Indonesia*	*Congo*	*Cuba*
Hungary	*Kyrgyzstan*	*Kiribati*	*Demographic Republic of Congo*	*Dominica*
Iceland	*Latvia*	*Democratic People's Republic of Korea*	*Cote d'Ivor*	*Dominican Republic*
Ireland	*Lithuania*	*Laos*	*Djibouti*	*Ecuador*
Italy	*Moldova*	*Macau*	*Egypt*	*El Salvador*
Luxembourg	*Romania*	*Malaysia*	*Equatorial Guinea*	*French Guiana*
Netherlands	*Russia*	*Maldives*	*Eritrea*	*Grenada*
Norway	*Slovenia*	*Mongolia*	*Ethiopia*	*Guadaloupe*
Poland	*Taijkistan*	*Myanmar*	*Gabon*	*Guatemala*
Portugal	*Turkmenistan*	*Nepal*	*Gambia*	*Guyana*
Slovak Republic	*Ukraine*	*New Caledonia*	*Ghana*	*Haiti*
Spain	*Uzbekistan*	*Pakistan*	*Guinea*	*Honduras*
Switzerland	and also for statistical reasons:	*Papua New Guinea*	*Guinea-Bissau*	*Jamaica*
Sweden	*Cyprus*	*Philippines*	*Kenya*	*Martinique*
Turkey	*Gibraltar*	*Samoa*	*Lesotho*	*Netherlands Antilles*
United Kingdom	*Malta*	*Singapore*	*Liberia*	*Nicaragua*
Pacific		*Solomon Islands*	*Libya*	*Panama*
Japan		*Sri Lanka*	*Madagascar*	*Paruguay*
Korea, Republic		*Thailand*	*Malawi*	*Peru*
New Zealand		*Tonga*	*Mali*	*St. Kitts and Nevis*
Australia		*Vietnam*	*Mauritania*	*Saint Lucia*
		Vanuatu	*Mauritius*	*St. Vincent and Grenadines*
		Middle East	*Morocco*	*Surinam*
		Bahrain	*Mozambique*	*Trinidad and Tobago*
		Iran	*Namibia*	*Uruguay*
		Iraq	*Niger*	*Venezuela*
		Israel	*Nigeria*	
		Jordan	*Reunion*	
		Lebanon	*Rwanda*	
		Kuwait	*Sao Tome and Principe*	
		Oman	*Senegal*	
		Qatar	*Sychelles*	
		Saudi Arabia	*Sierra Leone*	
		Syria	*Somalia*	
		United Arab Emirates	*South Africa*	
		Yemen	*Sudan*	
			Swaziland	
			United Republic of Tanzania	
			Togo	
			Tunisia	
			Uganda	
			Zambia	
			Zimbabwe	

Appendix 3: Global energy scenarios

i. International Energy Agency – World Energy Outlook

The International Energy Agency has developed two scenarios in which the expected procession of technological, economical and sociological change is different (IEA, 2006). The first scenario is called the Reference Scenario which assumes that policy plans of 2006 will be carried out and that the energy supply and end-use technology will slowly become more efficient. The world population grows steadily with a rate of 1 percent per year and their GDP with 3.3 percent per year. Per capita income grows fastest in developing countries. The price of fossil fuels will be significantly higher in 2030. The Reference Scenario is used as a business-as-usual baseline. The second scenario is the Alternative Policy Scenario which considers the development of the energy system if governments implement policy plans concerning energy security and carbon dioxide emissions. These plans specifically aim at improving the efficiency of the energy supply and the reduction of dependency on fossil fuels. They lead to about 10 percent less energy use and a significant role for biofuels in road transport, and hence help mitigate the harmful effects on the environment. Table 5 shows how policy measures for biofuels are implemented in the Alternative Policy Scenario. A general overview of the contribution of all energy carriers in both energy scenarios is found in Table 6.

Table 5: Examples of biofuel policy measures in the Alternative Policy Scenario (source: IEA, 2006).

Country	Policy/measure	Implementation in the Alternative Policy Scenario
USA	EPACT 2005 requires ethanol use to increase to 7.5 billion gallons in 2012, and remain at that level from 2013 onwards.	Target met and strengthened
Japan	A target of biofuel use in the transport sector of 500 000 kilolitres of oil equivalent in 2010.	Target met and prolonged
EU	To boost the percentage of biofuels to 5.75% of fuels sold by 2010	Target met and strengthened
China	National standard for ethanol fuel usage. Pilot programmed are installed in 9 trial provinces.	Ethanol use increased
India	To promote biofuels through fiscal incentives, plus design and development efforts.	Increased use of biofuels

Table 6: Future energy sector according to IEA, 2006

	Contribution to World Primary Energy Demand					
Source	Today (2008) [EJ] *	Today (2008) [%]	Reference Scenario (2030) [EJ]	Reference Scenario (2030) [%]	Alternative Policy Scenario (2030) [EJ]	Alternative Policy Scenario (2030) [%]
Fossil fuels	412	*80,8%*	581	*81,2%*	496	*76,8%*
Nuclear energy	31	*6,2%*	36	*5,0%*	45	*6,9%*
Biomass (incl. waste)	52	*10,2%*	69	*9,6%*	71	*11,1%*
Hydropower	11	*2,2%*	17	*2,4%*	18	*2,7%*
Other renewables (solar, wind, geothermal, wave, tidal)	3	*0,6%*	12	*1,7%*	16	*2,4%*
Total	509	*100,0%*	716	*100,0%*	645	*100,0%*

* based on extrapolation from 2004 demands, using 2004-2015 growth rates stated for the reference scenario

ii. Shell – Energy Scenarios 2050

Shell has developed two scenarios that describe alternative ways the future may develop (Shell, 2008). In the first scenario – called Scramble – policymakers pay little attention to more efficient energy use until supplies are tight. Likewise, greenhouse gas emissions are not seriously addressed until there are major climate shocks. In Scramble growth in coal and biofuels becomes particularly significant. In the second scenario – Blueprints – growing local actions begin to address the challenges of economic development, energy security and environmental pollution. A price is applied to a critical mass of emissions giving a huge stimulus to the development of clean energy technologies, such as carbon dioxide capture and storage, and energy efficiency measures. Initially oil production is raised to maintain lower prices and defer the development of more costly substitutes, but benefits also begin to emerge from accelerated growth in distributed power generation from wind and solar energy.

Table 7: Future energy sector according to Shell, 2008

	Contribution to World Primary Energy Demand					
Source	Today (2008) [EJ] *	Today (2008) [%]	Scramble Scenario (2030) [EJ]	Scramble Scenario (2030) [%]	Blueprints Scenario (2030) [EJ]	Blueprints Scenario (2030) [%]
Fossil fuels	408	*80,9%*	523	*71,4%*	521	*75,2%*
Nuclear energy	30	*6,0%*	36	*4,9%*	34	*4,9%*
Biomass (incl. waste)	47	*9,3%*	92	*12,6%*	59	*8,5%*
Hydropower **	10	*2,0%*	13	*1,8%*	13	*1,9%*
Other renewables (solar, wind, geothermal, wave, tidal)	9	*1,8%*	69	*9,4%*	66	*9,5%*
Total	505	*100,0%*	733	*100,0%*	693	*100,0%*

* based on interpolation between demands in 2000 and in 2010, using a calculated compound annual growth rate
** based on the fraction in the electricity consumption mix (blueprints scenario). Subtracted from 'other renewables'

iii. IIASA / World Energy Council – Global Energy Perspectives

The World Energy Council (WEC, 2007) has developed three cases, each containing one or more scenarios that share similar driving force characteristics:

- A: High-growth future of vigorous economic development and rapid technological improvements (3 scenarios):
  - A1: High growth; Ample oil and gas, leads to dominance of these sources to the end of the 21st century.
  - A2: High growth; Return to coal, due to scarce oil and gas resources.
  - A3: High growth; Fossil phase-out, due to rapid technological change in nuclear and renewable energy technologies.
- B: Middle course; Intermediate economic growth and more modest technological improvements :
  - B: Middle Course (reference baseline)
- C: Ecologically driven; Incorporates challenging environmental and energy taxes to simultaneously protect the environment and transfer wealth from industrialized to developing countries to enhance economic equity. (2 scenarios):
  - C1: new renewables and a phase-out of nuclear energy (proves a transient technology).
  - C2: with renewables and new nuclear (new generation of nuclear reactors is developed that is inherently safe and small scale).

Table 8: Future energy sector according to WEC, 2007

	Contribution to World Primary Energy Production													
Source	Today (2008) [EJ] *	Today (2008) [%]	A1 Scenario (2030) [EJ]	A1 Scenario (2030) [%]	A2 Scenario (2030) [EJ]	A2 Scenario (2030) [%]	A3 Scenario (2030) [EJ]	A3 Scenario (2030) [%]	B Scenario (2030) [EJ]	B Scenario (2030) [%]	C1 Scenario (2030) [EJ]	C1 Scenario (2030) [%]	C2 Scenario (2030) [EJ]	C2 Scenario (2030) [%]
Fossil fuels	373	*77,5%*	588	*75,4%*	612	*78,4%*	523	*67,0%*	484	*73,6%*	365	*69,8%*	356	*68,1%*
Nuclear energy	27	*5,7%*	61	*7,8%*	29	*3,7%*	70,47	*9,0%*	58	*8,8%*	31,05	*5,9%*	49,2	*9,4%*
Biomass (incl. waste)	52	*10,8%*	57	*7,3%*	77	*9,9%*	102	*13,1%*	59	*8,9%*	65	*12,5%*	62	*11,9%*
Hydropower	24	*5,0%*	36	*4,6%*	34	*4,3%*	40	*5,1%*	32	*4,8%*	35,43	*6,8%*	33,64	*6,4%*
Other renewables (solar, wind, geothermal, wave, tidal)	5	*1,0%*	38	*4,9%*	29	*3,7%*	45	*5,7%*	25	*3,8%*	26	*5,0%*	22	*4,2%*
Total	481	*100,0%*	780	*100,0%*	780	*100,0%*	780	*100,0%*	659	*100,0%*	523	*100,0%*	523	*100,0%*

* based on interpolation between demands in 2000 and in 2010 from scenario B (reference), using a calculated compound annual growth rate

iv. IPCC – SRES scenarios

The Intergovernmental Panel on Climate Change has created four storylines, which combine two sets of divergent tendencies: one set varying between strong economic values and strong environmental values, the other set between increasing globalization and increasing regionalization (IPCC, 2000). The storylines are summarized below:

- A1 storyline and scenario family: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies.
- A2 storyline and scenario family: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.
- B1 storyline and scenario family: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.
- B2 storyline and scenario family: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development.

Although each storyline has its own scenario family, they are best reflected in the, so called, marker Emission Scenarios (A1 AIM, A2 ASF, B1 IMAGE, B2 MESSAGE respectively) (IPCC, 2000).

Table 9: Future energy sector according to IPCC, 2008c

	Contribution to World Primary Energy Demand									
Source	Today (2008) [EJ] *	Today (2008) [%]	A1 Marker Scenario (2030) [EJ]	A1 Marker Scenario (2030) [%]	A2 Marker Scenario (2030) [EJ]	A2 Marker Scenario (2030) [%]	B1 Marker Scenario (2030) [EJ]	B1 Marker Scenario (2030) [%]	B2 Marker Scenario (2030) [EJ]	B2 Marker Scenario (2030) [%]
Fossil fuels	408	*85,7%*	716	*80,1%*	630	*87,4%*	546	*80,2%*	530	*79,3%*
Nuclear energy	14	*3,0%*	53	*5,9%*	32	*4,4%*	20	*2,9%*	23	*3,4%*
Biomass (incl. waste)	24	*5,1%*	85	*9,5%*	32	*4,4%*	54	*7,9%*	61	*9,1%*
Hydropower	24	*5,0%*	29	*3,3%*	26	*3,6%*	34	*5,1%*	23	*3,5%*
Other renewables (solar, wind, geothermal, wave, tidal) **	6	*1,2%*	11	*1,2%*	1	*0,2%*	27	*3,9%*	31	*4,6%*
Total	476	*100,0%*	894	*100,0%*	721	*100,0%*	681	*100,0%*	668	*100,0%*

* based on interpolation between the average demands in 2000 and in 2010 in all marker scenarios, using a calculated compound annual growth rate
** hydropower (electricity) share subtracted
Notes: - For the share of hydropower today, the 2005 value from IPCC AR4 wg chapter 4 (p.264) was used as closest estimate.
- The B1 nuclear energy value was obtained from B1 Message (Globally Harmonized Scenario), as it was not included in the marker.

v. Greenpeace – Global Energy Outlook

Two different scenarios are used here to characterize the wide range of possible paths for the future energy supply system: a Reference Scenario, reflecting a continuation of current trends and policies, and the Energy [R]evolution Scenario, which is designed to achieve a set of dedicated environmental policy targets. Reduction of carbon dioxide emissions and the phase-out of nuclear power are the main focus points in the latter. To achieve this, investments are made in electricity and heat generation from renewable sources and the production of biofuels for transport (Greenpeace, 2008).

