ILLINOIS INSTITUTE OF TECHNOLOGY

# Advanced Wind Integration Study

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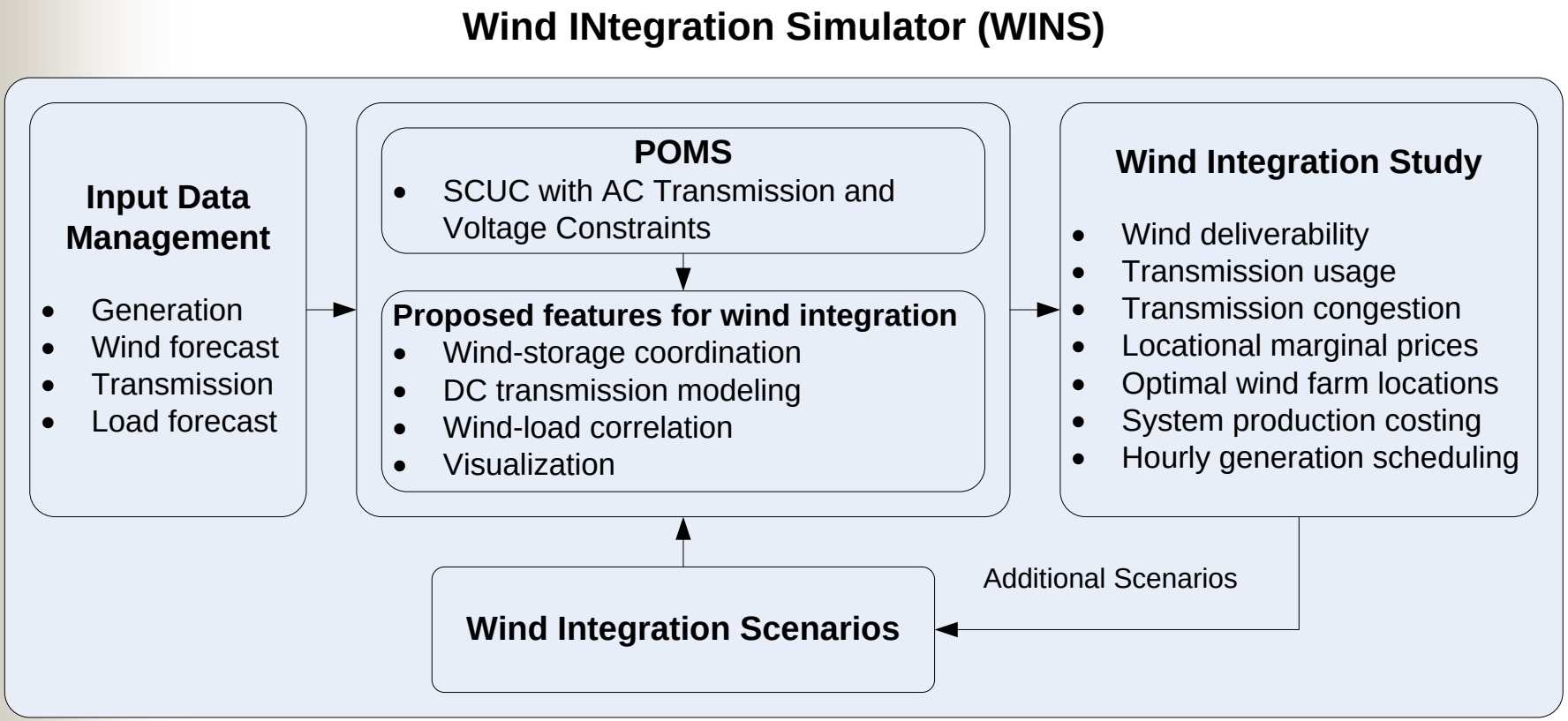
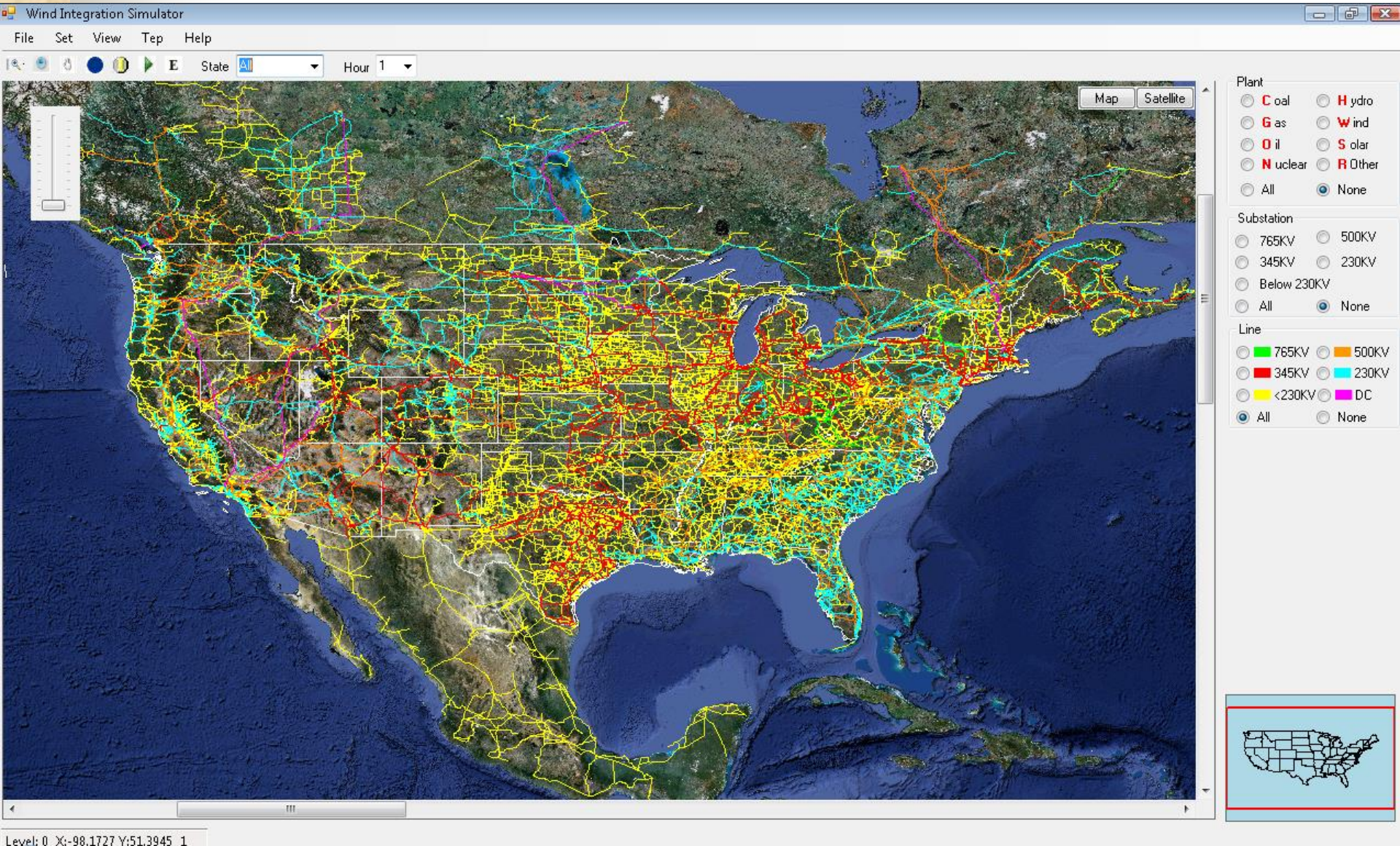
# Task 8.0 Advanced Wind Integration Study for Utility-Grade Operation

