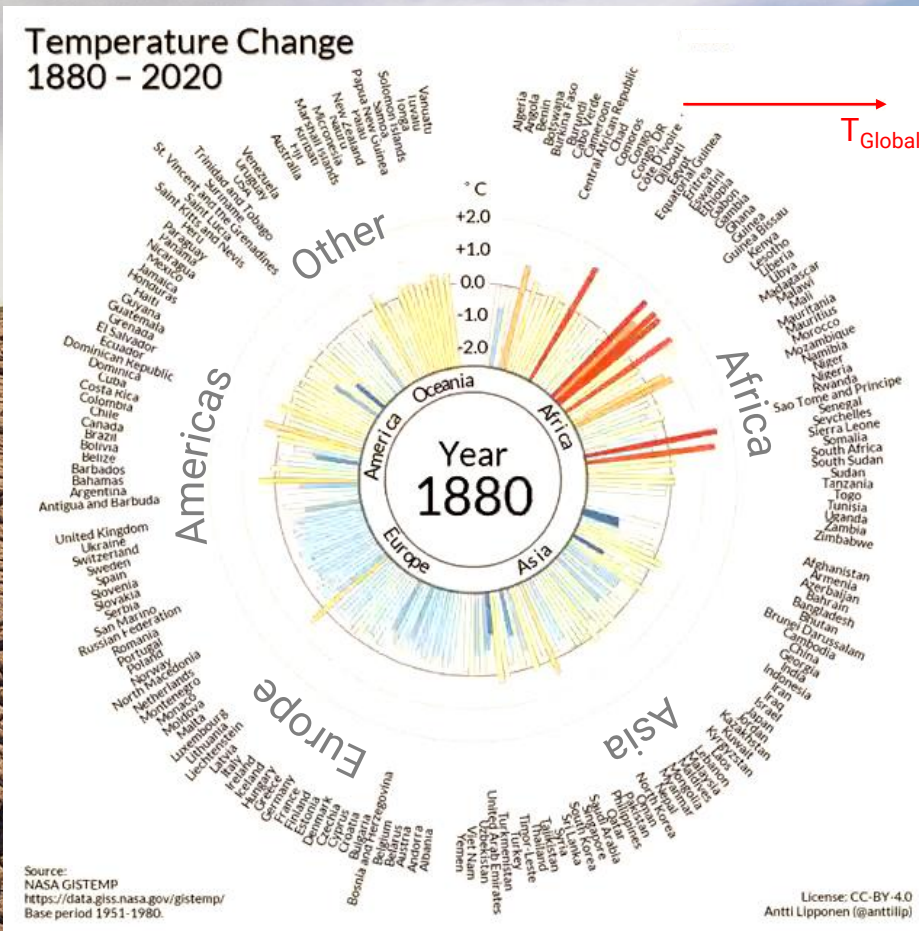
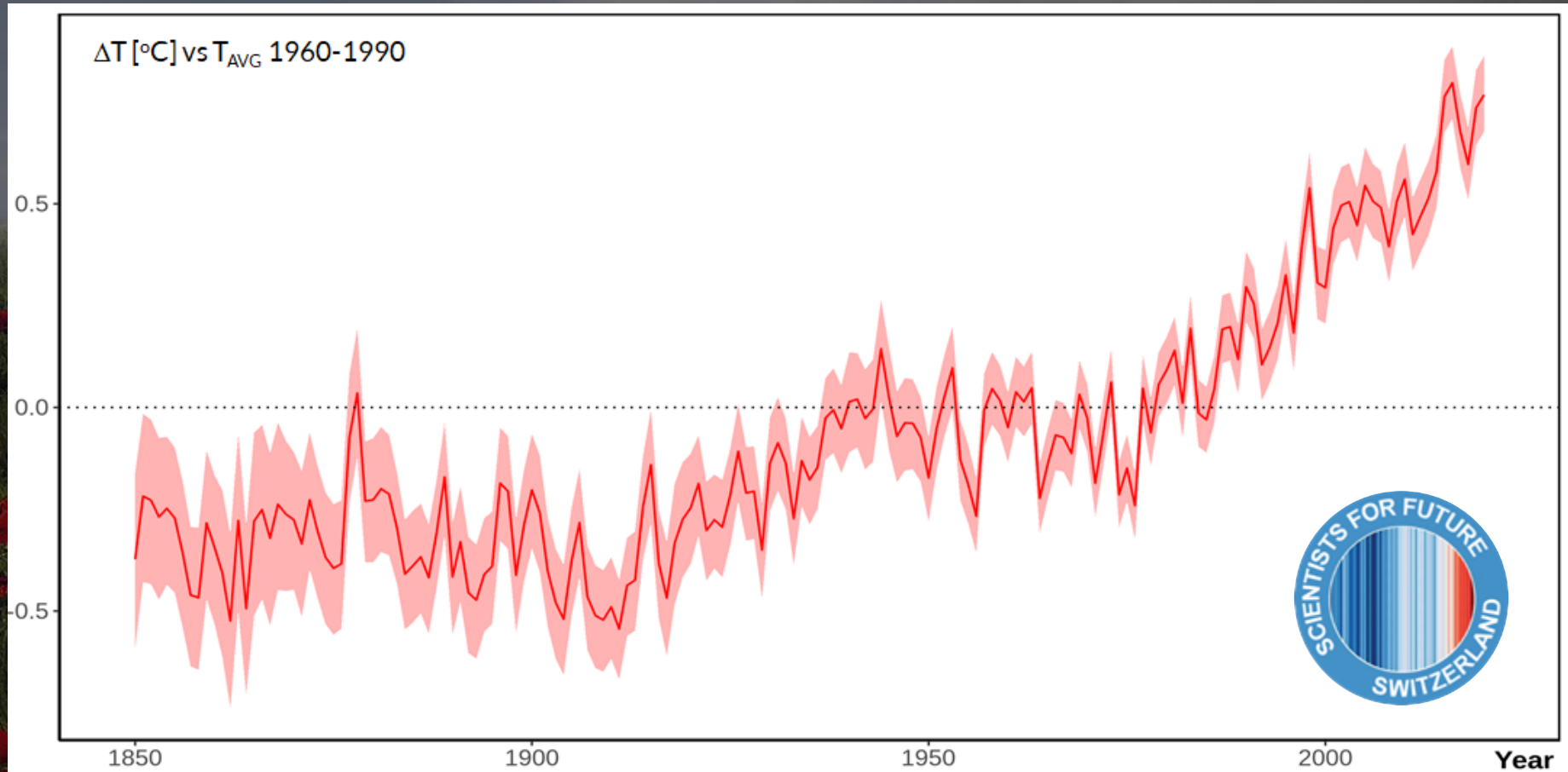


