Relative Comparison of the Rate of Convergence of Collaborative Systems of Systems: A Quantified Multi-Case Study

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Relative Comparison of the Rate of Convergence of Collaborative Systems of Systems

- Introduction
- Modelling Approach
  - Conceptual Dynamic Bayesian Network
- Initiatives to Counter Improvised Explosive Devices as a System of Systems
  - Factors which influence convergence of functionality
  - Constituent systems and Metrics of functionality
- U.S. Smart Grid as a System of Systems
  - Factors which influence convergence of functionality
  - Constituent systems and Metrics of functionality
  - Representative model of the System of Systems
- Expected Results

Introduction

- Several industries including Defense, Transportation, Health Care and Energy are **pursuing increasingly ambitious functionality** through Systems of Systems
- The **functionality evolves over time** to provide a highly sophisticated and integrated capability
- System of Systems engineers need to be able to **describe the status** of the System of Systems to stakeholders and customers
- This presentation describes a modeling approach which will **quantify the relative rate of convergence** of a System of Systems
- The model will incorporate representations of **factors which influence** the rate of convergence
- Observations from **analyzing multiple case studies** will be instrumental for refining the construct of the model and the representation of the factors
- The analysis will focus on documented, incremental functionality of System of Systems such as the **Smart Grid** and the operational infrastructure created collaboratively by the Joint Improvised Explosive Device Defeat Capability Approval and Acquisition Management Process
- **The model will advance the state of the art** of architecting System of Systems by improving the ability to describe current and forecasted functionality
- It is envisioned that the convergence metric will provide **translation of technical progress to business capability** that can be used to communicate status to stakeholders and customers and be **used to make comparative decisions** among competing Systems of Systems.

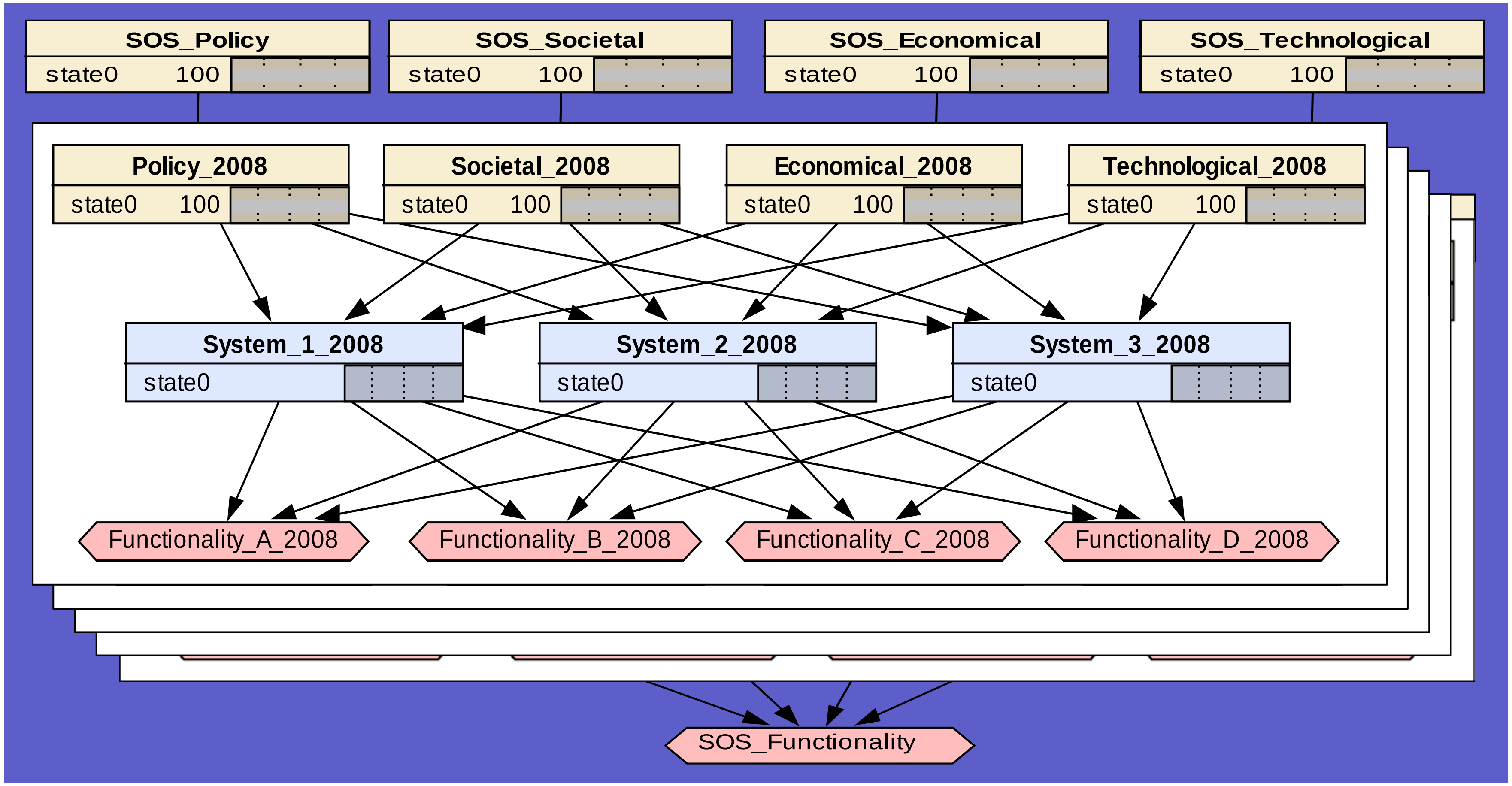
Modelling Approach – Dynamic Bayesian Network

