

Insights into the Collaboration of Industry and Academia in the Energy Sector

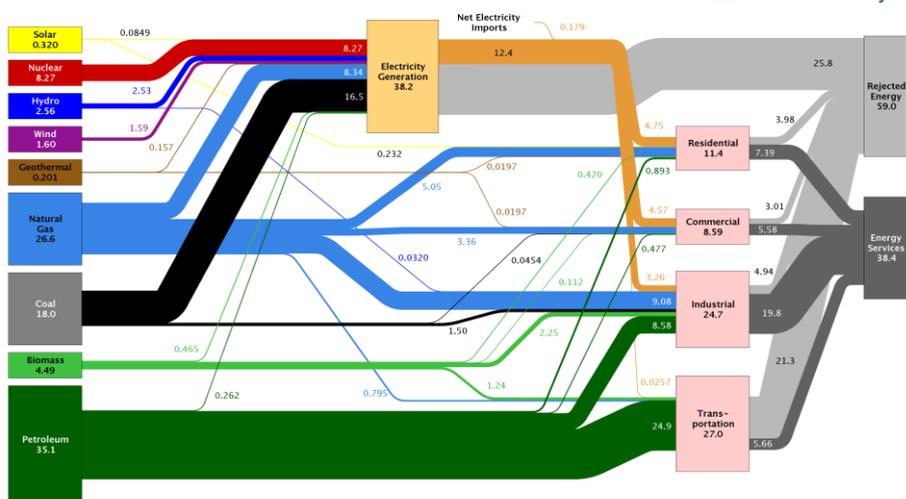
April 29, 2016

Monty Alger
Director, Institute for Natural Gas Research
Penn State University

US Energy and Carbon Balances

Lawrence Livermore National Laboratory

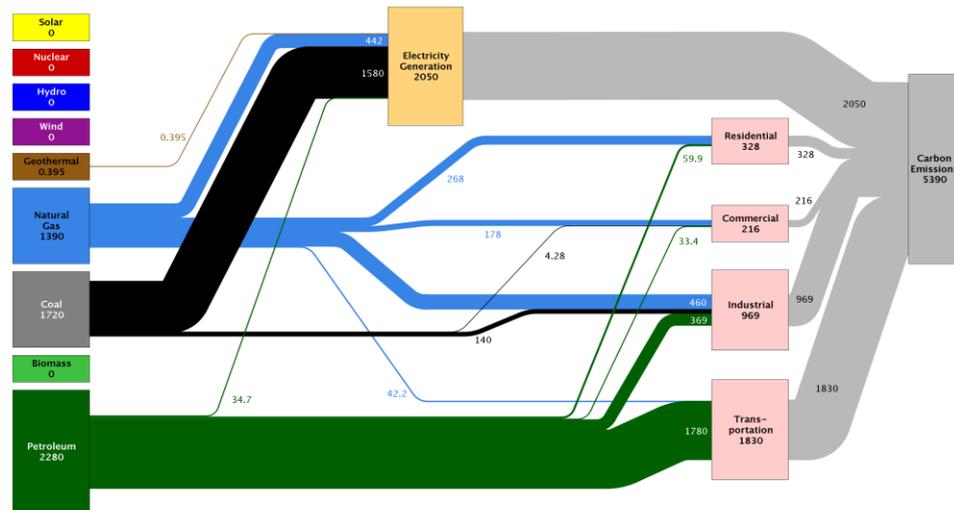
Estimated U.S. Energy Use in 2013: ~97.4 Quads



Source: LLNL 2014. Data is based on DOE/EIA-0035(2014-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate". The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Lawrence Livermore National Laboratory

Estimated U.S. Carbon Emissions in 2013: ~5,390 Million Metric Tons



Source: LLNL 2014. Data is based on DOE/EIA-0035(2014-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon emissions are attributed to their physical source, and are not allocated to end use for electricity consumption in the residential, commercial, industrial and transportation sectors. Petroleum consumption in the electric power sector includes the non-renewable portion of municipal solid waste. Combustion of biologically derived fuels is assumed to have zero net carbon emissions - the lifecycle emissions associated with producing biofuels are included in commercial and industrial emissions. Totals may not equal sum of components due to independent rounding errors. LLNL-MI-410527

Petroleum 36.1%
Natural Gas 27.4%
Coal 18.5%

} 82%

Nuclear 8.5%
 Biomass 4.6%
 Hydro 2.6%
 Wind 1.6%
 Solar 0.3%
 Geothermal 0.2%

100%

Electricity 38%
Transportation 34%

} 72%

Industrial 18%
 Residential 6%
 Commercial 4%

100%

Energy is “Big” – Global Scale



Global Energy Use = ~ 3 Cubic Miles of Oil

*Source	Number	Cost (US\$ trillion's)	Area	
			(km ²)	(sq mi)
Three Gorges Dam, China	496	15	3,135,712	1,210,736
Nuclear plants	6,448	32	25,792	9,920
Coal plants	12,896	8	25,792	9,920
Wind turbines	4,072,160	8	678,694	262,044
Rooftop photovoltaics	11,315,000,000	169	158,410	61,162

Scale of Fossil Energy Supply (~82% Total Supply)