Table 10: Future energy sector according to Greenpeace, 2008

	Contribution to primary energy demand					
Source	Today (2008) [EJ] *	Today (2008) [%]	Reference scenario (2030) [EJ]	Reference scenario (2030) [%]	[R]evolution scenario (2030) [EJ]	[R]evolution scenario (2030) [%]
Fossil fuels	413	*81,2%*	591	*82,0%*	355	*67,6%*
Nuclear energy	31	*6,0%*	35	*4,8%*	7	*1,4%*
Biomass (incl. waste)	51	*9,9%*	66	*9,1%*	83	*15,8%*
Hydropower	11	*2,3%*	17	*2,4%*	16	*3,0%*
Other renewables (solar, wind, geothermal, wave, tidal)	3	*0,6%*	12	*1,7%*	64	*12,2%*
Total	508	*100,0%*	721	*100,0%*	526	*100,0%*

* based on interpolation between demands in 2005 and 2010 (reference scenario), using a calculated compound annual growth rate

vi. European Renewable Energy Council (EREC) – Renewable Energy Scenarios to 2040

The EREC has developed two scenarios that specifically address the development of renewable energy on a global level:

- The Advanced International Policies Scenario (AIP), which assumes: ambitious growth rates for renewable energy sources (RES), increased promotion of renewables by regions already active in RES and other regions following their example, higher prices for conventional energy supply, growing support for electrification of the less and least developed regions by renewables, additional measures on the international level for climate protection, and strengthened international cooperation on environmental protection and international equity.
- The dynamic current policies scenario (DCP), which is based on less international cooperation than in the AIP scenario, but expects ambitious policy measures on national level at least in the industrialized part of the world. It is assumed that the commitment to renewables development in the very proactive countries continues to strengthen and will be adopted also by others at least in the industrialized part of the world as national policies. In the least developed countries renewables will be a competitive alternative to conventional sources in the near future, even without special promotion.

Table 11: Future renewable energy sector according to EREC, 2007

	Contribution to primary energy demand					
Source	Today (2008) [EJ] *	Today (2008) [%]	Advanced International Policy scenario (2030) [EJ]	Advanced International Policy scenario (2030) [%]	Dynamic Current Policies scenario (2030) [EJ]	Dynamic Current Policies scenario (2030) [%]
Biomass (incl. waste)	51,94	*11,5%*	104,0	*20,1%*	93,0	*14,3%*
Hydropower	10,00	*2,2%*	14,3	*2,8%*	12,4	*1,9%*
Other renewables (solar, wind, geothermal, wave, tidal, SHP)	4,69	*1,0%*	61,3	*11,9%*	37,6	*5,8%*
Total RES	66,63	*14,8%*	179,6	*34,7%*	143,0	*22,0%*
World primary energy consumption	451,15	*100,0%*	517,2	*100,0%*	650,9	*100,0%*

* based on extrapolation between years 2001 and 2010 in the DCP scenario using given growth rates

On a European level the European Commission has published scenarios with the PRIMES model (Capros et al, 2008). All policy scenarios involve meeting the overall Greenhouse Gas (GHG) emission reduction target, the Renewable Energy Sources (RES) ratio and the biofuels targets. The scenarios are defined as follows:

- Baseline scenario (BL): continuation of current trends and policies; includes no new policy initiatives to change underlying energy trends, besides policies in place or in the process of being implemented in the Member-States by the end of 2006.
- EC Proposal without RES trading (RSAT): scenario corresponding to the effort sharing scheme proposed by the EC which meets the targets (ETS (sectoral CO_2 cap), Non-ETS and RES) separately in the EU and does not allow exchange of Guarantees of Origin (GOs) among the Member-States (they meet their RES targets domestically)
- EC Proposal with CDM without RES trading (RSAT-CDM): same as scenario RSAT, but part of emission reduction can be justified by emission reduction credits taken from the Clean Development Mechanisms (CDM) lowering the carbon value to a uniform price of 30 €/tCO2.
- EC Proposal with RES trading (NSAT): same as scenario RSAT, but exchange of GOs among the Member-States is allowed, resulting in RES developing differently from RES obligations by Member-State but overall RES developing on a cost effective basis.
- EC Proposal with CDM and with RES trading (NSAT-CDM): same as NSAT, but with possibility to take emission credits from CDM lowering the carbon value to a uniform price of 30 €/tCO2.
- Cost-Efficiency Scenario (CES): meets the targets at least energy system cost by equalizing marginal costs of GHG emission reduction and marginal costs of RES deployment across all sectors and all Member-States.
- Cost-Efficiency Scenario with CDM (CES-CDM): same as scenario CES, but with possibility to take emission credits from CDM at a price of 30 €/tCO2.
- High Oil & Gas prices Baseline (HOG-BL): Alternative business-as-usual projection assuming high import prices for oil and gas,
- Cost Efficiency scenario with high prices (HOG-CES): same as scenario CES, but built on the basis of the high oil and gas prices Baseline scenario.

Appendix 4: Overview of biofuel consumption in road transport

	Biofuels for transport							
	Bio-ethanol				**Bio-diesel**			
	consumption 2005 (PJ/yr)	*source*	consumption 2030 (PJ/yr)	*source*	consumption 2005 (PJ/yr)	*source*	consumption 2030 (PJ/yr)	*source*
OECD								
North America	**367.27**		**1643.95**		**11.45**		**269.42**	
United States	359.42	a	1526.72	r	11.45	a	269.42	r
Canada	7.86	a	117.23	r	0.00	a	0.00	r
Mexico	0.00	a	0.00	t	0.00	a	0.00	t
Europe	**25.72**		**1098.72**		**109.7**		**853.42**	
Austria	0.00	a	19.01	s	1.97	a	18.39	s
Belgium	0.00	a	23.02	s	0.00	a	16.44	s
Czech Republic	0.00	a	19.40	s	0.11	a	24.20	s
Denmark	0.00	a	8.88	s	0.00	a	12.77	s
Finland	0.00	a	8.83	s	0.00	a	7.22	s
France	3.25	a	170.92	s	13.76	a	184.21	s
Germany	7.68	a	226.91	s	75.45	a	110.33	s
Greece	0.00	a	12.22	s	0.00	a	15.66	s
Hungary	0.12	a	13.47	s	0.00	a	9.75	s
Iceland	0.00	a	0.00	t	0.00	a	0.00	t
Ireland	0.00	a	8.25	s	0.04	a	11.11	s
Italy	0.00	a	213.98	s	7.56	a	121.72	s
Luxembourg	0.00	a	4.75	s	0.04	a	9.88	s
Netherlands	0.00	a	29.59	s	0.00	a	27.69	s
Norway	0.00	a	0.00	t	0.00	i	0.00	t
Poland	1.57	a	46.58	s	0.57	a	55.90	s
Portugal	0.00	a	13.42	s	0.01	i	16.73	s
Slovak Republic	0.00	a	5.75	s	0.42	a	5.35	s
Spain	5.23	a	94.91	s	6.12	a	93.02	s
Switzerland	0.03	a	0.00	t	0.26	a	0.00	t
Sweden	5.88	a	21.36	s	0.30	a	15.81	s
Turkey	0.00	a	0.94	o	2.03	n	10.75	o
United Kingdom	1.98	a	156.54	s	1.10	a	86.50	s
Pacific	**0.50**		**121.42**		**0.45**		**0.00**	
Japan	0.00	a	83.74	r	0.00	a	0.00	r
Korea (Rep.)	0.00	a	0.00	t	0.45	a	0.00	t
New Zealand	0.00	a	0.00	t	0.00	a	0.00	t
Australia	0.50	a	37.68	t	0.00	a	0.00	t
Transition Economies	**0.03**		**55.35**		**0.23**		**66.48**	
Former USSR and Balkans								
Albania	0.00	a	0.00	t	0.00	a	0.00	t
Armenia	0.00	a	0.00	t	0.00	a	0.00	t
Azerbaijan	0.00	a	0.00	t	0.00	a	0.00	t
Belarus	0.00	a	0.00	t	0.00	a	0.00	t
Bosnia and Herzegovina	0.00	a	0.00	t	0.00	a	0.00	t
Bulgaria	0.00	a	5.05	s	0.00	a	9.45	s
Croatia	0.00	a	0.00	t	0.00	a	0.00	t
Estonia	0.00	a	1.64	s	0.00	a	2.69	s
Serbia-Montenegro	0.00	a	20.08	o	0.00	a	4.06	o
former Yugoslav Republic of Macedonia	0.00	a	0.00	t	0.00	a	0.00	t
Georgia	0.00	a	0.00	t	0.00	a	0.00	t
Kazakhstan	0.00	a	0.00	t	0.00	a	0.00	t
Kyrgyzstan	0.00	a	0.00	t	0.00	a	0.00	t
Latvia	0.00	a	2.97	s	0.11	a	4.45	s
Lithuania	0.03	a	4.48	s	0.11	a	3.48	s
Republic of Moldova	0.00	a	0.00	t	0.00	a	0.00	t
Romania	0.00	a	14.68	s	0.00	a	18.26	s
Russia	0.00	a	0.00	r	0.00	a	16.75	r
Slovenia	0.00	a	4.36	s	0.00	a	5.36	s
Tajikistan	0.00	a	0.00	t	0.00	a	0.00	t
Turkmenistan	0.00	a	0.00	t	0.00	a	0.00	t
Ukraine	0.00	a	0.00	t	0.00	a	0.00	t
Uzbekistan	0.00	a	0.00	t	0.00	a	0.00	t
and also for statistical reasons:								
Cyprus	0.00	a	1.24	s	0.00	a	1.64	s
Gibraltar	0.00	a	0.00	t	0.00	a	0.00	t
Malta	0.00	a	0.85	s	0.00	a	0.34	s
Developing countries								
Developing Asia	**29.36**		**743.39**		**7.54**		**629.88**	
Afghanistan	*0*		0.00	t	*0*		0.00	t
Bangladesh	0.00	a	0.00	t	0.00	a	0.00	t

