Resilience in Asset Management

Perspectives on how the need for increased infrastructure resilience redefines key Asset Management strategies and practices

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Points of conversation

01

Asset Resilience

Global context and challenges that demand a focus on increasing physical asset resilience

02

Asset Lifecycle

Taking a holistic approach to asset management across the entire asset lifecycle

03

Asset Resilience Landscape

How climate and disaster resilience are changing the asset management and asset lifecycle landscape and considerations/approaches

04

Q&A

Discussions and a conversation around asset management resilience change impacts

Global Context

The global landscape - demanding human and business resilience

Global Environmental Crises

Global Supply Chain instability and disruptions

Changing Power Utility Operating Models

Digitalisation & the IoT (Industry 4.0+)

Ageing Workforce and need for a future-proof skills profile

Non-traditional power/energy providers entering rapidly

Data overload & misinformation – making sense of the disorder

Social & Geo-political drivers, risks & derailers

Global Financial Crises and infrastructure funding

Clean Power Generation within a Just Energy Transition

Ageing and unreliable plant

Resource scarcity & cost (oil, gas, water & skilled staff)

Resources capable of enabling a low carbon energy future

New generation of professionals with Unconventional Learning Preferences

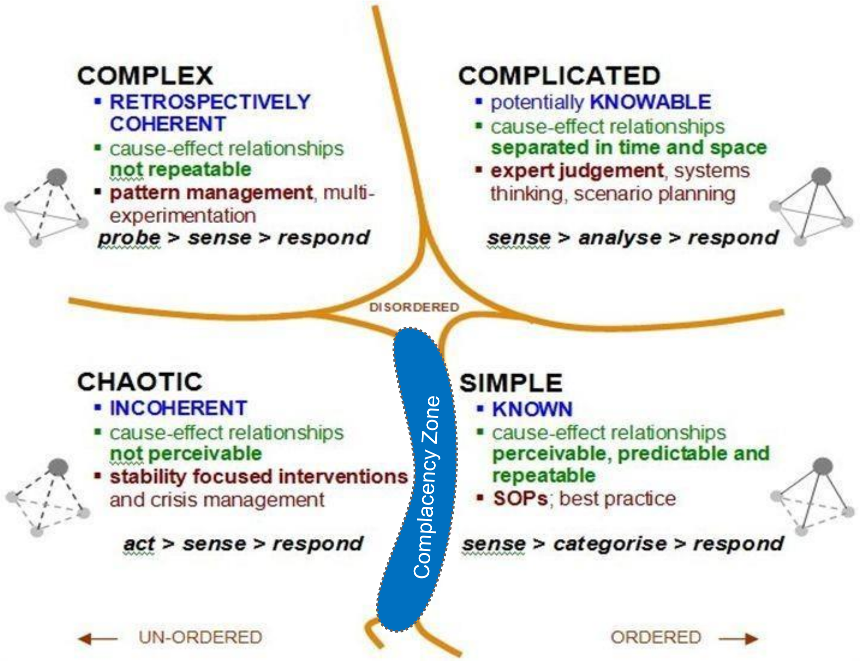
Increasing workforce discontent & even disengagement (strikes)

A holistic approach to Asset Resilience

Why Critical Infrastructure & Asset Resilience matters so much

Critical infrastructure inter-dependence lead to an increase in probability and severity of failures cascading across multiple different socio-economic eco-systems – this requires a whole systems and asset lifecycle centric approach to create organizational resilience in critical infrastructure such as power generation.

And resilience challenges, therefore, often fall in the categories of complicated, complex and even chaotic (how we make "sense" and perceive the world around us).



The CYNEFIN Framework© – Dave Snowden

Electrical Power is a ***FUNDAMENTAL SOCIO-ECONOMIC ENABLER***!

A whole systems and asset lifecycle centric approach

The expectation should be to consider critical aspects regarding power plant reliability, availability, maintainability, and resilience in context to ***total asset lifecycle*** in the following dimensions:

- **Plant** (Mechanical integrity, appropriate asset and reliability strategies, specialist knowledge of complex behaviors involved when it comes to resilience challenges, operational experience (OE) on plant behavior and physics of failure of power plant assets, etc.)

- **People & Societal Impact** (Well-defined and focused competency frameworks; clear roles and responsibilities, resilience training and development, sharing of operational experience, etc.)

- **Process and Management Systems** (All technical and related business processes to effectively manage plant - geared at supporting resilience, efficiency and ability to respond effectively to resilience issues.)

- **Technology** (Appropriate use of asset design and plant health condition information to support better decision-making; use of enabling and smart technologies to improve plant data monitoring and support improved response to plant failures and resilience risks [known and developing]).

How Resilience are changing AM approaches

Design Requirements: *Abnormal is the new normal*

- Consider the **additional Physics of Failure imposed on assets** due to adverse weather conditions
- Consider **reduction in useful asset life (design life)** due to adverse conditions (and risk mitigation strategies for this)
- **Increased introduction of smart-sensors** and monitoring technology required to be more responsive in adverse conditions
- **FMECA analysis** must now also **consider impact of *external* influences** (beyond plant boundary)
- Defining the performance data required in **SCADA/PLC systems and field instrumentation design** more implicitly to enable ML (enabling increased predictive capability)
- **"1 in 50, or 1 in 100 year events" are much more frequent** – so must be factored into design criteria and design for safety considerations: Mitigating the potential risks must consider ALARP principles from an impact perspective.
- **Generation plant design can no longer be done in isolation** – whole power system influences must be considered.

