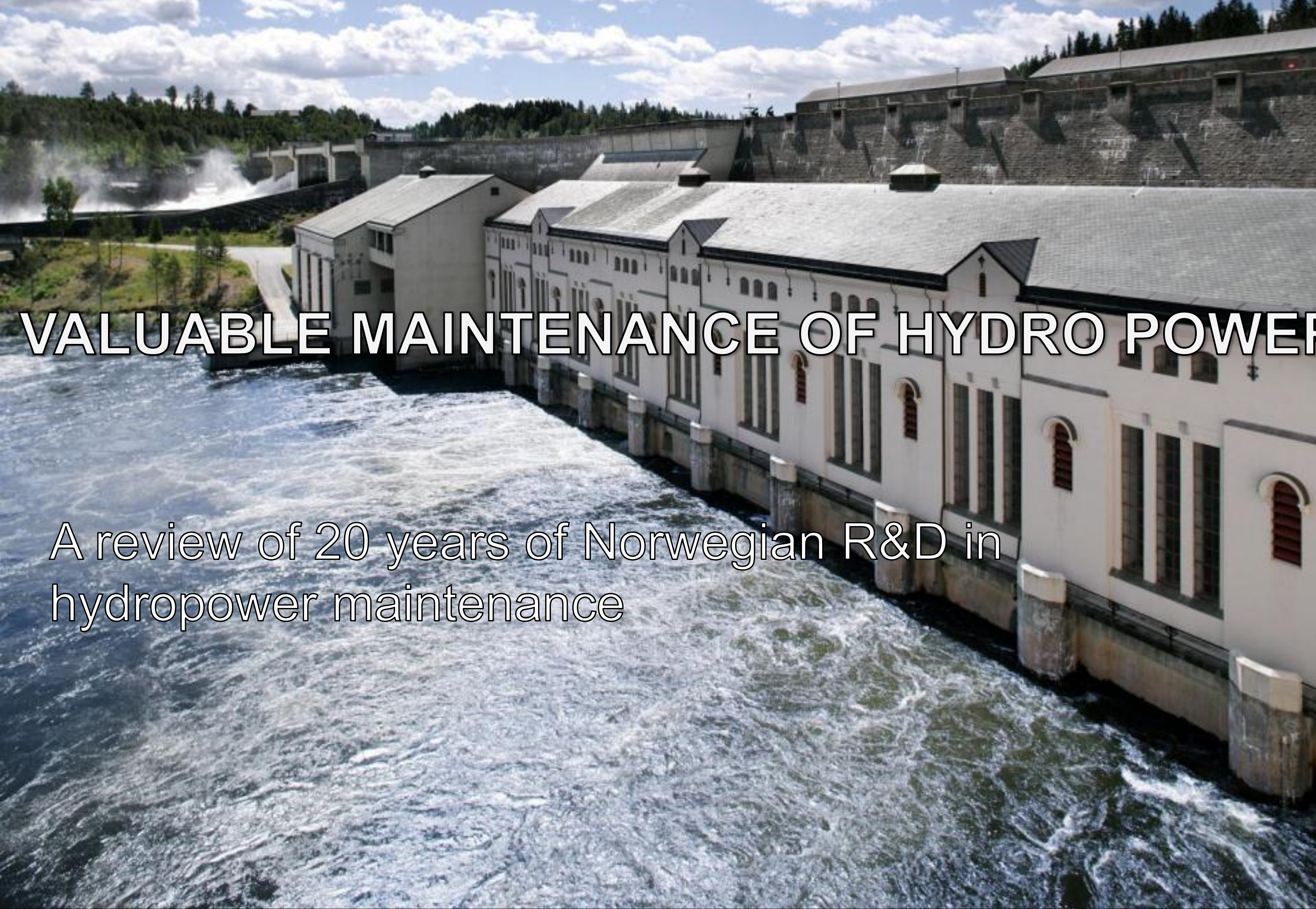


VALUABLE MAINTENANCE OF HYDRO POWER

A review of 20 years of Norwegian R&D in hydropower maintenance

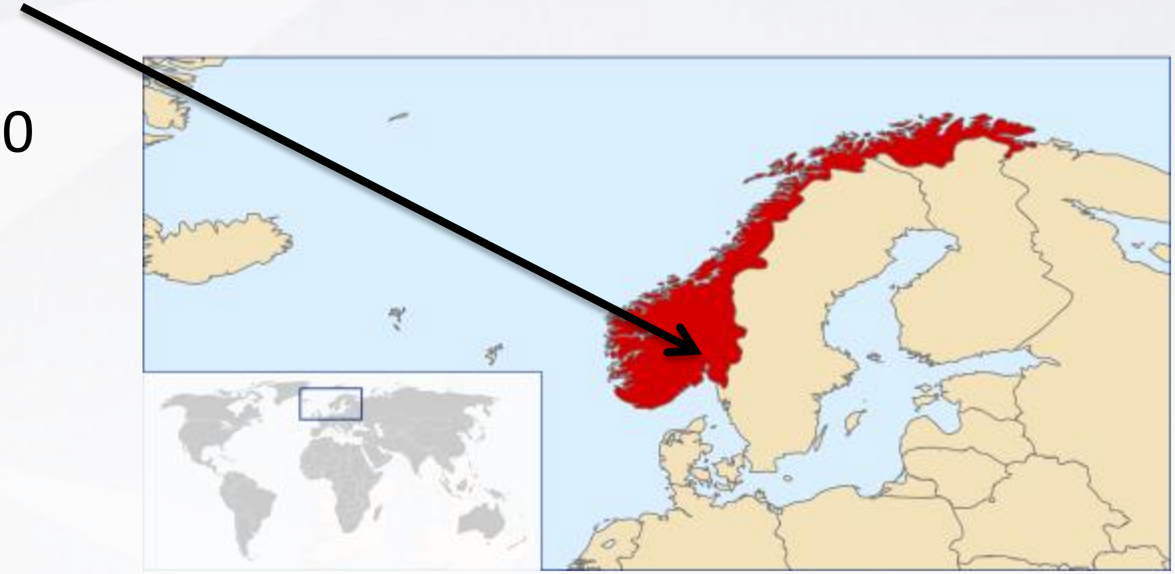
EnergiNorge

Outline

- Background
- Key results
- Failure model
