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CIVIL AND ENVIRONMENTAL ENGINEERING

# Modeling of Power Generation Pollutant Emissions Based on Locational Marginal Prices for Sustainable Water Delivery

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# Project Overview

- **Reduce energy consumption and environmental impact of water distribution systems**
- Develop a real-time pump optimization (RPO) software tool

Great Lakes Protection Fund

Ideas in Action

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# Pilot Study: DWSD

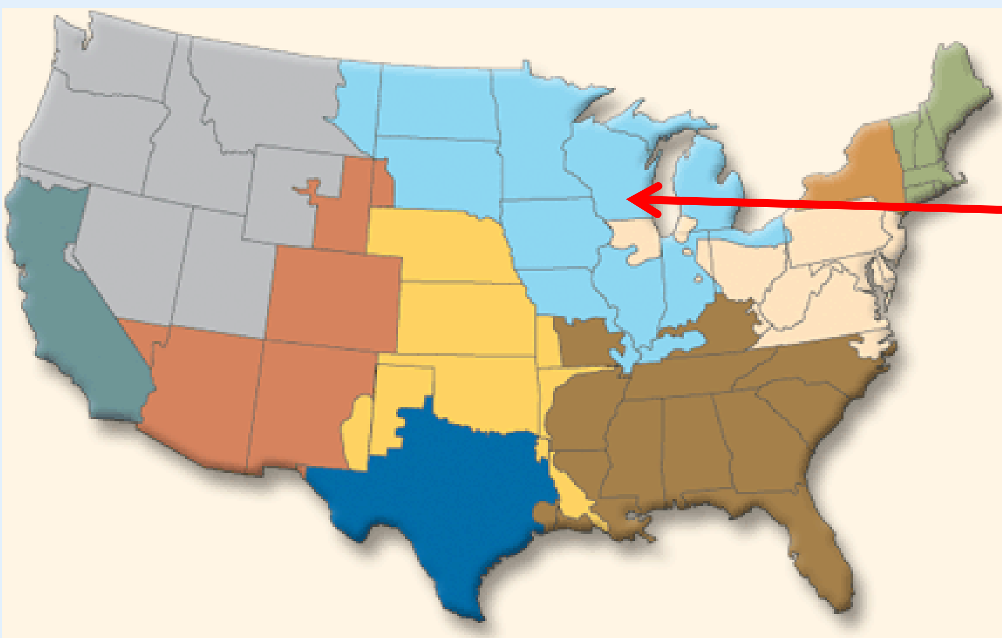
- Detroit Water & Sewerage Department (DWSD)
  - 4 million customers
  - **~300 Million KW-Hours annually**
  - 220 billion gallons annually
- DTE Energy footprint
- MISO dispatch

# Methodology

- Energy Optimization
- Economic Optimization
- **Environmental Optimization**
  - **Link pump power consumption to pollutant emissions** associated with energy generation
  - **Shift pumping loads** to advantageously utilize clean generation units

# Linking Consumption to Emissions

1. Source Identification
   - Dispatch adjusted every 5 minutes within MISO
2. Emissions Quantification
   - Function of generator type