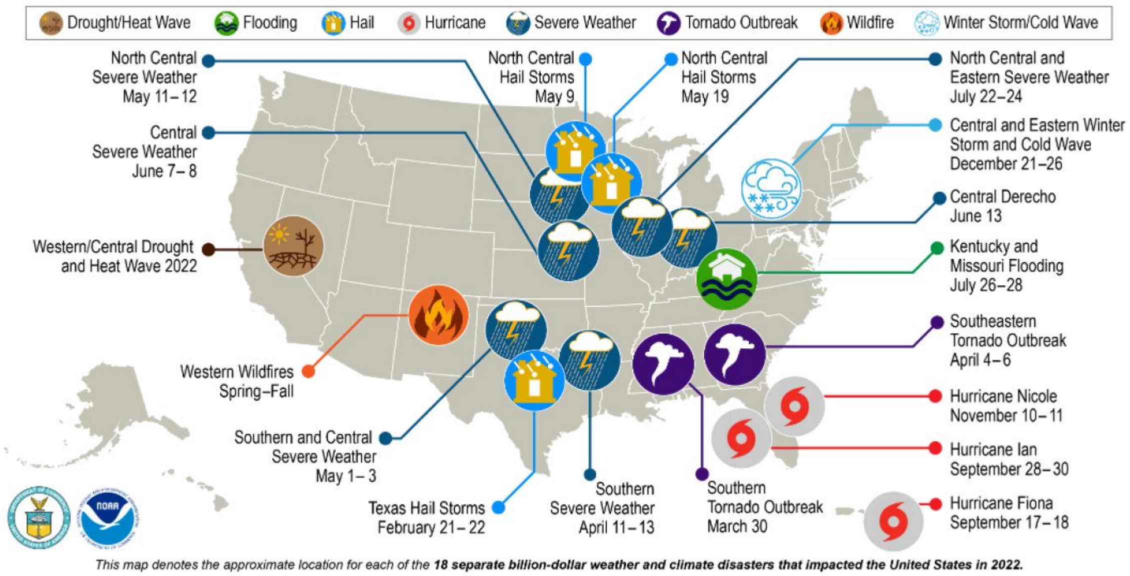
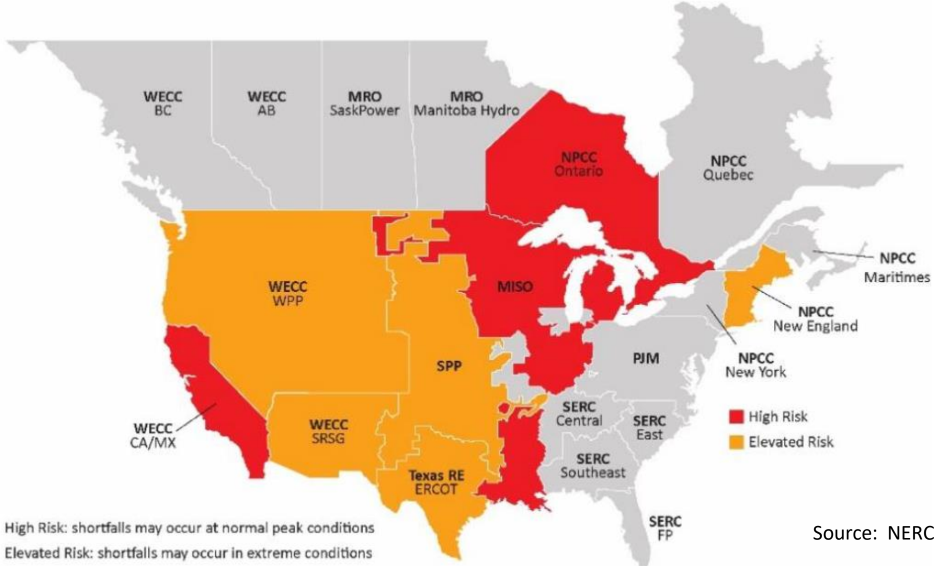


Figure 1.1: 2022 U.S. Billion-Dollar Weather and Climate Disasters[22]



Source: NERC

Figure 1: Risk Area Summary 2023–2027

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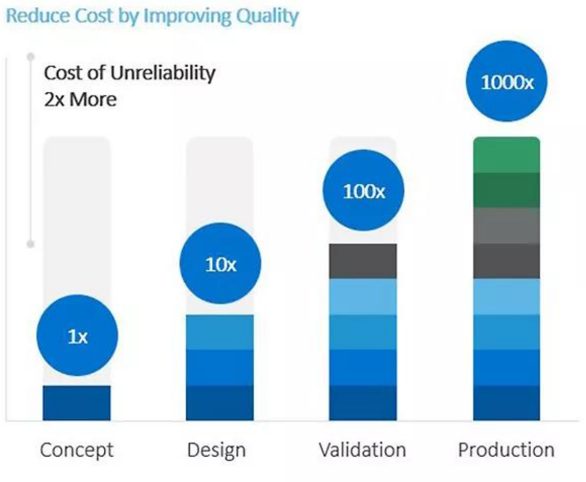
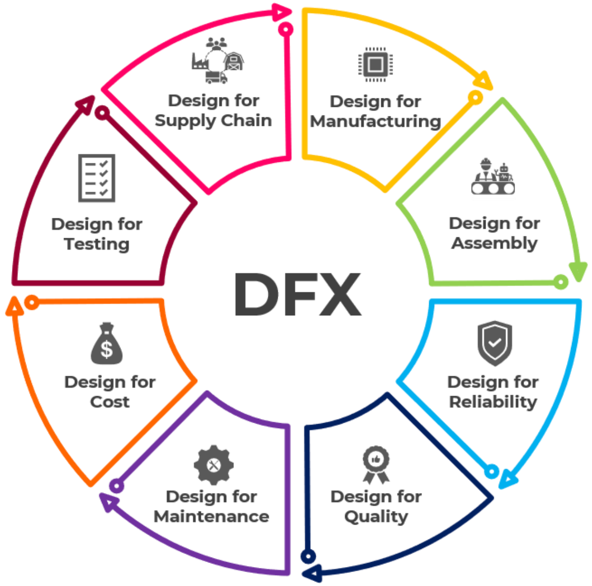
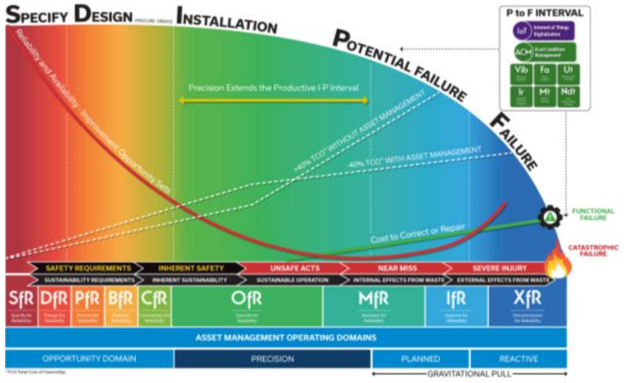
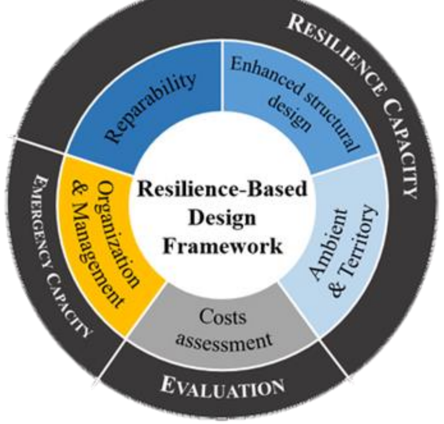
Asset Design Processes - From DfR to DfR^2

