Cognitive plants through proactive self-learning hybrid digital twins

COGNITWIN

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Deliverable Report

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Executive Summary

This report presents the Coordination and Performance Indicators measurement framework for the COGNITWIN project per August 2021 (M24).

The metrics and related measurements are related to the 8 main COGNITWIN objectives. The report describes the KPI metrics and associated measurements approaches and plans which also are associated with the various 8 workpackages of COGNITWIN.

In order to monitor the progress and evolution for the likelihood of meeting the pilot KPIs (from each of the pilots in WP1, WP2 and WP3) and the relationship to the technology and innovation KPIs a 6 monthly evaluation framework will be instansiated with measurements collected from each COGNITWIN partner per M30, M36 and M42 – with first report for this planned per M30.

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Acronyms

KPI	Key Performance Indicator
DT	Digital Twin
GTC	Gas Treatment Centre
IoT	Internet of Things
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency

1 Introduction - Key Performance Indicators and Measurement framework

This report presents the Coordination and Performance Indicators measurement framework for the COGNITWIN project per August 2021 (M24).

The metrics and related measurements are related to the 8 main COGNITWIN objectives, which also are associated with the various 8 workpackages of COGNITWIN.
The metrics and related measurements approaches are presented first for the six COGNITWIN pilots from WP1, WP2 and WP3 and related to the COGNITWIN objectives 1, 2 and 3.

The key performance indicators for the technology workpackages of WP4 and WP5 are presented next together with the individual KPIs for the eight COGNITWIN Technology partners. The COGNITWIN objectives 4 and 5 are related to WP4 and WP5. The metrics and measurement approach for the COGNITWIN Innovations and Business impact is presented next as related to the responsibilities of WP6, and the COGNITWIN objectives 6 and 7.
The metrics and associated KPI measurements for COGNITWIN Communication and Dissemination are presented based on the work for this done in WP7, and the COGNITWIN Objectives 5 and 8.
Finally the project management from WP8 is presented with the progress monitoring approach for the Administrative coordination, Technical coordination and Innovation Impact coordination.

In order to monitor the progress and evolution for the likelihood of meeting the pilot KPIs (from each of the pilots in WP1, WP2 and WP3) and the relationship to the technology and innovation KPIs a 6 monthly evaluation framework will be instansiated with measurements collected from each COGNITWIN partner per M30, M36 and M42 – with first report planned per M30.

2 Key Performance Indicators and Measurement framework – (WP1, WP2 and WP3 (Pilots))

2.1 KPIs and Measurements for Pilots – (WP 1, 2 and 3)

The following COGNITWIN Objectives 1, 2 and 3 are related to KPIs and Measurements for the COGNITWIN Pilots.

COGNITWIN Objective 1: *COGNITWIN for Industry Process Excellence* - **Show improved performance in cognitive production plants by a technology demonstration of fully digitalized pilots**. Major elements will be to introduce robust, accurate and cost-efficient sensors using retro-fitting as well as novel new sensors as needed to achieve the planned cognitive elements in form of proactive self-learning digital twins.

Status: The improved performance is in progress through the 6 pilots in the areas of Aluminium Production Process, Silicon Production Process, Steel Production Process Engineering Boiler operations through Digital Twin technology demonstrators of WP1, WP2 and WP3.
The project has the following objectives of Improved Performance in Cognitive production Plants through Cognitive Digital Twins in the selected process industry types, as further described in the deliverables D6.1 and D6.2 and detailed in the deliverables D1.1/D1.2, D2.1/D2.2 and D3.1/D3.2. – and also in D6.2 – with D1.3, D2.3 and D3.3 planned for M32
The work towards these objectives is in progress as reported in the deliverables Dx.1 and Dx.2 from the pilot work packages WP1, WP2 and WP3, respectively. The baseline KPIs for the

evaluation towards the end of the project has been reported in deliverable D6.1. It is still too early in the project to measure the actual effects of the pilot demonstrators.

COGNITWIN Objective 2: *Cognitive Digital Twins for Cognitive retrofitting.* Enabling an efficient and well defined approach for "cognitive augmentation" of physical assets, processes and systems, as a means for Cognitive Digital Transformation in Process industry,
It will be measured through the easieness and completeness of using Cognitive Digital Twins as main building blocks for modeling cognitive plants. We aim at being able to a) model all (100%) elements of a plant, b) by requiring moderate modelling skills for at least 75% modelling tasks. In addition, the success will be measured by its easiness and performances (see KPIs in each pilot) of applying cognitive digital twins in different application areas covered by selected pilots.

Status: *Cognitive* Digital Twins are in progress as the main focus in the project phase from M30 to M42. The work towards this is being coordinated in the Cognitive Digital Twin task in WP5, as reported in the deliverables D5.1 and D5.2 from the WP5, and will be applied for the pilots in work packages WP1, WP2 and WP3, respectively. The analysis of easiness and completeness will be undertaken in the forthcoming project periods, when cognition support has been further introduced.

COGNITWIN Objective 3: *Hybrid Twins for Optimised process performance* **by hybrid models that not only combines models and data-driven models, but additionally use machine learning, AI and the connected data bases to pro-active forecast and communication, as well as self-learning by recognition of pattern in the data**
It will be measured through the ratio of successfully recognition of previously known and unknown situations in the selected pilots. We aim at being able to know by i) recognition of 100% previously known situations, and ii) how to react on situations that occur for the first time in 80% cases.

Status: *Hybrid Twins are in progress and the main focus of the next project phase from M18 to M30.* The work towards this is in progress as reported in the deliverables D5.1 and D5.2 from the work package WP5. In particular with the aim of combining multiple models through Hybrid Digital Twins. The recognition of unknown situations will be addressed in the context of Cogntive Digital Twins for the final project phase.

The following describes the individual KPIs for each of the six industrial pilots in WP1, WP2 and WP3. It is still too early in the project to measure the actual effects of the pilot demonstrators, but in the next period a 6 monthly based measurement framework will be set up to follow up the metrics with incremental measurements for the project milestones of M30, M36 and M42.

