SINTEF

Prediktivt underhåll
- Erfarenheter från MonitorX

Thomas Welte

2018-03-20

Workshop: Digitaliseringen inom energisektorn

Outline

- SINTEF
- MonitorX project
- MonitorX: Results and experience

Lessons learned

SINTEF

Thomas Welte

SINTEF – One of Europes largest research institutes

2000
employees

70
nationalities

3800
customers

3,2 kr billion
turnover

500 million
international sales

Applied research, technology and innovation

Expertise and competance from marine to space:

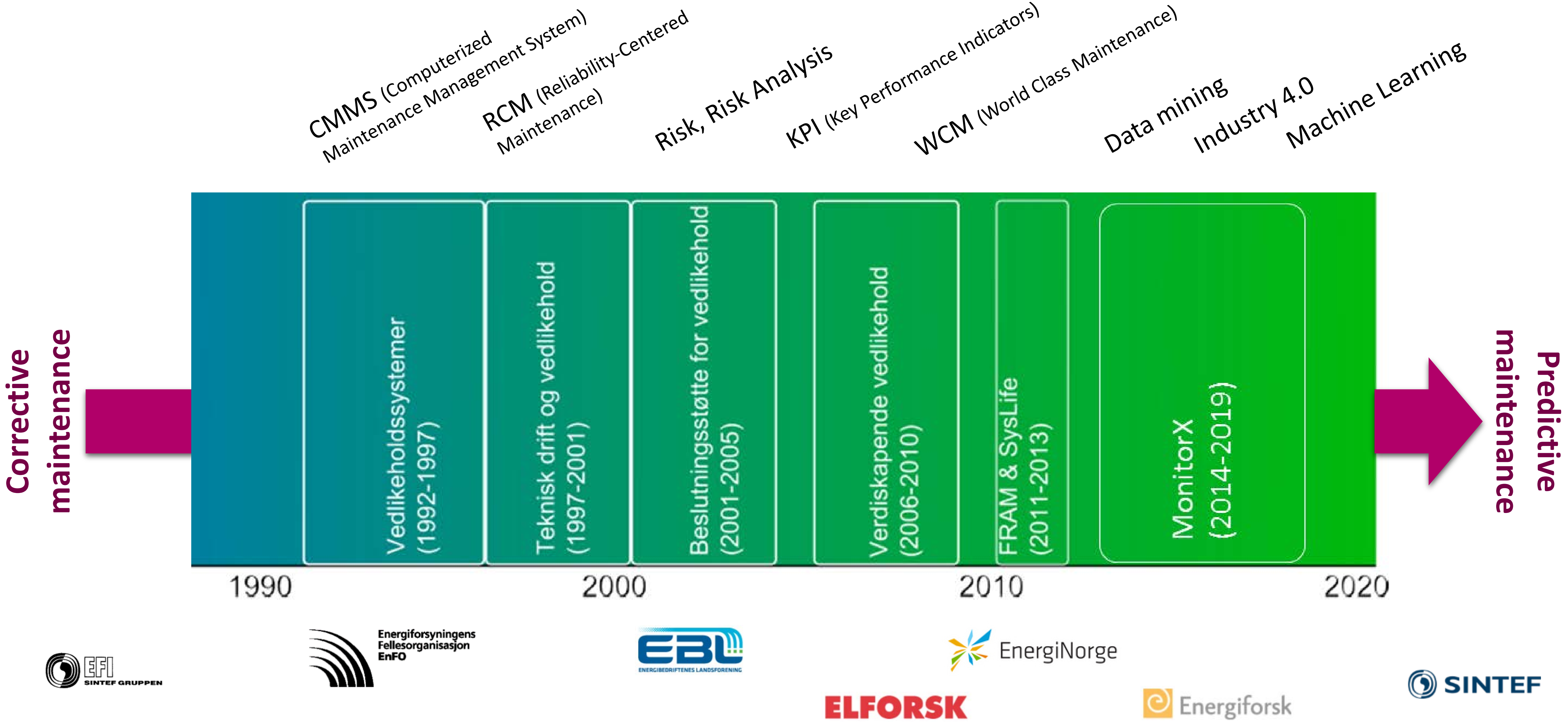
- Renewable energy
- Marine
- Industry
- Building and infrastructure
- Materials
- Micro and nano technology
- Climate and environment
- Oil and gas
- Health and welfare
- Society
- ICT
- Bio technology

SINTEF

The MonitorX project

Thomas Welte

Maintenance hydro – Projects, topics, methods

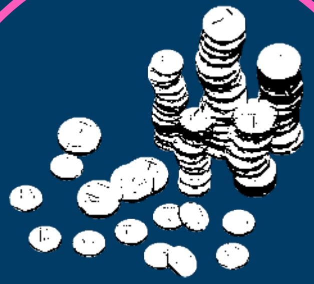


MonitorX

Optimal levetidsutnyttelse av vannkraftanlegg basert på overvåking av teknisk tilstand og risiko
(Optimal utilization of hydropower asset lifetime by monitoring of technical condition and risk)

IPN

07/15 - 06/19



17,2 mill

**20 (+14)
partners**

www.sintef.no/projectweb/MonitorX

SINTEF

MonitorX – Project partners

Project owner: EnergiNorge

Financing: Forskningsrådet

+ participating companies

Norwegian power companies:

BKK, ECO, Eidsiva, Lyse, Sira-Kvina Kraftselskap, NTE, Skagerak Energi, Glitre Energi, Statkraft, Hydro, TrønderEnergi, Østfold Energi

Equipment manufacturers and service providers:

Voith, Karsten Moholt, Hymatek controls, Andritz Hydro

RnD partners:

SINTEF, NTNU, Universidad Pontificia ICAI ICADE Comillas Madrid

Swedish power companies represented by Energiforsk:

Energiforsk

Vattenfall, Umeå Energi, Fortum, Uniper, Statkraft, Skellefteå Kraft, Holmen, Jönköping Energi, Elektra AB Edsbyns Elverk, Energi karlstadsenergi.se, Varberg Energi, Jämtkraft, Sollefteåforsen AB

MonitorX - Background

- Many measurements available already today
  - SCADA / control system (+ additional equipment/sensors)
  - These data are potential data sources for other purposes than control only
- Today, these data are not much used for decisions related to maintenance and reinvestment
- Power companies have a potentially large benefit when using these data

Foto: Shalom Jacobovitz, https://commons.wikimedia.org/wiki/File%3AMavericks_Surf_Contest_2010b.jpg

Hydropower plant 2017

MonitorX - Aims

industri 4.0
big data
internet of things
machine learning
internet of services
cyber-physical systems
data mining
predictive maintenance

Results

- Models, algorithms and corresponding software prototypes for optimal lifetime utilization
- Demonstrate practical application in selected power plants (cases)

Benefits

- Reduced maintenance costs by ... :
  - ... avoiding (catastrophic) faults ...
  - ... avoiding unnecessary component replacements ...
  - ... prioritizing the most critical components for maintenance ...
  - ... optimized maintenance ...
- ... through early warnings of ageing and potential faults.

Knowledge gain

- How can hydropower plant operators utilize the mentioned concepts and methods for maintenance of their plants?
- What are the possibilities, challenges and restrictions?
- How can monitoring data be used to carry out maintenance more predictive?

