SEMINAR : HUMANITARIAN ENGINEERING

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COLORADO STATE UNIVERSITY

WELCOME

MY BACKGROUND

- **Designed Semi Conductor Testing Equipment**

- **Worked at NIST on Superconductor Test Equipment**

- **Worked in Aerospace Mechanism Design**

- **Hubble Robotics**

- **GMI (Global Precipitation Measurement Instrument)**

- **Molniya Orbitor**

- **Mars "Curiosity" Lander (a.k.a. Mars Science Laboratory and also deployed on "Perseverance"**
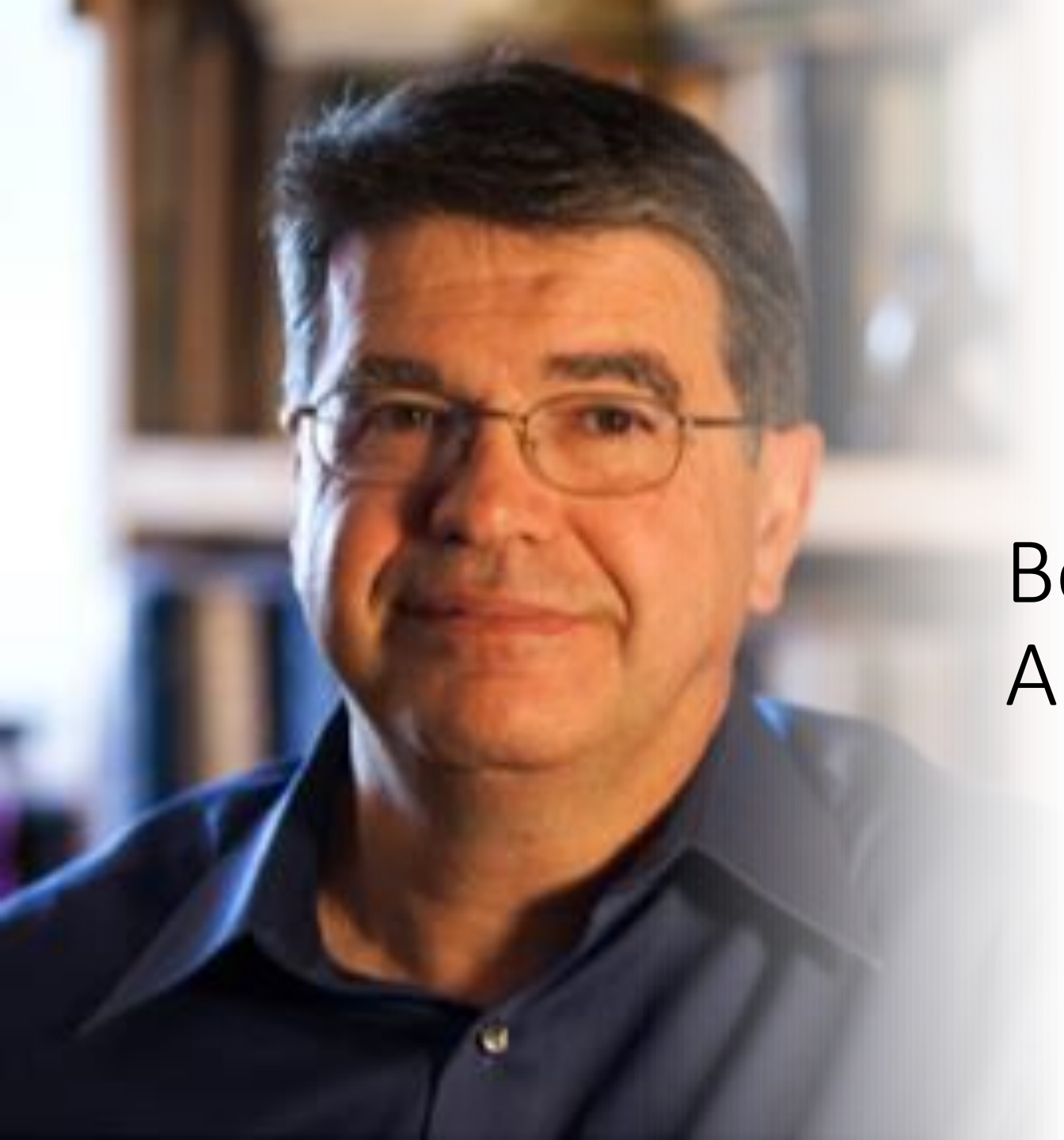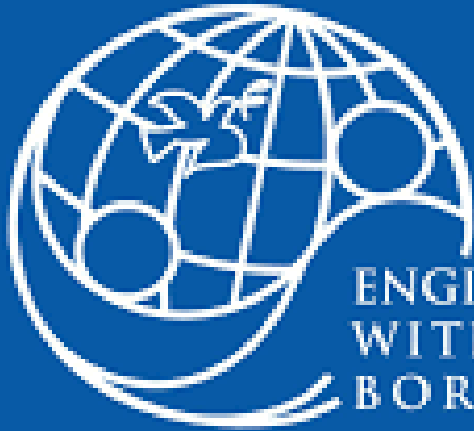
Mars Curiosity/ Perseverance

- https://www.youtube.com/watch?v=gZX5GRPnd4U
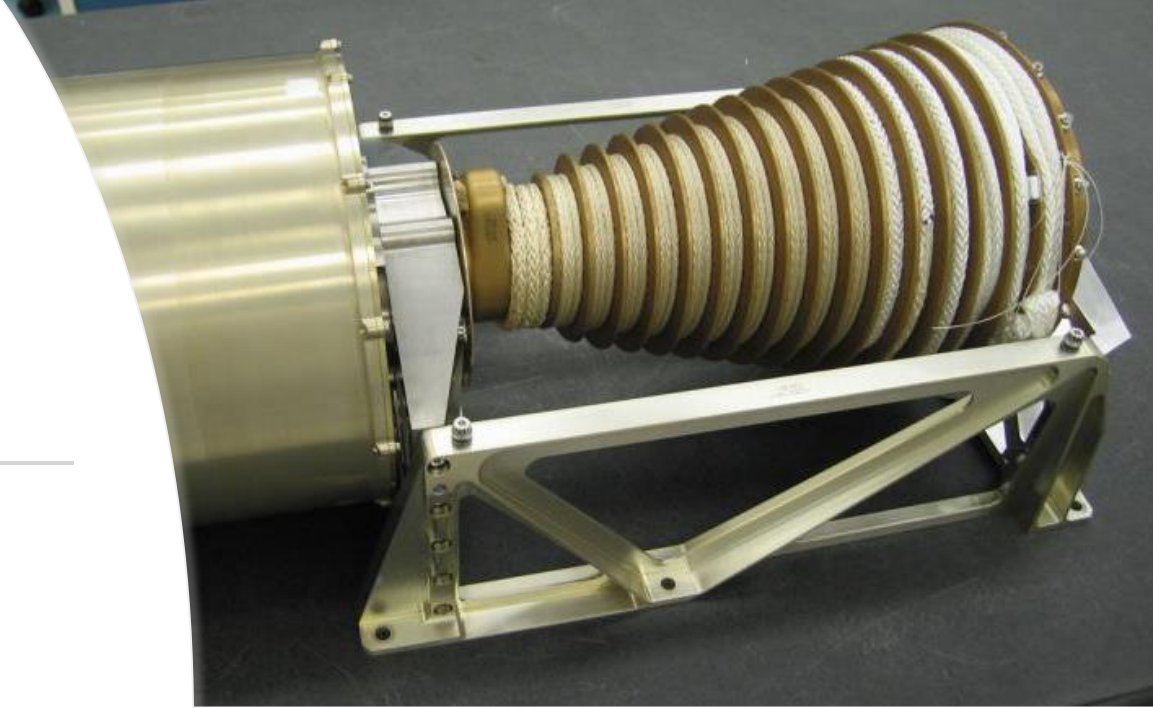
My motivation this context

Bernard Amadei
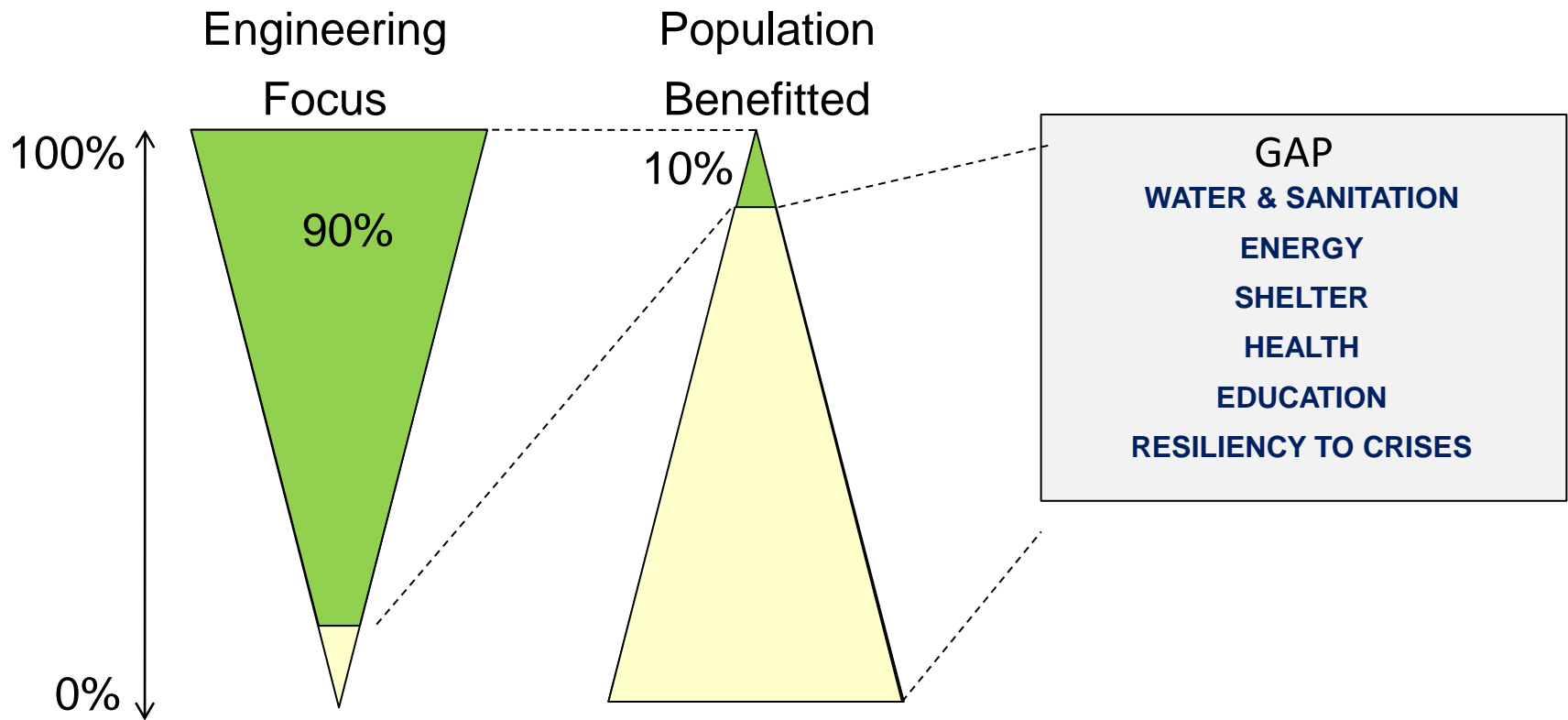
Engineers Without Borders

HUMANITARIAN ENGINEERING

Humanitarian Engineering is a method of problem solving directed at cultivating the wellbeing of underserved people.

It often merges engineering technical skills with other areas of knowledge to derive appropriate solutions that are sustainable, participatory and aimed to improve the resilience and capacity of vulnerable communities.

A LARGE GAP REMAINS BETWEEN TODAY'S TECHNOLOGICAL ADVANCES AND THE NEEDS OF THE WORLD'S MAJORITY

Engineering Focus

Population Benefitted

100%

90%

0%

10%

GAP
WATER & SANITATION
ENERGY
SHELTER
HEALTH
EDUCATION
RESILIENCY TO CRISES

Why incorporate this into curriculum?

- "The majority of the world's designers focus all their efforts on developing products and services exclusively for the richest 10% of the world's customers. Nothing less than a revolution in design is needed to reach the other 90%."

  - *Dr. Paul Polak, International Development Enterprises*

Why Humanitarian Engineering?

- 2 billion people around the world do not have access to clean and safe drinking water

- 3.6 billion people – 46% of the world's population – lack adequate sanitation services

- Malaria poses a risk to approximately 3.3 billion people or approximately half of the world's population.

- Each day, 25,000 people, including more than 10,000 children, die from hunger and related causes

- 1.6 billion people around the world lack adequate housing and basic services, with projections that this could rise to 3 billion by 2030

- the number of people around the world who live without electricity is nearly 776 million

- 773 million adults in the world (around 14% of the population) cannot read or write.

- Two billion people, or a quarter of the world's population, now lives in conflict-affected areas

Human Development

"Human Development is about creating an environment in which people can develop their full potential and lead productive, creative lives in accord with their needs and interests. " (UNDP)

