Allocation recommendations for multipurpose reservoirs

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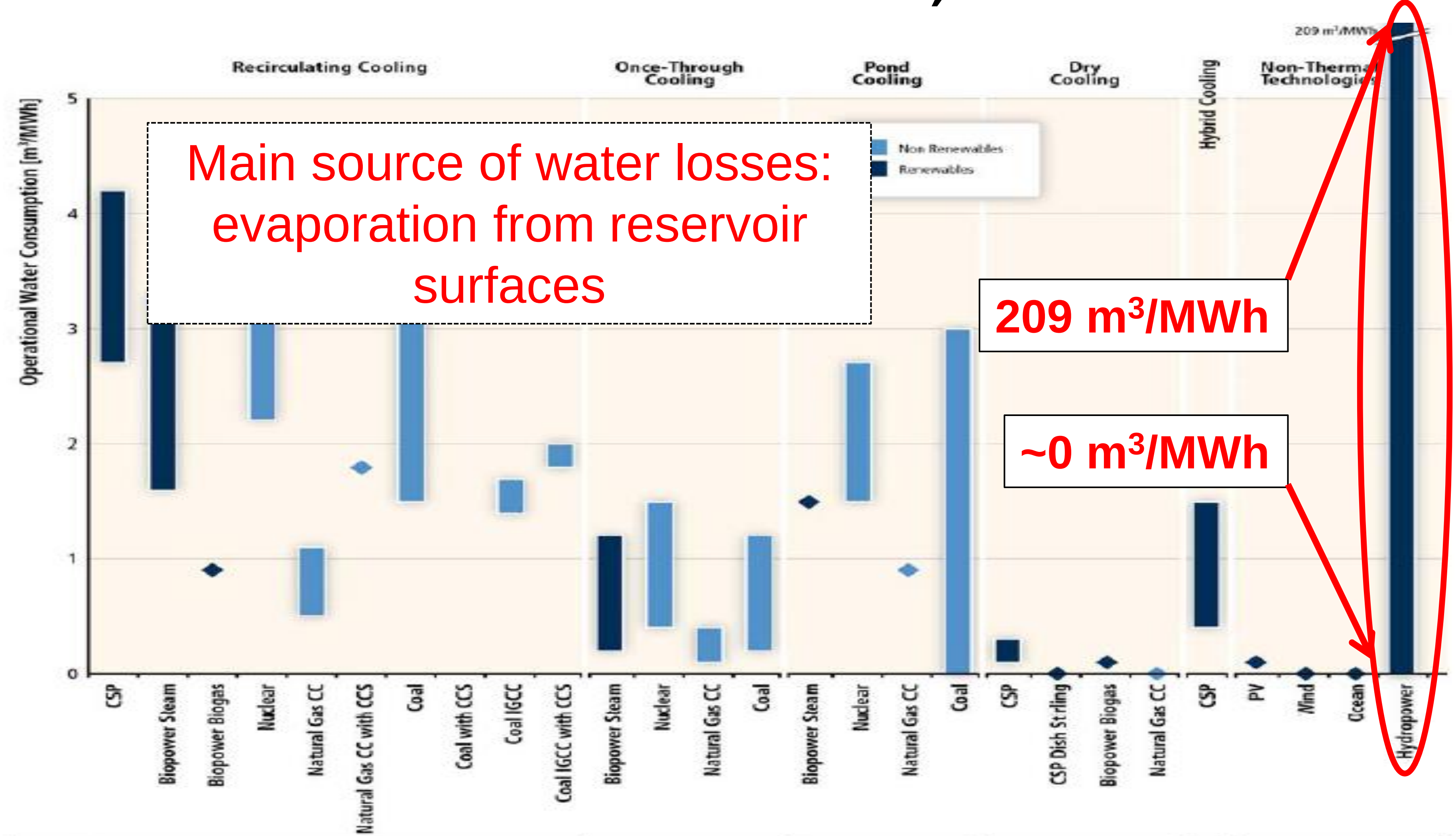
Water consumption from energy generation: *Source: IPCC SRREN, 2011*