At M24 It is still likely that these KPIs will be met by the end of the project, and in order to monitor the evolution towards this a framework with 6 months incremental measurements is being planned from M30.

2.1.1 Aluminium Production Process (Hydro)

Aluminium Production Process: Increase efficiency of 10% by achieving symbiosis between the actual production (electrolysis) and the cleaning technology (Gas Treatment Centre GTC). Improved environmental impact and optimize energy consumption by maximizing the efficiency of the Gas Treatment Centre.. Since the pilot is divided into several cases, in which all aim to increase the raw material stability to the electrolysis and energy consumption of the GTC, each of the cases (numbered 1-3) are set up with a tangible KPI's. These KPI's will play into the overall KPI's in the application. Matched and even distribution of HF to primary alumina feed, by demonstrating primary feed matching HF mass flow (calculated from logged operational data). 2. Keep constant temperature for best possible adsorption, i.e. 90°C ±5°C (from logged data) 3. Reduce the power consumption on the 3x 1 200 kW fans by 5%, measured by logged energy consumption from fans before and after activation of Case 3.

Table 1 Hydro pilot KPIs summary

Hydro - Gas Treatment Centre (GTC)	
KPIs	• Reduce suction rate overall by 10%, i.e. for the pilot in question, 1500 MWh/y saved fan work, and increased available recovered thermal energy of 13500 MWh/y • Reduce energy consumption in GTC by 15% • Maintain balanced flow distribution to different filter compartments within ±5% • Decrease process disturbance by preventive maintenance by 5%

Progress: It is still likely that these KPIs will be met by the end of the project.

2.1.2 Silicon Production Process (Elkem)

Silicon Production Process: Improve KPIs for post taphole silicon. The most important KPIs are: 1. Post-taphole yield (tonnage cast/tonnage tapped). These values are measured for each batch. 2. Hit-rate on chemical composition (intended product/actual product) 3. Specific energy use (kWh/tonnage cast). The energy is the electrical energy fed to the submerged arc-furnace. The goal of the project is (for relative values) to: Increase PTH yield from 100 to 102, increase hit rate on intended products from 100 to 102, Reduce energy consumption from 100 to 99, increase lifetime of ladles from 100 to 105 – based on relative initial values (100).

Table 2 ELKEM pilot KPIs summary

ELKEM – Post taphole silicon yield	
KPIs	• Increase post taphole output by up to 1% - for pilot plant this equals 400 MT/year for a gross value of 6.5 MNOK, or equivalent to an industry potential of 1.6 MEuro per 100 000 metric ton produced. • Increase PTH yield from 100 to 102 • increase hit rate on intended products from 100 to 102 • Reduce energy consumption from 100 to 99 • increase lifetime of ladles from 100 to 105

Progress: It is still likely that these KPIs will be met by the end of the project.

2.1.3 Steel Production Process (SIDENOR)

Progress: It is still likely that these KPIs will be met by the end of the project.

Steel Production Process: . Lifetime of refractory lining: Reference of 80 heats for total ladle relining and partial relining (slag line) at 40 heats. Reduction of the critical refractory depth for renewing the refractory lining: Initial refractory has 6 or 7 inches (155 mm or 180 mm) in different parts of the ladle. Final value of 50 mm is considered safe.

Table 3 SIDENOR pilot KPIs summary

SIDENOR - Cognitive Digital Twin of Steel Laddle	
KPIs	• Money saved by the pilot due to decreased ladle refractory consumption • Profits from process production due to decreased maintenance time • Lifetime of refractory lining: Reference of 80 heats for total ladle relining and partial relining (slag line) at 40 heats • Reduction of the critical refractory depth for renewing the refractory lining: Initial refractory has 6 or 7 inches (155 mm or 180 mm) in different parts of the ladle. Final value of 50 mm is considered safe.

Progress: It is still likely that these KPIs will be met by the end of the project.

2.1.4 Steel Production Process (Saarstahl AG)

Steel Production Process: . 15% improved efficiency. 10% lower environmental impact through optimized production processes. 90% improved automatic error detection.

Table 4 Saarstahl pilot KPIs summary

Saarstahl - Steel rolling lines	
KPIs	• Improve rolling line efficiency – target 15% • Lower environmental impact through optimized production processes – target 10% • Improved automatic error detection – target 90%

Progress: It is still likely that these KPIs will be met by the end of the project.

2.1.5 Steel Production Process (NOKSEL)

Steel Production Process: Real-time online monitoring of process efficiency with minimal latency - Target: 100 ms. Accuracy of data analytics, and AI algorithms -Target % 100. Percentage of Type 1 error in anomaly detection (incorrect rejection of a true null hypothesis) - Target % 0.5. Percentage of Type 2 error in anomaly detection (failure to reject a false null hypothesis) - Target % 0.5 Reduction in machine downtime - Target % 10. Reduction in energy consumption - Target % 10. 15% improved efficiency. 10% lower environmental impact through optimized production processes. 90% improved automatic error detection.

Table 5 NOKSEL pilot KPIs summary

NOKSEL – Digital Twin Powered Condition Monitoring (and Control) in Steel Manufacturing Industry	
KPIs	• Real-time online monitoring of process efficiency with minimal latency - Target: < 100 ms • Accuracy of data analytics, and AI algorithms -Target > % 95 • Percentage of Type 1 error in anomaly detection (incorrect rejection of a true null hypothesis) - Target < 5% • Percentage of Type 2 error in anomaly detection (failure to reject a false null hypothesis) - Target < 5% • Reduction in machine downtime due to conducted predictive maintenance - Target % 10 • Reduction in energy consumption - Target % 10

Progress: It is still likely that these KPIs will be met by the end of the project.

