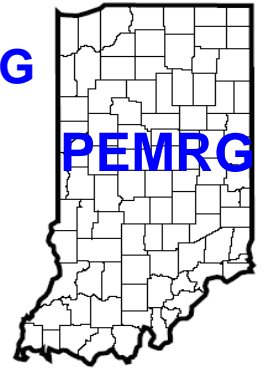


PURDUE ENERGY MODELING
RESEARCH GROUPS



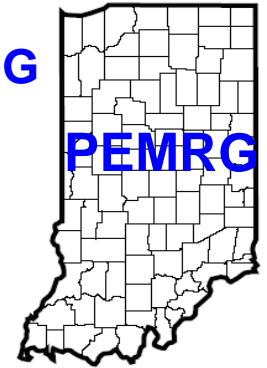
Factors that Affect the Design & Implementation of Clean Coal Technologies in Indiana (Draft Final Report)

Presentation to the
Center for Coal Technology Research

Purdue University – November 17, 2005

by

Ronald L. Rardin, Principal Investigator and Director
Purdue Energy Modeling Research Groups (PEMRG)



The Project Team

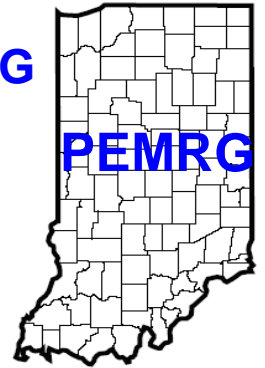
PURDUE:

- Ronald L Rardin, PI
- Zuwei Yu, CoPI
- Forrest Holland, CoPI
- Tony Black, GRA
- Jesse Oberbeck, GRA

(with help from other
SUFGR staff)

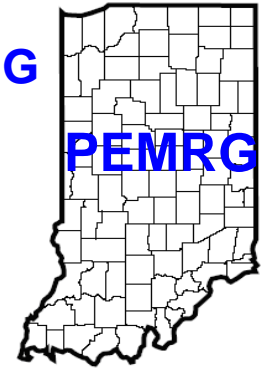
ADVISORS:

- Dick Foltz (& Gayle Mayo), IMPA
- Allen McKee, WVPA
- John Rupp (& Maria Mastalerz), IGS
- Francois Botha, ICCI
- Bill Simmons, Coalteck



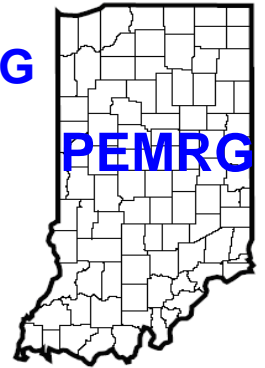
Scoping Study Vision

- How emerging Clean Coal Technology (CCT) solutions can be shaped & encouraged within Indiana
- Goal to increase environmentally responsible use of Indiana coal
- Focus on electric power generation, although chemical & other byproducts also considered



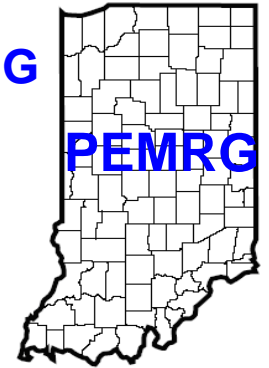
Clean Coal Technology (CCT)

- CCT \approx methods for using coal with substantially reduced environmental emissions
- Includes Integrated Gasification Combined Cycle (IGCC) with near zero emissions
- What coal-fired & combinations to include?
 - Supercritical PC (high temp & pressure)
 - Circulating Fluidized Bed (input with limestone)
 - Flue Gas Recycling (using & concentrating effluent)



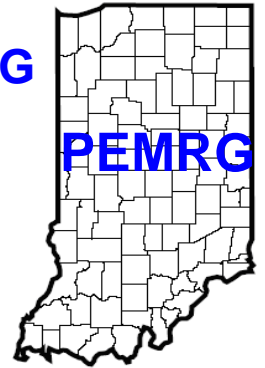
Two Dimensions of Interim Rpt

- Study begins by considering two dimensions or issue bundles
- First is the technologies: how they work, history & maturity, preferred fuels, estimated costs, new & retrofit plants, pollution removal, reliability/availability, coke, chemicals & FT fuel production, external R&D funding



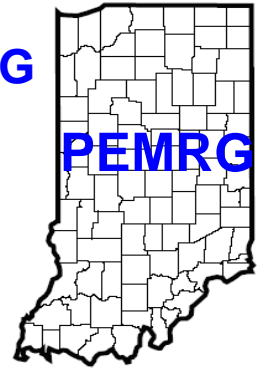
Two Dimensions of Interim Rpt

- Second is the Indiana environment: Indiana coal types, utility regulation, environmental regulation & compliance, human infrastructure, electricity demand growth, legacy boiler population, power transmission network, gas transmission network, coal transportation infrastructure



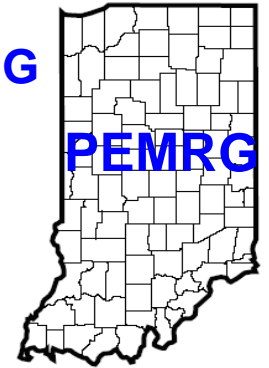
This Draft Final Report

- Scenario Investigation: analysis of how CCTs might evolve in the Indiana power context under alternative environmental regulation, cost & technology penetration hypotheses
- Hope to very roughly estimate implications for Indiana coal demand & electricity prices



This Draft Final Report

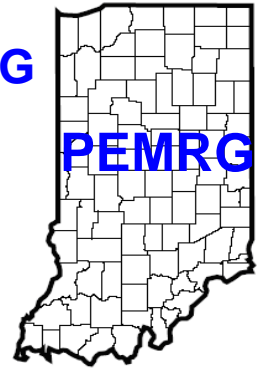
- CCTR Research Plan: What topics critical to CCT & Indiana coal use in the state require additional research as a result of the J2 scoping study?
- Public/Private Action Plan: What can & should be done to enhance CCT & Indiana coal use in the state?



