Road Map for the Control Center of the Future

Prepared for the Comité de Operación Económica del Sistema Interconectado Nacional, Perú

Prepared by the Electric Power Research Institute and the National Renewable Energy Laboratory under Pillar 2 (System Operator Technical Support) activities of the Global Power System Transformation Consortium

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NOTICE

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Acknowledgment and Disclaimer

This road map provides a structural approach, not a specific recommendation, that the National Renewable Energy Laboratory (NREL), Electric Power Research Institute (EPRI), and Global Power Sector Transformation (G-PST) proposes to Comité de Operación Económica del Sistema Interconectado Nacional (COES), for the possible implementation of best-in-class structure in all areas of control center operation (road map end point) and informed by high-level assessment of COES functional and capability model (road map start point). The document forthwith is not intended to be an implementation plan or course of action for COES to follow; rather, it is an indicative and visionary way of considering optimal approaches for meeting the demands of the future power system.

This control center research road map was made possible through funding from the Sequoia Foundation as part of support for the G-PST consortium. G-PST is an expert- and practitioner-driven initiative engaging key power system operators, research and educational institutes, governments, businesses, and stakeholders to overcome common barriers around the globe for fomenting clean energy transitions at an unprecedented scale. See www.globalpst.org for more details.

Peru's COES was identified as a good partner for this technical assistance because it is embarking on a shift to higher wind and solar energy penetrations in its power system and expressed interest in the possible recommended investment priorities to adapt to more variable generation as well as shifting energy demand profiles through electrification and increased growth rates.

List of Acronyms

CCOTF	Control Center of the Future
COES	Comité de Operación Económica del Sistema
EMS	energy management system
EPRI	Electric Power Research Institute
GDP	gross domestic product
G-PST	Global Power System Transformation Consortium
NERC	North American Electric Reliability Corporation
NMM	Network Model Management
NREL	National Renewable Energy Laboratory
ORC	operations readiness center
OT	operations technology
SCADA	Supervisory Control and Data Acquisition
SEIN	Sistema Electrico Interconectado Nacional
TSO	Transmission System Operator

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1 Introduction

As power systems across the world undergo transformative changes in resource mix, end-use demand, and transmission expansion and technologies, advanced methods and tools will be required in the control center of the entities tasked with transmission system monitoring and control. Given the high reliability requirements, regulation, and pace of innovation, the transmission control rooms have generally evolved slowly, in tandem with the evolution of the transmission grid. However, the rapidity of change of transmission systems is leading to previously unforeseen system risks and challenges. In systems that are weakly interconnected, or have high renewables penetrations and rapid demand growth, the monitoring and control tools in the control center are not adequate for assessing and addressing the risks that are highly likely to impact the system. The Peruvian electricity system is likely to face these challenges in the decades ahead, with its projected rapid expansion in demand, variable renewable generation, and network growth.

While there are some interesting and useful solutions available today, there is much more research and development and application to be carried out to help bring new architectures' data, tools, processes, and human factor improvements into the real-time control center environment.

This research road map will lay out the pathway to the COES Control Center of the Future (CCOTF). It is an ambitious and visionary plan that targets an industry-leading control center for system operators. The road map covers all aspects of the control center, from data points to facility design. It should be noted that COES are already far advanced in terms of application development and data visualization when benchmarked against other Transmission System Operators (TSOs). This road map aims to take this excellent progress as a starting point and build toward an innovative future design.

2 Peru System Context

2.1 Focus on 2026–2030

The Peru electricity system is anticipated to undergo significant growth in the next decades. Based on the 2021–2030 transmission plan update, it is anticipated that approximately $1.6 billion U.S. dollars will be invested in transmission infrastructure projects. This will be necessary due to anticipated demand growth, which will require proportional generation growth. Approximately USD $981 million is envisaged for 11 projects and construction works, which are planned to start during 2020–21 and be complete by 2026. The remaining USD $659 million is earmarked for 13 projects, for which construction will begin after 2021.[1]

The following sections analyze the growth in Peruvian demand, generation, and the network over the next decade with reference to the control center needs.

2.1.1 Future Demand

The projections in demand growth are based on the COES transmission plan update 2021–2030.[2] The projections are primarily based on the gross domestic product (GDP) growth of the country from 2020 to 2030, taking the GDP reduction from the COVID-19 pandemic into account. In the most optimistic growth rate scenario, GDP is expected to grow by 5.0% annualized across the decade.

Peak demand is expected to grow from 8.1 GW in 2021 to 13.5 GW in 2030 in the most optimistic GDP growth rate scenario an annualized 5% growth in demand.

What Does This Mean for the Control Center?

An increase in peak demand year on year of approximately 5% will result in increased generation to be managed to balance the system.

New or increased demand in new locations will change power flows on the system, and growth in demand will cause transmission congestion and stability issues, where previously there may not have been any.

As major vehicle manufacturers cease production of internal combustion engines in the coming years, and global manufacturers

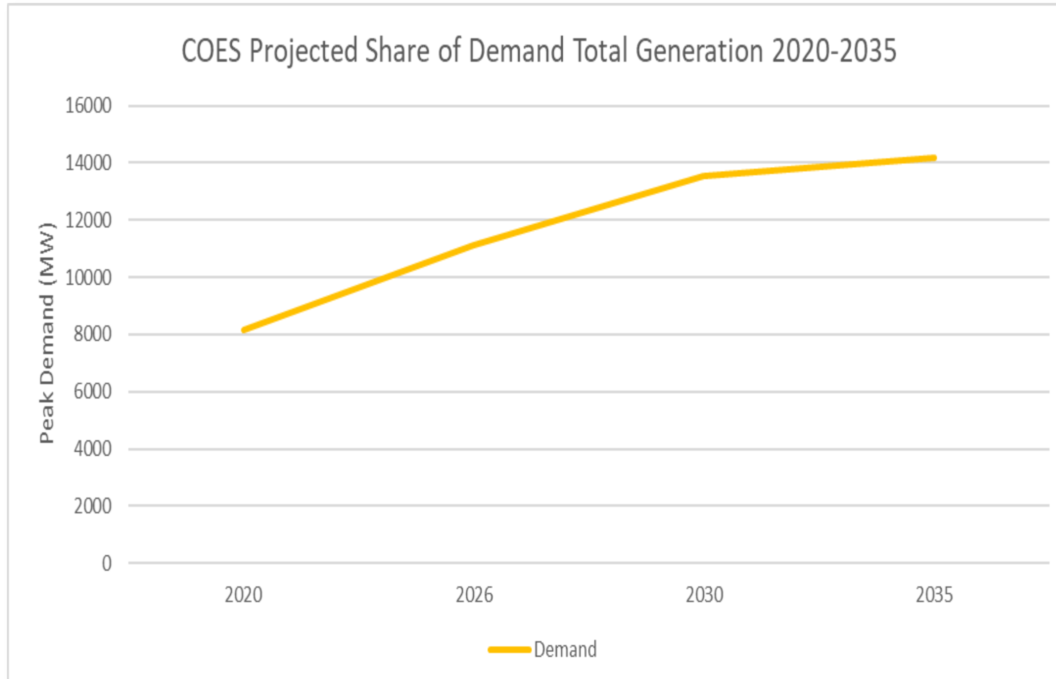


Figure 1. Projected future demand from 2021 to 2030, based on the most optimistic GDP growth projection of 5% to 2030. [Source: Dirección De Planificación De Transmisión Propuesta Definitiva De Actualización Del Plan De Transmisión 2021-2030 Octubre-2020]

[1] Source: Global Transmission Report - https://globaltransmission.info/archive.php?id=40566

[2] Source: Dirección De Planificación De Transmisión Propuesta Definitiva De Actualización Del Plan De Transmisión 2021-2030 Octubre-2020

adapt to decarbonization drives, electrification of transport, heat, agriculture, and industry is expected to increase to meet climate goals. Electrifying sectors of society will require improved demand forecasts for planning and more accurate real-time monitoring of distribution level demand.

Some of this increased electrification will bring higher levels of flexibility from electric vehicles and batteries, but these will need to be coordinated, monitored, optimized, and potentially controlled by the COES control center or distribution system operators.

2.1.2 Future Generation

The projections for growth in generation are based on the COES Transmission Plan Update 2021–2030.[3] Six scenarios were studied as part of the plan for 2026, 2030, and 2035. Because generation is unpredictable on a daily basis, percentages of overall capacity are a better metric for trending than raw MW statistics. For the purposes of the road map, the scenarios were averaged to give a general projection or trend.

