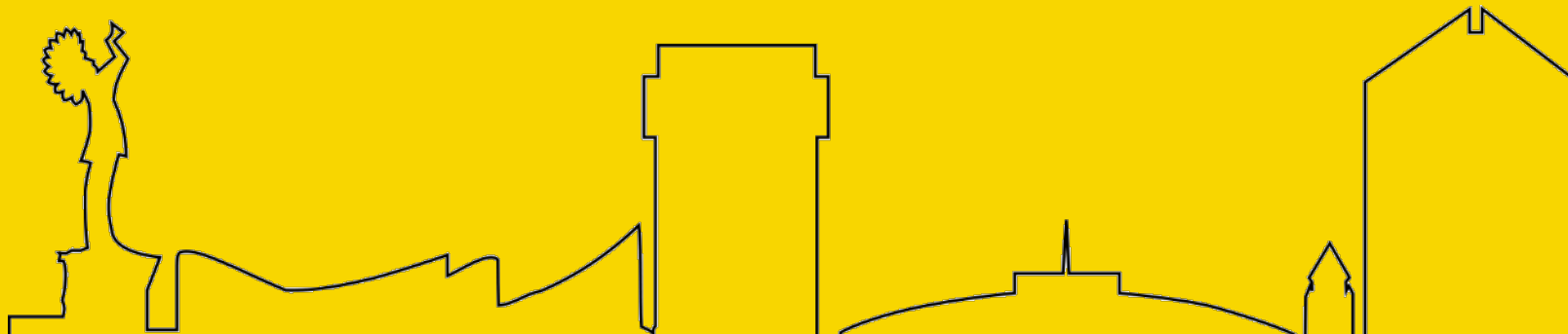


# Wide-Area Electric Grid Visualization Using Pseudo-Geographic Mosaic Displays

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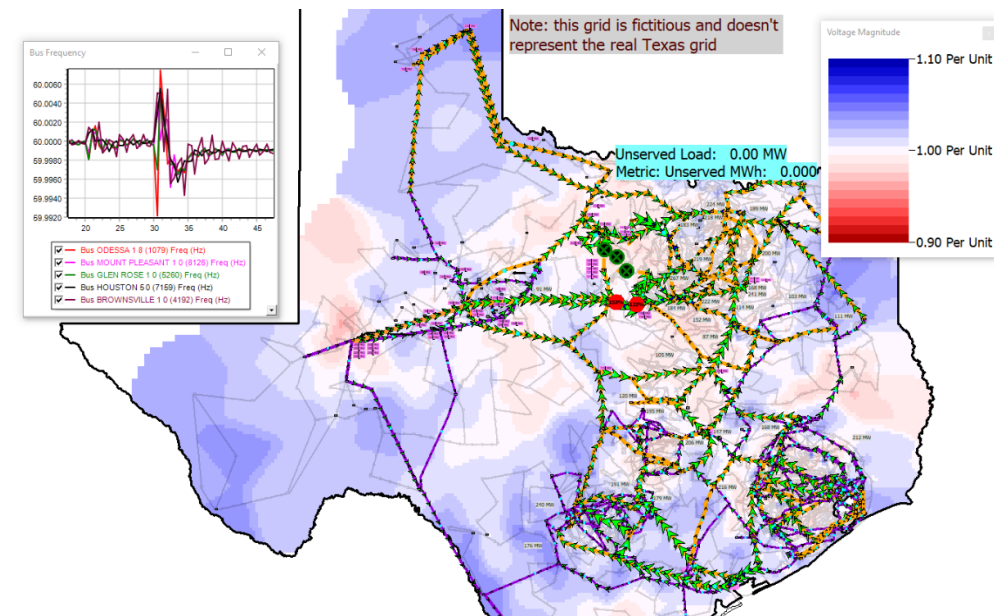
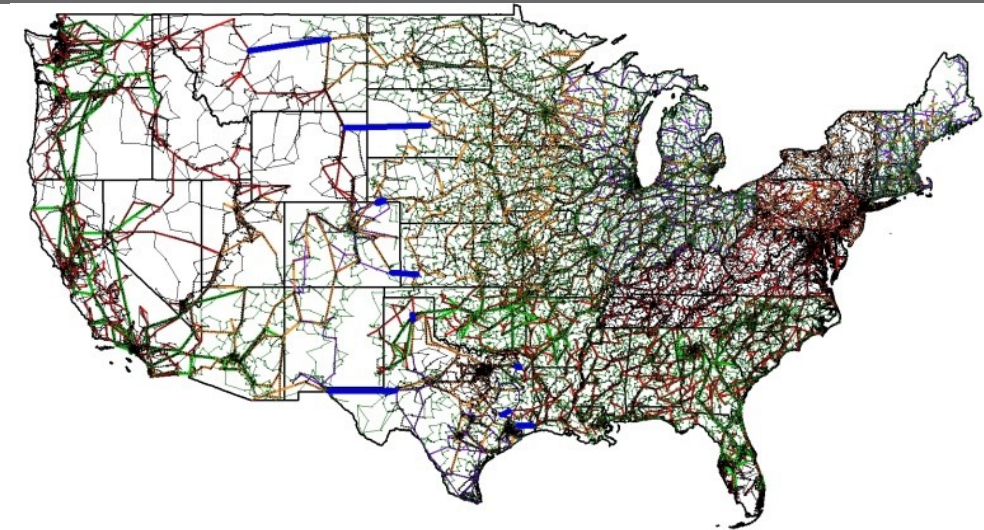
51<sup>st</sup> North American Power Symposium

# Motivation

- Maintain situational awareness by presenting system data in an informative way for system engineers and operators
  - Preserve relative geographic relationships
  - Use display space effectively