N:	18	4	1	5	4	1	16	2	7	3	1	3	3	9	1	1	1	7	11	2	1	2	4	2	2	1	4
Sources:	11	3	1	5	4	1	8	1	2	1	1	3	3	4	1	1	1	2	4	2	1	2	2	2	2	1	2

Main source of water losses: evaporation from reservoir surfaces

209 m³/MWh

~0 m³/MWh

Rationale for our study

Lack of clear methodology identified:

IPCC (2011, Chapter 5, page 44) states that '*allocation schemes for determining water consumption from various reservoir uses in the case of multipurpose reservoirs can significantly influence reported water consumption values'.*

IPCC (2011) states in Technical Summary, page 74 *'the multipurpose nature of most hydropower projects makes allocation of total impacts to the several purposes challenging. Many LCAs to date allocate all impacts of hydropower projects to the electricity generation function, which in some cases may overstate the emissions for which they are 'responsible"*.

Rationale for our study, cont'd

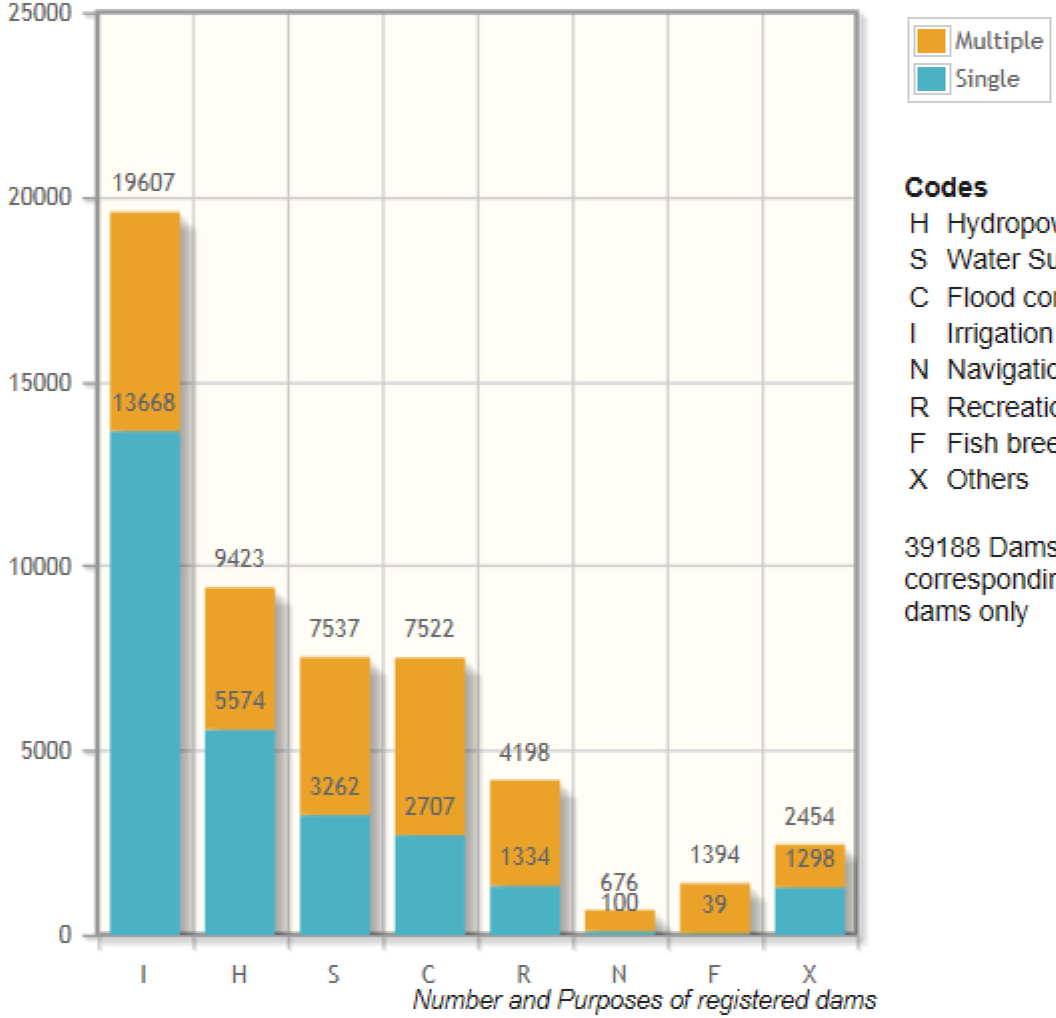
The problem/lack of methodology also confirmed by Mekonnen and Hoekstra, 2012; Demeke et al., 2013; Bakken et al., 2013.

