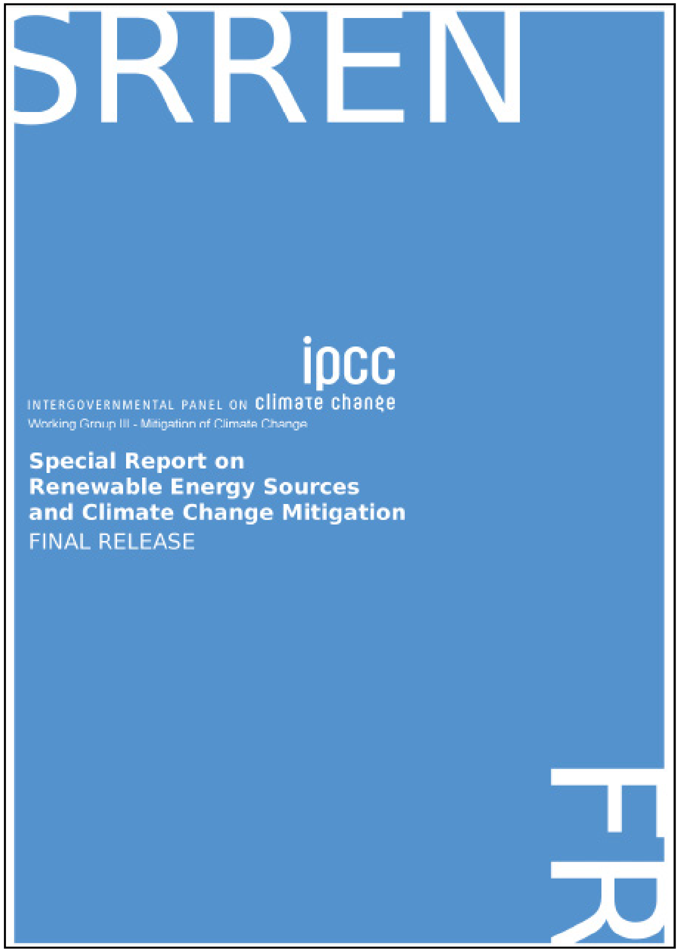
EcoManage WP3: Water consumption/footprint for hydropower
Ånund Killingtveit @NVE 21 Jan 2015

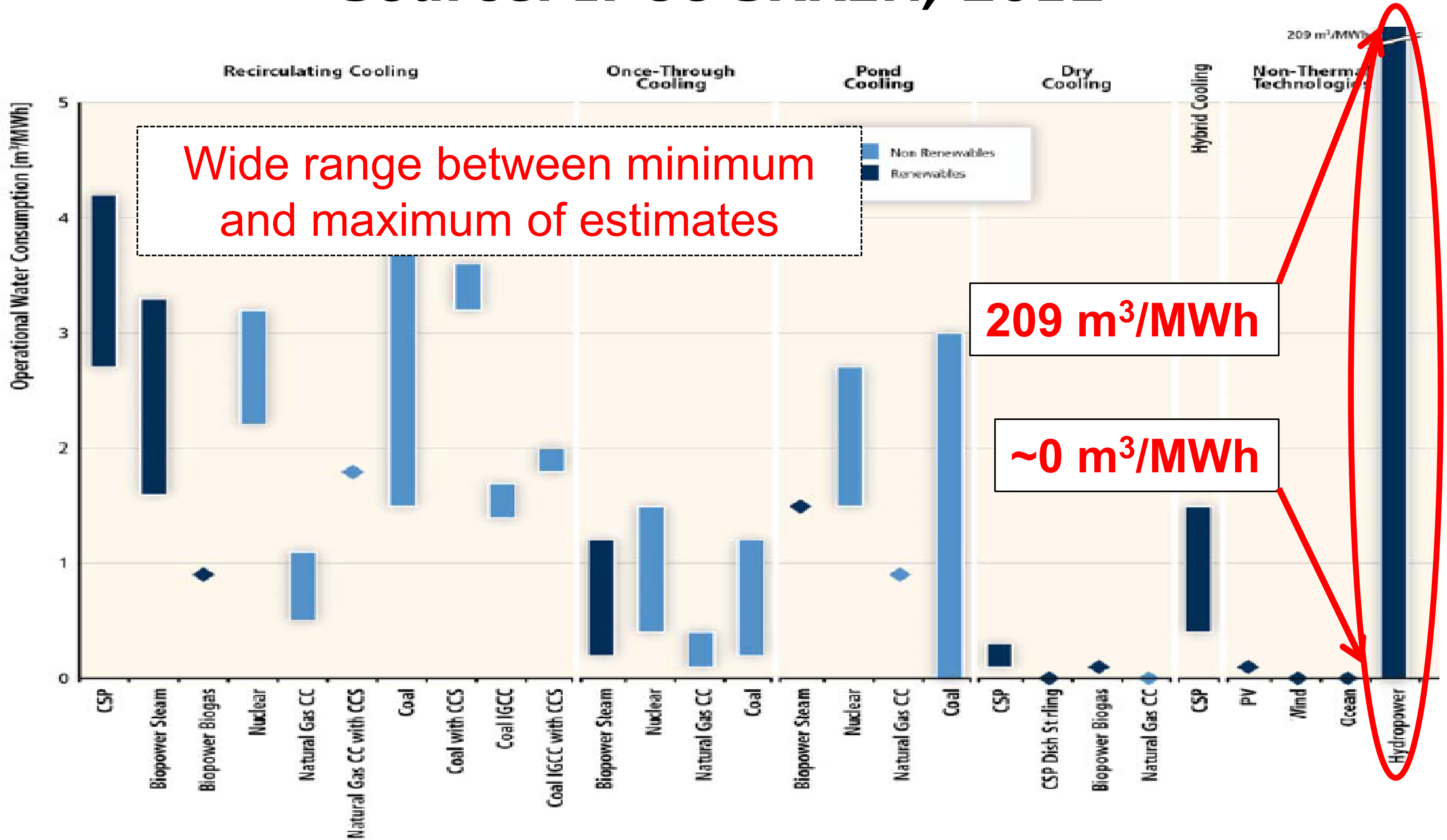
What raised the attention?