The share of variable renewable energy (wind and solar) is projected to grow from approximately 5% in 2020 to 13% in 2026. While relatively small in the overall capacity, it does represent a 2.5-times increase in the share of wind and solar that the control center must plan for ahead of time and manage in real time.

There is an anticipated fall from 60% to 40% in the share of generation from hydro generation between 2020 and 2026, which is anticipated to be offset by thermal generation. In the longer term, to 2035, wind and solar are expected to grow but at a relatively slow rate to make up 21% of the total generation share.

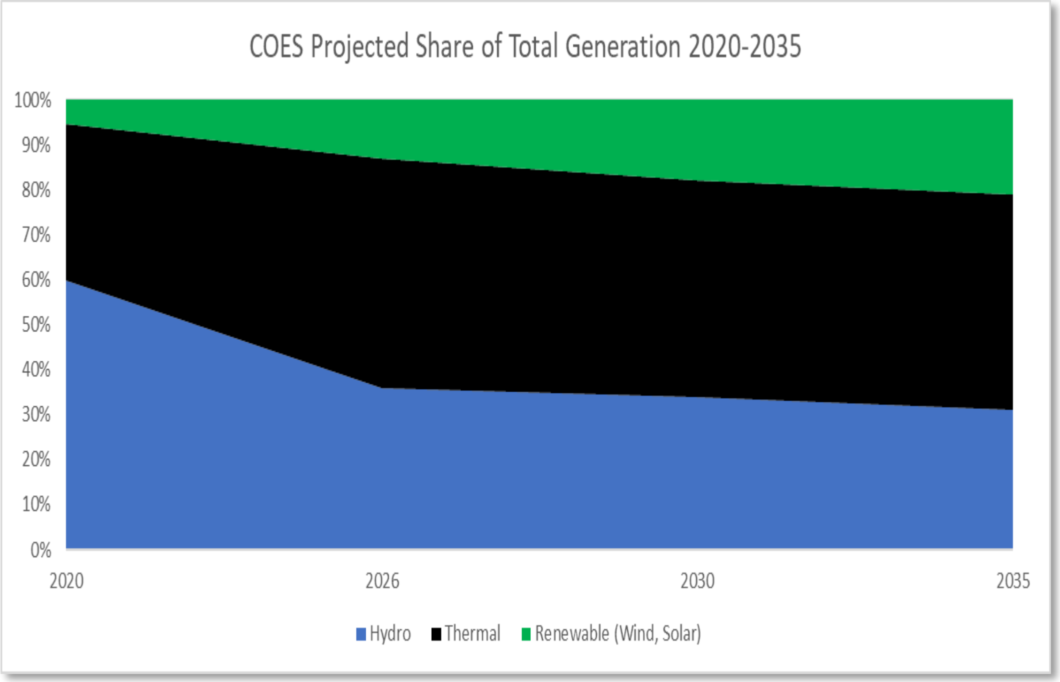


Figure 2. Projected share of total generation from 2026 to 2035, based on averaging planning scenarios. [Source: Futuros De Oferta Dirección De Planificación De Transmisión Propuesta Definitiva De Actualización Del Plan De Transmisión, Periodo 2021 - 2030 October]

What Does This Mean for the Control Center?

Wind and solar are variable resources that need to be forecast ahead of time and in real time. With a low share of overall capacity, there has been less importance on the forecast. As the share grows, the importance of forecast accuracy will increase, so forecast systems will need to be put in place. Wind and solar will likely be priority dispatch so that generation will have to be accepted when it produces; however, there will likely be a need for monitoring and controllability to perform curtailments and reduce constraints due to congestion.

[3] Source: Dirección De Planificación De Transmisión Propuesta Definitiva De Actualización Del Plan De Transmisión 2021-2030 Octubre-2020

Study capability and decision support will have to be enhanced to account for increased renewables as a result of the increased unpredictability. Due to not having synchronous inertia, wind and solar resources may raise stability issues when they replace thermal generation units on the system. This may be mitigated through grid services supplied by the smart inverters themselves, but that eventuality is outside the range of this road map. Existing study tools and visualization capabilities will need to be enhanced to take account of rising renewables.

2.1.3 Future Transmission Network

The extra high voltage transmission network is expected to be considerably enhanced in the coming years. The most significant development is the completion of the 500-kV ring system around the country and the interconnection to Ecuador, Colombia, and Chile.

- $981 million USD to be spent on network upgrades to 2026, encompassing 11 major 500-kV and 220-kV projects
- $659 million USD to be spent on network upgrades to 2030, encompassing 13 major 500-kV and 220-kV projects.

These growth rates do not include high-voltage projects or subtransmission and are intended to give an indication of the scale of investment in transmission infrastructure to 2030. At least a dozen power transmission projects are expected to go into service in Peru this year amid forecast double-digit growth in electricity consumption. In 2021, new substations Malabrigo, Chiribamba (Caudalosa), Campo Verde, Alto Zapata (Moquegua Ciudad), Puno Sur, and Maravilla, along with the expansion of the Motil substation, are expected. Also set to go online are the 138-kV lines Santiago de Cao-Malabrigo (41.4 km), Aguaytía-Pucallpa (second circuit and 132 km), Moquegua-Alto Zapata (Moquegua Ciudad, 6 km), and Totorani-Puno Sur (10.6 km), and the 220-kV link San Juan-Balnearios (8.83 km).[4]

Figure 3. Vision for the Peru transmission system based on the COES transmission plan 2021–2030

What Does This Mean for the Control Center?

Rapidly expanding network growth will have an impact on the COES control center in a number of important ways:

- Larger transmission footprint to monitor and control
- A change to the mental model of the operator and new flow patterns, contingencies, and system issues likely
- Increased need to model the network in multiple control center tools
- Increased outages on the system, testing of equipment, and protection and control alarms to the control center
- Increased quantity of protection and control devices to be monitored in real time.

[4] Source: https://www.bnamericas.com/en/news/peru-to-shore-up-regional-power-dispatch-in-2021

2.1.4 Summary

From the perspective of the control center in COES, there will be significant change in the next 5–10 years. The COES transmission plan, projected rate of demand growth, and new network assets will bring considerable need for new data and control center tools.

Given the inherent uncertainty in forecasting the future, the focus for COES is on a shorter timeframe (i.e., to 2026). The projections are likely to change due to external forces. The demand growth rates are based on the most optimistic GDP growth rates, the generation growth rates are averages of various scenarios in the transmission plan, and network construction projects may be delayed. The road map will need to be regularly reviewed to ensure it aligns with current projected growth rates. However, the core elements of the plan will remain the same, and there is an ability to adapt and fine-tune the road map as the decade unfolds.

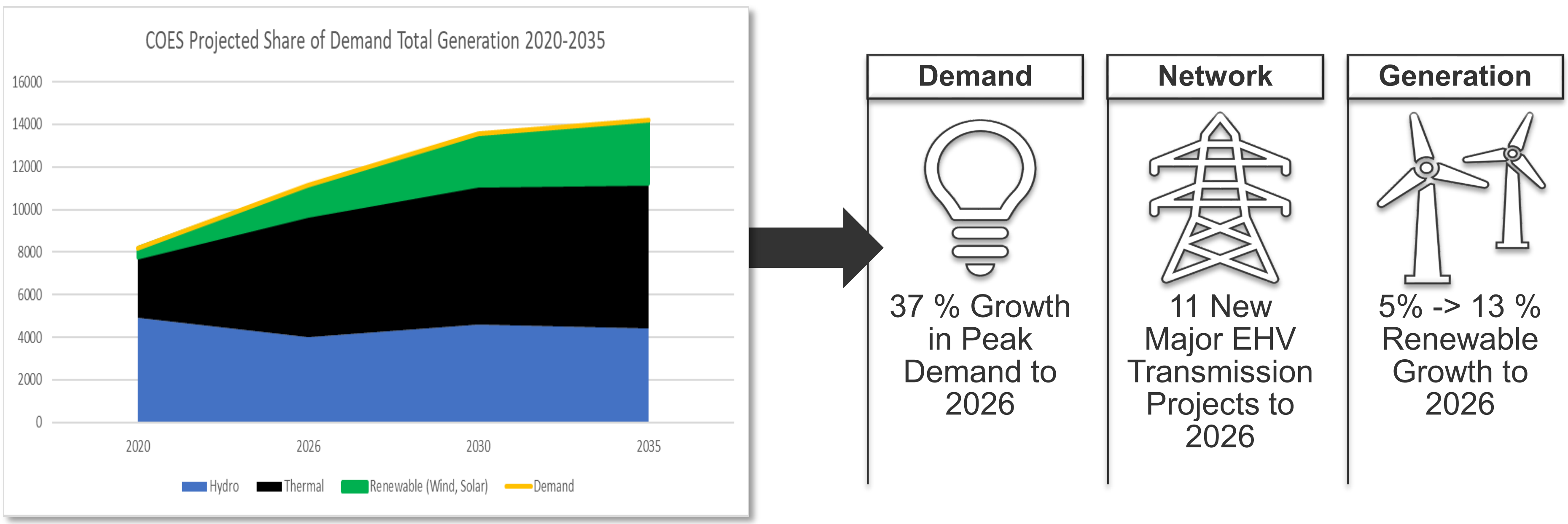


Figure 4. Demand growth and projected share of generation capacity from 2020–2035 based on statistics from COES Transmission Plan