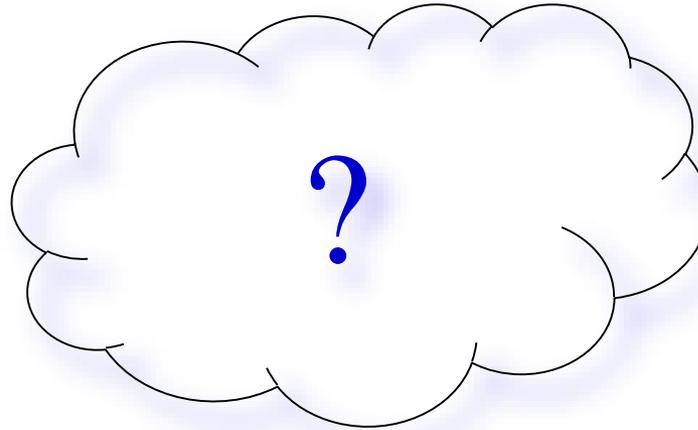


Sustainability – *“People, Planet, and Profits”*

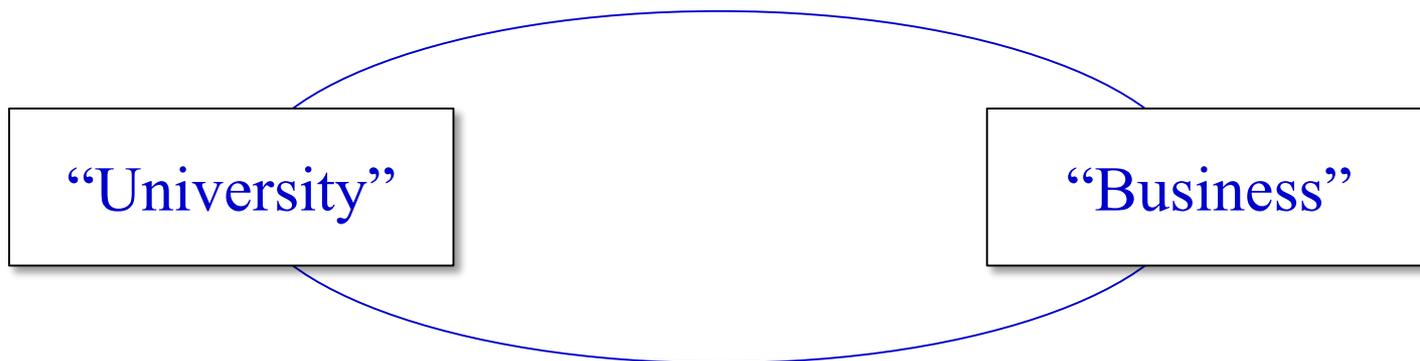


Source: Professor Roland Clift, Centre
for Environmental Strategy (CES)

“Discovery”

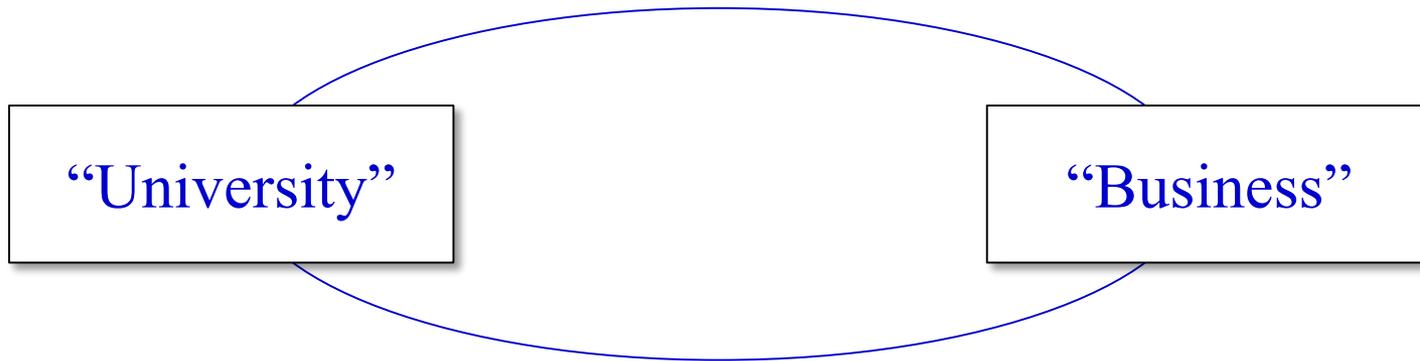


Sales



Goals:

- Develop an Energy Transformation Process - establish role for natural gas
- Build collaboration practices to engage and reduce innovation cycle time
- Advance learning through application of best in class technology
- Education of the public, future scientists, engineers, policy-makers and leaders



Mission:

Build a new research, development and education collaboration among students, faculty and external partners for economic growth and transition to low-carbon energy supply through unconventional oil and gas

Vision:

Enable the design, creation, development and commercialization of energy solutions integrating unconventional oil and gas energy

Enabling Change: GE CCRINGSS Collaboration

GE to invest in Penn State center to study natural gas supply chains

September 24, 2014

UNIVERSITY PARK, Pa. -- GE announced that it will invest up to \$10 million in Penn State to establish a new innovation center focused on driving cutting-edge advancements in the natural gas industry. The Center for Collaborative Research on Intelligent Natural Gas Supply Systems at Penn State (CCRINGSS) will engage Penn State researchers and students from many disciplines in collaborative work with various industry stakeholders. The center will seek to advance efficiency and environmental sustainability both through technological innovations and improved supply chain management.

"Natural gas is extremely important as a domestic energy source for the United States and continues to serve as a crucial element in revitalizing Pennsylvania's economy," said U.S. Congressman Glenn Thompson. "I fully support the work that Penn State and GE will be doing through CCRINGSS to support new research innovations and create real-world applications that will build upon existing partnerships led by the University to make a positive impact on the industry and the communities of Pennsylvania."

Thompson spoke at a luncheon Sept. 24, during which Penn State President Eric Barron outlined the creation of the center. GE Senior Vice President and Chief Technology Officer Mark Little, other representatives from GE, and several members of Penn State's academic leadership also attended.