- This is a joint effort
  - Funded by U.S. department of Energy
  - IIT
    - Dr. Mohammad Shahidehpour, Dr. Zuyi Li
    - Graduate Students (Mr. Wei Tian, Mr. Kaveh Aflaki)
  - McCoy Energy
    - Mr. Paul McCoy
  - Wiedman Power System Consulting
    - Mr. Thomas Wiedman
  - Acciona Wind Energy USA
    - Mr. Frank Bristol
  - National Renewable Energy Laboratory
    - Mr. Erik Ela

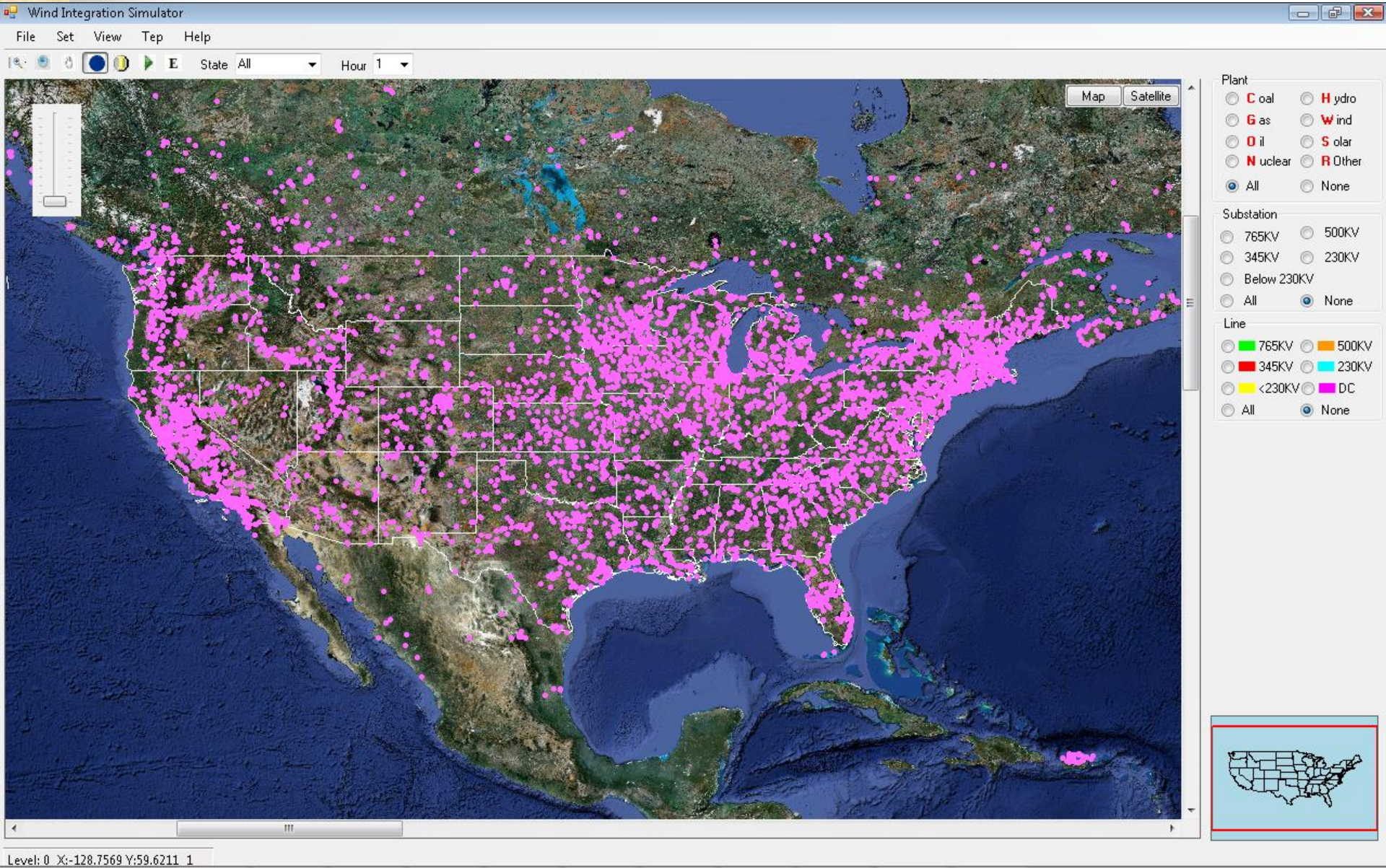
# Development of Wind Integration Tool - WINS