Tackling Climate Change

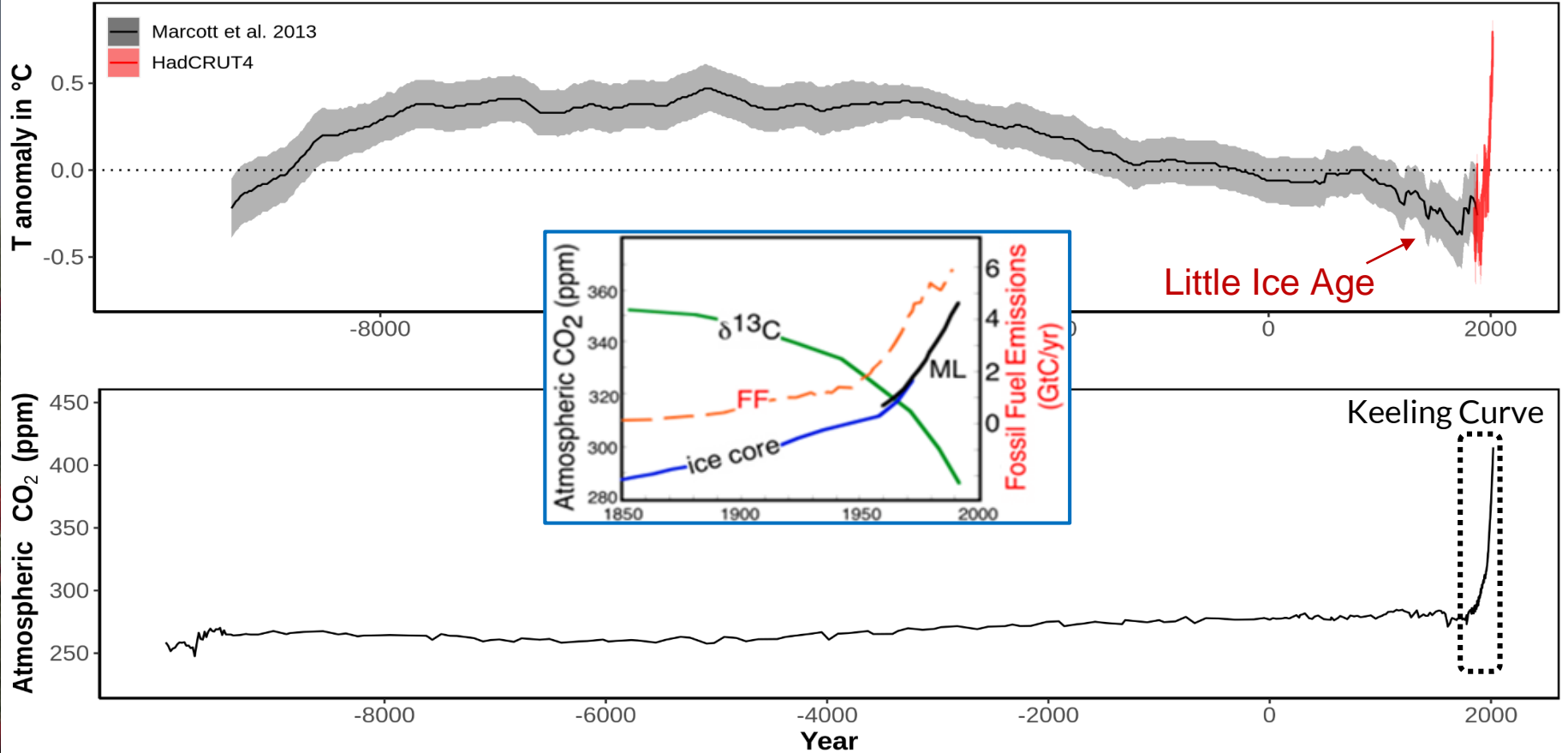
A Systems Engineering Perspective



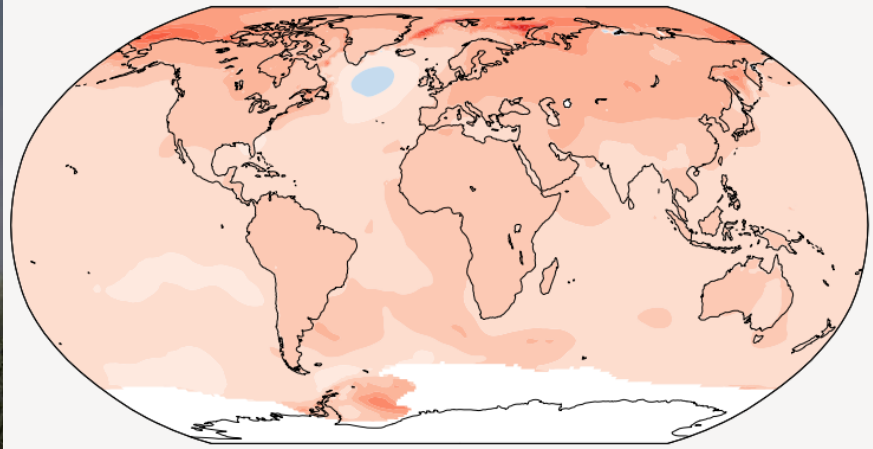
Climate Change: It's not a matter of *if*, but *when* (and *how bad*)!



Climate Change: We do know enough to take action!

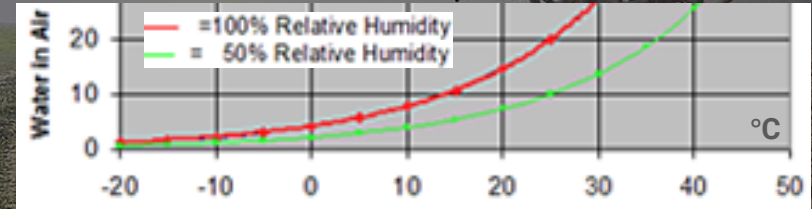


Climate Change: "...but it'll be only one degree!"

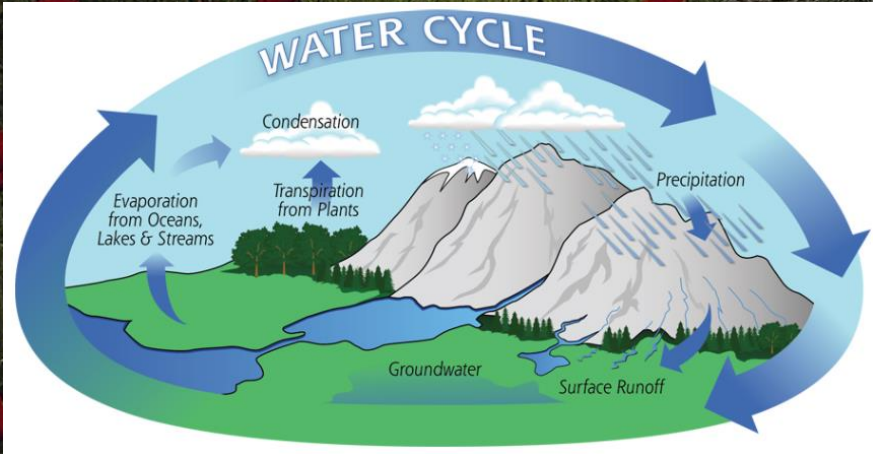


Warming at 1 °C affects all continents and is generally larger over land than over the oceans. So Northern Europe will heat up by 2-3 °C!

An important, and well researched, consequence will be the effects on the world's water cycle.



+2°C → >10% Vapour



- | <u>Direct</u> | <u>Consequences</u> | <u>Indirect</u> |
|---|-------------------------------|------------------------|
| • longer dry periods | • "natural" catastrophes | |
| • heavier rain | • frequent & longer heatwaves | |
| • more energy available for winds and thunderstorms | • water shortages | • loss of biodiversity |
| • more evaporation from soil | • food shortage | |

| What can we as Systems Engineers do?

