DOE Carbon Storage Program Tools for Risk Management and CCUS Value Chain Integration

NATIONAL ENERGY TECHNOLOGY LABORATORY

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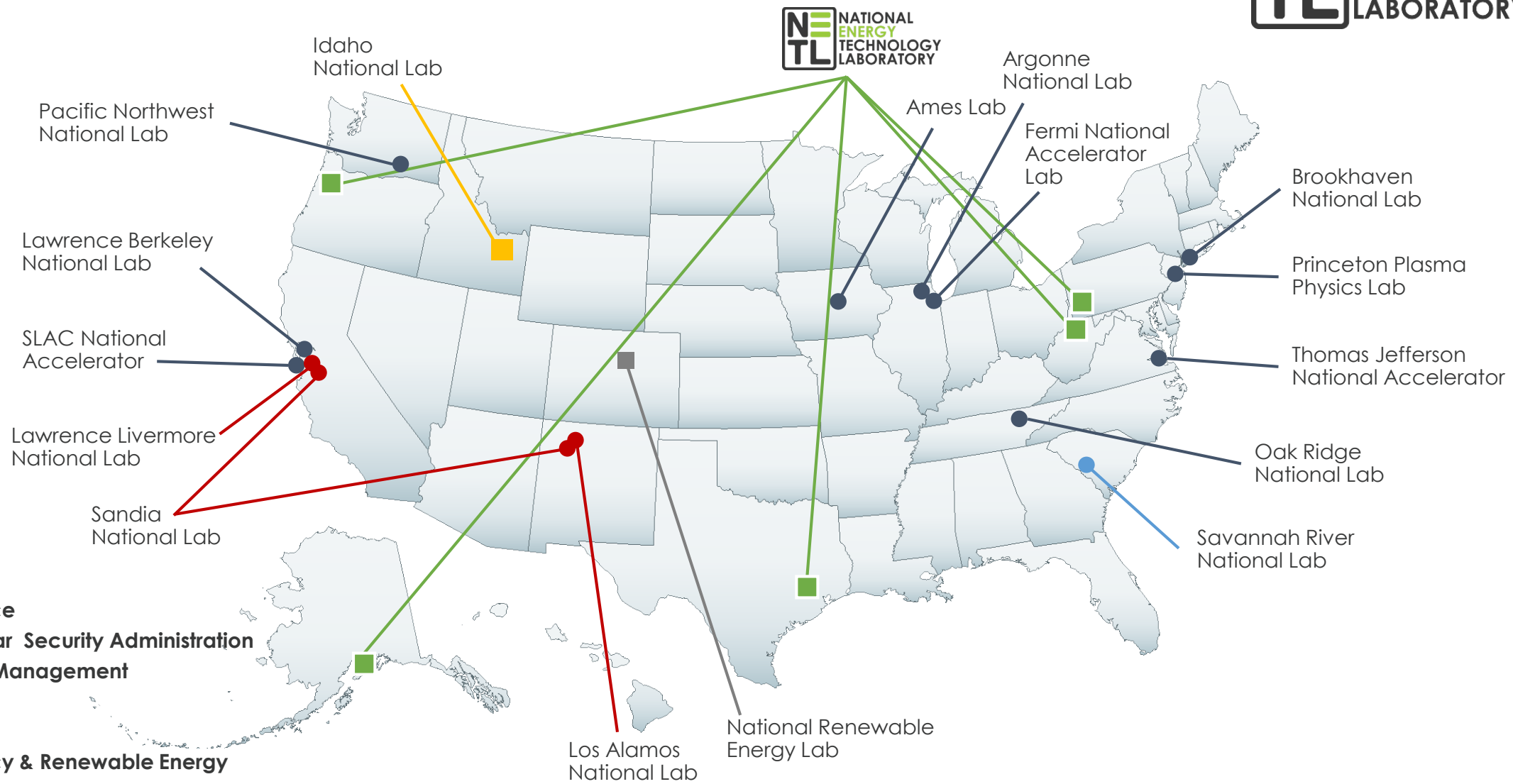
U.S. DOE, NETL

Maryland Energy Administration
CO_2 Sequestration Workshop
Tuesday November 19, 2019
Baltimore, Maryland

Solutions for Today | Options for Tomorrow

U.S. DEPARTMENT OF ENERGY

The National Laboratory System



NETL Snapshot

NATIONAL ENERGY TECHNOLOGY LABORATORY

NETL is…

900+ R&D projects/**50** states

3 labs across U.S.

