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

Data: World Resources Institute CAIT
Blank map: Canuckguy & others

no data   0   6,469 megatonnes CO2e
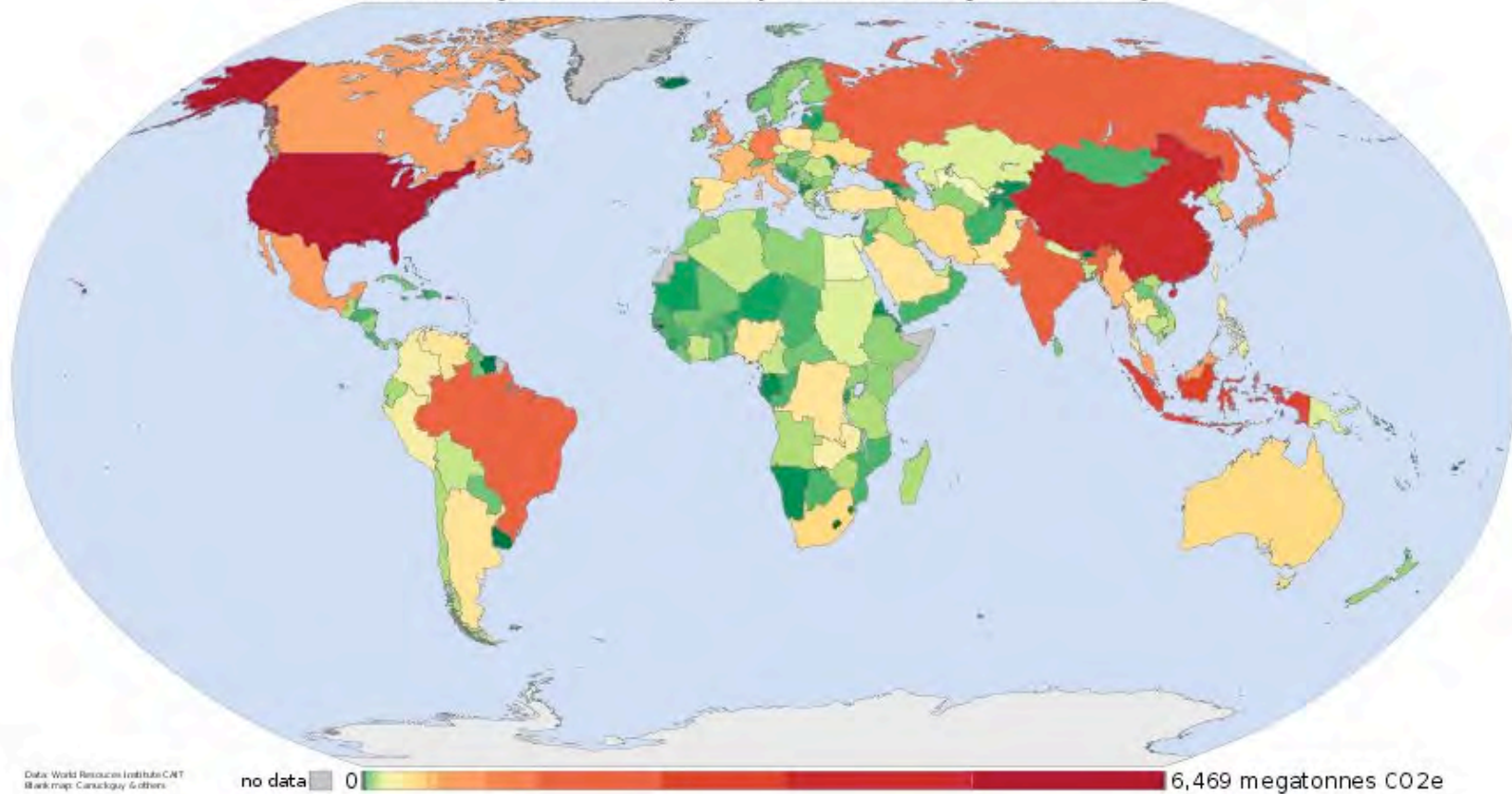
GHG and Other Major Source of Air Pollutants 2006(Megaton)

	CO$_2$	CH$_4$*	N$_2$O*	SO$_2$	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$_2$ Equivalent

1

Some Thoughts on Climate Change and Software Engineering Research

Lin LIU[1], He ZHANG[1], Sheikh AHAMED[2]

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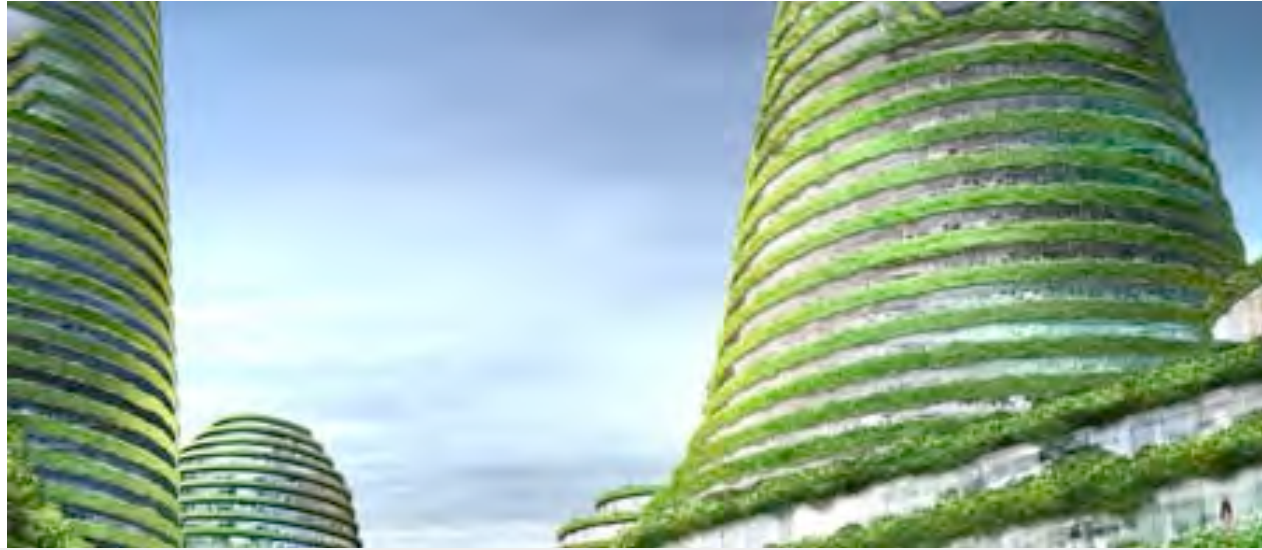
Green Software Infrastructure

As we are entering the "Energy-Climate Era", what will the world look like in 20 years' time?

