Energy Risk Lab

Austin, TX

September 10, 2014

Purpose of Today

- Explore decision-making under conditions of uncertainty
- Understand interaction between EPA rules
- Explore motivators for gas capacity additions in comparison to motivators for other electric generation additions
- Explore regulatory roles, options, and bottlenecks when faced with decision-making requirements when the future is unknown and dynamic.

Today's Agenda

- Overview of Mercury and Air Toxics Standard (MATS)
- MATS scenario exercise
- The Calamity Round
- Section 111 of the CAA (including the Clean Power Plan, Sect. 111d)
- Wrap Up and Discussion

As we know, there are known knowns.
There are things we know we know.
We also know there are known unknowns.
That is to say we know there are some things we do not know.
But there are also unknown unknowns, the ones we don't know we don't know.
– Donald Rumsfeld

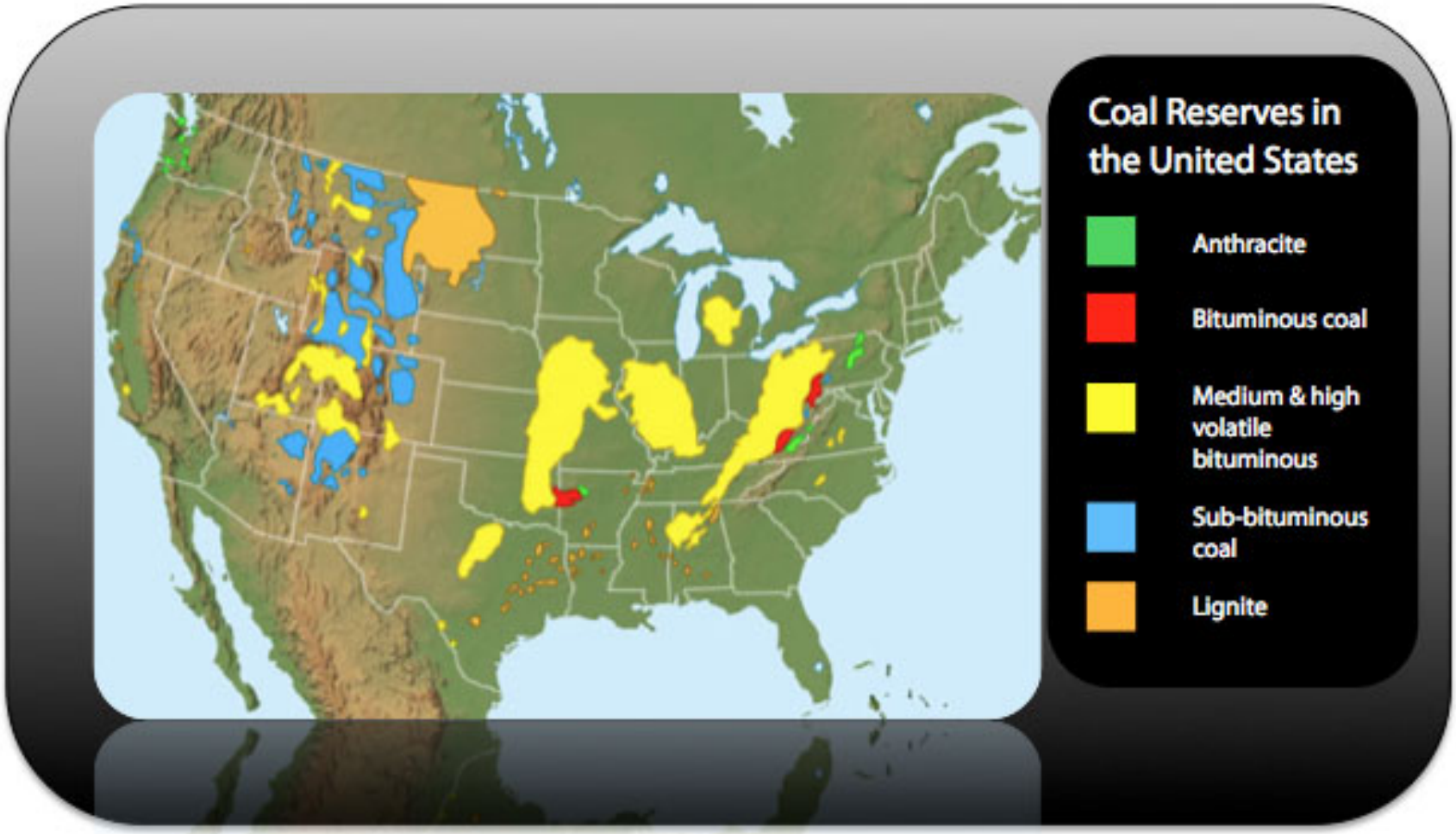
Knowns and unknowns affecting the electric sector:

- Environmental rules (i.e. MATS)
- Fuel prices (i.e. gas)
- Policy preferences (i.e. RPS, EERS)
- Markets, regulations, people
- Many others!

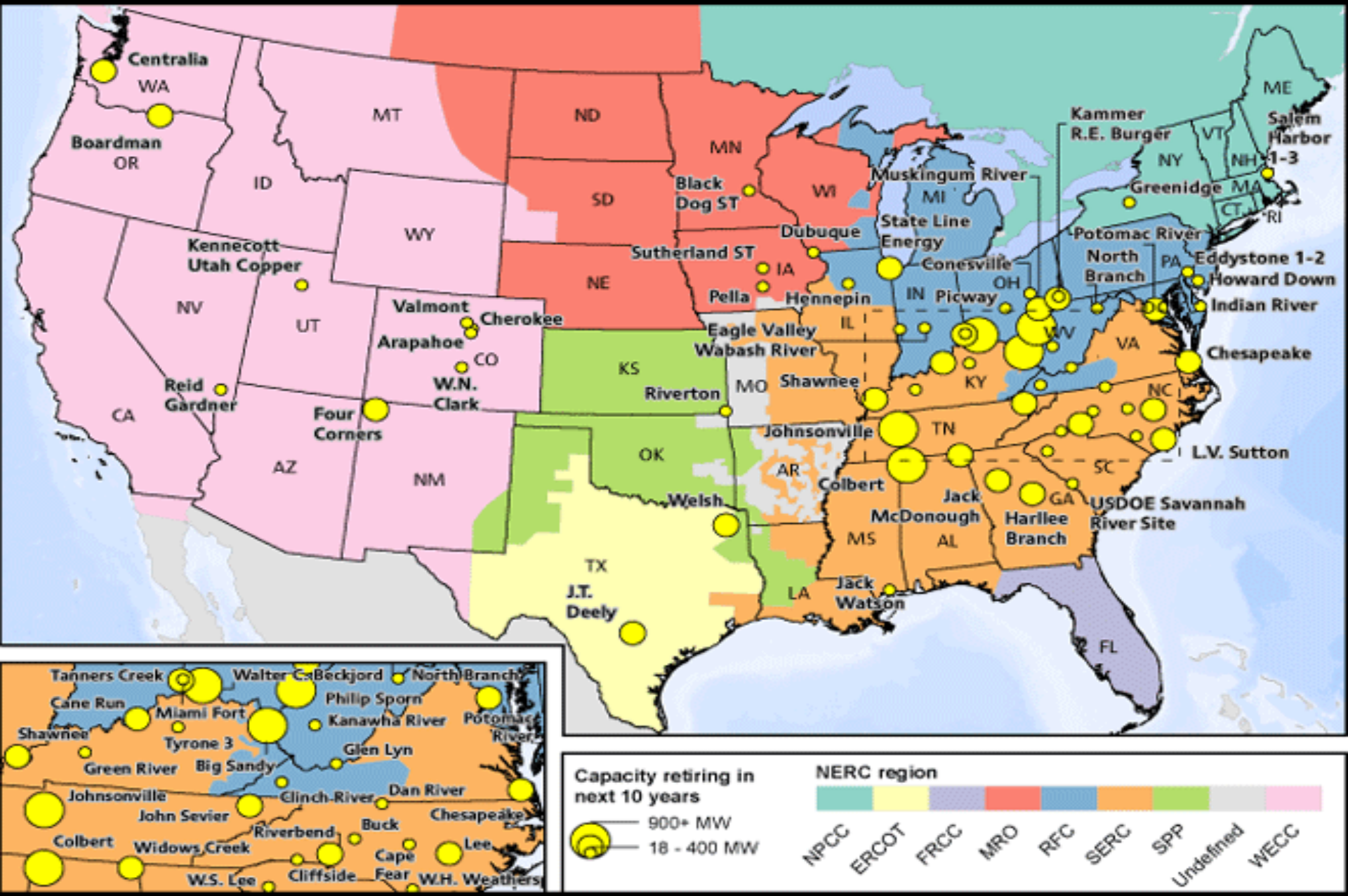
What does the Mercury and Air Toxics Standards (MATS) require?

- Reduction of the following pollutants
  - Mercury (Hg)
  - Hydrogen chloride (HCl)
  - Filterable particulate matter (fPM)
- Compliance period
  - 3 years
  - + 1 for technology installation (add controls, upgrade transmission, build replacement power)
  - + 1 additional for reliability critical units

Emissions Vary by Coal Type



Announced coal plant capacity retirements 2011-2020



As of Sept. 14, 2011
Source: SNL Energy
Map credit: Jesse Bellavance

SNL

What are the compliance options?

RETIRE

- Long term PPAs
- Market capacity purchase

REPOWER

- Natural gas, biomass, other
- Switch to low sulfur coal
- Partial or full plant replacement

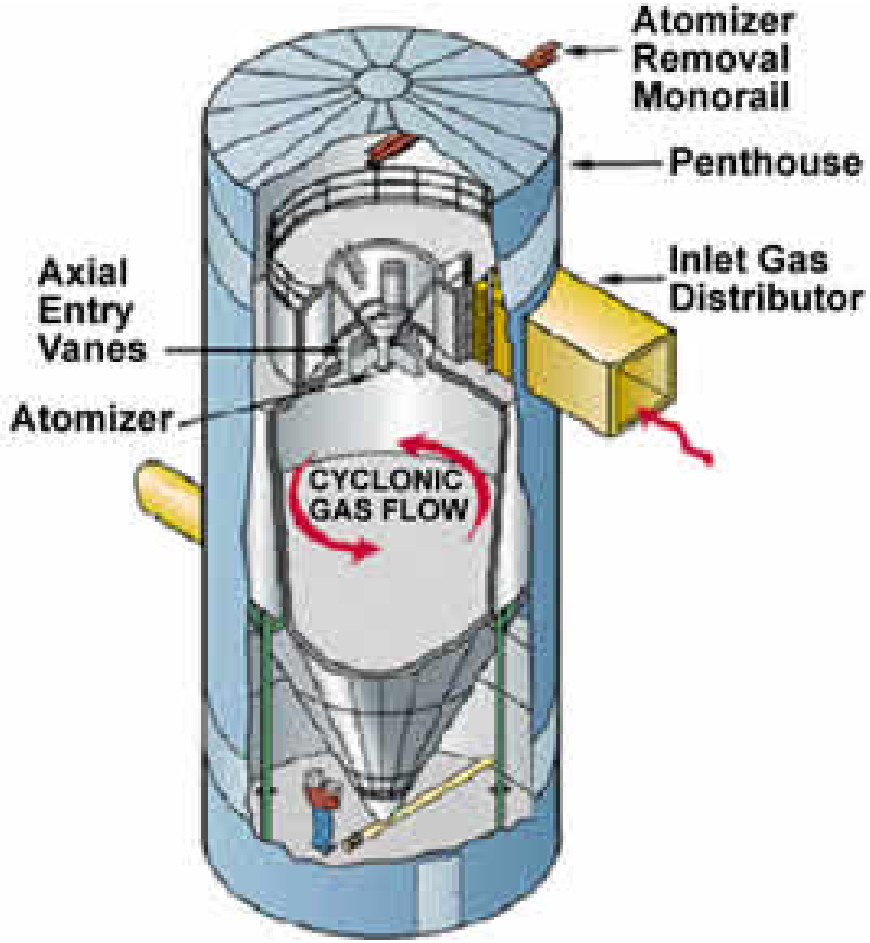
RETROFIT

- Upgrade ESP or Baghouse
- Scrubber
- ACI

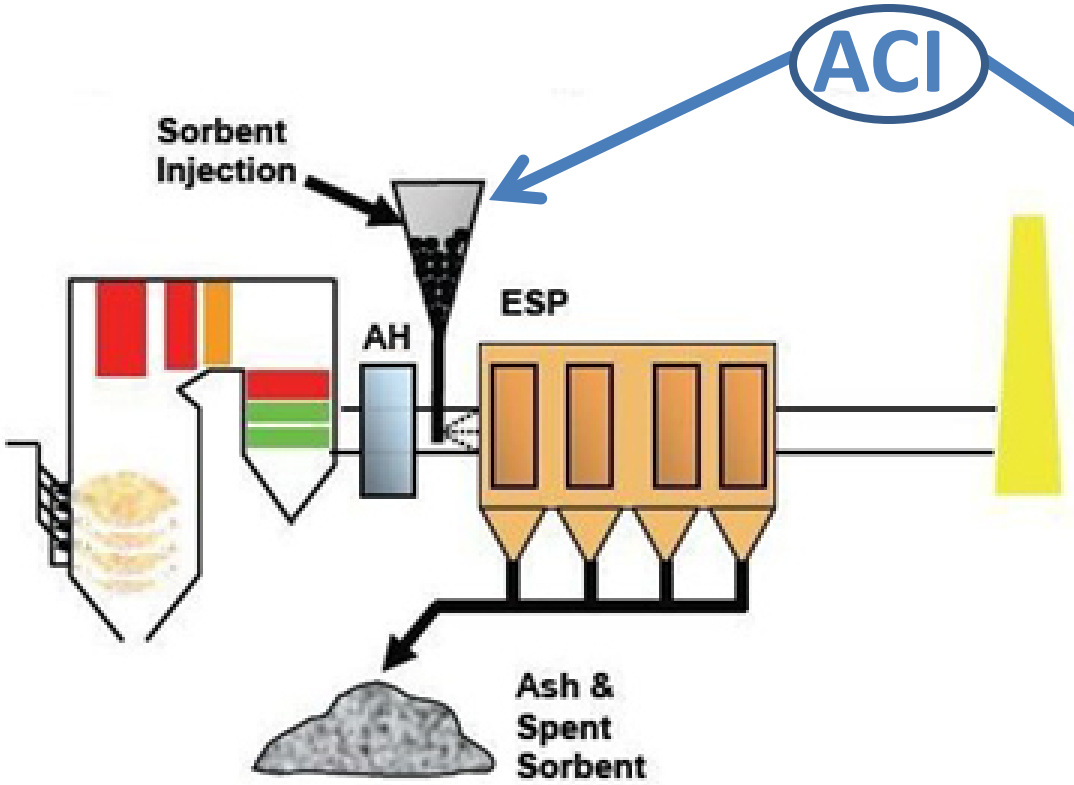
Control technology for MATS

- Mercury
  - Scrubbers: Flue Gas Desulfurization (FGD)
  - Activated Carbon Injection (ACI)
- Non-mercury metals
  - Fabric Filter
  - Electrostatic Precipitator (ESP)
- Acid Gases
  - FGD Scrubber
- PM2.5
  - Fabric filter, or Baghouse – 100% solution for PM compliance. Existing may need upgrades
  - Electrostatic Precipitator (ESP)

FGDs: big, pricey, and effective



ACI: Inexpensive, Less Coverage



The Correct Control Equation

- ACI + Baghouse? Baghouse + FGD? ESP + FGD? In the real world, the most appropriate configuration to control MATS pollutants is dependant upon fuel, existing infrastructure, and controls. It will vary plant by plant.

- **In this lab you are limited to two MATS pollutant control options: ACI and FGD.**
  - ACI controls for mercury only and requires sub-bituminous coal.
  - FGD addresses all MATS pollutants – and more. No coal rank restriction.

Demand Side Resources

- Not strictly a compliance option for MATS
- Underexplored as useful companion strategy
- Can be utilized to
  - Assist in outage periods while installing controls
  - Assist with reliability
  - Control cost of implementation
- Benefits
  - May have shorter lead time
  - May delay costs
  - May address demand growth

What are Demand Side Resources in this Lab?

- Technologies or programs that reduce* the load on electricity network:
  - **Energy Efficiency** – Technologies and Programs (projected to double by 2015 in Eastern Interconnection)
  - **Demand Response/Load Management** – Changes* in end-use electricity
  - **Smart grid** – reduce GTD losses, data provided by smart meters can help ID savings opportunities, can enable demand response
  - **Volt/Var, System Efficiency –** smart grid application for distribution grid; demand reduction, energy loss reduction, improved power quality

Lead times

- What has to happen before you start operating your power plant?
  - Develop your strategy (retire, retrofit, repower)
  - Design or redesign plant
  - Secure capital $$
  - Obtain permits
  - Parts and equipment procurement
  - Construction and outages

Variable inputs for retrofit time

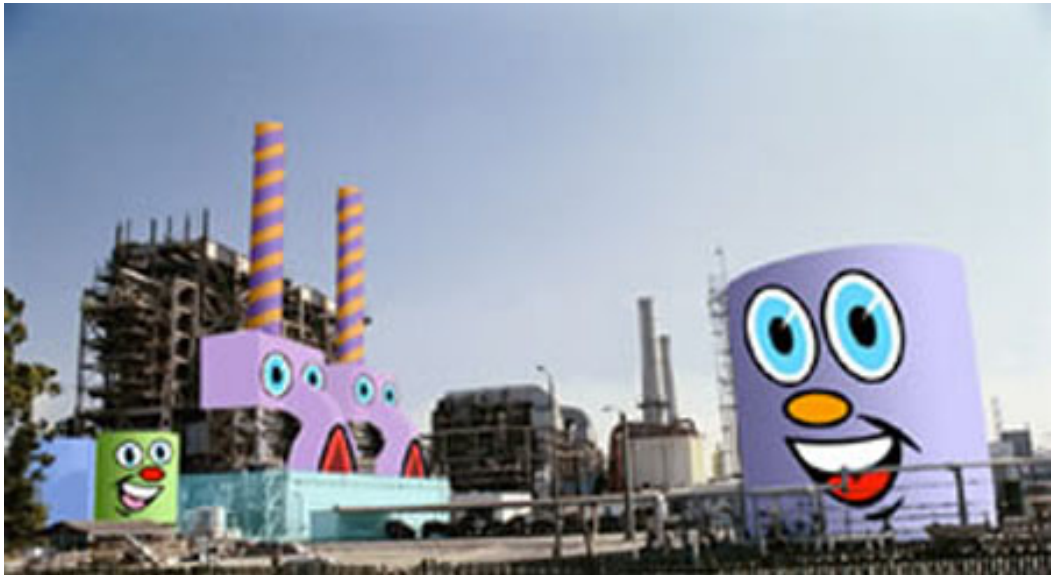
- Supply chain availability
  - Engineers, manufacturers, fabrication shops, craft labor, construction managers
- Cost
  - As compliance date approaches, more manpower needed, costs rise for overtime pay, supply rush, etc.
- Time crunch
  - ISO estimates 4-6 maintenance cycles for outage management, but the last two will be very busy
- How do you solve a bottleneck?

New Source Performance Standard and Replacement of Coal

- Requires all new plants to have CO2 emissions approximately as low as combined cycle gas.

- What does this mean? In Round 1 of the Lab you can't replace a coal plant with another non-CCS coal plant.

Game On



Meet your team!

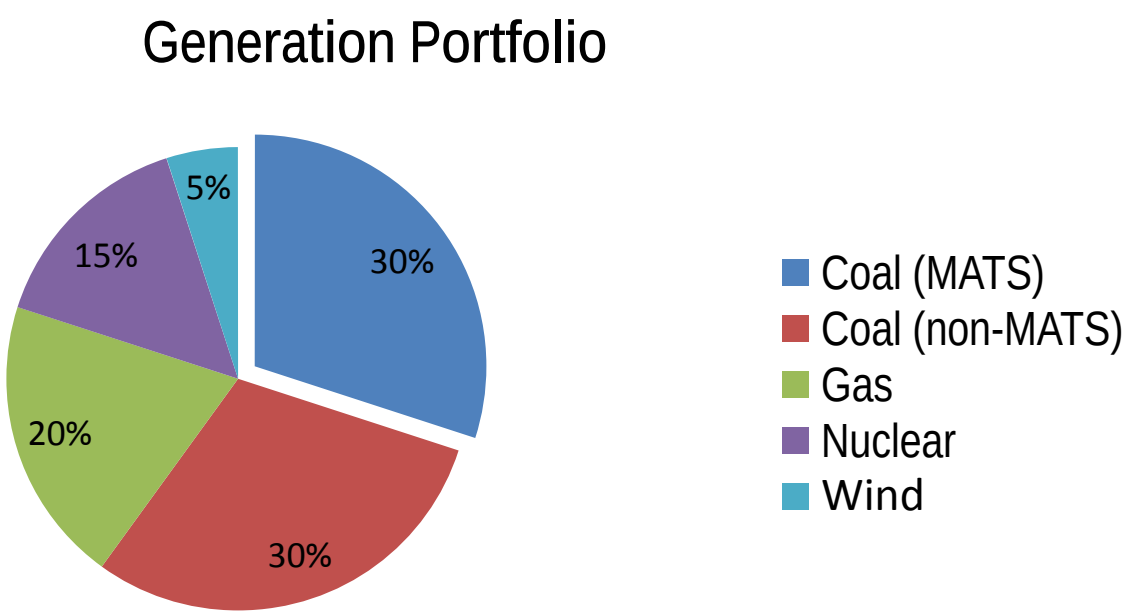
Order of Play

- Round 1: The MATS round
- Round 2: Navigate Calamity
- Round 3: The 111d round
- Round 4: The Impossible Box

Your Electricity Portfolio

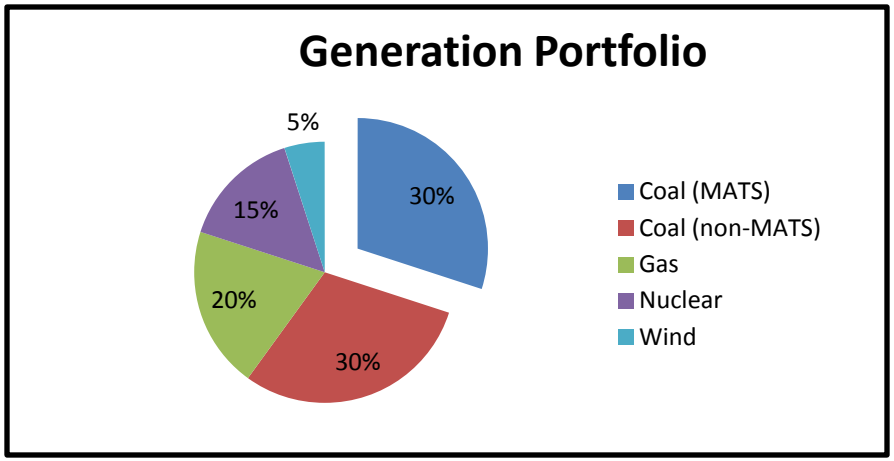
Net Capacity: 10,000 Megawatts
Primary Energy Source: Coal
Coal producing state and net importer
Vertically integrated utilities

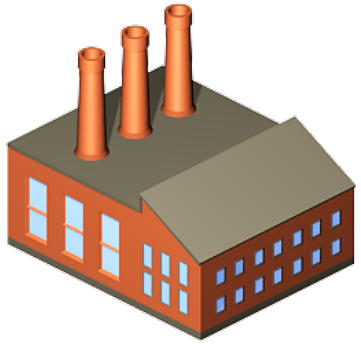
40 % Industrial/commercial sector vs. 60% res
Average retail price: $0.08/kWh
Participates in RTO market
Includes reserve margin (12%)



Round 1

- Select compliance strategy for six plants
- Meet your power plants!