$1.03B FY19 budget

Workforce

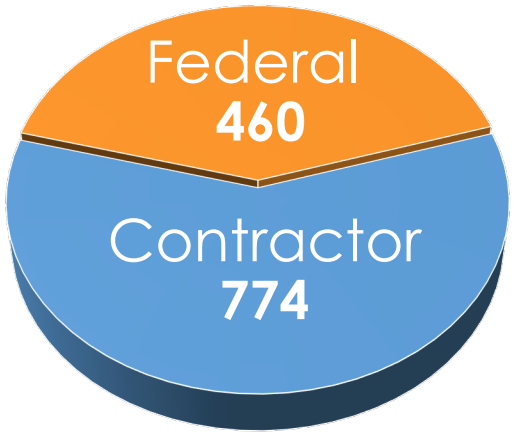
1,234 Full Time Equivalent Employees (FTEs)

78 Joint Faculty

124 Postdoctoral Researchers

101 Graduate Students

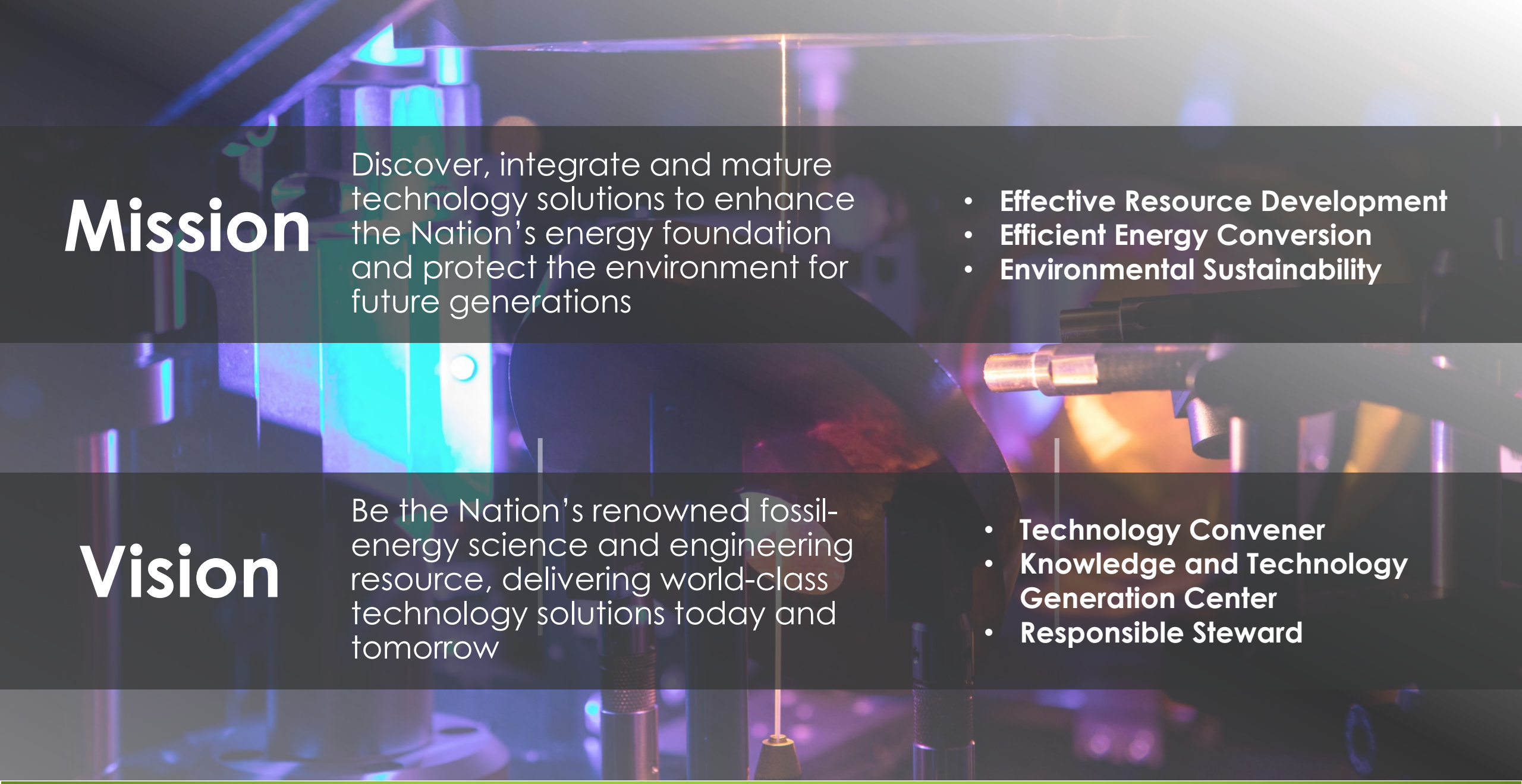
43 Undergraduate Students



FTE WORKFORCE

NETL possesses an array of authorities to manage & implement complex R&D programs

