

Carbon Cycling in Hydropower Reservoirs

U.S. Perspectives and Prospects for Research

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Climate State of the Science: GHG Emissions from Hydro Reservoirs

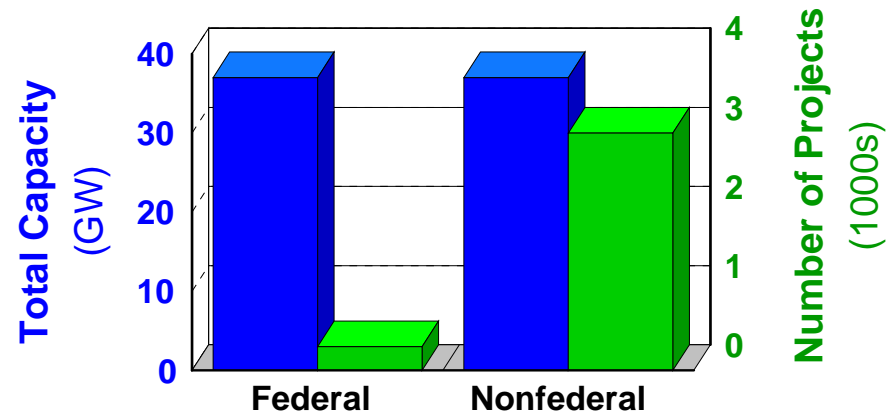
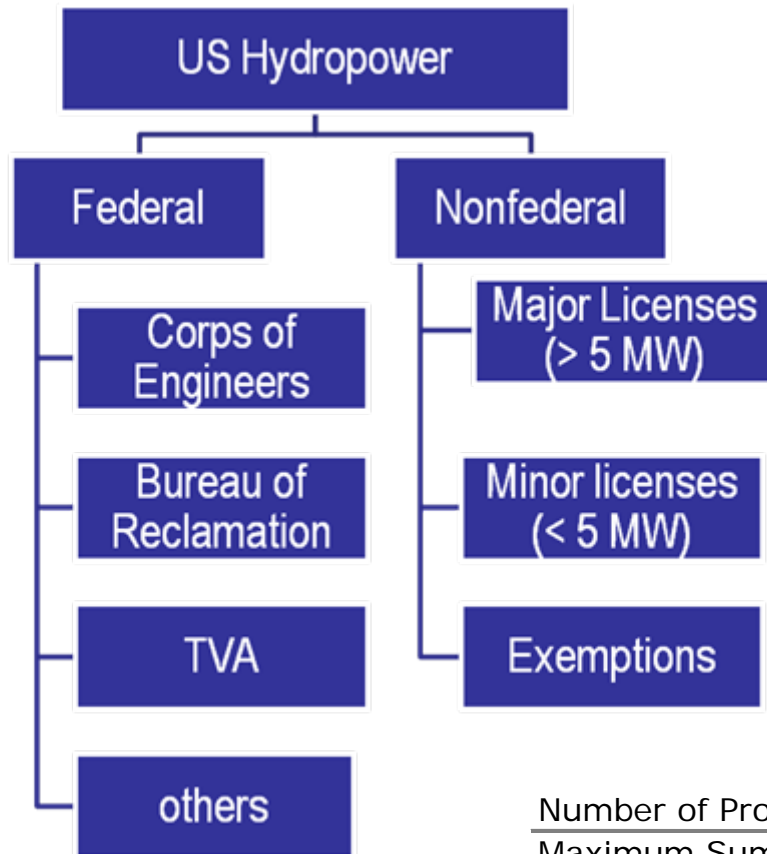
A Dialogue with Experts

