Steel industry and environmental footprint data collection and aggregation

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Abstract

The collection and presentation of environmental footprint data in the steel industry is a complex and continuously changing task in any producing industry value network. It's implementation and continuous evolution need to be cost and engineering efficient while protecting critical data from not being misused. From recent research results it's obvious that currently used cyber and automation technology has considerable shortcoming. Thus calling for a wider usage modern IT technology. This will require both new competences and migration strategies. This position paper summarises the applicable standards for environmental footprint data. Further is discusses technology and competence aspect of importance to any player in a steel production network.

1 Introduction

The cyber information part of steel production becomes more and more important. The traditional focus has been support to production efficiency and product quality. Emerging needs are related to upstream and downstream value network interactions to improve competitiveness. This will require resilience to unforeseen interruptions and data leakages. In addition, comes society demands like the green deal and measures to support fair trade and business where digital product passport is one example.

In such perspective cyber competences are becoming a critical key skill in parallel with classical production process knowledge for any producing industry including the steel industry. These are concrete results of the Industry 4.0 initiative from 2011.

2 Governing regulations and standards

The European green deal policies drives the societal climate ambitions in Europe. Example of such policies are e.g. EU Emissions Trading System, EU

Climate Adaptation Strategy [1–3].

The effects of these policies are monitored by tools like the European Industrial Emissions Portal: `https://industry.eea.europa.eu`

To this aim, a set of standards are supporting the quantification of carbon, water and other contributions to the environmental footprints has been developed. Following is a collection of the currently most important standards related to the steel industry.

Since 2018, ISO 14067 [4] assists organizations to perform and report a carbon footprint for products and the EN 19694 [5] series in the determination of greenhouse gas (GHG) emissions in energy intensive industries.

Carbon footprint of buildings is part of the environmental performance assessment as covered by CEN/TC 350 [6] 'Sustainability of construction works' standards, EN 15804+A2 [7] for construction products and EN 15978 [8] for buildings, expressed as "Global Warming Potential" GWP-indicator, as defined in EN ISO 14067 [4]. Further work on the assessment of methane emissions in the gas transmission and distribution infrastructure is under its initial developments in CEN/TC 234 [9] 'Gas infrastructure'.

EN ISO 14046 [4] specifies principles, requirements and guidelines related to water footprint assessment of products, processes and organizations based on life cycle assessment (LCA).

A more general approach has been followed by development of standards, which focus on the cost of using or impacting the natural environment.

The ISO 14030 [10] family of standards is being developed and will be relevant to stimulate climate-proof debt[1] instruments. Moreover, standards are currently being developed defining a framework and principles for assessing and reporting investments and financing activities related to climate change, as well as assessing projects, assets and activities seeking green finance.

Finally, standards on Sustainable Finance are being developed that include terms and definitions and a framework with principles and guidelines for implementation (ISO/TC 322 [11] 'Sustainable finance').

At EU-wide level, CEN is involved in the Environmental Footprint initiative, and closely follows the applicability of the EU Eco-Management and Audit Scheme (EMAS) [12] of verification, reporting and validation of energy efficiency and carbon footprint. The EMAS Regulation, reproducing sections of ISO 14001 [13], helps organizations to publish their carbon footprint in a transparent, verifiable and third party verified manner and thus provides the prerequisite for demonstrating compliance with policies and strategies at corporate and societal level.

EN ISO 14090 [14] series provide guidance and technical specification including for climate adaptation planning and vulnerability assessment. This includes the integration of adaptation within or across organizations, understanding impacts and uncertainties and how these can be used to inform solutions to enhance resilience in any organizational unit or sector e.g in cities, infrastructure sys-

[1] Climate debt is the debt said to be owed to developing countries by developed countries for the damage caused by their disproportionately large contributions to climate change.

tems like transport, agriculture and health. The ISO 14090 suggests looking at the 'organization' as a system of systems, with interdependencies stretching past the usual management chain and, for example, suggests thinking about the future resilience of supply chains.

Standards focusing on "Resilience" also include climate factors and provide standards on integrated management and resilience indicators (ISO/TC 268 [15] 'Sustainable cities and communities', CEN/TC 465 [16] 'Sustainable and Smart Cities and Communities')

European Standards play a vital role in increasing society's resilience to climate change. A key element (action #7 out of 8) in the present EU Strategy on Adaptation to Climate Change is ensuring a more resilient infrastructure. The work of the CEN CENELEC Coordination Group on Climate Change Adaptation (ACC-CG) [17] and related TCs in the energy, construction and transport sectors aim at revising infrastructural standards and play a key role in realizing this element of the EU Strategy. Recently, new activities have been added. The ACC-CG will support in standardizing adaptation measures (e.g.: green roofs) which will help in accelerating the performance and use of these measures. Furthermore, action start towards inclusion on future climatic information in construction standards, helping to make constructions across Europe more resilient to climate change.

