



25th anniversary
annual INCOSE
international symposium
Seattle, WA
July 13 - 16, 2015



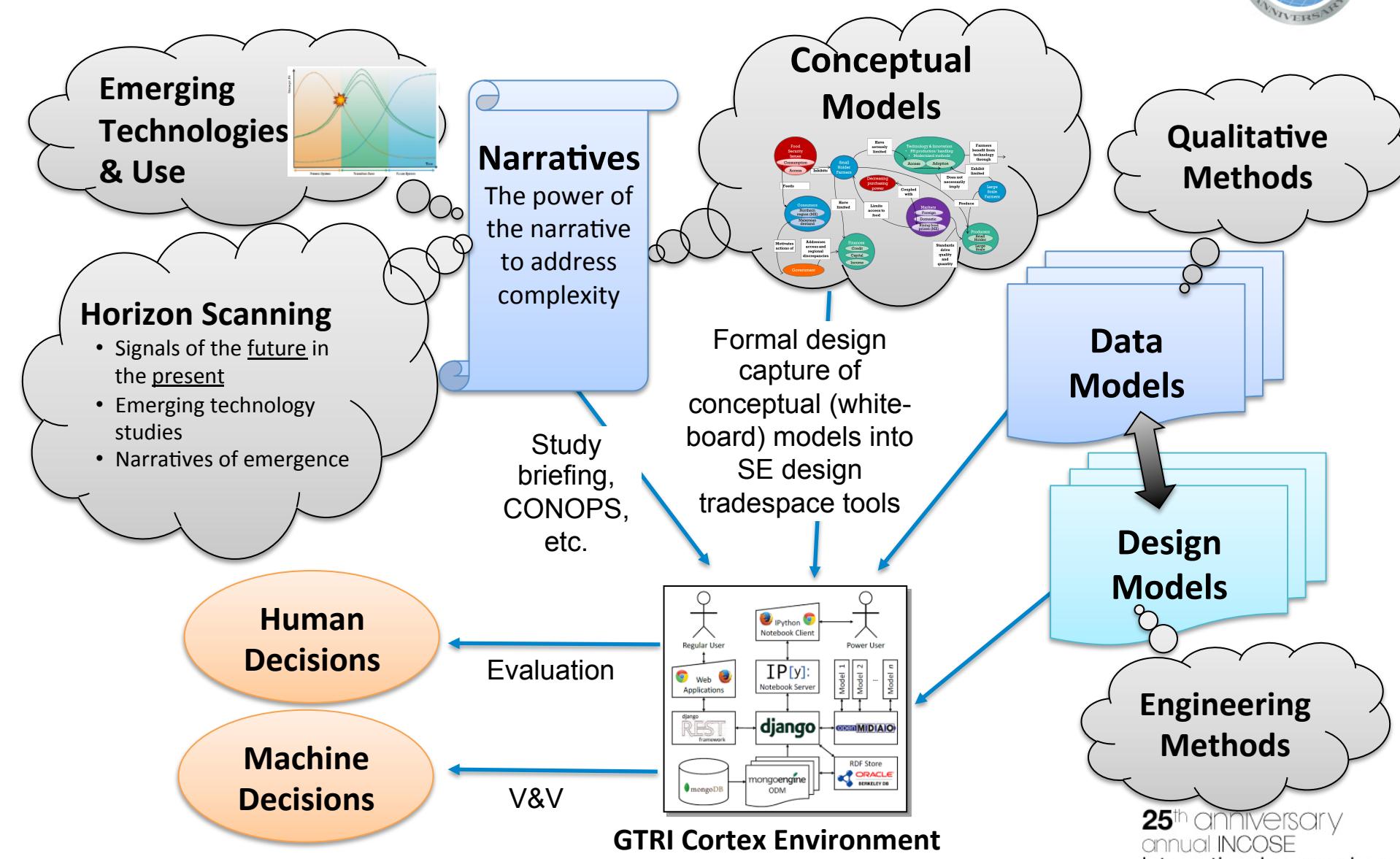
Use of Systemigrams to Identify Emergence in Complex Adaptive Systems

Tom McDermott, Molly Nadolski, Lindsey Sheppard
Georgia Tech Research Institute, Atlanta, GA

Overview

- Increased need for Sociotechnical Modeling Frameworks
 - Expanding socioeconomic and sociotechnical complexity
 - Discussed: need to model regional political and technical shifts in emerging natural gas markets
- Increased need to combine Strategic Foresight and Systems Engineering
 - Useful life of predictive trend data becoming ever shorter
 - Discussed: U.S. transformations in natural gas are driving regional changes in the industry and across global energy markets, well beyond impact of technology and U.S. production shifts
- Increased need for Qualitative Analysis toolsets