	Bio-ethanol				Bio-diesel			
	consumption 2005 (PJ/yr)	*source*	consumption 2030 (PJ/yr)	*source*	consumption 2005 (PJ/yr)	*source*	consumption 2030 (PJ/yr)	*source*
Bhutan	*0*		0.00	t	*0*		0.00	t
Brunei Darussalam	0.00	a	0.00	t	0.00	a	0.00	t
Cambodia	0.00	a	0.00	t	0.00	a	0.00	t
People's Republic of China	17.83	b	362.86	r	4.10	b	181.43	r
Chinese Taipei	0.00	a	0.00	t	0.00	a	0.00	t
Fiji	*0*		0.00	t	*0*		0.00	t
French Polynesia	*0*		0.00	t	*0*		0.00	t
India	5.02	a	188.41	r	0.00	a	0.00	r
Indonesia	0.00	a	12.52	r	0.08	j	83.78	r
Kiribati	*0*		0.00	t	*0*		0.00	t
DPR of Korea	0.00	a	0.00	t	0.00	a	0.00	t
People's Democratic Republic of Lao	0.00	a	0.00	t	0.00	a	0.00	t
Macau	*0*		0.00	t	*0*		0.00	t
Malaysia	0.00	a	0.00	t	3.25	k	352.80	t
Maldives	*0*		0.00	t	*0*		0.00	t
Mongolia	0.00	a	0.00	t	0.00	a	0.00	t
Myanmar	0.00	a	0.00	t	0.00	a	0.00	t
Nepal	0.00	a	0.00	t	0.00	a	0.00	t
New Caledonia	*0*		0.00	t	*0*		0.00	t
Pakistan	4.89	c	134.81	t	0.00	a	0.00	t
Papua New Guinea	*0*		0.00	t	*0*		0.00	t
Philippines	0.06	a	1.63	t	0.07	l	7.76	t
Samoa	*0.00*		0.00	t	*0*		0.00	t
Singapore	0.00	a	0.00	t	0.00	a	0.00	t
Solomon Islands	*0*		0.00	t	*0*		0.00	t
Sri Lanka	0.00	a	0.00	t	0.00	a	0.00	t
Thailand	1.57	a	43.17	t	0.04	a	4.11	t
Tonga	*0*		0.00	t	*0*		0.00	t
Vietnam	0.00	a	0.00	t	0.00	a	0.00	t
Vanuatu	*0*		0.00	t	*0*		0.00	t
Middle East	**0**		**0.00**		**0.00**		**25.12**	
Bahrain	0.00	a	0.00	t	0.00	a	0.00	t
Islamic Republic of Iran	0.00	a	0.00	t	0.00	a	0.00	t
Iraq	0.00	a	0.00	t	0.00	a	0.00	t
Israel	0.00	a	0.00	t	0.00	a	0.00	t
Jordan	0.00	a	0.00	t	0.00	a	0.00	t
Lebanon	0.00	a	0.00	t	0.00	a	0.00	t
Kuwait	0.00	a	0.00	t	0.00	a	0.00	t
Oman	0.00	a	0.00	t	0.00	a	0.00	t
Qatar	0.00	a	0.00	t	0.00	a	0.00	t
Saudi Arabia	0.00	a	0.00	t	0.00	a	0.00	t
Syria	0.00	a	0.00	t	0.00	a	0.00	t
United Arab Emirates	0.00	a	0.00	t	0.00	a	25.12	p
Yemen	0.00	a	0.00	t	0.00	a	0.00	t
Africa	**10.23**		**133.98**		**0.00**		**12.56**	
Algeria	0.00	a	0.00	t	0.00	a	0.00	t
Angola	0.00	a	0.00	t	0.00	a	0.00	t
Benin	0.00	a	0.00	t	0.00	a	0.00	t
Botswana	0.00	a	0.00	t	0.00	a	0.00	t
Burkina Faso	*0*		0.00	t	*0*		0.00	t
Burundi	*0*		0.00	t	*0*		0.00	t
Cameroon	0.00	a	0.00	t	0.00	a	0.00	t
Cape Verde	*0*		0.00	t	*0*		0.00	t
Central African Republic	*0*		0.00	t	*0*		0.00	t
Chad	*0*		0.00	t	*0*		0.00	t
Comoros	*0*		0.00	t	*0*		0.00	t
Congo	0.00	a	0.00	t	0.00	a	0.00	t
Democratic Republic of Congo	0.00	a	0.00	t	0.00	a	0.00	t
Cote d'Ivoire	0.00	a	0.00	t	0.00	a	0.00	t
Djibouti	*0.00*		0.00	t	*0*		0.00	t
Egypt	0.00	a	0.00	t	0.00	a	0.00	t
Equatorial Guinea	*0*		0.00	t	*0*		0.00	t
Eritrea	0.00	a	0.00	t	0.00	a	0.00	t
Ethiopia	0.00	a	0.00	t	0.00	a	0.00	t
Gabon	0.00	a	0.00	t	0.00	a	0.00	t
Gambia	*0*		0.00	t	*0*		0.00	t
Ghana	0.14	d	1.84	t	0.00	a	0.00	t
Guinea	*0*		0.00	t	*0*		0.00	t
Guinea-Bissau	*0*		0.00	t	*0*		0.00	t
Kenya	0.07	d	0.92	t	0.00	a	0.00	t
Lesotho	*0*		0.00	t	*0*		0.00	t

	Bio-ethanol				**Bio-diesel**			
	consumption 2005 (PJ/yr)	*source*	consumption 2030 (PJ/yr)	*source*	consumption 2005 (PJ/yr)	*source*	consumption 2030 (PJ/yr)	*source*
Liberia	*0*		0.00	t	*0*		0.00	t
Libya	0.00	a	0.00	t	0.00	a	0.00	t
Madagascar	*0*		0.00	t	*0*		0.00	t
Malawi	0.14	d	1.84	t	*0*		0.00	t
Mali	*0*		0.00	t	*0*		0.00	t
Mauritania	*0*		0.00	t	*0*		0.00	t
Mauritius	*0*		0.00	t	*0*		0.00	t
Morocco	0.00	a	0.00	t	0.00	a	0.00	t
Mozambique	0.00	a	0.00	t	0.00	a	0.00	t
Namibia	0.00	a	0.00	t	0.00	a	0.00	t
Niger	*0*		0.00	t	*0*		0.00	t
Nigeria	0.00	a	0.00	t	0.00	a	0.00	t
Reunion	*0*		0.00	t	*0*		0.00	t
Rwanda	*0*		0.00	t	*0*		0.00	t
Sao Tome and Principe	*0*		0.00	t	*0*		0.00	t
Senegal	0.00	a	0.00	t	0.00	a	0.00	t
Sychelles	*0*		0.00	t	*0*		0.00	t
Sierra Leone	*0*		0.00	t	*0*		0.00	t
Somalia	*0*		0.00	t	*0*		0.00	t
South Africa	9.73	d	127.54	t	0.00	a	12.56	q
Sudan	0.00	a	0.00	t	0.00	a	0.00	t
Swaziland	*0*		0.00	t	*0*		0.00	t
United Republic of Tanzania	0.00	a	0.00	t	0.00	a	0.00	t
Togo	0.00	a	0.00	t	0.00	a	0.00	t
Tunisia	0.00	a	0.00	t	0.00	a	0.00	t
Uganda	*0*		0.00	t	*0*		0.00	t
Zambia	0.00	a	0.00	t	0.00	a	0.00	t
Zimbabwe	0.14	d	1.84	t	0.00	a	0.00	t
Latin America	**315.26**		**893.25**		**2.31**		**157.63**	
Antigua and Barbuda	*0*		0.00	t	*0*		0.00	t
Argentina	0.00	a	0.00	t	0.71	e	12.23	t
Bahamas	*0*		0.00	t	*0*		0.00	t
Barbados	*0*		0.00	t	*0*		0.00	t
Belize	*0*		0.00	t	*0*		0.00	t
Bermuda	*0*		0.00	t	*0*		0.00	t
Bolivia	0.00	a	0.00	t	0.00	a	0.00	t
Brazil	313.53	a	818.52	r	1.54	m	144.44	r
Chile	0.00	a	0.00	t	0.00	a	0.00	t
Colombia	0.68	a	29.30	t	0.00	a	0.00	t
Costa rica	0.00	a	0.00	t	0.00	a	0.00	t
Cuba	0.00	a	0.00	t	0.00	a	0.00	t
Dominica	*0*		0.00	t	*0*		0.00	t
Dominican Republic	0.00	a	0.00	t	0.00	a	0.00	t
Ecuador	0.00	a	0.00	t	0.00	a	0.00	t
El Salvador	0.00	a	0.00	t	0.00	a	0.00	t
French Guiana	*0*		0.00	t	*0*		0.00	t
Grenada	*0*		0.00	t	*0*		0.00	t
Guadaloupe	*0*		0.00	t	*0*		0.00	t
Guatemala	0.00	a	0.00	t	0.00	a	0.00	t
Guyana	*0*		0.00	t	*0*		0.00	t
Haiti	0.00	a	0.00	t	*0*		0.00	t
Honduras	0.00	a	0.00	t	0.003	f	0.05	t
Jamaica	0.00	a	0.00	t	0.00	a	0.00	t
Martinique	*0*		0.00	t	*0*		0.00	t
Netherlands Antilles	0.00	a	0.00	t	0.00	a	0.00	t
Nicaragua	0.00	a	0.00	t	0.00	a	0.00	t
Panama	0.00	a	0.00	t	0.00	a	0.00	t
Paraguay	1.05	g	45.43	t	0.00	a	0.00	t
Peru	0.00	a	0.00	t	0.00	a	0.00	t
St. Kitts and Nevis	*0*		0.00	t	*0*		0.00	t
Saint Lucia	*0*		0.00	t	*0*		0.00	t
St. Vincent and Grenadines	*0*		0.00	t	*0*		0.00	t
Surinam	*0*		0.00	t	*0*		0.00	t
Trinidad and Tobago	0.00	a	0.00	t	0.00	a	0.00	t
Uruguay	0.00	a	0.00	t	0.05	h	0.92	t
Venezuela	0.00	a	0.00	t	0.00	a	0.00	t
World total (sum of regions)	**748.38**		**4690.06**		**131.70**		**2014.51**	

Source notes:

a IEA Statistics - Biogasoline and biodiesel consumption in the transport sector in 2005
b USDA FAS (2006) - GAIN Report CH6049
c USDA FAS (2008) - GAIN Report PK8033
d Dufey (2006)
e USDA FAS (2008) - GAIN Report AR8027
f USDA FAS (2008) - GAIN Report HO9006
g USDA FAS (2007) - GAIN Report PA7004
h USDA FAS (2007) - GAIN Report UY8004
i Eurostat database (values increased by 10% to obtain HHV)
j USDA FAS (2006) - GAIN Report IN6047
k USDA FAS (2009) - GAIN Report MY9026
l USDA FAS (2009) - GAIN Report RP9019
m USDA FAS (2006) - GAIN Report BR6008
n Kleindorfer, P.R. & Öktem, Ü.G. (2007)
o Biofuels international (2007) *Driving the market forward.* Issue 4, Vol. 1. September 2007
p EmBio (2008) Company website of Emirates Biodiesel LLC. UAE
q USDA FAS (2007) - GAIN Report SF7044
r Alternative Policy Scenario (IEA, 2006)
s EU27 RSAT-CDM without RES trading scenario (Capros et al.,2008)
t remaining 2030 regional consumption, ascribed according to the 2005 consumption share
NB. numbers in italic are unknown and assumed zero