From a supplier stand point also standards used by customer as well as end user internal "standards" to meet their market, need to be considered.

Finally it is important to emphasis that standards are not static and they are regularly update and may even have an end-of-life.

2.1 Company internal standards

Since long many companies has own internal standards which in many cases goes clearly beyond the legal requirements. The reason for this is found in customer relation and targeted customer segments. Typical example are e.g. automotive and mobile phone industry. Thus internal steel company "standards" are established to track product quality data of business and customer relation importance.

Such down-stream requirements have to be considered by up-stream suppliers. Thus creating dynamic changes to what data an up-stream need to provide in their daily business. This calls for very agile capacities in providing different data to different customers.

3 Sharing of environmental footprint data

In the time being, business and political consideration on which environmental foot print data to share and how have emerged! It is clear that regulations will mandate the collection and sharing of some environmental footprint data.

For an individual player in the steel value network there are both sociopolitical and business reasons to share or not share data. Sociopolitical debates can be generated based on shared data or based on rumors regarding non-shared data. Similar data will be part of how market communication is built. Thus careful handling of potentially sociopolitical or business interesting data becomes a strategic value for players in the steel value network. Its here important to observe that data can contain concrete information targeted by industrial espionage. Data can as well be indirect from which interesting information can be inferred. For leaked or stolen indirect data the owner does not have control over the analysis and interpretation of the data.

Industrial steel associations may formulate sociopolitical messages which need to be based on facts coming member data. Careful and respectful handling of such data then becomes politically and business important.

The above considerations call for data security measures to be addressed by the industrial value network. Two data security areas are to be considered:

- Data leakage and theft
- Shared data usage

Data leakage and theft can occur at data sources and/or at data storage. Central data storage is today normally protected at some level. Data at the sources are today less and on many, probably the vast majority of, cases not at all protected. The protection strategy is a "I fence" around the plant and the company. These fences today have many not well known openings due to operational and convenience reasons. This is an area that need to become a strategic of part of industrial operations.

For on purpose shared data within a value network the important question becomes for what purpose and action this data can be used by the receiving party. This is an area where intense research is conducted. It should be noted that on-purpose shared data will happen at data centre level all the way down to the far edge in the cyber world. Thus strategic considerations need to cover the whole cyber data continuum from edge to cloud.

4 Bottlenecks of environmental foot print data collection

Our production industry, including steel, faces a number of technology, organisational and cultural bottlenecks on their path to become efficient and flexible in collecting, protecting, sharing and using data for production, business and society communication.

Since the data and cyber part of production is moving from a support functionality to a critical core part of any production, most companies need to upgrade their view on data and cyber capabilities. Looking at currently very successful production companies like Tesla and other green field producers who started as "IT companies" they first form an IT architecture to which they have merged existing knowledge on mechanical and production. Most other companies have added the automation and IT knowledge to their existing product and production competence. Thus, company cultural and organisational position in addition to technology becomes part of the potential bottlenecks needed to address in a production world with increasing society and customer interest to environmental impact of produced goods.

Given the societal urgency and market trends related to environmental impacts it's rather likely that upgrade and new policies in combination with rapid changes in market demand should expected. This forces industry to continuous update of their related capabilities. Based on this flexible and efficient approach, such capabilities will become a larger and larger part of the company competitiveness portfolio.

4.1 Company internal

To meet above society and market changes the steel industry has already started work to meet the EU regulations and existing standards. This work utilises, to a very large extent, existing automation technology to capture such data. Considerable new investments in data capture and handling together with the associated engineering has already been taken.

The expected needs for flexible, changeable and up-gradable cyber, automation and data handling technology will put related costs in focus. Thus efficiency in this respect will contribute to market competitiveness.

4.1.1 Technology

Many of the new requirements, as environmental footprint data, are solved by building yet another solution to address the need. In this way providing dedicated solutions based on specific requirements. It works but for every changes in the requirements costly updates and extensions will be needed.

