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Nexus Modeling and Analysis

Using Tools to Influence Policy

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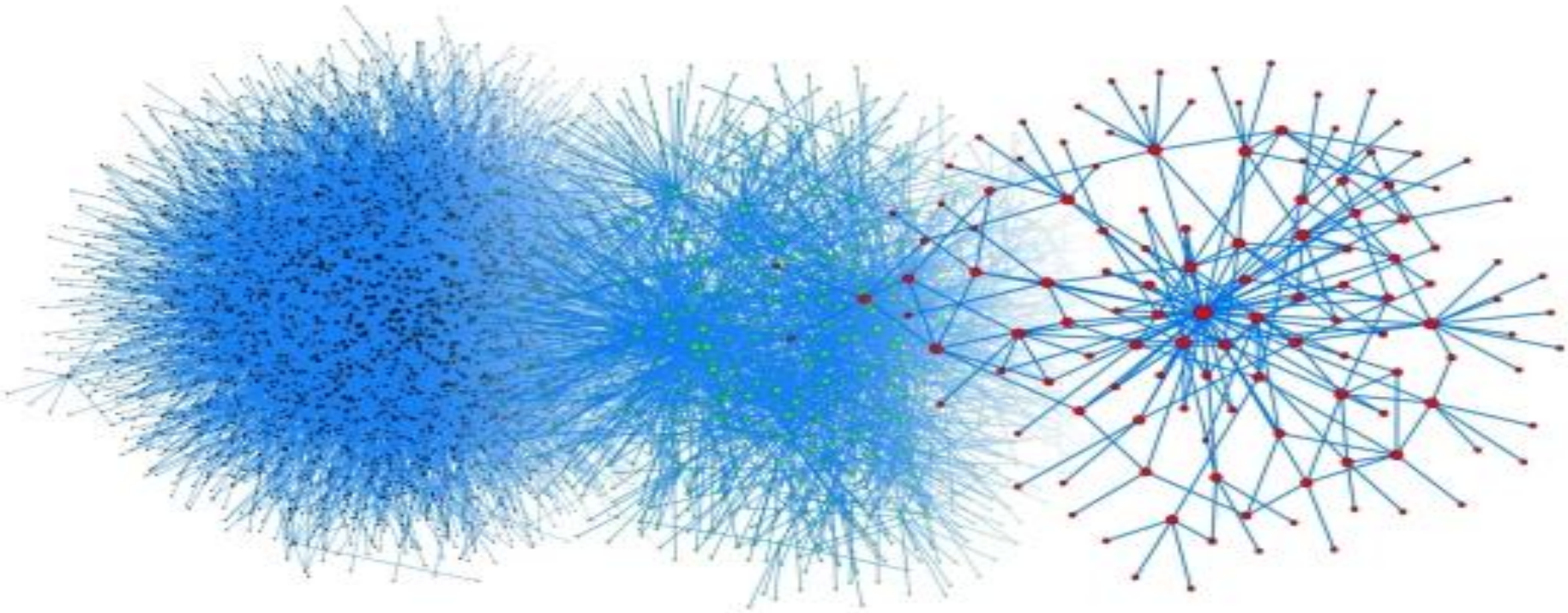

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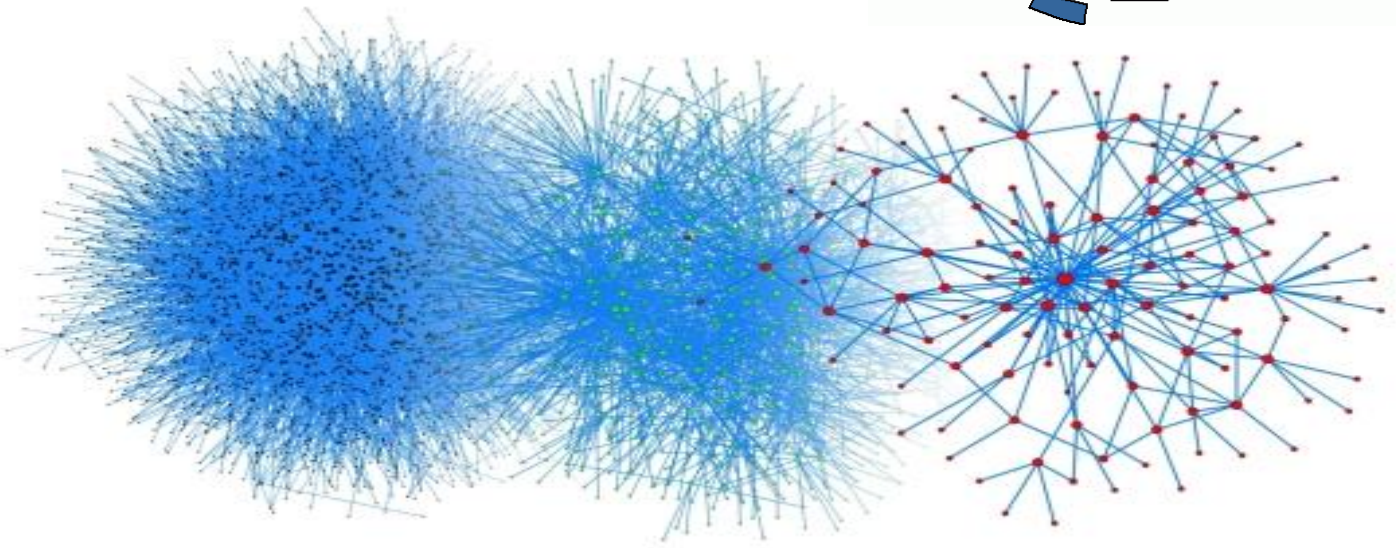
Coupled Human-Environment Systems



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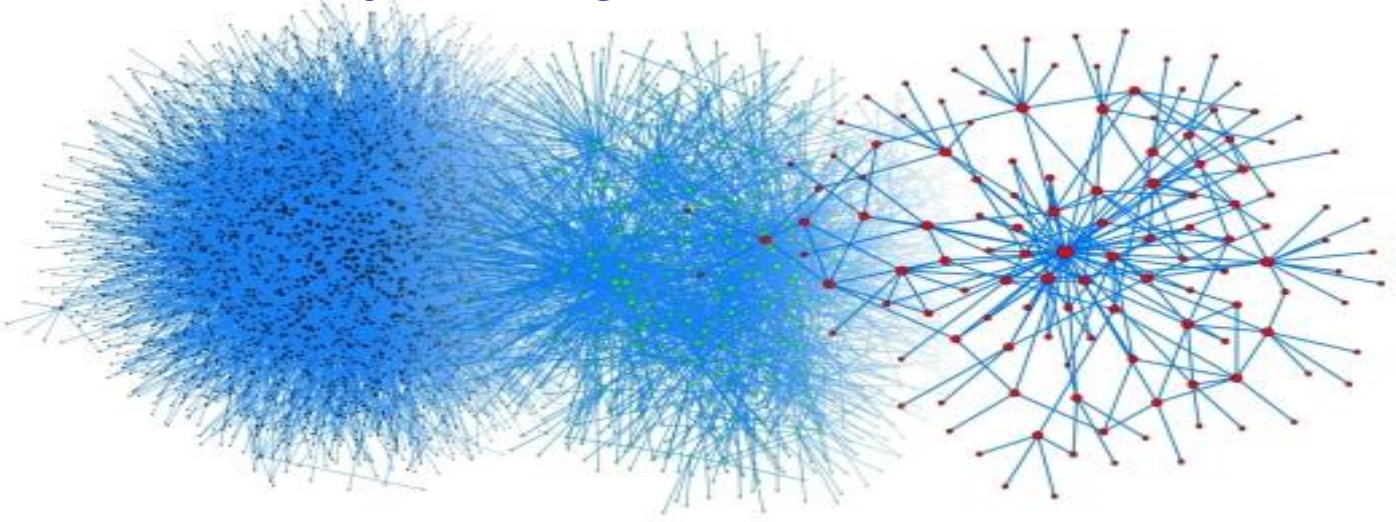
Coupled Human-Environment Systems

- Bounded rationality
- Limited certainty
- Limited predictability
- Indeterminate causality
- Evolutionary change



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Solving One Problem without Creating New Ones

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Solving One Problem without Creating New Ones

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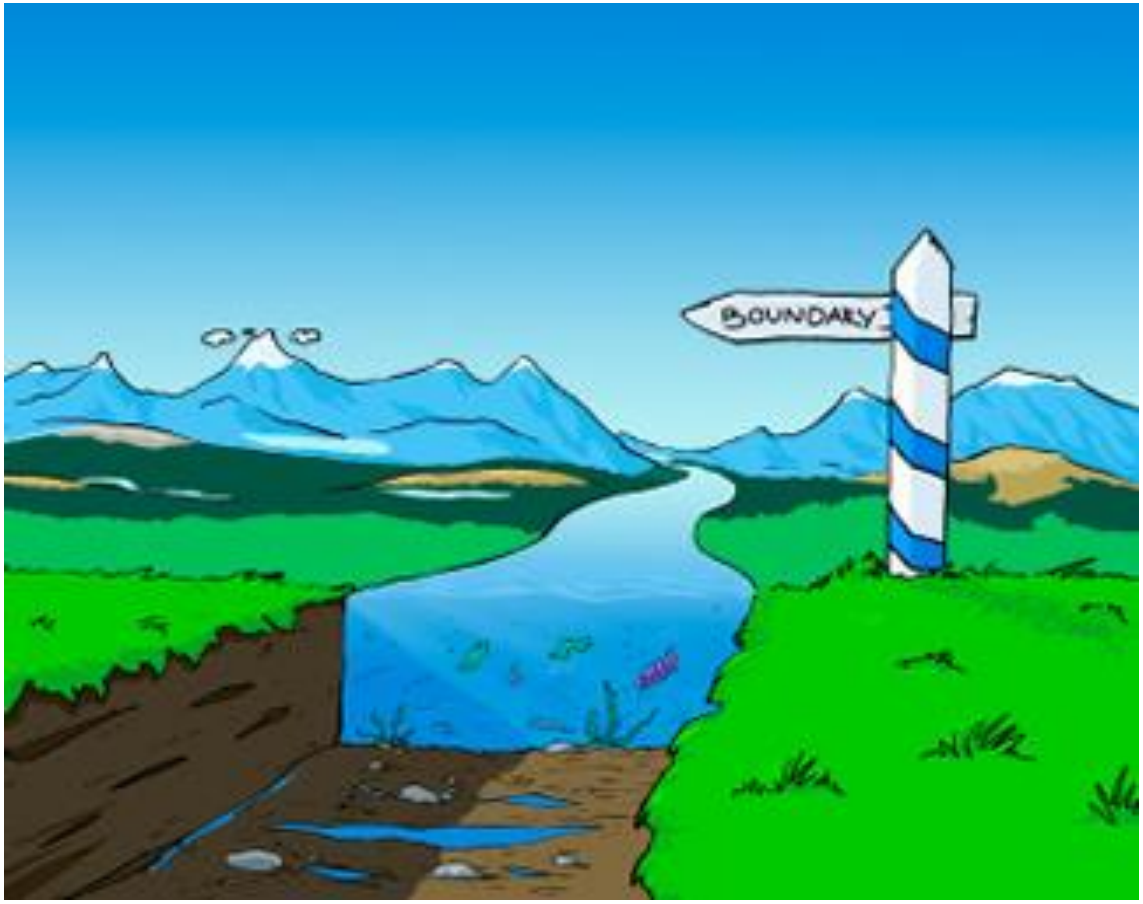
Issue 1: Arbitrary System Boundaries