World Bank Income Groups
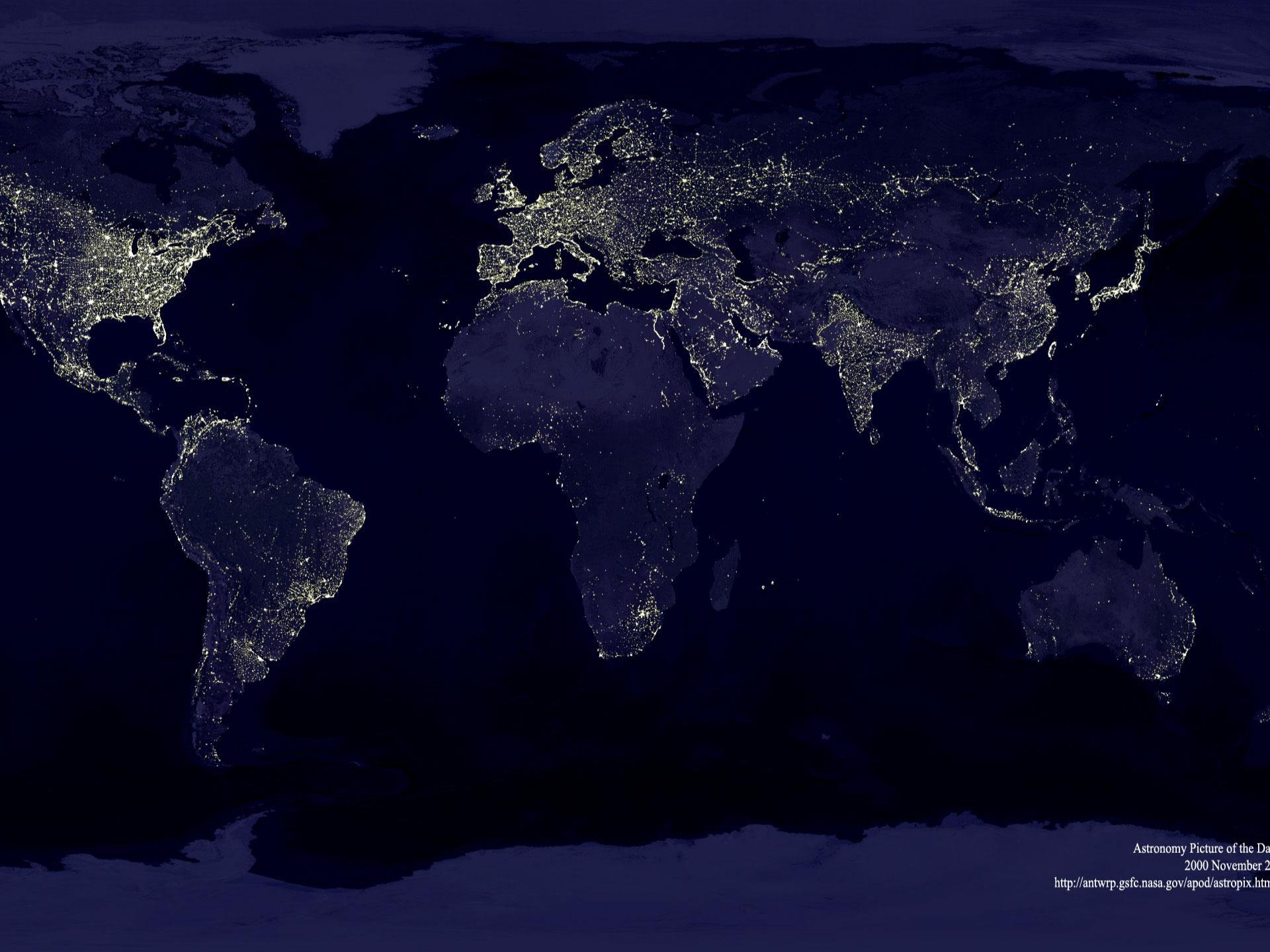

World Bank income groups, 2022

The World Bank's income classifications split countries into one of four categories determined by the country's gross national income (GNI) per capita. The GNI thresholds between income groups have changed through time based on World Bank definitions.
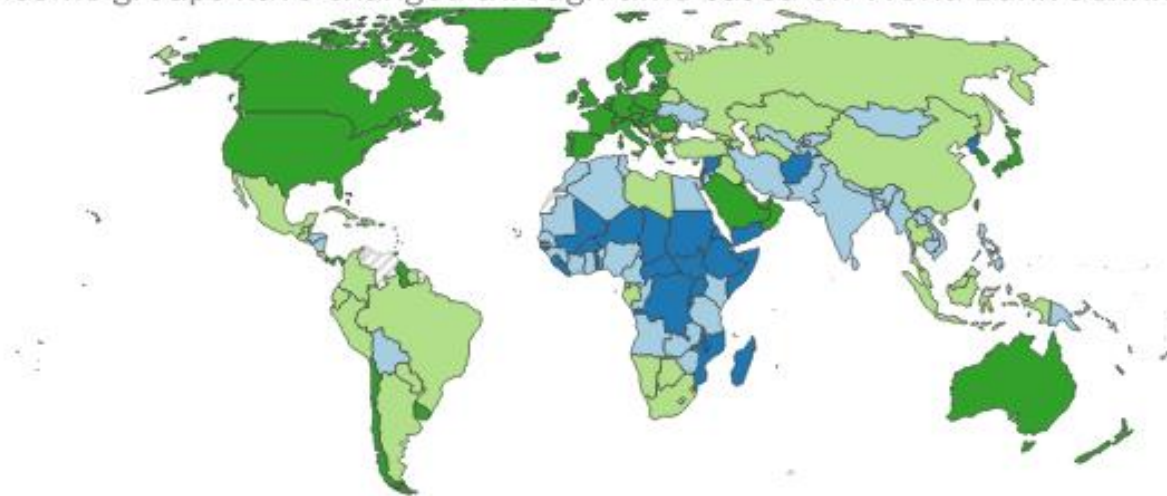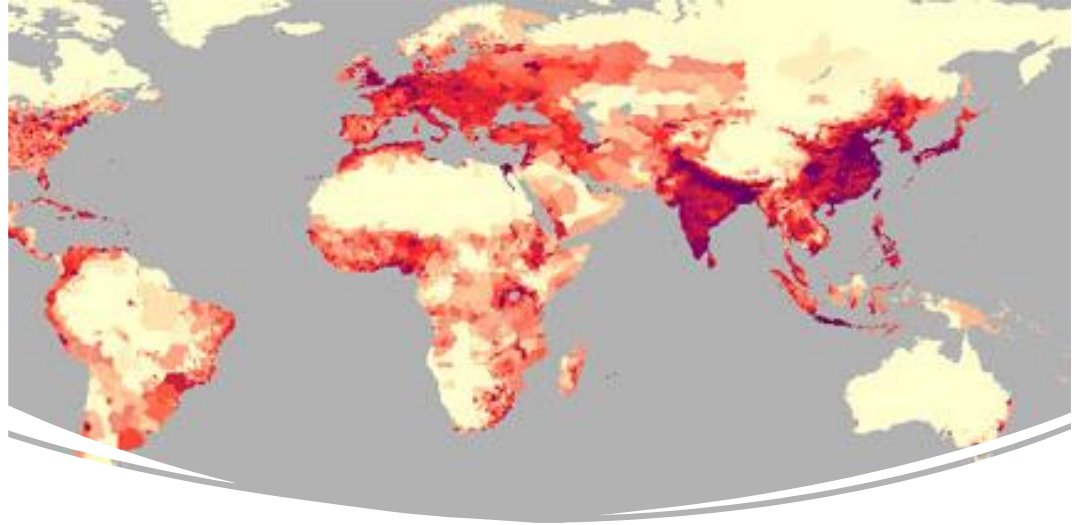
Our World in Data

Low-income   Lower-middle-income   Upper-middle-income   High-income   No data
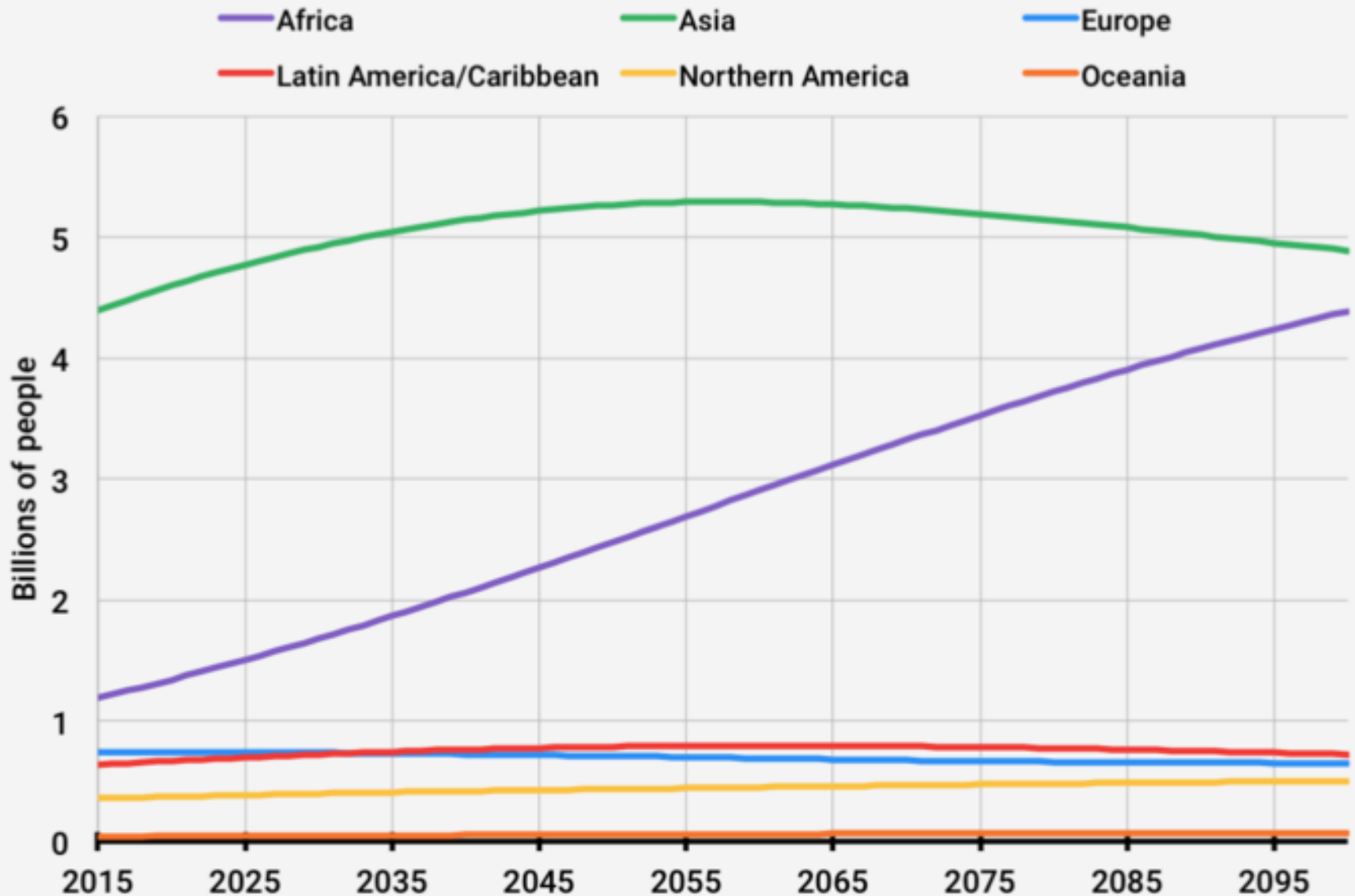
Data source: World Bank (2023)

OurWorldInData.org/economic-growth | CC BY

Global Population 8.1 Billion! In April 2024 (and growing)

Population projections, 2015-2100

- Africa
- Asia
- Europe
- Latin America/Caribbean
- Northern America
- Oceania

Billions of people

6
5
4
3
2
1
0

2015   2025   2035   2045   2055   2065   2075   2085   2095

TECH INSIDER

Increased Population equates to Increase Energy Demand
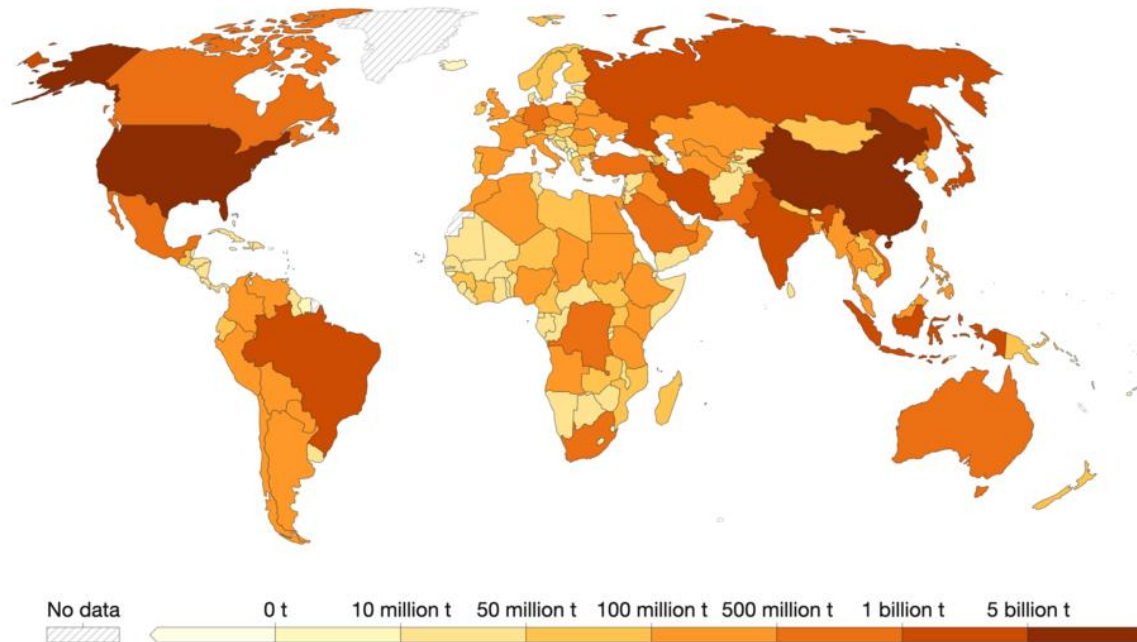
Demand for energy dominated by:

- USA: we consume 10 times the global average

- China and India: Have growing economies and standards of living which means increased industrialization. China has surpassed the US in carbon emissions.

- developing countries are increasing their energy use

Developed Countries disproportionately contribute to greenhouse emissions

Greenhouse gas emissions, 2021

Greenhouse gas emissions include carbon dioxide, methane and nitrous oxide from all sources, including agriculture and land use change. They are measured in carbon dioxide-equivalents over a 100-year timescale.

Our World in Data

No data   0 t   10 million t   50 million t   100 million t   500 million t   1 billion t   5 billion t

Source: Calculated by Our World in Data based on emissions data from Jones et al. (2023)
Note: Land use change emissions can be negative.
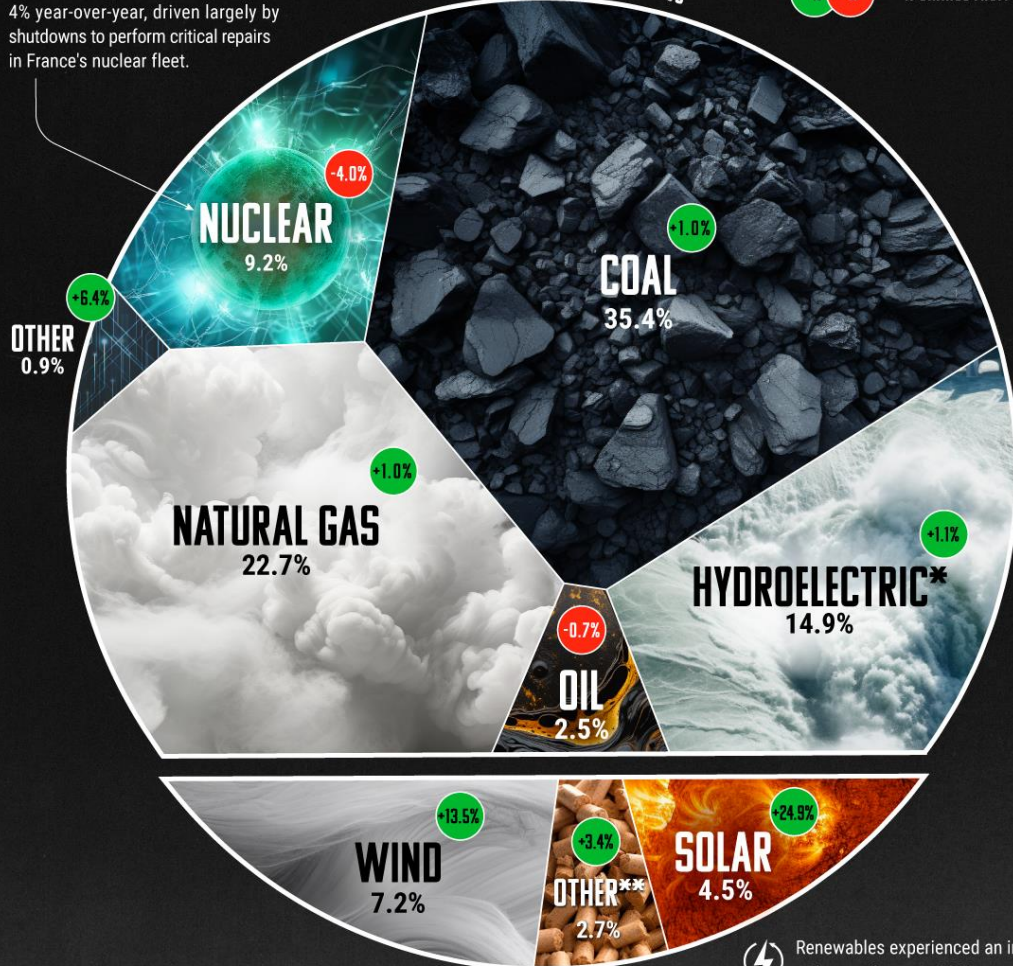OurWorldInData.org/co2-and-greenhouse-gas-emissions • CC BY

ELECTRICITY SOURCES BY FUEL 2022

Nuclear energy saw the largest decline, 4% year-over-year, driven largely by shutdowns to perform critical repairs in France's nuclear fleet.

+% -% = % CHANGE FROM 2021

NON-RENEWABLE | 85.6%

NUCLEAR 9.2% -4.0%

OTHER 0.9% +6.4%

COAL 35.4% +1.0%

NATURAL GAS 22.7% +1.0%

OIL 2.5% -0.7%

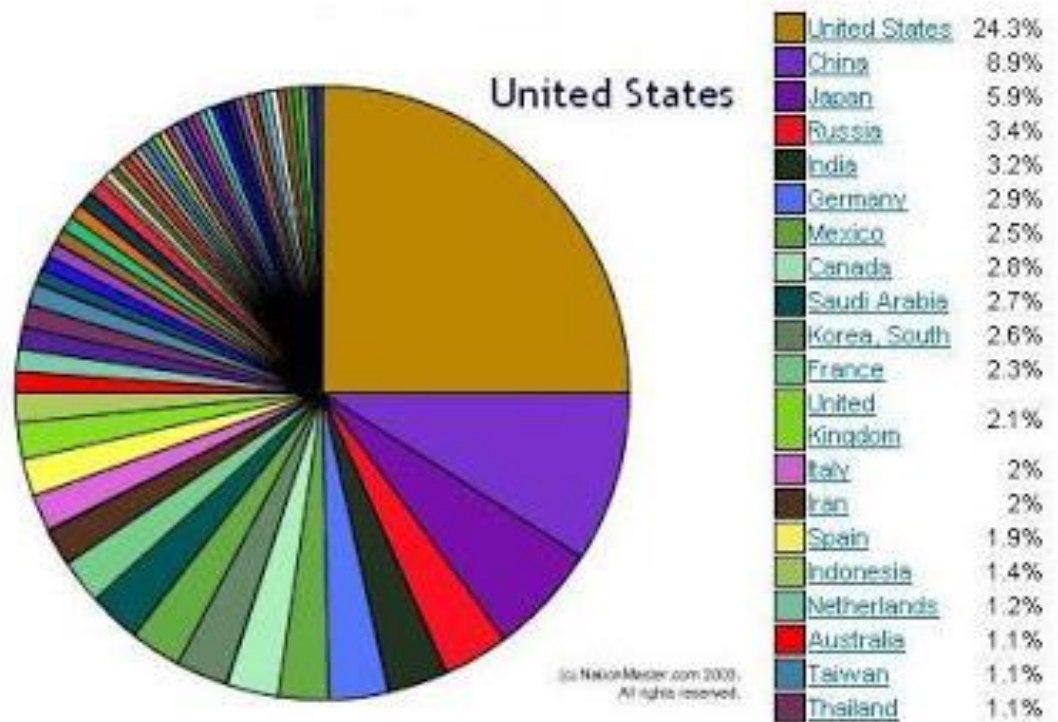HYDROELECTRIC* 14.9% +1.1%

WIND 7.2% +13.5%

OTHER** 2.7% +3.4%

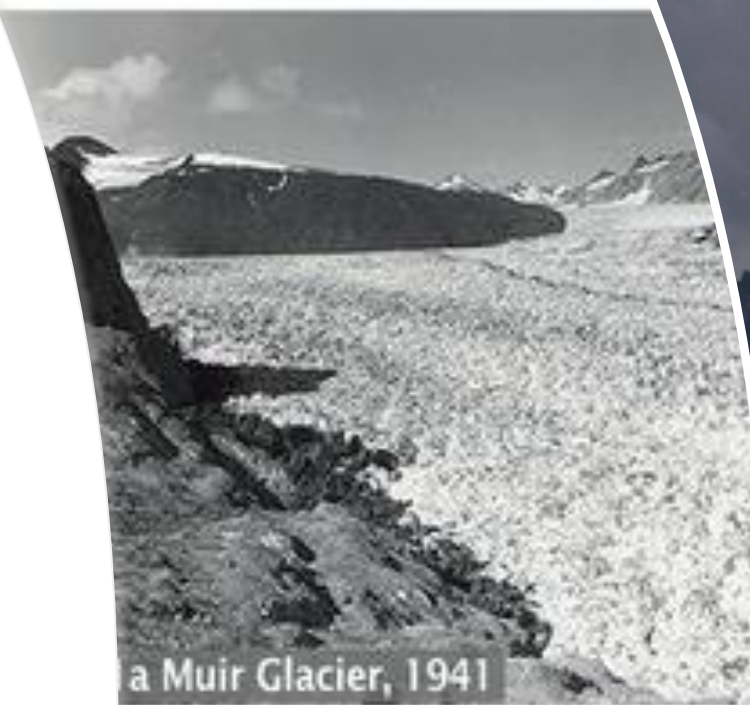SOLAR 4.5% +24.9%

RENEWABLES | 14.4%

Renewables experienced an impressive 15% growth rate in 2022, compared to oil, natural gas, coal, and hydro, which together mustered an anemic 0.4%.

