# Impacts of Electricity Generation Portfolio on Water Resources

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# Introduction

## Purpose

– investigate interdependencies between electricity portfolio composition and water needs

## Motivations

– concerns with water availability and relationship to power generation

– $CO_2$ reduction studies

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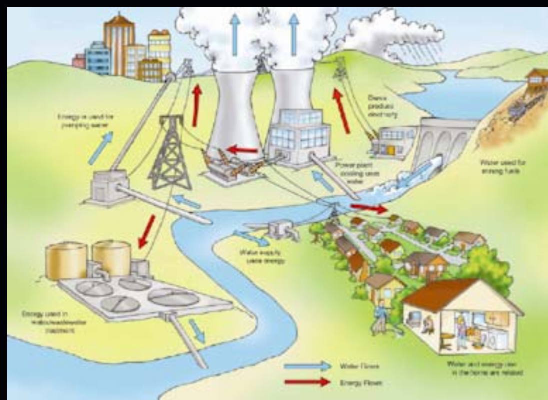
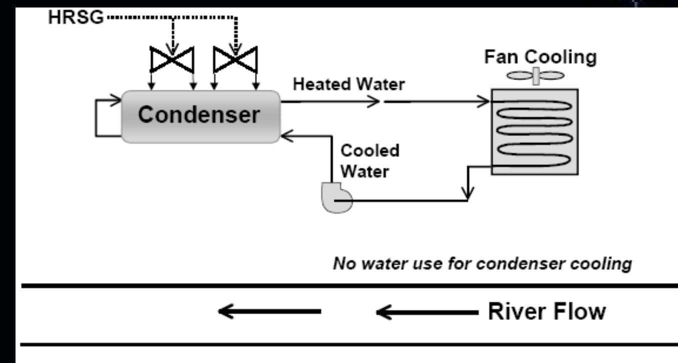
## 1. Energy-Water Interdependence



## 2. Plants and Cooling Systems




## 3. Methodology

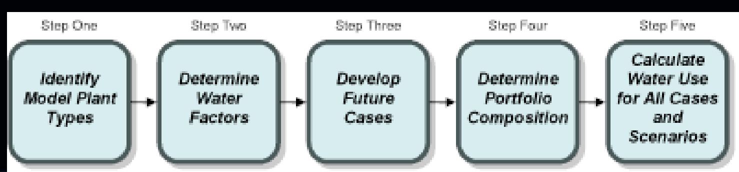
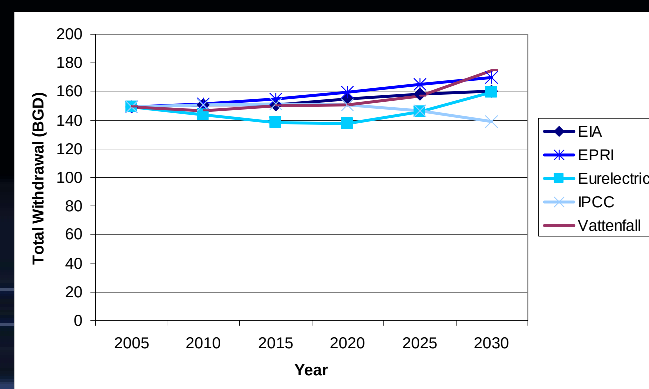
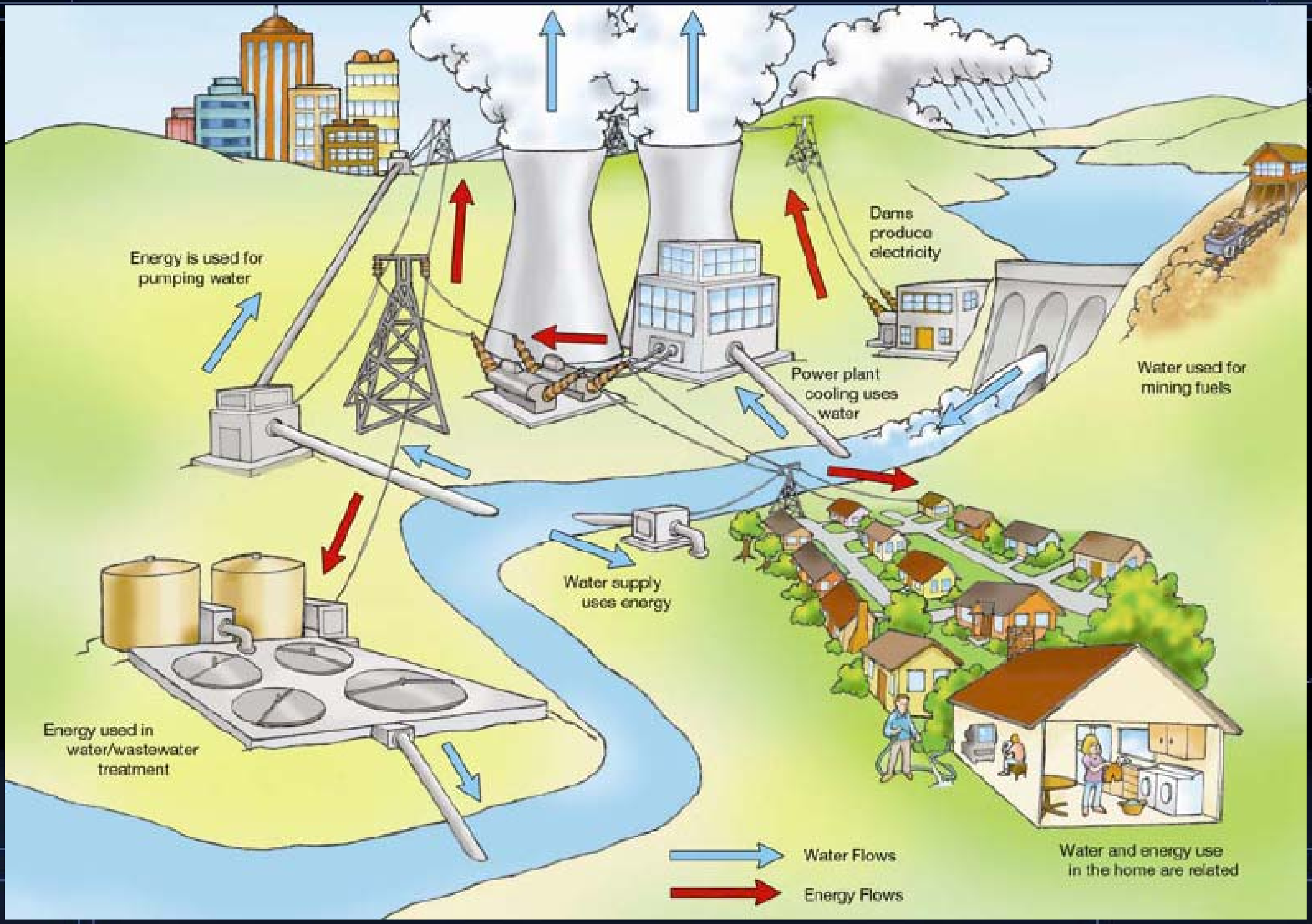