# Visualization Practices

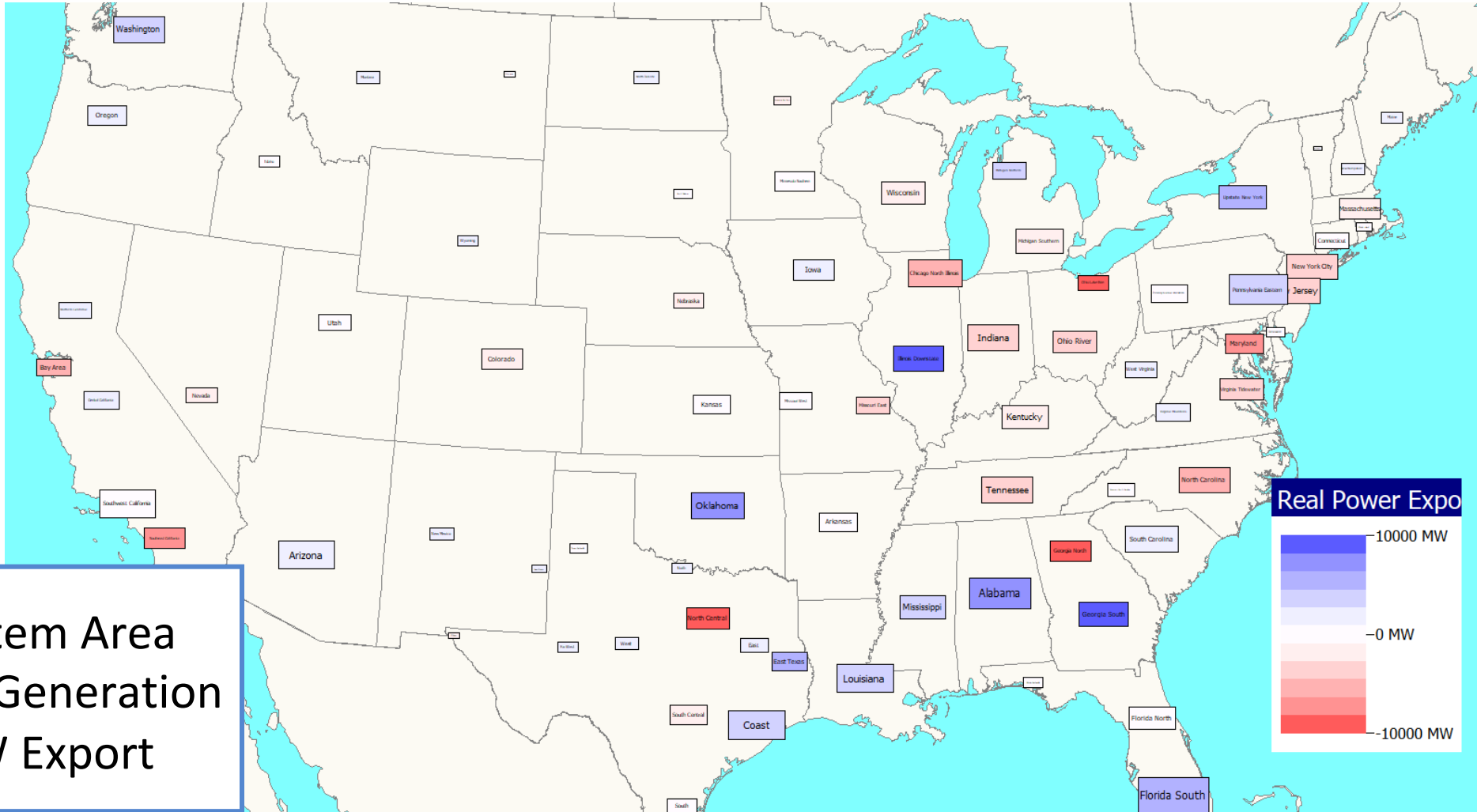
- Geographic representation of entire grid
  - Branch flows
  - Contour Maps
- However, these present challenges
  - Areas of interest may compose a small geographic footprint
  - Visualization dense with information



Synthetic Grid test cases publicly available at: <https://electricgrids.engr.tamu.edu/electric-grid-test-cases/>

