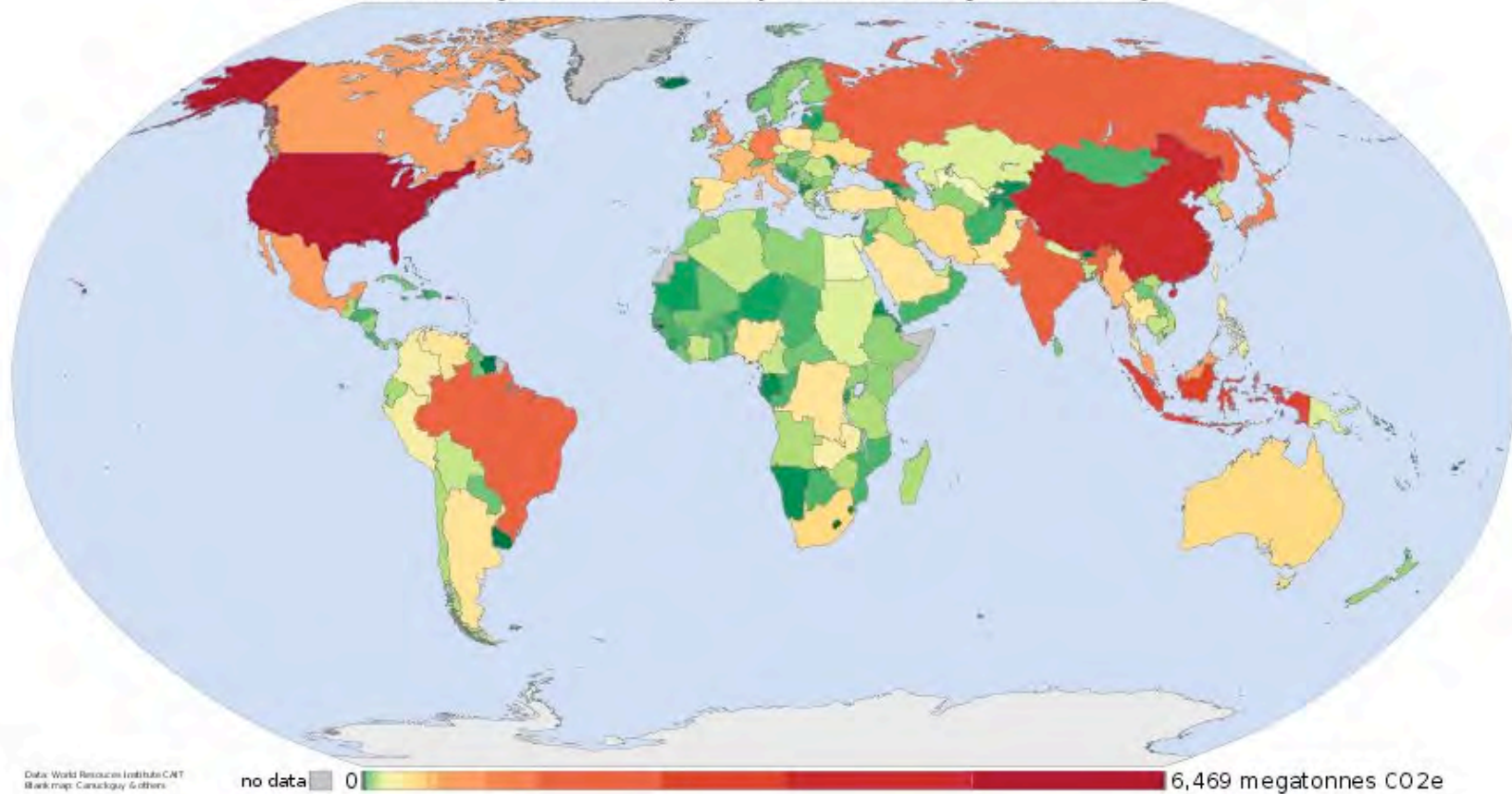


Greenhouse gas emissions by country in 2000 (including land-use change)



### GHG and Other Major Source of Air Pollutants 2006(Megaton)

	CO <sub>2</sub>	CH <sub>4</sub> *	N <sub>2</sub> O*	SO <sub>2</sub>	Black Carbon Aerosol
China	3051	959	538	19.95	1.19
World Total	23172	6340	3570	105	6.63
World Ranking	2	1	1	1	1

\* In CO<sub>2</sub> Equivalent

# Some Thoughts on Climate Change and Software Engineering Research

Lin LIU<sup>1</sup>, He ZHANG<sup>1</sup>, Sheikh AHAMED<sup>2</sup>

1. School of Software, Tsinghua University
2. Department of Mathematics, Statistics and Computer Science, Marquette University