Figure 4-1: Flow Chart of Methodology for Analysis

## 4. Results



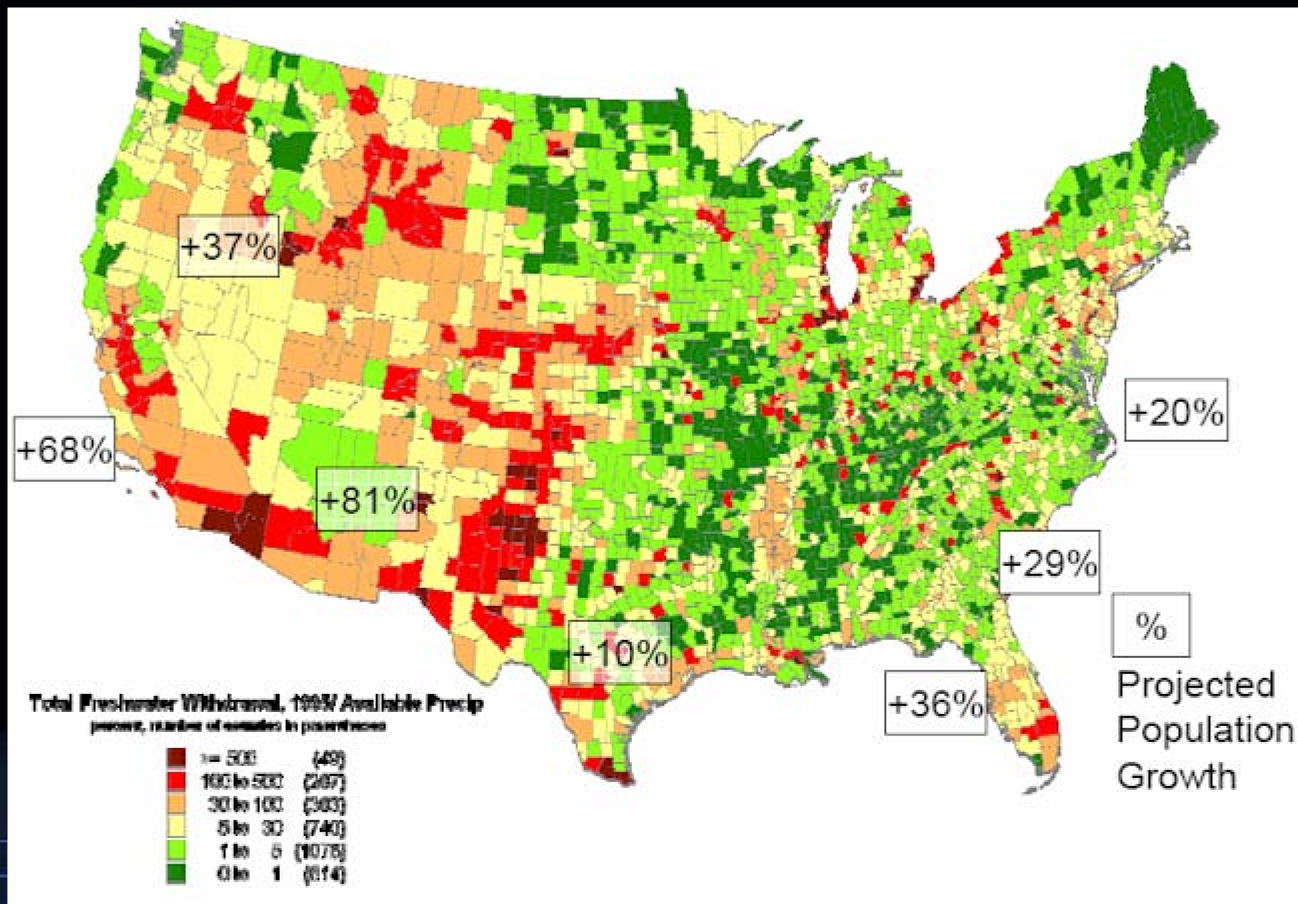
# Energy-Water Interdependence




*DOE, 2006*

# Electricity and Water Issues

- **Population → key driver**



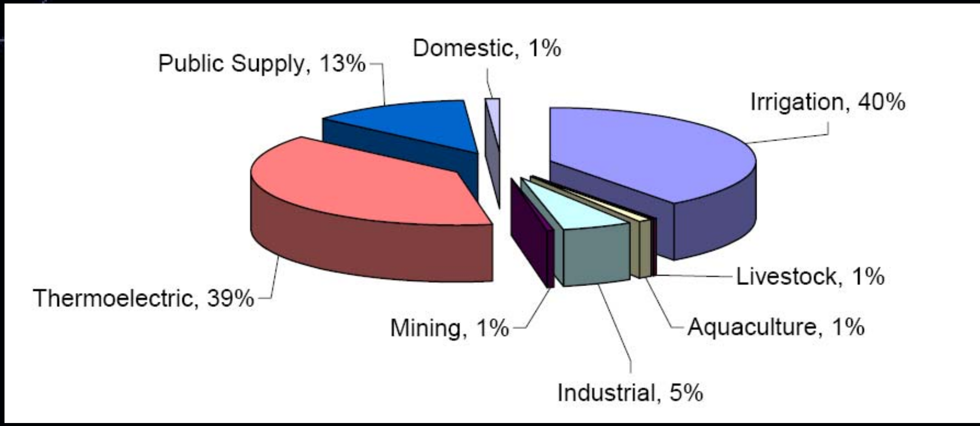

*DOE, 2006*

# Electricity and Water Issues

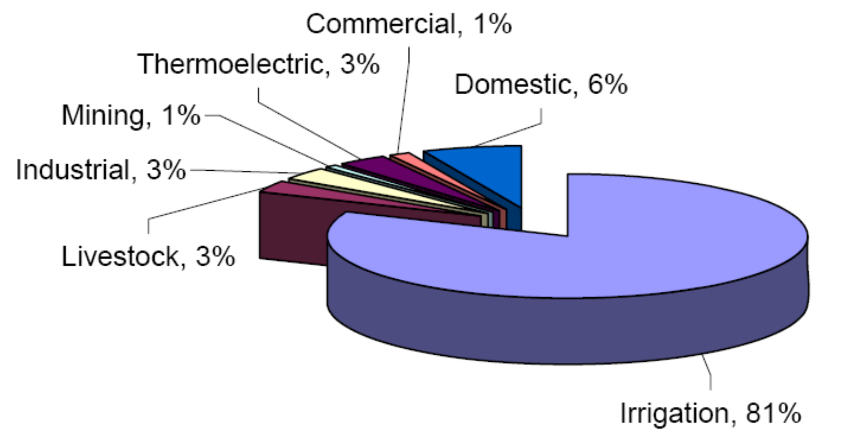
- **Water dilemmas on state/national level**
- **Lack of current assessments**
- **Energy consumption increase of 31% by 2030**
- **Climate change exacerbates concerns**
- **Constraints on power plant siting and operation due to water concerns**

# Current Daily Water Use Statistics

**TE Water Withdrawals: 39% (136 of 346 BGD)**




**TE Water Consumption: 3% (3 of 100 BGD)**




*NETL, 2006*

# Previous TE Water Needs Analyses

| *Previous Research* | *This Study* |
| --- | --- |
| **Water-Consuming Technologies** | **Prospective Technology Portfolios (Generation and Water-Consuming)** |