# Geographic Data Views

- Automatically update geographic display with system values of interest

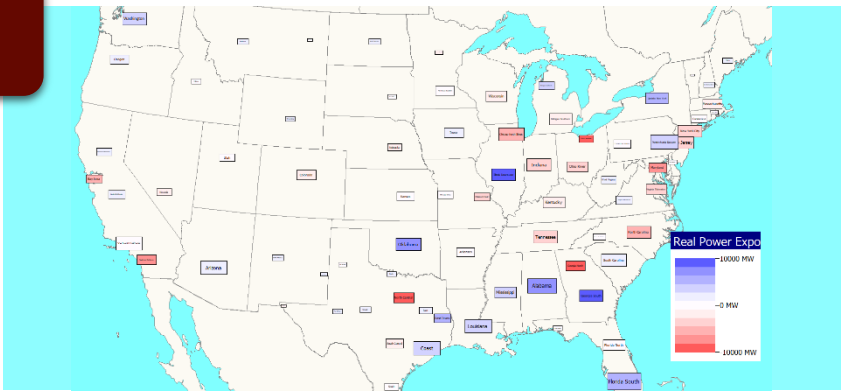


**Label:** System Area  
**Size:** MW Generation  
**Color:** MW Export

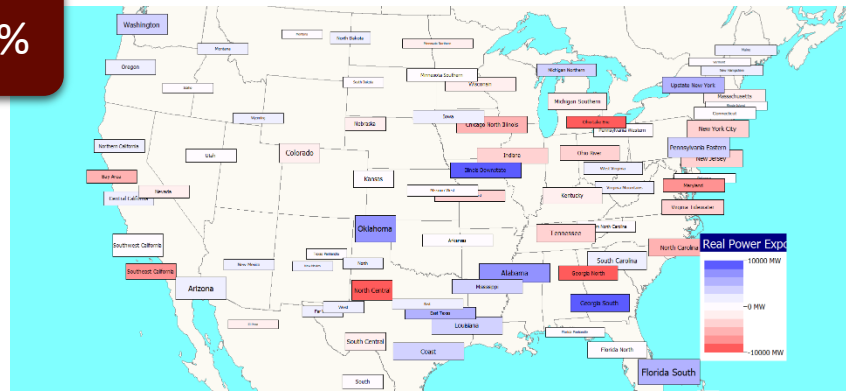
# Pseudo-Geographic Mosaic Displays

- Maintains approximate geographic relationships using more display space

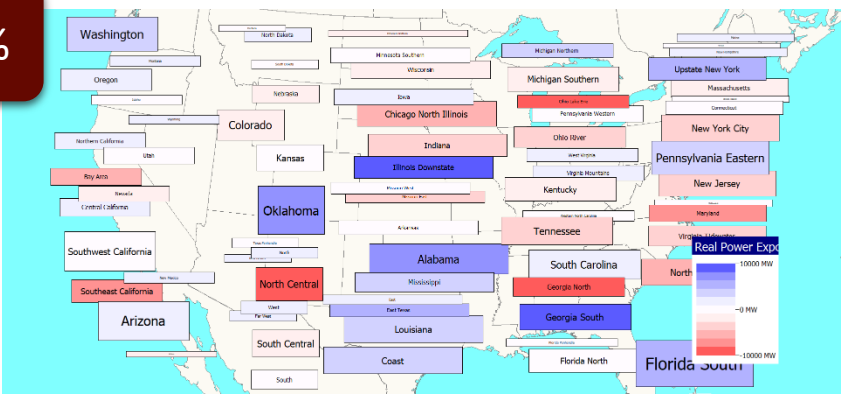
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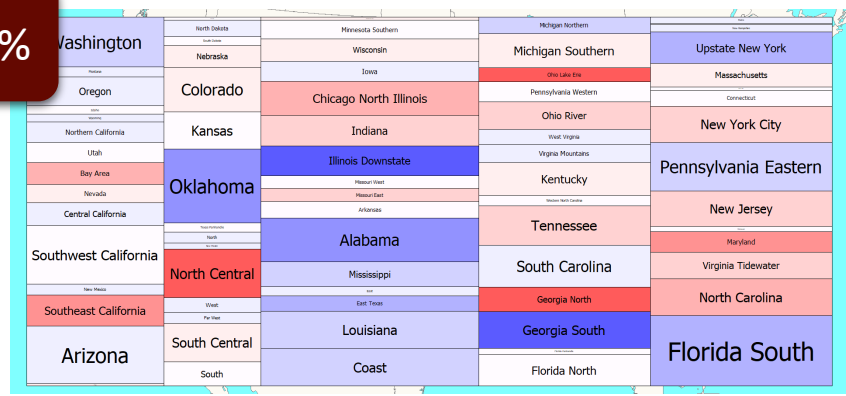
25%



60%



100%



Can be used to convey:

- Element status
- System operating conditions

Can aid:

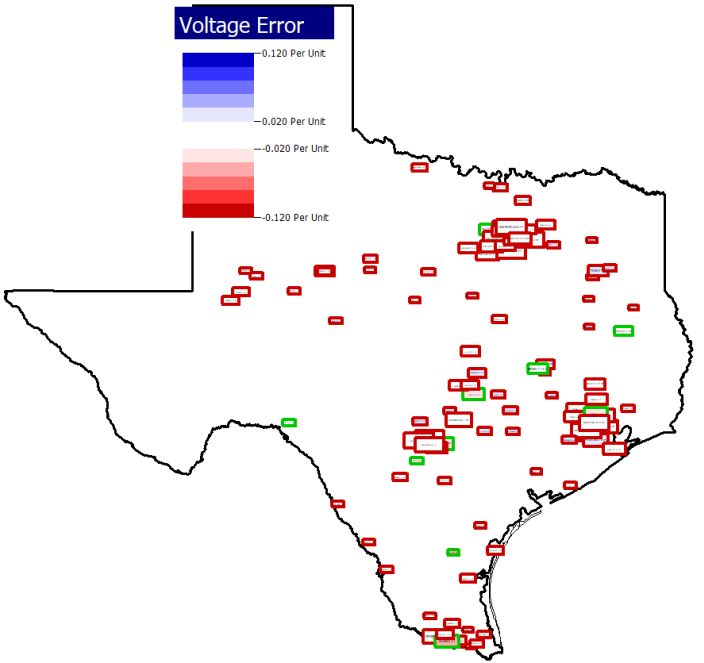
- Situational awareness
- Data interpretation
- Quick comparisons across studies

# PGMD Layout Algorithm

- Basis similar to treemap algorithm
  - Nested rectangles used to visualize tree structure
- Mosaic Displays based on this layout set to have uniform column width
  - Width is set to depend on the sum of size metrics of the tiles represented
  - Height dependent on size metrics relative to other column elements
- Alternate layout approach options to come!