MonitorX – Project phases

Current status, preparation → Cases → Implementation & Conclusion

Case 1

Case 2

Case 3

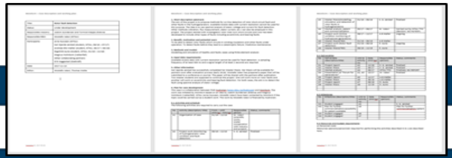
Case 5

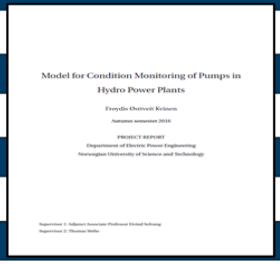
Case 6

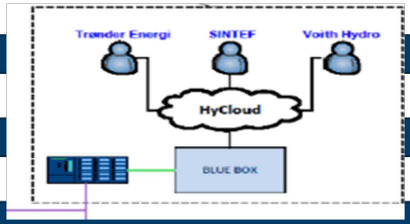
Case 7/8

Case 10

Case 11







Models for risk monitoring and condition-based maintenance (report)

MonitorX – Summary of results, recommen-dations for implemen-tation of results and further work (report)

2015 | 2016 | 2017 | 2018 | 2019

Problem/case identification and description → Modelling & algorithm and prototype development → Testing / demonstration

MonitorX – Cases (ongoing)

	Scope	Aim	Partners
1	Rotor fault detection	Detecting rotor inter-turn faults in generator rotor windings	NTNU, Vattenfall, Eidsiva, Statkraft
2	Condition monitoring of pumps	Detecting faults and degraded condition for pumps (leakage water, cooling water) in hydropower plants	NTNU, SINTEF, Vattenfall, TrønderEnergi
3	Condition monitoring headrace tunnel	Detecting tunnel collapses (rock falls, …)	Andritz, Sira-Kvina
5	Audio Surveillance	Normality control, audio cavitation detection, audio exploration	Andritz, Statkraft, NTNU, SINTEF
6	Bearing monitoring	Detect condition changes and faults	SINTEF, Comillas, BKK
7 / 8	Kaplan hydraulic system monitoring	Detecting condition of Kaplan hydraulic mechanism	Comillas, Glitre
		Detecting oil leakages	Comillas, Skellefteå
10	SCADA data collection system in Brattset power station	Establish good and continuous access to SCADA data	Voith, TrønderEnergi

SINTEF

SINTEF

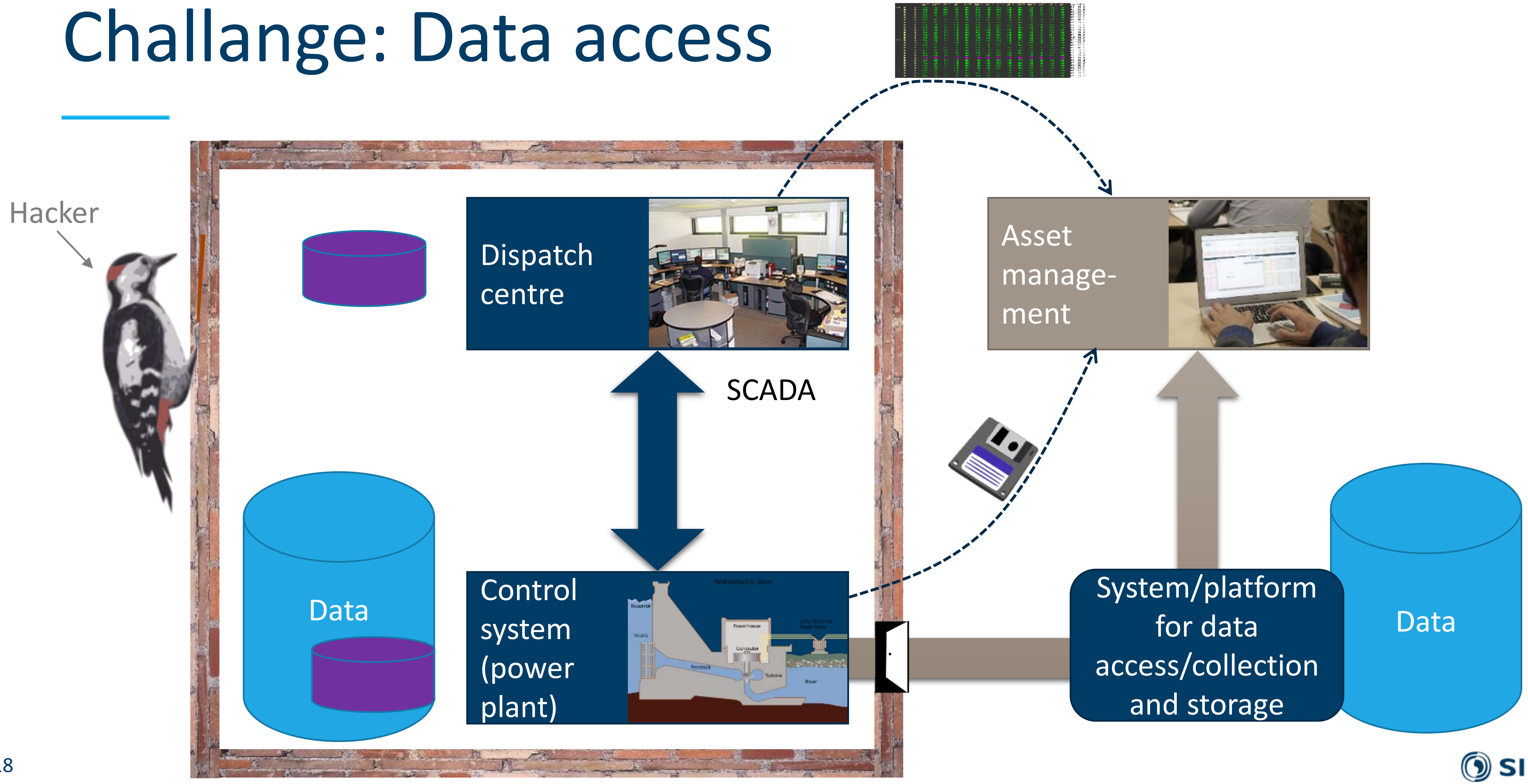
MonitorX: Results and experience

Thomas Welte

Where to start?

Model development ←→ Data collection

Challange: Data access



C10. Data collection from power plant's control system (i)

- Aim: Make signals that are colected/used in SCADA and power plant available to the plant operator (for other purposes than control).
- Status
  - Data collection system up and running since March 2017
  - 1100 signals from the power plant's control system are available with the system
  - Data access established for MonitorX project participants (NTNU, SINTEF, etc.)

VOITH

TrønderEnergi®

SINTEF

EnergiNorge

Recent developments

- Power companies establish and start to use systems/digital platforms for large scale collection, storage and analysis of (SCADA) data

OSIsoft. VOITH Conwide AB

GE ABB ORACLE Microsoft KONGSBERG ...

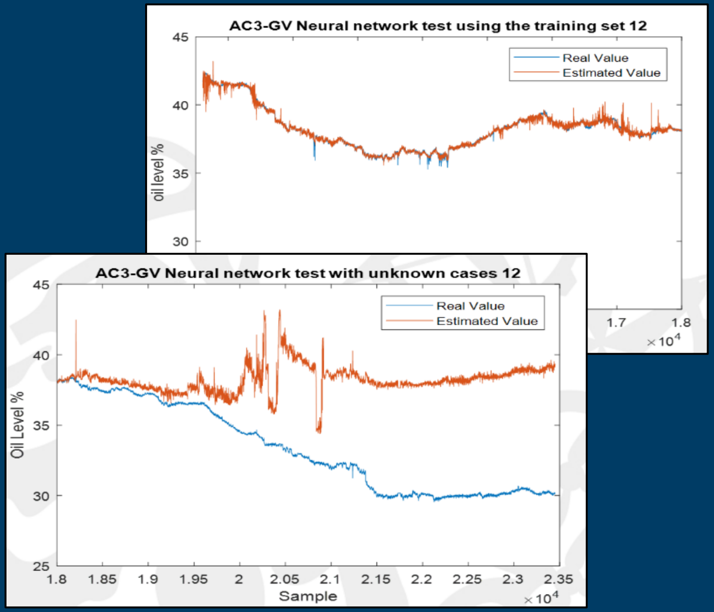
SINTEF

Which data? Resolution?