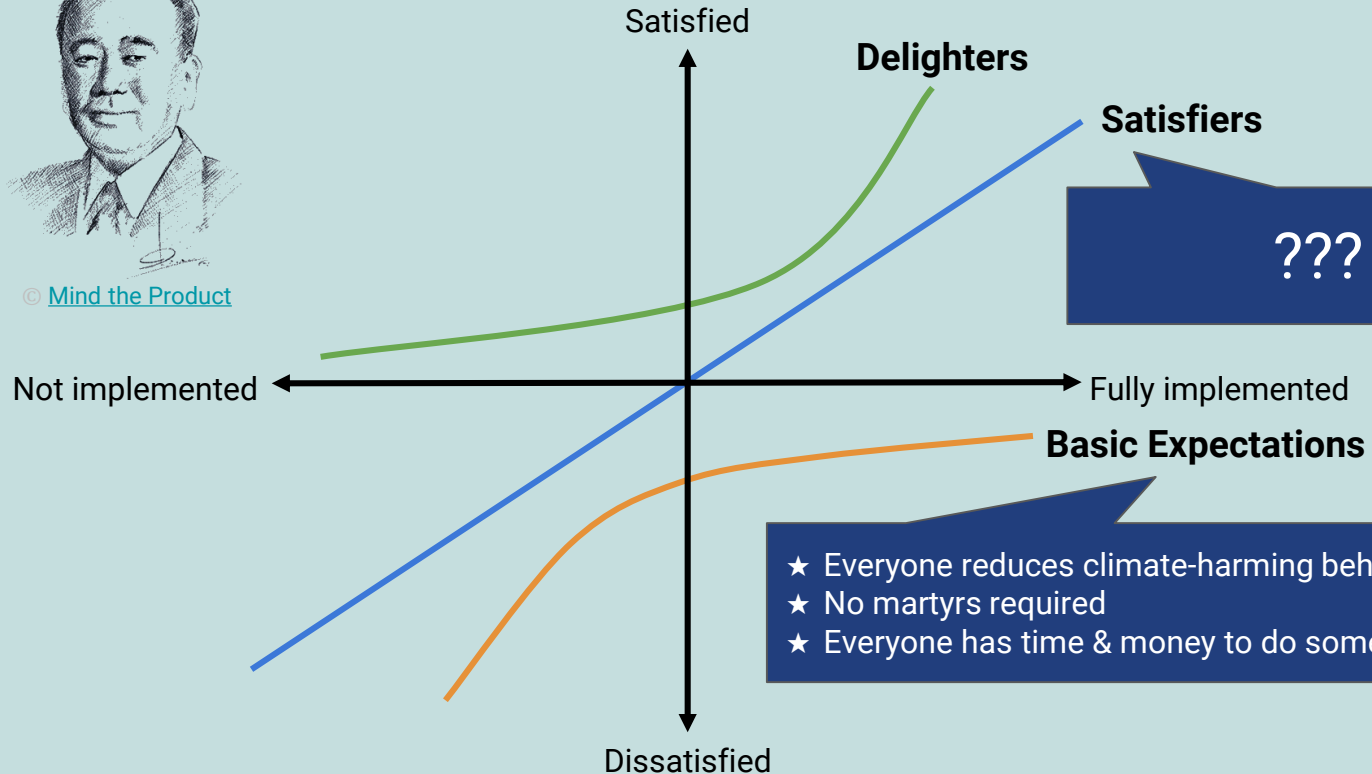


What can we as Systems Engineers do?

The Kano Model for Systems Engineers:



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???

- ★ Everyone reduces climate-harming behavior.
- ★ No martyrs required
- ★ Everyone has time & money to do something.

Tackling Climate Change is a highly complex problem

And we are trained to deal with exactly this!

Systems Engineers

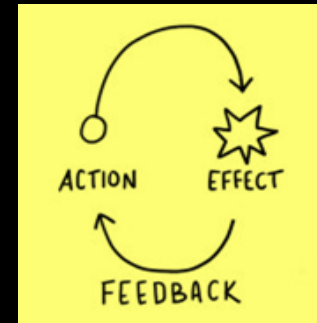
- ★ view the problem in its (often complex) context
- ★ are not overwhelmed by complexity
- ★ can find solutions for complex problems

System Thinking



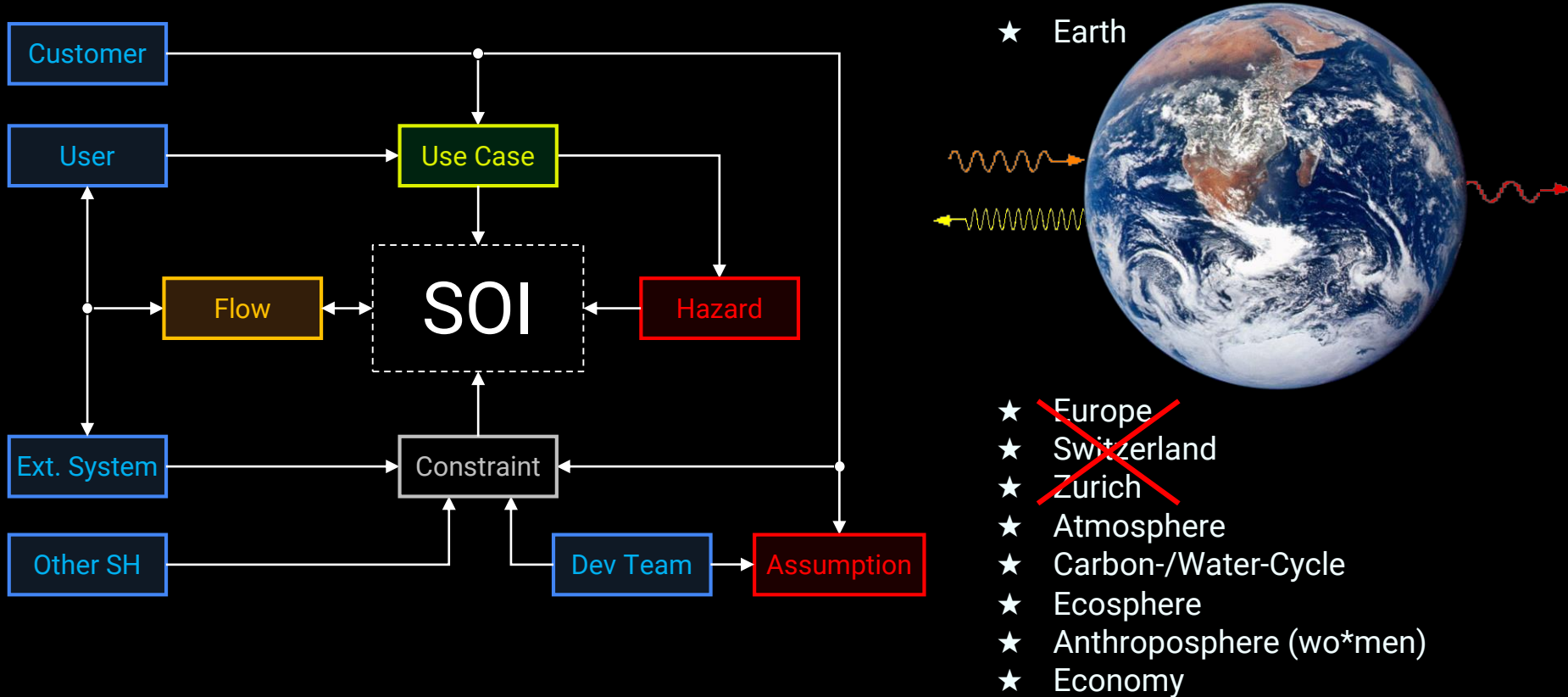
Dealing with Complexity

- ★ Elicit Scope (Define System of Interest)
- ★ Analyse external Relations & Connections
- ★ Break down Problem into smaller Problems
- ★ Accepting and preparing for emergence
- ★ Identify Patterns
- ★ Model the Problem (Abstraction)



