

# *Life-Cycle Analysis of Water Use for Hydrogen Production Pathways*

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The 2013 DOE Fuel Cell Technologies Program Annual Merit Review and Peer Evaluation Meeting

Arlington, VA

May 14, 2013

Project ID: an039

# ***Project Overview***

## **Timeline**

- Start: April 2013
- End: Oct. 2013
- % complete: 15%

## **Budget**

- Funding received in FY12: \$0K
- Funding for FY13: \$100K

## **Barriers to Address**

- Indicators and methodology for evaluating sustainability
- Overcome inconsistent data, assumptions, and guidelines
- Develop models and tools
- Conduct unplanned studies and analyses

## **Partners/Collaborators**

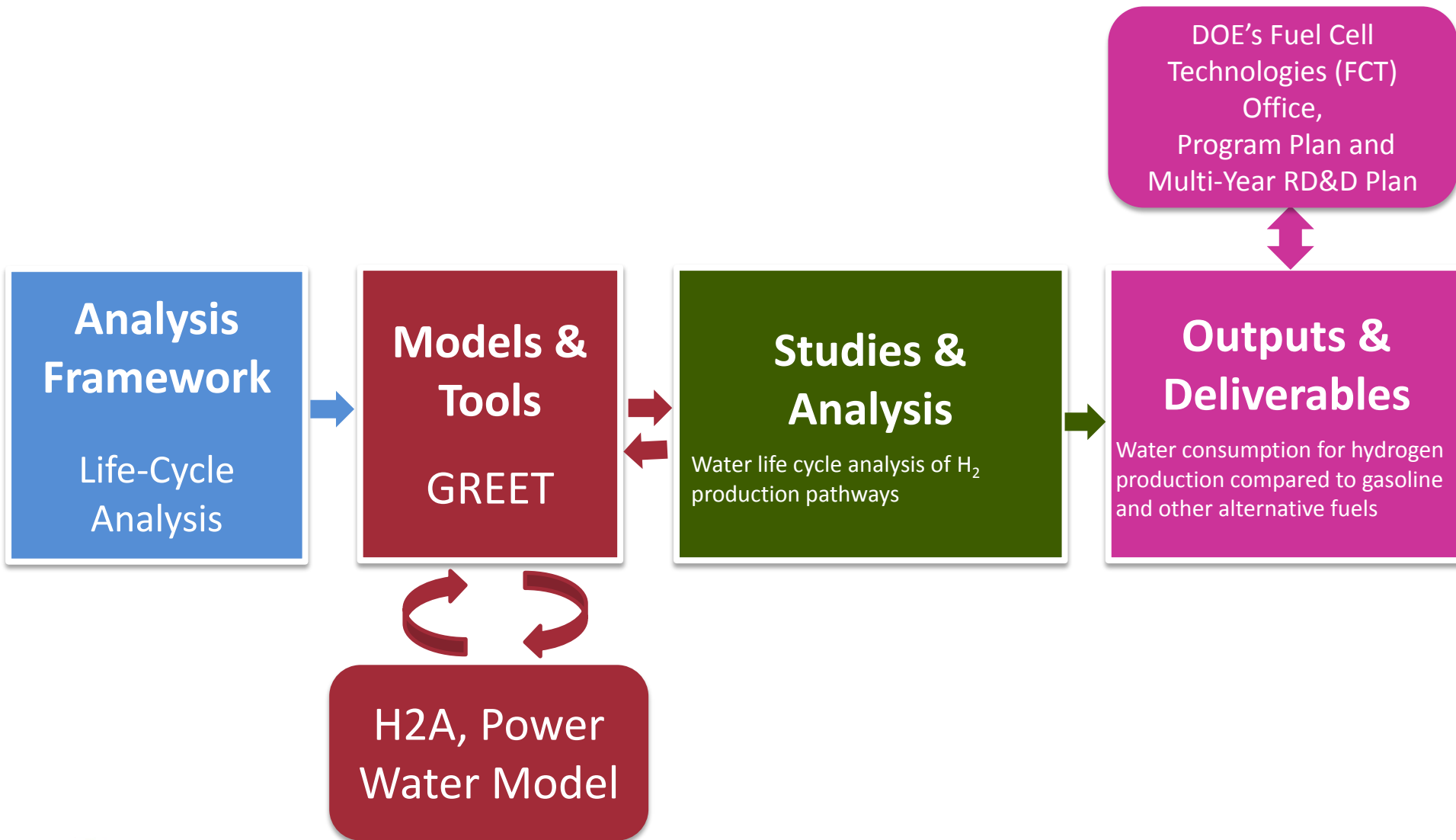
- Industry stakeholders



# Relevance

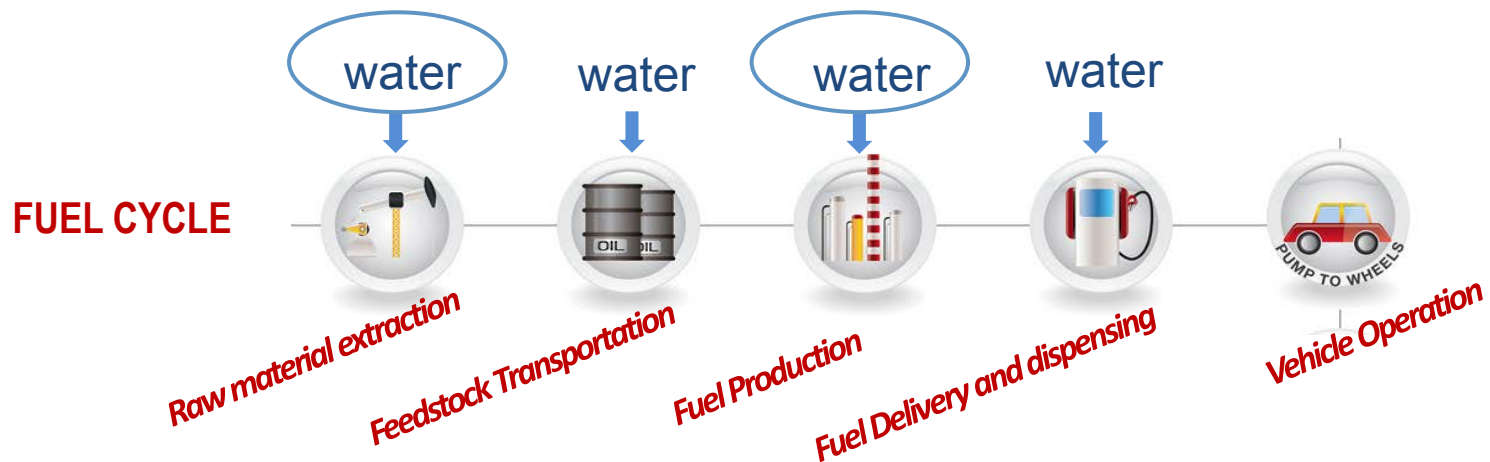
- ❑ Establish a baseline of life-cycle water consumption for baseline fuels and feedstock sources
- ❑ Evaluate water consumption for hydrogen production processes
- ❑ Assess impact of feedstock source on life-cycle water consumption for hydrogen production
- ❑ Identify major contributors in upstream supply chain to water consumption of hydrogen pathways and improvements of efficient water use
- ❑ Identify vulnerabilities with respect to resource availability by region for large scale hydrogen production

# Water LCA of Hydrogen Production Pathways



# Scope of Water LCA – Relevance

- Water consumption is not in current GREET version for any fuel pathways; Argonne water consumption analysis so far has been done outside of GREET
- New effort began recently for water consumption analysis with GREET platform
- Focus of this project is on fuel cycle water consumption for hydrogen and baseline fuels
- Assess water consumed per kg<sub>H2</sub> and per mile relative to baseline gasoline vehicle



# Approach and Data Sources

- ❑ Approach: build water LCA modeling capacity with the GREET model
  - Address water resource use across fuel production stages, with focus on production of feedstocks and fuels
  - Address emerging water LCA issues related to H<sub>2</sub> fuel pathways
  - Develop consistent methodology and system boundary
  - Maintain openness and transparency of LCAs
- ❑ Data Sources:
  - Water consumption data inventory and assessment tools developed at Argonne so far
  - ANL Power Water model
  - H2A models
  - Open literature