- Program planning, development, and execution
- Legal, Financial, Procurement and Head of Contracting Authority (HCA)
- Project Management Expertise



Mission

Discover, integrate and mature technology solutions to enhance the Nation's energy foundation and protect the environment for future generations

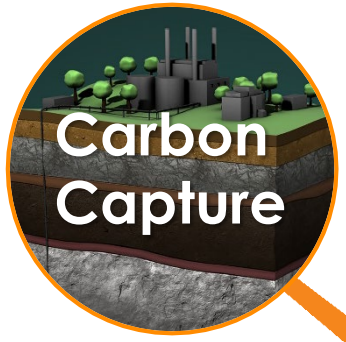
- **Effective Resource Development**
- **Efficient Energy Conversion**
- **Environmental Sustainability**

Vision

Be the Nation's renowned fossil-energy science and engineering resource, delivering world-class technology solutions today and tomorrow

- **Technology Convener**
- **Knowledge and Technology Generation Center**
- **Responsible Steward**

Integrated R&D Approach for Future Commercial-Scale Deployment



2017
Large Capture Pilots Initiated

2020
R&D Completed for Carbon Capture 2nd Generation Technologies

2025
Integrated CCS Projects initiated

2035
Advanced technologies available for broad commercial-scale deployment

2017
Initiate Storage Feasibility for Integrated CCS

2022
Commercial-scale storage complexes characterized

CCS and CCU Value Chains

Source: NETL, Cost and Performance Baseline for Fossil Energy Plants, Revision 3, July 2015

Analysis Capability Across the CCUS Value Chain

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CO_2 Capture

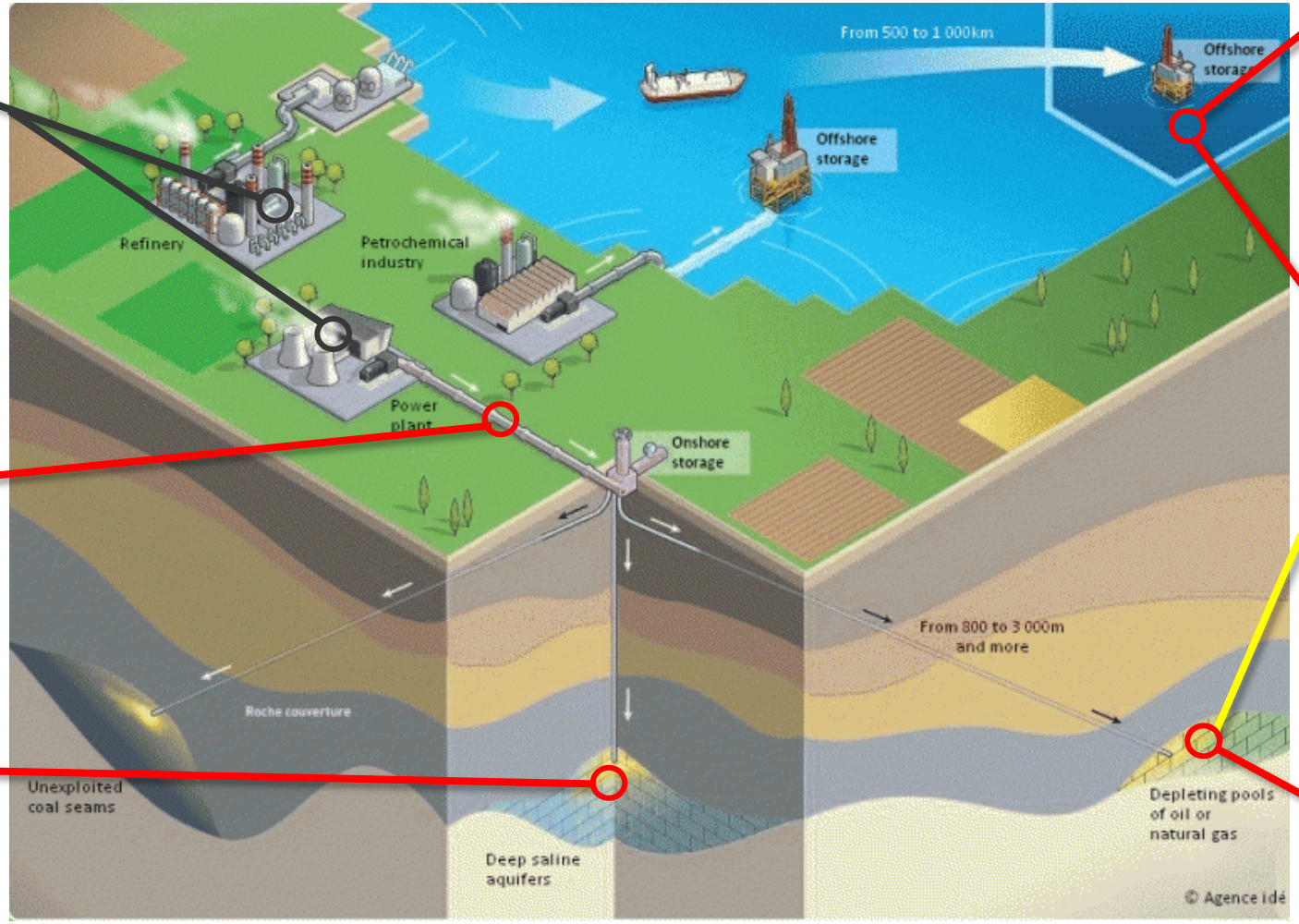
- NETL Cost of Capturing CO_2 from Industrial Sources
- NETL Baseline Studies for Fossil Energy Power Plants
- CCSI^2 Toolset