Design for Reliability to Design for eXcellence to Design for Reliability AND Resilience

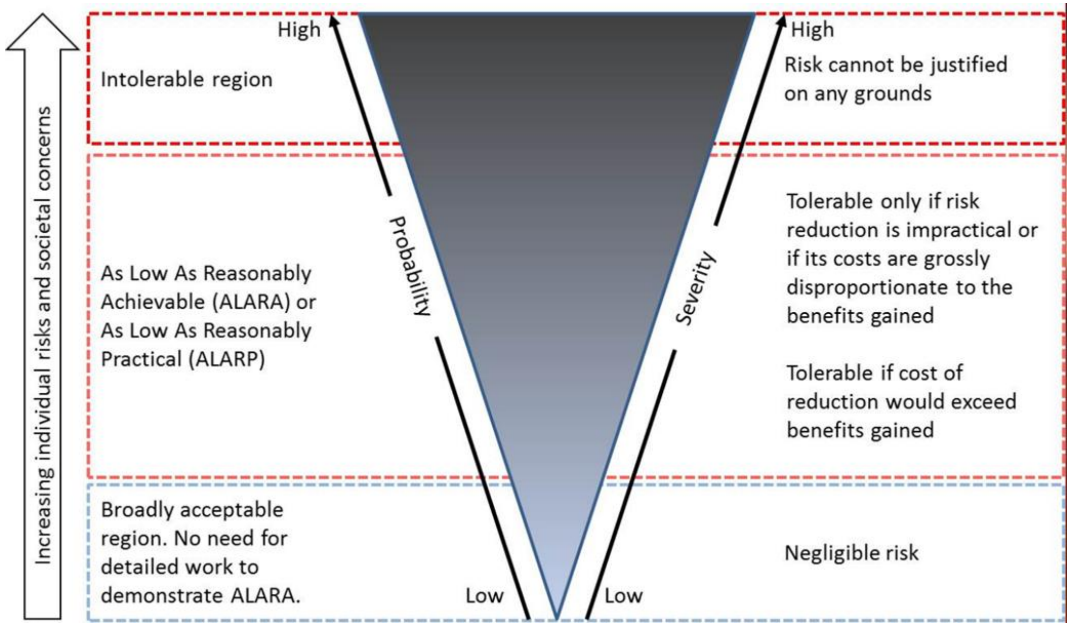








Source: www.reliabiltyweb.com



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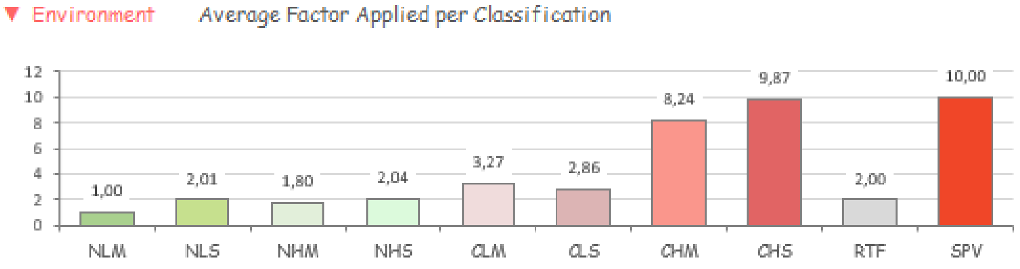
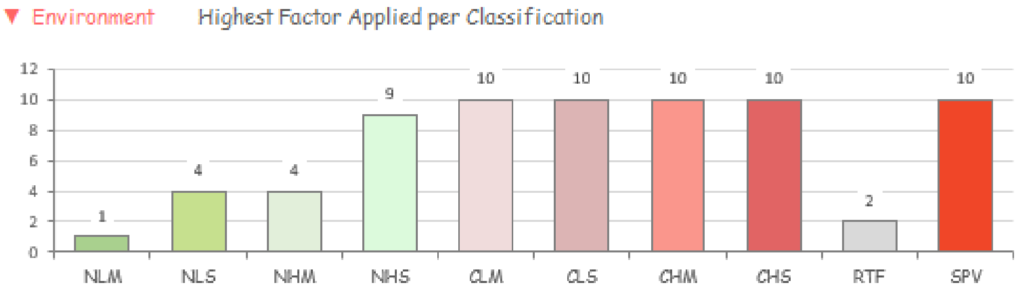
Asset Criticality Ranking – More Risk-Informed

Moving from *One-Directional* Criticality Assessment to Bi-Directional Risk Assessments*





Ranking Value	Environmental Impact
1	No Discernable Environmental Effect caused by System
2	System Normal operation noticeably impaired, with Environmental impact
3	Poor System RAM performance Detracts from environmental compliance Goals
4	Poor System RAM Prevents effective Environmental Management
5	Poor System RAM Loss of environmental control Function
6	Poor System RAM result in Imminent Environmental Non-Compliance (with Warning)
7	Poor System RAM result in Immediate Environmental Non-Compliance (without Warning)
8	Poor System RAM result in Penalty/Fine for Environmental Non-Compliance
9	Poor System RAM result in Immediate Environmental Violation/Shutdown (with Warning)
10	Poor System RAM result in Immediate Environmental Violation/Shutdown (without Warning)