## Green Software Infrastructure

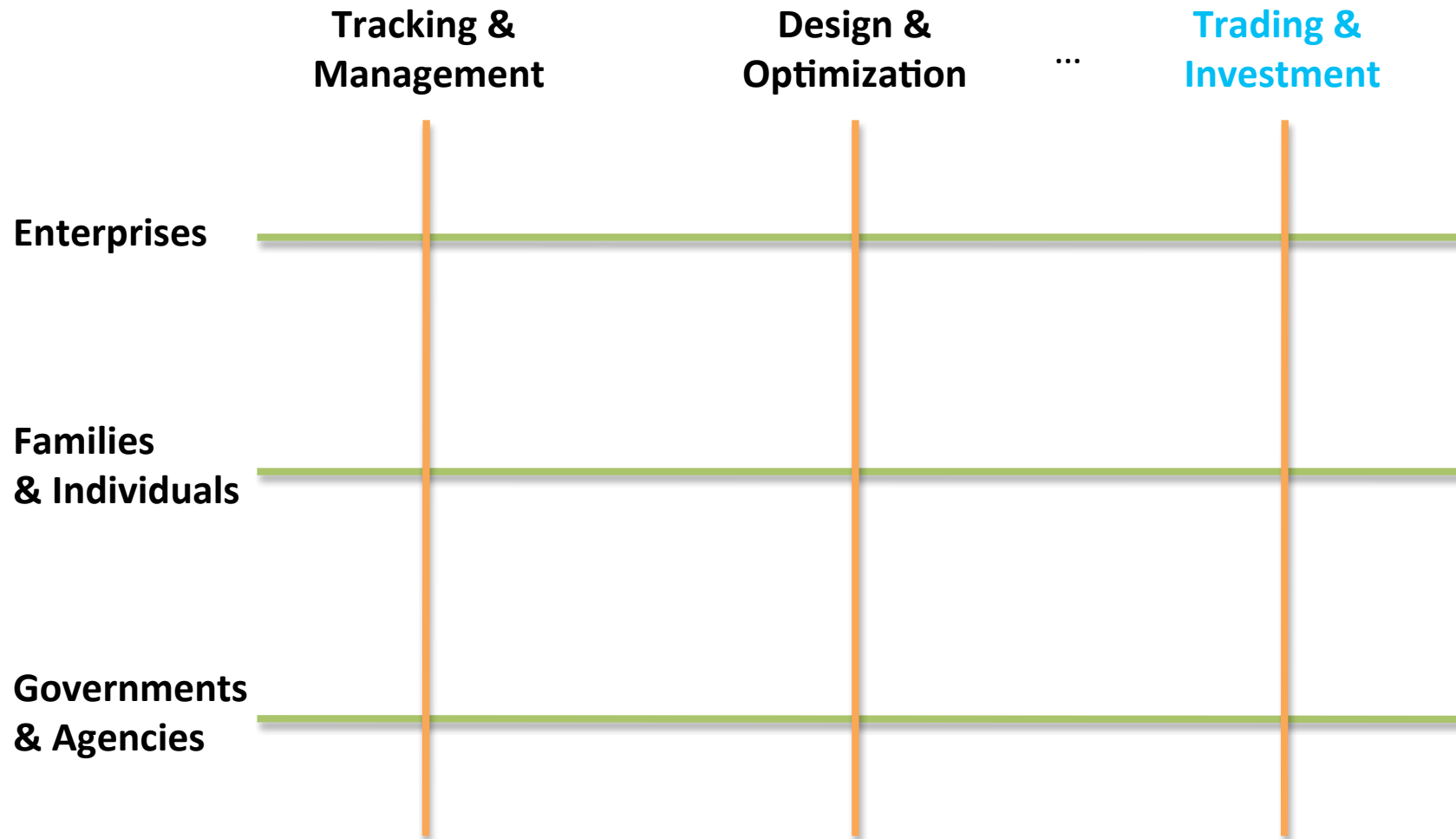


**As we are entering the “Energy-Climate Era”, what will the world look like in 20 years’ time?**

# Green Software Infrastructure Participates Initiatives

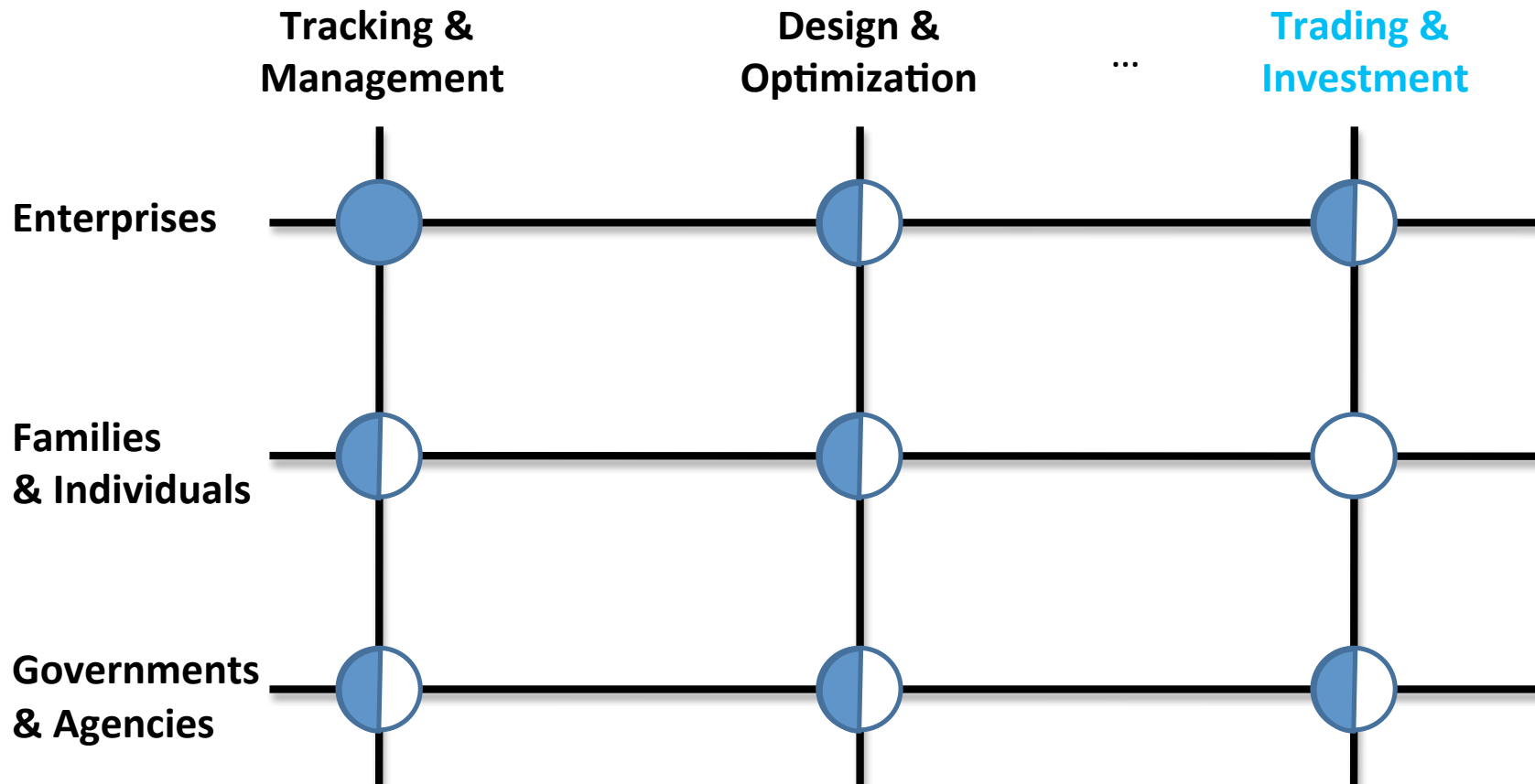
- **For Enterprises**
  - Cut Cost
  - Gain Higher Profit or Competitive Advantage
  - Comply with Standards and Regulation
  - Avoid Potential Regulatory Risks
- **For Families and Individuals**
  - Reduce Household Expenses
  - Make Profit from Environmental Investment
  - Make Contributions to Protect the Environment
- **For Government and Agencies**
  - Find Better Solutions for Climate Change Problem
  - Better Policy and Rule Making