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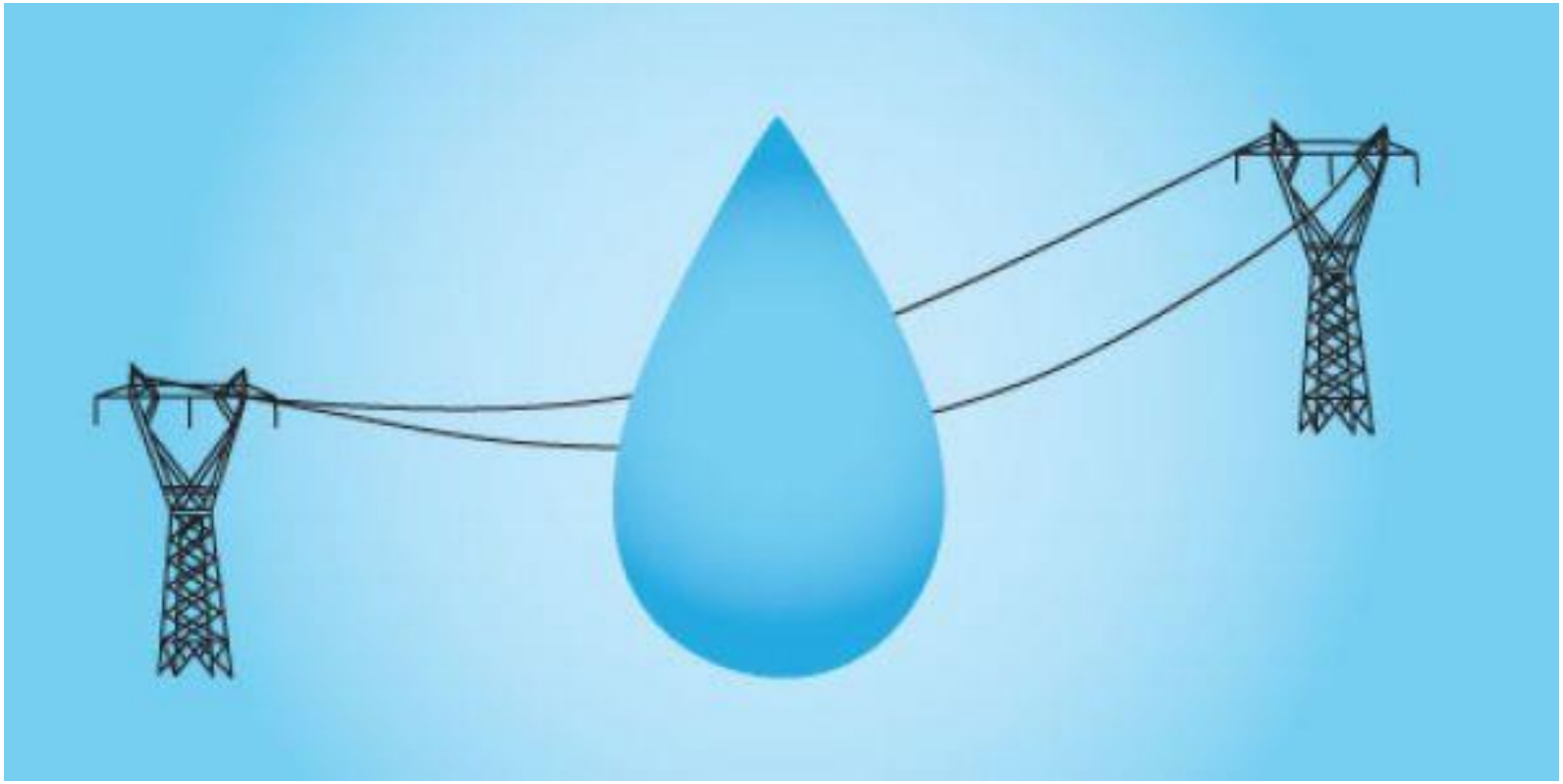
Water Footprint of Energy?



Hadian and Madani, The water demand of energy: implications for sustainable energy policy development, *Sustaina*bility, 2013.
Madani and Khatami, Water for energy: Inconsistent assessment standards and inability to judge properly, *Current Sustainable/Renewable Energy Reports*, 2015

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Water Footprint of Energy

The water footprint of the global energy supply mix increases by 37% to 66% in the next two decades.

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Water Footprint of Energy

Energy's water footprint per unit of energy production; increases by 5-10% in 2012-2035.

The water footprint of the global energy supply mix increases by 37% to 66% in the next two decades.

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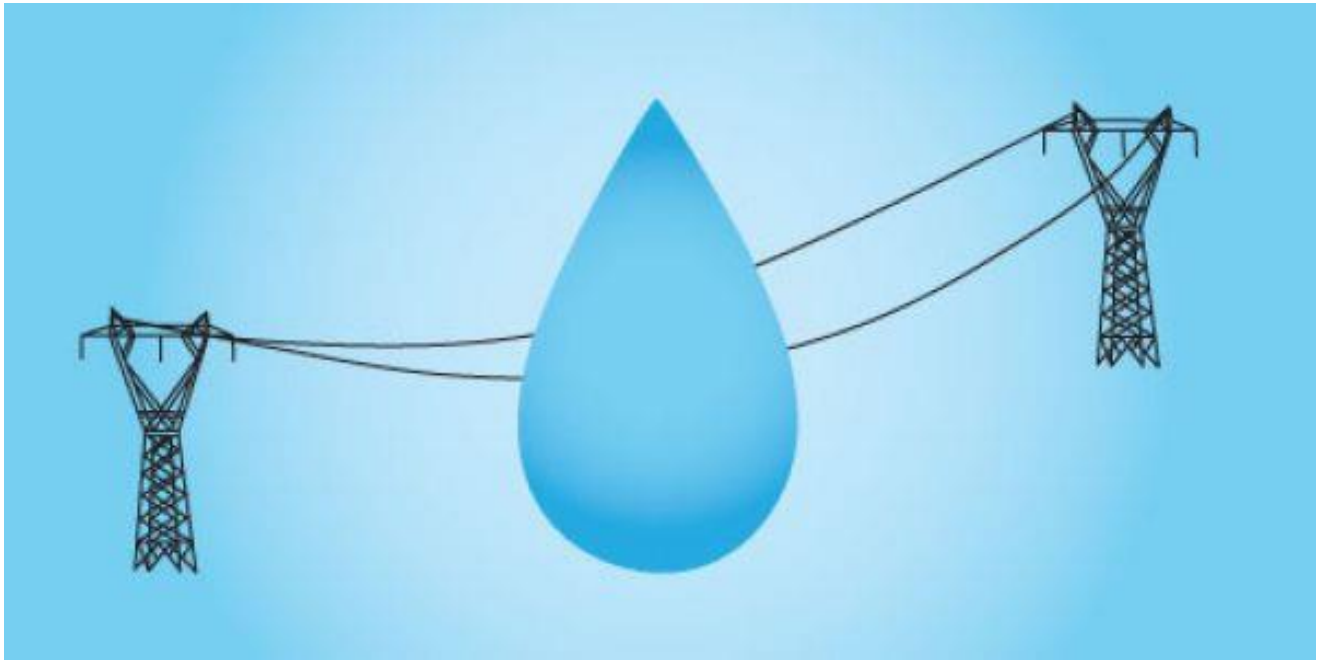
Possible Policy Insight?



Renewable energies are bad!?

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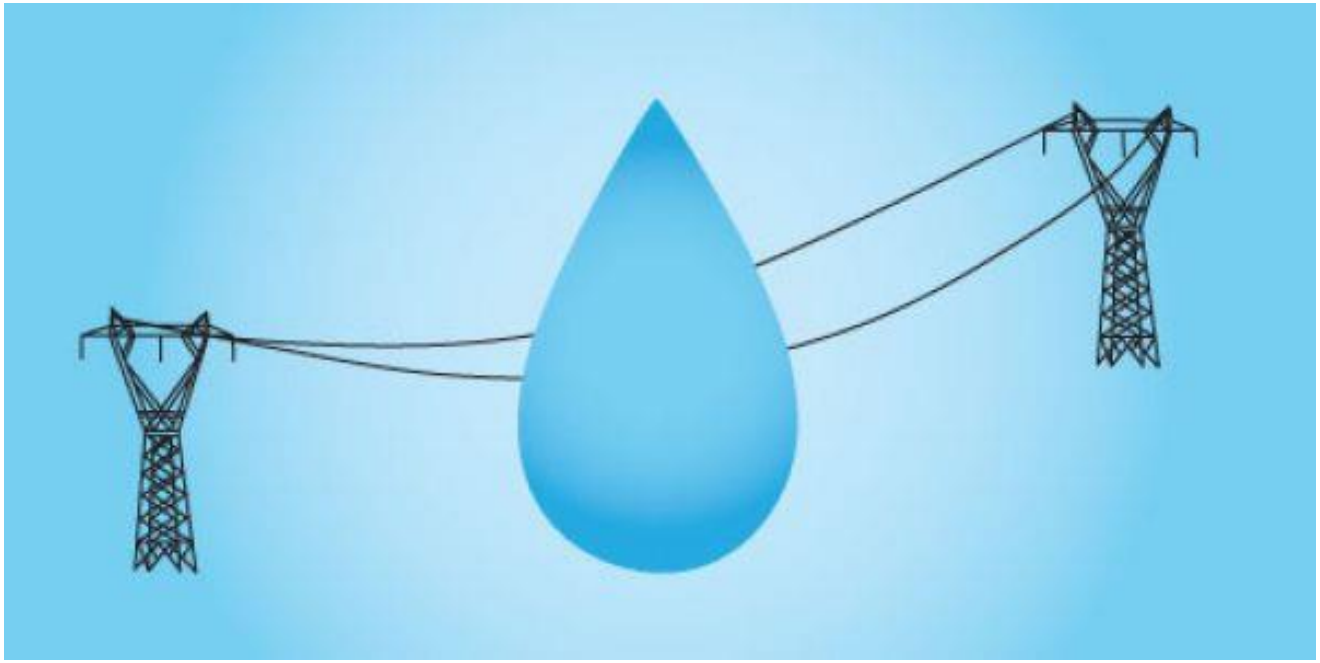
Possible Policy Insight?



Renewable energies are bad!?

No. Expand your boundaries and use consistent metrics.

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Sustainability of Green Energies?

Carbon footprint:
The carbon dioxide equivalent/energy production

Water footprint:
The total amount of freshwater /energy production

Ecological/Land footprint:
The amount of land and sea area /energy production

Cost:
Levelized cost/energy production

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Trade-offs and Uncertainty

Hadian and Madani, A system of systems approach to energy sustainability assessment: Are all renewables really green?, *Ecological indica*tors, 2015

Energy Sources	Carbon footprint (gCO2eq/kwh)	Water footprint (m^3/GJ)	Land footprint (m^2/GWh)	Cost (USD_{2010}/MWh)
Biomass	**130-420[a]**	**20-64**	**14433-21800**	**77-150-320**
Concentrated Solar Power	**8.8-63[a]**	**0.118-2.180**	**340-680**	**150-200-310**
Solar Photovoltaic	**18-180**	**0.0064-0.303**	**704-1760**	**84-160-210**
Wind: Onshore	**7-56**	**0.0002-0.0012**	**2168-2640**	**51-84-160**
Wind: Offshore	**8-35**	**0.0002-0.0012**	**2168-2640**	**110-250**
Hydropower	**1-2200**	**0.3-850**	**538-3068**	**9-150**
Coal	**740-910**	**0.079-2.1**	**83-567**	**30-120**
Oil	**657-866**	**0.214-1.19**	**1490**	**85-224**
Natural Gas	**410-650**	**0.076-1.240**	**623**	**34-150**
Nuclear	**3.7-110**	**0.018-1.45**	**63-93**	**45-150**
Geothermal	**6-79**	**0.0073-0.759**	**33-463**	**18-190**

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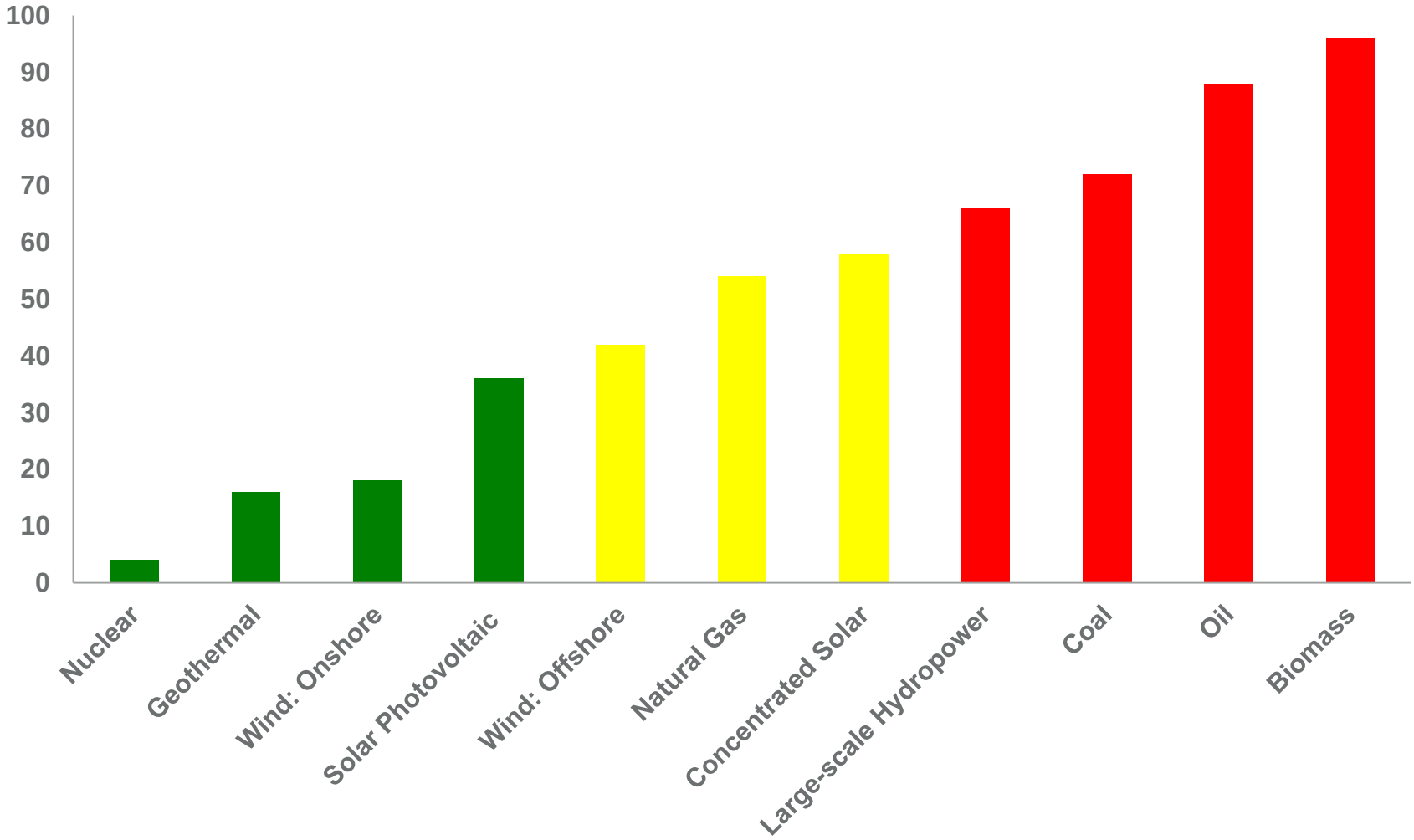
Relative Aggregate Footprint

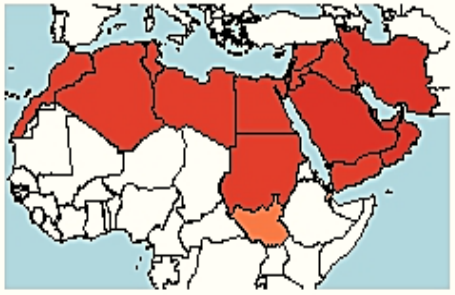


Relative Desireability of Energy Technologies

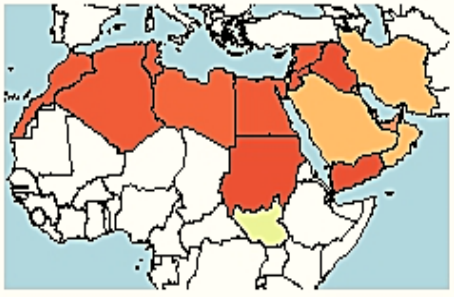
0 — 100

Given national resource availability in a given country red indicates the technology underperforms alternatives while green indicates the technology is preferable.

