Carl von Ossietzky
Universität
Oldenburg

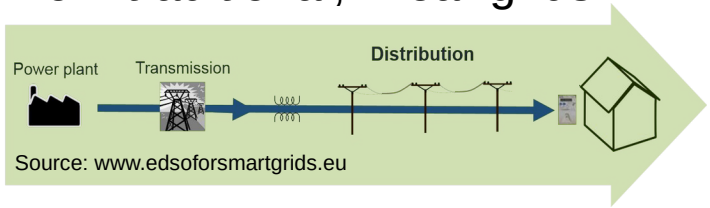
What is this thing called….

Resilience of Energy Systems?

Adrian Jimenez

Carl von Ossietzky Universität Oldenburg

From traditional, linear grids…



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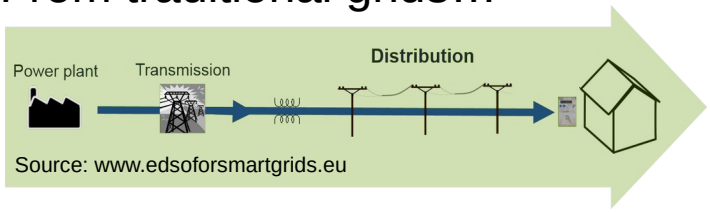

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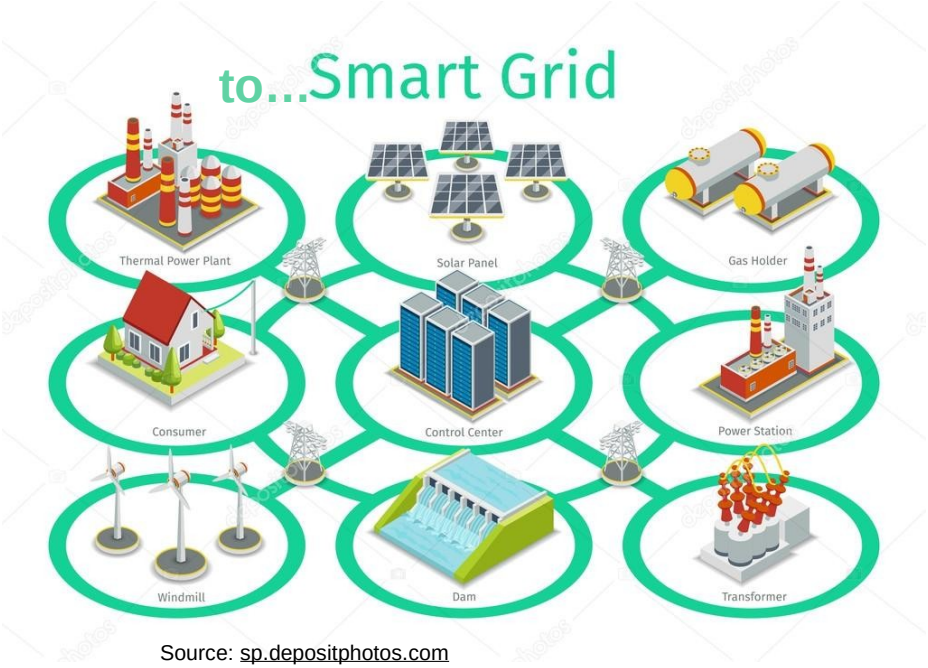

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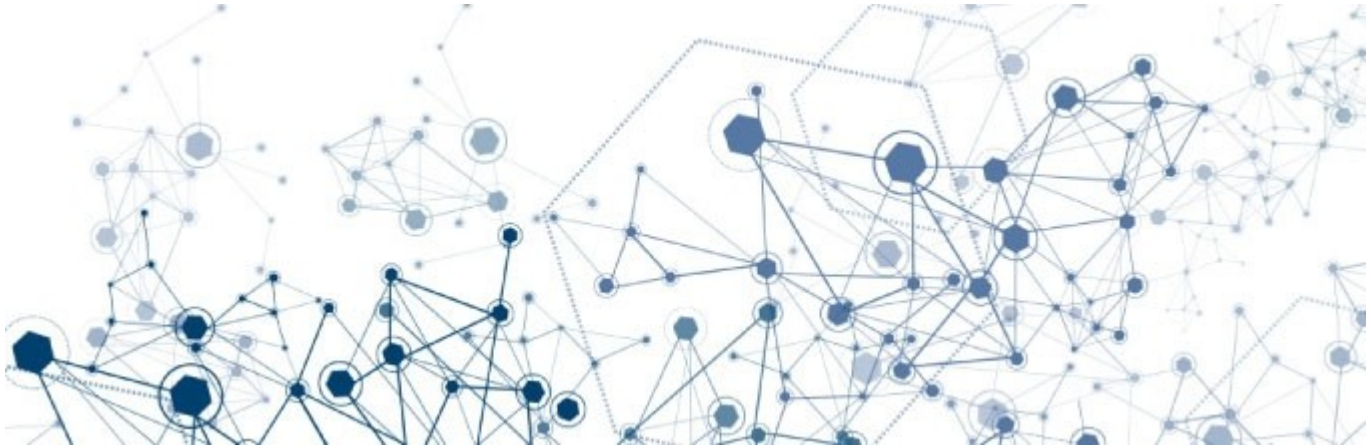
Agenda

Resilience

- **Why resilience in renewable energy systems?**
- **Related concepts**
- **Resilience principles**



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Why resilience?