# Green Software Matrix



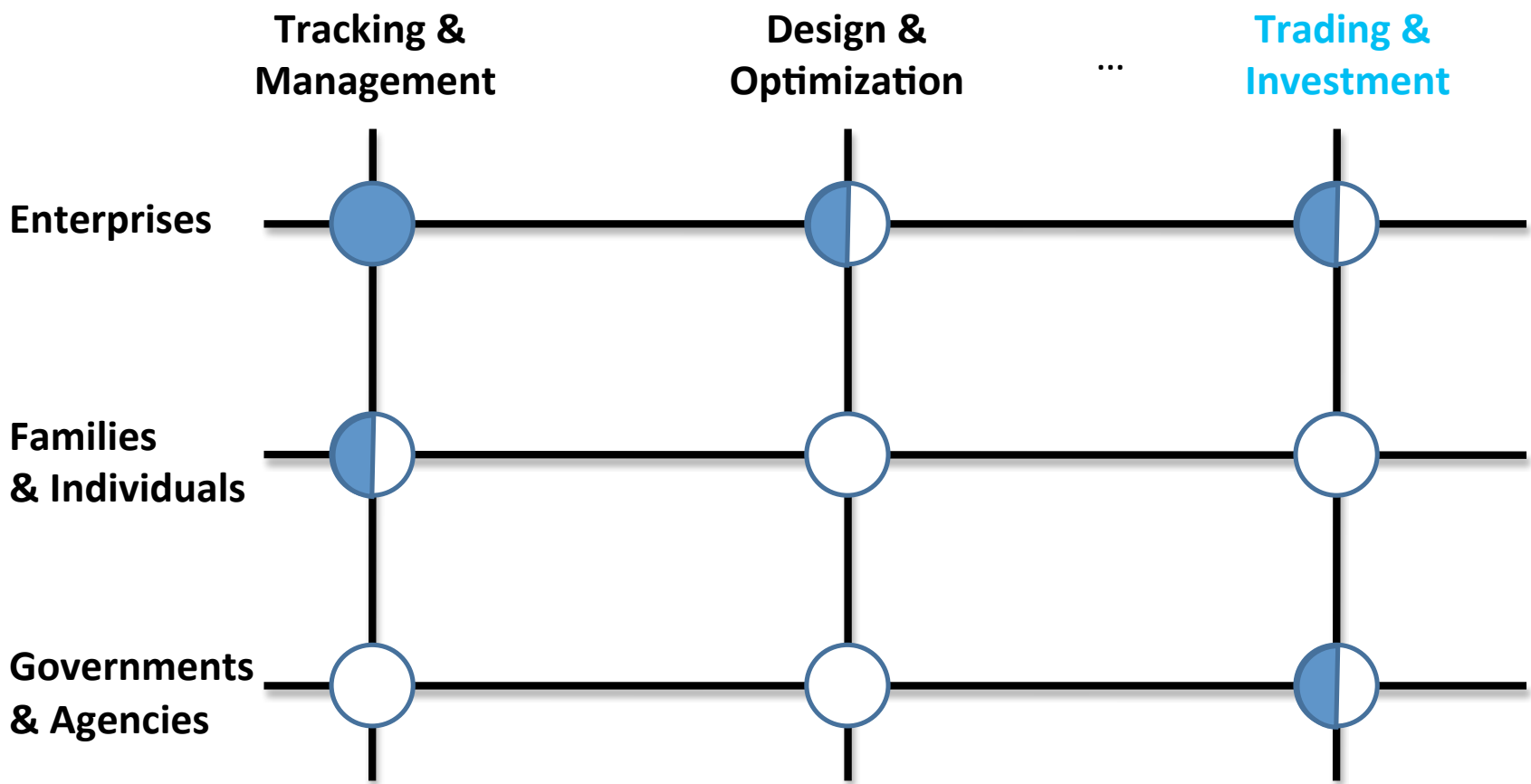
# Green Software Matrix

## Current Status



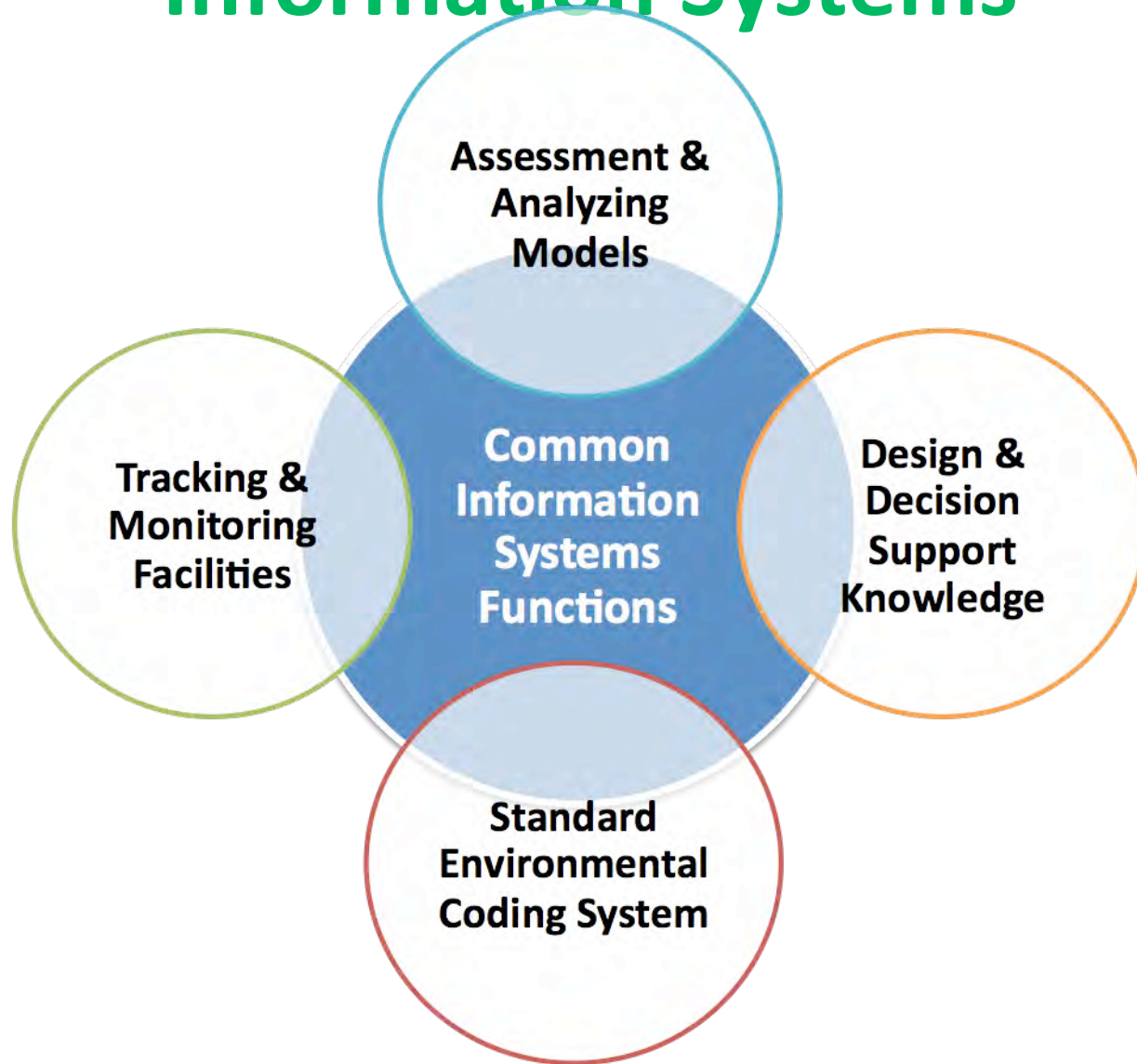
- Existing Software Systems Could Satisfy User Needs
- ◐ Existing Software Systems Couldn't Satisfy User Needs
- No Related Software Systems

# Green Software Matrix (GHG Emission Related) Current State



- Existing Software Systems Could Satisfy User Needs
- ◐ Existing Software Systems Couldn't Satisfy User Needs
- No Related Software Systems

# Typical Structure of Environmental Information Systems



# Green Software Infrastructure Non-Functional Requirements

- Dependable
- Flexible ← Single Task and Simple Kind of Usage  
Quickly Abandoned
- Easy to Use ← Need Professionals to Maintain  
Operation Training Required
- Open to System Integration ← Hard for System Integration
- Protect User Privacy

# Opportunities for Software Researchers

- “Connecting the Dots”

**Sharing and Management of Inter-Domain Knowledge**

- Improve Software Quality

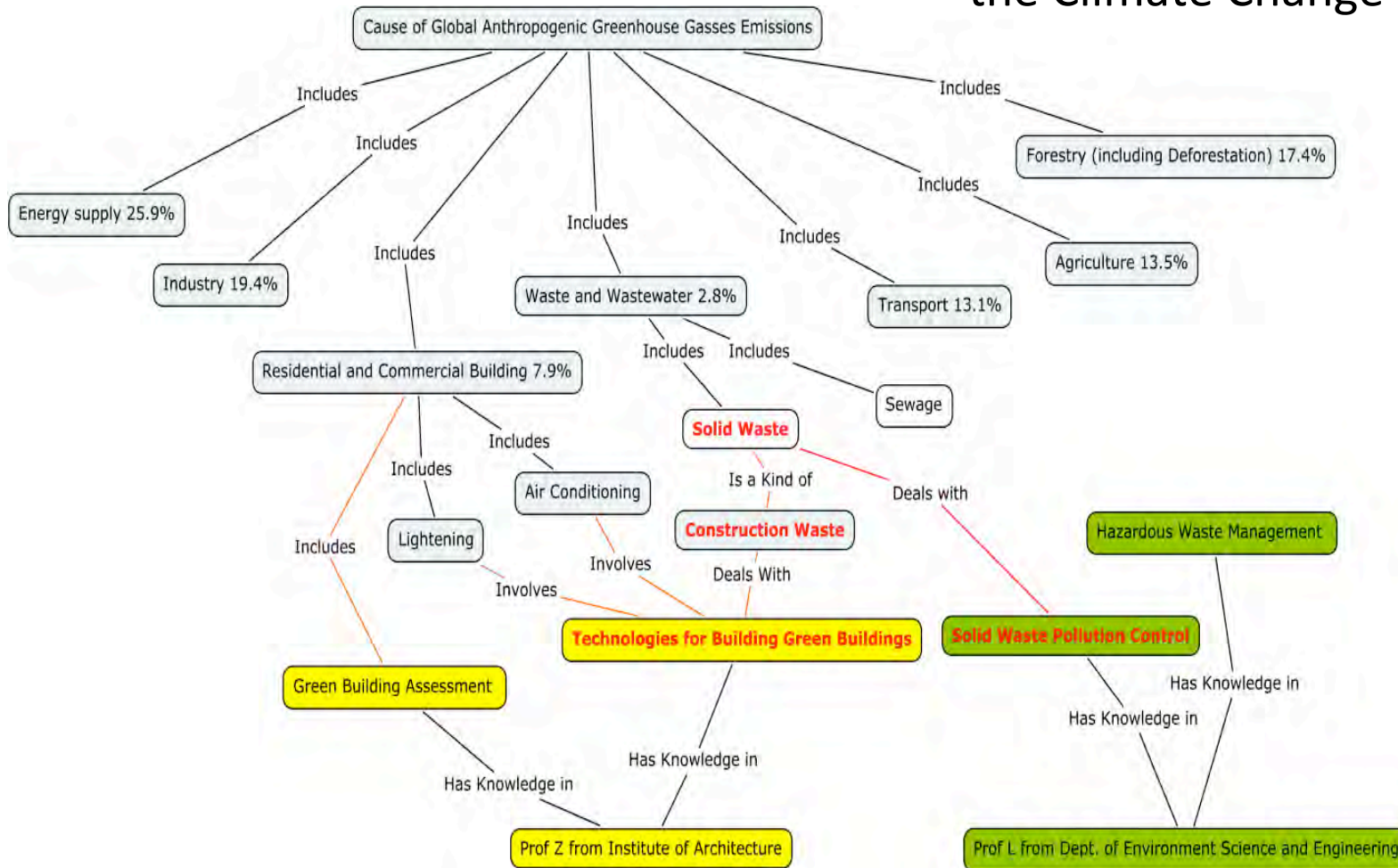
- Improve Engineering Productivity

**Software Engineering for Environmental Software and Software Related to Climate Change**

# **SHARING AND MANAGEMENT OF INTER-DOMAIN KNOWLEDGE**

# Why Inter-Domain Knowledge Sharing and Management?

- Cross-disciplinary Nature of the Climate Change Challenge



# Why Inter-Domain Knowledge Sharing and Management?



Massive Biofuel Production Caused World Wide Food Shortage and Deforestation.