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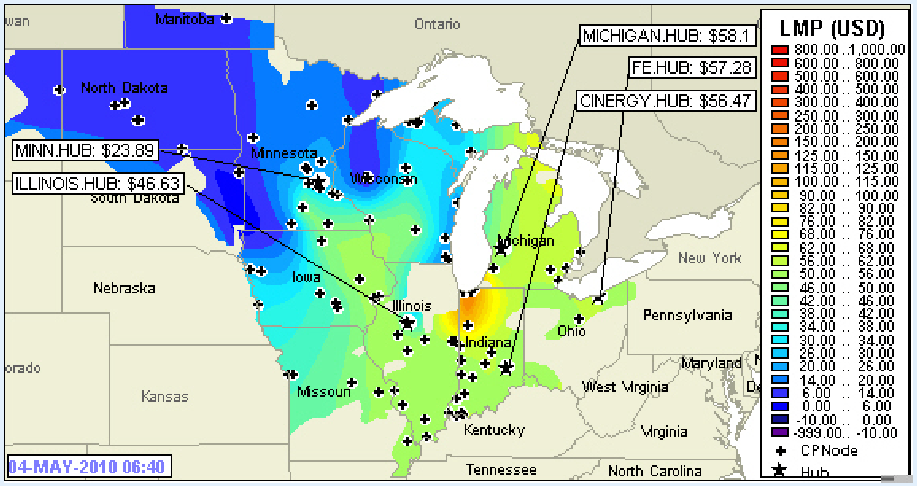
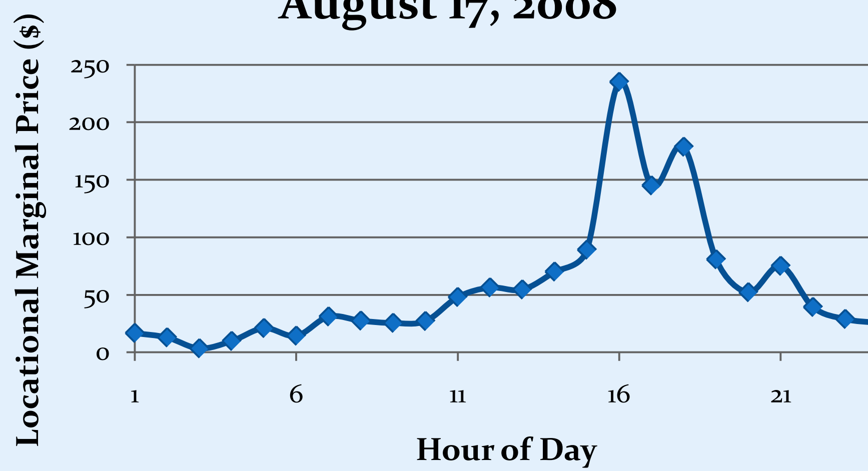
# Linking Consumption to Emissions




LMP Curve can be developed for all CPNodes on any given day

LMPs are determined for thousands of Commercial Pricing Nodes (CPNodes)

**Harbor Beach Price Curve for August 17, 2008**



# Linking Consumption to Emissions

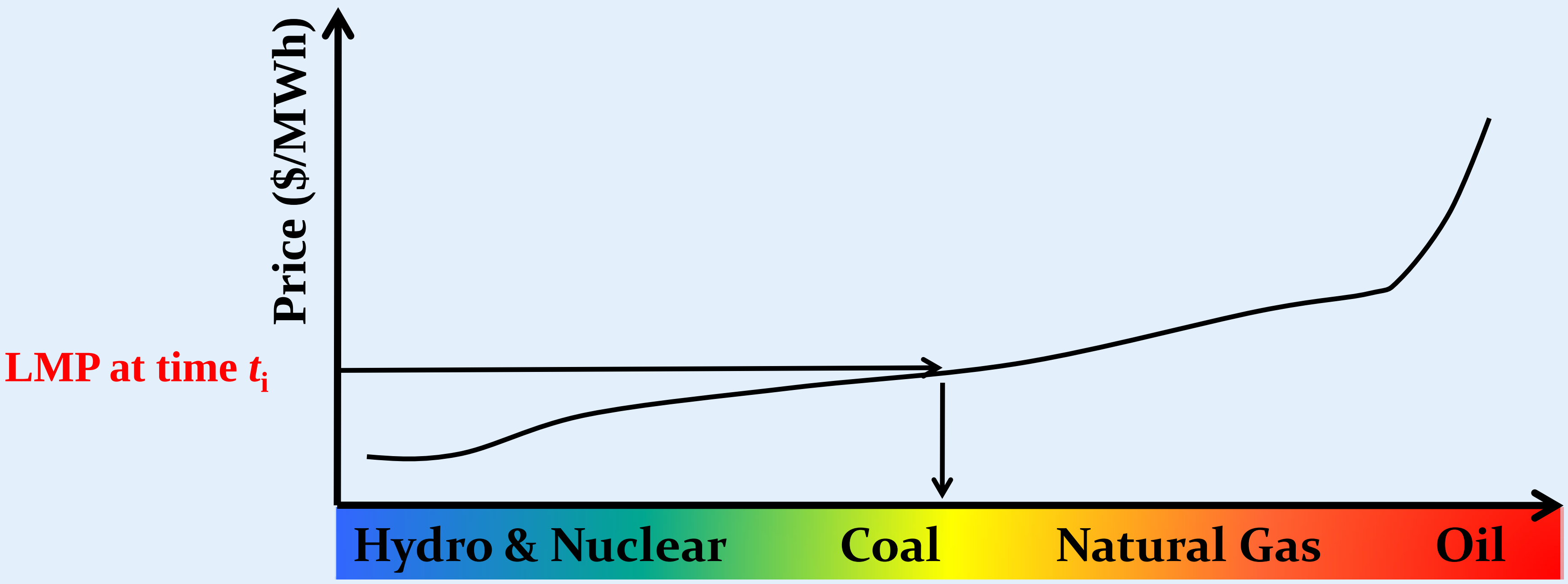
Sources could be derived by:

**Energy Bid Price** OR **Generator Type**

- MISO bid prices are confidential
- Identify **type of generation units**
  - Calculate marginal cost for each generator type
  - Calculate pollutant emissions per unit of power generation

# From LMP to Gen Type

- Find the LMP (real time, hour-ahead, or day-ahead)
- Map the LMP to the type of generation unit



# Identify Power Generation Units

- Step 1: Calculate the heat rate

$$Heat\ Rate\ \left(\frac{MMBtu}{MWh}\right) = \frac{Fuel\ Quantity\ Consumed\ for\ Electricity\ (MMBtu)}{Electricity\ Net\ Generation\ (MWh)}$$

- Step 2: Determine average monthly fuel price
- Step 3: Calculate variable cost of electric generation

$$Electric\ Generation\ Fuel\ Cost\ \left(\frac{\$}{MWh}\right) = Heat\ Rate\ \left(\frac{MMBtu}{MWh}\right) * Price\ of\ Fuel\ \left(\frac{\$}{MMBtu}\right)$$

- Step 4: Compute electric generation cost statistics
- Step 5: Define generation type LMP ranges

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# Key Assumption

- Pilot study - DWSD
- DTE Energy network is unconstrained
  - The next incremental change in demand will be supplied by the cheapest generator inside the network or the same source outside
  - Use LMPs to model pollutant emissions
- Check Assumption
  - 97.7% of DTE LMPs are within 1 standard deviation of the mean

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# Results – Source Identification

- Calculate Locational Marginal Price (LMP) range at which each type of generator will be producing power on the margin

| Michigan - July 2008 | |
|---|---|
| **Marginal Generator Type** | **LMP Range ($)** |
| Nuclear / Renewable | <19.25 |
| Coal | 19.25 - 78.88 |
| Combined Cycle NG | 78.88 - 128.58 |
| Other Natural Gas | 128.58 - 140.28 |
| Residual Fuel Oil | 140.28 - 202.20 |
| Simple Cycle NG | 202.20 - 277.11 |
| Distillate Fuel Oil | >277.11 |

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# Results – Time on Margin

- Calculate percentage of time generators were on the margin using LMP ranges
  - All generators in DTE system for 2008

| Fuel/Generator Type | Total Hours |
|---|---|
| Nuclear/Renewable | 85,699 (10.02 %) |
| Coal | 556,107 (65.01 %) |
| Combined Cycle NG | 147,007 (17.18 %) |
| Other Natural Gas | 23,386 (2.73 %) |
| Residual Fuel Oil | 30,247 (3.54 %) |
| Simple Cycle Natural Gas | 13,012 (1.52 %) |
| Distillate Fuel Oil | 2,158 (0.25 %) |