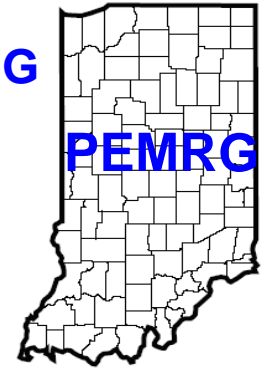
Prospect of CO₂ Regulation

Initiative	Freeze time	Reduction time	Reduction (% or levels)	Comments
Kyoto Protocol		2008-2012	5.2	For 38 countries only
McCain-Lieberman	Worst case: 2010	2010 2020	To 2000 levels To 1990 levels	
9 Northeastern states	2009-2019	2020 & beyond	10	
California		2010 2020 2050	2000 levels 1990 levels 80% below 1990	

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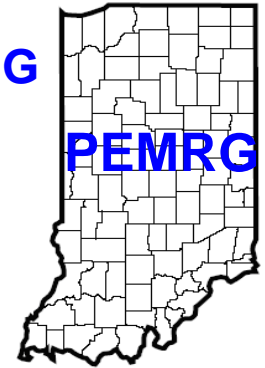


Scenario Analysis



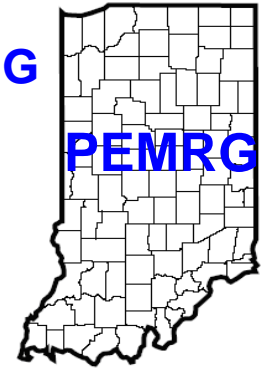
Scenarios Around CO₂

	No CO ₂	CO ₂ Recovery on New Baseload Required	CO ₂ Recovery on 150% of New Baseload Required
Super Critical Pulverized Coal	PC no CO₂	PC CO ₂	PC CO ₂ +50
IGCC with No Backup	IGNobk no CO ₂	IGNobk CO ₂	IGNobk CO ₂ +50
IGCC with Backup	IGbk no CO ₂	IGbk CO ₂	IGbk CO ₂ +50
Atmospheric Fluidize Bed Combustions	FB no CO ₂	FB CO ₂	FB CO ₂ +50



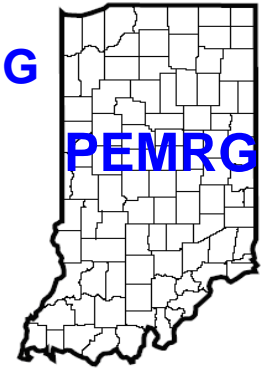
Cost & Heat Rate Assumptions

Plant type	Heat rate	Capital cost	Fixed O&M (5)	Variable O&M
IGCC (no CO ₂ no backup)	8,800	\$1,350/kW (1)	\$40/kW-year	\$0.8/MWh
IGCC (no CO ₂ w/ backup)	8,800	\$1490/kW (7)	\$41/kW-year	\$0.85/MWh
IGCC (w/ CO ₂ no backup)	11,200	\$1750/kW	\$41/kW-year	\$0.85/MWh
IGCC(w/ backup & CO ₂)	11,200	\$1,900/kW(4)	\$42	\$0.90/MWh
PC-SC (no CO ₂)	9,600	\$1,200/kW(2)	\$35/kW-yr	\$0.7/MWh
AFBC (no CO ₂)	9,700	\$1,120/kW(3)	\$31	\$0.85/MWh
PC-SC (with CO ₂) [3]	11,600	\$2,100/kW (6)	\$37	\$0.80/MWh
AFBC (with CO ₂) [3]	11,860	\$2,000/kW (6)	\$33	\$0.95/MWh

