

ipcc

INTERGOVERNMENTAL PANEL ON climate change



ohnthescone

# HYDROPOWER

Litteraturhuset, 23. mai, 2011

Tormod A. Schei

- **2006: process initiated**
- **2008: "Scoping" -140 experts and scientist**
  - Structure, topics, list of contents decided
- **2009: - First of 7 meetings of Lead Authors (CLAs/LAs)**
- **2011: 9<sup>th</sup> of may – Report adopted**
- **Consensus on content**



> 120 authors  
> 350 external experts – comments, inputs, corrections, 2 rounds  
194 governments and their experts – 2 rounds  
24 766 comments  
~ 4000 referred papers/reports  
~2000 comments – hydro chapter alone  
Treatment of the individual comment published online

- Brasil
- USA
- Ghana
- China
- El Salvador
- France
- Norway
  
- Objective: To be policy relevant but not policy prescriptive



## Special Report on Renewable Energy Sources and Climate Change Mitigation

1. Renewable Energy and Climate Change **Introductory Chapter**

2. Bioenergy

3. Direct Solar Energy

4. Geothermal Energy

5. Hydropower

6. Ocean Energy

7. Wind Energy

**Technology Chapters**

8. Integration of Renewable Energy into Present and Future Energy Systems

9. Renewable Energy in the Context of Sustainable Development

10. Mitigation Potential and

11. Policy, Financing and Imp

World Summit on Sustainable Development (Johannesburg 2002)  
al hydro renewable

Bonn International Conference on Renewable Energies (2004) –  
large hydro proposed to be excluded - this was rejected