# Key Milestones

- ❑ Evaluate water consumption for hydrogen production
  - Process water
  - Cooling water (wet vs. dry, once through vs. recycling)
  - Upstream and indirect water use
- ❑ Hydrogen pathways for initial evaluation:
  - Steam methane reforming of conventional and shale gas
  - Electrolysis with various power plant types
  - Biomass gasification with corn stover, forest residues, and dedicated energy crops
- ❑ Examine water consumption for baseline fuels and major feedstocks and process fuels – update of past ANL estimates
  - Gasoline and diesel from petroleum (conventional oil and oil sands)
  - Electricity generation (fossil, non-fossil, renewables)
  - Biomass feedstocks and biofuels

# Hydrologic Cycle – Approach

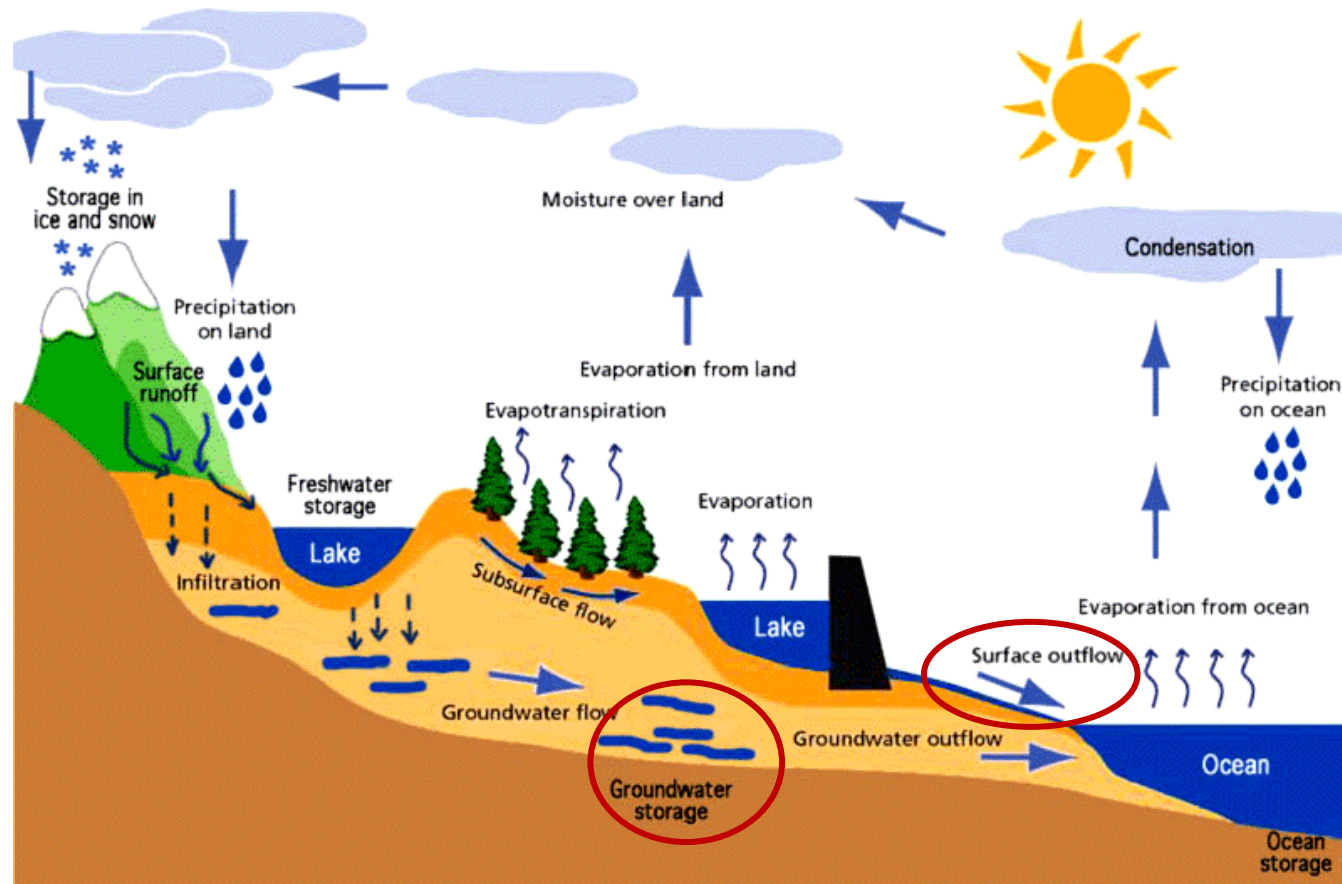
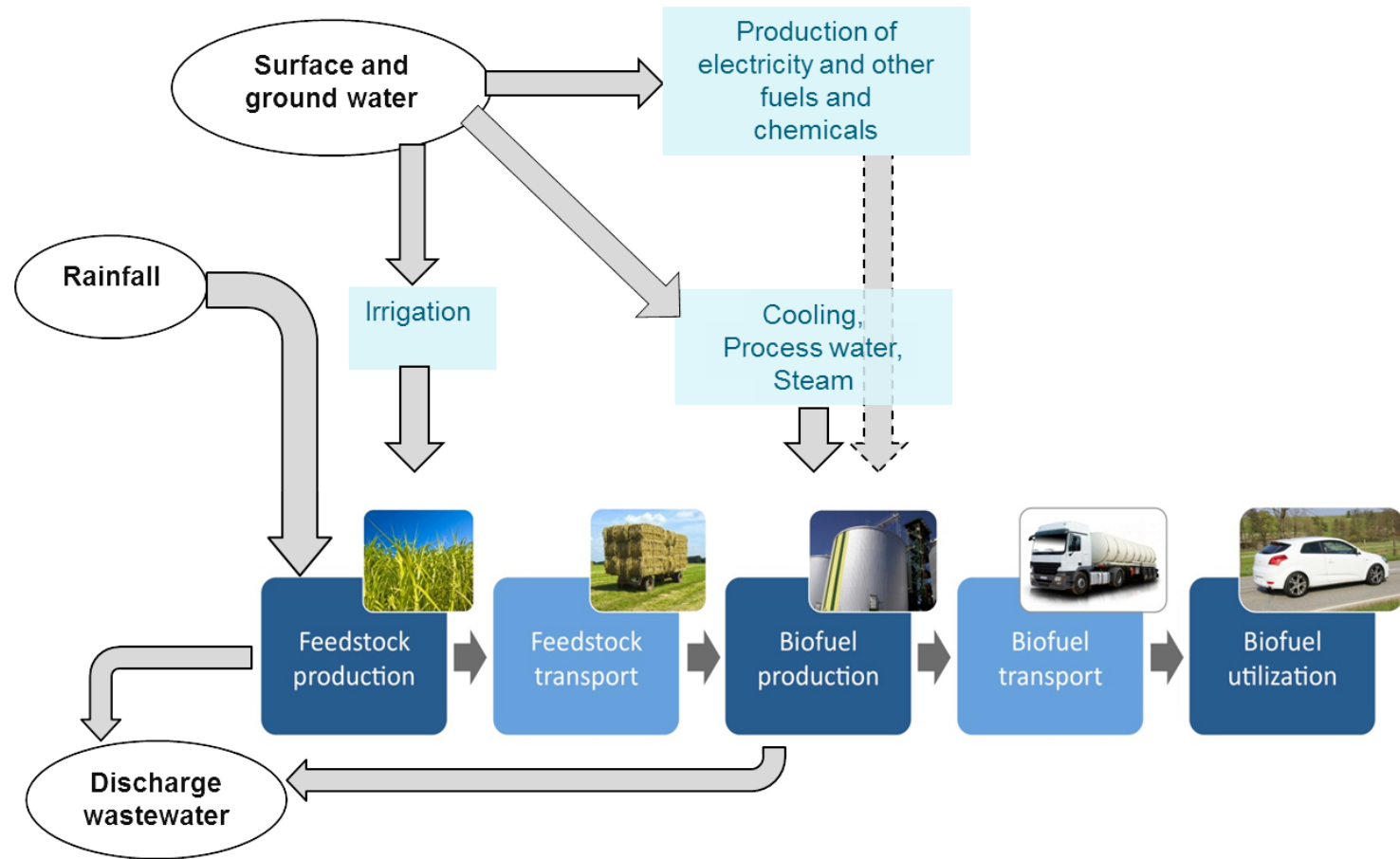