| ↓ | ↓ |
| **Water Use** | **Water Use** |

- **EPRI (2002) → "U.S. Water Consumption for Power Production – The Next Half Century"**
- **NETL (2006) → "Estimating Freshwater Needs to Meet Future TE Generation Requirements"**

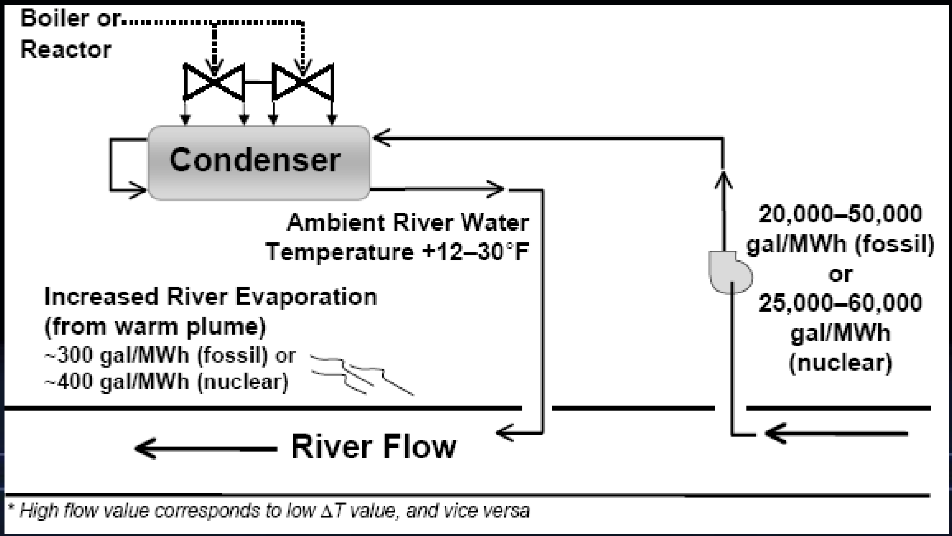
# TE Generation and Water

- **85% of electricity from thermoelectric plants**
- **Water primarily used for cooling but also for boiler and emissions scrubbing**
- **Total water use determined by generating and cooling technologies as well as location**

# Basic Cooling Technologies

**Once-through cooling**

- **High withdrawal, low consumption**
- **Installed mostly before 1970s**
- **Still used in half of generating capacity**

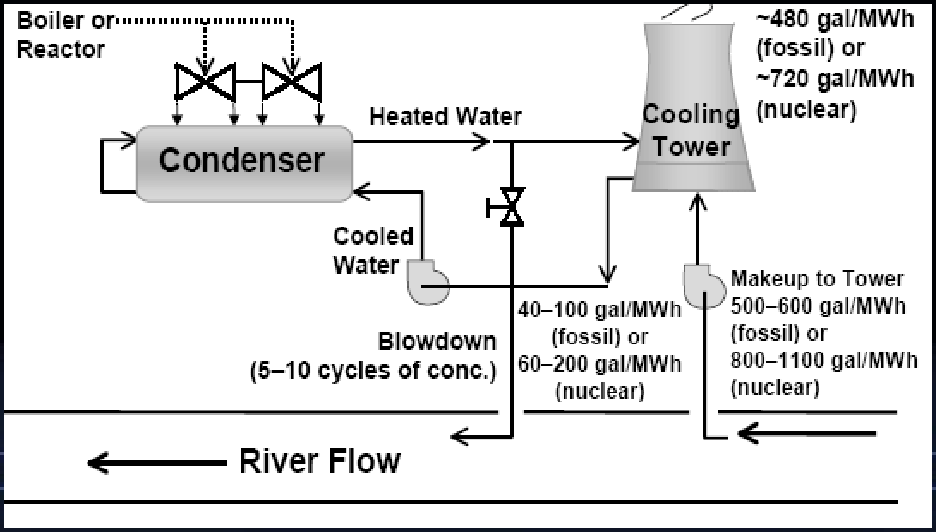



*EPRI, 2002*

# Basic Cooling Technologies

**Recirculating cooling**

- **Low withdrawal, high consumption**
- **Installed mostly after 1970s**
- **Extra energy requirements to treat water**