Outward Facing Impact & Risk

Ranking Value	Environmental Impact
1	No Discernable Environmental Effect caused by System
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+

Inward Facing Impact & Risk

Ranking Value	Resilience Impact
1	No Discernable impact on system due to adverse Climate/External environmental impacts
2	System Normal operation slightly impaired by adverse Climate/External environmental impacts
3	System RAM performance notably impacted due to adverse Climate/External environmental impacts
4	System RAM performance significantly impacted by adverse Climate/External environmental impacts
5	System RAM 25-50% Loss of Function due to adverse Climate/External environmental impacts
6	System RAM 50-75% Loss of Function due to adverse Climate/External environmental impacts
7	System RAM > 75% Loss of Function due to adverse Climate/External environmental impacts
8	Single Unit Loss of Function due to adverse Climate/External environmental impacts
9	Multi-Unit Loss of Function due to adverse Climate/External environmental impacts
10	Entire Power Plant Loss of Function due to adverse Climate/External environmental impacts

* 2025 ACR Toolkit Enhancement

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Asset - Risk Matrix

Fixed Weighted Risk Assessment to Variable Criteria Weighting and Risk Assessment*

Example Classification

System Criticality Ranking (SCR)	Value	System Dropdown Selection
Safety	1	No Safety Concern
Environment	10	Immediate Violation (without Warning)
Plant Availability	10	Plant Shut Down (all Units)
Heat Rate Efficiency	2	20 > Reduction ≥ 0
Cost Factor	10	System Cost 10
System Criticality Ranking (SCR)	17.46	Min = 2.24, Max =22.36

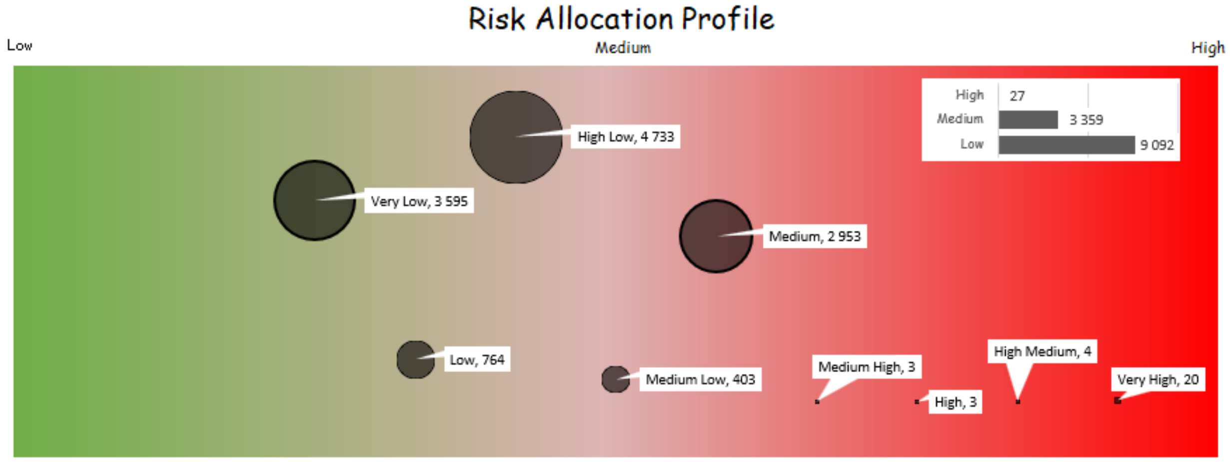
Component Criticality Ranking (CCR)	Value	Component Dropdown Selection
Safety	10	Redundant Safety System 2.1
Environment	7	Immediate Non-Compliance (without Warning)
System Availability	2	Component Availability 2
Heat Rate Efficiency	5	60 > Reduction ≥ 50
Cost Factor	3	Component Cost 3
Operational Criticality Ranking (OCR)	13.67	Min = 2.24, Max =22.36
Component Criticality Ranking (CCR)	238.82	Min = 5, Max =500
Asset Failure Probability Factor (AFPF)	2	Min = 1, Max = 10
Maintenance Priority Index (MPI)	477.64	Min = 5, Max = 5,000

Calculations

System Criticality Ranking (SCR)	17.46	System: SQROOT(Safety^2 + Environment^2 + Availability^2 + Efficiency^2 + Cost^2)
Operational Criticality Ranking (OCR)	13.67	Component: SQROOT(Safety^2 + Environment^2 + Availability^2 + Efficiency^2 + Cost^2)
Component Criticality Ranking (CCR)	238.82	Calculated: System Criticality Ranking (SCR) * Operating Criticality Ranking (OCR)
Maintenance Priority Index (MPI)	477.64	Calculated: Component Criticality Ranking (CCR) * Asset Failure Probability Factor (AFPF)

Maintenance Priority for 12 480 Components

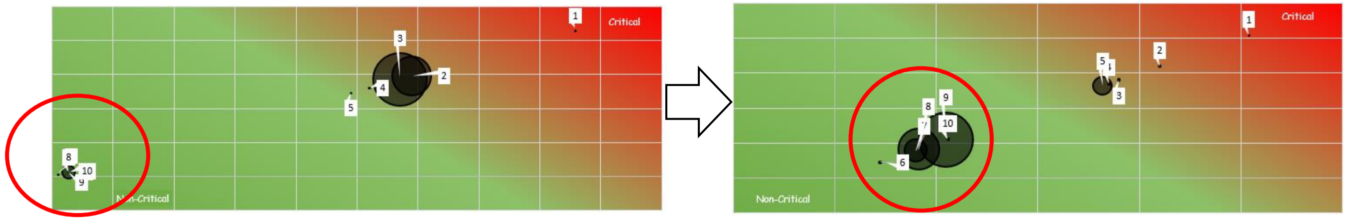
	RTF	NLM	NLS	NHM	NHS	CLM	CLS	CHM	CHS	SPV
10	1			1		2	3			20
9					1			1		
8		1	1			1	1			
7	2		2	2 253	1					
6					60	12				
5			1		1	1				
4		1	3	2 319	237	72	137	1		
3	19		9	31	2	4	22	318	11	
2			127	547	609	1 646	47	17	155	1
1	2	10	3 566	36	44	118	2			1