2.2 COES Mission, Vision, and Values

When developing a road map for the future, it is important to ensure the corporate direction of the organization is aligned and a core part of the vision. COES publishes their mission, vision, and values, which are illustrated in Figure 5. The mission, vision, and values are referred to regularly in this road map and form a core part of the company's direction.

Mission

- Manage the National Interconnected Electric System with transparency, impartiality and excellence; and propose plans for its development in order to **sustainably** guarantee **the security and quality** of electricity supply to the country in the **most economical way possible.**

Vision

- To be a technical reference in the electricity sector in Peru and in the region.

Values

- Our clients, external and internal, are our priority.
- We contribute to the economic development of Peru.
- We transparently share our actions.
- We make sure that our work is impartial and professional.
- We care about doing our job better every day.
- We are constantly looking for new ways to improve the way we work.

Figure 5. COES mission, vision, and values

3 CCOTF Design Framework

3.1 Traditional Approach to Control Room Design

Control centers traditionally had rooms dominated by large overview pictures of the system under control. This design concept began as a mimic panel (often called a “map board”) with bulbs, meters, and drawn lines showing interconnecting stations. It was traditionally at the center of the room and an area for people to gather around to assess and monitor the system. Operators operated the system in real time, controlling all resources and transmission equipment manually with little automation.

In the 1970s, with the advent of Supervisory Control and Data Acquisition (SCADA), energy management systems (EMS), and improved visualization technologies, the mimic panels were replaced with dynamic representations of the system under control. Some processes began to be automated and improved visualisations began to proliferate.

Though the system, and tools to monitor and control it, has evolved in recent decades, the traditional approach to control room design has endured, until recently. The control rooms of 2021 look like the control rooms of 1970 and, due to only exchanging the videowall for a mimic panel, today’s control centers are ostensibly like the control centers of the 1950s or earlier.

While the demand, generation, and network growth projections are more certain to 2026, this road map document the systems and tools that will need to be developed and deployed in the control center in Peru to meet projected system changes by 2026 but also be sustainable and fit for purpose for the system of 2030 and beyond. To do this, an innovative and advanced vision for the future of control center operations is required. The road map sketches a path of development from today’s system in 2021 to the **probable** developments of 2026 (Stage 3) and the **possible** developments in 2030 (Stage 5).

3.2 Vision for the CCOTF

The context for the future of the Peru electricity system, based on the COES transmission system plan, was set out previously. This shows major increases in demand and the transmission network with corresponding increases in generation capacity.

The vision for the CCOTF to 2030 ensures the operator is still the key person in charge of system operations. Operators ensure a safe, secure, reliable, resilient, economic, and sustainable power system.

The operator’s role is expected to continue the trend of recent decades in moving further from real time (focusing on forecast and risk assessment), as automation of real-time processes will continue.

Operators will seamlessly move between automatic and manual control processes, as required. To decipher an exponential increase in data, operators should have a single situational awareness view of the system (“Hypervision”), which will oversee the automatic processes and control center tools. To enable this transformative change, an advanced simulator (or “operations readiness center” [ORC]) of the system for training and studying the network in real time will be required. It should be an exact replica of the system model and its data and act as a sandbox facility to test new and improved control center tools.

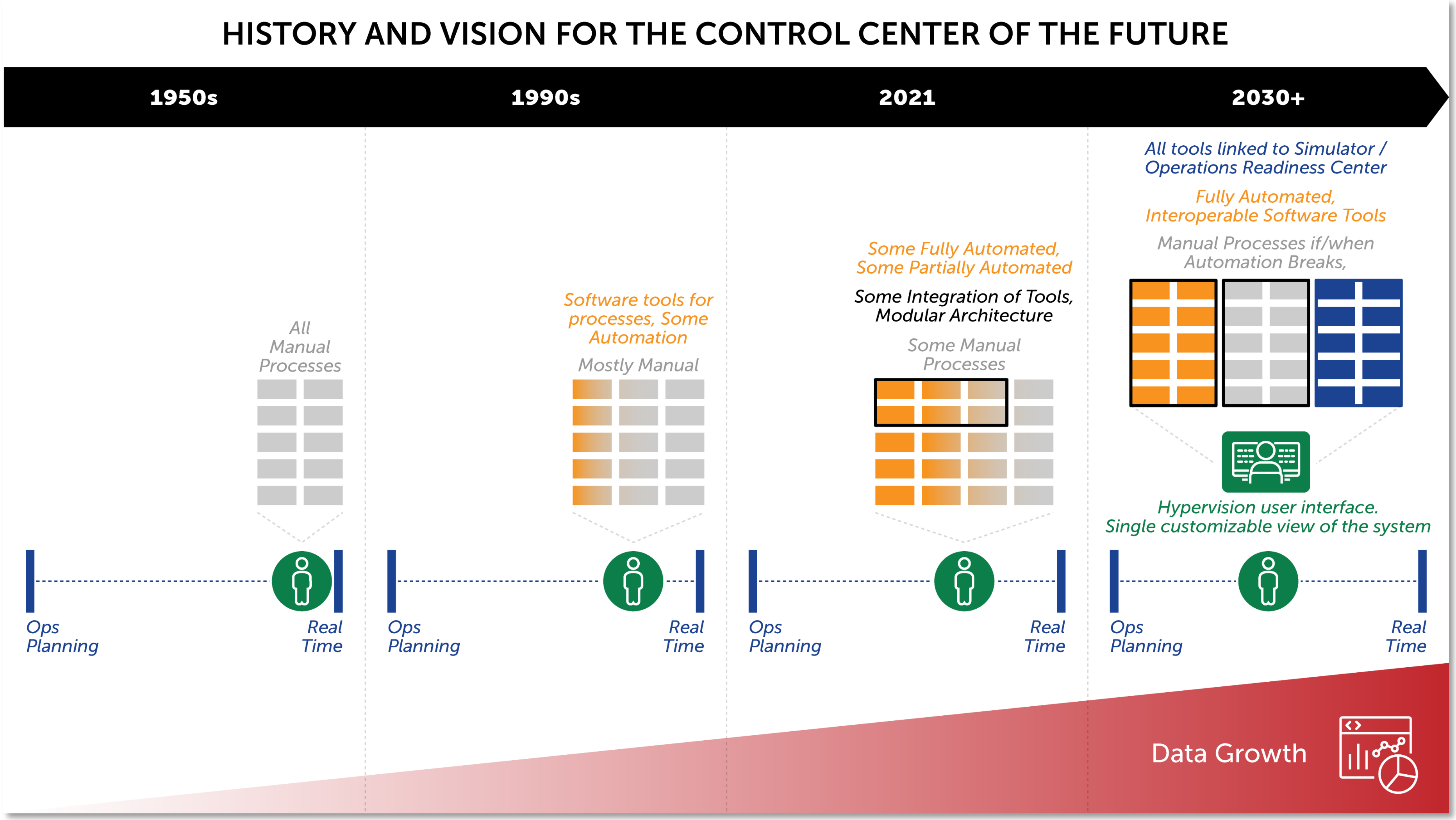


Figure 6. History and vision for the CCOTF

3.3 CCOTF Foundations and Pillars

The elements of the CCOTF vision for the COES control center are pieced together as part of a complete, color-coded CCOTF framework, shown in Figure 7. The vision and purpose are served by four foundations and an integration and interoperability layer (shown in black) and 11 supporting CCOTF pillars.