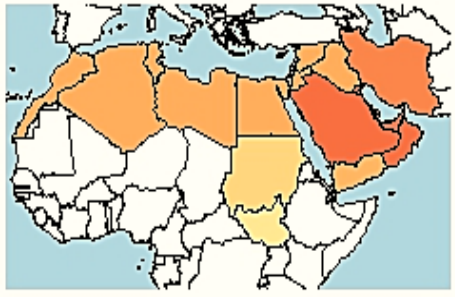
Biomass



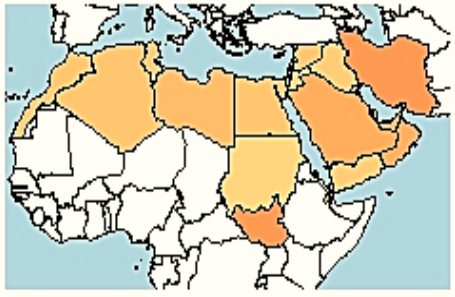
Large Scale Hydropower



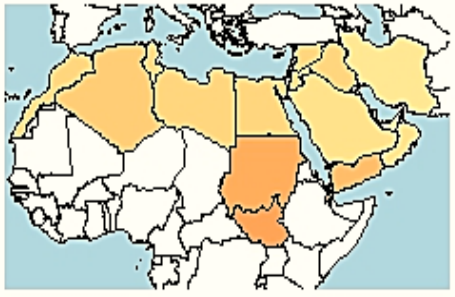
Coal



Oil



Concentrated Solar



Natural Gas

Nuclear

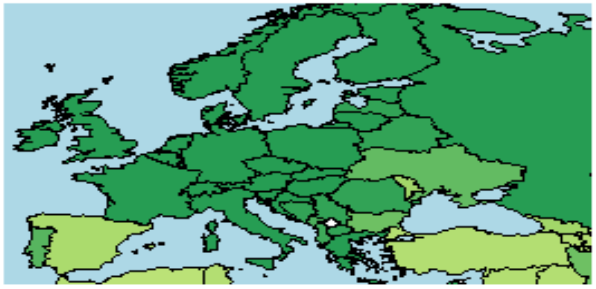
Wind-Offshore

Solar Photovoltaic

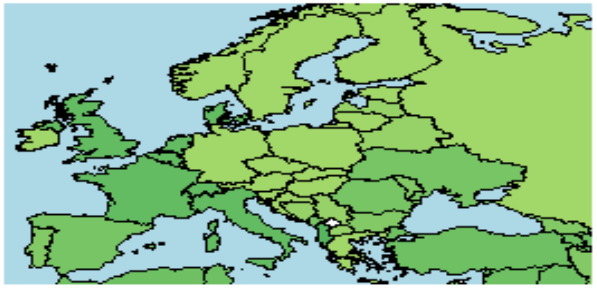
Geothermal

Wind-Onshore

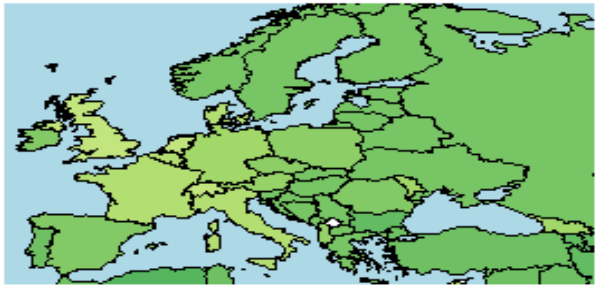
a.Nuclear



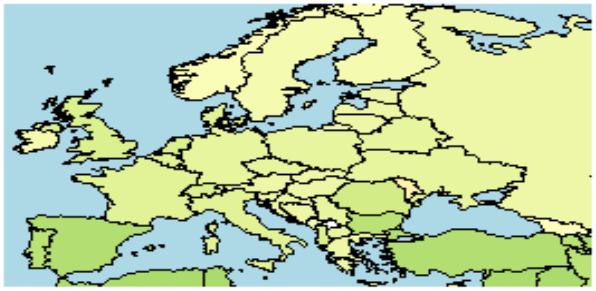
b.Geothermal



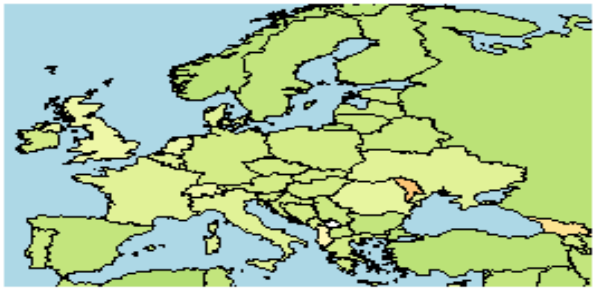
c.Onshore.Wind



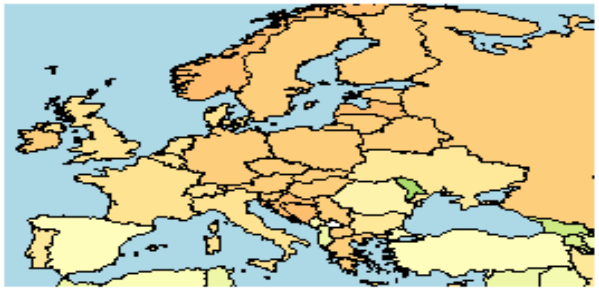
d.PV



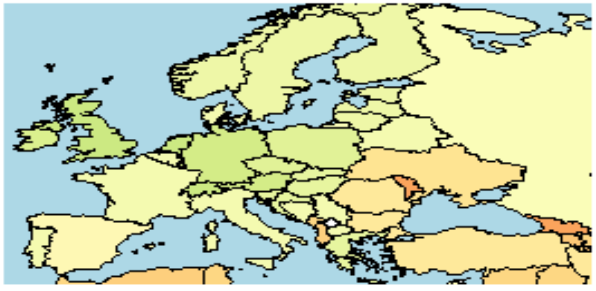
e.Offshore.Wind



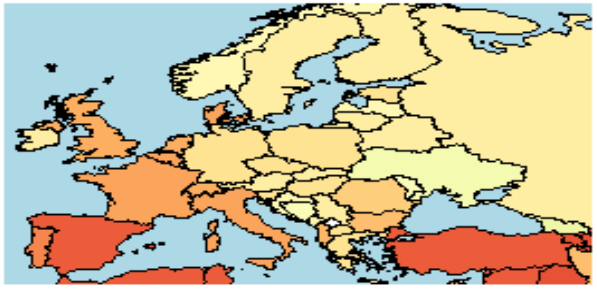
f.Gas



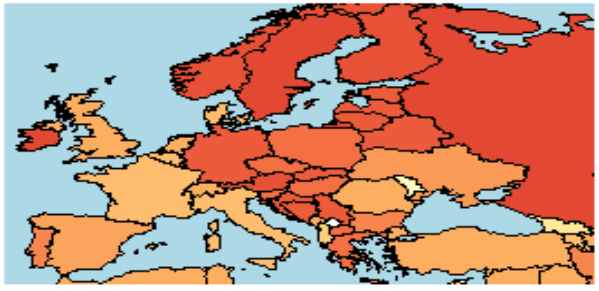
g.CSP



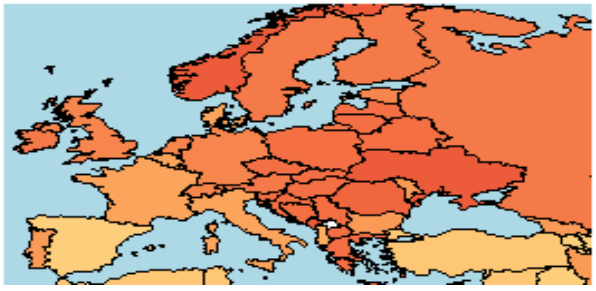
h.Hydro



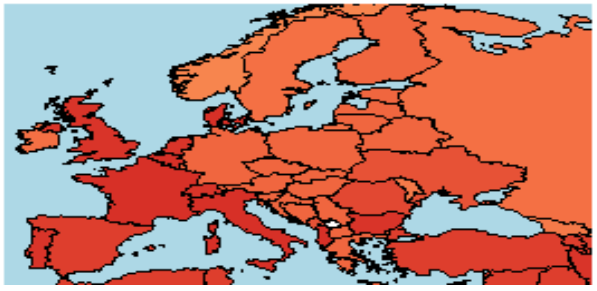
i.Coal



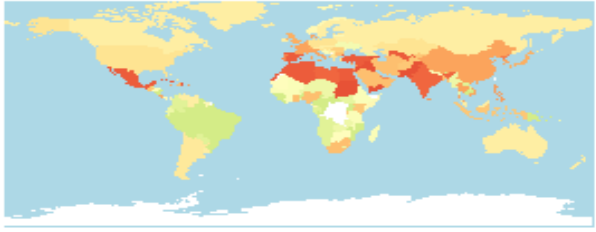
j.Oil



k.Biomass



l.Hydro World



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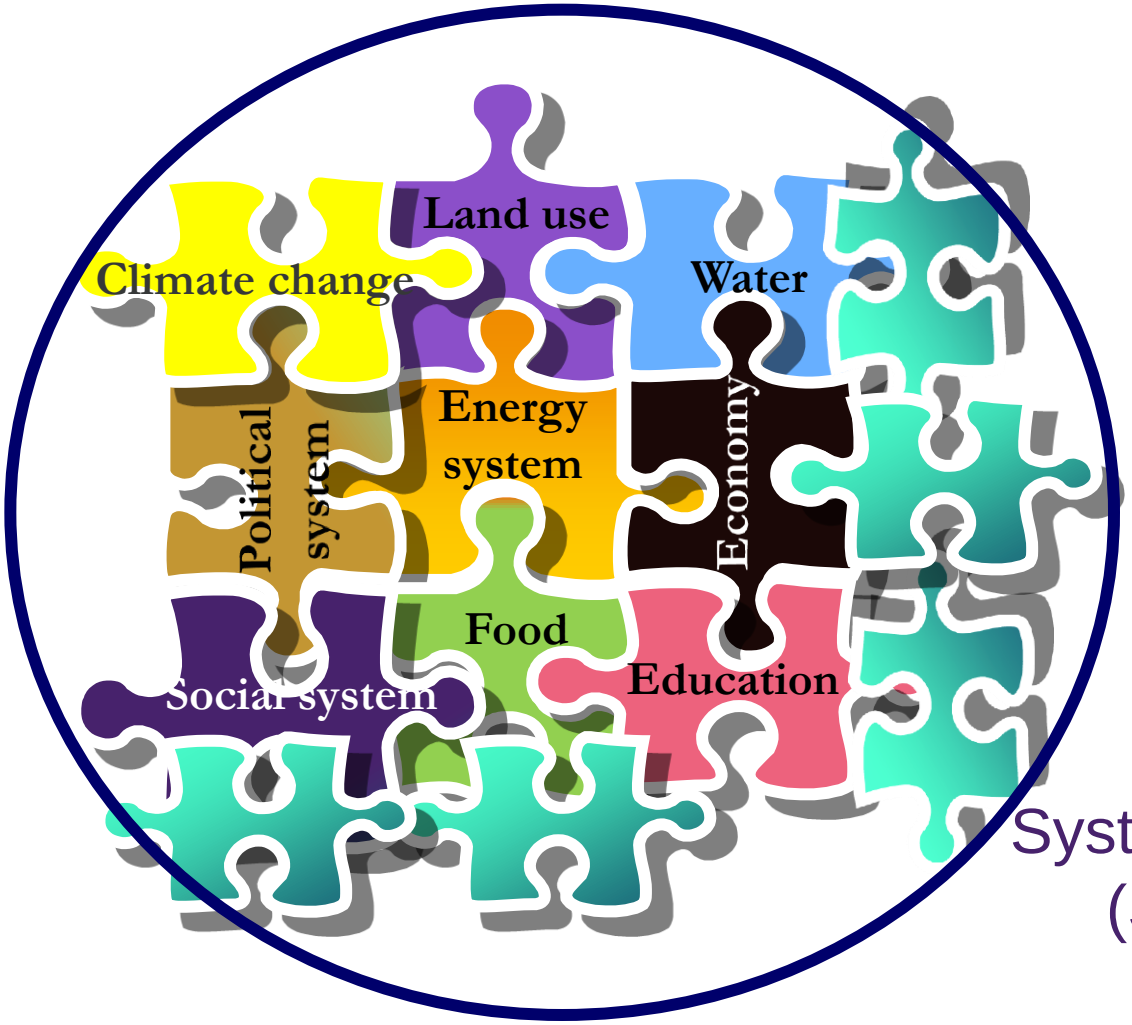
