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Risk Assessment

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Storage in Saline Formations R&D Workshop

Core R&D Goals – Table 3-8

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NETL[1] Carbon Sequestration Technology Program Plan

Simulation and Risk Assessment Objective	Description/Application	Research Focus
Risk Assessment, Identification, and Quantification	Risk assessment is the systematic identification of features, events, or processes (FEPs) … … potential "pathways" … … consequences.	1. Develop standard processes for risk assessment. 2. Develop risk assessment databases for FEPs to predict risk and impacts in different types of geologic formations. 3. Compare the predictive methods against observations to demonstrate reliability and accuracy as well as to reduce uncertainties. 4. Integrate risk assessment with simulation, operation design, and monitoring activities to optimize performance.

[1]National Energy Technology Laboratory

Core R&D Goals – Table 3-8

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Research Focus for Risk Assessment
1. Develop standard processes for risk assessment.
2. Develop risk assessment databases for FEPs to predict risk and impacts in different types of geologic formations.
3. Compare the predictive methods against observations to demonstrate reliability and accuracy as well as to reduce uncertainties.
4. Integrate risk assessment with simulation, operation design, and monitoring activities to optimize performance.

Core R&D Goals – Table 3-8

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Research Focus
1. Develop standard processes for risk assessment.
• Well developed yet different processes in use: by Schlumberger Carbon Services, Quintessa, DNV, URS; Shell, BP, others • Variety is good; a single standard process would impede thoroughness in Risk ID and would engrain gaps in perception • Recommendation: Instead, catalog, characterize, and set performance criteria for the available processes

Scoring FEPs

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3rd : Lbg, Likelihood of Sbg

2nd : Sbg, "Best-Guess" Severity

1st : Sub, "Upper Bound" Severity

	FEP Class	sq	Feature, Event, Process	FEP Description	Notes and Scenarios	Sub	Sbg	Lbg
46	Setting - surface	1	**Climate and Weather At Project Site**	Weather and climate at the project site entail hazards and operational challenges. Human health and safety, mechanical operations, and fluid phase may be affected. Weather may affect travel to site or to offsite monitoring locations. I n the long run, climate change (e.g. in flood-prone areas) could affect operations.				
33	Setting - surface	2	**Land and Water Use**	Land and water use by humans in the near-surface environment may have implications for CO2 leakage, contaminant transport, and exposure pathways. This includes uses of natural or semi-natural tracts of land and water, rural and agricultural lands and waters, and urban and industrial land, and includes recreational and productive uses.				
76	Setting - surface	3	**Infrastructure: Surface and Shallow**	Existing roads, pipelines, and utilities near the project site may be vulnerable to project activities and may raise operational or siting conflicts. Pipelines and power lines present hazards if their locations are poorly known.				
25	Setting - people	4	**Community Characteristics**	Features related to characteristics, behavior, and lifestyles (economic, recreational, and other aspects) of the population near a project site. Community characteristics may imply specific cultural attributes, impact types, or exposure paths that affect the choice of project site.				

Severity and Likelihood Scales on Risk Matrix

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During the Project negative impact related to this risk element would be ...		
	Verbal Expression	Semi-Quantitative Probabilities
1	Very Unlikely	≤ 1%
2	Unlikely	≤ 3%
3	Medium Likelihood	≤ 10%
4	Likely	≤ 30%
5	Very Likely	≤ 90%