*EPRI, 2002*

# Advanced Cooling Technologies

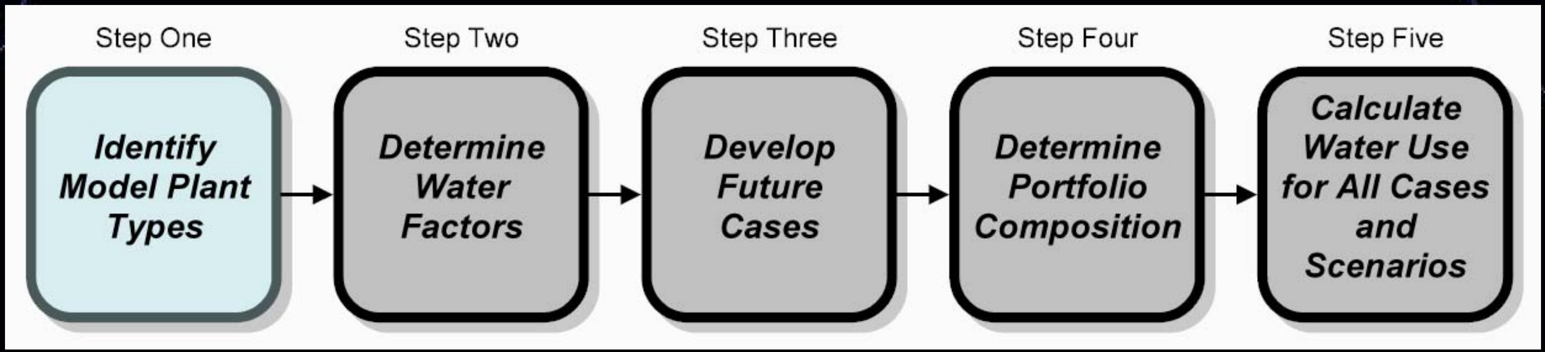
## Dry cooling

- Air cooling → no need for cooling water
- Parasitic losses reduce efficiency
- Costly to build, operate, and maintain

## Hybrid cooling

- Use combination of wet and dry cooling
- Reduces water use while improving performance in hot, arid climates

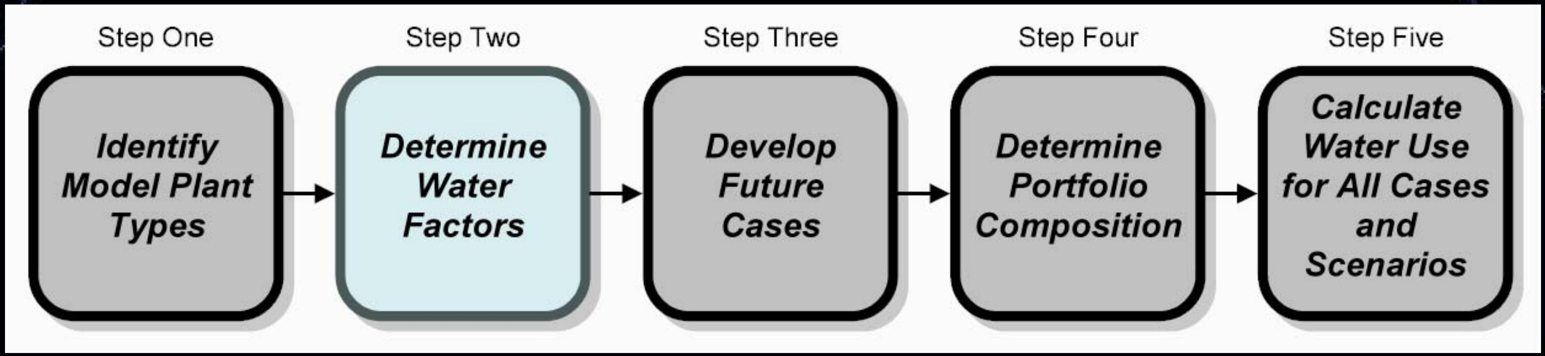
# Methodology




## Step One

- – Plant: coal, other fossil, c.c., nuclear, IGCC
- – Water source: freshwater (saline not used)
- – Cooling system: once-through, wet recirculating, cooling pond, dry
- – Boiler type (coal only): supercritical, subcritical
- – FGD type (coal only): wet, dry, none

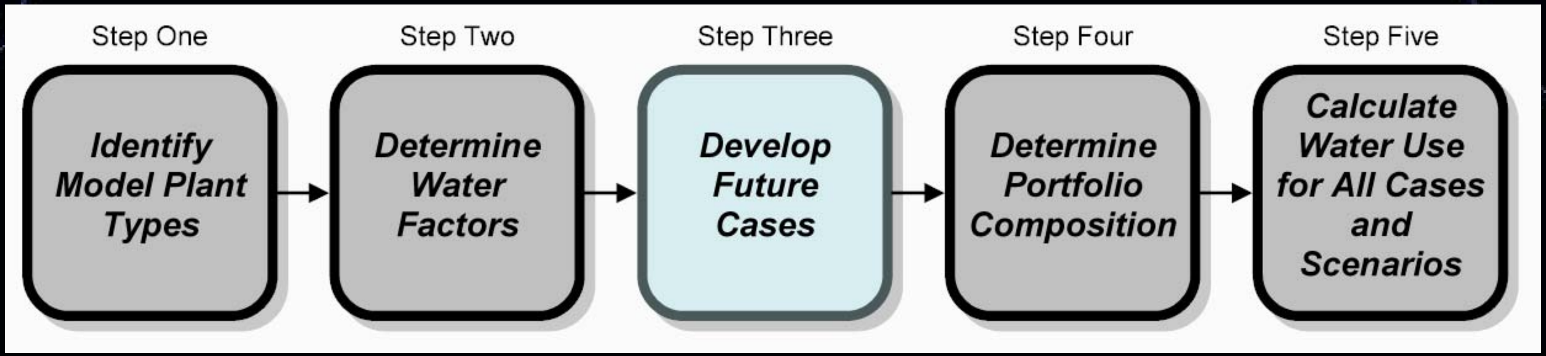
# Methodology




## Step Two

- Determine water withdrawal and consumption factors for each model plant configuration (in gallons per kilowatt-hour)
- 2006 NETL study water use factors