MonitorX cases C6 & C7

Bearing and Kaplan condition monitoring

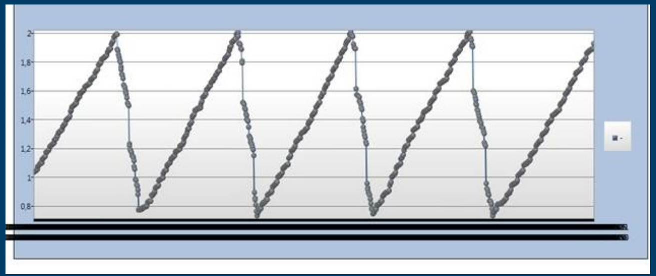
- 1 hr average values

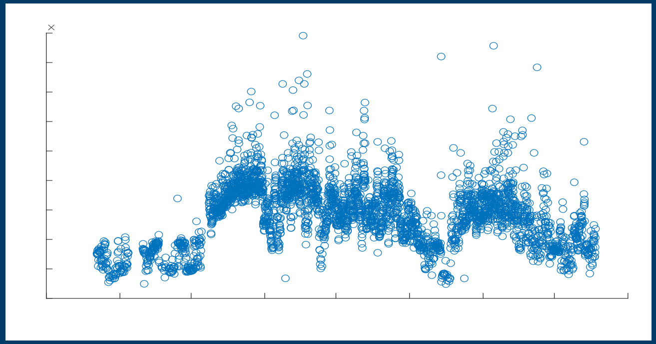


MonitorX case C2

Monitoring of drainage pump behaviour

- 1 … 10 sec. values

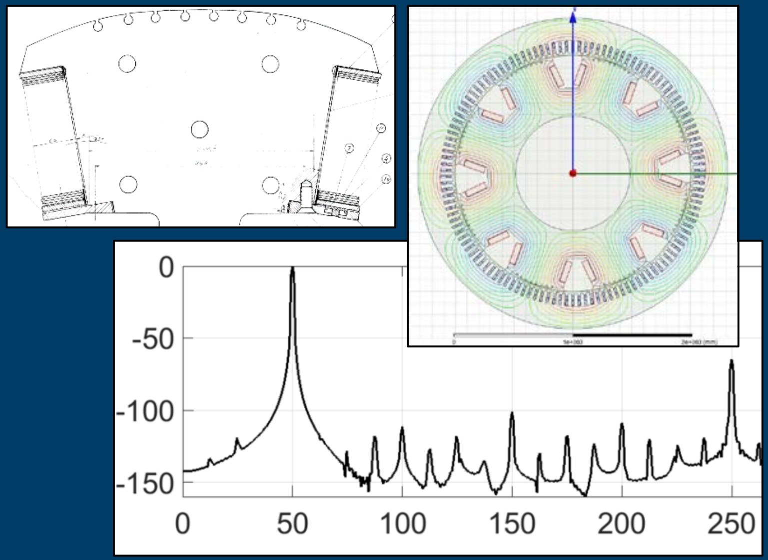




MonitorX case C1

Detection of rotor inter-turn faults

- (min. 2 …) 4 kHz



Types of models?

C1 C2 C6 C7 C5

physical under-standing ⟷ data-driven

C10 / simple

C2

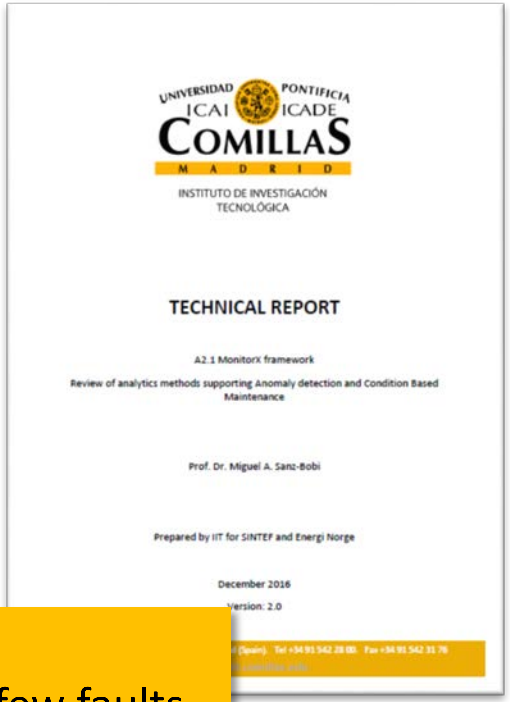
C6

C7

C1

C5 / advanced

- Visualization of data – $x(t)$
- Simple models
  (e.g. duration start & stop sequences, valve opening, etc.)
- Simple statistics, correlations, trending, etc.
- Advanced statistical analysis, frequency analysis, machine learning


UNIVERSIDAD PONTIFICIA ICAI ICADE COMILLAS MADRID

INSTITUTO DE INVESTIGACIÓN TECNOLÓGICA

TECHNICAL REPORT

A2.1 Monitorx framework

Review of analytics methods supporting Anomaly detection and Condition Based Maintenance

Prof. Dr. Miguel A. Sanz-Bobi

Prepared by IIT for SINTEF and Energi Norge

December 2016

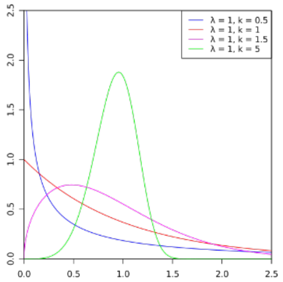
Version: 2.0

Hydropower:
High reliability & few faults
→ Normal behavior models
→ Anomaly detection

SINTEF

Classic statistical reliability methods vs. monitoring

- Choice depends on intended application (type of decision, size of population, time horizon, etc.)
- Statistics useful to "build" good data-driven monitoring models



Weibull distribution

iea wind

EXPERT GROUP REPORT ON
RECOMMENDED PRACTICES

17. WIND FARM DATA COLLECTION AND RELIABILITY
ASSESSMENT FOR O&M OPTIMIZATION

FIRST EDITION, 2017

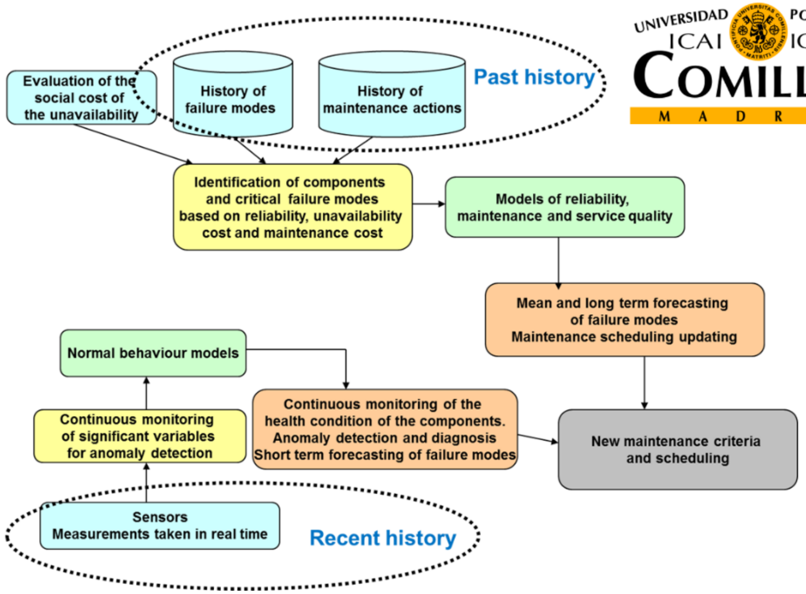
Table 10: Prediction horizon of different models

