Contribution of STAMP to the Risk Management of CO_2 Capture, Transport and Storage Projects

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   - CTSC, Climate Change, Risks & Risk Management
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Research Question

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Is the safety control structure of CTSC projects effective enough?

In which context and why some CTSC projects are more successful than others?

A systemic approach is proposed for Risk Management of CTSC projects.

CTSC & Climate Change (1/2)

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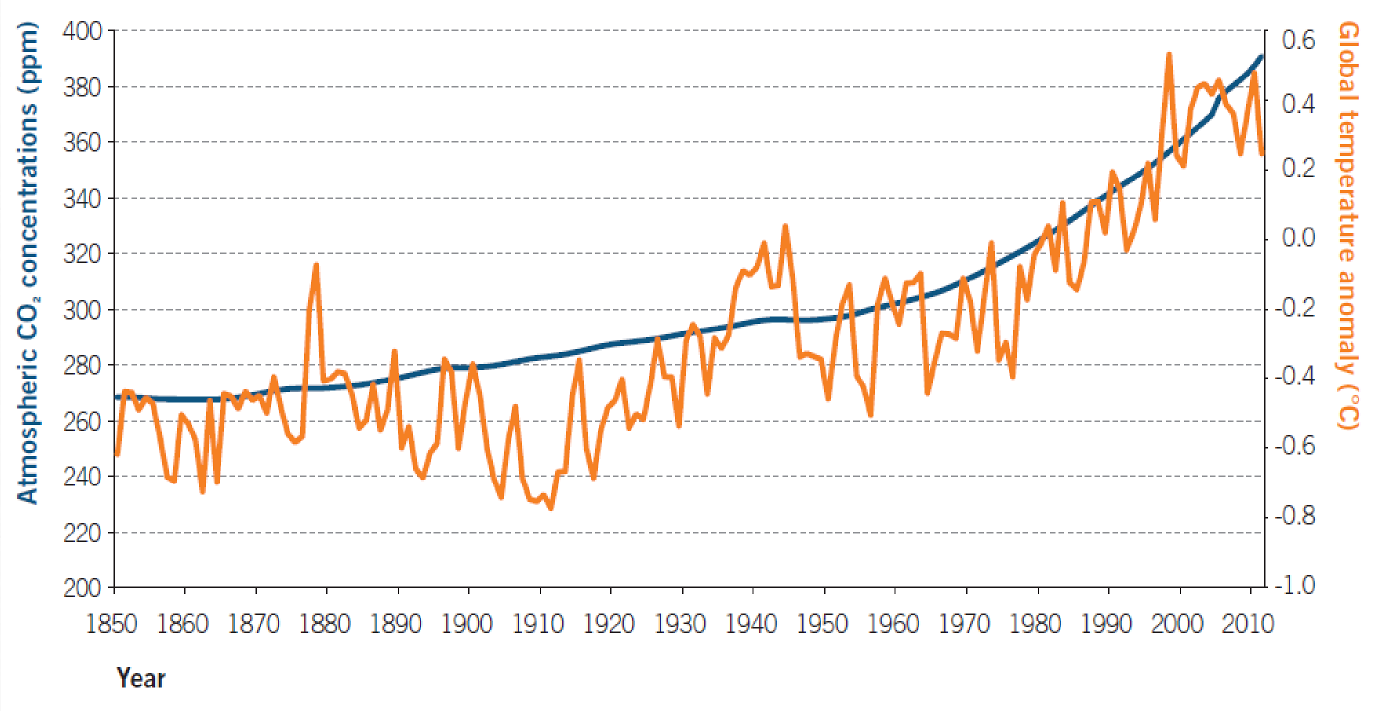

[GCCSI, 2011]

CTSC & Climate Change (2/2)

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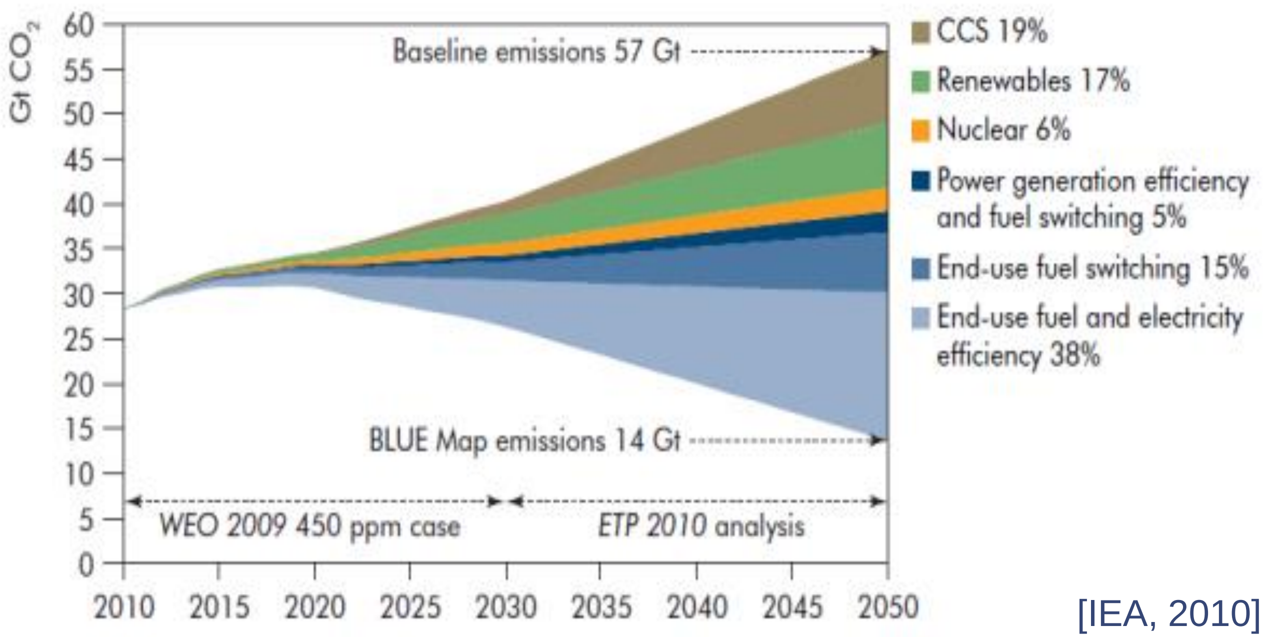