CO_2 Transport

FE/NETL CO_2 Transport Cost Model
SimCCS$^{2.0}$

CO_2 Storage

- FE/NETL CO_2 Saline Storage Cost Model
- NRAP risk assessment tools



Offshore CO_2 Storage

FE/NETL Offshore CO_2 Saline Storage Cost Model

Offshore CO_2 EOR

FE/NETL Offshore CO_2 EOR Evaluation Tool

CO_2 EOR Life Cycle

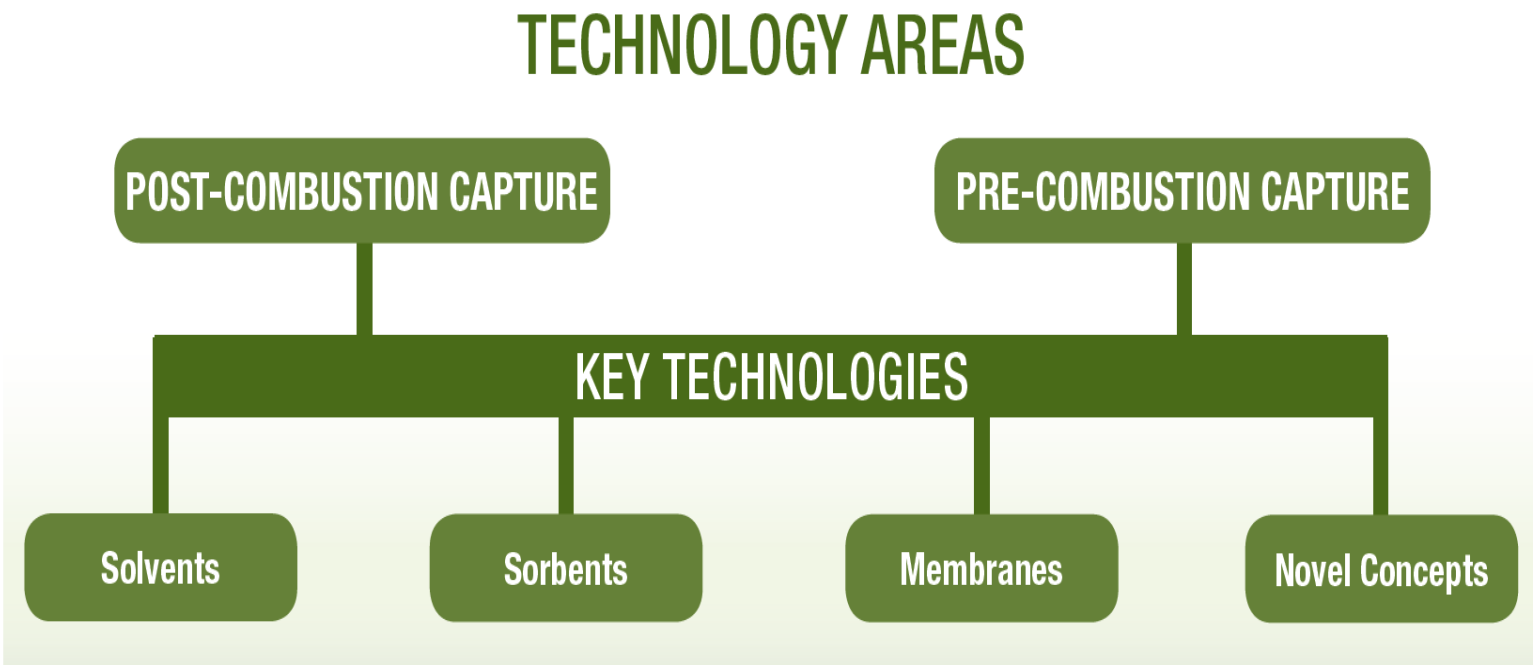
CO_2 EOR Life Cycle (CELiC) Model

CO_2 EOR

FE/NETL Onshore CO_2 EOR Evaluation Tool

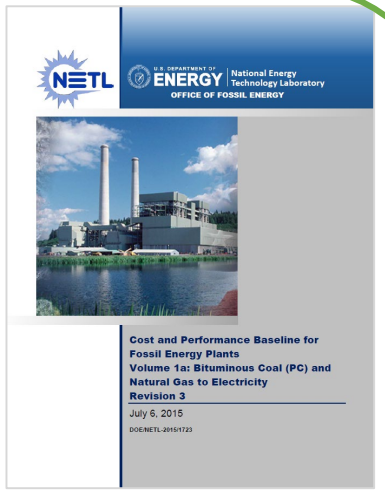
Image Source: Club CO_2 Website: http://www.captage-stockage-valorisation-co2.fr/en/ccus-glance#!prettyPhoto