# 2,000 Bus Switched Shunt Visuals

**Label:** Shunt Name  
**Size:** Shunt Nominal MVA  
**Fill Color:** Shunt Regulation Voltage Error  
**Outline Color:** Switched Shunt Status

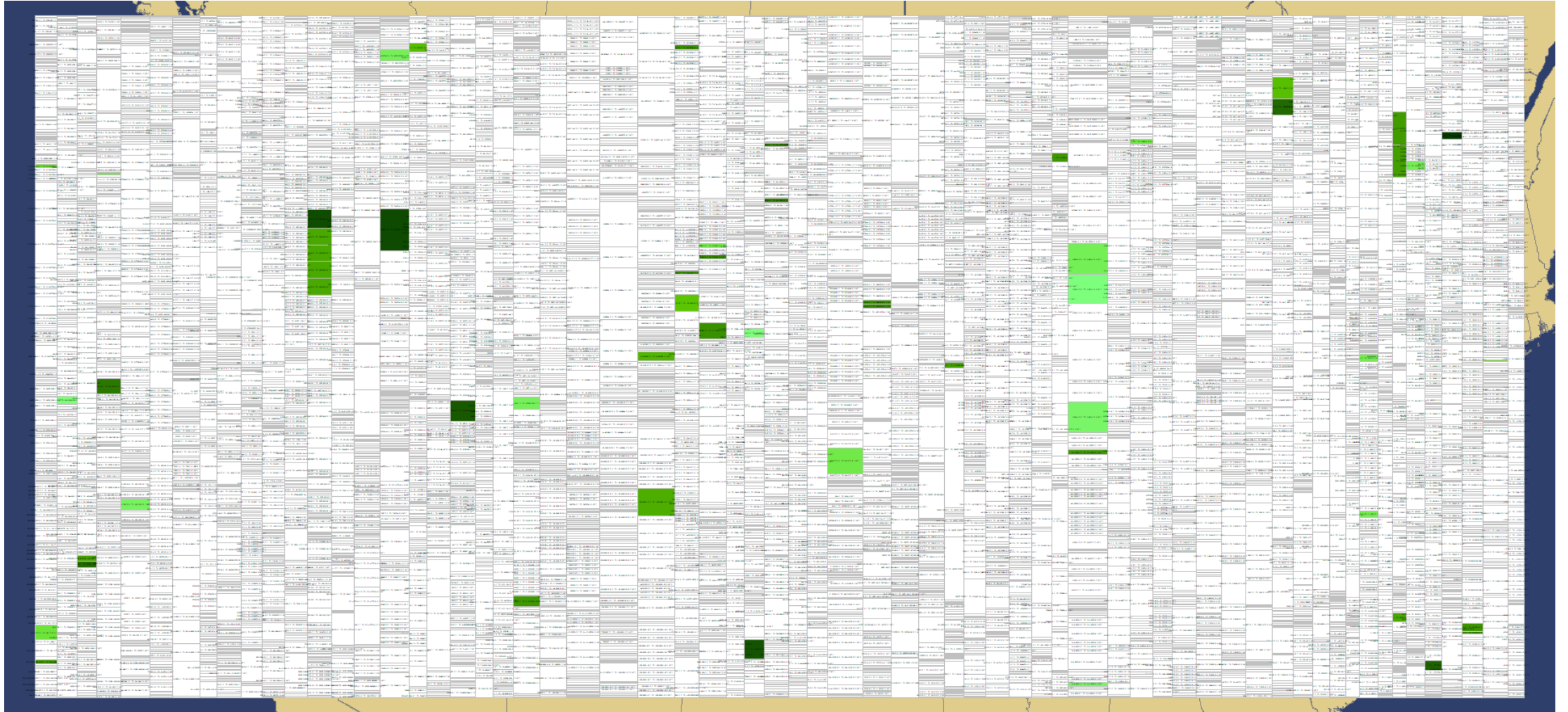


**GDV**

ABILENE 10 #1	WEATHERFORD 10 #1	FLOWER MOUND 20 #1	JOSEPHINE 0 #1	TYLER 4 1 #1
ABILENE 13 #1	FORT WORTH 24 0 #1	LEWSVILLE 0 #1	MESQUITE 3 0 #1	LUFKIN 3 1 #1
ABILENE 40 #1	SAN ANTONIO 31 0 #1	KILLEEN 3 1 #1	HASLET 0 #1	LUFKIN 3 1 #2
ROSCOE 50 #1	SAN ANTONIO 51 0 #1	GEORGETOWN 1 0 #1	SOUTHLAKE 0 #1	WILLIS 2 0 #1
ROSCOE 51 #1	CONVERSE 0 #1	AUSTIN 22 0 #1	DALLAS 26 0 #1	CONROE 2 0 #1
ROSCOE 51 #1	AUSTIN 10 0 #1	LEANDER 2 0 #1	DALLAS 42 0 #1	HOUSTON 30 0 #1
BIG SPRING 1 0 #1	SAN ANTONIO 34 0 #1	AUSTIN 10 0 #1	NORTH RICHLAND HILLS 2 0 #1	HOUSTON 2 0 #1
SAN ANGELO 1 0 #1	SAN ANTONIO 9 0 #1	SAN MARCOS 1 #1	DALLAS 23 0 #1	HOUSTON 82 0 #1
PEARSALL 0 #1	MISSION 4 1 #1	SARITA 1 1 #1	DALLAS 40 #1	HOUSTON 77 0 #1
EAGLE PASS 1 #1	PHARR 0 #1	EDINBURG 1 0 #1	ARLINGTON 3 0 #1	HOUSTON 77 0 #1
LAREDO 7 1 #1		RIO HONDO 0 #1	FORT WORTH 15 0 #1	HOUSTON 10 0 #1
LAREDO 4 1 #1		WESLACO 0 #1	DALLAS 44 0 #1	HOUSTON 72 0 #1
		SAN BENITO 0 #1		PEARLAND 2 0 #1
				TEXAS CITY 2 0 #1