[IEA, 2010]

Objective: halving the emissions by 2050 (compared to the current amount ~ 390 ppm)

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CTSC Chaire d'enseignement et de recherche Captage, Transport et Stockage du CO_2

CTSC Technology

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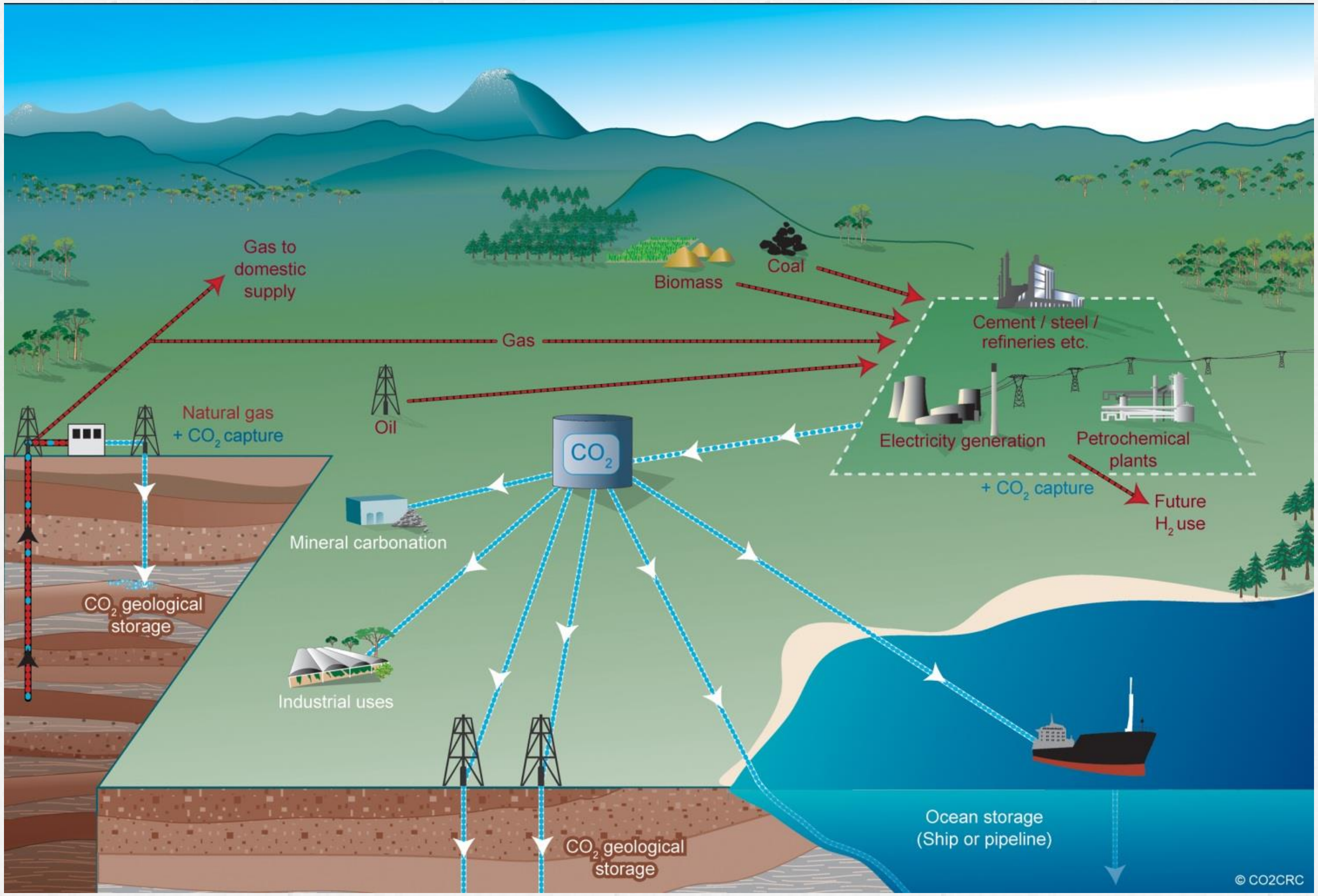