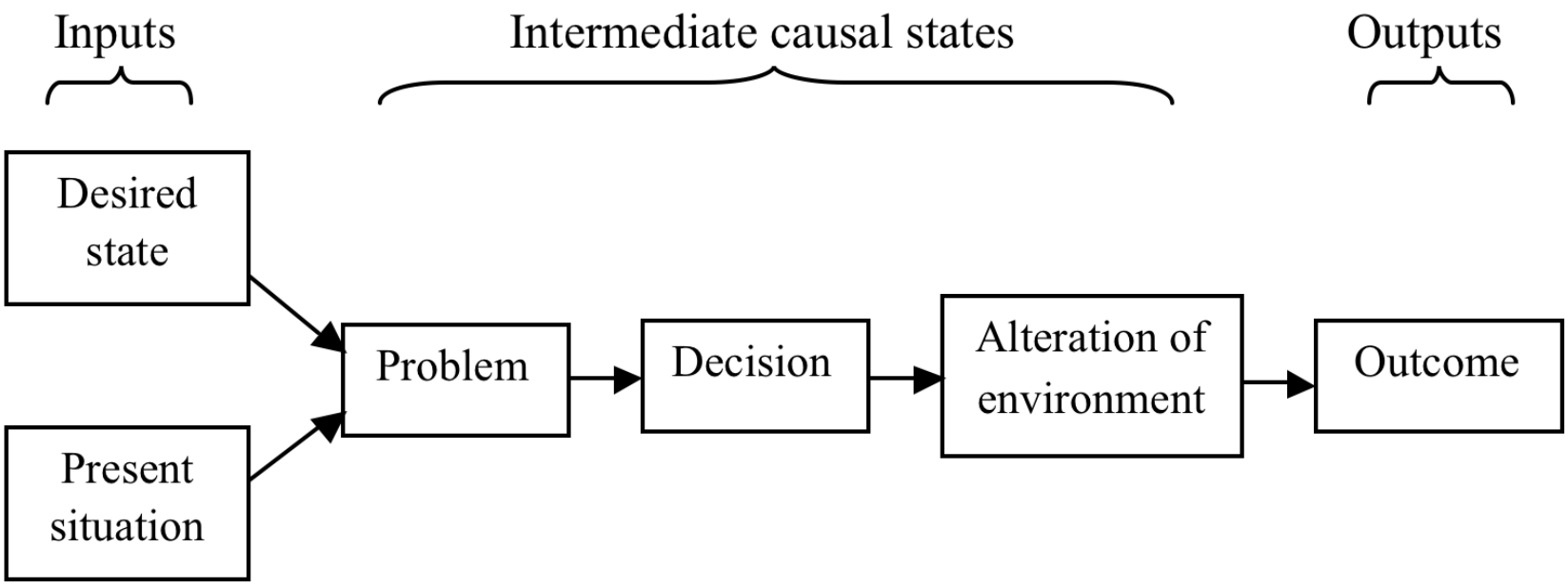
Analysing and Managing Complexity



System of Systems (SOS)

Issue 2: Linear Thinking



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Zayandeh-Rud River System

- Urban
- Agricultural
- Industrial
- Environmental
- High population
- Extensive water transfers

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Zayandeh-Rud River System

- Urban
- Agricultural
- Industrial
- Environmental
- High population
- Extensive water transfers
- Continuous water shortages

Gohari et al.,, Water transfer as a solution to water shortage: a fix that can backfire, *Journal of Hydrology*, 2013

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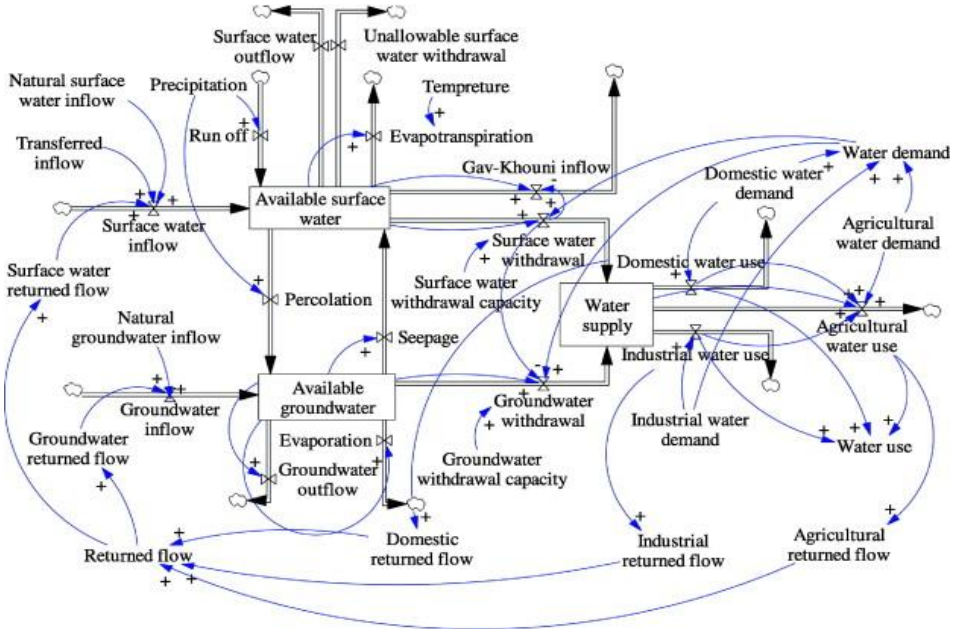
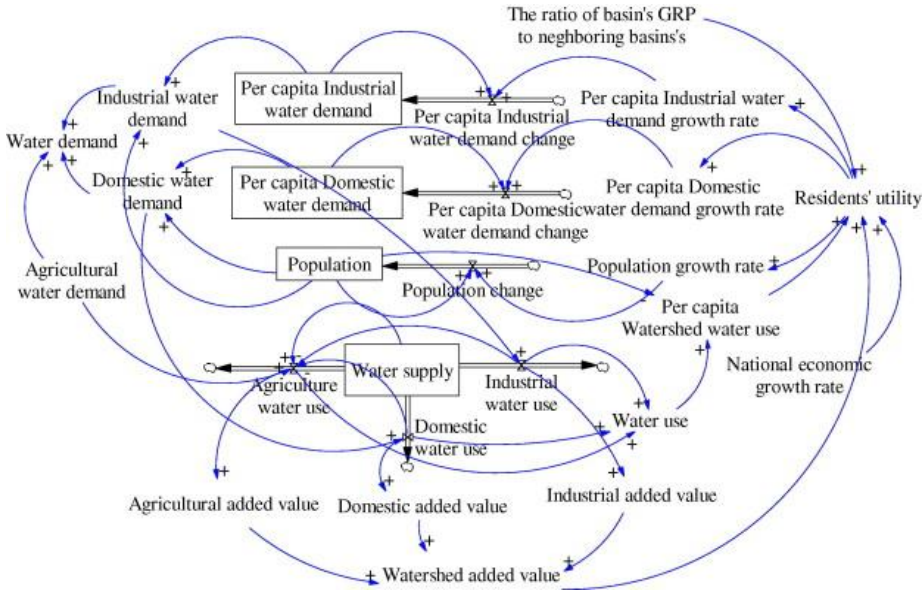
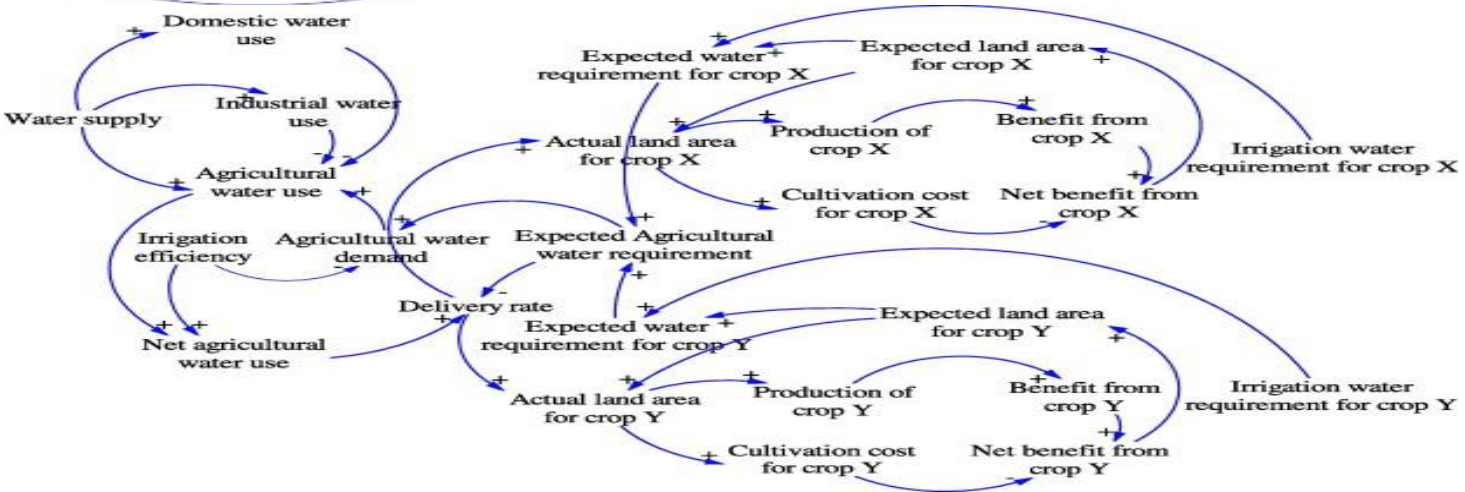
Is Water Transfer a Sustainable Solution?







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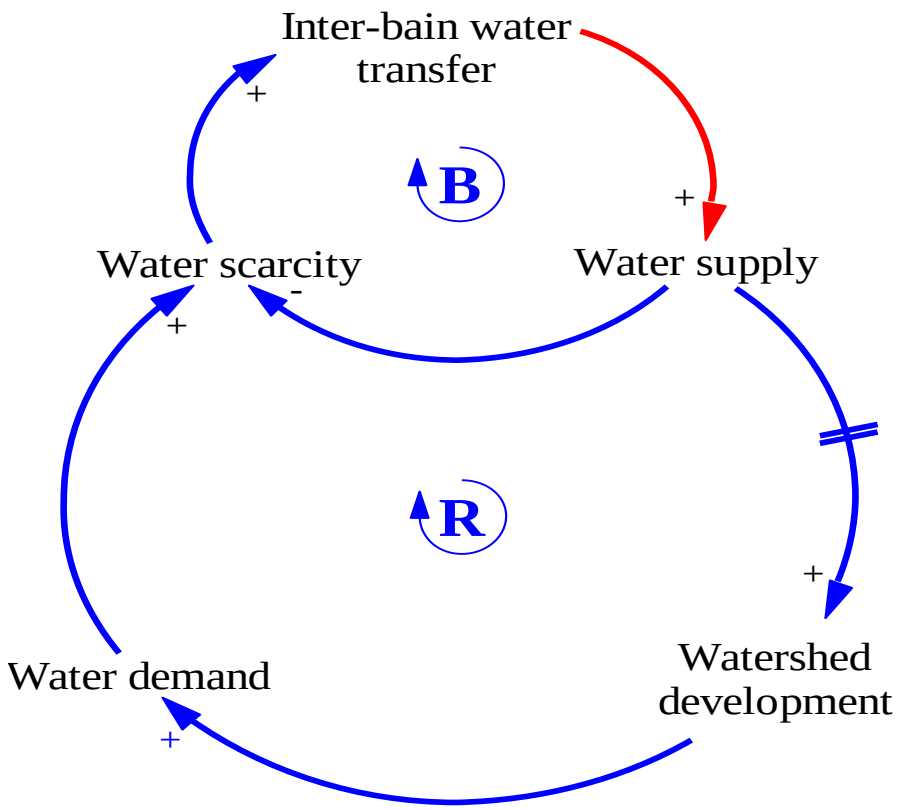
Fix that Backfires