**PGMD**

# 10,000 Bus Case – Line Loading PGMD





# 2000 Bus Case – Generator PGMD

PANHANDLE 10 #1	MIAMI 0 #1	VERNON 11 #1	BRIDGEPORO 1 #1	BRIDGEPORO 4 #1	SHREVEPORT 1 #1	MURKIN 1 #1	DENTON 1 #1	GREENVILLE 1 #1	PARIS 2 #1	WILLIS 10 #1	CHANNELVIEW 1 #1	MOUNT PLEASANT 13 #1
PANHANDLE 21 #1			PALO PINTO 1 #1	BRIDGEPORO 3 #1	SHREVEPORT 2 #1	SHREVEPORT 3 #1		MCKINNEY 18 #1	PARIS 13 #1		CHANNELVIEW 7 #1	
RALLS 14 #1			PALO PINTO 1 #1		SHREVEPORT 4 #1	SHREVEPORT 5 #1	DALLAS 24 #1	MCKINNEY 14 #1	PARIS 16 #1		CHANNELVIEW 18 #1	
O DONNELL 21 #1	PANHANDLE 22 #1	WICHITA FALLS 13 #1	PALO PINTO 12 #1	BRIDGEPORO 7 #1	SHREVEPORT 6 #1	SHREVEPORT 7 #1	DALLAS 23 #1	MCKINNEY 15 #1	PARIS 12 #1		CHANNELVIEW 15 #1	MOUNT PLEASANT 15 #1
O DONNELL 11 #1	FLUVANNA 22 #1		PALO PINTO 13 #1	BRIDGEPORO 5 #1	SHREVEPORT 8 #1	SHREVEPORT 9 #1	DALLAS 22 #1	MCKINNEY 13 #1	PARIS 15 #1		CHANNELVIEW 19 #1	MOUNT PLEASANT 14 #1
	FLUVANNA 1 #1		PALO PINTO 15 #1	BRIDGEPORO 6 #1	SHREVEPORT 10 #1	SHREVEPORT 11 #1		MCKINNEY 18 #1	PARIS 14 #1		CHANNELVIEW 13 #1	
			GOLDENWATER 14 #1	BRIDGEPORO 8 #1	SHREVEPORT 12 #1	SHREVEPORT 13 #1			PARIS 17 #1		CHANNELVIEW 14 #1	
			MARBLE FALLS 25 #1	BRIDGEPORO 2 #1			DALLAS 17 #1	THOMPSONS 8 #1		HOUSTON 53 #1	CHANNELVIEW 10 #1	MT. ENTERPRISE 4 #1
BIG SPRING 31 #1	SYNDER 2 #1	ARCHER 21 #1	MARBLE FALLS 26 #1	POOLVILLE 4 #1	GLEN ROSE 13 #1	ARLINGTON 15 #1	ENNIS 3 #1	THOMPSONS 14 #1		HOUSTON 57 #1	CHANNELVIEW 18 #1	MT. ENTERPRISE 5 #1
GOLDSMITH 0 #1	SNYDER 11 #1	OLNEY 12 #1	MARBLE FALLS 24 #1	POOLVILLE 2 #1	ARLINGTON 14 #1	ARLINGTON 16 #1	ENNIS 2 #1	THOMPSONS 13 #1		HOUSTON 58 #1	CHANNELVIEW 11 #1	MT. ENTERPRISE 3 #1
ODESSA 16 #1	HERMLEIGH 3 #1		MARION 18 #1	POOLVILLE 3 #1				THOMPSONS 4 #1		HOUSTON 59 #1		MT. ENTERPRISE 6 #1
ODESSA 17 #1	ROSCOE 11 #1	GRAHAM 3 #1	MARION 15 #1				DALLAS 19 #1	THOMPSONS 7 #1		HOUSTON 55 #1		JACKSONVILLE 15 #1
ODESSA 13 #1	ROSCOE 22 #1	ALBANY 15 #1	MARION 17 #1				DALLAS 14 #1	THOMPSONS 6 #1		HOUSTON 56 #1	PASADENA 26 #1	
ODESSA 110 #1	ROSCOE 22 #1	ALBANY 15 #1	MARION 13 #1	GLEN ROSE 12 #1			DALLAS 16 #1	THOMPSONS 3 #1		HOUSTON 54 #1	PASADENA 24 #1	BAYTOWN 25 #1
	TRENT 11 #1	ABILENE 22 #1	MARION 14 #1		AUSTIN 23 #1	BASTROP 7 #1	DALLAS 15 #1	THOMPSONS 9 #1		HOUSTON 58 #1	PASADENA 23 #1	BAYTOWN 23 #1
	ROSCOE 30 #1	SAN ANTONIO 14 #1			AUSTIN 24 #1	BASTROP 6 #1	DALLAS 18 #1	THOMPSONS 12 #1		HOUSTON 59 #1	PASADENA 27 #1	BAYTOWN 26 #1
ODESSA 18 #1	ROSCOE 30 #1	SAN ANTONIO 14 #1			AUSTIN 26 #1	BASTROP 3 #1	DALLAS 16 #1	THOMPSONS 5 #1		HOUSTON 60 #5	PASADENA 25 #1	BAYTOWN 24 #1
ODESSA 15 #1	ROSCOE 52 #1	SAN ANTONIO 16 #1			CEDAR CREEK 15 #1	BASTROP 5 #1	DALLAS 15 #1	THOMPSONS 10 #1		PASADENA 14 #1	DEER PARK 8 #1	
ODESSA 14 #1	SWEETWATER 20 #1	SAN ANTONIO 15 #1		AUSTIN 10 #7	CEDAR CREEK 13 #1		DALLAS 18 #1	THOMPSONS 10 #1		HOUSTON 411 #1	DEER PARK 10 #1	LAPORTE 6 #1
ODESSA 11 #1	SWEETWATER 20 #1	SAN ANTONIO 15 #1		AUSTIN 10 #8	CEDAR CREEK 14 #1	TAF 10 #1		THOMPSONS 10 #1		HOUSTON 410 #1	DEER PARK 9 #1	LAPORTE 5 #1
ODESSA 12 #1	WINGATE 4 #1	ELMENDORF 6 #1		NEW BRAUNFELS 15 #1	TAF 21 #1	GREGORY 4 #1		THOMPSONS 10 #1		HOUSTON 49 #1	DEER PARK 11 #1	LAPORTE 7 #1
MONAHAN 1 #1	WINGATE 3 #1	ELMENDORF 8 #1		NEW BRAUNFELS 16 #1	SARITA 21 #1	GREGORY 6 #1				HOUSTON 48 #1	DEER PARK 6 #1	
MONAHAN 15 #1	WINGATE 2 #1	ELMENDORF 9 #1		NEW BRAUNFELS 17 #1	SARITA 31 #1	GREGORY 7 #1		JEWETT 14 #1		HOUSTON 49 #1	DEER PARK 7 #1	LAPORTE 8 #1
MONAHAN 13 #1	WINGATE 2 #1	ELMENDORF 5 #1		NEW BRAUNFELS 14 #1	SAN PERLITA 0 #1	GREGORY 2 #1	LA GRANGE 4 #1			HOUSTON 48 #1	DEER PARK 8 #1	
MCCAMEY 11 #1	WINGATE 2 #1	ELMENDORF 10 #1		NEW BRAUNFELS 17 #1	SEBASTIAN 10 #1	GREGORY 3 #1	LA GRANGE 3 #1	FRANKLIN 6 #1		HOUSTON 48 #1	DEER PARK 7 #1	
	WINGATE 2 #1	ELMENDORF 10 #1		NEW BRAUNFELS 17 #1	SEBASTIAN 21 #1	GREGORY 5 #1	LA GRANGE 5 #1			HOUSTON 48 #1	DEER PARK 7 #1	
	WINGATE 2 #1	ELMENDORF 10 #1		NEW BRAUNFELS 17 #1	SEBASTIAN 21 #1	GREGORY 5 #1	LA GRANGE 5 #1			HOUSTON 48 #1	DEER PARK 7 #1	
IRAAN 11 #1	WINGATE 2 #1	ELMENDORF 10 #1		NEW BRAUNFELS 17 #1	SEBASTIAN 21 #1	GREGORY 5 #1	LA GRANGE 5 #1			HOUSTON 48 #1	DEER PARK 7 #1	
CHRISTOVAL 2 #1	WINGATE 2 #1	ELMENDORF 10 #1		NEW BRAUNFELS 17 #1	SEBASTIAN 21 #1	GREGORY 5 #1	LA GRANGE 5 #1			HOUSTON 48 #1	DEER PARK 7 #1	
	WINGATE 2 #1	ELMENDORF 10 #1		NEW BRAUNFELS 17 #1	SEBASTIAN 21 #1	GREGORY 5 #1	LA GRANGE 5 #1			HOUSTON 48 #1	DEER PARK 7 #1	
BRACKETVILLE 21 #1	WINGATE 2 #1	ELMENDORF 10 #1		NEW BRAUNFELS 17 #1	SEBASTIAN 21 #1	GREGORY 5 #1	LA GRANGE 5 #1			HOUSTON 48 #1	DEER PARK 7 #1	