- Success criteria

Hammern hydropower plant

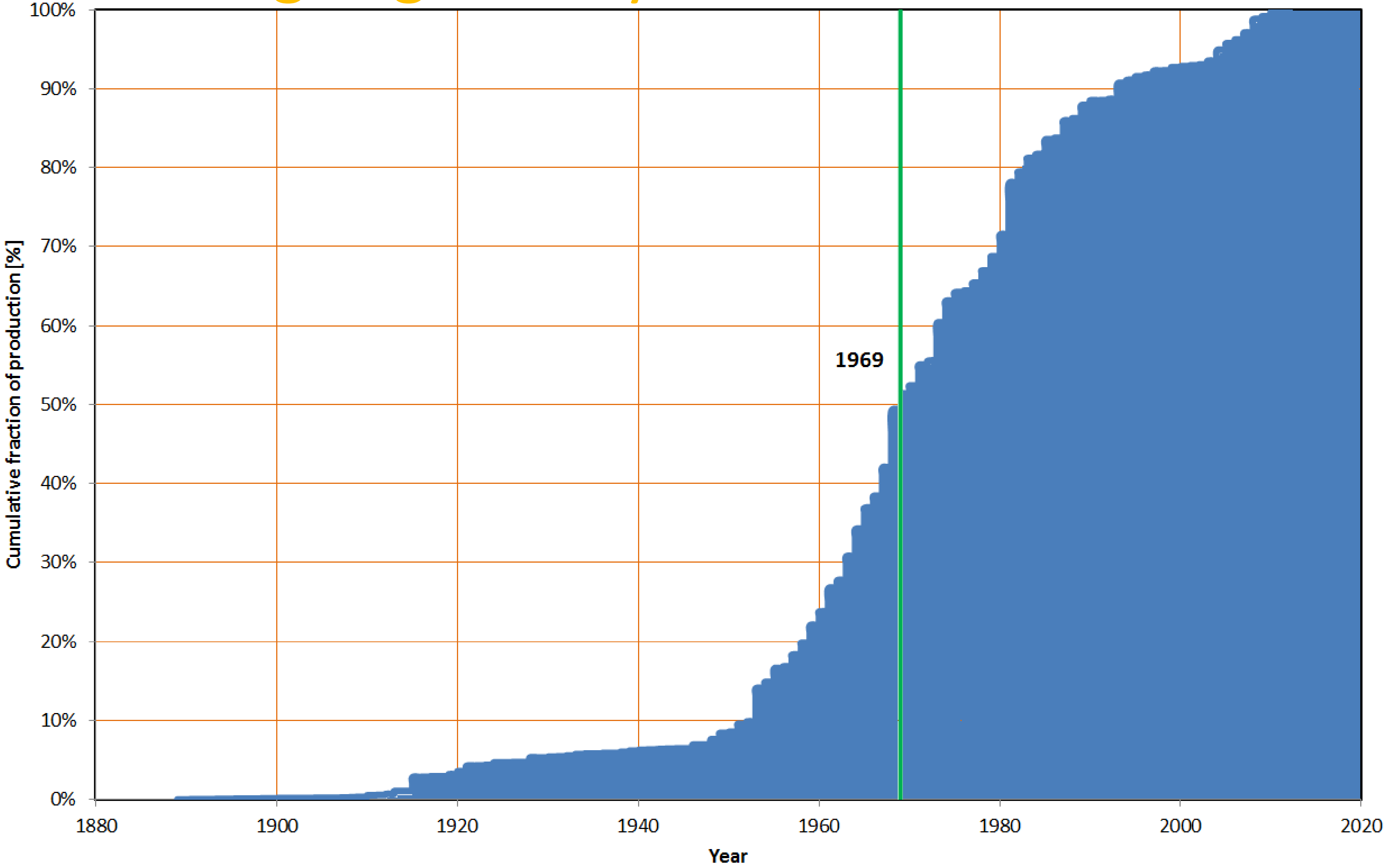
Operational since 1900
Uppgrating 1927



Hydropower in Norway

Around 1400 power plants, around 2000 units
Installed capacity 30 172 MW
Annual production 130.2 TWh