Model	short term ← prediction horizon → long term			
	<<MTTF*	< MTTF	MTTF	≥ 2 MTTF
Stochastic models		■	■	■
Failure rate models			■	■
Lifetime distributions		■		
Stochastic degradation models		■		
Physical models		■		
Machine learning	■	■		

*Condition monitoring systems that provide warnings and alarms hour

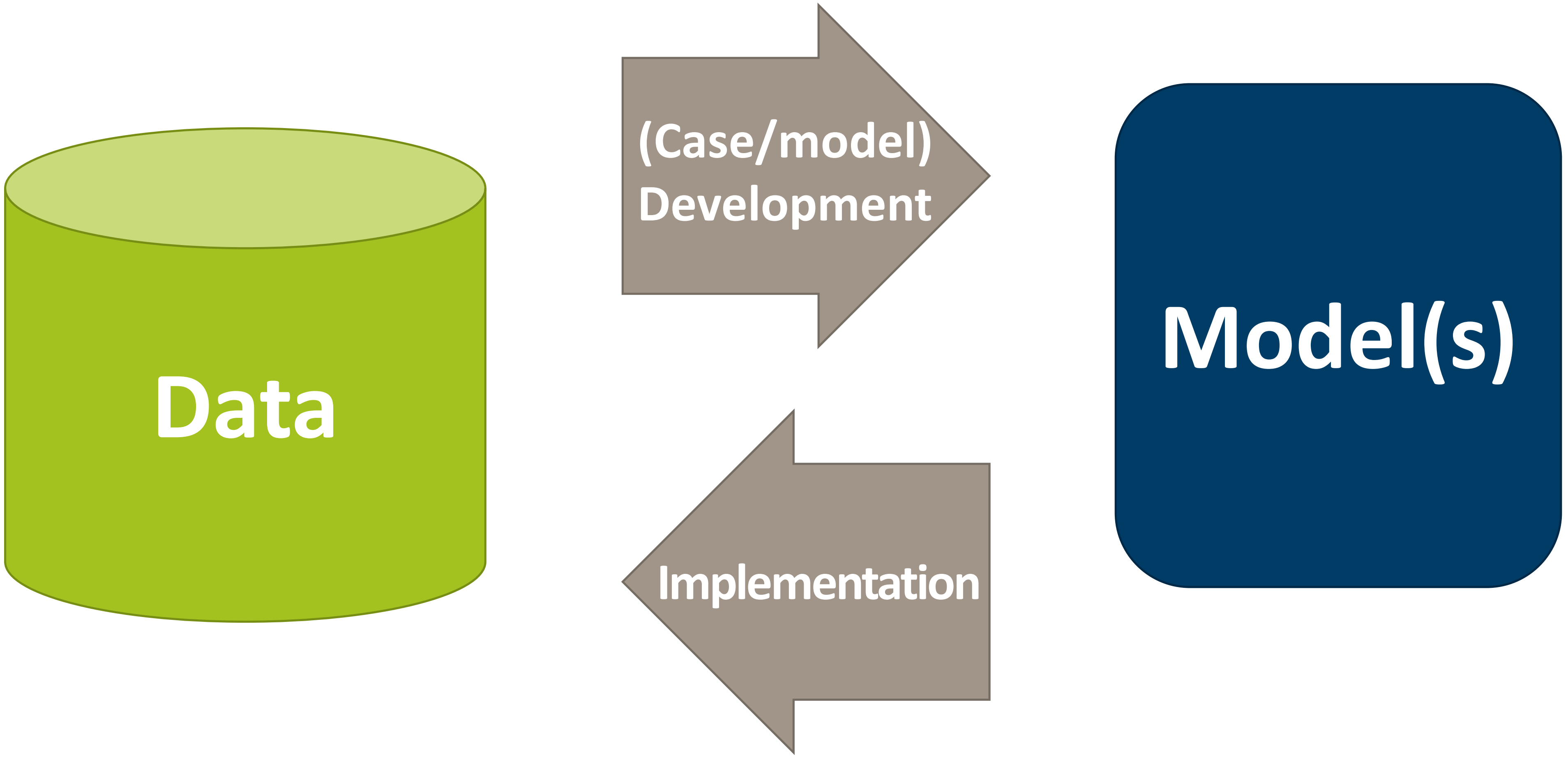
Table 11: Prediction capability depending on size of group

Model	small ← size of population → large	
	single unit, item	group, population
Stochastic models	■	■
Failure rate models		■
Lifetime distributions	■	■
Stochastic degradation models	■	
Physical models	■	
Machine learning	■	