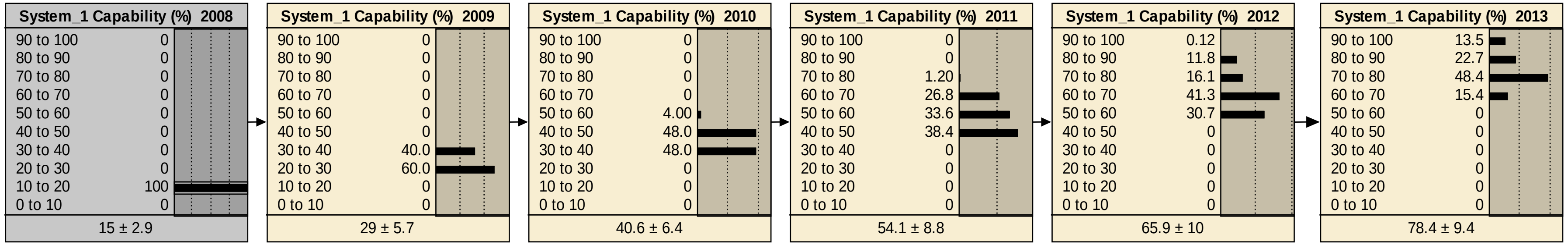
- Identify Quantifiable Factors which Influence the Rate of Convergence
  - Policy – Legislation, Directives, Control Documents, Vision Statements
  - Societal – Public or Subversive Support or Resistance
  - Economic – Financial/Quantifiable Factors to Close the Business Case
  - Technological – Capability to Interoperate, Capacity to Contribute
- Specify the Systems and the System of Systems; Determine Metrics for Functionality
- Construct Relative Conditional Tables for each System Based on Relevant Observations or Expert Elicitation
- Validate the Model; Use the Model to Explore Contributions of and Dynamics with the Factors which Influence

Dynamic Bayesian Networks are Directed Acyclic Graphical models of Stochastic processes

Conceptual Dynamic Bayesian Network

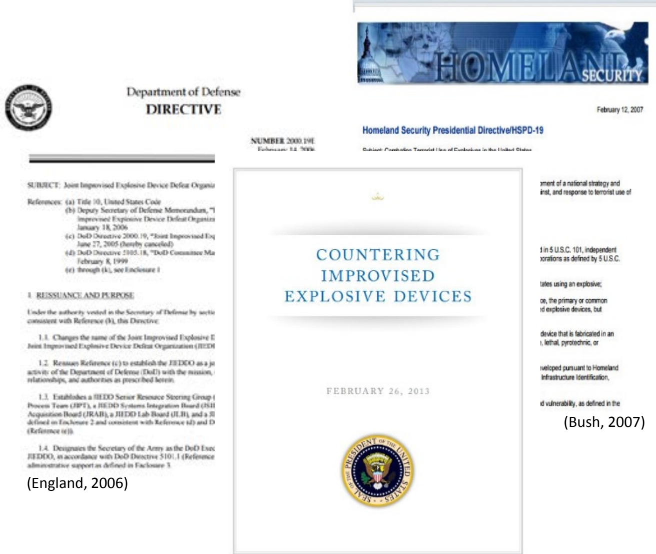
- Factors which Influence may be directed towards one system or many
- Systems may be closely related or diverse
- Time Phased Convergence of System Capability (and resultant Functionality) may be depicted
- A SoS-level DBN is comprised of nested System-level DBN





Counter – Improvised Explosive Device SOS Factors which Influence

Policy



(England, 2006)

(Bush, 2007)

(Obama, 2013)

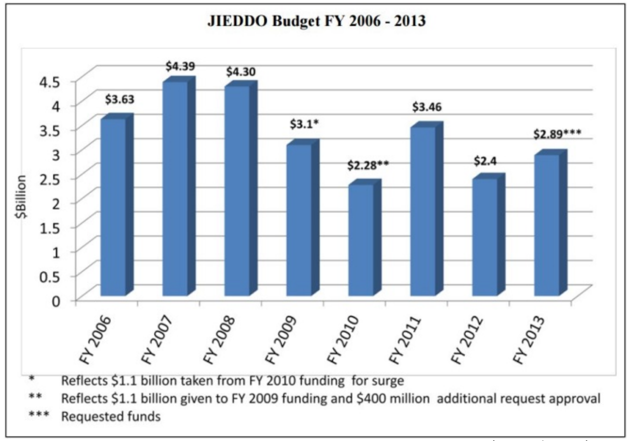
Societal

(MCCS, 2015)

(Wikipedia, 1997)

(amymillsmusic, 2013)

Economic



(Patacsil, 2013)

Technological

(JIDA, 2014)

(Darack, 2008)