Number of Components per Risk Allocation | Selection Criteria Data

Very Low	3 595	Medium Low	403	High	3
Low	764	Medium	2 953	High Medium	4
High Low	4 733	Medium High	3	Very High	20

Unit (s)	All
Classification	CLM
Risk Level	2



Assets with initial Low weight and resilience impact

Criticality Criteria Weight and resilience changes result in notable changes to the risk profile

* 2025 ACR Toolkit Enhancement

Human Resilience impacts

The ability to MANAGE and LEAD through Resilience Impacts and be adaptable to continuous CHANGE

Ability to recognize context:

- See (Environmental, Emotional & Relational Scanning)
- Analyze
- Anticipate

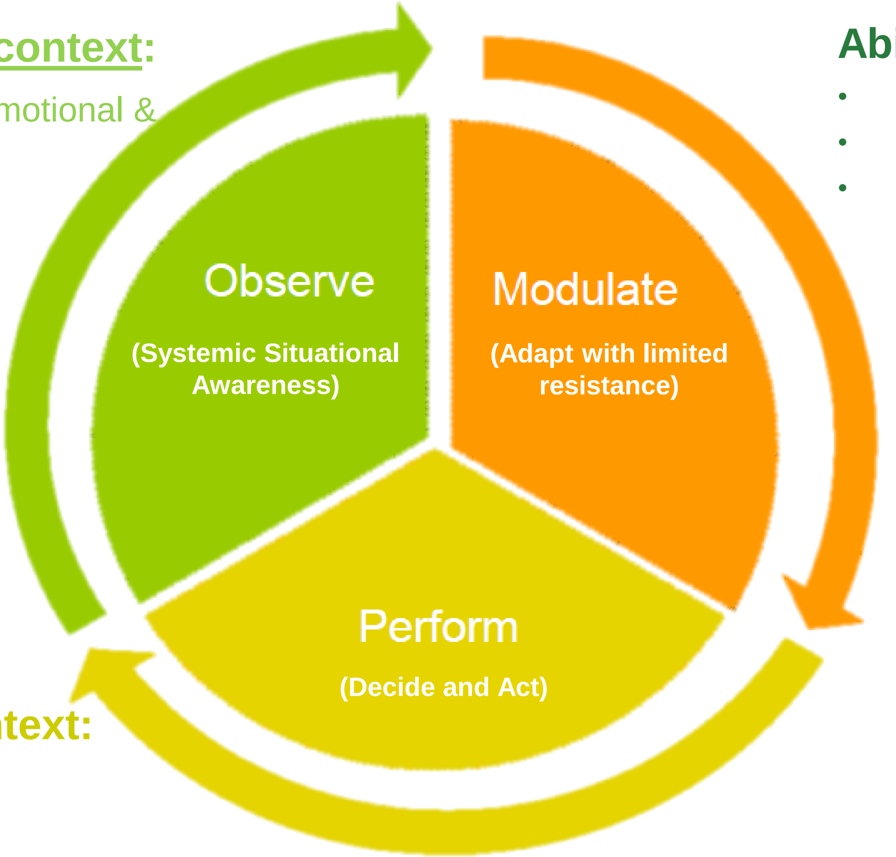
Competencies:

General: Honesty, Psychological Safety, ***Active*** Observation (research, polling)

Self: Honest self-appraisal

Team: Team Advocate

Experience is an asset, but can also create "blind spots"



Ability to act on context:

- Decide
- Resource
- Implement

Competencies:

General: Resource Management, Technical & Interpersonal skills

Self: Build an environment where you can succeed, Confidence (thru experience or OE)

Team: Dependability & Timeliness, Field interaction

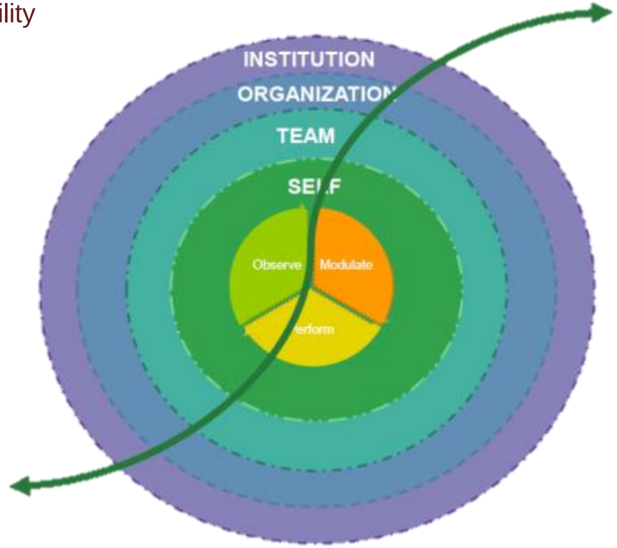
Ability to align with context:

- Assimilate
- Accommodate
- Adapt

Competencies:

Self: Self-Awareness (Needs, strengths, weaknesses, inputs/ outputs), Composure, Stress Management