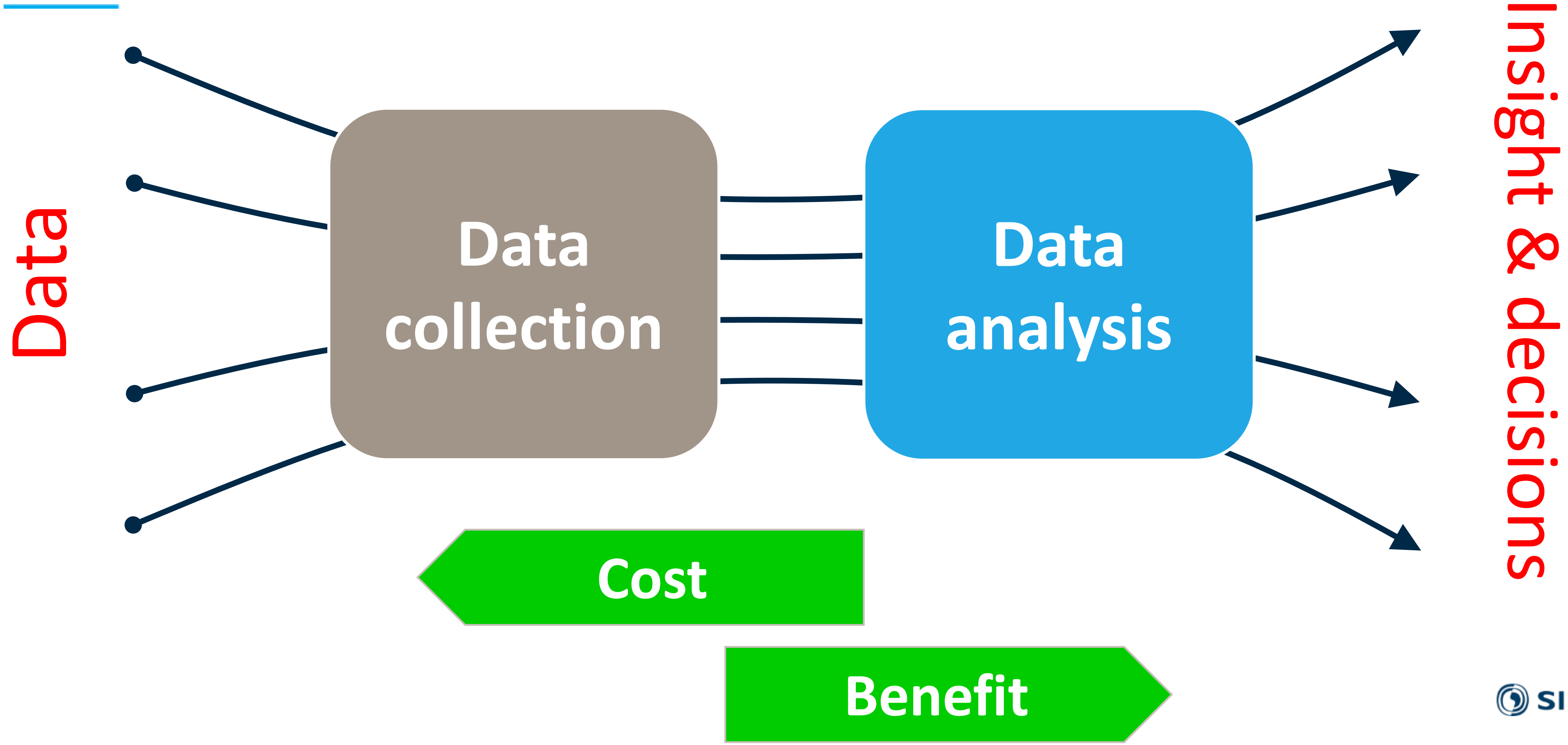


UNIVERSIDAD PONTIFICIA ICAI ICADE COMILLAS MADRID

Cases/models: Development vs. implementation



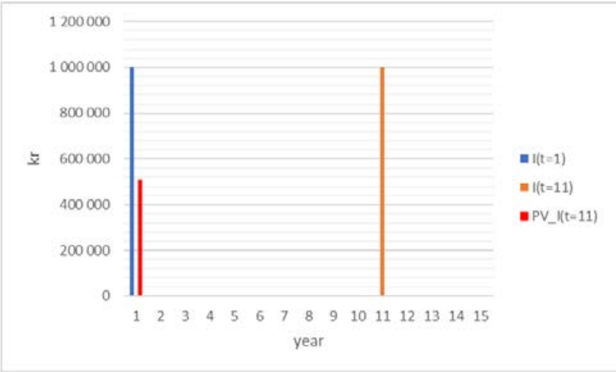
Data collection vs. data analysis



Potential benefits of monitoring

- Less manual inspections and power station visits
- Early warnings of potential faults, resulting in fewer (very expensive) corrective maintenance tasks
- Higher availability since maintenance can be carried out in periods when power plant is not needed for power production
- New possibilities to control effects of operation-related loads on machinery
- Lifetime extension through better follow-up of real condition

Source: Wikipedia

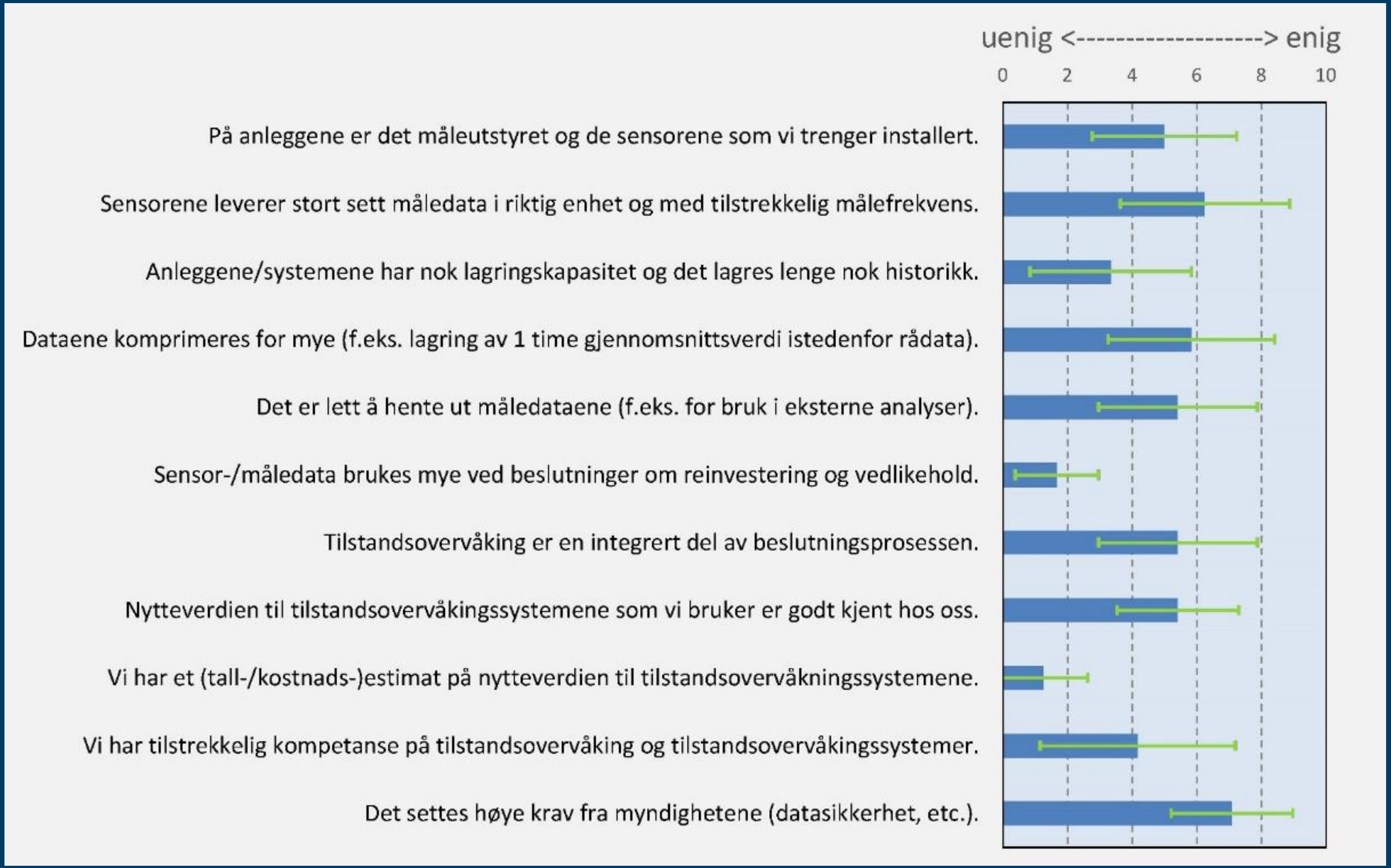


Status condition monitoring (2015)

<u>MonitorX survey 2015:</u>

General topics included:

1. Measurements and sensors
2. Storage
3. Data collection and IT infrastructure
4. Availability of and access to collected/stored data
5. Analysis
6. Use in decision making (reinvestment/maintenance)
7. Benefit and cost-benefit evaluation
8. Competence and requirements