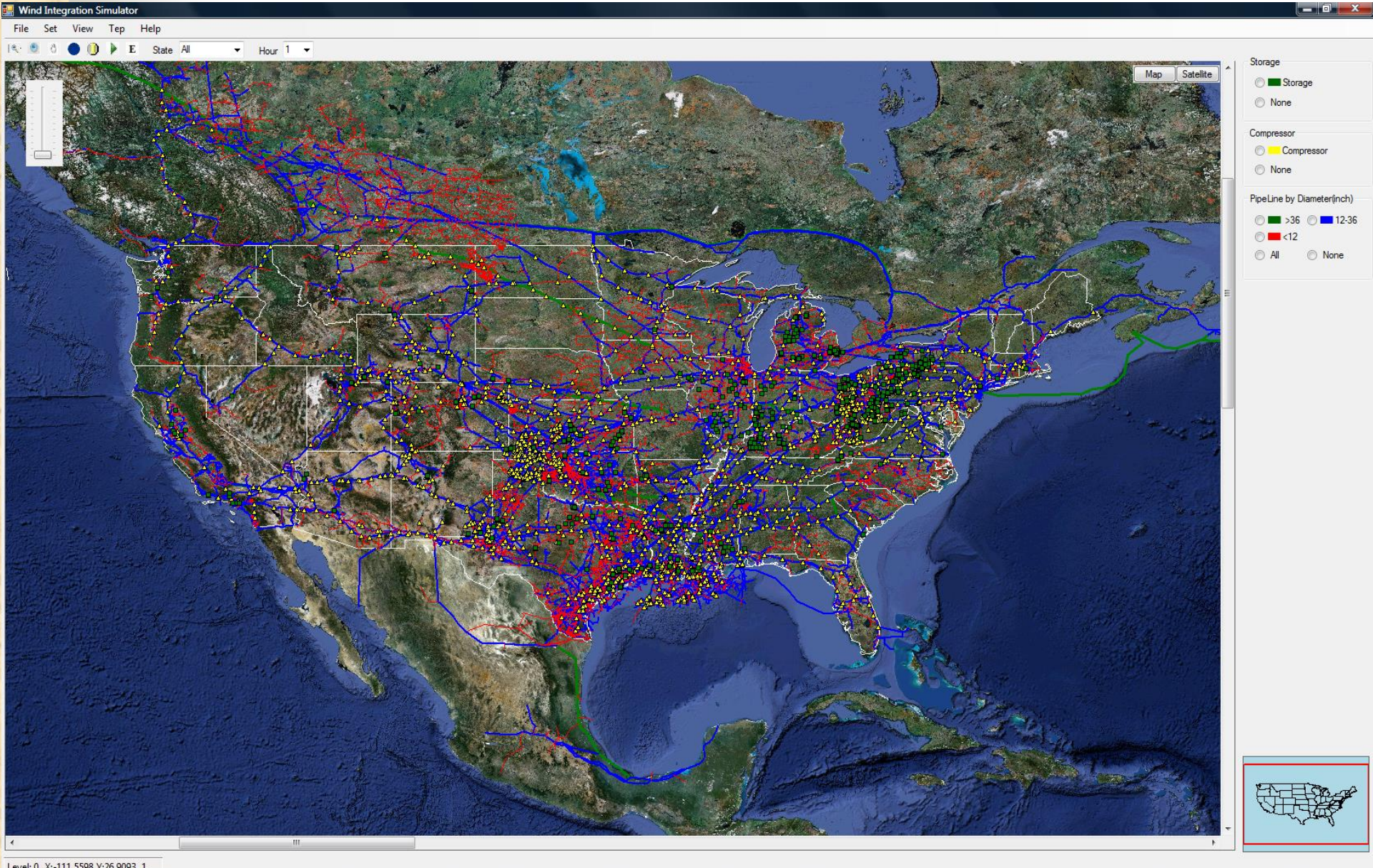
# Transmission System in the United States



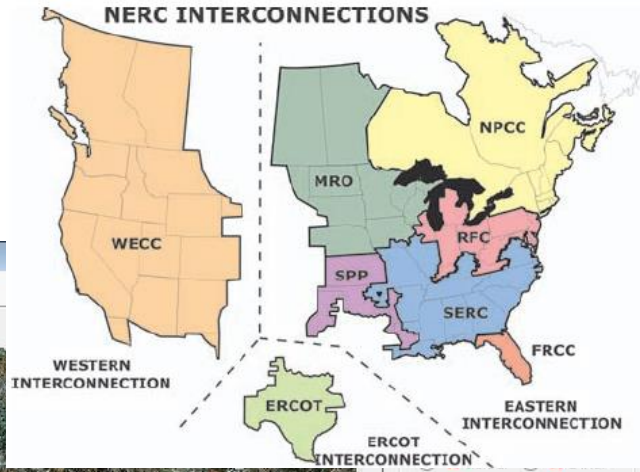
# Power Plants in the United States



# Natural Gas System in the United States



# Eastern Interconnection




Wind Integration Simulator

File Set View Tep Help

State All Hour 1

All None

Substation

765KV 500KV

345KV 230KV

Below 230KV

All None

Line

765KV 500KV

345KV 230KV

<230KV DC

All None

Values

Gen. Dispatches

Trans. Flows(MW)

Trans. Flows(MVAR)