Appendix 5: Feedstock for biofuels

	Bio-ethanol					Bio-diesel				Source notes general:
	wheat	corn	sorghum	sugarbeet	sugarcane	soya	rapeseed	oil palm	jatropha	numbers in italic are assumed based on neighbouring countries
OECD										Source notes for liquid biofuels (per row):
North America	**10%**	**55%**	**2%**	**0%**	**33%**	**33%**	**33%**	**33%**	**0%**	
USA	0%	95%	5%	0%	0%	100%	0%	0%	0%	*based on Dufey (2006)*
Canada	30%	70%	0%	0%	0%	0%	100%	0%	0%	*based on USDA FAS (2006) - GAIN Report Number: CA6029*
Mexico	0%	0%	0%	0%	100%	0%	0%	*100%*	0%	*based on USDA FAS (2007) - GAIN Report Number: MX7042*
Europe	**42%**	**6%**	**0%**	**52%**	**0%**	**9%**	**91%**	**0%**	**0%**	
Austria	60%	13%	0%	27%	0%	0%	*100%*	0%	0%	*based on Konrad (2006)*
Belgium	67%	0%	0%	33%	0%	0%	*100%*	0%	0%	*based on BioWanze (2008)*
Czech Republic	0%	26%	0%	74%	0%	0%	100%	0%	0%	*based on Breyerová (2007) and Dufey (2006)*
Denmark	62%	0%	0%	38%	0%	0%	100%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Finland	0%	0%	0%	100%	0%	0%	100%	0%	0%	*based on Kautola et al. (date unknown)*
France	10%	0%	0%	90%	0%	0%	100%	0%	0%	*based on Dufey (2006)*
Germany	100%	0%	0%	0%	0%	0%	100%	0%	0%	*based on Dufey (2006)*
Greece	0%	0%	0%	100%	0%	100%	0%	0%	0%	*based on USDA FAS (2007) - GAIN Report Number: GR7003*
Hungary	100%	0%	0%	0%	0%	0%	100%	0%	0%	*based on USDA FAS (2006) - GAIN Report Number: HU6005*
Iceland	0%	0%	0%	*100%*	0%	0%	*100%*	0%	0%	*assummed*
Ireland	19%	0%	0%	81%	0%	0%	100%	0%	0%	*based on SEI (2004)*
Italy	100%	0%	0%	0%	0%	0%	100%	0%	0%	*based on Dufey (2006)*
Luxembourg	0%	0%	0%	*100%*	0%	0%	*100%*	0%	0%	*assumed*
Netherlands	50%	0%	0%	50%	0%	0%	100%	0%	0%	*based on NOVEM (2003)*
Norway	100%	0%	0%	0%	0%	0%	100%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Poland	0%	0%	0%	100%	0%	0%	100%	0%	0%	*based on Dufey (2006)*
Portugal	11%	55%	0%	34%	0%	0%	*100%*	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Slovak Rep.	60%	40%	0%	0%	0%	0%	100%	0%	0%	*based on Müllerová & Mikulík (2008)*
Spain	100%	0%	0%	0%	0%	0%	100%	0%	0%	*based on Dufey (2006)*
Switzerland	32%	0%	0%	68%	0%	0%	100%	0%	0%	*based on Biofuels Platform (2009)*
Sweden	100%	0%	0%	0%	0%	0%	100%	0%	0%	*based on Dufey (2006)*
Turkey	0%	0%	0%	100%	0%	100%	0%	0%	0%	*based on İçöz et al. (2008) and Kleindorfer & Öktem (2007)*
UK	0%	0%	0%	100%	0%	0%	100%	0%	0%	*based on Dufey (2006)*
Pacific	**13%**	**47%**	**1%**	**0%**	**40%**	**45%**	**55%**	**0%**	**0%**	
Japan	0%	0%	0%	0%	100%	100%	0%	0%	0%	*based on USDAFAS (2006) - GAIN Report Number: JA6024*
Korea (Rep.)	12%	86%	2%	0%	0%	80%	20%	0%	0%	*based on FAOSTAT (2003) and USDA FAS (2007) - GAIN Report KS7052*
New Zealand	0%	100%	0%	0%	0%	0%	100%	0%	0%	*based on USDA FAS (2007) - GAIN Report Number: NZ7003*
Australia	39%	0%	2%	0%	59%	1%	99%	0%	0%	*based on Dufey (2006) and FAOSTAT (2009)*
Transition Economies										
Former USSR and Balkans	**58%**	**22%**	**0%**	**20%**	**0%**	**29%**	**71%**	**0%**	**0%**	
Albenia	100%	0%	0%	0%	0%	100%	0%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Armenia	93%	6%	0%	1%	0%	0%	*100%*	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Azerbaijan	73%	13%	0%	14%	0%	100%	0%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Belarus	29%	2%	0%	69%	0%	0%	100%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Bosnia-Herzegovina	45%	55%	0%	0%	0%	60%	40%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Bulgaria	83%	17%	0%	0%	0%	0%	100%	0%	0%	*based on USDA FAS (2006) - GAIN Report Number: BU6006*
Croatia	21%	52%	0%	27%	0%	74%	26%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Estonia	100%	0%	0%	0%	0%	0%	100%	0%	0%	*based on BBN (2008) and USDA FAS (2006) - GAIN Report SW6012*
Serbia-Montenegro	30%	70%	0%	0%	0%	98%	2%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
former Yugoslav Rep. of Macedonia	100%	0%	0%	0%	0%	0%	100%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Georgia	100%	0%	0%	0%	0%	100%	0%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Kazakhstan	3%	97%	0%	0%	0%	87%	13%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Kyrgyzstan	0%	100%	0%	0%	0%	12%	82%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Latvia	0%	0%	0%	100%	0%	0	100%	0%	0%	*based on Ministry of Agricul. (2006) and USDA FAS (2006) - GAIN Report SW6012*
Lithuania	100%	0%	0%	0%	0%	0	100%	0%	0%	*based on USDA FAS (2007) - GAIN Report Number: LH7001*
Moldova	0%	100%	0%	0%	0%	0	*100%*	0%	0%	*based on Vassilieva (date unknown)*
Romania	0%	0%	0%	100%	0%	0	100%	0%	0%	*based on ENERO (2005)*
Russia	50%	50%	0%	0%	0%	0	100%	0%	0%	*based on USDA FAS (2007) - GAIN Report Number: RS7044*
Slovenia	0%	0%	0%	100%	0%	0%	100%	0%	0%	*based on NV Consultants (2007) and Reuters Limited (2006)*
Taijkistan	87%	12%	1%	0%	0%	50%	50%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Turkmenistan	90%	1%	0%	9%	0%	0%	*100%*	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Ukraine	0%	0%	0%	*100%*	0%	64%	36%	0%	0%	*based on USDA FAS (2006) - GAIN Report Number: UP6010*
Uzbekistan	97%	3%	0%	0%	0%	0%	100%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
and also for statistical reasons:										
Cyprus	100%	0%	0%	0%	0%	0%	100%	0%	0%	*based on Solsten (1991)*
Gibraltar	*100%*	0%	0%	0%	0%	0%	*100%*	0%	0%	*assumed*
Malta	*100%*	0%	0%	0%	0%	0%	*100%*	0%	0%	*assumed*
Developing countries										
Developing Asia	**9%**	**24%**	**0%**	**0%**	**66%**	**24%**	**10%**	**60%**	**7%**	
Afghanistan	0%	0%	0%	0%	*100%*	*100%*	0%	0%	0%	*assumed*
Bangladesh	0%	100%	0%	0%	0%	0%	100%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Bhutan	0%	0%	0%	0%	*100%*	*100%*	0%	0%	0%	*assumed*
Brunai	100%	0%	0%	0%	0%	0%	0%	100%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Cambodia	0%	48%	0%	0%	52%	35%	0%	65%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
China	0%	90%	0%	0%	10%	90%	0%	0%	10%	*based on Dufey (2006)*
Chinese Taipei	0%	*100%*	0%	0%	0%	*100%*	0%	0%	0%	*assumed*
Fiji	0%	0%	0%	0%	100%	0%	0%	100%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
French Polynesia	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	*assumed*
India	0%	0%	0%	0%	100%	0%	0%	0%	100%	*based on Dufey (2006)*
Indonesia	0%	0%	0%	0%	100%	0%	0%	100%	0%	*based on Dufey (2006)*
Kiribati	0%	0%	0%	0%	*100%*	0%	0%	100%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Democratic People's Rep. of Korea	0%	100%	0%	0%	0%	100%	0%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Laos	0%	32%	0%	0%	68%	100%	0%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Macau	0%	*100%*	0%	0%	0%	*100%*	0%	0%	0%	*assumed*
Malaysia	0%	0%	0%	0%	100%	0%	0%	100%	0%	*based on FAOSTAT (2009) and USDA FAS (2007) - GAIN Report MY7014*
Maldives	0%	0%	0%	0%	*100%*	0%	0%	100%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Mongolia	0%	100%	0%	0%	0%	0%	*100%*	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Myanmar	2%	10%	0%	0%	88%	24%	8%	68%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Nepal	100%	0%	0%	0%	0%	0%	100%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
New Caledonia	100%	0%	0%	0%	0%	0%	0%	100%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Pakistan	0%	0%	0%	0%	100%	0%	0%	100%	0%	*based on Dufey (2006) and USDA FAS (2007) - GAIN Report SF7044*
Papua New Guinea	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	*assumed*
Philippines	0%	0%	0%	0%	100%	0%	0%	100%	0%	*based on Dufey (2006)*
Samoa	0%	0%	0%	0%	100%	0%	0%	100%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Singapore	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	*assumed*
Solomon Islands	0%	0%	0%	0%	*100%*	0%	0%	100%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Sri Lanka	0%	3%	0%	0%	97%	0%	0%	100%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Thailand	0%	0%	0%	0%	100%	10%	0%	90%	0%	*based on Dufey (2006) and USDA FAS (2007) - GAIN Report TH7070*
Tonga	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	*assumed*
Vietnam	0%	0%	0%	0%	100%	0%	0%	0%	100%	*based on USDA FAS (2008) - GAIN Report Number: KS8063*
Vanuatu	0%	100%	0%	0%	0%	0%	0%	100%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Middle East	**58%**	**12%**	**25%**	**3%**	**2%**	**15%**	**0%**	**62%**	**23%**	
Bahrain	*50%*	0%	*50%*	0%	0%	0%	0%	*100%*	0%	*assumed*
Iran	51%	6%	0%	22%	21%	100%	0%	0%	0%	*based on FAOSTAT (2009) - Country Food Balance Sheet 2003*
Iraq	*50%*	0%	*50%*	0%	0%	0%	0%	*100%*	0%	*assumed*

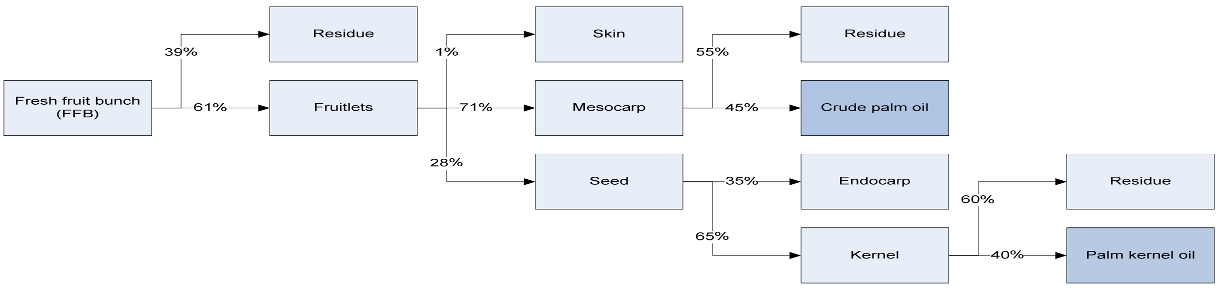
	Bio-ethanol					Bio-diesel				Source notes general:
	wheat	corn	sorghum	sugarbeet	sugarcane	soya	rapeseed	oil palm	jatropha	numbers in italic are assumed based on neighbouring countries
Israel	0%	100%	0%	0%	0%	0%	0%	0%	100%	based on USDA FAS (2007) - GAIN Report Number: IS7017
Jordan	79%	20%	1%	0%	0%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Lebanon	96%	3%	1%	0%	0%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Kuwait	86%	14%	0%	0%	0%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Oman	*50%*	0%	*50%*	0%	0%	0%	0%	*100%*	0%	assumed
Qatar	*50%*	0%	*50%*	0%	0%	0%	0%	*100%*	0%	assumed
Saudi Arabia	90%	1%	9%	0%	0%	0%	0%	0%	*100%*	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Syria	77%	4%	0%	19%	0%	100%	0%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
United Arab Emirates	*50%*	0%	*50%*	0%	0%	0%	0%	0%	*100%*	assumed
Yemen	30%	9%	61%	0%	0%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Africa	**8%**	**28%**	**19%**	**2%**	**44%**	**22%**	**5%**	**63%**	**10%**	
Algeria	100%	0%	0%	0%	0%	0%	100%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Angola	0%	60%	0%	0%	40%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Benin	0%	78%	16%	0%	6%	16%	0%	84%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Botswana	0%	6%	94%	0%	0%	*100%*	0%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Burkina Faso	0%	24%	59%	0%	17%	100%	0%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Burundi	0%	31%	18%	0%	51%	19%	0%	81%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Cameroon	0%	28%	20%	0%	52%	8%	0%	92%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Cape Verde	0%	46%	0%	0%	54%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Central African Rep.	0%	47%	17%	0%	36%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Chad	0%	11%	54%	0%	35%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Comoros	0%	100%	0%	0%	0%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Congo	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Demographic Rep. of Congo	0%	0%	0%	0%	100%	15%	0%	85%	0%	based on USDA FAS (2009) - GAIN Report Number: E49042
Cote d'Ivor	0%	41%	0%	0%	59%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Djibouti	0%	17%	0%	0%	83%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Egypt	0%	100%	0%	0%	0%	*100%*	0%	0%	0%	based on USDA FAS (2005) - GAIN Report Number: EG5013
Equatorial Guinea	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	assumed
Eritrea	4%	6%	90%	0%	0%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Ethiopia	17%	34%	20%	0%	29%	56%	44%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Gabon	0%	12%	0%	0%	88%	76%	0%	24%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Gambia	0%	50%	50%	0%	0%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Ghana	0%	50%	0%	0%	50%	0%	0%	0%	100%	based on Dufey (2006)
Guinea	0%	27%	0%	0%	73%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Guinea-Bissau	0%	56%	31%	0%	13%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Kenya	0%	0%	0%	0%	100%	0%	0%	0%	100%	based on Dufey (2006) and Oddobo (2008)
Lesotho	28%	46%	26%	0%	0%	*100%*	0%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Liberia	0%	0%	0%	0%	100%	14%	0%	86%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Libya	100%	0%	0%	0%	0%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Madagascar	0%	11%	0%	0%	89%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Malawi	0%	0%	0%	0%	100%	0%	0%	0%	100%	based on Dufey (2006)
Mali	0%	27%	48%	0%	25%	0%	0%	0%	100%	based on Oddobo (2008) and FAOSTAT (2009) - Country Food Balance Sheet 2003
Mauritania	0%	8%	92%	0%	0%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Mauritius	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Morocco	53%	1%	0%	36%	10%	50%	50%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Mozambique	0%	64%	16%	0%	20%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Namibia	17%	70%	13%	0%	0%	*100%*	0%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Niger	0%	0%	77%	0%	23%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Nigeria	0%	35%	59%	0%	6%	37%	0%	63%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Reunion	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	assumed
Rwanda	0%	25%	53%	0%	22%	100%	0%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Sao Tome and Principe	0%	100%	0%	0%	0%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Senegal	0%	28%	13%	0%	59%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Sychelles	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	assumed
Sierra Leone	0%	17%	36%	0%	47%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Somalia	0%	*33%*	*33%*	0%	*34%*	0%	0%	*100%*	0%	assumed
South Africa	0%	0%	0%	50%	50%	80%	0%	0%	20%	based on Dufey (2006) and USDA FAS (2007) - GAIN Report SF7044
Sudan	3%	0%	57%	0%	40%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Swaziland	0%	0%	0%	0%	100%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
United Rep. of Tanzania	0%	50%	14%	0%	36%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Togo	0%	74%	26%	0%	0%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Tunisia	100%	0%	0%	0%	0%	0%	100%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Uganda	0%	37%	14%	0%	49%	100%	0%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Zambia	0%	39%	0%	0%	61%	100%	0%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Zimbabwe	0%	0%	0%	0%	100%	0%	0%	0%	100%	based on Dufey (2006)
Latin America	**1%**	**9%**	**1%**	**0%**	**89%**	**17%**	**3%**	**79%**	**1%**	
Antigua and Barbuda	0%	100%	0%	0%	0%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Argentina	0%	0%	0%	0%	100%	100%	0%	0%	0%	based on USDA FAS (2007) - GAIN Report Number: AR7016
Bahamas	0%	100%	0%	0%	0%	0%	0%	*100%*	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Barbados	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Belize	0%	0%	0%	0%	100%	69%	0%	31%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Bermuda	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	assumed
Bolivia	2%	12%	3%	0%	83%	100%	0%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Brazil	0%	0%	0%	0%	100%	90%	0%	0%	10%	based on Dufey (2006) and USDA FAS (2006) - GAIN Report BR6008
Chile	35%	23%	0%	0%	42%	0%	100%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Colombia	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on Dufey (2006)
Costa rica	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Cuba	0%	2%	0%	0%	98%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Dominica	0%	4%	0%	0%	96%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Dominican Rep.	0%	1%	0%	0%	99%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Ecuador	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on Dufey (2006)
El Salvador	0%	12%	3%	0%	85%	4%	0%	96%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
French Guiana	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	assumed
Grenada	0%	4%	0%	0%	96%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Guadaloupe	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	assumed
Guatemala	0%	6%	0%	0%	94%	27%	0%	73%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Guyana	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Haiti	0%	15%	7%	0%	78%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Honduras	0%	9%	0%	0%	91%	0%	0%	86%	14%	based on FAOSTAT (2009) - FBS 2003 & USDA FAS (2009) - GAIN Report HO9006
Jamaica	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Martinique	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	assumed
Netherlands Antilles	0%	0%	0%	0%	*100%*	0%	0%	*100%*	0%	assumed
Nicaragua	0%	12%	2%	0%	86%	47%	0%	53%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Panama	0%	4%	0%	0%	96%	1%	0%	99%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Paruguay	10%	22%	0%	0%	68%	100%	0%	0%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Peru	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on Dufey (2006)
St. Kitts and Nevis	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Saint Lucia	0%	0%	0%	0%	*100%*	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
St. Vincent and Grenadines	0%	3%	0%	0%	97%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Surinam	0%	0%	0%	0%	100%	1%	0%	99%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Trinidad and Tobago	0%	0%	0%	0%	100%	0%	0%	100%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003
Uruguay	0%	0%	0%	0%	100%	100%	0%	0%	0%	based on USDA FAS (2007) - GAIN Report Number: UY7002
Venezuela	0%	15%	5%	0%	80%	2%	0%	98%	0%	based on FAOSTAT (2009) - Country Food Balance Sheet 2003