1. **Data Models and Streaming**
2. **EMS / SCADA**
3. **YUPANA (Market Management System)**
4. **Control Room Tools**
5. **Operations Planning Tools**
6. **Hypervision and Decision Support**
7. **Asset Control**
8. **Operator Training**
9. **Simulator/ORC**
10. **Building and Facility Design**
11. **Hardware and Ergonomics.**

To get as complete a CCOTF road map as possible, it is important to consider the foundations and pillars as part of a single, overarching framework. Stage road maps will be developed for each of the five color-coded groupings, tracing a path of development from today's system in 2021, to the **probable** developments of 2026 (Stage 3), and to the **possible** developments in 2030 (Stage 5). The road map represents a technology maturity trend for the CCOTF, showing the development steps needed to deliver on the vision.

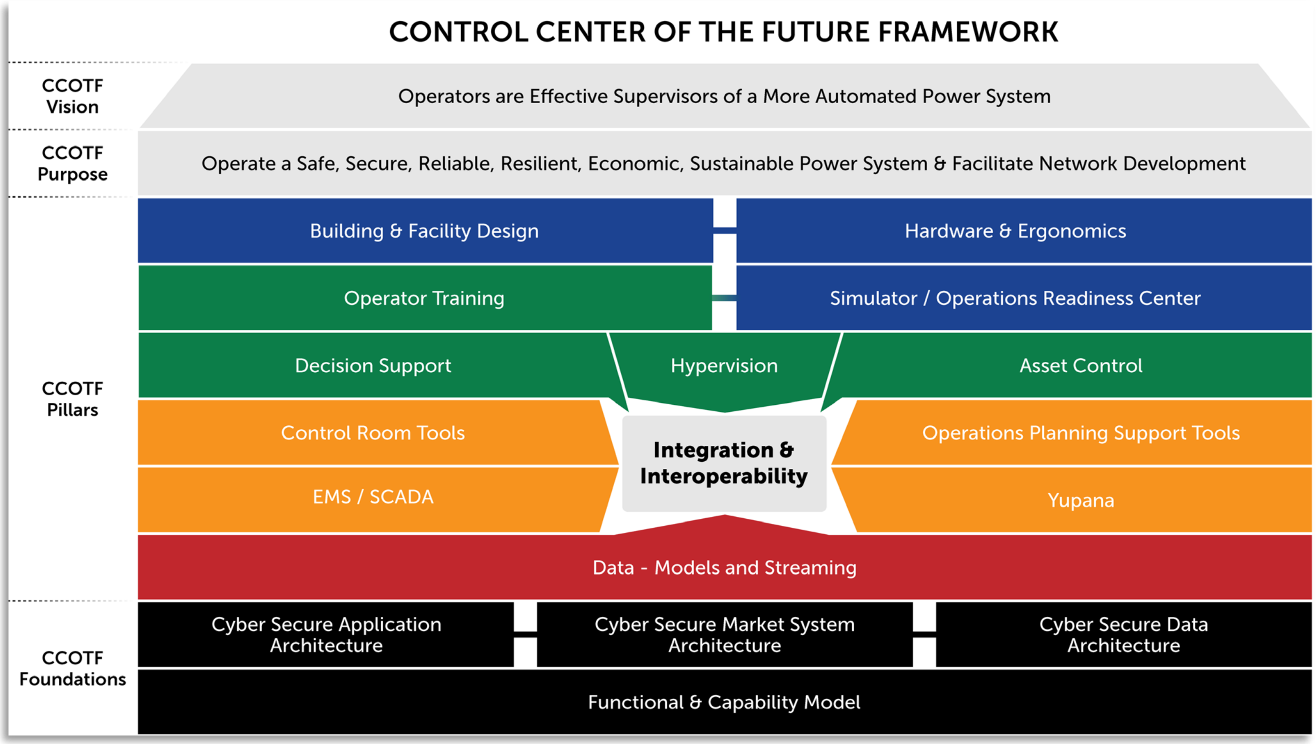


Figure 7. CCOTF framework (c) EPRI 2021

Each of the five pillar groupings are assessed in the same way, highlighting:

- The drivers for the changes to the CCOTF pillars, based on the projected future demand, generation, and network
- The vision for the pillars, aligned to CCOTF and COES visions
- The operational requirements from 2021 to 2030.
- The value of developing the pillar to achieve the vision
- Risks associated with not developing the pillar
- The road map and implementation plan for each pillar toward 2030.

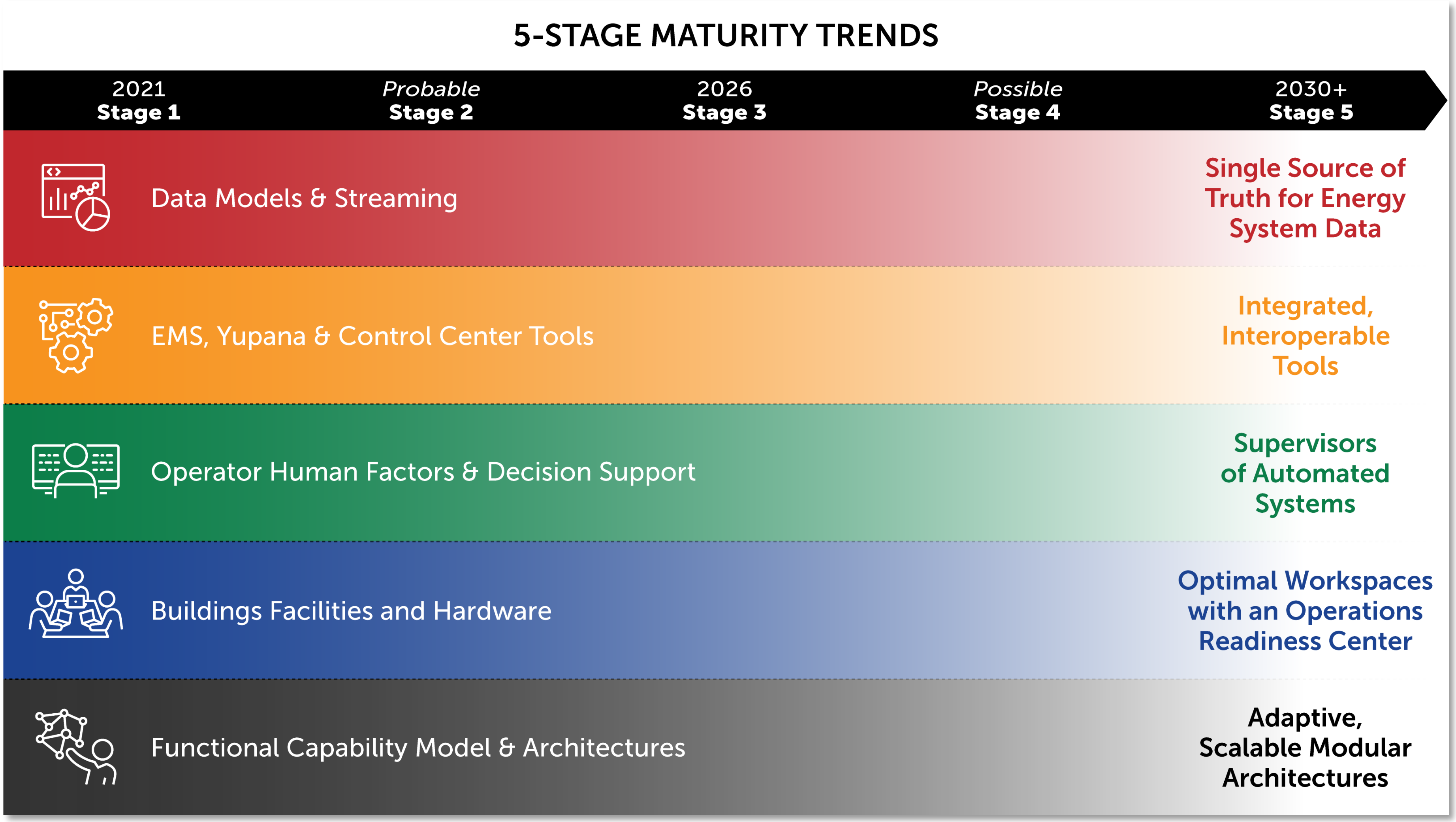


Figure 8. CCOTF for COES summary of framework

3.4 Functional and Capability Model and Architectures

3.4.1 Drivers for Change and CCOTF Vision

The CCOTF is supported by foundational enabling capabilities and technology, which are definitions of precisely what the control room is designed to do (also referred to as the functional model). They describe how data, IT applications, and market systems link together in cybersecure architectures.