CO_2 Capture



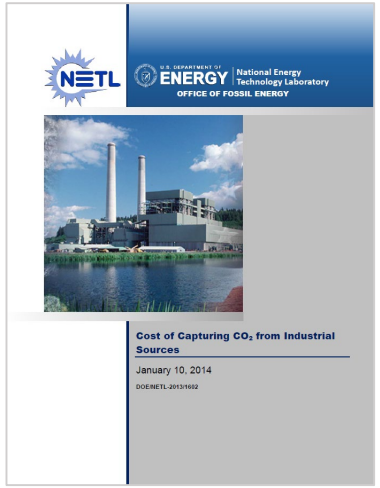
NETL Baseline Studies for Fossil Energy Power Plants

Publicly Available: https://netl.doe.gov/node/7512



NETL Cost of Capturing CO_2 from Industrial Sources

Publicly Available: https://www.netl.doe.gov/energy-analysis/details?id=1836



CCSI Toolset

Carbon Capture Simulation Initiative

www.acceleratecarboncapture.org

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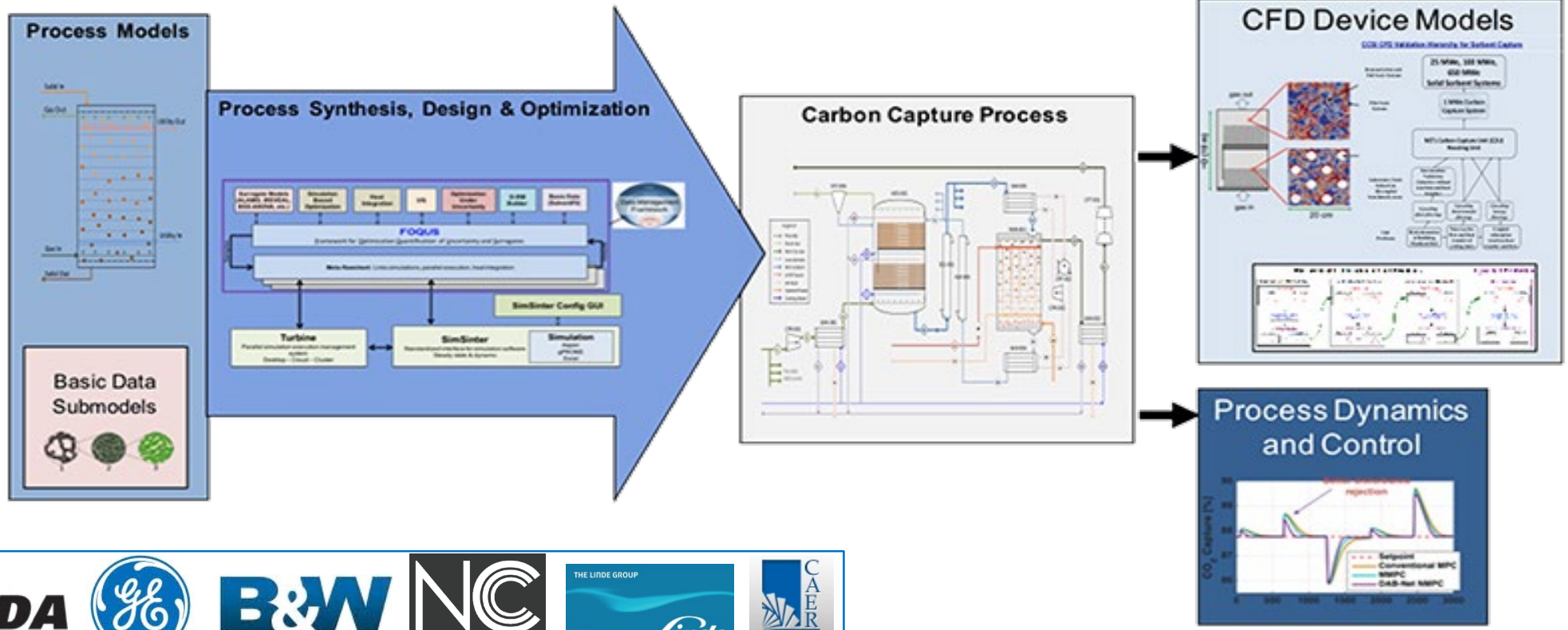