- 14 575 TWh/yr –  
> four times  
current annual  
generation

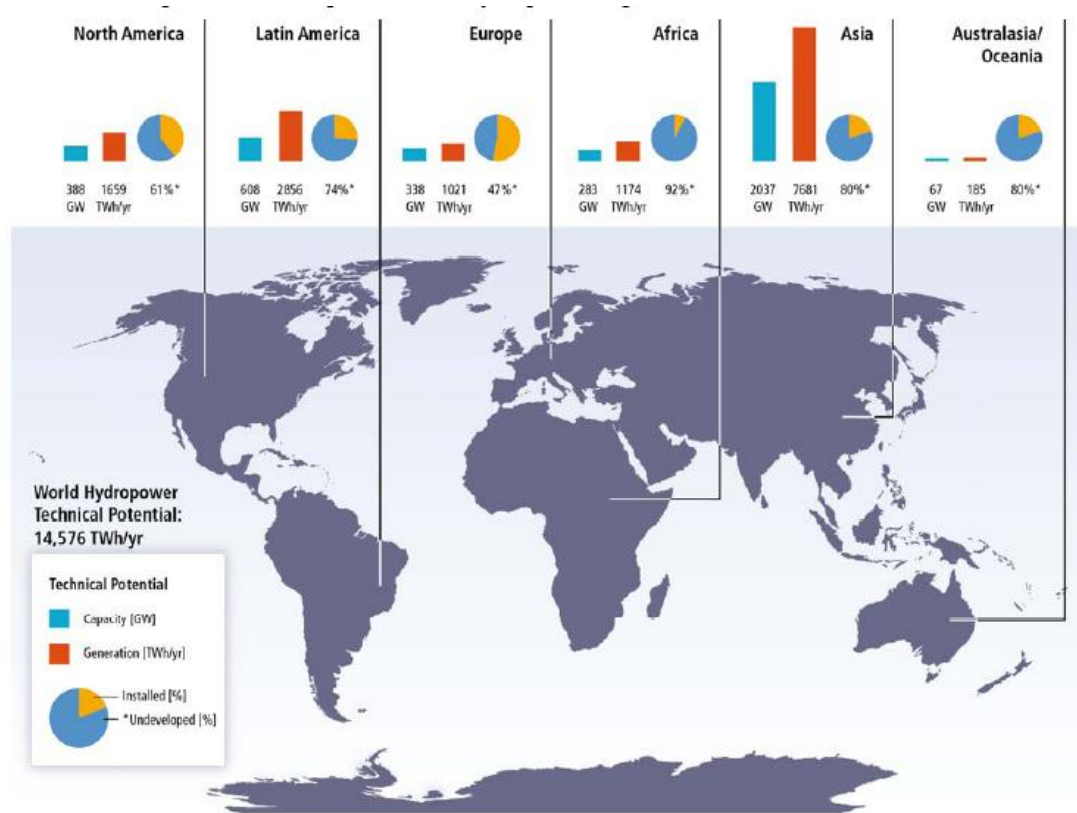
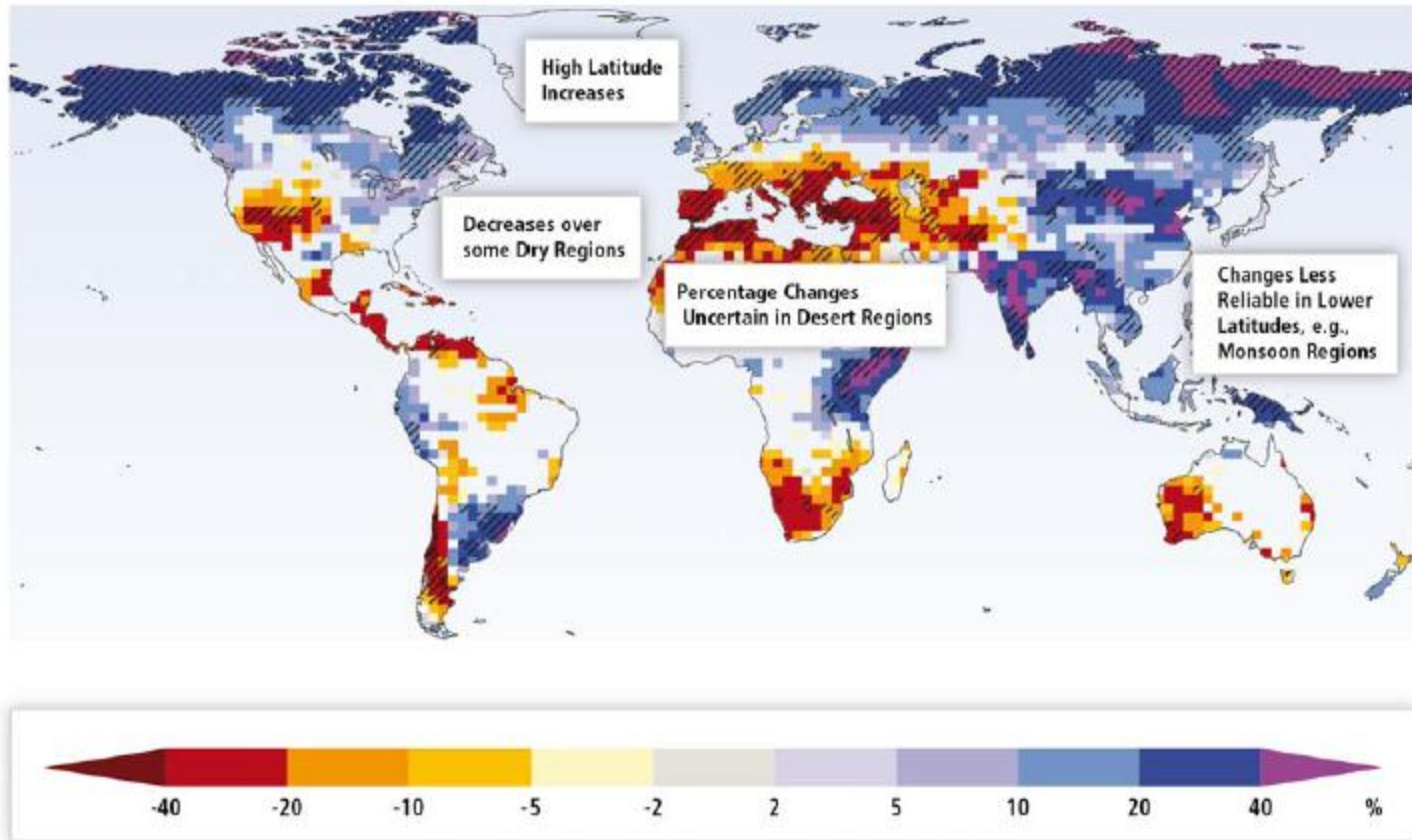


Figure 5.2 | Regional hydropower technical potential in terms of annual generation and installed capacity, and percentage of undeveloped technical potential in 2009. Source: IJHD (2010).

World region	Technical potential, annual generation TWh/yr (EJ/yr)	Technical potential, installed capacity (GW)	2009 Total generation TWh/yr (EJ/yr)	2009 Installed capacity (GW)	Un-developed potential (%)	Average regional capacity factor (%)
North America	1,659 (5.971)	388	628 (2.261)	153	61	47
Latin America	2,856 (10.283)	608	732 (2.635)	156	74	54
Europe	1,021 (3.675)	338	542 (1.951)	179	47	35
Africa	1,174 (4.226)	283	98 (0.351)	23	92	47
Asia	7,681 (27.651)	2,037	1,514 (5.451)	402	80	43
Australasia/Oceania	185 (0.666)	67	37(0.134)	13	80	32
<b>World</b>	<b>14,576 (52.470)</b>	<b>3,721</b>	<b>3,551 (12.783)</b>	<b>926</b>	<b>75</b>	<b>44</b>