[IPCC, 2005]

CTSC Projects Current Status

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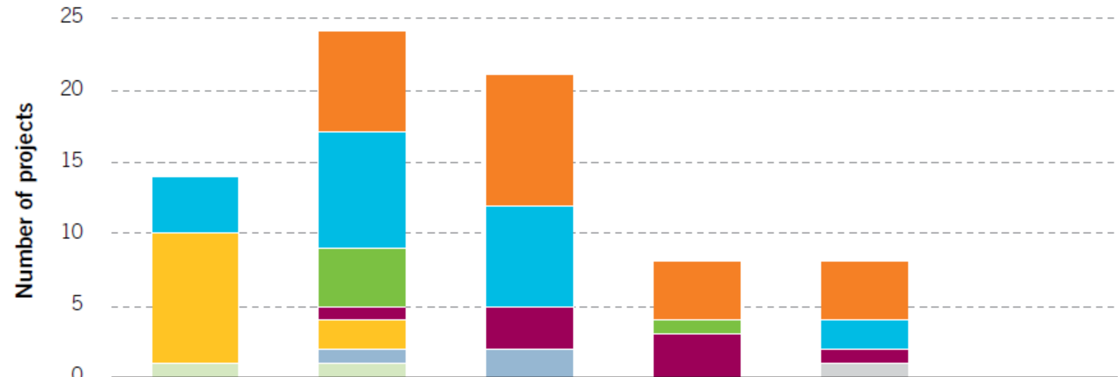

	Identify	Evaluate	Define	Execute	Operate	**Total**
United States	0	7	9	4	4	**24**
Europe	4	8	7	0	2	**21**
Australia and New Zealand	0	4	0	1	0	**5**
Canada	0	1	3	3	1	**8**
China	9	2	0	0	0	**11**
Middle East	0	1	2	0	0	**3**
Other Asia	1	1	0	0	0	**2**
Africa	0	0	0	0	1	**1**
Total	**14**	**24**	**21**	**8**	**8**	**75**

[GCCSI, 2012]

Most (10/16) of the operational projects: EOR

CTSC & Risks (1/2)

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- CO_2 Capture Risks:
  - Vent gas
  - Liquid & solid wastes
  - Impurities such as H_2S, SO_x, NO_x, N_2, O_2, H_2O => Corrosion

- CO_2 Transport Risks, depends on:
  - Transportation mode
  - Local topography
  - Meteorological conditions
  - Population density
- Most significant issues:
  - Leakage
  - Corrosion (Impurities)

- CO_2 Storage Risks:
  - Local risks, e.g. human beings, animals & plants, and potable water sources
  - Global risks: CO_2 atmospheric release

CTSC & Risks (2/2)

1. Research Question
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- It is essential to analyze the risks associated to CTSC whole chain.
- Eight major risk categories are identified.

Long term reliability of the technology

↓

Acceptability of CTSC projects

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Requirement of a novel systemic approach

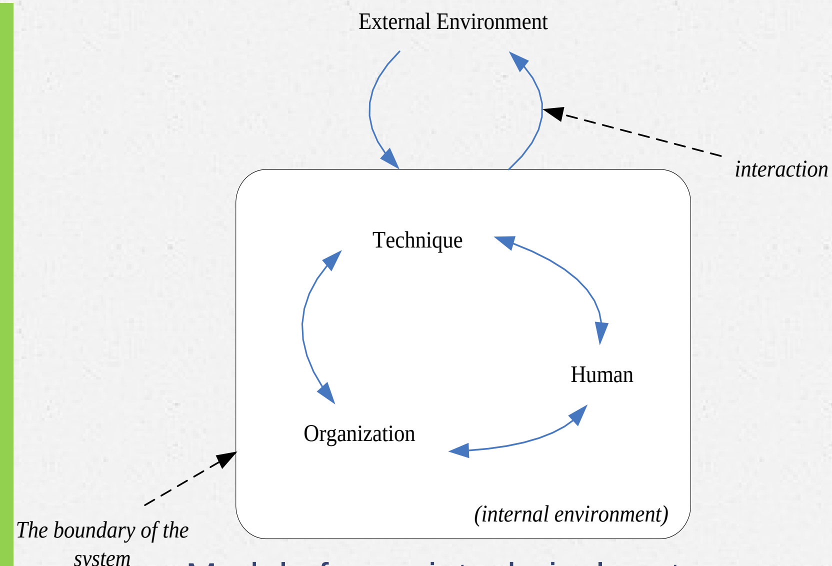
CTSC is a complex sociotechnical system

Complex System:

"composed of many parts that interact with and adapt each other."

"the behavior cannot be adequately understood by only studying their component parts, because the behavior arises through the interactions among those parts."

[IRGC, 2010]



Model of a sociotechnical system

A systemic approach is necessary to identify & analyze the risks affecting CTSC projects and their interconnections.

