Properties of Energy CI/KR Sector

- **Energy vs. Power:** *Energy* is the ability to do work; *Power* is the rate of doing work
  - *Power* is measured in units like KW (kilowatts) and horsepower (ft-lb/second)
  - *Energy* is measured in units like KWh (kilowatt-hour)
  - Mathematical relationship: Energy = Power x Time

- The *energy sector* is concerned with *extraction and delivery of fuels* to power plants

- The *power sector* is more concerned with *producing power* from power plants and delivering it to consumers.
Energy CIKR contains several supply chains:

- **Coal supply chain**: This critical supply chain is dependent on rail or delivery to power plants
  - US leads the world in coal reserves
  - Powder River Basin is the largest source of coal in the US and delivery depends on rail
  - US is dependent on coal, but environmental regulations reduce the availability of coal
  - Coal is a declining source of energy for the US, but not China
Properties of Energy CI/KR Sector (Cont.)

- Gas and oil supply chains: Most US energy comes from oil and natural gas (NG) supply chain networks
  - Vulnerable to disruptions to their transmission pipelines that form supply chains
  - Supply chains are from Canada, the Gulf of Mexico and foreign sources
Properties of Energy CI/KR Sector (Cont.)

- **Competitive exclusion principle:**
  - Ownership of gas and oil refineries and pipelines is highly concentrated
  - Refineries densely clustered,
  - Limited transmission links
  - Concentration of storage terminals portray energy supply chain networks
  - Robustness is limited because few assets are redundant
U.S. Energy Sector

Figure 12-1 in Text
Energy density is defined as the amount of energy stored in a given system or region of space per unit volume of mass, though the latter is more accurately termed specific energy. Often only the useful or extractable energy is measured, which is to say that chemically inaccessible energy such as rest mass energy is ignored. (Source: Wikipedia)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Density (KWh/gal)</th>
<th>CO2 Emission (Lb./Million BTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li-ion battery</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Natural gas</td>
<td>27</td>
<td>117</td>
</tr>
<tr>
<td>Gasoline</td>
<td>38</td>
<td>157</td>
</tr>
<tr>
<td>Coal</td>
<td>76</td>
<td>216</td>
</tr>
<tr>
<td>U-235</td>
<td>1,500,000,000</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 12-1 in Text
Demand for Energy

Energy use by fuel: 1980-2035

- History
- Projections

- Renewables
- Biofuels
- Liquids
- Natural gas
- Nuclear
- Coal

Year

Quadrillion BTU

1980 2008 2020

Figure 12.2 in Text
Evolution of Regulation

- **Regulation of sale and transportation**: Federal Power Act of 1935 and the Natural Gas Act of 1938
- **Regulation of natural gas facilities**: 1940 amendments to Natural Gas Act and 1954 *Phillips Petroleum v. Wis.*
- **Interstate commerce**: In 1967, intrastate utilities are jurisdictional if linked to supply lines to others outside of the state
- **FPC becomes FERC**: 1977 FPC reorganizes to FERC
- **Unified Interstate commerce**: 1978 National Energy Act (NEA) unifies intra/inter-state gas markets
- **Deregulation**: 1985 FERC Order 436 and 1992 FERC Order 636 opens pipelines to competitors and introduces price controls.
Electric Sector ISAC (ES-ISAC)

- Provide threat and warning information within the electric energy sector
- The ES-ISAC provides its members:
  - Information on threats and vulnerabilities
  - How to respond to threats
  - A forum to communicate best practices in a secure environment
Vast Coal Reserves Exist in the Powder River Basin of Wyoming

Figure 12.3 in Text
Petroleum Administration for Defense Districts (PADD)
Major Components of Gas and Oil Supply Chains

![Diagram of gas and oil supply chains](image)

Figure 12.4 in Text
Pipeline sequencing

Transmix

Premium Gasoline, Diesel Fuel, Regular Gasoline

Figure 12.6 in Text
Gulf of Mexico Oil Pipeline Network

Figure 12.7a in Text
Gulf of Mexico Oil Pipeline Network

- Louisiana Offshore Oil Port (LOOP)
  - America's first and only deep-water port.
  - Provides tanker offloading and temporary storage services for crude oil transported on some of the largest tankers in the world.
  - Most tankers offloading at LOOP are too large for U.S. inland ports

Source: Louisiana Department of Transportation and Development
Colonial Pipeline Network