R&D 100 55 Years of Invention

carbon sequestration leadership forum

ADA ENVIRONMENTAL SOLUTIONS · GE · B&W thebabcock&wilcoxcompany · NC NATIONAL CARBON CAPTURE CENTER · THE LINDE GROUP Linde · CAER

Industry Collaborators

Open-source tools at: https://github.com/CCSI-Toolset/

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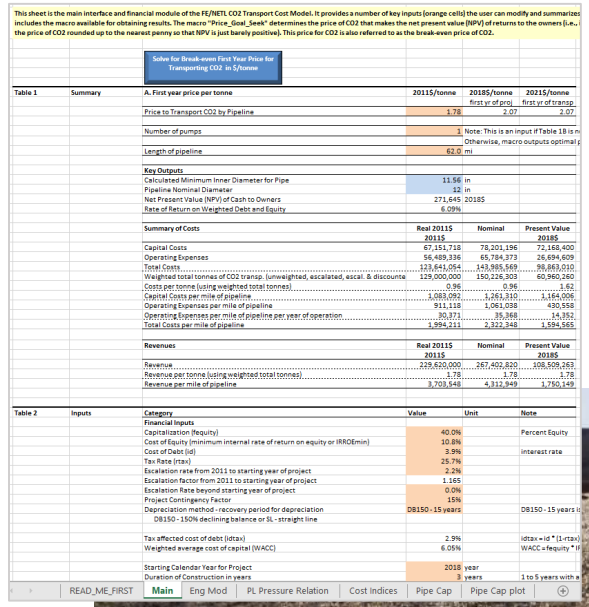
Carnegie Mellon · WestVirginiaUniversity · PRINCETON UNIVERSITY · BOSTON UNIVERSITY · THE UNIVERSITY OF TEXAS AT AUSTIN

Onshore CO_2 Pipeline Transport Cost

FE/NETL CO_2 Transport Cost Model

- Mimics CO_2 transport operations to estimate the costs associated with potential CO_2 pipeline project
- Point-to-point transport cost modeling
- Includes capital and operation and maintenance costs and project cash flows
- Latest updates: new financial parameters and methodology updated to obtain costs in real dollars



This sheet is the main interface and financial module of the FE/NETL CO2 Transport Cost Model. It provides a number of key inputs (orange cells) the user can modify and summarizes includes the macro available for obtaining results. The macro "Price_Goal_Seek" determines the price of CO2 that makes the net present value (NPV) of returns to the owners (i.e., the price of CO2 rounded up to the nearest penny so that NPV is just barely positive). This price for CO2 is also referred to as the break-even price of CO2.

Solve for Break-even First Year Price for Transporting CO2 in $/tonne

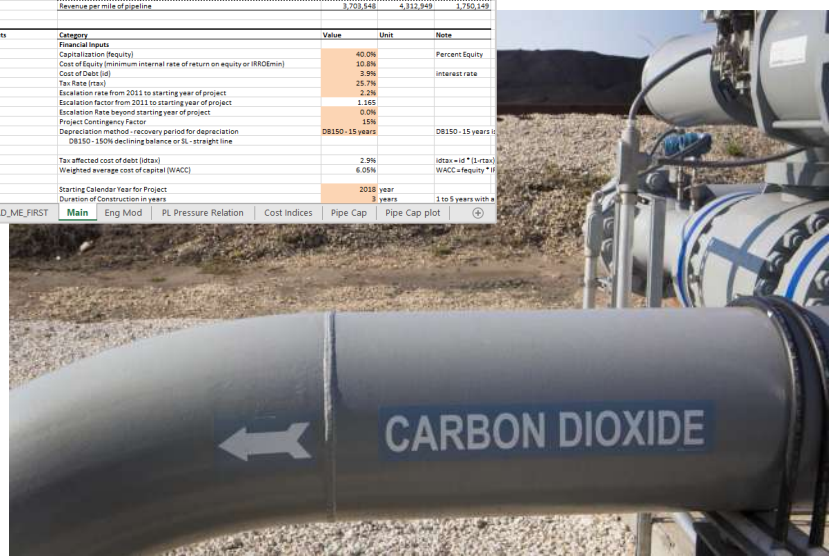
Table 1	Summary	A. First year price per tonne	2011$/tonne	2018$/tonne first yr of proj	2021$/tonne first yr of transp
		Price to Transport CO2 by Pipeline	1.78	2.07	2.07
		Number of pumps	1	Note: This is an input if Table 1B is n	
				Otherwise, macro outputs optimal p	
		Length of pipeline	62.0 mi		
		Key Outputs			
		Calculated Minimum Inner Diameter for Pipe	11.56 in		
		Pipeline Nominal Diameter	12 in		
		Net Present Value (NPV) of Cash to Owners	271,645 2018$		
		Rate of Return on Weighted Debt and Equity	6.09%		