Proposed Methodology, Outline

1	• Research Question
2	• Context
3	• Proposed methodology & Application
4	• Conclusions

1. Identifying major risks associated to CTSC (according to literature review, projects documentation and discussion with experts)
2. Assigning the risks to different CTSC subsystems and project phases
3. Defining the nature of risks and their consequences
4. Extracting the risks related to the very first phases of the project
5. Modeling the major risks using a systemic approach
6. Applying the systemic approach to model the safety control structure of different case studies

1: Identifying major risks

- 1 Research Question
- 2 Context
- 3 Proposed methodology & Application
- 4 Conclusions

1

- Identifying major risks associated to CTSC (according to literature review, projects documentation and discussion with experts)

Overview of risks affecting CTSC project progress			
1	Project permits not obtained	21	BLEVE
2	Technology scale-up	22	Lack of financial resources
3	Public Opposition	23	Lack of political support
4	Lack of knowledge/qualified resources for operating the unit	24	Phase change & material problems
5	Corrosion	25	High cost of project
6	Using the existing facilities (specially pipelines)	26	Lower Capture efficiency due to the upstream plant flexible operation
7	CO_2 out of specification	27	CO_2 leakage from compression unit
8	CO_2 plumes exceed the safe zone	28	Pipeline construction
9	Legal uncertainties	29	CO_2 leakage from pipeline
10	Safety related accident	30	Unavailability of regulations regarding different types of storage (offshore/onshore)
11	Uncertainties in stakeholders requirements/perceptions - Communication problems	31	Leakage through manmade pathways such as abandoned wells
12	Public availability of sensitive information	32	Well integrity
13	Change in policies/priorities	33	CO_2 migration
14	Financial crisis impact on financial support of CCS projects	34	Injectivity reduction over time
15	Unavailability of a monetary mechanism for CO_2	35	Uncertainties regarding the storage performance (capacity/injectivity/containment)
16	Construction field conditions	36	CO_2 leakage from storage to the surface
17	Geographical infrastructure	37	Model and data issues
18	Proximity to other industrial plants	38	Uncertainties related to storage monitoring
19	Energy consumption	39	Soil contamination
20	Maintenance and control procedures (including ESD system)		

A list of 39 risks

Examples:

1. Project permits not obtained

3. Public Opposition

22. Lack of financial resources

2: Risks, CTSC subsystems & project phases

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2 • Assigning the risks to different CTSC subsystems and project phases

RISK	SUBSYSTEM	AFFECTED PROJECT PHASE
Example: Project permits not obtained	C	Opportunity
	T	Definition and Planning
	S	Engineering
	W	Construction
		Operation (Injection of CO_2)
		Post-injection (Monitoring)

3: Nature of Risks & Consequences

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3 • Defining the nature of risks and their consequences

RISK	SUBSYSTEM	RISK NATURE	NATURE OF CONSEQUENCES
Example: Project permits not obtained	C	T	T
	T	P	P
	S	S	S
	W	P/S	P/S
		HSE	HSE
		L	L
		O/H	O/H
		F/E	F/E

T=Technical, P=Project, S=Social, P/S=Policy/Strategy, HSE=Health, Safety, Environment, L=Legal, O/H=Organizational/Human, F/E=Financial/Economic

4: Extracting the Risks of 1st phases

4 • Extracting the risks related to the very first phases of the project

Major risks affecting CTSC project progress (in the first phases)			
1	Project permits not obtained	10	Unavailability of a monetary mechanism for CO_2
2	Technology scale-up	11	Geographical infrastructure
3	Public Opposition	12	Lack of financial resources
4	Lack of knowledge/qualified resources for operating the unit	13	Lack of political support
5	Legal uncertainties	14	High cost of project
6	Uncertainties in stakeholders requirements/perceptions - Communication problems	15	Unavailability of regulations regarding different types of storage (offshore/onshore)
7	Public availability of sensitive information	16	Uncertainties regarding the storage performance (capacity/injectivity/containment)
8	Change in policies/priorities	17	Model and data issues
9	Financial crisis impact on financial support of CCS projects	18	Uncertainties related to storage monitoring

5: Modeling the major risks/safety control structure

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5 • Modeling the major risks using a systemic approach