This is possibly the most important aspect of the CCOTF road map: a well-designed functional model and architectures are key dependencies for well-designed data flows and software systems in the control center. Without these foundational elements in place, the CCOTF is destined to become disjointed and incoherent, with different elements and systems not properly aligned and managed, diverging as the system evolves.

The CCOTF road map begins with the development of the functional model, which defines the functions, roles, responsibilities, key performance indicators, purposes, and assets under control in the control center.

A capability model correlates to the functional model, outlining the capabilities required in the company to achieve the requisite functions from the functional model. This includes human resources, hardware, facilities, IT resources and so on. Design of a functional and capability model and reference architecture for the CCOTF is not within scope of this research road map; however, it is proposed as the first step in the road map. It should be noted that there is no worldwide industry standard reference architecture, but there are initiatives with EPRI and vendors to develop one that can be adopted in the coming years. The CCOTF and COES vision align as COES seeks to be a technical reference for the electricity sector in Peru.

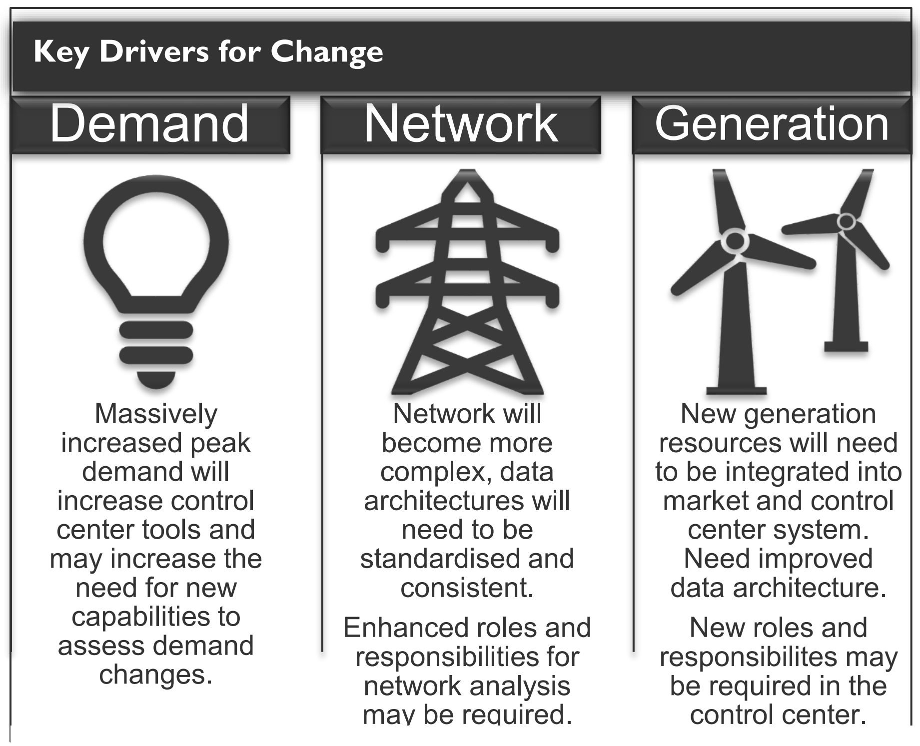


Figure 9. Key drivers for change for the functional capability model and architecture

An important consideration is the interconnection and interoperability between the COES, the transmission and distribution system owners and operators, and market participants. These areas of responsibilities, functions, data exchange, etc., should be incorporated in the architecture design, most likely in the **Cybersecure Application Architecture** implementation, as without alignment with the entities that interconnect with COES the system will be difficult to adapt and scale for future growth in demand, generation, and the network.

3.4.2 Operational Requirements for Functional Capability and Architectures in the CCOTF

To accommodate the range of new control center and operations planning tools that will be required in the CCOTF and the massively increased data loads for operators, new architectures for the applications should be designed.
To define the roles and responsibilities, a simple reference functional model for the control center is shown below, which defines all the:

- **Purposes** (e.g., compliance with Peruvian and international standards related to the control room supervision. By 2030, the COES mission of operating with safety, quality, and at a minimum operating cost must be considered)
- **Key Performance Indicators** (e.g., by 2030, each SCO process must have at least one key performance indicator)
- **Functions** (e.g., COES should supervise distributed generation, manage the short-term market and monitor the security of the Sistema Electrico Interconectado Nacional (SEIN) at the generation and transmission level.)
- **Processes** (e.g., by 2030, all processes of the control room should be integrated with internal process management of COES and its quality standards.)
- **Tools** (e.g., EMS, YUPANA, and control center tools. Each process must have an IT support system, dedicated servers, and redundancy for high reliability in all processes.)
- **Assets** (e.g., network, generation and market participants, customers, etc.)

This functional model will feed into:

1. The COES control center capability model for the CCOTF
2. The application, data, and market architectures.

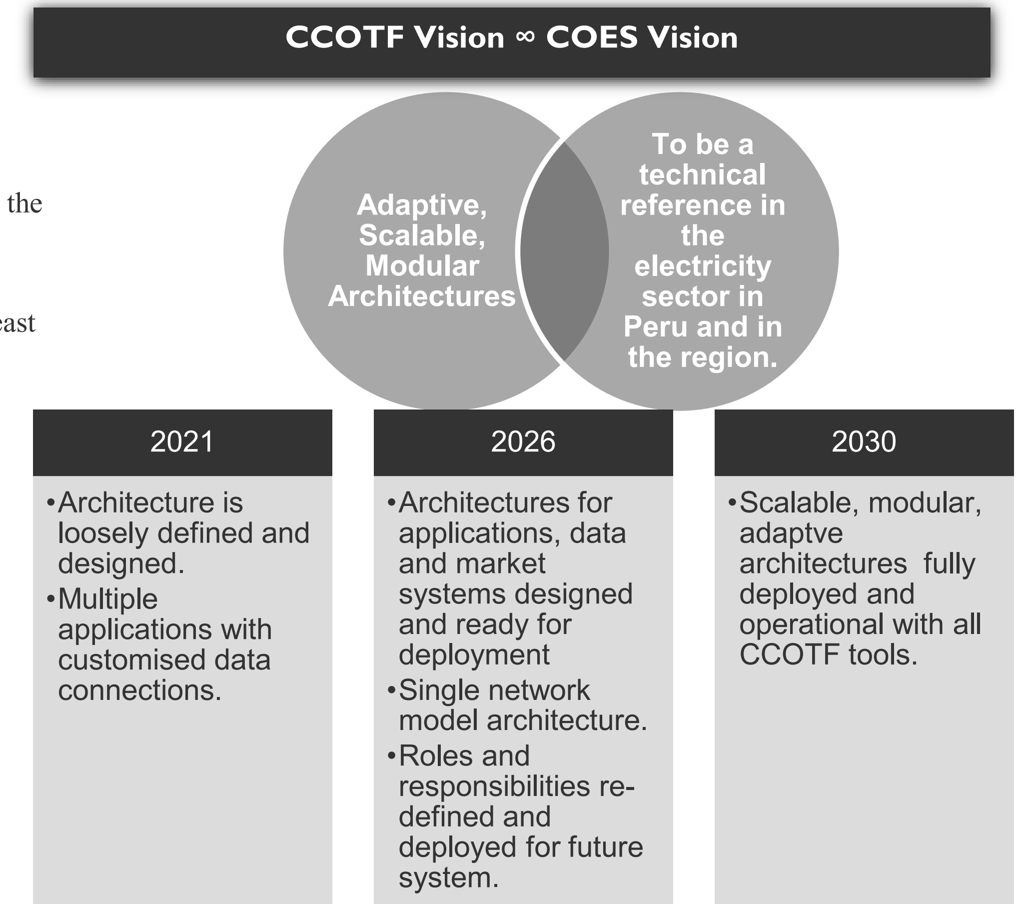


Figure 10. Vision and operational requirements to 2030

The outcome of the development of these pillars should be a modernized, modular, flexible architecture design that aligns with the functional model of the control center. The architectures should be scalable in line with the functional model, meaning that if a new process is added to the control center in the future, it is added to the functional model and is added as a "plug-in" module to the architecture.