The hydropower sector asks for clarification.

ISO Standard of Water footprint also suffers from clear guidelines on allocation.

The work will also be useful for other environmental indices/parameters, such as energy efficiency and emission of green-house gases (ref. IPCC, 2014).

Single versus multipurpose reservoirs



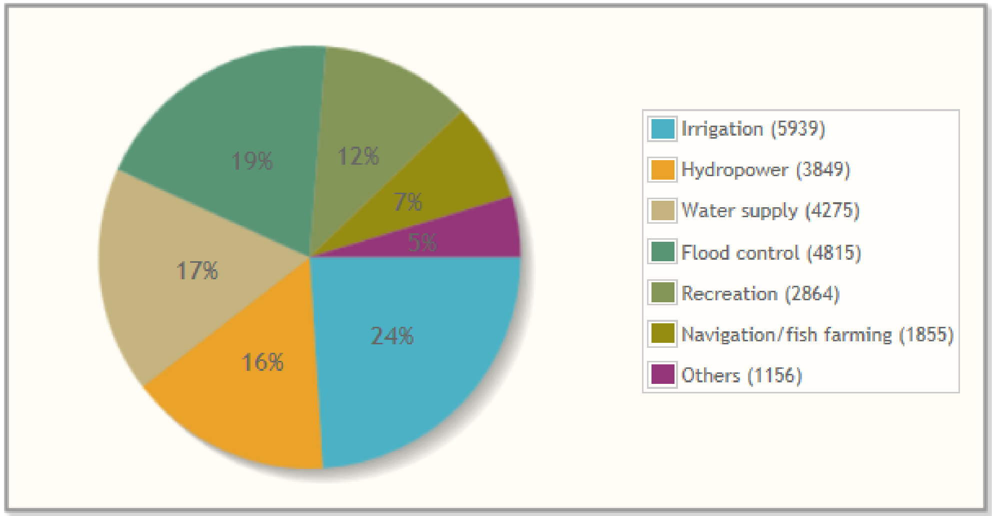
Codes
H Hydropower
S Water Suply
C Flood control
I Irrigation
N Navigation
R Recreation
F Fish breeding
X Others