Resilience: Use of the term

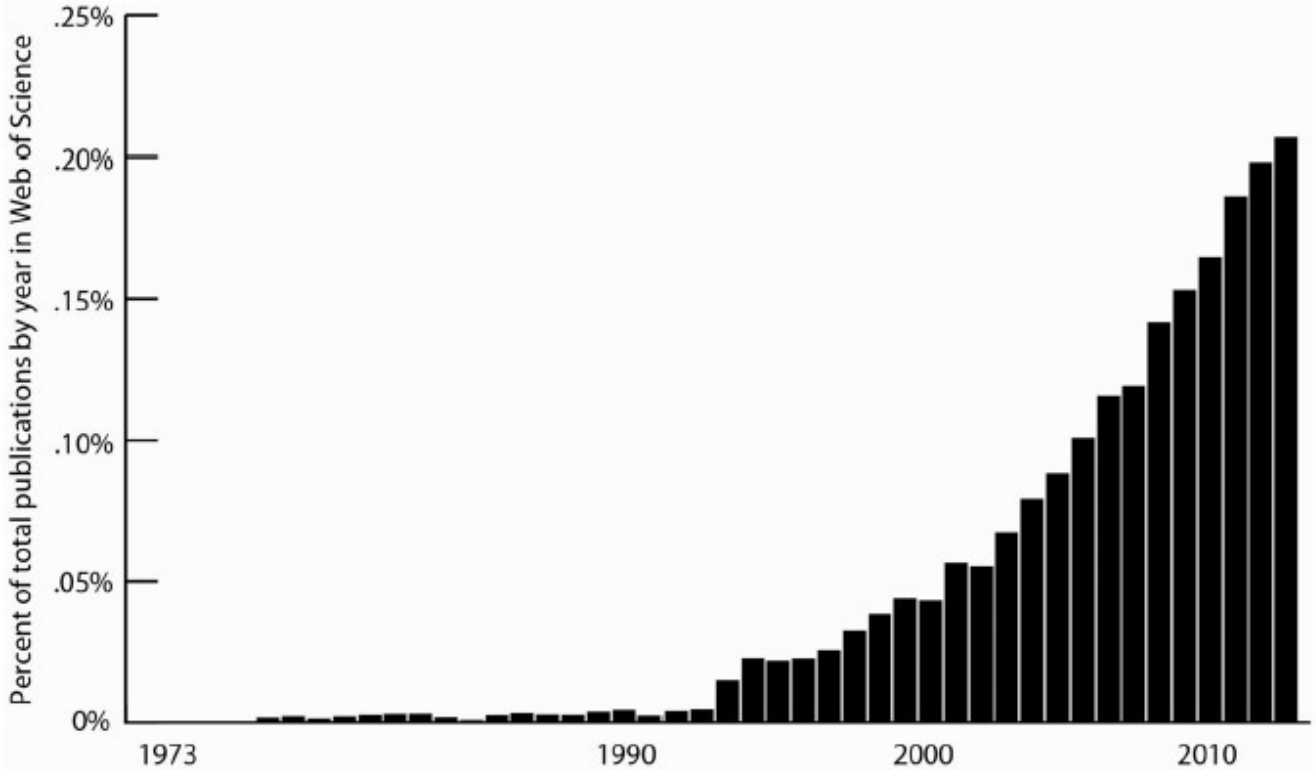
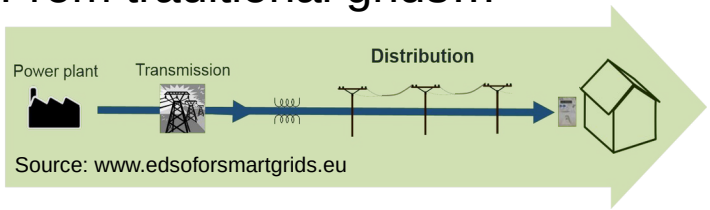


Figure 1 Rise of resilience in the literature (1973–2014). The figure represents the percentage of publications per year containing "resilience or resilient or resiliency" in the title, abstract, or keywords. *Data from*: Web of Science (2014).

Source: Meerow/Newell 2015

Why resilience in RE Systems?

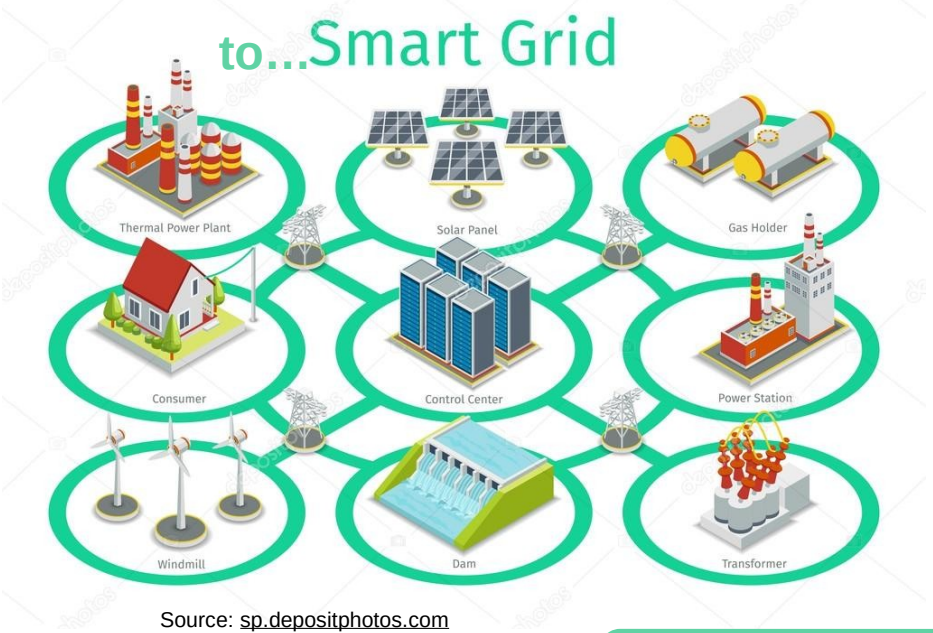
From traditional grids…



Source: www.edsoforsmartgrids.eu

Bidirectional

Sector coupling

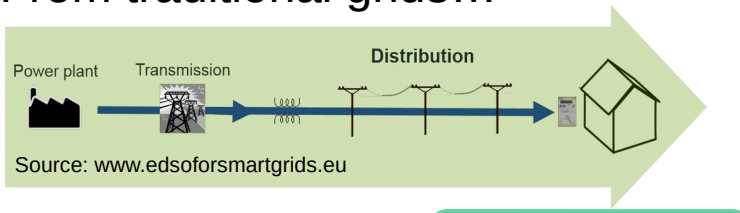


Source: sp.depositphotos.com

Fluctuating generation

Why resilience in RE Systems?