3.4.3 Value of Developing and Enhancing a Functional Model and Architecture Foundations

Developing a functional and capability model for the control center will allow human resources and capital expenditure to be allocated in the most efficient and agreeable manner. A functional capability model is a foundational element and will be an agreed upon framework for everybody associated with COES operations, operations planning, IT/operations technology (OT), and the control center. Examples of functional capability models in the industry include the EPRI model and a work domain analysis model.

IT customizations are expensive and resource-intensive to develop and maintain. Changes to high-reliability system data transfer links are difficult for critical real-time OT systems, once established. Developing well-designed, cybersecure architectures will have long-term cost savings in the procurement, deployment, and maintenance of control center and operations support tools in the future.

3.4.4 Risks to Developing and Enhancing the Functional Model and Architecture Foundations

The risks associated with the development and enhancement of a functional and capability models and architecture are shown in Figure 11. The most important risk to be considered and addressed is cybersecurity breaches that could occur if there is an inadequate architecture design for the system under control. Existing well-established frameworks for cyber security in the industry include the North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection standards or the National Institute of Standard and Technology Cybersecurity Framework.

A well-designed functional and capability model will help to optimize both the IT and human resources for the future control center.

If this effort is not carried out, there is a risk that resources will be misallocated, and there may be insufficient human resources for future system operation.

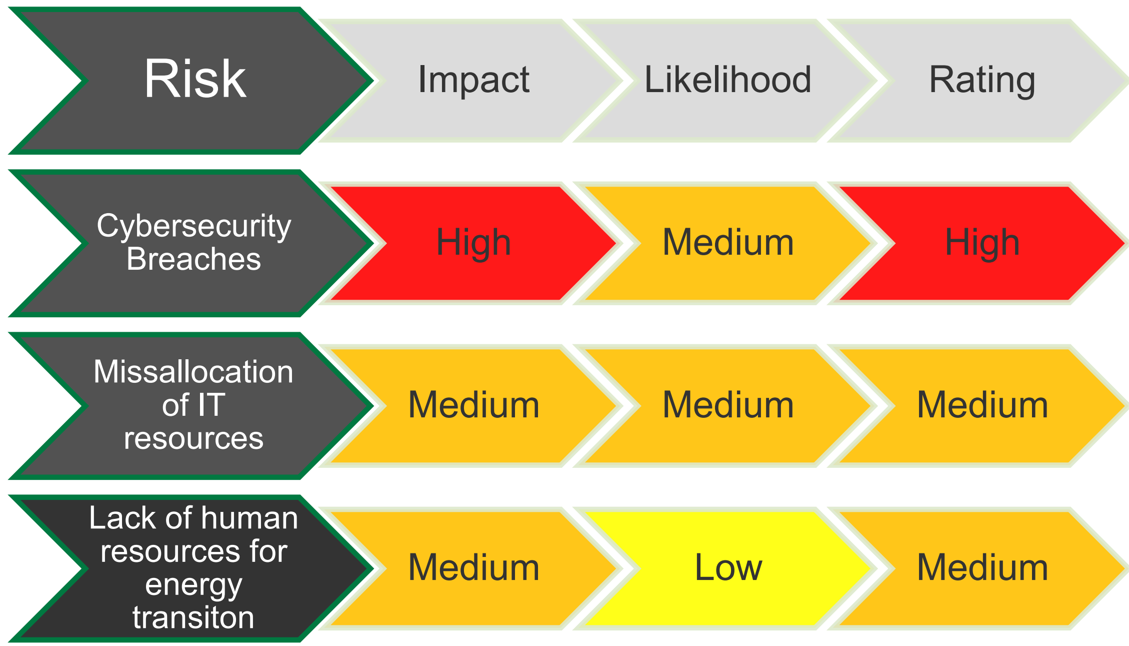


Figure 11. Risk register for developing and enhancing the functional capability model and architectures

3.4.5 Road Map for Functional and Capability Model for CCOTF

CONTROL CENTER OF THE FUTURE FUNCTIONAL & CAPABILITY MODELS AND ARCHITECTURES

	2021 **Stage 1**	*Probable* **Stage 2**	2026 **Stage 3**	*Possible* **Stage 4**	2030+ **Stage 5**
Functional and Capability Model	Develop a Functional Model for control center & system operations	Develop a capability model for control center & system operations. Integrate with architecture design	Review and update F&C model based on the evolving power and market systems	Enhance F&C model for all Peru energy system (distribution, generation, demand)	F&C model foundation of flexible architecture & Peru system digital twin
Data, Application and Market Architectures	Establish baseline for existing IT/OT, data, market architectures. Identify gaps and design priorities	Development and adoption of cyber security standards. Engagement with EMS/MMS & software vendors, distribution and market participants on OT/IT architecture	Development and deployment of new application & data architecture based on the F&C model	Development and deployment of new market architecture.	Fully integrated architectures, standardised across the Peru energy industry

Review (between Stage 3 and Stage 4)

Future State: Adaptive, Scalable Modular Architectures

Figure 12. Road map for the functional and capability model and architectures

3.4.6 How to Deliver the Road Map: Implementation Plan

The resources in COES required to deliver the functional and capability model elements of the road map are expected to be subject matter experts in the IT and operations directorate and the control center.

The resources in COES required to deliver the architecture road map projects are expected to be focused on the IT and OT subject matter experts and teams and will require engagement with outside resources, such as consultants, most likely in cybersecurity standards and architecture design.

The architecture should be developed and deployed in line with major upgrades to EMS and OT systems, as part of these resource-intensive projects.

This road map will likely also require engagement with other energy sector entities in Peru, especially distribution system operators, market participants, generators, demand, and regulators, toward the second half of the decade.