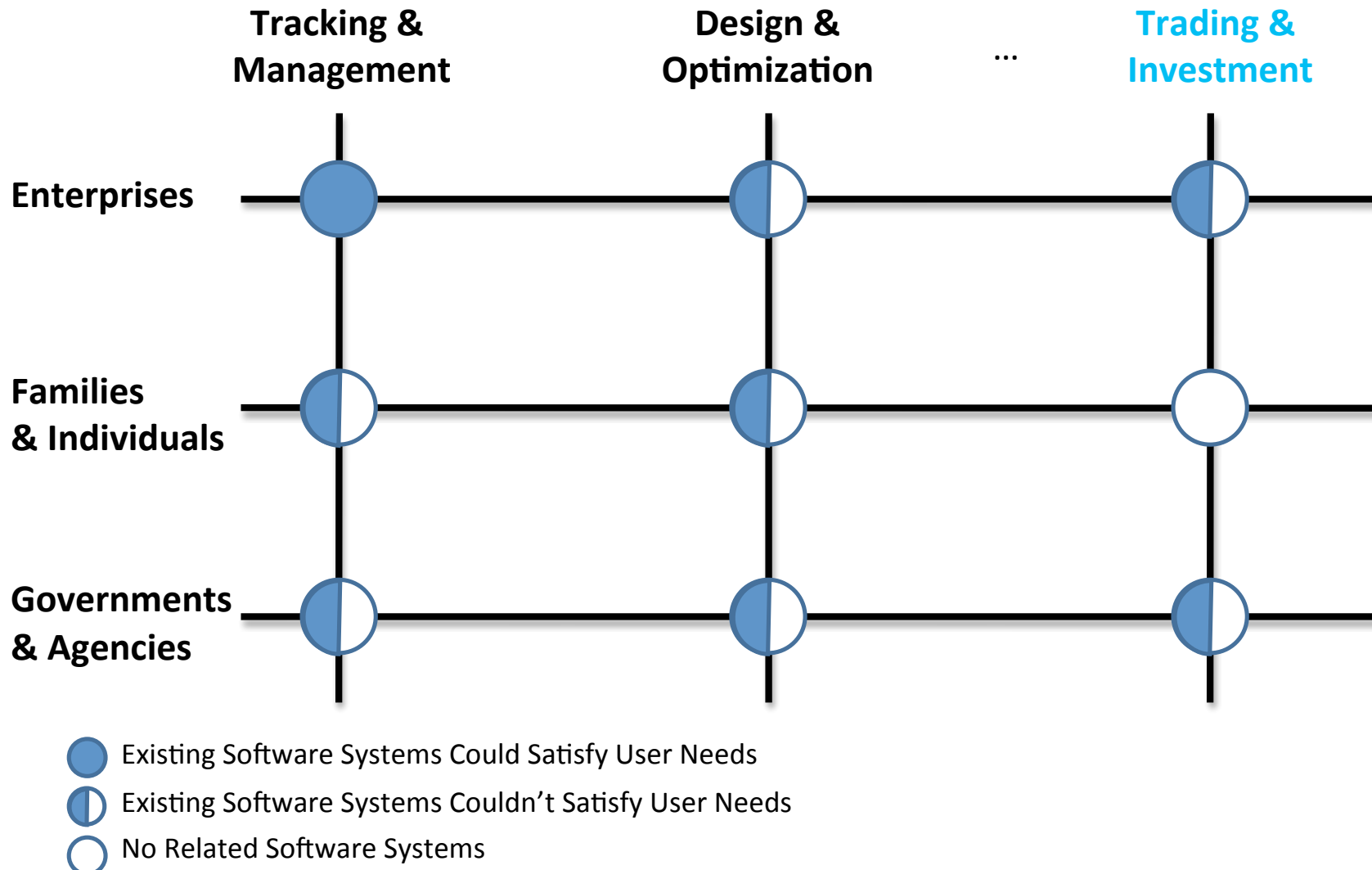# Green Software Infrastructure Participates Initiatives

- **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

	Tracking & Management	Design & Optimization	...	Trading & Investment
Enterprises				
Families & Individuals				
Governments & Agencies				

Green Software Matrix
Current Status

Tracking & Management **Design & Optimization** ... **Trading & Investment**

Enterprises

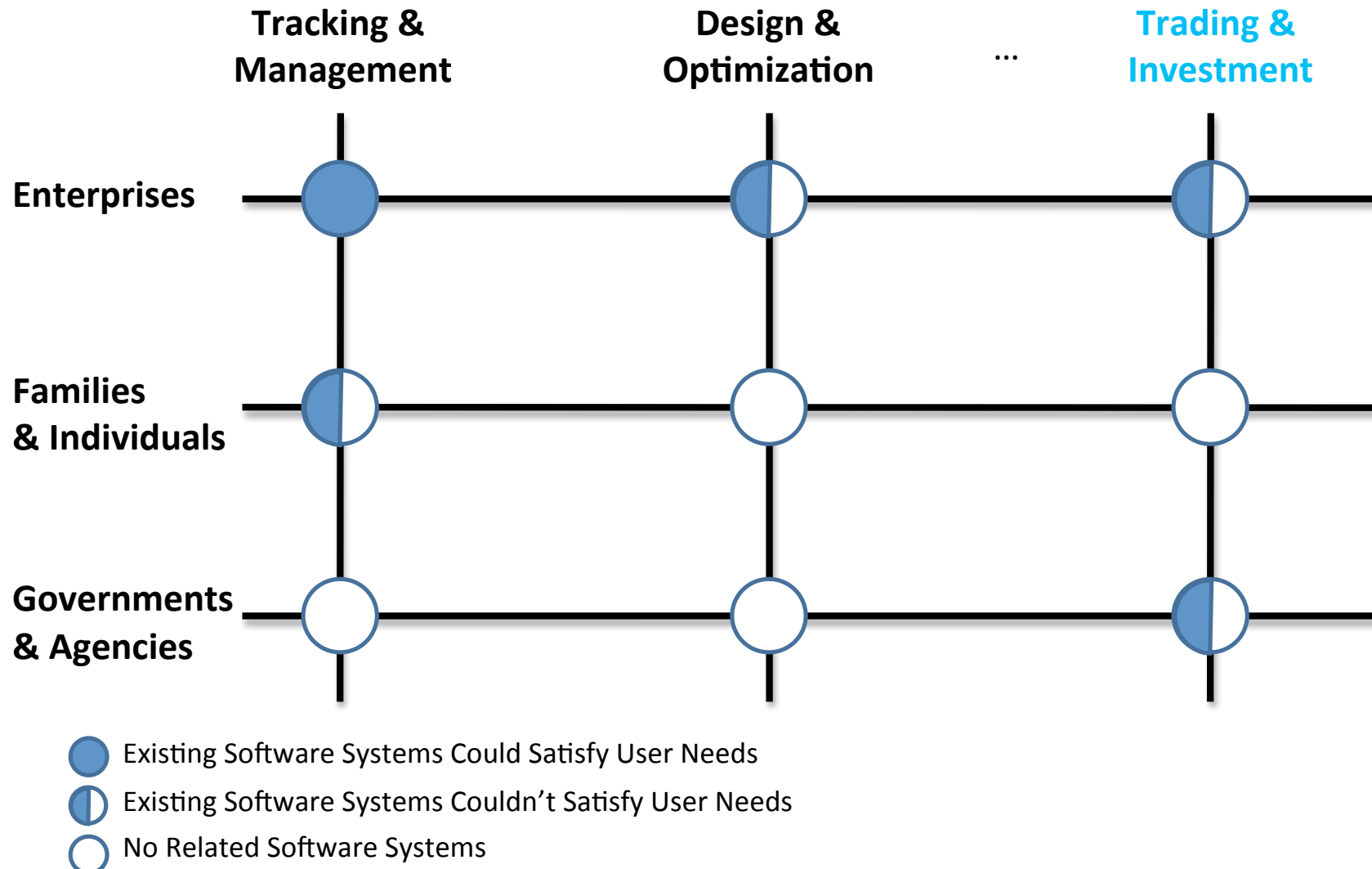**Families & Individuals**

Governments & Agencies

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

	Tracking & Management	**Design & Optimization**	...	**Trading & Investment**
Enterprises	●	◐		◐
Families & Individuals	◐	○		○
Governments & Agencies	○	○		◐