The most modern automation and digitalisation technologies is a combination of microservice based cloud technology e.g., AWS, Azure or similar. This is most often combined with legacy ISA-95 [18] based automation technology based on ERP, MES, SCADA, DCS and PLC technology. Industry4.0 and 5.0 technologies, based on microservice architecture is emerging. Commercial technology is most often based on service-bus concepts integrating the ISA-95 technology layers enabling working but not very flexible solutions. The most recent developments target a wide interoperability approach where legacy technologies like e.g. OPC-UA, Modbus, ASi, Fieldbus, Profibus etc. can be dynamically integrated based on protocol and encoding translators or adaptors. Example of such architectures and reference implementations are Eclispe Arrowhead, Eclipse Basyx, FiWare, LWM2M [19–23]. Most of these are open source with emerging commercial support.

It is clear that new technology will impact how it is operated in organisations. Comparing classical production companies with new production companies, like Tesla and other recent green field producers, considerable differences can be detected. The new production companies have a very integrated IT/automation organisation with a strategy of having a considerable internal competence at all layers of the IT/automation architecture. Thus significantly reducing their dependency on suppliers and third party technology. The opposite is very often found in older production companies who have a large dependency on key automation suppliers. This difference can today be referred to as the IT/OT cultural difference, which reflects how important the IT/OT cyber data part is for real regarded in the company.

4.1.2 Integration Up- and Down-stream in the value network

In the today production operation there is an increasing integration to customers, suppliers and in-house subcontractor. Here considerable contractual and technology issues need to be addressed regarding cyber and automation data transfer and data usage. New requirements will be introduced regarding how shared production information subsequently is allowed to and may be used. This will require considerable number of technology, procedure and contractual issues to be addressed. On the technology side two different approaches are seen - interoperability and traceability or "standardisation/alignment", in-between the involved actors.

Recent EU project results indicate that the interoperability approach provides considerably more flexibility and is significantly more time and cost efficient [24].

Collecting the relevant environmental data upstream and downstream of steel production operations exhibits a number of concrete technology challenges. These are connected to traceability and key questions are:

- Traceability at what level: product, process, time, ...
- Traceability of what: material, where from/to,

The expected dynamic data environment also points to need for e.g. new sensor technology, new data extraction approaches and time and cost efficient integration thereof. Here again the microservice architectural approach shows superior performance compared with the current legacy ISA-95 technology.

5 Environmental digital data models

So far only data collection and transport technology have been addressed. The data itself and the meaning of it are yet another complicated part of the integration within production value networks. From section 2 it is obvious that numerous standards are involved only for the environmental data, each standard with its own data model. These standardised data models need to be combined with all other standards used for e.g. asset, operational and maintenance used in the steel industry value network. Regarding data models, we should also bear in mind the life cycle of standardized data models, 5-10 year is a common data model life time. This should be compared with production technology life time of 10-50 years, electronics life time of 5-15 years and software life cycle of weeks to years.

So we could formulate the following question:

- Which "standardised" data models should be used or
- which data model interoperability approach should be used?

It is clear that the standardisation approach will incur considerable costs for dedicated translation of data model standards within a production value network. Considering the life cycle discussion above such costs will prevail for the life time of the plant. This points to engineering approach based on automated machine translation supported by enhanced data models featuring semantic and metadata information. It is clear that current research results have lead to some useful tools but a general solution is still years from industrialisation. Indicating that more research is needed.

5.1 Digital data model harmonisation and aggregation

Data needed for the regulated and company internal reasons will come from multiple sources within each company and from upstream and downstream interactions. It's clear that there will be a large number of data models involved since data comes from sources of different age produced to be compliant with different standards and standard generations. This situation will rapidly incur large costs for every change in regulations and/or internal policies.

5.2 Benefits and Risks

Working with standardised or policy defined data model provides the benefit of a stable data format. Considering that the by standards and policy requested data is inferred from wide range of heterogeneous sets of data models and their life cycle the risk is that even such standardised and policy defined data models will change/evolve to rapidly over time.