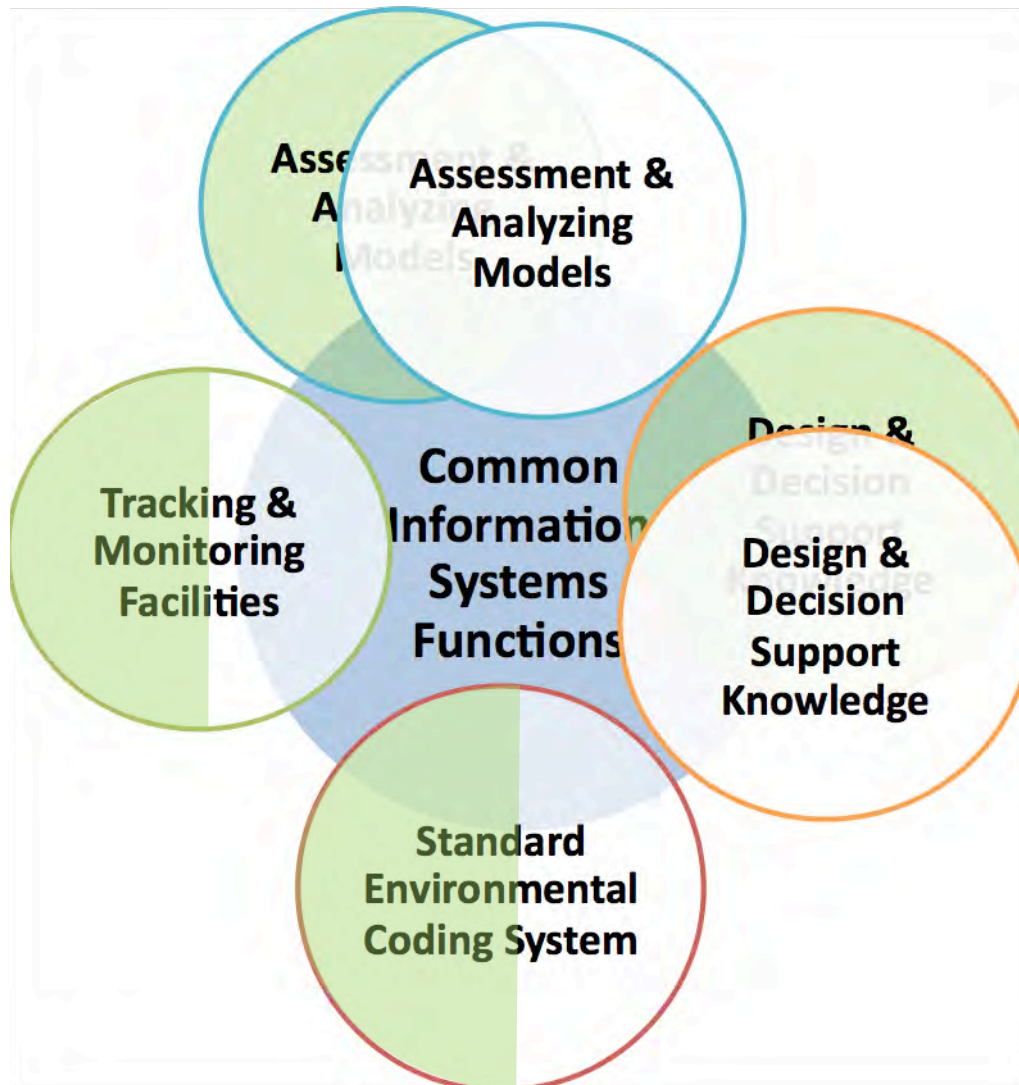
China have Invested Hundreds of Billions RMB in Wind Power. But the Result isn't Satisfying.



In China, the Production of PV Panels Consumes Large Amounts of Energy and has Caused Serious Environmental Problems.

- Cross-disciplinary Nature of the Climate Change Challenge
- Lack of Inter-Domain Knowledge Sharing and Management Support could Lead to disastrous Consequences.

# Why Inter-Domain Knowledge Sharing and Management?



- Cross-disciplinary Nature of the Climate Change Challenge
- Lack of Inter-Domain Knowledge Sharing and Management Support could Lead to disastrous Consequences.
- Inter-Domain Knowledge Sharing and Management is required for System Integration.

# Challenges

- How to help experts in different domains to share knowledge and work efficiently together?

- Can the Ideas and Techniques for Conceptual modeling in the Software Engineering Practices Help?

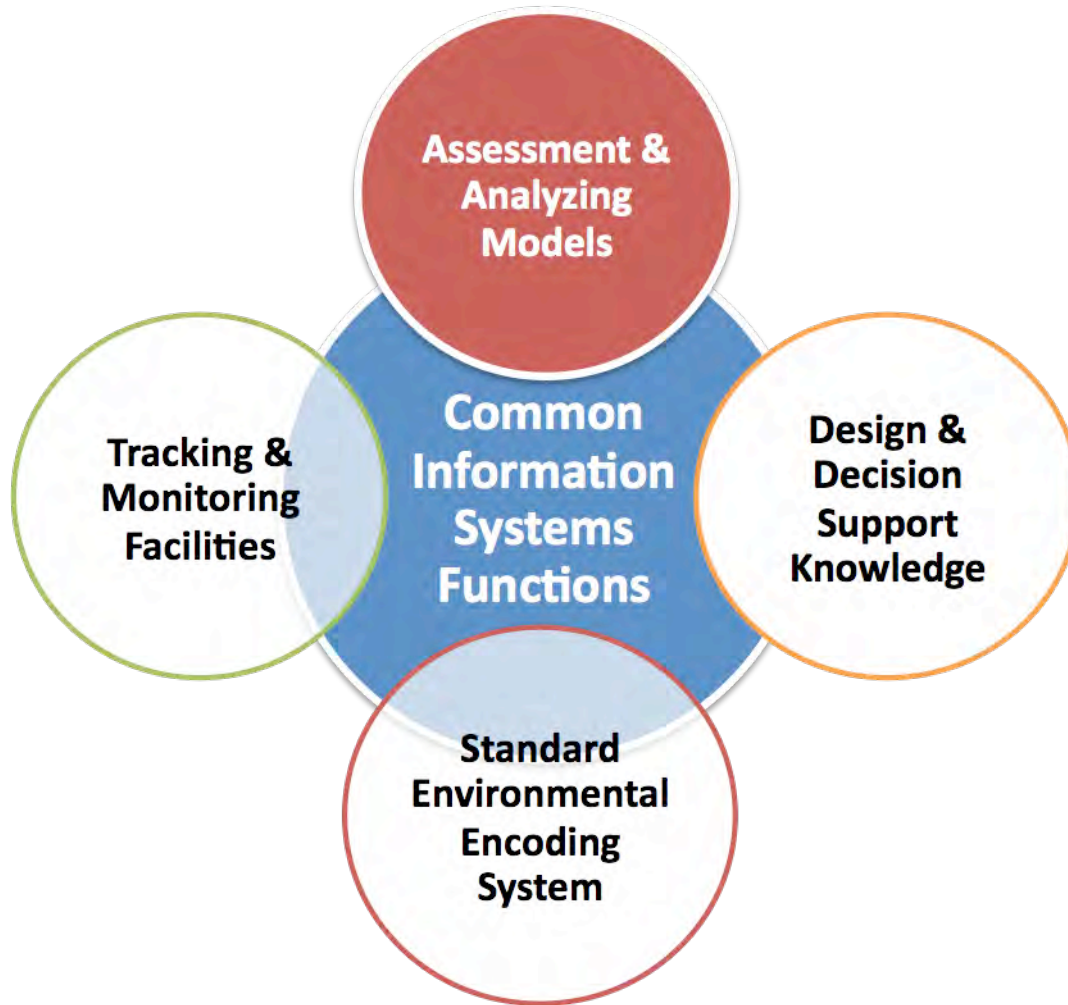
If yes, how to do it?