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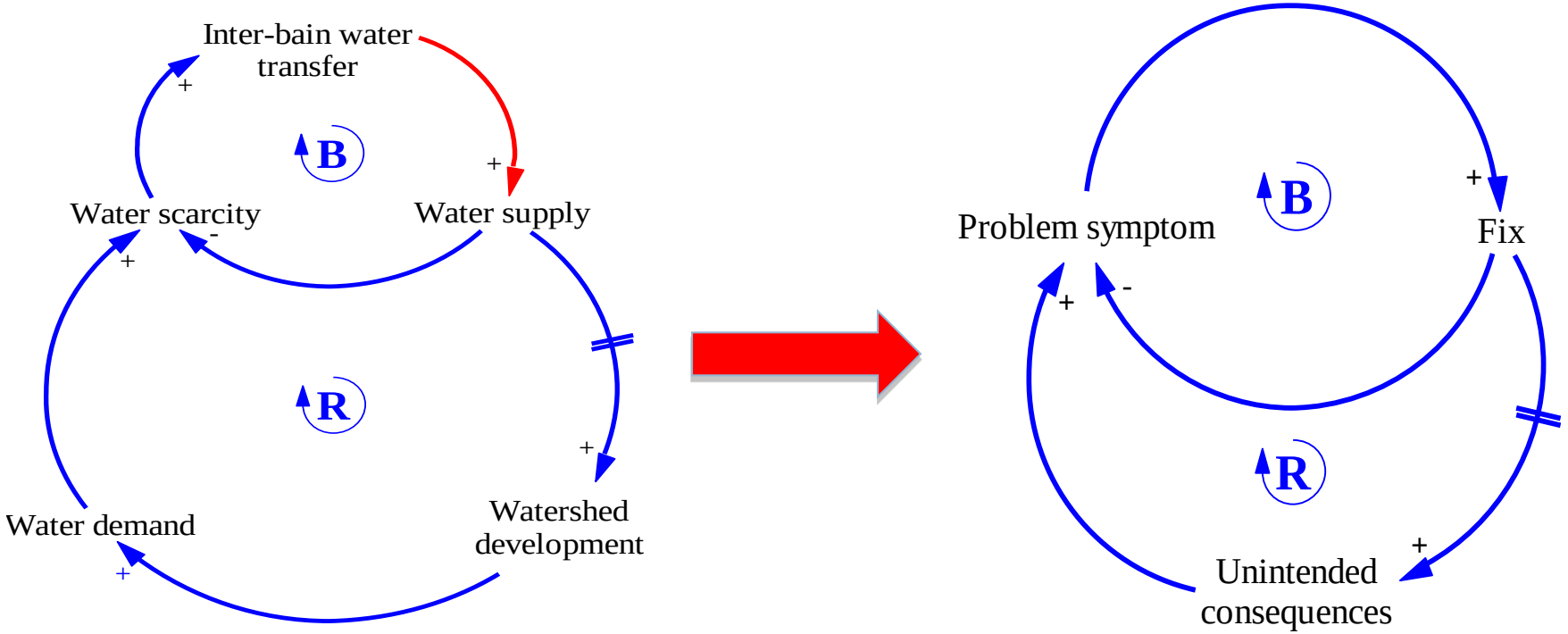
Fix that Backfires



Symptom Management

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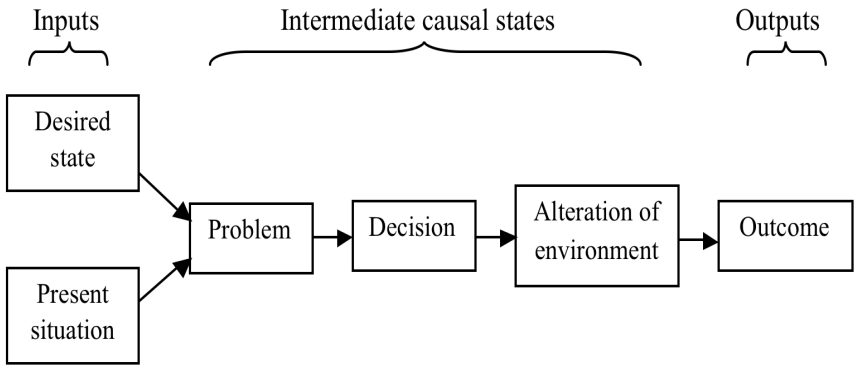
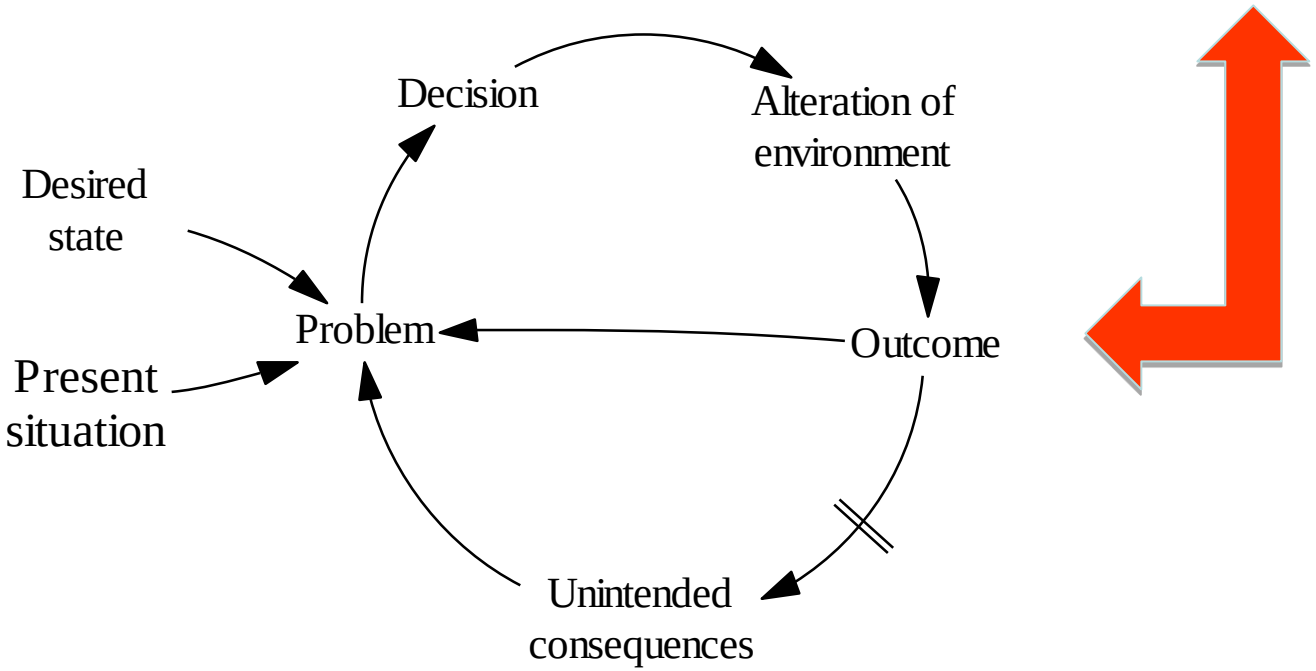
Non-linear Thinking





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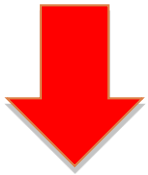
Linear Thinking?

Global Warming (Symptom)

Greenhouse gas emissions

Fossil Fuels (Source)



Reducing carbon dioxide by any means!

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Linear Thinking?

Global Warming (Symptom)

↑

Greenhouse gas emissions

↑

Fossil Fuels (Source)

↓

Reducing carbon dioxide by any means!

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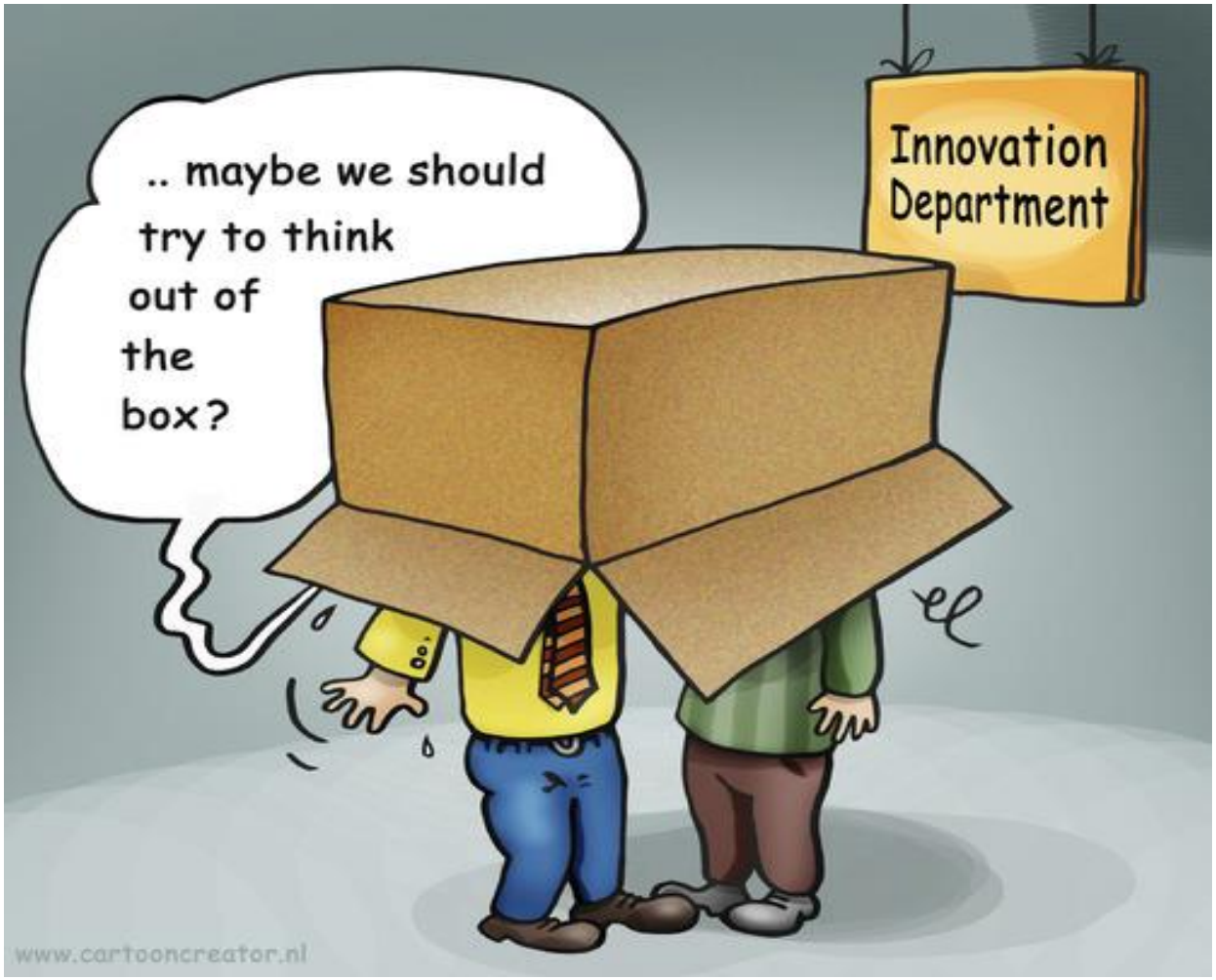
Getting Rid of the Mental Frames



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Issue 3: The Inherent Group Rationality Assumption

Madani, Game theory and water resources, *Journal of Hydrology*, 2010.

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Who Manages Coupled Human-Nature Systems?

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Who Manages Coupled Human-Nature Systems?