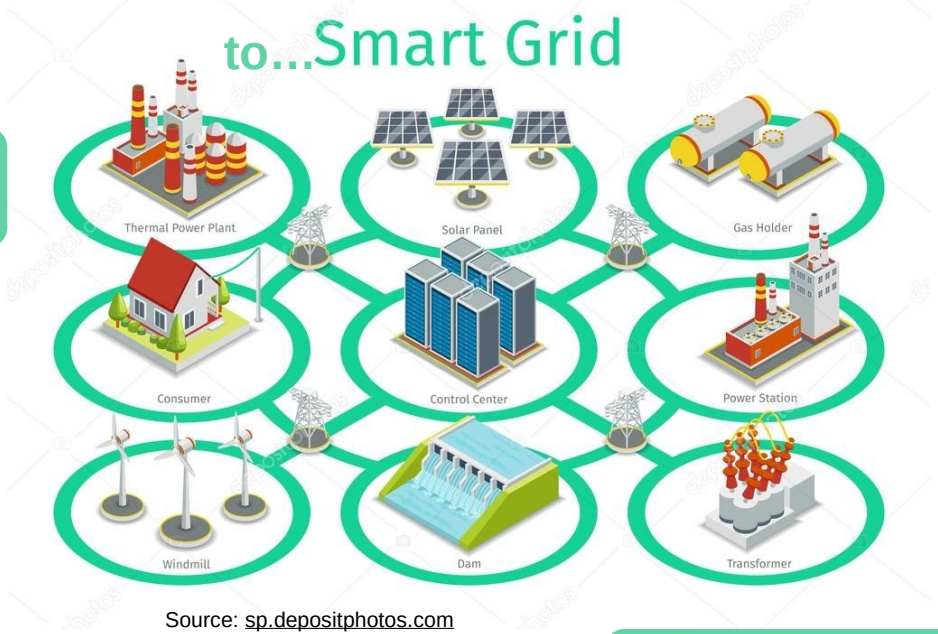
From traditional grids…



Consumers/ Prosumers

Bidirectional

Sector coupling



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Redundant structures

Fluctuating generation

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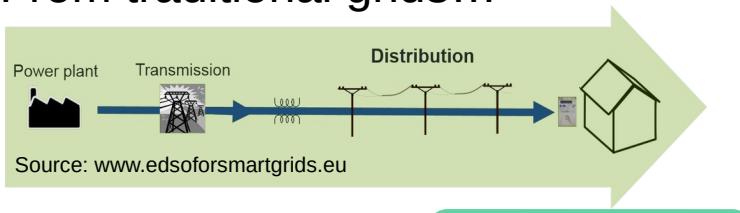
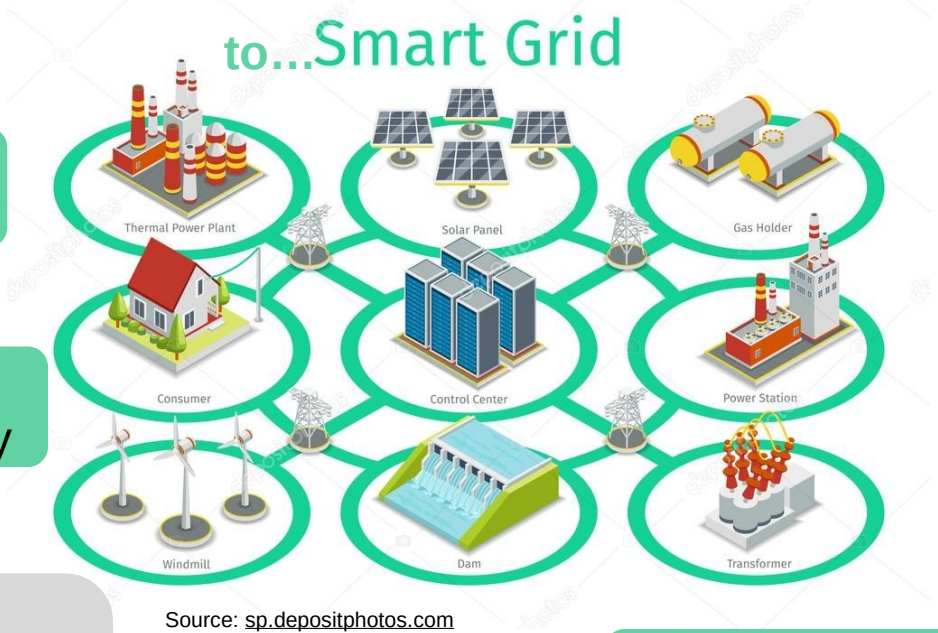


Consumers/ Prosumers

Bidirectional

Sector coupling

Higher complexity



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Redundant structures

Fluctuating generation

Big challenge:
How does such a system behave and function under (unknown) changing conditions?

Why resilience in RE Systems?

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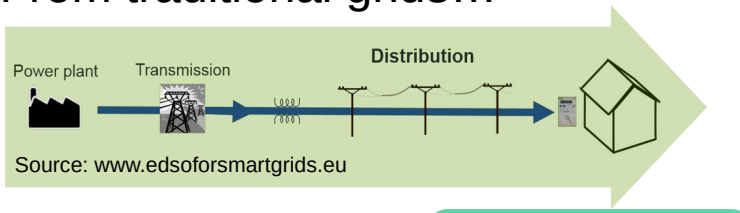


Bidirectional

Sector coupling

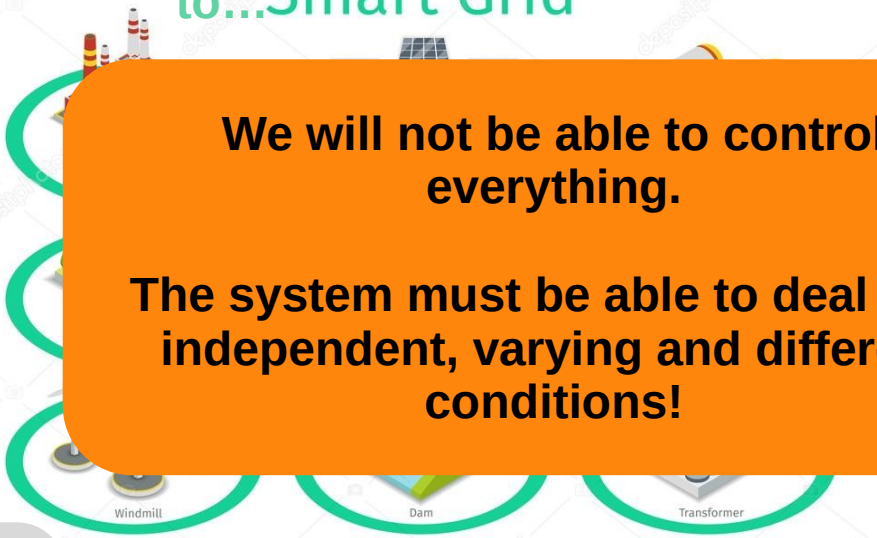
to...Smart Grid

Consumers/ Prosumers

Higher complexity

We will not be able to control everything.

The system must be able to deal with independent, varying and different conditions!



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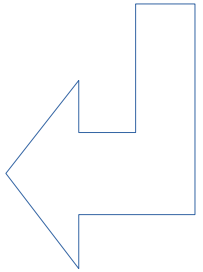
How will we make this?



Why resilience in RE Systems?