Oil consumption by Nation

United States	24.3%
China	8.9%
Japan	5.9%
Russia	3.4%
India	3.2%
Germany	2.9%
Mexico	2.5%
Canada	2.8%
Saudi Arabia	2.7%
Korea, South	2.6%
France	2.3%
United Kingdom	2.1%
Italy	2%
Iran	2%
Spain	1.9%
Indonesia	1.4%
Netherlands	1.2%
Australia	1.1%
Taiwan	1.1%
Thailand	1.1%

United States

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Evidence of Change

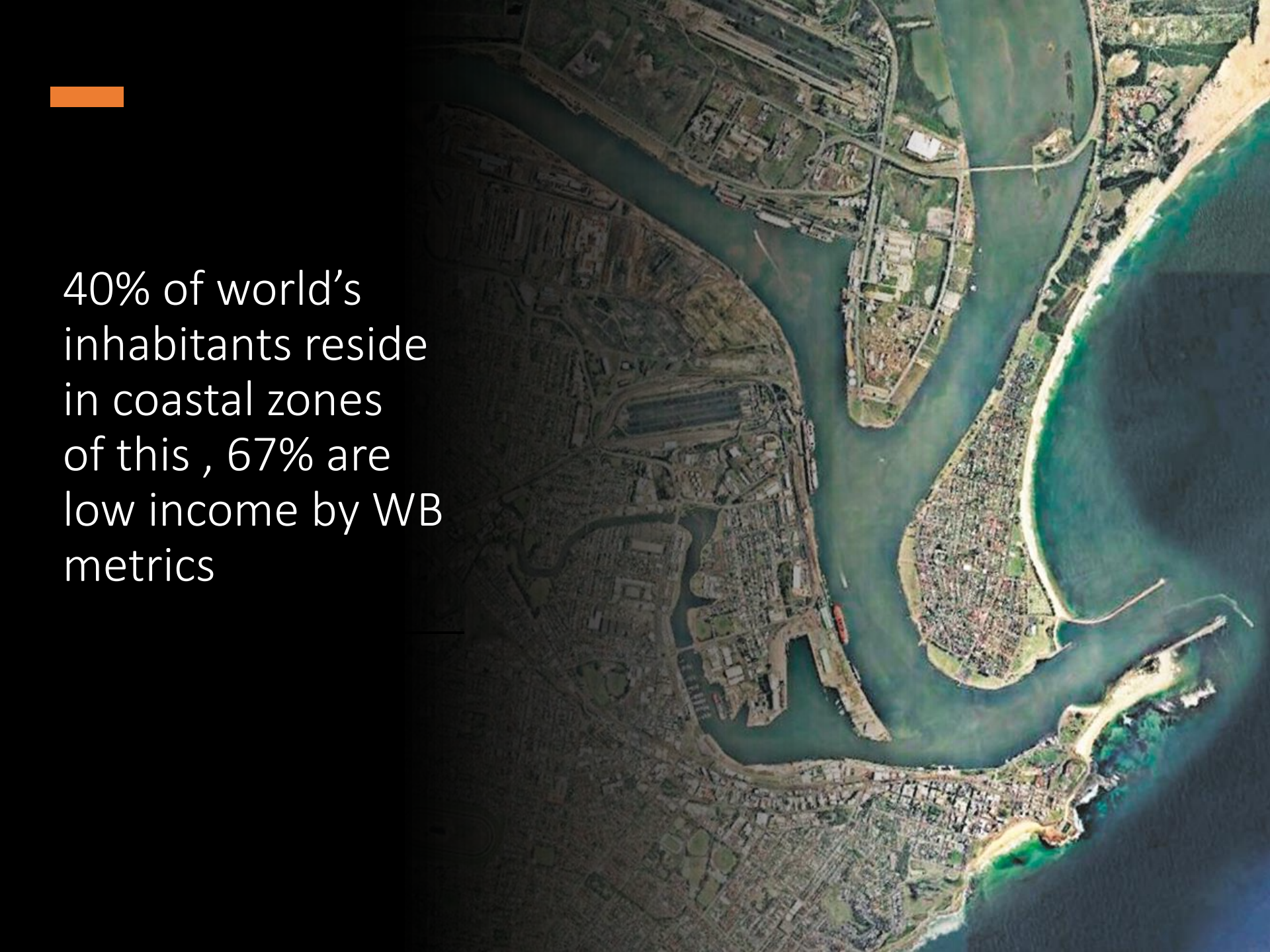chasing ice

a Muir Glacier, 1941

ig. 7.1b Muir Glacier, 2004

e Kozlowski

More Extreme Weather

A 2020 World Bank paper estimated that between 32 million and 132 million additional people will be pushed into [extreme poverty](#) by 2030 due to climate change.

40% of world's inhabitants reside in coastal zones of this , 67% are low income by WB metrics

The countries most vulnerable to climate change

The Notre Dame Global Adaptation Initiative index gauges countries' vulnerability based on their exposure, sensitivity and ability to adapt to the negative impacts of climate change.

Vulnerability to climate change

Low   High
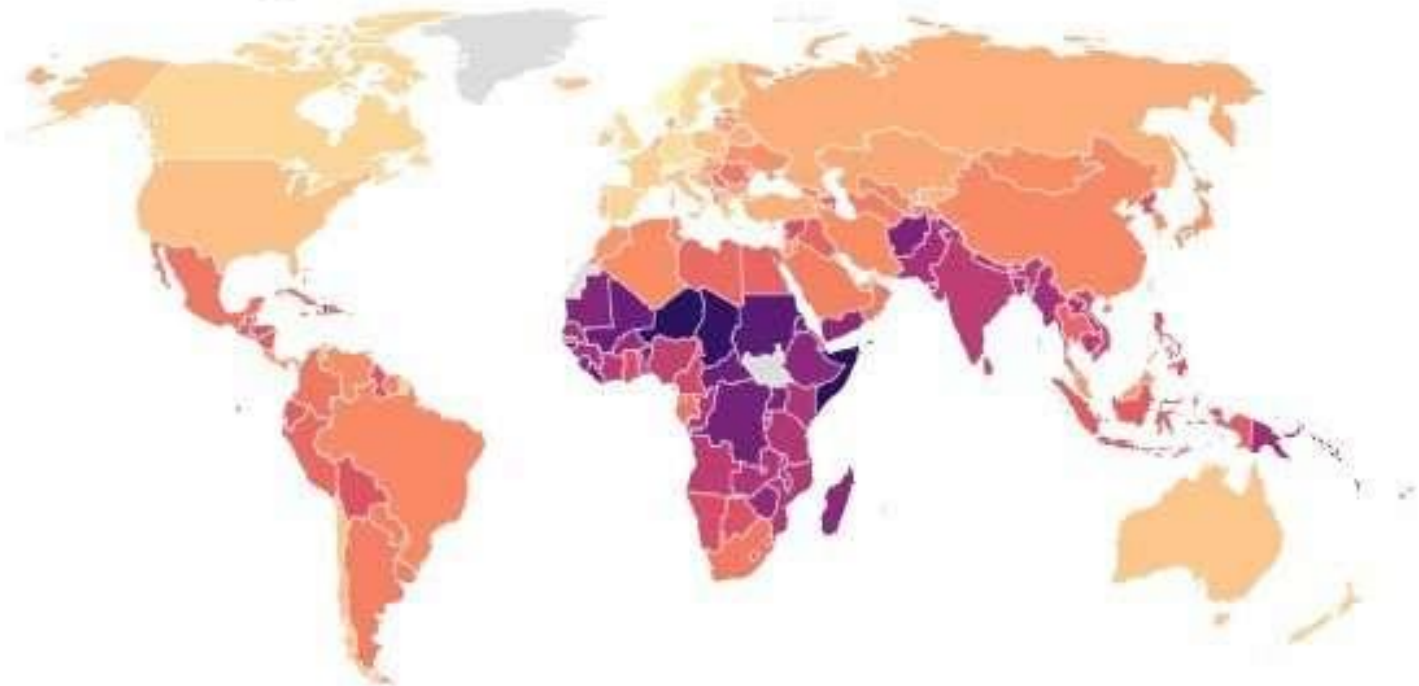
Darker colors reflect greater vulnerability; gray indicates no data available

Engineers' role

Sustainable solutions that build capacity and resilience.

Humanitarian Engineering = Building Capacity and Resilience

Creating Secure and Stable Communities

".. a community that allows *all* of its members to enjoy a quality of life where basic human needs and rights and meaningful work are fulfilled. It is a community that has access to resources and knowledge, thus capable of sustaining itself economically, socially, and environmentally. "
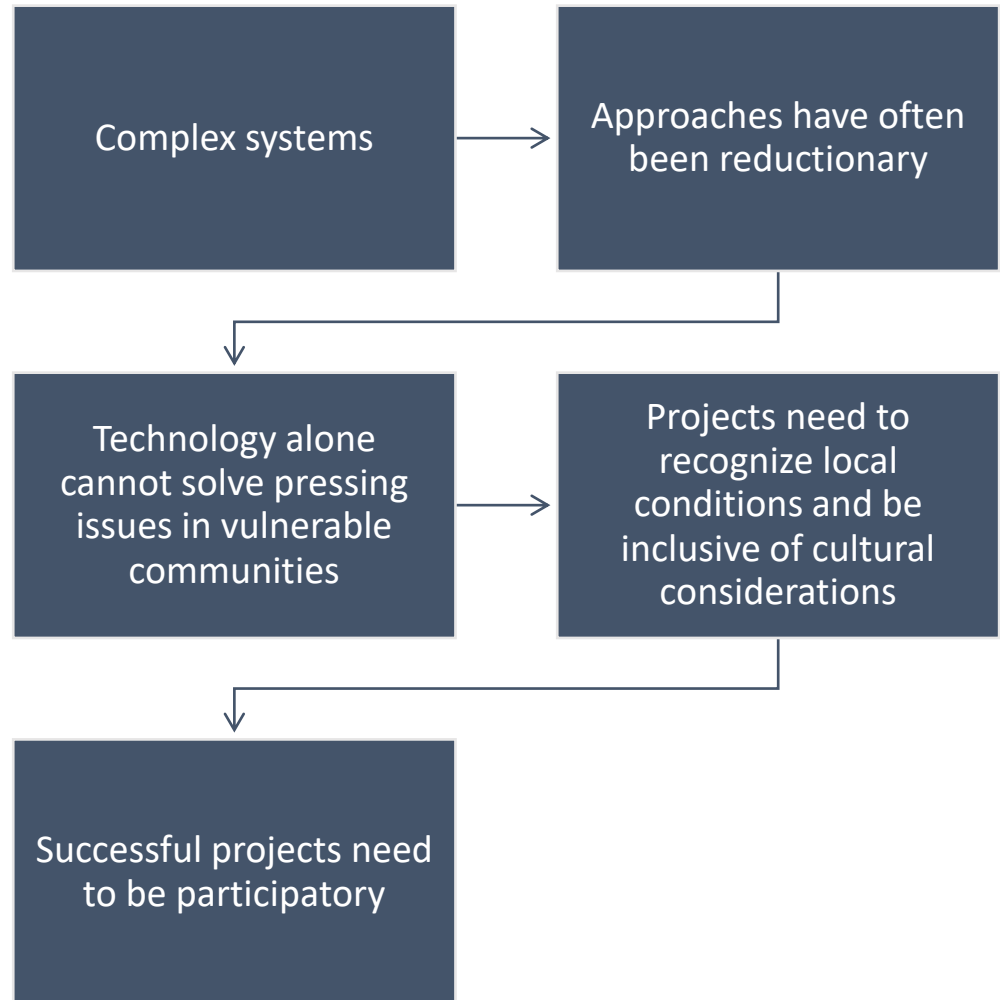
Does the process used in the framework help community users generate information to solve problems they have identified, using methods that increase their capacity to solve similar problems in the future?

Technology's role

Why has development aid so often failed ?

Complex systems → Approaches have often been reductionary

Technology alone cannot solve pressing issues in vulnerable communities → Projects need to recognize local conditions and be inclusive of cultural considerations

Successful projects need to be participatory

Applying Systems Thinking to Community Development
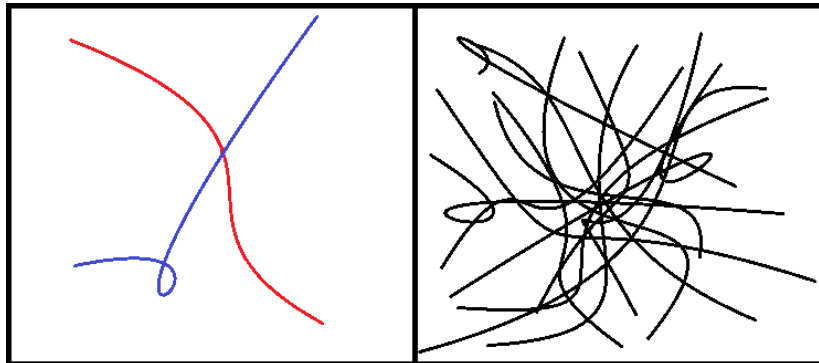
Traditional Problem **Wicked Problem**

Social problems are complex and sometimes hard to define

Often a perfect or singular solution does not exist

Traditional problems are often "tame" problems.
Social problems are often what we can call
"Wicked Problems"

Sustainable Community Development

A sustainable community manages its human, natural, and financial capital to meet current needs while ensuring that adequate resources are available for future generations

- Multidisciplinary approach …

People, Planet, Prosperity…the triple bottom line

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD

1 NO POVERTY

2 ZERO HUNGER

3 GOOD HEALTH AND WELL-BEING

4 QUALITY EDUCATION

5 GENDER EQUALITY

6 CLEAN WATER AND SANITATION

7 AFFORDABLE AND CLEAN ENERGY

8 DECENT WORK AND ECONOMIC GROWTH

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

10 REDUCED INEQUALITIES

11 SUSTAINABLE CITIES AND COMMUNITIES

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

13 CLIMATE ACTION

14 LIFE BELOW WATER

15 LIFE ON LAND

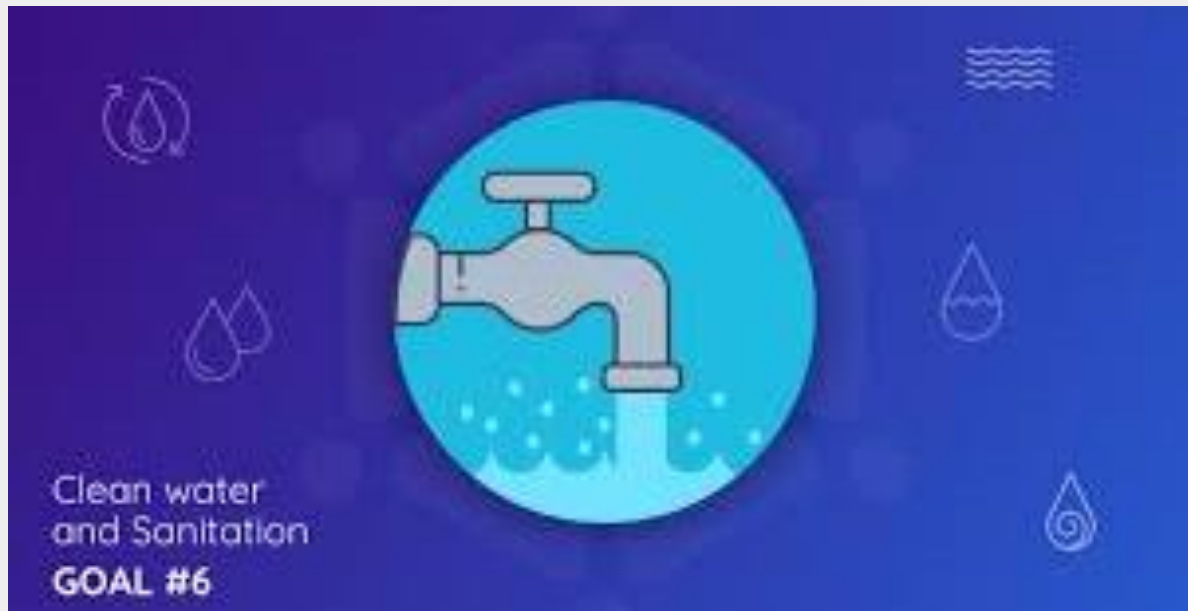16 PEACE, JUSTICE AND STRONG INSTITUTIONS