17 September 2009

Hotel Delta Montreal

Montreal, QC

US Hydropower infrastructure is split between feds and nonfeds



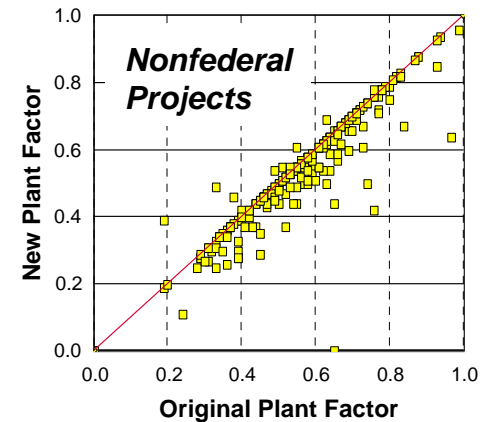
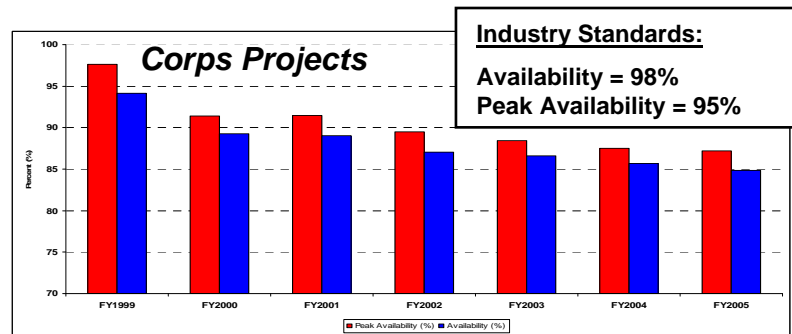
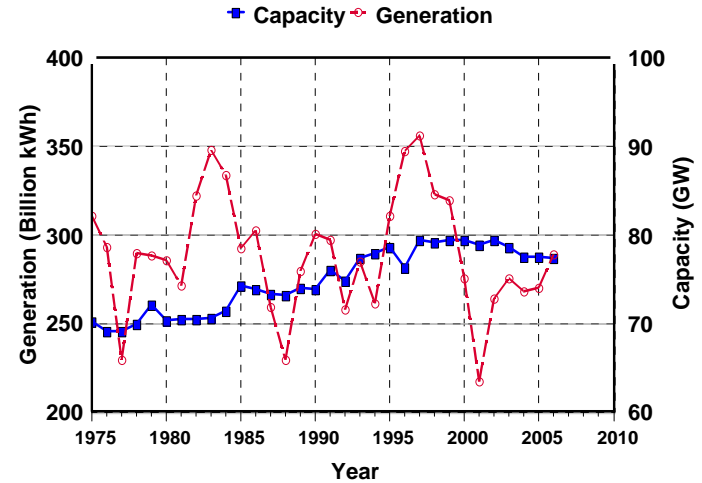
Approximately equal amounts of capacity, but 10x more nonfederal projects.

	United States		
	Federal	Non-Federal	Total
Number of Projects	156	1282	1438
Maximum Summer Capacity	42.2 GW	56.8 GW	98.9 GW
Hydro	39.4 GW	40.4 GW	79.8 GW
Pumped Storage	2.8 GW	16.3 GW	19.1 GW

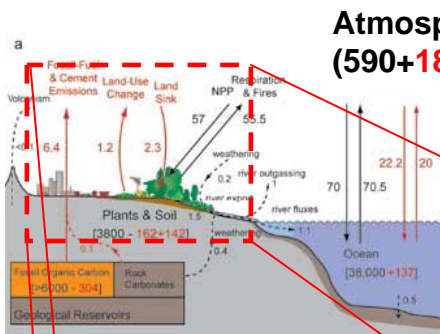
Issues Confronting US Hydropower Assets

- Hydropower capacity not increasing
- Federal projects are progressively less available for generation
- Availability of Corps projects is steadily dropping
- Nonfederal projects have lower capacity factors after relicensing (renewal if operating licenses through the FERC)
- Available industry funding is consumed in regulatory compliance and competitive markets
- Industry lacks basic project-level information (technology utilization, generation profiles, water use, etc.)
- Industry learning to quantify value of hydropower grid services

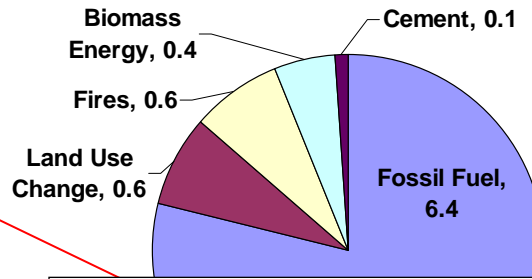
Historical trends in Capacity and Generation



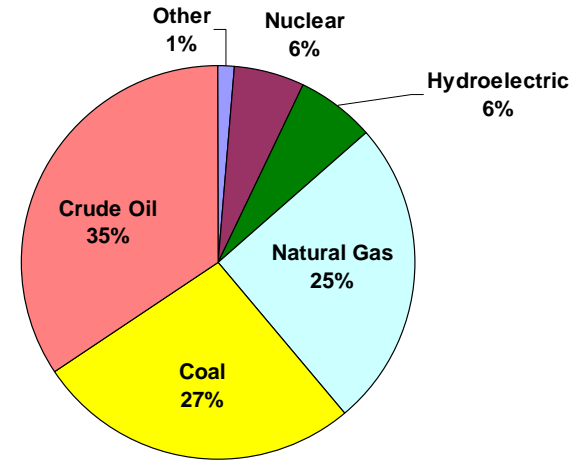
Reservoir Emissions in the Global Context