IPCC Special Report on Renewable Energy (2012):

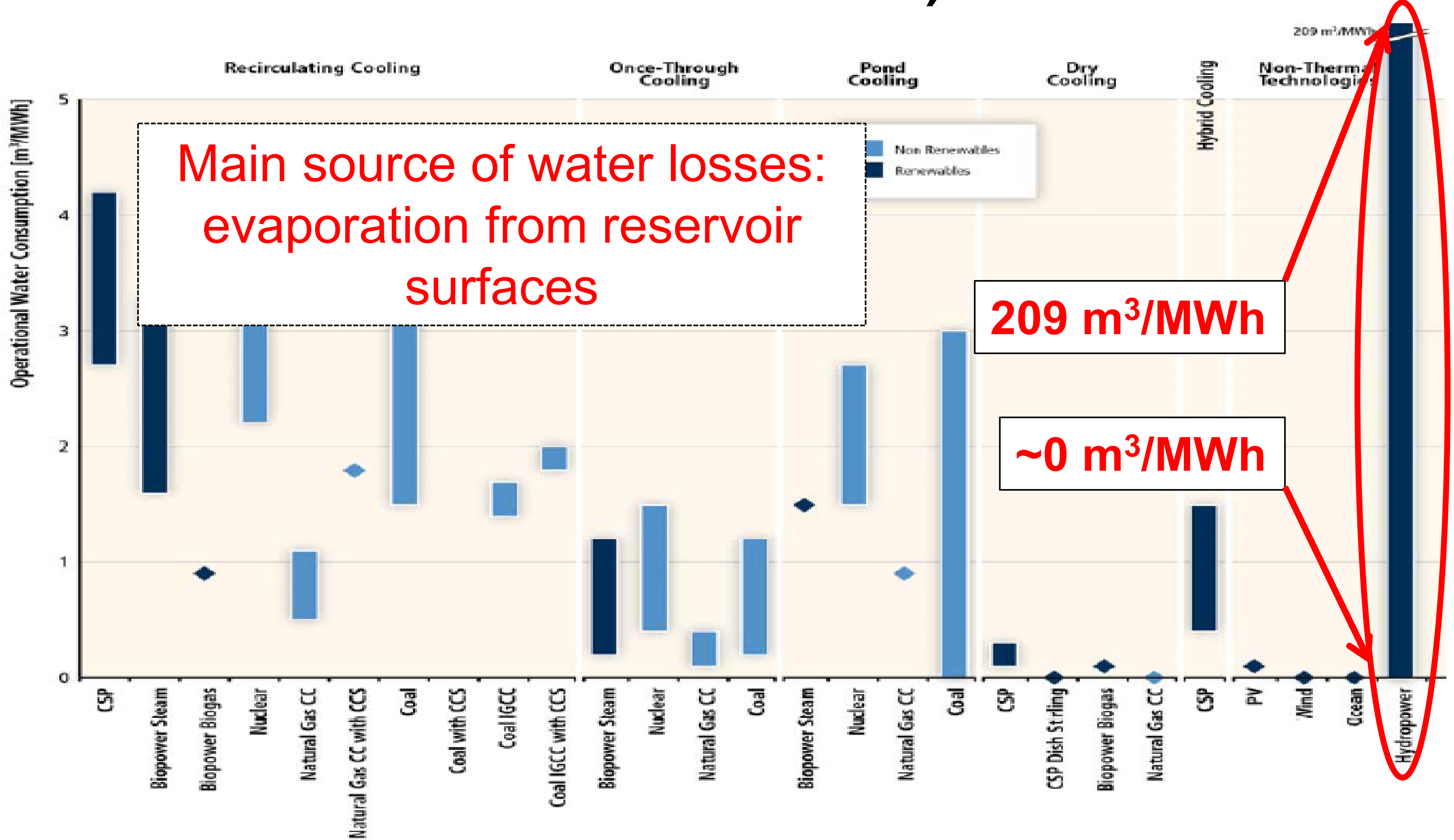
- What is the potential for renewable sources to replace fossil-based fuels?
- The different technologies benchmarked with respect to various criteria, including ‘water needed to produced 1 MWh electricity (*water consumption*)’