# Possible impact of climate change

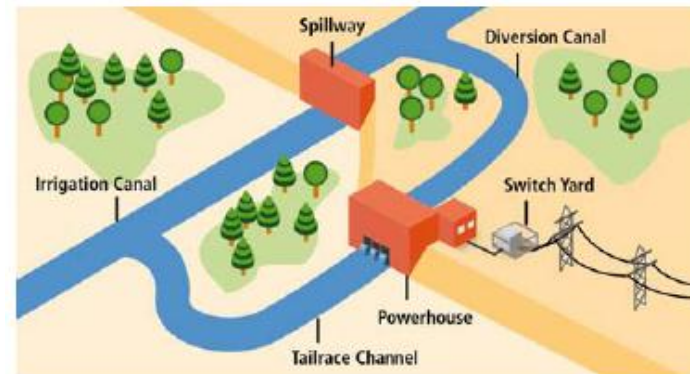
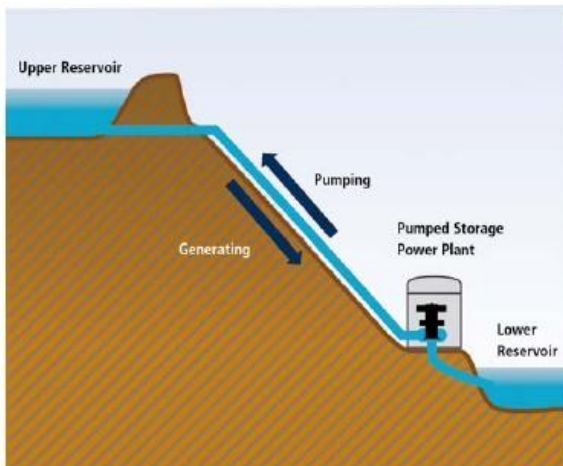
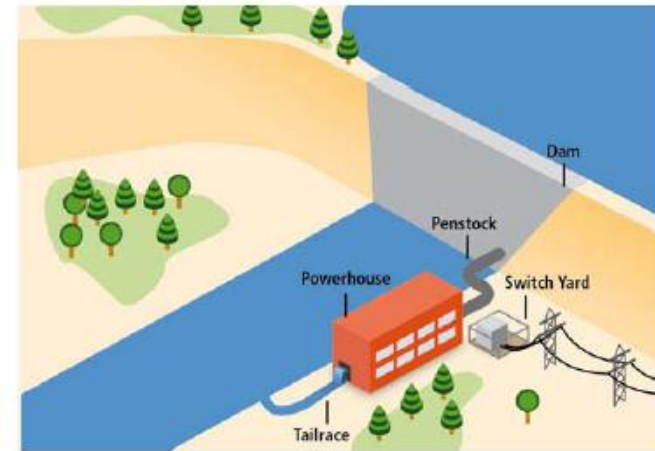
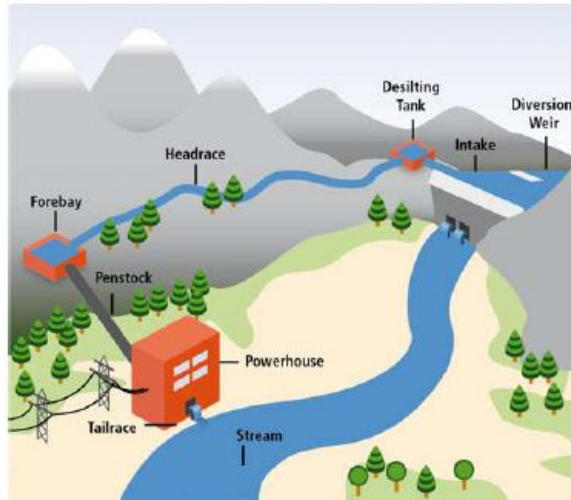


**Figure 5.4** | Large-scale changes in annual runoff (water availability, in percent) for the period 2090 to 2099, relative to 1980 to 1999. Values represent the median of 12 climate model projections using the SRES A1B scenario. White areas are where less than 66% of the 12 models agree on the sign of change and hatched areas are where more than 90% of models agree on the sign of change. Source: IPCC (2007a).

Region	Power Generation Capacity (2005)		Change by 2050 TWh/yr (PJ/yr)
	GW	TWh/yr (PJ/yr)	
Africa	22	90 (324)	0.0 (0)
Asia	246	996 (3,586)	2.7 (9.7)
Europe	177	517 (1,861)	-0.8 (-2.9)
North America	161	655 (2,358)	0.3 (≈1)
South America	119	661 (2,380)	0.3 (≈1)
Oceania	13	40 (144)	0.0 (0)
TOTAL	737	2931 (10,552)	2.5 (9)

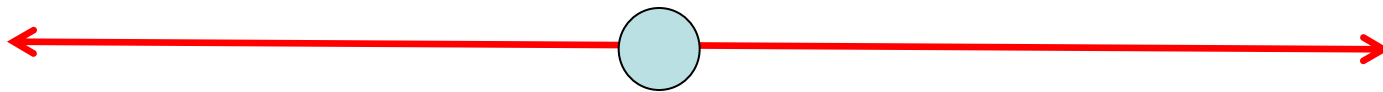
For hydropower the overall impacts on the global potential is expected to be slightly positive. However, results also indicate the possibility of substantial variations across regions and even within countries (SPM)

# Technology and applications



# No world wide definition on size classes

“Hydropower --- cover a continuum in project scale”.