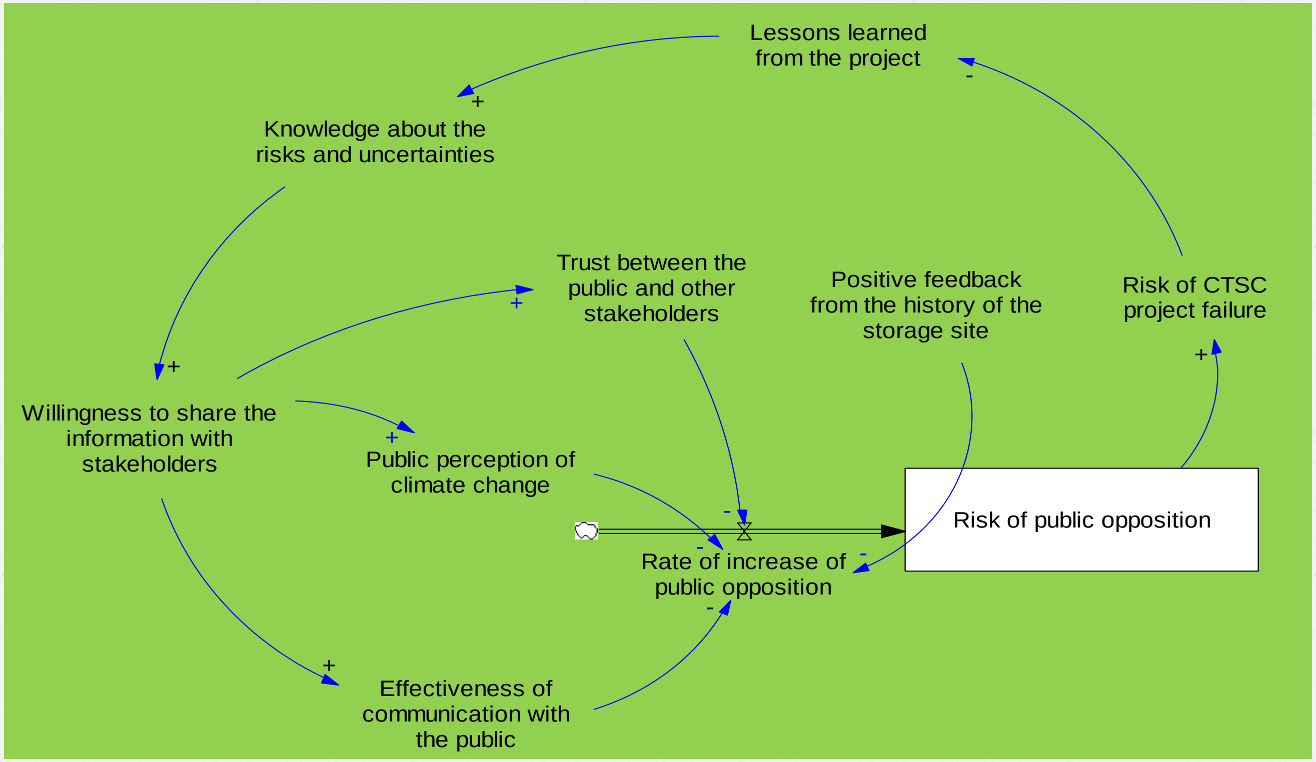
Objective: Modeling & Analyzing CTSC Safety Control Structure, using the concepts of STAMP & System Dynamics

1. Define the goal of safety structure
2. Determine system safety constraints
3. Develop the basic safety control structure
4. Specify responsible actors (controllers) for maintaining safety constraints
5. Identify required control actions for each controller
6. Define inadequate control actions leading to a hazardous state
7. System dynamics models, to understand the positive & negative feedbacks
8. Propose an improved safety control structure

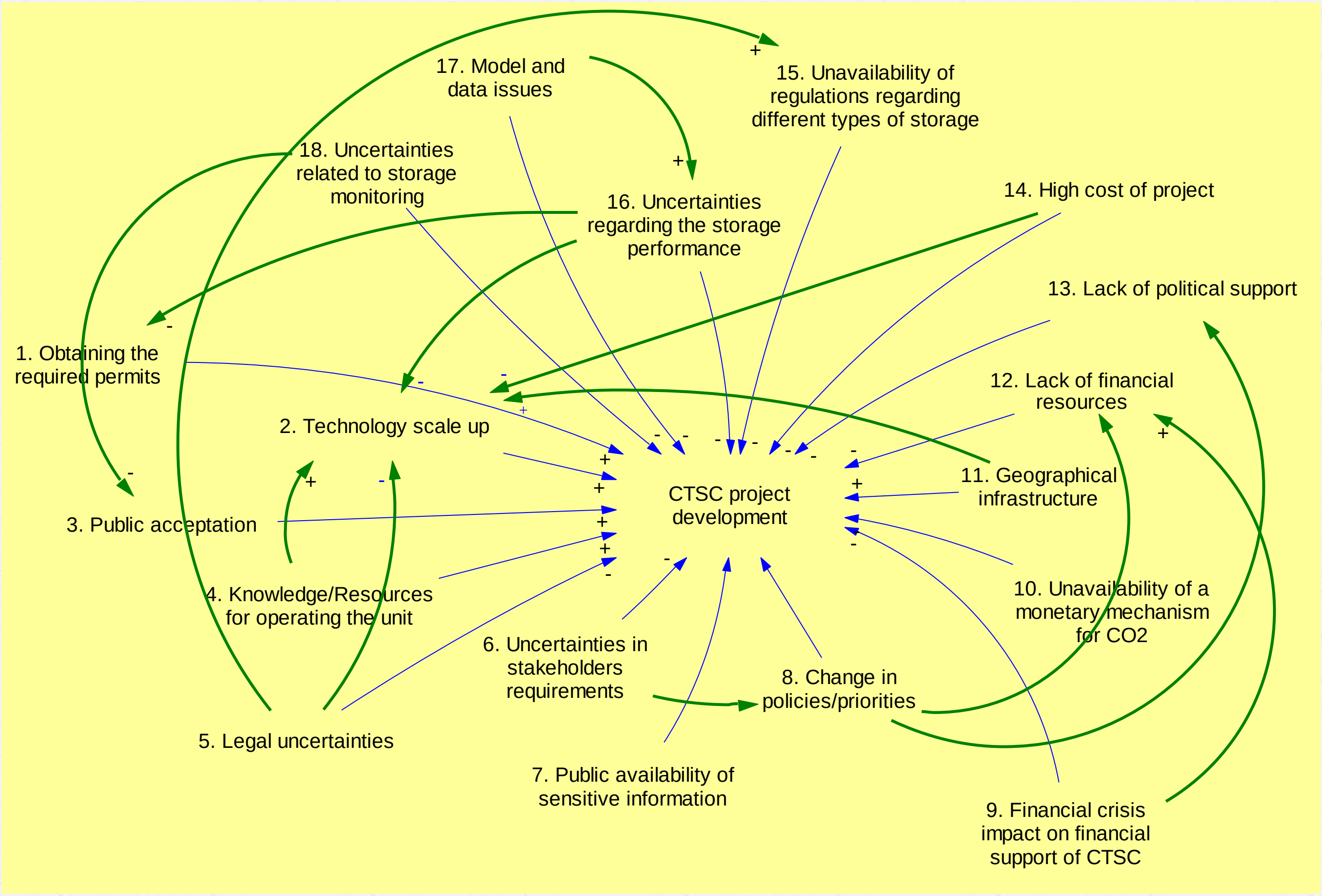
Example: Risk of Public Opposition (1/2)