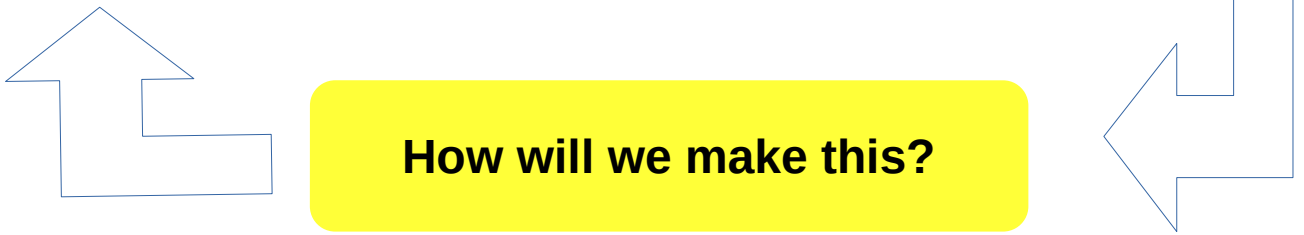
We need energy systems

- able to prepare for, cope with and recover from **any kind of stressor** or event, while maintaining the system's service.

- with the capacity to deal with change and continue to develop.

We will not be able to control everything.

The system must be able to deal with independent, varying and different conditions!



How will we make this?

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How will we make this?

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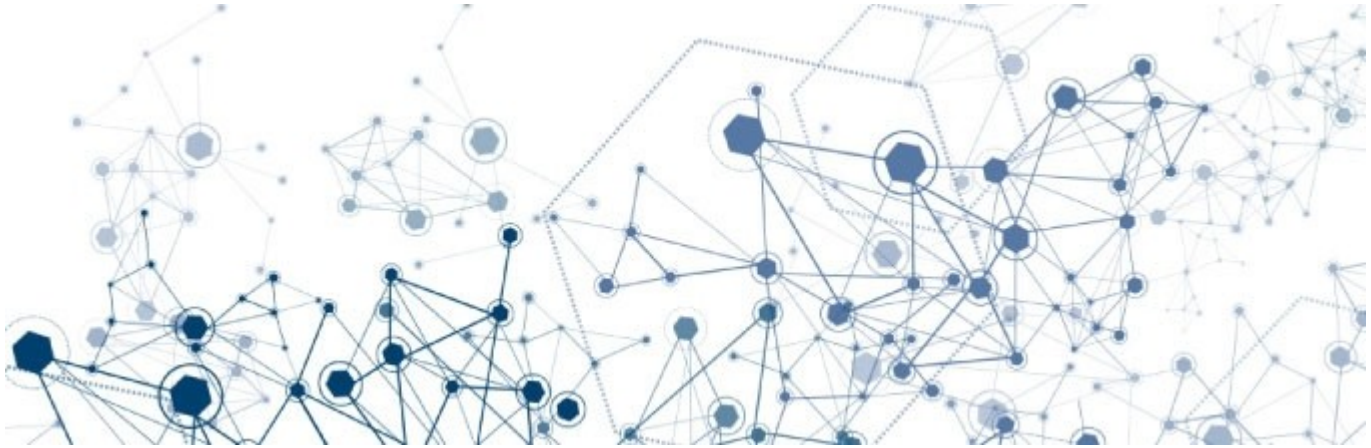

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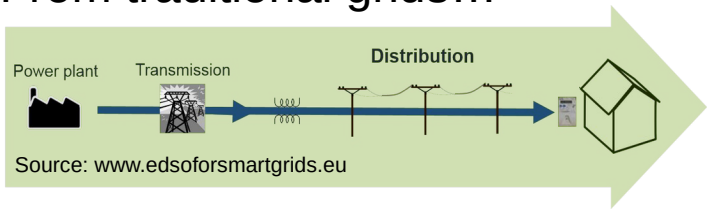
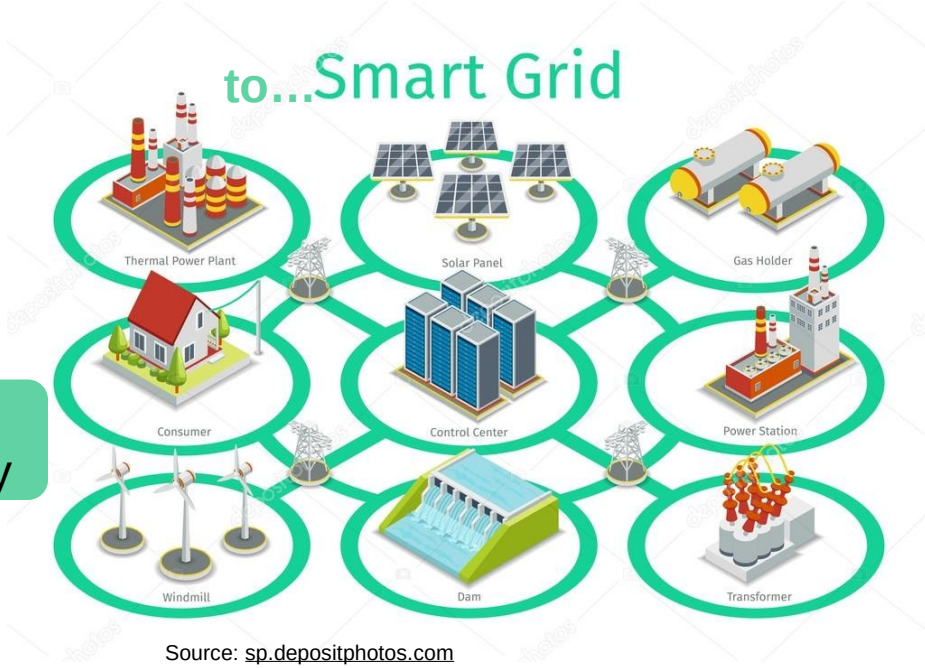


Source: www.edsoforsmartgrids.eu

What does this mean?

Higher complexity

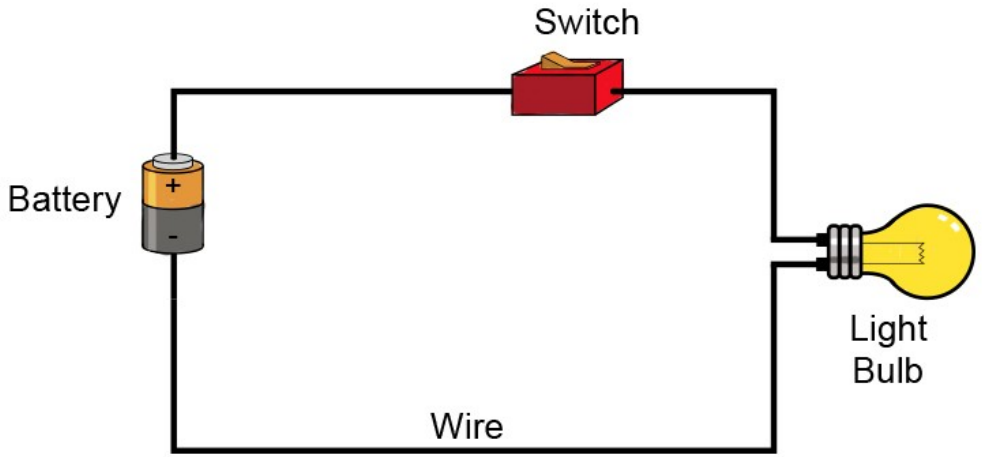


Source: sp.depositphotos.com

Complexity

A system can be

- **Simple:** The system is completely observable and predictable (inputs, outputs, processes). **Linear interaction**