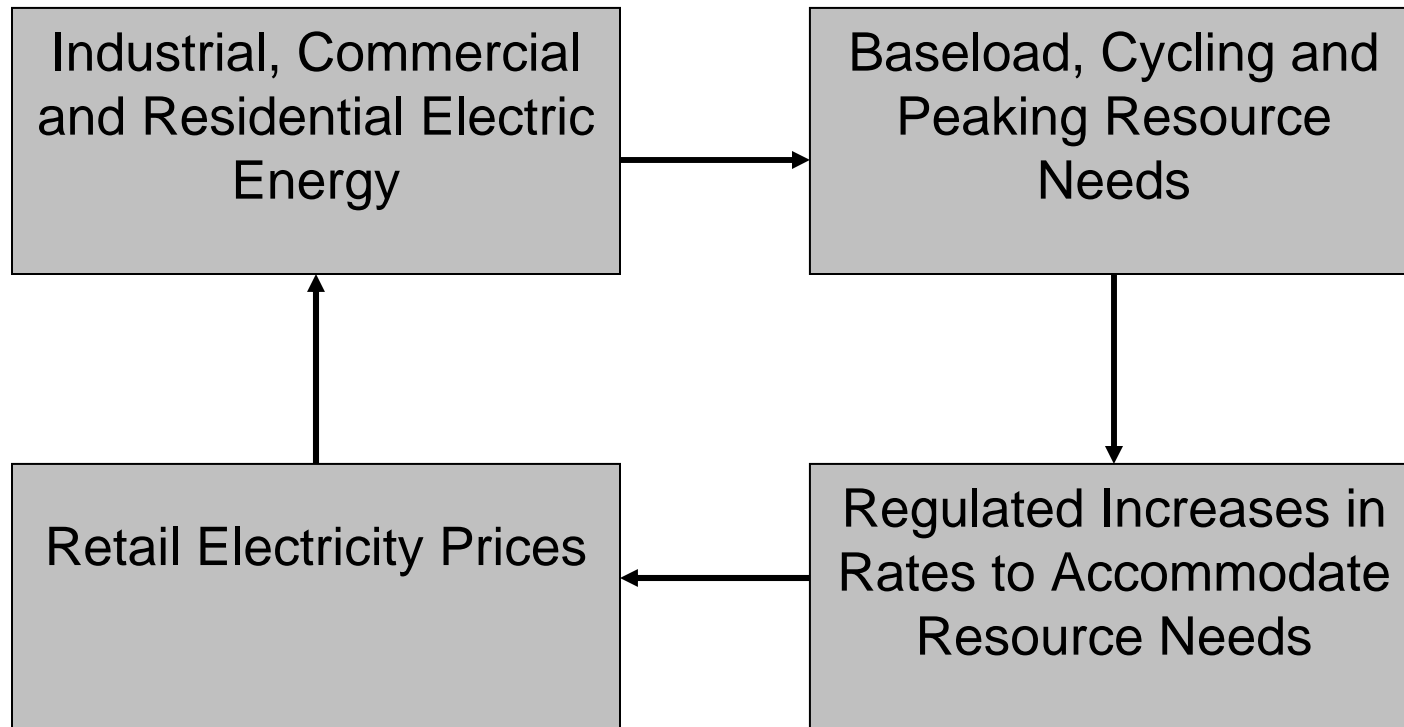


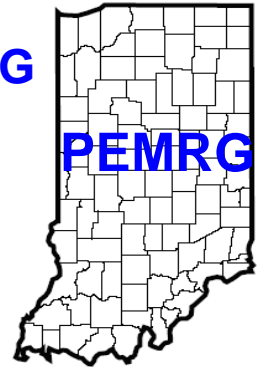
Availability & Recovery Assumptions

Plant type	Availability	Comments	Percent of CO ₂ Recovered
IGCC (no CO ₂ and no backup gasifier)	80	90% is assumed for the case with backup	85
PC-SC (no CO ₂)	86		85
AFBC (no CO ₂)	85		85
IGCC(with CO ₂ but no backup)	78	88% for the case with CO ₂ and backup	85
PC-SC (with CO ₂)	84		85
AFBC (with CO ₂)	83		85