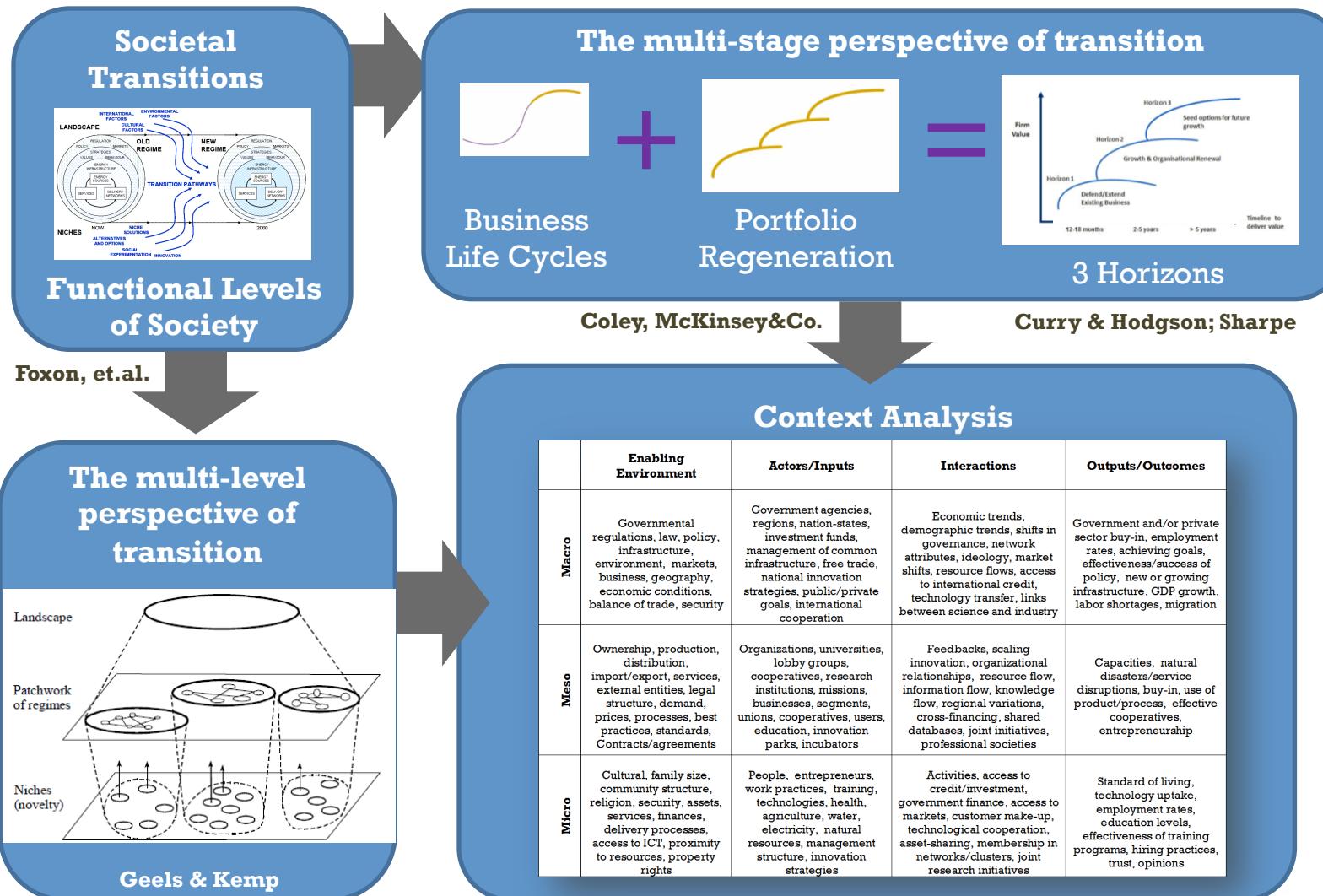
One Future of Systems Engineering



GTRI Cortex Environment

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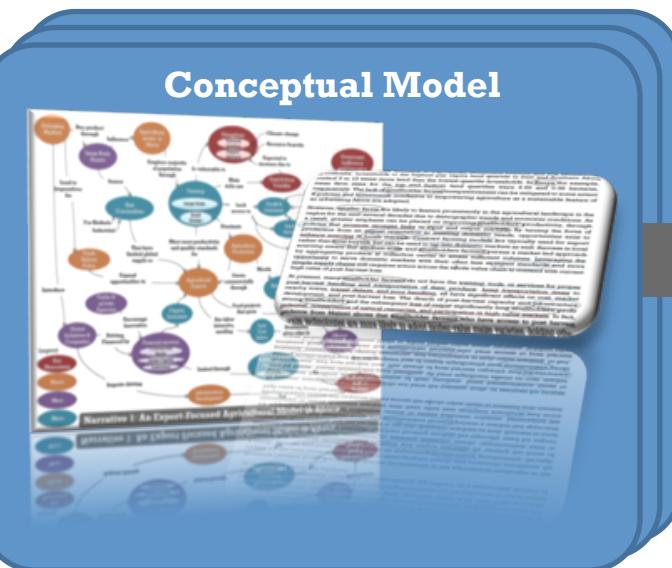
Methodology 1: Strategic Foresight



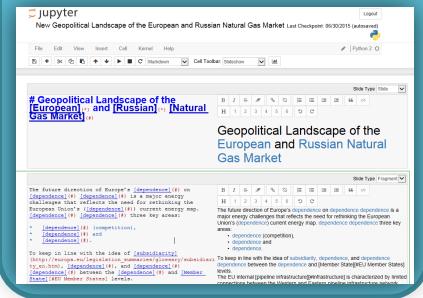
Methodology 2: Multi-Level Models



Context Analysis



Interactive Reports



Enterprise Systems Analysis
Technical Report SERC 2015 TR 020-4

January 14, 2015

Dr. Michael J. Pennock, Stevens Institute of Technology
Dr. William B. Rouse, Stevens Institute of Technology
Dr. Doug Bodner, Georgia Institute of Technology
Dr. Christopher Gaffney, Stevens Institute of Technology
Mehrnoush Oghabie, Stevens Institute of Technology
Pallavi Prasad, Georgia Institute of Technology



Engineered Resilient Systems: Tradespace Tools Research

Technical Report SERC-2015-TR-020-5

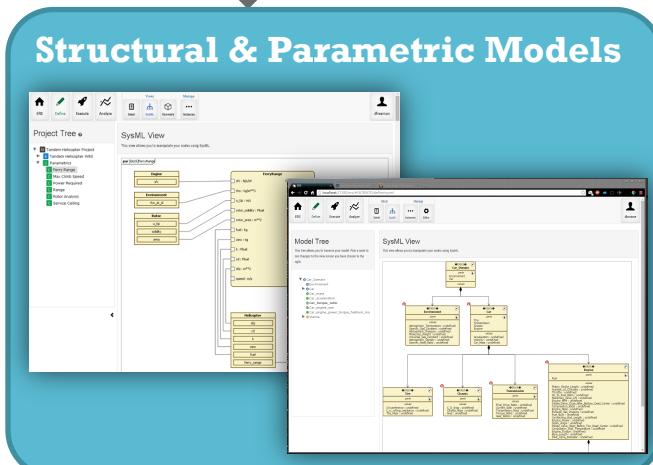
June 1, 2015

Principal Investigator: Dr. Tommer R. Ender, Georgia Tech Research Institute

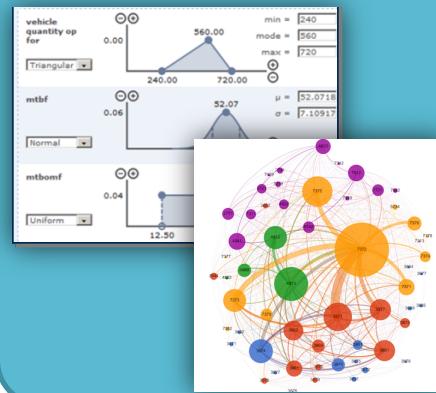
Research Team:	
Bryan Ake	Dr. Santiago Balestrini-Robinson (<i>author</i>)
Daniel Browne (<i>author</i>)	Dr. William Marshall
Dr. Dane Freeman (<i>author</i>)	Devraj Mehta
L. Drew Pipher	Dr. Valerie Sitterle (<i>author</i>)

Sponsor: Engineer Research and Development Center, U.S. Army Corps of Engineers

Boardman & Sausser



Tradespace Visualization



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Research Project



“Geopolitical Implications of the ‘Golden Age of Gas’: A Framework for Modeling & Assessing Alternative Futures”

Narratives

5 regional futures:

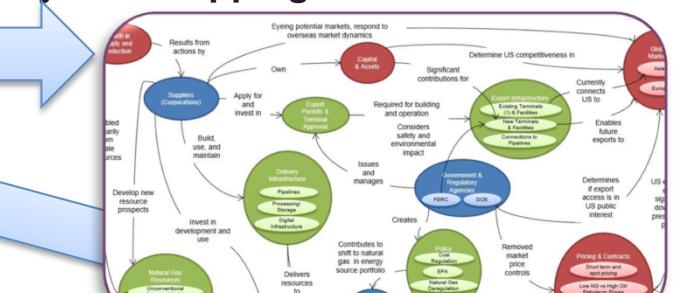
- USA
- EU & Russia
- Mid-East/East Med
- Central/East Asia
- China



- Expert workshop facilitation
- Public shaping: Sam Nunn Policy Forum
- Continued methodology workshops

Expert Meetings

System Mapping & Multi-Level Models



Stakeholders:

- Policy-Makers (Defense, Security)
- Decision-Makers, Private Sector (Energy, etc.)