Bus LMPs

Bus Voltages Magnitude

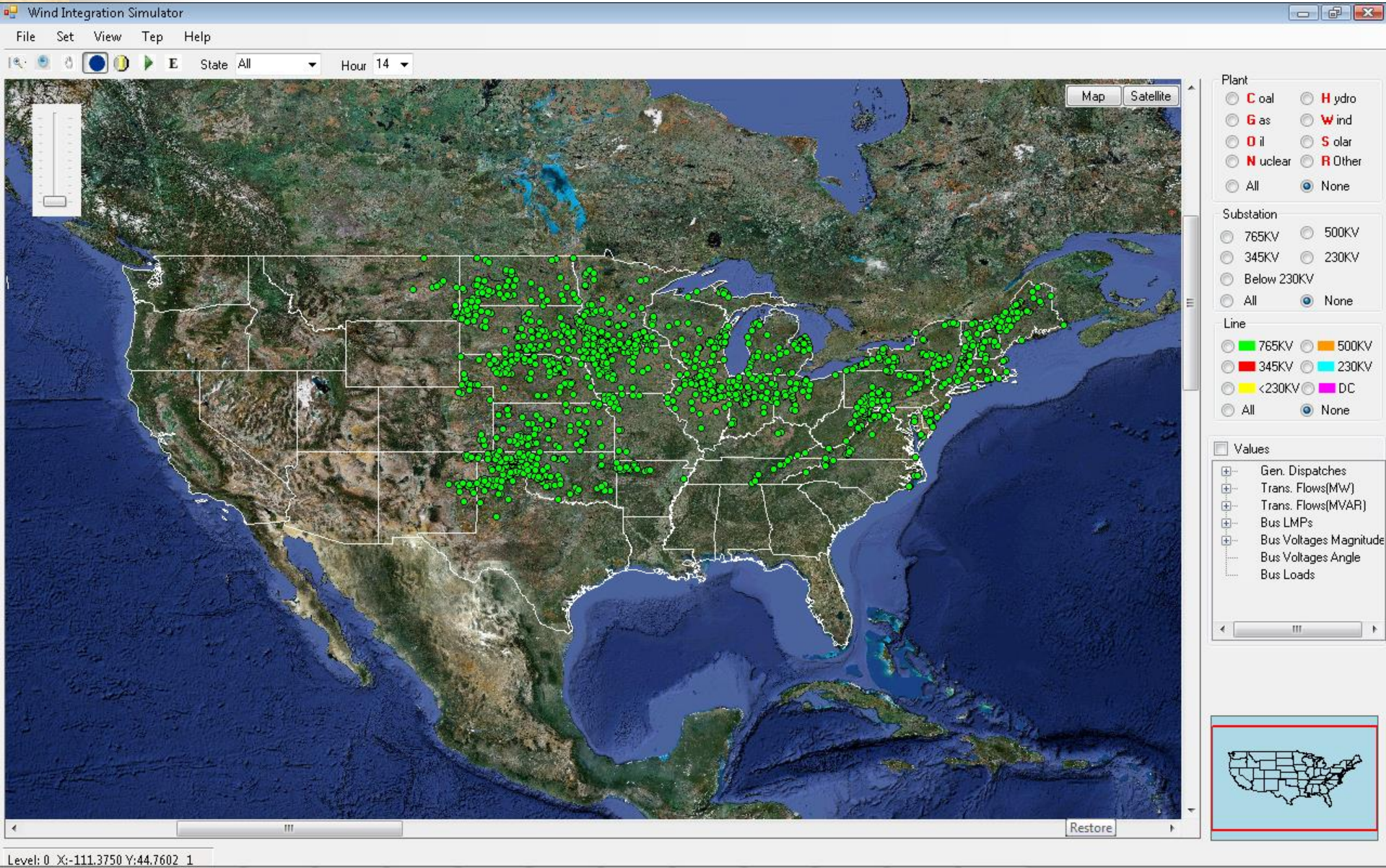
Bus Voltages Angle

Bus Loads

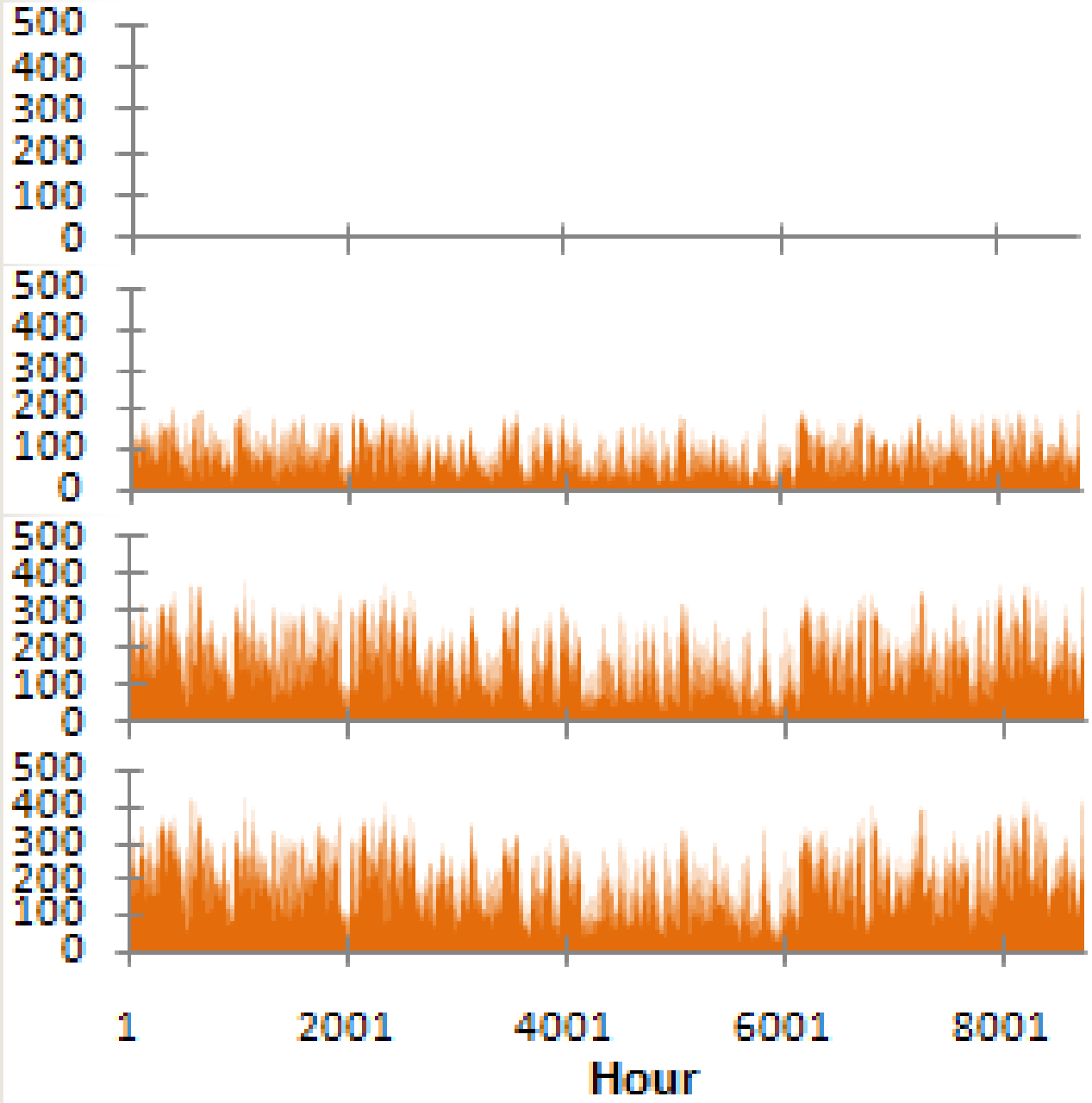
Restore

Level: 1 X:-96.4601 Y:24.8144 1