Source: mammothmemory.net

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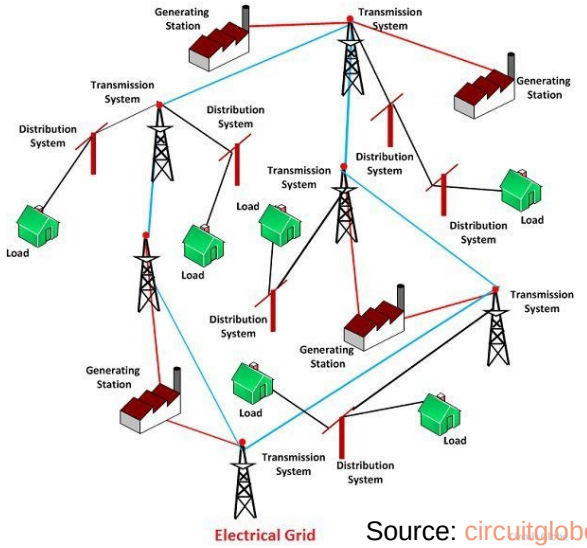
Complexity

A system can be

- **Simple:** The system is completely observable and predictable (inputs, outputs, processes). **Linear interaction**
- **Complicated:** Completely predictable. Many components. The connection between components is **linear and straightforward**.

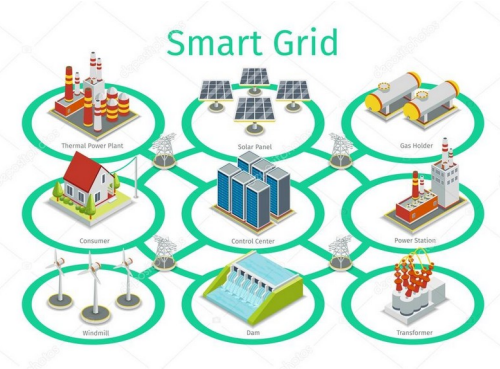


Source: circuitglobe.com

Complexity

A system can be

- **Simple:** The system is completely observable and predictable (inputs, outputs, processes). **Linear interaction**
- **Complicated:** Completely predictable. Many components. The connection between components is **linear and straightforward**.
- **Complex:** network of components, many-to-many communication channels, sophisticated information processing. **Prediction of system states difficult.** Have a major element of surprise – **emergence and Non-linear interaction**



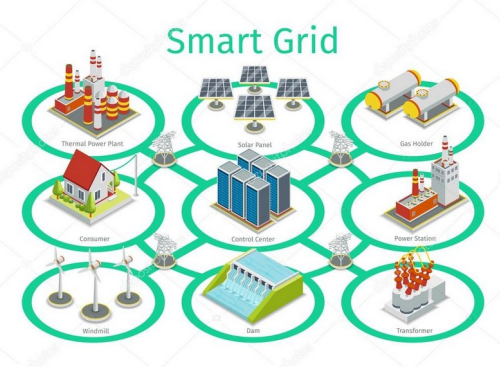
Complexity

- **Complex System:** network of components, many-to-many communication channels, sophisticated information processing.
  - **Prediction of system states difficult**
  - Have a major element of surprise
  - **Emergence**
  - **Non-linear interaction**

A complex system is the one where its components interconnected produce outputs unreachable by their own.

in other words, in complex systems:

the whole is more than the sum of its parts.



Some definitions of Complexity

- "*systems exhibit patterns that emerge from interactions between individual components in unexpected and nonlinear ways*". (Meerow & Newell 2015, p.2)

- The impossibility of complete observation and representation of phenomena that would require connecting each element with every other element. (Meed 2002, p.74)

- "… *a simple system is one to which a notion of state can be assigned once and for all … Thus in a complex system, the causal reasons become intertwined in such a way, that no dualistic language of state plus dynamic laws can completely describe it*". (Byrne & Callaghan 2014, p.3)

Changing conditions : stressors and disturbances

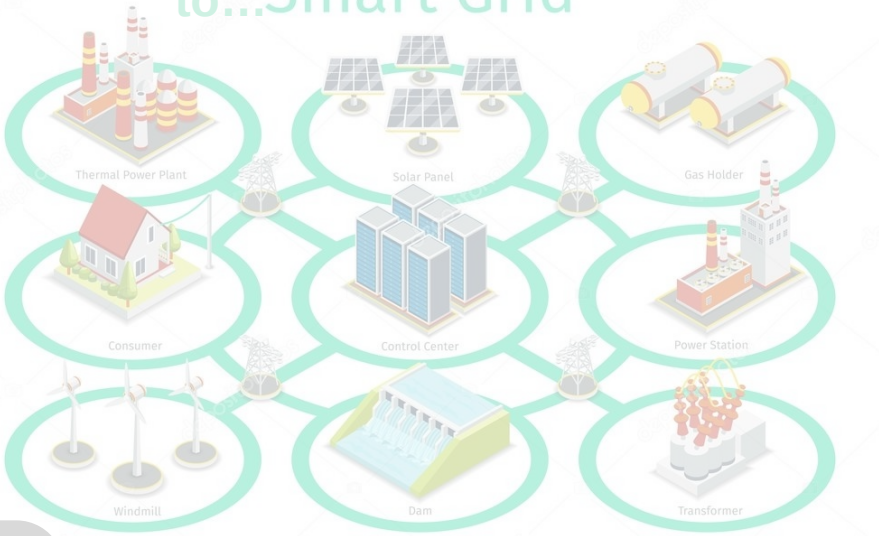
What can really happen?

Consumers/ Prosumers

Higher complexity

Bidirectional

Sector coupling



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Redundant structures

Fluctuating generation

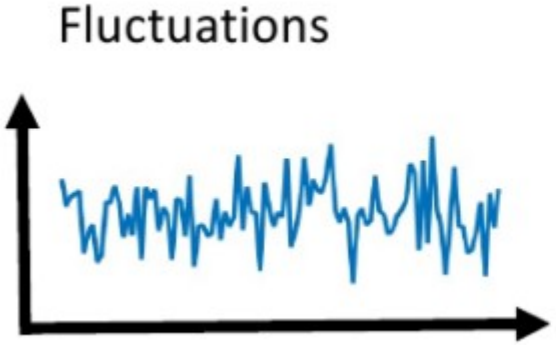
Big challenge:
System behaviour and function under (unknown) changing conditions?