# Design Considerations

- Who is your audience and why will they be using the displays?
  - “Snapshot” of grid
  - Long-term users
- How to depict data?
  - Tile sizing
  - Tile placement
  - Colors
- What to depict?
  - Substations
  - Generators
  - Loads
  - Shunts
  - Lines
  - ...

# Generator Size and Type

**Label:** Generator Bus Number

**Size:** Max MW

**Color:** Fuel Type

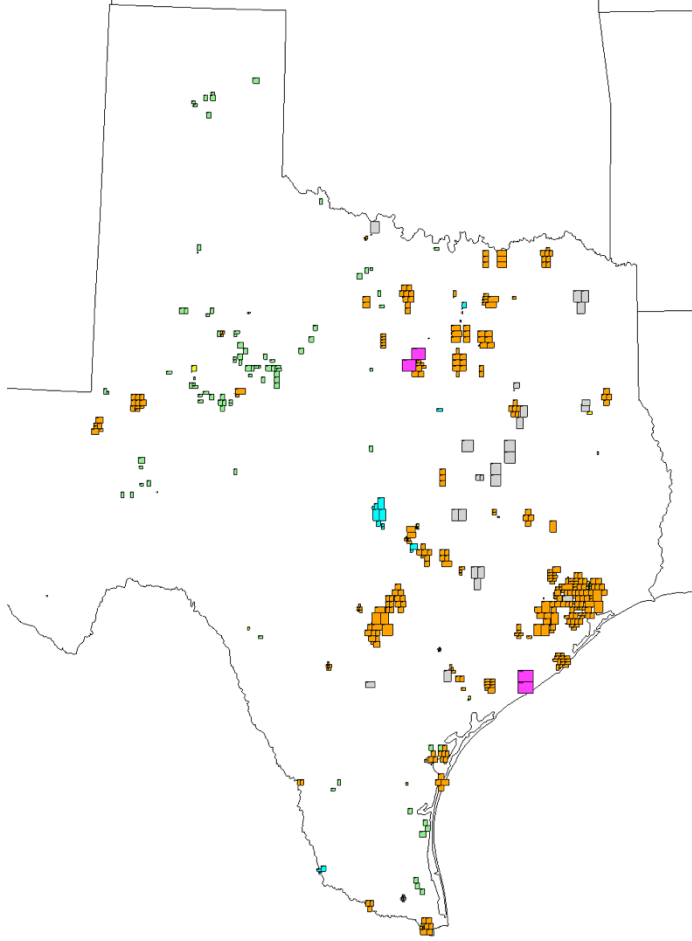
- Magenta = Nuclear
- Gray = Coal
- Orange = Natural Gas
- Blue = Hydro
- Green = Wind
- Yellow = Solar

Note that overlapping tiles make it difficult to discern fuel mix in urban areas.