Project Values	Value	Health & Safety	Environment	Schedule	Financial	Reservoir Suitability	Storage Security	Capacity Building	Societal Acceptance
	Goal	No lost days due to health or safety incidents.	No adverse environmental impacts.	Maintain project schedule.	Execute project within financial budget.	Demonstrate CO_2 injection into a deep saline formation, at industrial-scale rates and volumes.	Demonstrate containment of injected CO_2 within the intended reservoir volume.	Build industrial ability to conduct CCS by conducting and disseminating industry-leading research.	Public buy-in of project.
Light	-1	Minor Injury or Illness, First Aid	Minor Temporary Impact Limited to Project Worksite	<1 month delay to injector spud; need speedup to enable injecting by end 2012	<$100 K	Temporary limited issues with injectivity	Of the multiple measurement techniques the project uses to show containment, one is inconclusive.	Limited, temporary loss of ability to collect, store & disseminate project knowledge	Individuals opposed to project
Serious	-2	Temp. Disability, Hospital to 1 day, Lost Days 1-100	Significant Temporary Impact On or Near Project Worksite	1-3 month delay to injector spud; severe speedup to enable injecting by end 2012	$100-500 K	Lower than expected capacity at chosen site impacts long-term injectivity	Either direct-detection or modeling fails to show containment.	Limited permanent or significant temporary loss of ability to collect, store & disseminate project knowledge	Local allegations of unethical practice or mismanagement
Major	-3	Perm. Disability, Lost Days >100, Intensive Care >1 day	Significant Long-Term Impact On or Near Project Worksite	3-9 month delay to injector spud; delay injection readiness to mid-2013	$500K-2 M	Reservoir quality marginal at chosen site for commercial scale injection rate or volume	Both direct-detection and modeling fail to show containment.	Significant permanent loss of ability to collect, store & disseminate project knowledge	Majority local opposition or substantial negative local media coverage
Catastrophic	-4	Fatality	Significant Long-Term Impact to 1/4 sq mi	9-15 month delay to injector spud; delay injection readiness to late 2013	$2-7 M	Chosen site is unsuitable for commercial scale injection rate or volume	Strong suspicion of impactful leakage; weak or no data to show otherwise.	Failure to disseminate knowledge outside of project	Int'l media coverage of violations, questionable ethics, or mismanagement
Multi-Catastrophic	-5	Multi-Fatality	Major Long-Term Impact > 1/4 sq mi	>15 month delay to injector spud or project canceled due to schedule impacts	>$7 M	Chosen site is unsuitable for both commercial scale injection and pilot testing	Significant persistent CO_2 leak to groundwater or surface.	*Project actually reduces the amount of knowledge in the world (knowledge sequestration).*	Widespread demand for legal ban on similar projects

-25 to -20	BLACK	NON-OPERABLE:	Evacuate the zon	area/country
-16 to -10	RED	INTOLERABLE:	Do not take this	
-9 to -5	YELLOW	UNDESIRABLE:	Demonstrate AL	efore proceeding
-4 to -2	GREEN	ACCEPTABLE:	Proceed careful	continuous improvement
-1	BLUE	NEGLIGIBLE:	Safe to pro	

MITIGATION

Control Measures

PREVENTION

LIKELIHOOD

SEVERITY

		Improbable 1	Unlikely 2	Possible 3	Likely 4	Probable 5
Light	-1	-1 1L	-2 2L	-3 3L	-4 4L	-5 5L
Serious	-2	-2 1S	-4 2S	-6 3S	[illegible]	-10 5S
Major	-3	-3 1M	-6 2M	-9 3M	-12 4M	-15 5M
Catastrophic	-4	-4 1C	-8 2C	-12 3C	-16 4C	-20 5C
Multi-Catastrophic	-5	-5 1MC	-10 2MC	-15 3MC	-20 4MC	-25 5MC

White arrow indicates decreasing risk

“Keypoint” keypads and software (ppt add-in)