Appendix 6: Oil palm information

Composition of the oil palm

	Literature value	Source	Value in this research	
Fresh Fruit Bunch (FFB) weight	23-27kg	Poku (2002)	23 kg	i
Fruit/bunch	60-65%	Poku (2002)	61%	i
Oil/bunch	21-23%	Poku (2002)	24%	j
Kernel/bunch	5-7%	Poku (2002)	11%	j
Mesocarp/bunch	44-46%	Poku (2002)	43%	j
Mesocarp/fruit	71-76%	Poku (2002)	71%	i
Kernel/fruit	21-22%	Poku (2002)	18%	j
Shell/fruit	10-11%	Poku (2002)	10%	j
Skin (Exocarp)/fruit	?		1%	i
Seed (Endocarp + kernel)/fruit	?		28%	i
Shell (Endocarp)/seed	35%	Cornelius (1983)	35%	i
Kernel/seed	65%	Cornelius (1983)	65%	i
Mesocarp oil/fruit	29%	Yusoff (2006)	32%	j
Kernel oil/fruit	?		7%	j
Mesocarp oil/mesocarp	46-50%	Yusoff (2006)	45.4%	i
Kernel oil/bunch	3-5%	Janick & Paull (2008)	4%	j
Kernel oil/kernel	39.5%	Akinoso (2006), Akpanabiatu et al. (2001)	39.5%	i
Crude palm oil yield	3-6 ton/ha	DOPR (2009)	5 ton/ha	j

i) value imposed
j) value returned / calculated



Composition of oil palm fruit components used for oil

Composition crop g per 100 g fresh weight	Source	Carbo-hydrates	Proteins	Fats/oils	Lignins	Organic acids	Minerals	Fibres	Moisture
Oil palm mesocarp	Yusoff (2006), Bora et al. (2003)	8.2	2.1	45.4	0.0	0.6	1.2	4.3	38
Oil palm kernel	Akinoso (2006), Akpanabiatu et al. (2001)	31.4	7.3	39.5	0.0	0.0	1.1	14.7	6

Energy content of palm oil and diesel

	MJ / kg fresh weight	Source
Energy content of crude mesocarp oil (HHV)	41.84	Zakariah (2009)
Energy content of crude kernel oil (HHV)	39.70	Zakariah (2009)
Energy content of biodiesel from oil palm fruit (HHV)	16.33	calculated

Information about oil palm growth

Country	Crop / weather station location	Latitude/longitude	Yield FFB (kg/ha in 2007)[i]	Yield fruit (kg/ha)	Crop water requirement (mm/growing period)	Irrigation requirement (mm/growing period)
Honduras	Tela	15.72oN, 87.48oW	15823	9652	1362	131
Indonesia	Jakarta	6.18oS, 106.83oE	17181	10480	1545	449
Malaysia	Nakhon Ratchasima	14.97oN, 102.12oE	21144	12898	1431	27
Philippines	Kuala Lumpur	3.11oN, 101.55oE	11846	7226	1468	636
Thailand	Manila	14.58oN, 120.98oE	14686	8958	1421	644

i) FAO (2009c)

CROPWAT oil palm growth profile

Parameter	Value	Remark
Crop coefficients (Kc ini, Kc mid, Kc end)	1.0, 1.0, 1.0	Fruits are harvested year-round
Growth period stages (Init., dvlmnt., mid., late) (days)	91, 91, 92, 91	Existing plantation assumed
Rooting depth (Init., final) (meters)	1.0, 1.0	Based on Syahrinudin (2005)
Depletion factor (all stages)	0.65	For palm trees (Allen et al., 1998)
Yield response factor (Ky I, II, III, IV))	1.0, 1.0, 1.0, 1.0	Default
Planting day / month	N/A	Existing plantation, year-round harvesting

Water footprint of biodiesel from oil palm

Country	Water footprint of palm fruit (m^3/ton)			Water footprint of biodiesel from palm fruit (m^3/GJ)		
	Green	Blue	Total	Green	Blue	Total
Honduras	1415	151	1566	87	9	96
Indonesia	1046	428	1474	64	26	90
Malaysia	1089	21	1110	67	1	68
Philippines	1151	880	2031	70	54	124
Thailand	867	719	1586	53	44	97

Appendix 7: Annual water footprints of biofuels for road transport (km^3/yr)

	Bio-ethanol						Bio-diesel						Total bio-fuel					
	2005			2030			2005			2030			2005			2030		
	blue	green	total	blue	green	total	blue	green	total	blue	green	total	blue	green	total	blue	green	total
OECD																		
North America	**15.0**	**15.5**	**30.5**	**68.2**	**71.2**	**139.3**	**2.5**	**2.6**	**5.1**	**58.2**	**61.2**	**119.4**	**17.4**	**18.1**	**35.5**	**126.3**	**132.4**	**258.7**
USA	14.5	15.0	29.5	61.7	63.84	125.5	2.5	2.6	5.1	58.2	61.20	119.4	17.0	17.6	34.6	119.8	125.0	244.9
Canada	0.4	0.5	0.9	6.5	7.3	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.9	6.5	7.3	13.8
Mexico	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Europe	**1.3**	**1.1**	**2.4**	**46.0**	**48.4**	**94.4**	**6.3**	**9.9**	**16.2**	**68.9**	**92.5**	**161.5**	**7.6**	**11.0**	**18.6**	**114.9**	**140.9**	**255.9**
Austria	0.0	0.0	0.0	0.7	0.9	1.6	0.0	0.1	0.1	0.0	0.7	0.7	0.0	0.1	0.1	0.7	1.6	2.3
Belgium	0.0	0.0	0.0	0.7	1.2	1.9	0.0	0.0	0.0	0.6	2.0	2.6	0.0	0.0	0.0	1.3	3.2	4.5
Czech Republic	0.0	0.0	0.0	0.4	0.6	1.0	0.0	0.0	0.0	1.7	2.2	3.9	0.0	0.0	0.0	2.1	2.8	4.9
Denmark	0.0	0.0	0.0	0.2	0.2	0.4	0.0	0.0	0.0	0.5	1.2	1.7	0.0	0.0	0.0	0.7	1.4	2.1
Finland	0.0	0.0	0.0	0.2	0.3	0.5	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.2	0.5	0.7
France	0.0	0.1	0.1	2.4	2.7	5.1	0.9	1.0	1.9	11.5	13.6	25.1	0.9	1.1	2.0	13.9	16.3	30.2
Germany	0.2	0.3	0.4	5.0	8.2	13.2	3.7	5.9	9.6	5.4	8.6	14.0	3.9	6.1	10.0	10.4	16.8	27.2
Greece	0.0	0.0	0.0	0.4	0.1	0.5	0.0	0.0	0.0	9.8	0.1	9.9	0.0	0.0	0.0	10.2	0.3	10.5
Hungary	0.0	0.0	0.0	1.5	1.0	2.5	0.0	0.0	0.0	1.5	1.6	3.1	0.0	0.0	0.0	3.0	2.6	5.6
Iceland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ireland	0.0	0.0	0.0	0.1	0.2	0.3	0.0	0.0	0.0	0.3	0.9	1.2	0.0	0.0	0.0	0.4	1.1	1.5
Italy	0.0	0.0	0.0	12.6	18.4	31.0	0.8	2.0	2.8	13.4	31.4	44.8	0.8	2.0	2.8	26.1	49.8	75.9
Luxembourg	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.4	1.2	1.6	0.0	0.0	0.0	0.5	1.3	1.8
Netherlands	0.0	0.0	0.0	0.6	0.8	1.4	0.0	0.0	0.0	0.9	2.4	3.3	0.0	0.0	0.0	1.5	3.2	4.7
Norway	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Poland	0.1	0.0	0.1	1.6	1.2	2.8	0.1	0.1	0.1	5.2	4.9	10.1	0.1	0.1	0.2	6.8	6.2	13.0
Portugal	0.0	0.0	0.0	1.3	0.4	1.7	0.0	0.0	0.0	6.9	2.3	9.3	0.0	0.0	0.0	8.3	2.8	11.0
Slowak Republic	0.0	0.0	0.0	0.5	0.3	0.8	0.1	0.0	0.1	0.7	0.6	1.3	0.1	0.0	0.1	1.1	0.9	2.1
Spain	0.8	0.5	1.2	13.6	8.2	21.9	0.0	0.7	0.7	0.4	10.0	10.4	0.8	1.1	1.9	14.0	18.2	32.2
Switzerland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sweden	0.2	0.3	0.5	0.8	0.9	1.8	0.0	0.0	0.0	0.7	1.7	2.4	0.2	0.3	0.5	1.6	2.6	4.2
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.8	3.6	0.6	4.2	0.7	0.1	0.8	3.6	0.6	4.2
UK	0.0	0.0	0.1	3.2	2.5	5.7	0.1	0.1	0.1	5.3	6.3	11.6	0.1	0.1	0.2	8.5	8.8	17.3
Pacific	**0.0**	**0.0**	**0.1**	**1.1**	**8.6**	**9.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**1.1**	**8.6**	**9.7**
Japan	0.0	0.0	0.0	0.4	5.4	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	5.4	5.8
Korea (Rep.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Australia	0.0	0.0	0.1	0.8	3.2	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	3.2	4.0
Transition Economies	**0.0**	**0.0**	**0.0**	**4.4**	**3.4**	**7.8**	**0.0**	**0.0**	**0.0**	**20.2**	**15.8**	**36.0**	**0.0**	**0.0**	**0.0**	**24.6**	**19.2**	**43.8**
Former USSR and Balkans																		
Albenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Armenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Azerbaijan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Belarus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bosnia-Herzegovina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bulgaria	0.0	0.0	0.0	0.6	0.4	1.0	0.0	0.0	0.0	5.8	3.4	9.2	0.0	0.0	0.0	6.4	3.8	10.2