● 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

Assessment & Analyzing Models

Tracking & Monitoring Facilities

Common Information Systems Functions

Design & Decision Support Knowledge

Standard Environmental Coding System
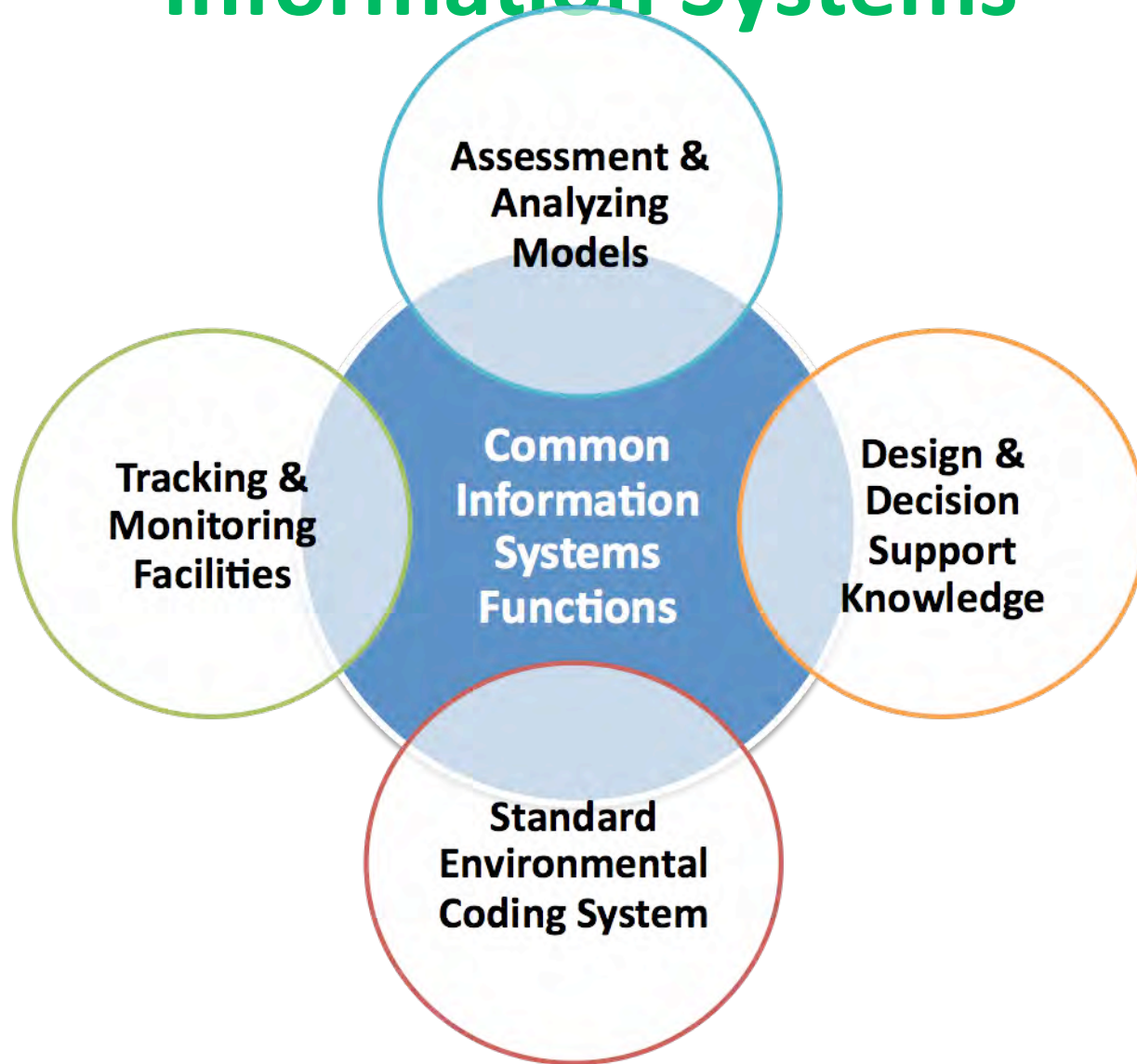
Green Software Infrastructure Non-Functional Requirements

- 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
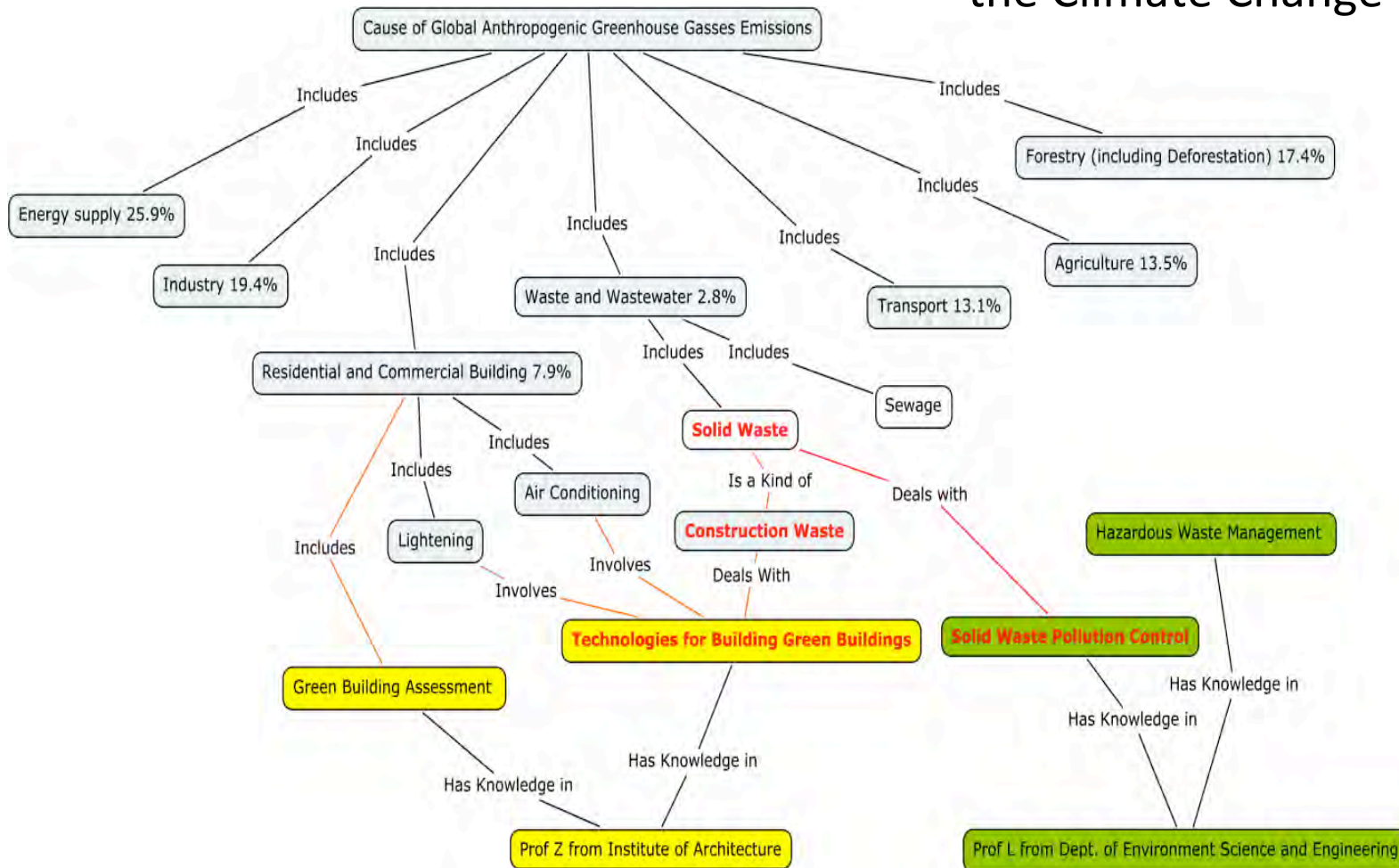
Why Inter-Domain Knowledge Sharing and Management?