SUFG Modeling System



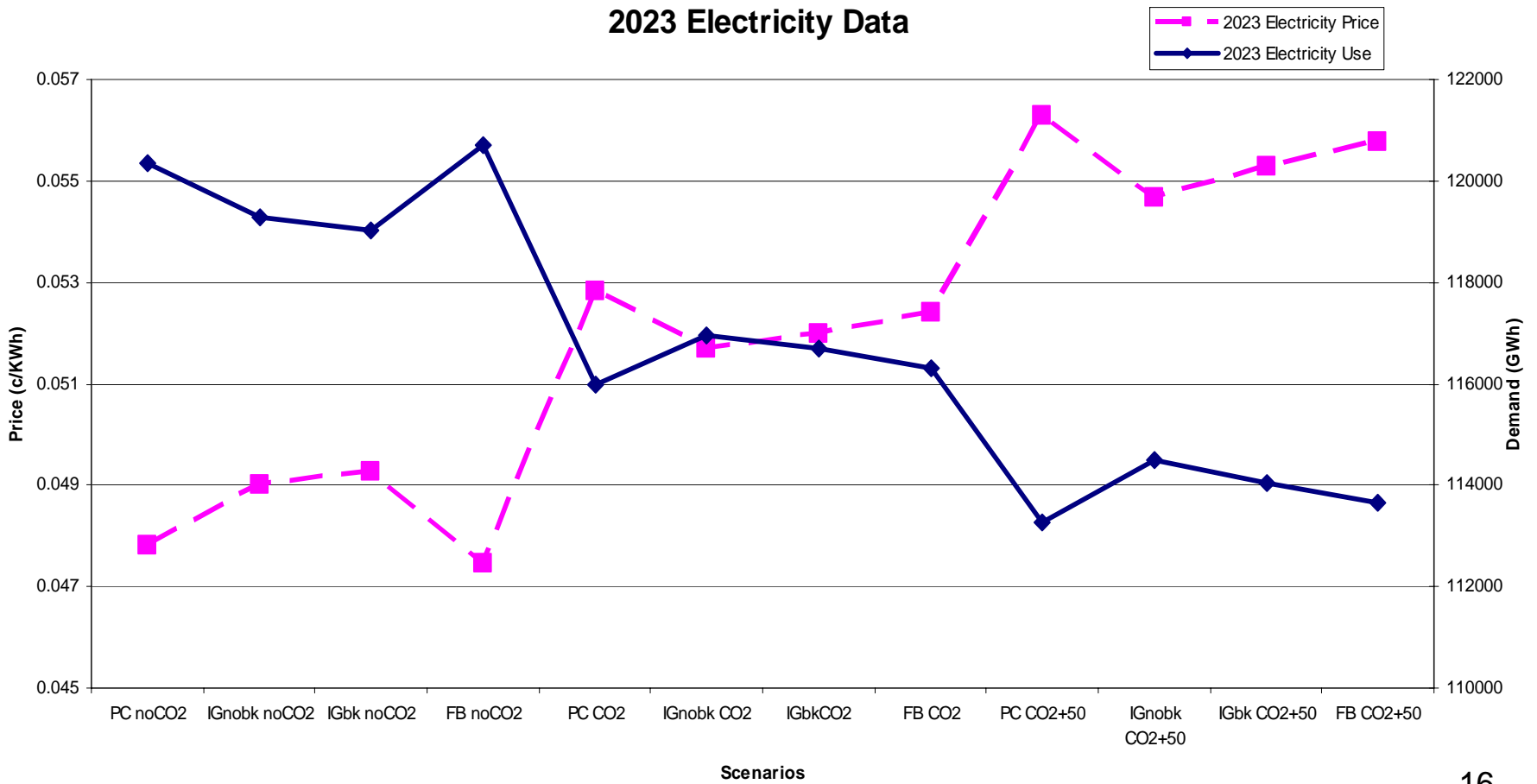


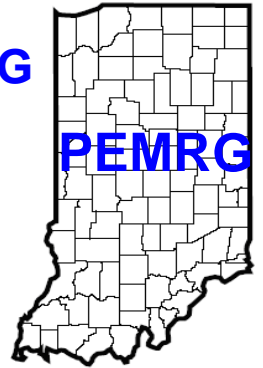
Simplifying Assumptions

- SUFG Forecast assumptions on macro economics
- CO₂ limits in effect after 2010, study through 2023
- New baseload is CCT & CO₂ per scenario
- Retrofit simulated by adding 50% to new capacity and making it “must take”
- New plants assumed to use Indiana coal
- Generic plants without geography or sequestering
- Indiana is a closed system – no trade or other sources
- Cycling & peaking capacity expansion assumed natural gas