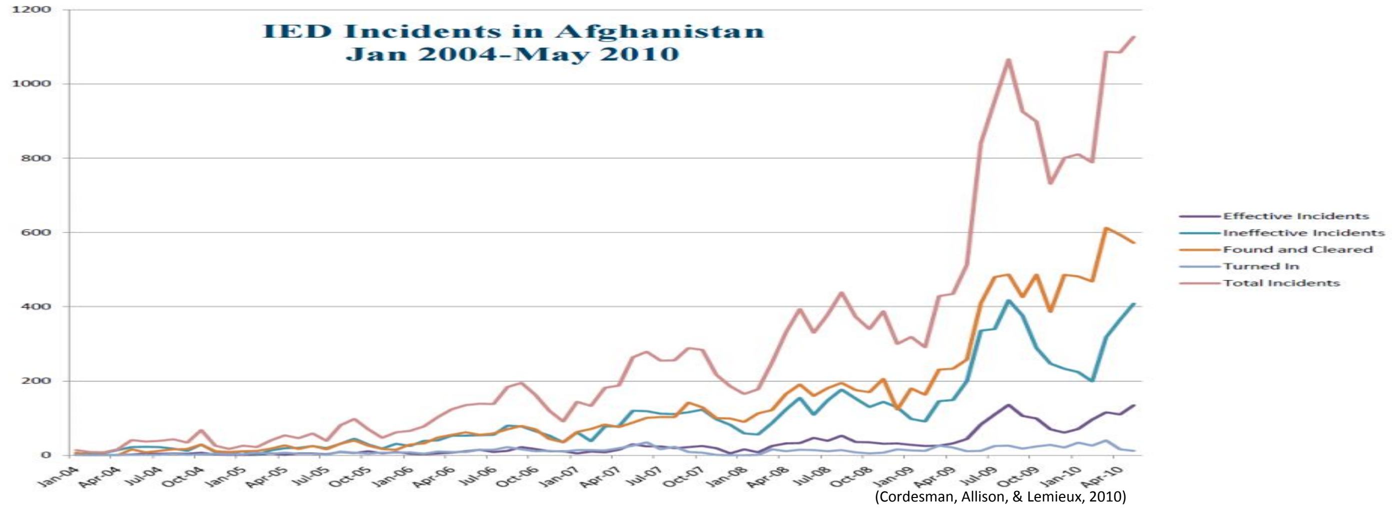
(JIDA, 2014)

(JIDA, 2014)

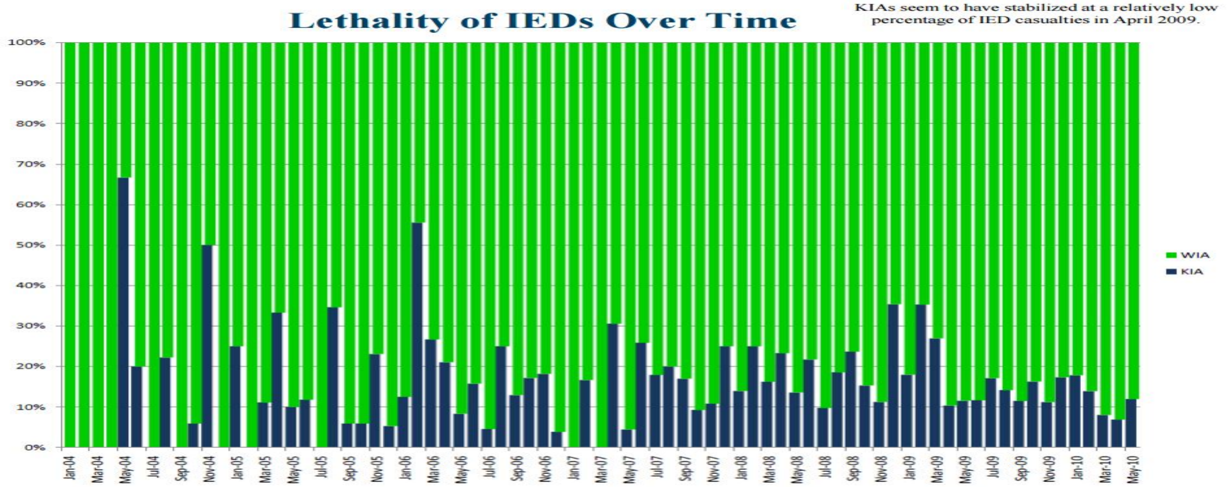
(JIDA, 2014)

Counter – Improvised Explosive Device SOS Systems and Functionality

Words are from: (Wikipedia, 2015)
Word Cloud created with (WordItOut, 2015)