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?
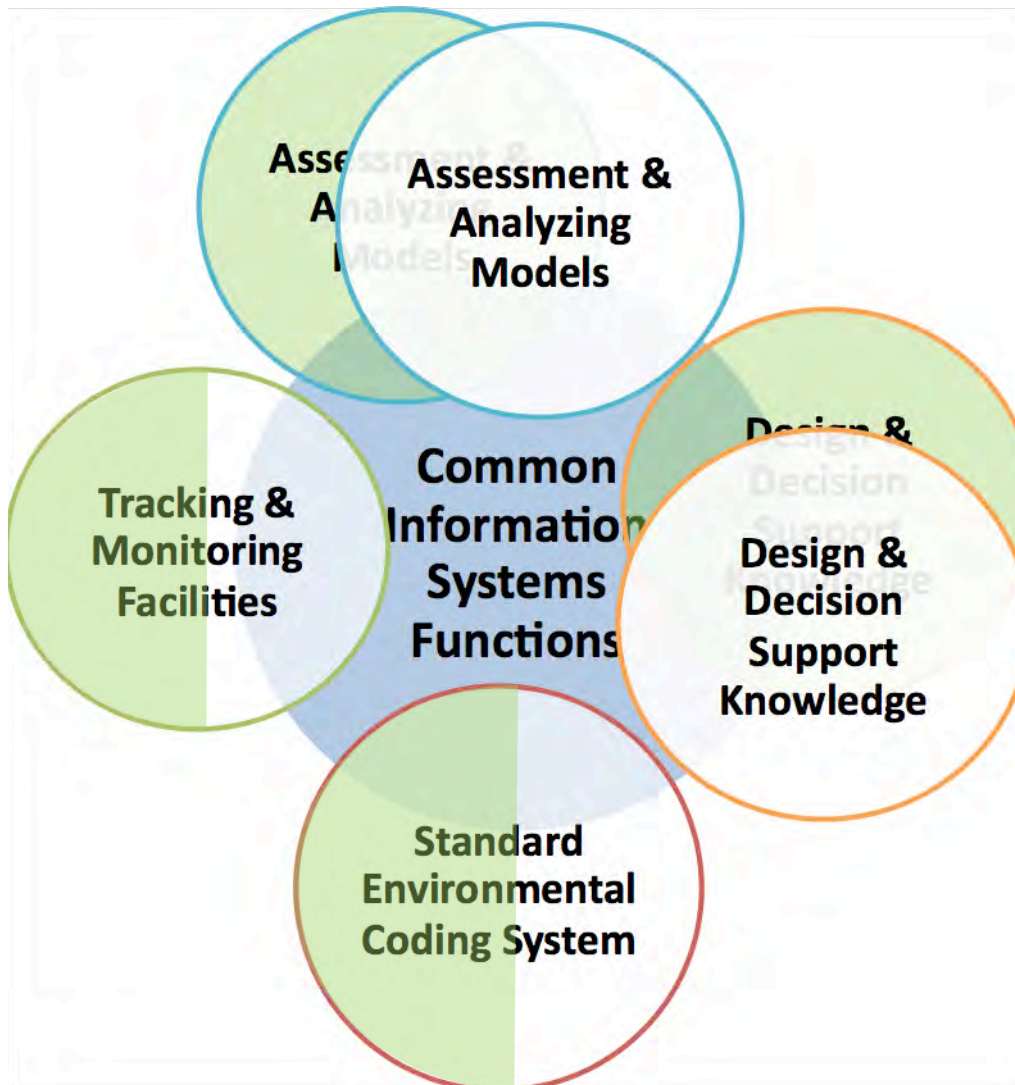
- Cross-disciplinary Nature of the Climate Change Challenge

- 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
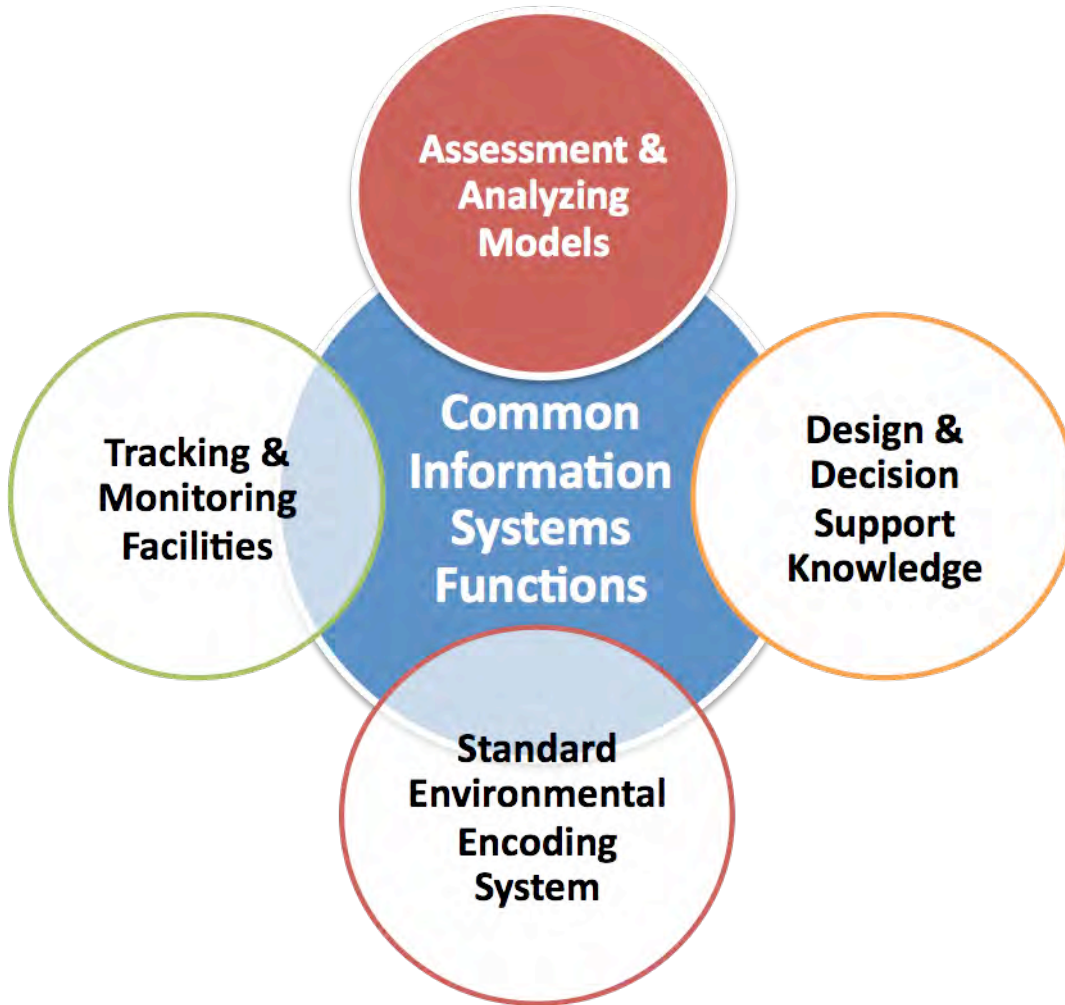
Software for Scientific Research and Engineering