Image from: [http://uncloaked.files.wordpress.com/2012/03/hydrologic\\_cycle.gif](http://uncloaked.files.wordpress.com/2012/03/hydrologic_cycle.gif)

- Only fresh surface water and groundwater will be considered for water LCA



# Biofuel Water Footprint Accounting – Approach



- Water withdrawal: fresh water uptake from surface or groundwater
- Water consumption: net water consumed through the production process (evaporated or incorporated into the product)
- Fuel pathway water LCA in this analysis: accounts for water consumption of LCA stages of fuel pathways

# *Water use analysis at Argonne – Relevance*

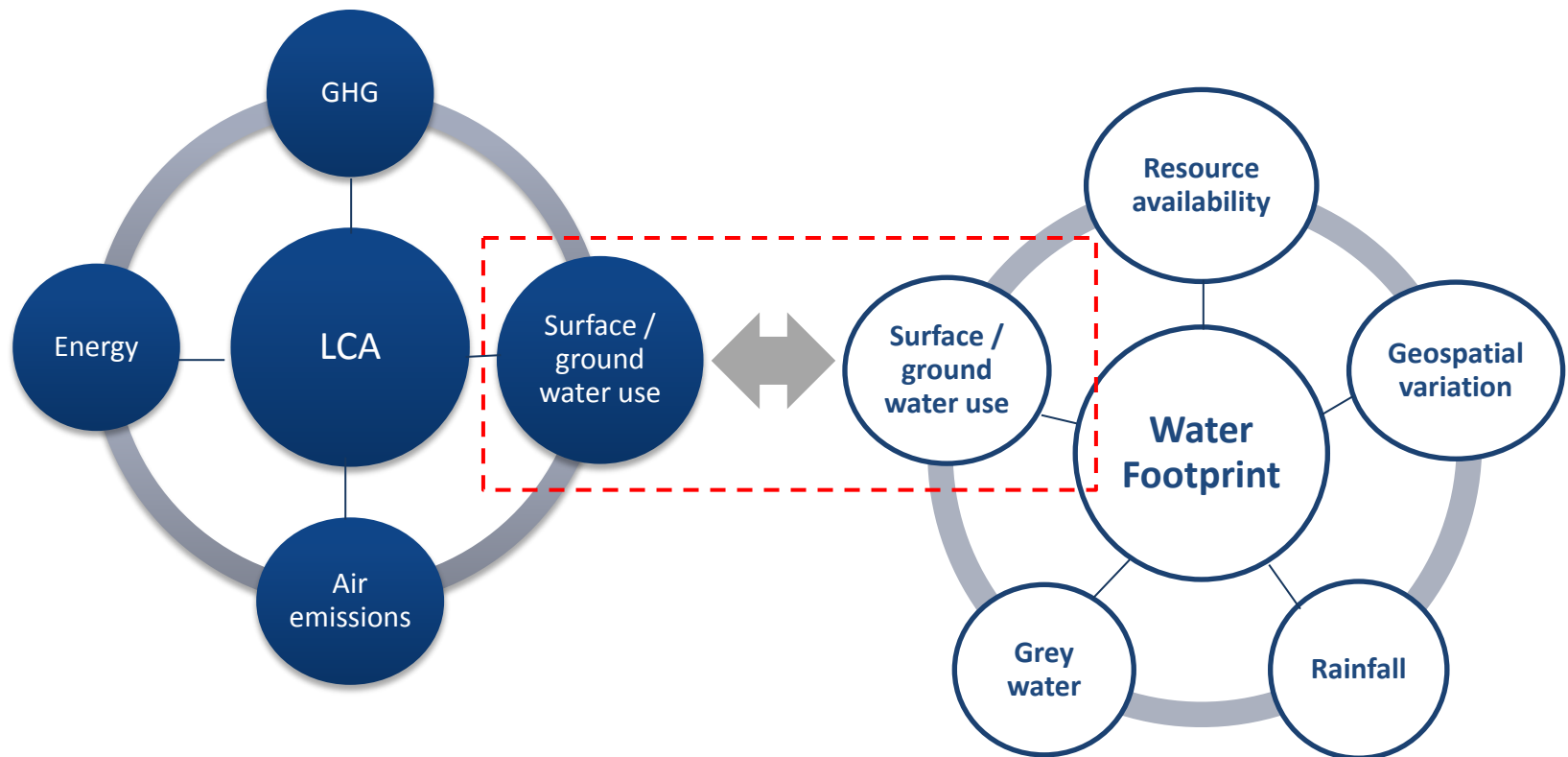
- ❑ Supported by BETO since 2007, Argonne assessed water use for:
  - ✓ Water consumption of biofuels
  - ✓ Water consumption of petroleum gasoline and diesel
  - ✓ Water withdrawal of electricity generation (fossil, non-fossil, renewables)
- ❑ Supported by VTP, currently assessing water use for conventional and shale gas