Team: Foresight and adaptability



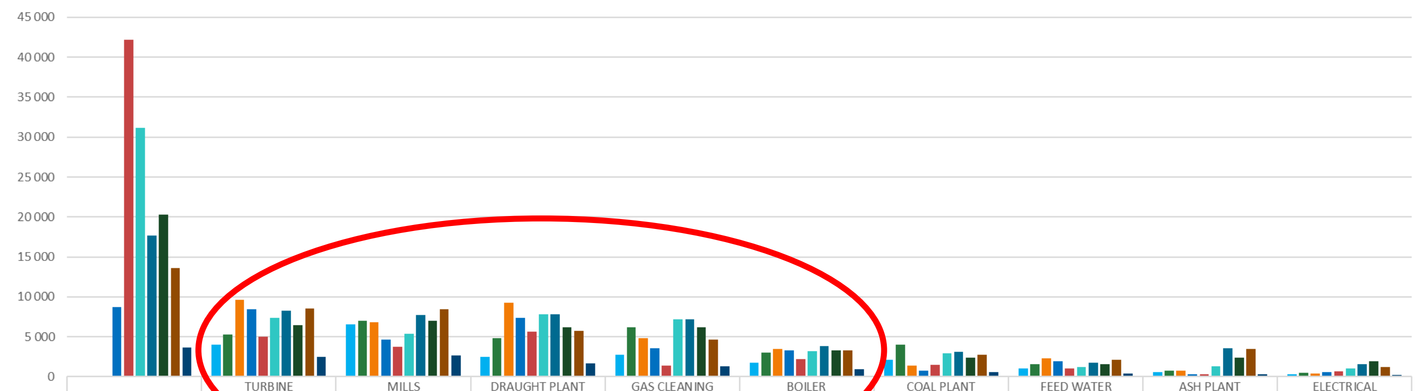
The level of capability needed will radically increase as you move through the barriers and layers from self to institution.

Source & Acknowledgement: Dr Lisa Lande, IAEA

Human Resilience & Capability Matters

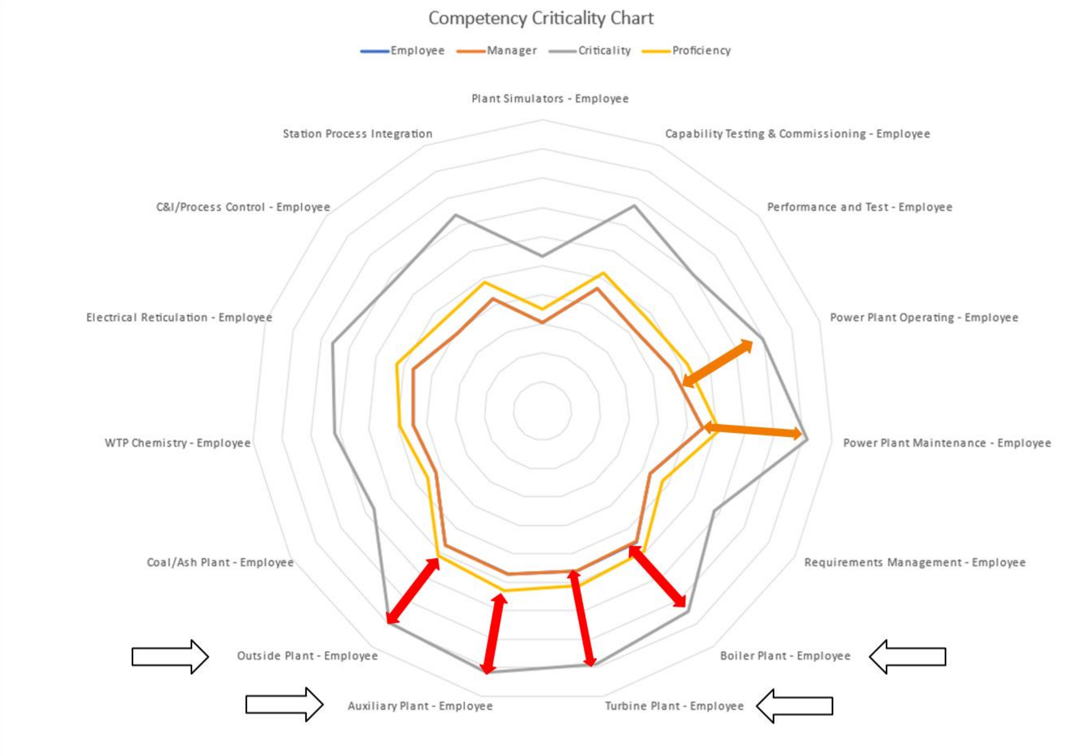
Skill & Capability does have correlation with plant performance!

MWLOSS - Cause Category 2013-2022



		TURBINE	MILLS	DRAUGHT PLANT	GAS CLEANING	BOILER	COAL PLANT	FEED WATER	ASH PLANT	ELECTRICAL
2013	48	4 025	6 510	2 460	2 790	1 755	2 092	1 014	585	349
2014	11	5 254	7 024	4 802	6 148	[illegible]	4 013	1 617	797	481
2015	36	9 612	6 796	9 294	4 826	3 445	1 416	2 281	739	404
2016	8 758	8 494	[illegible]	7 392	3 570	3 276	740	1 959	311	574
2017	42 198	4 978	3 705	5 602	1 374	2 218	1 526	1 072	349	648
2018	31 122	7 391	5 366	7 824	7 163	3 161	2 925	1 254	1 290	1 062
2019	17 688	8 238	7 761	7 796	7 147	3 817	3 128	1 772	3 599	1 577
2020	20 279	6 447	7 006	6 161	6 233	3 328	2 354	1 578	2 391	1 903
2021	13 632	8 543	8 404	5 768	4 683	3 277	2 740	2 143	3 458	1 233
2022	3 694	2 443	2 639	1 636	1 326	907	603	359	322	223

2013 2014 2015 2016 2017 2018 2019 2020 2021 2022



- S&C Proficiency Gaps most notable in the plant areas contributing to the most pant load losses (Boiler & Auxiliaries, Turbine and Auxiliaries and Emission Management Technologies)
- Extends to Operator and Maintenance S&C's vital to maintain asset health with complex equipment arrangements

Radar Graphs: Map employee/manager skill & competency (S&C) rating against criticality of the dimension for the job role and the required level of proficiency.