- If no, what kind of support do we need?

domains?

**SOFTWARE ENGINEERING  
FOR ENVIRONMENTAL SOFTWARE AND  
SOFTWARE RELATED TO CLIMATE CHANGE**

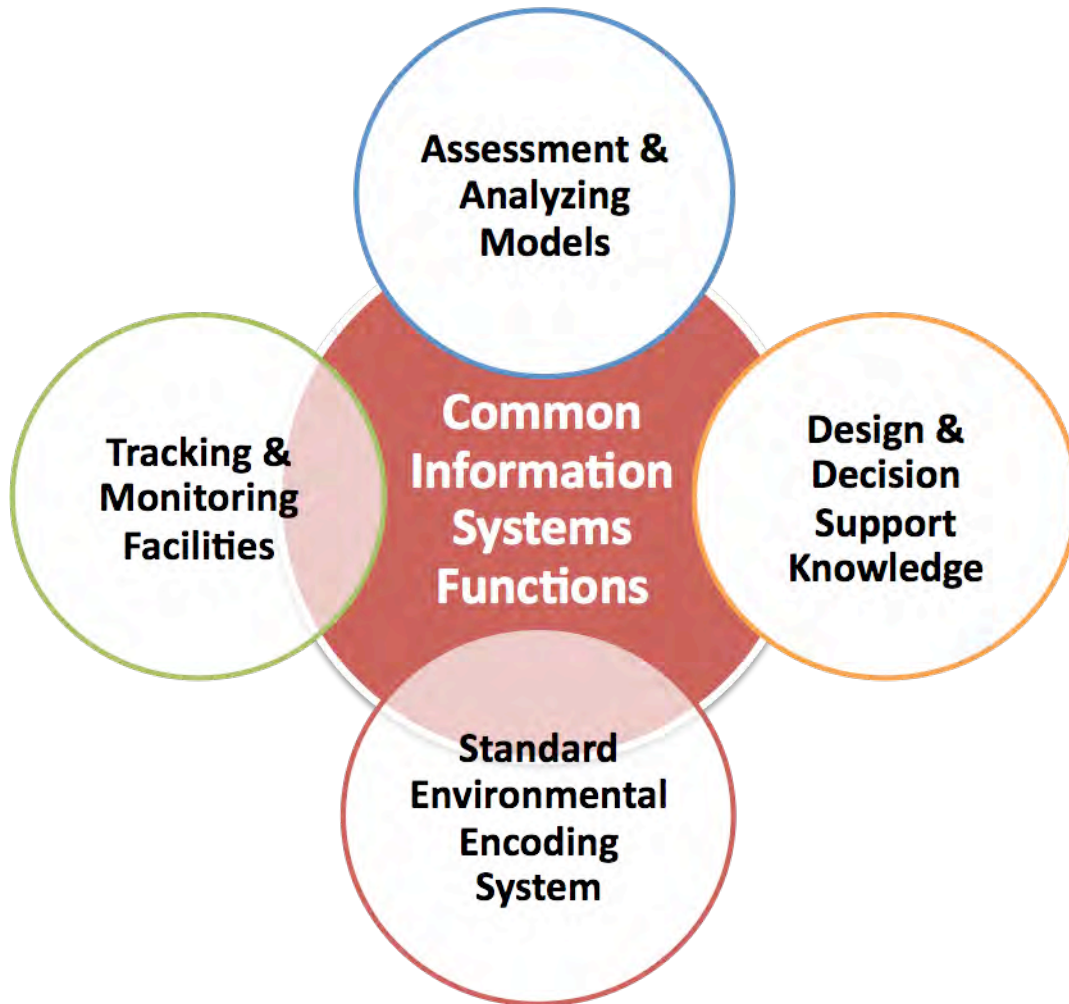
# Software Engineering for Existing Environmental Software



## Software for Scientific Research and Engineering

- Focuses More on Computation Model and Domain Knowledge
- Usually Developed by Domain Experts
- Usually Take Long Time to Develop
- Simple Task and Simple Kind of Usage
- Usually Not Easy to Maintain

# Software Engineering for Existing Environmental Software



**Environmental Management Information Systems and etc.**

- Focuses More on the Common Information System Functions
- Usually Developed by Software Engineers
- Usually Follows the Software Engineering Standards

• Usually Not Able to Adept to Requirements Change and Quickly Abandoned

## Requirements

- Environment Protection will serve as a Rising Non-Functional Requirements, Competing With Other Functional and Non-Functional Requirements.

## Design

- Environment Protection Needs has to be Operationalized and Embedded into Design Solutions and Design Alternatives.

## Testing

- Environment Protection Software Systems and Products has to be Evaluated for Its Impact to the Surrounding Environments.

## Evolution

- Software System Has to Evolve and Adapt to the Changing Requirements from Environmental Related Reasons.

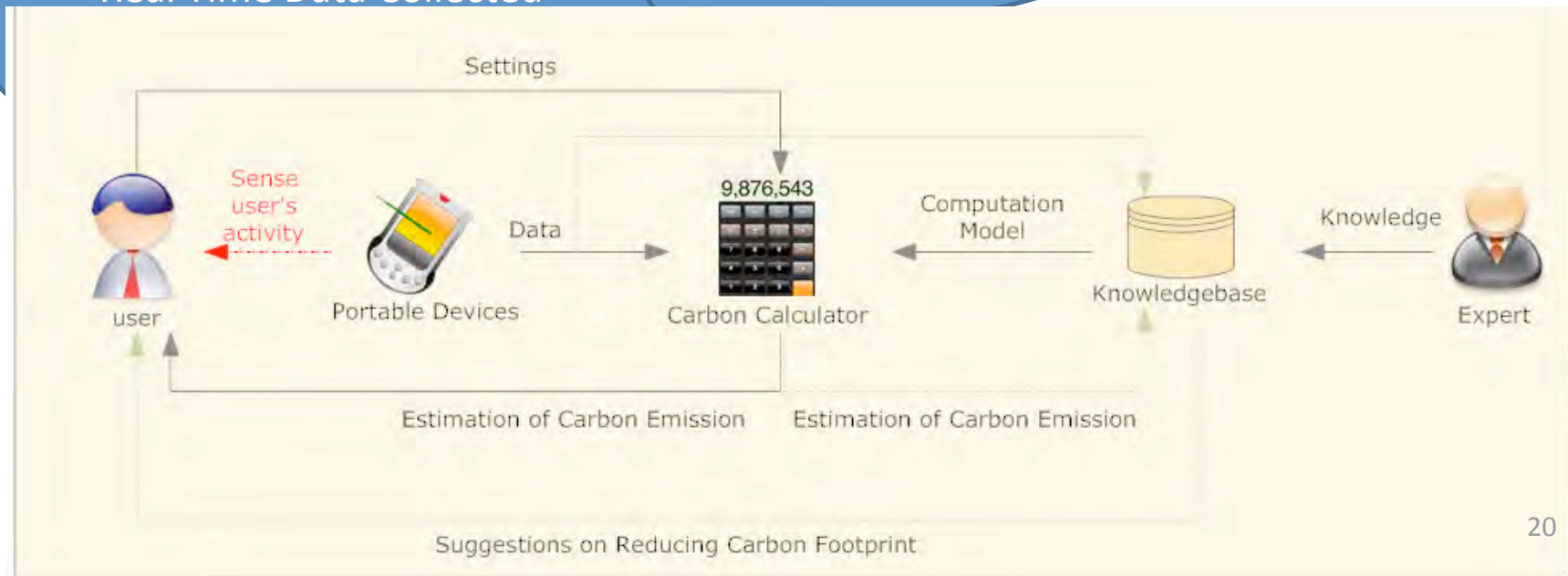
# Personal Carbon Calculator for Individual Users based on Conceptual Framework