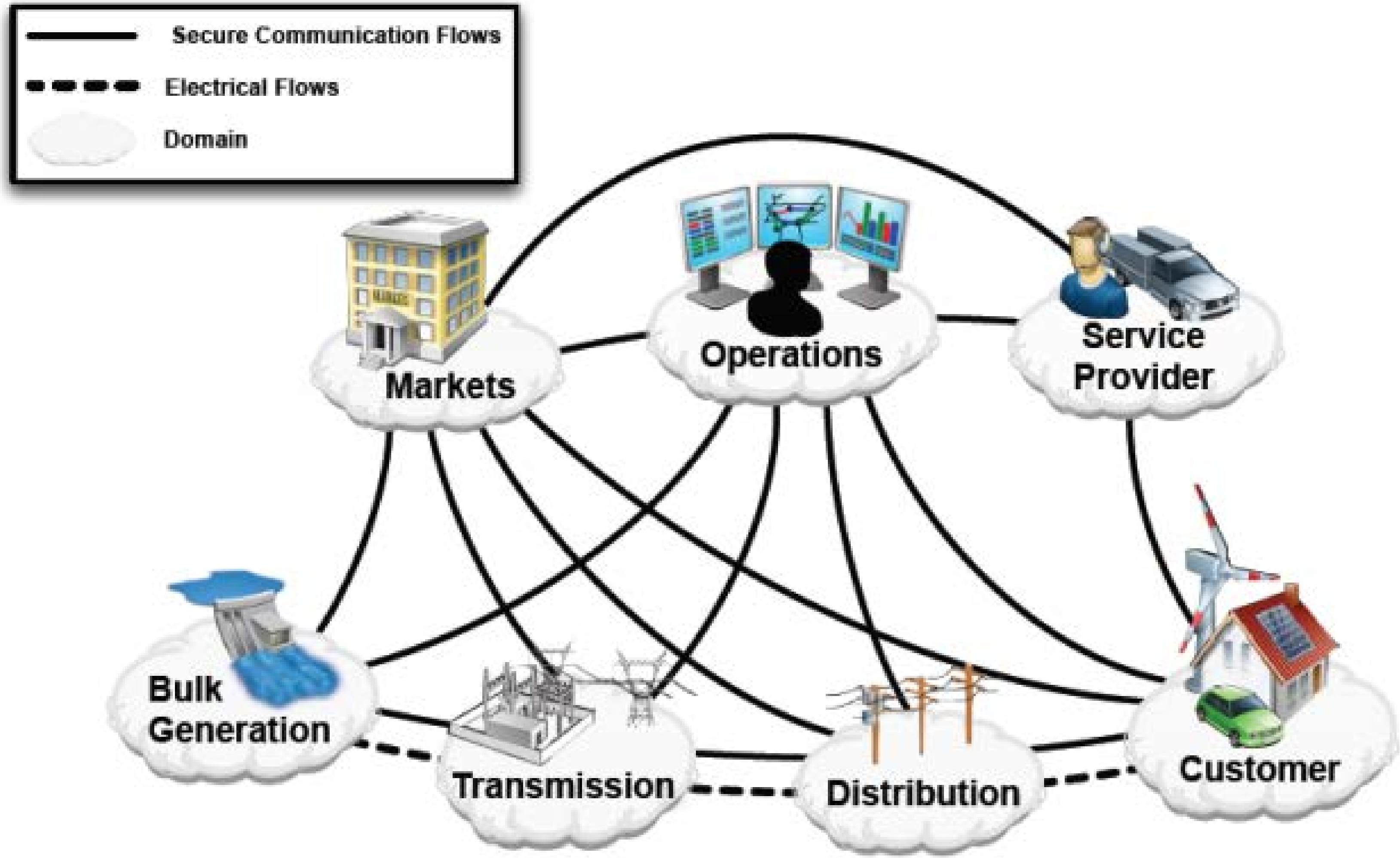
(Cordesman, Allison, & Lemieux, 2010)



(Cordesman, Allison, & Lemieux, 2010)

The C-IED SOS and Factors are Dynamic

U.S. Smart Grid Framework

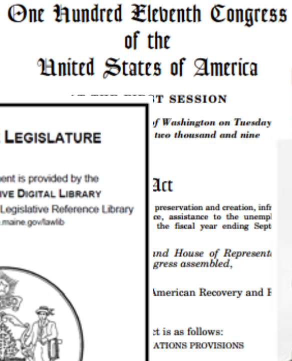


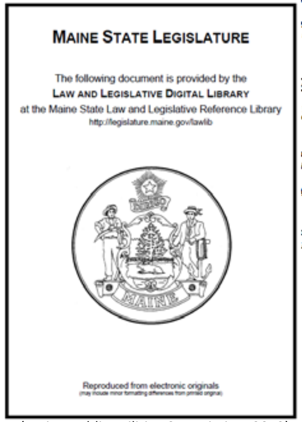
NIST Smart Grid Framework 1.0 January 2010

Office of the National Coordinator for Smart Grid Interoperability. (2010). *NIST Framework and Roadmap for Smart Grid Interoperability Standards.* Retrieved from NIST Public Affairs: http://www.nist.gov/public_affairs/releases/upload/smartgrid_interoperability_final.pdf

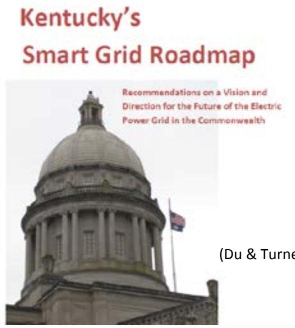
Smart Grid - Factors which Influence

Policy

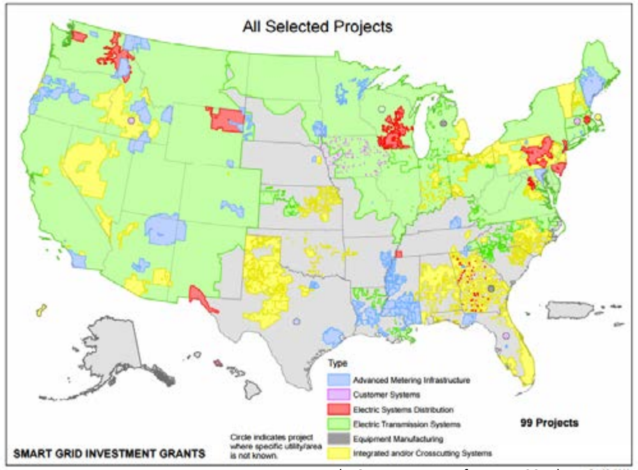




(Maine Public Utilities Commission, 2012)