2.1.6 Engineering (Sumitomo SHI FW)

Engineering Boiler operations - The measurable target improvements of KPIs are set to – Improved boiler operating efficiency: +0.05-0.10 % in average as cont. Performance. Lower operating costs, boiler O&M cost: -100 k€/year during the first 5 years. Smaller emissions, decrease emissions avoid limit exceedings: overall levels -20%. Improved reliability and availability: +0.3-0.5 % in plant availability"

Table 6 Sumitomo pilot KPIs summary

Sumitomo SHI FW – Boiler Operations	
KPIs	• Decreased emissions, avoid limit exceedings: overall levels -20% • Improved boiler operating efficiency: +0.05-0.10 % in average as continuous performance • Lower operating costs, boiler O&M cost: -100 k€/year during the first 5 years • Improved reliability and availability: +0.3-0.5 % in plant availability

Progress: It is still likely that these KPIs will be met by the end of the project.

3 KPIs and Measurements for Technologies – (WP 4 and 5)

3.1 Technical objectives, metrics and measurements

The following COGNITWIN Objectives 4 and 5 are related to KPIs and Measurements for COGNITWIN Technologies.

COGNITWIN Objective 4: *CogniTwin Interoperability Toolbox as a Service*. **A reference architecture for the cognitive elements including of Big Data, Databases, IoT, Smart Sensors, Machine Learning, and AI technologies that realizes hybrid modelling, self-**

adaptivity and cognitive recognition, leveraging/extending the existing work into relevant communities.

It will be measured through the percent of reuse of the elements of the architecture in the imp lementation of the use cases. We aim at being able to use each of the modules from the Toolbox in at least two use cases. Currently the focus in the first phase has been to use the components in one use case. The plan for the next phase is to seek replicated usage of components in particular related to digital twin representations and pipelines in more than two use cases, and also to identify possible re-use of components also outside of the consortium through future market activities.

Status: A Digital Twin reference architecture has been made in WP4 – and is used as the basis for the COGNITWIN Toolbox development in WP4 and WP5. The work towards this is in progress as reported in the deliverables D4.1 and D4.2 and the forthcoming D4.3 (M30) from the work package WP4. The project is pilot driven with a focus on the demonstration of technologies initially within one pilot, and then with a further aim to expand and replicate use of technologies within further pilots and use case opportunities. Pilot driven means that we will focus on the creation of components that meets the needs of the pilots, and then seek to generalise this components so that they can be used in multiple usage situations. The aim of the COGNITWIN Toolbox is to be the basis for the further use of components and pipeline elements in multiple use case situations.

COGNITWIN Objective 5: *COGNITWIN for increasing European technology dominance.* **Ensure the dominance of the Europe in technologies related to cognitive plants, thereby influencing the further development of Big Data, Databases, IoT, Smart Sensors, Hybrid Modelling, Machine Learning and AI technologies** in relevant communities, focusing on the capabilities of the developed technologies for creating new generations of self-adaptive and cognitive algorithms and models. *It will be measured through the influence on the relevant Industry standards, especially in the emerging domain of Digital Twins.*

Status: The influence by technology development and innovation has a foundation in the technologies developed and applied in the technical work packages 4 and 5. The developed tools and components will be structures into the COGNITWIN Toolbox, and the analytics and AI services will be provided through D5.1 and D5.2 and the forthcoming D5.3(M30).
The technologies in progress will be further promoted through the exploitation strategies in WP6 and standards impact for Digital Twins as managed by WP7.

In order to monitor the progress and evolution for the likelihood of meeting the technical KPIs (for WP4 and WP5) a 6 monthly evaluation frameworks will be instantiated with measurements collected from each technical partner per M30, M36 and M42 – with first report due per M30

The following figure 1 shows the partner components (in red) in the COGNITWIN Toolbox Portal. Figure 2 shows some of the component entry points in the Toolbox Portal. Table 1 and Table 2 shows a mapping between the six COGNITWIN pilots and how they are using technology components from WP4 and WP5 to meet their needs – shown by an x – and also the potential for further usage of components across pilots shown by (x).