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Reply Mini Plus Keypad

S_{bg}, FEP #1

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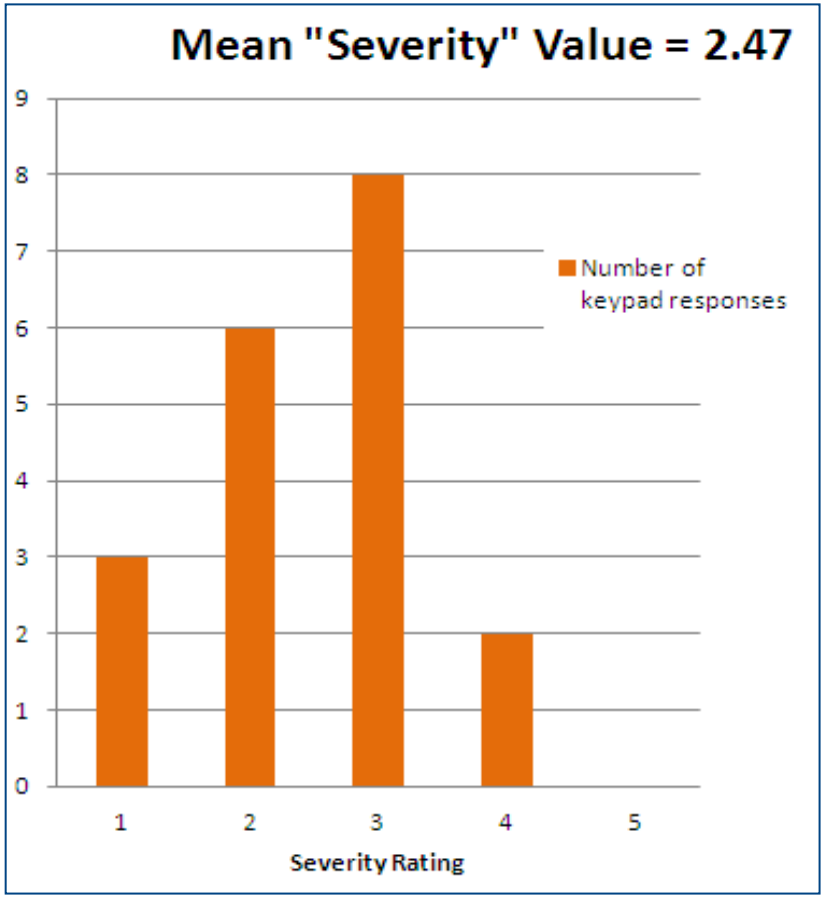
Best-Guess Severity of negative impacts to project values

1. 1
2. 2
3. 3
4. 4
5. 5

S_{bg}: What is your Best-Guess Severity of potential negative impacts associated with this FEP?



Core R&D Goals – Table 3-8

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Research Focus
2. Develop risk assessment databases for FEPs to predict risk and impacts in different types of geologic formations.
• Carbon Services' internal databases: >300 FEPs, 934 scenarios, and 1027 risk reduction actions • Size is easy. Refining and mining are not. • Needs: Semantics tools, utilities for linkages.

Core R&D Goals – Table 3-8

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Research Focus
4. Integrate risk assessment with simulation, operation design, and monitoring activities to optimize performance.
• Develop and articulate practices for risk assessment "early and often" • Expand "simulation" to cover entire integrated storage systems – including human and decision factors • Add "… and contingency planning" to the list

Core R&D Goals – Table 3-8

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Research Focus
3. Compare the predictive methods against observations to demonstrate reliability and accuracy as well as to reduce uncertainties.
• Pertains to simulations, to risk analysis … what are suitable performance criteria for Risk Assessment? • Recommendation? Develop metrics for thoroughness in Risk Assessment

HAVE WE IDENTIFIED

ALL

THE RISKS?

Ways to Subdivide the Universe of Risk

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a) Project Phases

b) Areas of Professional Expertise

c) Project Values (Risk Receptors or Targets)

d) Scenarios

e) FEPs (Features, Events, and Processes)