# Methodology



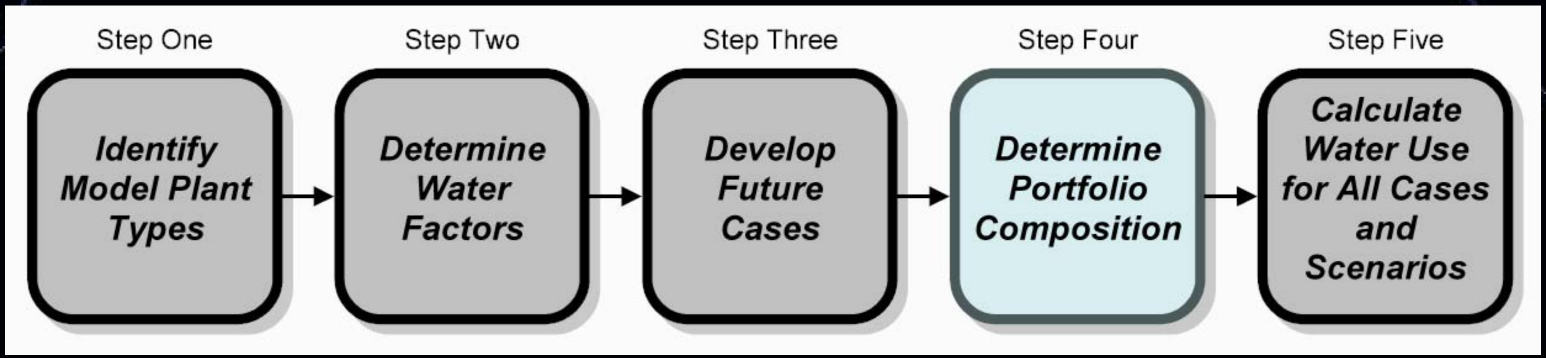

## Step Three

– **Develop future cases that predict deployment trends for water-related plant technologies**

# Methodology

- **Case One (status quo case)**
  - **Additions and retirements proportional to current water source and cooling system type**
- **Case Two (regulatory-driven case)**
  - **All additions use freshwater and wet recirculating cooling**
- **Case Three (regulatory-light case)**
  - **Additions: 90% freshwater/wet recirculating cooling; saline/once-through cooling**
- **Case Four (dry cooling case)**
  - **Additions: 25% dry cooling; 75% wet recirculating cooling**
- **Case Five (conversion case)**
  - **Case Two; 5% of existing freshwater once-through retrofitted with wet recirculating cooling every 5 years beginning in 2010**

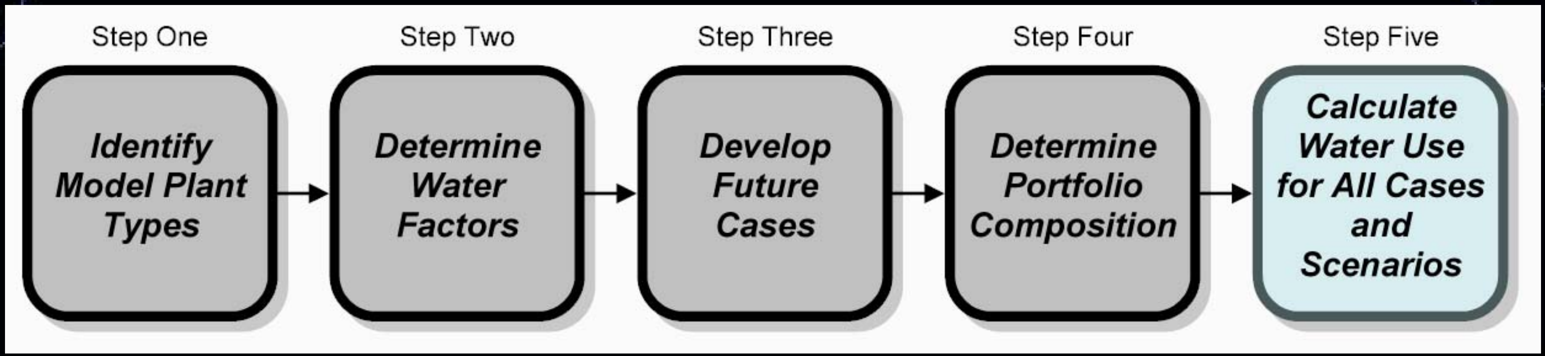
# Methodology




## Step Four

– **Determine portfolio composition by apportioning into model plant categories using future technology deployment case data**

# Methodology




## Step Five

- Calculate total national water withdrawal and consumption until 2030 for all future scenarios
- Water use (BGD) = A*B*C
  - A = daily generation (for particular plant type)
  - B = water use scaling factor (for specific model plant)
  - C = percentage portfolio share (for specific model plant)

# Portfolio Scenarios

**Generation Share Percentages by Plant Type for 2030**

| | Percentage (%) | | | | |
|---|---|---|---|---|---|
| | *EIA* | *EPRI* | *Eurelectric* | *IPCC* | *Vattenfall* |
| **Coal** | 59.6 | 53.8 | 23.4 | 18.8 | 31.0 |
| **Other Fossil** | 1.7 | 0.6 | 1.9 | 0.0 | 5.0 |
| **Combined Cycle** | 13.5 | 8.8 | 19.6 | 8.5 | 11.0 |
| **Nuclear** | 16.6 | 25.4 | 29.9 | 27.9 | 21.0 |
| **Renewables** | 8.6 | 11.3 | 25.2 | 44.7 | 32.0 |

## Data Sets Used

- EIA Annual Energy Outlook (2007)
- EPRI Prism Study (2007)
- Eurelectric "The Role of Electricity" Study (2007)
- IPCC Fourth Assessment Report (2007)
- Vattenfall/McKinsey Study (2007)