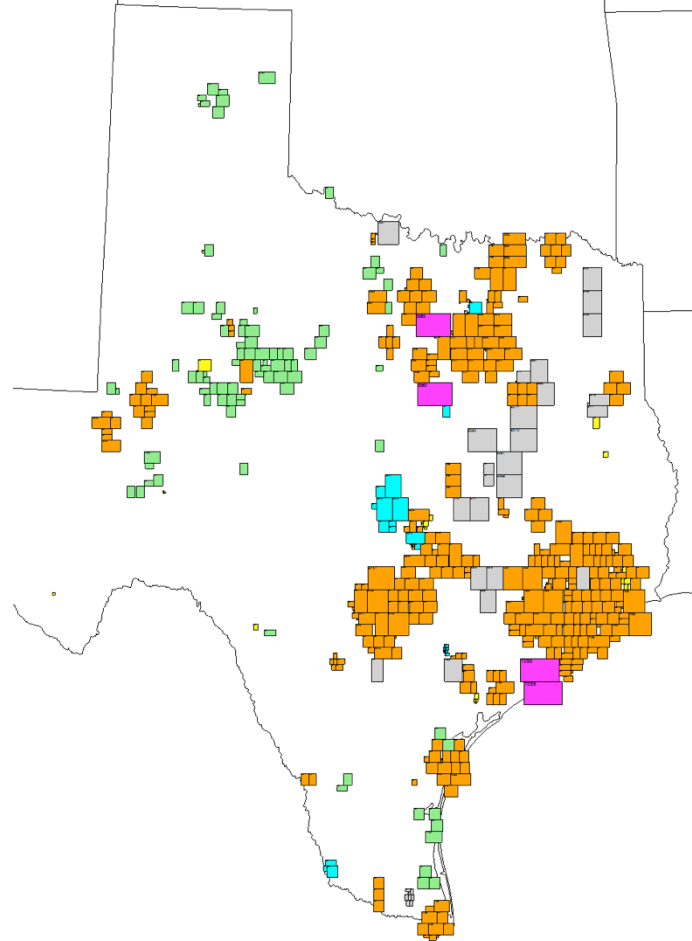
5%

50%

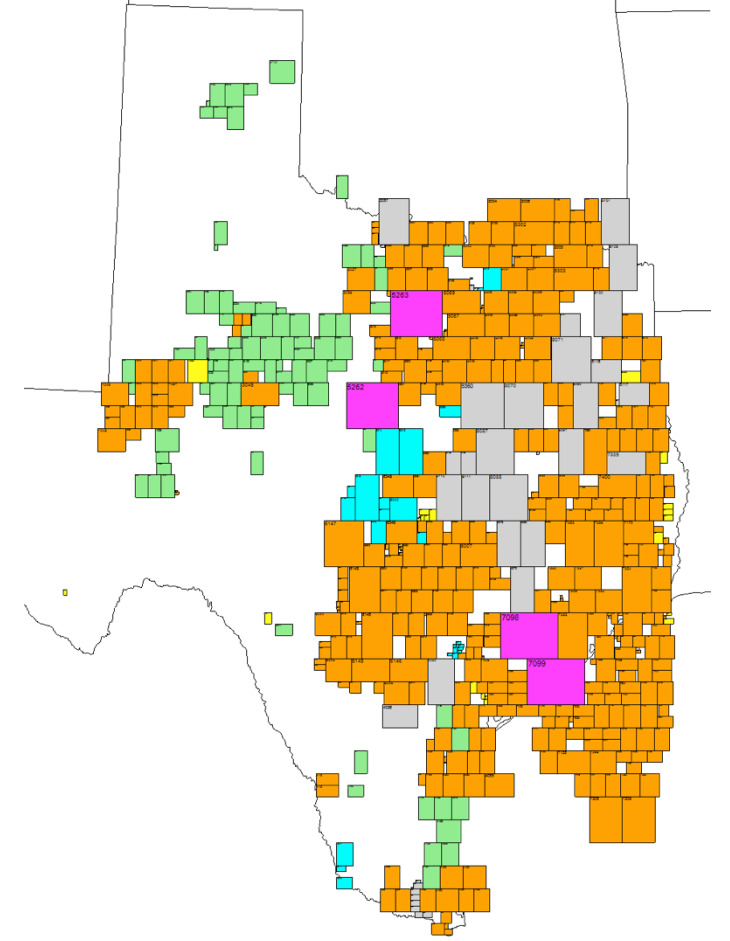
# Horizontal Packing



2%



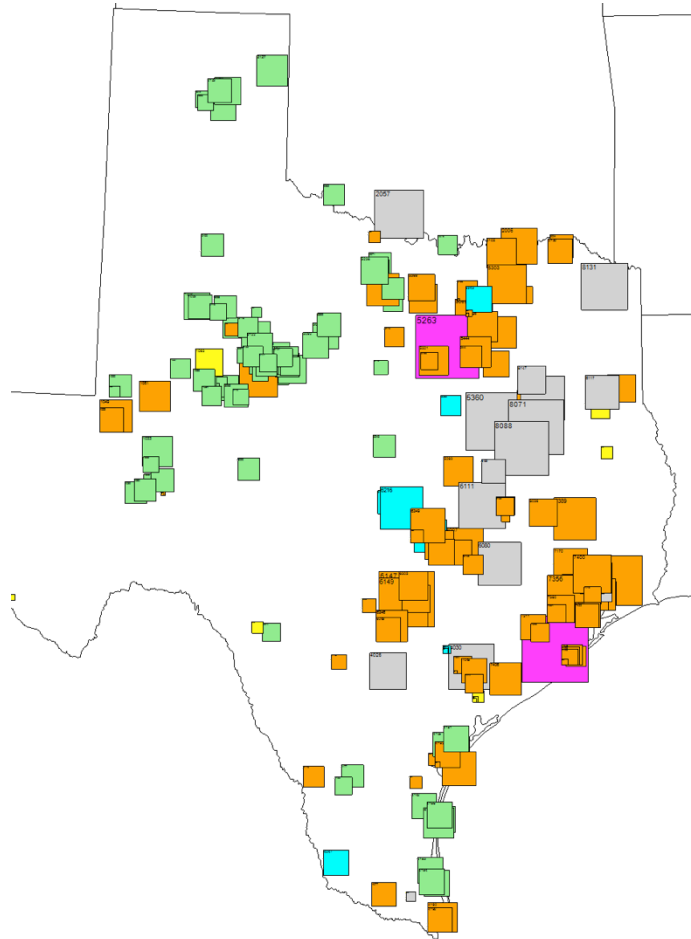
10%



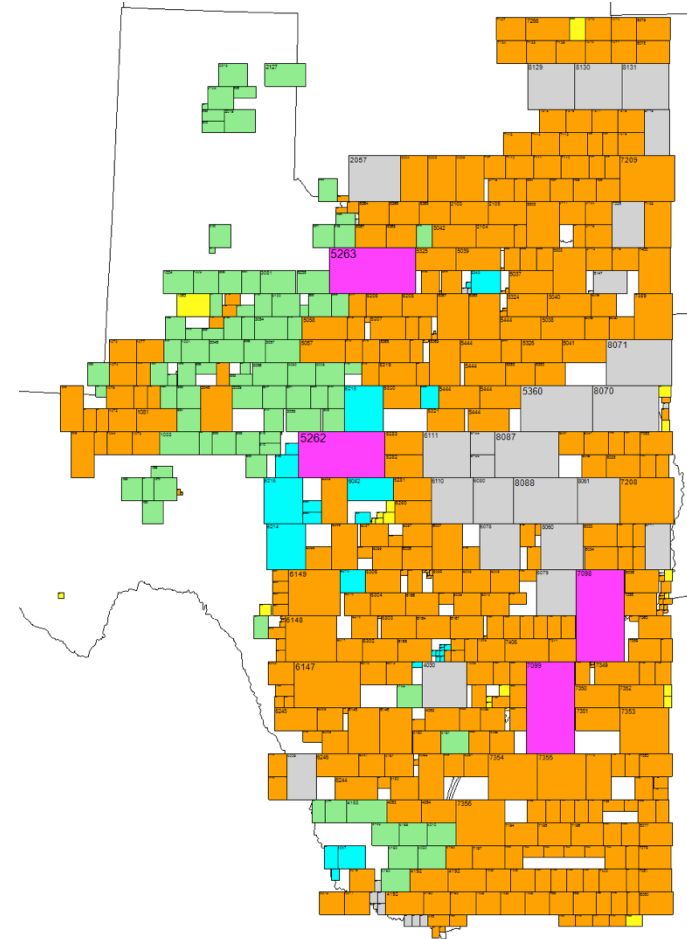
30%

# Horizontal Packing Comparison, 50%

Same information, different impression.



PGMD – no Horizontal Packing

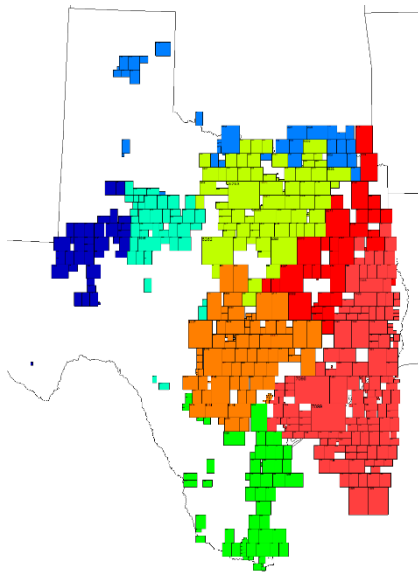


PGMD with Horizontal Packing