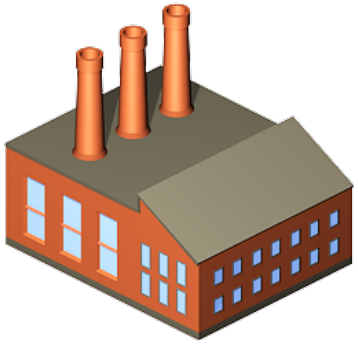




TAKOMA PARK
300 MW

Built in 1969
Proximity to gas line: 15 miles
Fuel: bituminous coal
Pollution control: electrostatic precipitator

Coal Rank Switch, Add ACI & Baghouse	$264 M
Add FGD & Baghouse	$330 M
Replace / Repower (Gas)	$300 M
Retire (market replacement)	$?

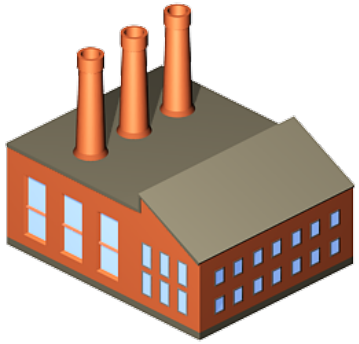


FOREST GLEN
1100 MW

Built in 1985
Fuel: sub-bituminous coal
Once-through cooling system
Proximity to gas line: 50 miles
Pollution control: baghouse & SCR

Add ACI	$88 M
Add FGD	$880 M
Replace / Repower (Gas)	$1.1B

CO2 emissions @ 5000t/MW/y: 5.5m t/yr



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Once-through cooling system
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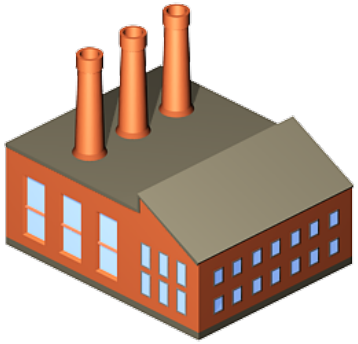
Coal Rank Switch, Add ACI & Baghouse	$264 M
Add FGD & Baghouse	$330 M
Replace / Repower (Gas)	$300 M

CO2 emissions @ 5000t/MW/y: 1.5m t/yr

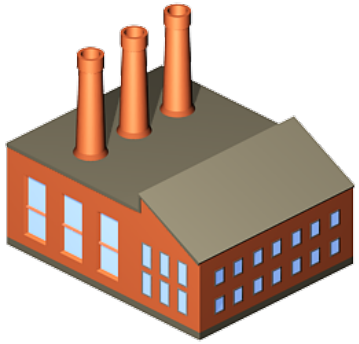


TENLEYTOWN
600 MW

Built in 1970
Fuel: sub-bituminous coal
Once-through cooling system
Proximity to gas line: over 50 miles
Pollution control: electrostatic precipitator & baghouse

Add ACI	$48 M
Add FGD	$480 M
Replace / Repower (Gas)	$600 M

CO2 emissions @ 5000t/MW/y: 3m t/yr

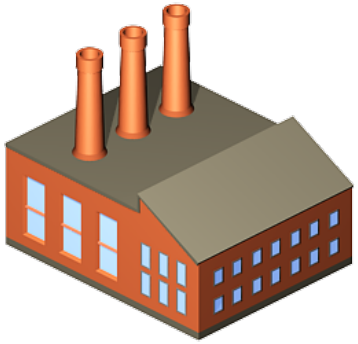


TYSONS II
200 MW

Built in 1963
Fuel: sub-bituminous coal
Once-through cooling system
Proximity to gas line: connected
Pollution control: electrostatic precipitator

Add ACI & Baghouse	$76 M
Add FGD & Baghouse	$220 M
Replace / Repower (Gas)	$200 M

CO2 emissions @ 5000t/MW/y: 1m t/yr

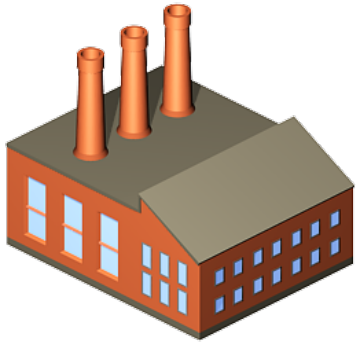


BETHESDA
700 MW

Built in 1973
Fuel: bituminous coal
Once-through cooling system
Proximity to gas line: 20 miles
Pollution controls: baghouse, electrostatic precipitator, selective catalytic reduction (SCR)

Switch Coal Rank, Add ACI	$406 M
Add FGD	$560 M
Replace / Repower (Gas)	$700 M

CO2 emissions @ 5000t/MW/y: 3.5m t/yr



SHADY GROVE
100 MW

Built in 1957
Fuel: sub-bituminous coal
Once-through cooling system
Proximity to gas line: 100 miles
Fuel: sub-bituminous coal
Pollution controls: electrostatic precipitator

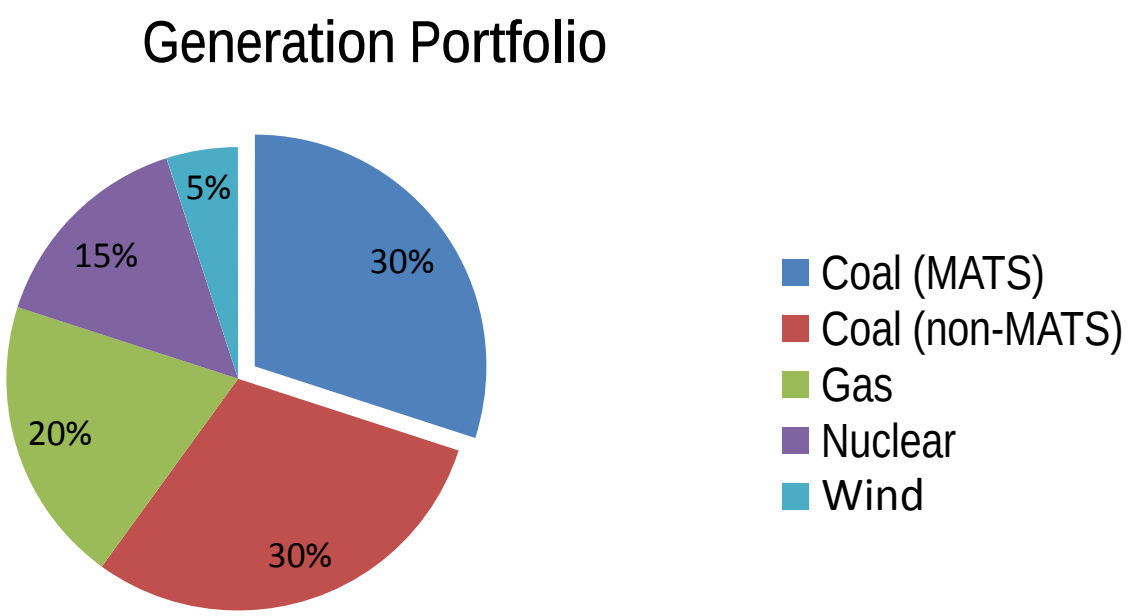
Add ACI & Baghouse	$38 M
Add FGD & Baghouse	$800 M
Replace / Repower (Gas)	$100 M

CO2 emissions @ 5000t/MW/y: 0.5m t/yr

Your Electricity Portfolio

Net Capacity: 10,000 Megawatts
Primary Energy Source: Coal
Coal producing state and net importer
Vertically integrated utilities

40 % Industrial/commercial sector vs. 60% res
Average retail price: $0.08/kWh
Participates in RTO market
Includes reserve margin (12%)



What are the compliance options?

RETIRE

- Long term PPAs
- Market capacity purchase

REPOWER

- Natural gas, biomass, other
- Switch to low sulfur coal
- Partial or full plant replacement

RETROFIT

- Upgrade ESP or Baghouse
- Scrubber
- ACI

Develop a Strategy for MATS Compliance

RETROFIT:

- Flue Gas Desulfurizer + Baghouse
- Baghouse + ACI*
- *sub-bituminous only

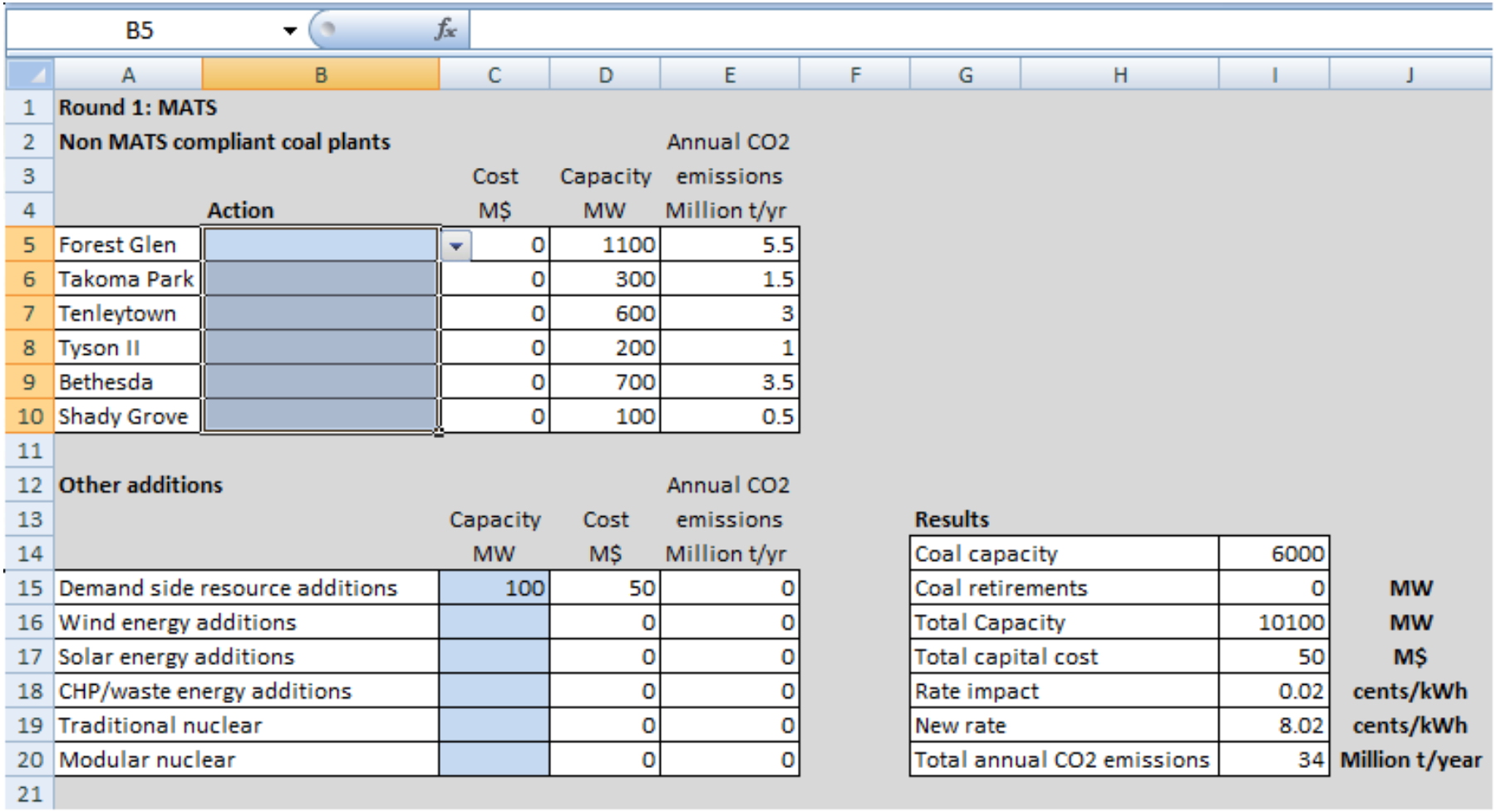
REPLACE: with new non-coal unit

REFUEL:

- from bituminous to sub-bituminous coal
- coal to natural gas

RETIRE: Must be replaced with a new unit, demand-side resources, or other

Put Away Your Calculators!



B5

	A	B	C	D	E	F	G	H	I	J
1	**Round 1: MATS**									
2	**Non MATS compliant coal plants**				Annual CO2					
3			Cost	Capacity	emissions					
4		**Action**	M$	MW	Million t/yr					
5	Forest Glen		0	1100	5.5					
6	Takoma Park		0	300	1.5					
7	Tenleytown		0	600	3					
8	Tyson II		0	200	1					
9	Bethesda		0	700	3.5					
10	Shady Grove		0	100	0.5					
11										
12	**Other additions**				Annual CO2					
13			Capacity	Cost	emissions		**Results**			
14			MW	M$	Million t/yr					
15	Demand side resource additions		100	50	0		Coal capacity	6000		
16	Wind energy additions			0	0		Coal retirements	0	**MW**	
17	Solar energy additions			0	0		Total Capacity	10100	**MW**	
18	CHP/waste energy additions			0	0		Total capital cost	50	**M$**	
19	Traditional nuclear			0	0		Rate impact	0.02	**cents/kWh**	
20	Modular nuclear			0	0		New rate	8.02	**cents/kWh**	
							Total annual CO2 emissions	34	**Million t/year**	
21										

Shopping Cart

POLLUTION CONTROL CONSTRUCTION COSTS

- FGD: $800,000/MW
- ESP: $200,000/MW
- Baghouse: $300,000/MW
- ACI: $80,000/MW

REFUEL

- Coal Rank Switch: bituminous to sub-bituminous: $500,000/MW

DELIVERY INFRASTRUCTURE

- 30” Gas pipeline (firm): $5m/mile
- Electric Transmission (infinite length): $1m/MW

NEW RESOURCES

- Natural Gas (CCGT): $1m/MW
- Nuclear (traditional, large-scale): $10m/MW
- Nuclear (small modular reactors): $7m/MW
- Wind Energy: $2m/MW (by energy, not nameplate capacity)
- Solar Energy: $5m/MW
- Demand Side Resources: $0.5m/MW
- CHP / Waste Energy (up to 500 MW): $0.5m/MW

DECARBONIZATION

- Heat Rate Improvement: +$200,000/MW
- CCS: $7m/MW
- Advanced Gas Turbine technology: +$3m/MW

Round 1: MATS Discussion

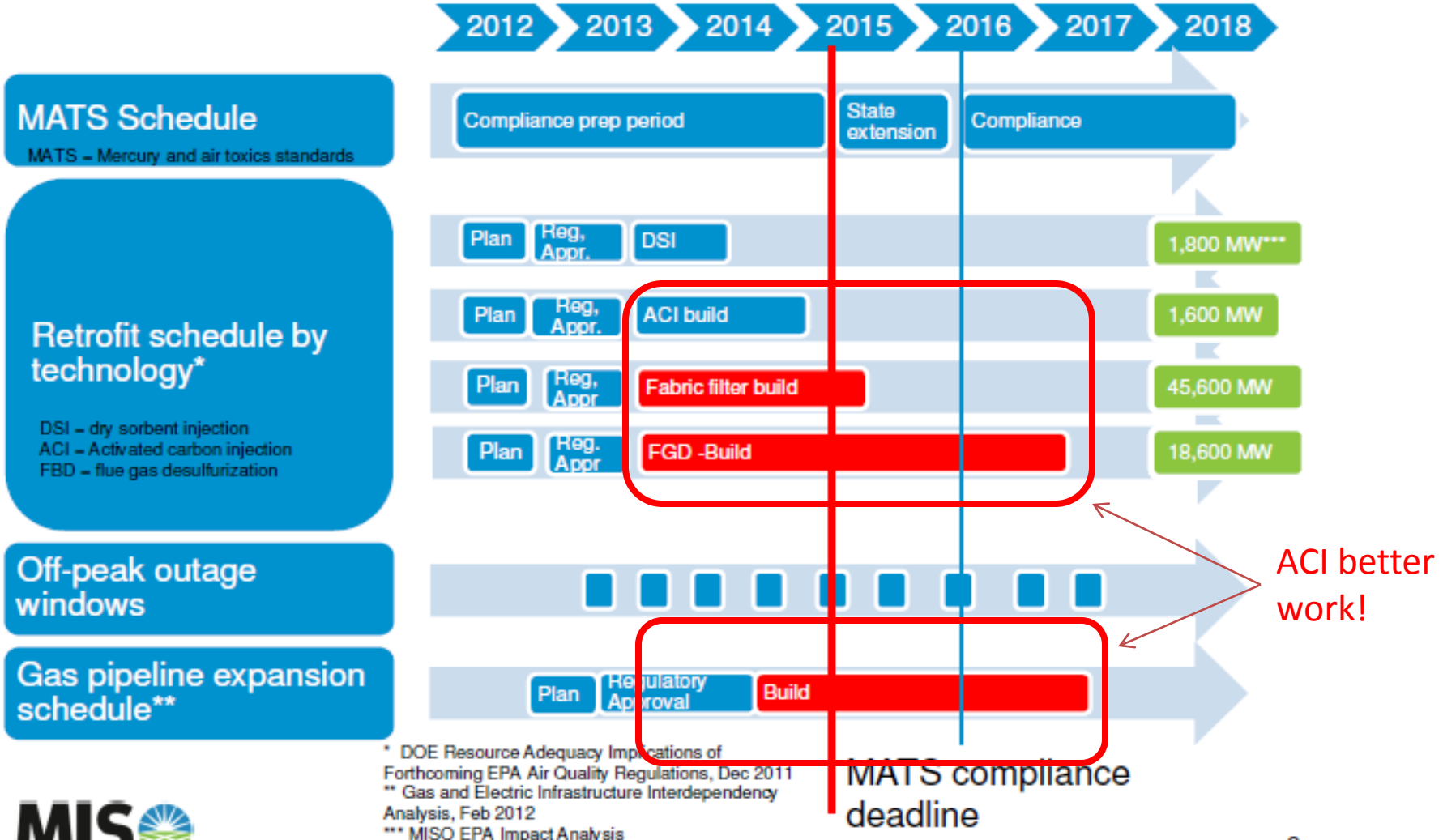
1. What are the biggest challenges you are facing?
2. What strategies did you use to make decisions?
3. Trade-offs of different control options
4. Unknowns in decision-making (retire, refuel)
5. **What regulatory structures provided opportunities and obstacles?**
6. **How can costs be contained through demand-side measures?**

On to the next round!