Tackling Climate Change is a highly complex problem

Elicit Scope and Analyse Relations & Connections



Tackling Climate Change is a highly complex problem

Patterns, Modelling, and Abstraction

"Without a strong economy, we will not get the climate problem under control."
(Christian Lindner, Member of the German Bundestag)



"Economy will no longer be viable without climate protection"
(Oliver Verbeke, Member of the German Bundestag)

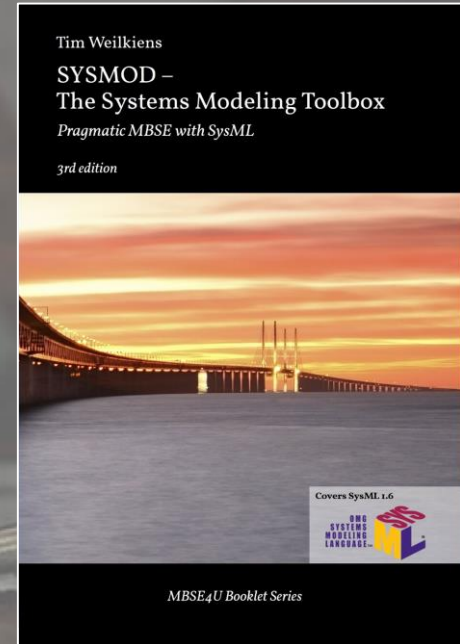
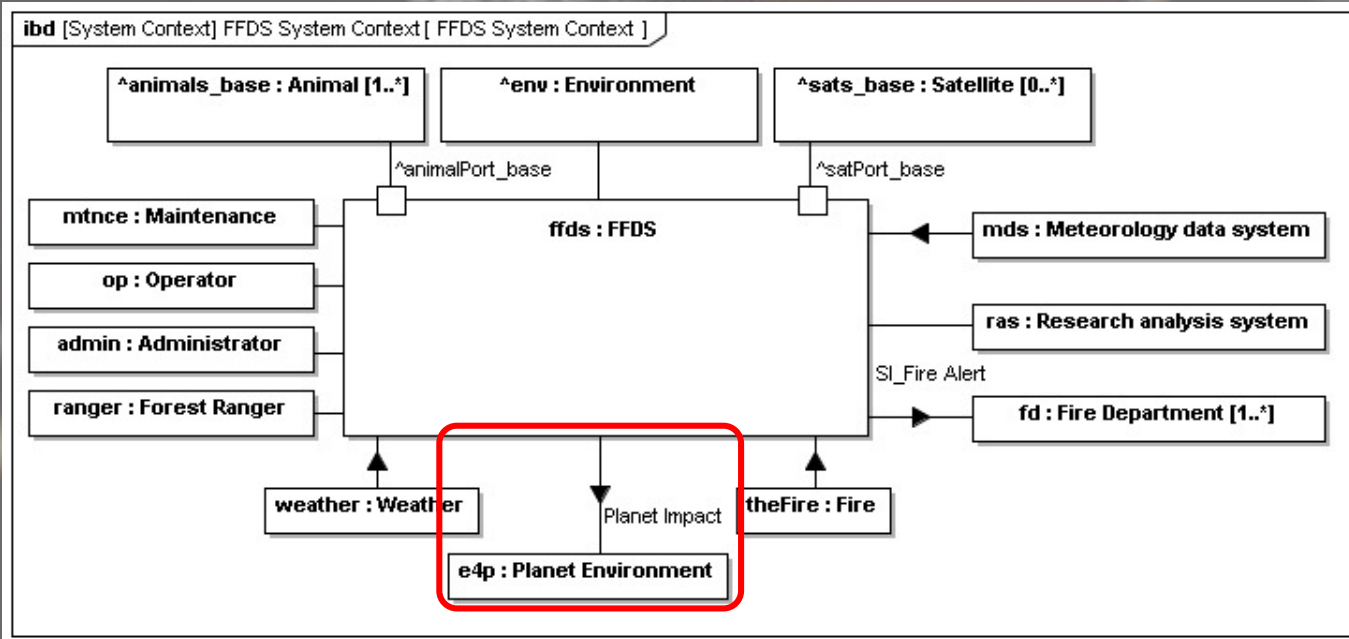
Ecologic Systems

Social Systems

Economic Systems

Establishing Sustainability in our Toolbox

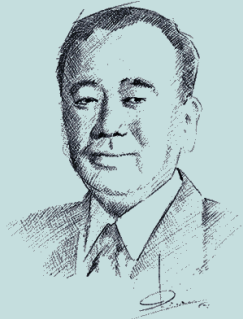
“Every small step can have an impact, many small steps can make a change”



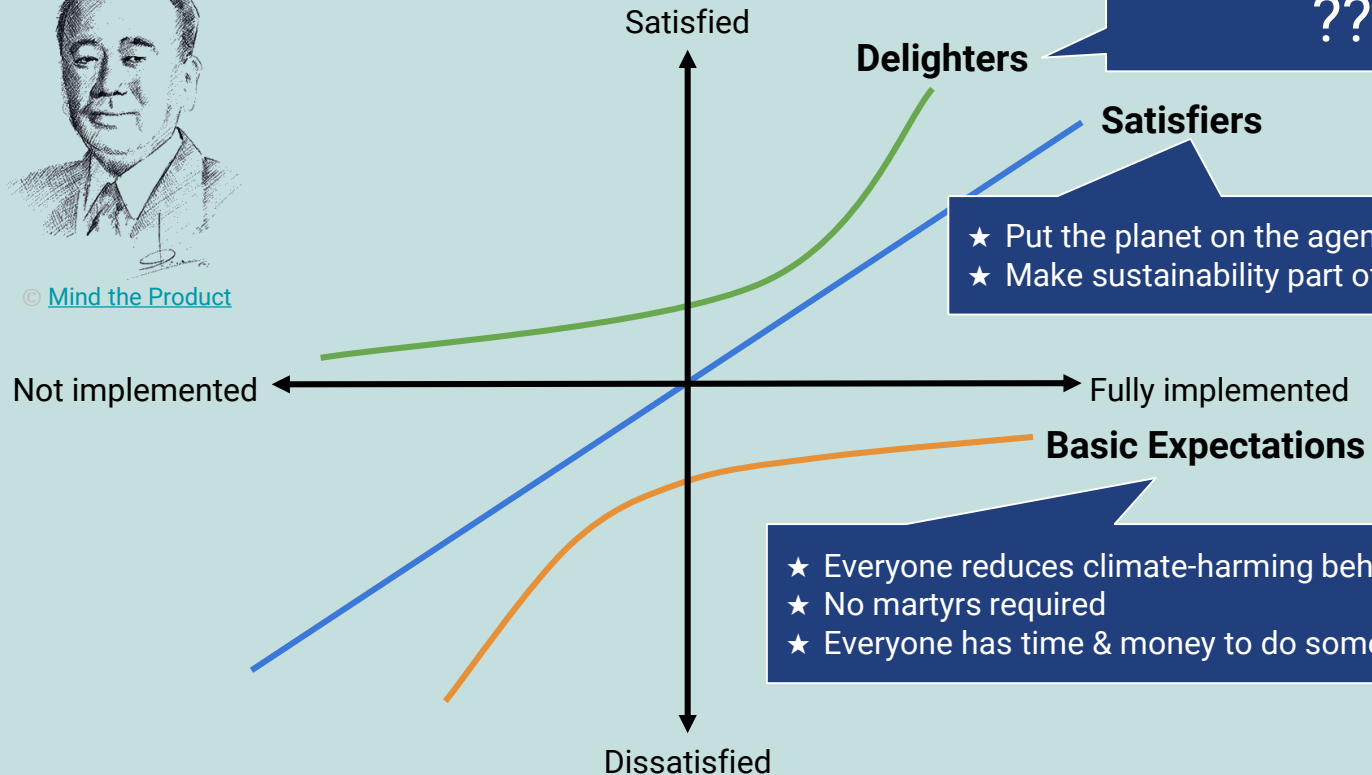
SYSMOD has introduced a new actor category:
Planet Environment is part of the context analysis to consider the impact on the planet.