MW

**Table 5.3** | Small-scale hydropower by installed capacity (MW) as defined by various countries.

Country	Small Scale Hydro as defined by installed capacity (MW)	Reference Declaration	29
Brazil	≤30	Brazil Government Law No. 9648, of May 27, 1998	
Canada	<50	Natural Resources Canada, 2009: <a href="http://canmetenergy-nrcan.gc.ca/eng/renewables/small_hydropower.html">canmetenergy-canmetenergie.nrcan-nrcan.gc.ca/eng/renewables/small_hydropower.html</a>	
China	≤50	REN 21, 2010	
EU Linking Directive	≤20	EU Linking directive, Directive 2004/101/EC, article 11a, (6)	
India	≤25	Ministry of New and Renewable Energy, 2010: <a href="http://www.mnre.gov.in/">www.mnre.gov.in/</a>	
Norway	≤10	Norwegian Ministry of Petroleum and Energy. Facts 2008. <i>Energy and Water Resources in Norway</i> ; p.27	
Sweden	≤1.5	European Small Hydro Association, 2010: <a href="http://www.esha.be/index.php?id=13">www.esha.be/index.php?id=13</a>	
USA	5–100	US National Hydropower Association. 2010 Report of State Renewable Portfolio Standard Programs (US RPS)	

“ - it may be more useful to evaluate a hydropower project on its sustainability or economic performance, thus setting out more realistic indicators.”

# Integration into broader energy systems

- Rural electrification
- decentralized
- centralized



# Support to other generation including renewable energy

- Storage hydro
- Pumped storage
- Short response time / black start
- Keeping thermal plants at their optimum
- Balancing variable RE

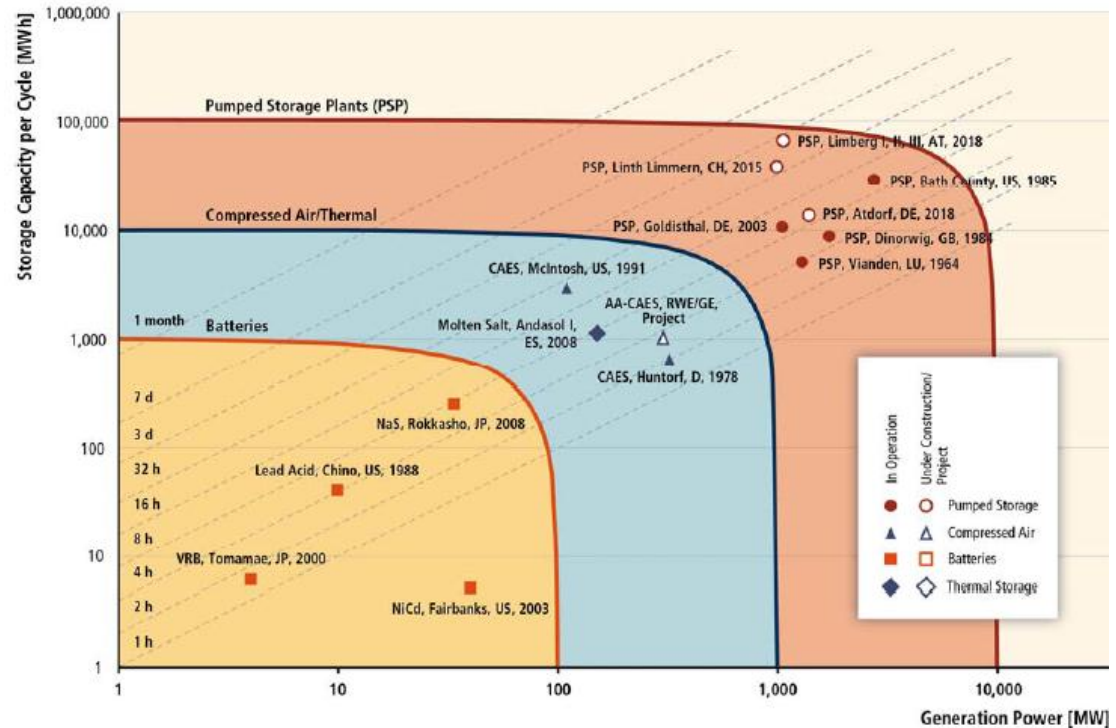
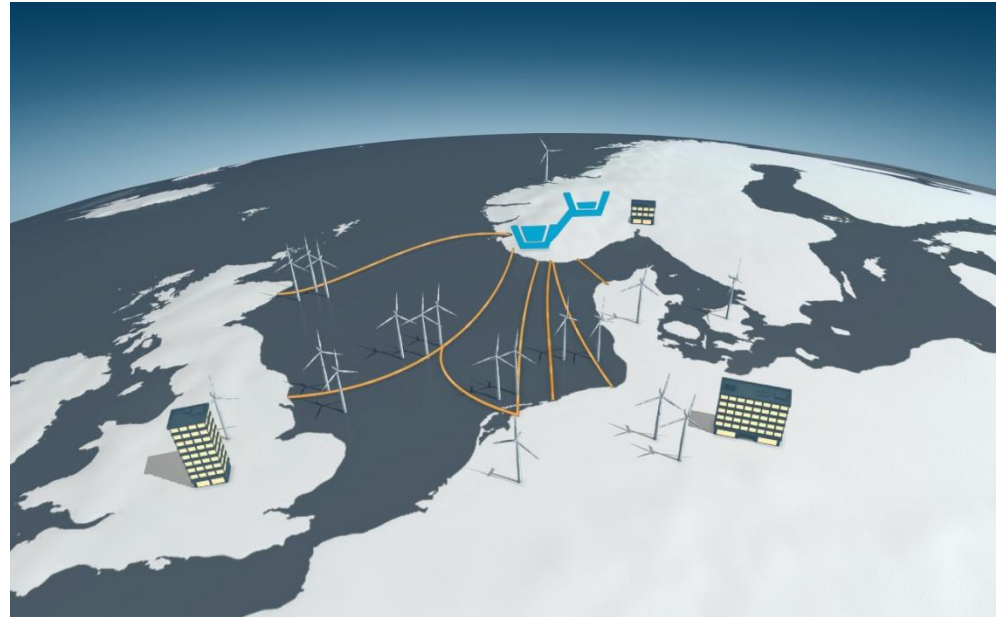