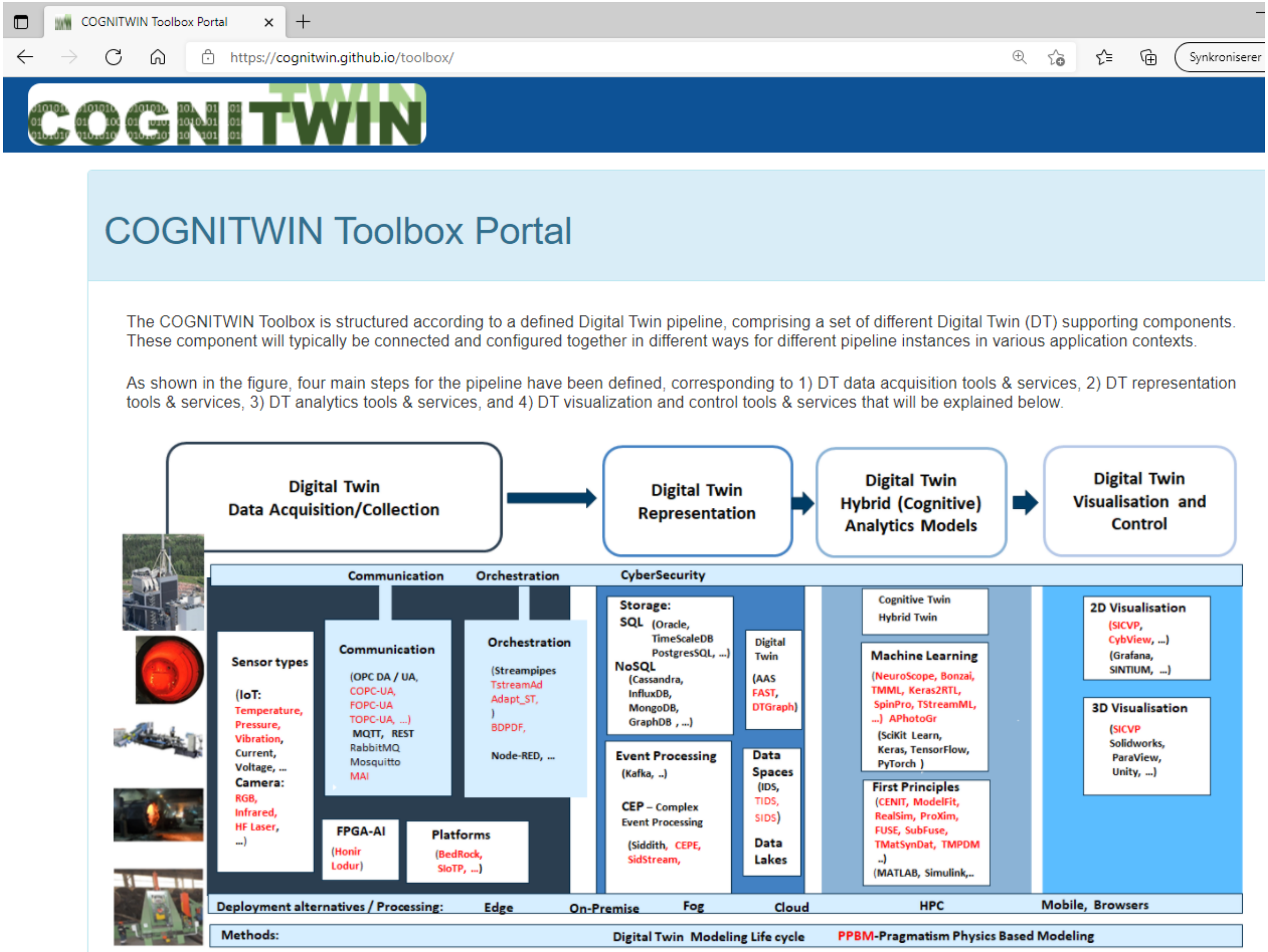

Figure 1 Startpage for COGNITWIN Toolbox Portal

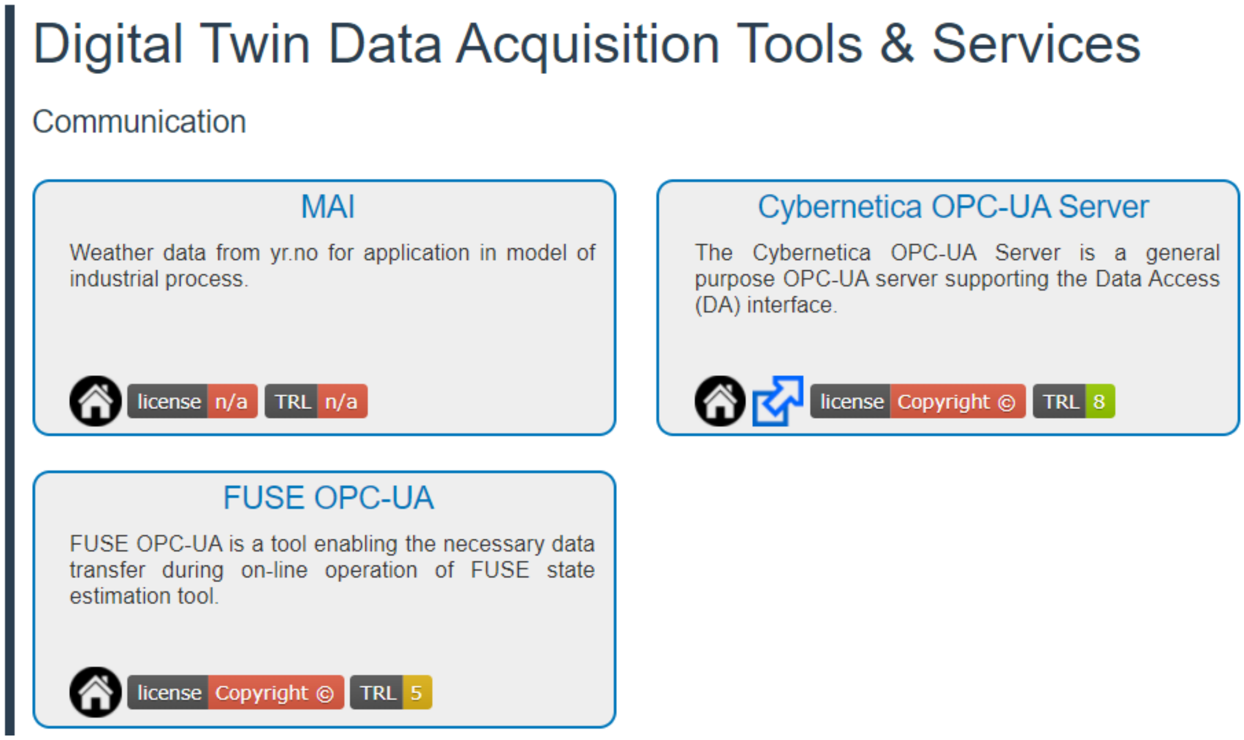

Figure 2 Examples of some components in the COGNITWIN Toolbox

Table 7 COGNITWIN Toolbox WP4 components for the requirements x and potential needs (x) for each pilot