	Bio-ethanol						**Bio-diesel**						**Total bio-fuel**					
	2005			2030			2005			2030			2005			2030		
	blue	green	total	blue	green	total	blue	green	total	blue	green	total	blue	green	total	blue	green	total
Croatia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Estonia	0.0	0.0	0.0	0.2	0.2	0.4	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.4	0.5
Serbia-Montenegro	0.0	0.0	0.0	1.3	1.4	2.7	0.0	0.0	0.0	0.8	0.7	1.5	0.0	0.0	0.0	2.1	2.1	4.2
former Yugoslav Rep. of Macedonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Georgia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kazakhstan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kyrgyzstan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Latvia	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.1	0.3	0.3
Lithuania	0.0	0.0	0.0	0.4	0.4	0.7	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.4	0.5	0.8
Moldova	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Romania	0.0	0.0	0.0	1.4	0.7	2.1	0.0	0.0	0.0	3.2	3.4	6.6	0.0	0.0	0.0	4.6	4.1	8.7
Russia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	3.2	12.2	0.0	0.0	0.0	9.1	3.2	12.2
Slovenia	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	1.2	4.3	5.5	0.0	0.0	0.0	1.2	4.4	5.7
Taijkistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Turkmenistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ukraine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uzbekistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
and also for statistical reasons:																		
Cyprus	0.0	0.0	0.0	0.3	0.1	0.4	0.0	0.0	0.0	0.1	0.3	0.4	0.0	0.0	0.0	0.4	0.4	0.8
Gibraltar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Malta	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.2	0.1	0.3
Developing countries																		
Developing Asia	**1.7**	**1.8**	**3.5**	**46.2**	**41.6**	**87.8**	**1.0**	**1.6**	**2.6**	**48.5**	**90.8**	**139.3**	**2.7**	**3.4**	**6.1**	**94.7**	**132.4**	**227.1**
Afghanistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bangladesh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bhutan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brunai	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cambodia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
China	0.7	1.3	2.0	14.3	27.1	41.4	1.0	1.4	2.4	45.1	61.1	106.3	1.7	2.7	4.4	59.4	88.2	147.6
Chinese Taipei	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fiji	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
French Polynesia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
India	0.4	0.2	0.6	16.3	5.9	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.6	16.3	5.9	22.2
Indonesia	0.0	0.0	0.0	0.5	0.9	1.4	0.0	0.0	0.01	2.2	5.4	7.6	0.0	0.0	0.0	2.7	6.2	9.0
Kiribati	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DPR Korea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Laos	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Macau	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Malaysia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.4	23.5	24.0	0.0	0.2	0.2	0.4	23.5	24.0
Maldives	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Bio-ethanol						Bio-diesel						Total bio-fuel					
	2005			2030			2005			2030			2005			2030		
	blue	green	total	blue	green	total	blue	green	total	blue	green	total	blue	green	total	blue	green	total
Mongolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Myanmar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nepal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Caledonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pakistan	0.5	0.2	0.6	12.6	5.0	17.6	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.6	12.6	5.0	17.6
Papua New Guinea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Philippines	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.4	0.5	1.0	0.0	0.0	0.0	0.5	0.6	1.1
Samoa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Singapore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solomon Islands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sri Lanka	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thailand	0.1	0.1	0.2	2.4	2.7	5.1	0.0	0.0	0.0	0.4	0.2	0.6	0.1	0.1	0.2	2.7	3.0	5.7
Tonga	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vietnam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vanuatu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Middle East	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**9.4**	**6.7**	**16.1**	**0.0**	**0.0**	**0.0**	**9.4**	**6.7**	**16.1**
Bahrain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iran	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iraq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Israel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jordan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lebanon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kuwait	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oman	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Qatar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Saudi Arabia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
United Arab Emirates	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	6.7	16.1	0.0	0.0	0.0	9.4	6.7	16.1
Yemen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Africa	**0.5**	**0.3**	**0.8**	**7.0**	**3.6**	**10.6**	**0.0**	**0.0**	**0.0**	**4.5**	**1.1**	**5.6**	**0.5**	**0.3**	**0.8**	**11.5**	**4.7**	**16.2**
Algeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Angola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Botswana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burkina Faso	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burundi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cameroon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cape Verde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Central African Republic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chad	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Bio-ethanol						Bio-diesel						Total bio-fuel					
	2005			2030			2005			2030			2005			2030		
	blue	green	total	blue	green	total	blue	green	total	blue	green	total	blue	green	total	blue	green	total
Comoros	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Congo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Demographic Rep. of Congo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cote d'Ivor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Djibouti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Egypt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Equatorial Guinea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eritrea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethiopia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gabon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gambia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ghana	0.0	0.0	0.0	0.1	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.5
Guinea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guinea-Bissau	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kenya	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Lesotho	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Liberia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Libya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Madagascar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Malawi	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Mali	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mauritania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mauritius	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Morocco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mozambique	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Namibia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Niger	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reunion	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rwanda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sao Tome and Principe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Senegal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sychelles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sierra Leone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Somalia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
South Africa	0.5	0.2	0.8	6.7	3.1	9.9	0.0	0.0	0.0	4.5	1.1	5.6	0.5	0.2	0.8	11.2	4.2	15.5
Sudan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Swaziland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
United Rep. of Tanzania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Togo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Bio-ethanol						Bio-diesel						Total bio-fuel					
	2005			2030			2005			2030			2005			2030		
	blue	green	total	blue	green	total	blue	green	total	blue	green	total	blue	green	total	blue	green	total
Tunisia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uganda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zambia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zimbabwe	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Latin America	**13.1**	**18.1**	**31.2**	**40.7**	**50.9**	**91.6**	**0.5**	**0.2**	**0.7**	**42.5**	**6.2**	**48.8**	**13.7**	**18.3**	**31.9**	**83.2**	**57.1**	**140.3**
Antigua and Barbuda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Argentina	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	1.4	1.6	3.0	0.1	0.1	0.2	1.4	1.6	3.0
Bahamas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barbados	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Belize	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bermuda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bolivia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brazil	13.0	18.0	31.0	33.9	47.0	80.9	0.4	0.0	0.5	40.9	4.3	45.3	13.4	18.1	31.5	74.8	51.4	126.2
Chile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Colombia	0.0	0.0	0.1	1.7	0.6	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7	0.6	2.3
Costa rica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cuba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dominica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dominican Republic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ecuador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
El Salvador	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
French Guiana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grenada	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guadaloupe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guatemala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guyana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Haiti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Honduras	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jamaica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Martinique	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands Antilles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nicaragua	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Panama	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paruguay	0.1	0.1	0.2	5.0	3.3	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	5.0	3.3	8.3
Peru	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
St. Kitts and Nevis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Saint Lucia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
St. Vincent and Grenadines	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surinam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trinidad and Tobago	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uruguay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.5	0.0	0.0	0.0	0.2	0.3	0.5
Venezuela	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
World total (sum of regions)	**31.6**	**36.8**	**68.5**	**213.6**	**227.8**	**441.4**	**10.5**	**14.4**	**24.9**	**252.2**	**274.4**	**526.6**	**42.2**	**51.2**	**93.4**	**465.8**	**502.1**	**967.9**

Appendix 8: Water balance data

	Total supply	*Productive flows*		*EFR*	*Available IRWR*	*Human appropriation of blue water per sector*							
	Annual endogenous precipitation (km^3/yr)	**Annual IRWR (blue water) (km^3/yr)**	**Annual ET (green water) (km^3/yr)**	**Environmental flow requirement (km^3/yr)**	**WA_blue (km^3/yr)**	**Industrial withdrawals (km^3/yr)**		**Domestic withdrawals (km^3/yr)**		**Agricultural withdrawals (km^3/yr)**		**Blue WF of biofuels (km^3/yr)**	
	long-term avg.	*long-term avg.*	*long term avg.*	*80% of IRWR*	*long-term avg.*	*current*	*2030*	*current*	*2030*	*current*	*2030*	*current*	*2030*
OECD													
North America	**12625.0**	**6059.0**	**6566.0**	**4847.2**	**1211.8**	**256.6**	**281.6**	**83.4**	**110.9**	**263.5**	**214.0**	**35.5**	**258.7**
USA	5800.8	2800.0	3000.8	2240.0	560.0	220.69	191.20	60.85	81.57	197.75	181.80	34.6	244.9
Canada	5352.2	2850.0	2502.2	2280.0	570.0	31.57	36.52	8.99	8.09	5.41	3.57	0.9	13.8
Mexico	1472.0	409.0	1063.0	327.2	81.8	4.29	53.84	13.59	21.19	60.34	28.62	0.0	0.0
Europe	**4009.5**	**2137.0**	**1872.5**	**1709.6**	**427.4**	**138.5**	**143.3**	**44.9**	**75.9**	**110.5**	**134.2**	**18.7**	**255.9**
Austria	93.1	55.0	38.1	44.0	11.0	1.35	1.99	0.74	0.74	0.02	0.19	0.1	2.3
Belgium	25.8	12.0	13.8	9.6	2.4	7.68	6.63	0.99	1.25	0.36	0.26	0.0	4.5
Czech Rep.	53.4	13.2	40.2	10.5	2.6	1.47	6.10	1.05	2.14	0.06	0.10	0.0	4.9
Denmark	30.3	6.0	24.3	4.8	1.2	0.32	0.30	0.41	0.40	0.54	0.64	0.0	2.1
Finland	181.4	107.0	74.4	85.6	21.4	2.07	2.50	0.34	0.43	0.07	0.10	0.0	0.7
France	478.0	178.5	299.5	142.8	35.7	29.76	19.11	6.28	8.61	3.92	8.86	2.0	30.2
Germany	250.0	107.0	143.0	85.6	21.4	31.93	27.89	5.81	4.21	9.31	1.51	10.0	27.2
Greece	86.1	58.0	28.1	46.4	11.6	0.25	2.18	1.27	0.87	6.25	13.01	0.0	10.5
Hungary	54.8	6.0	48.8	4.8	1.2	4.48	5.17	0.71	1.04	2.45	1.60	0.0	5.6
Iceland	199.8	170.0	29.8	136.0	34.0	0.1	0.05	0.05	0.03	0.00	0.00	0.0	0.0
Ireland	78.6	49.0	29.6	39.2	9.8	0.87	0.52	0.26	0.16	0.00	0.06	0.0	1.5
Italy	250.8	182.5	68.3	146.0	36.5	16.29	10.67	8.07	6.36	20.01	15.97	2.8	75.9
Luxembourg	2.4	1.0	1.4	0.8	0.2		0.05		0.05	0.00	0.00	0.0	1.8
Netherlands	32.3	11.0	21.3	8.8	2.2	4.76	4.05	0.49	2.14	2.69	0.80	0.0	4.7
Norway	458.0	382.0	76.0	305.6	76.4	1.46	1.19	0.5	0.37	0.23	0.17	0.0	0.0
Poland	194.0	53.6	140.4	42.9	10.7	12.75	17.55	2.1	2.24	1.35	0.39	0.2	13.0
Portugal	78.6	38.0	40.6	30.4	7.6	1.37	1.87	1.08	1.35	8.81	4.24	0.0	11.0
Slovak Rep.	40.4	12.6	27.8	10.1	2.5		2.95		1.01	0.00	0.54	0.1	2.1
Spain	321.7	111.2	210.5	89.0	22.2	6.6	7.45	4.79	5.50	24.24	34.12	1.9	32.2
Switzerland	63.5	40.4	23.1	32.3	8.1	1.9	2.04	0.62	0.79	0.05	0.02	0.0	0.0
Sweden	280.7	171.0	109.7	136.8	34.2	1.61	1.41	1.09	1.00	0.26	0.23	0.5	4.2
Turkey	459.5	227.0	232.5	181.6	45.4	4.3	2.61	6.2	28.07	29.60	50.96	0.8	4.2
UK	296.3	145.0	151.3	116.0	29.0	7.19	19.00	2.07	7.16	0.28	0.38	0.2	17.3
Pacific	**5362.6**	**1316.0**	**4046.6**	**1052.8**	**263.2**	**21.5**	**44.8**	**23.7**	**22.2**	**79.1**	**32.8**	**0.3**	**9.7**
Japan	630.2	430.0	200.2	344.0	86.0	15.8	20.93	17.4	13.95	55.23	3.37	0.0	5.8
Korea (Republic)	127.0	67.0	60.0	53.6	13.4	3.05	17.47	1.79	4.63	4.96	4.94	0.2	0.0
New Zealand	468.4	327.0	141.4	261.6	65.4	0.2	0.31	1.02	0.62	0.89	0.46	0.0	0.0
Australia	4136.9	492.0	3644.9	393.6	98.4	2.4	6.13	3.52	2.96	18.01	23.99	0.1	4.0
Transition Economies	**10138.4**	**4960.3**	**5178.1**	**3968.2**	**992.1**	**91.9**	**74.3**	**29.5**	**89.7**	**191.2**	**194.9**	**0.0**	**43.8**
Former USSR and Balkans													
Albania	42.7	26.9	15.8	21.5	5.4	0.19	0.12	0.46	0.13	1.06	2.51	0.0	0.0
Armenia	16.8	6.9	9.9	5.5	1.4	0.13	0.32	0.88	1.71	1.94	2.70	0.0	0.0
Azerbaijan	38.7	8.1	30.6	6.5	1.6	2.36	2.29	0.521	2.40	9.33	12.78	0.0	0.0
Belarus	128.3	37.2	91.1	29.8	7.4	1.3	0.54	0.65	1.30	0.84	0.34	0.0	0.0
Bosnia-Herzegovina	52.6	35.5	17.1	28.4	7.1		1.06		0.52	0.00	0.02	0.0	0.0
Bulgaria	67.4	21.0	46.4	16.8	4.2	8.21	9.56	0.32	2.34	1.97	7.27	0.0	10.2
Croatia	62.9	37.7	25.2	30.2	7.5		1.36		0.65	0.00	0.04	0.0	0.0
Estonia	28.2	12.7	15.5	10.2	2.5	0.06	0.76	0.09	0.36	0.01	0.02	0.0	0.5
Serbia-Montenegro	81.2	44.0	37.2	35.2	8.8					0.00		0.0	4.2
former Yugoslav Rep. of Macedonia	15.9	5.4	10.5	4.3	1.1		0.69		0.21	0.00	0.77	0.0	0.0
Georgia	71.5	58.1	13.4	46.5	11.6	0.208	0.66	0.358	2.36	1.06	1.71	0.0	0.0