17 PARTNERSHIPS FOR THE GOALS

SUSTAINABLE DEVELOPMENT GOALS

WASH

Water Sanitation and Hygiene

Clean water and Sanitation
GOAL #6

Food Security
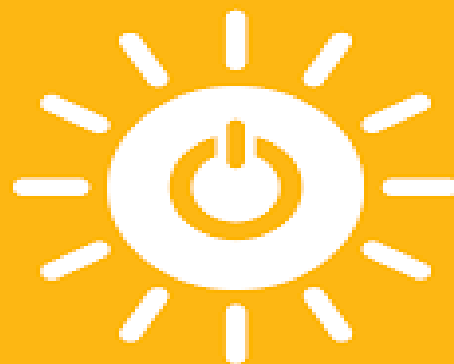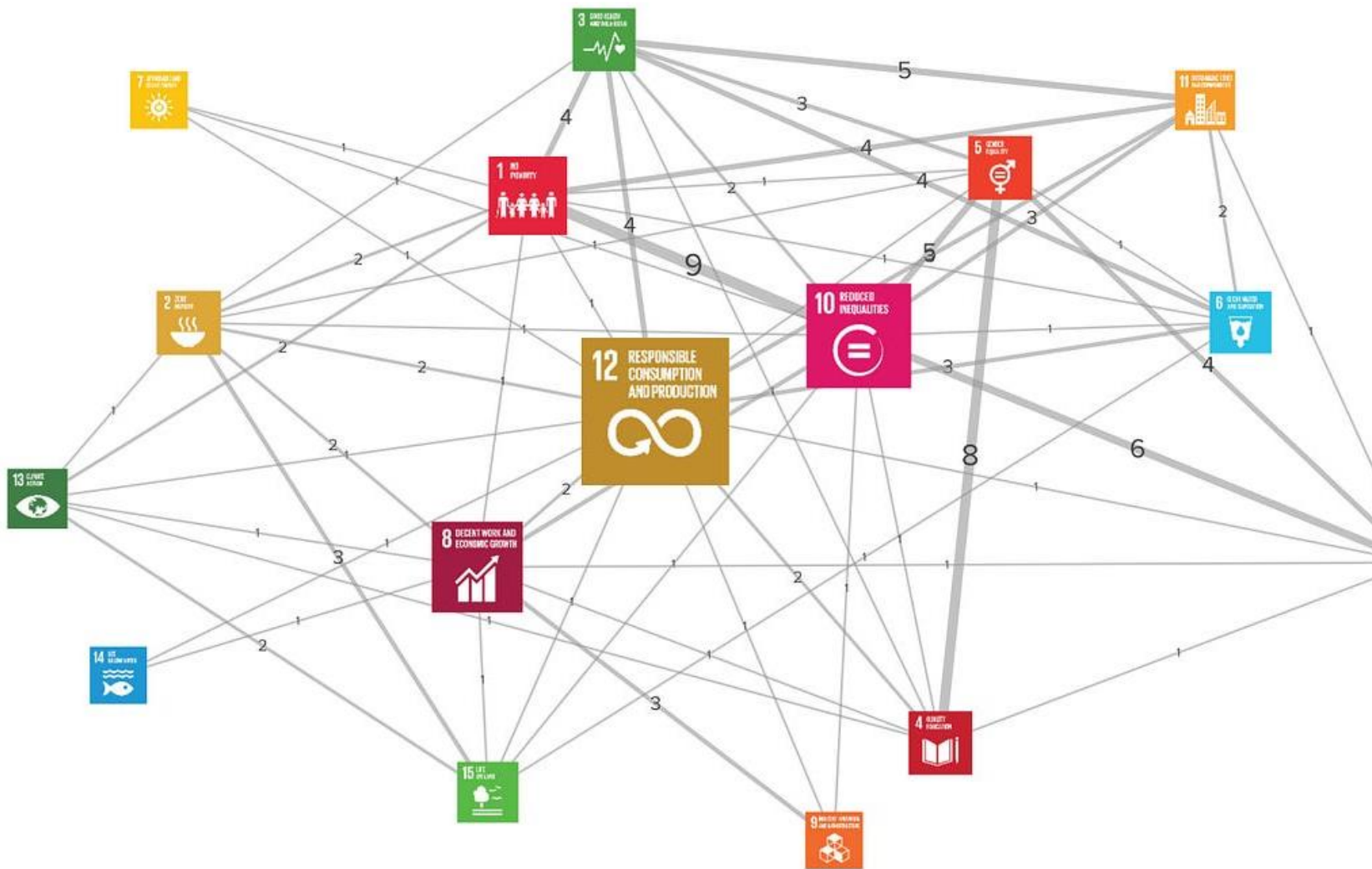
SUSTAINABLE DEVELOPMENT GOAL

2
___

Zero Hunger
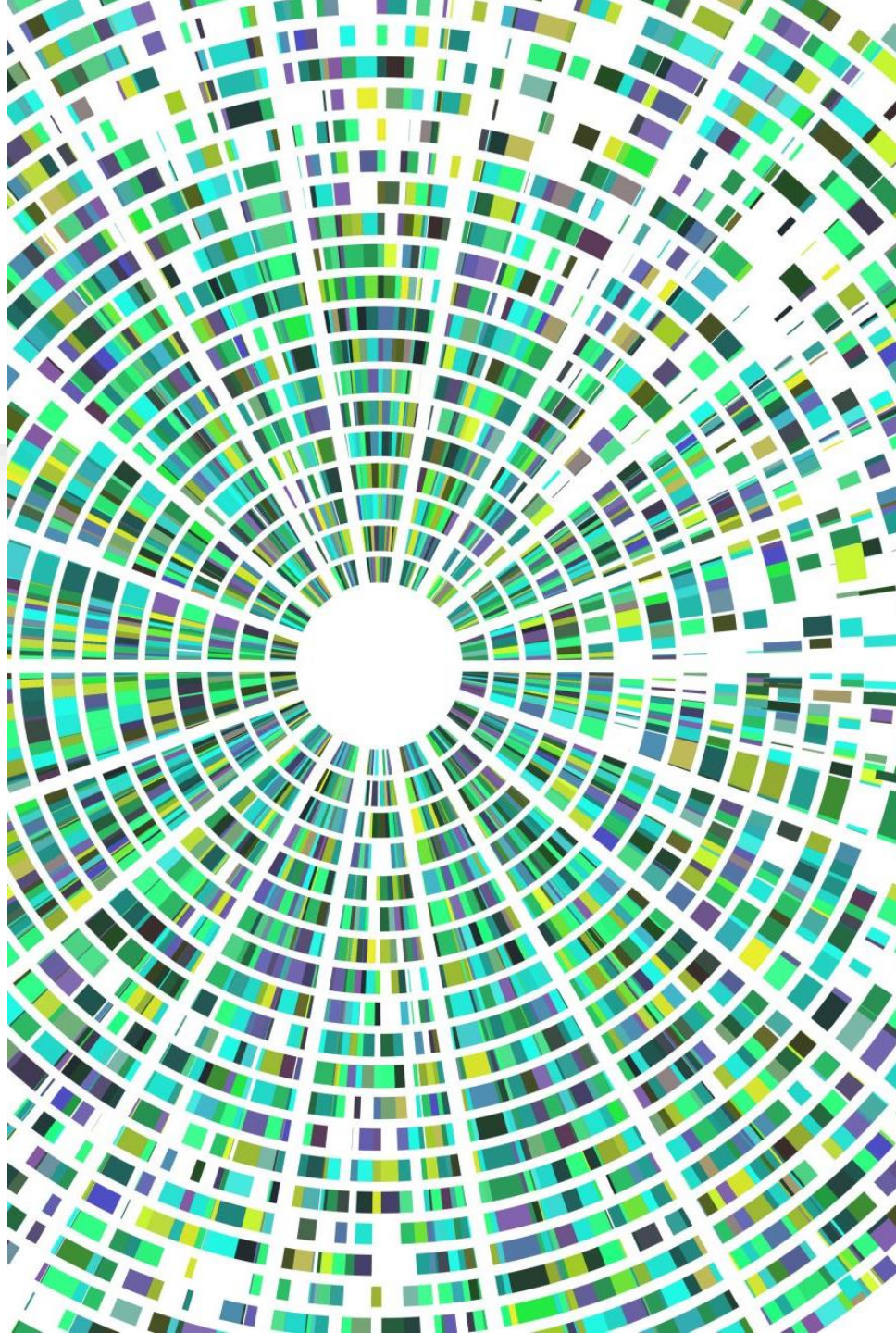
Energy

7 AFFORDABLE AND CLEAN ENERGY

The UN goals are global which has merit as a unifying strategy, but local context is important and too often ignored

Participatory methods

- Stake Holder input
- Understanding local conditions
- Allowing communities to develop their own solutions
- Assist

A different engineering challenge

(1) time t

(2) time $t+dt$

v

$v+dv$

m

$m-dm_e$

m_e

J_e

dm_e

v_e

m_e

J_e

VS
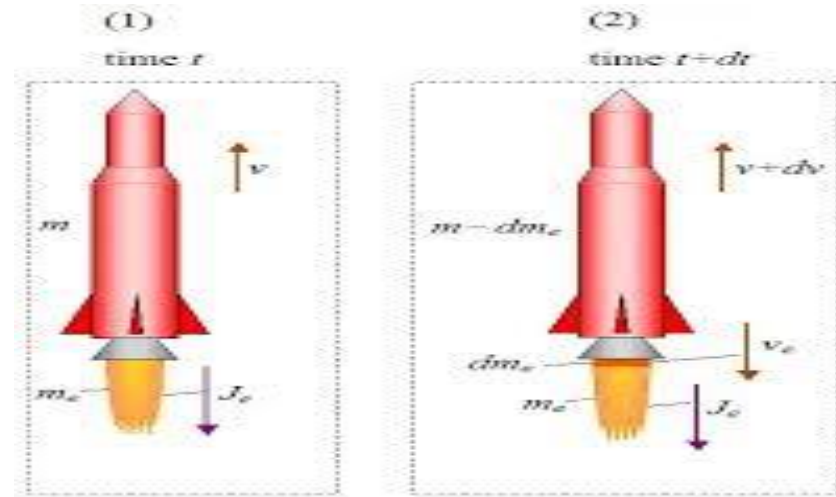
ΣF
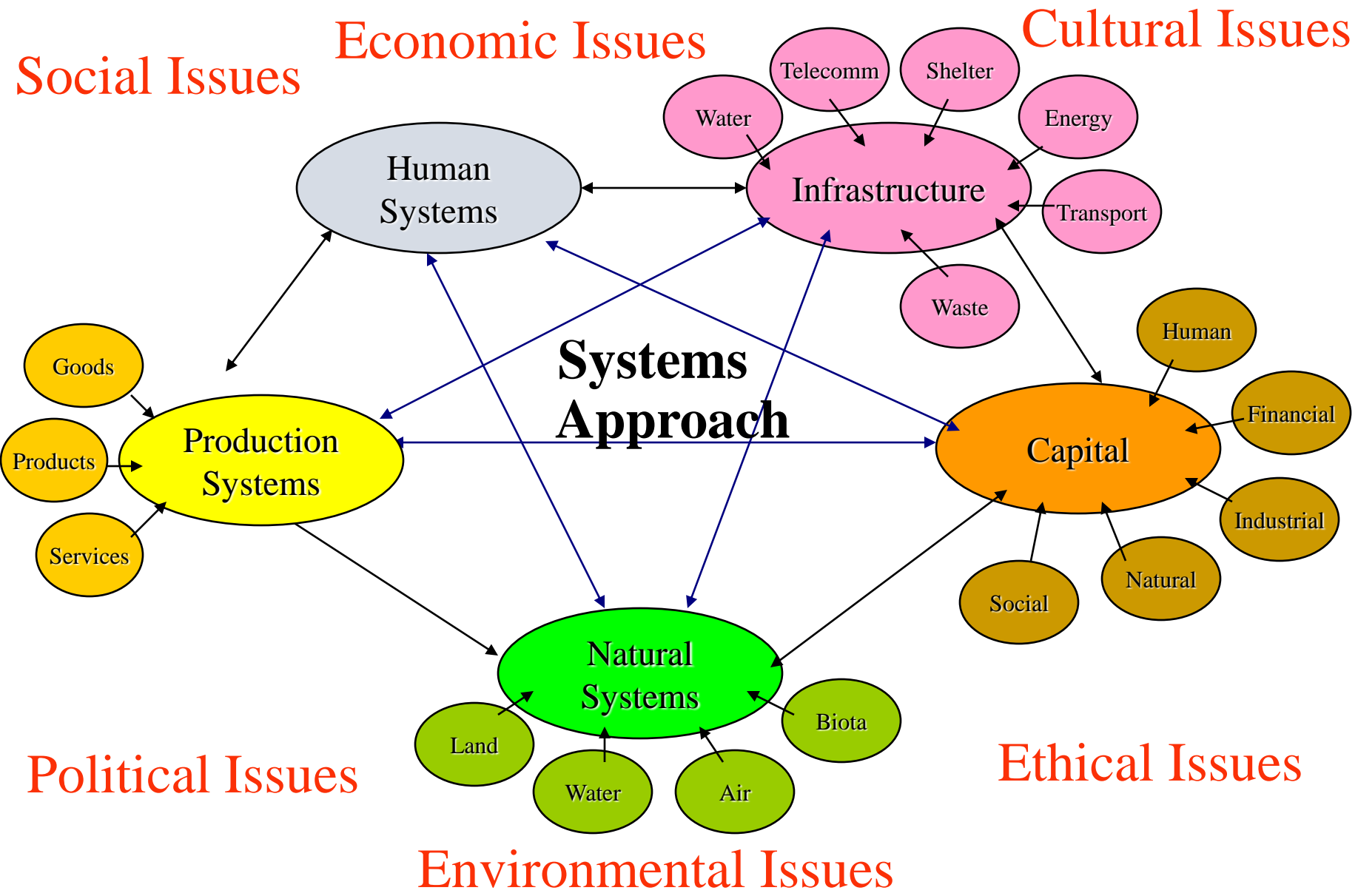
Systems thinking applied to many scenarios
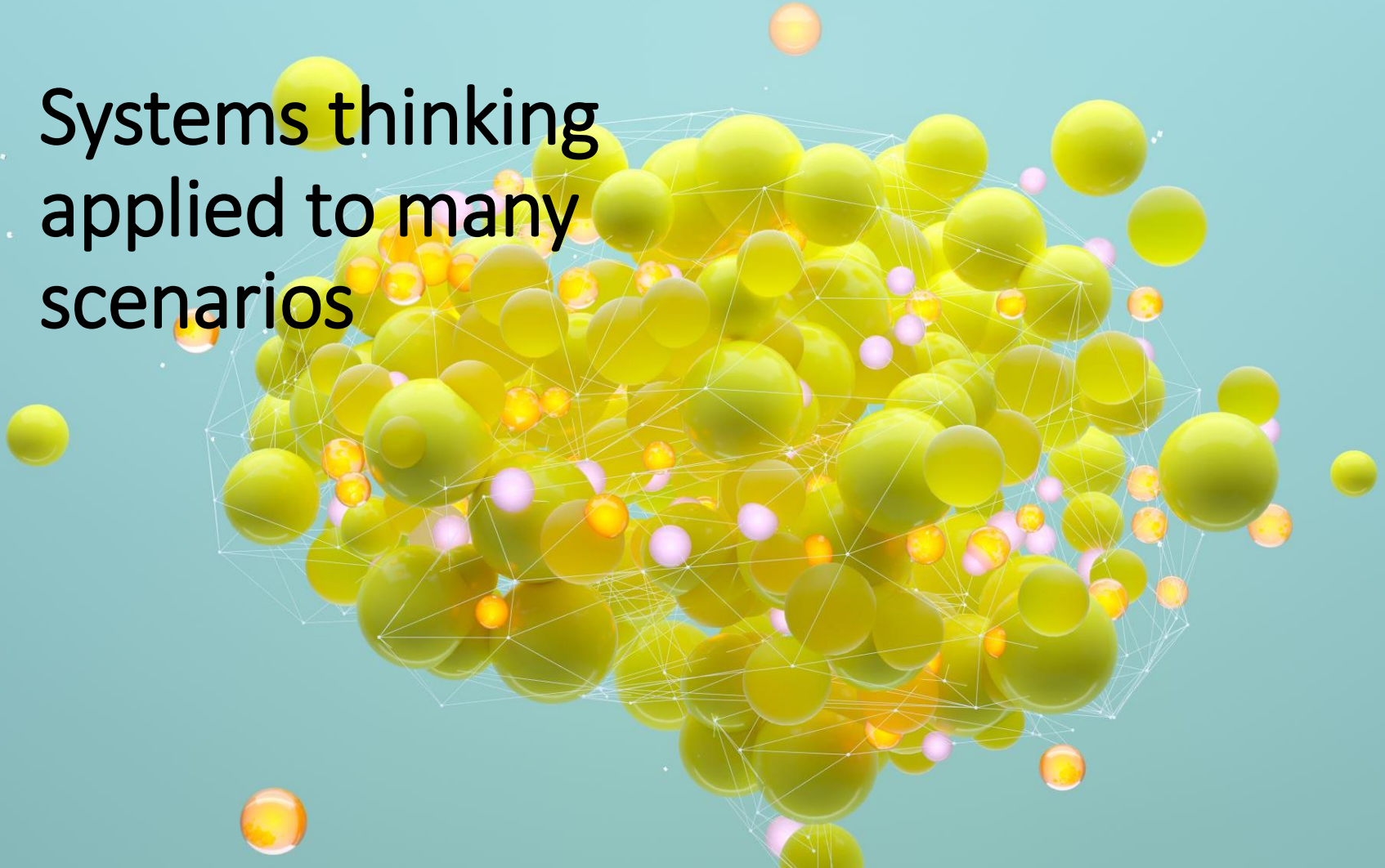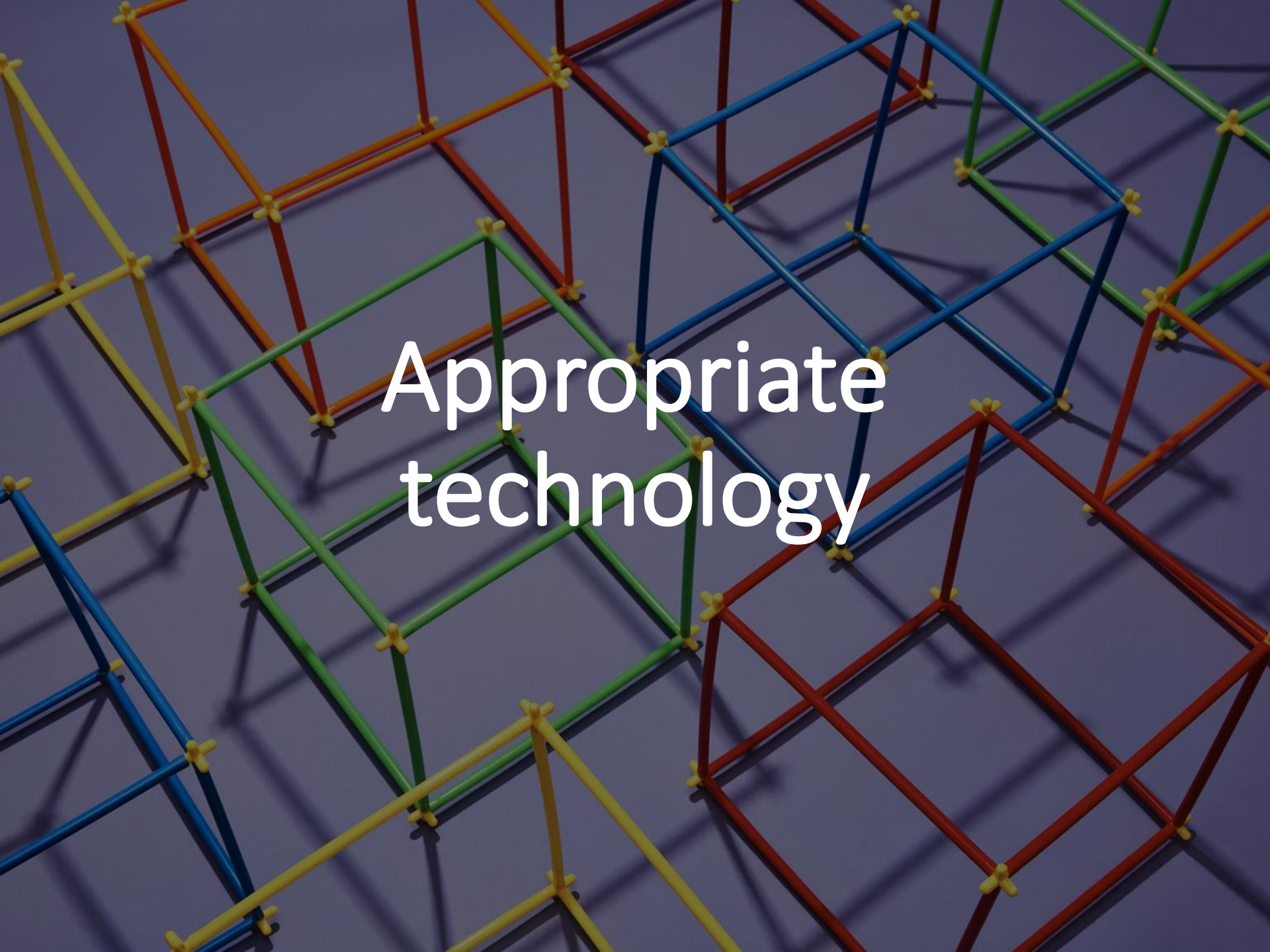
Pillars of Sustainability: A System Perspective