**Atmosphere
(590+187) Gt C**



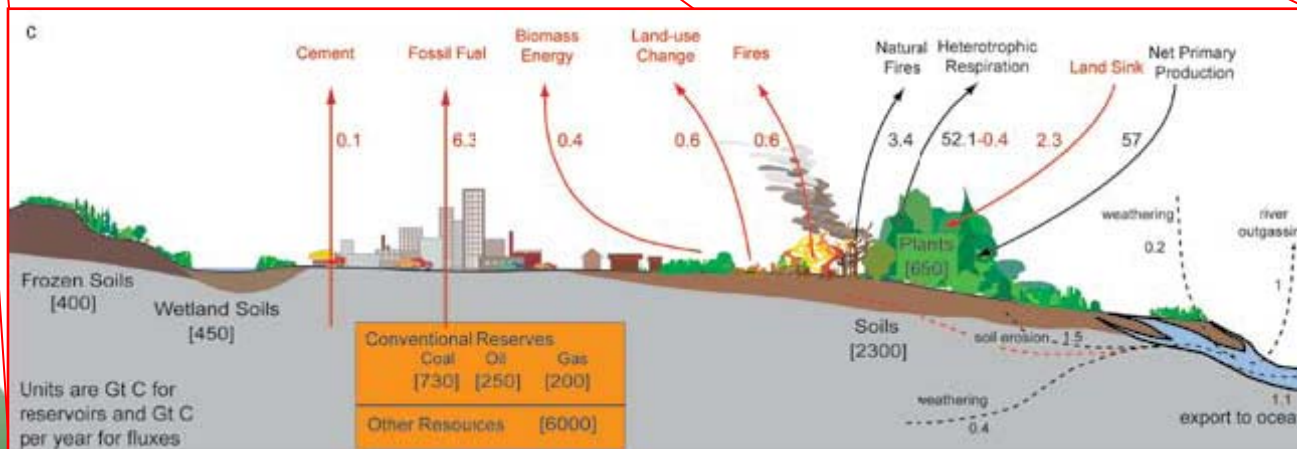
**An extrapolated estimate:
0.3 Gt C/year or 4% from water storage
reservoirs (St Louis et al. 2000)**



**World Primary Energy Production,
460 quadrillion Btu/year (2000-2005 avg)**
Source: EIA (2008)

Source: The First State of the Carbon Cycle Report (SOCCR), 2007, <http://cdiac.ornl.gov/SOCCR/>