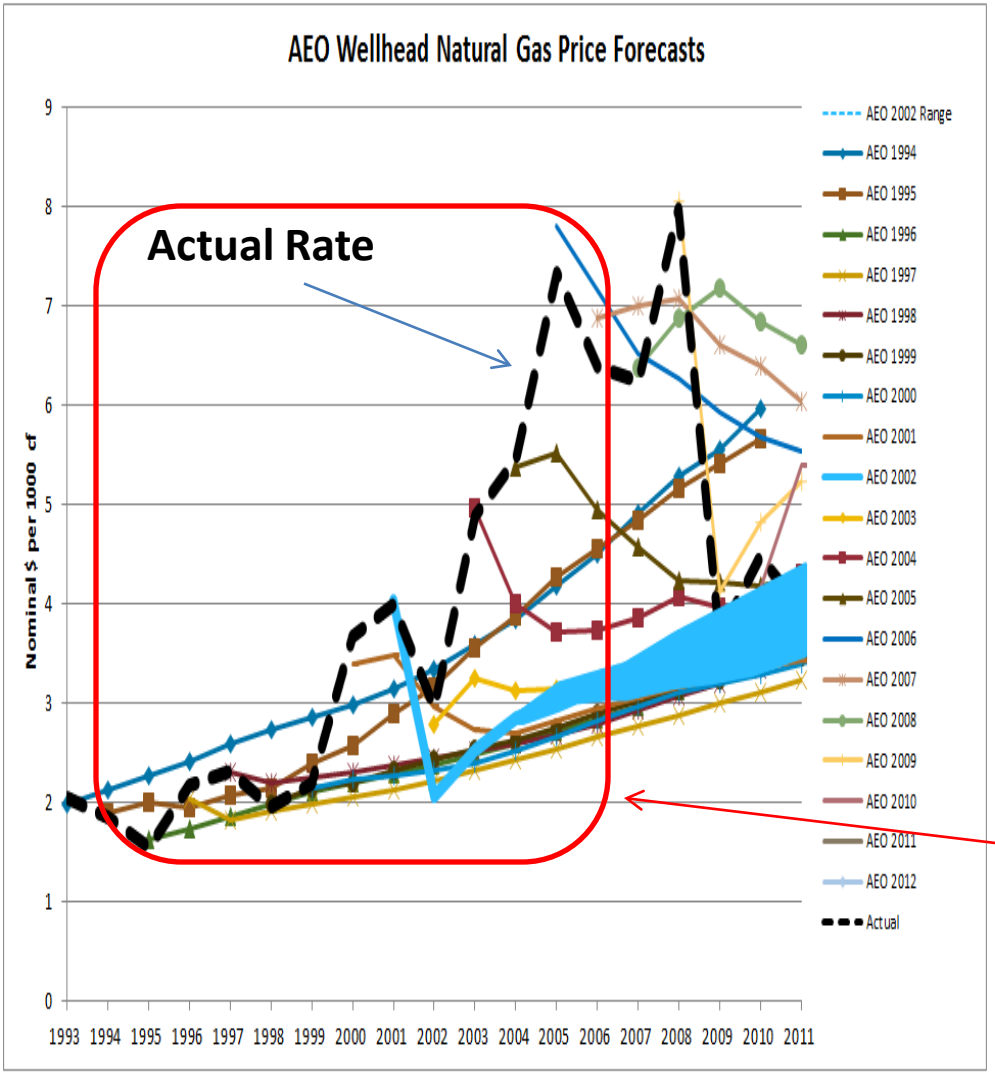
Round 2: Calamities

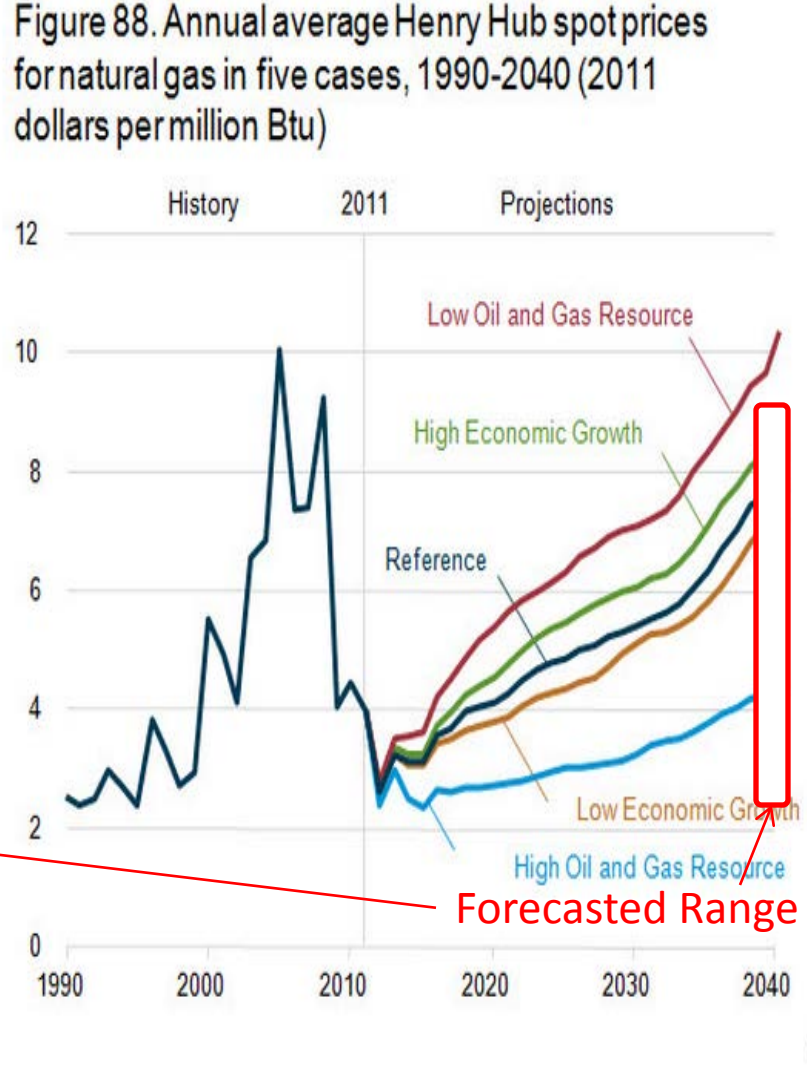
1. MATS timing and technology issues
2. Gas price volatility and uncertainty
3. Gas pipeline and supply constraints
4. Nuclear relicensing and waste
5. Renewables and disruptive technology
6. Policy backlash possibilities
7. Carbon capture, utilization and storage
8. Load acting as supply

Do You Have Enough Time?

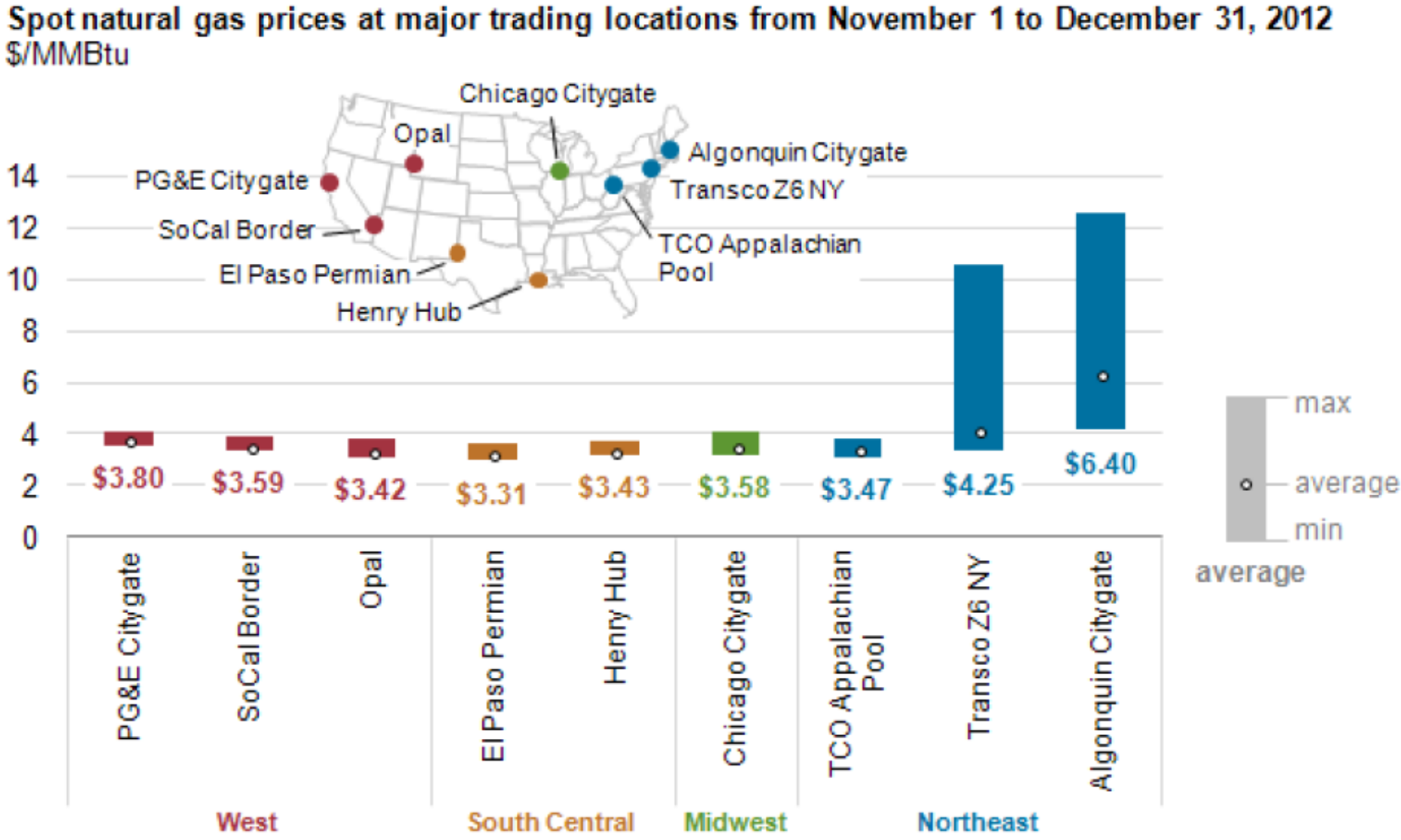


How helpful are forecasts?



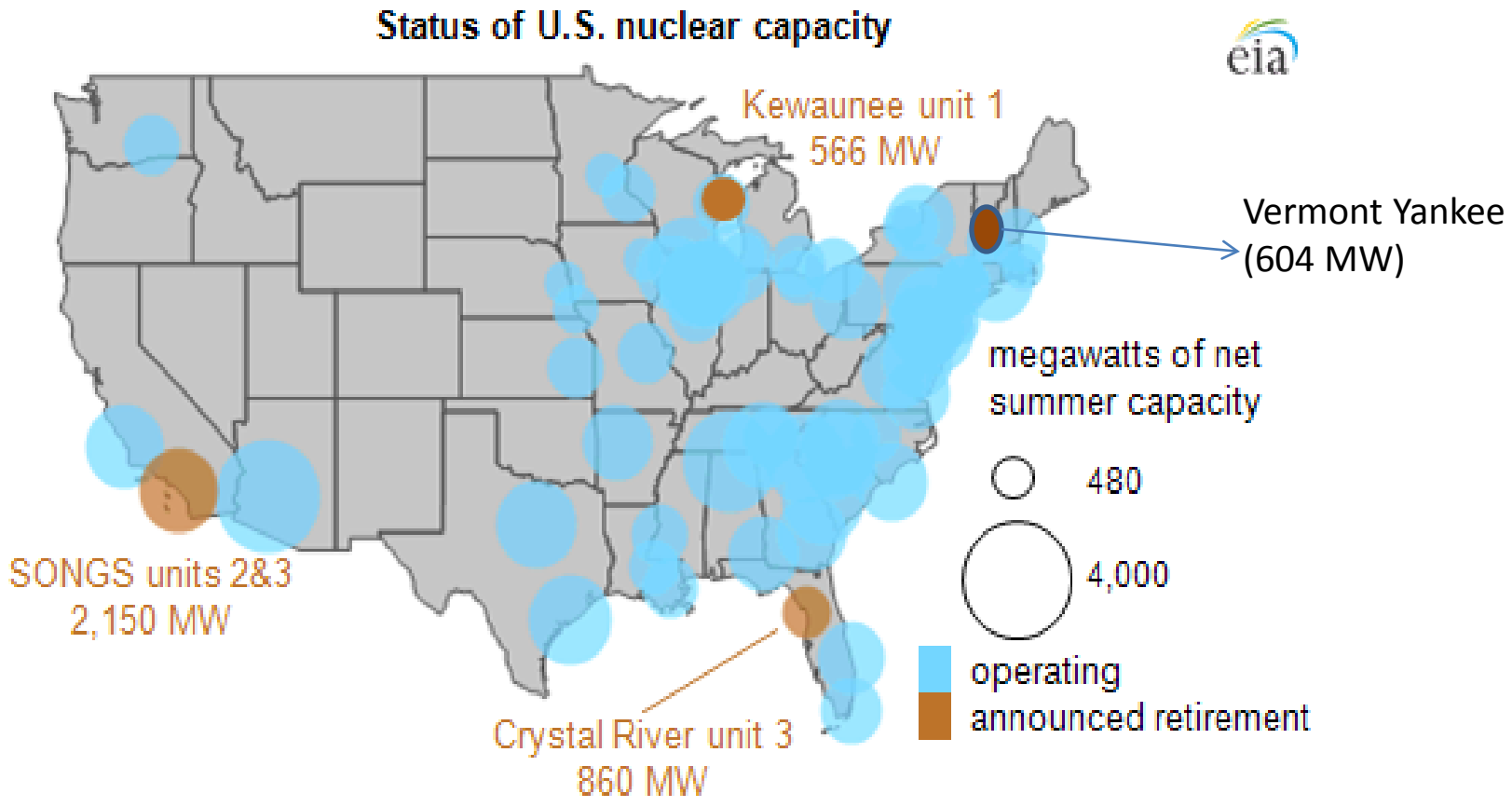


What if Gas Gets Constrained?



Source: U.S. Energy Information Administration based on Ventyx, Energy Velocity Suite.

Nuclear Relicensing and Retirement

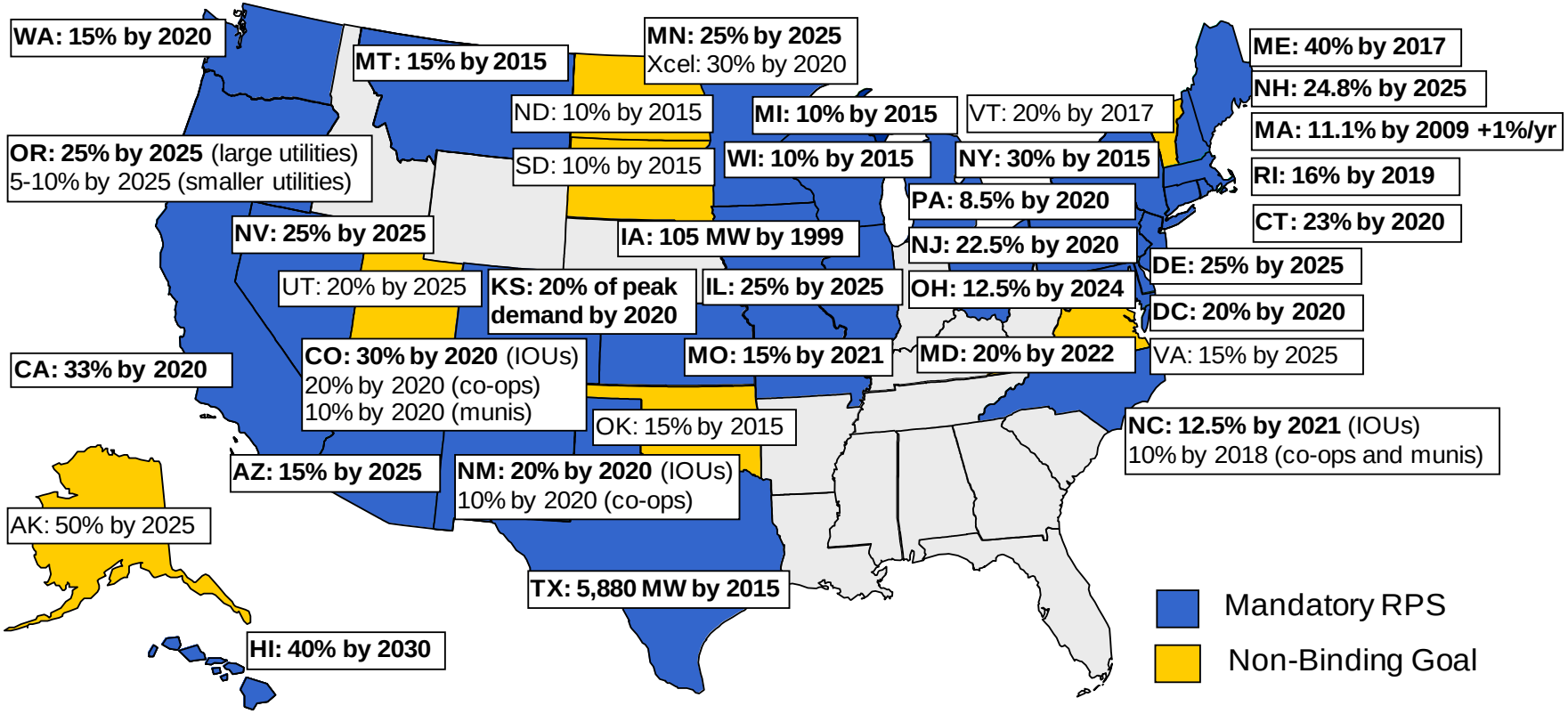


Five large uprate projects abandoned; four new reactors coming online.

RPS Policies Exist in 29 States and DC

7 More States Have Non-Binding Goals

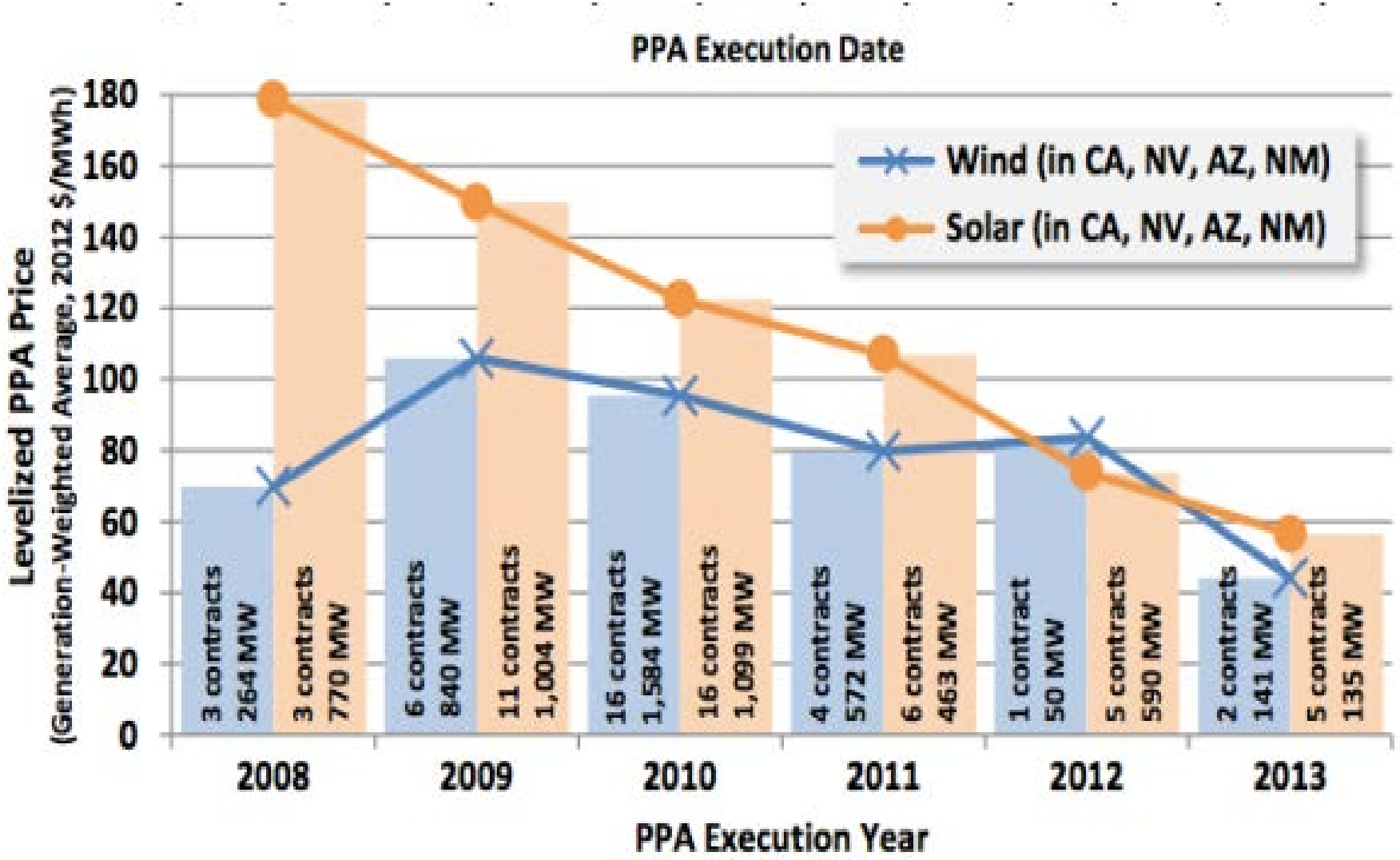
Existing State RPS Policies Apply to 55% of Total U.S. Retail Electricity Sales in 2012



Source: Berkeley Lab

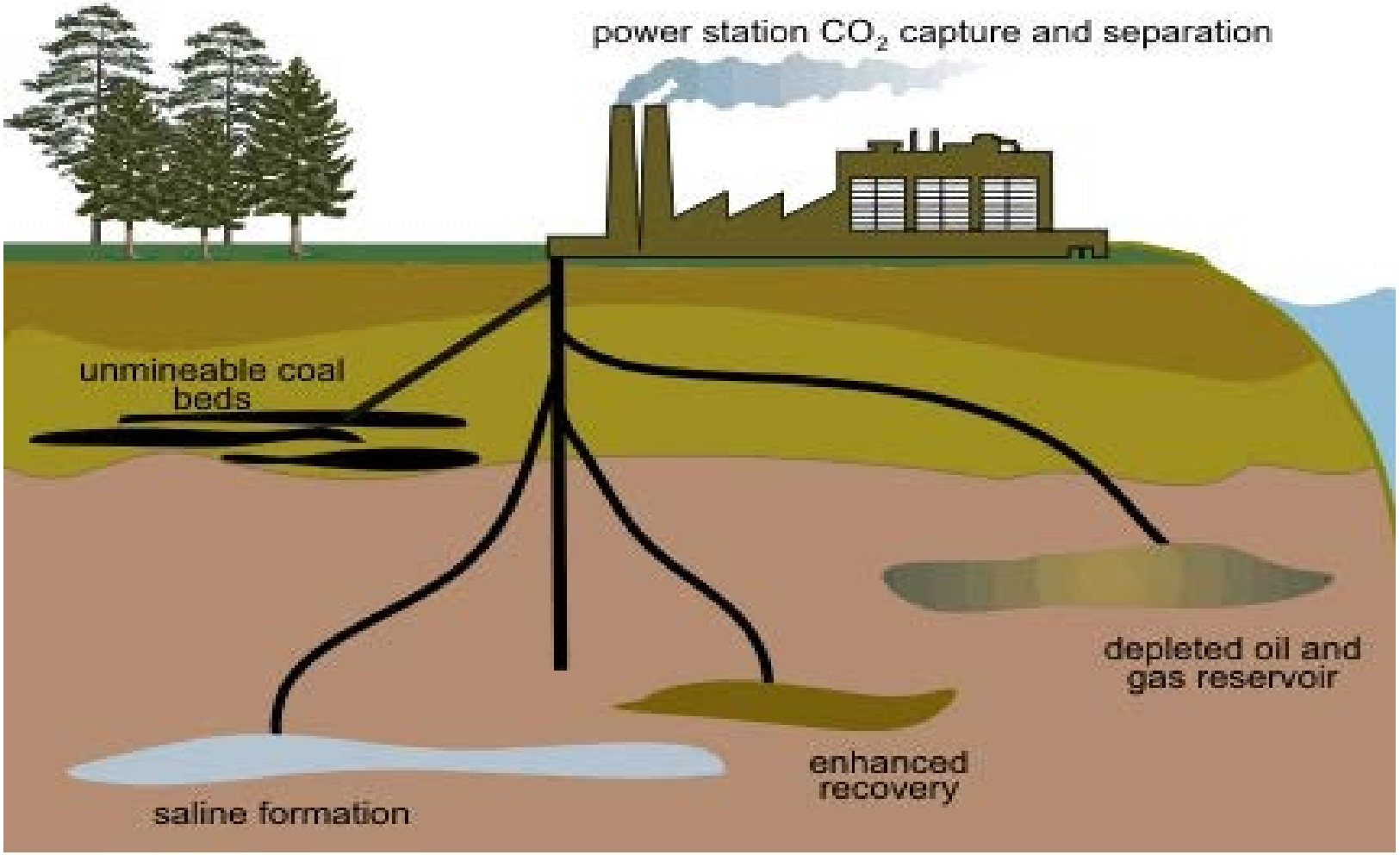
Notes: Compliance years are designated by the calendar year in which they begin. Mandatory standards or non-binding goals also exist in US territories (American Samoa, Guam, Puerto Rico, US Virgin Islands)