# Land-based Wind Sites (EI, 580GW)



# Wind Integration Scenarios



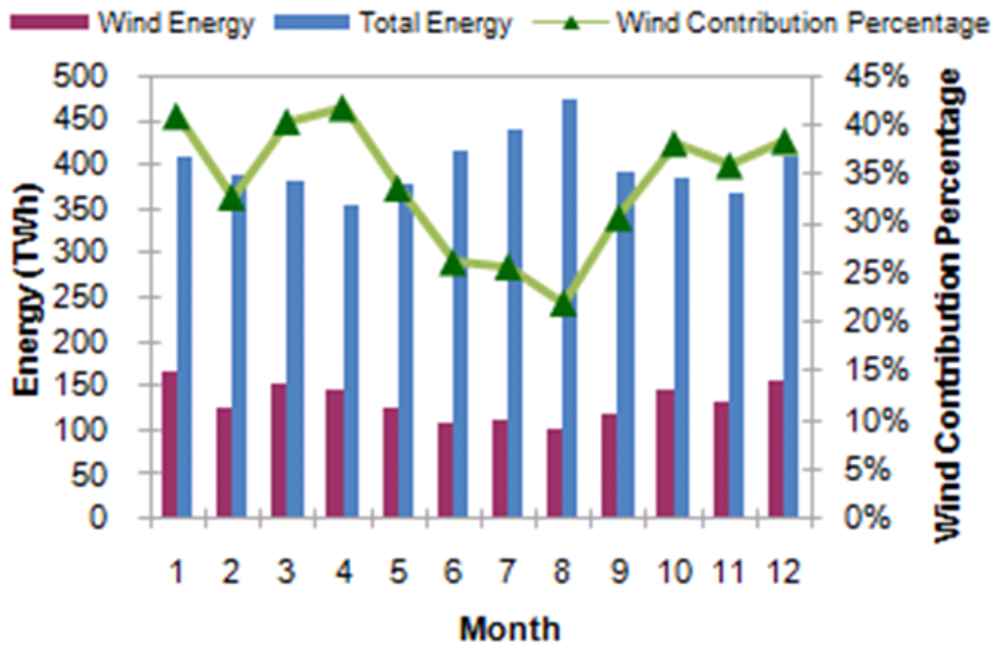

Scenario 1: No Wind

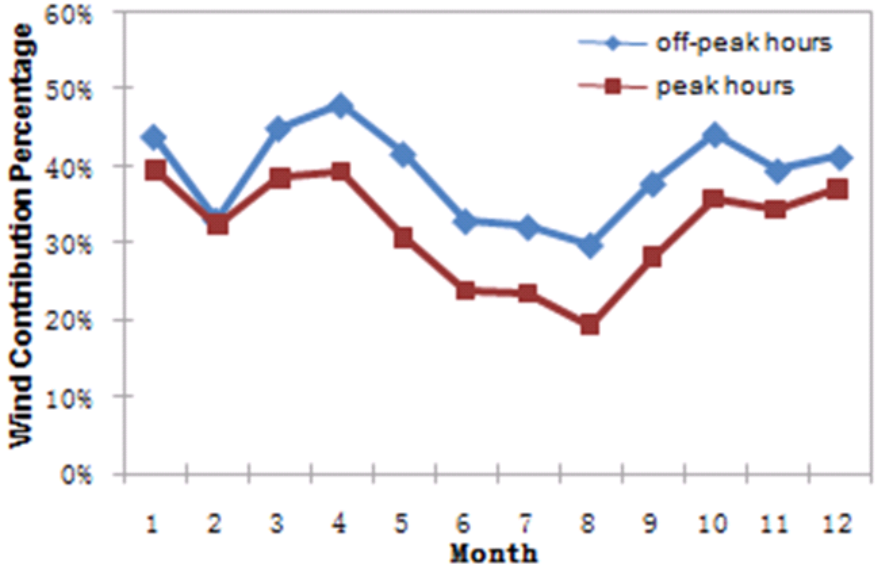
Scenario 2: Wind with Capacity Factor >= 40%