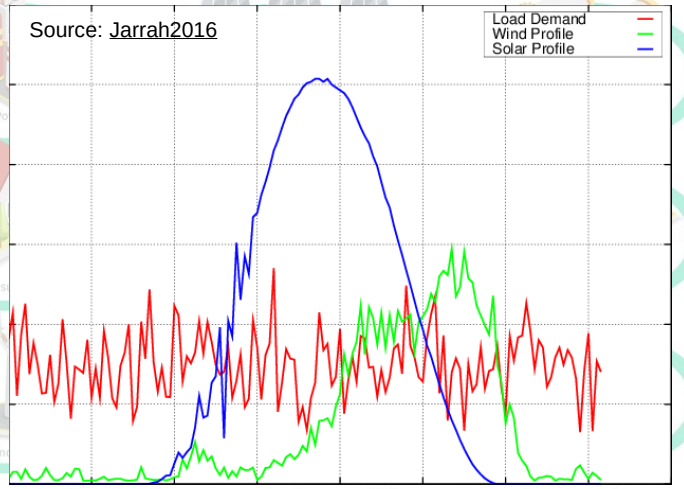
Changing conditions : stressors and disturbances

What can really happen?

Consumers/ Prosumers

Higher complexity





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Redundant structures

Fluctuating generation

Big challenge:
System behaviour and function under (unknown) changing conditions?

+ Climate change: droughts, floods, heat waves...

Changing conditions : stressors and disturbances

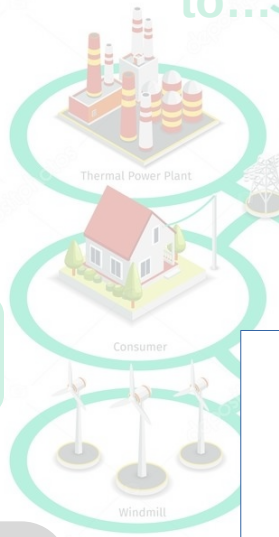
What can really happen?

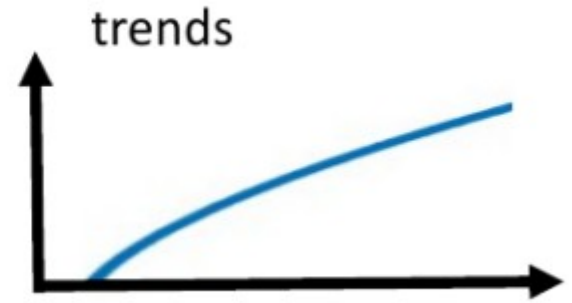
Bidirectional

Sector coupling

Consumers/ Prosumers

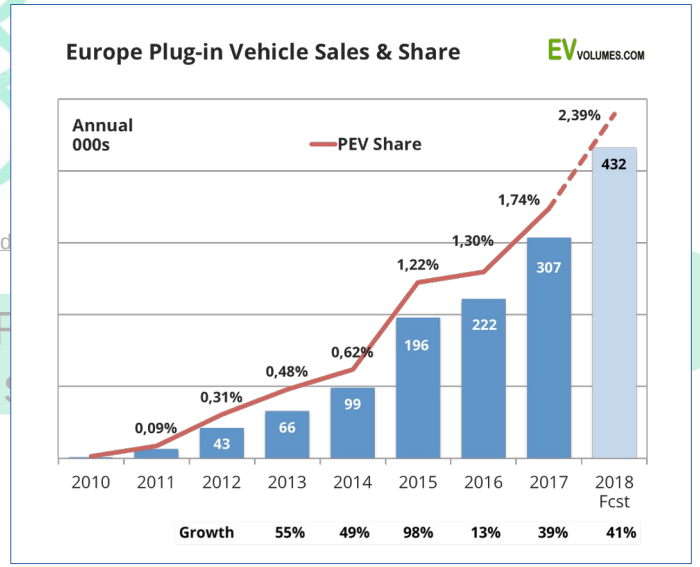
Higher complexity





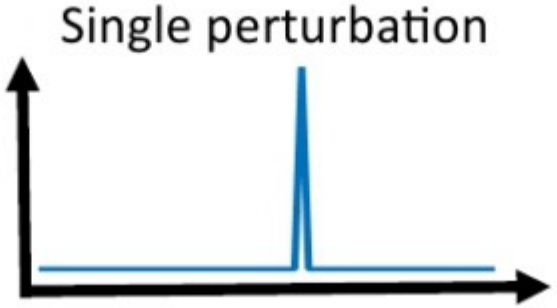
Source: sp.d

Big challenge:
System behaviour and function under (unknown) changing conditions?



Changing conditions

What can really happen?

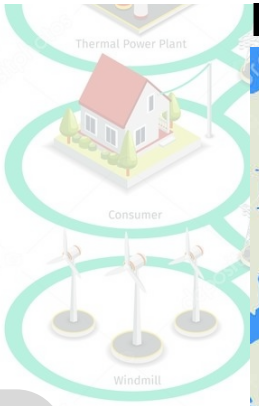


Sector coupling

Consu
Prosumers

Higher complexity

Grid

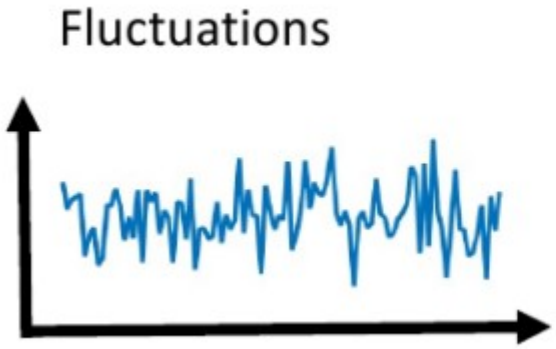


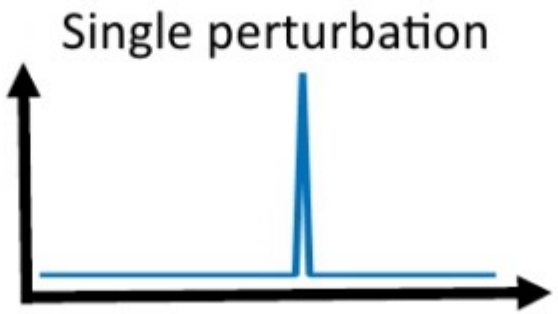
Source: sp.de

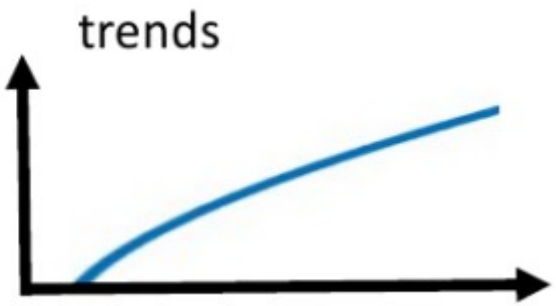
North Stream Pipeline blast

Big challenge:
System behaviour and function under (unknown) changing conditions?