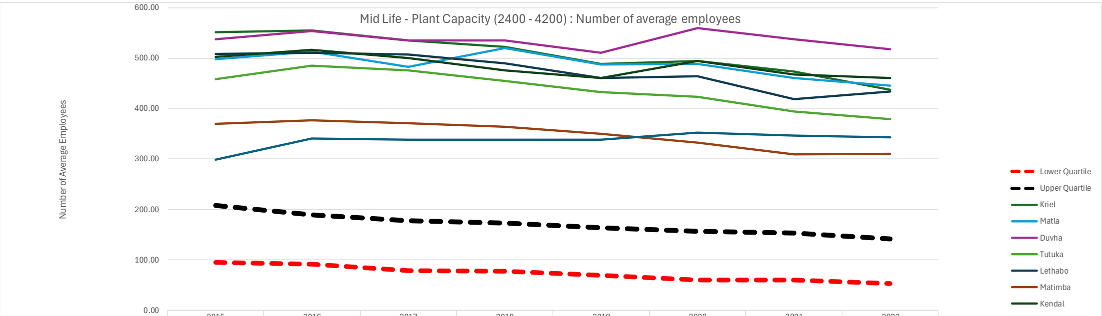
Asset Performance Analytics

Focused & Fixed Analytic base to *Adaptive, Flexible and Multi-dimensional* Analytics

Select	EPRI Range to be Graphed	25.0%	75.0%	Plant-Centric Comparison
Life Cycle	Metrics to be Graphed	Plant Operating Capacity (Min - Max)		Ignore Records that have Metrics Value Missing: / Number of Average Employees
Mid Life	Number of average employees	2,400	4,200	0

8 Sites

Will ignore sites that have 0 metrics values missing



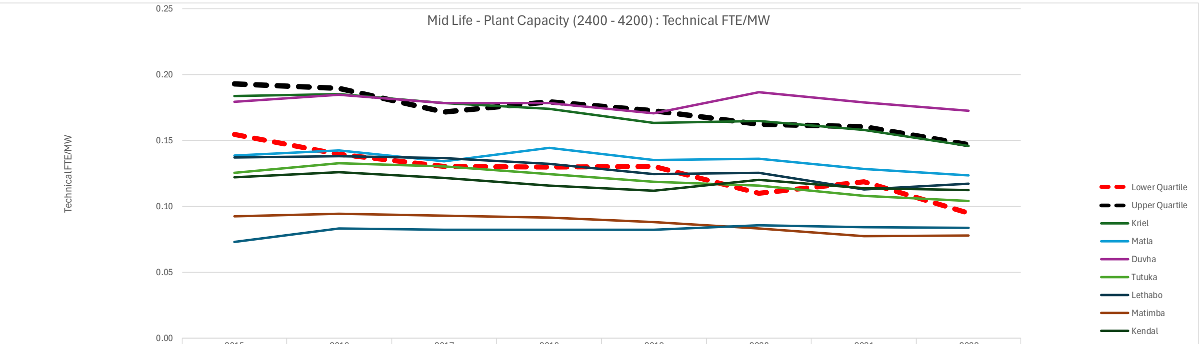
	2015	2016	2017	2018	2019	2020	2021	2022
Lower Quartile	94.00	91.00	78.50	77.00	69.25	59.50	59.25	52.75
Upper Quartile	207.75	189.25	177.25	172.00	163.50	156.25	152.75	141.00
Kriel	551.00	555.00	535.00	522.00	489.00	494.00	473.00	437.00
Matla	498.00	513.00	483.00	520.00	487.00	489.00	461.00	445.00
Duvha	538.00	554.00	535.00	535.00	511.00	559.00	537.00	518.00
Tutuka	458.00	485.00	476.00	455.00	433.00	423.00	394.00	379.00
Lethabo	508.00	511.00	507.00	490.00	461.00	464.00	418.00	434.00
Matimba	369.00	377.00	371.00	364.00	350.00	332.00	309.00	310.00
Kendal	502.00	517.00	500.00	476.00	460.00	494.00	468.00	461.00
Majuba	299.00	341.00	338.00	338.00	338.00	352.00	346.00	343.00

Evaluation of metrics on a more individualized basis to draw business insights

Select	EPRI Range to be Graphed	25.0%	75.0%	Plant-Centric Comparison
Life Cycle	Metrics to be Graphed	Plant Operating Capacity (Min - Max)		Ignore Records that have Metrics Value Missing: / Technical FTE/MW
Mid Life	Technical FTE/MW	2,400	4,200	1

8 Sites

Will ignore sites with missing metrics values

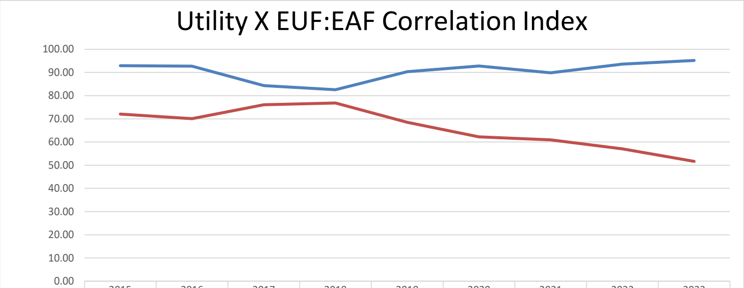


	2015	2016	2017	2018	2019	2020	2021	2022
Lower Quartile	0.15	0.14	0.13	0.13	0.13	0.11	0.12	0.09
Upper Quartile	0.19	0.19	0.17	0.18	0.17	0.16	0.16	0.15
Kriel	0.18	0.19	0.18	0.17	0.16	0.16	0.16	0.15
Matla	0.14	0.14	0.13	0.14	0.14	0.14	0.13	0.12
Duvha	0.18	0.18	0.18	0.18	0.17	0.19	0.18	0.17
Tutuka	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.10
Lethabo	0.14	0.14	0.14	0.13	0.12	0.13	0.11	0.12
Matimba	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08
Kendal	0.12	0.13	0.12	0.12	0.11	0.12	0.11	0.11
Majuba	0.07	0.08	0.08	0.08	0.08	0.09	0.08	0.08

Enabling resilience analytics by allowing analytics across asset performance metrics to be interrogated in an adaptive manner, to bring new business insights by exposing statistically significant relationships.

In this example, considering employee numbers (FTE) in isolation may indicate above average staff numbers.