Subdivision Scheme (a): Project Phases

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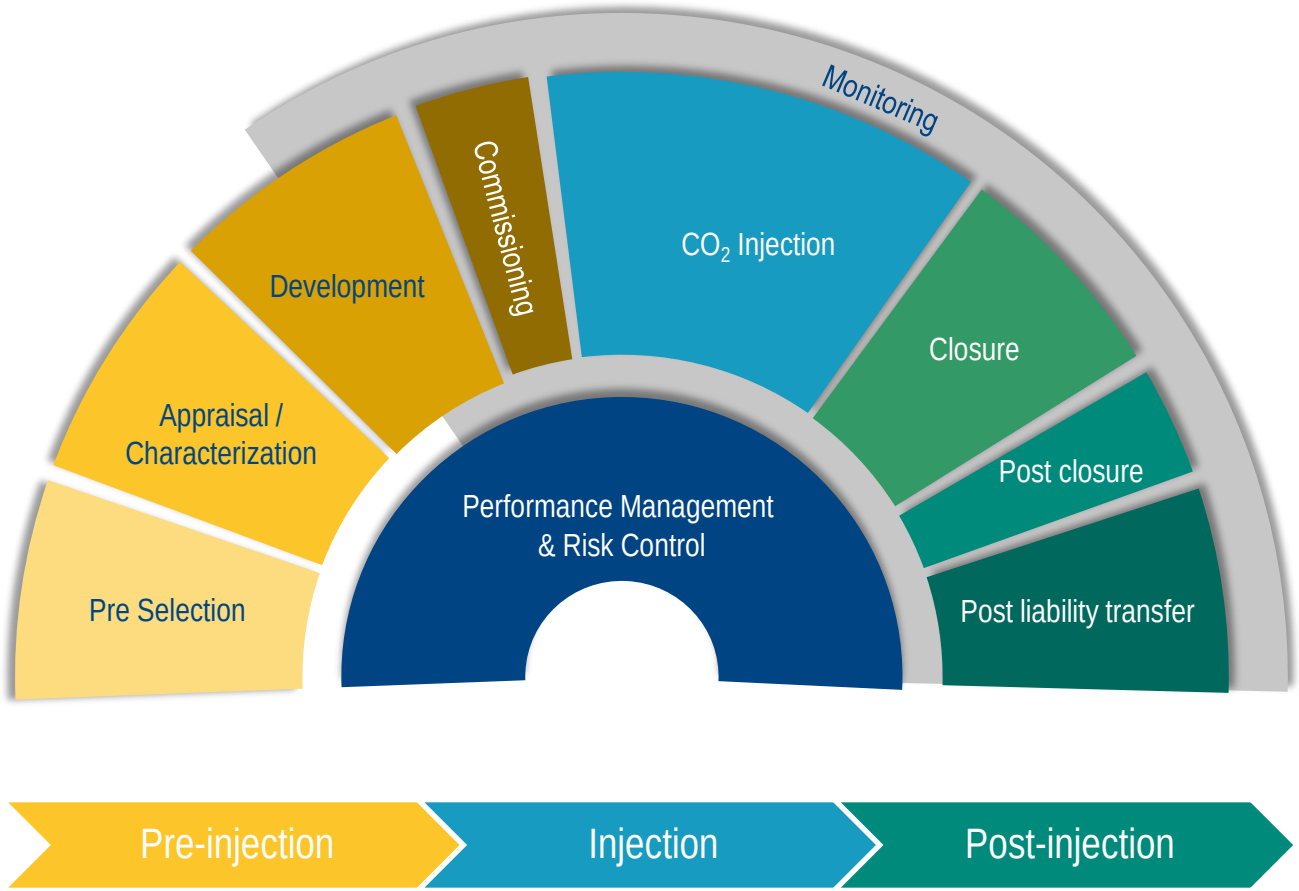

CarbonWorkFlow © mark of Schlumberger

Subdivision Scheme (b): Areas of Expertise

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	100	88	86	83	70	85	63	62	Group Skills
Individual Participants	***Measuremt & Modeling***	***Geology***	***CO2 Injection Effects***	***Well Operations***	***Surface Physical Setting***	***Project Mgmt***	***Legal & Regulatory***	***Cultural Setting***	*Areas of Expertise*
Manager 1	5	3	3	4	4	5	0	5	
Permit Spec. 2	0	5	0	5	5	0	5	5	
Manager 4	1	2	1	3	4	5	5	4	
Communicator 2	1	2	2	2	4	4	4	4	
Data Manager 1	3	4	2	1	3	4	2	4	
Geochemist 3	5	4	5	2	2	4	4	4	
Communicator 1	1	1	1	1	1	3	1	4	
Local Stakeholder 1	1	2	1	2	3	1	1	4	
Economist 2	0	0	1	0	2	4	1	3	
Permit Spec. 1	2	2	2	2	3	4	4	3	
Manager 3	5	3	4	2	3	4	2	3	
Geologist 3	4	5	4	4	3	3	3	3	
Economist 1	5	1	3	0	1	2	2	3	
Geologist 4	2	5	4	4	4	1	0	3	
Engineer 1	4	0	5	4	2	5	3	2	
Geophysicist 2	5	3	5	3	2	3	2	2	
Manager 2	3	3	3	5	1	4	2	1	
Geochemist 1	4	4	4	2	3	4	0	1	
Geologist 2	5	5	4	4	1	4	3	1	
Regulator 2	1	1	2	2	2	1	4	1	
Monitoring Spec. 1	4	2	3	1	2	1	0	1	
Geochemist 2	1	4	4	1	3	0	0	1	
Regulator 1	2	5	3	3	4	4	5	0	
Risk Manager 1	3	5	3	3	2	4	3	0	
Hydrogeologist 1	5	4	5	4	1	4	3	0	
Well Spec. 1	3	3	4	5	1	2	2	0	
Monitoring Spec. 3	5	1	4	3	1	2	1	0	
Geophysicist 1	5	4	4	4	0	2	1	0	
Geologist 1	5	5	0	3	0	1	0	0	
Monitoring Spec. 2	5	0	0	0	3	0	0	0	
Petrophysicist 1	5	0	0	4	0	0	0	0	