Risk: Public opposition
Safety Constraints:
- Local population agreement should be assured. - In case of opposition, measures should be in place to reduce the risk of project delay or cancellation.
Who is responsible for maintaining the safety constraint?
Project owner
Required Control Actions:
- Direct communication with the community from the initial phases of the project - Giving information to the public in a less complicated manner (not too technical) - Making the public trust them by highlighting the mutual benefits from the project development (including CTSC role in Climate Change mitigation) - Making the public trust them by sharing the uncertainties and risks
(Examples of) Inadequate Control Actions leading to a hazardous state:
- Direct communication with the stakeholders is not provided. - Communication with the stakeholders is performed indirectly (via media or third parties, for example). - Direct communication with the stakeholders is provided too late. - Project developers do not continue to directly communicate with the stakeholders during the life cycle of the project.

Example: Risk of Public Opposition (2/2)



Example of a regrouped model



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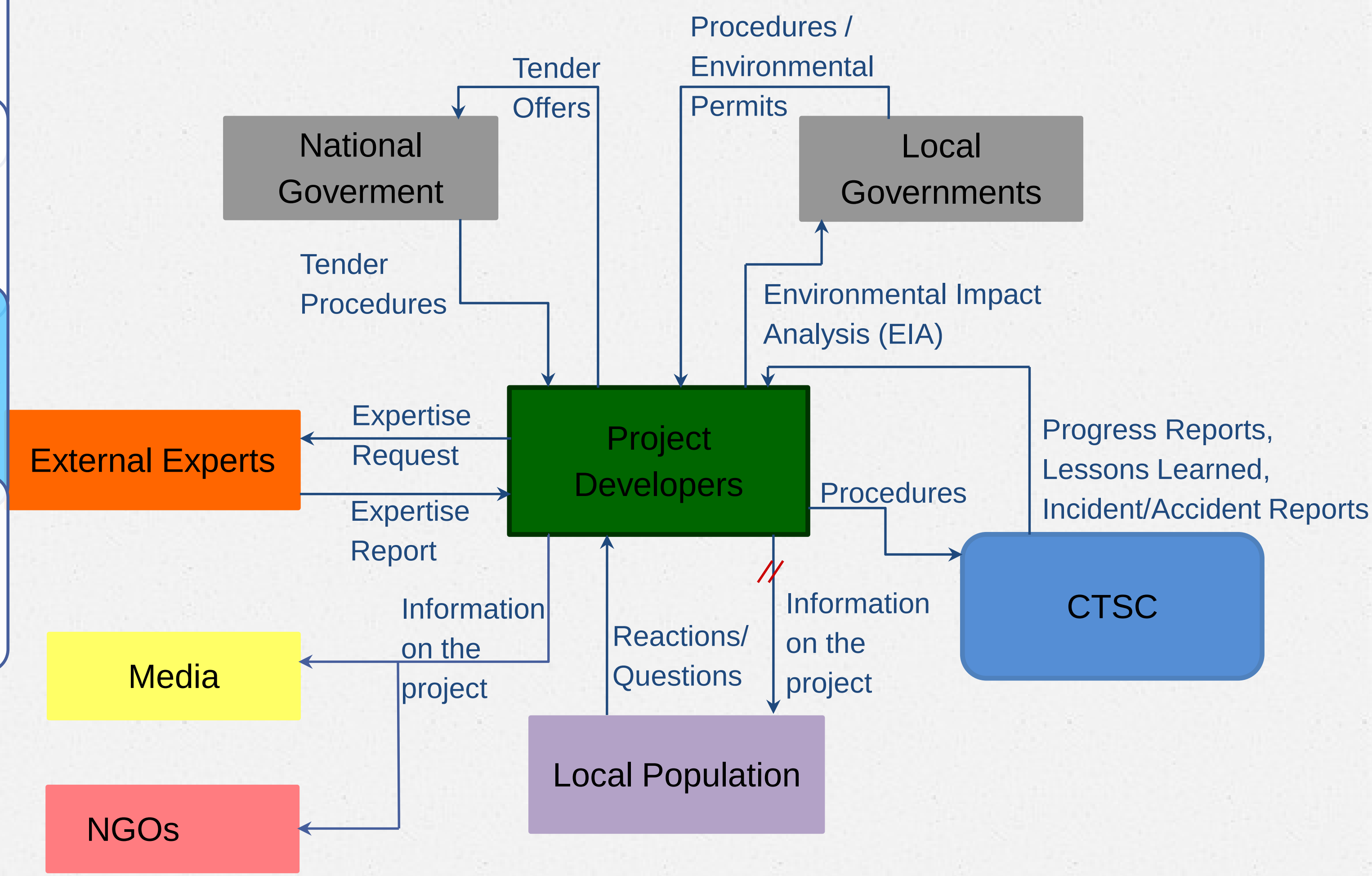
6: Application for Case Studies