Selected Argonne reports on water analysis:

<http://greet.es.anl.gov/publication-consumptive-water>

<http://greet.es.anl.gov/publication-watertool>

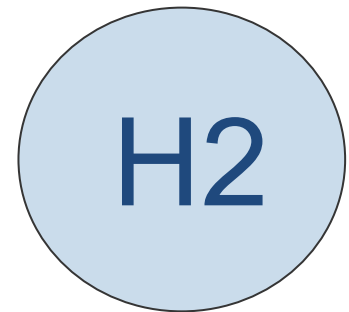
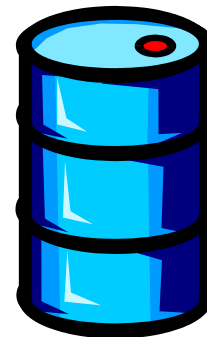
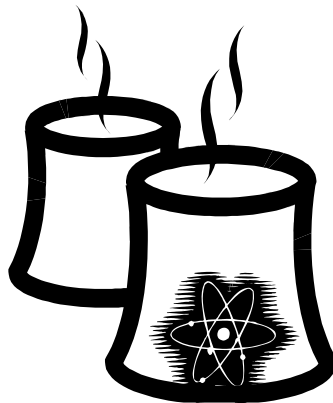
# Linkage of Water Resource Assessment and LCA – Relevance



- ❑ Water resource (or water footprint) assessment is spatially specific
- ❑ LCA addresses total water use along fuel production pathways
- ❑ Water footprint assessment completed so far provides data needed for water LCA