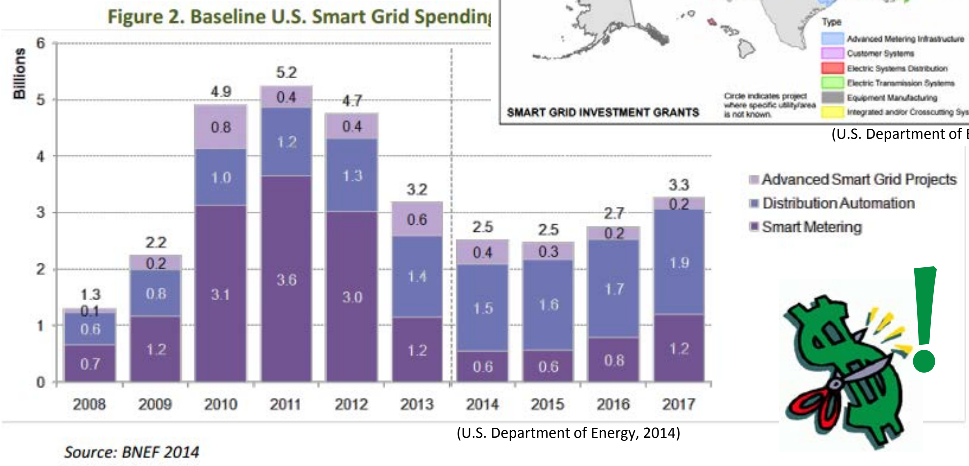


(Du & Turner, 2012)



(U.S. Department of Energy, 2014)

Economic



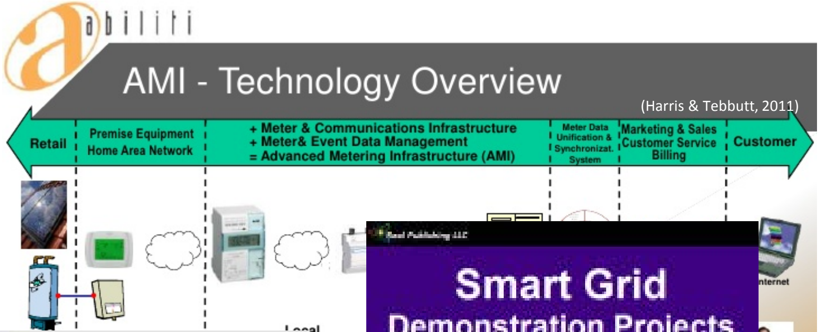
(U.S. Department of Energy, 2014)

Societal

(BC Centre for Disease Control, 2014)

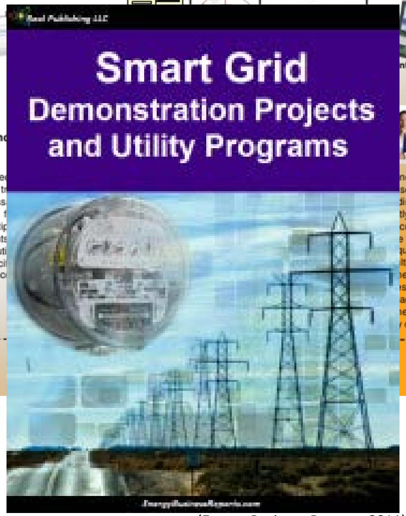
(SkyVision Solutions, 2015)

Technological



(Harris & Tebbutt, 2011)

(Robinson, 2015)



(Energy Business Reports, 2011)

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Smart Grid – Factors which Influence AMI Deployment