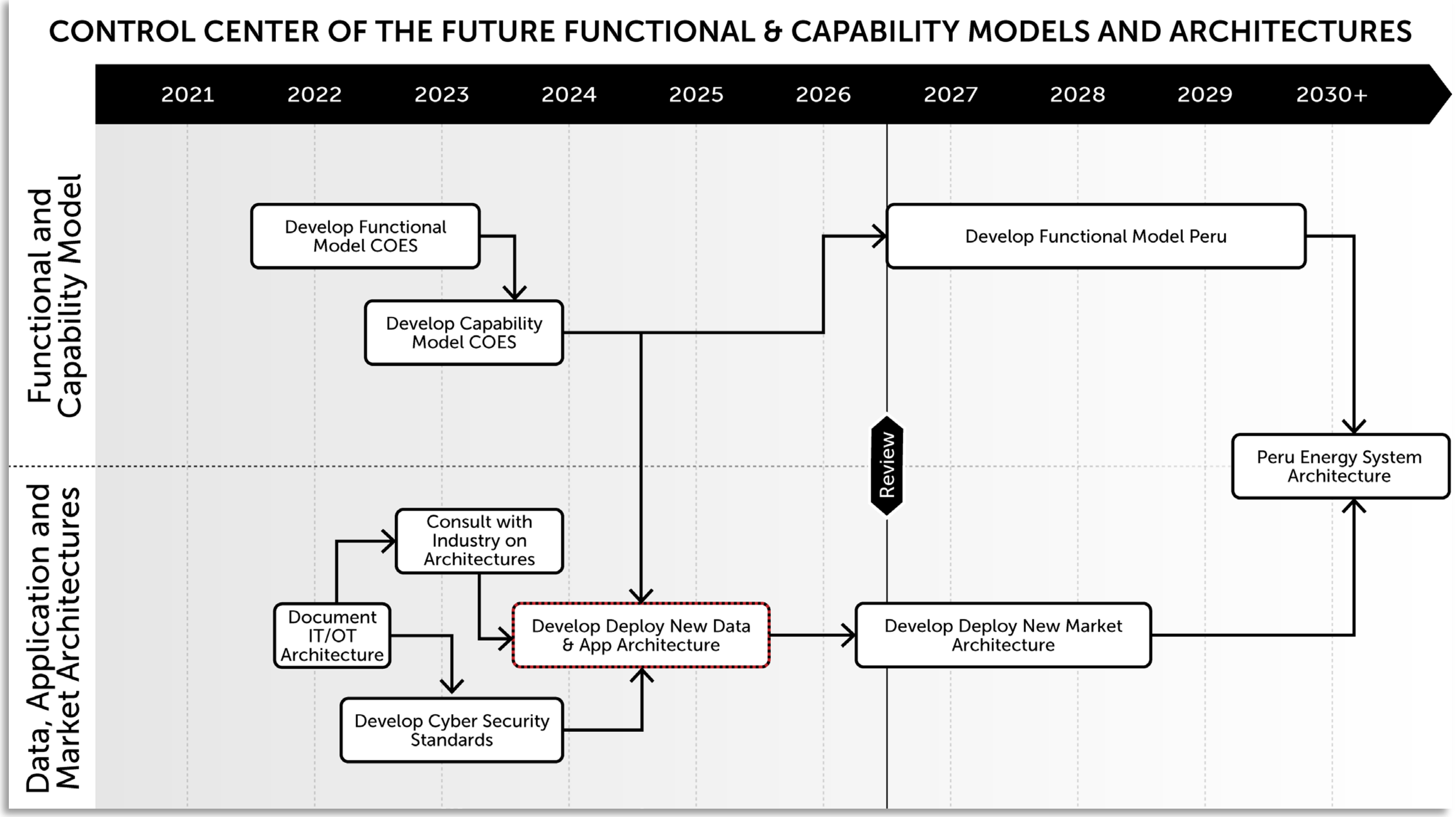


Figure 13. Functional and capability model and architecture implementation plans

3.4.7 Key Actions

- **Functional and Capability Model**
  - **Develop Functional Model COES:** based on available references for a functional model such as work domain analysis.
  - **Develop Capability Model COES:** this model must be based on delimiting the field of action of the control center.
  - **Develop Functional Model Perú:** this model would be the vision for the future, as an expected model for the energy sector.
- **Data, Application and Market Architectures**
  - **Establish Baseline Architectures and Consult on Architecture:** this activity is a consultancy that COES must request from a third party to provide a diagnosis of the current architecture, and to provide recommendations for a comprehensive information-based architecture.
  - **Develop Cybersecurity Standards:** currently, COES cybersecurity is based on the NERC Critical Infrastructure Protection standard, and in the future, it will be necessary to implement the changes and updates made to said standard.
  - **Develop and Deploy New Data and App Architecture.**
    - Architectures should be designed to ensure that applications and data exchange are seamlessly interoperable with one another and utilize the most up-to-date and verified data exchange standards and protocols. For example, YUPANA should be seamlessly linked with the EMS.
  - **Develop and Deploy New Market Architecture**
    - If new rules or regulations are required for the market in Peru, a new market architecture may be needed which emphasizes system services, capacity, reserve, etc. The market systems (currently YUPANA) will have to be well-designed and scalable for future systems. It should be interoperable.
  - **Peru Energy System Architecture**
    - Independent COES architectures may not be adequate for the Peru energy system of the future. The future energy system may incorporate demand response, distribution system congestion, distributed energy resources, water usage, electrification of society, hydrogen, mining, etc. Some advanced companies are trying to develop a full country-wide energy sector architecture, showing how data flows between entities, and platforms and applications integrate and are interoperable between core functions.

3.5 Data Models and Streaming

Data - Models and Streaming

3.5.1 Drivers for Change and CCOTF Vision

The Data pillar of the CCOTF is obviously critical to all aspects of control center operations. Without data, there is no need for a control center. It is visually shown in Figure 7 as an output of the architectures, flowing into the control center software applications. These include EMS, YUPANA, and control room and operations engineering/planning support tools via an interoperable integration (which is linked to the architecture design).

For the road map, data is categorized further into data models and streaming data, because both elements are inherently different.

The data model should be a representation of the system and attributes under control of system operators. Standardized dynamic models exist for generators, loads, and network devices. These can be parameterized by the vendors, based on their proprietary information. The model should be securely held with a single expert team with broad responsibility for model data updates across all the functional entities.

Streaming data refers to data that is fed to the control center in real time from physical objects on the system. Traditionally this has been from SCADA data, but recently, more granular data from phasor measurement units and substations' Intelligent Electronic Devices assets (although not in use today in Peru, in the future this may be transmitted via IEC the 61850 protocol) is available to system operators. In general, while this might be useful data, careful consideration should be given to how this data is organized, governed, and structured, to improve decision making and avoid information overload. The management of streaming data and model data will be the key enabler for machine learning and data analytics techniques to be used in the CCOTF.

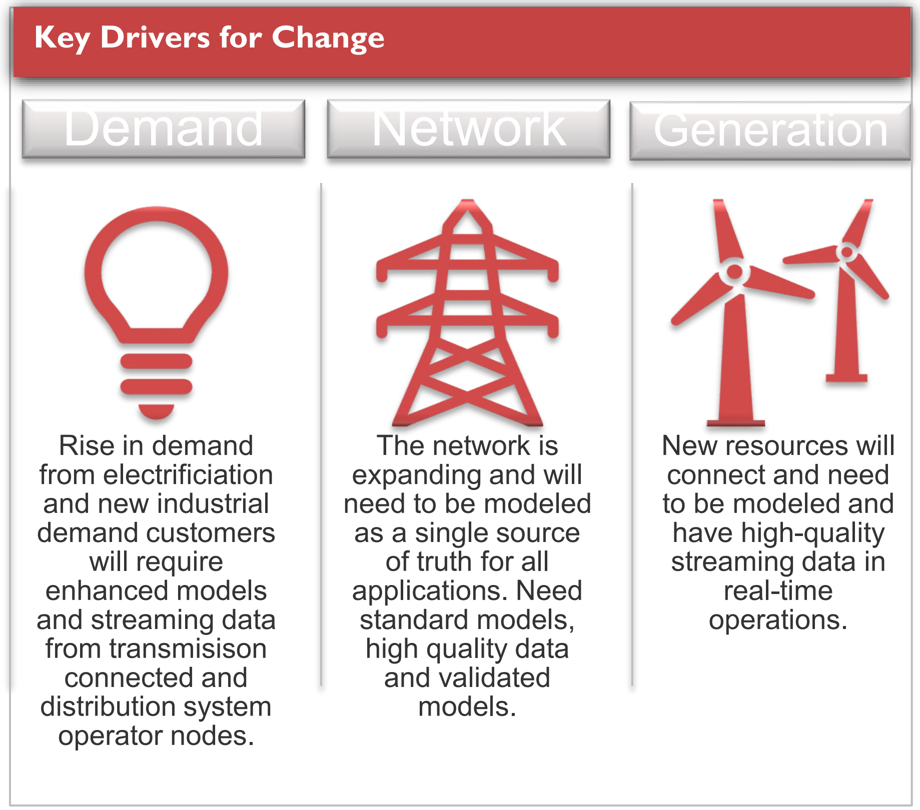


Figure 14. Key drivers for change for the Data Models and Streaming pillar

In an idealized world there is one single model that all entities use and is interoperable with all CCOTF systems. Because the models are never perfect, they should be regularly validated and updated from real-world events. The CCOTF vision for data is to be the single source of truth for energy sector data in Peru, which aligns with the COES vision to be the technical reference for the electricity sector in Peru.

3.5.2 Existing COES Modeling Systems

The existing network model management processes and systems are decentralized, in different formats, and require dedicated and independent model updating, validation, and data gathering among the most outstanding. There is linkage between the Operations and Planning Directorate through the model management in PowerFactory, but the EMS Integrated Network Management module is the primary modelling tool in Operations. The EMS model feeds Organon and Real Time Marginal Cost process cyclically and automatically. PowerFactory models are updated from Planning Directorate and YUPANA in Operation Directorate, involving some manual processing.

Models in each system across the COES company are maintained by a specific team, using different formats and with different levels of granularity. Although the updating of the models is sequential, there are integration opportunities in them, with the aim of standardizing and centralizing them.