Human Behavior – GHG Emission Computational Models

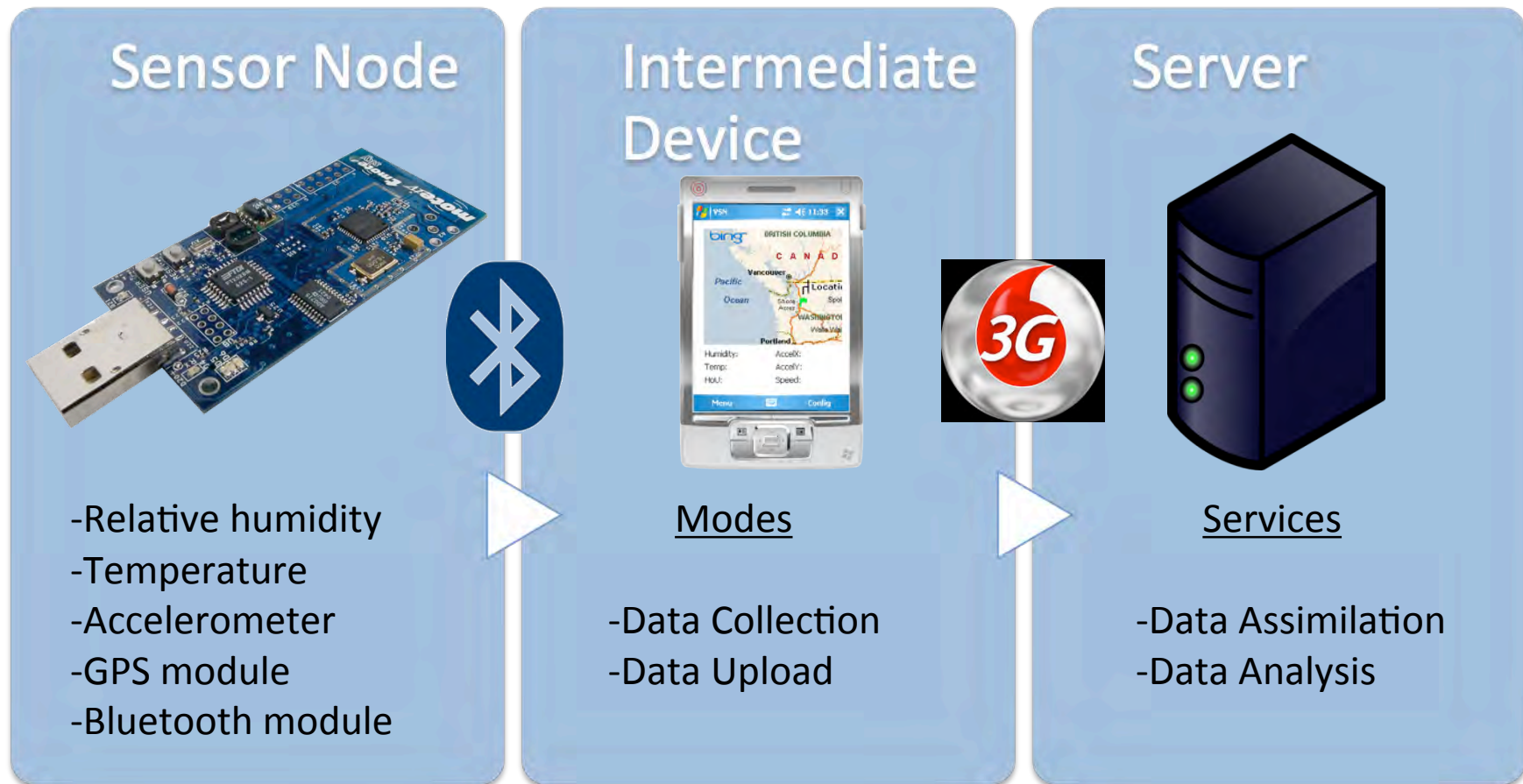
GHG Emission Reduction Knowledge

Human Behavior – GHG Emission Conceptual Framework

Real Time Data Collected



# How Data Collection Works



# Sample screens of our prototype

The screenshot displays two browser windows. The left window shows the 'VSN Server - Main Page' with a file selection interface. The right window shows the 'VSN Server - Display' page, which features a title 'VSN Network Server' and a data table. Below the table is a 'Get Map' button and a map showing an aerial view of a building complex with a red location marker.

Please select a file:  
200909131038.bt  
Submit

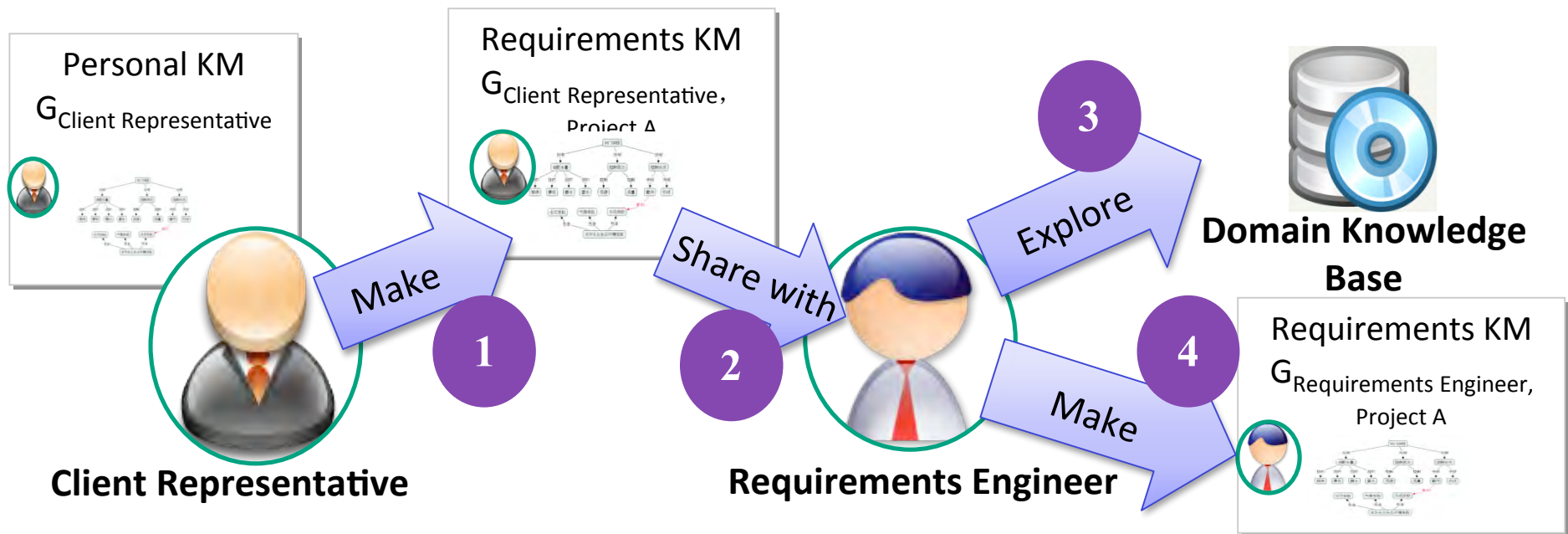
### VSN Network Server

ID	Longitude	Latitude	Temp	Humidity	HoU	Accel X	AccelY	Speed	Src	Date	Timestamp
1	43.040325	-87.9332683333333	72.4	36.5	0	0	0	0	1	20090913061450	2009-09-13 23:11:09
2	43.040325	-87.9332683333333	72.4	36.5	0	0	0	0	1	20090913061450	2009-09-13 23:11:25
3	43.0381673648906	-87.9287299782506	77.7	44.4	0	0	0	0	1	20090913105213	2009-09-13 23:11:30
4	43.0381673648906	-87.9287299782506	77.7	44.5	0	0	0	0	1	20090913105228	2009-09-13 23:11:30
5	43.0381673648906	-87.9287299782506	77.7	44.5	0	0	0	0	1	20090913105243	2009-09-13 23:11:30
6	43.0381673648906	-87.9287299782506	77.7	44.5	0	0	0	0	1	20090913105258	2009-09-13 23:11:30
7	43.0381673648906	-87.9287299782506	77.7	44.5	0	194	215	0	1	20090913105312	2009-09-13 23:11:30
8	43.0381673648906	-87.9287299782506	77.7	44.5	1	0	211	0	1	20090913105327	2009-09-13 23:11:30
9	43.0381673648906	-87.9287299782506	77.7	44.5	1	202	236	0	1	20090913105342	2009-09-13 23:11:30
10	43.0381673648906	-87.9287299782506	77.7	44.5	1	0	234	0	1	20090913105356	2009-09-13 23:11:30