	New York	2008	2009	2010	2011	2012	2013	2014

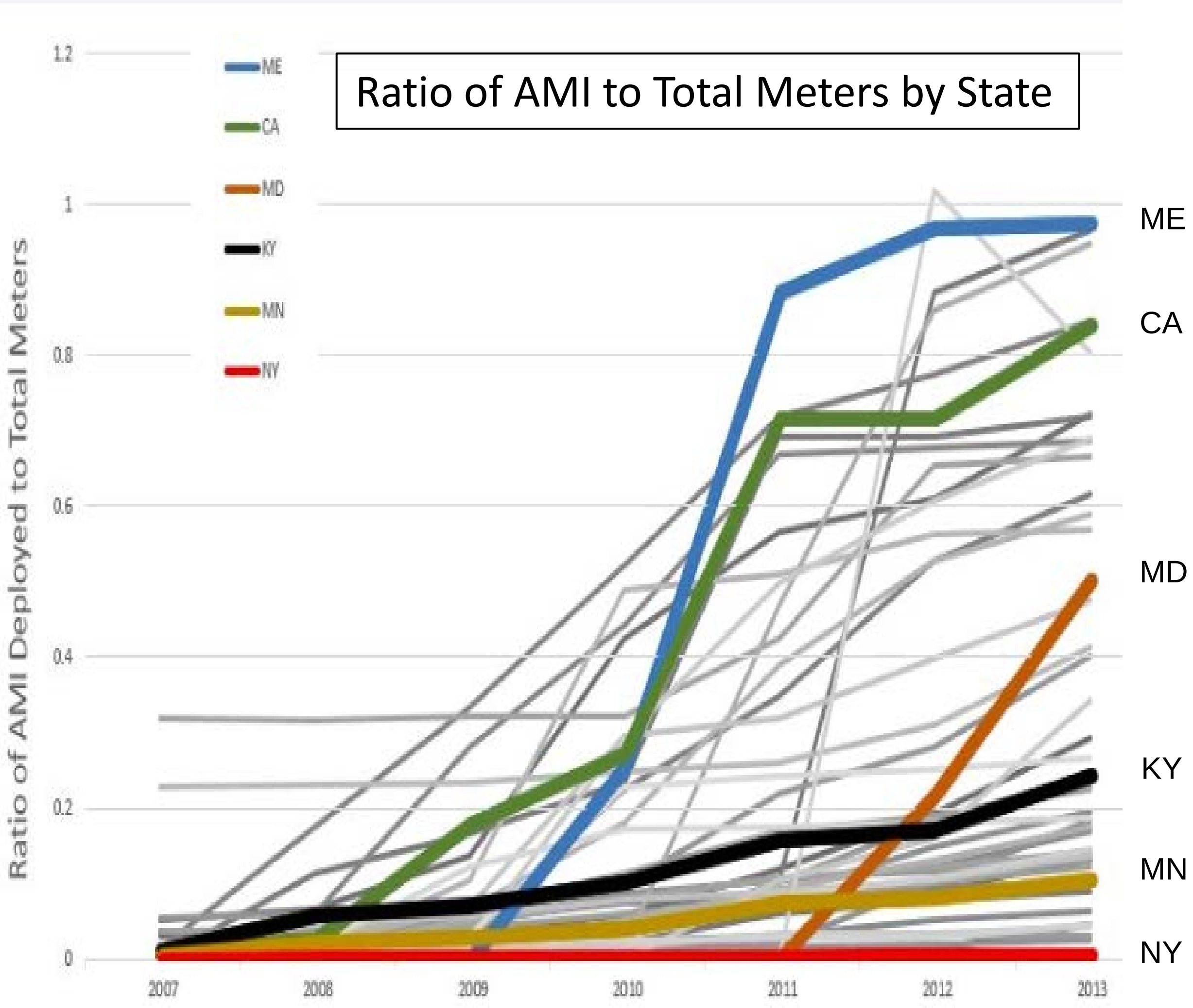
	Minnesota	2008	2009	2010	2011	2012	2013	2014

	Kentucky	2008	2009	2010	2011	2012	2013	2014

	Maryland	2008	2009	2010	2011	2012	2013	2014

	California	2008	2009	2010	2011	2012	2013	2014

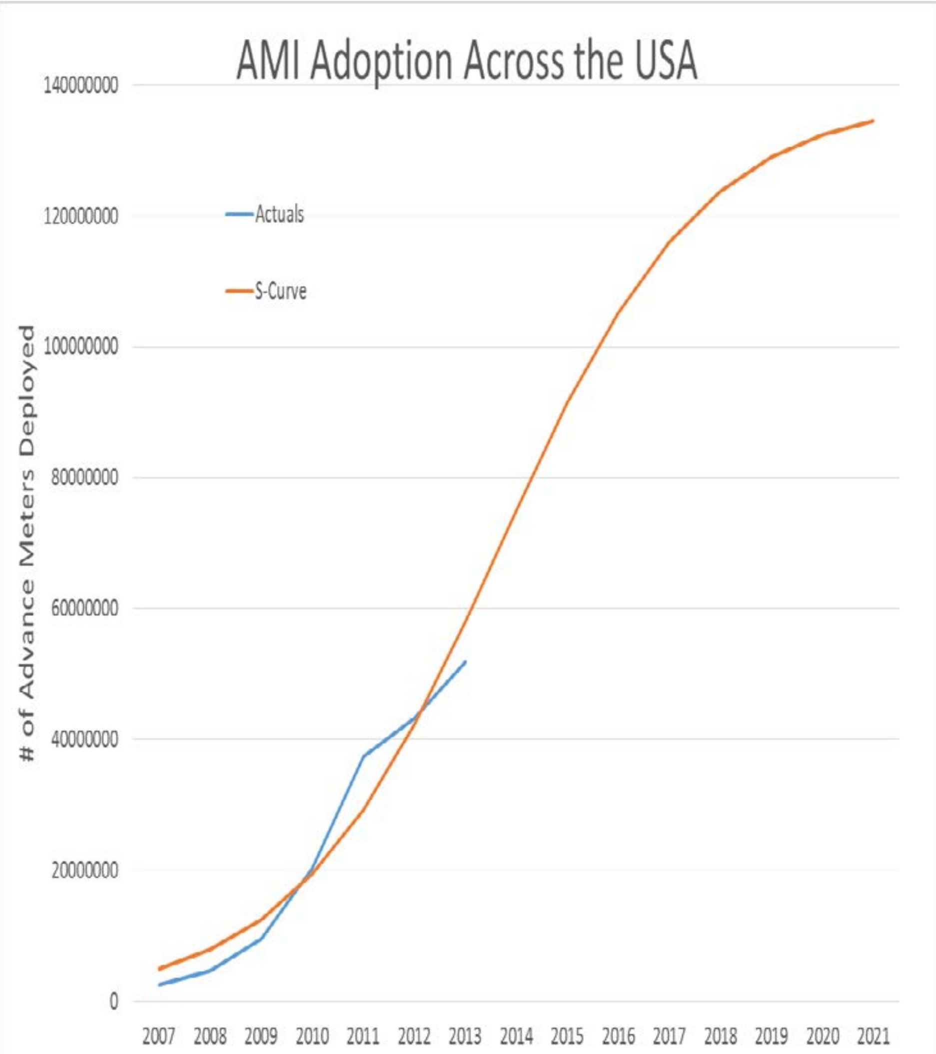
	MAINE	2008	2009	2010	2011	2012	2013	2014
Legislative	roadmap	0	0	1	1	1	1	1
	policy statement	0	0	1	1	1	1	1
	resistence	-1	-1	-1	-1	-1	-1	-1
Societal	opt-out	0	0	0	1	1	1	1
	customer education pro	1	1	1	1	1	2	2
	dynamic pricing							
Economical	arra funding	0	0	51.43	257.6	395.4	405.2	237
Technological	demonstration project		126					
Evidence	AMI FOM (Growth)	0	0	0.255	0.628	0.087	0.005	TBD