Multi-Participant Multi-Objective

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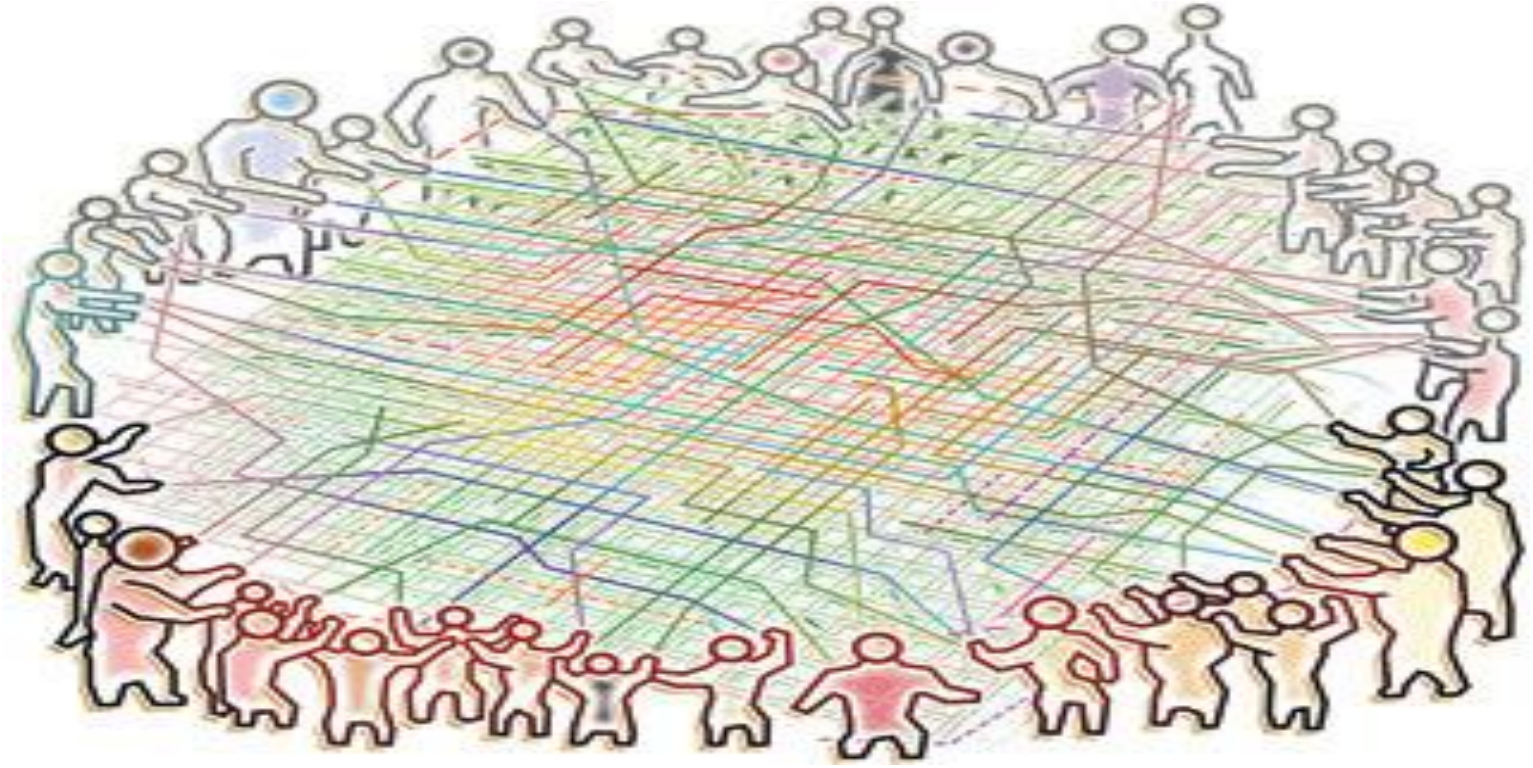
Individual Rationality vs. Group Rationality



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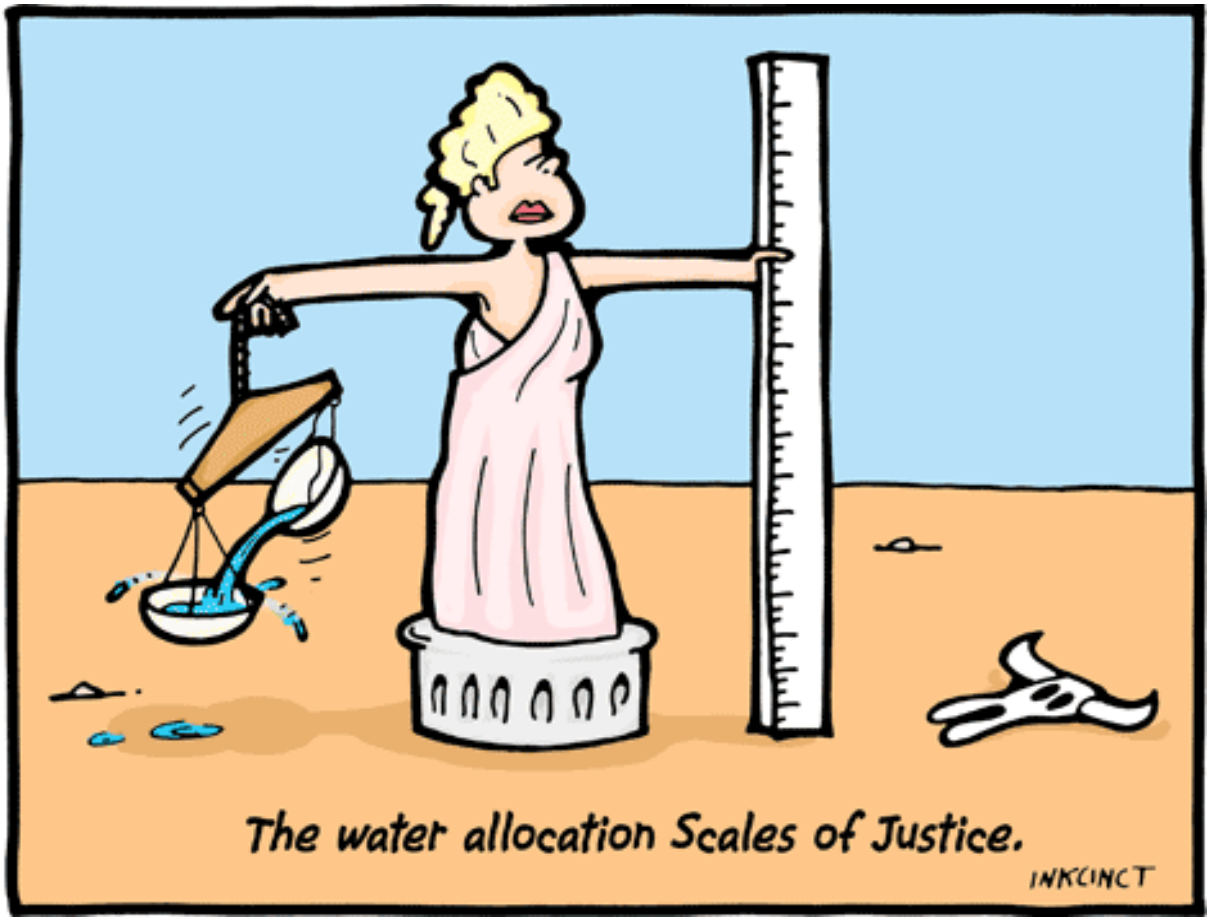
Different Notions



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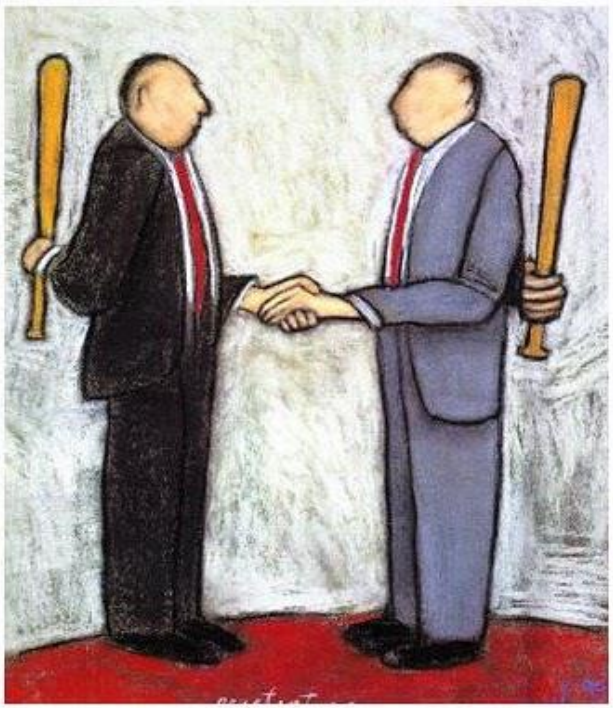
Co-existence of Conflict and Cooperation (Coopetition)



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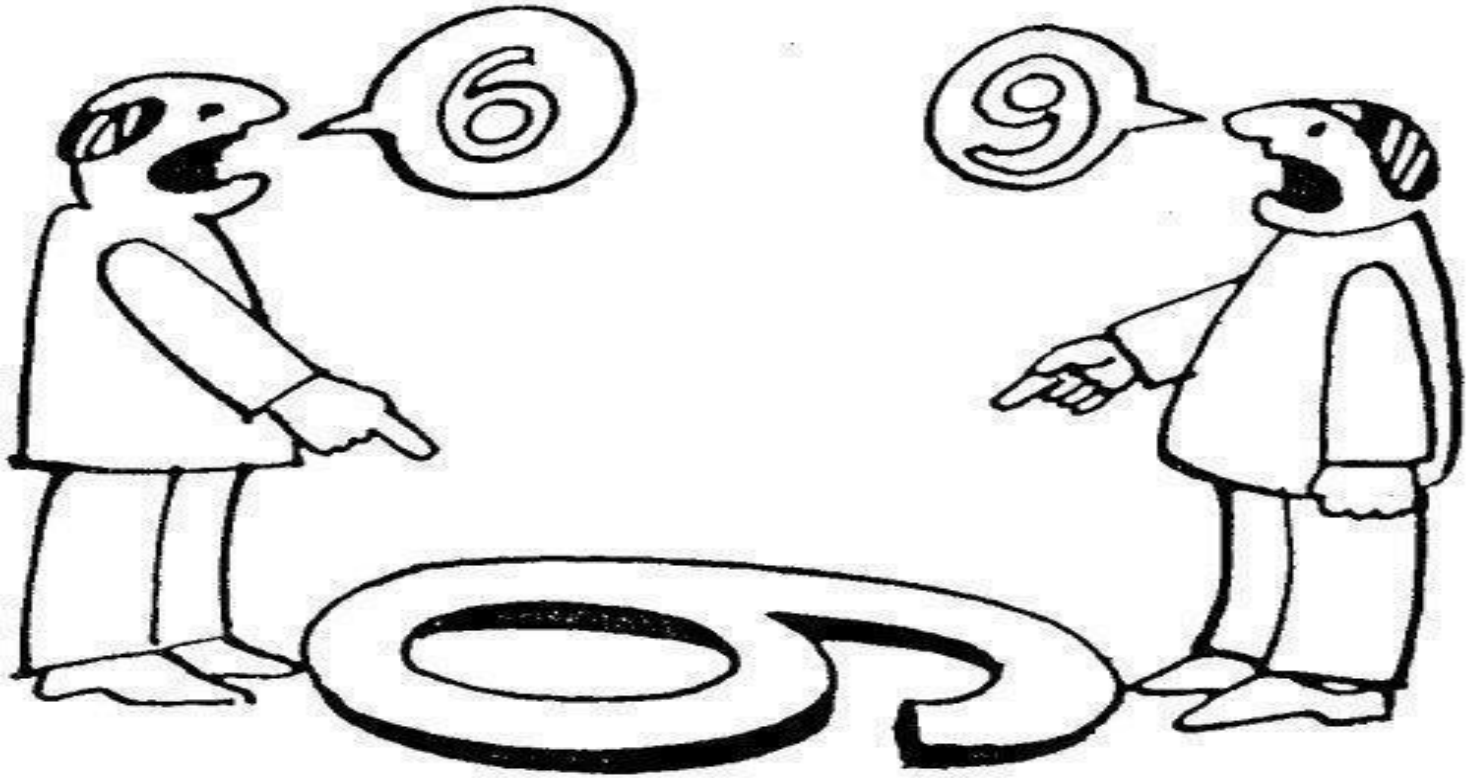
Narratives



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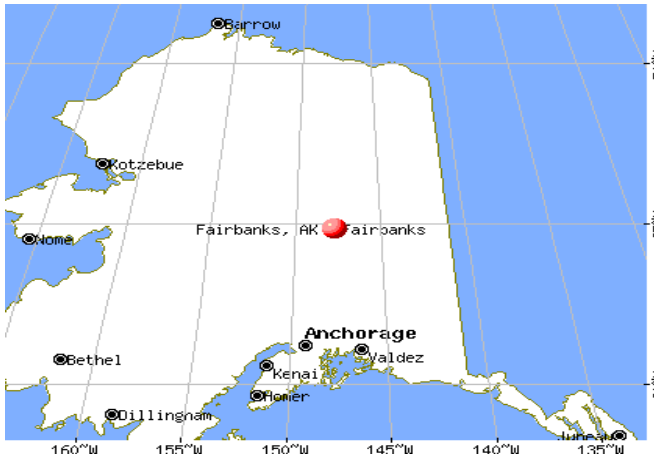
City of Fairbanks Energy Supply Issues

- Accessibility: Potential energy sources are far from Fairbanks
- Affordability: Fairbanks residents pay twice Anchorage prices for energy
- Agreement: Decision-makers and public have not reached a consensus on their ideal solution



Read et al., Stakeholder-driven multi-attribute analysis for energy project selection under uncertainty, *Energy*, 2017.