Water consumption from energy generation*:*
Source: IPCC SRREN, 2012



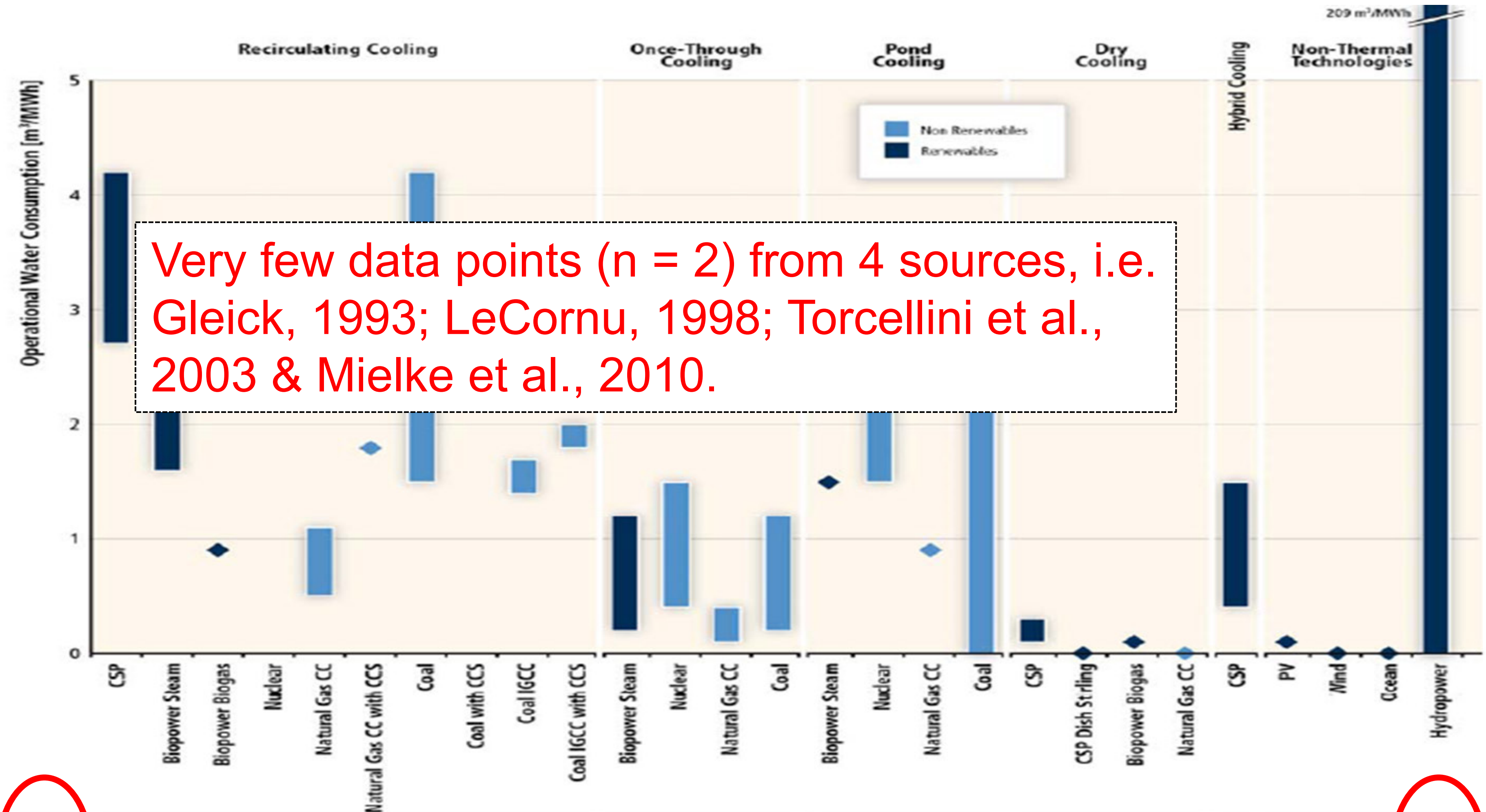
N:	18	4	1	5	4	1	16	2	7	3	1	3	3	9	1	1	1	7	11	2	1	2	4	2	2	1	4
Sources:	11	3	1	5	4	1	8	1	2	1	1	3	3	4	1	1	1	2	4	2	1	2	2	2	2	1	2