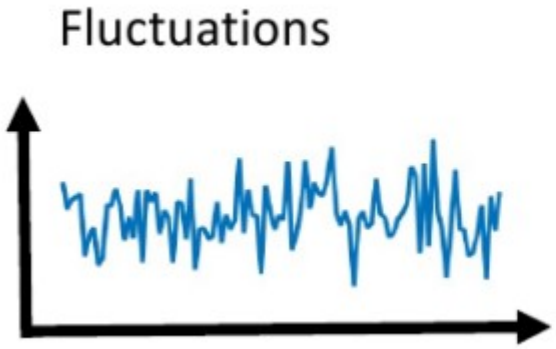
Different changing conditions: stressors / disturbances

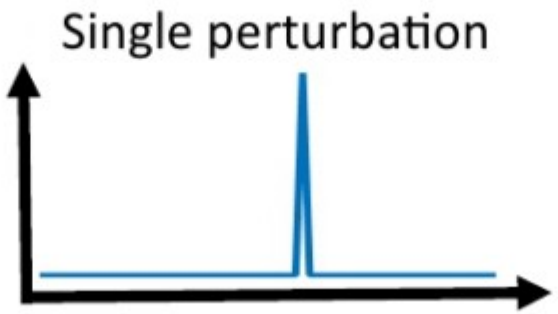


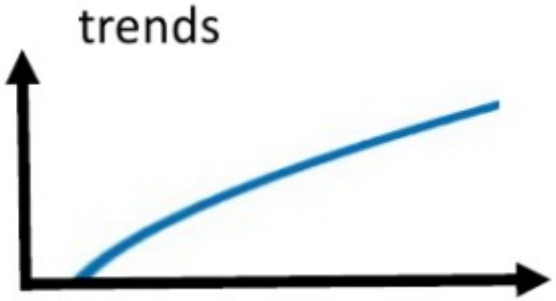




Different changing conditions: stressors / disturbances







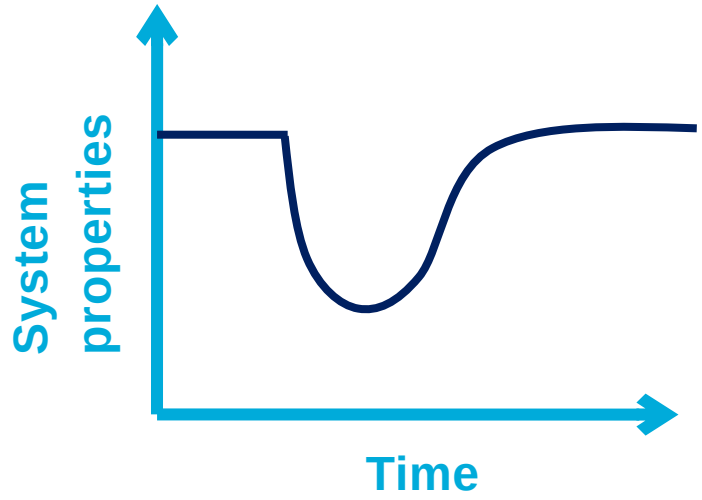
- Known
- (Un)known

- Internal
- External

- Short Term
- Long Term

So, what is resilience?

What is resilience?



Resilience is:

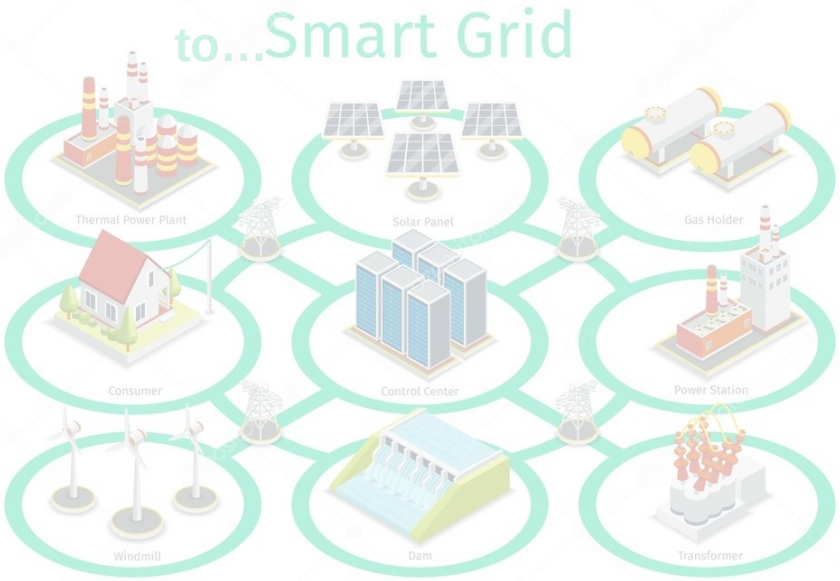
- the ability of a system to prepare for, cope with and recover from **any kind of stressor** or event, while maintaining the system's service.

(Gössling-Reisemann2016)

- the capacity of a system to deal with change and continue to develop.

(Simonsen et al., 2021, p.3)

What make systems resilient?

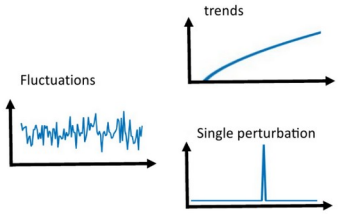


Source: sp.depositphotos.com

Resilient capacities are

- The internal reaction of systems towards a disturbance.
- They are derived from the system and rarely can be seen as a specific element.

What make systems resilient?