- 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
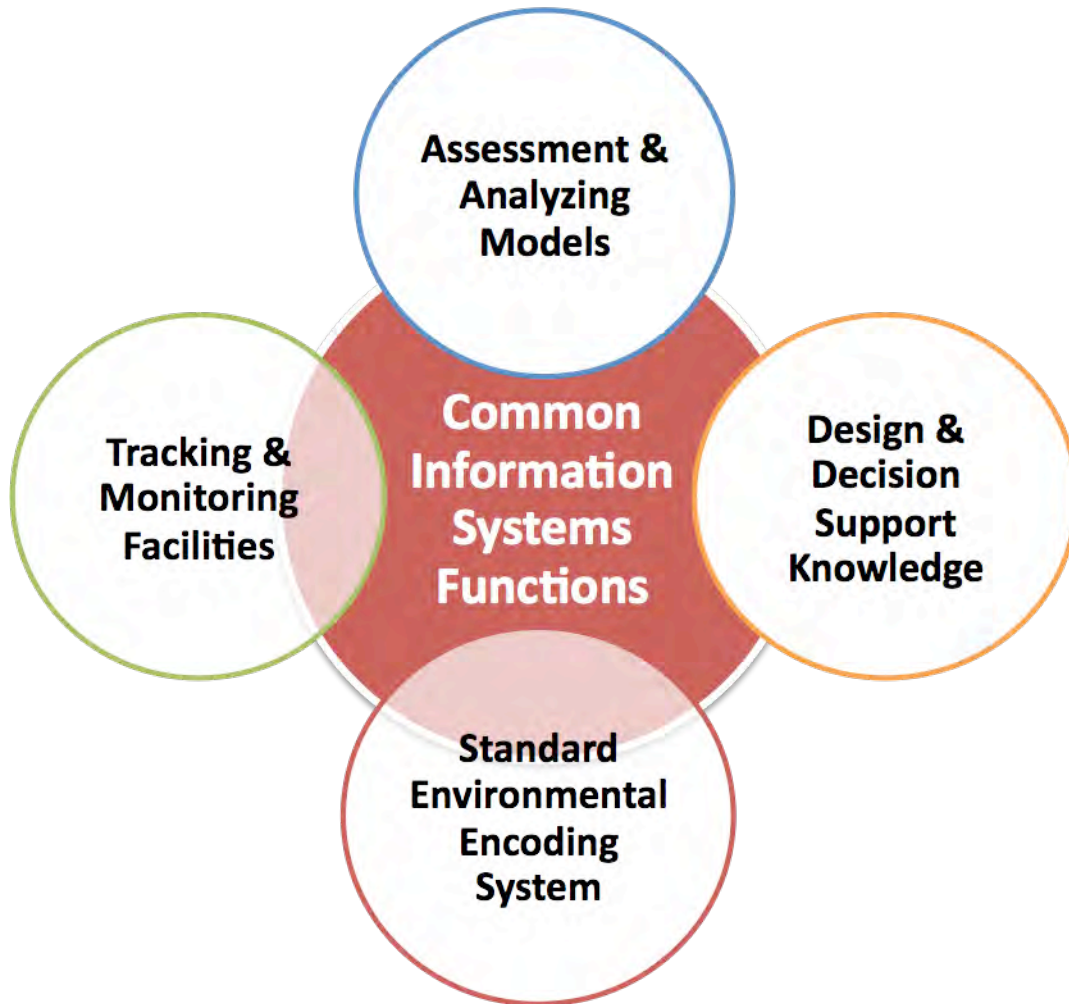
Environmental Management Information Systems and etc.

• **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**

18

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

Settings

Sense user's activity

Data

9,876,543

Computation Model

Knowledge

user

Portable Devices

Carbon Calculator

Knowledgebase

Expert

Estimation of Carbon Emission

Estimation of Carbon Emission

Suggestions on Reducing Carbon Footprint
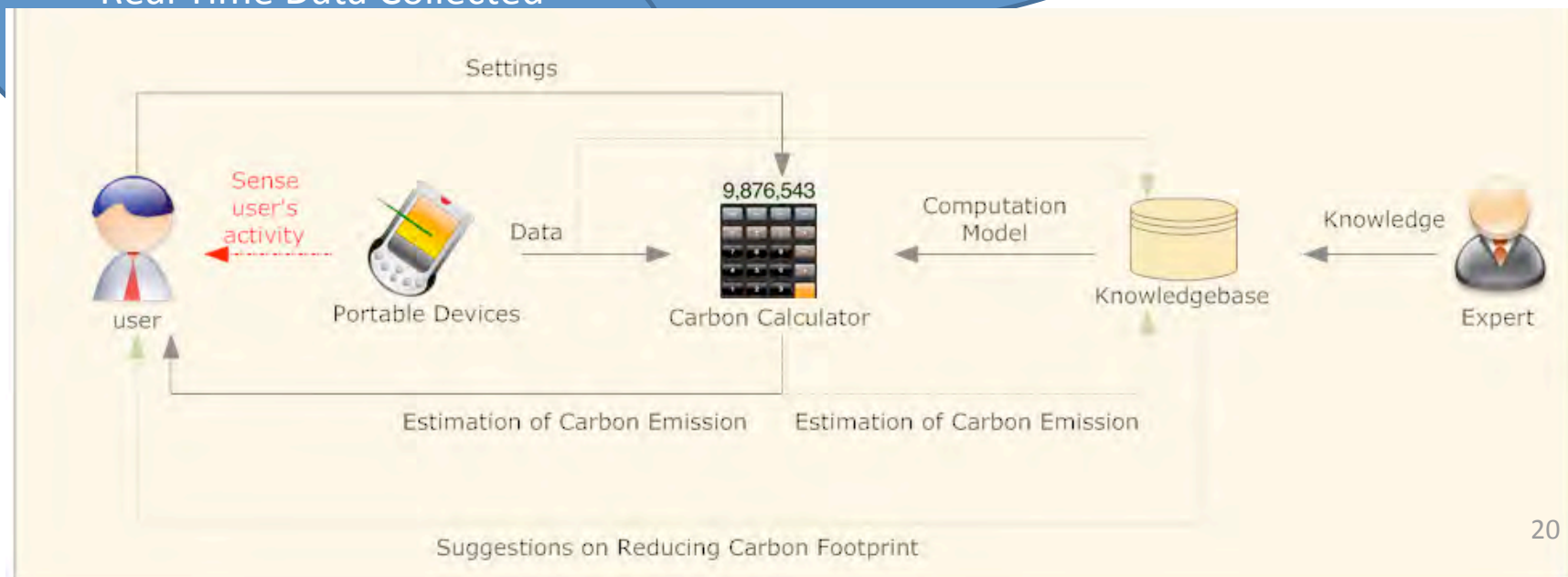
How Data Collection Works