Water consumption from energy generation: *Source: IPCC SRREN, 2012*



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

Water consumption from energy generation: *Source: IPCC SRREN, 2012*



Very few data points (n = 2) from 4 sources, i.e. Gleick, 1993; LeCornu, 1998; Torcellini et al., 2003 & Mielke et al., 2010.

	CSP	Biopower Steam	Biopower Biogas	Nuclear	Natural Gas CC	Natural Gas CC with CCS	Coal	Coal with CCS	Coal IGCC	Coal IGCC with CCS	Biopower Steam	Nuclear	Natural Gas CC	Coal	Biopower Steam	Nuclear	Natural Gas CC	Coal	CSP	CSP Dish Stirling	Biopower Biogas	Natural Gas CC	CSP	PV	Wind	Ocean	Hydropower
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

IPCC SRREN (2012) states

- *Upper values for hydropower result from few studies measuring <u>gross evaporation</u> values, and <u>may not be representative.</u>*

- *Research may be needed to determine the <u>net effect</u> of reservoir construction on the evaporation in the specific watershed.*

- *<u>Allocation schemes</u> for determining water consumption from various reservoir uses in the case of multipurpose reservoirs can significantly influence reported water consumption values.*

Water footprint of energy

Primary energy carriers		Global average water footprint (m^3/GJ)
Non-renewable	Natural gas	0.11
	Coal	0.16
	Crude oil	1.06
	Uranium	0.09
Renewable	Wind energy	0.00
	Solar thermal energy	0.27
	Hydropower	22 (=80 litres/KWh)
	Biomass energy	70 (range: 10-250)

[Gerbens-Leenes, Hoekstra & Van der Meer, 2008]

Water footprints for energy: Water consumed by energy type

Energy Type	Water consumed (m3/MWh)
Wind	~0
Nuclear	0.3
Gas	0.4
Coal	0.6
Oil/Petrol	4
Hydropower	80
Bio-fuel (1st gen.)	66-90

Source: UNESCO-IHE

ENVIRONMENT & ENERGY DAILY

ENERGY POLICY: Senate panel to take up hydropower, water use measures

(03/28/2011)
Katie Howell, E&E reporter

The Senate Energy and Natural Resources panel convenes Thursday to discuss three measures that address hydropower and the impact of energy development on water resources.

The committee's third legislative hearing this Congress will focus on two bills to boost hydropower in the United States and on the water section of the broad energy bill that passed out of the committee in 2009.

Why this concern in the HP sector?