Average age ~ 43 years



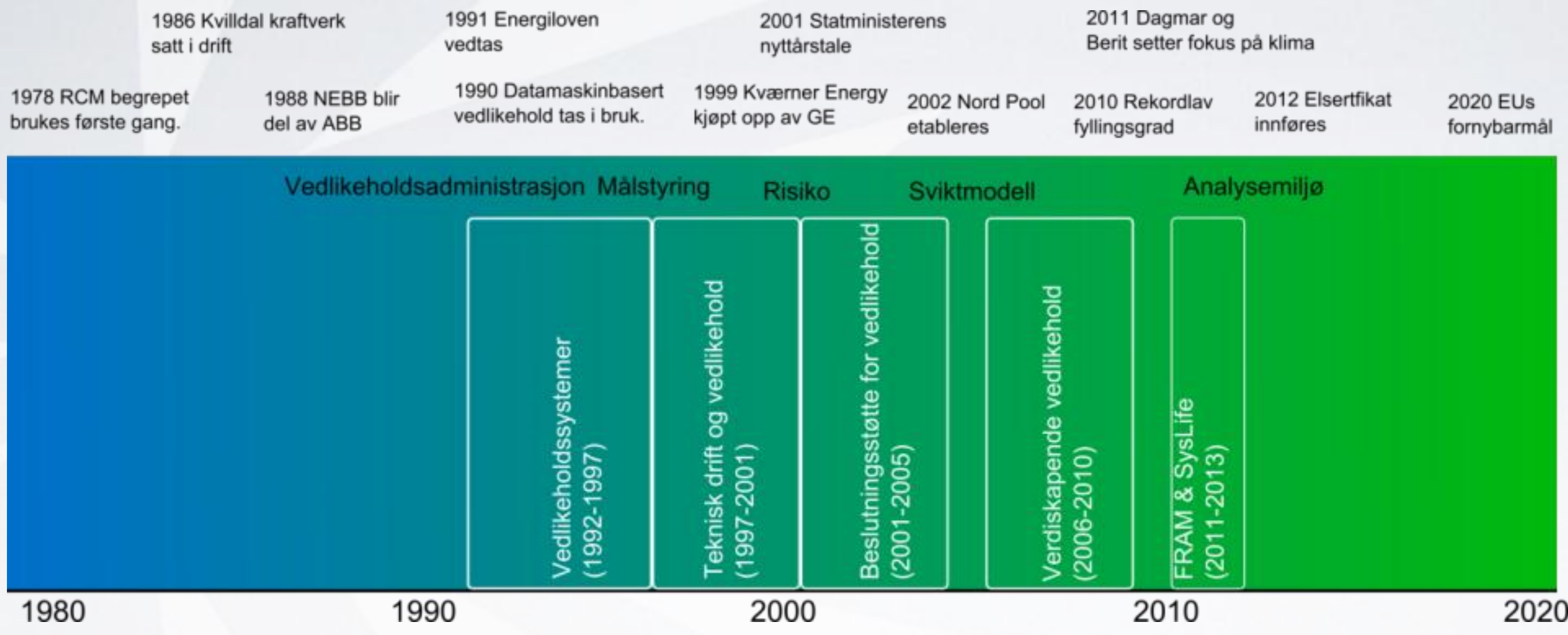
EnergiNorge

20 years of collaborative R&D in hydro O&M

- Maintenance systems (1992-1997)
- Technical operation and maintenance (1997-2001)
- Decision tools for maintenance planning (2001-2005)
- Value added mainenance in power production (2006-2010)

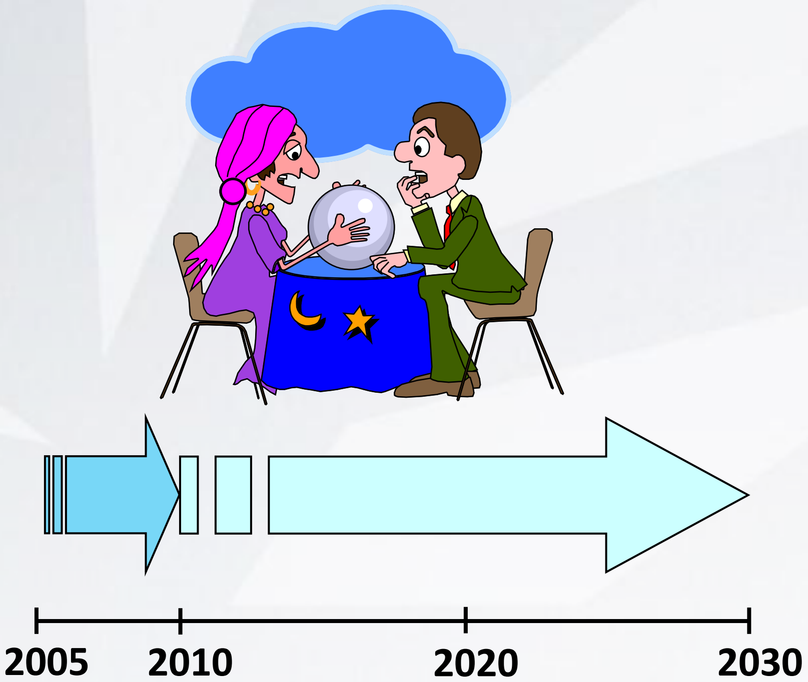
EnergiNorge

Timeline



EnergiNorge

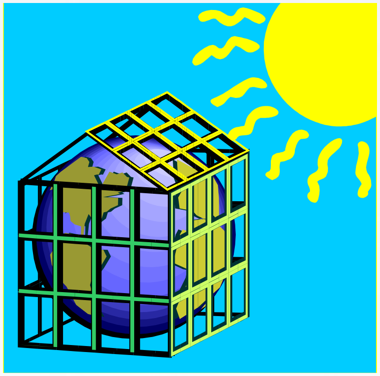
Hydropower maintenance towards 2030



- To develop scenarios for hydropower in Scandinavia in general, and maintenance and rehabilitation in particular.
- To identify new technical, organizational, commercial and regulatory solutions and products.
- To identify need for new knowledge to meet future challenges.

Common features

- Some of the scenarios have common features
  - Inflection point (negative → positive)
  - Climate changes
  - Green energy
  - Peak power has high value
  - Recruitment problems
  - Competence building
  - Large energy companies
  - Maintenance
    - Continuous monitoring
    - Pit stop maintenance
  - Hydropower will still play an important role in the energy system in 2030

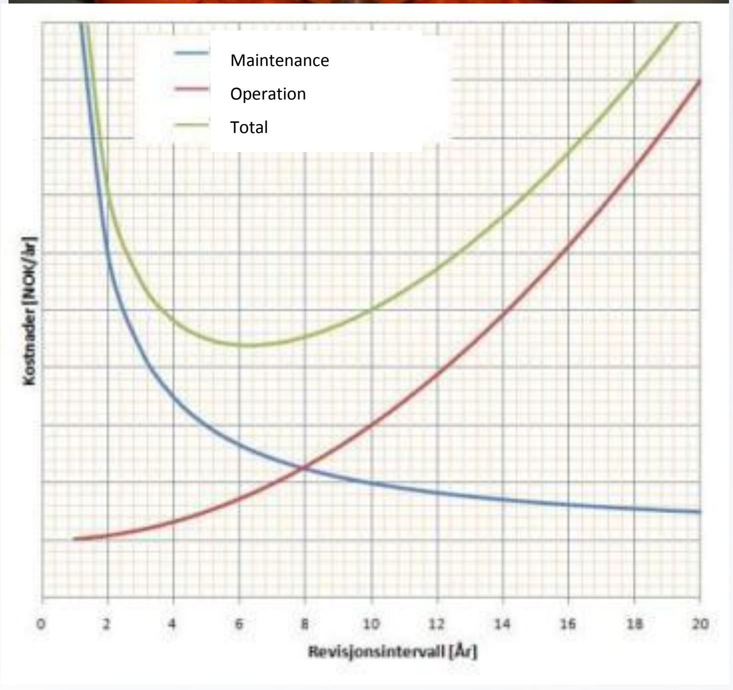


Conclusions

- Scenario process resulted in
  - 93 mini scenarios, 5 main scenarios
  - List of challenges and recommendations for the hydropower industry in Norway and Sweden
- Scenarios can be used to create a basis for
  - identification of challenges, possibilities and restrictions
  - robust decision under uncertainty
- Easy to involve different persons / groups
- Challenge to distance oneself from daily routine to become creative
- Process requires good management and guiding