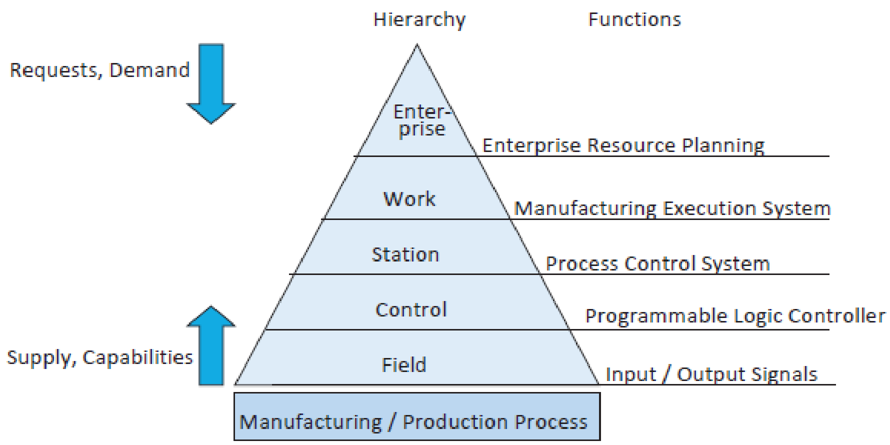

Figure 1: The currently dominated automation architecture is ISA-95 pyramid covering from the shop floor to the enterprise resource planning, ERP, level.

6 Technology requirements - data collection and sharing

The above discussion makes it clear that the cyber data investments will be an area for continuous investments for regulation, internal policy and technology reasons. Thus becoming an area of strategic importance in production of steel and other most other products and services. Such strategies need to consider a number of areas to be of value. Important areas to consider are:

- IT/OT architecture direction
- Architecture implementation framework
- Technology and data interoperability
- Data storage strategy
- Data and information security strategy
- Maintainability of IT/OT infrastructure
- Evolution of IT/OT architecture and infrastructure
- Operational robustness
- Engineering costs
- SW update strategies including, test, validation and verification

A few of these are further detailed below.

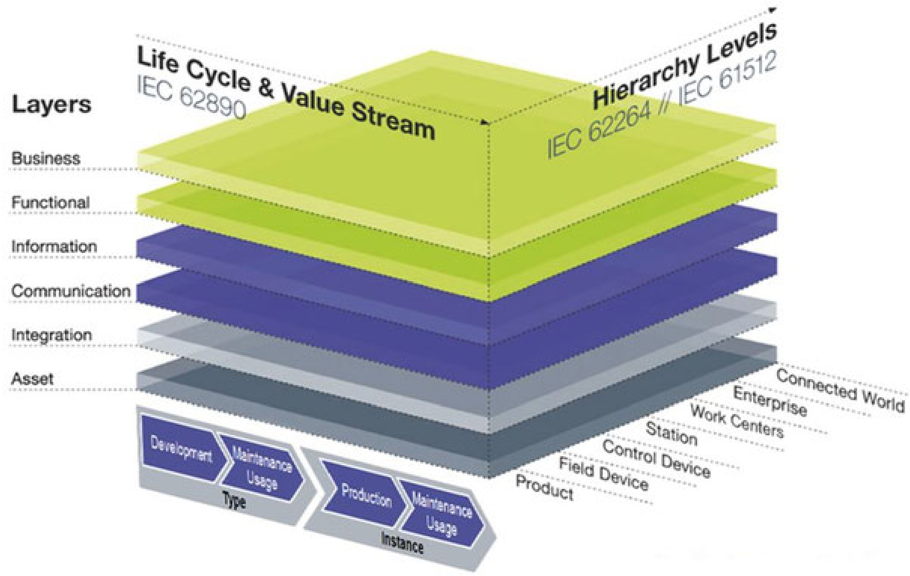

Figure 2: Industry4.0 architecture RAMI4.0 is a considerable extension of ISA-95 architecture.

6.1 IT/OT architectures

The currently dominated OT architecture is ISA-95 [18], cf. Figure 1, upon which most production today is based on. Industry4.0 and upcoming Industry5.0 introduces a strong need for OT/IT integration and as well adding humans into such OT/IT architectures. The current trend points towards a more wide spread usage of Internet and wireless (5G,..) technologies in favour of legacy ISA-95 technologies.

Thus, Internet based Service Oriented Architecture (SOA) or microservice architecture seems to be the dominating direction. The microservice architecture is clearly dominant at the IT cloud level and most research at the automation edge level is directed towards microservice based architectures intended to replace today's ISA-95 legacy technology. Research has clearly demonstrated that the Internet based microservice architecture direction enables implementation of Industry4.0 architectures like RAMI4.0 [25] (cf. Figure 2) and IIRA to cost much lower costs (cost and time reduction of 30-95%) compared to current legacy OT/IT approaches [24]. Further integration of e.g. new human-machine interaction technologies based on human to machine language interoperability supported by sound/voice recognition and ML/AI technologies will support the Industry5.0 development.