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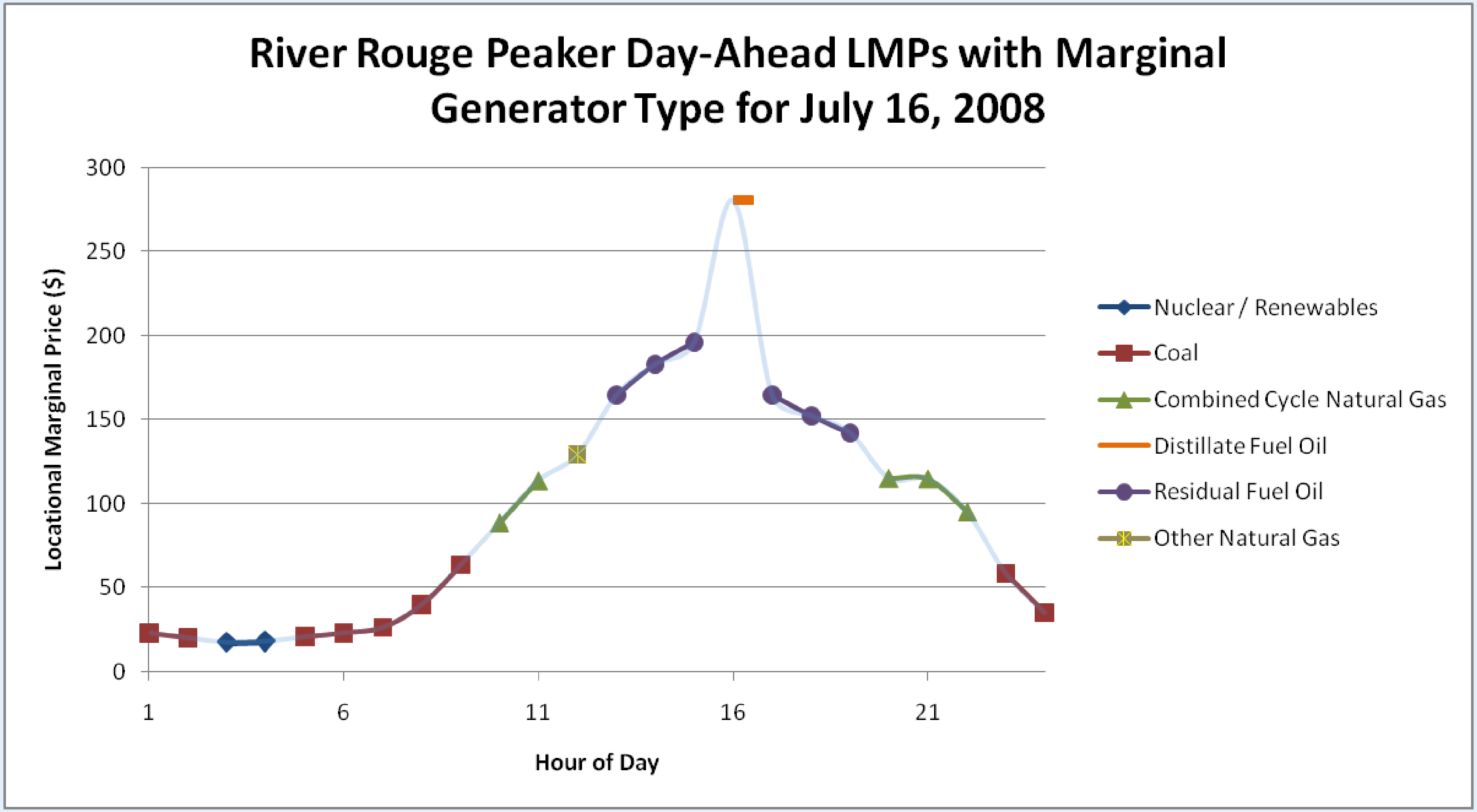
# Results – LMP Ranges