Educational Module

Learning Objectives:

- regional challenges in the global marketplace
- short, medium, and long term competitive strategy
- skills for collaboration

Computational Model & Visualizations of Flows & Physical Interconnections:

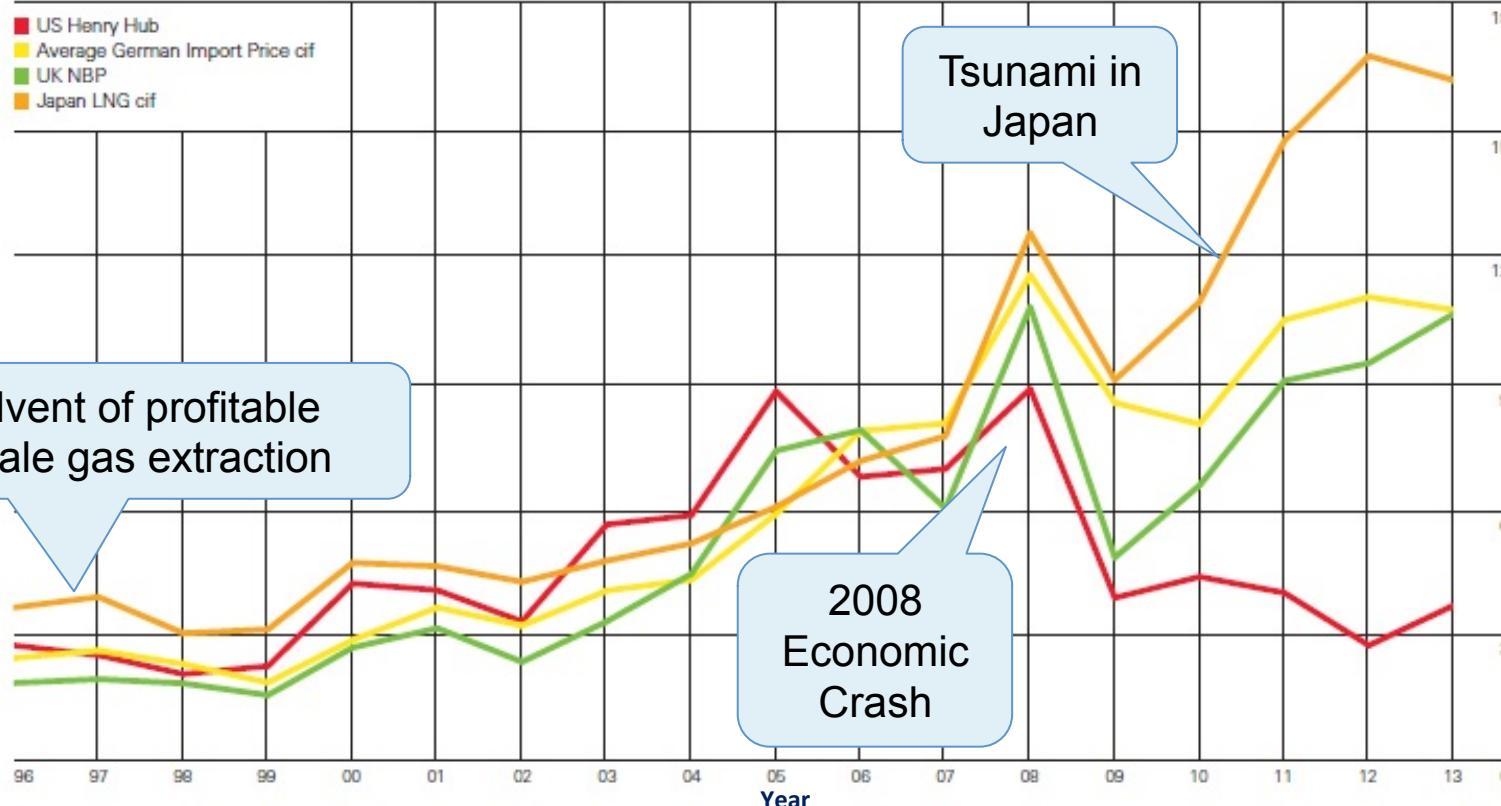
- Resilient/Diversified Distribution/Infrastructure
- Better Economic Models
- Power in Social Networks

Conceptual Models

International Natural Gas Prices



Prices
\$/Mmbtu



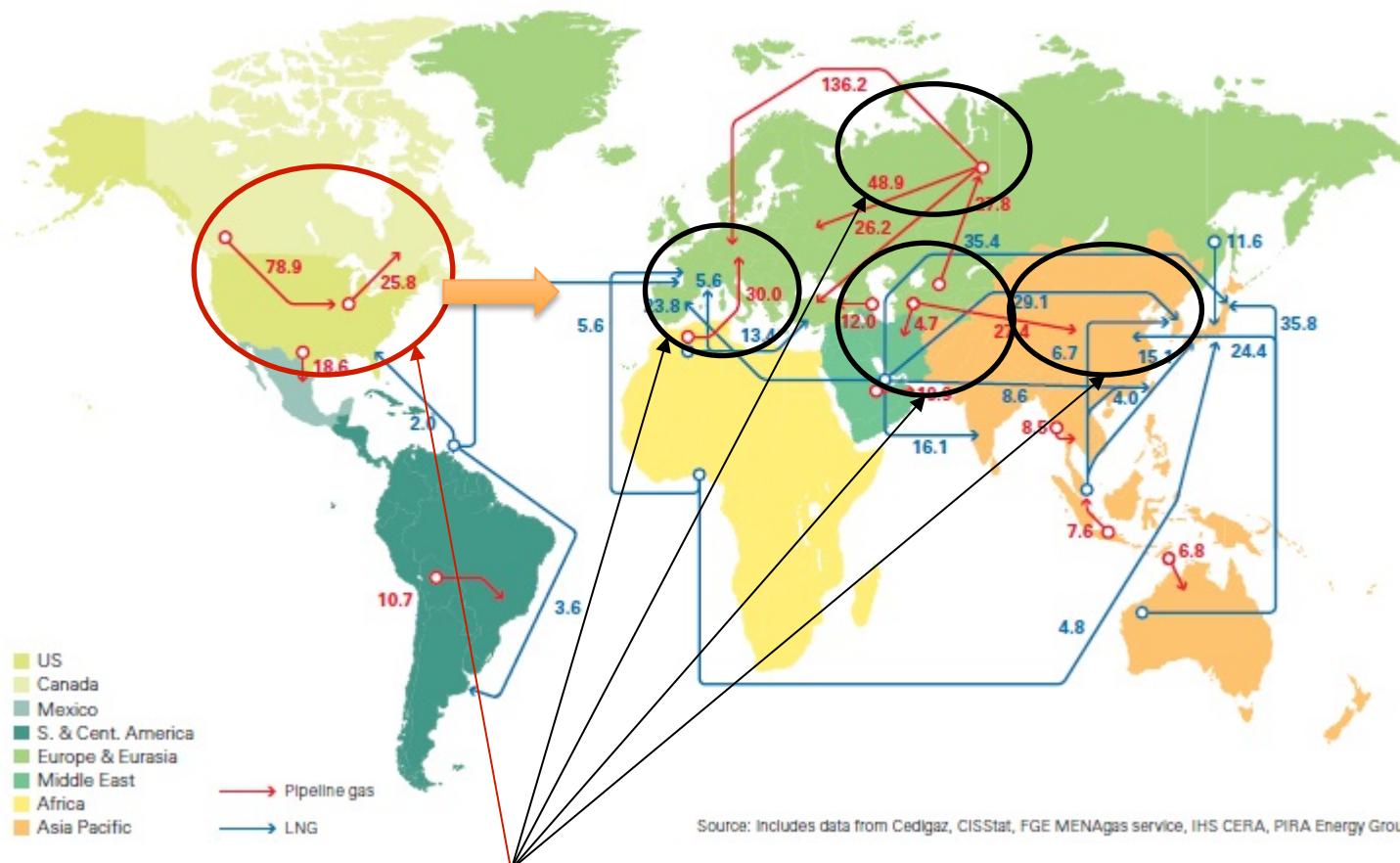
Source: BP Statistical Review of World Energy, June 2014.