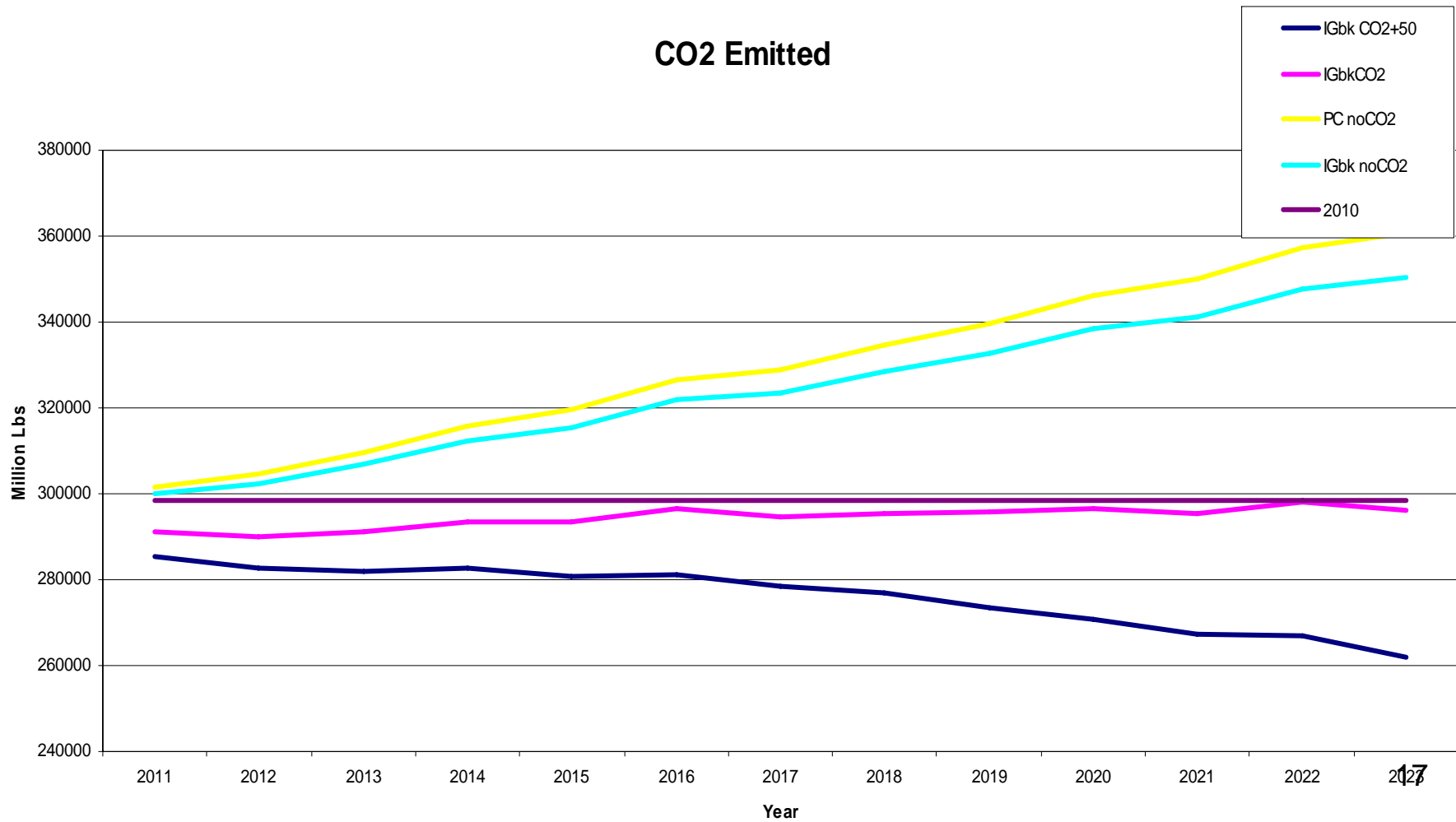


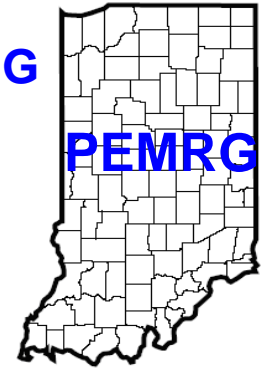
Energy Demand & Price





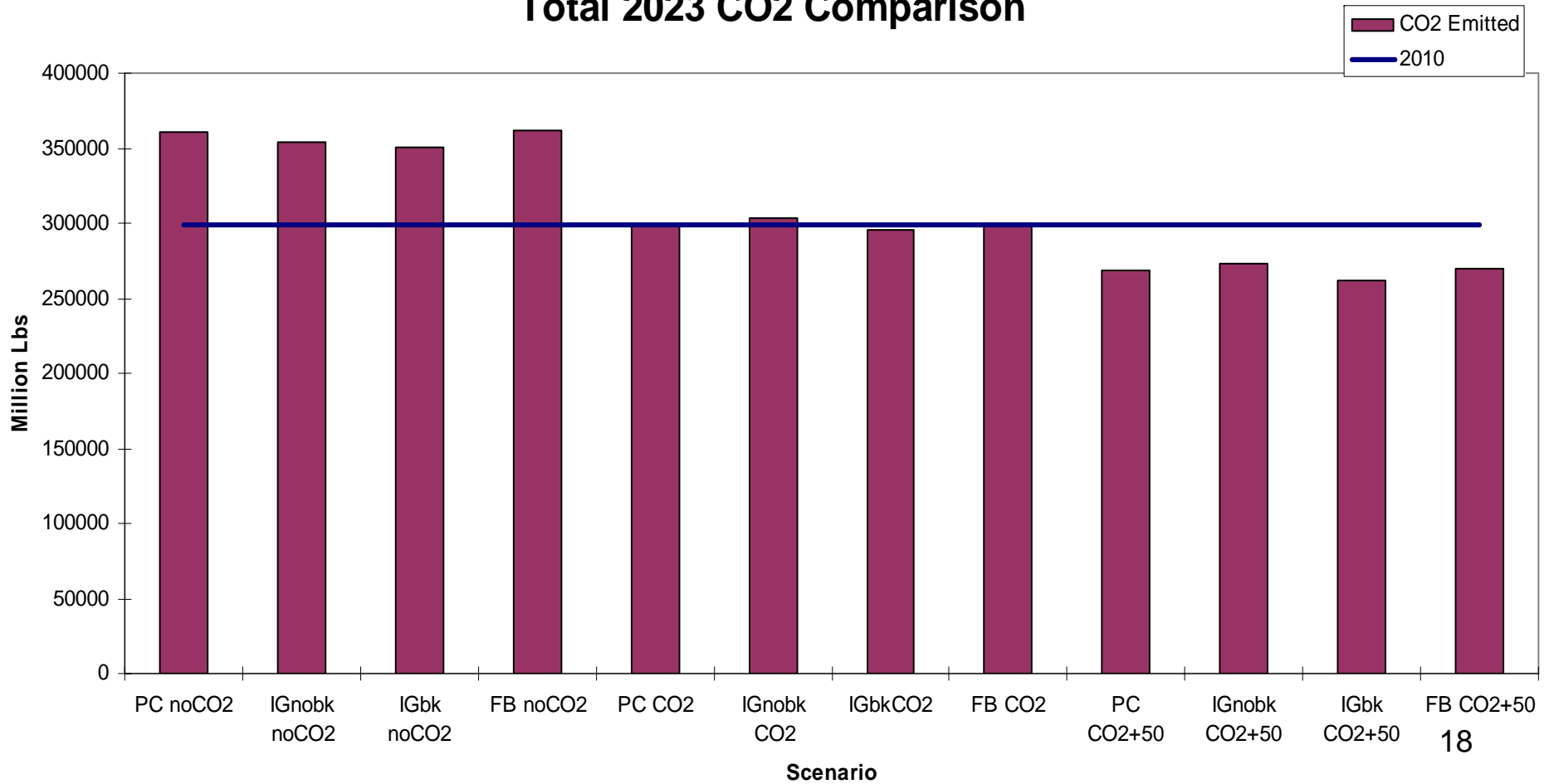
CO₂ Emission over Time





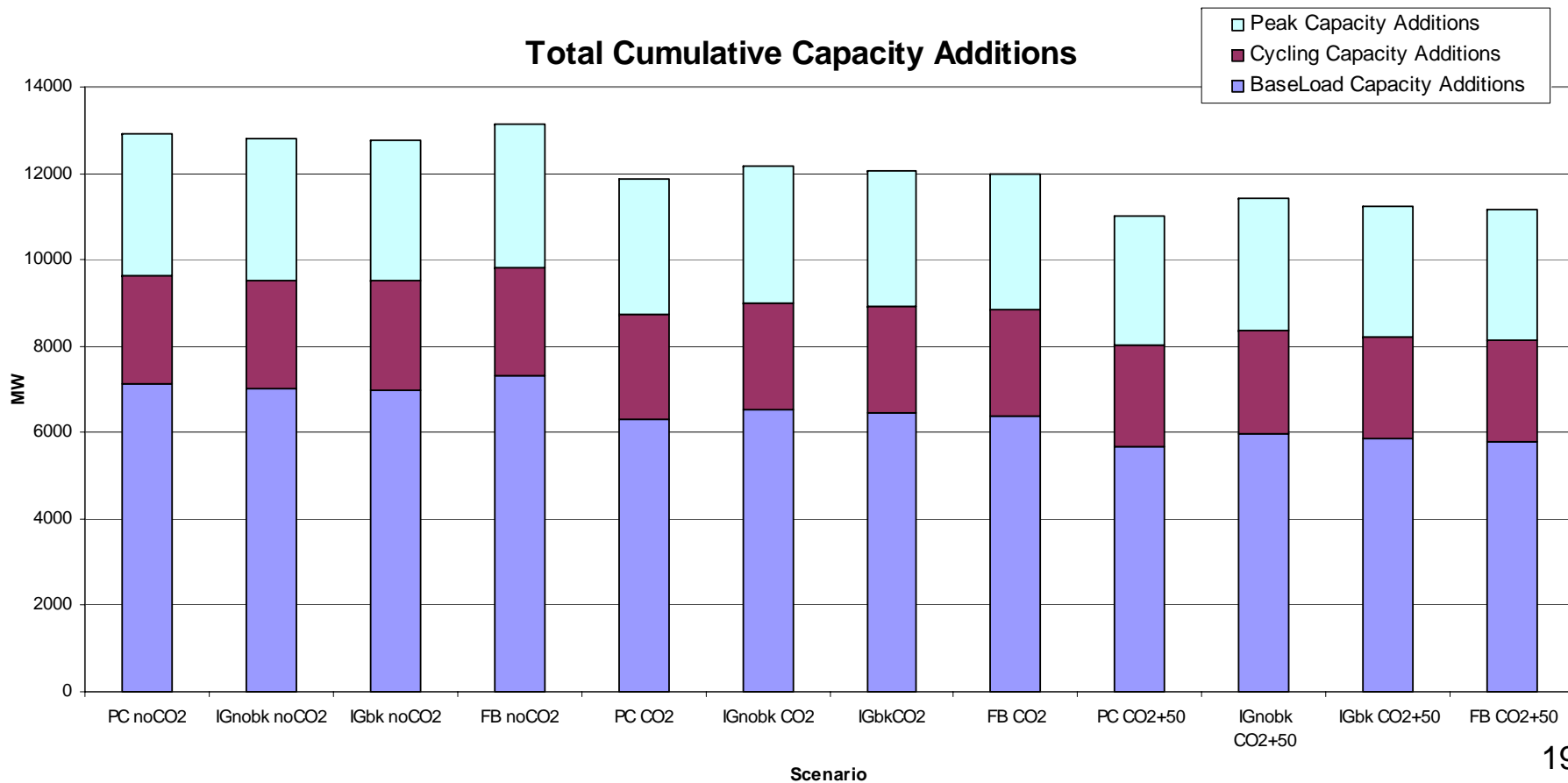
CO₂ in 2023 by Scenario

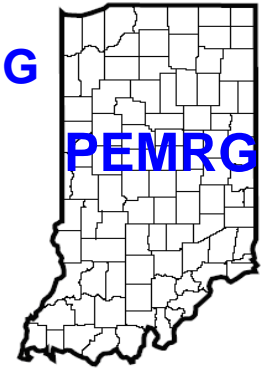
Total 2023 CO2 Comparison





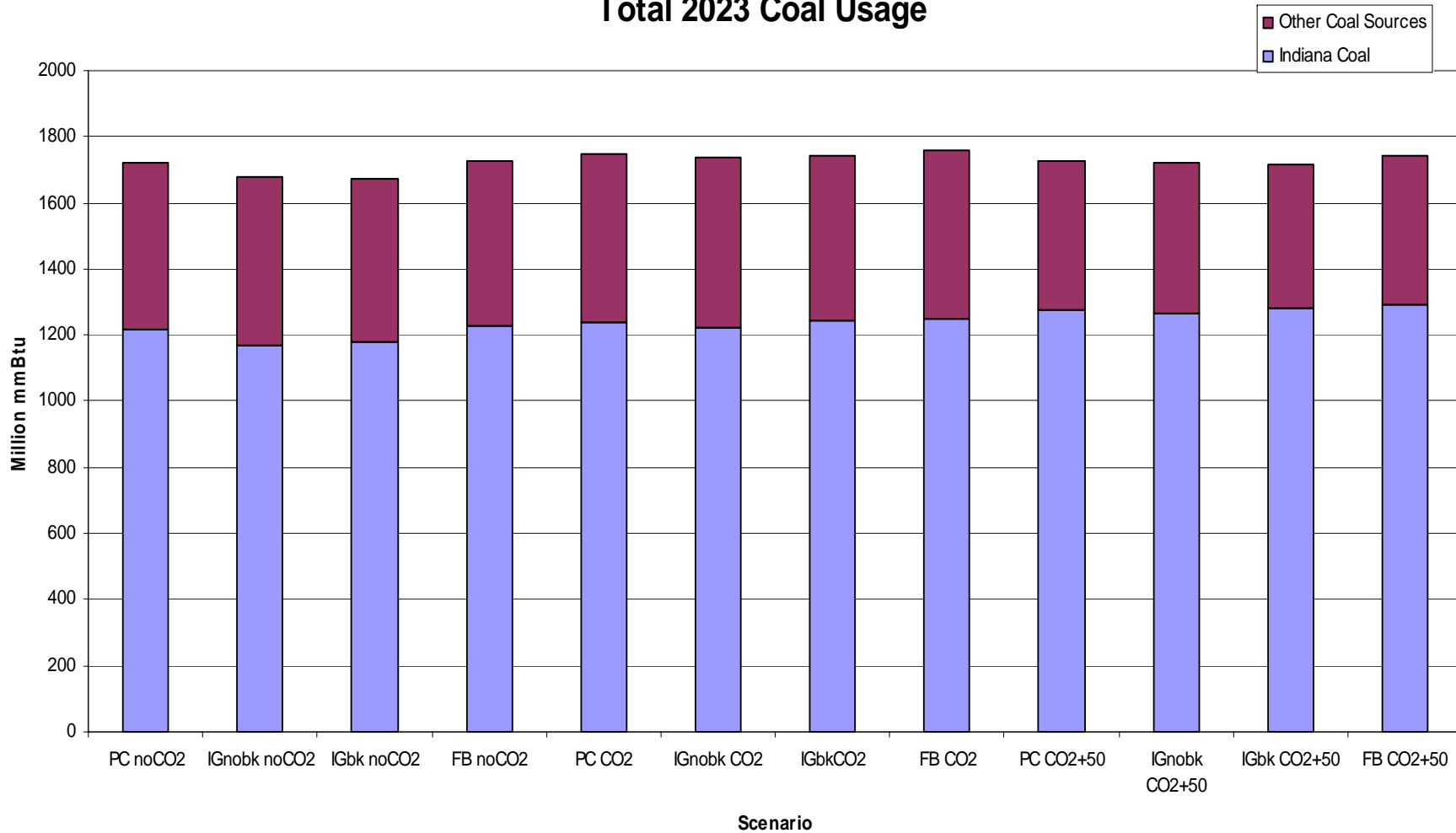
Cumulative Capacity Expansion



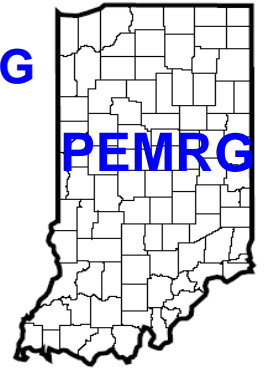


Coal Usage

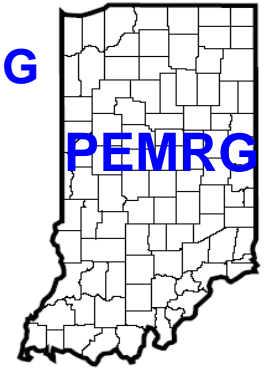
Total 2023 Coal Usage