Renewables: Price



“Environmental Moderation”

Carbon Utilization & Storage



Combined Heat & Power

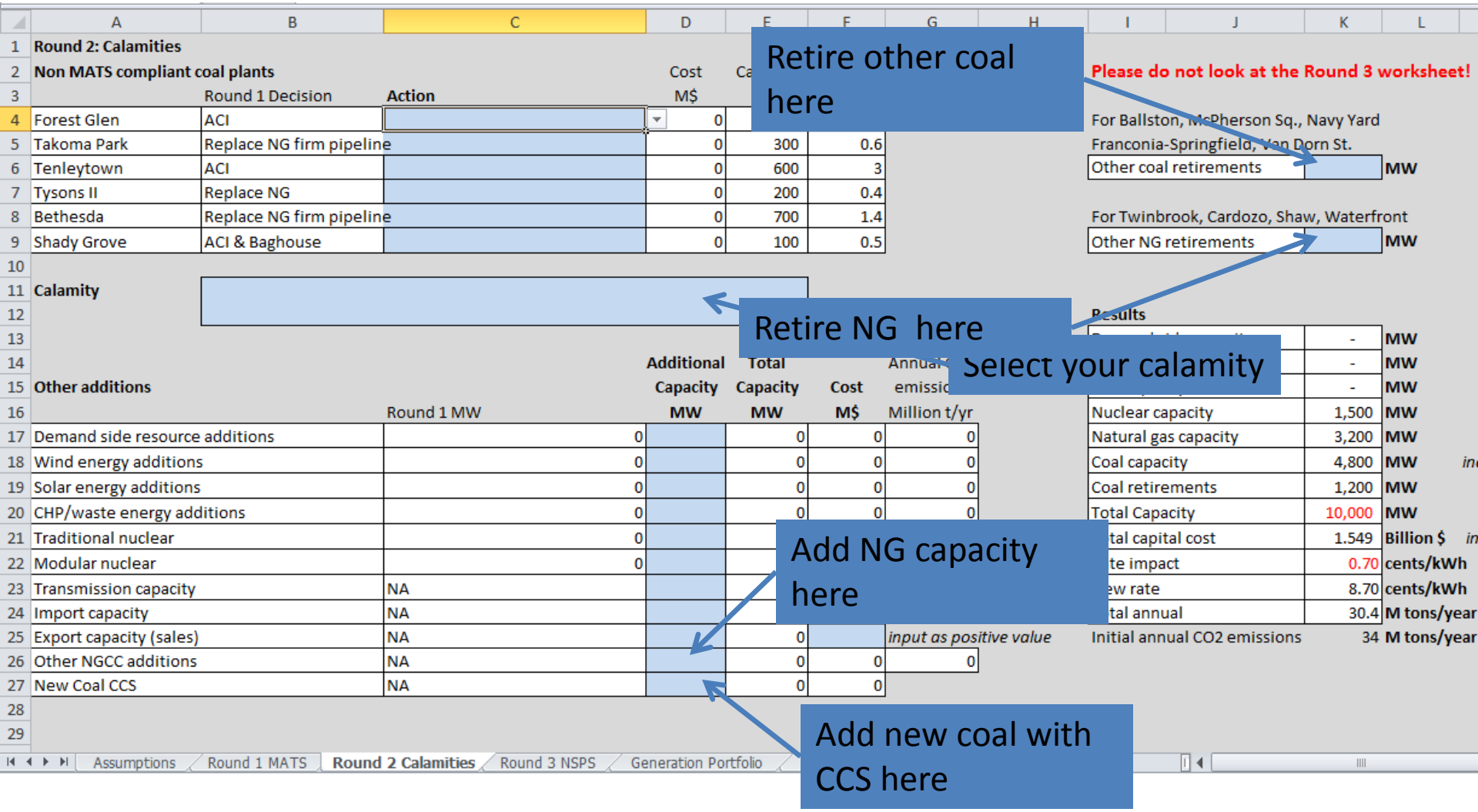
- We often make steam to turn turbines
- CHP uses that steam for heat and other applications.
- Often found in industrial, urban and “campus” situations
- Trade it in the game

Load-side Supply: Integration

- Hawaii integration plans: on track to 40% RE by 2030, large contribution from solar distributed PV

- What will make this work?
  - Relatively high price of a kW
  - System flexibility
  - Smarter grid

Round 2 Worksheet



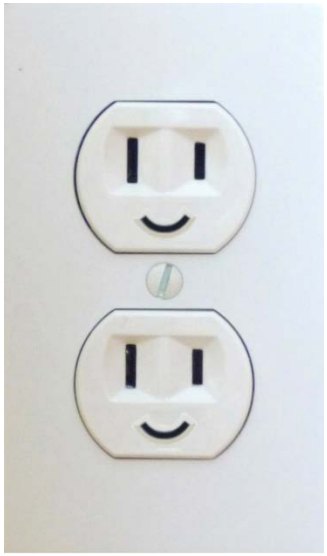
Retire other coal here

Retire NG here

Select your calamity

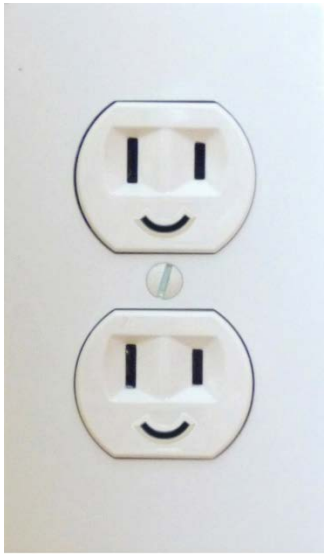
Add NG capacity here

Add new coal with CCS here



Do More With less!

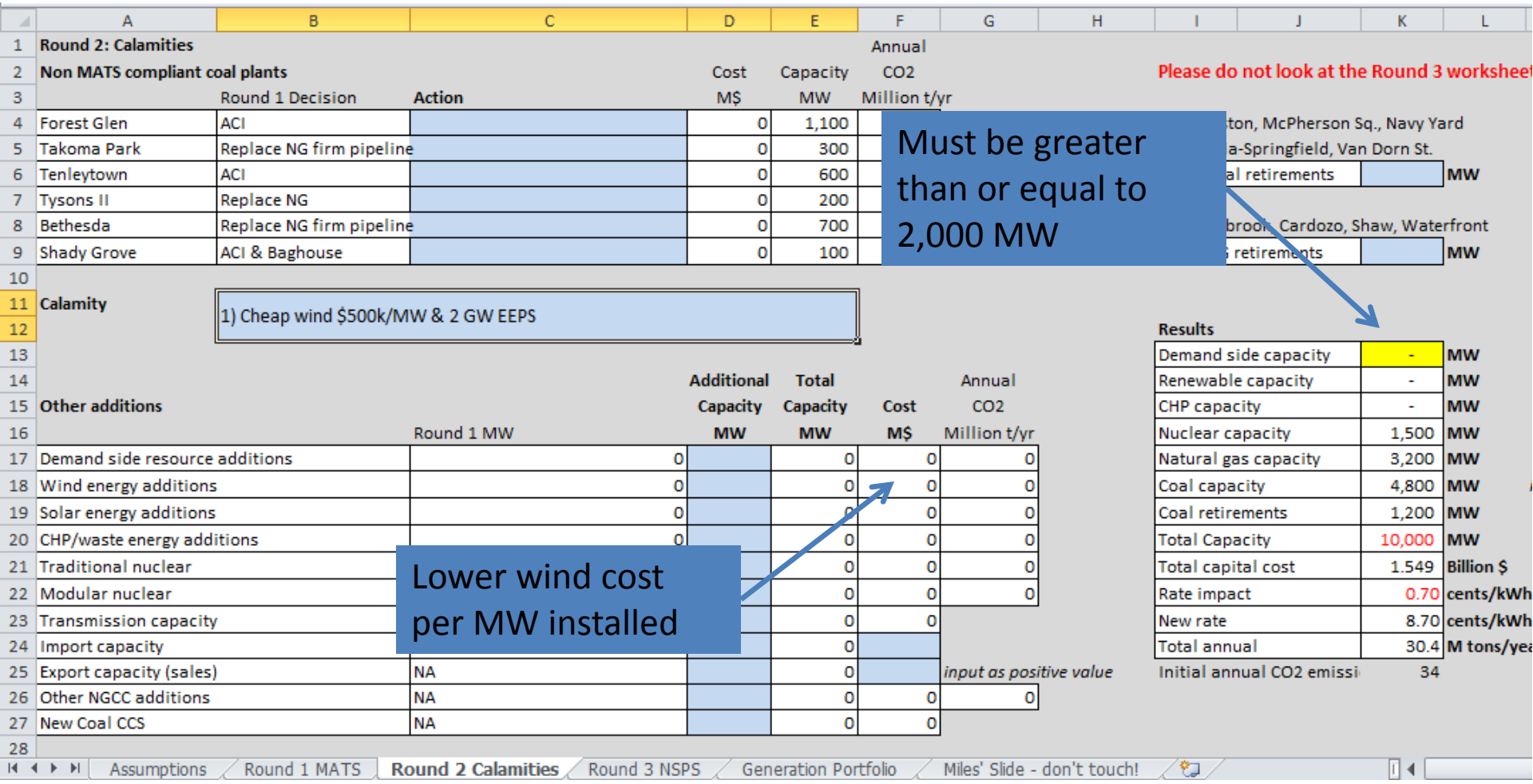
New energy efficiency resource standard means at least 2000 MW of demand-side resources



Easy, Breezy

What a wind resource! Steady supply means cost falls to $500,000 / MW

Calamity 1: Cheap wind & Efficiency Portfolio Standard



Round 2: Calamities

Non MATS compliant coal plants

	Round 1 Decision	Action	Cost M$	Capacity MW	Annual CO2 Million t/yr
Forest Glen	ACI		0	1,100	
Takoma Park	Replace NG firm pipeline		0	300	
Tenleytown	ACI		0	600	
Tysons II	Replace NG		0	200	
Bethesda	Replace NG firm pipeline		0	700	
Shady Grove	ACI & Baghouse		0	100	

Please do not look at the Round 3 worksheet

...ton, McPherson Sq., Navy Yard

...a-Springfield, Van Dorn St.

...al retirements — MW

...brook, Cardozo, Shaw, Waterfront

...retirements — MW

Must be greater than or equal to 2,000 MW

Calamity

1) Cheap wind $500k/MW & 2 GW EEPS

Other additions

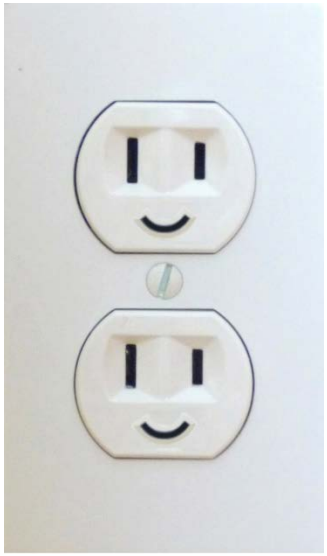
	Round 1 MW	Additional Capacity MW	Total Capacity MW	Cost M$	Annual CO2 Million t/yr
Demand side resource additions	0		0	0	0
Wind energy additions	0		0	0	0
Solar energy additions	0		0	0	0
CHP/waste energy additions	0		0	0	0
Traditional nuclear			0	0	0
Modular nuclear			0	0	0
Transmission capacity			0	0	
Import capacity			0		
Export capacity (sales)	NA		0		*input as positive value*
Other NGCC additions	NA		0	0	0
New Coal CCS	NA		0	0	

Lower wind cost per MW installed

Results

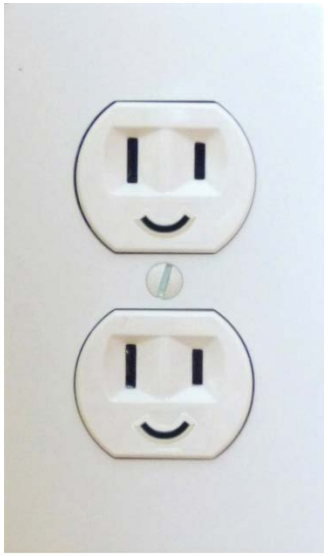
Demand side capacity	-	MW
Renewable capacity	-	MW
CHP capacity	-	MW
Nuclear capacity	1,500	MW
Natural gas capacity	3,200	MW
Coal capacity	4,800	MW
Coal retirements	1,200	MW
Total Capacity	10,000	MW
Total capital cost	1.549	Billion $
Rate impact	0.70	cents/kWh
New rate	8.70	cents/kWh
Total annual	30.4	M tons/yea
Initial annual CO2 emissi	34	

Assumptions | Round 1 MATS | **Round 2 Calamities** | Round 3 NSPS | Generation Portfolio | Miles' Slide - don't touch!



Good Day Sunshine!

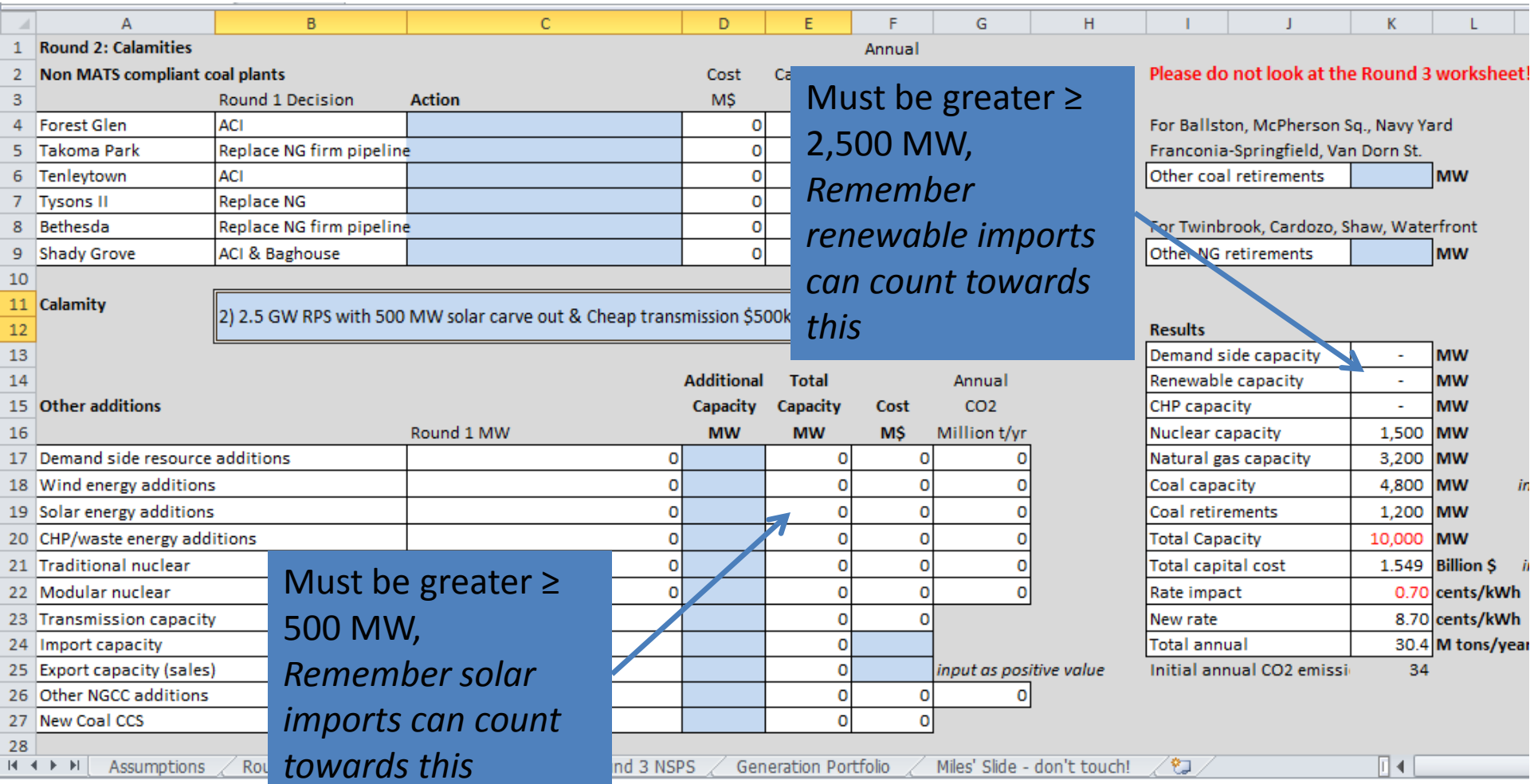
The legislature creates a Renewable Portfolio Standard of 2500 MW, with a 500 MW solar carve-out



Flat, Friendly Farmland!

You make siting and building transmission look sooo easy! Transmission is now $500,000/MW for your team

Calamity 2: Renewable Portfolio Standard with solar carve out & Cheap transmission



Round 2: Calamities

Non MATS compliant coal plants

	Round 1 Decision	Action	Cost M$	Annual Ca
Forest Glen	ACI		0	
Takoma Park	Replace NG firm pipeline		0	
Tenleytown	ACI		0	
Tysons II	Replace NG		0	
Bethesda	Replace NG firm pipeline		0	
Shady Grove	ACI & Baghouse		0	

Calamity

2) 2.5 GW RPS with 500 MW solar carve out & Cheap transmission $500k

Other additions

	Round 1 MW	Additional Capacity MW	Total Capacity MW	Cost M$	Annual CO2 Million t/yr
Demand side resource additions	0		0	0	0
Wind energy additions	0		0	0	0
Solar energy additions	0		0	0	0
CHP/waste energy additions	0		0	0	0
Traditional nuclear	0		0	0	0
Modular nuclear	0		0	0	0
Transmission capacity			0	0	
Import capacity			0		
Export capacity (sales)			0		*input as positive value*
Other NGCC additions			0	0	0
New Coal CCS			0	0	

Must be greater ≥ 500 MW, *Remember solar imports can count towards this*

Must be greater ≥ 2,500 MW, *Remember renewable imports can count towards this*

Please do not look at the Round 3 worksheet!

For Ballston, McPherson Sq., Navy Yard Franconia-Springfield, Van Dorn St.

Other coal retirements		MW

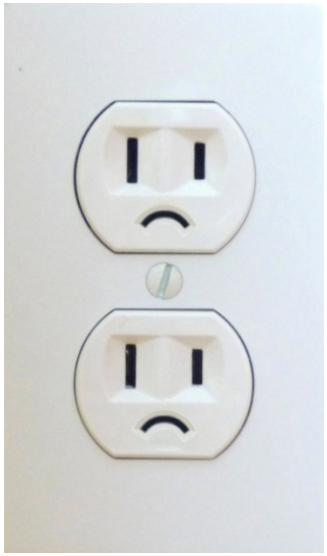
For Twinbrook, Cardozo, Shaw, Waterfront

Other NG retirements		MW

Results

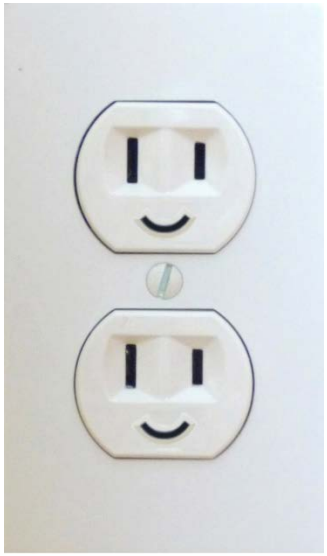
Demand side capacity	-	MW
Renewable capacity	-	MW
CHP capacity	-	MW
Nuclear capacity	1,500	MW
Natural gas capacity	3,200	MW
Coal capacity	4,800	MW
Coal retirements	1,200	MW
Total Capacity	10,000	MW
Total capital cost	1.549	Billion $
Rate impact	0.70	cents/kWh
New rate	8.70	cents/kWh
Total annual	30.4	M tons/year
Initial annual CO2 emissi	34	

Assumptions | Rou | nd 3 NSPS | Generation Portfolio | Miles' Slide - don't touch!



Waste Storage Accident!