Scenario 3: Wind with Capacity Factor >= 30%

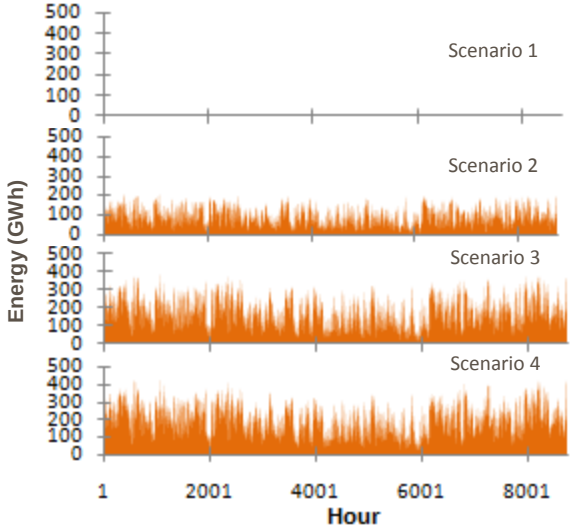
Scenario 4: All Candidate Wind Sites

# Wind Energy Contribution (Scenario 3)



# Wind Replacing Gas and Coal



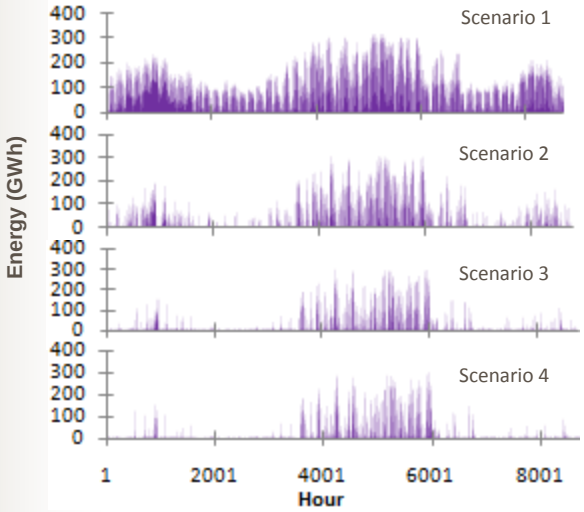

Hourly Wind Energy

Scenario 1: No Wind

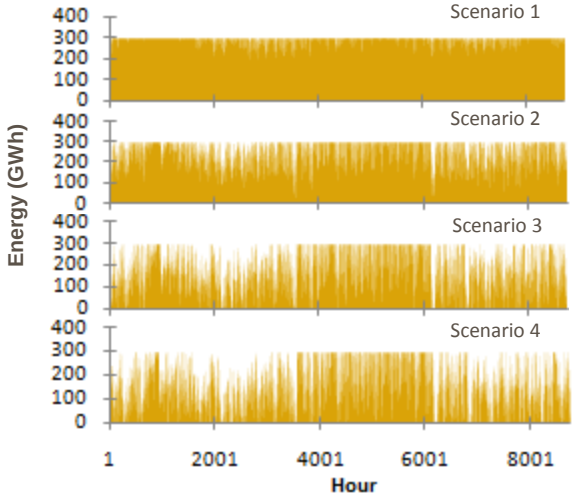
Scenario 2: Wind with Capacity Factor >= 40%