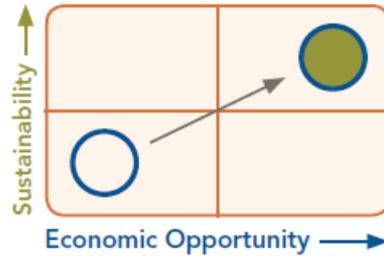
GE / CCRINGSS Goals:

- Mission of CCRINGSS is to engage many disciplines, and stakeholders
- To create a deep understanding of natural gas supply chain systems - including technical innovation, design, investments, and operations
- Generation of new knowledge, dissemination of knowledge, engagement of stakeholders of the natural gas supply chain
- Education of current and future scientists, engineers, policy-makers and managers

- GE 5 Year Investment with Penn State
- Support New Collaboration Model – Natural Gas Supply Chain

Focus Areas - Institute for Natural Gas Research

Energy System Transformation



- Balance Innovation, Investment and Policy
- “Learn by Doing”, Penn State Operating Station
- Translate to any Energy System

Organization – All Penn State



Innovation



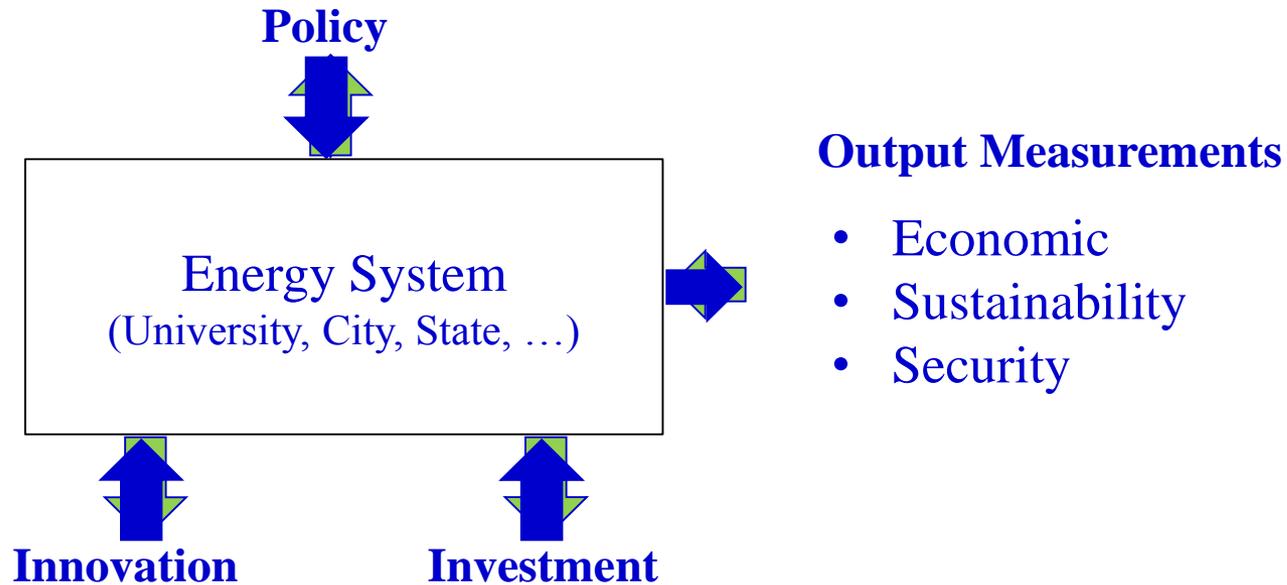
- Projects – Innovation Sessions
- Programs – Lean Start-up Model
- Full IP ownership option

Technology-Enabled Collaboration



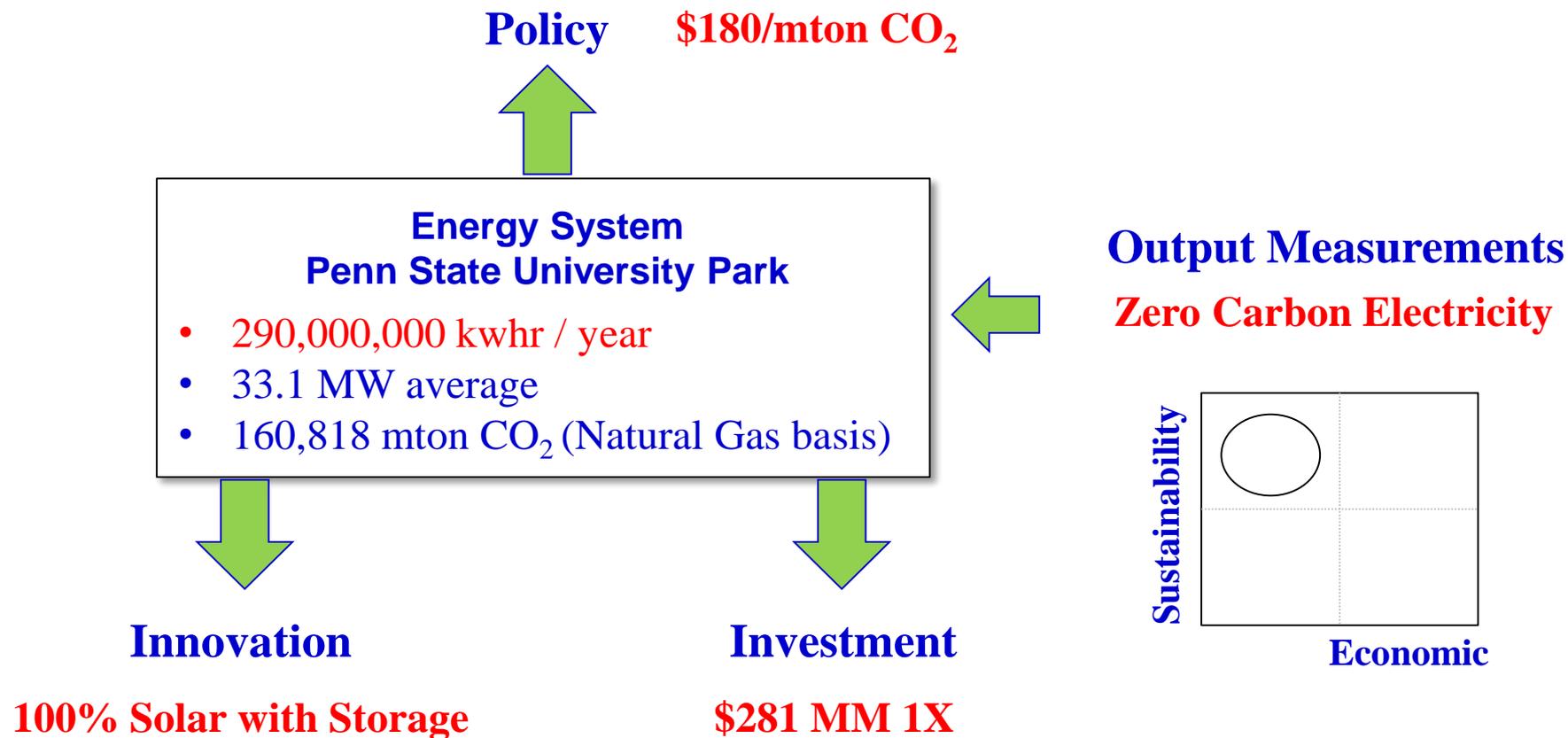
- Use online platform for University and Business connections
- Priorities from external sponsors
- Existing best-in-class content