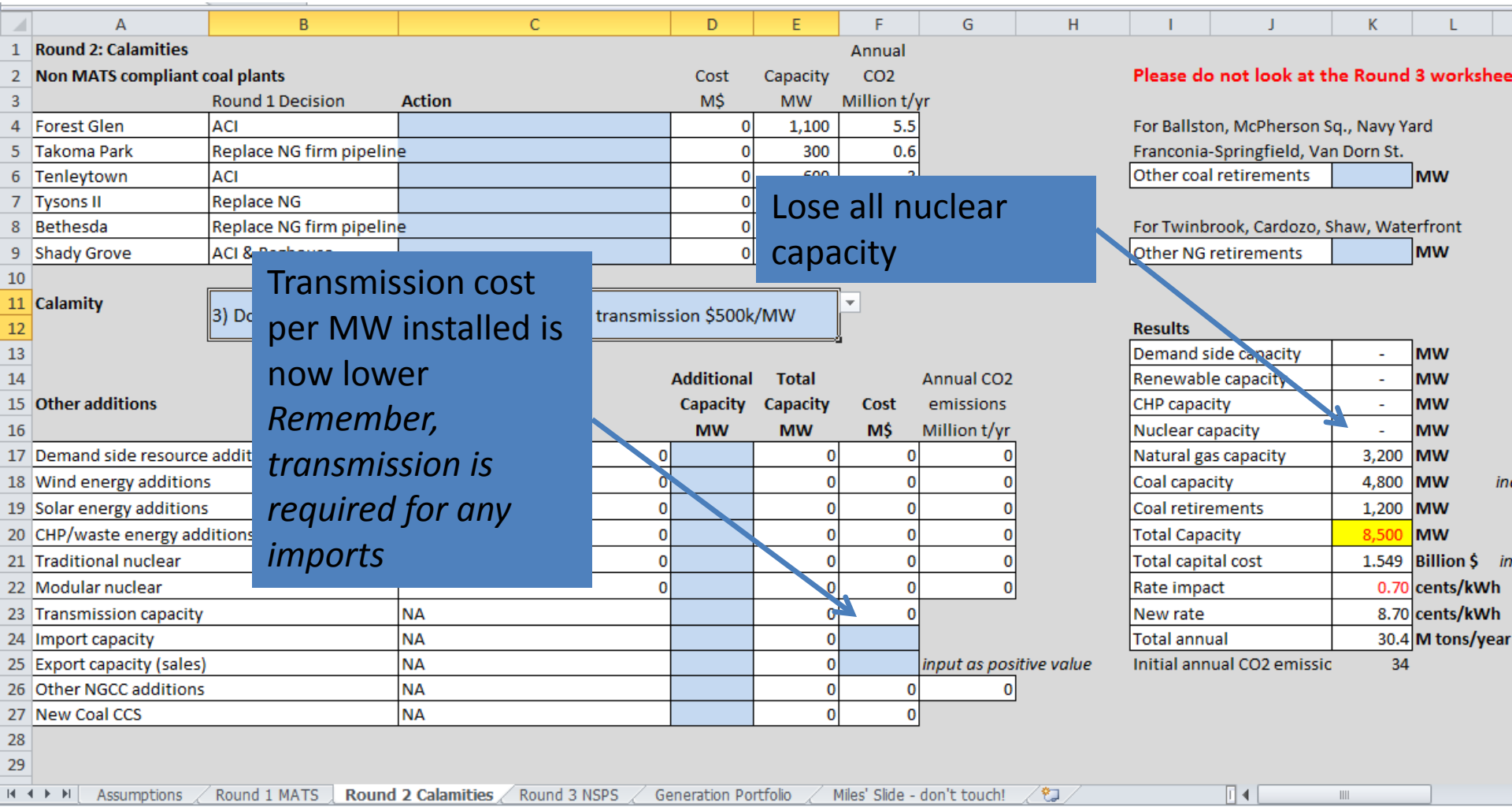
Cooling ponds at a domestic interim waste facility fail. Legislature bids “adieu” to nuclear energy for your team.



Flat, Friendly Farmland

You make siting and building transmission look sooo easy! Transmission is now $500,000/MW for your team.

Calamity 3: Domestic nuclear storage accident & Cheap transmission



Round 2: Calamities

Non MATS compliant coal plants

	Round 1 Decision	Action	Cost M$	Capacity MW	Annual CO2 Million t/yr
Forest Glen	ACI		0	1,100	5.5
Takoma Park	Replace NG firm pipeline		0	300	0.6
Tenleytown	ACI		0	600	3
Tysons II	Replace NG		0		
Bethesda	Replace NG firm pipeline		0		
Shady Grove	ACI & Rooftop		0		

Calamity 3) Do… transmission $500k/MW

Other additions

		Additional Capacity MW	Total Capacity MW	Cost M$	Annual CO2 emissions Million t/yr
Demand side resource addit	0		0	0	0
Wind energy additions	0		0	0	0
Solar energy additions	0		0	0	0
CHP/waste energy additions	0		0	0	0
Traditional nuclear	0		0	0	0
Modular nuclear	0		0	0	0
Transmission capacity	NA		0	0	
Import capacity	NA		0		
Export capacity (sales)	NA		0		*input as positive value*
Other NGCC additions	NA		0	0	0
New Coal CCS	NA		0	0	

Please do not look at the Round 3 workshee

For Ballston, McPherson Sq., Navy Yard Franconia-Springfield, Van Dorn St.

Other coal retirements — MW

For Twinbrook, Cardozo, Shaw, Waterfront

Other NG retirements — MW

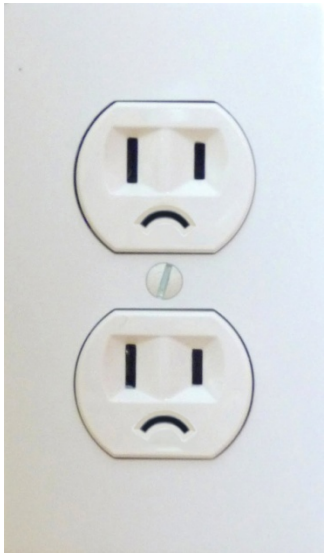
Results

Demand side capacity	-	MW
Renewable capacity	-	MW
CHP capacity	-	MW
Nuclear capacity	-	MW
Natural gas capacity	3,200	MW
Coal capacity	4,800	MW
Coal retirements	1,200	MW
Total Capacity	8,500	MW
Total capital cost	1.549	Billion $
Rate impact	0.70	cents/kWh
New rate	8.70	cents/kWh
Total annual	30.4	M tons/year
Initial annual CO2 emissic	34	

Lose all nuclear capacity

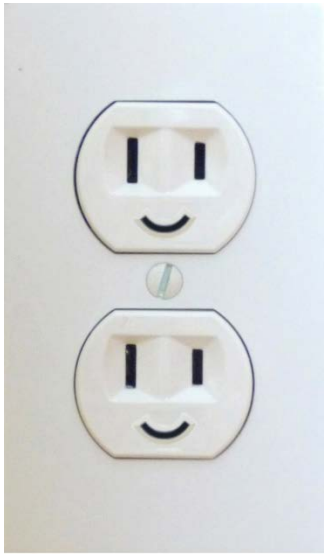
Transmission cost per MW installed is now lower *Remember, transmission is required for any imports*

Assumptions | Round 1 MATS | **Round 2 Calamities** | Round 3 NSPS | Generation Portfolio | Miles' Slide - don't touch!



Retirement and Backlash

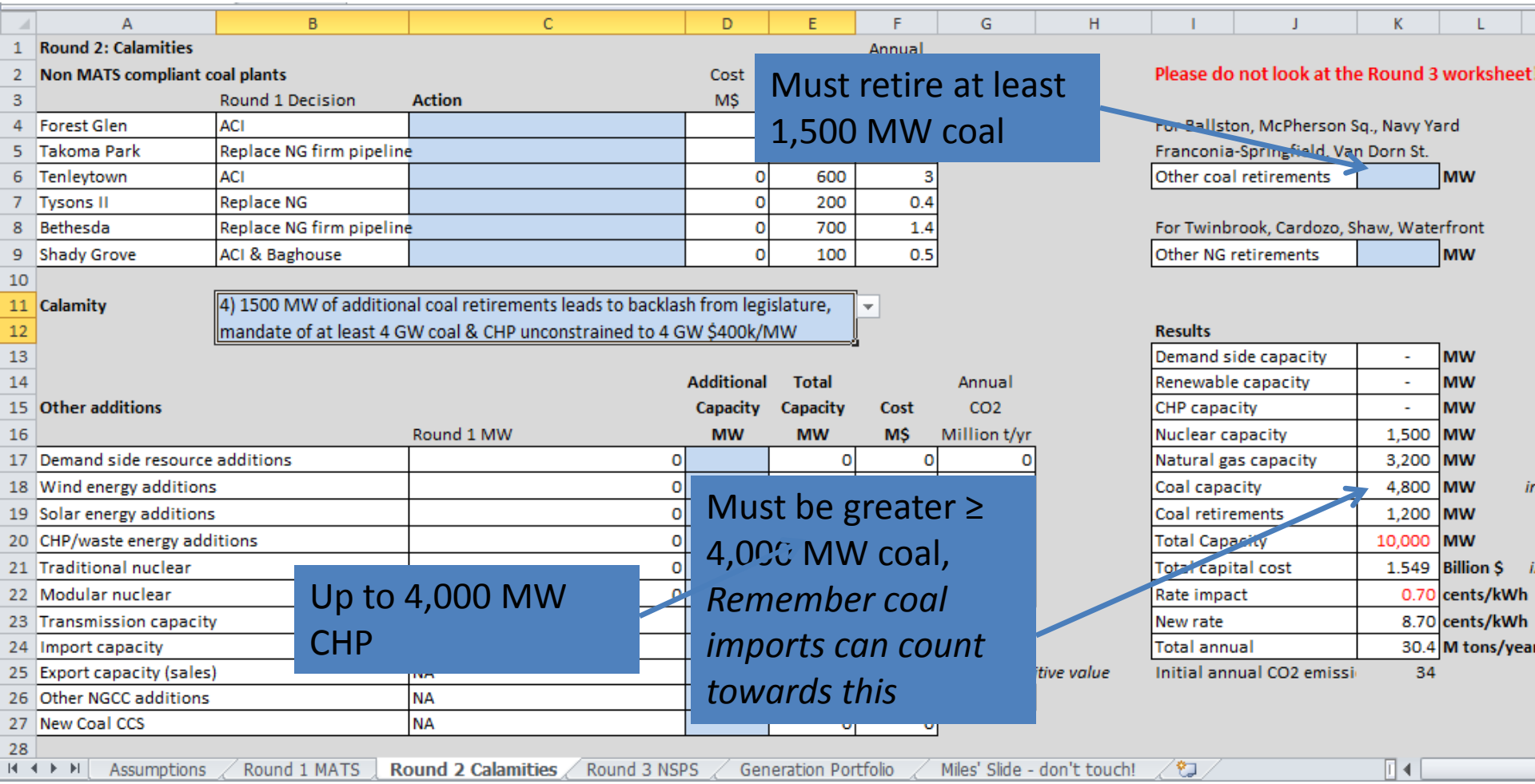
An additional 1500 MW announced retirement. The legislature passes a "Save Our Jobs Act" requiring your team to get 40% of supply from coal-fueled resources



CHP Unleashed

Combined Heat And Power is no longer limited to 500MW for your team – it's now limited to 4000MW. And cheap! Cost reduced to $400,000 / MW

Calamity 4: Additional coal retirement leads to backlash from legislature & CHP unconstrained



Round 2: Calamities

Non MATS compliant coal plants

	Round 1 Decision	Action	Cost M$		Annual
Forest Glen	ACI				
Takoma Park	Replace NG firm pipeline				
Tenleytown	ACI		0	600	3
Tysons II	Replace NG		0	200	0.4
Bethesda	Replace NG firm pipeline		0	700	1.4
Shady Grove	ACI & Baghouse		0	100	0.5

Calamity: 4) 1500 MW of additional coal retirements leads to backlash from legislature, mandate of at least 4 GW coal & CHP unconstrained to 4 GW $400k/MW

Other additions	Round 1 MW	Additional Capacity MW	Total Capacity MW	Cost M$	Annual CO2 Million t/yr
Demand side resource additions	0		0	0	0
Wind energy additions	0				
Solar energy additions	0				
CHP/waste energy additions	0				
Traditional nuclear	0				
Modular nuclear	0				
Transmission capacity					
Import capacity					
Export capacity (sales)	NA				
Other NGCC additions	NA				
New Coal CCS	NA				

Must retire at least 1,500 MW coal

Please do not look at the Round 3 worksheet

For Ballston, McPherson Sq., Navy Yard Franconia-Springfield, Van Dorn St.

Other coal retirements		MW

For Twinbrook, Cardozo, Shaw, Waterfront

Other NG retirements		MW

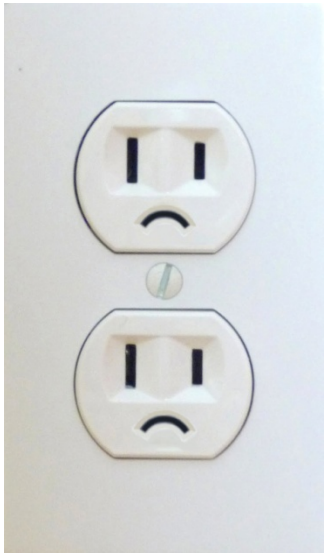
Up to 4,000 MW CHP

Must be greater ≥ 4,000 MW coal, *Remember coal imports can count towards this*

Results

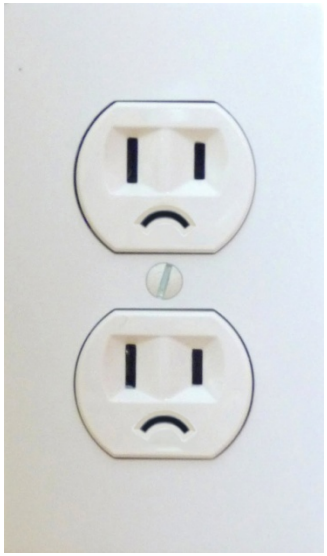
Demand side capacity	-	MW
Renewable capacity	-	MW
CHP capacity	-	MW
Nuclear capacity	1,500	MW
Natural gas capacity	3,200	MW
Coal capacity	4,800	MW
Coal retirements	1,200	MW
Total Capacity	10,000	MW
Total capital cost	1.549	Billion $
Rate impact	0.70	cents/kWh
New rate	8.70	cents/kWh
Total annual	30.4	M tons/year
Initial annual CO2 emissi	34	

Assumptions | Round 1 MATS | Round 2 Calamities | Round 3 NSPS | Generation Portfolio | Miles' Slide - don't touch!



ACI Fails!

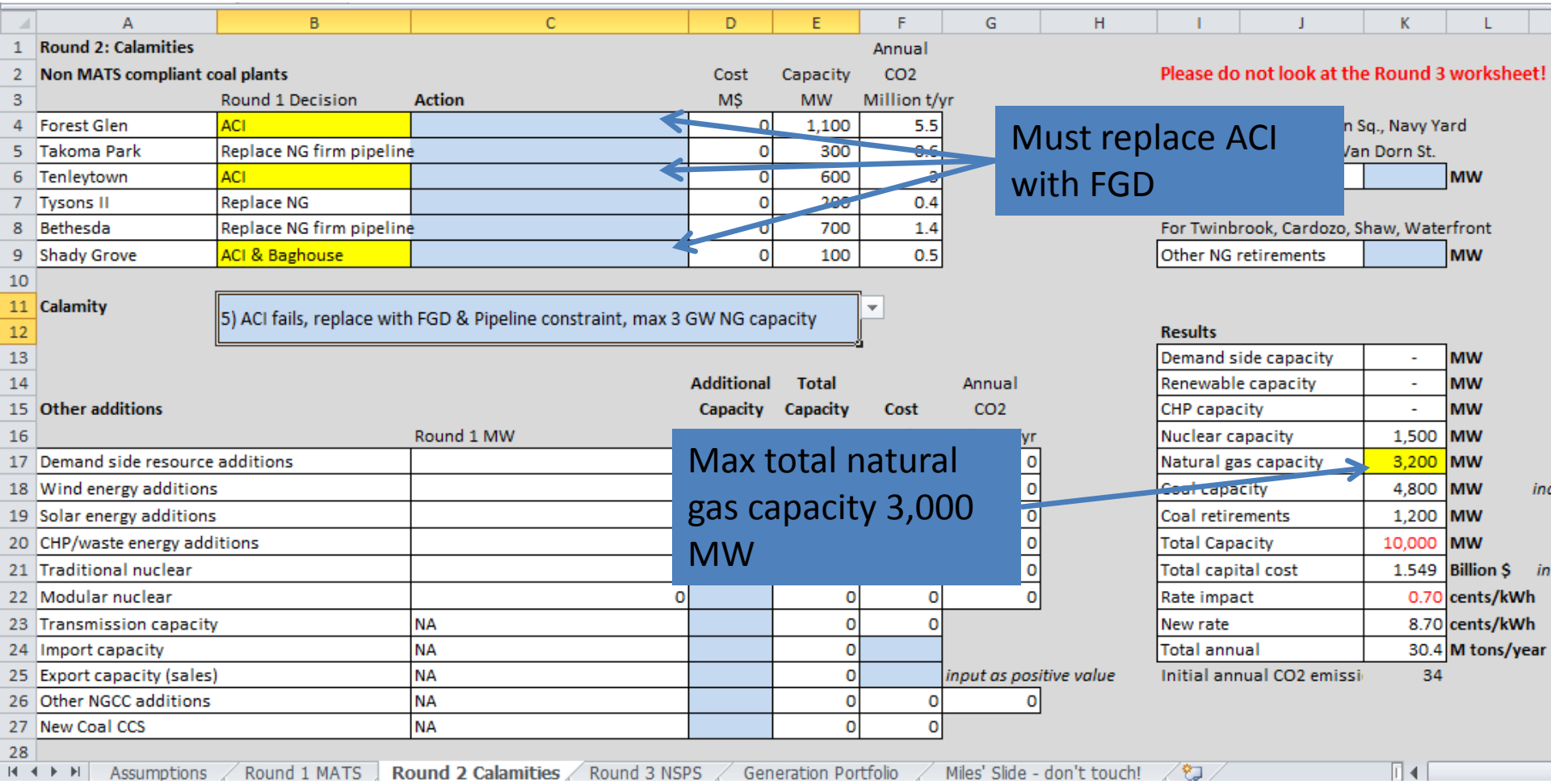
For each coal-fired unit using ACI, you must now use an FGD. Oh, ACI, to think we trusted you!



Neighbors Say "No Way"

Pipeline constraint from a neighboring state means new gas-fired capacity limited to 1000 MW (3000 MW total)

Calamity 5: ACI fails, must replace with FGD & Pipeline constraint limits natural gas



Round 2: Calamities

Non MATS compliant coal plants

	Round 1 Decision	Action	Cost M$	Capacity MW	Annual CO2 Million t/yr
Forest Glen	ACI		0	1,100	5.5
Takoma Park	Replace NG firm pipeline		0	300	0.5
Tenleytown	ACI		0	600	3
Tysons II	Replace NG		0	200	0.4
Bethesda	Replace NG firm pipeline		0	700	1.4
Shady Grove	ACI & Baghouse		0	100	0.5

Must replace ACI with FGD

Please do not look at the Round 3 worksheet!

n Sq., Navy Yard
Van Dorn St.
MW

For Twinbrook, Cardozo, Shaw, Waterfront

Other NG retirements		MW

Calamity

5) ACI fails, replace with FGD & Pipeline constraint, max 3 GW NG capacity

Other additions

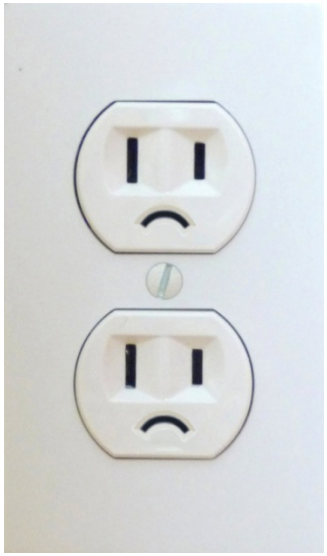
	Round 1 MW	Additional Capacity	Total Capacity	Cost	Annual CO2 yr
Demand side resource additions					0
Wind energy additions					0
Solar energy additions					0
CHP/waste energy additions					0
Traditional nuclear					0
Modular nuclear	0		0	0	0
Transmission capacity	NA		0	0	
Import capacity	NA		0		
Export capacity (sales)	NA		0		*input as positive value*
Other NGCC additions	NA		0	0	0
New Coal CCS	NA		0	0	

Max total natural gas capacity 3,000 MW

Results

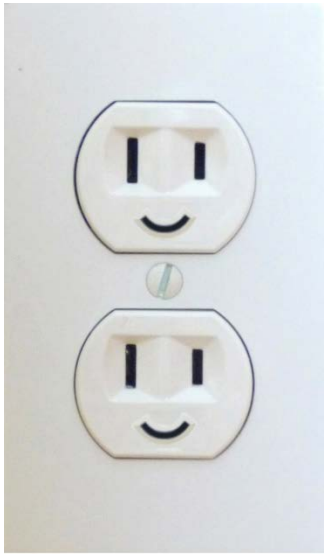
Demand side capacity	-	MW
Renewable capacity	-	MW
CHP capacity	-	MW
Nuclear capacity	1,500	MW
Natural gas capacity	3,200	MW
Coal capacity	4,800	MW
Coal retirements	1,200	MW
Total Capacity	10,000	MW
Total capital cost	1.549	Billion $
Rate impact	0.70	cents/kWh
New rate	8.70	cents/kWh
Total annual	30.4	M tons/year
Initial annual CO2 emissi	34	

Assumptions | Round 1 MATS | **Round 2 Calamities** | Round 3 NSPS | Generation Portfolio | Miles' Slide - don't touch!



Premium Gas!