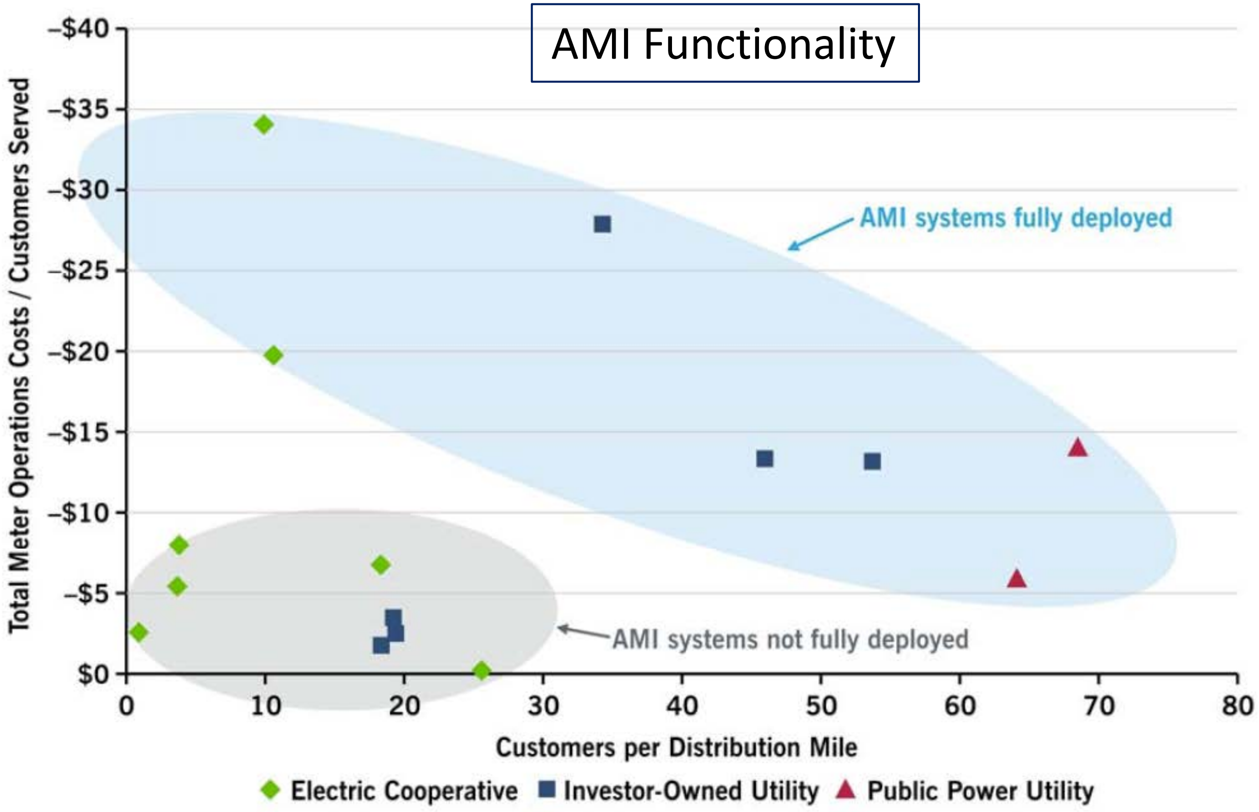
(U.S. Energy Information Administration, 2007 - 2013)

State Public Utility Commissions and Utility Industries Deploy the Smart Grid Constituent Systems Independently

Smart Grid AMI – Phased SOS Deployment



(U.S. Energy Information Administration, 2007 - 2013)