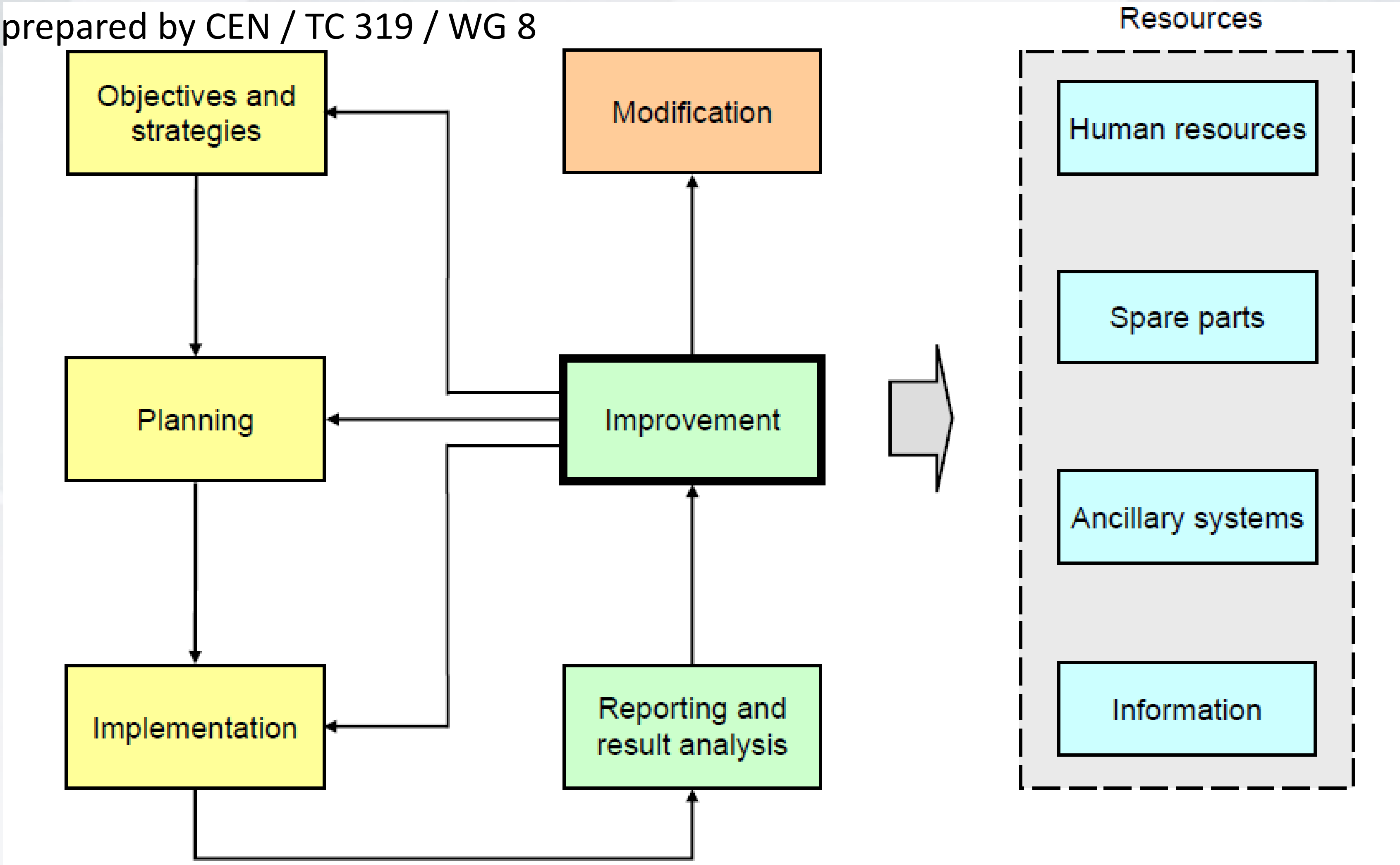
Key results

- Maintenance philosophy
- Decision tools
  - Technical-economic model
  - Multi-criteria decision aid
  - Optimal Maintenance Toolbox v 3.0
- Testing of maintenance paradigm
  - RCM
  - Online monitoring
  - 5s
  - Pit stop
  - WCM