It clear that successful implementation, usage and evolution of RAMI4.0 [25] and beyond will need new technology integration frameworks, tools and

Features	Arrowhead	AUTOSAR	BaSyx	FIWARE	IoTivity	LWM2M	OCF
Key principles	SOA, Local Automation Clouds	Runtime, Electronic Control Unit (ECU)	Variability of production processes	Context awareness	Device-to-device communication	M2M, Constrained networks	Resource Oriented REST, Certification
Real-time	Yes	Yes	No	No	Yes (IoTivityConstrained)	No	No
Run-time	Dynamic orchestration and authorization, monitoring, and dynamic automation	Runtime Environment layer (RTE)	Runtime environment	Monitoring, dynamic service selection and verification	No	No	No
Distribution	Distributed	Centralize	Centralize	Centralize	Centralize	Centralize	Centralize
Open Source	Yes	No	Yes	Yes	Yes	Yes	No
Resource accessibility	High	Low	Very low	High	Medium	Medium	Low
Supporters	Arrowhead	AUTOSAR	Basys 4.0	FIWARE Foundation	Open Connectivity Foundation	OMA SpecWorks	Open Connectivity Foundation
Message patterns	Req/Repl, Pub/sub	Req/Repl, Pub/sub	Req/Repl,	Req/Repl, Pub/sub	Req/Repl, Pub/sub	Req/Repl	Req/Repl
Transport protocols	TCP, UDP, DTLS/TLS	TCP, UDP, TLS	TCP	TCP, UDP, DTLS/TLS	TCP, UDP, DTLS/TLS	TCP, UDP, DTLS/TLS, SMS	TCP, UDP, DTLS/TLS, BLE
Communication protocols	HTTP, CoAP, MQTT, OPC-UA	HTTP	HTTP, OPC-UA	HTTP, RTPS	HTTP, CoAP	CoAP	HTTP, CoAP
3rd party and Legacy systems adaptability	Yes	Yes	Yes	Yes	No	No	No
Security Manager	Authentication, Authorization and Accounting Core System	Crypto Service Manager, Secure Onboard Communication	--	Identity Manager Enabler	Secure Resource Manager	OSCORE	Secure Resource Manager
Standardization	Use of existing standards	AUTOSAR standards	Use of existing standards	FIWARE NGSI	OCF standards	Use of existing standards	OCF standards

Figure 3: A comparison of primarily open-source implementation frameworks addressing Industry4.0 and the architecture RAMI4.0.

engineering skills to implement the above listed strategic areas.

6.2 Technology integration frameworks

To efficiently implement data collection and sharing solutions supporting engineering frameworks and tools will be very useful. To enable above described OT/IT technology transitions we find commercial proposals and offerings from the classical OT automation industry (Siemens, ABB, Schneider, Valmet, GE, ...) complemented by a very large number for specific market and use case IT based offerings from primarily smaller player. From the large IT cloud industry (Microsoft, Amazon, Google, IBM, ...) a set of IT cloud technologies are offered to the market. However, these very often only concerns the data collection and storage. Comparing a not to old review of commercial offerings [26] with what you can find Q1 2023 reveals that it is a turbulent market with considerable consolidation which is still going on.

In addition thereto, a set of microservice based open source initiatives are actively being developed. The most modern open source initiatives are Eclipse Arrowhead [19, 20], FiWare [22], Eclipse Basyx [21], LWM2M [23]. A recent comparison of primarily open source SOA/microservice initiatives intended for the industry [27], can be seen in Figure 3.

6.3 Technology and data interoperability

Considerable cost can be related to non-interoperable technology and data. Thus, a company approach to interoperability, covering their legacy technology and data, current investment and expected future development, seams necessary. Strategic interoperability choices will be related to architecture, implementation framework, evolution aspect, life cycle aspect, vendor lock in aspects and more. It is clear that interoperability strategy choices will, for long time steer necessary investments their associated costs and development time.

6.4 Data storage strategies

Data and information produced in an OT/IT automation/digitalisation environment need to be captured somewhere. For the purpose there are a number of data space initiatives like e.g. Gaia-X, Catena-X, IDS [28–30] all supported by the European commission and the interest in enabling data sharing and availability of large amount of data useful for future AI usage.

There are of course numerous commercial offerings from the cloud business led by e.g. Microsoft, Amazon, Google. In addition there are a set of open source technologies which are widely used, examples are e.g. Kafka, MySQL, MongoDB, MariaDB.