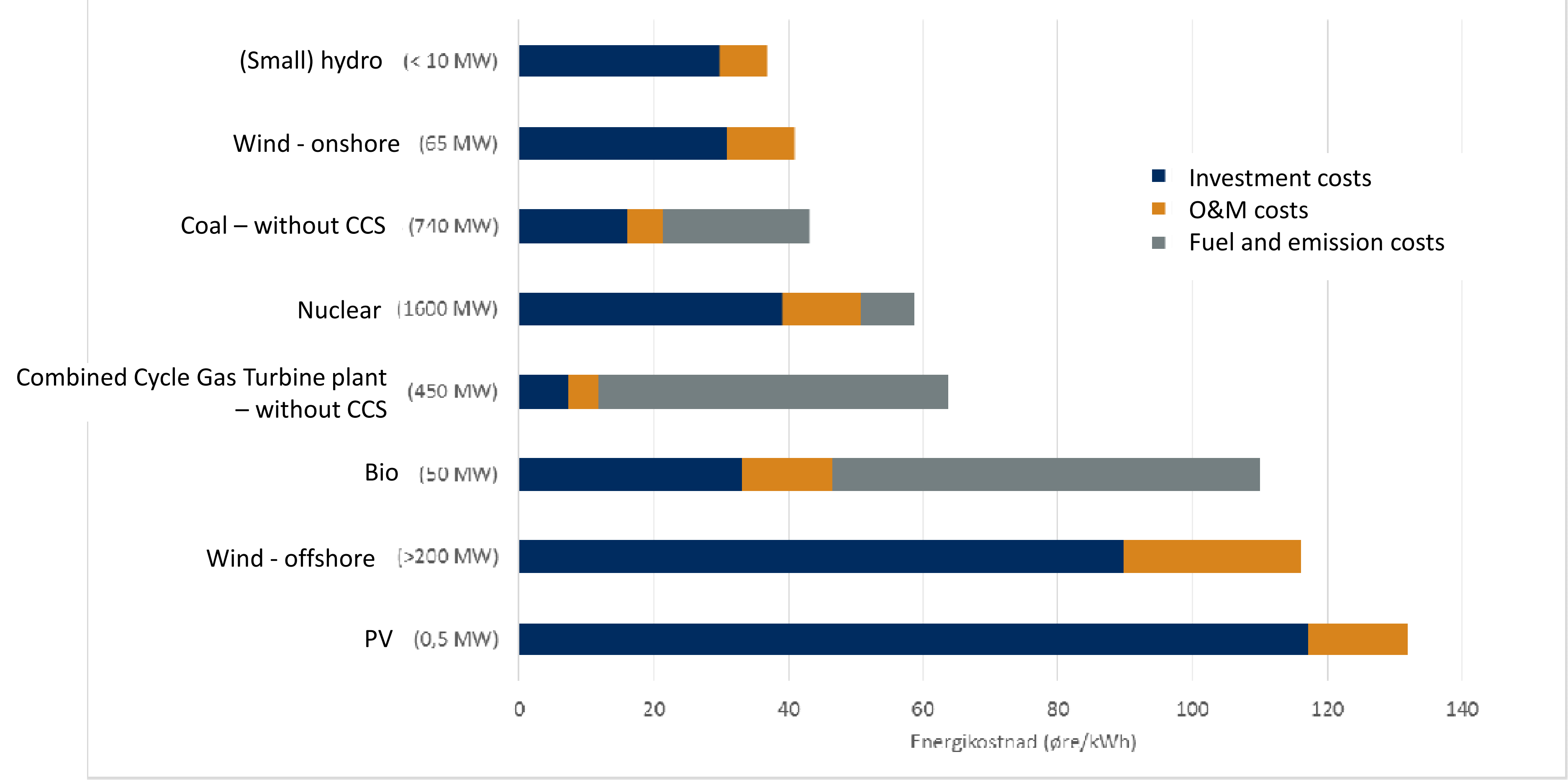
SINTEF

Costs electricity production, NO/nordic

O&M costs
Hydro: 3 €/MWh
Wind: 30 €/MWh
(Large European electricity producer. 2014)

Hydro: Already cheap, low O&M costs.
Is it worth to invest in condition monitoring?
Which investments are cost-beneficial?

Existing (Large) hydro (> 10 MW) (source: NVE 2015)



Kilde: NVE

SINTEF

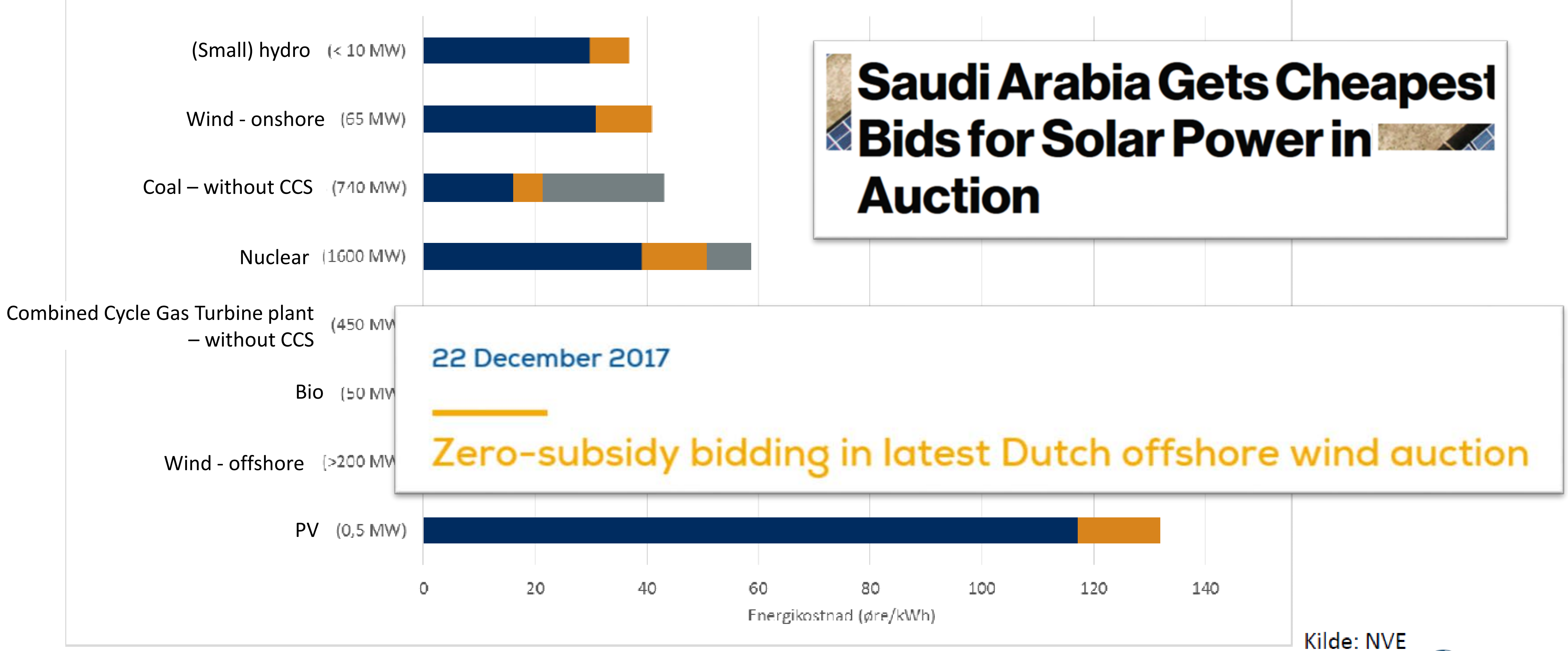
NVE 2015: http://publikasjoner.nve.no/rapport/2015/rapport2015_02a.pdf

Costs electricity production, NO/nordic

O&M costs
Hydro: 3 €/MWh
Wind: 30 €/MWh
(Large European electricity producer. 2014)

Hydro: Already cheap, low O&M costs.
Is it worth to invest in condition monitoring?
Which investments are cost-beneficial?

Existing (Large) hydro (> 10 MW) (source: NVE 2015)