- The picture on hydropower is very inconsistent
- Very limited data/investigations and immature concept
- A fear that these numbers can be taken as ‘typical water footprint of hydropower’

- Potentially a large reputational and business risk
- Might disqualify hydropower based on an unfair methodological basis
- The water footprint methodology seems to gain an increasing foothold

Main source of water losses: evaporation from reservoir surfaces

A hydropower dam and reservoir (Nyamba ya Mungu, Tanzania)

Evaporation loss from reservoir E_G (Gross evaporation)?

Evaporation loss from wetland area without the dam E_0?

Net evaporation loss $E_N = E_G - E_0$

Water is also used for Irrigation downstream

What is most important:
Lost water compared to regulated flow?

Basis for calculations

1. $$Gross\ water\ consumption = \frac{Evaporation\ reservoir}{Annual\ power\ production}$$

2. $$Net\ water\ consumption = \frac{Evaporation\ reservoir - Evaporation\ before\ inundation}{Annual\ power\ production}$$

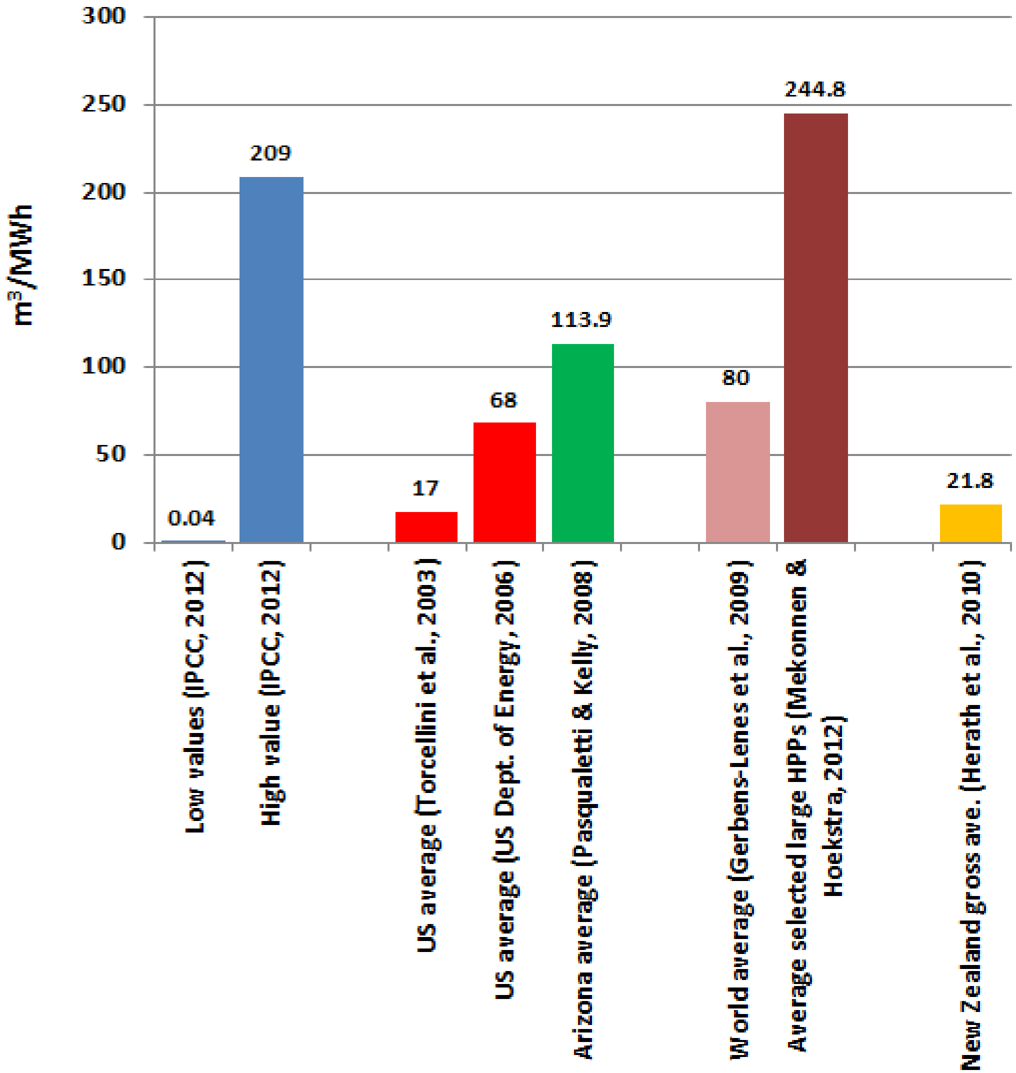
Water consumption from hydropower production: review of published estimates