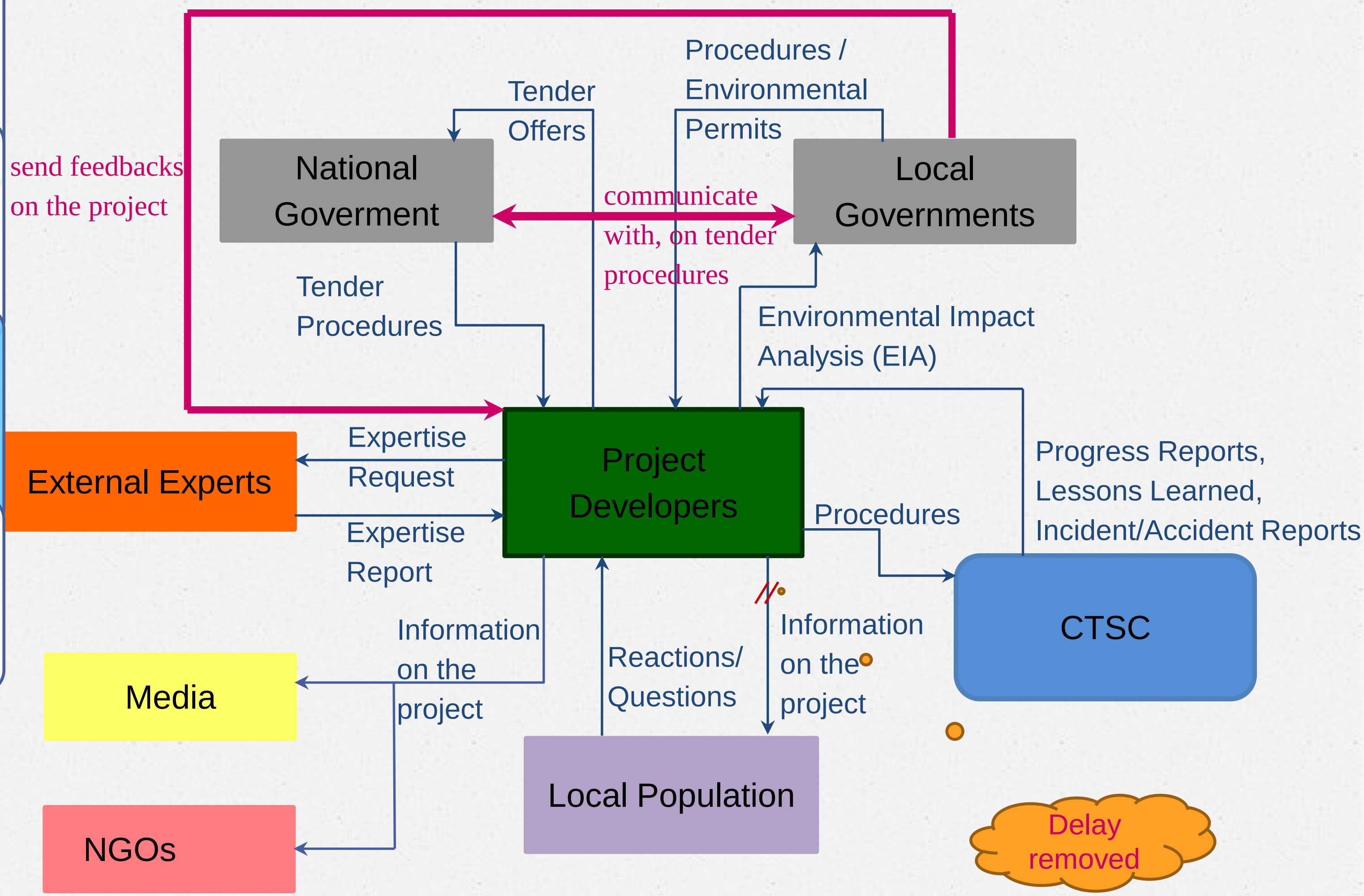
6 • Applying the systemic approach to model the safety control structure of different case studies