Subdivision Scheme (c): Project Values

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Project Values Applied to Risk Evaluation	Value	Project Management	Safety & Health	Environment	Reservoir Characterization	Monitoring	Stakeholder Relations
	Goal	Plan and execute within budget and on schedule; manage risk comprehensively and effectively.	No lost days due to health or safety incidents.	No adverse environmental impacts.	Evaluate ability of reservoir formation to accept and retain commercial-scale volumes of CO_2.	Monitoring and simulation give robust tracking of injection effects and strong guidance for future projects.	Public support and regulatory approval of project.

Subdivision Scheme (d): Scenarios

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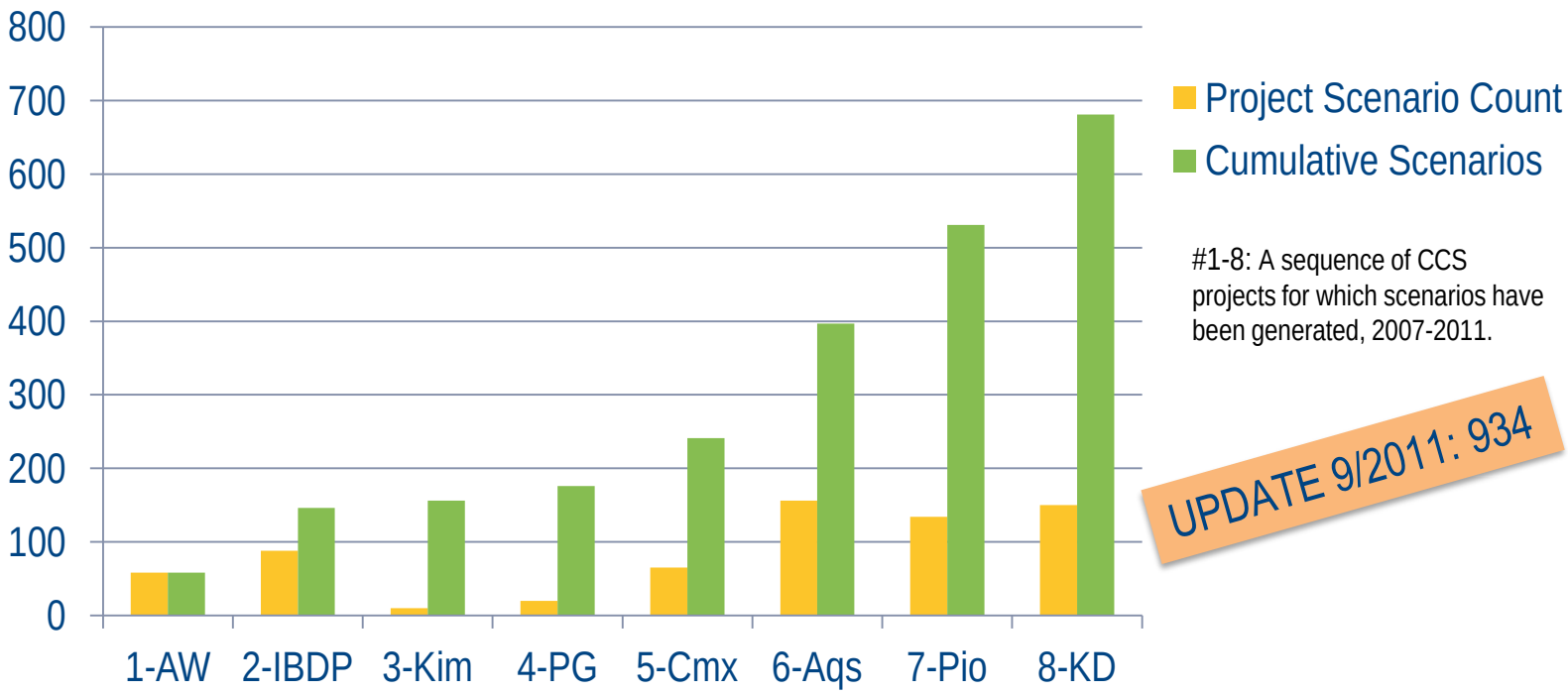
- Scenarios are complete, concrete, and narrow; “complete sentences”
- The number of plausible scenarios is infinite.
- The number of *important* plausible scenarios is …?