Tor Haakon Bakken[1&2], Ånund Killingtveit[1], Kolbjørn Engeland[2], Knut Alfredsen[1] & Atle Harby[2]

[1] Norwegian University of Science and Technology, Trondheim, Norway
tor.haakon.bakken@sintef.no

[2] SINTEF Energy Research, Trondheim, Norway

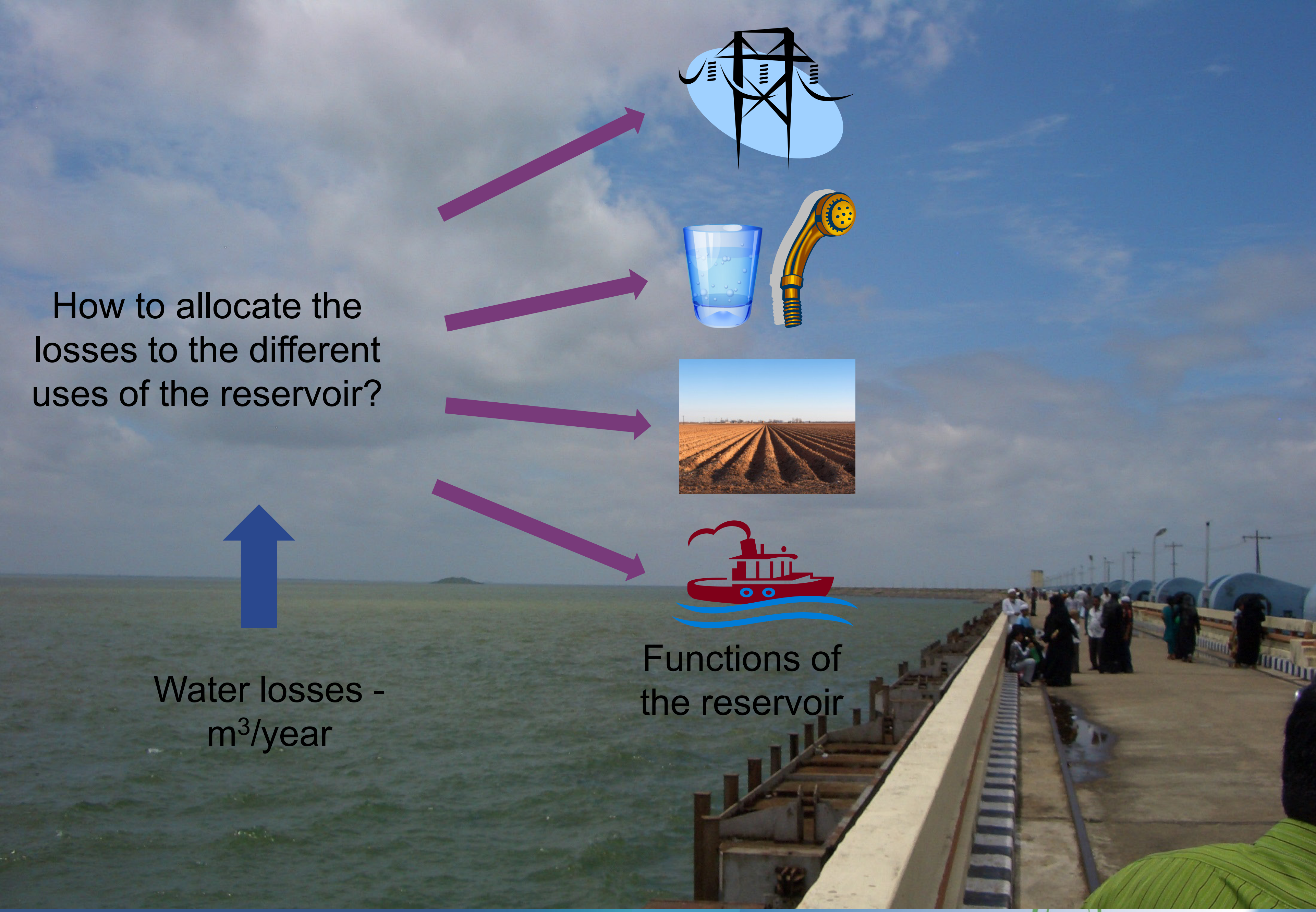
Selected benchmarks published – Gross values