Environment (air, water, land, plants, animals)

Society (education, health, safety, opportunity)

Economy (money, jobs, trade, business)

Sustainability
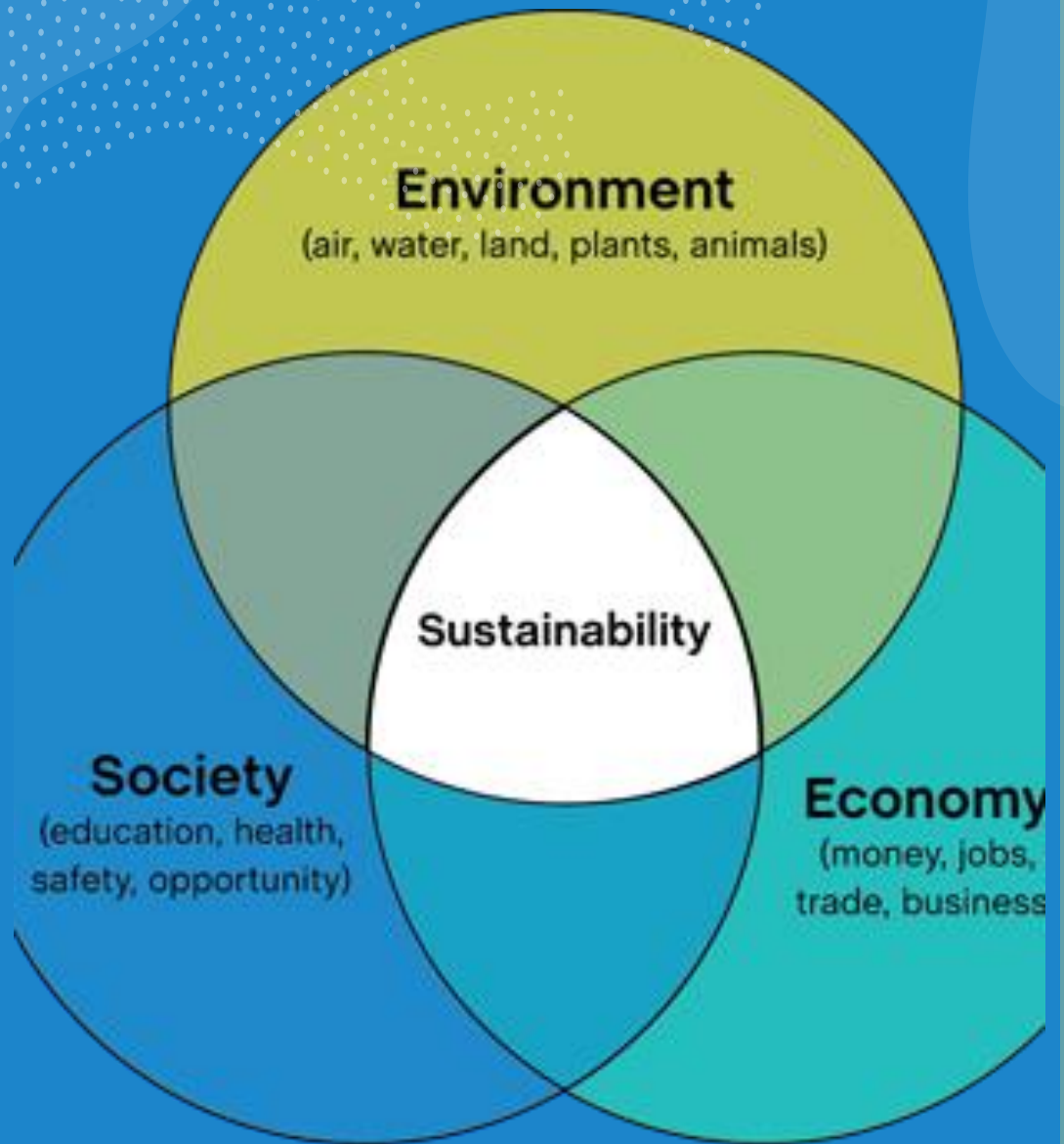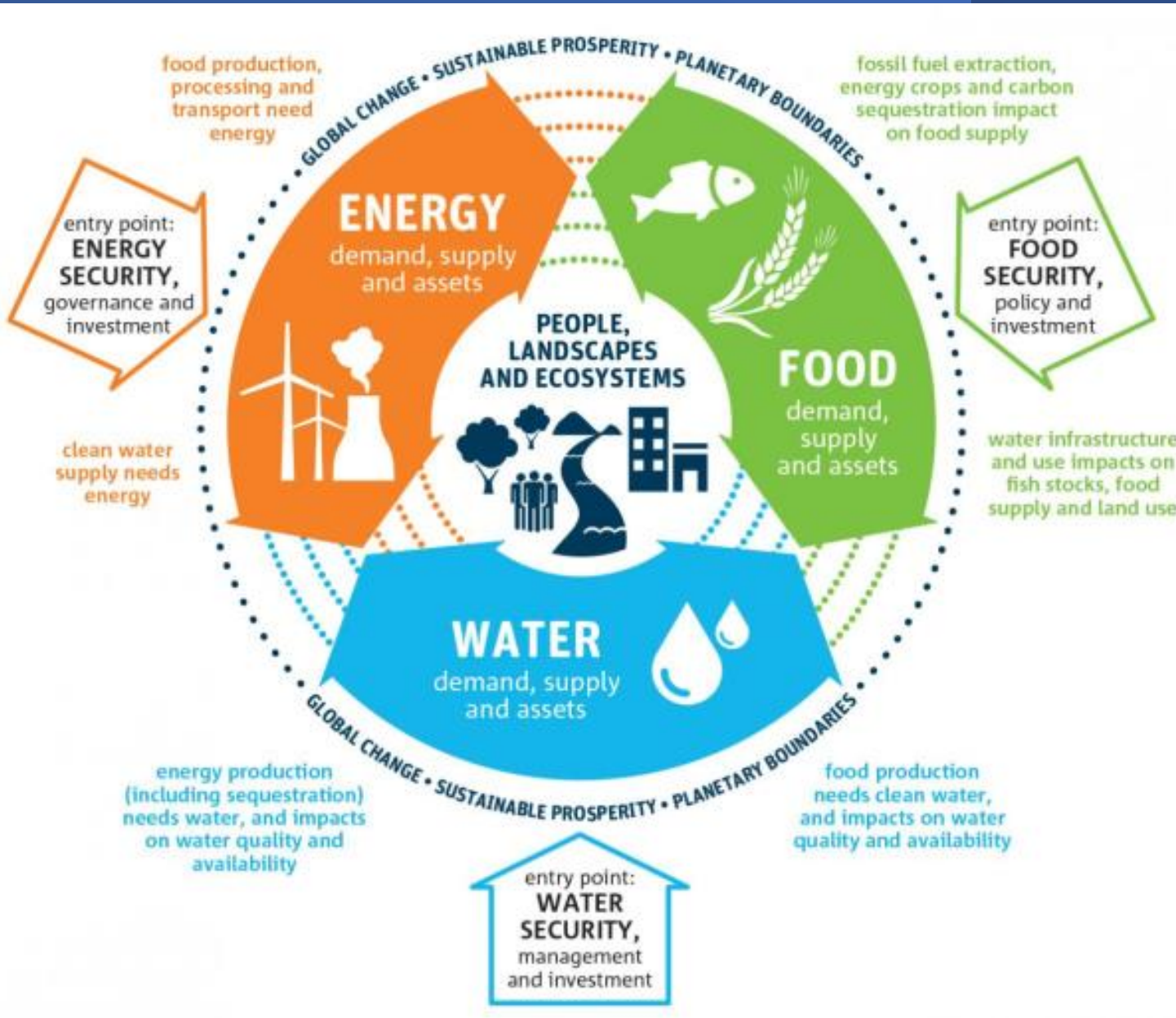
A systems framework: food & nutrition security
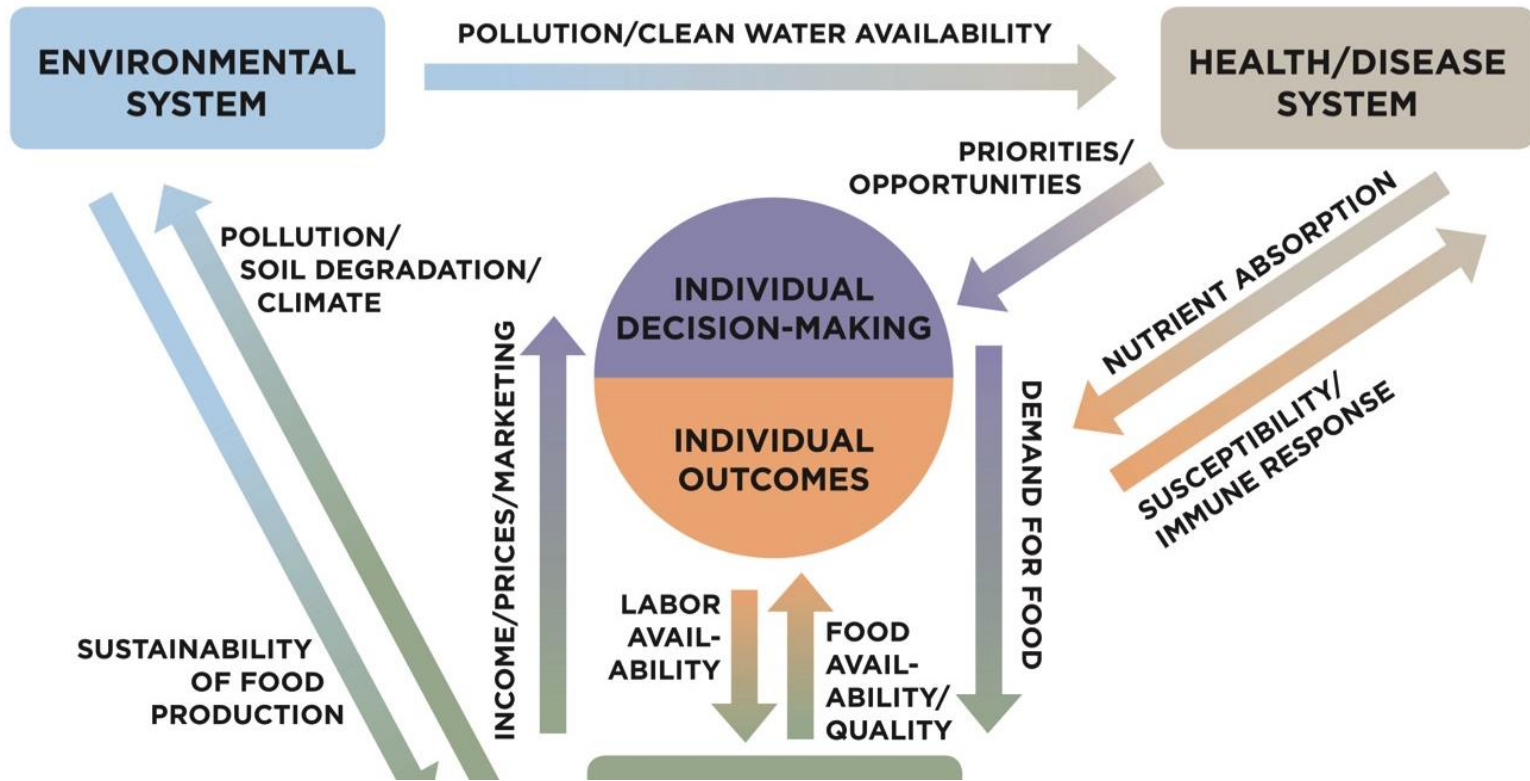
Appropriate technology