Energy System Transformation - Approach



- Define an Energy System / Baseline & Goals
- Options for system improvement
- Evaluate innovation, investment and policy
- Priorities, Plans and Projects
- Local Implementation / Global Reporting

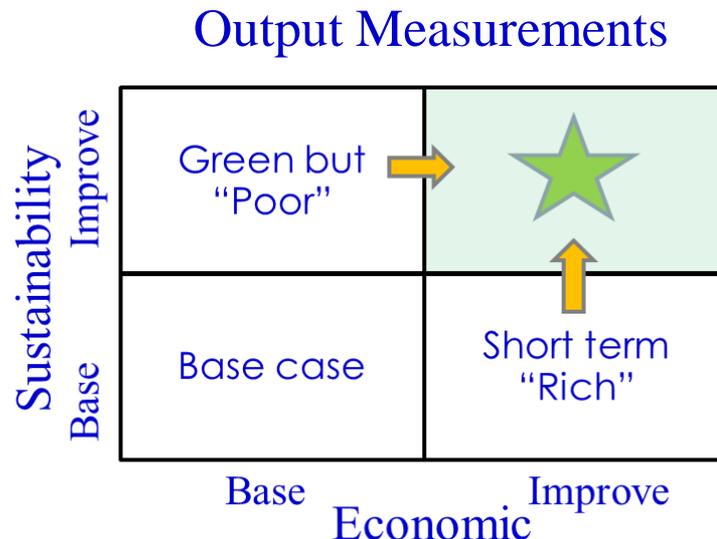
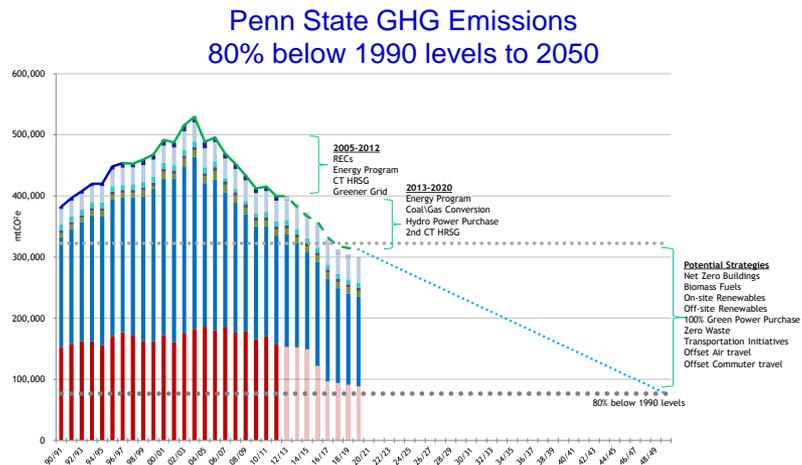
Energy System Transformation - Example



Order of Magnitude: Solar \$2/watt; 2X capacity; 1.5 Tracking; Storage \$3/watt; 1.22 lb. CO₂/kwhr

Energy System Transformation – Penn State

Beyond 2020



13

Penn State Operating Station

- Penn State Emissions Strategic Plan
- “Learn by Doing” - 24 campuses, \$6B Assets, Platform Research
- Engagement - OPP, students, suppliers, community
- Develop, translate and benchmark externally
- 4 Learning Factory Projects Spring 2016
- Real time LCA measurement of CO₂-e

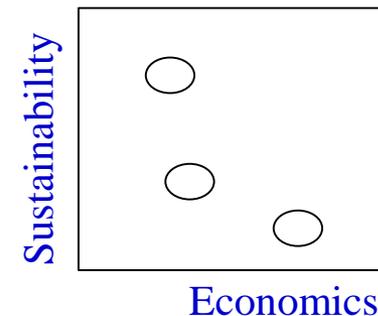
Measurements



Analysis



Benchmarking



Cloud Based Data Layer (<http://Measurabl.com>)