Figure 5.13 | Storage and installed capacity of selected large electricity storage sites (Vennemann et al., 2010).

Note: PSP = Pumped storage plants; CAES = compressed air energy storage, AA-CAES = advanced adiabatic compressed air energy storage; Batteries: NaS = sodium-sulfur, NiCd = nickel cadmium, VRB = vanadium redox battery.

- Securing a high penetration of variable RE in a given grid
- Norwegian storage hydro or pumped storage in a future wind driven Europe



- 11 sensitive issues identified and discussed

Hydrological regimes  
Reservoir creation  
Water quality  
Sedimentation  
Biological diversity  
Barriers for fish migration and navigation  
Involuntary population displacement  
Affected people and vulnerable groups  
Public health  
Cultural heritage  
Sharing development benefits



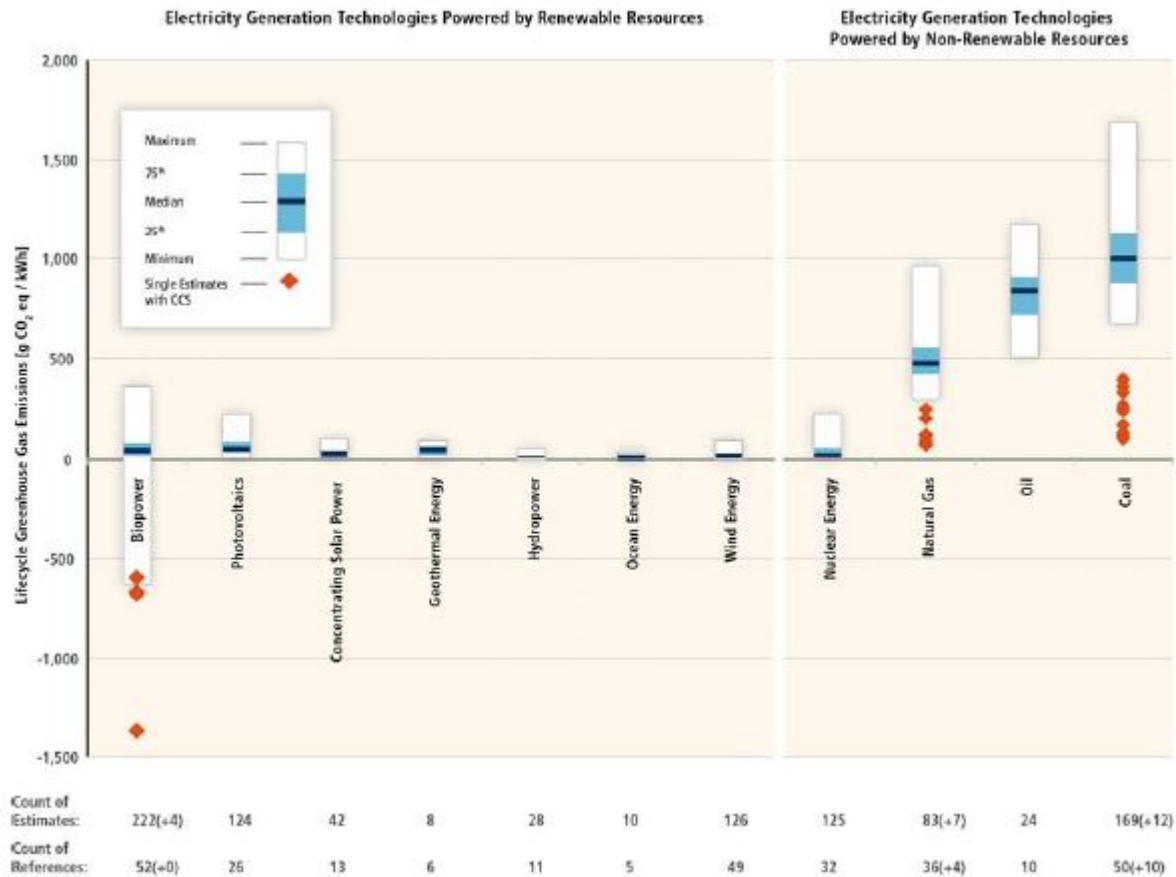
The Multiplier effect of large hydro projects:  
for every dollar of value generated – an  
additional 0,4 -1 USD<sub>2005</sub> of indirect benefits  
(WB)