Pilot type	Pilot	Task	WP4 Toolbox COMPONENTS																					
			MAI (SINTEF)	Cybernetica OPC UA (Cybernetica)	FUSE OPC UA (UOULU)	Tstream(Teknopar)	BD Pipelines DF (SINTEF)	Honir (Scortex)	Lodur (Scortex)	Bedrock (SINTEF	Steel4 IoTP (Teknopar)	FAST (Fraunhofer)	Tmat SynDat (Teknopar)	DT Graph (SINTEF)	StreamPipes + Siddhi (Fraunhofer)	CEP Editor (Fraunhofer)	IDS Connectors (SINTEF)	Trusted Factory Connector	COGNITWIN Toolbox Portal	Steel4 TCP (Teknopar)	Cybernetica Viewer (Cybernetica)	Sensor library (SINTEF)	Sensor data quality framework	
Non-ferrous	Hydro	WP4																						
		COGNITWIN Interoperability Toolbox													(x)				x					
		Digital Twin Cloud Platform, Data Space and Cyber Security		x	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)			(x)	(x)		(x	(x)			
		Sensors, Understanding Sensor Data & Quality Assurance	x																			(x)	(x)	
		Realtime sensor/data processing													(x)	(x)								
	Elkem	WP4																						
		COGNITWIN Interoperability Toolbox													(x)				x					
		Digital Twin Cloud Platform, Data Space and Cyber Security		x	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)			(x)	(x)		(x	(x)			
		Sensors, Understanding Sensor Data & Quality Assurance	(x)																			(x)	(x)	
		Realtime sensor/data processing													(x)	(x)								
Steel	Saarstahl	WP4																						
		COGNITWIN Interoperability Toolbox													(x)				x					
		Digital Twin Cloud Platform, Data Space and Cyber Security		(x)	(x)	(x)	(x)	x	x	(x)	(x)	(x)	(x)	(x)			(x)	(x)		(x	(x)			
		Sensors, Understanding Sensor Data & Quality Assurance	(x)																			(x)	(x)	
		Realtime sensor/data processing													(x)	(x)								
	Sidenor	WP4																						
		COGNITWIN Interoperability Toolbox													(x)				x					
		Digital Twin Cloud Platform, Data Space and Cyber Security		(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)	x	(x)	(x)			(x)	(x)		(x	(x)			
		Sensors, Understanding Sensor Data & Quality Assurance	(x)																			(x)	(x)	
		Realtime sensor/data processing													x	(x)								
	Noksel	WP4																						
		COGNITWIN Interoperability Toolbox													(x)				x					
		Digital Twin Cloud Platform, Data Space and Cyber Security		(x)	(x)	x	(x)	(x)	(x)	(x)	(x)	x	x	(x)			(x)	(x)		(x	(x)			
		Sensors, Understanding Sensor Data & Quality Assurance	(x)																			(x)	(x)	
		Realtime sensor/data processing													x	(x)								
Engineering	Sumitomo	WP4																						
		COGNITWIN Interoperability Toolbox													(x)				x					
		Digital Twin Cloud Platform, Data Space and Cyber Security		(x)	x	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)			(x)	(x)		(x	(x)			
		Sensors, Understanding Sensor Data & Quality Assurance	(x)																			(x)	(x)	
		Realtime sensor/data processing													(x)	(x)								

Table 8 COGNITWIN Toolbox WP5 components for the requirements x and potential needs (x) for each pilot

Pilot type	Pilot	Task	WP5 Toolbox COMPONENTS																					
			DFKI - : generation of photorealistic data	DFKI: Neuroscope	Nissatech: D2Lab-C	SINTEFs BEDROCK	TEKNOPAR Industrial Big Data Analytics (IBVA)	TEKNOPAR Machine Learning Library (TMLL)	SINTEF Open Framework and Tools (SOFT)	Machine learning for hybrid models (SINTEF)	Pragmatic framework for development of hybrid models	Cybernetica CENIT	Cybernetica Cognitive CENIT	Cybernetica ModelFit	Cybernetica RealSim	Cybernetica Viewer	Cybernetica ProXim	Cybernetica OPC UA Server	Bonzai (Scortex)	Como (Scortex)	Keras / tensorflow (Scoretex)	Physics-based model and data for state estimation (OULU)	Associated tools/models for plant modelling and simulation	Finite Markov Chains Matlab toolbox (MCPC) (OULU)
Non-ferrous	Hydro	Plant Digital Twins with ML/AI				(x)								x	(x)	(x)	(x)							
		Multi-variate Sensor analytics,Deep Learning																						
		Deep Learning Performance																						
		Hybrid Digital Twins				(x)			(x)	(x)	(x)	x						x				(x)		
		Cognitive Digital Twins			(x)							x	x											
	Elkem	Plant Digital Twins with ML/AI				(x)								x	(x)	x	(x)		(x)	(x)	(x)			
		Multi-variate Sensor analytics, Deep Learning																	(x)	(x)	(x)			
		Deep Learning Performance																	(x)	(x)	(x)			
		Hybrid Digital Twins				(x)			(x)	(x)	(x)	x						x				(x)		
		Cognitive Digital Twins			(x)							x	x											
Steel	Saarstahl	Plant Digital Twins with ML/AI	x	x															x	x	x			
		Multi-variate Sensor analytics, Deep Learning	x	x															x	x	x			
		Deep Learning Performance	x	x															x	x	x			
		Hybrid Digital Twins	x	x																				
		Cognitive Digital Twins	x	x																				
	Sidenor	Plant Digital Twins with ML/AI				(x)								(x)	(x)	(x)	(x)							
		Multi-variate Sensor analytics, Deep Learning																						
		Deep Learning Performance																						
		Hybrid Digital Twins				(x)			(x)	(x)	x	(x)						(x)				(x)		
		Cognitive Digital Twins			x	(x)						(x)	(x)											
	Noksel	Plant Digital Twins with ML/AI				(x)	x	x																
		Multi-variate Sensor analytics, Deep Learning					x	x																
		Deep Learning Performance																						
		Hybrid Digital Twins				(x)	x	(x)														(x)		
		Cognitive Digital Twins				(x)	(x)	(x)																
Engineering	Sumitomo	Plant Digital Twins with ML/AI												(x)	(x)	(x)	(x)		(x)	(x)	(x)	x	x	
		Multi-variate Sensor analytics, Deep Learning																	(x)	(x)	(x)			
		Deep Learning Performance																	(x)	(x)	(x)			
		Hybrid Digital Twins				(x)	(x)	(x)	(x)	(x)	(x)	(x)						(x)				x		(x)
		Cognitive Digital Twins			(x)	(x)	(x)	(x)				(x)	(x)									x		

The relationships between the pilot requirements and needs and the provided technologies from WP4 and WP5 with use of corresponding components will be followed up with incremental analysis of requirements fullfilment with incremental reports on this for the project milestones of M30, M36 and M42. A further requirements analysis in fortcoming deliverables from WP1, WP2 and WP3 – and corresponding deliverables from WP4 and WP5, will elaborate further on the mappings between pilot requirements and needs and the offerings of the various technology components in the COGNITWIN Toolbox.

3.2 Technology partner specific KPI's

The following describes the individual KPIs for each of the eight technology partners, related to the COGNITWIN Toolbox components. This will be followed up in the context of the provided technology components and their matches with pilots requirements and needs for the project milestones of M30, M36 and M42.