**Human-induced fluxes to atmosphere,
8.1 Gt C/year (1990s mean values)**
Source: SOCCR (2007)



Land Components of the Global Carbon Cycle

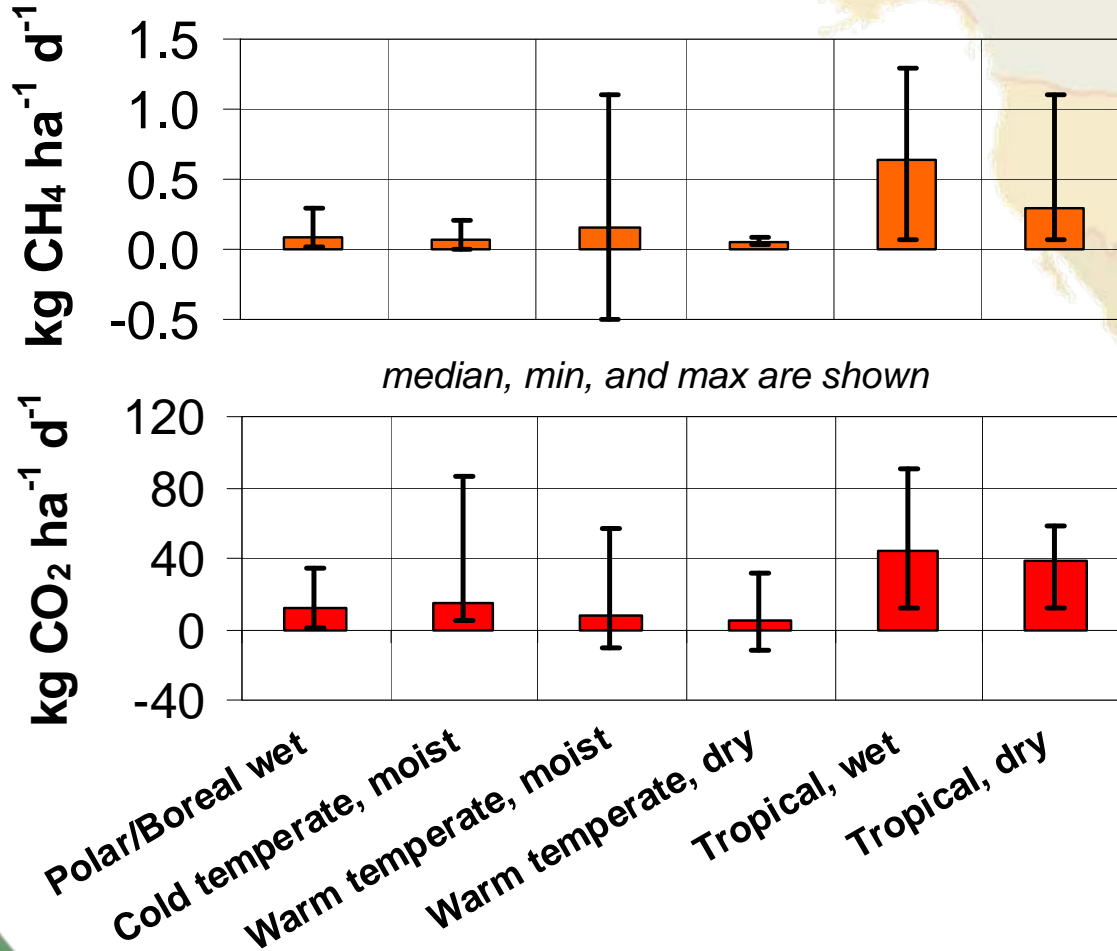
The Carbon Cycle includes:

- Fluxes
- Storage

Human-induced changes in both must be tracked!

Non Site-Specific (Default) Emissions Factors

Default factors for diffusive emissions of GHGs



IPCC-NGGIP (2006) *Guidelines for National Greenhouse Gas Inventories Vol. 4 Appendix 1, Possible Approach for Estimating CO₂ Emissions from Lands Converted to Permanently Flooded Land: Basis for Future Methodological Development*

IPCC-NGGIP (2006) *Guidelines for National Greenhouse Gas Inventories Vol. 4 Appendix 1, CH₄ Emissions from Flooded Land: Basis for Future Methodological Development*

Problems with power density as an index

CDM Executive Board: Definition of thresholds in terms of power density for hydroelectric power plants “Noting the scientific uncertainties concerning GHG emissions from reservoirs and that these uncertainties will not be resolved in the short term, a simple and transparent criteria, based on thresholds in terms of power density (installed power generation capacity divided by the flooded surface area: W/m^2), are to be used to determine the eligibility of hydroelectric power plants for CDM project activities. The thresholds are as follows:

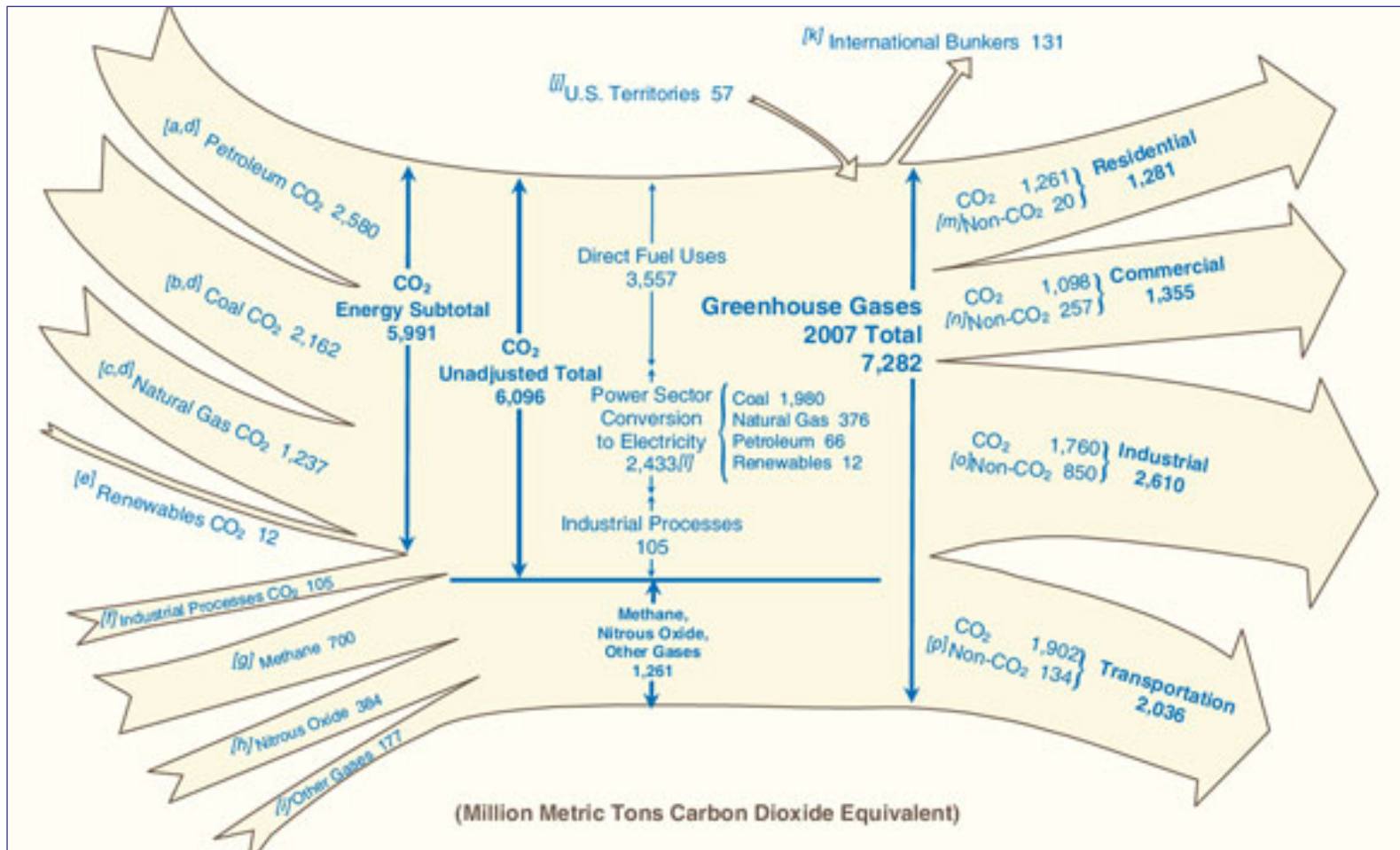
- Power densities less than or equal to $4 W/m^2$ cannot use current methodologies;
- Power densities greater than $4 W/m^2$ but less than or equal to $10 W/m^2$ can use the current [Approved Methodology], with an emission factor of $90 g-CO_2 eq/kWh$ for project reservoir emissions;
- Power densities greater than $10 W/m^2$ can use current [Approved Methodologies], and the project emissions from the reservoir may be neglected.” *Source: CDM in CHARTS, Feb. 2008*

For 245 projects worldwide greater than 30MW, average power density is $2.95 W/m^2$ (Rosa, 2005). **Many existing projects would require new methodologies to be considered under CDM—more science will be needed.**

U.S. examples of Power Density

Project	State	River	Surface Area km^2	Capacity MW	Power Density W/m^2
Conowingo - Exelon	MD	Susquehanna River	37	548	14.81
Hoover/Lake Mead - USBR	AZ-NV	Colorado River	660	2080	3.15
Wolf Creek - COE-LRN	KY	Cumberland River	203	270	1.33
Ellis / Trimble - AECC	AR	Arkansas River	28	32	1.17
Cherokee - TVA	TN	Holston River	123	124	1.01
Chatuge - TVA	NC	Hiwassee River	37	10	0.27

US Agency Perspectives



Report #: DOE/EIA-0573(2007)
Released Date: December 3, 2008

US Energy Information Administration

Reservoir GHG Forums

- IPCC-National GHG Inventories Programme (2006 Guidelines)
 - *"Possible Approach for Estimating CO₂ Emissions from Lands Converted to Permanently Flooded Land: Basis for Future Methodological Development"*
 - *"CH₄ Emissions from Flooded Land: Basis for Future Methodological Development"*