# Emissions Quantification

**Emissions factors**

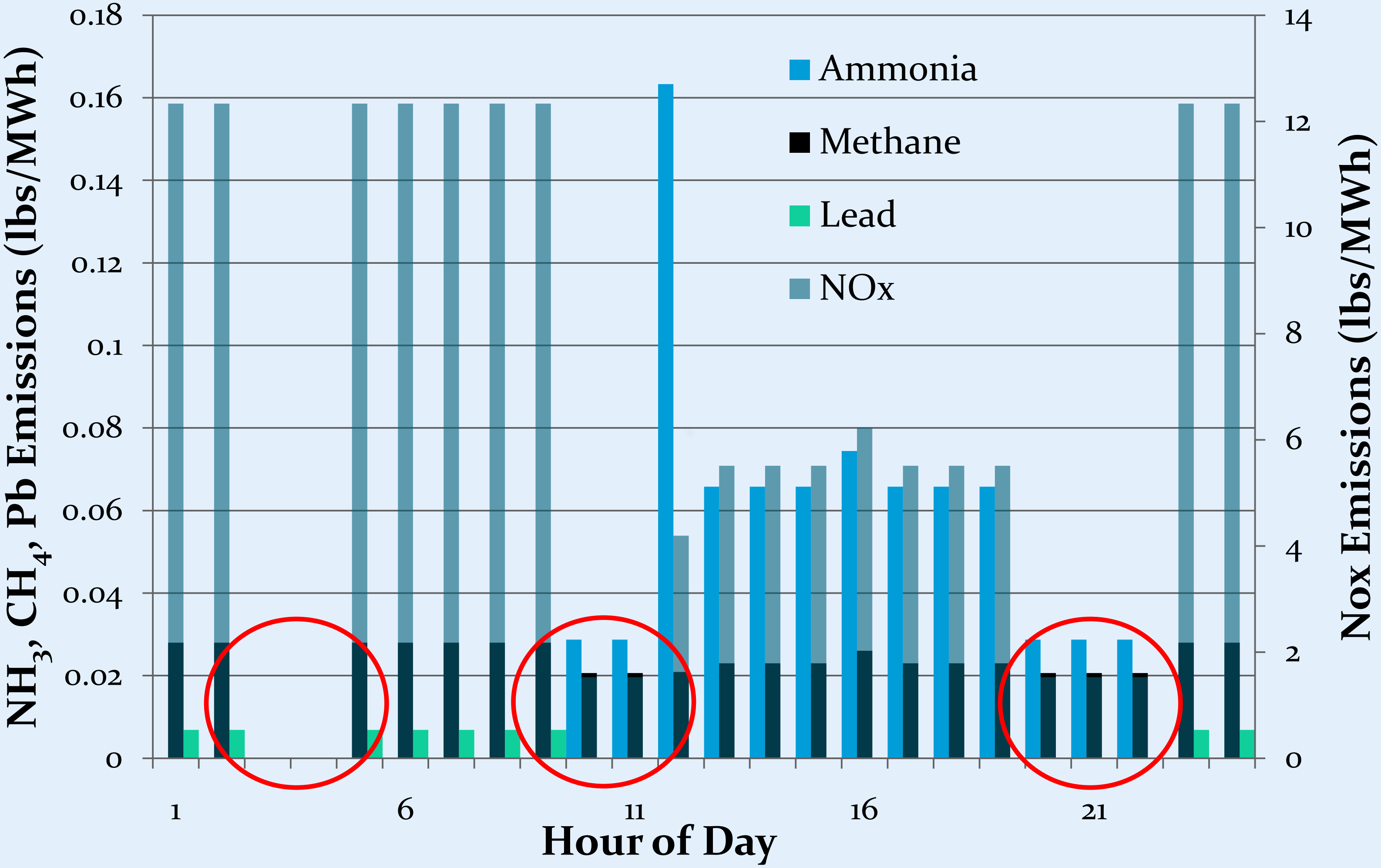
- Describe the mass of pollutant per amount of energy generated (e.g. lbs/MWh)
- Serve as transfer function