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Energy Supply Alternatives

	Description
A1	Large diameter pipeline Edmonton -> Chicago
A2	LNG export North Slope to Valdez
A3	Bullet line to Anchorage, spur Fairbanks
A4	Small diameter pipeline: North Slope to Fairbanks
A5	LNG trucking project
A6	Big Lake gas pipeline: Beluga to Fairbanks
A7	High Voltage, DC line from North Slope
A8	Coal to liquids power plant in Fairbanks
A9	Susitna Dam

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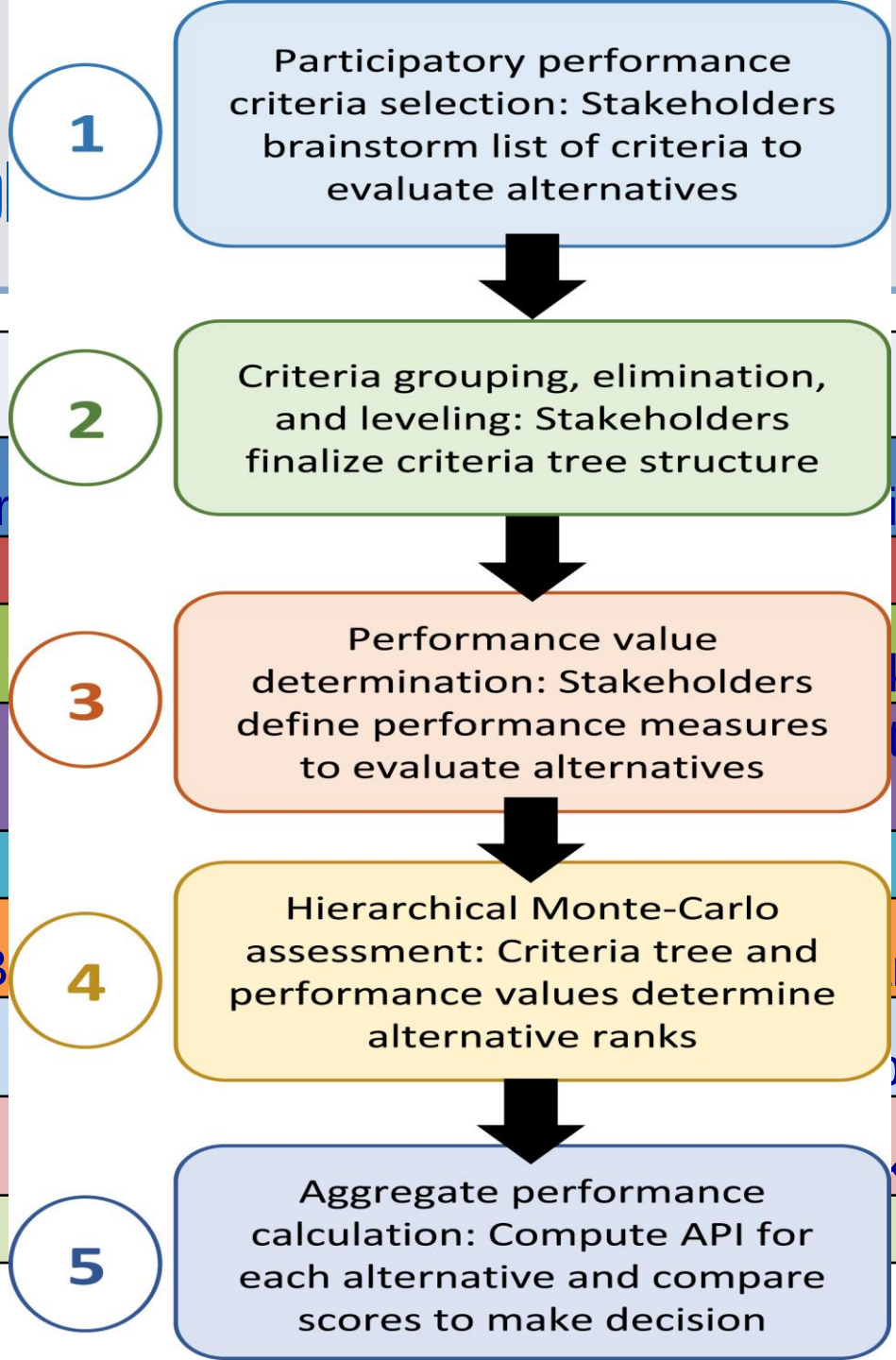
Energy Suppl



A1	Lar		icago
A2			
A3			ks
A4			to
A5			
A6	B		nks
A7			pe
A8			ks
A9			

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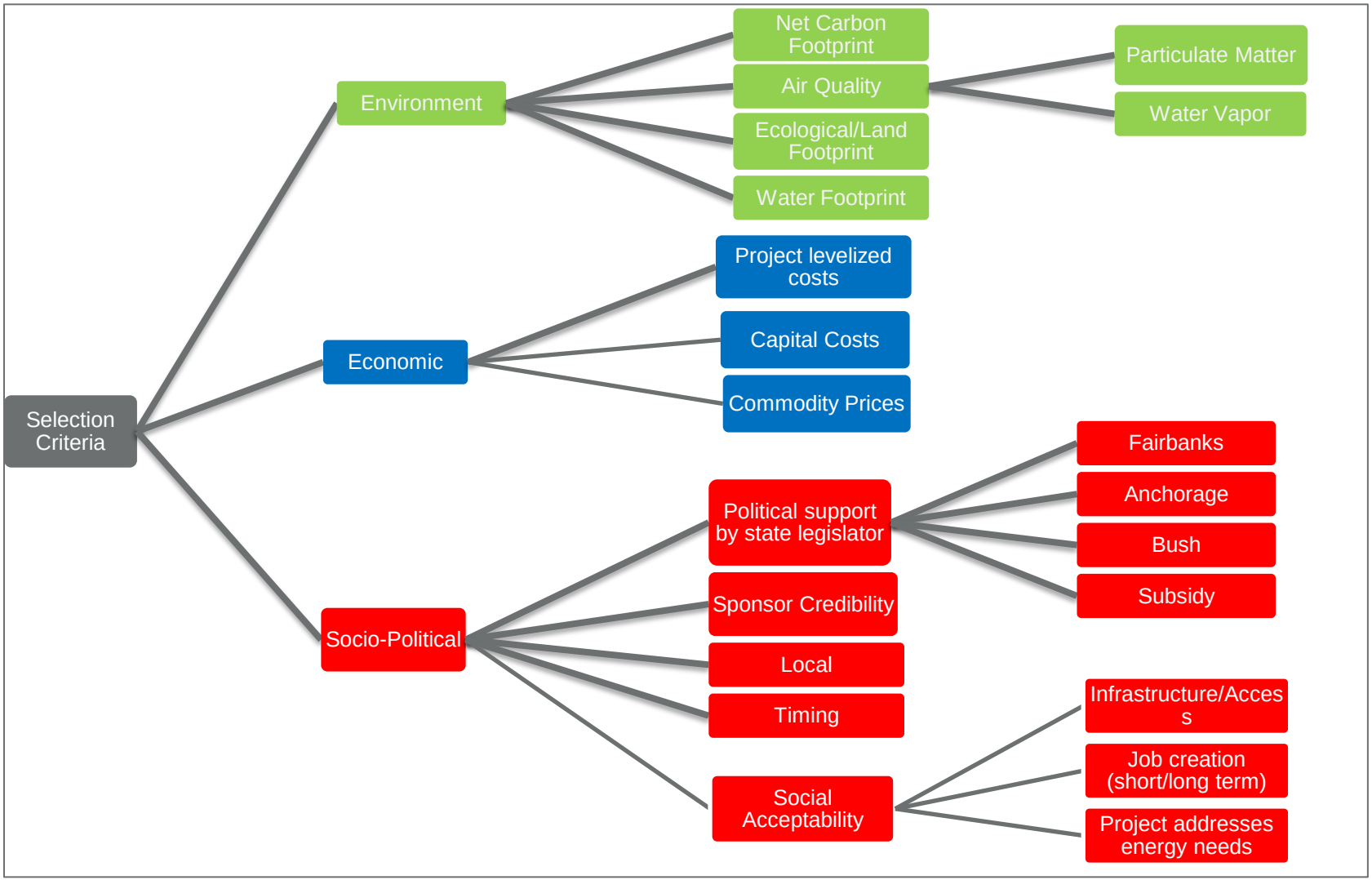
Shared Vision Modelling



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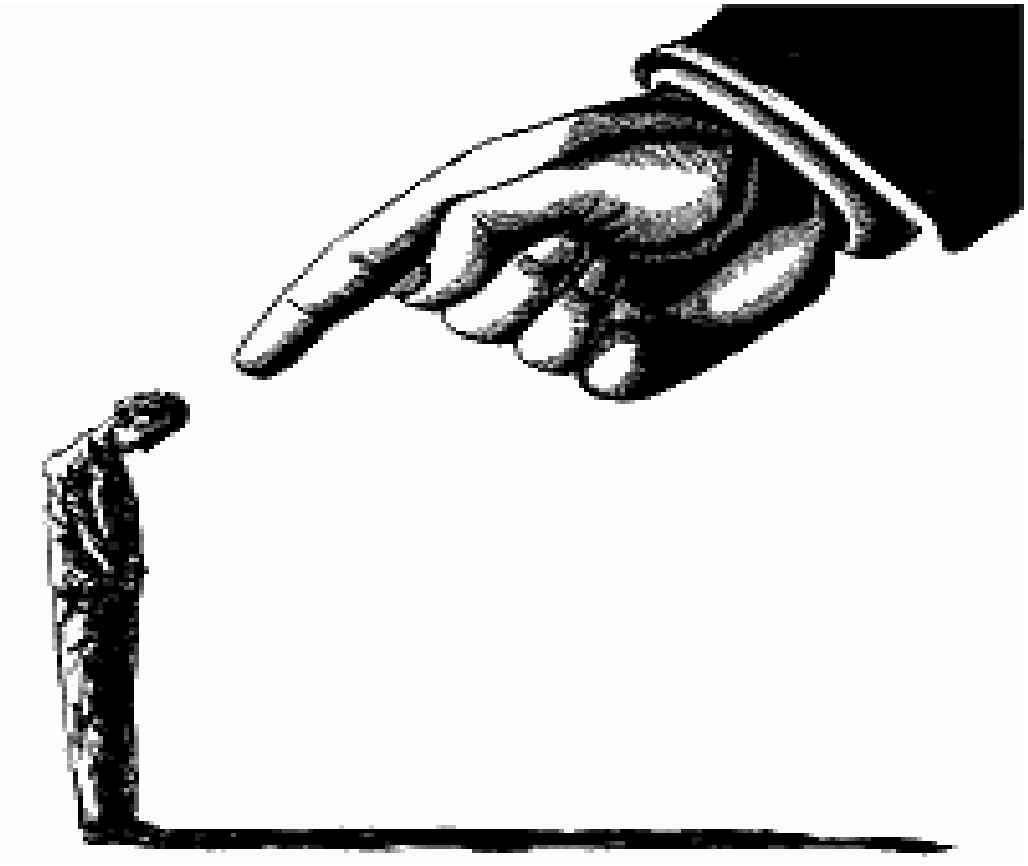
Social Planner vs. Individual Planner

Social Planner Models Fail



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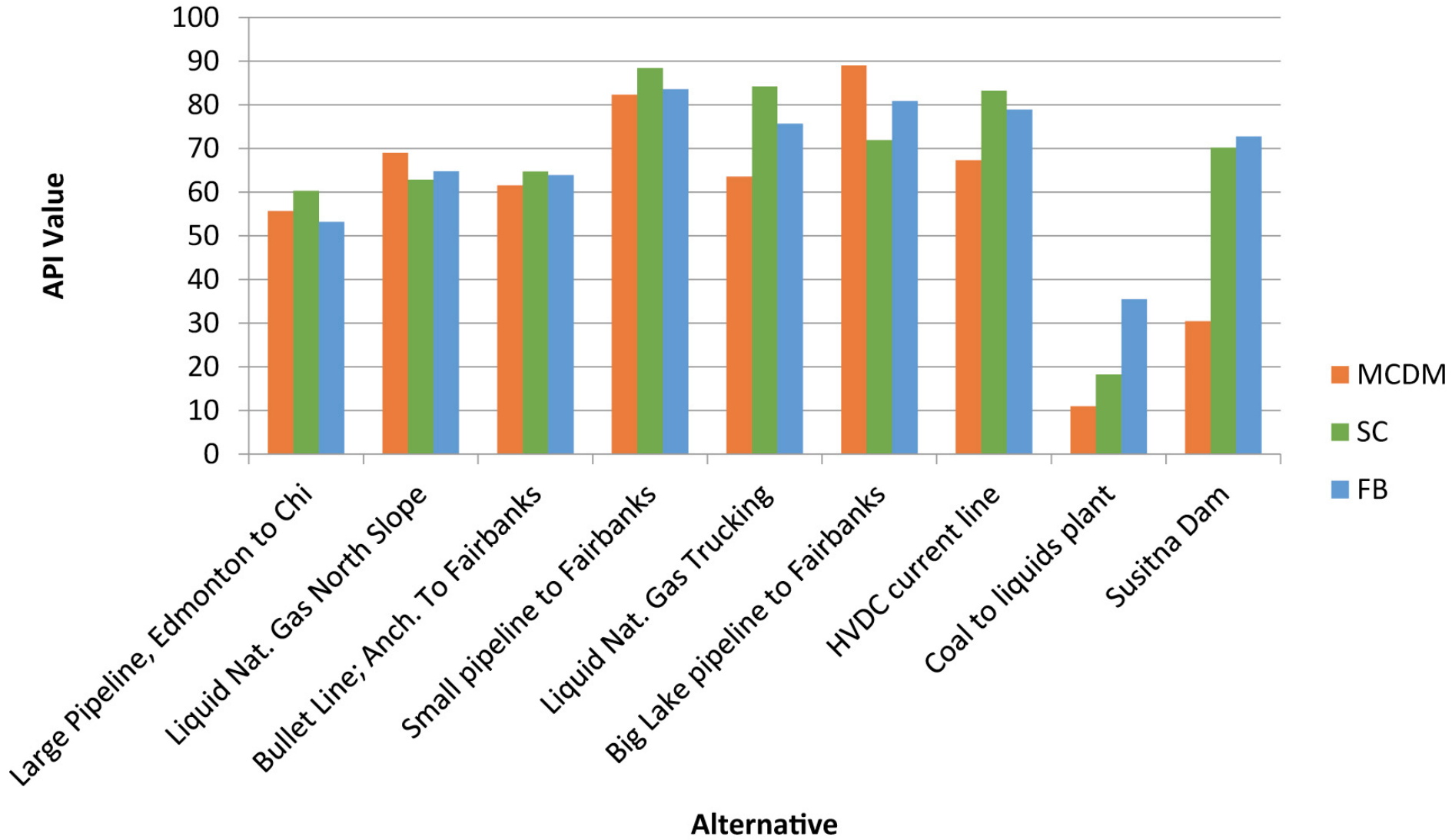
Sensitivity to Cooperation