- Increasingly better tools exist to enhance SD performance
  - Stakeholder involvement
  - Benefit sharing
  - EIAs
  - SIAs
  - International Guidelines and Criteria (e.g IFC, IHA)



Figure 5.14 | Evolution of environmental and social impact assessment and management (adapted from UNEP, 2007).

# Mitigating climate change



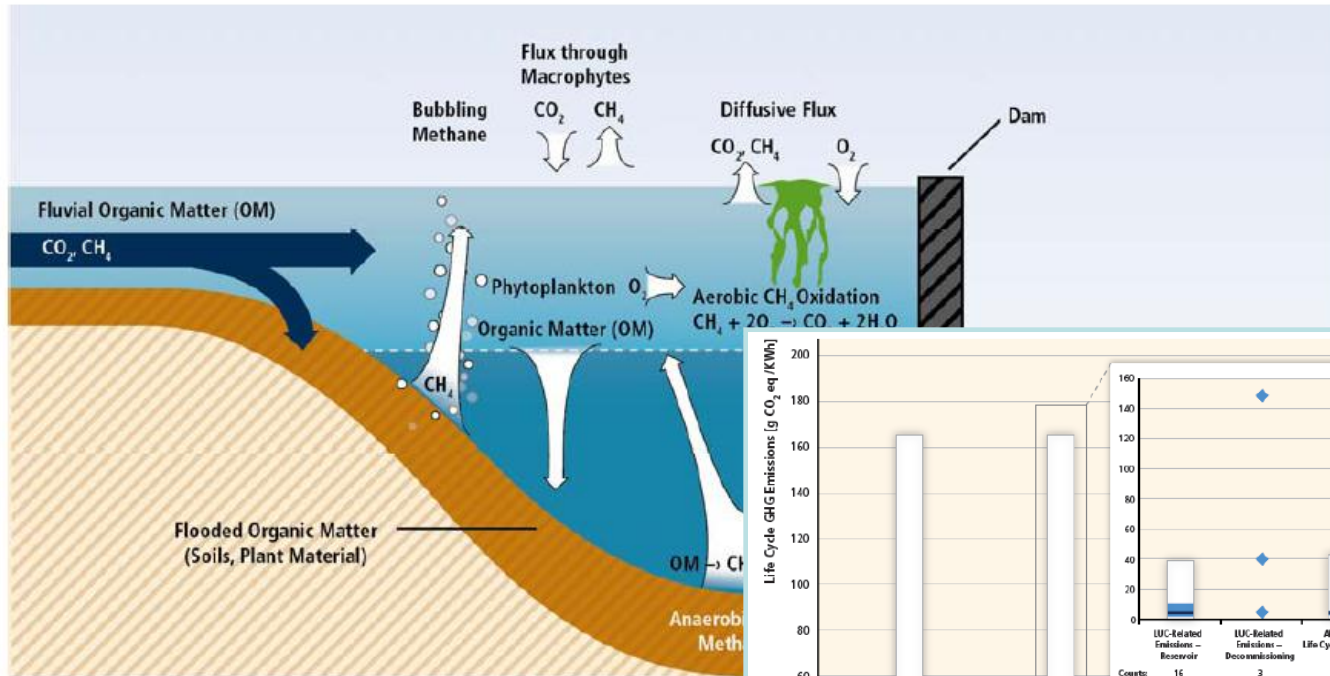


Figure 5.16 | Carbon dioxide and methane pathways in a hypolimnion (adopted from Guerin et al., 2008).