	Total supply	*Productive flows*		*EFR*	*Available IRWR*	*Human appropriation of blue water per sector*							
	Annual endogenous precipitation (km^3/yr)	**Annual IRWR (blue water) (km^3/yr)**	**Annual ET (green water) (km^3/yr)**	**Environmental flow requirement (km^3/yr)**	**WA_blue (km^3/yr)**	**Industrial withdrawals (km^3/yr)**		**Domestic withdrawals (km^3/yr)**		**Agricultural withdrawals (km^3/yr)**		**Blue WF of biofuels (km^3/yr)**	
	long-term avg.	*long-term avg.*	*long term avg.*	*80% of IRWR*	*long-term avg.*	*current*	*2030*	*current*	*2030*	*current*	*2030*	*current*	*2030*
Kazakhstan	680.4	75.4	605.0	60.3	15.1	5.78	5.94	0.59	1.73	28.63	30.13	0.0	0.0
Kyrgyzstan	106.5	46.5	60.1	37.2	9.3	0.31	0.35	0.32	1.12	9.45	7.94	0.0	0.0
Latvia	41.4	16.7	24.7	13.4	3.3	0.1	0.09	0.16	0.60	0.04	0.04	0.0	0.3
Lithuania	42.8	15.6	27.2	12.4	3.1	0.04	2.44	0.21	0.30	0.02	0.06	0.0	0.8
Moldova	15.2	1.0	14.2	0.8	0.2	1.33	0.82	0.22	1.30	0.76	1.36	0.0	0.0
Romania	152.0	42.3	109.7	33.8	8.5	7.97	6.62	2	3.66	13.21	23.45	0.0	8.7
Russia	7854.7	4312.7	3542.0	3450.2	862.5	48.66	30.50	14.38	38.65	13.64	22.87	0.0	12.2
Slovenia	23.5	18.7	4.9	14.9	3.7		0.81		0.23	0.00	0.01	0.0	5.7
Taijkistan	98.9	66.3	32.6	53.0	13.3	0.56	0.96	0.44	1.30	10.96	6.21	0.0	0.0
Turkmenistan	78.7	1.4	77.4	1.1	0.3	0.19	0.32	0.42	0.97	24.04	16.68	0.0	0.0
Ukraine	341.0	53.1	287.9	42.5	10.6	13.28	6.08	4.56	15.31	19.69	14.77	0.0	0.0
Uzbekistan	92.3	16.3	76.0	13.1	3.3	1.2	2.00	2.77	12.40	54.37	42.97	0.0	0.0
and also for statistical reasons:													
Cyprus	4.6	0.8	3.8	0.6	0.2	0.0035	0.02	0.0675	0.09	0.18	0.23	0.0	0.8
Gibraltar	0.0	0	0.0	0.0	0.0					0.00		0.0	0.0
Malta	0.2	0.05	0.1	0.0	0.0	0.0005	0.00	0.04	0.00	0.01	0.00	0.0	0.3
Developing countries													
Developing Asia	**23608.2**	**11281.4**	**12326.8**	**9025.1**	**2256.3**	**229.7**	**282.1**	**123.3**	**636.2**	**1547.6**	**1439.1**	**6.1**	**227.1**
Afghanistan	213.4	55.0	158.4	44.0	11.0		0.80		2.60	22.84	60.66	0.0	0.0
Bangladesh	383.8	105.0	278.8	84.0	21.0	0.52	0.47	2.53	38.35	76.35	35.54	0.0	0.0
Bhutan	103.4	95.0	8.4	76.0	19.0	0.005	0.00	0.02	0.51	0.40	0.13	0.0	0.0
Brunai	15.7	8.5	7.2	6.8	1.7		0.00		0.00	0.00	0.00	0.0	0.0
Cambodia	344.6	120.6	224.1	96.5	24.1	0.02	0.09	0.06	0.30	4.00	1.54	0.0	0.0
China	5994.7	2812.4	3182.3	2249.9	562.5	161.97	113.08	41.47	255.36	426.85	343.75	4.4	147.6
Chinese Taipei	87.4		87.4	0.0	0.0							0.0	0.0
Fiji	47.4	28.6	18.8	22.8	5.7	0.01	0.01	0.01	0.01	0.05	0.00	0.0	0.0
French Polynesia	0.0		0.0	0.0	0.0					0.00		0.0	0.0
India	3558.8	1260.5	2298.3	1008.4	252.1	35.21	60.82	52.24	203.90	558.39	686.86	0.6	22.2
Indonesia	5146.5	2838.0	2308.5	2270.4	567.6	0.56	14.50	6.62	21.09	75.60	15.31	0.0	9.0
Kiribati	0.0	0	0.0	0.0	0.0					0.00		0.0	0.0
DPR Korea	127.0	67.0	60.0	53.6	13.4	3.05	3.83	1.79	5.79	4.96	2.29	0.0	0.0
Laos	434.4	190.4	243.9	152.3	38.1	0.17	0.52	0.13	1.14	2.70	0.61	0.0	0.0
Macau	0.0		0.0	0.0	0.0							0.0	0.0
Malaysia	948.2	580.0	368.2	464.0	116.0	1.9	13.61	1.52	3.70	5.60	0.32	0.2	24.0
Maldives	0.6	0.03	0.6	0.0	0.0	0.0001		0.00332		0.00		0.0	0.0
Mongolia	377.4	34.8	342.6	27.8	7.0	0.12	0.02	0.09	0.05	0.23	1.03	0.0	0.0
Myanmar	1414.6	880.6	534.0	704.5	176.1	0.18	0.36	0.41	1.57	32.64	5.54	0.0	0.0
Nepal	220.8	198.2	22.6	158.6	39.6	0.06	0.04	0.3	7.38	9.82	6.29	0.0	0.0
New Caledonia	0.0	0	0.0	0.0	0.0		0.01		0.03	0.00	0.00	0.0	0.0
Pakistan	393.3	55.0	338.3	44.0	11.0	3.47	7.17	3.27	33.80	162.65	250.77	0.6	17.6
Papua New Guinea	1454.1	801.0	653.1	640.8	160.2	0.03	0.03	0.04	0.10	0.00	0.00	0.0	0.0
Philippines	704.3	479.0	225.3	383.2	95.8	2.69	36.43	4.73	19.40	21.10	4.19	0.0	1.1
Samoa	0.0	0	0.0	0.0	0.0		0.00		0.00	0.00	0.00	0.0	0.0
Singapore	1.5	0.6	0.9	0.5	0.1	0.0969		0.0855		0.01		0.0	0.0
Solomon Islands	87.5	44.7	42.8	35.8	8.9		0.00		0.00	0.00	0.00	0.0	0.0
Sri Lanka	112.3	50.0	62.3	40.0	10.0	0.31	0.56	0.3	1.55	12.00	5.19	0.0	0.0
Thailand	832.4	210.0	622.4	168.0	42.0	2.14	5.92	2.17	2.16	82.75	6.55	0.2	5.7
Tonga	0.0	0	0.0	0.0	0.0		0.00		0.00	0.00	0.00	0.0	0.0
Vietnam	604.0	366.5	237.5	293.2	73.3	17.23	23.79	5.54	37.41	48.62	12.48	0.0	0.0
Vanuatu	0.0	0	0.0	0.0	0.0		0.00		0.00	0.00	0.00	0.0	0.0