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Geopolitics & the “Golden Age of Gas”



Major trade movements 2013
Trade flows worldwide (billion cubic metres)



- Five geopolitical regions have strongly differentiated “forces” driving regional oil & gas enterprises

Gas Network Transformation



Developing Phase:

Limited infrastructure and less developed institutions

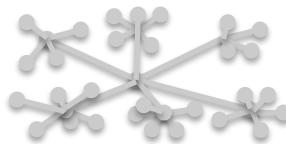
Point-to-point



Growth Phase:

Anchoring networks around large scale supply and demand sources

Hub-and-spoke



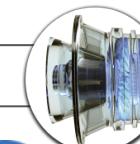
Mature phase:

Extensive networks, overlapping networks

Multiple Networks



Time



Large
“Anchor”
Systems
Pipe or
LNG

A blue icon depicting a stylized industrial facility with pipes and storage tanks, accompanied by two interlocking gears.

Distributed
“Satellite” Systems
LNG or CNG

A blue icon of a truck with a large cylindrical tank, representing a mobile or distributed system.

Linking
infrastructure for
efficiency and
resilience

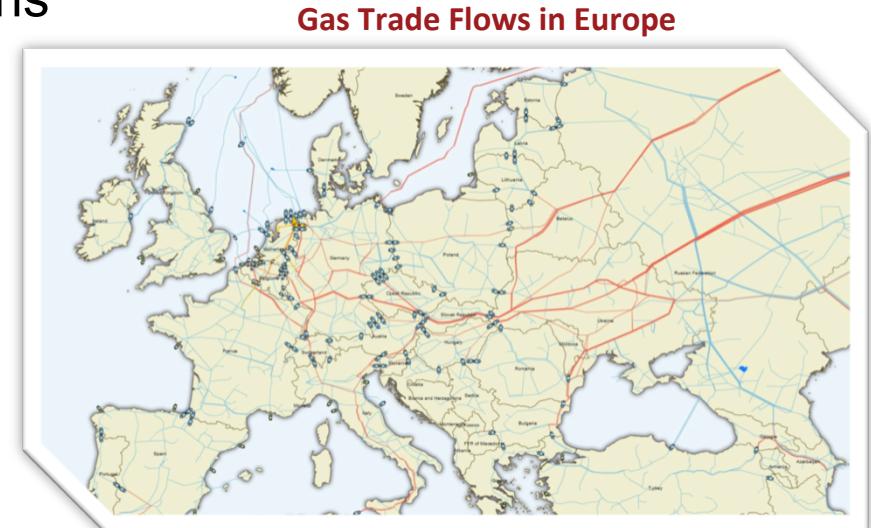
- These are changing the **network relationships** and **market behaviors** in natural gas landscape, and altering the global energy landscape