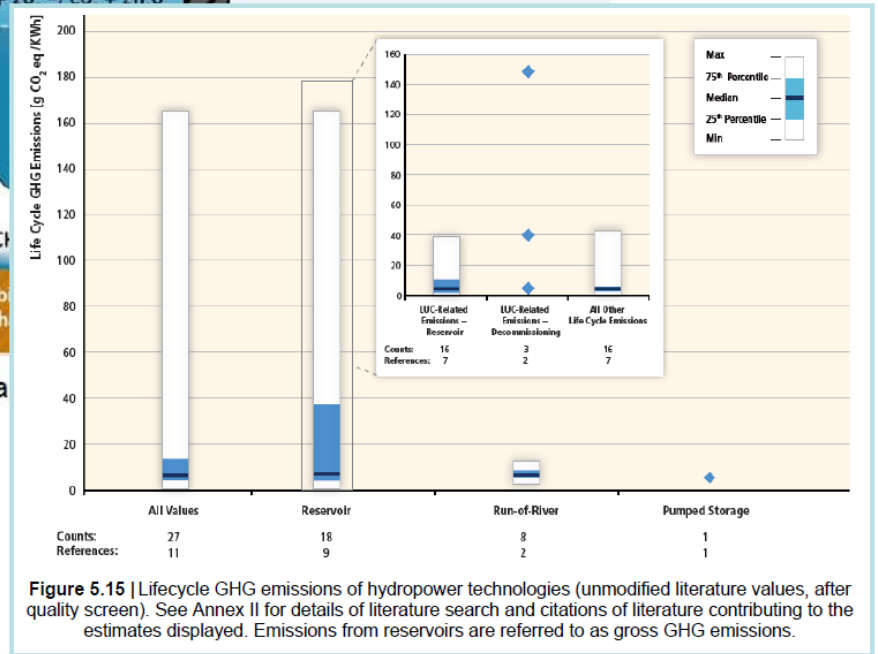
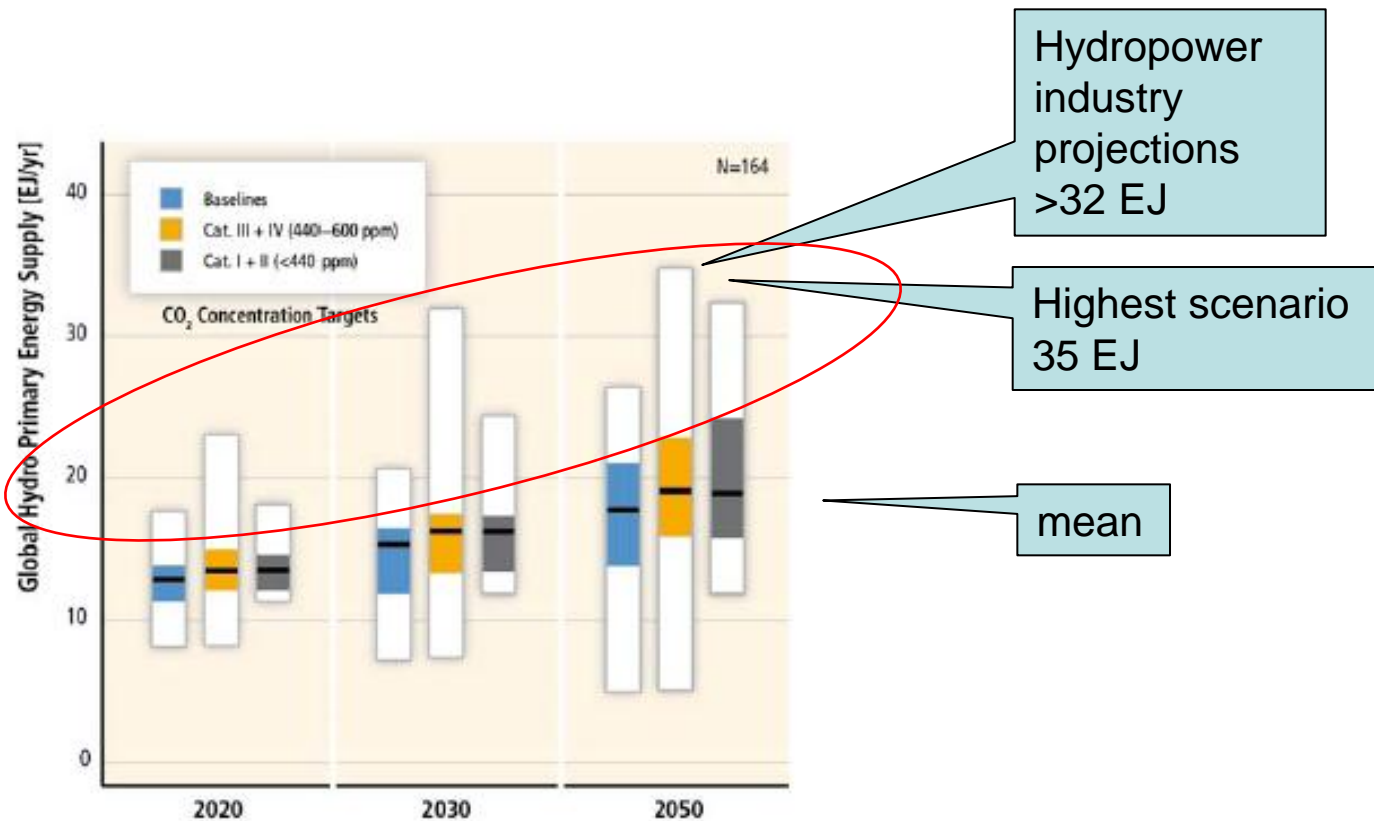
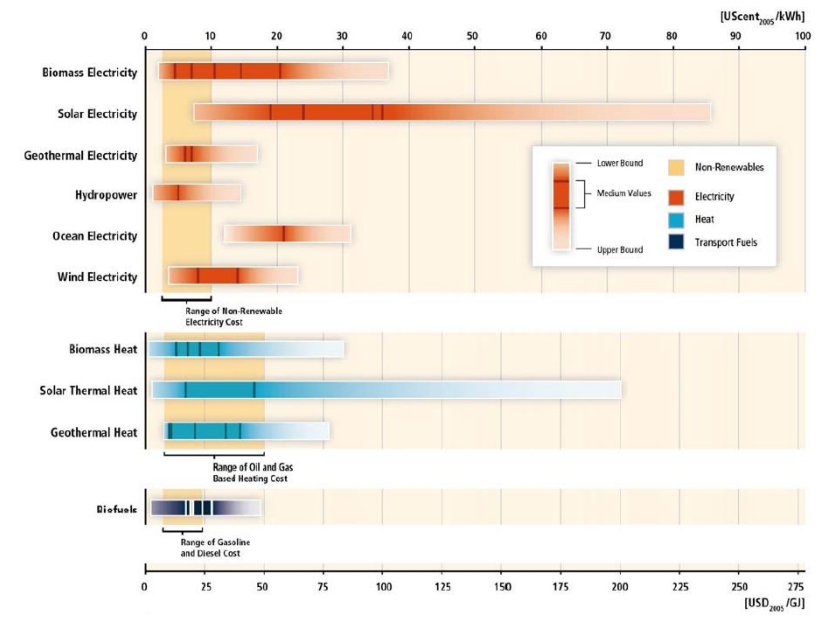