		Summary of Costs	Real 2011$ 2011$	Nominal	Present Value 2018$
		Capital Costs	67,151,718	78,201,196	72,168,400
		Operating Expenses	56,489,336	65,784,373	26,694,609
		Total Costs	123,641,054	143,985,569	98,863,010
		Weighted total tonnes of CO2 transp. (unweighted, escalated, excl. & discounte	129,000,000	150,226,303	60,960,260
		Costs per tonne (using weighted total tonnes)	0.96	0.96	1.62
		Capital Costs per mile of pipeline	1,083,092	1,261,310	1,164,006
		Operating Expenses per mile of pipeline	911,118	1,061,038	430,558
		Operating Expenses per mile of pipeline per year of operation	30,371	35,368	14,352
		Total Costs per mile of pipeline	1,994,211	2,322,348	1,594,565

		Revenues	Real 2011$ 2011$	Nominal	Present Value 2018$
		Revenue	229,620,000	267,402,820	108,509,263
		Revenue per tonne (using weighted total tonnes)	1.78	1.78	1.78
		Revenue per mile of pipeline	3,703,548	4,312,949	1,750,149

Table 2	Inputs	Category	Value	Unit	Note
		Financial Inputs			
		Capitalization (fequity)	40.0%		Percent Equity
		Cost of Equity (minimum internal rate of return on equity or IRROEmin)	10.8%		
		Cost of Debt (id)	3.9%		interest rate
		Tax Rate (rtax)	25.7%		
		Escalation rate from 2011 to starting year of project	2.2%		
		Escalation factor from 2011 to starting year of project	1.165		
		Escalation Rate beyond starting year of project	0.0%		
		Project Contingency Factor	15%		
		Depreciation method - recovery period for depreciation	DB150 - 15 years		DB150 - 15 years i
		DB150 - 150% declining balance or SL - straight line			
		Tax affected cost of debt (idtax)	2.9%		idtax = id * (1-rtax)
		Weighted average cost of capital (WACC)	6.05%		WACC = fequity * if
		Starting Calendar Year for Project	2018 year		
		Duration of Construction in years	3 years		1 to 5 years with a

READ_ME_FIRST | Main | Eng Mod | PL Pressure Relation | Cost Indices | Pipe Cap | Pipe Cap plot



Publicly Available: https://netl.doe.gov/energy-analysis/details?id=543

Photo: Marie D. De Jesus, Staff / Houston Chronicle; Accessed 11/18/2019 from: https://www.houstonchronicle.com/business/energy/article/As-Congress-promotes-carbon-capture-lack-of-13064586.php

SimCCS$^{2.0}$

An open-source tool to optimize CO_2 capture, transport, and storage infrastructure