Source: P. Evans and Mike Farina, Age of Gas and the Power of Networks, GE, 2013

Scenario: Development of the European Natural Gas Landscape

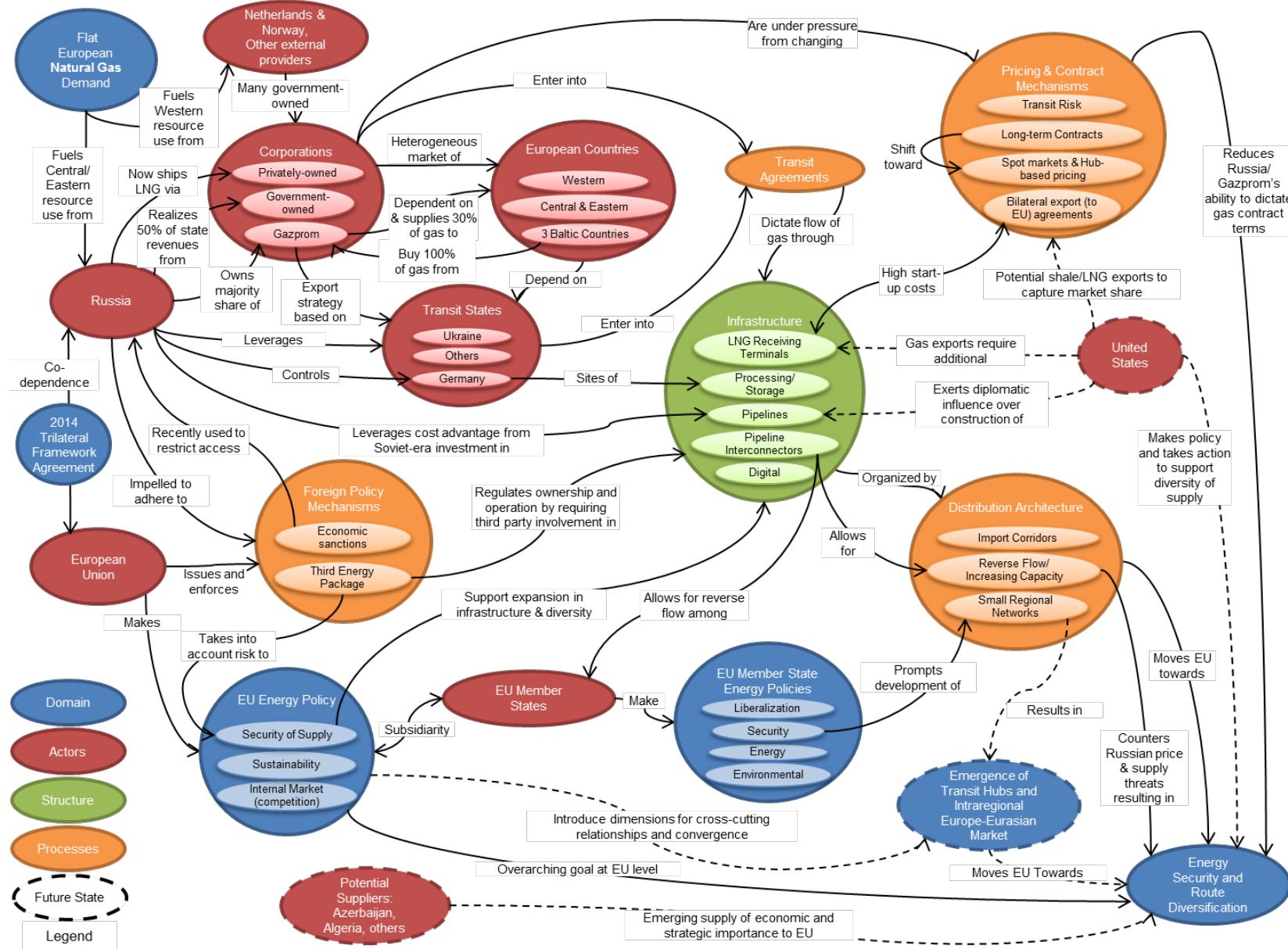


- European energy policy
 - Internal market (competition), security of supply, and sustainability
 - EU level and 28 Member States
 - Differing levels of regulation, pricing, public-private ownership
- Infrastructure
 - West vs East limited connections
 - Transmission networks, reverse flow, interconnectors
 - Storage facilities
- Security of supply
 - Gazprom export monopoly
 - Europe depends on 30% Russian NG supplies
 - Baltic states receive 100%

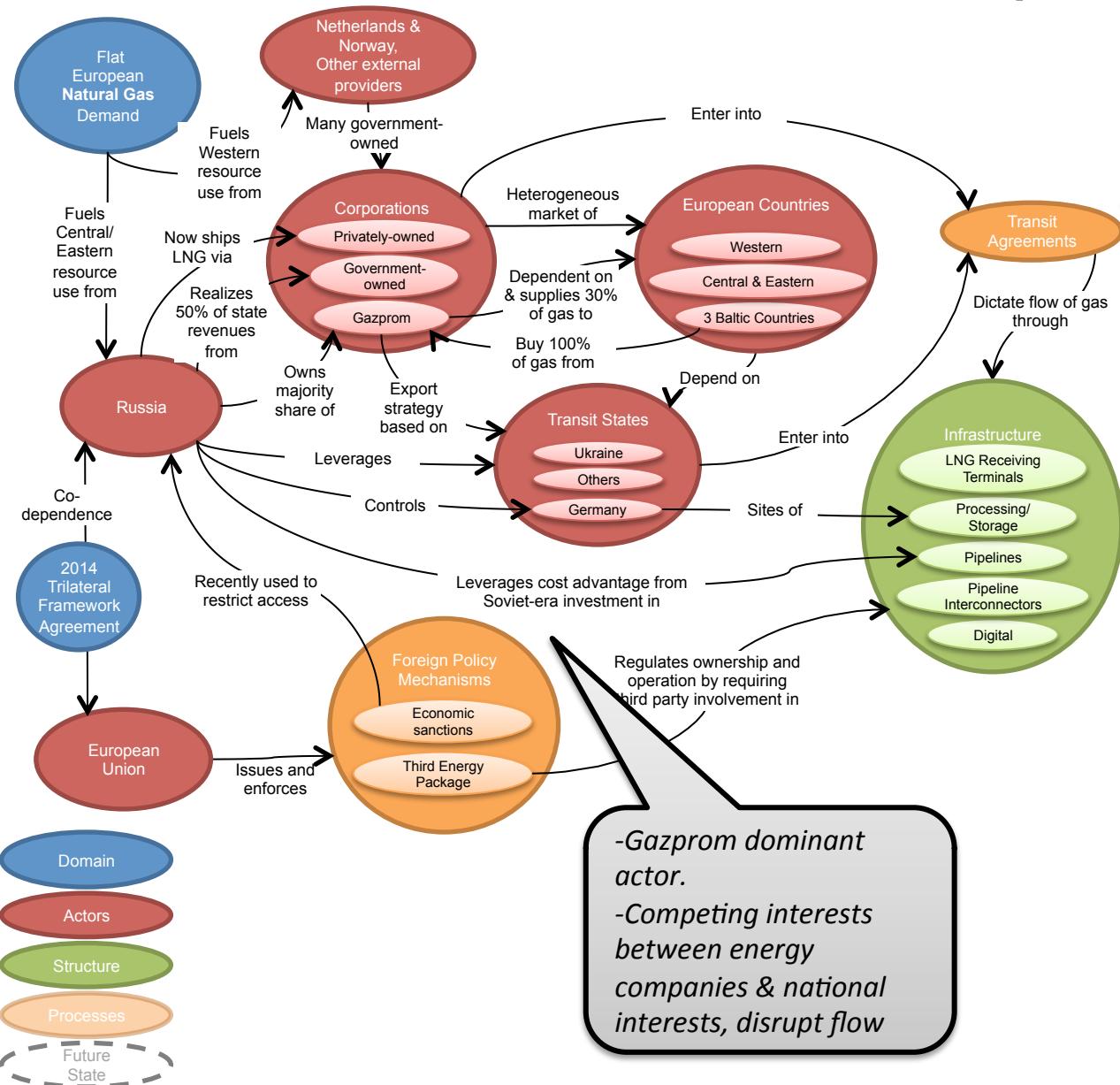


Source: IEA, Dec 2014.