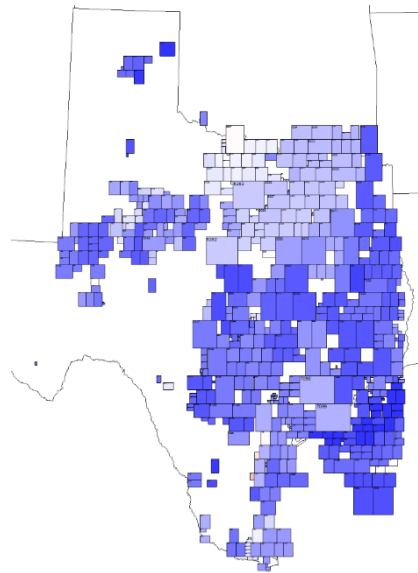
# PGMD Opportunities

- Quick visual comparison across studies with changing system conditions
- Dynamic visualization loops
- Display multiple attributes or system parameters
- Various layout algorithms

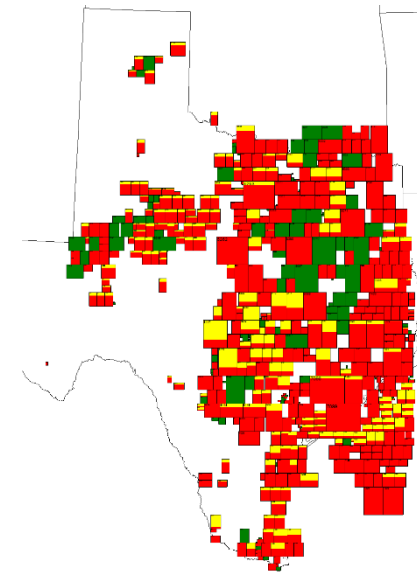
Areas



Voltage



Status & Dispatch



# Questions?

Jessica Wert

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