Kilde: NVE

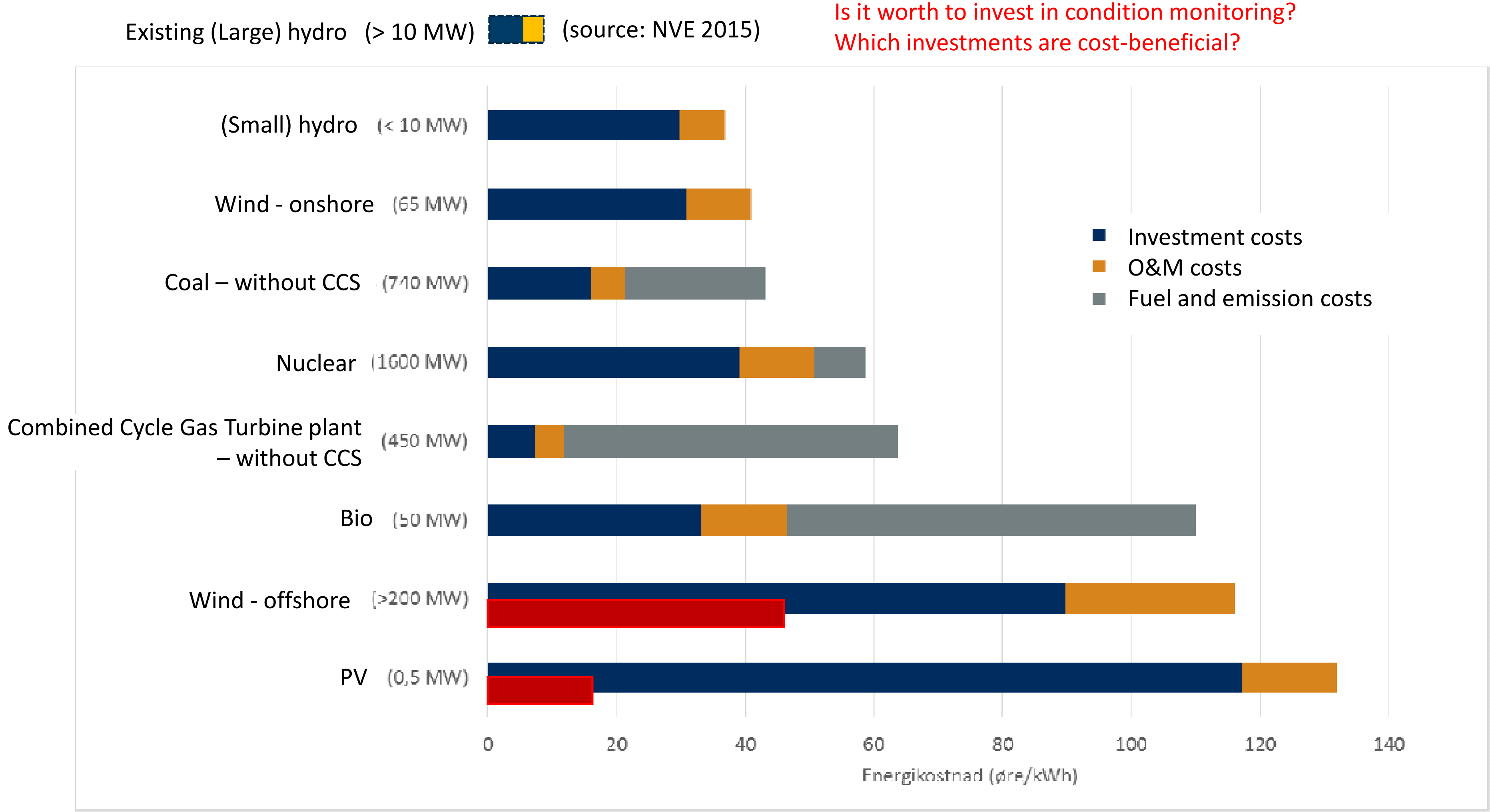
SINTEF

NVE 2015: http://publikasjoner.nve.no/rapport/2015/rapport2015_02a.pdf

Costs electricity production, NO/nordic

O&M costs
Hydro: 3 €/MWh
Wind: 30 €/MWh
(Large European electricity producer. 2014)

Hydro: Already cheap, low O&M costs.
Is it worth to invest in condition monitoring?
Which investments are cost-beneficial?



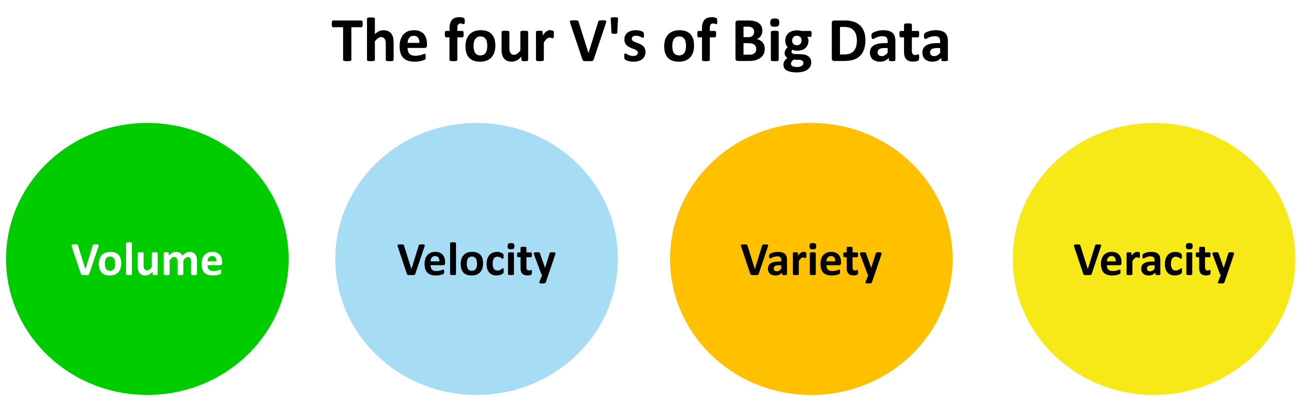
Kilde: NVE

NVE 2015: http://publikasjoner.nve.no/rapport/2015/rapport2015_02a.pdf

Data quality

Veracity

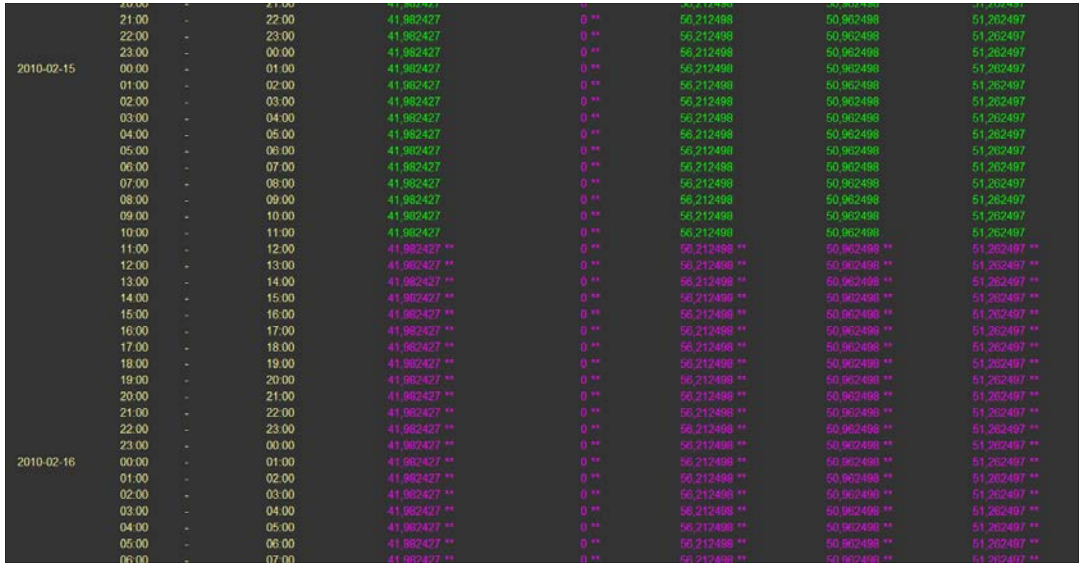
- Can you trust the data?
- Data quality
    - Completeness
    - Correctness / calibration
    - Contradiction
    - …



IBM, 2017, The four V's of Big Data

31464		18:00	-	19:00	40,637634	61,888542
31465		19:00	-	20:00	40,163165	61,166146
31466		20:00	-	21:00	41,055016	62,521875
31467		21:00	-	22:00	40,922888	62,247881
31468		22:00	-	23:00	40,511296	61,708333
31469		23:00	-	00:00	40,228674	61,176563
31470	2011-02-04	00:00	-	01:00	39,711159	60,286979
31471		01:00				
31472		02:00				
31473		03:00				
31474		04:00				
31475		05:00				
31476		06:00				