What can we as Systems Engineers do?

The Kano Model for Systems Engineers:



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???

Delighters

Satisfiers

- ★ Put the planet on the agenda
- ★ Make sustainability part of their toolbox

Basic Expectations

- ★ Everyone reduces climate-harming behavior.
- ★ No martyrs required
- ★ Everyone has time & money to do something.

Climate Change Heroes: Very Delightful

BUT WE MUST NOT RELY ON THEM!

seamach
ENERGY

**PROJECT
DRAWDOWN.**



EnerKite
Flugwindkraftanlagen



**THE OCEAN
CLEANUP**

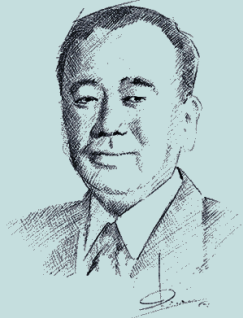
 **climeworks**



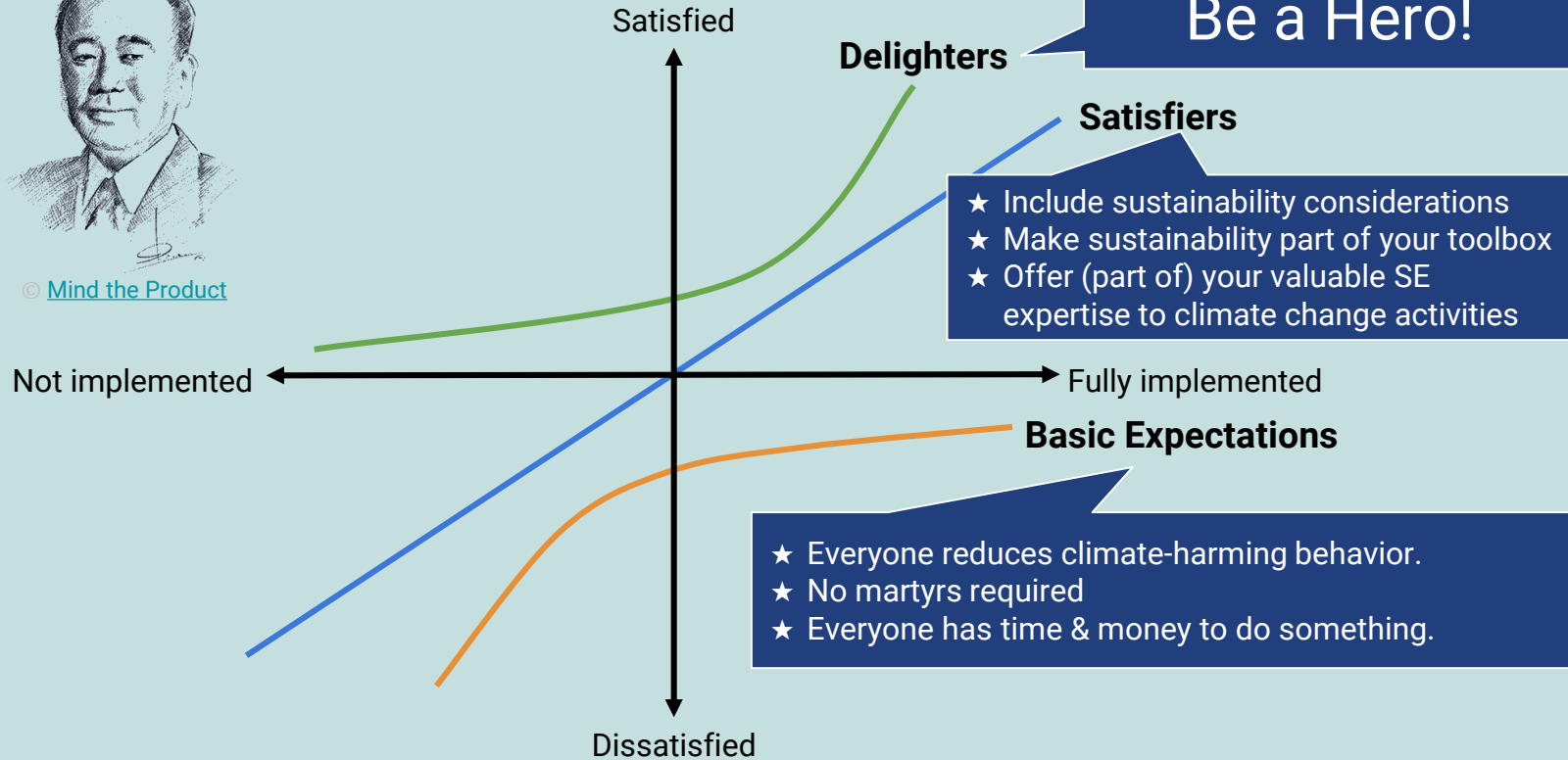
...and countless more!

What can we as Systems Engineers do?

The Kano Model for Systems Engineers:



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Experts for the Planet

Mind-set to use the expertise for sustainability
Use valuable resources for the right things

X4P

FAIR FOR OUR PLANET

Are you an Expert who cares about Sustainability?
Are you a Sustainability Project that needs Expert Services?
We help heroes of our planet find each other.

X4P COMMUNITY

FAIR STORIES

We report on the real actions to show what works and that something is being done.

X4P PRACTICES

FAIR WORK

We know good practices, standards and proven methods in many areas. We bring sustainability to the table.