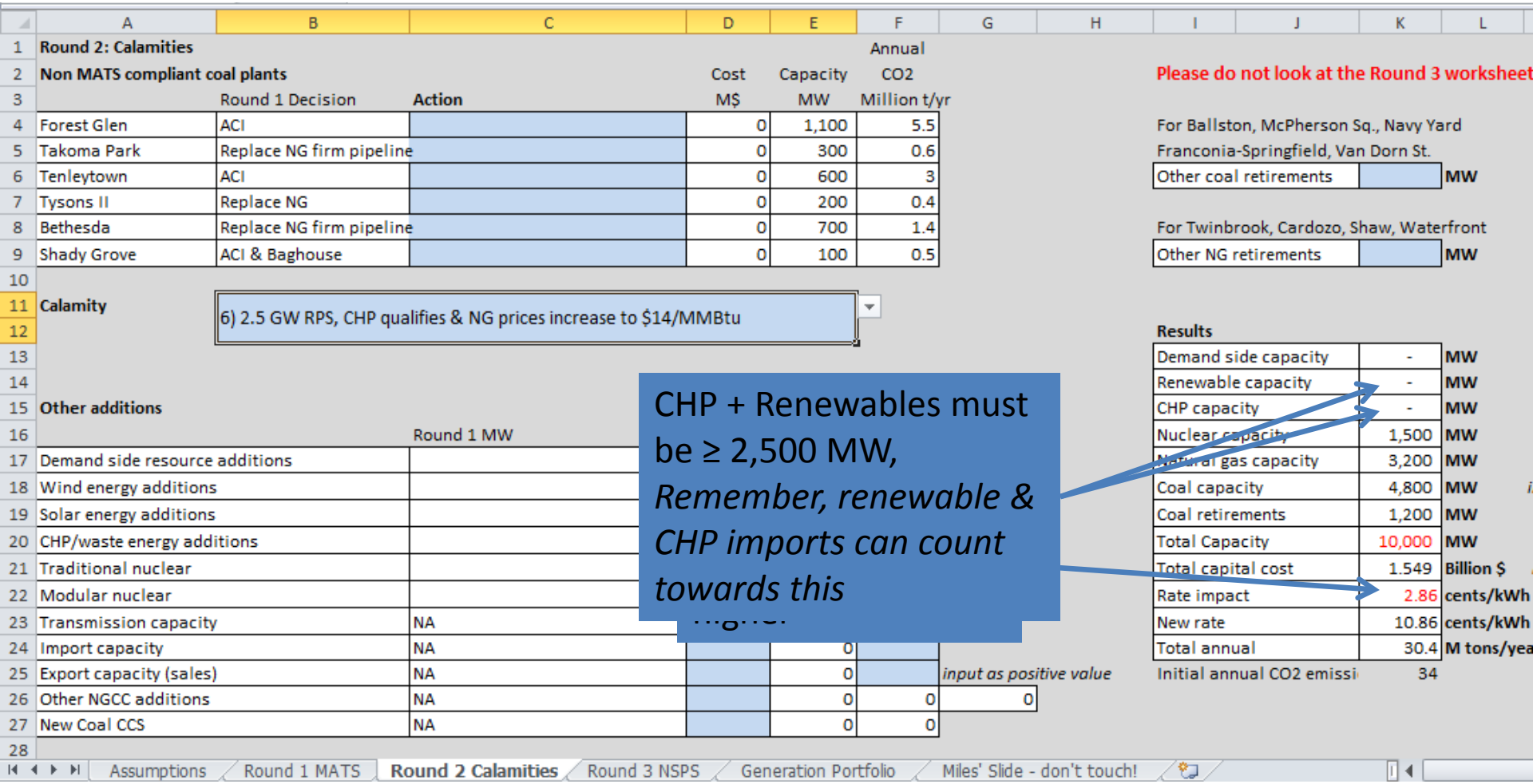
The price of natural gas jumps from $5/mmbtu to $14/mmbtu for your team.



Renewables are Rock Stars

25% RPS passes in your legislature: Wind, Solar, Biomass, Geothermal, and CHP are eligible.

Calamity 6: Renewable Portfolio Standard including CHP & High natural gas prices



Round 2: Calamities

Non MATS compliant coal plants

	Round 1 Decision	Action	Cost M$	Capacity MW	Annual CO2 Million t/yr
Forest Glen	ACI		0	1,100	5.5
Takoma Park	Replace NG firm pipeline		0	300	0.6
Tenleytown	ACI		0	600	3
Tysons II	Replace NG		0	200	0.4
Bethesda	Replace NG firm pipeline		0	700	1.4
Shady Grove	ACI & Baghouse		0	100	0.5

Please do not look at the Round 3 worksheet

For Ballston, McPherson Sq., Navy Yard Franconia-Springfield, Van Dorn St.

Other coal retirements		MW

For Twinbrook, Cardozo, Shaw, Waterfront

Other NG retirements		MW

Calamity

6) 2.5 GW RPS, CHP qualifies & NG prices increase to $14/MMBtu

Other additions

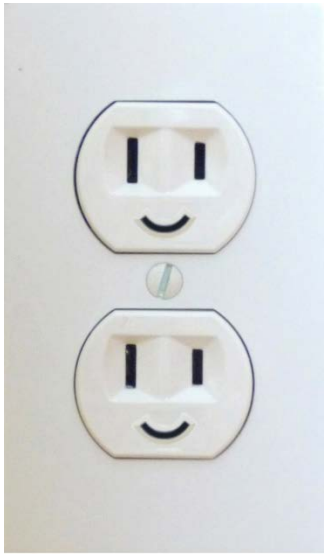
	Round 1 MW				
Demand side resource additions					
Wind energy additions					
Solar energy additions					
CHP/waste energy additions					
Traditional nuclear					
Modular nuclear					
Transmission capacity	NA				
Import capacity	NA		0		
Export capacity (sales)	NA		0		*input as positive value*
Other NGCC additions	NA		0	0	0
New Coal CCS	NA		0	0	

CHP + Renewables must be ≥ 2,500 MW, *Remember, renewable & CHP imports can count towards this*

Results

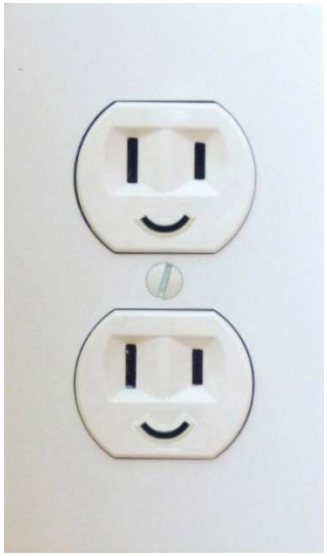
Demand side capacity	-	MW
Renewable capacity	-	MW
CHP capacity	-	MW
Nuclear capacity	1,500	MW
Natural gas capacity	3,200	MW
Coal capacity	4,800	MW
Coal retirements	1,200	MW
Total Capacity	10,000	MW
Total capital cost	1.549	Billion $
Rate impact	2.86	cents/kWh
New rate	10.86	cents/kWh
Total annual	30.4	M tons/yea
Initial annual CO2 emissi	34	

Assumptions | Round 1 MATS | **Round 2 Calamities** | Round 3 NSPS | Generation Portfolio | Miles' Slide - don't touch!



Sunny Days Ahead!

Local solar resources are amazing: cost falls to $3M / MW



Black Gold! (Texas Tea!)

Enhanced Oil Recovery resources in your State bring carbon capture & storage costs down to $1M / MW

Calamity 7: EOR opportunity creates cheap CCS & Cheap solar

Round 2: Calamities

Non MATS compliant coal plants

	Round 1 Decision	Action	Cost M$	Capacity MW	Annual CO2 Million t/yr
Forest Glen	ACI		0	1,100	5.5
Takoma Park	Replace NG firm pipeline		0	300	0.6
Tenleytown	ACI		0	600	3
Tysons II	Replace NG		0	200	0.4
Bethesda	Replace NG firm pipeline		0	700	1.4
Shady Grove	ACI & Baghouse		0	100	0.5

Calamity: 7) EOR opportunity reduces price of CCS to $1M/MW & Cheap solar $3M/MW

Other additions		Additional Capacity MW	Total Capacity MW	Cost M$	Annual CO2 emissions Million t/yr
Demand side resource additic	0		0	0	0
Wind energy additions	0		0	0	0
Solar energy additions	0		0	0	0
CHP/waste energy additions	0		0	0	0
Traditional nuclear	0		0	0	0
Modular nuclear	0		0	0	0
Transmission capacity			0	0	
Import capacity	NA		0		
Export capacity (sales)	NA		0		*input as positive value*
Other NGCC additions	NA		0	0	0
New Coal CCS	NA		0	0	

Lower solar cost per MW installed

New coal with CCS cost is cheaper

Please do not look at the Round 3 worksh

For Ballston, McPherson Sq., Navy Yard Franconia-Springfield, Van Dorn St.

Other coal retirements		MW

For Twinbrook, Cardozo, Shaw, Waterfront

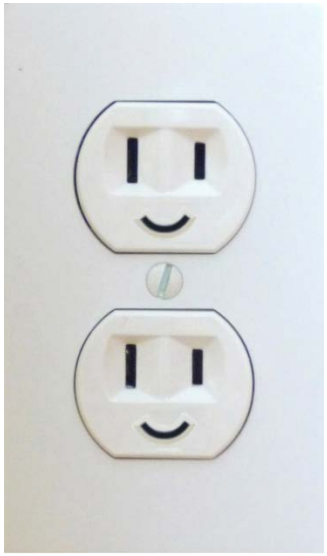
Other NG retirements		MW

Results

Demand side capacity	-	MW
Renewable capacity	-	MW
CHP capacity	-	MW
Nuclear capacity	1,500	MW
Natural gas capacity	3,200	MW
Coal capacity	4,800	MW
Coal retirements	1,200	MW
Total Capacity	10,000	MW
Total capital cost	1.549	Billion $
Rate impact	0.70	cents/kW
New rate	8.70	cents/kW
Total annual	30.4	M tons/ye
Initial annual CO2 emissic	34	

Assumptions | Round 1 MATS | **Round 2 Calamities** | Round 3 NSPS | Generation Portfolio | Miles' Slide - don't touch!

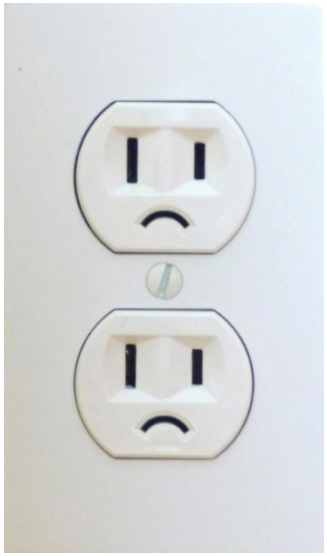
Some of you will face “special” challenges



Sweet!

Industrial customer demand for steam goes bananas.

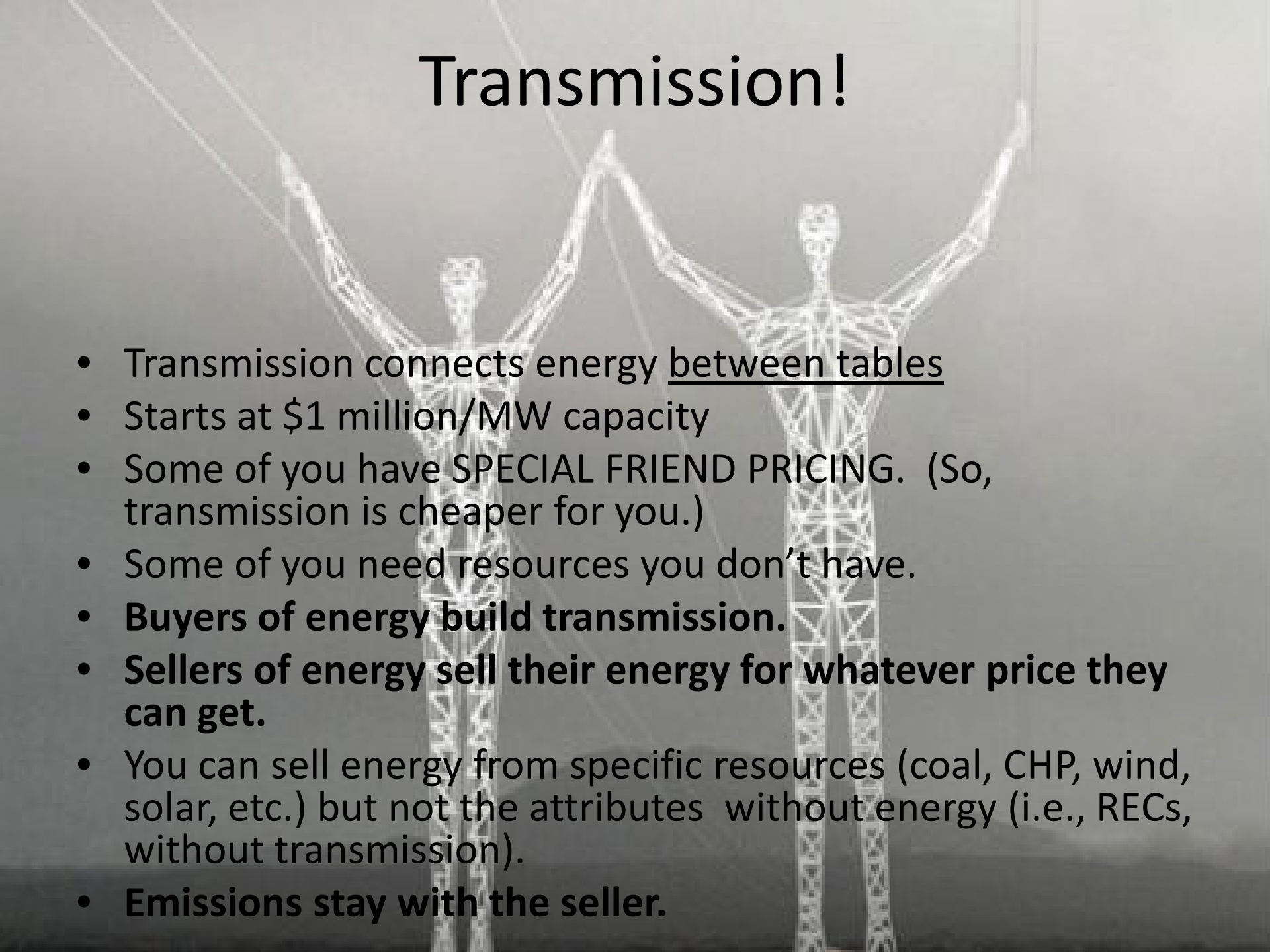
Your CHP investment creates 1000 jobs!



Dude, the Haiku

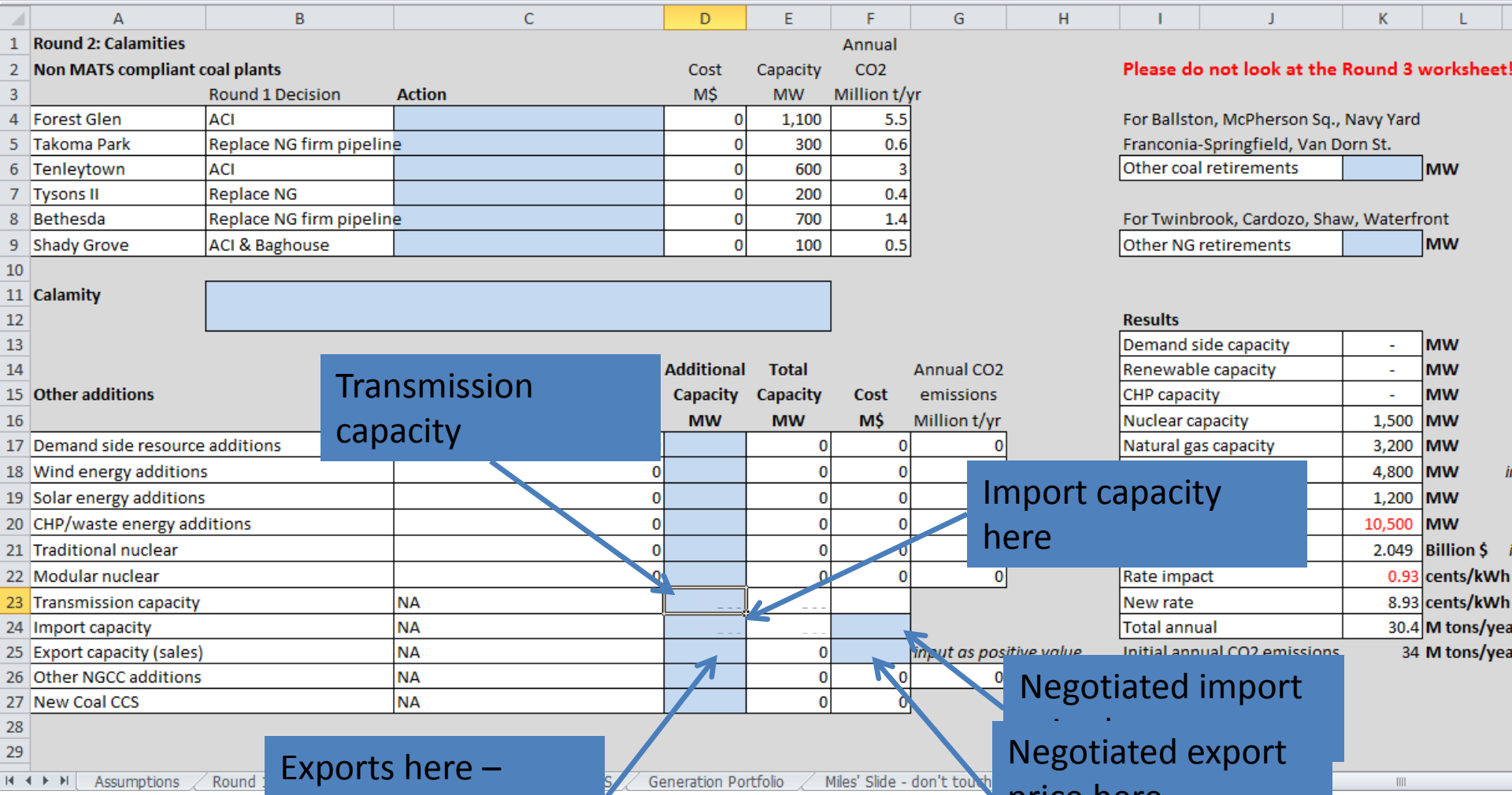
Angry ratepayers
express distress at rising rates.
Sad haiku, for you.

Transmission!



- Transmission connects energy between tables
- Starts at $1 million/MW capacity
- Some of you have SPECIAL FRIEND PRICING. (So, transmission is cheaper for you.)
- Some of you need resources you don't have.
- **Buyers of energy build transmission.**
- **Sellers of energy sell their energy for whatever price they can get.**
- You can sell energy from specific resources (coal, CHP, wind, solar, etc.) but not the attributes without energy (i.e., RECs, without transmission).
- **Emissions stay with the seller.**

Round 2 Trading



Round 2: Calamities

Non MATS compliant coal plants

	Round 1 Decision	Action	Cost M$	Capacity MW	Annual CO2 Million t/yr
Forest Glen	ACI		0	1,100	5.5
Takoma Park	Replace NG firm pipeline		0	300	0.6
Tenleytown	ACI		0	600	3
Tysons II	Replace NG		0	200	0.4
Bethesda	Replace NG firm pipeline		0	700	1.4
Shady Grove	ACI & Baghouse		0	100	0.5

Calamity

Other additions

		Additional Capacity MW	Total Capacity MW	Cost M$	Annual CO2 emissions Million t/yr
Demand side resource additions			0	0	0
Wind energy additions	0		0	0	
Solar energy additions	0		0	0	
CHP/waste energy additions	0		0	0	
Traditional nuclear	0		0	0	
Modular nuclear	0		0	0	0
Transmission capacity	NA				
Import capacity	NA				
Export capacity (sales)	NA		0		*input as positive value*
Other NGCC additions	NA		0	0	0
New Coal CCS	NA		0	0	

Please do not look at the Round 3 worksheet!

For Ballston, McPherson Sq., Navy Yard Franconia-Springfield, Van Dorn St.

Other coal retirements ____ MW

For Twinbrook, Cardozo, Shaw, Waterfront

Other NG retirements ____ MW

Results

Demand side capacity	-	MW
Renewable capacity	-	MW
CHP capacity	-	MW
Nuclear capacity	1,500	MW
Natural gas capacity	3,200	MW
	4,800	MW
	1,200	MW
	10,500	MW
	2.049	Billion $
Rate impact	0.93	cents/kWh
New rate	8.93	cents/kWh
Total annual	30.4	M tons/yea
Initial annual CO2 emissions	34	M tons/yea

Transmission capacity

Import capacity here

Negotiated import

Exports here – *positive value*

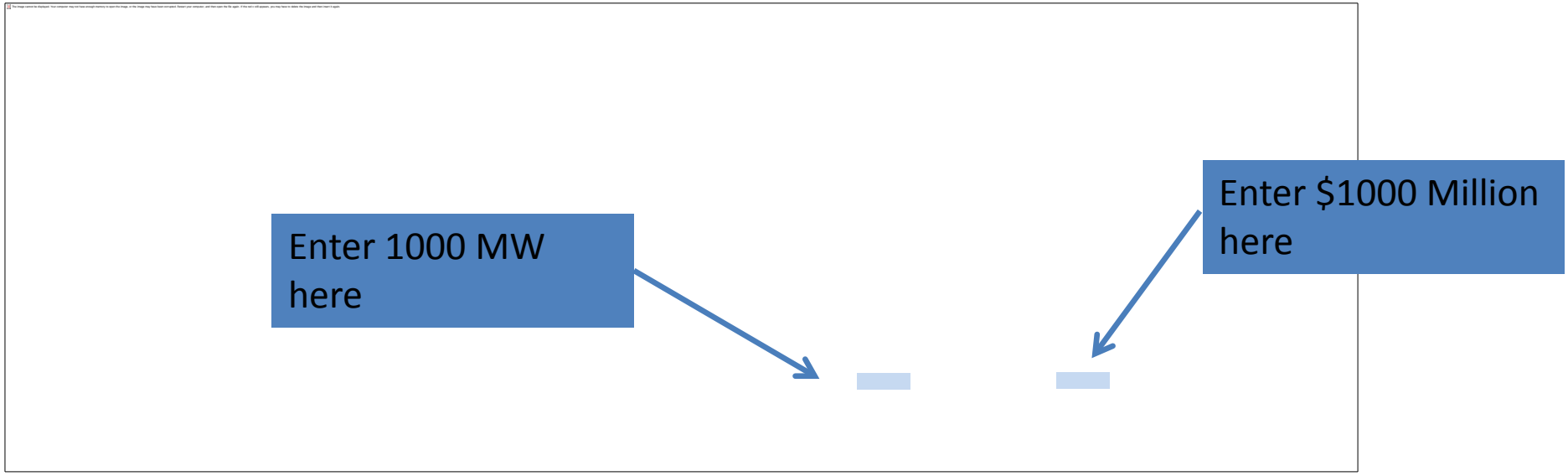
Negotiated export price here – *positive value*