39188 Dams data corresponding to registered dams only

Source: ICOLD

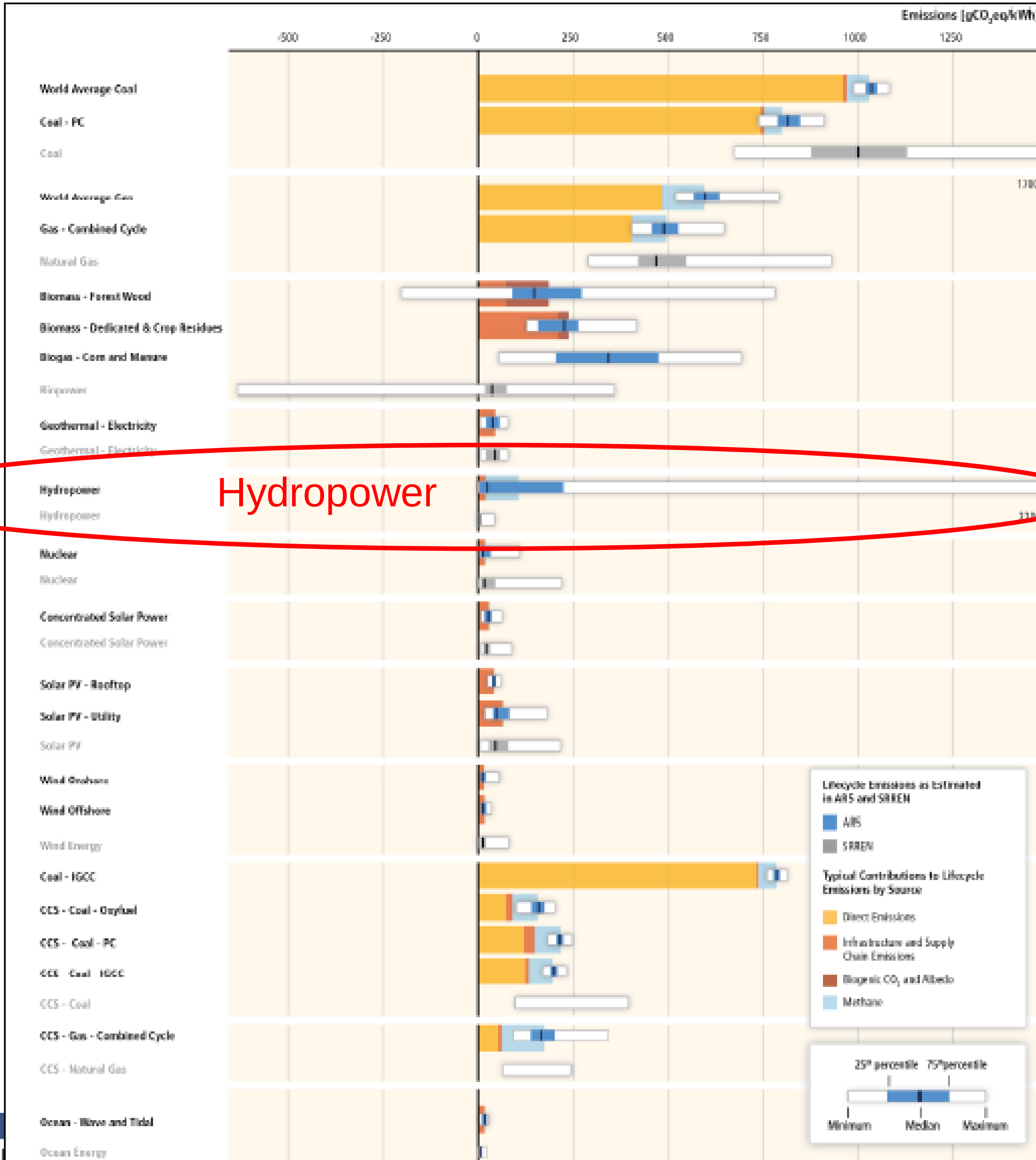
Multipurpose reservoirs

What is the purpose of the <u>multipurpose</u> reservoirs?



The ICOLD statistics: Among those 9423 registered large dams with hydropower production, more than 40% have multipurpose function.

Source: ICOLD



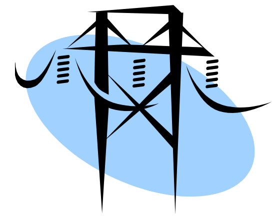
Comparative lifecycle greenhouse gas emissions from electricity supplied by commercially available technologies (fossil fuels, renewable, and nuclear power).

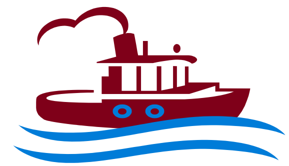
Same allocation problem for GHGs.