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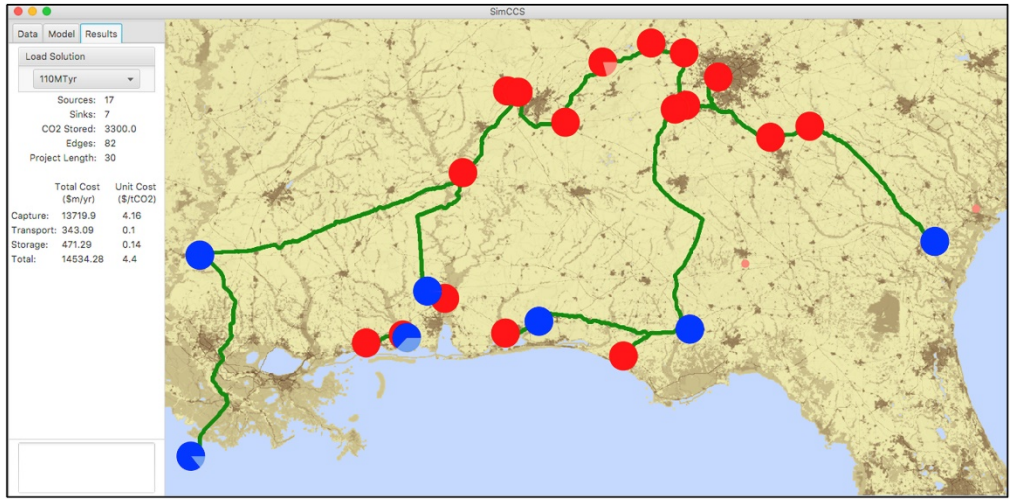
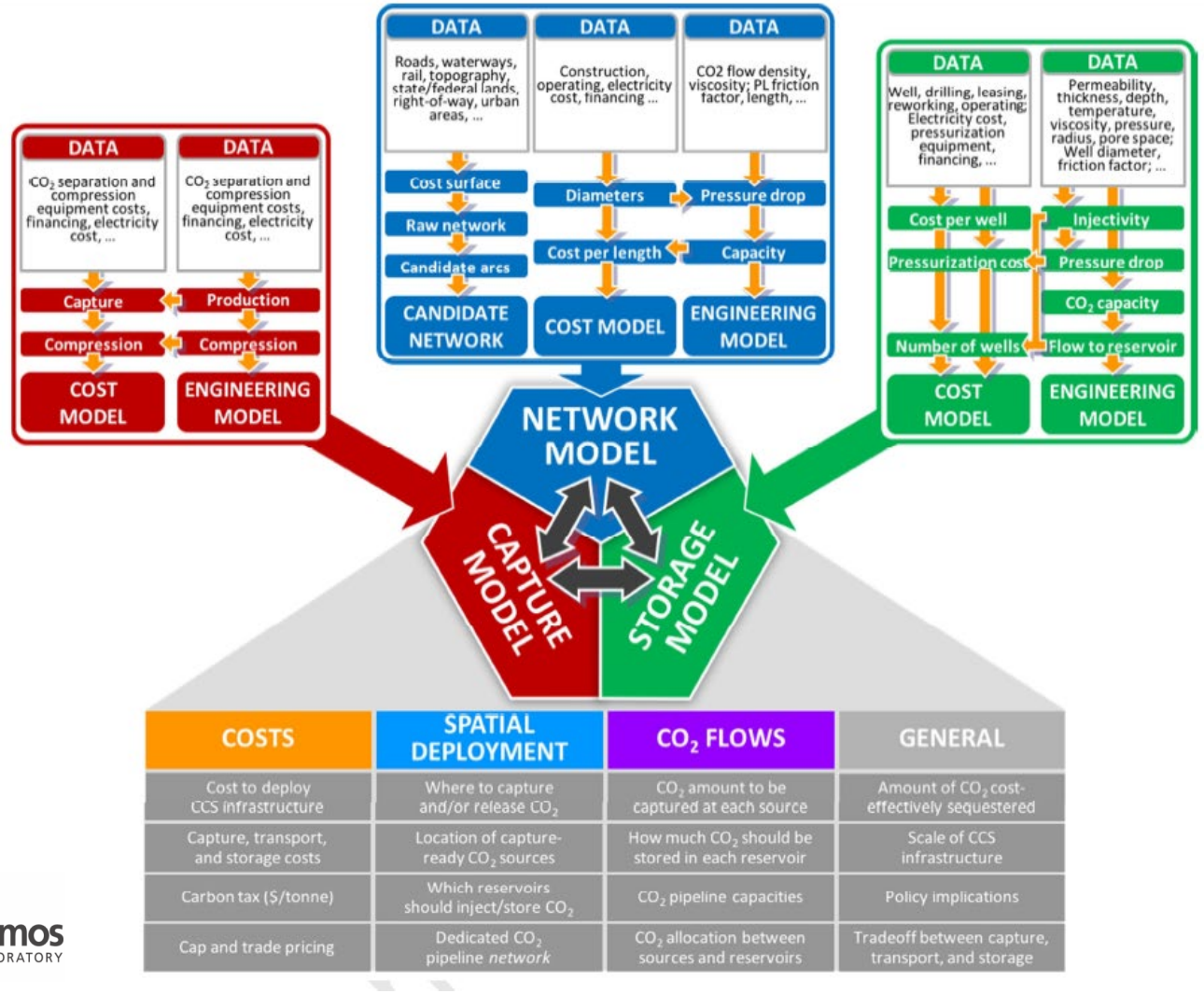
Enables stakeholders to design CCS infrastructure networks.





https://github.com/SimCCS/SimCCS

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Middleton et al. (2019) SimCCS: An open-source tool for optimizing CO2 capture, transport, and storage infrastructure. *Environmental Modelling & Software. In press*

Carbon Storage Programmatic Structure
Technical Priorities

- Predicting and monitoring CO_2 plume and brine pressure front movement, stabilization, and impacts.
- Optimization of reservoirs for CO_2 storage capacity.
- Developing and validating risk-assessment strategies.
- Mitigating risks, such as leakage from old wells and induced seismicity.
- Carrying out (large-volume and Fit-for-Purpose) field tests for different storage types and depositional environments.