3.2.1 Cybernetica

Cybernetica - **relevant KPIs**
Sensor faults should be detected, isolated and alarmed:

- Abrupt sensor faults should immediately be detected, and no faulty measurements should be used for model updates (100 % wild-point rejection).
- Consecutive faulty measurements should, after a configurable number of samples, lead to an alarm and automatic re-configuration of the online application.

3.2.2 Teknopar

Teknopar - **relevant KPI’s**

- Latency in real-time visualization of sensor data < 100 ms
- Accuracy of AI algorithms > 95%
- Type I Error in estimations < 5%
- Type II Error in estimations < 5%
- Please note that the KPIs are updated to be more realistic and feasible.

3.2.3 Fraunhofer

Fraunhofer - **relevant KPI’s**

- % of the AAS specification part I that has been implemented
- Number of endpoints defined by the AAS specification part II that have been implemented
- Number of use cases realized by FAST
- Number of (external) developers that use or contribute to FAST

3.2.4 Scortex

Scortex **relevant KPI’s**

- Robustness: Enable 5 year warranty. Which makes our solution easier to sell.

- Integration: Lower maintenance and integration costs
- Performance: Enable business with high FPS required (which is what we do today)
- Energy: Enable to provide a greener solution

3.2.5 Nissatech

Nissatech **relevant KPI's**

- KPI1. Process-understanding: it is a user-driven validation, where a user will validate the soundness and completeness (KPIs) of information provided in health assessment. The goal is to have soundness > 85% and completeness > 90% (measured as precision and recall).
- KPI2. Technical: it is automatic testing with predefined scenarios/data, measuring the service execution time and resource consumption (KPIs). The goal is to decrease delay in presenting results (< 10min) and decrease the infrastructure costs.
- KPI3. User experience: since the users should interacts with the system intensively, it is very important to measure user satisfaction. Overall satisfaction with the service, consisting of UX and business value): greater that 90%. UX: min 90%, Business: min 90%

3.2.6 DFKI

DFKI **- relevant KPI's:**

- Increase automatic detection of erroneous billets
- Increase trackability of billets in Nauweiler

3.2.7 SINTEF

SINTEF **- relevant KPI's**

- Number of current and possible future usages of each of the various Digital Twin Toolbox components
- Number of use cases/pilots realized by each component
- Levels of user satisfaction for the components/solutions provided for the various pilots - Overall satisfaction with the service, consisting of UX and business value): greater than 90%. UX: min 90%, Business: min 90%
- Number of (external) developers that use or contribute to each component
- Number of components exposed for future standardisation and teaching

3.2.8 UOULU

UOULU **- relevant KPI's:**

- UOULU has its goals of exploitation in research and education.
- UOULU participates in supporting Sumitomo in reaching its KPI's.

4 KPIs and Measurements for Innovations and Business Impact - (WP 6)

The following COGNITWIN Objectives 6 and 7 are related to KPIs and Measurements for Innovations and Business Impact.

In order to monitor the progress and evolution for the likelihood of meeting the innovation and business impact KPIs (from WP6) a 6 monthly evaluation frameworks will be instandiated with measurements collected from each COGNITWIN partner per M24, M30, M36 and M42 – with first report due after the results per M24 (October 2021).

COGNITWIN Objective 6: *CogniTwin for SPIRE*. **Ensure the knowledge transfer of results and experiences from the COGNITWIN project** to the SPIRE Process Industry community, focusing in particular on active participation in the new SPIRE DG7 Digitalisation group and in SPIRE organized events. Impact will be measured through the influence on SPIRE members and association communities
Impact will be measured through the influence on SPIRE members and association communities – by activity engagement in these organisations

Status: The first steps toward knowledge transfer of results and experiences for SPIRE and P4Planet has started as managed by WP6. During the COVID-19 situtation few events have taken place within SPIRE. The work towards this is in progress as will be reported on in the WP6 Deliverable D6.2. Initial Exploitation Plan: Process Industry Impact report and Initial Business due for M24. There has been participation in some initial meetings in the SPIRE DG7 Digitalisation group, but this group has not been active during the latest Corona period.

COGNITWIN Objective 7: *CogniTwin for boosting European industry*. **Provide competitive advantage to the European industry, esp. SMEs in the global market**, through better exploitation of the synergies between Big Data, Databases, IoT, Smart Sensors, Hybrid Modelling, Machine Learning and AI technologies for an efficient resolution of complex process industrial challenges.

It will be measured through the number of the proposed business plans for exploiting CogniT win of the participating industries (incl. boosting of businesses through associated Digital Innovation Hubs -DIHs[2]).
Status: The exploitation of results is in progress through innovations from the partners as managed by WP6. The work towards this is in progress as will be reported on in the WP6 Deliverable D6.2. Initial Exploitation Plan: Process Industry Impact report and Initial Business due for M24. By M18 the development of business plans has been initiated by all of the 14 COGNITWIN partners.

The following lists the planned innovations from COGNITWIN:

Innovations:

1. TEKNOPAR CoTwins: A Micro Service Based Open Architecture to Develop Multi Model, Collaborative and Cognitive Digital Twins
2. Scortex FPGA compute platform
3. Nissatech cognitive tool-wear monitoring
4. Cybernetica CENIT: Digital twins for estimation, optimisation and control of industrial processes
5. Fraunhofer FAST
6. SINTEF – COGNITWIN Digital Twin Toolbox portal – and SINTEF components
7. Optimization and optimal control of GTC in aluminium production
8. Cognitive digital twin of steel ladle
9. Optimization of silicon process
10. Fouling management in energy boilers with fuel characterization
11. Tracking system for rolled bars in the rolling mill
12. Cognitive digital twin powered condition monitoring (and control) in steel pipe manufacturing industry

Further details on this, including related business impact, is elaborated on in deliverable D6.2 " Initial Exploitation Plan: Process Industry Impact Report and Initial Business Plan".