- 'IPCC-values'
- US averages, based on 2 different datasets
- World average based on 2 different datasets
- 2 regional averages (Arizona and NZ)

Findings from our review on the concept of assessment

- "No way" around the fact that HP has a large water consumption in some regions, given the current approach (gross evaporation) of calculating water consumption/footprint.
- But, are high water consumption rates problematic?
- No solution on how to handle "impacts" on the water resources, brief sketches of concepts proposed by e.g. Ridoutt & Pfister, 2010; Pfister et al., 2011; Hoekstra et al., 2011; Zeng et al., 2012.


How to allocate the losses to the different uses of the reservoir?
Water losses - m3/year
Functions of the reservoir

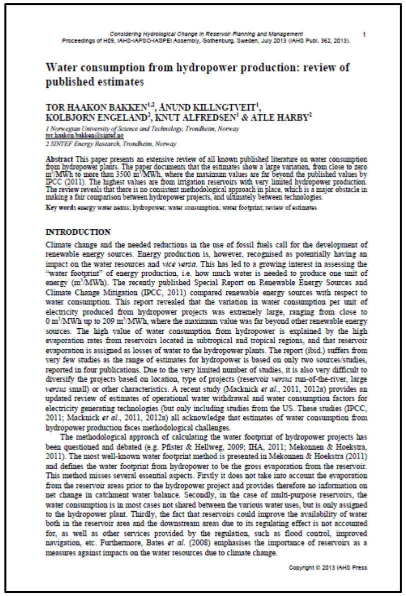
Case studies:

(1) India
(2) Egypt
(3) Spain
(6) Turkey
(7) Albania
(4) Ethiopia – Blue Nile
(5) Ethiopia – Omo River

Summed up

- The recently published values vary a lot and new studies are even far beyond values published by IPCC (2011).
- The concept of assessment appears to be over-simplified.
- It appears as a contradiction to assign water losses to reservoirs as their main purpose is to increase the water availability for various purposes.
- The impact of the (high) water consumption/footprint values should be assessed, in a local or regional context.
- But, water losses occur and should be taken into consideration in the planning and operation of reservoirs.
- Improved quantitative descriptions of reservoirs influence on water availability needed

Documentation



Considering Hydrological Change in Reservoir Planning and Management
Proceedings of H09, IAHS-IAPSO-IASPEI Assembly, Gothenburg, Sweden, July 2013 (IAHS Publ. 362, 2013).

Water consumption from hydropower production: review of published estimates

TOR HAAKON BAKKEN[1,2], ÅNUND KILLINGTVEIT[1], KOLBJØRN ENGELAND[2], KNUT ALFREDSEN[1] & ATLE HARBY[2]

INTRODUCTION

Copyright © 2013 IAHS Press

Bakken, T.H., Killingtveit, Å., Engeland, K., Alfredsen, K., & Harby, A. (2013) Water consumption from hydropower production: review of published estimates. IAHS-AISH publication. volume 362.

Journal of Sustainable Development; Vol. 6, No. 8; 2013
ISSN 1913-9063 E-ISSN 1913-9071
Published by Canadian Center of Science and Education

Water Allocation With Use of the Building Block Methodology (BBM) in the Godavari Basin, India

Tor Haakon Bakken[1,2], Eva Skarbøvik[3], A. K. Gosain[4], K. Palanisami[5], Julian Sauterleute[1], Helene Egeland[2], K. R. Kakumanu[5], Nagothu Udaya Sekhar[3], Atle Harby[1], K. Tirupataiah[7] & Per Stålnacke[3]

[1] SINTEF Energy Research, Trondheim, Norway
[2] Norwegian University of Science and Technology, Trondheim, Norway
[3] Bioforsk, F. A Dahls vei 20, 1432 Ås, Norway
[4] Indian Institute of Technology Dehli, Hauz Khas, New-Dehli, India
[5] IWMI International Water Management Institute, C/O ICRISAT, Patancheru, Andhra Pradesh, India
[6] SINTEF Energy Research, Forskningsveien 3B, Pb 124 Blindern, Oslo, Norway
[7] WALAMTARI, Rajendranagar, Himayat Sagar, Hyderabad, India

Received: May 28, 2013 Accepted: July 12, 2013 Online Published: July 23, 2013
doi:10.5539/jsd.v6n8p93 URL: http://dx.doi.org/10.5539/jsd.v6n8p93

Abstract

1. Introduction

Bakken, T.H., Skarbøvik, E., Gosain, A.K., Palanisami, K.; Sauterleute, J.,Egeland, H., Kakumanu, K.R., Nagothu, S., Harby, A., Tirupataiah, K., & Stålnacke, P. (2013) Water Allocation With Use of the Building Block Methodology (BBM) in the Godavari Basin, India. Journal of Sustainable Development. volum 6 (8).