Figure 5.15 | Lifecycle GHG emissions of hydropower technologies (unmodified literature values, after quality screen). See Annex II for details of literature search and citations of literature contributing to the estimates displayed. Emissions from reservoirs are referred to as gross GHG emissions.



- 164 scenarios

- Cost →
- Payback ↘
  - Time
  - Ratio
- Lifetime
  - 60-100?
  - Most HPPs buildt still in operation
- Flexibility
- Storage



Technology	Energy payback time (years)		Most commonly stated lifetime (years)	Energy ratio (kWh <sub>e</sub> /kWh <sub>prim</sub> )	
	Low value	High value		Low value	High value
Brown coal, new subcritical	1.9	3.7	30	2.0	5.4
Black coal, new subcritical	0.5	3.6	30	2.5	20.0
Black coal, supercritical	1.0	2.6	30	2.9	10.1
Natural gas, open cycle	1.9	3.9	30	1.9	5.6
Natural gas, combined cycle	1.2	3.6	30	2.5	8.6
Heavy-water reactors	2.4	2.6	40	2.9	5.6
Light-water reactors	0.8	3.0	40	2.5	16.0
Photovoltaics	0.2	8.0	25	0.8	47.4
Concentrating solar	0.7	7.5	25	1.0	10.3
Geothermal	0.6	3.6	30	2.5	14.0
Wind turbines	0.1	1.5	25	5.0	40.0
Hydroelectricity	0.1	3.5	70	6.0	280.0

- Freshwater scarcity
  - Today about 700 million people
  - By 2035 about three billion people
- 45,000 large dams world wide
  - ~75% built for irrigation, flood control, navigation, urban water supply schemes
  - ~25% for used for hydropower alone
    - or as multipurpose reservoirs
- Multipurpose hydropower
  - e.g. water supply, irrigation, flood control, navigation, recreation, tourism, etc. – and energy
- Need for dams creating usable water
  - the HPP as enabling financial mechanism