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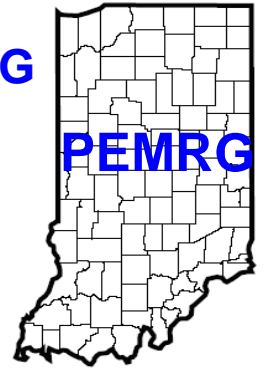


CCTR Research Plan



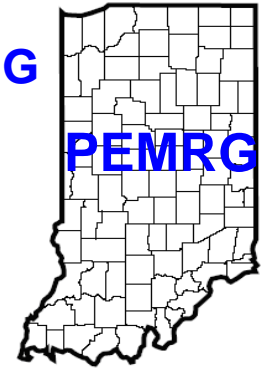
Statewide Optimization for CO₂

- Policy tool for assessing implementation of CCT, and potentially, CO₂ regulation & sequestration
- Work in two phases
 - Phase I – further investigation of component issues
 - Phase II – optimization modeling



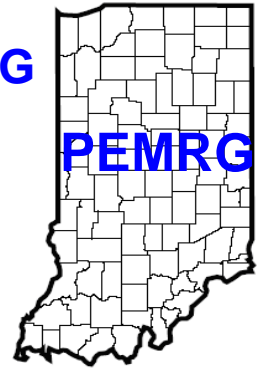
Statewide Optimization for CO₂

- Component issues
 - CO₂ capture technologies
 - New CCT technologies
 - Configuration design for availability & min cost
 - CO₂ sequestration (location, pipelines, etc.)
 - Power transmission from mine mouth plants
 - Cap & trade impacts
 - Better cost estimates



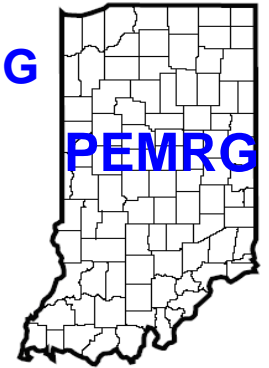
Statewide Optimization for CO₂

- Optimization model
 - Choose construction and upgrades
 - Meet projected demand
 - Comply with CO₂ regulations
- Treat state in regions so that transmission geography and cap & trade can be incorporated