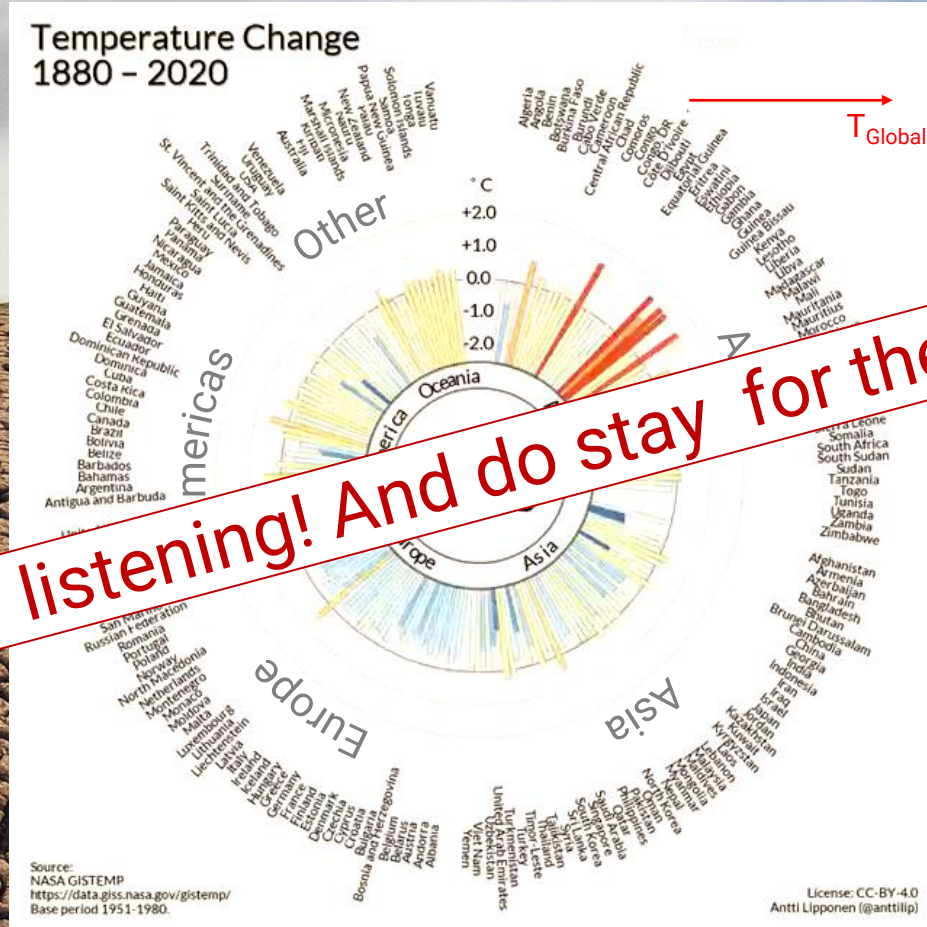
X4P MARKET

FAIR SERVICES

Search specifically for experts and project sponsors who are committed to sustainability.

Tackling Climate Change

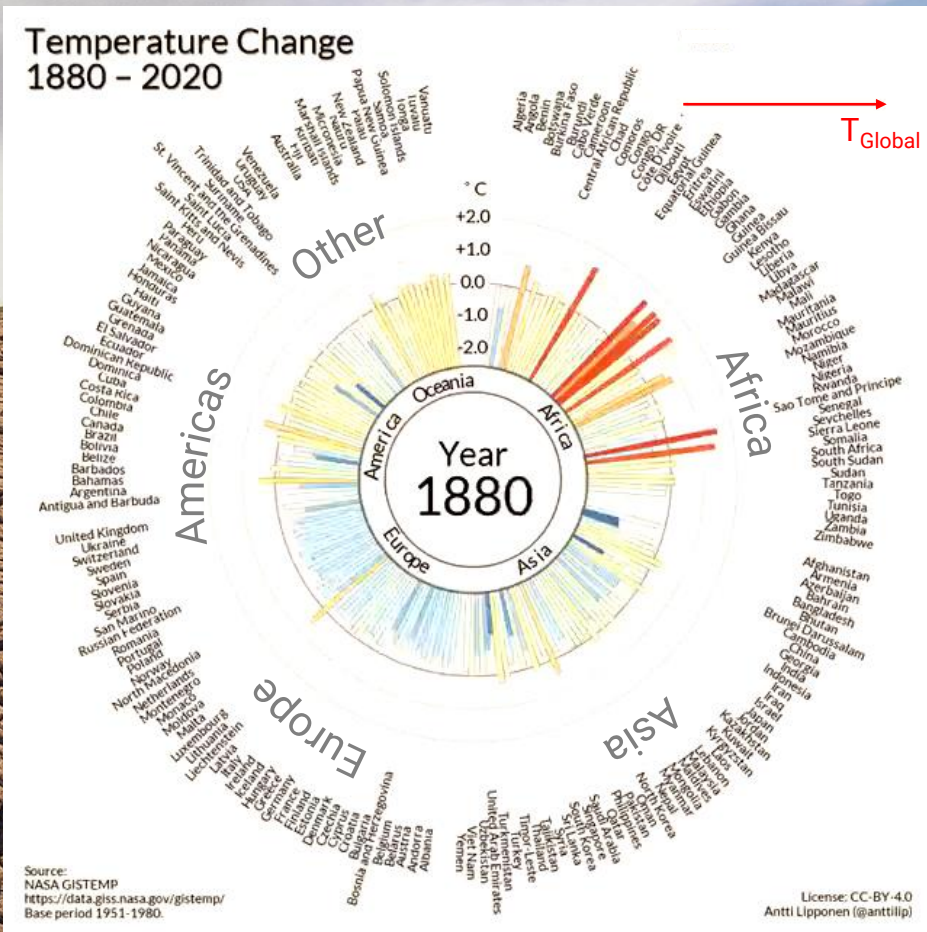
A Systems Engineering Perspective



Thank you for listening! And do stay for the Workshop!



Tackling Climate Change WORKSHOP





Arms Crossed

Finally, a short exercise.
Don't worry, we are engineers, so
without communicating and touching.

1. Take everything from your hands!
2. Cross your arms like these two here!
3. Notice which arm is up!
4. Relax and do it again!
5. Notice which arm is up!

**Raise your hand when your left arm
was up!**

**Raise your hand when your right arm
was up!**

**Now cross your arms so that the other
arm is at the top.**



**When conditions change,
habits must change**



*First we form habit, they they form us. Conquer your bad habits
or they will conquer you.*

(Rob Gilbert, sport psychologist)