Source: IPCC AR5 WGIII (2014)

The situation

Water losses - m^3/year





Water use in the reservoir

Functions of the reservoir

Scope of work

1. Review the most common approaches for the distribution of resources consumption, based on the principles outlined by the ISO standard 14044 (2006).

2. Demonstrate the use of the various allocation approaches based on real datasets/cases and assess the appropriateness of the various allocation procedures.

3. Propose recommendations and guidelines for the operative use of the allocation procedure in multi-purpose reservoirs with hydropower production.

4. Consider the relevance of these burden-distributing guidelines for LCA studies of multipurpose reservoirs with respect to other topics.

Allocation methods

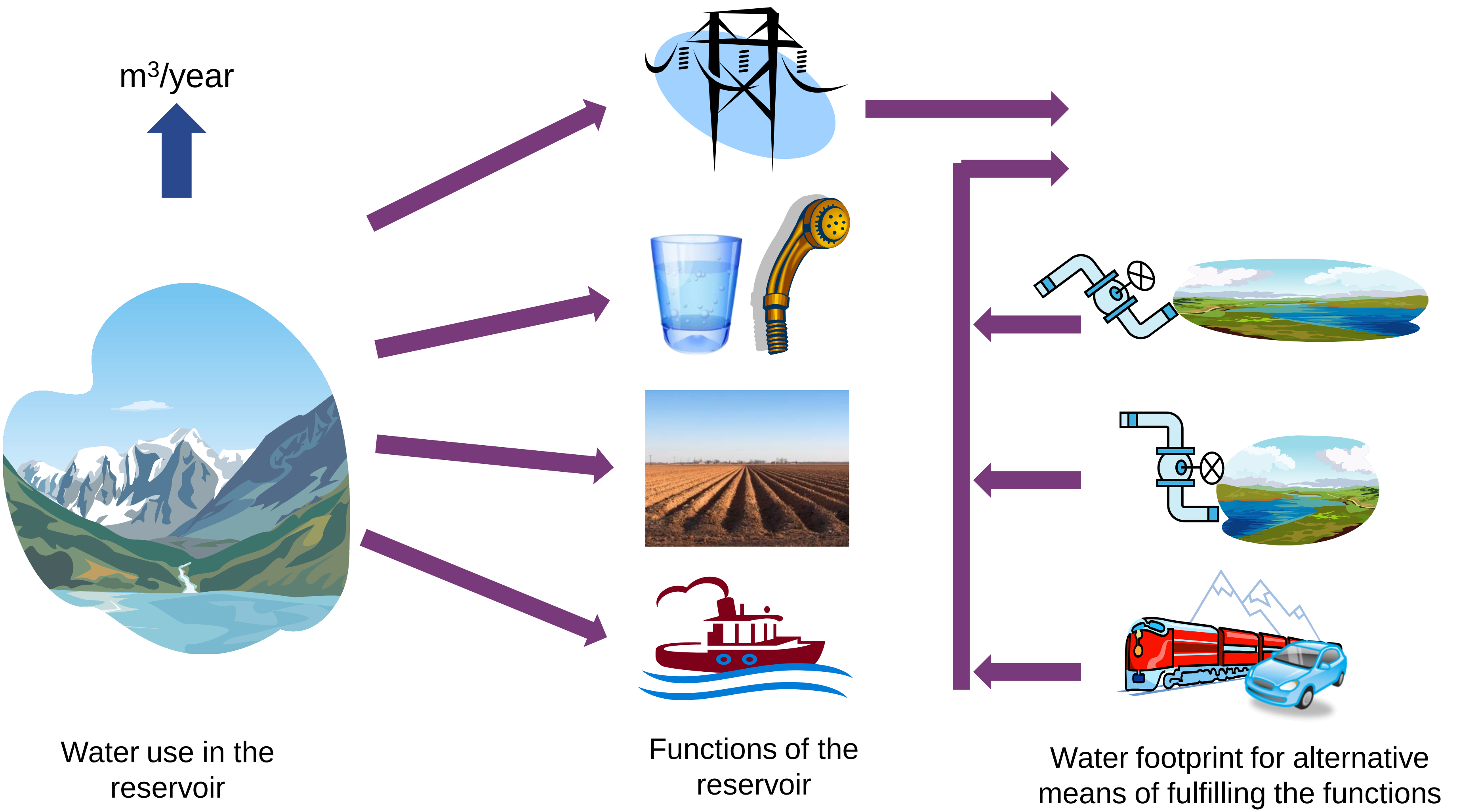
Allocation models tested based on recommendations for burden-distribution in multifunctional processes by (ISO 14044, 2006):