Sensor Node

-Relative humidity
-Temperature
-Accelerometer
-GPS module
-Bluetooth module

Intermediate Device

Modes

-Data Collection
-Data Upload

Server

Services

-Data Assimilation
-Data Analysis
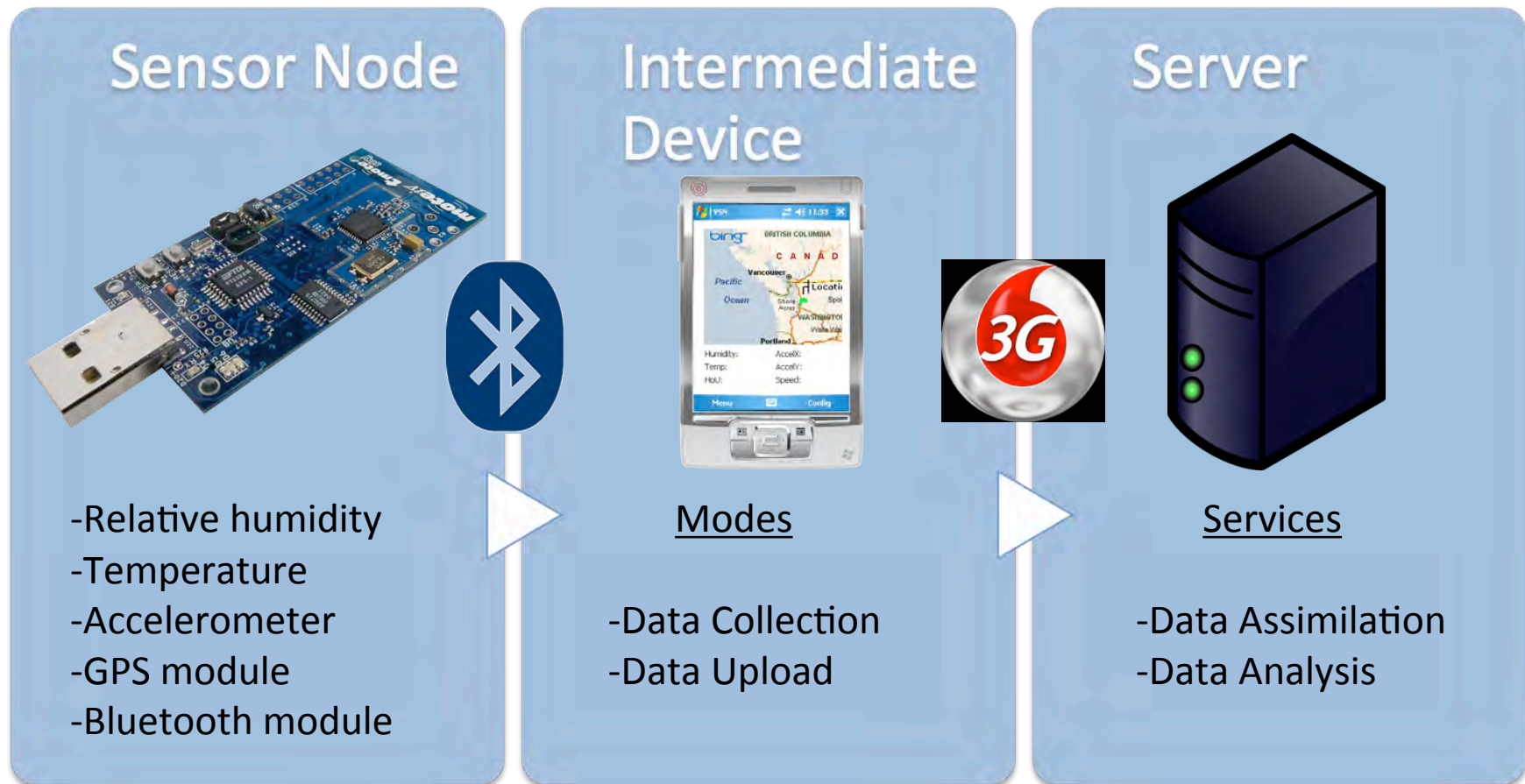
Sample screens of our prototype