32136		18:00	-	19:00	42,156492	68,377083
32137		19:00	-	20:00	41,754083	67,617708
32138		20:00	-	21:00	41,748468	67,694271
32139		21:00	-	22:00	42,245396	68,576562
32140		22:00	-	23:00	41,279774	66,931144
32141		23:00	-	00:00	41,369455	67,051563
32142	2011-02-04	00:00	-	01:00	41,617452	63,221354
32143		01:00	-	02:00	40,243648	61,107292
32144		02:00	-	03:00	39,914234	60,664583
32145		03:00	-	04:00	40,577741	61,648438
32146		04:00	-	05:00	40,811699	62,126562
32147		05:00	-	06:00	40,73496	62,098438
32148		06:00	-	07:00	39,830945	60,530208
32149		07:00	-	08:00	42,842457	65,471875



	21:00	-	22:00	41,982427	0 **	56,212498	50,962498	51,262497
	22:00	-	23:00	41,982427	0 **	56,212498	50,962498	51,262497
	23:00	-	00:00	41,982427	0 **	56,212498	50,962498	51,262497
2010-02-15	00:00	-	01:00	41,982427	0 **	56,212498	50,962498	51,262497
	01:00	-	02:00	41,982427	0 **	56,212498	50,962498	51,262497
	02:00	-	03:00	41,982427	0 **	56,212498	50,962498	51,262497
	03:00	-	04:00	41,982427	0 **	56,212498	50,962498	51,262497
	04:00	-	05:00	41,982427	0 **	56,212498	50,962498	51,262497
	05:00	-	06:00	41,982427	0 **	56,212498	50,962498	51,262497
	06:00	-	07:00	41,982427	0 **	56,212498	50,962498	51,262497
	07:00	-	08:00	41,982427	0 **	56,212498	50,962498	51,262497
	08:00	-	09:00	41,982427	0 **	56,212498	50,962498	51,262497
	09:00	-	10:00	41,982427	0 **	56,212498	50,962498	51,262497
	10:00	-	11:00	41,982427	0 **	56,212498	50,962498	51,262497
	11:00	-	12:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	12:00	-	13:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	13:00	-	14:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	14:00	-	15:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	15:00	-	16:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	16:00	-	17:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	17:00	-	18:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	18:00	-	19:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	19:00	-	20:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	20:00	-	21:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	21:00	-	22:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	22:00	-	23:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	23:00	-	00:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
2010-02-16	00:00	-	01:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	01:00	-	02:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	02:00	-	03:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	03:00	-	04:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	04:00	-	05:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **
	05:00	-	06:00	41,982427 **	0 **	56,212498 **	50,962498 **	51,262497 **

Needs for standardization

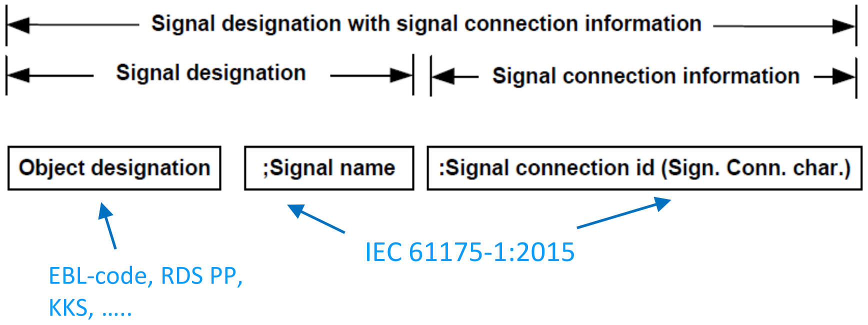
- Different designation
- Exchange of information between different systems
- New working group at Energi Norge

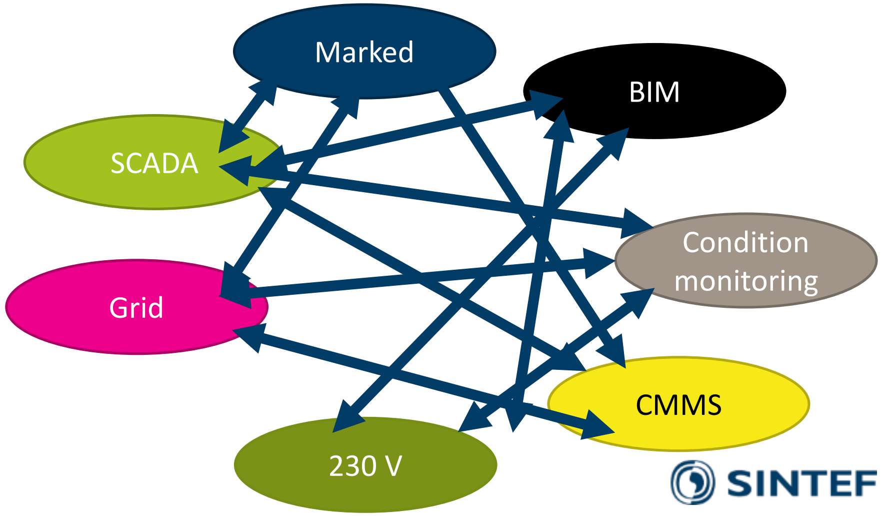
Temperature measurement	Signal name SCADA
Statorkjerne spor 4/5 PK 4 TH	STATORKJSP4/5
Statorkjerne spor 4/5 PK 4 BK	STATORKJSP4_5
Statorkjerne spor 64/65 PK 14 TH	STATORKJSP64/65
Statorkjerne spor 64/65 PK 14 BK	STATORKJSP64_65
Statorkjerne spor 136/137 PK 25 TH	STATORKJSP136/137
Statorkjerne spor 136/137 PK 25 BK	STATORKJSP136_137
Statorkjerne spor 4/5 PK 14 TH	STATORKJSP4/5.1
Statorkjerne spor 4/5 PK 14 BK	STATORKJSP4/5.2
Statorkjerne spor 136/137 PK 14 TH	STATORKJSP136/137.1
Statorkjerne spor 136/137 PK 14 BK	STATORKJSP136_137.1

10 temp. measurements – 6 different names!

Typically: 9 – 11 measurements (signals) for thrust bearing

Martin Hviid Nielsen
Rådgiver
mhn@energinorge.no
93877418
Pressebilder





SINTEF

Responsibility, competence and work processes

Responsibility

- In-house / external

Power plant operator

Manufacturer

IT service provider

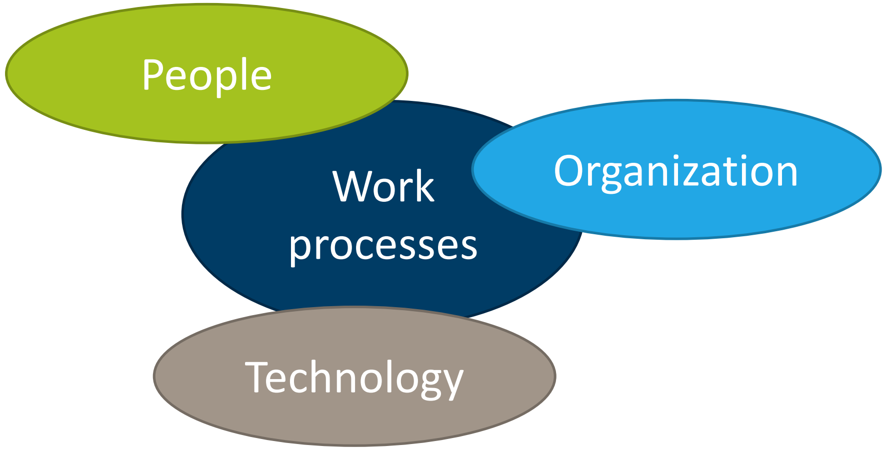
Consultancy

Competence

- Technical (mechanical, electro, …)
- IT/data science
- Management
- …

Work processes

- New technology → New ways of working



SINTEF

Teknologi for et bedre samfunn