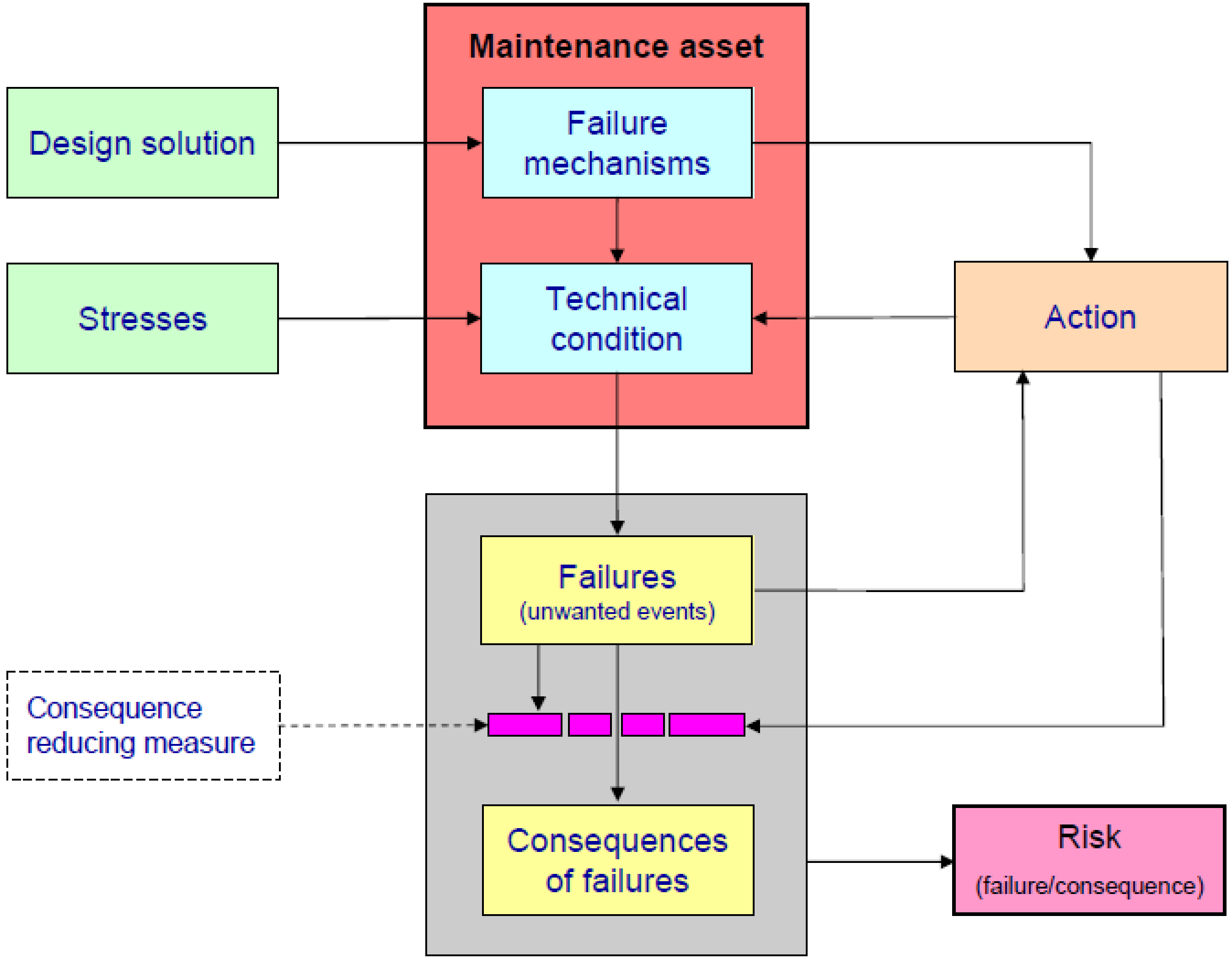


World class maintenance

Maintenance management processes according to a draft European standard prepared by CEN / TC 319 / WG 8