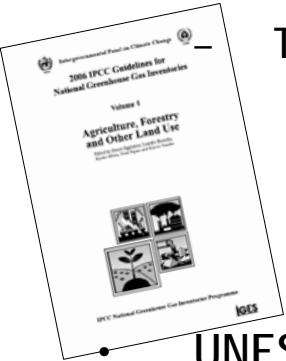
Tiered levels of detail:

1. Aggregate area data and default emissions factors – diffusive only, 10-year limit
2. Country-specific emissions factors
3. Disaggregated areas and factors, detailed measurements, lifetime emissions, ALL fluxes and pathways, differentiates flooded-matter vs. watershed organic loadings

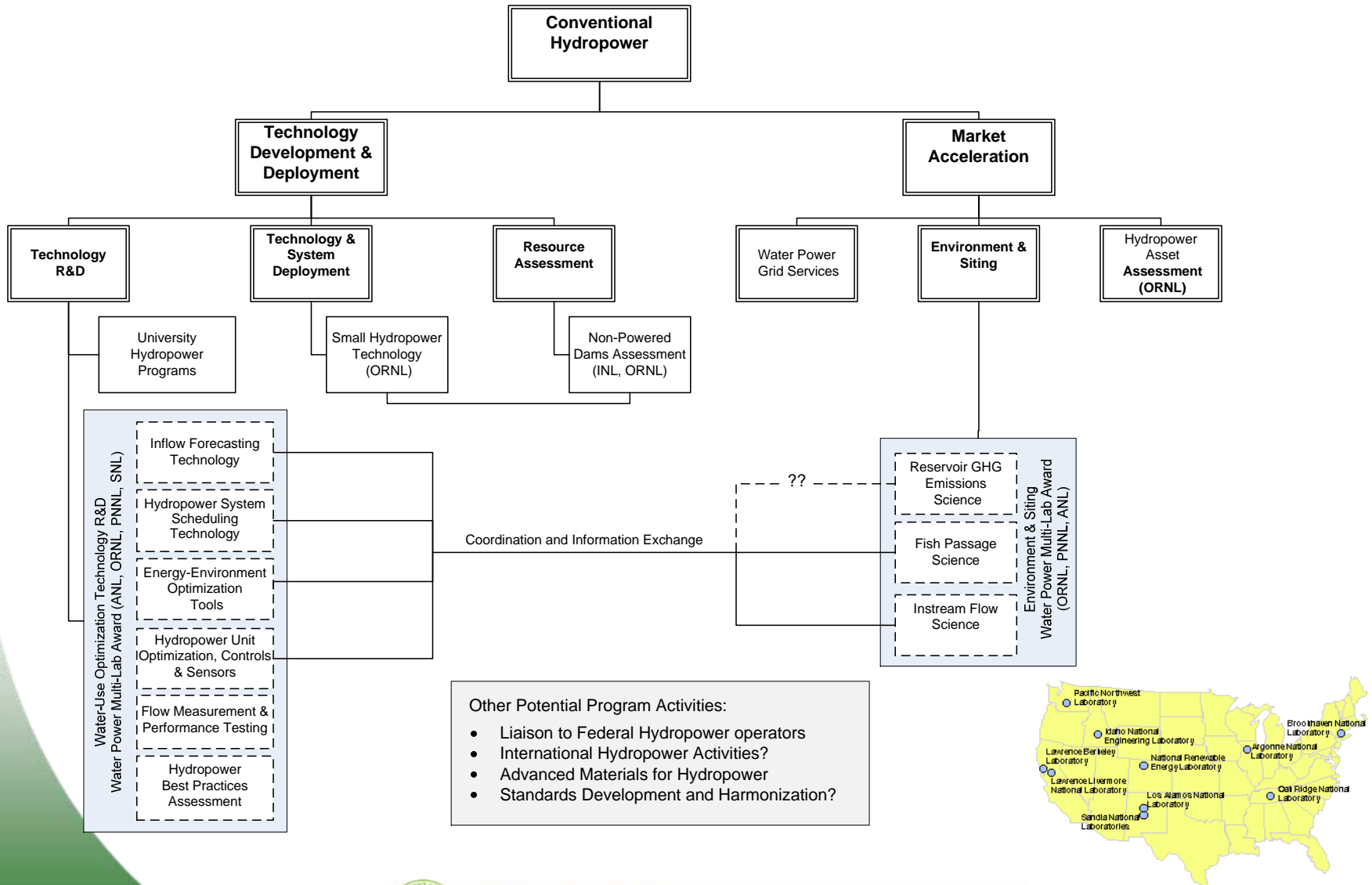
UNESCO-IHA Reservoir GHG Research Initiative – Site Specific Assessment

