Methodology for estimating water requirements for energy production

1 Introduction

Water is critical to energy production in each of the *World Energy Outlook* scenarios. WEO-2012 includes projections of the water requirements for energy production, expressed as withdrawal and consumption, by scenario, region and energy source over the period 2010-2035. This document describes how these projections were derived.

Section 2 introduces key definitions for the purposes of this analysis. Section 3 describes the calculation of water requirements for energy production and underpinning assumptions.

2 Definitions

For this analysis, 'water' refers to accessible freshwater. That is, water with less than 500 parts per million of dissolved salts. It is this subset of water resources for which the water-energy nexus is of greatest consequence, given its importance for human use and its finite nature. Energy production uses significant volumes of non-freshwater, such as saline water from the sea and underground aquifers, treated wastewater, storm water and produced water from oil and gas operations. These water sources are not included in our projections of water requirements for energy production.

We project two distinct types of water use: *withdrawal* and *consumption*. Withdrawal is the volume of water removed from the environment for use. Consumption is the amount of water withdrawn that is not returned directly to the environment, having evaporated or been transported to another location outside the water basin. Water withdrawal is therefore, by definition, always greater than or equal to consumption. Discharge refers to the amount of water withdrawn that is returned directly to the environment, albeit sometimes degraded physically or chemically by use; it is not explicitly calculated in this analysis.

3 Water requirements for energy production

Water is ubiquitous in energy production. Its use impacts water availability when water is consumed or withheld for a long period as in a hydropower reservoir, potentially affecting other users downstream and ecosystems. Water quality can also be degraded physically or chemically by use, even when the volume used is relatively minimal, and may pose environmental hazards when discharged. Conversely, water availability can pose an acute risk to energy projects that require large volumes for operation or those built in a water basin that faces scarcity concerns. Being able to assess these risks is aided by improved understanding of present and future water requirements for energy production.

3.1 Primary energy production

In order to quantify the water requirements for primary energy production, we conducted a comprehensive review of published water withdrawal and consumption factors for relevant stages of oil, gas, coal and biofuels production. The relevant components of energy production where water is used are listed in Table 1. Water factors were taken from the most recent sources available, and as much as possible from operational rather than theoretical estimates. These were then compiled into source-to-carrier ranges for each fuel, disaggregated by production chain.

The production chains were disaggregated as follows:

- Oil – conventional oil (primary and secondary recovery), oil sands, gas-to-liquids, coal-to-liquids and enhanced oil recovery (by various methods);
- Gas – conventional gas and shale gas; and,
- Biofuels – sugarcane ethanol, corn ethanol, lignocellulosic ethanol, soybean biodiesel, rapeseed biodiesel and palm oil biodiesel.

Table 1: Key uses of water for primary energy production.

Fuels	Description
Oil and gas	Drilling, well completion and hydraulic fracturing; injection into the reservoir in secondary and enhanced oil recovery; oil sands mining and in-situ recovery; upgrading and refining into products.
Coal	Cutting and dust suppression in mining and hauling; washing to improve coal quality; re-vegetation of surface mines; long-distance transport via coal slurry.
Biofuels	Irrigation for feedstock crop growth; wet milling, washing and cooling in the fuel conversion process.

Average water factors for production chains were also attained from literature, by region where data was available, and with IEA analysis. These average water factors were then applied across the *WEO-2012* energy supply projections at an equivalent level of disaggregation by scenario and modelling region. The water factors applied were generally global, meaning for example that the same water factor was used for conventional oil production everywhere. The most notable exception to this was particular biofuels, whose water withdrawal and consumption factors for biomass feedstock can range widely depending on where they are grown.

3.2 Power generation

In order to quantify the water requirements for power generation, we conducted a comprehensive review of published water withdrawal and consumption factors for electricity generation technologies by cooling system type. Cooling system choice has the most significant impact on water requirements for power plants, although water is used for other purposes (Table 2). The cooling systems included were once-through, wet cooling tower, wet cooling pond, dry and hybrid. Water factors were taken from the most recent sources available, and as much as possible from operational rather than theoretical estimates. Water factors compiled did not account for water used to produce the input fuel, as this may be supplied outside of the country where power is generated.

Table 2: Key uses of water for power generation.

Fuels	Description
Thermal (fossil fuel, nuclear and bioenergy)	Boiler feed, *i.e.* the water used to generate steam or hot water; cooling for steam-condensing; pollutant scrubbing using emissions-control equipment.
Concentrating solar power and geothermal	System fluids or boiler feed, *i.e.* the water used to generate steam or hot water; cooling for steam-condensing.
Hydropower	Electricity generation; reservoir storage (for operating hydro-electric dams or energy storage).

WEO-2012 projections for power generation in each scenario, region and generating technology were split by cooling technology using present shares based on information from Platts. In most cases, shares of cooling technologies were held constant through time, with several exceptions where known policies and plans were accommodated (*e.g.* the United States, where environmental regulations are phasing out once-through cooling and China, where several nuclear power plants be constructed inland). Average water factors from literature were then applied to the *WEO-2012* power generation projections disaggregated by cooling system.