Get Map

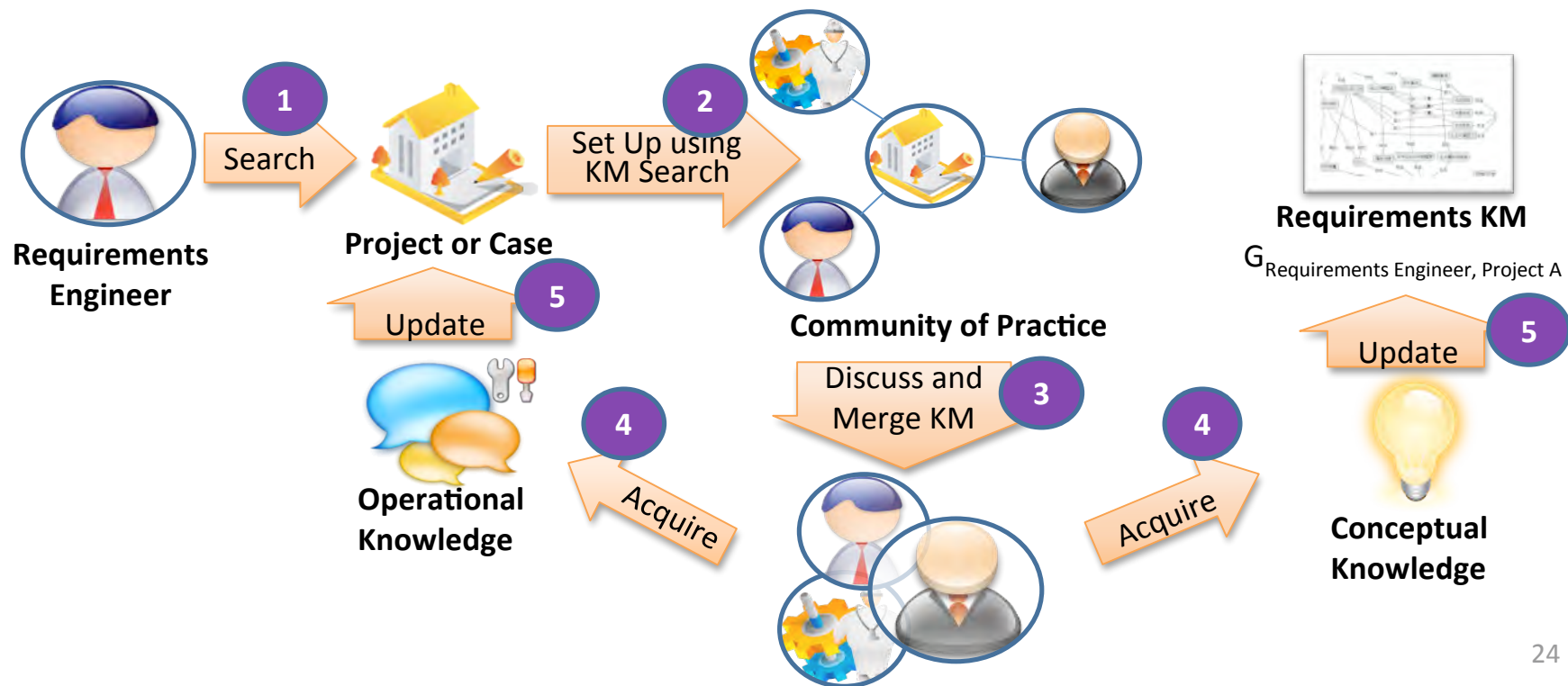
# Sharing Requirements Knowledge Using Knowledge Map