# Results – Withdrawals

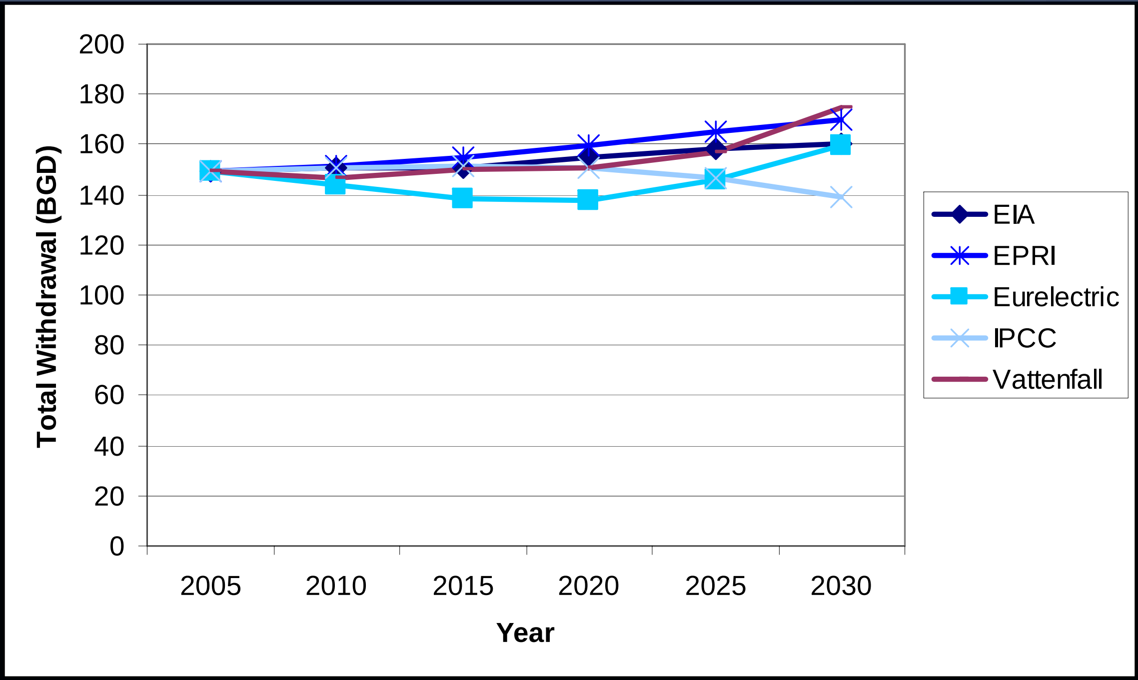
- For status quo case, daily withdrawals range from ~140 BGD to 175 BGD
- Changes in projected TE generation portfolio do not exert large impacts on future water withdrawals

Average Daily U.S. Freshwater Withdrawal (BGD) from Thermoelectric Generation for Various Portfolio Scenarios with Case One Assumptions

| | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| EIA | 149 | 151 | 150 | 155 | 158 | 160 |
| EPRI | 149 | 152 | 155 | 159 | 165 | 170 |
| Eurelectric | 149 | 144 | 138 | 138 | 146 | 159 |
| IPCC | 149 | 151 | 152 | 151 | 146 | 139 |
| Vattenfall | 149 | 147 | 150 | 151 | 157 | 175 |

**Uncertainty range (for each value): ±14 BGD**

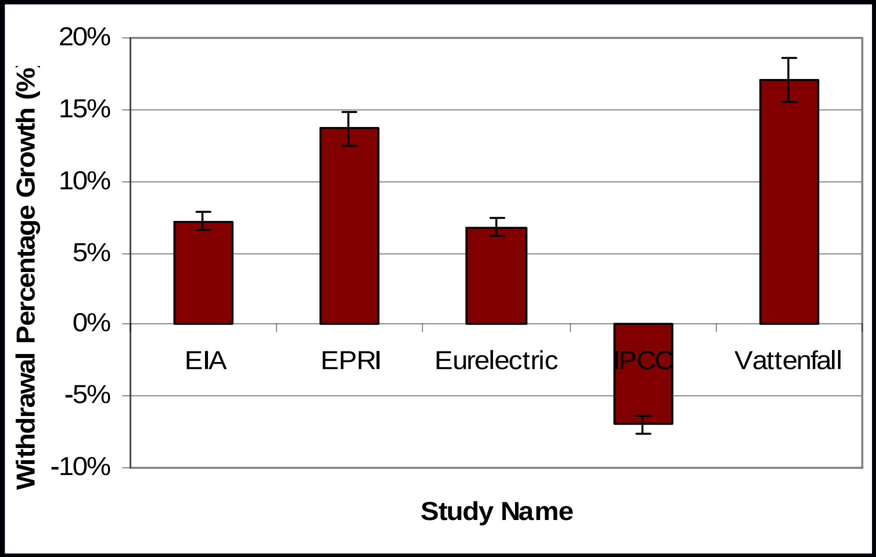
# Results – Withdrawals




**Average Daily U.S. Freshwater Withdrawal from Thermoelectric Generation for Various Portfolio Scenarios with Case One Assumptions**

- **Ratio of TE to renewables exerts greater impact on withdrawals than TE breakdown**

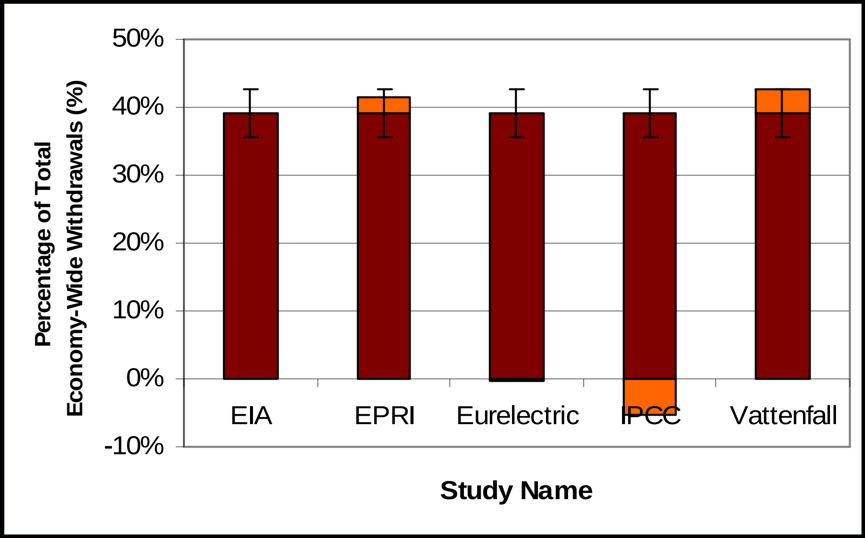
# Results – Withdrawals




**Percentage Change in Freshwater Withdrawals from Thermoelectric Generation between 2005 and 2030 with Case One Assumptions**