Scenario: Development of the European Natural Gas Landscape



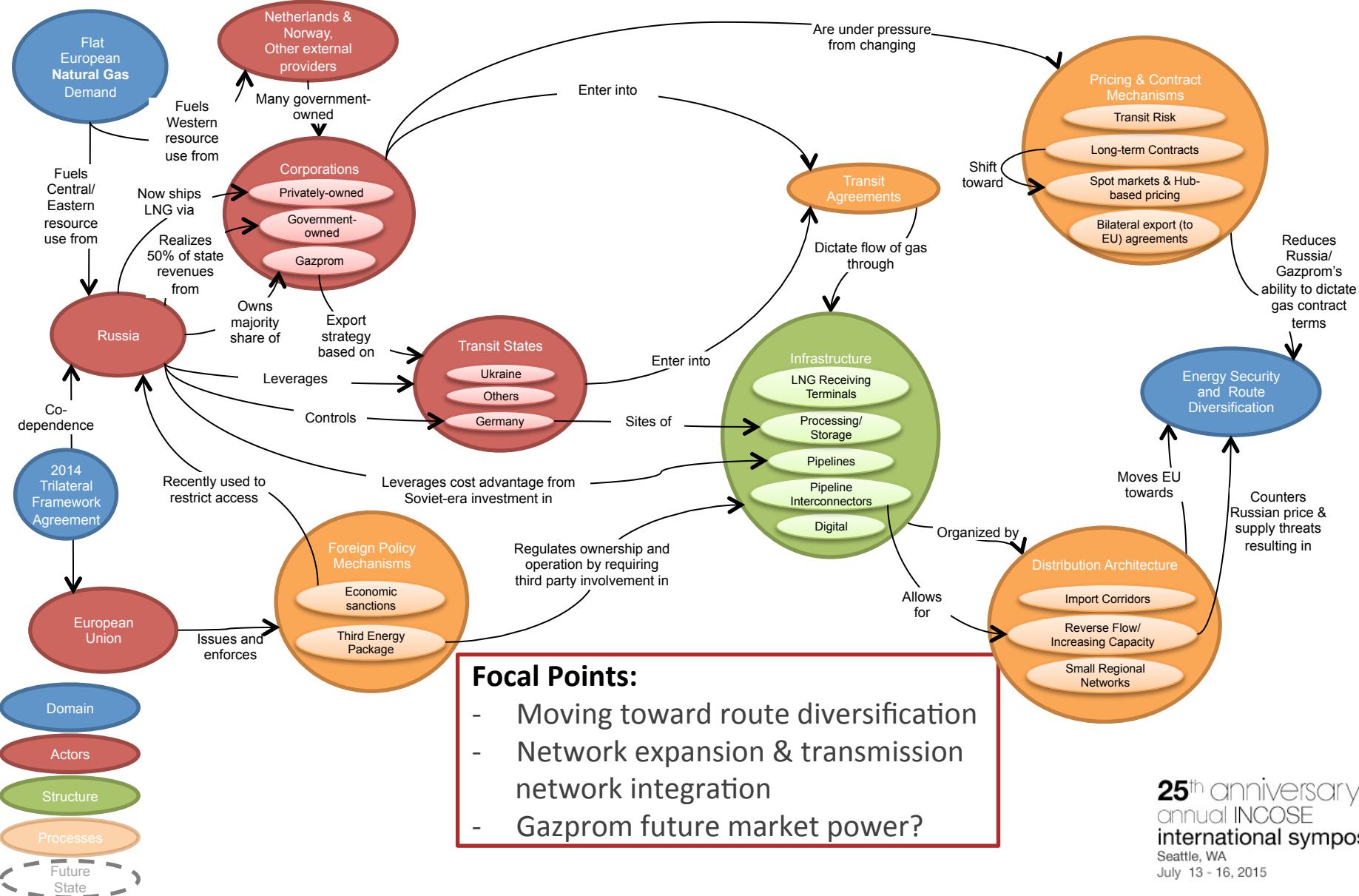
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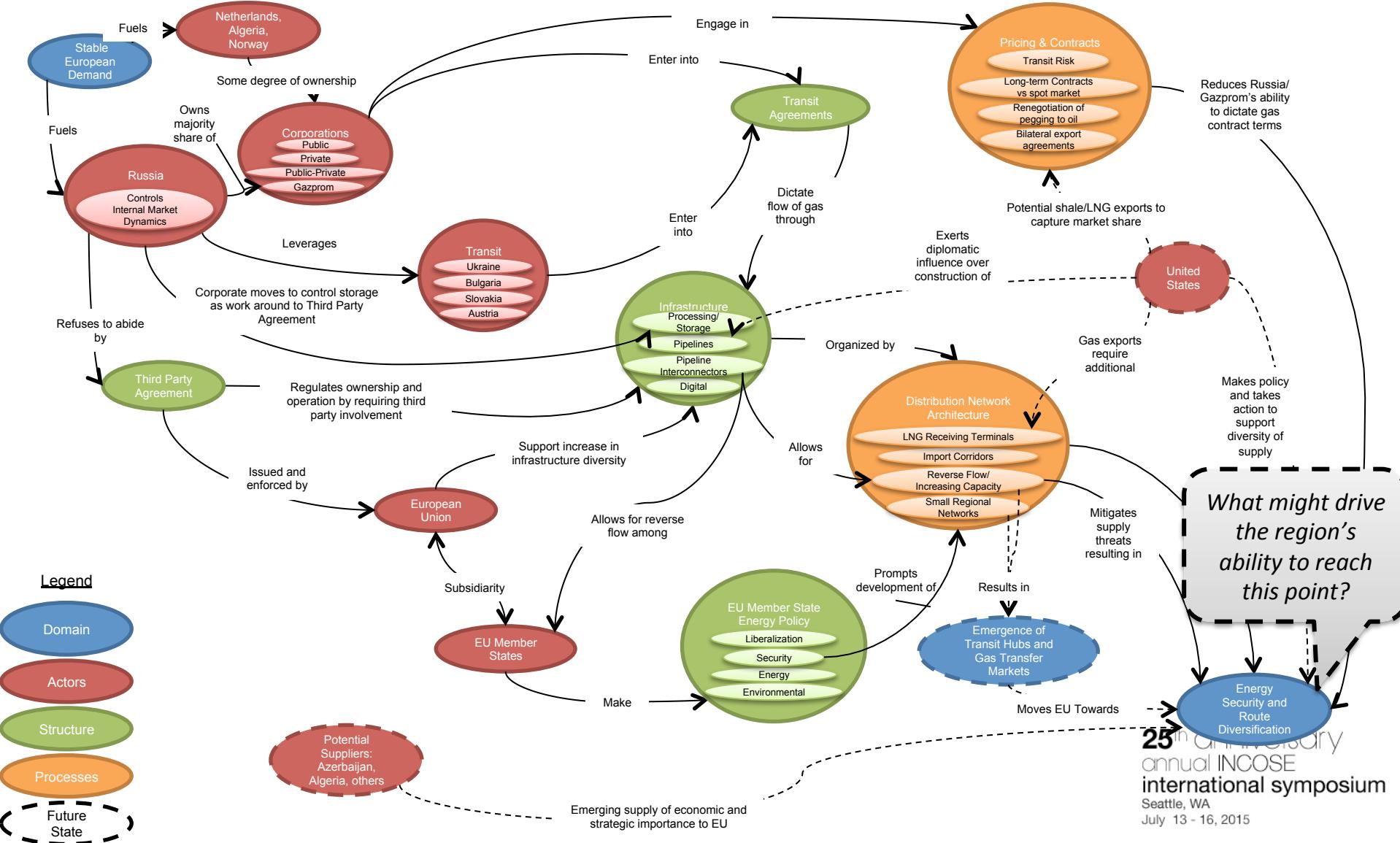
Focal Points:

- Russia's regional stronghold
- Factors shaping ownership and operation of infrastructure
- “Security of supply” risks

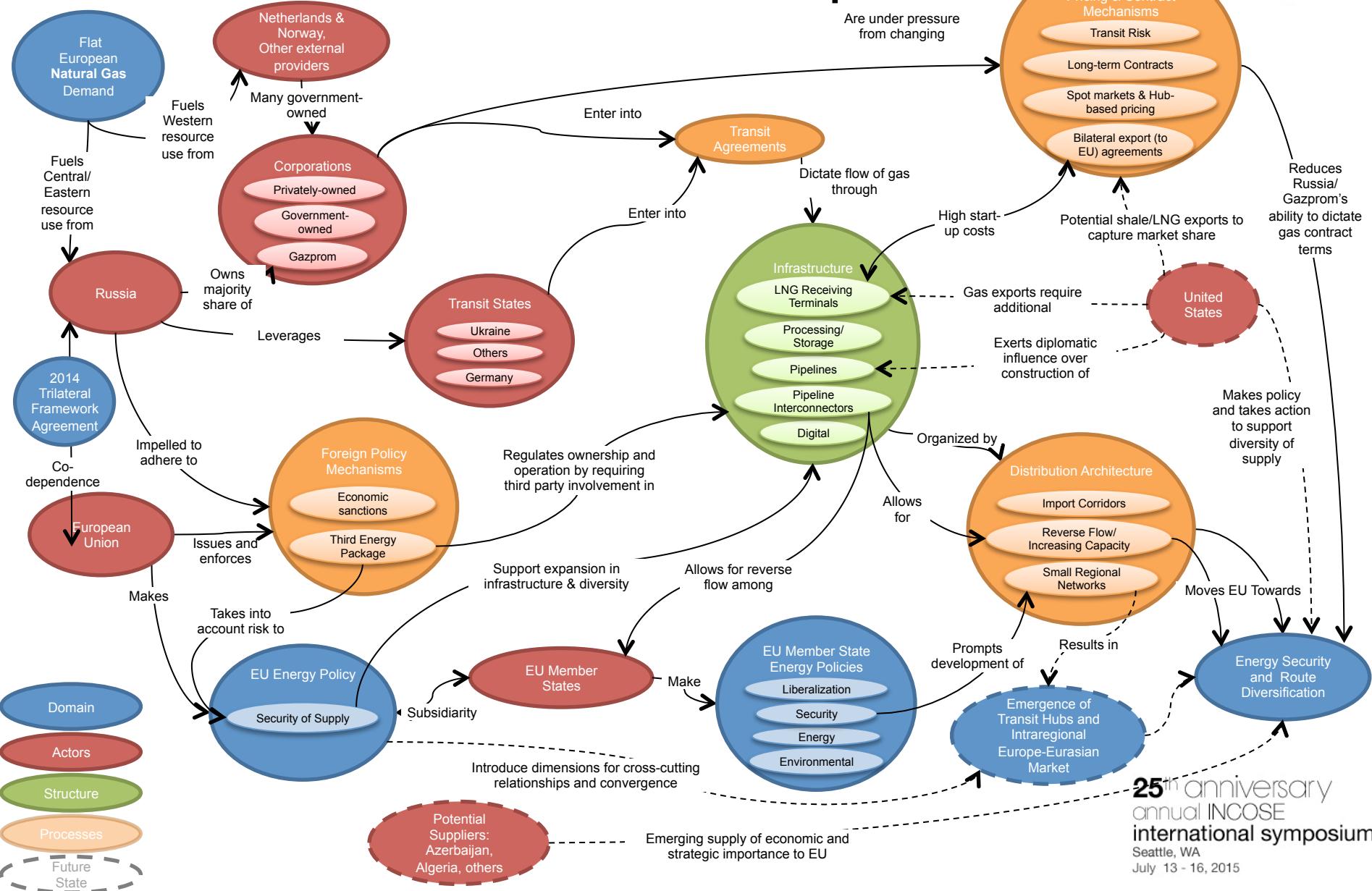
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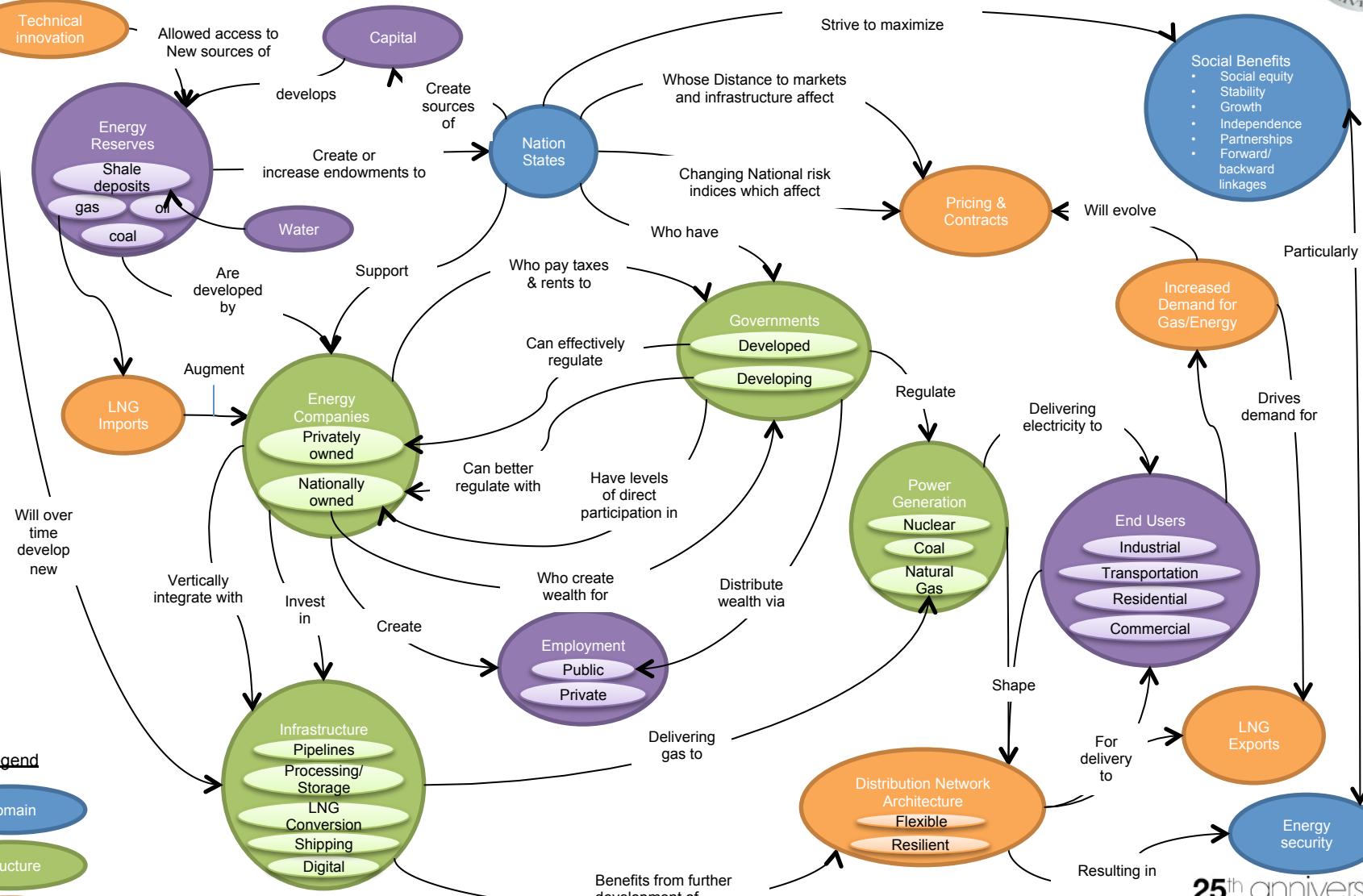
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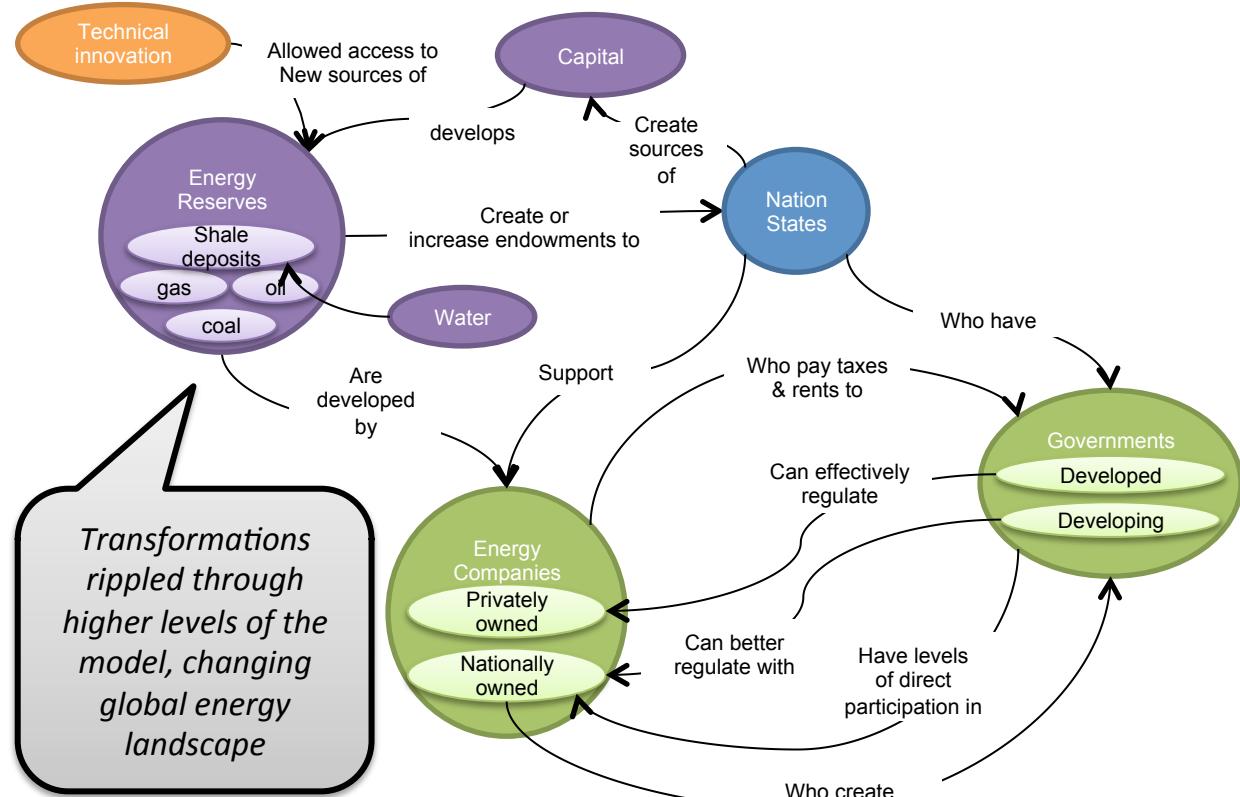
General System Structure