Scenario 3: Wind with Capacity Factor >= 30%

Scenario 4: All Candidate Wind Sites

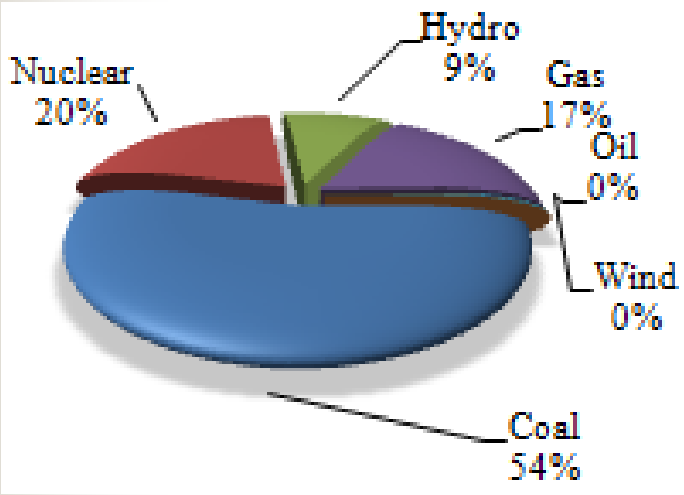



Energy Provided by Gas Units

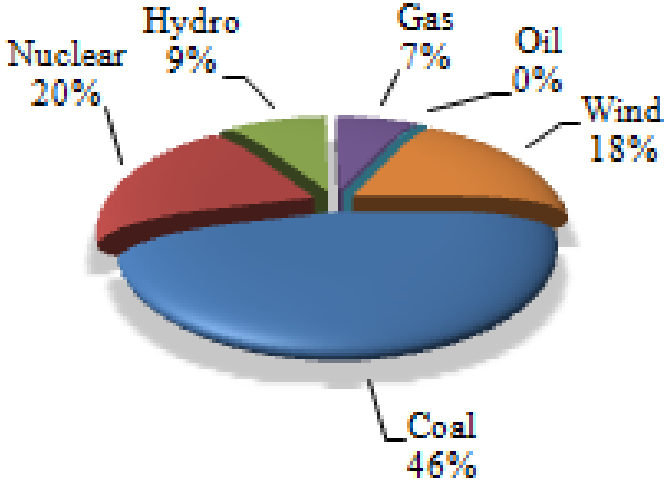



Energy Provided by Coal Units

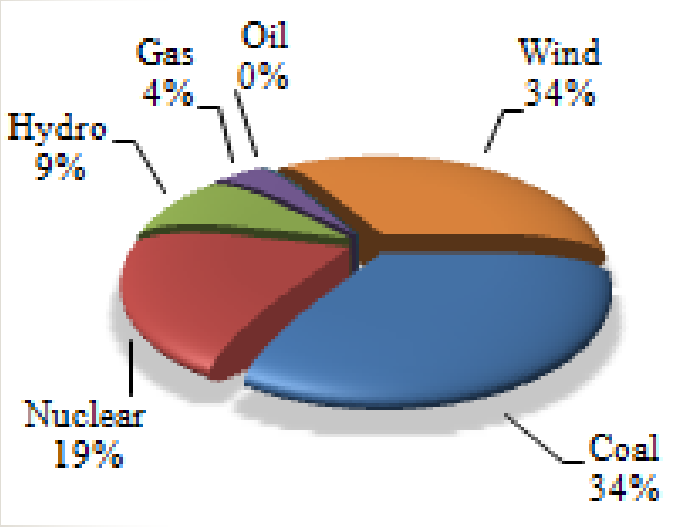
# Wind Replacing Gas and Coal



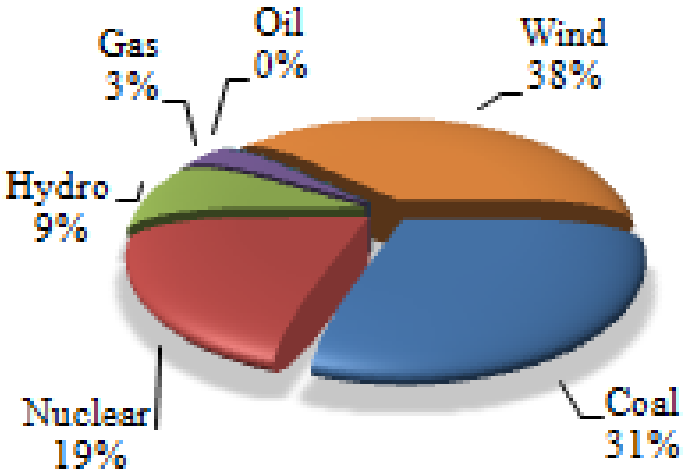

Scenario 1:No Wind




Scenario 2: Wind with Capacity Factor >= 40%

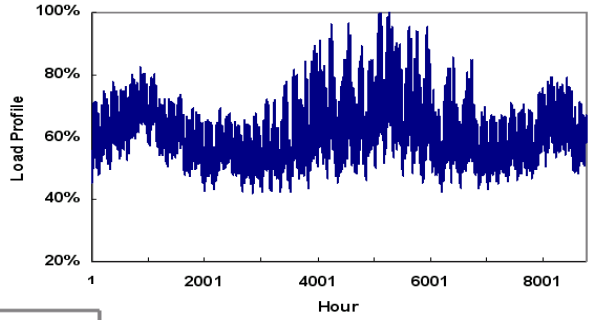


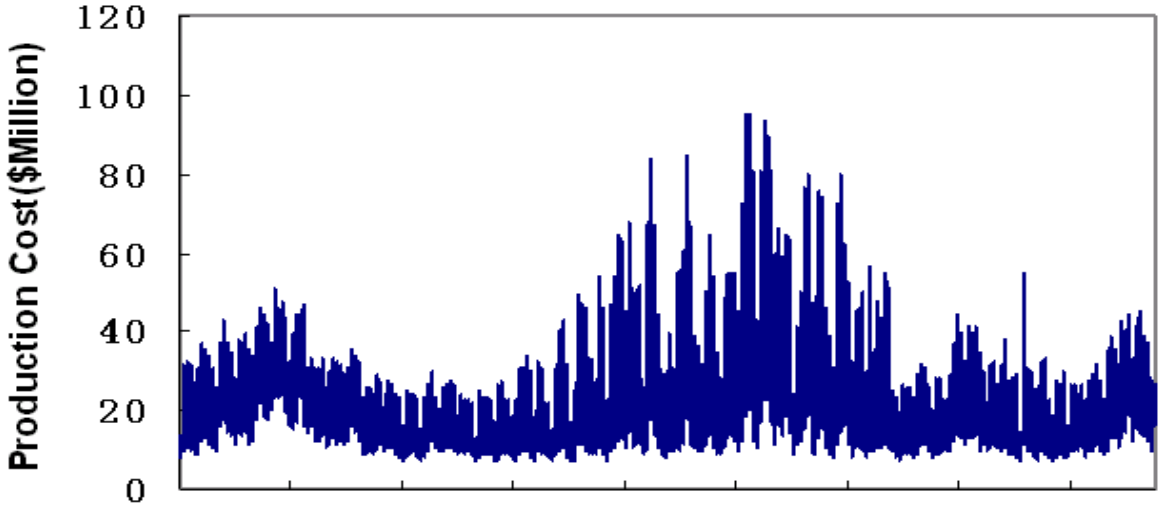

Scenario 3: Wind with Capacity Factor >= 30%



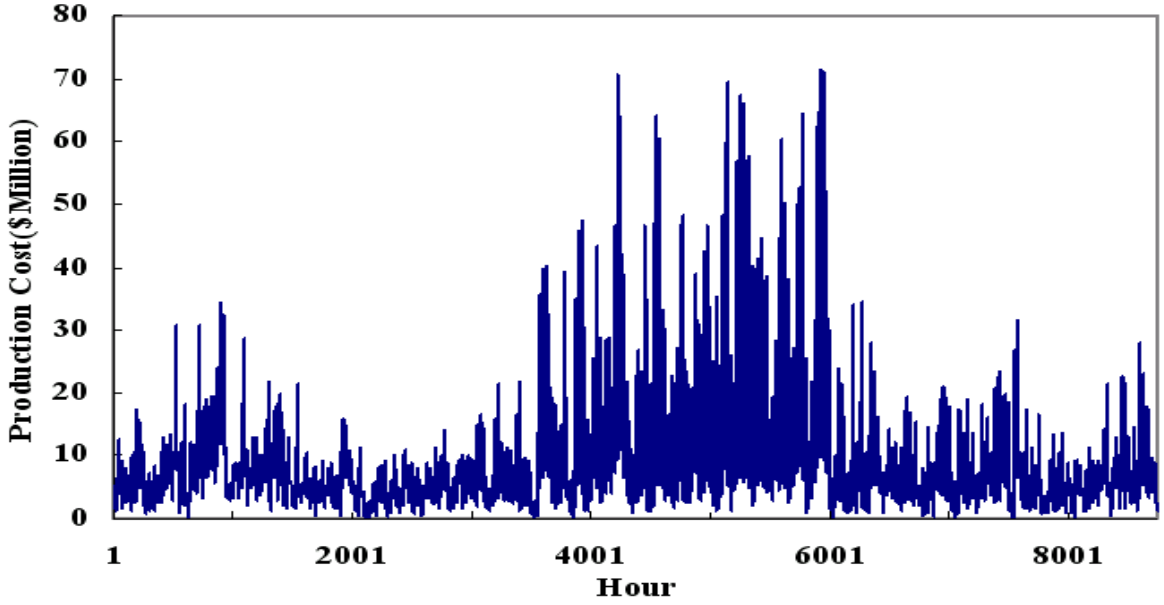

Scenario 4: All Candidate Wind Sites

# Production Cost



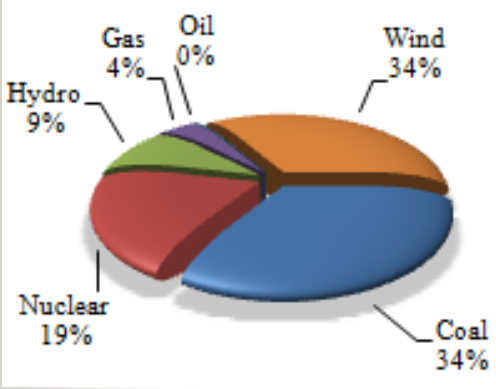




Scenario 1: No Wind

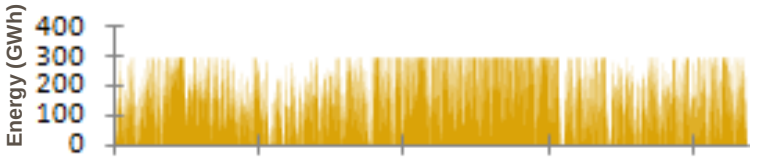


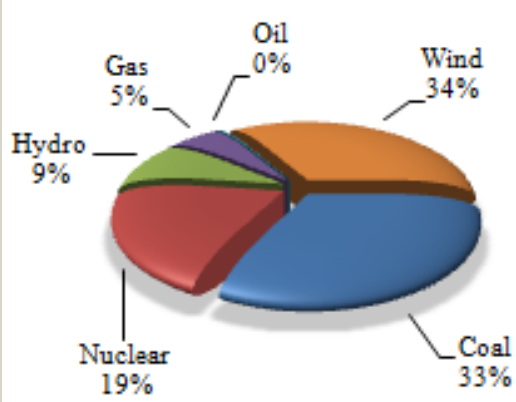

Scenario 3: Wind with Capacity Factor >= 30%

# Carbon Tax Sensitivity

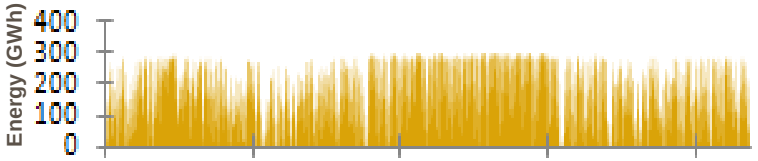


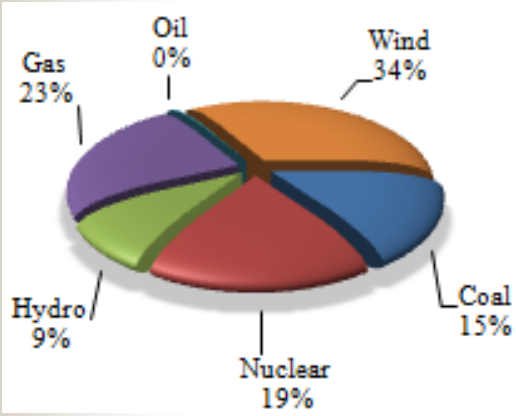

No Carbon Tax
with 30% CF Wind



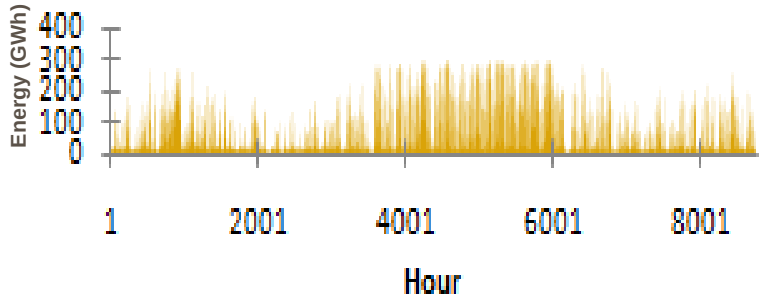




Low Carbon Tax with
30% CF Wind




High Carbon Tax
with 30% CF Wind



# Summary of All Scenarios

| Scenarios. | | Wind Capacity (GW) | Wind Energy (TWh) | Wind Energy Contribution (%) | Production Cost ($ Billion) | Average Production Cost ($/MWh) |
|---|---|---|---|---|---|---|
| No Wind | | 0 | 0 | 0 | 217.5 | 45.64 |
| $CF \geq 40\%$ | | 230.5 | 845.2 | 17.67 | 130.4 | 27.25 |