Figure 12.7b in Text
Figure 12.8 in Text
Oil Pipeline Hazards

Oil Pipeline Hazards: 2002-2012

- Equipment: 35%
- Corrosion: 25%
- Miscellaneous: 15%
- Human Error: 10%
- Excavation: 8%
- Outside forces: 6%
- Nature: 3%

Figure 12.9a in Text
Gas Pipeline Hazards

Gas Pipeline Hazards: 2002-2009

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Frequency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion</td>
<td>20%</td>
</tr>
<tr>
<td>Age</td>
<td>18%</td>
</tr>
<tr>
<td>Operation</td>
<td>15%</td>
</tr>
<tr>
<td>Nature</td>
<td>12%</td>
</tr>
<tr>
<td>Excavation</td>
<td>12%</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>11%</td>
</tr>
<tr>
<td>Human Error</td>
<td>10%</td>
</tr>
</tbody>
</table>

Figure 12.9b in Text
Storage Hazards

Storage Hazards: 1963-2002

- Lightning/Static: 40%
- Operation/Reaction: 30%
- Leaks/Ruptures: 20%
- Equipment: 10%
- Sabotage: 10%
- Open Flame: 5%
- Nature: 5%

Figure 12.10 in Text
Energy Sector Fault Tree

Figure 12.12 in Text
Energy Sector Fault Tree (Cont.)

Energy General Fault Tree: Risk, Vulnerability vs. Investment

Figure 12.11 in Text
Largest Refineries

<table>
<thead>
<tr>
<th>Rank#</th>
<th>Corporation</th>
<th>Refiner</th>
<th>Location</th>
<th>#Barrels/day</th>
<th>Market %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EXXON MOBIL</td>
<td>ExxonMobil</td>
<td>Baytown, TX</td>
<td>523,000</td>
<td>11.0%</td>
</tr>
<tr>
<td>2</td>
<td>EXXON MOBIL</td>
<td>ExxonMobil</td>
<td>Baton Rouge, LA</td>
<td>491,500</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>Texas City, TX</td>
<td>437,000</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>Beaumont, TX</td>
<td>348,500</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td>Lake Charles, LA</td>
<td>324,300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BP PLC</td>
<td>BP Products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ExxonMobil</td>
<td>ExxonMobil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Citgo Petroleum</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 12.2 in Text
Energy Fault Tree Values

<table>
<thead>
<tr>
<th>Name</th>
<th>Threat (%)</th>
<th>Vulnerability (%)</th>
<th>Elimination Cost (millions)</th>
<th>Consequence (millions)</th>
<th>Risk Initial</th>
<th>Allocation (millions)</th>
<th>Vulnerability Reduced (%)</th>
<th>Risk Reduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightning</td>
<td>100.00</td>
<td>38.00</td>
<td>100.00</td>
<td>2000.00</td>
<td>760.00</td>
<td>53.23</td>
<td>5.48</td>
<td>109.63</td>
</tr>
<tr>
<td>Operation</td>
<td>100.00</td>
<td>27.00</td>
<td>150.00</td>
<td>2000.00</td>
<td>540.00</td>
<td>50.46</td>
<td>8.91</td>
<td>178.18</td>
</tr>
<tr>
<td>Leaks</td>
<td>100.00</td>
<td>13.00</td>
<td>1000.00</td>
<td>2000.00</td>
<td>260.00</td>
<td>0.00</td>
<td>13.00</td>
<td>260.00</td>
</tr>
<tr>
<td>Equipment</td>
<td>100.00</td>
<td>31.90</td>
<td>200.00</td>
<td>2000.00</td>
<td>638.00</td>
<td>61.04</td>
<td>11.09</td>
<td>221.74</td>
</tr>
<tr>
<td>Corrosion</td>
<td>100.00</td>
<td>25.00</td>
<td>250.00</td>
<td>2000.00</td>
<td>500.00</td>
<td>40.78</td>
<td>14.79</td>
<td>295.76</td>
</tr>
<tr>
<td>Equipment</td>
<td>100.00</td>
<td>25.00</td>
<td>300.00</td>
<td>2000.00</td>
<td>500.00</td>
<td>28.19</td>
<td>18.47</td>
<td>369.49</td>
</tr>
<tr>
<td>Human Error</td>
<td>100.00</td>
<td>24.00</td>
<td>50.00</td>
<td>2000.00</td>
<td>480.00</td>
<td>32.20</td>
<td>3.10</td>
<td>62.02</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>100.00</td>
<td>22.00</td>
<td>400.00</td>
<td>2000.00</td>
<td>440.00</td>
<td>0.00</td>
<td>22.00</td>
<td>440.00</td>
</tr>
<tr>
<td>Age</td>
<td>100.00</td>
<td>18.30</td>
<td>100.00</td>
<td>2000.00</td>
<td>366.00</td>
<td>34.10</td>
<td>6.79</td>
<td>135.84</td>
</tr>
</tbody>
</table>