	Barendrecht	Lacq	Weyburn
Current Status	Cancelled (in detailed organization phase)	In operation	In operation
Scale	Demonstration	Pilot	LSIP
CO_2 storage rate	400,000 tonnes/year	60,000 tonnes/year	3 Mtpa
Storage type	Depleted gas field	Depleted gas field	EOR
Country	The Netherlands	France	The United States
Major issues	Public opposition	Technical challenges	- Public acceptance challenges - EOR as a long term storage option!
Main objective	Set down a foundation for CTSC LSIP in the Netherlands	Verify the feasibility of a CO_2 storage plant in France	Oil production increase
Concerning Industry	Oil & Gas	Oil & Gas	Oil & Gas

Example: Barendrecht, Initial Model



Example: Barendrecht, Improved Model



Proposed Safety Control Structure

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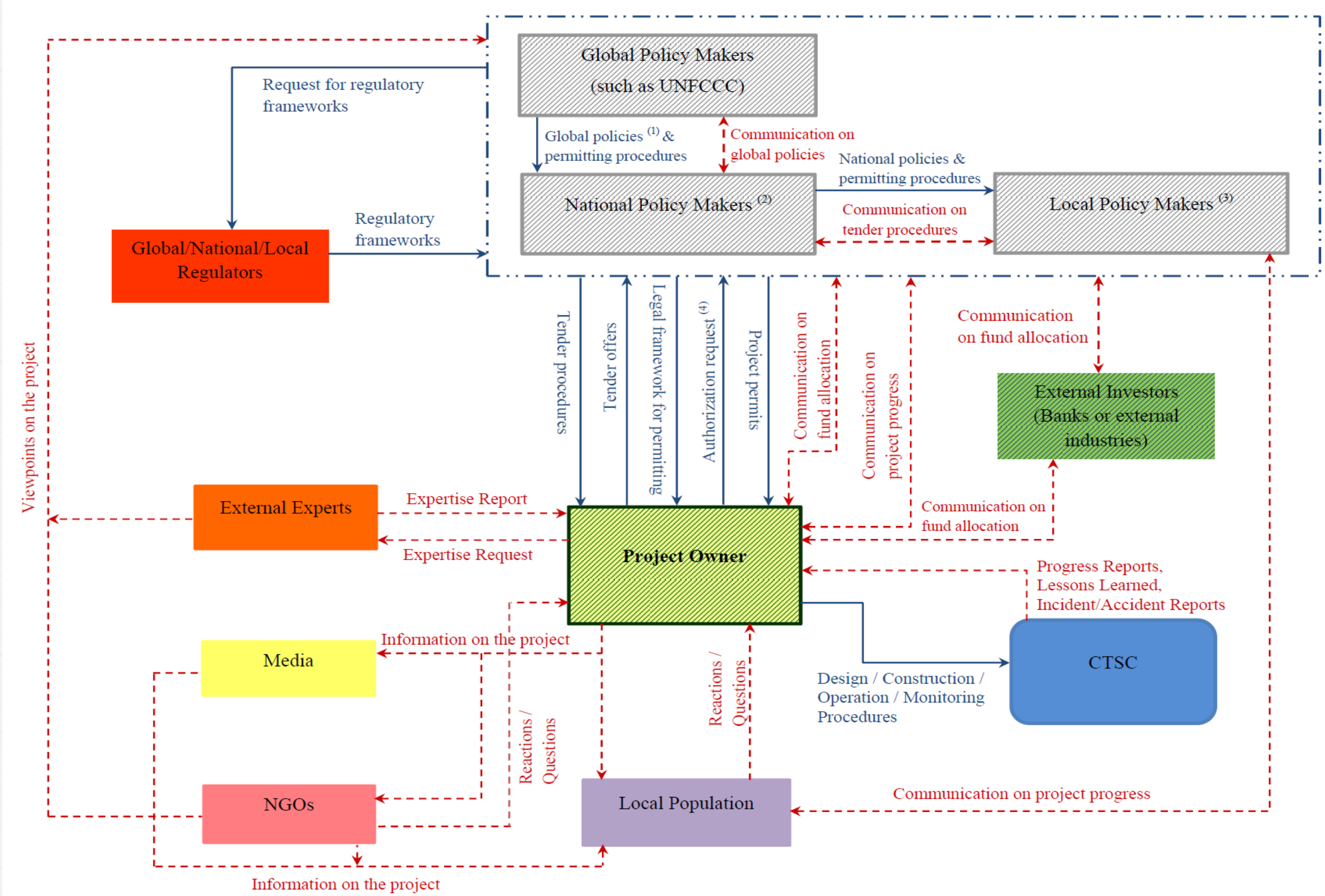

Conclusions, Advantages of the Methodology

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Overview:

- A novel methodology to model & analyze the risks & safety control structures
- Providing a means of decision making for CTSC projects development

Advantages:

- Presenting more comprehensive list and categories of risks
- Taking into account the complex network of risk interconnections by proposing a systemic modeling framework
- Underlining the significance of stakeholders role in the project success or failure

Many thanks for your attention

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