Sharing Requirements Knowledge Using Knowledge Map

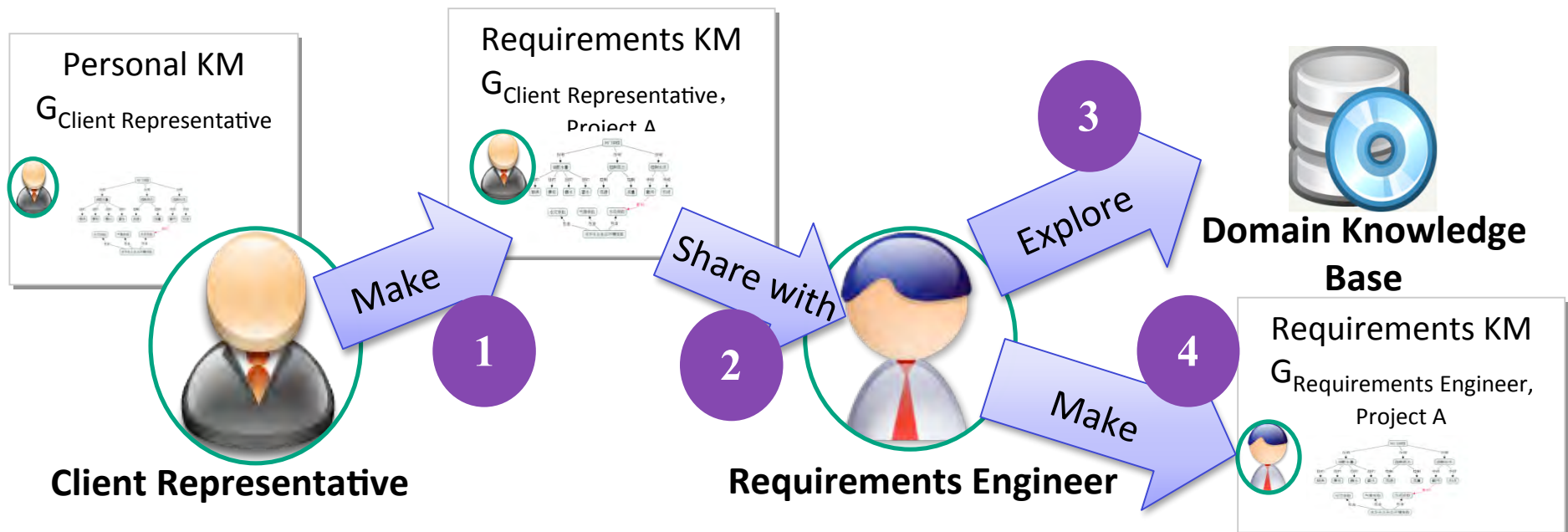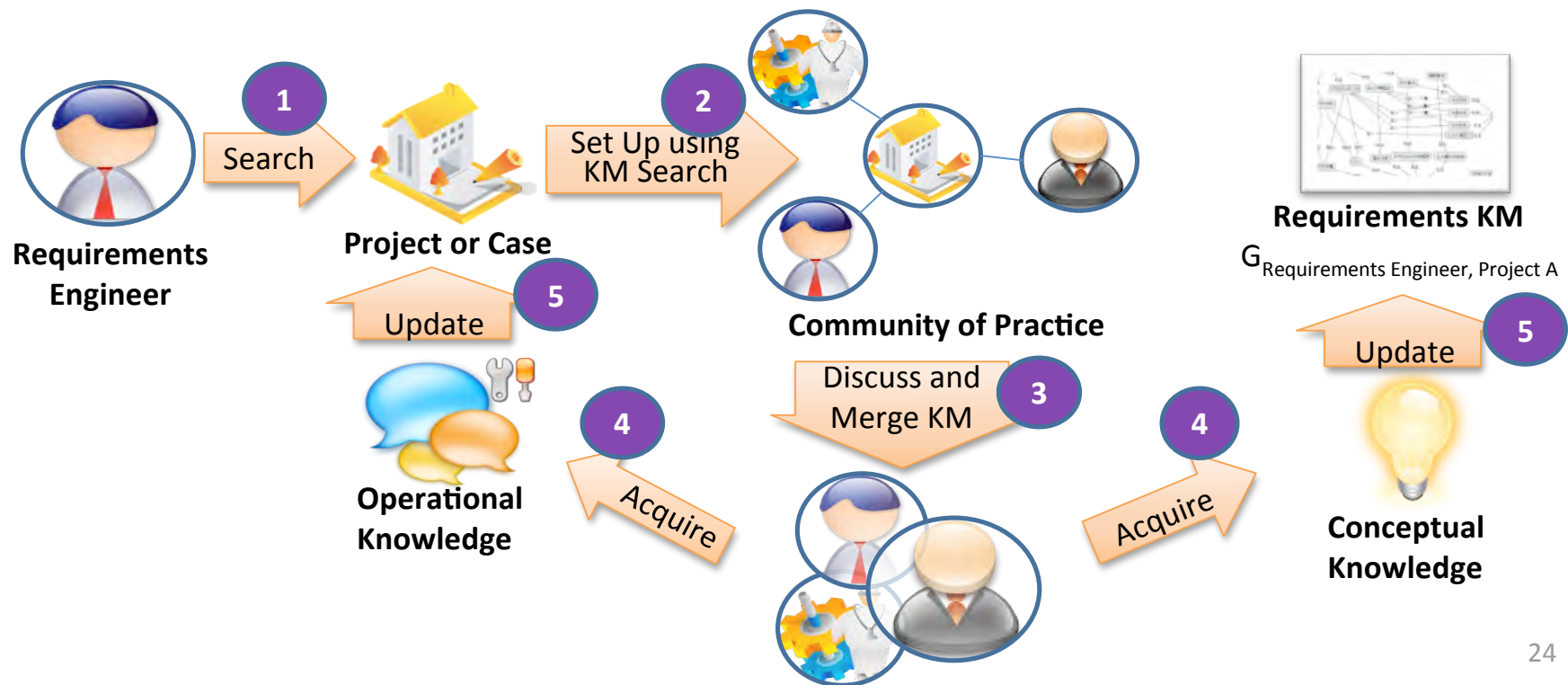1. Requirements Engineer Collects Basic Requirements Knowledge From the Knowledge Map and Domain Knowledge Base.
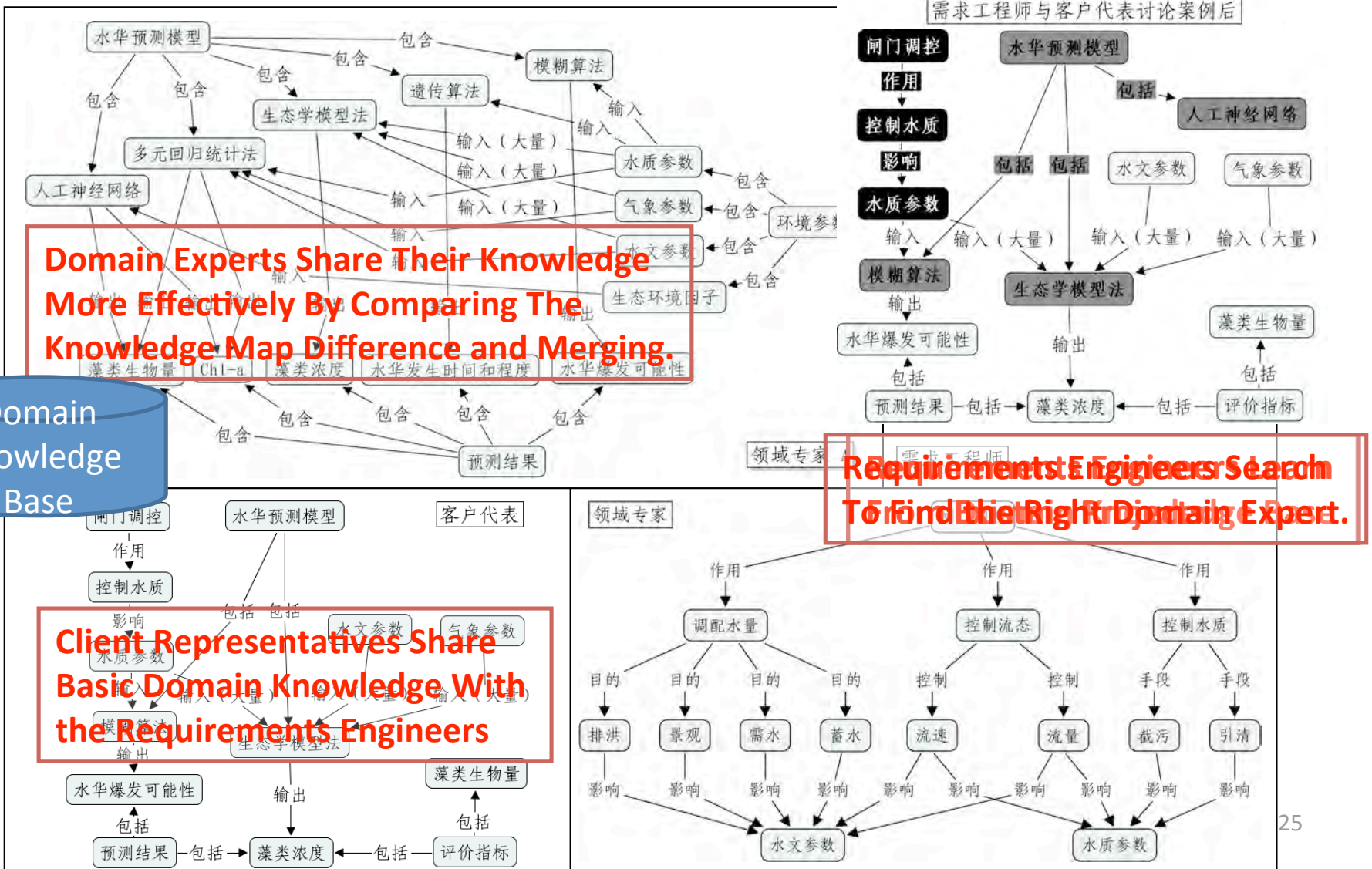
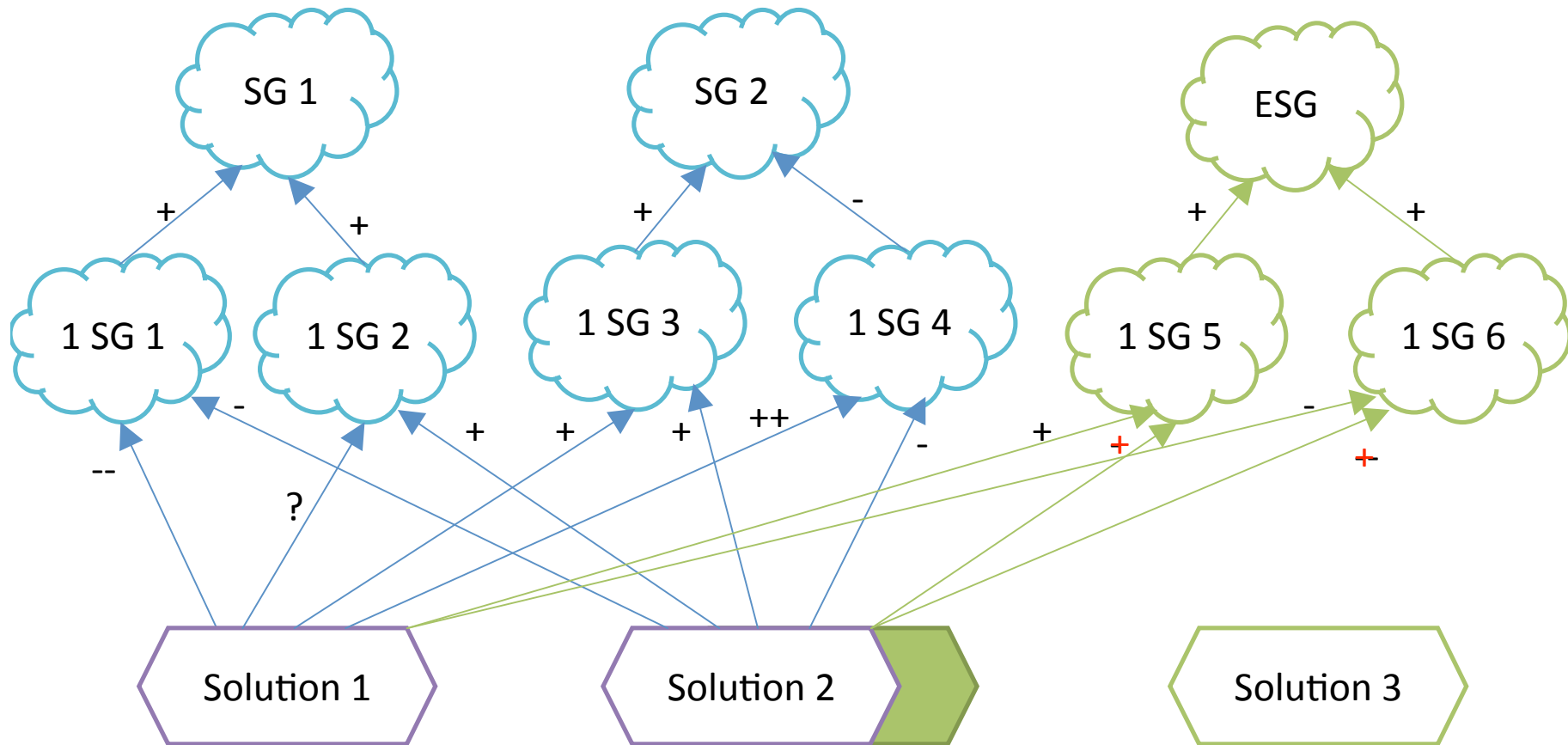# Sharing Requirements Knowledge Using Knowledge Map