Company N

City A

Penn State

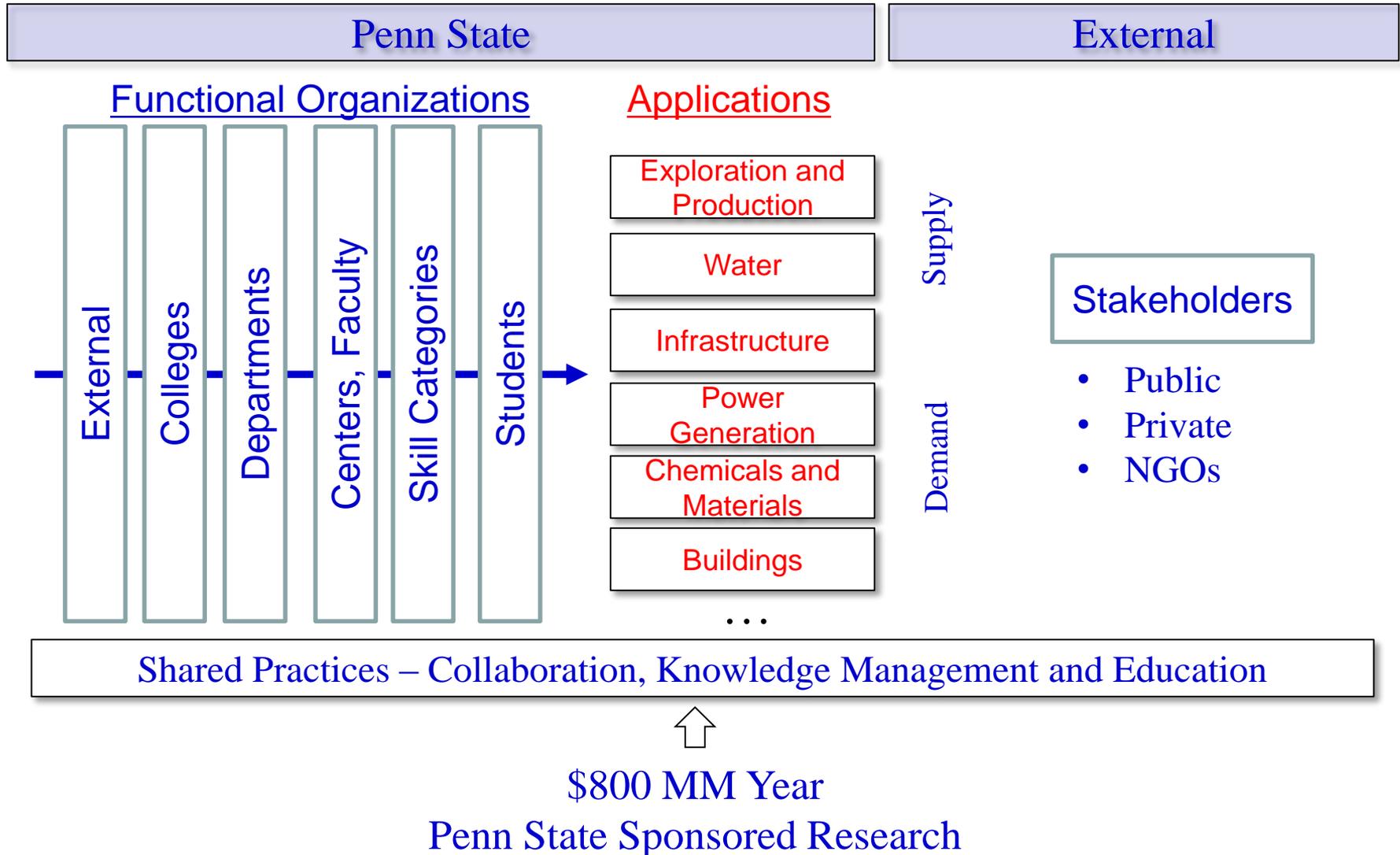
University B

University A

...

- Transformation Plan for Any Organization
- Benchmarking / Sharing of Practices
- Long-term Globally Consistent Reporting

Organization - Institute for Natural Gas Research

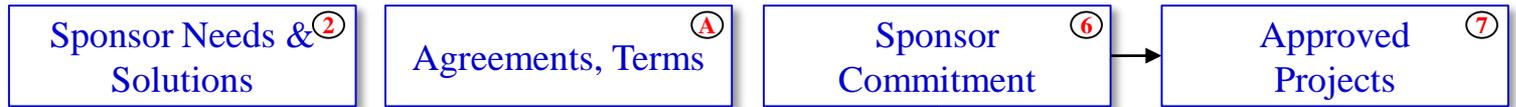


Penn State Energy University - DRAFT

Theme	Application	# of Projects	# Concepts	# Colleges	# Affiliate	# SIMs Faculty	# Pubs	# Centers	5 Yr Sum, Million \$
Design and Management	Climate Science and Ecosystem Change	0	0	12	0	131		0	59.4
	Energy Policy, Planning and Economics	0	2	18	5	28		0	6.3
	0	0	0	0	0	0	0	0	65.7
Energy Supply.	Oil and Gas Exploration and Production	0	65	12	37	71		11	28.9
	Water Processing	0	30	8	31	36		14	12.3
	CO2 Capture, Sequestration	0	0	5	1	16		0	6.3
	Coal Utilization	0	0	6	1	21		0	9.2
	Nuclear Energy	0	0	3	1	15		0	7.6
	Solar Energy	0	0	15	0	50		0	41.4
	Wind Energy	0	0	10	1	10		0	1.9
	Biomass Energy	0	0	14	1	85		0	49.3
0	0	0	0	0	0	0	0	156.9	
Energy Infrastructure.	Smart Grid	0	1	6	1	18		0	6.6
	Infrastructure	0	8	6	13	17		6	4.3
	Energy Storage	0	0	11	1	49		0	29.4
	Supply Chain Energy	0	7	3	14	6		1	0.9
	0	0	0	0	0	0	0	0	41.2
Energy Use	Energy Efficiency	0	0	6	0	5		0	1.4
	Power Systems	0	5	15	20	95		6	47.5
	Transportation Fuels and Advanced Vehicles	0	3	3	2	5		3	7.8
	Buildings	0	0	10	1	24		0	70.1
	Chemicals and Materials Products and Processes	0	5	3	16	9		3	3.1
	Combined Heat and Power (CHP)	0	1	5	1	5		0	2.6
0	0	0	0	0	0	0	0	132.4	
Education and Outreach	Human behavior, communications and ethics	0	0	0	1	0		0	0.0
	Education	0	10	6	9	15		0	2.5
	K12 Education	0	0	0	0	0		0	0.0
	0	0	0	0	0	0	0	0	2.5
398.8									