Regardless of data storage technology it is very clear that for large data lakes to be useful the data need to be provided with sufficient meta data. The meta data will provide information such as e.g. data model/ontology applied, origin and time of data. The annotation of data with appropriate meta data is today a very manual and expensive effort. This is one of the primary reasons for slow exploitation of the potential that large data lakes can provide.

6.5 Data and information security strategies

Due to the increasing sharing of data between players in production value network information and operations security need to be addressed in new ways. The classical "security fence" around the plant are not and will not be sufficient. Data and information security is one view point and operations security is another view point.

Data and information security are strongly related to data sharing with business and technology partners. This is primarily made under contractual agreements. Anyhow the fluidity of data and information calls for technology protection regarding to where and who plus for what usage. Which need to be manageable at reasonable costs. Some of the data space mentioned above initiatives has early approaches to data usage protection for which further advancements is still needed, given the situation of increasing cyber threats in our society.

6.6 Maintainability of IT/OT infrastructure

Maintenance of IT/OT infrastructure do need its own planning. As infrastructure is here regarded:

1. networking infrastructure: cabling, switches, routers, SOA core systems etc. from the very edge - shop floor to the cloud,
2. OT infrastructure: very often hardwired or configured at each ISA-95 layer,
3. IT based infrastructure: network configuration and sectioning are handled at router level, where sectioning can be expected to be more fine grained than the ISA-95 architecture levels and even become dynamic depending on operations situation.

The trend is clearly moving away from hardwired and static configurations of OT/IT infrastructure. Dynamic changes to IT infrastructure is expected to become the normal. This opens for faster and cheaper adaptation of the automation solutions to changing and evolving production demands. Suitable tools and knowledge around dynamic re-organisation of OT/IT infrastructure are still in early technology phases.

The different nature of OT and IT infrastructure calls for integration of operational and maintenance competences in plant organisations.

6.7 Evolution of IT/OT architecture and infrastructure

IT/OT automation/digitalisation solution will be changed and updated over its life time. The classical OT implementations based on ISA-95 have become very inflexible and thus very expensive and time consuming to update and extend. Compared to IT based and primarily microservice based architectures and implementations the classical OT implementation are expensive. Recent research indicates that very large savings can be made by applying microservice approaches to evolve classical OT architectures. In 28 industrial use-cases, spanning the whole IEC 81346 engineering process, savings of 30-97% of cost and time has reported [24].

6.8 Operational robustness

Requirements on operational robustness of automation systems and their collection of data will remain very demanding. The OT technology does meet such demands while the IT technology still have to improve. Since the major IT architecture path seems to be SOA and microservice technology necessary robustness can provided be applying well known concepts from the server, network and telecom world. Applying concepts on redundancy and resilience at the operational edge involving many resource constrained machines is still in early technology phases. This is an area calling for innovation actions and large scale demonstrations.

6.9 Engineering costs

It's clear that engineering cost for OT technology can be regarded as expensive. IT technology and particularly SOA/microservice based architectures is considerable much more cost effective. The Arrowhead Tools project has provided solid data on savings of 30-97% of cost and time [24].

R&D investments in both US and EU addresses engineering efficiency. Here model based engineering integrated with AI supported code generation seams to be the major direction see for example [31].

Usage of SOA/microservice, model based engineering and AI will most likely provide much reduced engineering costs to Industry4.0 and 5.0 automation systems including data collection for proving compliance with changing regulations. But making IT based solution robust enough for the production operations requirements will require new engineering competences in the IT/OT departments and their supply network.

6.10 Software update strategies including, test, validation and verification

Finally, a few words on Software (SW) updates and test, validation and verification (V&V). It is very well known that SW updates to complex automation and data logging systems brings considerable test and V&V cost and time.

Usage of SOA/microservice architecture from edge to cloud exhibits promising results on reducing test and V&V cost and time. Simple changes to automation system that previously costed 100k€ and took 6 months can now be made in an hour to a cost of 1k€.

An advantage of the SOA/microservice architecture approach is that a limited digital twin of the components/microsystem interacting with a SW updated microsystem can be used to autonomous test and V&V that the new SW will perform as expected. This is yet another area when innovation actions and real world demonstrations are important for a faster industrial uptake of such technology.

The explicit SW updates of a device or system is today a mainstream technology for IoT and embedded systems. For larger and very complex embedded, cloud and back-end systems SW update processes still is a demanding task.