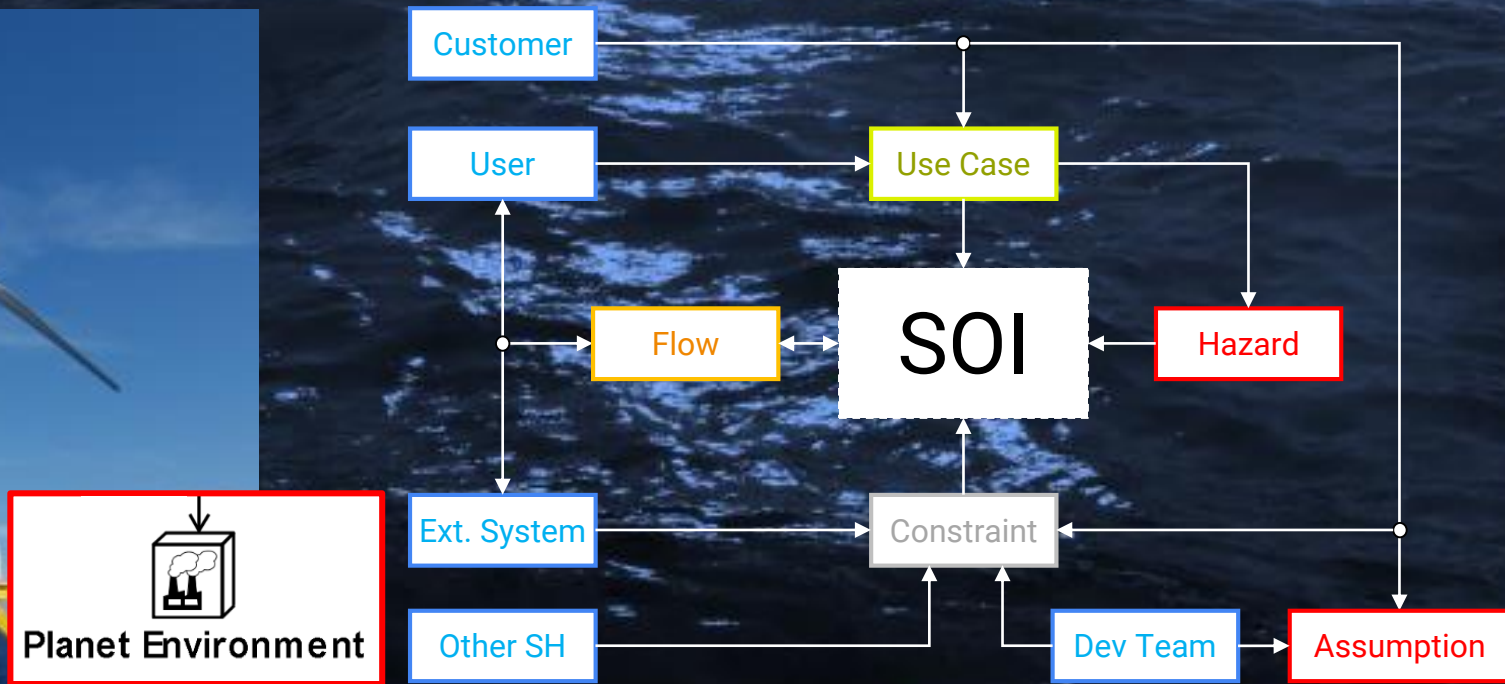
Can Systems Engineering help tackle Climate Change?

DISCUSSION

- Can SE help developing more sustainable solutions that have less negative impact on their environment?
- Can MBSE help to model the relationships and identify the direct (positive) as well as the indirect (positive or negative) impact of solutions?
- Can MBSE also help to model the world's relationships and identify the direct (positive) as well as the indirect (positive or negative) impact of solutions?
- What would be the modelling language for such an “SE World Model”?
Are the promises of SysML2's interoperability a step in the right direction?
- Or is such a multi-discipline complexity beyond SE's comfort zone and MBSE's modelling capabilities?

Applying SE Best Practices

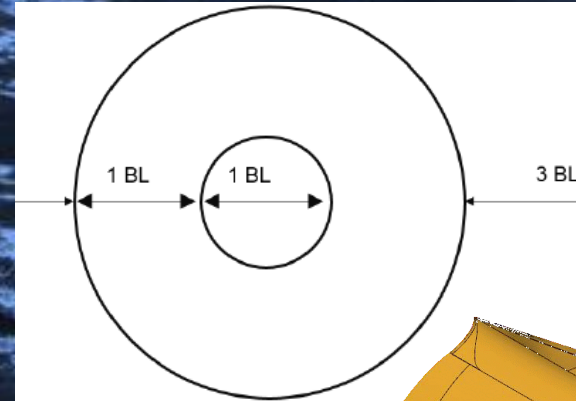
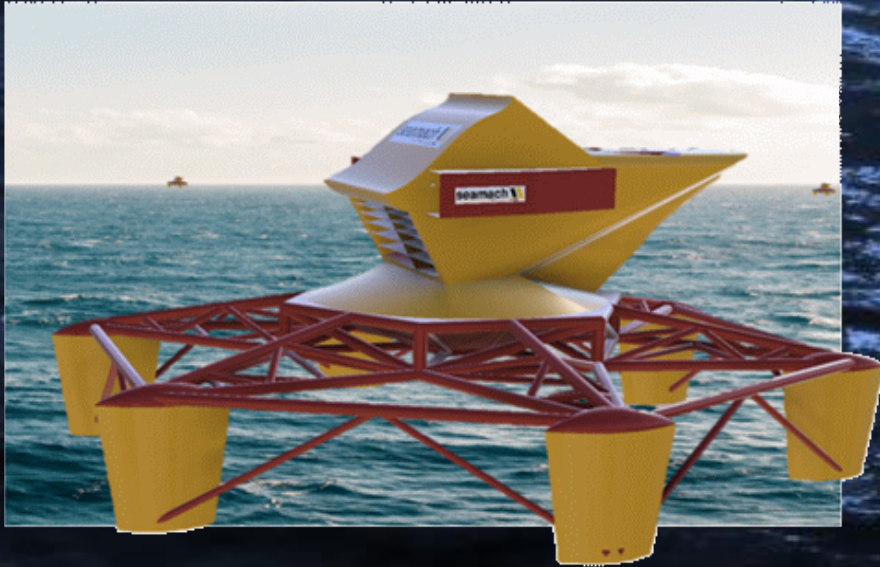
Example: Off-Shore Wind Power



$$P_{Max} = \frac{1}{2} * A_{Swept} * \rho * v_{Wind}^3$$

Applying SE Best Practices

Example: Off-Shore Wind Power



$$P_{\text{Max}} = \frac{1}{2} * A_{\text{Swept}} * \rho * v_{\text{Wind}}^3$$



...and you could also use them on-shore

Energy and carbon benefits

Re-enliven the dormant small turbine / urban wind industry in the UK

- 8 X more power in permitted development spaces
- 5 to 10kW turbines – highly viable in urban sites

Estimated carbon savings pa

- 10kW turbine ~ 2.7 T.eq CO₂/pa
- 50kW turbine ~ 13.6 T.eq CO₂/pa
- 250kW turbine ~ 46 T.eq CO₂/pa

Re-enliven the development of UK onshore wind

- Planning friendly turbines for co-location with solar PV farms
- Planning friendly 50kW+ to MW turbine scale-up pathway



Key social and environmental benefits

½ the height of traditional turbines for the same power

- Shrouded rotors and blades – not visible to the public
- Zero blade flicker
- Zero tower shadowing
- Quieter running – noise directed upwards
- Visible to birds and bats
- Always perfectly aligned to the wind
- Low ground impact – minimal concrete foundations
- Fast installation
- Job retention and creation
- Sustainable and circular economy