Innovation – External Engagement

Strategic



Collaboration



- VC's
- Ben Franklin
- Small Companies



Solution Creation



Integration

- 1) ----
- 2) ----
- 3) ----
- 4) ----

...
Prioritization

	A	B	C
1			
2			
3			
4			
5			

Project Management

Research

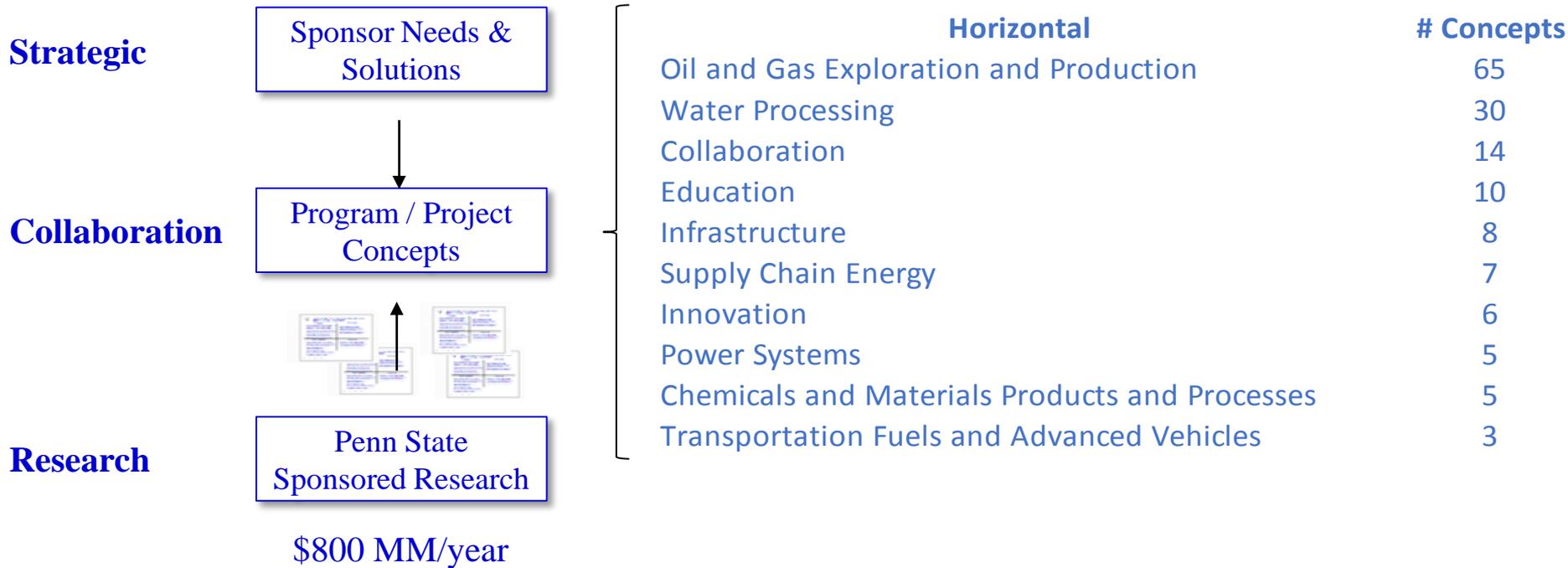


\$800 MM/year

Innovation Sessions

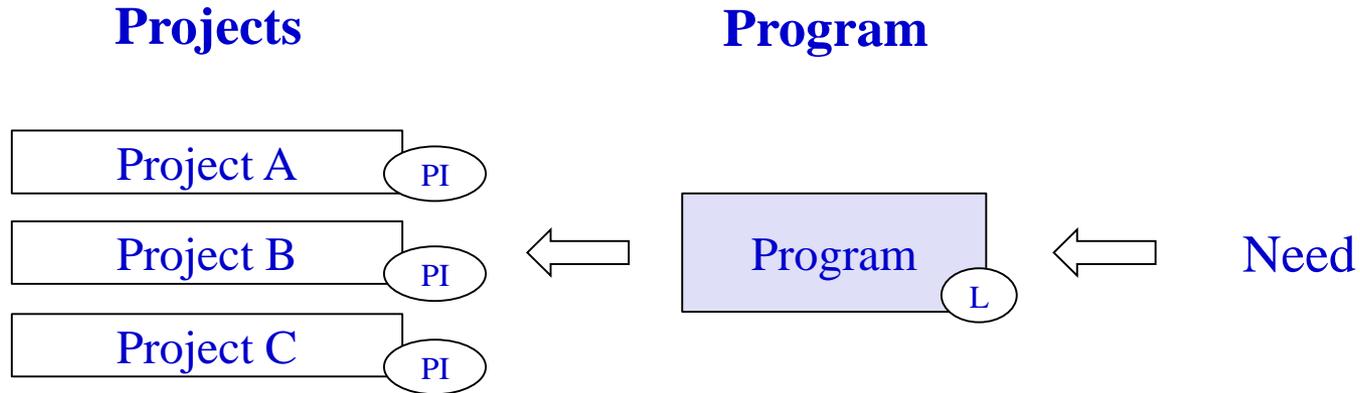


Innovation – Projects



- Growing Library of 1 Page Project Concepts
- Sharing & Translating Practices Across Penn State
- Developing Sponsored Research Programs

Innovation – Programs



Program:

- Integrate Multiple Faculty and Disciplines
- Translate External Need into University Projects
- Same Challenges Exist in Business