Failure model



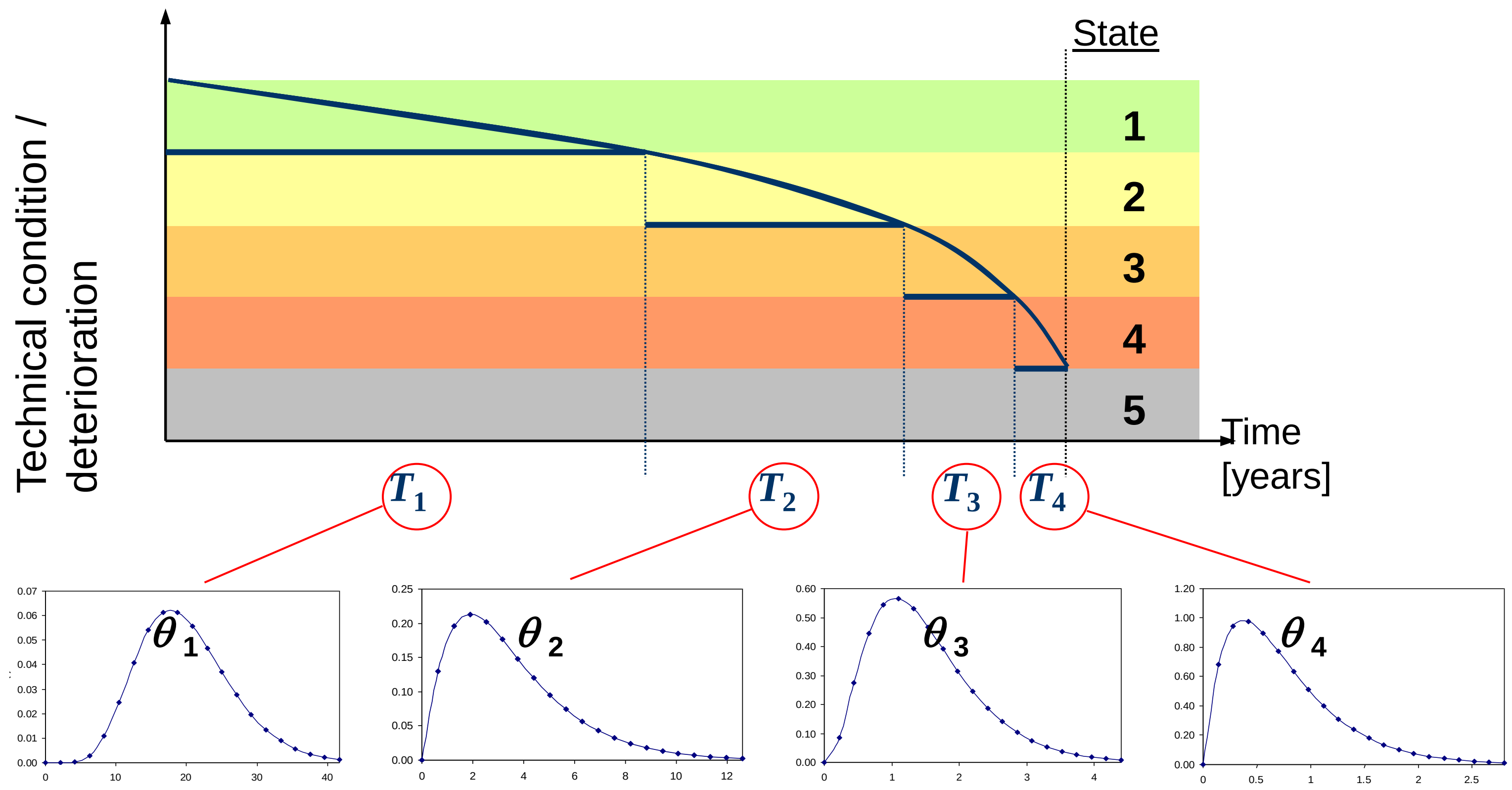
Technical condition states

- The condition development is often observable
- Condition monitoring handbooks by Energy Norway used to classify the condition

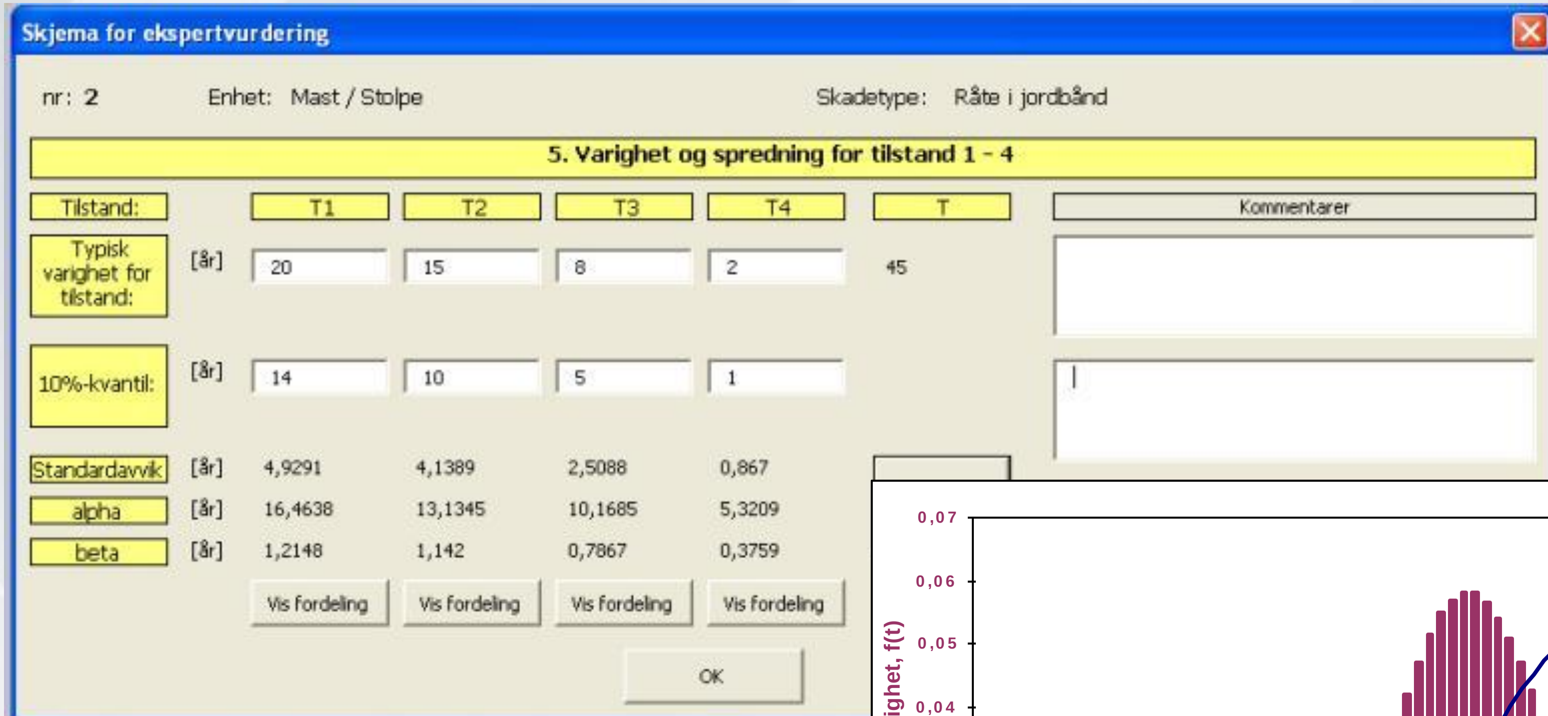
State	Description
1	No indication of degradation (“as good as new”)
2	Some indication of degradation. The condition is noticeably worse than “as good as new”.
3	Serious degradation. The condition is considerably worse than “as good as new”
4	The condition is critical.
5	Fault state.

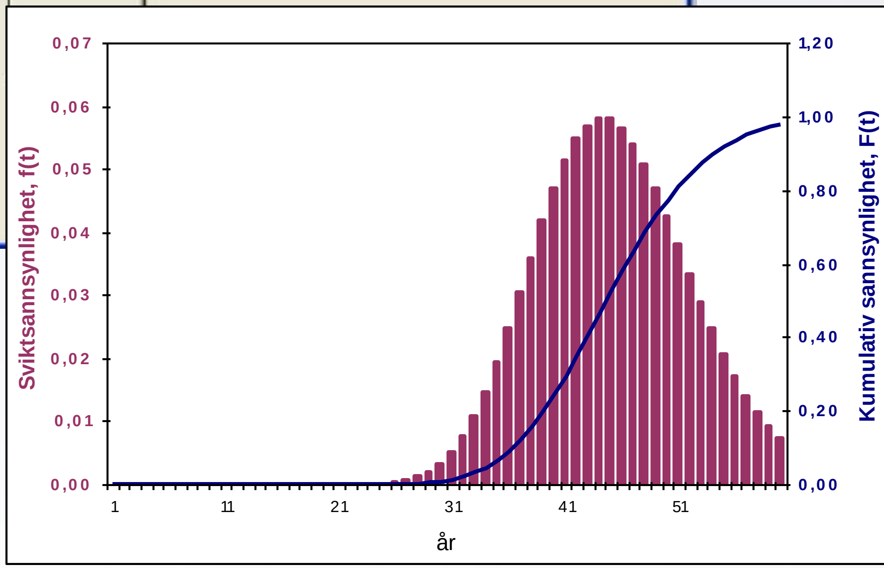
Lifetime model

- Linking the 5 states with the life curve:



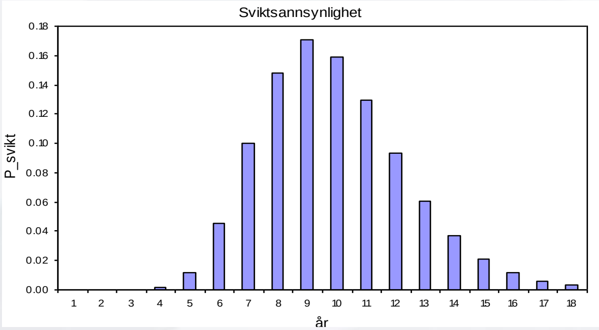
Expert judgement tool



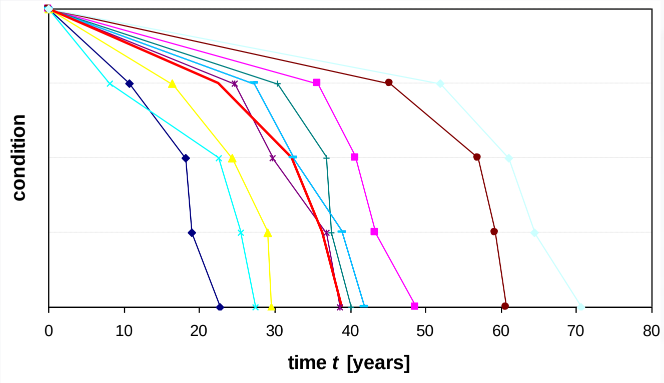


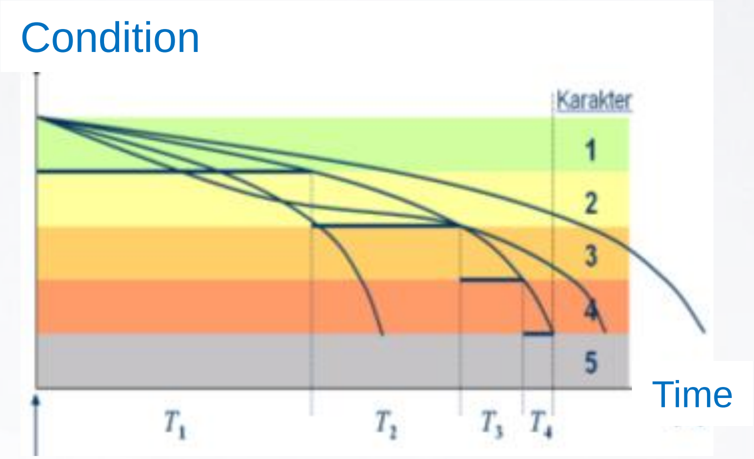
Results from the model

- Calculation of failure probability



- Calculation of expected remaining life
- Simulation of condition development





EnergiNorge

Case - Eidsiva:
Planning of maintenance work at Osa power plants using elements of pit stop methodology