$$EF = HR * WFF$$

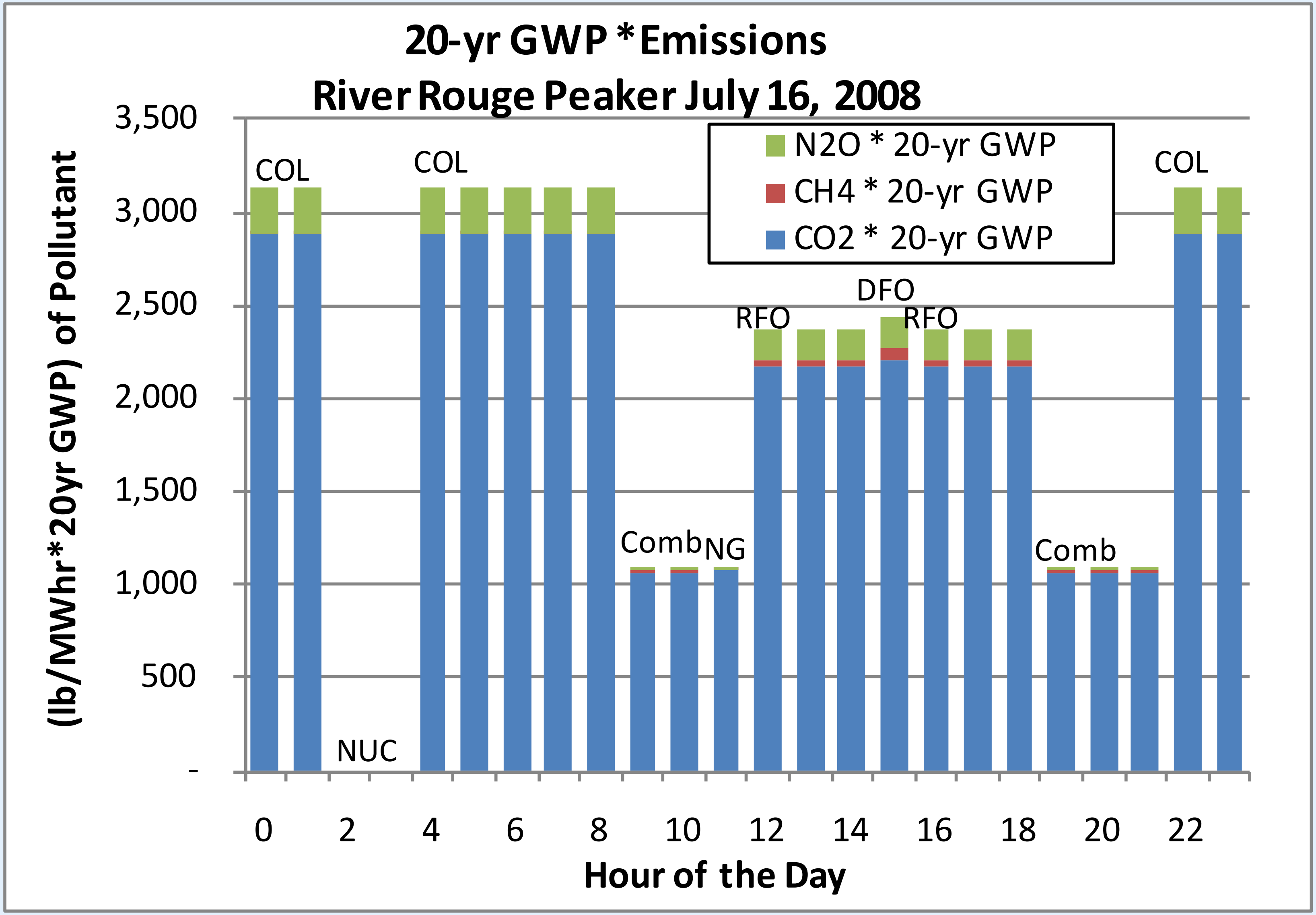
$$lbs / MWh = Quantity / MWh * lbs / Quantity$$

- An emissions model is created for various pollutants
  - Track individual pollutants or group of pollutants

# Results – Emissions Model



# Results – GHG Emissions Model



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# Pump Optimization

- This emissions model could be **updated every 5 minutes** using real-time MISO pricing.
- **Shifting of pumping loads**
  - Times of the day when overall emissions will be minimized.
  - Utilizing in-line and raised storage.

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# Conclusions

- Can use Locational Marginal Price (LMP) to determine pollutant emissions
  - Represents best possible estimate using publicly available data
- Model can be used to determine marginal generator type/emissions in real-time
- Model can be implemented into an RPO tool to optimize water distribution systems (e.g., DWSD) based on pollutant emissions

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# Questions / Comments

## Project Team:

CIVIL AND ENVIRONMENTAL ENGINEERING

TUCKER, YOUNG, JACKSON, TULL, INC.
CONSULTING ENGINEERS

UNIVERSITY of DAYTON

Connect With Confidence
Commonwealth associates, inc.

## Project Partners:

WATER & SEWERAGE DEPT.
DETROIT

DTE Energy

City of Monroe
Monroe, Michigan

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# Results – Emissions Factors

| Marginal Generator Type | July Ammonia Emission Factor (lbs/MWh) | July Methane Emission Factor (lbs/MWh) | July NOx Emission Factor (lbs/MWh) | July Lead Emission Factor (lbs/MWh) |
|---|---|---|---|---|
| Nuclear / Renewable | NA | NA | NA | NA |
| Coal | 0.0003168 | 0.02803 | 12.3345 | 0.003846 |
| Combined Cycle NG | 0.02870 | 0.02063 | 1.5246 | 4.484E-6 |
| Other Natural Gas | 0.1633 | 0.02087 | 4.1925 | 4.537E-6 |
| Residual Fuel Oil | 0.06582 | 0.02304 | 5.5126 | 0.0001613 |
| Simple Cycle NG | 0.04689 | 0.03370 | 4.1030 | 0 |
| Distillate Fuel Oil | 0.07440 | 0.02604 | 6.2313 | 0.0004353 |

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