5 KPIs and Measurements for Communication and Dissemination - (WP 7)

The following COGNITWIN Objectives 5 and 8 are related to KPIs and Measurements for Communication and Dissemination.

COGNITWIN Objective 5: *COGNITWIN for increasing European technology dominance.* **Ensure the dominance of the Europe in technologies related to cognitive plants, thereby influencing the further development of Big Data, Databases, IoT, Smart Sensors, Hybrid Modelling, Machine Learning and AI technologies** in relevant communities, focusing on the capabilities of the developed technologies for creating new generations of self-adaptive and cognitive algorithms and models. *It will be measured through the influence on the relevant Industry standards, especially in the emerging domain of Digital Twins.*

Status: The influence by technology development and innovation in progress through the exploitation strategies in WP6 and standards impact for Digital Twins as managed by WP7. The technical work towards this is in progress as reported in the deliverables D4.1 and D4.2 from the work package WP4. And D5.1 and D5.2 from WP5. Further standardisation activities related to Digital Twins are coordinated from WP7 as planned for in Deliverable D7.2. in particular for the Industrial Internet Consortium, the Digital Twin Consortium and ISO SC 41 IoT and Digital Twin, with active participation from Fraunhofer and SINTEF.

COGNITWIN Objective 8: Effective dissemination and ensuring transfer of knowledge and experience generated in the pilots to the wide (European) audience in different industrial sectors by providing practical experiences from large-scale pilots to hundreds of companies through
associated DIHs.

It will be measured through the success in accelerating the adoption of CogniTwin concepts throughout the entire European audience (industry, technology transfer and academia). Effective dissemination of major innovation outcomes to the current next generation of employees of the SPIRE sectors, through the development, by education/training experts, of learning resources with flexible usability. These should be ready to be easily integrated in existing curricula and modules for undergraduate level and lifelong learning programmes.

Status: *The dissemination of results is in progress through various events (6+) and scientific publications (6) as managed by WP7.* The work towards this is in progress as will be reported on in the WP7 Deliverable D7.3: Intermediate report on dissemination, due for M24. The work on education/training and the identification of relevant active DIHs will take place during the next phase of the project.

Until M24 the following progress towards the dissemination KPIs has been made:

Table 9: Current status of the KPIs and related measurements for dissmennation activities in COGNITWIN project.

Dissemination Activity	Target Audience(s)	KPI	Current Status
White Papers	All stakeholders	>=3	Basis for White papers established with 2 flyers + 1 video + 2 newsletters
Demonstrator	Industry	>=7	6 pilot demonstrators + 6 technology/Toolbox demonstrators
Participation in Exhibitions	Industry, IT service providers	>=2	None physical (due to Covid-19 restrictions)
Participation in Workshops	Industry, IT service providers	>=4	2 (with other SPIRE projects)
Participation in Conferences	Industry, IT service providers	>=4	4 (with publications)
Organisation of Workshops with External Exploitation Partner	Industry	>=2	0 (Planned for next phase)
Presentations to Potential Customers	Industry	>=10	0 (Planned for next pase)
Organisation of Workshop, Conference, Special Session	Research community	>=3	2 (Project workshops with

			other SPIRE projects(ref. above) + journal special issue editing
Journal Publications	Research community	>=5	3
Book chapter Publications	Research/Industry	>=1	2
Conference Publications	Research community	>=20	4
Dissemination outside EU	Industry, IT service providers	>=3	1 (Industrial Internet Consortium + Digital Twin Consortium)
Participation in Clusters	Members of EU Projects in process industry and AI/ML	>=10	2 (SPIRE Project cluster + BDVA)
Liaisons with National Initiatives (e.g., I4.0, IDS, etc.)	Manufacturers, Policy Makers, Integrators of Industrial Solutions	>=10	4 (I4.0, IDS, DigiPro Norway, Process-Turke

Further details on this is elaborated on in deliverable D7.3 " Intermediate report on Communication and Dissemination activities".

6 KPIs and Measurements for Coordination and Management - (WP 8)

6.1.1 Administrative Coordination

Administrative coordination of the project is being carried out the project coordinator. Here, detailed working methods and implementation is agreed. Under the umbrella of this WP 8 (Project Management), all the activities necessary to comply with the EC contractual obligations are grouped. All partners are providing the needed information to monitor project achievements and they will contribute to the production of administrative reports and documents for the European Commission (Reports, Financial Statements etc.). Additionally, the risk elements are being reassessed regularly according to the Risk Assessment and Management Action Plan. A recurring meeting plan to track administrative progress of the project has been established. The measurements of progress according to this is being reported in the regular periodic progress reports.

6.1.2 Technical Coordination

Scientific & Technical Coordination of the COGNITWIN project is being carried on in this task. Here, the business / technical relevance and excellence of the project innovation lines and results are

assessed and reported. During technical coordination, it will be ensured that technical aspects of the project are being implemented smoothly. This task is being carried out by the Scientific Coordinator who is monitoring the technical work implementation in all WPs and is responsible for identification of any inconsistencies among specifications/development work and among technical WPs. A recurring meeting plan (every 2 weeks) to track technical progress of the project has been established.
The COGNITWIN project is developed with a pilot driven approach towards the priorities of the technology contributions. This is done to ensure a good coordination between the technical development related to the COGNITWIN Toolbox and business relevance for the pilots for the related technical project innovations. The six pilots and the technical work packages have organised regular meetings on weekly, bi-weekly or monthly basis. The scientific/technical coordination across WPs has been done through weekly meeting in the WP4/WP5 group alternating with bi-weekly WP4 and WP5 focus, respectively. There has further been regular pilot specific meetings with the pilot owners and the pilot supporting technical WP4/WP5 team.

For the coordinated support of the pilots, the technical partners have shared responsibility for the pilots as follows:

- Hydro pilot – supported by technical WP4/WP5 team from Cybernetica and SINTEF
- ELKEM pilot – supported by technical WP4/WP5 team from SINTEF and Cybernetica
- Saarstahl pilot – supported by technical WP4/WP5 team from DFKI and SCORTEX
- SIDENOR pilot – supported by technical WP4/WP5 team from NST, SINTEF and Fraunhofer.
- Noksel pilot – supported by technical WP4/WP5 team from Teknopar and SINTEF
- Sumitomo – supported by technical WP4/WP5 team from UOULU and SINTEF

The measurements of progress according to this is being reported in the regular periodic progress reports.