If possible, allocation should be avoided by:

1A: Subdividing the product system – considered not possible

1B: Using system expansion/avoided burdens to include the additional functions (substitution), understood as **Water footprint for alternative means of fulfilling the functions** - considered inappropriate

Avoid allocation/substitution



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If allocation cannot be avoided, allocation should be based on:

2A: Physical relationships (mass, volume or energy)

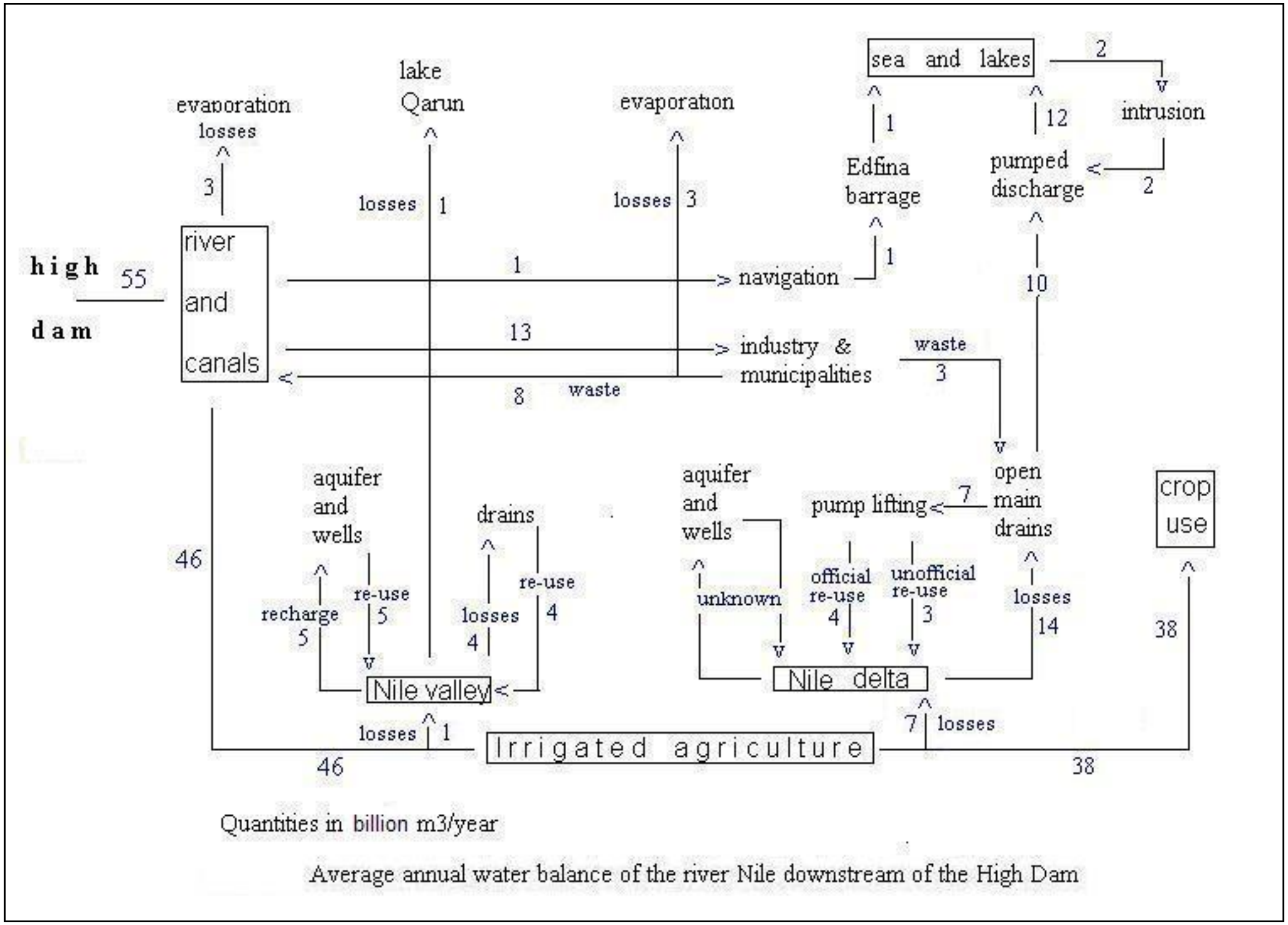
2B: Other relationships (economic or others relationship, e.g. explicit prioritizing)