1. Requirements Engineer Collects Basic Requirements Knowledge From the Knowledge Map and Domain Knowledge Base.

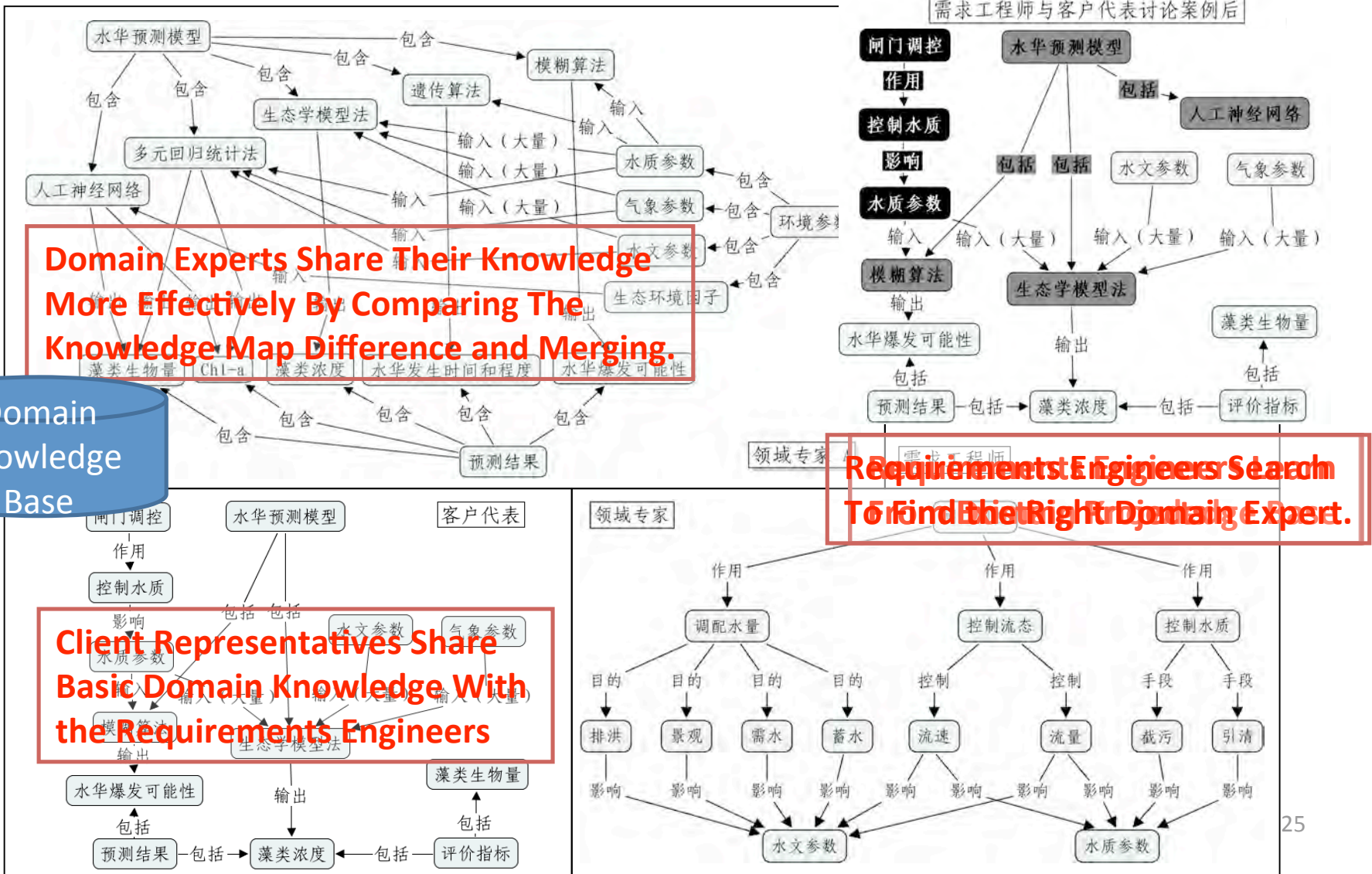


# Sharing Requirements Knowledge Using Knowledge Map

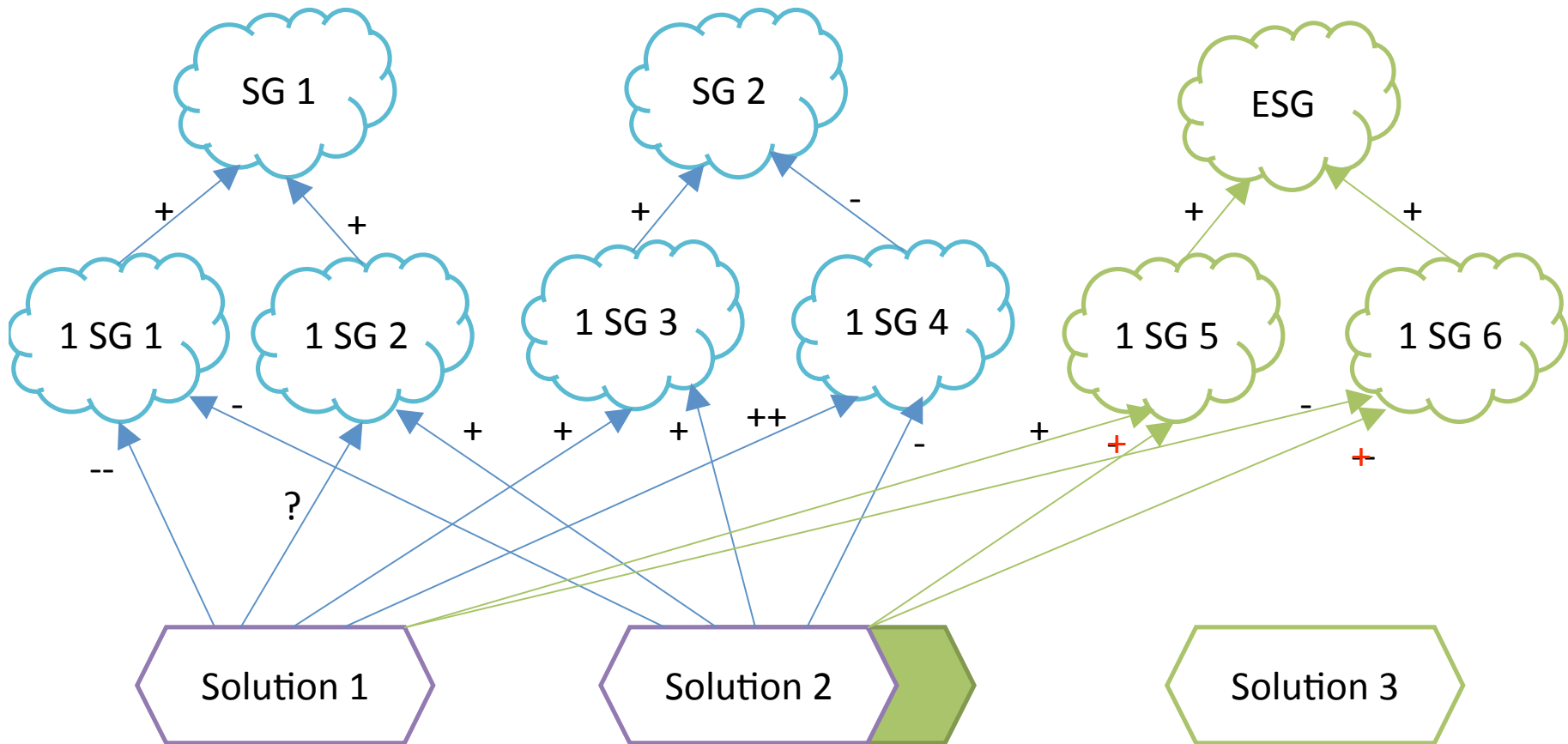
1. Requirements Engineer Collects Basic Requirements Knowledge from the Knowledge Map and Domain Knowledge Base.
2. Requirements Engineer Collects Requirements Knowledge with the Help from Community of Practice.



# Sharing Requirements Knowledge Using Knowledge Map



# Goal Model for Reducing IT System GHG Emissions



# Goal Model for Reducing IT System GHG Emissions

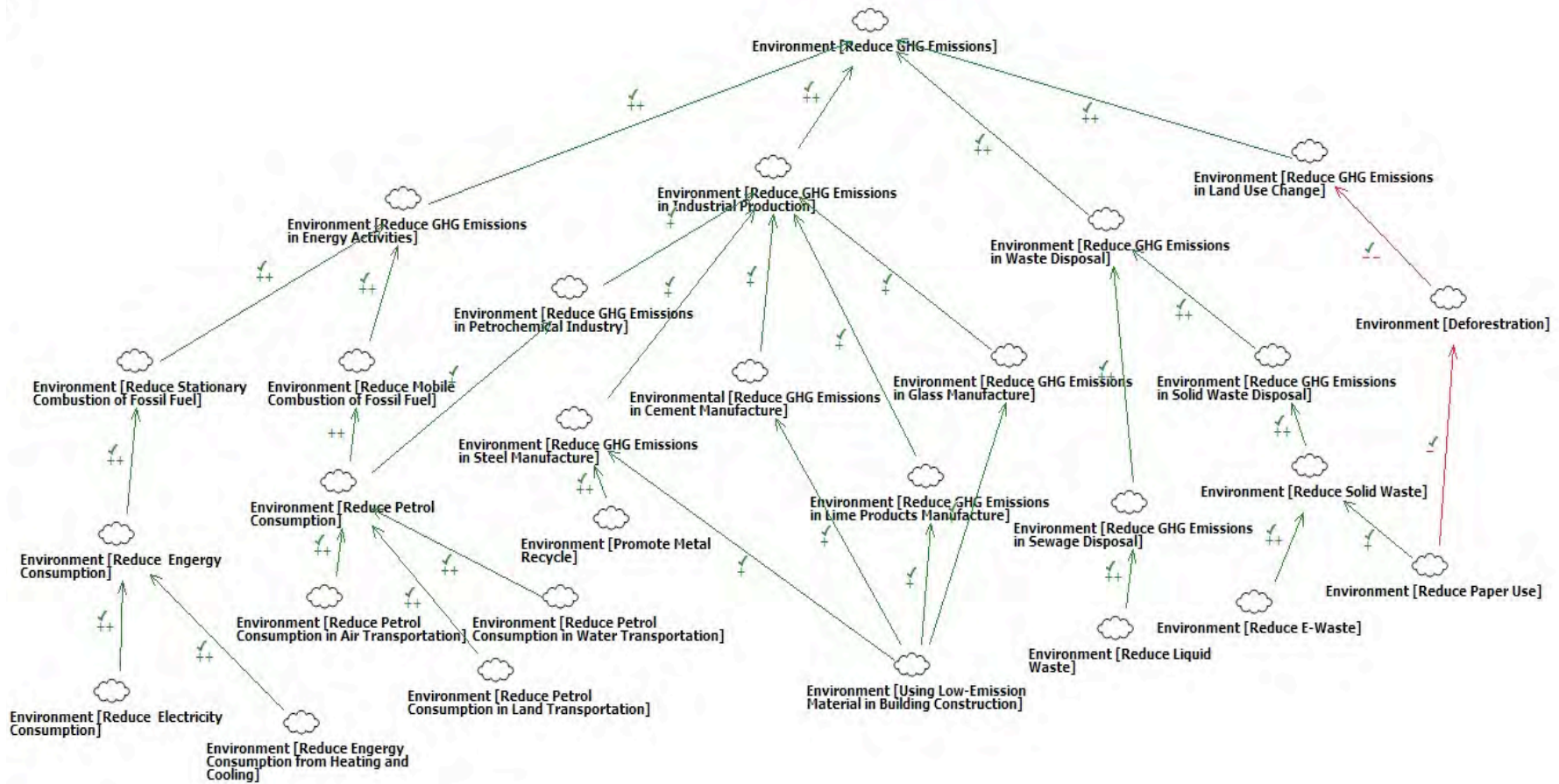


Figure 8 NFRs for Reducing IT Systems' GHG Emissions

# Summary

- Facilitate Proliferable Inter-Domain Knowledge Sharing and Management
- Understanding the Competing Needs and Concerns of Stakeholders
- Developing Effective Technical Operational Methods and Measures for Environmental Protection Goals