7 Technology selection strategy

The strategic areas listed above and the wide range of available architecture details, technology implementation frameworks and technology task offerings commercial and open-source aggregate to a very large and complex task for any producing company. In combination with each company current OT/IT architecture, cyber infrastructure status and strategy combined with their market ambitions indicate the complexity but also the importance of getting it right without excess investment and operational spending.

A future proof and cost efficient cyber part of any producing company require a strong internal cyber OT/IT knowledge. Such knowledge starts to be or already is a business-critical core part of any production business.

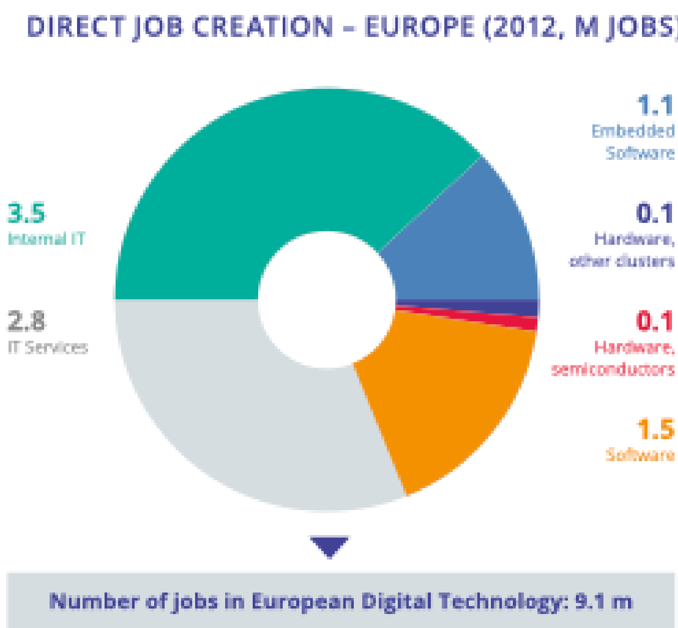

Figure 4: Digitalisation jobs in Europe by 2012. Source: EU, IDC, Destatis, Ronald Berger.

8 Competence

The here proposed strategies and technologies will require the relevant competence to be present in the organisations. The digitalisation and Industry4.0/5.0 transition in industry increases the importance of IT infrastructure and information management. Thus related competence have to be regarded as a top level strategic within any production organisation including steel production. To be successful this will require relevant digitalisation company competence from top management to the plant floor operations and management.

Recruiting for production relevant digitalisation competence is a competition for "brains" with all other domains in society requiring digitalisation competence. The digital competence "brain" supply can be illustrated by Figure 4. In 2012 roughly 9 million people worked with the digitalisation technology development, operations and maintenance field. Forecast for demand of these competences indicates a 30-50% growth 2020-2030 [2]. These growth rates are most likely not realistic to reach since the number of "brains" need is already 5-6% of the available work force.

To reduce the need for to many "brains" with digitalisation competence the industry can address **how to automate certain parts of digitalisation process to significantly reduce time and cost to operation usage**.

9 Conclusion

Enabling a robust, secure and cost-efficient collection of environmental footprint data from steel production is a non-trivial task. Data need to come from both upstream and downstream of the actual steel plant, requiring collection and integration of data from multiple stakeholders in the value network. Anyhow integrating legacy OT technology with modern IT technology based on SOA principles has the potential to provide the necessary technology platform for the task. Major challenges are connected to the development and operation of such environmental data collection and distribution platform. Of these challenges the one on having, recruiting and evolving personnel currently seems to be the very serious one.

Acknowledgment

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References

[1] Regulation (eu) 2023/435 of the european parliament and of the council of 27 february 2023 amending regulation (eu) 2021/241 as regards repowereu chapters in recovery and resilience plans and amending regulations (eu) no 1303/2013, (eu) 2021/1060 and (eu) 2021/1755, and directive 2003/87/ec. [Online]. Available: http://data.europa.eu/eli/reg/2023/435/oj

[2] European emission trade system. [Online]. Available: https://www.eea.europa.eu/data-and-maps/dashboards/emissions-trading-viewer-1

[2]Data comes from forecasts from US, UK, EU, and individual EU countries openly available.