- Development of reservoir GHG knowledge base
- Coordinated field measurements of carbon transport and GHG emissions
- Develop methodology to assess reservoir impact on the natural carbon cycle
- Empirical and process-based predictive modeling of reservoir impact
- Development of mitigation measures

US-DOE sponsored effort to will be coordinated with IHA/UNESCO



US-DOE Water Power Program is addressing the issue



- Other Potential Program Activities:
- Liaison to Federal Hydropower operators
 - International Hydropower Activities?
 - Advanced Materials for Hydropower
 - Standards Development and Harmonization?



Important Study Criteria for US effort

- A study of reservoir carbon cycling impacts must
 - place site-specific data and analysis for US reservoirs into peer-reviewed literature
 - enable comparison to tropical and boreal assessments
 - address possibility of seasonal and regional variability in US reservoirs
 - address carbon cycling as a function of reservoir age
 - establish the level of sensitivity of carbon cycling modifications (including emissions) to water management policies.
 - address long-term monitoring needs for demonstration cases

Important Study Criteria for US effort

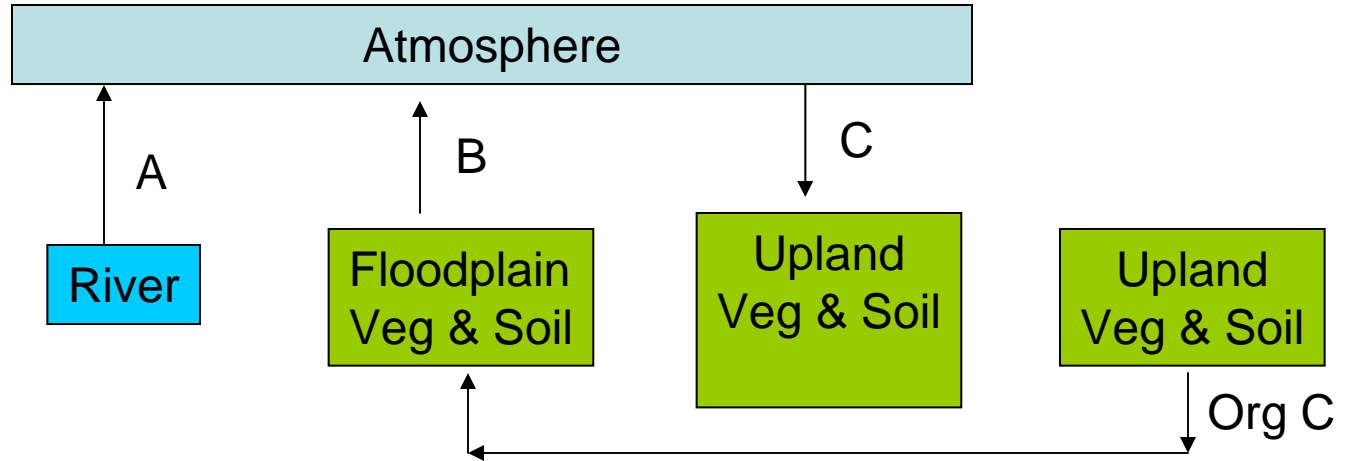
- Desirable study features
 - tiered risk assessment capability for large and small hydropower projects across US
 - automated assessment of reference watersheds for net analysis
 - leveraging of site-specific investments in water quality monitoring and modeling for re-licensing and water management policy analysis
 - support for future modeling efforts

Preliminary Concepts

Net Reservoir GHG emissions: CH₄
(E+F) - (A+B-C)