But evaluated against FTE/MW, the Utility's performance generally outperform those of comparative peers of same age plant and technology – showing a better RoI on staff utilization

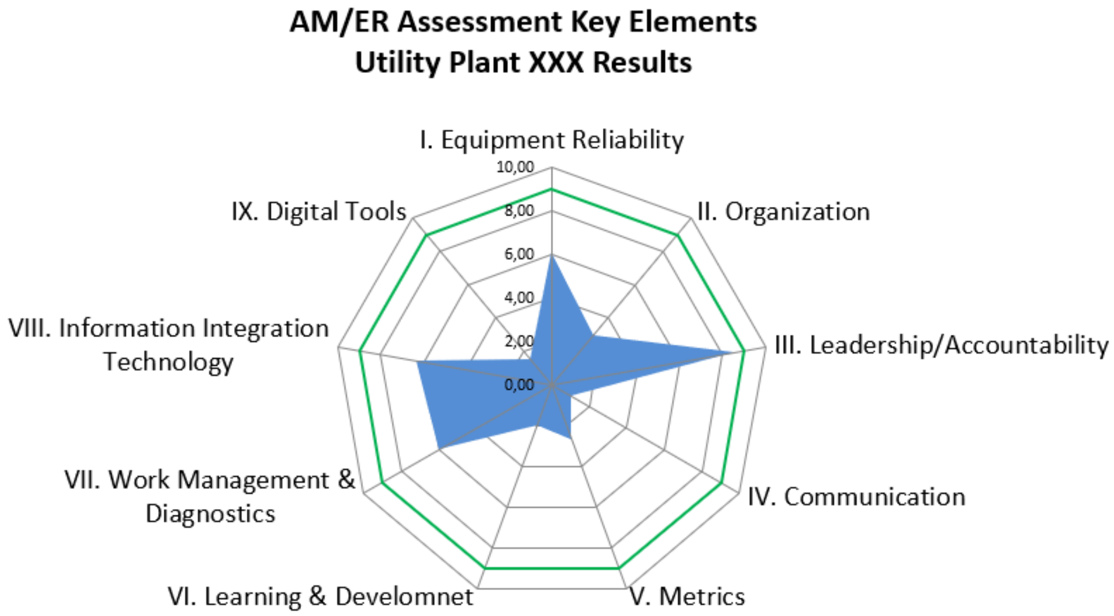


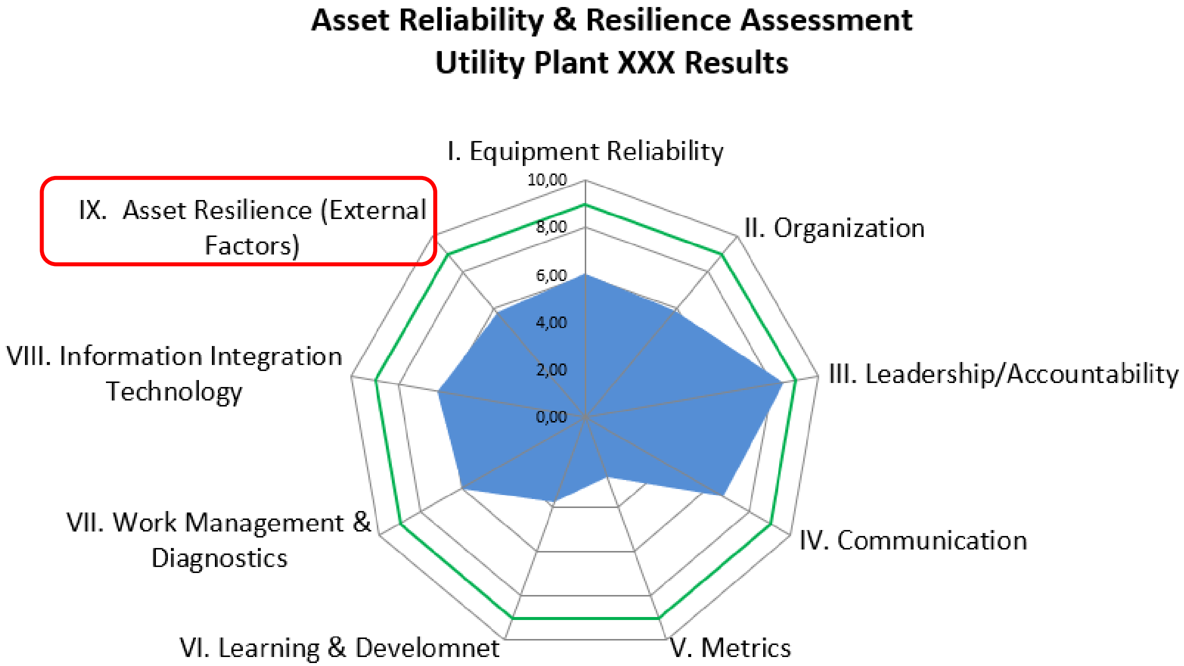
	2015	2016	2017	2018	2019	2020	2021	2022	2023
Average EUF	92.93	92.68	84.35	82.56	90.33	92.81	89.87	93.61	95.19
Average EAF	72.08	70.08	76.07	76.82	68.47	62.23	60.95	57.07	51.63

The statistical relevance correlation index between asset management performance metrics for Utility X Plants can be interrogated – in the example it is significantly strong and inversely related at -0,75.

Asset Benchmarking

Measuring Internal AM Processes and Efficiencies to ***Resilience Aware*** **Holistic Asset Management**





2 Key **External Factors** impacting Asset Management:

- Climate Impact & Disaster Resilience
- Cyber Threats (Cyber Security)

Collaboration initiative with EPRI Cyber Security Program in progress

In Closing… Some of the Opportunities

Improving understanding of asset behaviour and impacts of climate resilience on RUL – collaboration vehicles like ClimateREADi

Leveraging AI and Machine learning to be more predictive in understanding asset behaviour and making informed decisions about them

Industry & Country/Regional Collaboration on Disaster Resilient Infrastructure – Asset Owners, Designers, Constructors / Manufacturers & Society

Real-time asset tracking & Smart-Sensors (having near-real-time data available)

CLIMATE READi RESILIENCE AND ADAPTATION INITIATIVE

Advanced Analytics – Improving Adaptive & Predictive Capability of assets

Contextual climate and asset condition data sharing to improve knowledge and staff resilience/decision-making

Robotics and technology to remove / reduce human risk in adverse climate & weather conditions

Discussion - Q&A

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