Appropriate Technology

- Holistic Design

- Considers local context

- Sustainable Practices ➔ Systems Thinking

- Interconnections, Stocks, Flows etc

- Participatory Methods

- Local Context important
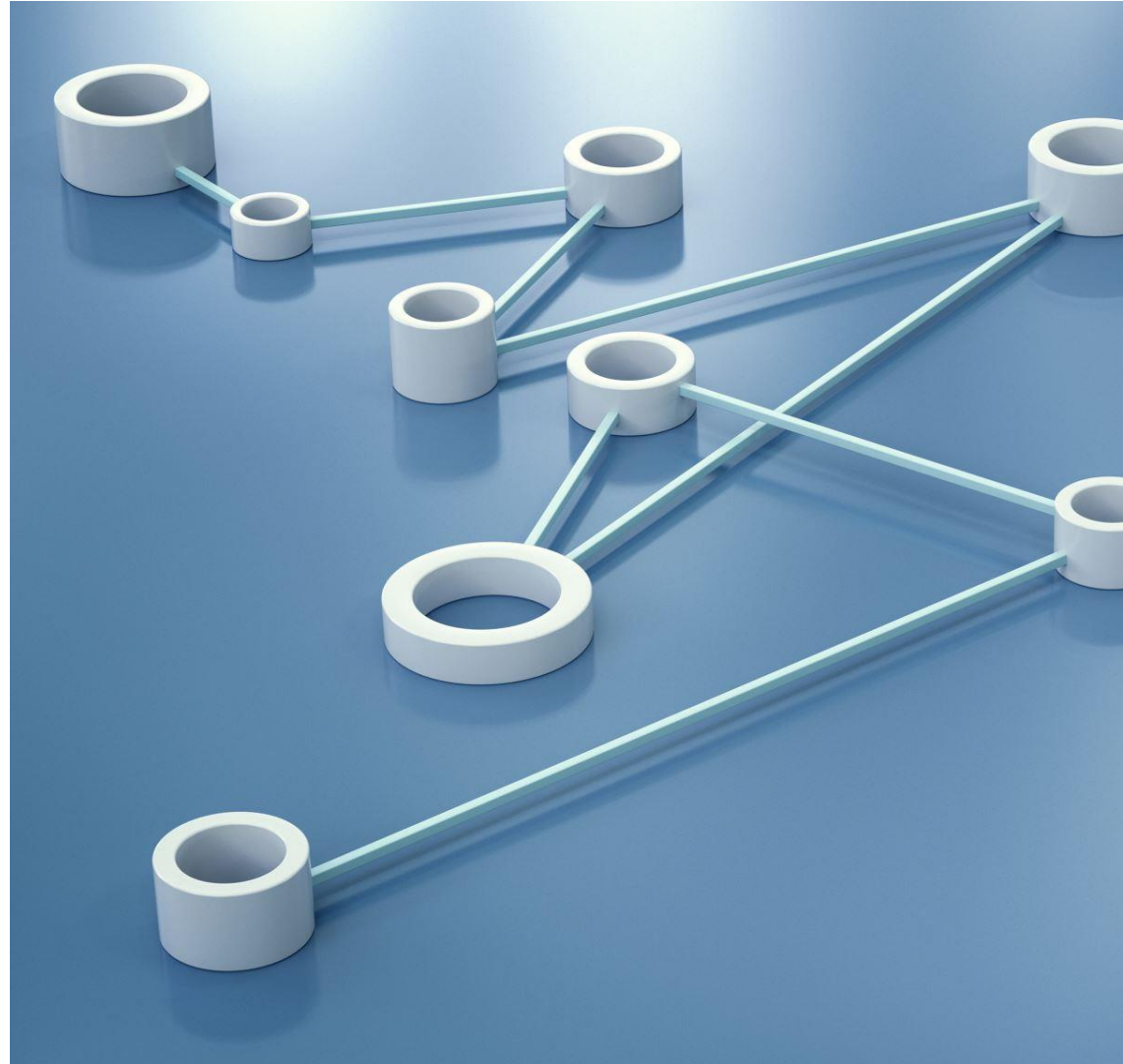
Human Centered Design

- Human-centered design is an approach to problem-solving commonly used in design, management, and engineering frameworks that develops solutions to problems by involving the human perspective in all steps of the problem-solving process.
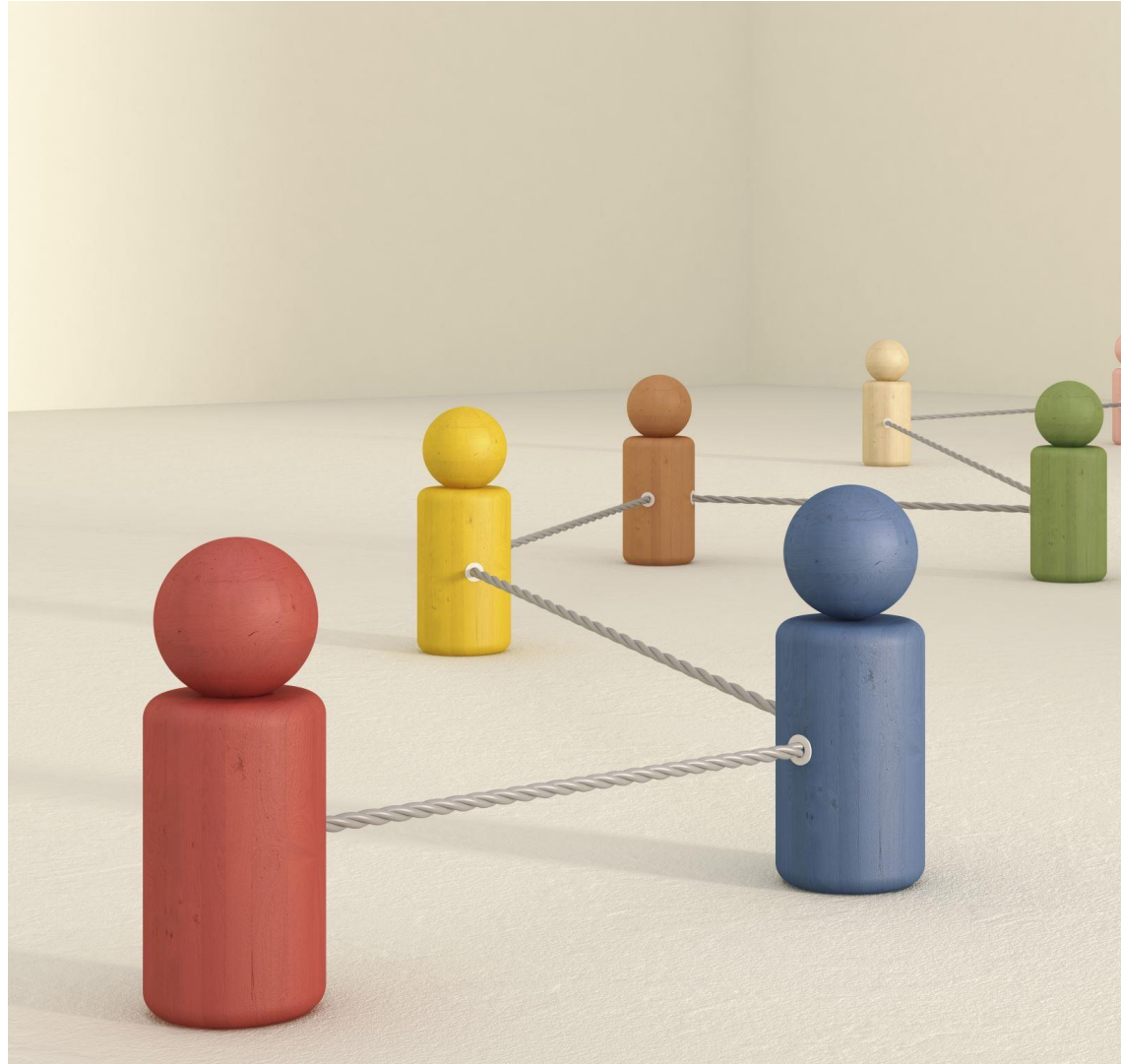
Some Projects

Humanitarian Engineering Study Abroad
COSTA RICA

Mexico Collaborative Project (funded by 100k Strong for Americas Initiative)

Humanitarian Technology for Emergency Disaster Response in Nepal

The Ghorka Earthquake

Basic Biosand Filter for Disaster Response in Nepal

पानि फिल्टर गर्ने उपकरण बनाउने तरिका

विशेष ध्यान दिन पर्ने कुराहरु ।।।

- यो उपकरणलाइ दुइ हप्ता सम्म पानी राखेर छोडे पछि फाइदाजनक किटाणु जम्मा हुन्छ जसले पानि फिल्टर गर्न मधत गर्छ, त्यसकारण यस उपकरणको प्रयोग दुइ हप्ता पछि गरेमा उचित हुनेछ ।

- यो उपकरण बाट फिल्टर गरिएको पानि पूर्णतय किटाणु मुक्त हुदैन ।

- त्यसैले ति किटाणुहरु मर्न पानीलाई उमालेर अथवा बोटलमा राखेर त्यो बोटललाइ ६-७ घण्टा घाममा राखे पछि मात्रै प्युनु होला ।

- पानि उमल्दा कम्तिमा पनि १ मिनेट उमाल्नु पर्छ, समुन्द्र बाट ५००० फीट (१००० मीटर) भन्दा माथि भएको ठाउँ हरुमा कम्तिमा पनि ३ मिनेट उमाल्नु पर्छ ।

- यी सबै कुराहरु ध्यानमा राखेर सफा र किटाणु मुक्त पानिको मज्जा लिनुहोस् ।

AT Assessment tool
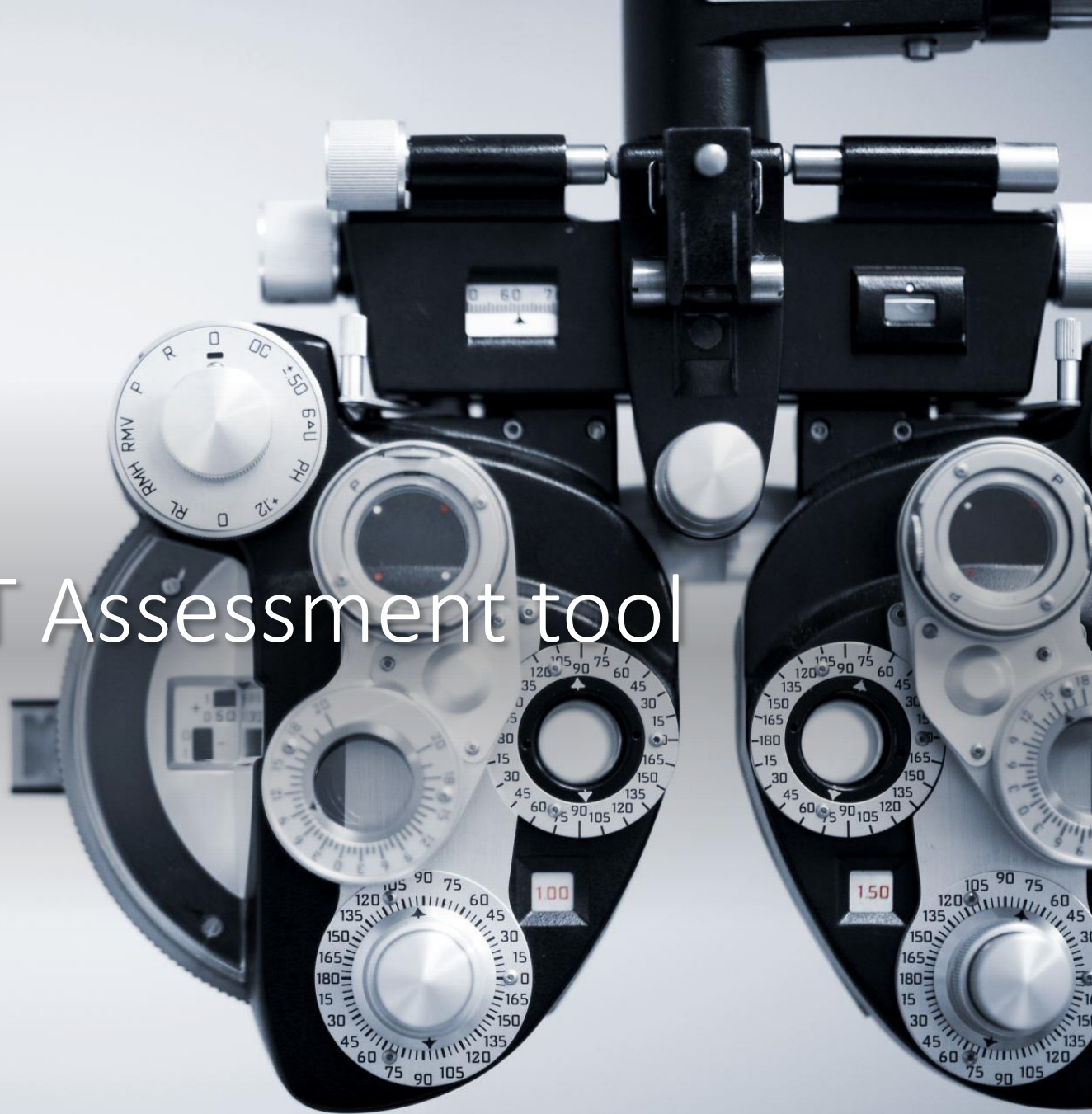
"Engineers often have failed to understand the social dimensions around technology transfer and implementation."

- Murphy et al., 2009

"'Appropriate technology is simply not appropriate,' said a senior USAID official commenting on a small-scale hydro scheme..."

Ellis & Hanson

1989

"This highlights the need to develop a decision support tool that can help decision-makers to select appropriate technology."

- Kalbar et al. 2012

Evaluation using MCDA

✓ Multiple considerations

✓ Systematic

✓ Well-suited to AT

Frequency of Occurrence

Cited Indicator
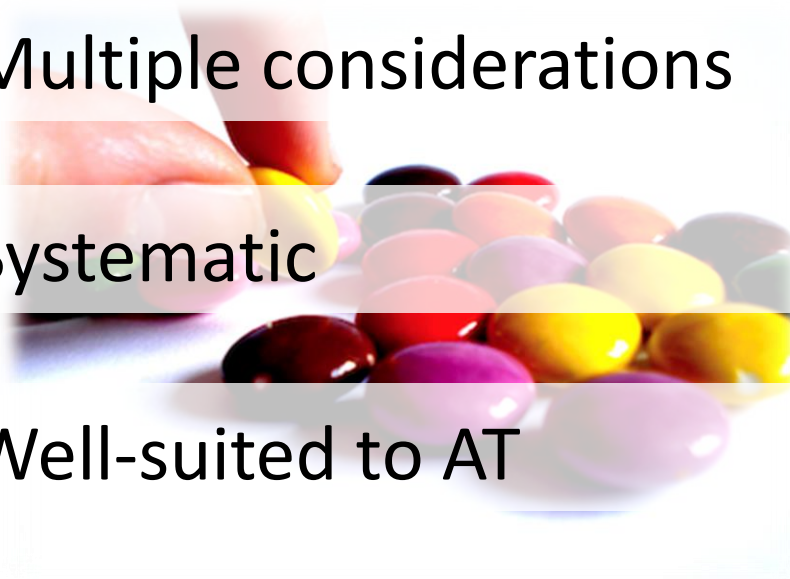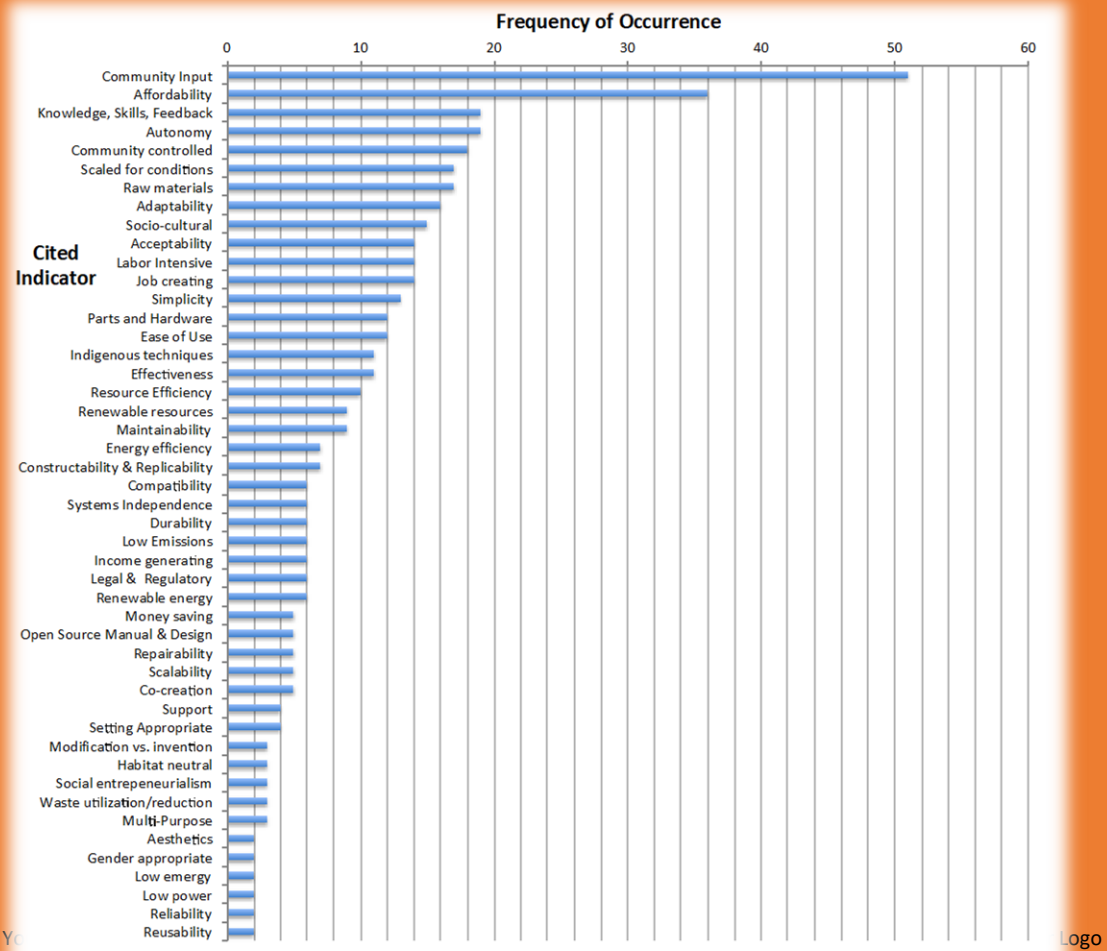
Indicators of Appropriateness from a Literature Meta-Analysis

Appropriate Technology Assessment Tool (ATAT)

STEP 1:
Indicate the TOTAL NUMBER of indicators you are scoring today.