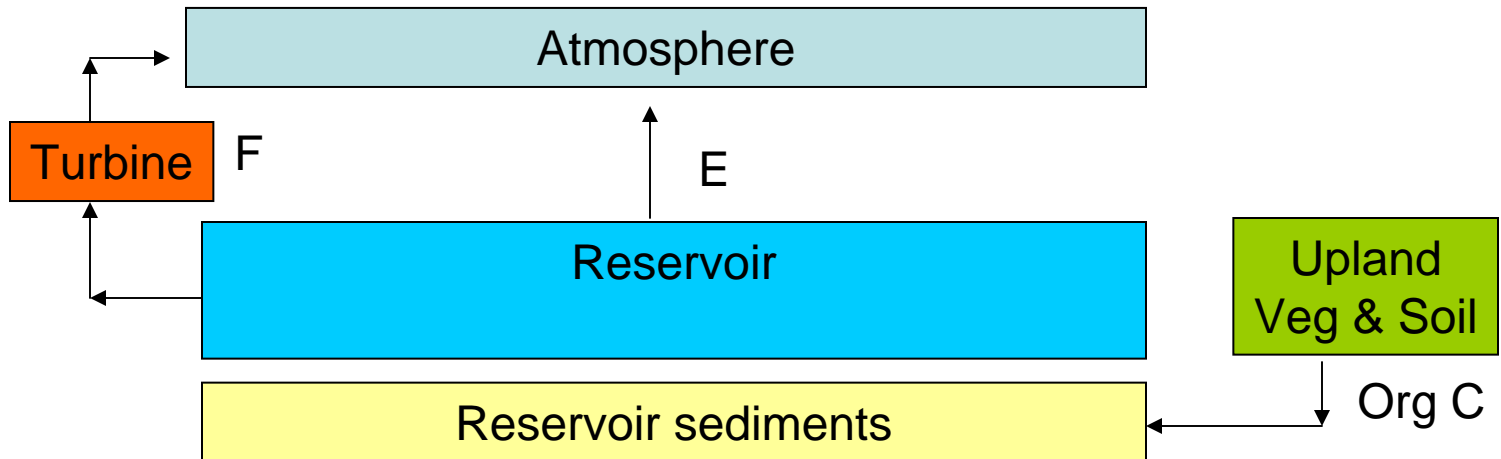
----- Area flooded by reservoir -----

Prior to Reservoir



Source: Pat Mulholland, ORNL

Post Reservoir Construction



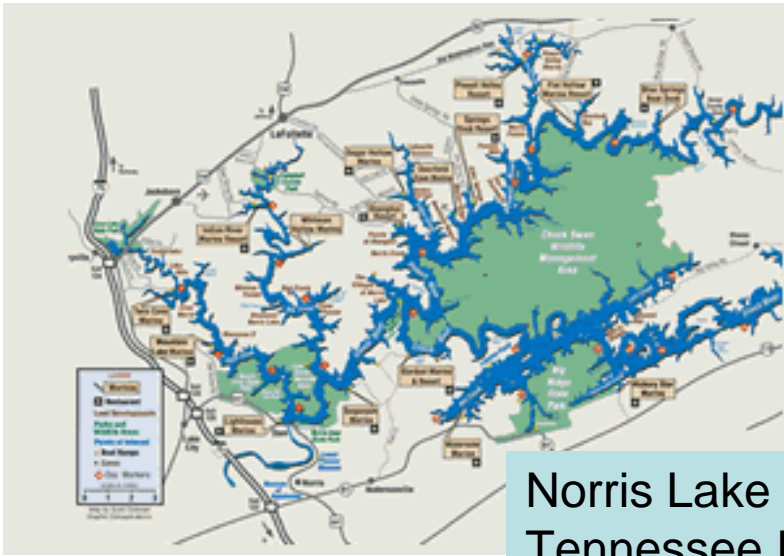
U.S. Department of Energy
Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable



ELECTRIC POWER RESEARCH INSTITUTE





Norris Lake
Tennessee River Basin, US



Demo Site Selection and Bases for Parameterization

Site Selection:

- Existing field sampling in place
- Operational water quality systems
- Calibrated WQ model availability

Ecoregions??

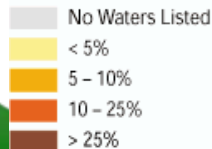
U.S. Population Density
(By Counties)

Development
Indexes??

Impaired Waters??

Basin Network??
Water Management??

Percent of
Impaired
Waters-1998
(Updated Feb. 2000)



Path Forward

- US-DOE effort begins in October 2009 as follow-on to EPRI scoping effort
- Partners: DOE, Oak Ridge and Pacific Northwest National Labs, EPRI, others TBD
- Funding will provide programmatic equipment inventory, field study expenses, analysis, publications
- Schedule:
 - Oct 2009 – Aug 2010: Sampling and analysis methodology testing in southeast US reservoir, site selection of multiple demonstration sites
 - 2010-2011: Field campaigns initiated in four US reservoirs
 - 2011-2012: Field campaigns conducted in additional 4 reservoirs
 - 2012: Final report and recommendations for long-term monitoring
- US-DOE may provide input to IEA-Hydropower Agreement

- Questions and follow-up info

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