Backup Slides

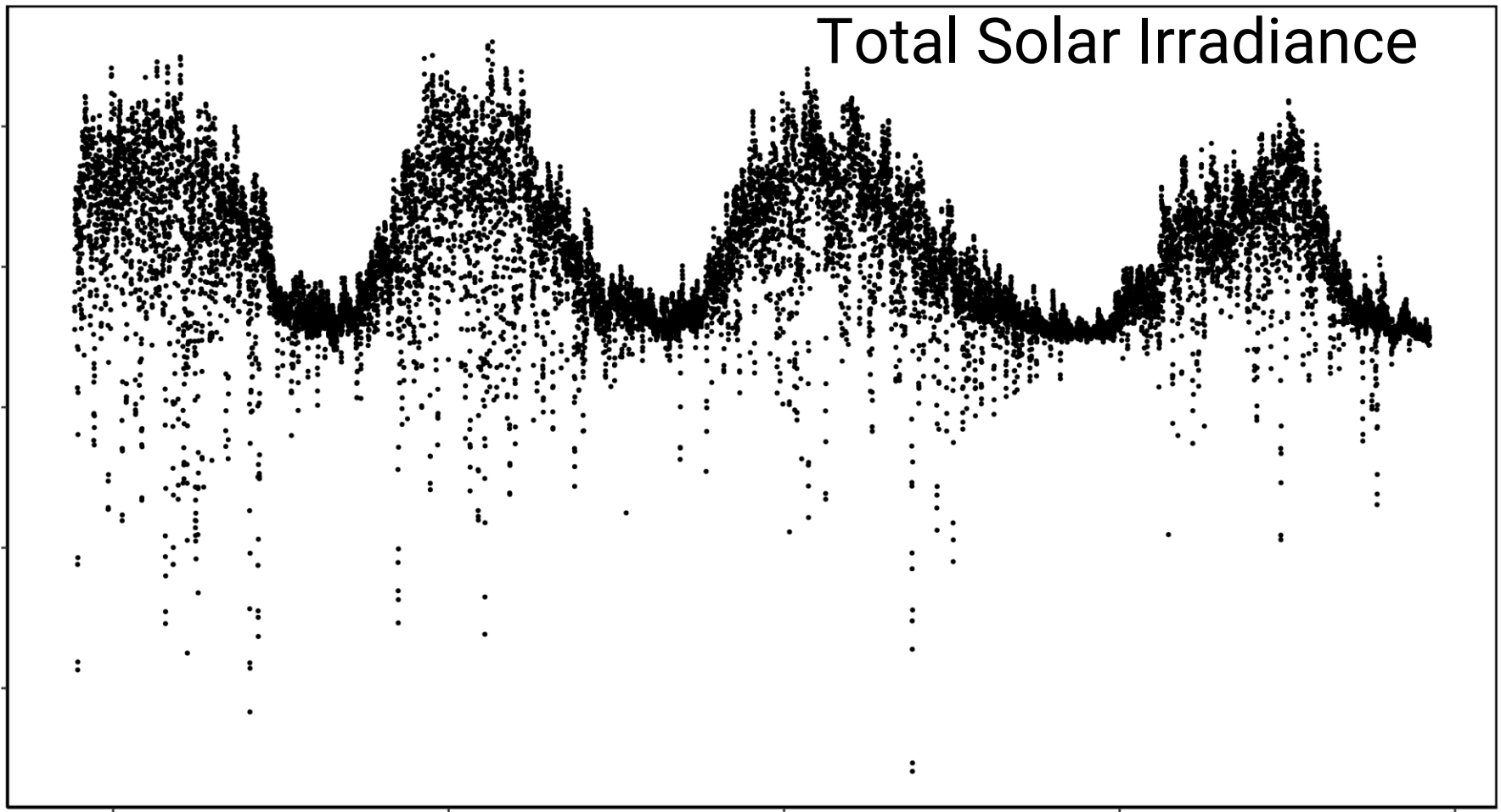
Total Solar Irradiance

Total solar irradiance (W/m^2)

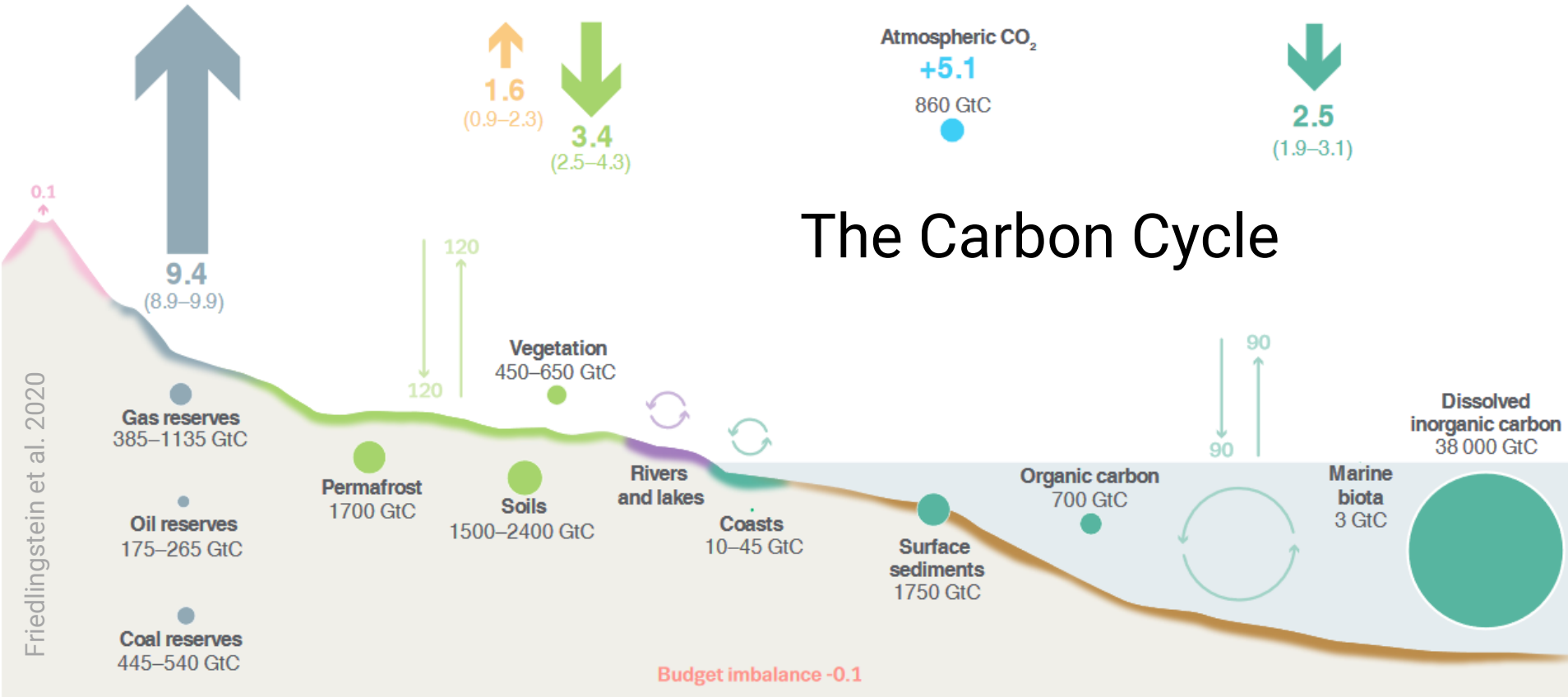
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1980 1990 2000 2010 2020

Year










The Carbon Cycle



Friedlingstein et al. 2020

Anthropogenic fluxes 2010–2019 average GtC per year

-  Fossil CO₂ E_{FOS}
-  Land-use change E_{LUC}
-  Land uptake S_{LAND}
-  Ocean uptake S_{OCEAN}
-  Atmospheric increase G_{ATM}
-  Carbon cycling GtC per year
-  Budget Imbalance B_{IM}
-  Stocks GtC

Climate Change: We do know enough to take action!