- **Overall daily TE withdrawals range (from 2005 and 2030): -7 to +17%**

# Results – Withdrawals




**Thermoelectric Percentage Share of Total Economy-Wide U.S. Freshwater Withdrawals in 2030 with Case One Assumptions**

- **Relative TE withdrawal changes would not exert major impact on economy-wide withdrawal percentage breakdown**

# Results – Consumption

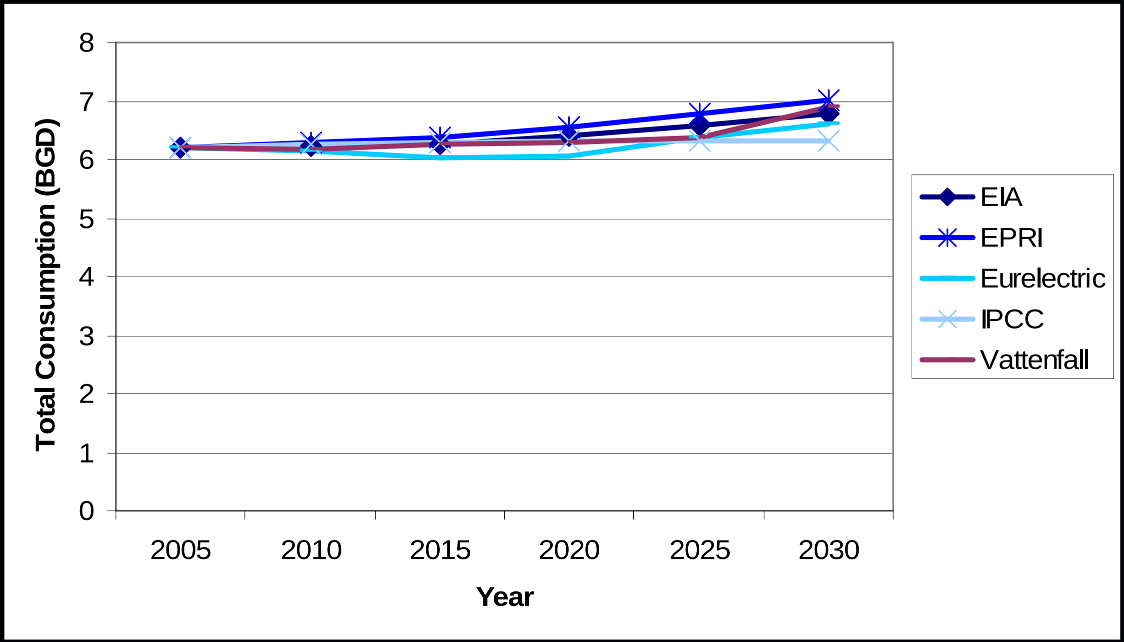
- For status quo case, daily consumption ranges from 6.3 BGD to 7.0 BGD
- Changes in projected TE generation portfolio do not exert large impacts on future water consumption

**Average Daily U.S. Freshwater Consumption (BGD) from Thermoelectric Generation for Various Portfolio Scenarios with Case One Assumptions**

| | *2005* | *2010* | *2015* | *2020* | *2025* | *2030* |
|---|---|---|---|---|---|---|
| **EIA** | 6.2 | 6.2 | 6.3 | 6.4 | 6.6 | 6.8 |
| **EPRI** | 6.2 | 6.3 | 6.4 | 6.5 | 6.8 | 7.0 |
| **Eurelectric** | 6.2 | 6.2 | 6.0 | 6.1 | 6.4 | 6.6 |
| **IPCC** | 6.2 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 |
| **Vattenfall** | 6.2 | 6.2 | 6.3 | 6.3 | 6.4 | 6.9 |

**Uncertainty range (for each value): ±0.8 BGD**

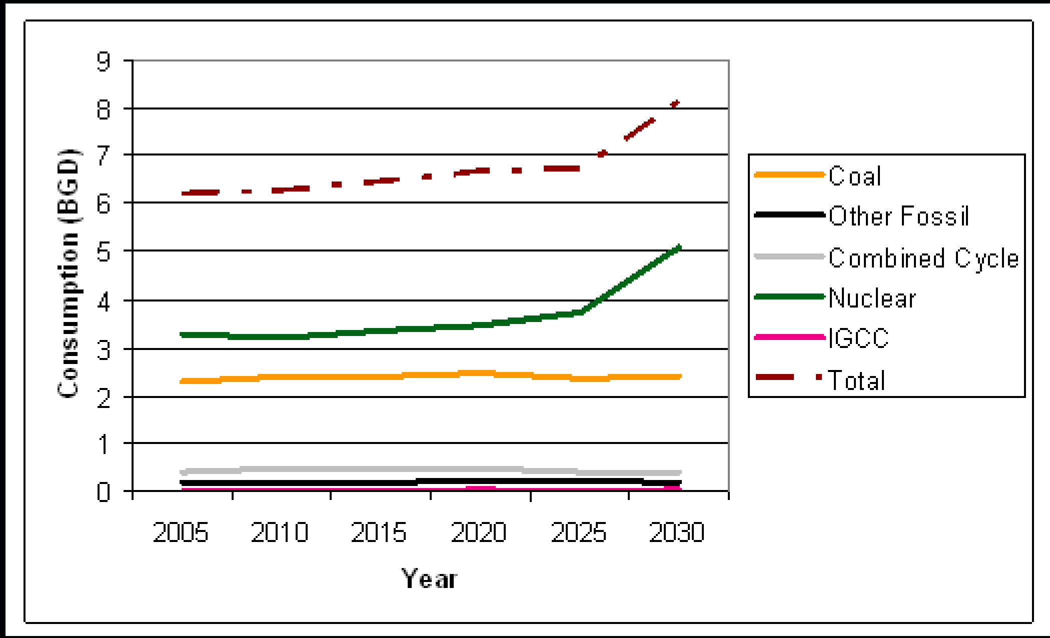
# Results – Consumption




**Average Daily U.S. Freshwater Consumption from Thermoelectric Generation for Various Portfolio Scenarios with Case One Assumptions**