#1-8: A sequence of CCS projects for which scenarios have been generated, 2007-2011.

UPDATE 9/2011: 934

FEPs Are Conceptual, Scenarios are Concrete

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FEPs	Scenarios
General & Conceptual	Specific & Concrete
Nouns +/- adjectives	Complete Sentences: subject, verb, & object
Overlapping; even redundant	Well Bounded
Can "paint the universe"	N Scenarios ⇨ N^x gaps?
Conducive to broad thinking of connections, relationships, integration	Conducive to focused thinking through of isolated chains of events
Durable / Eternal / Persistent (F's & P's)	Interruptible / Preventable / Mitigable
Correlation	Causation

Subdivision Scheme (e): FEPs

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- Features, Events, and Processes
- Any *thing* (concept) that is relevant to the project,
  or at least relevant to project risk
- FEPs are broad enough to overlap;
  are they broad enough to “paint the entire conceptual universe”?

FEP Categories: Quintessa / IEAGHG, 2007-present

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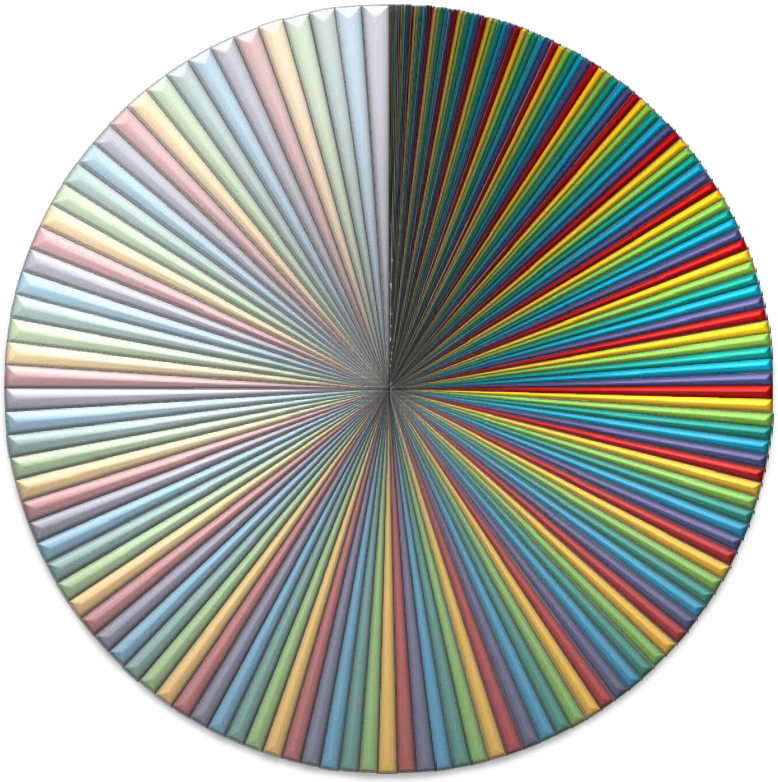
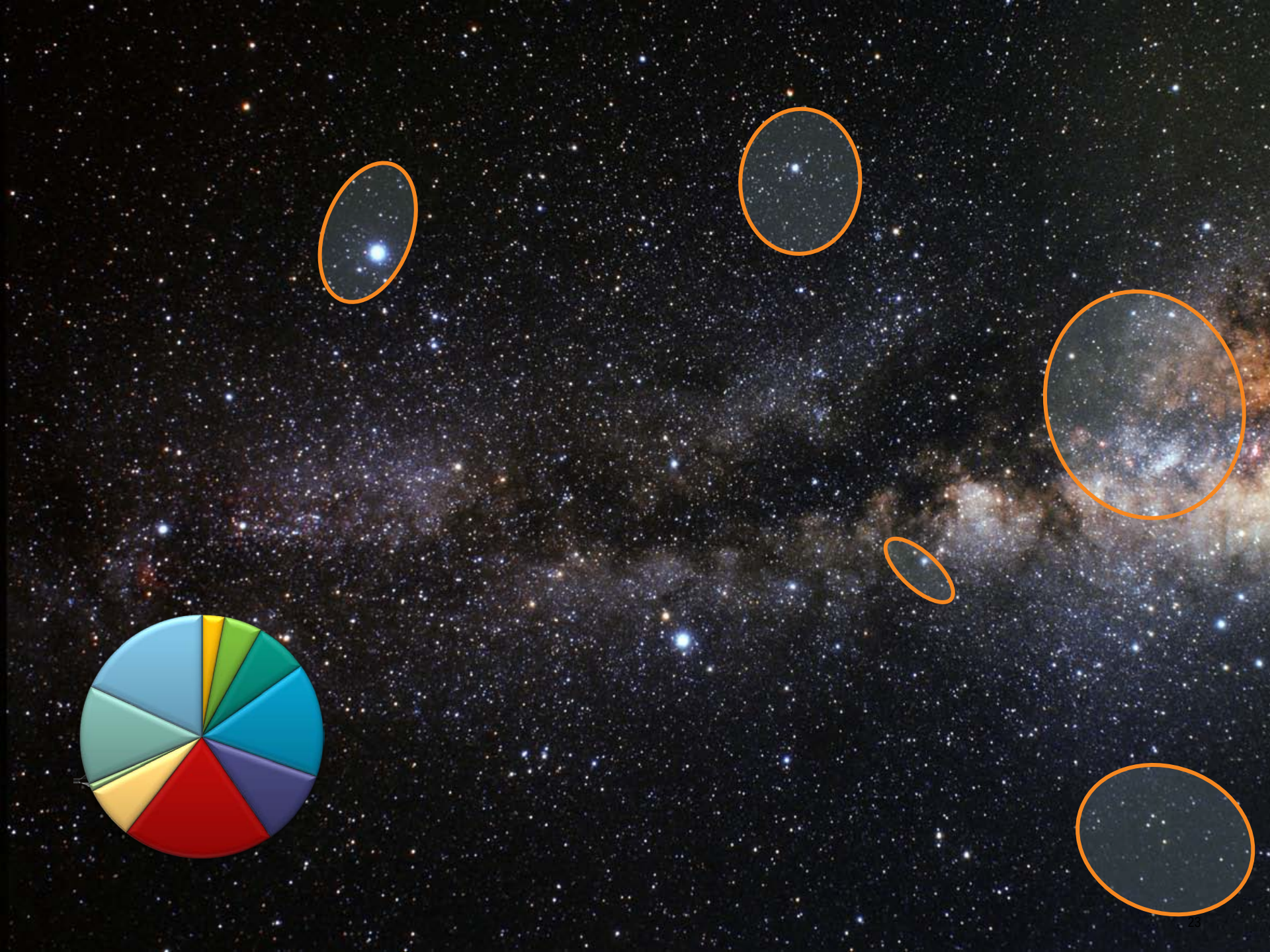
8 Categories of FEPs

- Basis
- External Factors
- CO2 Storage
- CO2 Properties, Interactions, and Transport
- Geosphere
- Boreholes
- Near-Surface Environment
- Impacts

Individual FEPs: Quintessa / IEAGHG, 2010



179 individual FEPs.