Legend

- Domain (Blue)
- Structure (Green)
- Processes (Orange)
- Resources (Purple)

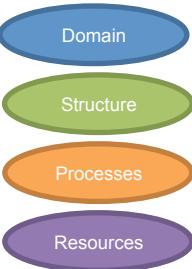
General System Structure



Focal Points:

- Energy company ownership
- Strong government presence and regulatory control
- National interests

Legend



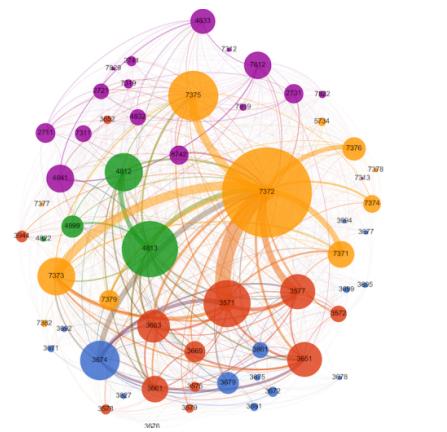
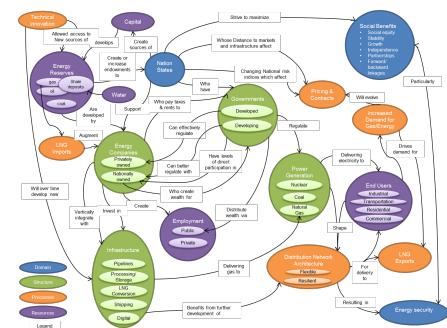
Outcomes

- Systemigrams are powerful tools for analyzing complex socio-technical systems
 - Identification of emergent phenomena and behaviors
 - Model network structures
 - Gaps in existing predictive models
- Provided a firm basis for a new research agenda in International Conflict
 - Regional similarities and differences
 - Changing political, economic, technological landscape
 - Data model representing use of oil and gas in international coercion, sanctioning, and conflict
- Prototype project for new family of conceptual and qualitative modeling tools
 - Transition of ERS

Future Work



- Next level of methodology and system models
 - Need for more understanding and modeling of physical and organizational networks
 - Computational models, visualizations, and simulations
 - Formal architectural models and conceptual modeling tools
 - International conflict in oil and gas networks
 - Need for more understanding and modeling of physical and organizational networks
 - Understand connections between conflict, coercion, network behaviors, points of vulnerability





Thank You!

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