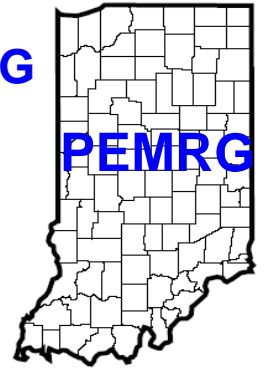
Retrofitting for CCT

- Of new plants built with upgrade in mind
- Systems of old plants
 - Least cost
 - Interaction among plants to maintain system reliability



Co-Production

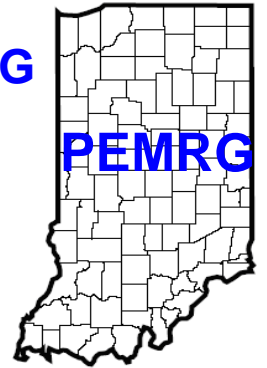
- Combinations of power, transportation fuels, fertilizer, etc.
 - Big opportunity with power to exploit variation of demand over day and season
 - Obama-Lugar may bring transportation fuel investment
- First part, optimization of single co-production facilities, probably to maximize investment return
- Also, regulation of co-production
 - In the rate base?
 - Who decides priorities between power and others?



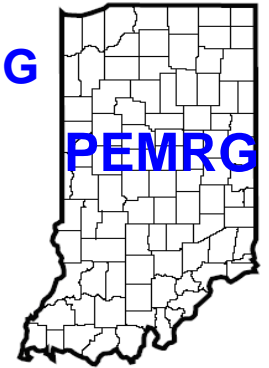
CCT Uncertainties & Risks

- Dealing with cost unpredictability
- Using CCT to hedge natural gas market volatility
- CCT to boost national security, e.g. in military fuels
- Risks in carbon sequestration
- Impact of power price increase on economics & employment, and how to mitigate the impact

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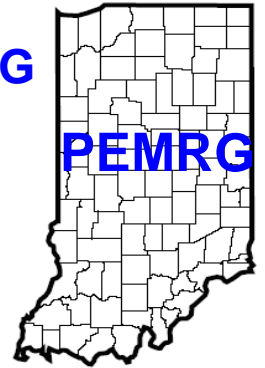


Public-Private Action Plan



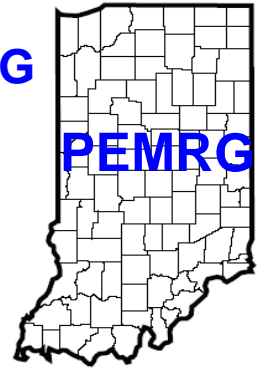
Indiana Clean-Coal Summit

- CCT and probably CO₂ regulation are coming
- Scenarios suggest something like 12K MW needed through 2023
- Uncertainties about costs and CO₂, technology maturity, siting, permitting, etc. has produced some paralysis



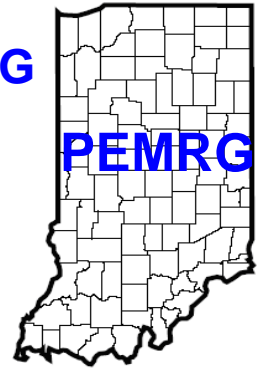
Indiana Clean-Coal Summit

- Need to assemble state officials, coal industry, power industry, consumer groups, etc. to find a way to accelerate CCT
- What extra incentives are needed?
- Can they be tied to use of Indiana coal?



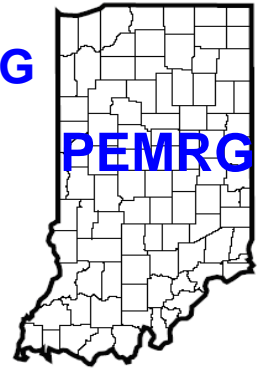
Sequestration Replaces Interest in Coal Characteristics

- Many CCTs, especially IGCC, are able to use wide variety of coals
 - No need to emphasize detail coal characteristics
- Much more needs to be understood about sequestration
 - Cost, risks, locations, adjacency to power transmission and mines



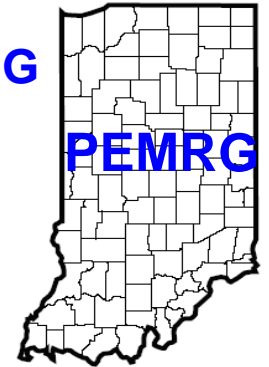
Preparation for Increased Coal Production

- If CCTs are implemented, coal demand will increase
- Could be dramatic for Indiana coal if incentives have strings
- Coal industry needs to prepare for this increase in capacity
- Community colleges need to enhance training of coal mining personnel



Long Term Transmission Agreements

- Federal ISO regulations for pricing power transmission rights pushing in the direction of short term FTRs
- Investment in new plants depends in part in partnering and shared cost of investment
 - This is made risky by uncertainty about cost to bring from production site to own market
- Need for federal regulatory reform to facilitate longer term transmission contracts



FutureGen

- Huge federal opportunity
 - Important chance to build human technical capital
- Indiana has been passive relative to other states
- Indiana has advantages
 - Coal reserves
 - Sequestration sites
 - Regulated rates and capital cost recovery
 - Wabash River project
 - Purdue and its agencies
- State activity must accelerate, probably in partnership with Illinois