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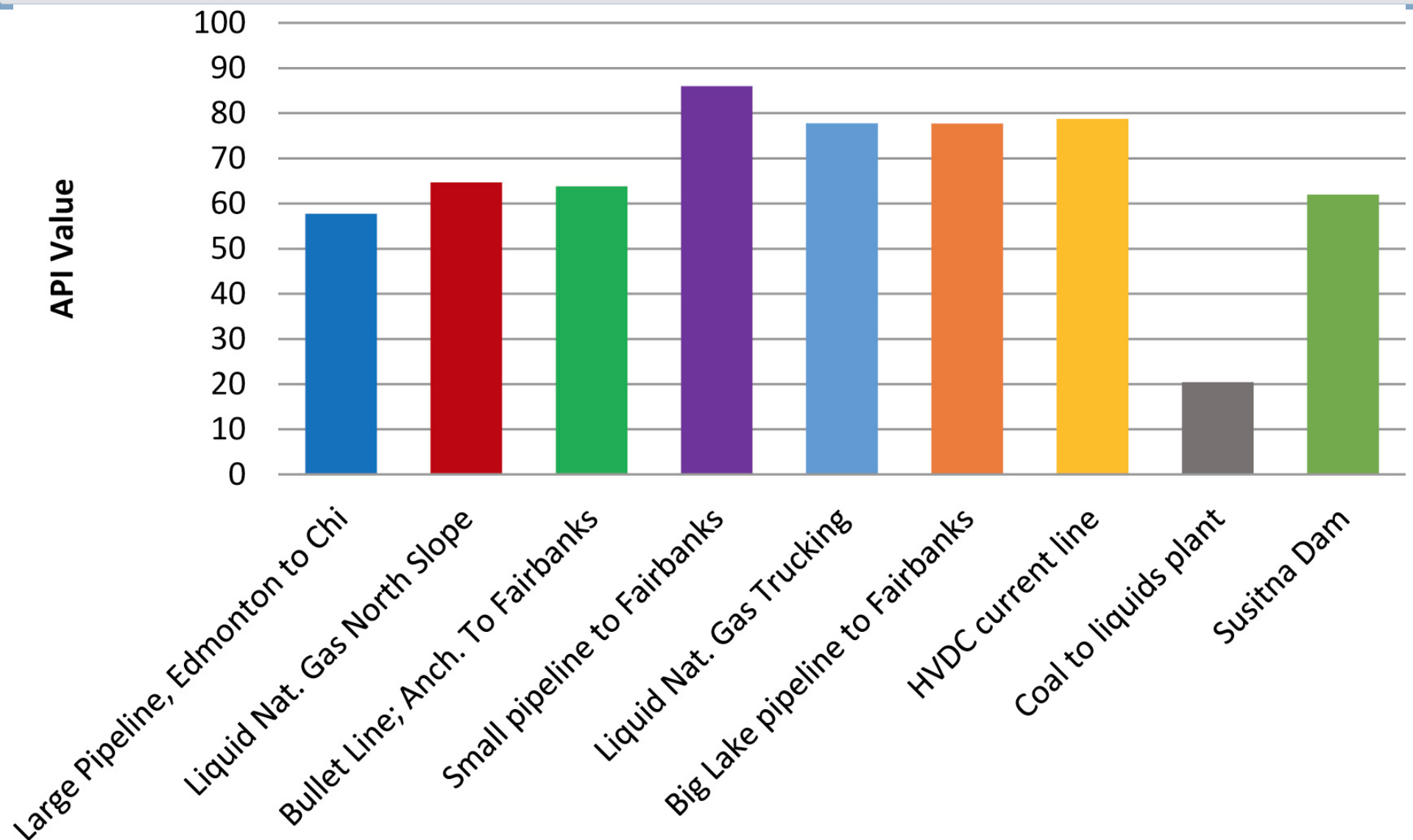
Results



Social Planner Models Fail

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Issue 4: Science-Policy Gap

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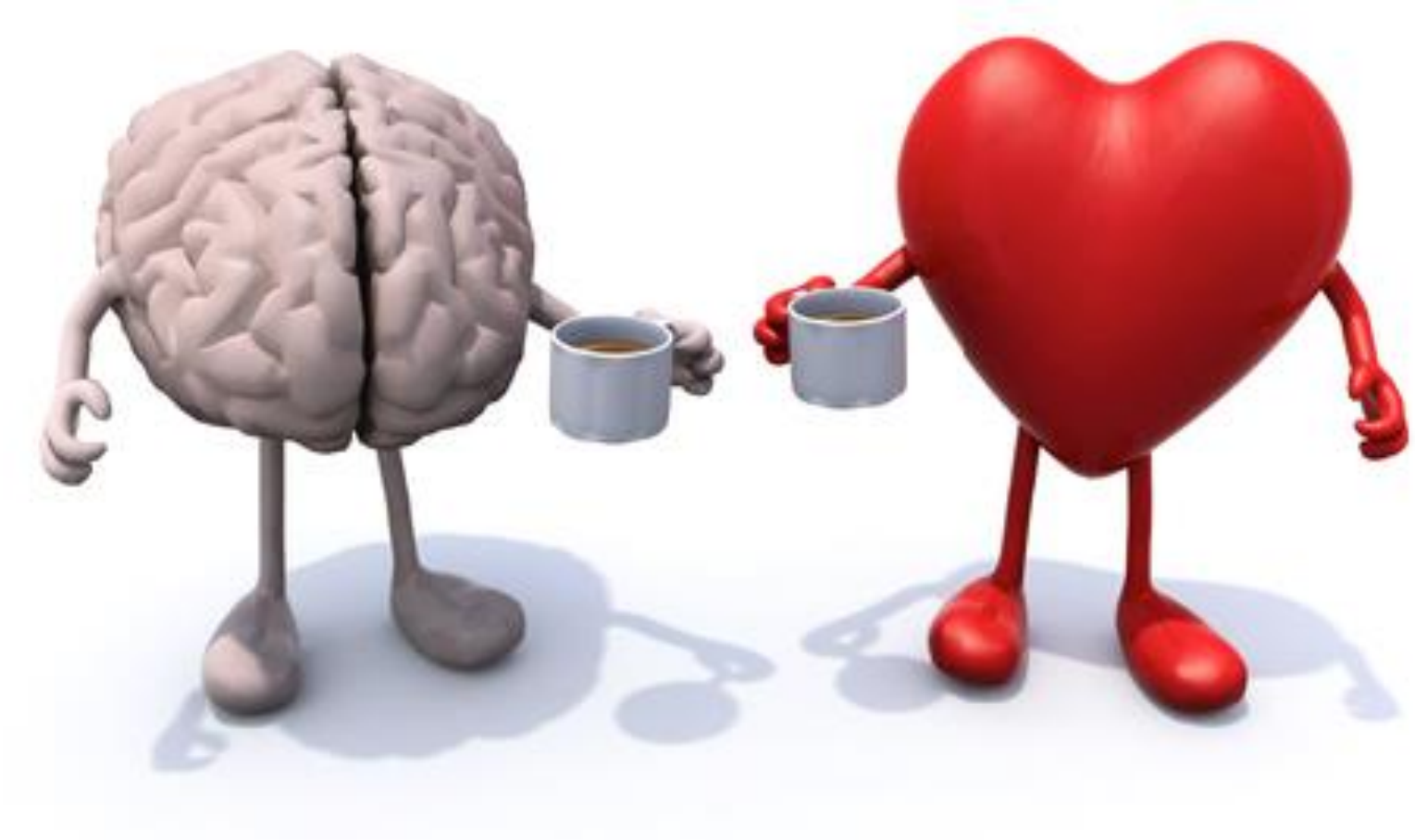
Modelers and Decision Makers



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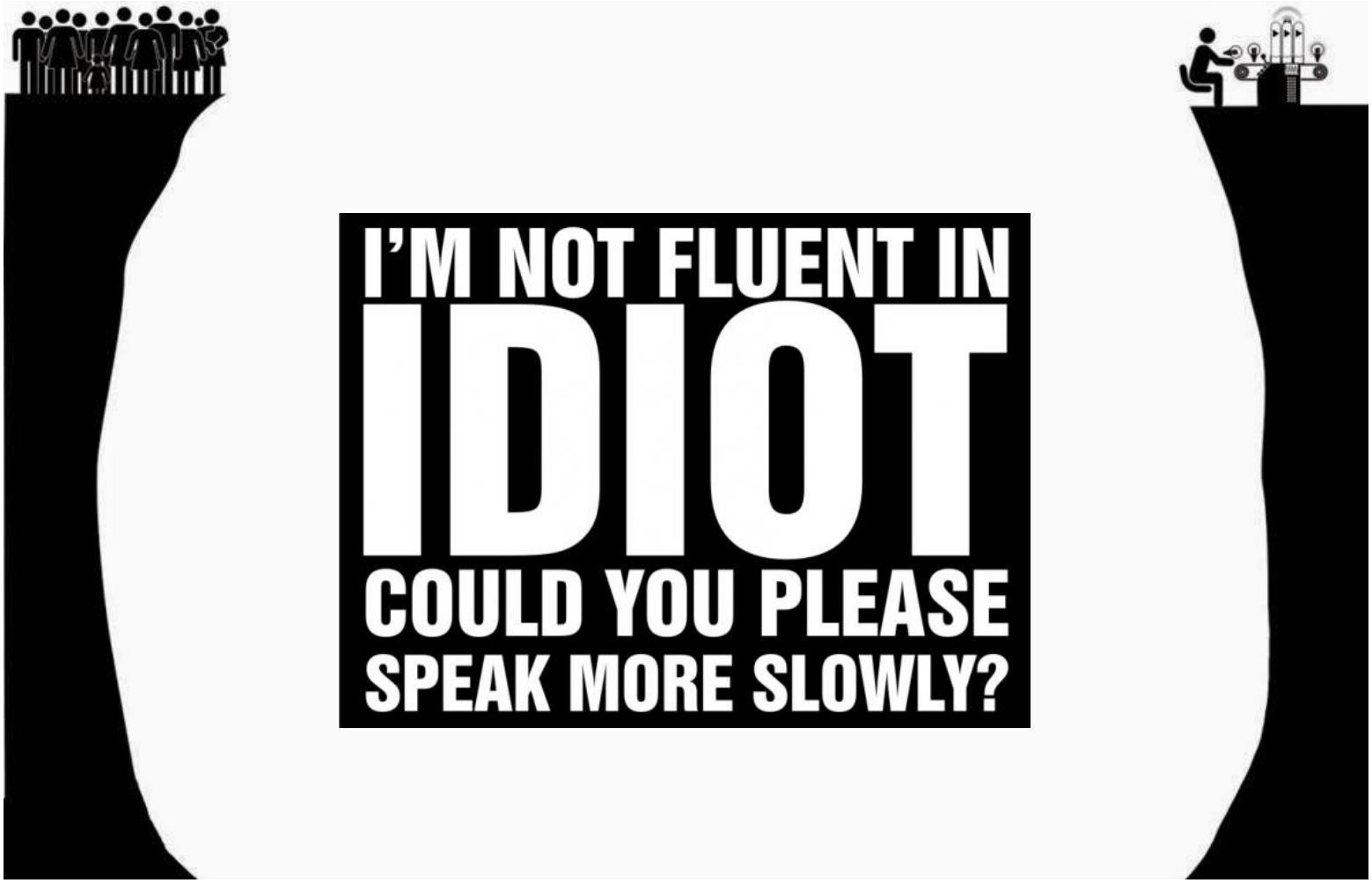
Communication Failure and Lack of Trust



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Solution Presentation & Packaging

What you see

What he sees

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Which Method to Use?


JOHN'S
WEATHER FORECASTING STONE
CONDITION
FORECAST
Stone is Wet
Rain
Stone is Dry
Not Raining
Shadow on Ground
Sunny
White on Top
Snowing
Can't See Stone
Foggy
Swinging Stone
Windy
Jumping Up & Down
Earthquake
Stone Gone
Tornado


THANK
YOU!