Assumptions | Round 1 | Generation Portfolio | Miles' Slide - don't touch

Trading Example

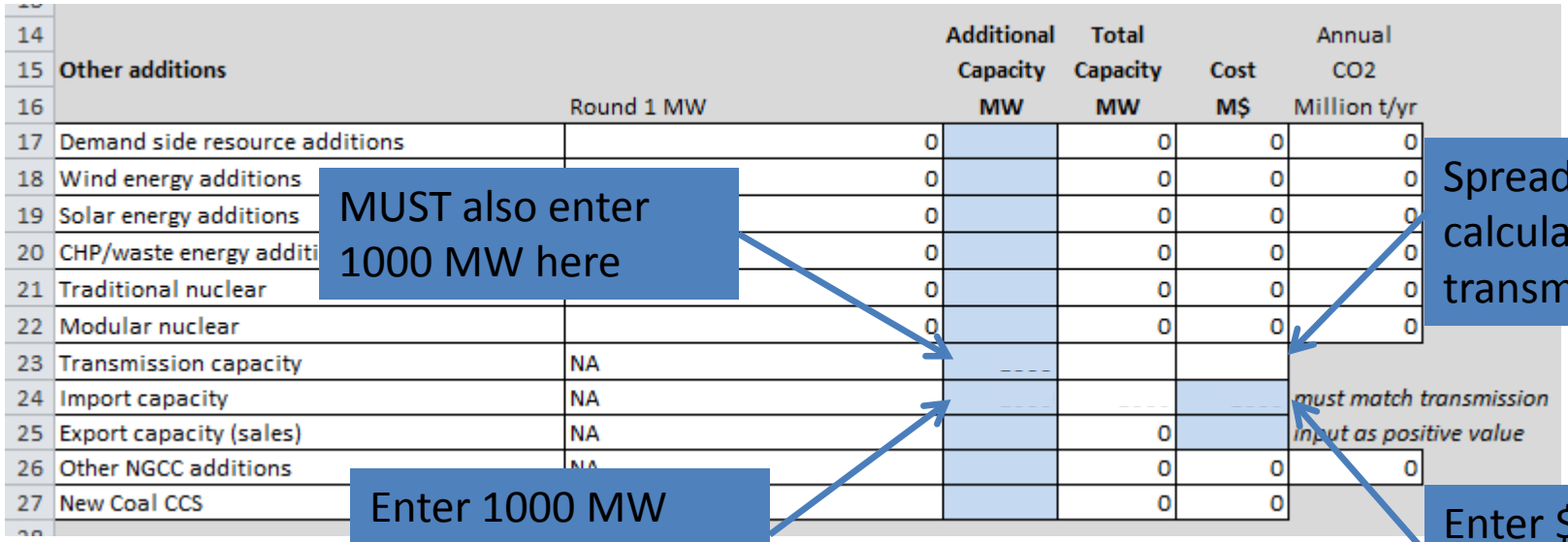
Team Longhorns sells Team Aggies 1000 MW of wind capacity and energy for $1 billion ($1M/MW)

Team Longhorns spreadsheet



Trading Example

Team Aggies spreadsheet



14							
15	**Other additions**		**Additional Capacity MW**	**Total Capacity MW**	**Cost M$**	Annual CO2 Million t/yr	
16		Round 1 MW					
17	Demand side resource additions	0		0	0	0	
18	Wind energy additions	0		0	0	0	
19	Solar energy additions	0		0	0	0	
20	CHP/waste energy additi	0		0	0	0	
21	Traditional nuclear	0		0	0	0	
22	Modular nuclear	0		0	0	0	
23	Transmission capacity	NA					
24	Import capacity	NA				*must match transmission*	
25	Export capacity (sales)	NA		0		*input as positive value*	
26	Other NGCC additions	NA		0	0	0	
27	New Coal CCS			0	0		

MUST also enter 1000 MW here

Spreadsheet will calculate transmission cost

Enter 1000 MW here

Enter $1000 Million here

We’re From The Lab, We’re Here To Help

Round 2: Discussion

1. What impact did gas tightening have on the overall portfolio?
2. What happened when nuclear waste and relicensing issues arose?
3. How would decisions for CSAPR (affecting NOx and other interstate pollutants) overlay with decisions for the MATS rule?
4. How did demand-side resources and EE impact the system? Were any constraints self-imposed, or externally imposed?
5. Do renewables change the picture?
6. What regulatory structures provided opportunities and obstacles?

Round 3: The Clean Power Plan – Section 111d for Existing Units

The Top Line

- President's 2013 Climate Action Plan called for power plant regulations
- Power plants ~ 30% of U.S. greenhouse gas emissions
- Suite of rules under Clean Air Act Section 111
  - New plants (proposed rule: January)
  - Modified/reconstructed (proposed rule: early June)
  - Existing plants (proposed rule: early June)
- Existing plants: federal-state process

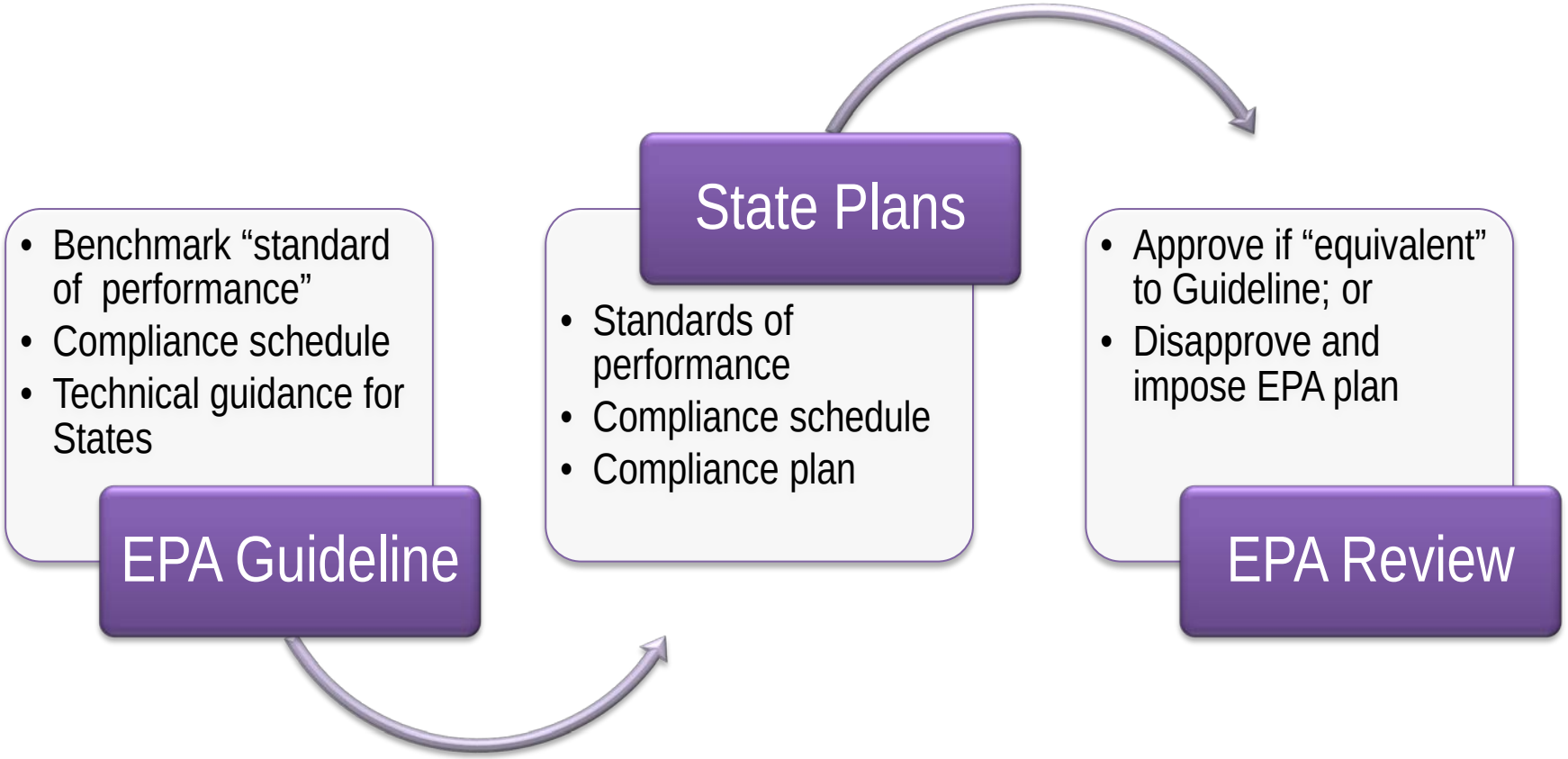
Section 111 of the Clean Air Act

- *Standards of performance* for major sources of pollution
  - Defined as an emission limitation based on "best system of emission reduction" that has been "adequately demonstrated" taking into account cost
- Sec. 111(***b***): standards of performance for **new** sources
  - *EPA* sets standard
- Sec. 111(***d***)*:* standards of performance for **existing** sources
  - *States* set standard subject to *EPA approval*
  - Relatively little experience with 111(d)

Section 111(d) Rulemaking

- EPA issues binding emissions rate goals to states
  - Proposed rule published June 18, 2014
  - Final rule due June 2015
- States submit compliance plans
  - Plans due June 30, 2016
  - “Equivalency” requirement
- EPA approves/disapproves
- Compliance deadline for power plants: 2020 - 2030

111(d) Federal-State Process



What's Covered:

- All fossil units 25 MW and over,
- Combustion turbines over 25 MW greater than 33% capacity factor.

- Estimate: 3,084 EGUs and NGCC units affected
- 532.4 GW of generating capacity
- This represents approximately half of total generating capacity in the U.S. as of the first quarter of 2014 (with the rest being primarily nuclear, hydro and wind), and 70 percent of U.S. fossil generating capacity.

Approaches inside the fenceline

- Heat rate improvements
- Conversion to lower carbon-intensive burning
- Unit operating limitations
- Emissions averaging over time
- Retirement / replacement

- Bubbling of multi-unit emissions on-site

Approaches as a system

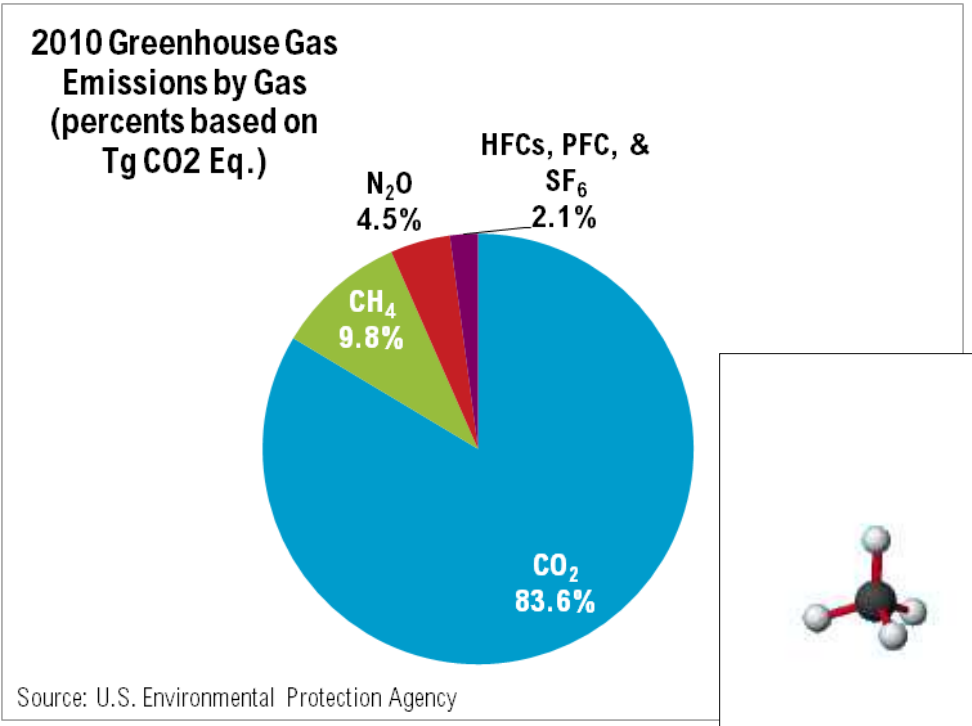
- Trading among units (single or multi-state) under an emissions budget (mass-based or rate-based)
- Actions not specific to covered units (lowering or displacing emissions and/or output at units)
  - New unit operations with lower emissions, including gas, nuclear, hydro, renewables
  - Demand-side measures
- Dispatch constraints
- Carbon pricing

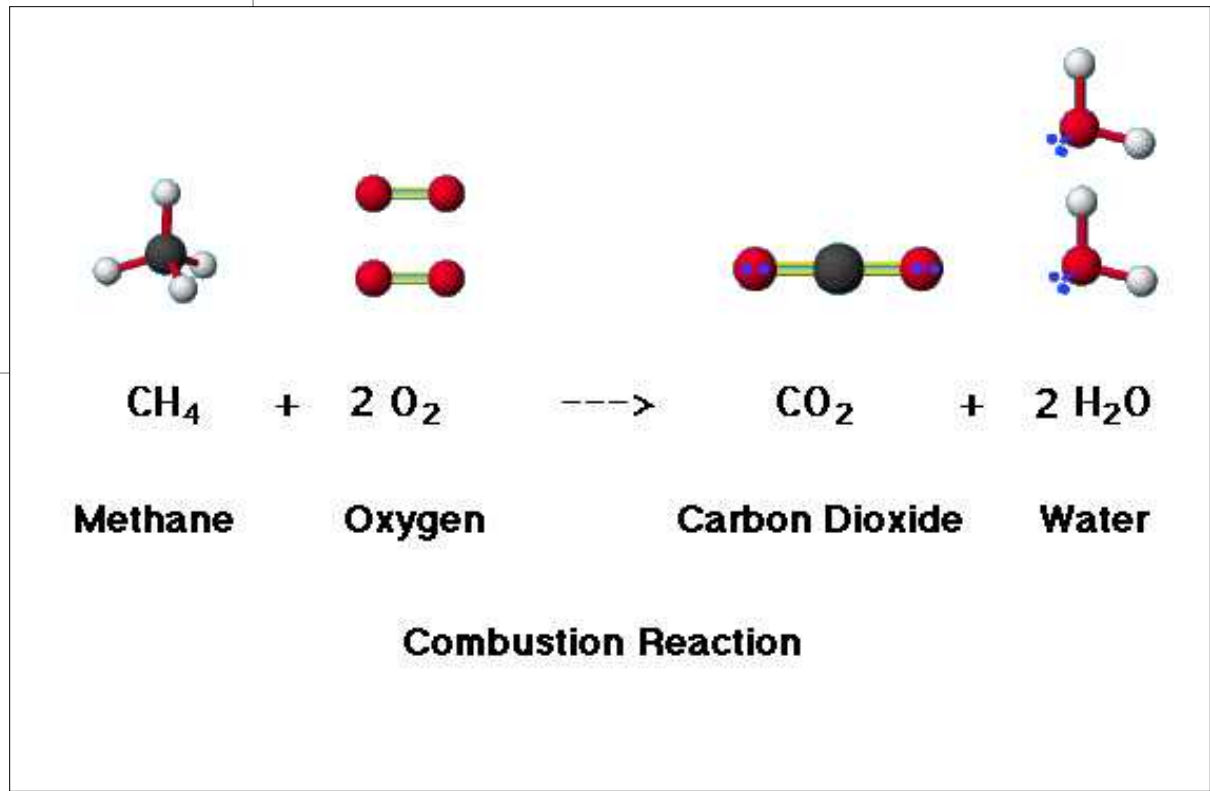
A brief primer on CO2 reductions

But first:

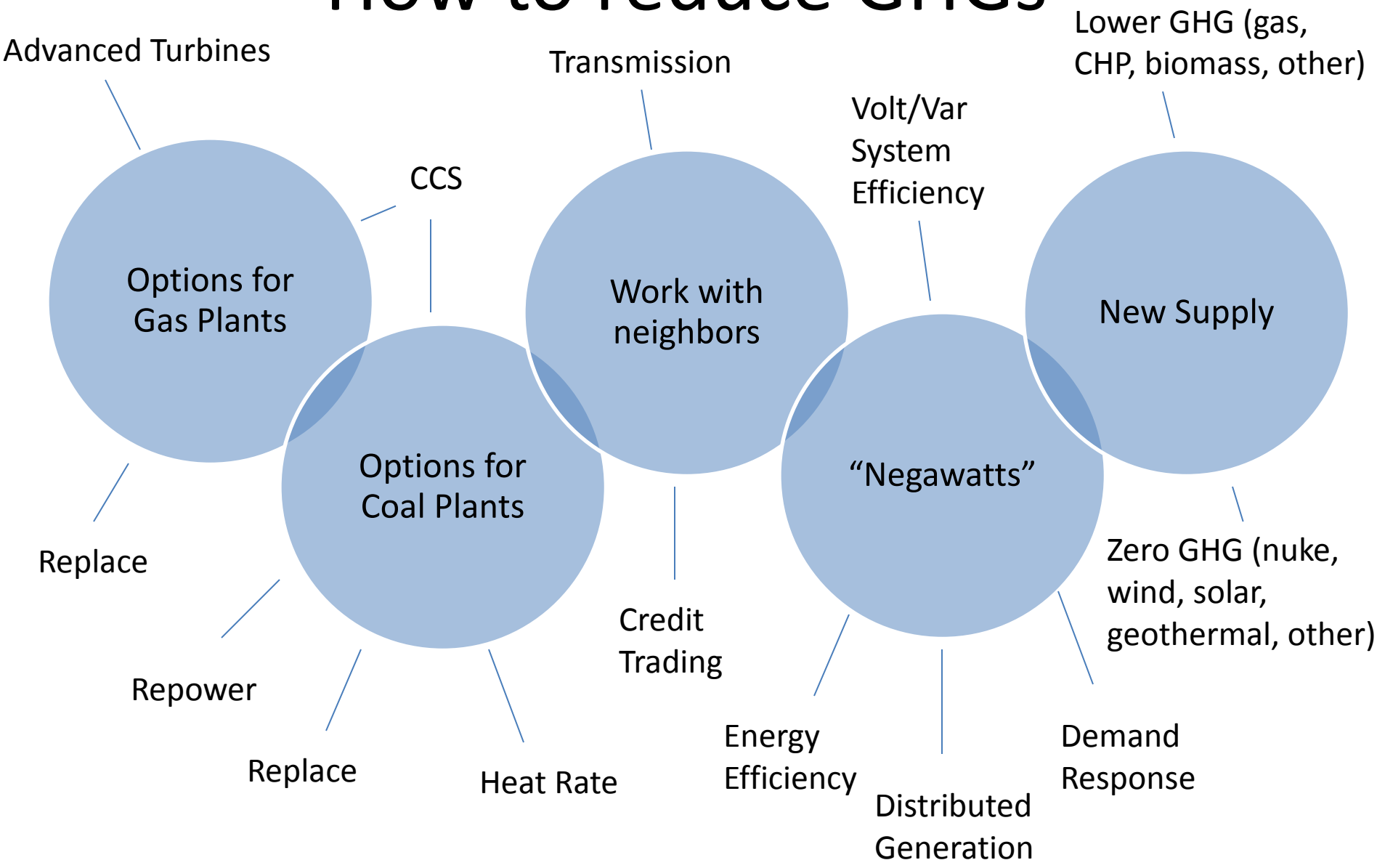
- The Lab takes no position on what happens when CO2 is emitted.
- The Lab takes no position on whether the emissions of CO2 should be regulated.
- The Lab explores what choices one has if one is required to reduce the emissions of CO2.