Maren Istad, SINTEF Energiforskning
Knut Ringsrud, Eidsiva Vannkraft

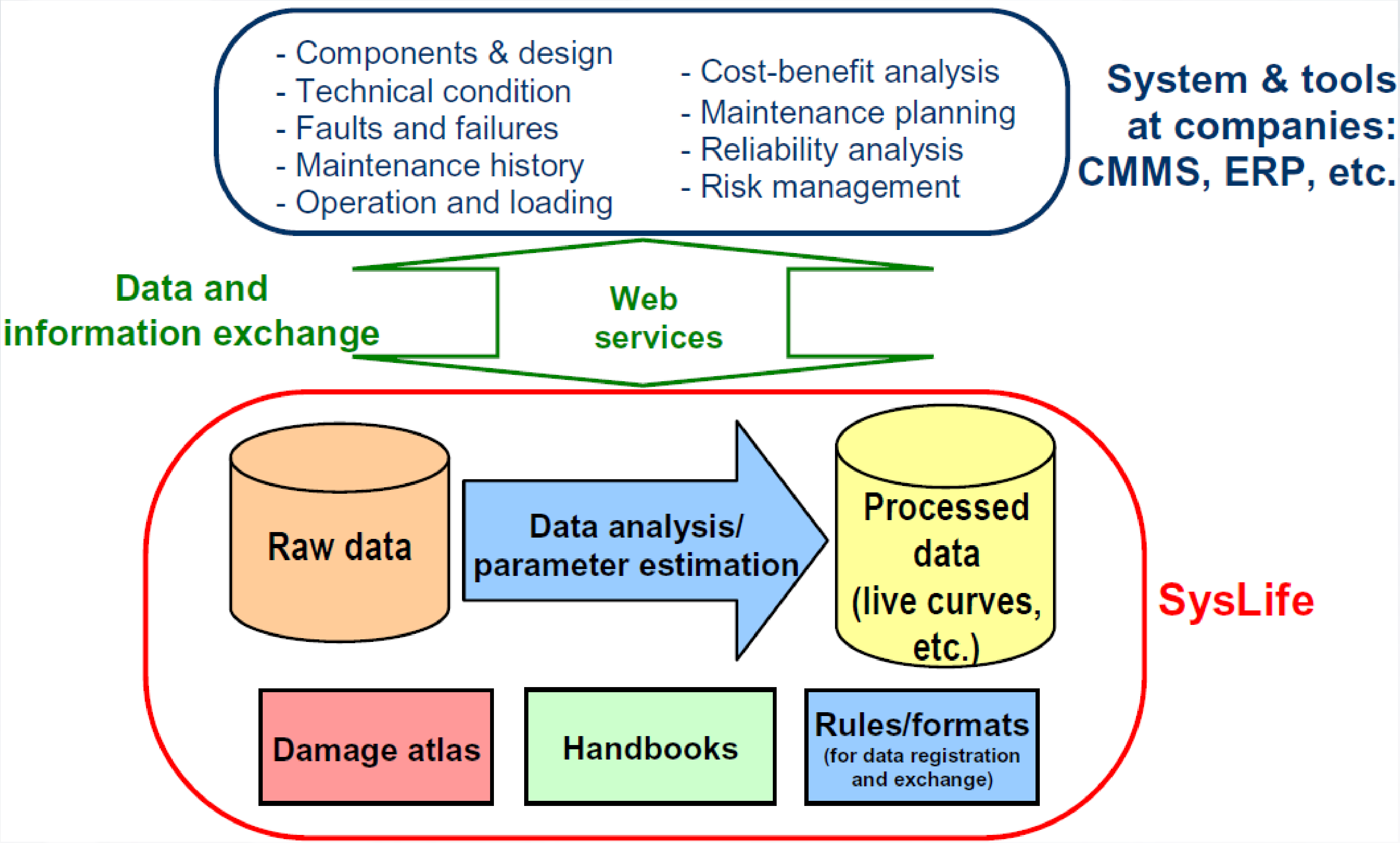
Eidsiva

Case – SN Power

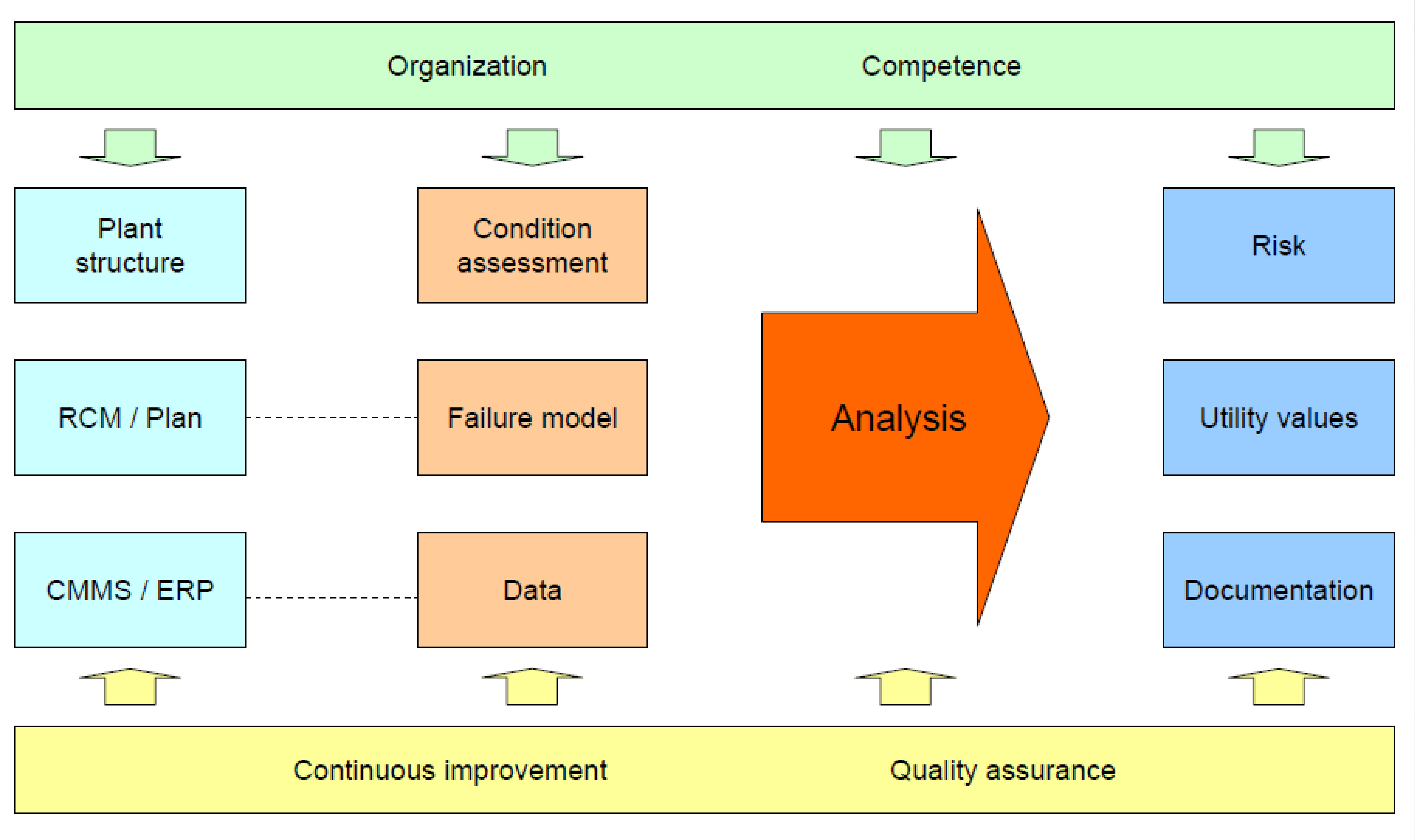
- Global maintenance strategy
  - RCM analysis
  - Systematic use of indicators
  - Contious improvement
- Methods and tools from the maintenance projects

Norwegian origin, global application

System collecting and sharing life time data (SysLife)



Framework for risk and profitability analysis based on tehcnical condition (FRAM)



Success criteria

1. Collaborative research project
2. Active involvement from the power companies
3. Support from the national research council
4. Training courses, seminars and workshops

The bottom line

Cost (2012 US$):

Power companies:	8.0 mil. US$
National research council:	4.8 mil US$
SUM:	**12.8 mil US$**

"*Correct implementation in our own organization will over time give an 20% added value to our maintenance*."

Statement from user group

Potential added annual value of maintenance: 128 mil US$