Example: Mandal River Basin (spatial boundaries)

Reservoirs upstream regulate the inflow to several downstream plants without immediate storage ('cascaded development')

Source: Bakken et al., 2013

Example: Aswan High Dam (volume allocation)



Source: Wikipedia.org

4 case studies

Data	Sri Ram Sagar Project, India	Aswan High Dam Project, Egypt	Mularroya dam, Spain	Porma Dam and reservoir, Spain
Evaporation rate [mm]	1696	3 000	1100	858
Surface area [km^2]	453	5 250	4.63	12.5
Total annual evaporation [mill. m^3]	768.3	15 750	5.09	10.7
Installed capacity [MW]	36	2 100	23.5	23.2
Annual power production [GWh]	236.5	2 520	25.9	48.8
Water consumption rate [m^3/MWh]	3248	6 250	196.6	255.9

Our findings

- Systems expansion/avoided burdens: inappropriate as it appears far too labor-intensive, and in most cases in arid regions it is hardly possible to find nearby alternatives for substitution, especially for the functions irrigations and flood control.

- Energy allocation: in all the examined cases this approach is based on the results of the volume allocation, while introducing simple assumptions on the relation between volume allocation and loss of energy production. This approach will hence experience the same methodological challenges as volume allocation, but will introduce additional uncertainties.

- Economic allocation: this approach can be based on results from volume and energy allocation, thus inherit all the methodological challenges from these approaches as well as incurring new uncertainties. Alternatively, macro-economic analysis can be applied with a different set of uncertainties. These two approaches can possibly produce very different results.

- Explicit prioritizing: This is a very simplistic approach that is easy to apply, but does not capture the multipurpose aspects of reservoirs if the top priority is assigned 100% of the burden.

Recommendations

- We consider volume allocation to be the most robust approach for allocating water consumption between competing functions in multipurpose reservoirs.
- We recommend that data should preferably be gathered from one source for all functions, to secure a consistent calculation approach.
- The system boundaries should be flexible, but preferably follow boundaries defined by the hydraulic system, as the volumes of water, energy allocation based on water volumes and possibly also economic value is to a large extent determined by the hydraulic system boundaries.
- We propose that a site visit should be undertaken if an allocation study is carried out, as this will reduce the uncertainties in the calculations, quality assure assumption and possible remove errors in the data.

Documentation

Allocation recommendations for multipurpose reservoirs – results for water consumption

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Abstract

The IPCC Special Report on Renewable Energy (Edenhofer et al. 2011) represented a benchmark in the assessment of water consumption from energy production. In the case of hydropower with multipurpose reservoirs, which is the case for more than 40 % of the large dams with hydropower production (ICOLD 2014), IPCC (Edenhofer et al.) pointed out that there was no clear methodology of distributing the burden of the water losses between the

Bakken et al. (2014): Submitted for publication