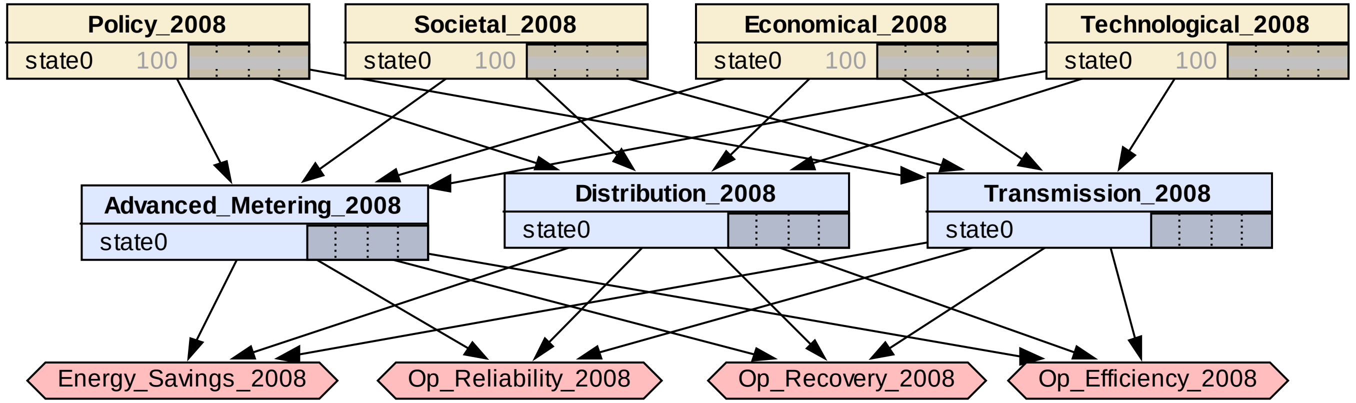


- Data represents project-level changes in meter operations costs
- Data are from 15 Smart Grid Investment Grant (SGIG) Projects
  - Represents 3.7 million operating smart meters
  - Based on operational experiences from April 1, 2011 to March 31, 2012

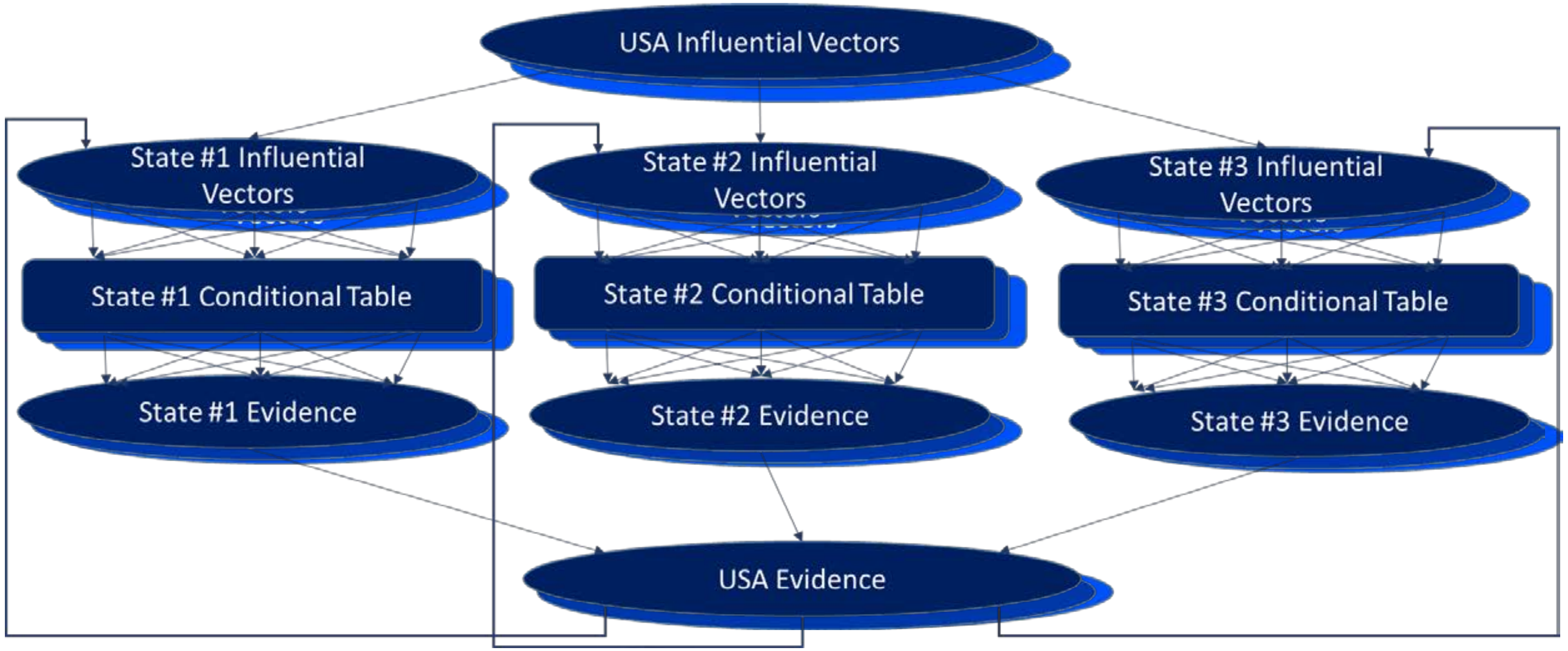
(U.S. Department of Energy, 2012)

Dynamic Bayesian Model of Smart Grid

System-level:
Single State; Single Year



System of Systems:
Multiple States; Multiple Years



Expected Outcomes

- Application of a Dynamic Bayesian Network to evaluate convergence will advance the state of the art of architecting System of Systems
- The model will improve the ability to describe current and forecasted functionality
- A convergence metric will be developed to:
  - Provide translation of technical progress to business capability in order to communicate status to stakeholders and customers
  - Make comparative decisions among factors influencing the convergence of Systems of Systems.

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NamaStar: the Ultimate SE/PM Challenge

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