| $CF \geq 30\%$ | | 481.5 | 1,596 | **33.37** | 86.8 | 18.14 |
| All Wind | | 580 | 1,816 | **38.00** | 77.0 | 16.10 |
| Fuel Price Sensitivity | 20% Lower | 230.5 | 845.2 | 17.67 | 118.9 | 24.87 |
| | 10% Lower | | 845.2 | 17.67 | 124.7 | 26.06 |
| | 10% Higher | | 845.2 | 17.67 | 135.7 | 28.36 |
| | 20% Higher | | 845.2 | 17.67 | 141.7 | 29.63 |
| Wind Gen. Sensitivity | 20% Lower | | 676.1 | 14.14 | 143.7 | 30.03 |
| | 10% Lower | | 760.6 | 15.9 | 136.8 | 28.59 |
| | 10% Higher | | 929.7 | 19.44 | 130.4 | 25.99 |
| | 20% Higher | | 1014 | **21.20** | 124.3 | 24.80 |
| Load Sensitivity | 20% Lower | | 845.2 | **22.07** | 64.0 | 16.73 |
| | 10% Lower | | 845.2 | 19.62 | 91.6 | 21.27 |
| | 10% Higher | | 845.2 | 16.29 | 178.5 | 34.65 |
| | 20% Higher | | 845.2 | 15.12 | 245.9 | 44.54 |
| Carbon Cost Sensitivity | Low Carbon Cost with 40% Wind | 230.5 | 845.2 | 17.67 | 406.8 | 84.97 |
| | High Carbon Cost with 40% Wind | 230.5 | 845.2 | 17.67 | 638.0 | 133.3 |
| | Low Carbon Cost with 30% Wind | 481.5 | 1,596 | 17.67 | 285.7 | 69.68 |
| | High Carbon Cost with 30% Wind | 481.5 | 1,596 | 17.67 | 448.0 | 93.59 |
| Load Management | No Wind Energy with Load Shedding | 0 | 0 | 0 | 208.7 | 44.00 |
| | Min 40% CF Wind with Load Shedding | 230.5 | 845.2 | 17.81 | 123.0 | 25.90 |
| | Min 30% CF Wind with Load Shedding | 481.5 | 1,596 | **33.53** | 80.6 | 16.97 |

# Locational Marginal Price (EI)