STEP 2:
Rank your indicator from most to least important (top to bottom)

STEP 3:
Rate this technology for each indicator

How many indicators today?

8

Indicator	Rating
Locally available raw materials	4
Resource efficiency	5
Job creating	4
Simplicity	4
Ease of Use	4
Uses renewable resources	4
Adaptability	3
Autonomy	4

PRESS HERE to Calculate Score

4.21

This is your AT's "Appropriateness" Score

6
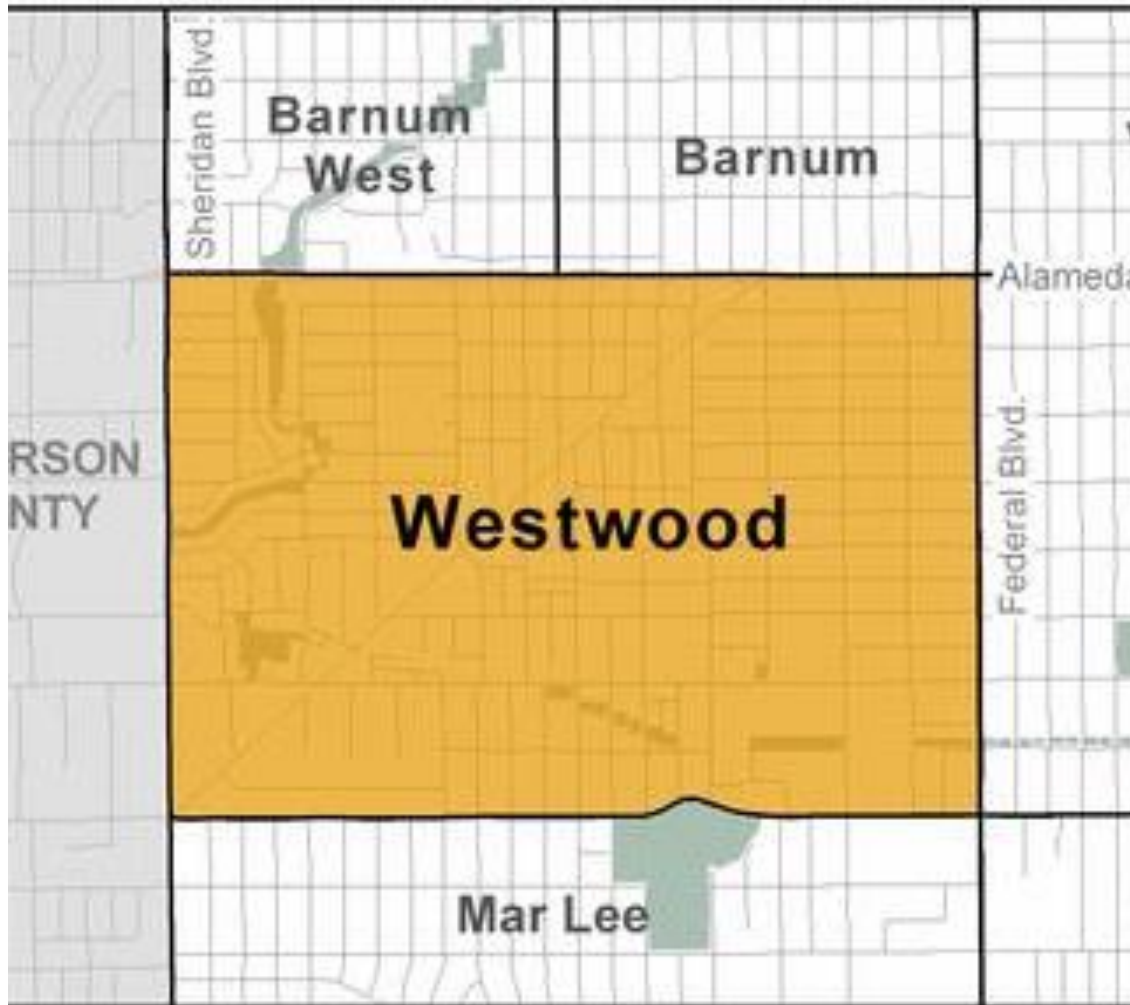
Westwood

Main Data Sources	Type (Primary/ Secondary)	Community Demographic Data	General Community Needs or Problems	Specific Community Food Problems	Specific Community Housing Problems	Information to help partner with Re:Vision	Community Strengths	How to Connect to Community	Additional Resources
First meeting at Re:Vision	1	X	X	X	X	X	X	X	X
Re:Vision's Files or Data	1	X	X	X		X			
Promatora Meeting	1		X	X	X	X	X	X	
Re:Vision Staff Meetings	1	X	X	X	X	X	X	X	X
Harvest Festival (observations)	1	X	X	X		X	X	X	X
Home Visits	1		X	X	X		X	X	
Other Garden Projects' Websites	2					X			X
LiveWell Westwood's Data	2	X	X	X	X		X		X
Re:Vision's Website	2	X		X		X			X
City Data's Website	2	X	X						
Piton Foundation's Website	2	X	X						
Online Census Data	2	X							

Household Statistics

- **Westwood residents paid $689 average rent. This equated to 95% the average rent price in Denver of $725**

- **Westwood household had 3.3 people. The greater Denver area had an average of 2.3 people per household**

- **21.1% of Westwood spoke "English not well or not at all" vs. 7.6% for the rest of Denver**

- **WESTWOOD HOUSEHOLDS HAD A MEDIAN HOUSEHOLD INCOME OF $31,886, WHICH WAS 57% THE MEDIAN HOUSEHOLD INCOME FOR DENVER OF $55,129**

Rank	Community Needs
1	Economic needs (jobs and income)
2	Violence or negative influencers (Gangs, drugs, alcohol, pornography, robberies)
3	Educational needs (better schools for children, more education for adults including about good food)
4	Poor housing stock (Windows, insulation, safety, expense of repairs)
5	Poor food options (No local grocery stores, expensive healthy food, limited space or time to garden)
6	Lack of sense of community (trash on streets, graffiti, abandoned buildings, stray dogs)
7	Health concerns (diabetes, high blood pressure, lack of insurance or adequate care)

HIGH ENERGY BILL$?

Rr 13 8/9
KILOWATTHOURS

Problem:

- Expensive monthly energy bills for residents of Westwood

COSTS

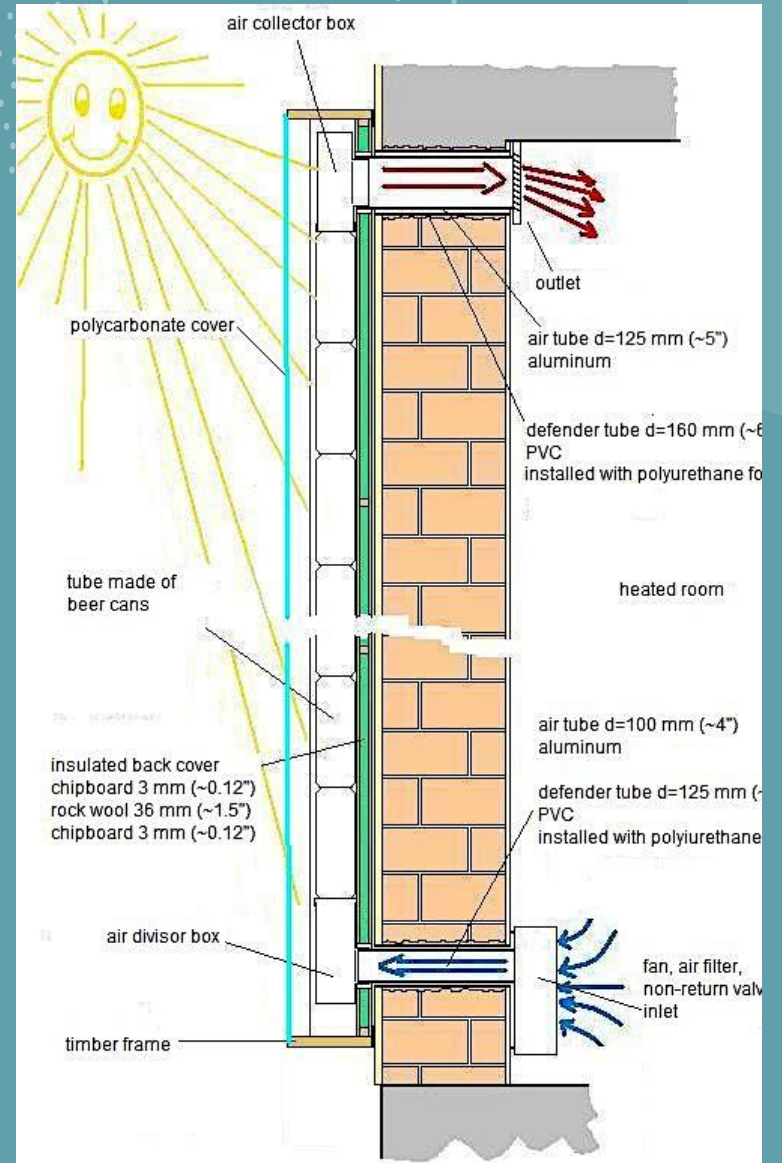images courtesy of http://isavenergy.com/;
http://valleyheating.socialtract.com/2012/08/28/energy-bills/

Six Potential Options

		Options										
		Supplemental Solar Furnace		Supplemental Solar PV Panels		KeepTraditional Furnace/No change		Supplemental Space Heaters		Reduce Heat Use		Improve Insulation or Efficiency	
Criteria	Weight	Score	ScorexWeight	Score	ScorexWeight	Score	ScorexWeight	Score	ScorexWeight	Score	ScorexWeight	Score	ScorexWeight
Capital cost	5	9	45	1	5	10	50	7	35	10	50	7	35
O&M cost	4	9	36	1	4	1	4	2	8	5	20	9	36
Cultural acceptability	3	5	15	8	24	10	30	8	24	1	3	5	15
Constructability	3	8	24	6	18	10	30	10	30	10	30	5	15
O & M reliability	4	8	32	8	32	2	8	9	36	2	8	9	36
Feasibility	3	6	18	1	3	10	30	9	27	10	30	6	18
Sustainability	2	8	16	9	18	1	2	0	0	10	20	9	18
Reproducibility	1	5	5	5	5	10	10	3	3	7	7	2	2
Environmental effects	2	9	18	9	18	3	6	0	0	10	20	9	18
Efficiency	3	4	12	8	24	3	9	4	12	0	0	8	24
Total score			**221**		**151**		**179**		**175**		**188**		**217**
Extra Facotrs													
Educational Potential	2	9	18	9	18	0	0	0	0	0	0	9	18
Local Economic Potential	2	9	18	2	4	0	0	0	0	0	0	7	14
Security	2	5	10	2	4	10	20	6	12	10	20	8	16
Health Concerns	2	9	18	10	20	4	8	8	16	2	4	9	18
New Totals			**285**		**197**		**207**		**203**		**212**		**283**

Focused Strategy: Solar Furnace

air collector box

polycarbonate cover

tube made of
beer cans

insulated back cover
chipboard 3 mm (~0.12")
rock wool 36 mm (~1.5")
chipboard 3 mm (~0.12")

air divisor box

timber frame

outlet

air tube d=125 mm (~5")
aluminum

defender tube d=160 mm (~6
PVC
installed with polyurethane fo

heated room

air tube d=100 mm (~4")
aluminum

defender tube d=125 mm (~
PVC
installed with polyiurethane

fan, air filter,
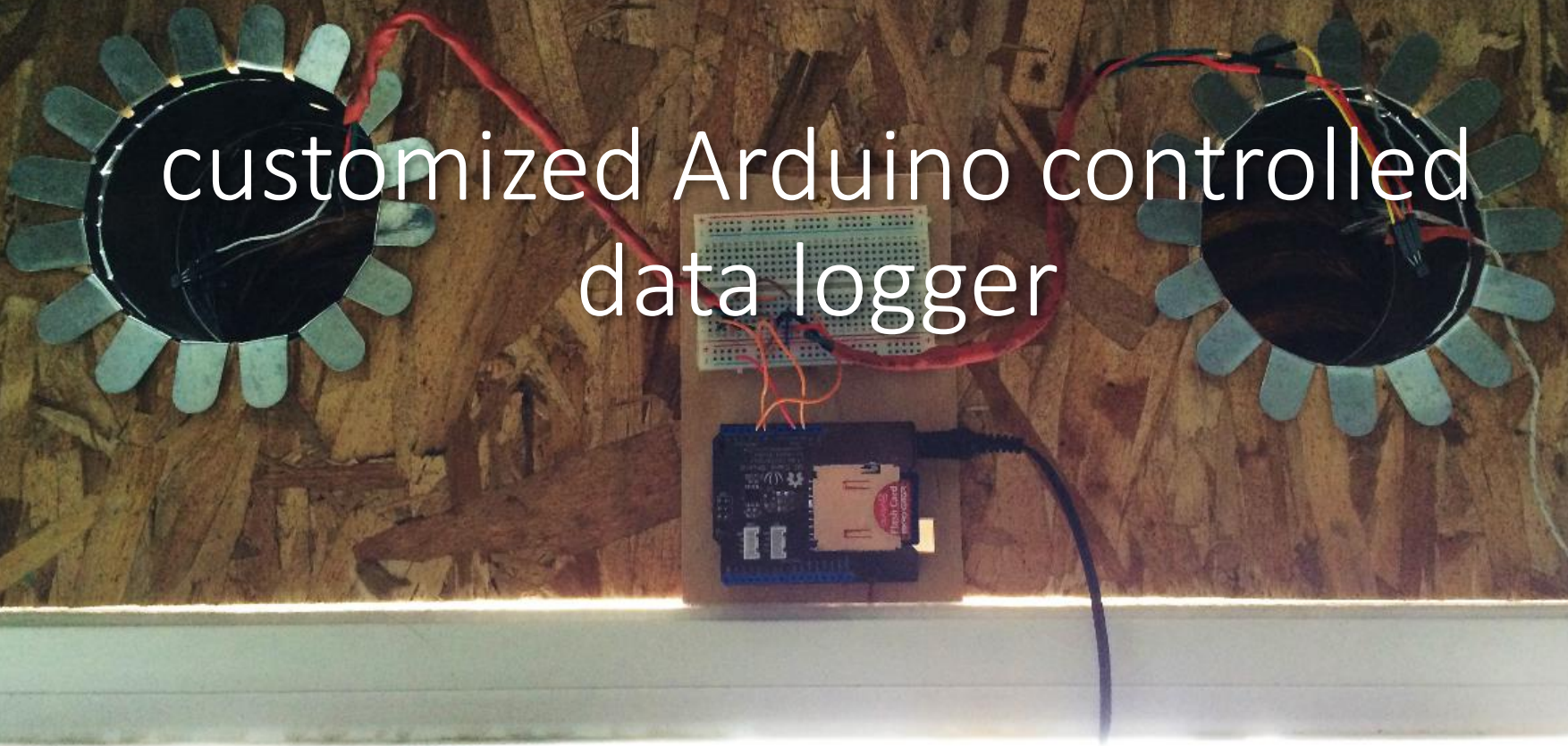non-return valv
inlet

- How It Works

Performance Prediction
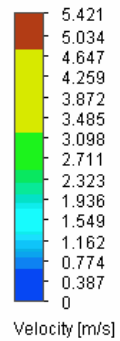
Furnace Modeling and Testing