Combustion means Releasing CO2



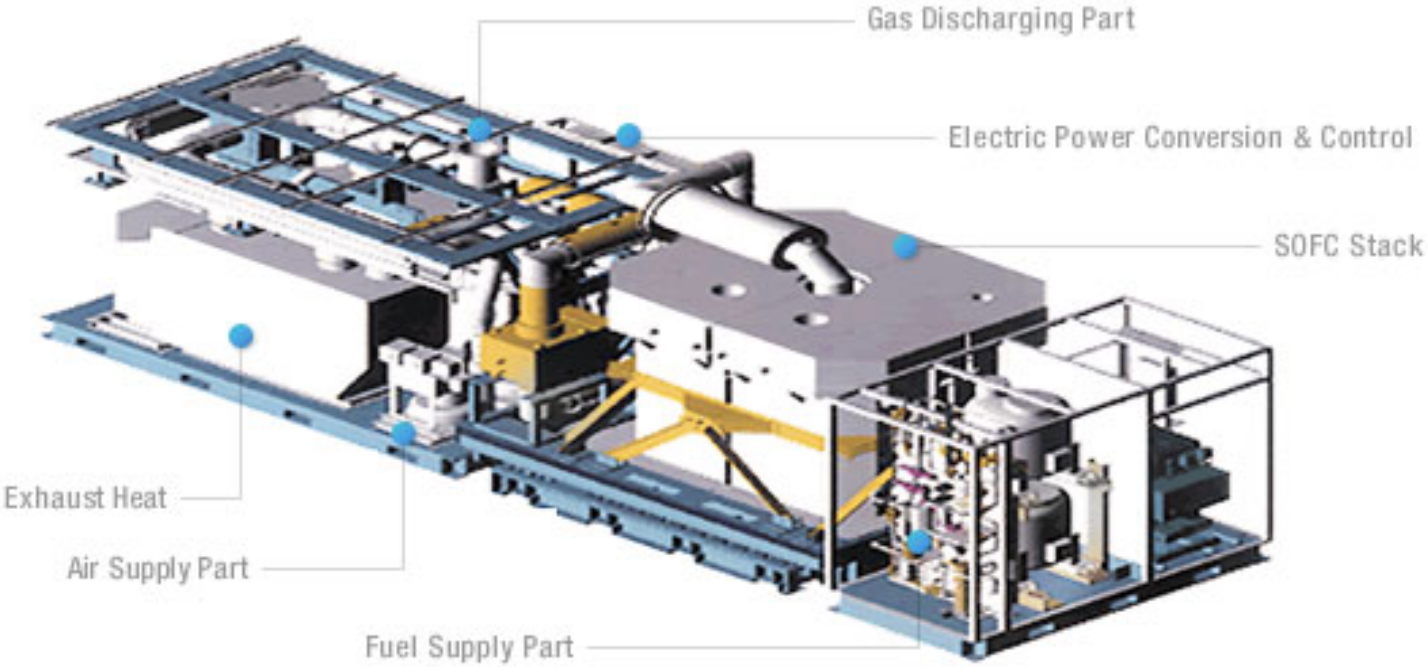


How to reduce GHGs

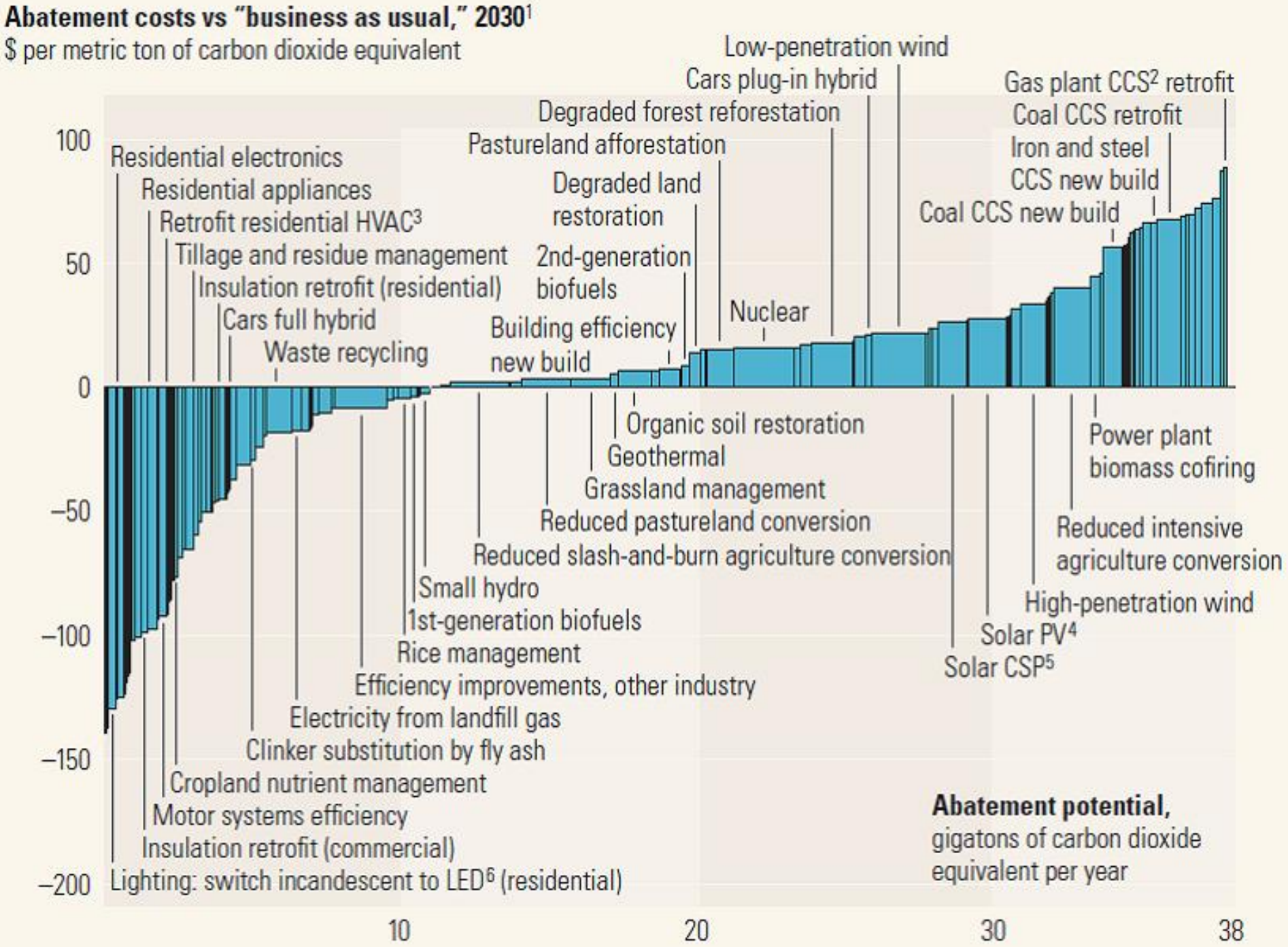


Gas Options

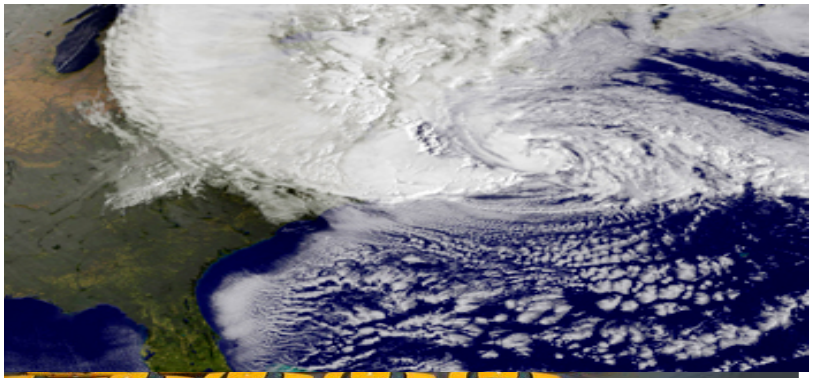
- Gas already has lower embedded CO2 emissions than coal, so gas switching helps
- Decarbonizing gas means higher efficiency, less dispatch, or new technology



30 seconds on Carbon Capture


Abatement costs vs "business as usual," 2030[1]
$ per metric ton of carbon dioxide equivalent
100
50
0
–50
–100
–150
–200
Residential electronics
Residential appliances
Retrofit residential HVAC[3]
Tillage and residue management
Insulation retrofit (residential)
Cars full hybrid
Waste recycling
Building efficiency new build
2nd-generation biofuels
Degraded land restoration
Pastureland afforestation
Degraded forest reforestation
Cars plug-in hybrid
Low-penetration wind
Nuclear
Coal CCS new build
Iron and steel CCS new build
Coal CCS retrofit
Gas plant CCS[2] retrofit
Power plant biomass cofiring
Reduced intensive agriculture conversion
High-penetration wind
Solar PV[4]
Solar CSP[5]
Organic soil restoration
Geothermal
Grassland management
Reduced pastureland conversion
Reduced slash-and-burn agriculture conversion
Small hydro
1st-generation biofuels
Rice management
Efficiency improvements, other industry
Electricity from landfill gas
Clinker substitution by fly ash
Cropland nutrient management
Motor systems efficiency
Insulation retrofit (commercial)
Lighting: switch incandescent to LED[6] (residential)
Abatement potential,
gigatons of carbon dioxide equivalent per year
10
20
30
38

“Hurricane Cruella”



Your Mission: Develop a State Compliance Plan

- A State Compliance Plan is a plan that describes strategies – “measures” – to demonstrate how your State will decrease emissions of the specified pollutant.
- The results of the new technology performance standards mean that

  your Compliance Plan must describe measures that reduce CO2 emissions over 10 years

  from 34 million tons of CO2/yr to 18 million tons CO2/yr.

Your Emissions Profile

Net Capacity: 10,000 Megawatts

80% of the fleet emits GHGs

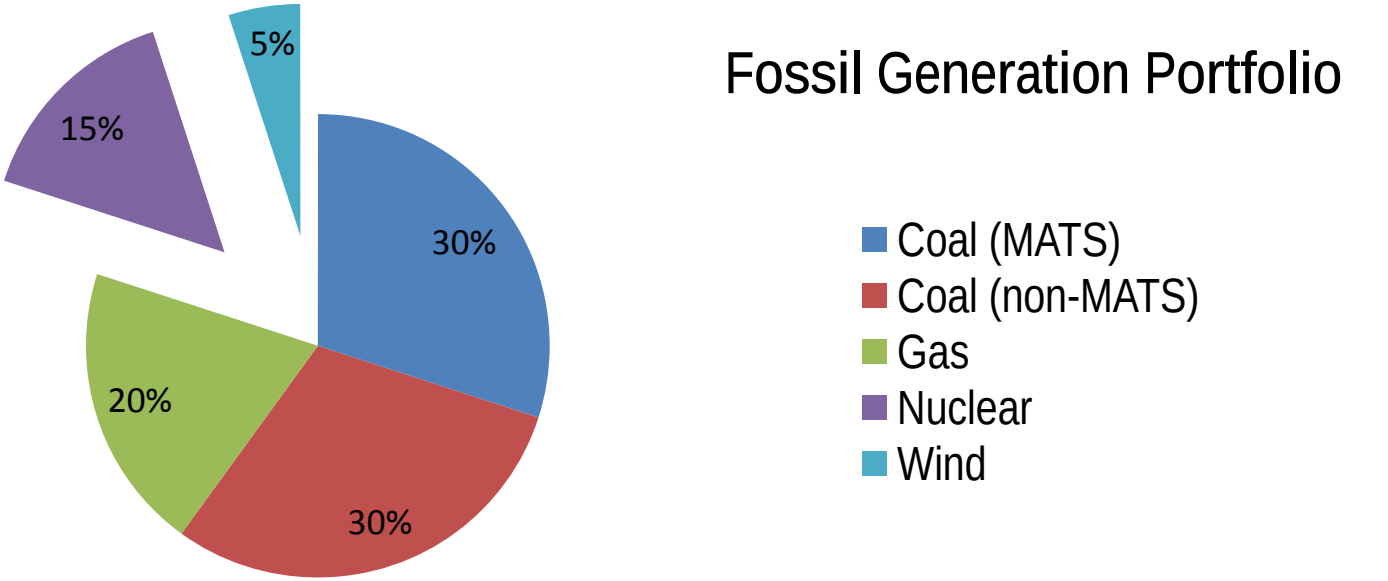
Coal fleet averages 5000 t/MW/yr

Gas fleet averages 2000 t/MW/yr

Nuclear, DSM, and RE assumed to have zero emissions

Fossil Fleet current avg. is 4,250 t/MW/yr

Fossil Fleet target 2,250 t/MW/yr



GHG Emissions Cart

NEW RESOURCES – GAME ONLY – REAL LIFE RESOURCE EMISSIONS ARE NOT THIS SIMPLE

- Natural Gas (CCGT) $1m/MW…….....2000 t/MW/yr ..(40% of unctrl coal emissions)
- Nuclear (traditional, large-scale): $10m/MW……..0
- Nuclear (small modular reactors): $7m/MW ……..0
- Wind Energy: $2m/MW (by energy, not nameplate capacity) ……..0
- Solar Energy: $5m/MW ……..0
- Demand Side Resources: $0.5m/MW……..0
- CHP / Waste Energy (up to 500MW): $0.5m/MW.....……..1000 t/MW/yr .. (20% of unctrl coal emissions)

DECARBONIZATION

- Coal only - 20% Heat Rate Improvement: $0.2m/MW…….....4000 t/MW/yr .. (80% of unctrl coal emissions)
- New CCS: $7m/MW ……0 for each MW applied
- Advanced Gas Turbines: $3 m/MW……1000 t/MW/yr

Your Current GHG Emissions

Units	MW	CO2 emissions, million t/yr
MATS-Affected coal		**5000 t/MW/y**
Tenleytown	600	3
Tysons 2	200	1
Shady Grove	100	0.5
Takoma Park	300	1.5
Forest Glen	1100	5.5
Bethesda	700	3.5
	3000	**15**
Non-MATS coal		**5000 t/MW/y**
Ballston	**3000**	**15**
McPherson Square		
Navy Yard		
Franconia-Springfield		
Van Dorn Street		
Gas Fired		**2000 t/MW/y**
Twinbrook	**2000**	**4**
Cardozo		
Shaw		
Waterfront		
Total	**8000**	**34**

EXTRA VALUE MENU – Assumes full price for everything. If your prices are lower, you can cut a better deal.

ZERO CARBON MEASURES

Build 500 MW **demand side resources**: $250 million 0 tons GHG

Build 1000 MW **large nuclear**: $10 billion 0 tons GHG

Build 250 MW **wind energy**: $500 million 0m tons GHG

Retrofit 1000 MW **Coal to CCS**: $7 billion 0 tons GHG

Build 500 MW **small modular nuclear**: $3.5 billion 0 tons GHG

Build 1000 MW **Advanced Gas Turbines** $3 billion 1m tons GHG

Build 250 MW **solar energy**: $2 billion 0 tons GHG

Build 500 MW* **CHP/Waste Energy**: $250 million .5m tons GHG *LIMIT of 500 MW

LOW CARBON MEASURES

Heat Rate improvement to 3000MW coal: $600 million Subtract 3m tons GHG from profile

BUILD TRANSMISSION to import energy $1 million/MW 0m tons GHG

Replace coal with $0.7 imported wind: $340/ton CO2

Replace coal with imported CHP: $300/ton CO2

Credit Trading break-even points

Replace coal with EE: $100/ton CO2

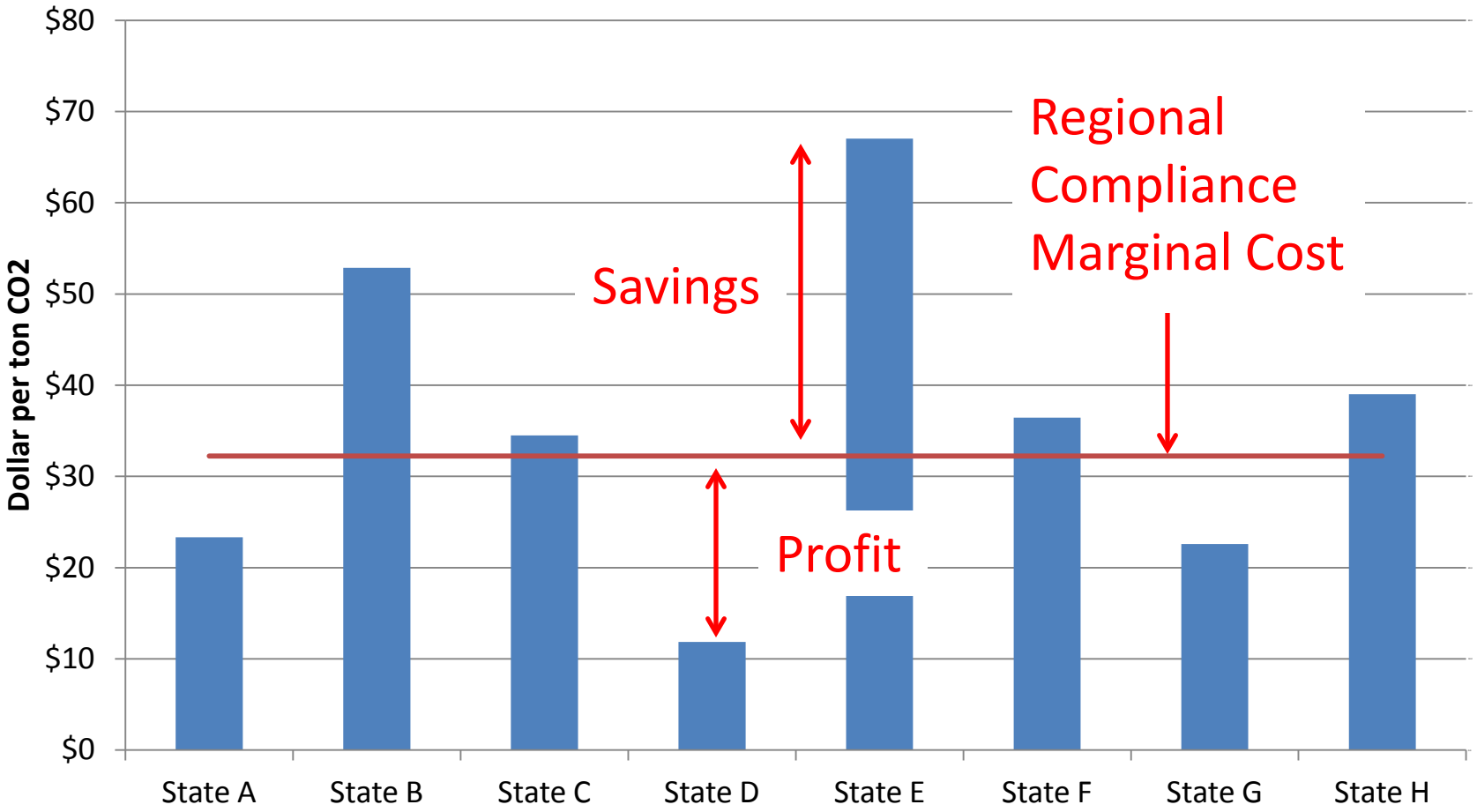
Replace gas with EE: $250/ton CO2

Replace coal with gas: $333/ton CO2

Replace coal with $0.5 wind: $100/ton CO2

Replace coal with local CHP: $125/ton CO2

Marginal Cost CO2 Reductions in 2020



Transmission and Credit Trading

- All emissions are credited where they occur
- If a neighbor can over-comply with CO2 regulations, (i.e. get below 18 M tons/yr) you can work out a deal to buy their CO2 credits.
- Transmission allows you to buy capacity and GHG reductions; credits only help with your GHG emissions reduction State Implementation Plan (SIP).

NSPS and the Spreadsheet Tool

Round 3: NSPS

Non MATS compliant coal plants

	Round 2 Decision	Action	Cost M$	Capacity MW	Annual CO2 Million t/yr
Forest Glen	0		0	1100	5.5
Takoma Park	0		0	300	1.5
Tenleytown	0		0	600	3
Tysons II	0		0	200	1
Bethesda	0		0	700	3.5
Shady Grove	0		0	100	0.5

Other additions	Total after Round 2 MW	**Additional Capacity MW**	**Total Capacity MW**	**Cost M$**	Annual CO2 Million t/yr	
Demand side resource additions	0		0	0	0	
Wind energy additions	0		0	0	0	
Solar energy additions	0		0	0	0	
CHP/waste energy additions	0		0	0	0	
Traditional nuclear	0		0	0	0	
Modular nuclear	0		0	0	0	
Transmission capacity	0		0	0		
Import capacity	0		0			
Export capacity (sales)	0		0		*input as positive value*	
CO2 credit purchases	NA	NA	NA			
CO2 credit sales	NA	NA	NA			*input as positive values*
HR improvements	NA		0	0	0	
New Coal CCS	0		0	0	0	
Advanced NG turbine	NA		0	0	0	
Other NGCC additions	0		0	0	0	

For Ballston, McPherson Sq., Navy Yard
Franconia-Springfield, Van Dorn St.

Other coal retirements		**MW**

For Twinbrook, Cardozo, Shaw, Waterfront

Other NG retirements		**MW**

Other transactions/unanticipated costs

	Rounds 1&2	Round 3	
Costs	0		**M$**
Revenues	0		**M$**

Legislature bars CO2 emissions trading?

No

Results

Demand side capacity	-	**MW**	
Renewable capacity	-	**MW**	
Natural gas capacity	2,000	**MW**	
Coal capacity	6,000	**MW**	*includes coal w/CCS*
Coal retirements	-	**MW**	
Total Capacity	10,000	**MW**	
Total capital cost	0.000	**Billion $**	*includes round 2*
Rate impact	0.00	**cents/kWh**	
New rate	8.00	**cents/kWh**	
Total annual CO2 emissions	34.0	**M tons/year**	*limit 18*

Emissions Trading Example

Team Aggies sells Team Longhorns 1 million tons CO2 emissions allowances for $500 million ($500/ton)

Team Aggies spreadsheet

	Other additions	Total after Round 2 MW	Additional Capacity MW	Total Capacity MW	Cost M$	Annual CO2 Million t/yr	
13	Demand side resource additions	600		600	0	0	
14	Wind energy additions	1000		1000	0	0	
15	Solar energy additions	0		0	0	0	
16	CHP/waste energy additions	500		500	0	0.5	
17	Traditional nuclear			0	0	0	
18	Modular nuclear			0	0	0	
19	Transmission capacity			0	0		
20	Import capacity			0			*must match transmission*
21	Export capacity (sales)	0		0			*input as positive value*
22	CO2 credit purchases	NA	NA	NA			
23	CO2 credit sales	NA	NA	NA			*input as positive values*
24	Heat Rate improvements	NA		0	0	0	
25	New Coal CCS	0		0	0	0	
26	Advanced NG turbine	NA		0	0	0	
27	Other NGCC additions	2000		2000	0	4	

Enter $500 Million here

Enter 1 Million tons per year here

Trading Example

Team Longhorns spreadsheet

	Other additions	Total after Round 2 MW	Additional Capacity MW	Total Capacity MW	Cost M$	Annual CO2 Million t/yr	
13	Demand side resource additions	300		300	0	0	
14	Wind energy additions	1300		1300	0	0	
15	Solar energy additions	0		0	0	0	
16	CHP/waste energy addition			500	0	0.5	
17	Traditional nuclear			0	0	0	
18	Modular nuclear			0	0	0	
19	Transmission capacity			0	0		
20	Import capacity	0		0			*must match transmission*
21	Export capacity (sales)	0		0			*input as positive value*
22	CO2 credit purchases	NA	NA	NA			
23	CO2 credit sales	NA	NA	NA			*input as positive values*
24	Heat Rate improvements	NA		0	0	0	
25	New Coal CCS	0		0	0	0	
26	Advanced NG turbine	NA		0	0	0	
27	Other NGCC additions	1000		1000	0	2	

Enter $500 Million here

Enter 1 Million tons per year here

Sect 111d / Clean Power Plan in Play

Reduce your CO2 emissions from 34m tons CO2/year to 18m tons CO2/year by 2023

1. Look at your fleet and make choices that reduce GHG emissions
    1. Different supply choices with low/no GHG profile
    2. Non-supply resource choices: demand, delivery
2. Look outside your fleet for reductions
3. Explore whether other tables might be able to offer credits or lower carbon power based on their strategies

Costs

- What were the rate impacts of your decisions?
- What will the effect on ratepayers be? Are there political risks?
- What will the effects on credit-worthiness be? Who bears them?

Strategy for 111d

- What is your compliance strategy? How much of each compliance option did you leverage to arrive at your emission target?
- Did you engage in any interstate transactions for compliance? (trading, transmission, resource averaging, etc.)
- What investments you make now will help in long-run?
- What are the trade-offs between compliance options?
- Are you anticipating emerging drivers, (i.e. regulatory, policy, market, technology)?
- Who do you need to be talking with to implement these measures?

Round 4: What about…

- Consider: S.316b rules
- Consider: Clean Energy Standard legislation
- Consider: No Carbon Pricing requirements
- Consider: Managing intermittent resources
- Consider: Rapid, energy-intense economic recovery
- Consider: Fracturing moratoria
- Consider: Flat utility revenues
- Consider: Competition for capital, financial health of utilities
- Consider: disruptive technologies or business models

YOUR MISSION: ESCAPE FROM THE IMPOSSIBLE BOX

Least-cost, Least-risk?

- What was the least risky course?
- What decisions seemed risk-avoidant but incurred consequences?
- What coordination would have helped from the outset? Is integrated gas / transmission / generation planning an answer?
- How did waiting for rule finalization affect decisions?
- Are there decision-making processes that steer towards lower-risk outcomes?
- What was the value of a diverse portfolio?

GAME OVER

- THANK YOU
- MERCI
- GRACIAS
- DOMO ARIGATO

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