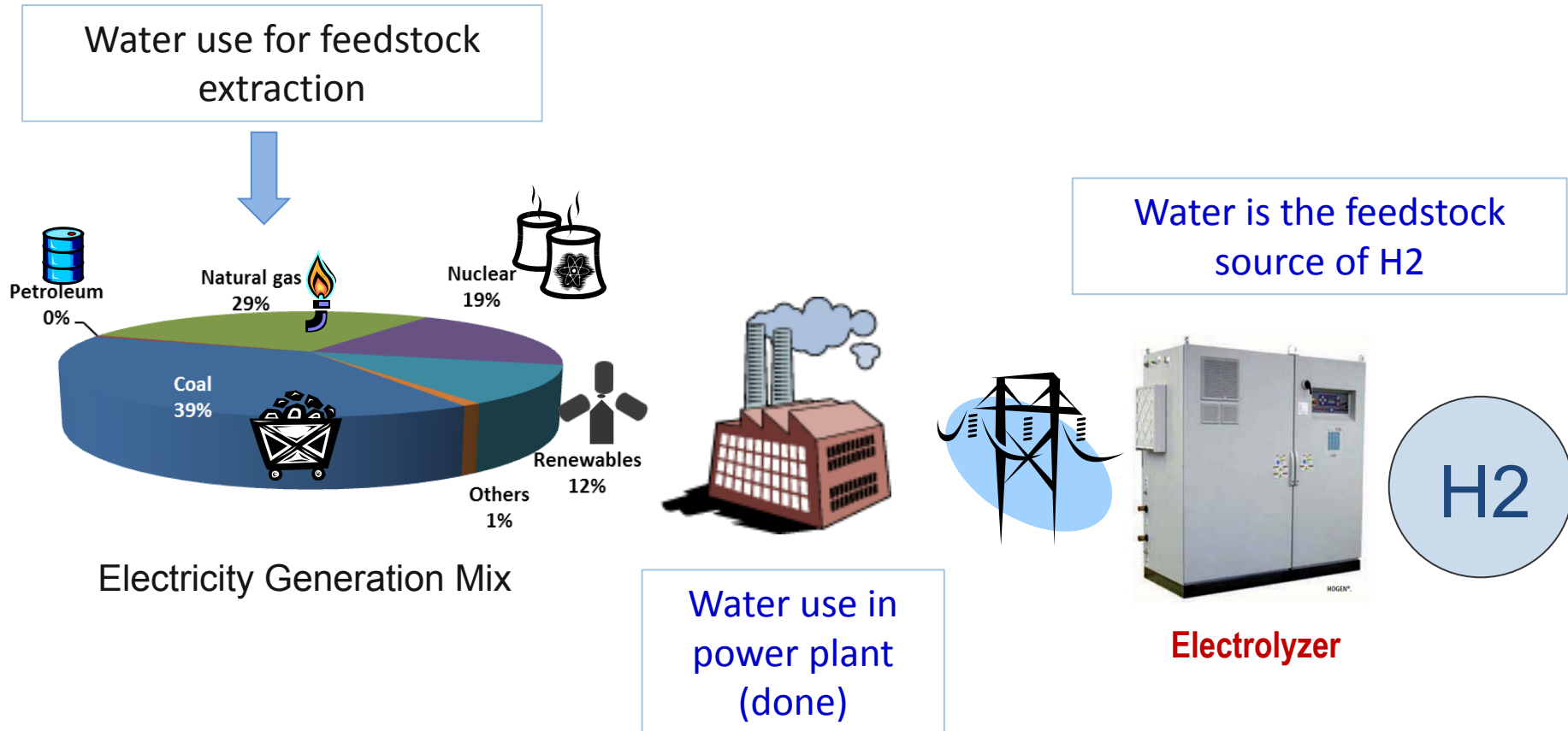
# Gaps with completed water footprint assessment – Relevance

- ❑ Several feedstocks have not been examined in depth:
  - Natural gas
  - Coal
  - Nuclear
  - Crude oil
- ❑ Fuel production gaps include hydrogen production processes



# Hydrogen pathways for water LCA – Approach

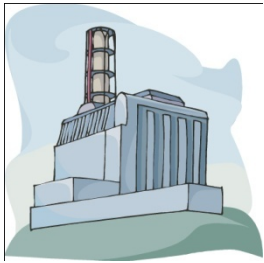
## (1) Electrolysis



# Hydrogen pathways for water LCA – Approach

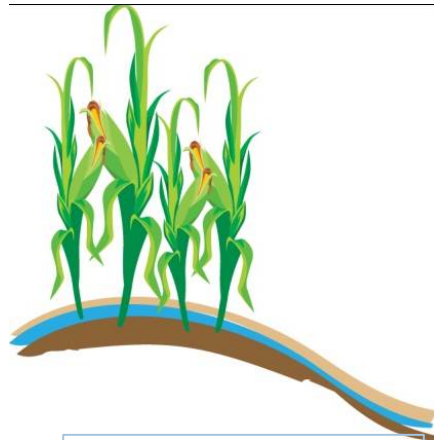
## (2) Biomass gasification

Fertilizer Production



Water use for  
Fertilizer  
production

Biomass farming



Water use for  
farming (done)