					Available IRWR	*Human appropriation of blue water per sector*							
	Annual endogenous precipitation (km^3/yr)	**Annual IRWR (blue water) (km^3/yr)**	**Annual ET (green water) (km^3/yr)**	**Environmental flow requirement (km^3/yr)**	**WA_blue (km^3/yr)**	**Industrial withdrawals (km^3/yr)**		**Domestic withdrawals (km^3/yr)**		**Agricultural withdrawals (km^3/yr)**		**Blue WF of biofuels (km^3/yr)**	
	long-term avg.	*long-term avg.*	*long term avg.*	*80% of IRWR*	*long-term avg.*	*current*	*2030*	*current*	*2030*	*current*	*2030*	*current*	*2030*
Middle East	**791.0**	**183.2**	**607.8**	**146.5**	**36.6**	**12.6**	**20.3**	**17.2**	**28.9**	**184.5**	**165.6**	**0.0**	**16.1**
Bahrain	0.1	0.004	0.1	0.00	0.0	0.0203	0.03	0.1779	0.34	0.16	0.00	0.0	0.0
Iran	372.4	128.5	243.9	102.80	25.7	1.1	14.52	6.2	8.55	86.00	84.70	0.0	0.0
Iraq	94.7	35.2	59.5	28.16	7.0	9.7	1.98	4.3	3.12	52.00	41.64	0.0	0.0
Israel	9.2	0.8	8.4	0.60	0.2	0.113	0.19	0.712	0.55	1.13	1.24	0.0	0.0
Jordan	9.9	0.7	9.2	0.55	0.1	0.0384	0.41	0.2913	0.69	0.61	0.81	0.0	0.0
Lebanon	6.9	4.8	2.1	3.84	1.0	0.15	0.30	0.38	1.62	0.78	0.52	0.0	0.0
Kuwait	2.2	0.00	2.2	0.00	0.0	0.0208	0.18	0.4005	0.49	0.49	0.03	0.0	0.0
Oman	26.6	1.4	25.2	1.12	0.3	0.019	0.07	0.134	0.48	1.17	0.68	0.0	0.0
Qatar	0.8	0.1	0.8	0.04	0.0	0.008	0.02	0.174	0.11	0.26	0.03	0.0	0.0
Saudi Arabia	126.8	2.4	124.4	1.92	0.5	0.70998	0.94	2.12994	7.37	20.83	15.56	0.0	0.0
Syria	46.7	7.1	39.5	5.71	1.4	0.595	1.35	1.426	3.19	14.67	14.24	0.0	0.0
United Arab Emirates	6.5	0.2	6.4	0.12	0.0	0.069	0.05	0.617	0.32	3.31	0.58	0.0	16.1
Yemen	88.3	2.1	86.2	1.68	0.4	0.068	0.27	0.272	2.11	3.06	5.62	0.0	0.0
Africa	**17310.6**	**3502.4**	**13808.2**	**2801.9**	**700.5**	**9.0**	**26.5**	**21.5**	**128.7**	**184.3**	**120.0**	**0.8**	**16.2**
Algeria	211.5	11.2	200.3	9.00	2.2	0.8	2.45	1.33	4.03	3.94	5.83	0.0	0.0
Angola	1258.8	148.0	1110.8	118.40	29.6	0.06	0.07	0.08	0.54	0.21	0.45	0.0	0.0
Benin	117.0	10.3	106.7	8.24	2.1	0.03	0.05	0.041	0.83	0.06	0.07	0.0	0.0
Botswana	241.8	2.4	239.4	1.92	0.5	0.035	0.03	0.079	0.12	0.08	0.09	0.0	0.0
Burkina Faso	204.9	12.5	192.4	10.00	2.5	0.006	0.00	0.104	1.60	0.69	0.24	0.0	0.0
Burundi	35.5	10.1	25.4	8.05	2.0	0.017	0.00	0.049	1.49	0.22	0.02	0.0	0.0
Cameroon	762.5	273	489.5	218.40	54.6	0.08	0.25	0.18	1.93	0.73	0.35	0.0	0.0
Cape Verde	0.9	0.3	0.6	0.24	0.1	0.0004	0.00	0.0016	0.02	0.02	0.00	0.0	0.0
Central African Republic	836.7	141	695.7	112.80	28.2	0.004	0.01	0.02	0.29	0.00	0.09	0.0	0.0
Chad	413.2	15.0	398.2	12.00	3.0		0.01	0.04	0.77	0.19	0.38	0.0	0.0
Comoros	2.0	1.2	0.8	0.96	0.2	0.0005	0.00	0.0048	0.00	0.00	0.00	0.0	0.0
Congo	562.9	222.0	340.9	177.60	44.4	0.01	0.02	0.032	0.08	0.00	0.04	0.0	0.0
Demographic Rep. of Congo	562.9	222	340.9	177.60	44.4	0.06	0.02	0.19	0.08	0.00	0.04	0.0	0.0
Cote d'Ivor	434.7	76.84	357.8	61.47	15.4	0.11	0.31	0.22	1.71	0.60	0.17	0.0	0.0
Djibouti	5.1	0.3	4.8	0.24	0.1		0.02		0.03	0.00	0.00	0.0	0.0
Egypt	51.4	1.8	49.6	1.44	0.4	4	14.43	5.3	19.61	59.00	51.96	0.0	0.0
Equatorial Guinea	60.5	26	34.5	20.80	5.2	0.017	0.00	0.09	0.46	0.00	0.00	0.0	0.0
Eritrea	45.1	2.8	42.3	2.24	0.6	0.001	0.02	0.031	0.56	0.55	0.35	0.0	0.0
Ethiopia	936.0	122.0	814.0	97.60	24.4	0.021	0.37	0.333	10.06	5.20	1.26	0.0	0.0
Gabon	490.0	164.0	326.0	131.20	32.8	0.01	0.06	0.06	0.10	0.05	0.01	0.0	0.0
Gambia	9.5	3.0	6.5	2.40	0.6	0.0036	0.00	0.007	0.23	0.02	0.02	0.0	0.0
Ghana	283.2	30.3	252.9	24.24	6.1	0.095	0.24	0.235	2.78	0.65	0.08	0.0	0.5
Guinea	405.9	226.0	179.9	180.80	45.2	0.03	0.08	0.12	1.37	1.36	0.24	0.0	0.0
Guinea-Bissau	57.0	16.0	41.0	12.80	3.2	0.008	0.00	0.023	0.21	0.14	0.11	0.0	0.0
Kenya	365.6	20.7	344.9	16.56	4.1	0.1	0.52	0.47	7.13	2.17	0.67	0.0	0.1
Lesotho	23.9	5.2	18.7	4.18	1.0	0.02	0.02	0.02	0.16	0.01	0.03	0.0	0.0
Liberia	266.3	200.0	66.3	160.00	40.0	0.02	0.06	0.03	0.42	0.06	0.00	0.0	0.0
Libya	98.5	0.6	97.9	0.48	0.1	0.132	0.23	0.61	0.82	3.58	5.83	0.0	0.0
Madagascar	888.2	337.0	551.2	269.60	67.4	0.23	0.00	0.42	6.26	14.31	3.44	0.0	0.0
Malawi	140.0	16.1	123.8	12.91	3.2	0.05	0.06	0.15	1.38	0.81	0.06	0.0	0.1
Mali	349.6	60.0	289.6	48.00	12.0	0.056	0.04	0.59	1.03	5.90	0.99	0.0	0.0
Mauritania	94.7	0.4	94.3	0.32	0.1	0.05	0.12	0.15	1.19	1.50	0.88	0.0	0.0
Mauritius	4.2	2.8	1.4	2.20	0.6	0.02	0.17	0.214	0.08	0.49	0.00	0.0	0.0
Morocco	154.7	29.0	125.7	23.20	5.8	0.36	1.05	1.23	4.48	11.01	12.10	0.0	0.0
Mozambique	827.2	100.3	726.9	80.24	20.1	0.01	0.02	0.07	1.16	0.55	0.44	0.0	0.0
Namibia	235.3	6.2	229.1	4.93	1.2	0.014	0.01	0.073	0.35	0.21	0.13	0.0	0.0
Niger	190.8	3.5	187.3	2.80	0.7	0.01	0.03	0.09	1.76	2.08	0.92	0.0	0.0
Nigeria	1062.3	221.0	841.3	176.80	44.2	0.81	1.72	1.69	26.83	5.51	1.27	0.0	0.0
Reunion	7.5	5.0	2.5	4.00	1.0					0.00		0.0	0.0
Rwanda	31.9	9.5	22.4	7.60	1.9	0.012	0.07	0.036	1.07	0.10	0.02	0.0	0.0
Sao Tome and Principe	3.1	2.18	0.9	1.74	0.4		0.00		0.00	0.00	0.00	0.0	0.0
Senegal	135.0	25.8	109.2	20.64	5.2	0.058	0.16	0.098	0.76	2.07	0.65	0.0	0.0
Sychelles	0.9	0	0.9	0.00	0.0					0.00		0.0	0.0
Sierra Leone	181.2	160.0	21.2	128.00	32.0	0.01	0.04	0.02	0.62	0.35	0.12	0.0	0.0
Somalia	180.1	6.0	174.1	4.80	1.2	0.002	0.00	0.015	1.04	3.28	2.09	0.0	0.0
South Africa	603.9	44.8	559.1	35.84	9.0	0.756	1.99	3.904	6.38	7.84	10.93	0.8	15.5

	Total supply	Productive flows		EFR	Available IRWR	Human appropriation of blue water per sector							
	Annual endogenous precipitation (km^3/yr)	**Annual IRWR (blue water) (km^3/yr)**	**Annual ET (green water) (km^3/yr)**	**Environmental flow requirement (km^3/yr)**	**WA_blue (km^3/yr)**	**Industrial withdrawals (km^3/yr)**		**Domestic withdrawals (km^3/yr)**		**Agricultural withdrawals (km^3/yr)**		**Blue WF of biofuels (km^3/yr)**	
	long-term avg.	*long-term avg.*	*long term avg.*	*80% of IRWR*	*long-term avg.*	*current*	*2030*	*current*	*2030*	*current*	*2030*	*current*	*2030*
Sudan	1042.0	30.0	1012.0	24.00	6.0	0.26	0.92	0.99	6.27	36.07	12.26	0.0	0.0
Swaziland	13.7	2.6	11.0	2.11	0.5	0.012	0.01	0.024	0.09	1.01	0.17	0.0	0.0
United Republic of Tanzania	1012.2	84	928.2	67.20	16.8	0.025	0.06	0.527	2.10	4.63	0.64	0.0	0.0
Togo	66.3	11.5	54.8	9.20	2.3	0.004	0.04	0.089	0.97	0.08	0.03	0.0	0.0
Tunisia	33.9	4.2	29.7	3.36	0.8	0.11	0.25	0.365	1.04	2.17	3.39	0.0	0.0
Uganda	284.5	39.0	245.5	31.20	7.8	0.05	0.16	0.13	3.45	0.12	0.16	0.0	0.0
Zambia	767.4	80.2	687.2	64.16	16.0	0.13	0.12	0.29	1.00	1.32	0.23	0.0	0.0
Zimbabwe	256.7	256.7	0.0	205.38	51.3	0.298	0.20	0.589	1.95	3.32	0.72	0.0	0.1
Latin America	**30127.4**	**13154.0**	**16973.4**	**10523.2**	**2630.8**	**23.2**	**107.7**	**36.9**	**98.1**	**127.0**	**67.4**	**31.9**	**140.3**
Antigua and Barbuda	0.5	0.1	0.4	0.042	0.0	0.001	0.00	0.003	0.00	0.00	0.00	0.0	0.0
Argentina	1642.1	276.0	1366.1	220.800	55.2	2.76	23.97	4.91	6.34	21.52	12.20	0.2	3.0
Bahamas	17.9	0.02	17.9	0.016	0.0		0.98		0.03	0.00	0.00	0.0	0.0
Barbados	0.6	0.1	0.5	0.064	0.0	0.04	0.04	0.03	0.02	0.02	0.00	0.0	0.0
Belize	39.1	16.0	23.1	12.800	3.2	0.11	0.00	0.01	0.02	0.03	0.01	0.0	0.0
Bermuda	0.0	0	0.0	0.000	0.0					0.00		0.0	0.0
Bolivia	1258.9	303.5	955.3	242.825	60.7	0.099	1.40	0.18	5.32	1.16	0.98	0.0	0.0
Brazil	15235.7	5418.0	9817.7	4334.400	1083.6	10.65	30.15	12.02	35.00	36.63	9.88	31.5	126.2
Chile	1151.6	884.0	267.6	707.200	176.8	3.16	28.96	1.42	3.33	7.97	25.14	0.0	0.0
Colombia	2974.6	2112.0	862.6	1689.600	422.4	0.4	2.12	5.39	8.34	4.92	1.93	0.1	2.3
Costa rica	149.5	112.4	37.1	89.920	22.5	0.46	0.60	0.79	0.56	1.43	0.19	0.0	0.0
Cuba	148.0	38.1	109.8	30.496	7.6	1	0.74	1.56	7.67	5.64	2.11	0.0	0.0
Dominica	1.6	0.0	1.6	0.000	0.0		0.00		0.00	0.00	0.00	0.0	0.0
Dominican Republic	68.7	21.0	47.7	16.796	4.2	0.06	1.66	1.09	1.28	2.24	0.84	0.0	0.0
Ecuador	591.8	432.0	159.8	345.600	86.4	0.9	0.62	2.12	2.47	13.96	1.41	0.0	0.0
El Salvador	36.3	17.75	18.5	14.200	3.6	0.2	0.28	0.32	0.97	0.76	0.07	0.0	0.0
French Guiana	260.6	134	126.6	107.200	26.8		0.01		0.01	0.00	0.00	0.0	0.0
Grenada	0.8	0.0	0.8	0.000	0.0		0.00		0.00	0.00	0.00	0.0	0.0
Guadaloupe	0.0	0	0.0	0.000	0.0		0.00		0.00	0.00	0.00	0.0	0.0
Guatemala	217.3	109.2	108.1	87.360	21.8	0.27	1.62	0.13	1.24	1.61	0.10	0.0	0.0
Guyana	513.1	241.0	272.1	192.800	48.2	0.01	0.00	0.03	0.25	1.60	0.35	0.0	0.0
Haiti	40.0	13.0	27.0	10.408	2.6	0.01	0.34	0.05	1.49	0.93	0.31	0.0	0.0
Honduras	221.4	95.9	125.5	76.743	19.2	0.1	0.48	0.07	0.45	0.69	0.28	0.0	0.0
Jamaica	22.5	9.4	13.1	7.523	1.9	0.07	0.24	0.14	0.39	0.20	0.02	0.0	0.0
Martinique	0.0	0	0.0	0.000	0.0		0.00		0.00	0.00	0.00	0.0	0.0
Netherlands Antilles	0.0	0	0.0	0.000	0.0		0.00		0.00	0.00	0.00	0.0	0.0
Nicaragua	310.9	189.7	121.1	151.792	37.9	0.03	0.94	0.19	2.64	1.08	0.34	0.0	0.0
Panama	203.3	147.4	55.9	117.936	29.5	0.04	0.60	0.55	0.79	0.23	0.04	0.0	0.0
Paruguay	459.5	94.0	365.5	75.200	18.8	0.04	0.08	0.1	1.19	0.35	0.25	0.2	8.3
Peru	2233.7	1616.0	617.7	1292.800	323.2	2.03	5.23	1.68	10.82	16.42	7.79	0.0	0.0
St. Kitts and Nevis	0.5	0.02	0.5	0.019	0.0		0.00		0.00	0.00	0.00	0.0	0.0
Saint Lucia	1.4	0	1.4	0.000	0.0		0.00		0.00	0.00	0.00	0.0	0.0
St. Vincent and Grenadines	0.6	0	0.6	0.000	0.0		0.00		0.00	0.00	0.00	0.0	0.0
Surinam	380.6	88.0	292.6	70.400	17.6	0.02	0.05	0.03	0.04	0.62	0.18	0.0	0.0
Trinidad and Tobago	11.3	3.8	7.4	3.072	0.8	0.08	1.25	0.21	0.52	0.02	0.01	0.0	0.0
Uruguay	222.9	59.0	163.9	47.200	11.8	0.04	0.12	0.08	0.83	3.03	1.35	0.0	0.5
Venezuela	1710.1	722.5	987.6	577.961	144.5	0.59	5.18	3.81	6.12	3.97	1.59	0.0	0.0
World total (sum of regions)	**103972.6**	**42593.2**	**61379.4**	**34074.5**	**8518.6**	**782.9**	**980.6**	**380.5**	**1190.6**	**2687.6**	**2367.9**	**93.4**	**967.9**

Source notes:

1) Preciptation, IRWR and 'current' withdrawal data obtained from AQUASTAT (FAO, 2008c)

2) Environmental flow requirement based on Hoekstra et al. (2009)

3) 2030 withdrawal data based on Alcamo et al. (2003)

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UNESCO-IHE
P.O. Box 3015
2601 DA Delft
The Netherlands

Website www.unesco-ihe.org
Phone +31 15 2151715

University of Twente

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