[3] Climat adaptation strategy. [Online]. Available: https://climate-adapt.eea.europa.eu/en/eu-adaptation-policy/strategy

[4] Greenhouse gases — carbon footprint of products — requirements and guidelines for quantification. [Online]. Available: https://www.iso.org/standard/71206.html

[5] En 19694-1:2016 stationary source emissions. determination of greenhouse gas (ghg) emissions in energy-intensive industries general aspects. [Online]. Available: https://www.en-standard.eu/bs-en-19694-1-2016-stationary-source-emissions-determination-of-greenhouse-gas-ghg-emissions-in-energ

[6] Cen tc 350 sc1 why standardization of circular construction is decisively important and what you can do to help. [Online]. Available: https://circulareconomy.europa.eu/platform/sites/default/files/the-new-cen-commission-on-circular-construction.pdf

[7] Csn en 15804+a2 - sustainability of construction works - environmental product declarations - core rules for the product category of construction products. [Online]. Available: https://www.en-standard.eu/csn-en-15804-a2-sustainability-of-construction-works-environmental-product-declarations-core-rules-for-t

[8] Csn en 15804+a2 sustainability of construction works - environmental product declarations - core rules for the product category of construction products. [Online]. Available: https://www.en-standard.eu/csn-en-15804-a2-sustainability-of-construction-works-environmental-product-declarations-core-rules-for-t

[9] Cen/tc 234 - gas infrastructure. [Online]. Available: https://standards.iteh.ai/catalog/tc/cen/cc25e361-921b-4ba1-822b-21062c37a4c0/cen-tc-234

[10] Iso 14030-1:2021 environmental performance evaluation — green debt instruments — part 1: Process for green bonds. [Online]. Available: https://www.iso.org/standard/43254.html

[11] Sustainable finance. [Online]. Available: https://www.iso.org/committee/7203746.html

[12] Eco-management and audit scheme (emas) - evaluate, report, and improve the environmental performance of your organisation. [Online]. Available: https://green-business.ec.europa.eu/eco-management-and-audit-scheme-emas_en

[13] Iso 14001 and related standards - environmental management. [Online]. Available: https://www.iso.org/iso-14001-environmental-management.html

[14] Iso 14090:2019 - adaptation to climate change — principles, requirements and guidelines. [Online]. Available: https://www.iso.org/standard/68507.html

[15] Iso/tc 268 - sustainable cities and communities. [Online]. Available: https://www.iso.org/committee/656906.html

[16] Cen/tc 465 sustainable cities and communities. [Online]. Available: https://standards.cencenelec.eu/BPCEN/2691595.pdf

[17] Environment and sustainability - cen-cenelec coordination group 'adaptation to climate change' (acc-cg). [Online]. Available: https://www.cencenelec.eu/areas-of-work/cen-cenelec-topics/environment-and-sustainability/climate-change/

[18] Isa95, enterprise-control system integration. [Online]. Available: https://www.isa.org/standards-and-publications/isa-standards/isa-standards-committees/isa95

[19] Eclispe arrowhead. [Online]. Available: http://www.arrowhead.eu

[20] Eclispe arrowhead. [Online]. Available: https://projects.eclipse.org/projects/iot.arrowhead

[21] Eclipse Basyx. [Online]. Available: https://projects.eclipse.org/projects/dt.basyx

[22] FiWare. [Online]. Available: http://www.fiware.org

[23] Lightweight m2m (lwm2m). [Online]. Available: https://omaspecworks.org/what-is-oma-specworks/iot/lightweight-m2m-lwm2m/

[24] Arrowhead tools major results. [Online]. Available: https://youtu.be/I6l70lKOSPI

[25] Reference architectural model industrie 4.0 (rami 4.0). [Online]. Available: https://ec.europa.eu/futurium/en/system/files/ged/a2-schweichhart-reference_architectural_model_industrie_4.0_rami_4.0.pdf

[26] H. Derhamy, J. Eliasson, J. Delsing, and P. Priller, "A survey of commercial frameworks for the internet of things," in *2015 IEEE 20th Conference on Emerging Technologies & Factory Automation (ETFA)*, 2015, pp. 1–8.

[27] C. Paniagua and J. Delsing, "Industrial frameworks for internet of things: A survey," *IEEE Systems Journal*, vol. 15, no. 1, pp. 1149–1159, 2021.

[28] Gaia-x - a federated and secure data infrastructure. [Online]. Available: https://gaia-x.eu/what-is-gaia-x/about-gaia-x/

[29] CATENA-X. [Online]. Available: https://catena-x.net/en/vision-goals

[30] International data spaces - the future of the data economy is here. [Online]. Available: https://internationaldataspaces.org

[31] P. Varga, "A note on using generative tools for research papers at the infocommunications journal," *INFOCOMMUNICATIONS JOURNAL*, 2023.