Biomass gasification

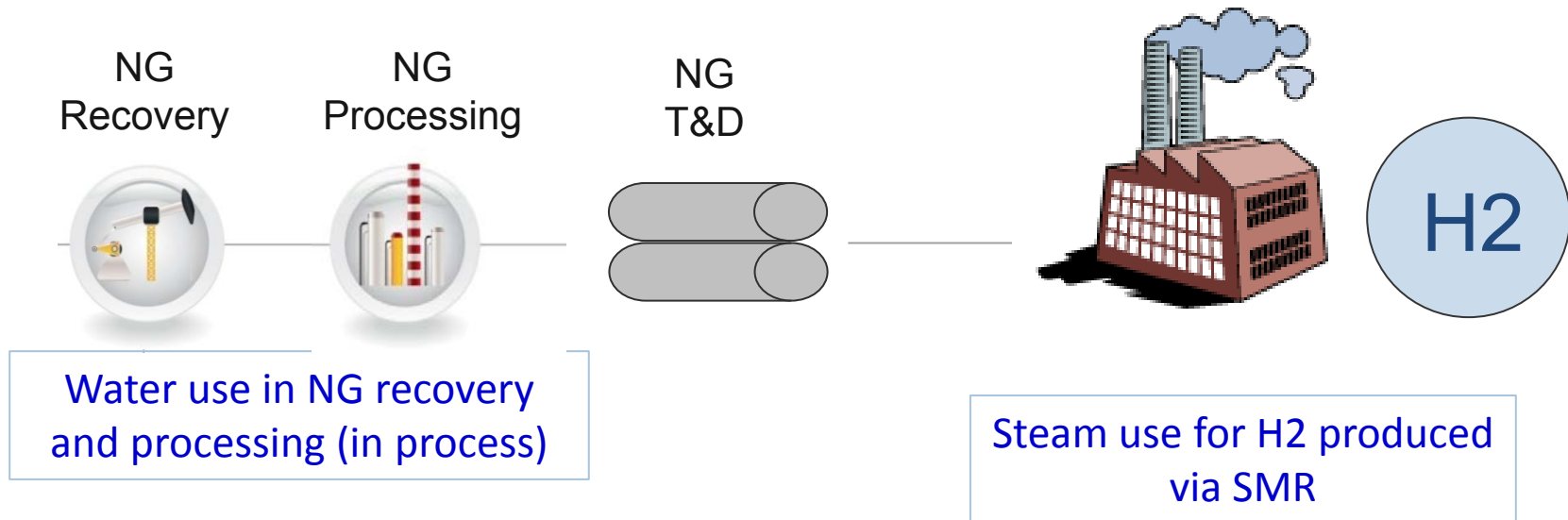


Water use for H<sub>2</sub>  
production

H<sub>2</sub>

# Hydrogen pathways for water LCA – Approach

## (3) Steam Methane Reforming



# *Summary*

- ❑ Project is in initial phase
- ❑ Project scope and major tasks have been defined
- ❑ Analysis approach and data sources have been decided
- ❑ Gaps and research issues have been identified





# ***Collaborations and Acknowledgments***

## Key Investigators/ Major Participants:

- Argonne National Laboratory: Michael Wang (PI), Amgad Elgowainy (CO-PI), and May Wu
- DOE, Fuel Cell Technologies Office, AAA Fellow: Jeni Keisman

## Acknowledgement:

- DOE, Fuel Cell Technologies Office, Systems Analysis Program Manager: Fred Joseck
- DOE, Biomass Energy Technologies Office: Kristen Johnson



## ***Future Work***

- ☐ Address outstanding issues related to water consumption in the upstream supply chain
- ☐ Upgrade GREET model by adding water use
- ☐ Evaluate emerging hydrogen feedstocks and production processes
- ☐ Continue to provide LCA technical support to DOE FCT program and industry stakeholders



# Acronyms

- ☐ ANL: Argonne National Laboratory
- ☐ BETO: Biomass Energy Technologies Office
- ☐ DOE: Department of Energy
- ☐ FCT: Fuel Cell Technologies
- ☐ GHG: Greenhouse Gases
- ☐ GREET: Greenhouse gases, Emissions, and Energy use in Transportation
- ☐ H<sub>2</sub>: Hydrogen
- ☐ LCA: Life Cycle Analysis
- ☐ NG: Natural Gas
- ☐ RD&D: Research, Development, and Demonstration
- ☐ SMR: Steam Methane Reforming
- ☐ VTP: Vehicle Technologies Program