Data Logging

customized Arduino controlled
data logger
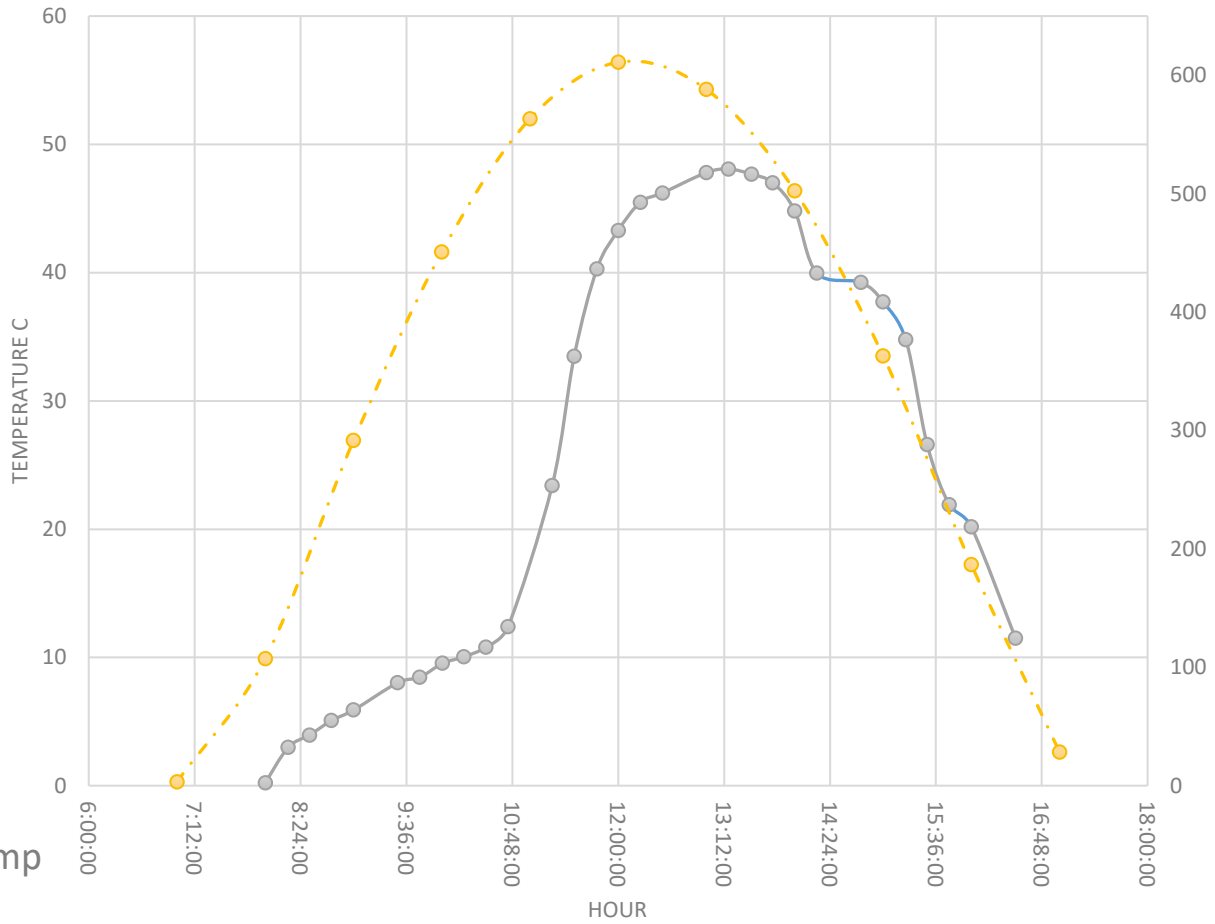
BTU produced during the day
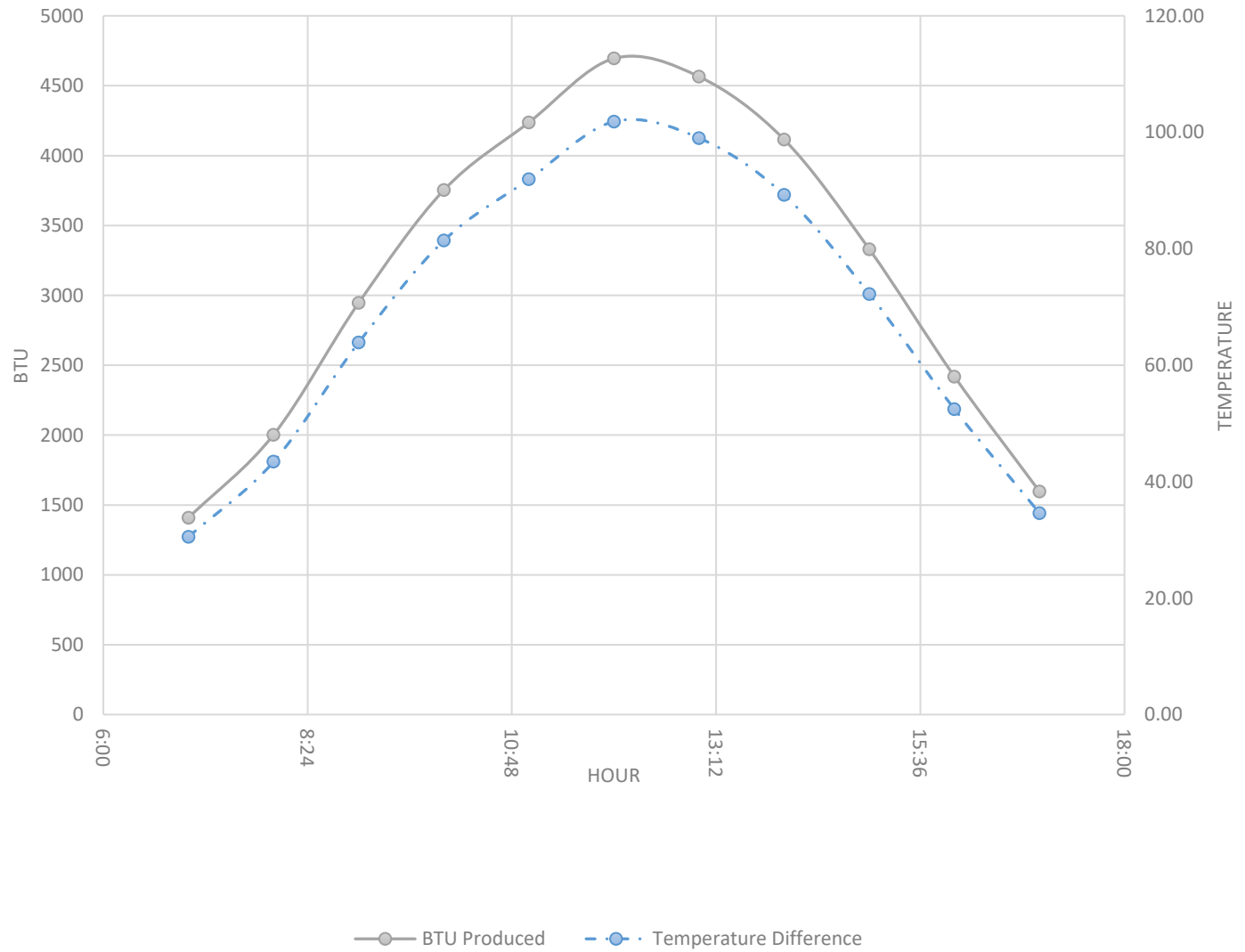
Solar furnace size vs Savings per month

Savings per month ($)

- 88: 12.00 (Avg. Sunny day), 9.97 (Avg. Cloudy Day)
- 144: 19.38 (Avg. Sunny day), 15.13 (Avg. Cloudy Day)
- 200: 28.79 (Avg. Sunny day), 21.59 (Avg. Cloudy Day)

Number of cans

Solar furnace size vs Savings over 5 yr lifespan

Savings over 5 yr lifespan ($)

- 88: 360 (Avg. Sunny day), 299 (Avg. Cloudy Day), 82 (Cost of Furnace)
- 144: 581 (Avg. Sunny day), 454 (Avg. Cloudy Day), 90 (Cost of Furnace)
- 200: 858 (Avg. Sunny day), 648 (Avg. Cloudy Day), 110 (Cost of Furnace)

Number of cans

Legend: Avg. Sunny day — Avg. Cloudy Day — Cost of Furnace
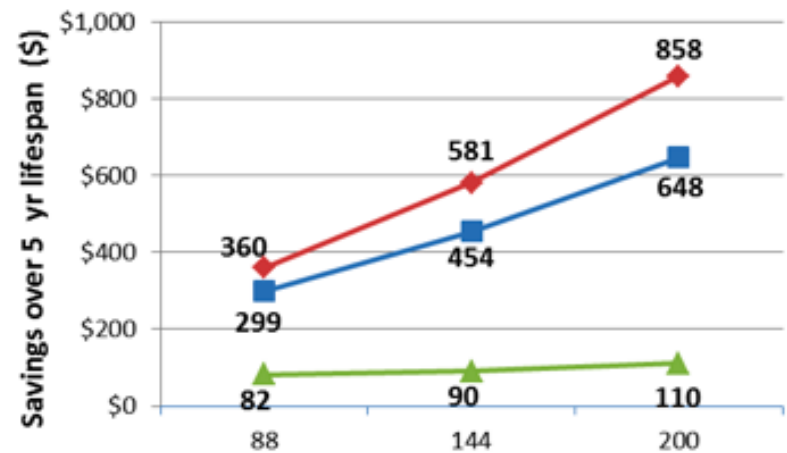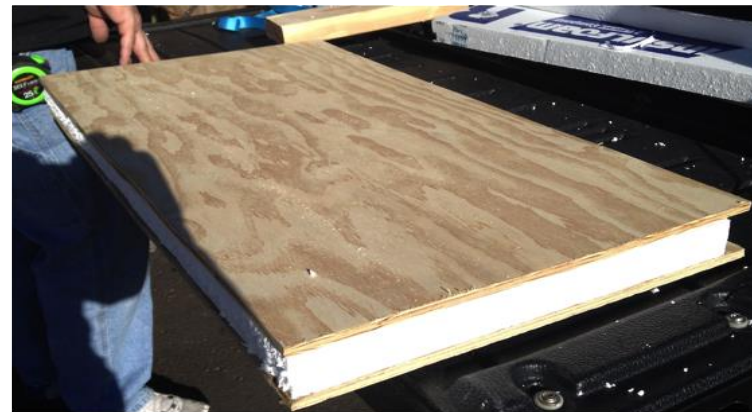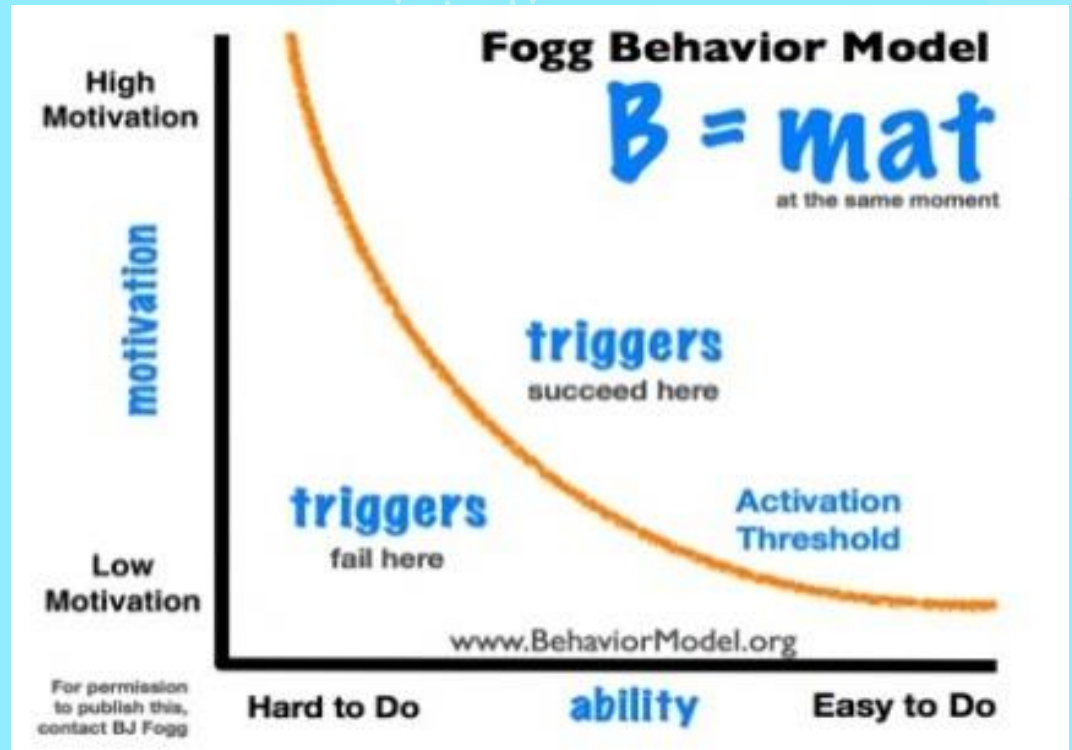
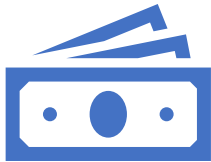Community focus group with the pilot solar furnace at Re:Vision

Installing Demonstration Units

Fogg Behavior Model

Ability

Affordable

Community have the skills to construct the devices.

Materials needed were readily accessible

TRIGGER

- First Demonstration Models Installed after First Cold Snap

Dear Heater

...

Love, Cat

FEEDBACK

Covid
Ventilator Project

Innovation for Emerging Markets

- The emerging world, long a source of cheap labor, now rivals the rich countries for business innovation (Economist, April 17, 2010)

- Frugal or constraint based innovation

- Hand held EKG: $80 Cost

- Tata Swach (Clean) water filter: $22 initial investment (3,000 liters, 200 days for a family of 5)

- Improved cooking stoves

- "Little Cool" fridge runs on batteries: $70

Cleaner Stove

earchers at Enviroft are
rging clean-burning
es that reduce smoke
use less wood. Although
designs have not been
ized, the stoves are likely
e principles known to
in other stoves. At
, an artist's conception
compact clean-
ing stove.

ATED GRATE
des space
fficient air
under
wood.

ic Enviroft: Apovecho Research Center

Assistive Technology

Ethics & Humanitarian Engineering

Local context is Important

Avoid the "White Savior Complex"

Build Trust

Sustainable Solutions to solve problems Community Identifies

Sustainable Solutions

Social Justice

Environmental Justice

Engineering For Peace

Systems Thinking is a useful tool

- Many problems with multiple variables are too complex for the linear thinking of traditional engineering methods.

- Systems Thinking can provide a tool to tackle these, avoid pitfalls and unintended consequences.

- While we often think of Systems Engineering being applied to areas like aerospace and computer engineering, it can also be useful as a tool to address complex sociotechnical problems….these are the biggest problems humanity is facing

And...

Our complex challenges need to be solved through a different paradigm
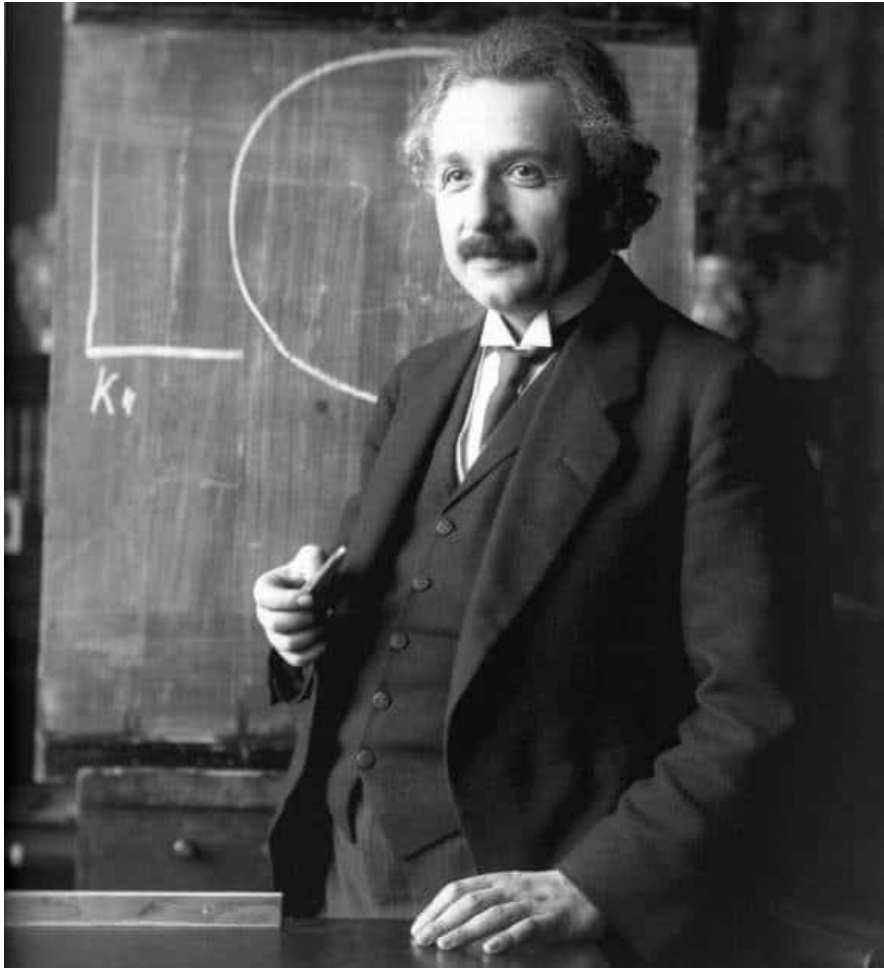
We cannot solve our problems wi[th] the same thinki[ng] we used when w[e] created them.

Albert Einstein - www.quoteikon.com