6.1.3 Innovation Impact Coordination

Innovation Management is being carried out in this task. Here, an agreement on detailed working methods and implementation routes will be made. Under the umbrella of this task all the activities necessary to comply with the IA contractual obligations and control points will also be grouped. The task involves the practical organization and management of the principles and concept for project results monitoring and control against innovation objectives. Recommendation for corrective actions will be issued for conflict situations if need. A periodic recommendation for the revision of objectives will be issued.

The innovation impact coordination is being managed in cooperation with WP6.

- Innovation impact for the pilots has been addressed through the KPI establishment with related baseline for each pilot.
- Innovation impact by the technology partners has been addressed through monitoring of the exploitable assets related to the components of the COGNITWIN Toolbox.
- A baseline for further innovation governance has been established through the first pilot demonstrators and the population of the COGNIWIN Toolbox during the first period, to be used for regular monitoring of the related KPIs for both pilots and technology components during the next phases of the project.

There is a regular monitoring and update of the progress towards the planned impact based on the identified performance indicators for each of the pilot plants in coordination with the pilots in WP1, WP2 and WP3. There is also a monitoring of the progress of the planned exploitable assets from the project and how these can have impact on European process industries linked to SPIRE and P4Planet as managed by WP6. The monitoring is following up the evolution of each of the 6 pilots and also all of the components in the COGNITWIN Toolbox. This will in the next phase also be enhanced with the monitoring of Digital Twin pipelines emerging from, and how these pipelines can serve as a foundation for replicated innovation.
A further detailed measurement framework is being set up for the more detailed monitoring of the innovation impact, in particular for the upcoming project periods of M30, M36 and M42.

Table 10 Pilot activities that lead to confirmation/verification of technical feasibility of new technology components

Partner	Prototypes
Hydro	(1) Hybrid digital twin for optimisation of GTC (Gas Treatment Centre) for stable alumina fluorination; (2) Competence to best retrofit and upgrade old GTC facilities through temperature control of gas flow into GTC filter compartments; (3) Utilisation of a combination of ordinary sensors to control gas flow based on operational needs in GTC (MAI, Cenit-App-Model, TensorFlow-Correlation-Analysis)
Elkem	(1) Use of IR camera for continuous measurement of melt temperature and slag coverage; (2) Data-driven algorithms for estimating the slag production in a ferrosilicon furnace; (3) Digital twin for estimation and control of a ferrosilicon refining process.
Saarstahl	Aerial-Photogram; Synthetic training data generation-Image
Sidenor	Toolbox for systematic prediction of ladle lifetime and maintenance need of ladles
Noksel	A Micro Service Based Open Architecture Using FIWARE to Develop Multi Model, Collaborative and Cognitive Digital Twins
Sumitomo	Fouling management in energy boilers with fuel characterization

The table above shows results in terms of technology development coming out of each of the six pilots. One part of the exploitation plan will be on use of these results within the process industry partner corporations.

Strongly related of the pilot-driven application development is the technology development carried out by the technological partners. These results are integrated into CogniTwin's toolbox. An overview is given in the next table. A second part of the exploitation plan will describe how the technology partners plan to further develop the technology, integrate the new developments into their product portfolio and how they plan to bring these products into the market.

Table 11 New products or process expected to be launched into the market

Partner	Innovations: New product (goods or service)
Cybernetica	Cybernetica OPC UA, Cybernetica Cognitive CENIT; Two application specific "Model and Application components" for Cybernetica CENIT: (1) estimation and control of a ferrosilicon refining process and (2) Hybrid digital twin for optimisation of GTC (Gas Treatment Centre) for stable alumina fluorination.
NST	TWear, StreamPipes-Siddhi, Toolbox for developing and managing business logic in Cognitive Twins, Cognition based tool-wear monitoring methodology and application
Teknopar	STEEL 4.0- IDBA, STEEL 4.0 IoTP, TStreamPipes- Adapters, STEEL 4.0 – ICPV, STEEL 4.0- TMLL, TMat- PdM, TMat SynDat, TStreamPipes-ML
SCORTEX	FPGA: Honir, Lodur, FPGA (field-programmable gate array) compute platform, Keras2RTL, Bonzai,
SINTEF	MAI, BedRock, BDPF, DT-Graph, Graft-SDQ, SlagModel, Correlation Analysis Library (CorrLib),
UOULU	FUSE – with SubFuse - Fuse OPC UA
Fraunhofer	FAST, Trusted IDS Factory Connector
DFKI	Aer-Photo, NeuroScope.

7 Conclusions

This report has presented an overview of the COGNITWIN Coordination and Performance Indicators Measurements per August 2021 (M24).

The metrics and related measurements have been related to the 8 main COGNITWIN objectives. The report has described the KPI metrics and associated measurements approaches and plans which also are associated with the various 8 workpackages of COGNITWIN.

The metrics and related measurements approaches are presented first for the six COGNITWIN pilots from WP1, WP2 and WP3.
The key performance indicators for the technology workpackages of WP4 and WP5 are presented next together with the individual KPIs for the eight COGNITWIN Technology partners. The metrics and measurement approach for the COGNITWIN Innovations and Business impact is presented next as related to the responsibilities of WP6.
The metrics and associated KPI measurements for COGNITWIN Communication and Dissemination are presented based on the work for this done in WP7.
Finally the project management from WP8 is presented with the progress monitoring approach for the Administrative coordination, Technical coordination and Innovation Impact coordination.

In order to monitor the progress and evolution for the likelihood of meeting the pilot KPIs (from each of the pilots in WP1, WP2 and WP3) and the relationship to the technology and innovation KPIs a 6 monthly evaluation framework will be instansiated with measurements collected from each COGNITWIN partner per M30, M36 and M42 – with first report for this planned for M30.