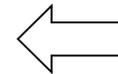
Innovation – Program Design Example

Project Concepts

Diagenesis and Loss of Function of Proppant Packs in Shale	Long-term Oil/Gas/Water Recovery in Unconventional and Conventional Reservoirs
Fracturing fluid loss and retention by reservoir formation – implications on productivity	Transport and production decline characteristics of liquid-rich gas shale plays
Multi-stage and multi-mechanism gas production enhancement in shale	Innovating Decline Curve Analysis for Unconventional Reservoirs with Spatial and Temporal Statistics

Program

Well
Restimulation
Tool

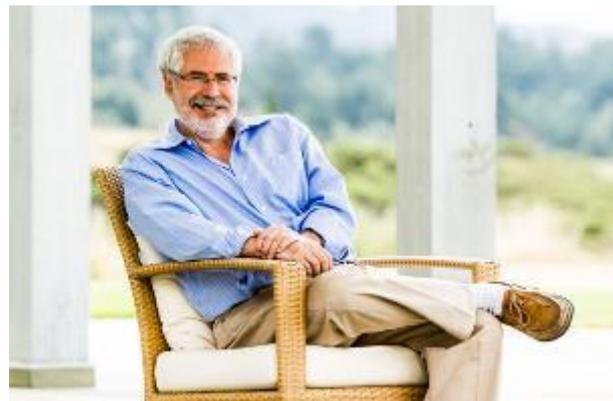


Initial Program Concept:

Develop a Tool to predict well behavior based on range of re-stimulation designs

- Discussions – Opportunity to Connect Multiple Project Concepts
- Need a Method to Design Program Tied to Market Need

Innovation – Developing New Programs



Steve Blank
www.SteveBlank.com

Harvard Business Review

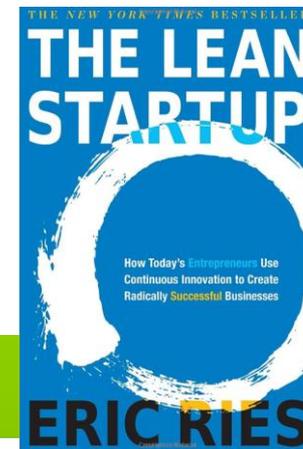
Why the Lean Start-Up Changes Everything



ENERGY.GOV
Office of Energy Efficiency & Renewable Energy

Home » Lab-Corps

LAB-CORPS



Lean Start-Up

Business Idea
(Program Concept)



Lean Program Design

Program Proposal



- “Reverse” Lean Start-up Model – Connect Research to Market Need
- Value Proposition, Customer Discovery, Pivoting, Lean Start up Canvases
- Program Development Course Pilot Spring 2016 – 4 Project Teams

Technology-Enabled Education



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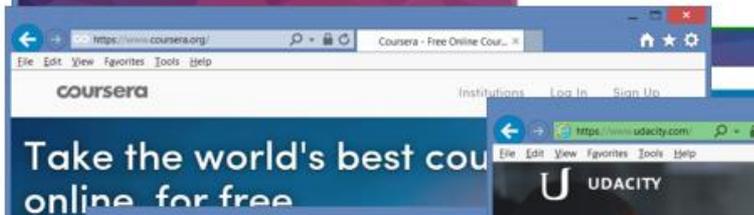
https://www.khanacademy.org/ | Khan Academy

KHANACADEMY

You only have to know one thing:
You can learn anything

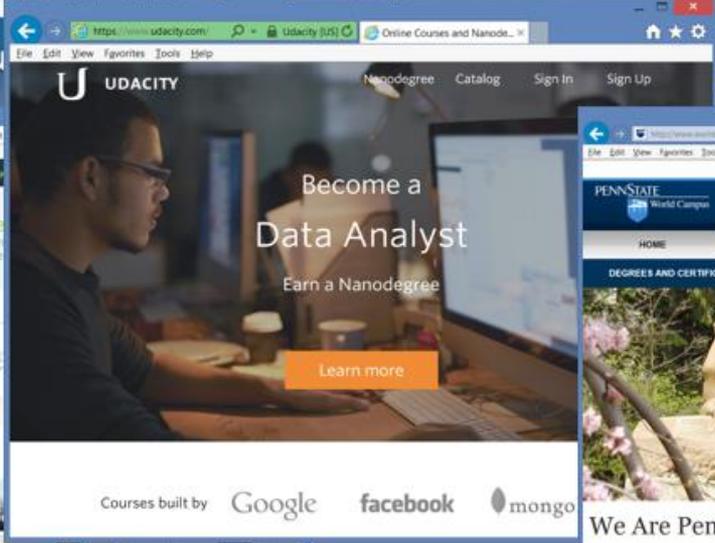
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We Are Penn State World Campus

"How Do I ... Fix a Leaky Faucet"

The screenshot shows a web browser window with the address bar containing 'https://www.youtube.com/results?sea' and a search bar with 'fix a leaky faucet'. The search results list several videos:

- How to Repair a Moen Shower/Tub valve** by ramonasplumber, 4 years ago, 1,261,751 views. A red box highlights the view count, with a red arrow pointing to the Ramona's Plumber website.
- How to Fix a Leaky Faucet with a Single Handle Design** by Lowe's Home Improvement, 4 years ago, 1,061,463 views.
- How to repair a leaky faucet** by finalvideoproduction, 6 years ago, 847,219 views.
- How to Repair a Delta Tub / Shower Valve** by ramonasplumber, 4 years ago, 823,662 views.

Greg Chick is Ramona's Plumber
15725 Snuz Mtn. Rd., Ramona, CA 92065
CA State Contractors Lic. 319039
email: greg@ramonasplumber.com
760-788-2889

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I'm also a regular contributor to the eLocal.com blog, as a plumbing expert.