Stressor	known
gradual / creeping	adaptive capacity
abrupt / sudden	resistance/robustness

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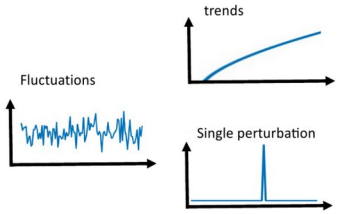

Stressor	known	unknown
gradual / creeping	adaptive capacity	innovation capacity
abrupt / sudden	resistance/robustness	improvisation capacity

Source: Holling (2001)

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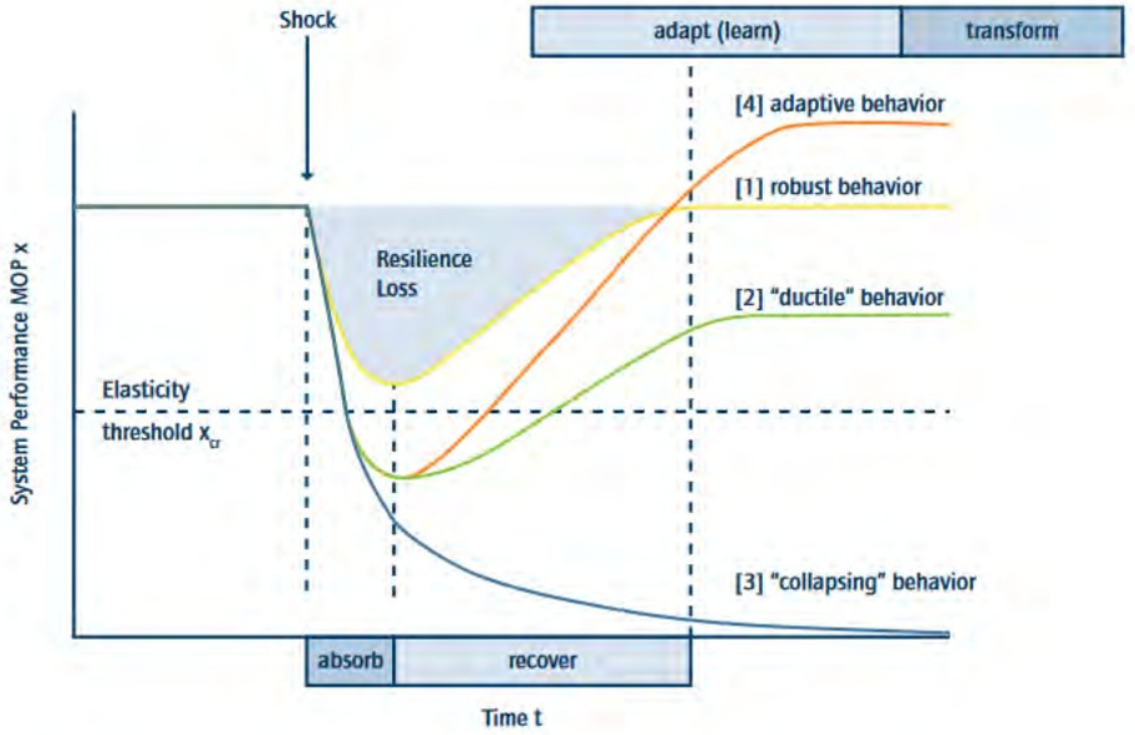
System behaviours/capacities

After the response

Adaptation & Transformation



Source: Holling (2001)

Absorb & Recover

During the response

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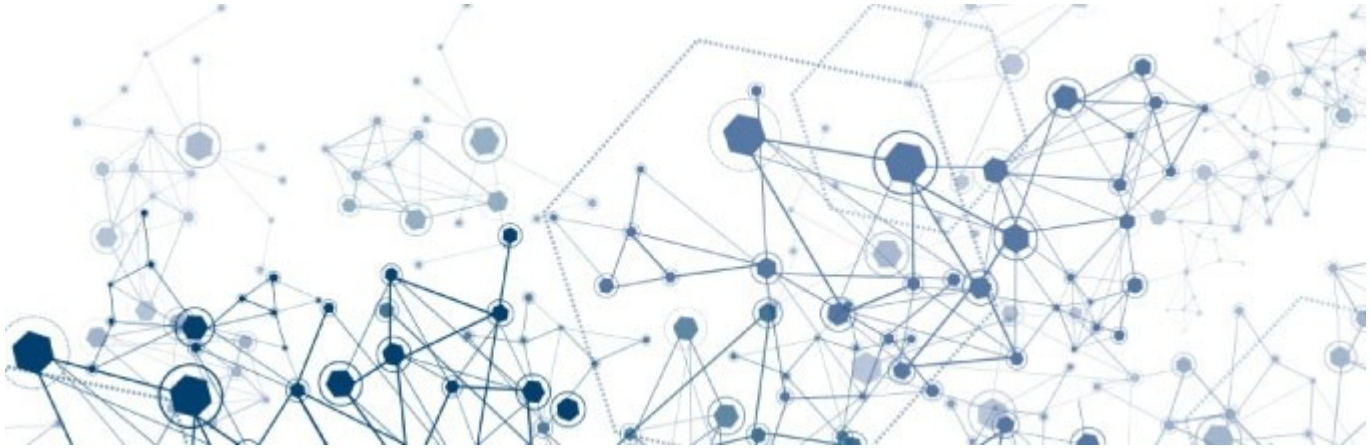
Agenda

Resilience

- First definition
- Related concepts
- **Resilience principles**



Resilience principles

(Simonsen et al., 2021)

1. Maintain diversity and redundancy
2. Manage connectivity
3. Manage slow variables and feedbacks
4. Foster CAS thinking
5. Encourage learning
6. Broaden participation
7. Promote polycentriy governance systems

Resilience principles
(Simonsen et al., 2021)

1. Maintain diversity and redundancy

- Conserve and value **redundancy**
- Focus less on maximum efficiency, even if it costs more
- Build diversity and redundancy into governance systems

Resilience principles
(Simonsen et al., 2021)

2. Manage connectivity

High levels of connectivity ->

facilitate recovery after a disturbance

… but also ->

spread disturbances faster

- **Map connectivity:** identify important elements and connections
- Optimize **(control!)** current connectivity patterns

Resilience principles
(Simonsen et al., 2021)

3. Manage slow variables and feedbacks

- **Strengthen feedbacks** that maintain desirable regimes
- Avoid actions that obscure feedbacks
- **Monitor** important slow variables
- Establish **governance structures** that can respond to monitoring information

Resilience principles
(Simonsen et al., 2021)

4. Foster complex adaptive systems thinking

- Adopt a **systems framework**
- Expect and account for change and **uncertainty**
- Investigate critical thresholds and nonlinearities
- Match institutions to systems processes

Resilience principles
(Simonsen et al., 2021)

5. Encourage learning

- Support long-term **monitoring** of key components
- Provide opportunities for **interaction**: network and create communities of practice
- Engage a **variety** of participants
- Ensure sufficient resources to enable learning processes to take place

Resilience principles
(Simonsen et al., 2021)

7. Promote polycentric governance

- **Multiple governing bodies** interact to make and enforce rules within a specific policy arena or locations
- Frame for **collective actions**

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References

Simonsen et al. 2021. Applying resilience thinking - Seven principles for building resilience in social-ecological systems. Stockholm Resilience Center.
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