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

Domain Knowledge Base

Domain Experts Share Their Knowledge More Effectively By Comparing The Knowledge Map Difference and Merging.

Requirements Engineers Search To Find The Right Domain Expert.

Client Representatives Share Basic Domain Knowledge With the Requirements Engineers

Goal Model for Reducing IT System GHG Emissions

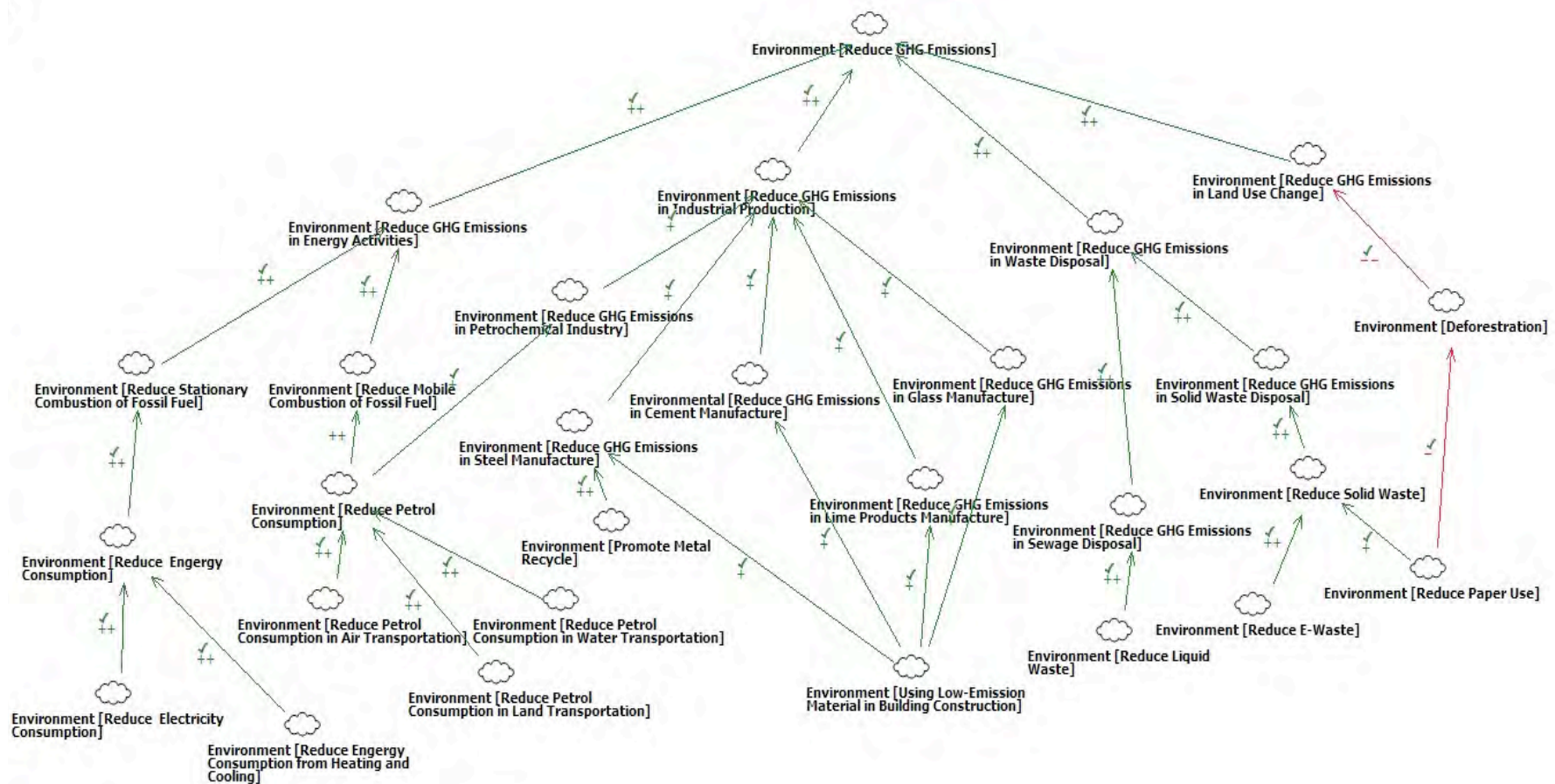# Goal Model for Reducing IT System GHG Emissions

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