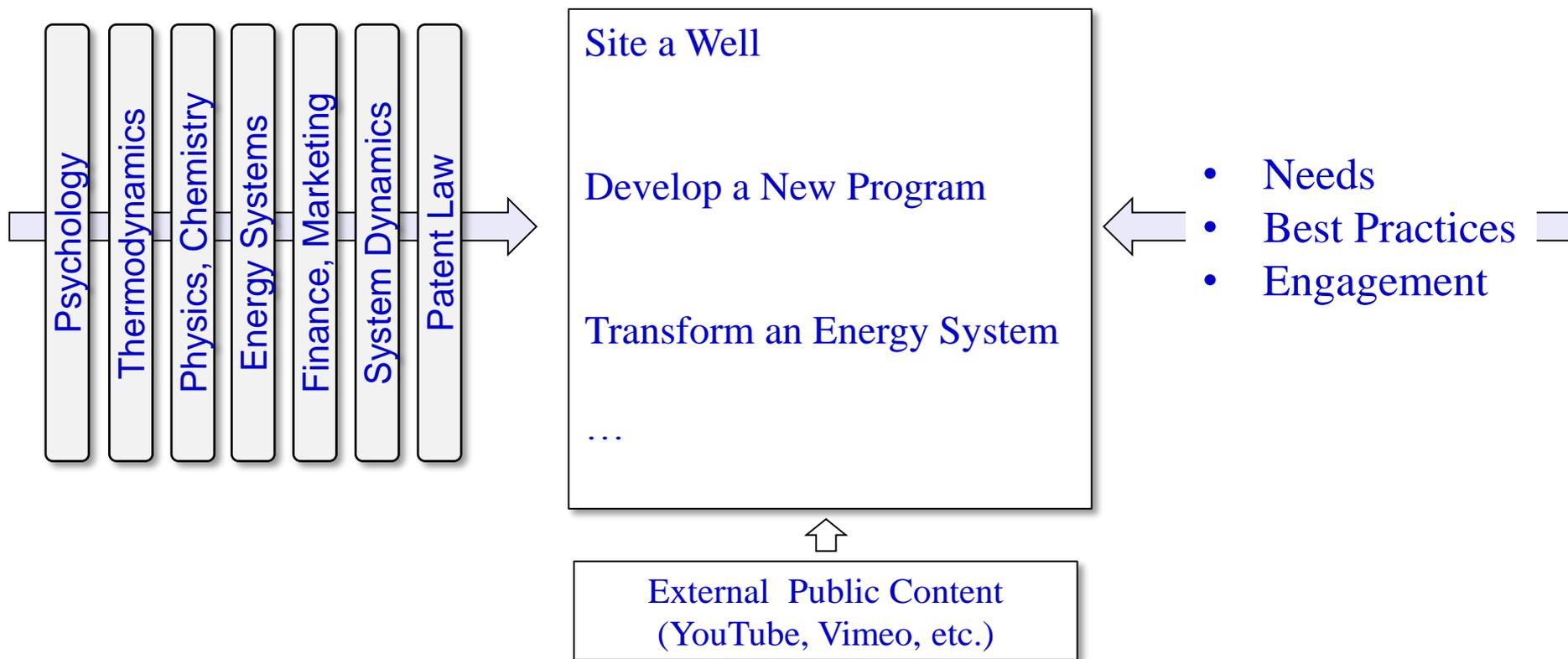
Technology-Enabled Collaboration

Penn State

Start Here

Business

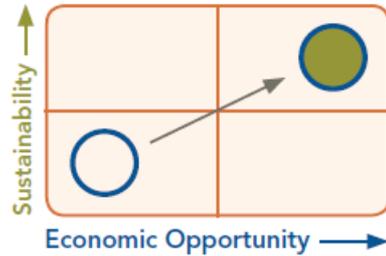
How do I ...



Use Online Technology to Build a New Integrated Collaboration Model

Focus Areas - Institute for Natural Gas Research

Energy System Transformation



- Balance Innovation, Investment and Policy
- “Learn by Doing”, Penn State Operating Station
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Organization – All Penn State



Innovation



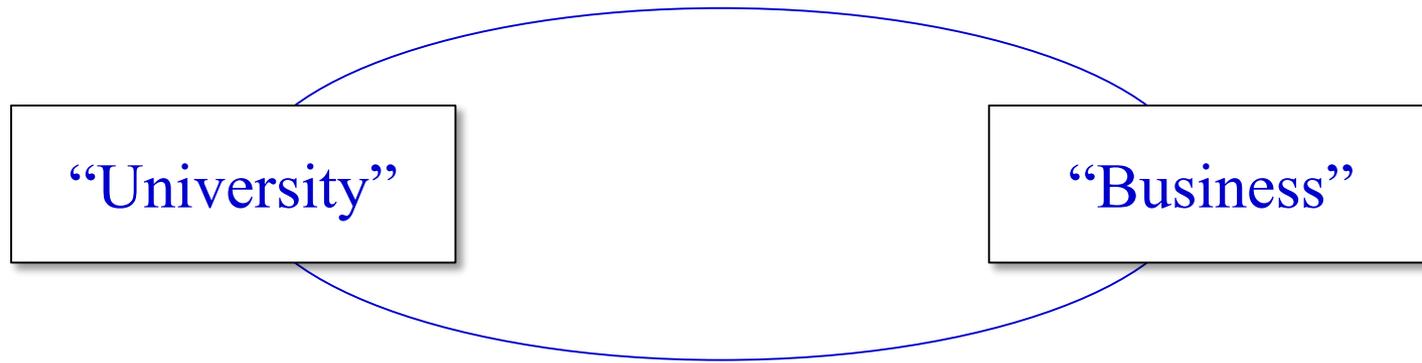
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- Programs – Lean Start-up Model
- Full IP ownership option

Technology-Enabled Collaboration



- Use online platform for University and Business connections
- Priorities from external sponsors
- Existing best-in-class content

Summary



- Building New Practices to Connect University and Business
- Reduce Innovation Cycle-time, Connection of Market with Research
- Use Technology to Enable an Integrated Learning Model
- Business Partnership Needed for Design, Iteration and Deployment

Thank You!