- **Nuclear generation share plays large role in determining water consumption**

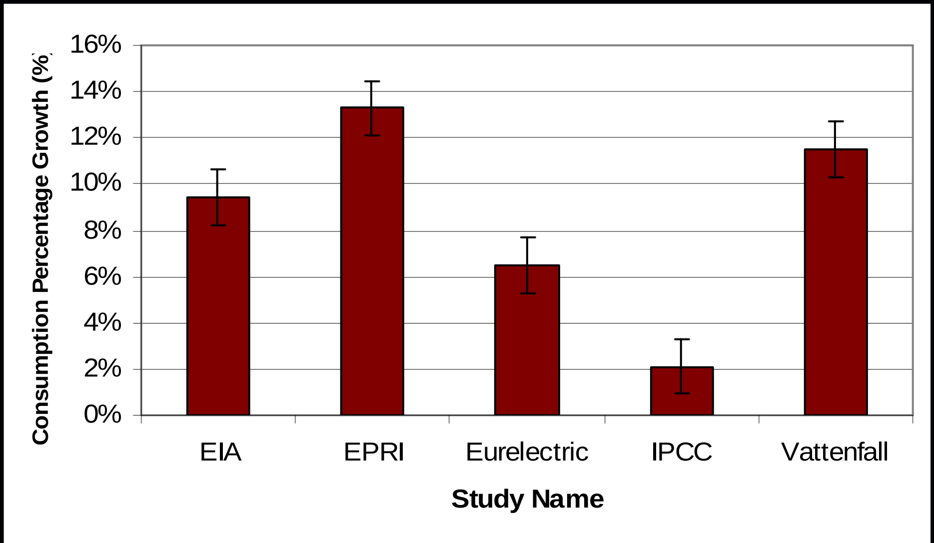
# Results – Consumption




**Average Daily U.S. Freshwater Consumption by Plant Type under Vattenfall Scenario with Case Two Assumptions**

- **Nuclear generation share plays large role in determining water consumption**

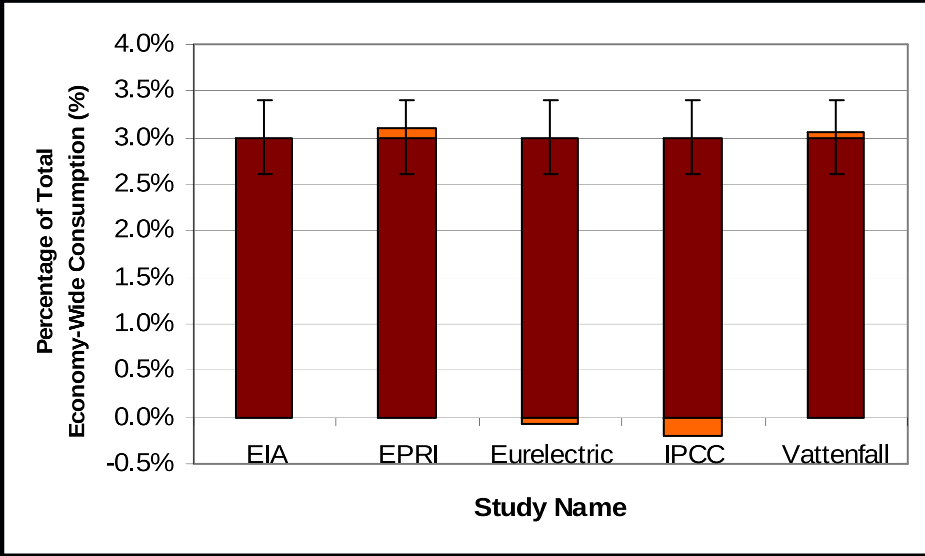
# Results – Consumption




**Percentage Change in Freshwater Consumption from Thermoelectric Generation between 2005 and 2030 with Case One Assumptions**

- **Overall daily TE consumption increases as much as 13% between 2005 and 2030**

# Results – Consumption




**Thermoelectric Percentage Share of Total Economy-Wide U.S. Freshwater Consumption in 2030 with Case One Assumptions**

- **Consumption increase equivalent to daily domestic water consumption of approximately 8.25 million people in U.S.**

# Results – IGCC

- IGCC penetration through 2030 exerts no considerable effects on withdrawals
- Strategic deployment of IGCC has capacity to make small to moderate reductions in consumption by 2030

**Average Daily U.S. Freshwater Consumption (BGD) from Thermoelectric Generation for Various IGCC Deployment Scenarios with Case Two Assumptions**

| | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| **0 Percent** | 6.2 | 6.4 | 6.7 | 7.1 | 7.8 | 8.5 |
| **20 Percent** | 6.2 | 6.4 | 6.7 | 7.1 | 7.7 | 8.3 |
| **40 Percent** | 6.2 | 6.4 | 6.7 | 7.1 | 7.6 | 8.2 |
| **60 Percent** | 6.2 | 6.4 | 6.7 | 7.0 | 7.5 | 8.0 |
| **80 Percent** | 6.2 | 6.4 | 6.7 | 7.0 | 7.5 | 7.8 |
| **100 Percent** | 6.2 | 6.4 | 6.7 | 7.0 | 7.4 | 7.6 |

**Error range (for each value): ±0.8 BGD**

# Issues for Further Investigation

- **Need for regional-level analysis to assess potential impacts**
- **Future additions:**
  - **Regional modeling**
  - **Improve model plant types (include CCS and non-TE plants)**
  - **Quantify plant efficiency tradeoffs due to advanced cooling**

# Conclusion

- Ratio of TE to renewables exerts greater impact on withdrawals than TE breakdown
- Overall daily TE consumption increases as much as 13.3% between 2005 and 2030
- Strategic deployment of IGCC has capacity to make small to moderate reductions in consumption by 2030
- Need for regional-level analysis to assess potential impacts

***Questions?***

# Acknowledgements


- **Department of Engineering and Public Policy at Carnegie Mellon University**
  - *Granger Morgan and Patti Steranchak*
- **Electric Power Research Institute**
  - *Revis James, Barbara Tyran*