Table 12.3 in Text
Core of the Gulf of Mexico Oil Network

Figure 12.13 in Text
## Largest NG Supply Chain Networks

<table>
<thead>
<tr>
<th>Rank</th>
<th>Name</th>
<th>Owner</th>
<th>Capacity -MMbbl/day</th>
<th>Length -miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transcontinental</td>
<td>Williams</td>
<td>7,362</td>
<td>10,636</td>
</tr>
<tr>
<td>2</td>
<td>Columbia</td>
<td>NiSource</td>
<td>7,276</td>
<td>11,215</td>
</tr>
<tr>
<td>3</td>
<td>Tennessee</td>
<td>El Paso</td>
<td>7,271</td>
<td>14,761</td>
</tr>
<tr>
<td>4</td>
<td>ANR</td>
<td>El Paso</td>
<td>6,667</td>
<td>10,600</td>
</tr>
<tr>
<td>5</td>
<td>Texas Eastern</td>
<td>Duke</td>
<td>6,438</td>
<td>12,118</td>
</tr>
<tr>
<td>6</td>
<td>Dominion</td>
<td>Dominion</td>
<td>6,275</td>
<td>10,000</td>
</tr>
<tr>
<td>7</td>
<td>El Paso</td>
<td></td>
<td>4,882</td>
<td>10,200</td>
</tr>
</tbody>
</table>

Table 12.4 in Text
Transportation Security Administration (TSA)

- Surface Division, Pipeline Security Branch, Office of Security Policy & Industry Engagement (OSPIE)
- Mission - Enhance the security preparedness of the nation's hazardous liquid and natural gas pipeline systems
- Objectives:
  - Reduce the level of risk through analysis and implementation of security programs
  - Increase the level of resiliency and robustness
  - Increase the level of domain awareness, information sharing, response planning and coordination

Pipeline and Hazardous Material Safety Administration (DOT)
Pipeline and Hazardous Materials Safety Administration (PHMSA), USDOT

- Mission - Protect people and the environment from the risks of hazmat transportation
- Establish national policy, set/enforce standards, educate and conduct research to avoid incidents.
- Prepare the public and first responders to reduce consequences if an incident does occur
- 2016 goals are:
  - Reduce the number of pipeline incidents involving death or major injury
  - Reduce the number of hazardous materials incidents involving death or major injury
Pipeline Safety and Security Initiatives

- **TSA**
  - Pipeline Corporate Security Review Program
  - International Pipeline Security Forum
  - Pipeline security stakeholder conference calls
  - Critical Facility Security Review Program

- **PHMSA**
  - National Pipeline Mapping System
  - PHMSA preparedness and response
  - Pipeline Safety Technical Advisory Committees
  - Pipeline Safety Research and Development

- MOU Annex between TSA and PHMSA on pipeline and hazmat
Identification of CI/KR and Risk Assessments
Strategic planning
Standards, regulations, guidelines and directives
Inspections and enforcement
PHMSA Technical Support (i.e. Argonne Labs)
Sharing information during an emergency response
Public communication, education and outreach
Communicating protective measures to affected organizations
Research and development
Legislative matters and budgets
Summary

- Coal is concentrated in just a few geographical areas in the US and distributed via rail
  - Regulation is the biggest threat to this asset and will limit its future use in power generation

- Gas and oil depend on supply chains that run from wells in the Gulf of Mexico and ND, and foreign wells in Canada and Saudi Arabia
  - The oil and natural gas networks are characterized by geographical clustering of refineries, (single-point of failure) pipelines and large-capacity and concentrated storage terminals. These are attractive targets because they are important
Oil and NG supply chains are regulated and are also undergoing radical transformation due to deregulation and environmental regulation.

They are subject to the **competitive exclusion principle**, which means the *entire nation depends on only a few hub carriers* to carry most of the supply.

- The uniqueness of these common carriers translates into high-consequence targets
- There is no choice but to protect these assets, because building redundancy is not economical
- Oil and NG supply chains will continue to be highly structured, low link redundant, high-risk networks
Energy supply chains are not likely to be enhanced in any significant way for decades.