Hydrology and Earth System Sciences
An Interactive Open Access Journal of the European Geosciences Union
| EGU.eu |

Home
Online Library HESS
Online Library HESSD
Papers in Open Discussion
Volumes and Issues
Special Issues
Most Commented Papers
Full Text Search
Title and Author Search
Alerts & RSS Feeds
General Information
Submission
Review
Production
Subscription
Comment on a Paper
Journal Metrics

Article | Discussion | Related Articles

Hydrol. Earth Syst. Sci. Discuss., 10, 8071-8115, 2013
www.hydrol-earth-syst-sci-discuss.net/10/8071/2013/
doi:10.5194/hessd-10-8071-2013
© Author(s) 2013. This work is distributed under the Creative Commons Attribution 3.0 License.

Review Status
This discussion paper is under review for the journal Hydrology and Earth System Sciences (HESS).

Water consumption from hydropower plants – review of published estimates and an assessment of the concept

T. H. Bakken[1,2], Å. Killingtveit[1], K. Engeland[2], K. Alfredsen[1], and A. Harby[2]

[1]Norwegian University of Science and Technology, Department of Hydraulic and Environmental Engineering, 7491 Trondheim, Norway
[2]SINTEF Energy Research, 7465 Trondheim, Norway

Abstract. Since the report from IPCC on renewable energy (IPCC, 2012) was published; more studies on water consumption from hydropower have become available. The newly published studies do not, however, contribute to a more consistent picture on what the "true" water consumption from hydropower plants is. The dominant calculation method is the gross evaporation

Bakken, T.H., Killingtveit, Å., Engeland, K., Alfredsen, K., & Harby, A. (2013). Water consumption from hydropower plants – review of published estimates and an assessment of the concept. Hydrology and Earth System Sciences. volum 17.

Documentation

Master: Lake Turkana

NTNU – Trondheim
Norwegian University of Science and Technology

Impacts of Cascade Hydropower Plants on the flow of the River System and Water level in Lake Turkana in Omo-Ghibe Catchment, Ethiopia

Mamuye Busier Yesuf

Hydropower Development
Submission date: June 2012
Supervisor: Ånund Killingtveit, IVM

Norwegian University of Science and Technology
Department of Hydraulic and Environmental Engineering

Master: Blue Nile

NTNU – Trondheim
Norwegian University of Science and Technology

The effect of Ethiopian hydropower reservoirs on the Blue Nile River flow regime

Muez Araya Tefferi

Hydropower Development
Submission date: June 2012
Supervisor: Ånund Killingtveit, IVM

Norwegian University of Science and Technology
Department of Hydraulic and Environmental Engineering

Master: Water indices

Technische Universität Braunschweig
LWI Leichtweiß-Institut

NTNU – Trondheim
Norwegian University of Science and Technology
Department of Hydraulic and Environmental Engineering IVM

Academic paper
submitted to attain the degree of

"Master of Science"

in the degree course Environmental Engineering

at the
Department of Hydraulic Engineering

of

Prof. Dr.-Ing. habil. Andreas Dittrich

Evaluation of methods measuring the water consumption of hydropower

Handed in by:
Sören Weichert
Matr.-Nr.: 3019020

Assistant Professor:
Knut Alfredsen
Professor, IVM, NTNU

Supervisor:
Tor Haakon Bakken
PhD Candidate, IVM, NTNU

Braunschweig, 19th November 2013

Master: Tydalen

Technische Universität Dresden

Estimation of evaporation from a Penman-Monteith model, parameterized from Eddy-Covariance measurements

Phillip Thumser

zum
Erlangen des akademischen Grades

DIPLOMINGENIEUR
(Dipl.-Ing.)

Betreuer: Bruno Giordano