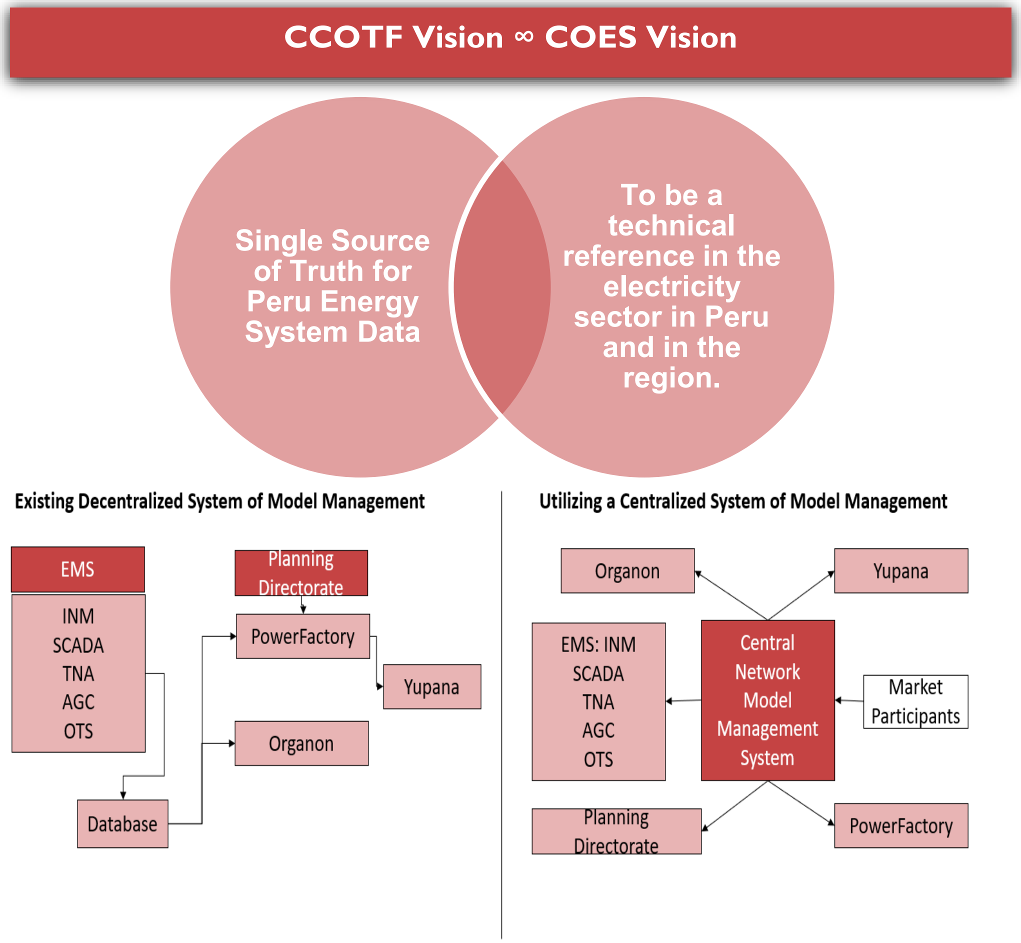


Figure 15. Vision for data models in the COES CCOTF, moving from a decentralized to centralized system

3.5.3 CCOTF Network Model Management

A centralized model management system has a single base model of the system that feeds all radial systems that require model data for analysis. It is standardized to the Common Information Model standard and can operate as an asset register or geographic information system. It uses variations of the base system for future or planned upgrades. Utilizing one model that is managed by one team of modeling experts and feeds all other systems has obvious benefits, for system operations accuracy and to reduce errors. The Integrated Model Manager in the EMS SCADA may serve as a central model management system, as could the model manager in PowerFactory.

3.5.4 Operational Requirements for Data Modeling and Streaming in the CCOTF

To ensure data is utilized in the most optimized manner to enable the EMS, YUPANA/market management system, and the control center and operations support tools, the models and streaming data will have to be:

- Structured
- Centralized
- Standardized
- Documented
- Validated
- High Quality
- Reliable and Resilient
- Available and Accessible.

By working toward structuring operational data and models in this way, the process of integrating new tools will be simplified. Having a central repository system for managing network models will be efficient from a human resource perspective and should eliminate errors.

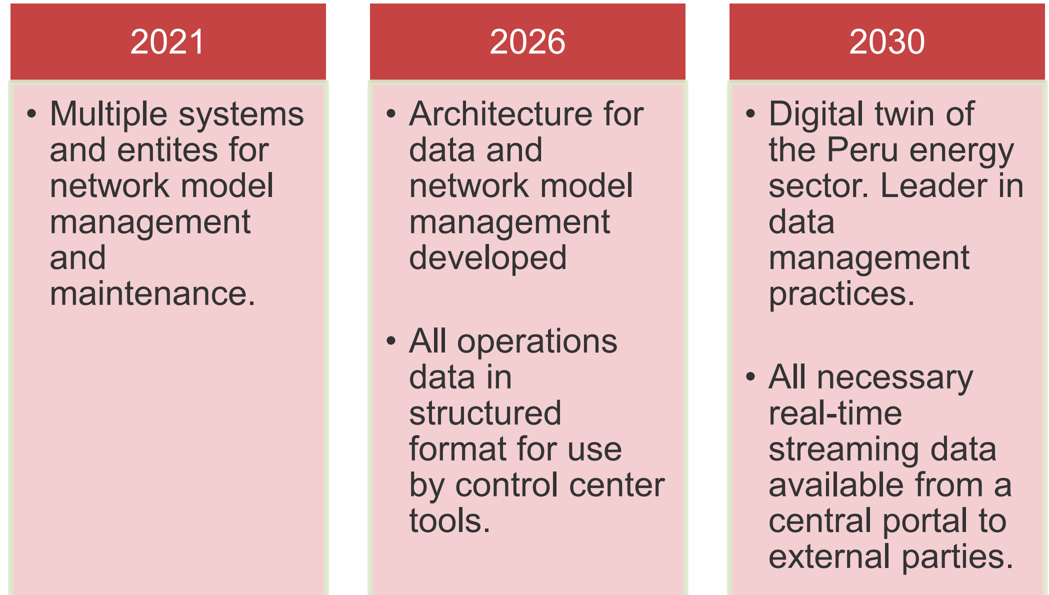


Figure 16. Operational requirements for CCOTF Data pillar to 2030

Structuring data and making it easily available, will make utilizing machine learning techniques to solve system problems in the future more straightforward.

By developing a standard approach, competencies, and technologies for management of transmission system data with transmission owners and operators, COES will lead the Peruvian energy sector in data management excellence, toward a digital twin for the energy sector of Peru.

3.5.5 Value of Developing and Enhancing Data Management Pillar

Developing model data and streaming data capability for operation and the control center will allow human resources to be optimized, eliminate duplication, and ensure accuracy in all systems. The data in the system can be validated, so that trust is gained in the accuracy of the model and its tools for stability analysis.

Making applicable data available will be valuable to the wider energy community in Peru, and the wider economy.

This will enable companies to establish themselves based on the best available data and to allow existing market participants to make the most advantageous decisions for investment, maintenance, and expansion.

3.5.6 Risks to Developing and Enhancing Data Capability

The risks associated with the development and enhancement of the data management capability are shown in Figure 17. The most important risks to be considered and addressed are accuracy of data, resource allocation, and cybersecurity.

Risk	Impact	Likelihood	Rating
Model Errors	Medium	High	High
Maintaining Multiple Systems	Medium	Low	Medium
Maintaining Knowledgeable Human Resources	Medium	Low	Medium
Cybersecurity	High	Medium	High

Figure 17. Risk register for developing and enhancing the data management capability

3.5.7 Road Map for Data Management for CCOTF

CONTROL CENTER OF THE FUTURE DATA MODELS AND STREAMING

	2021 **Stage 1**	*Probable* **Stage 2**	2026 **Stage 3**	*Possible* **Stage 4**	2030+ **Stage 5**
Data Models	Assessment of inventory of all models in COES. Map data flows	Model data governance and management responsibilities in place. Assessments on model data quality based on existing simulation system	Data architecture and network model management system designed.	Network model management system deployed for all applications. Engage other energy sector companies, market participants.	Digital twin model of Peru energy sector
Data Streaming	Inventory and metadata for all streaming data in control center and operations	Streaming data governance & responsibilities in place for streaming data archive. Assessments on data quality, improvement requirements. Data quality controls in place.	Internal data hub with all the streaming data archived. Structured for analysis, analytics, machine learning.	Control room tools use AI/ML techniques as standard with full archive of operations data for training	External data hub for streaming data for companies, stakeholders, research

Review (between Stage 3 and Stage 4)

Future State: Single Source of Truth for Energy System Data

Figure 18. Road map for the Data pillar for CCOTF

3.5.8 How to Deliver the Road Map: Implementation Plan

The projects to be delivered as part of the data models and data streaming will be primarily focused and led from the IT competency and directorate, and will be tied to the data architecture development, detailed above.

There should be extensive input from the engineering directorates of operations and planning as required on the data architecture and design.

In the later part of the decade—assuming Stage 3 has been reached and COES have industry leading governance, practices, and technology, deployed for the management of its models and data—it is recommended to engage with the wider Peru energy and electricity sector to align data and models and create a full digital twin of the Peru system.

This will allow external stakeholders access to the most up to date relevant data, to make business decisions and to encourage investment in the energy sector.

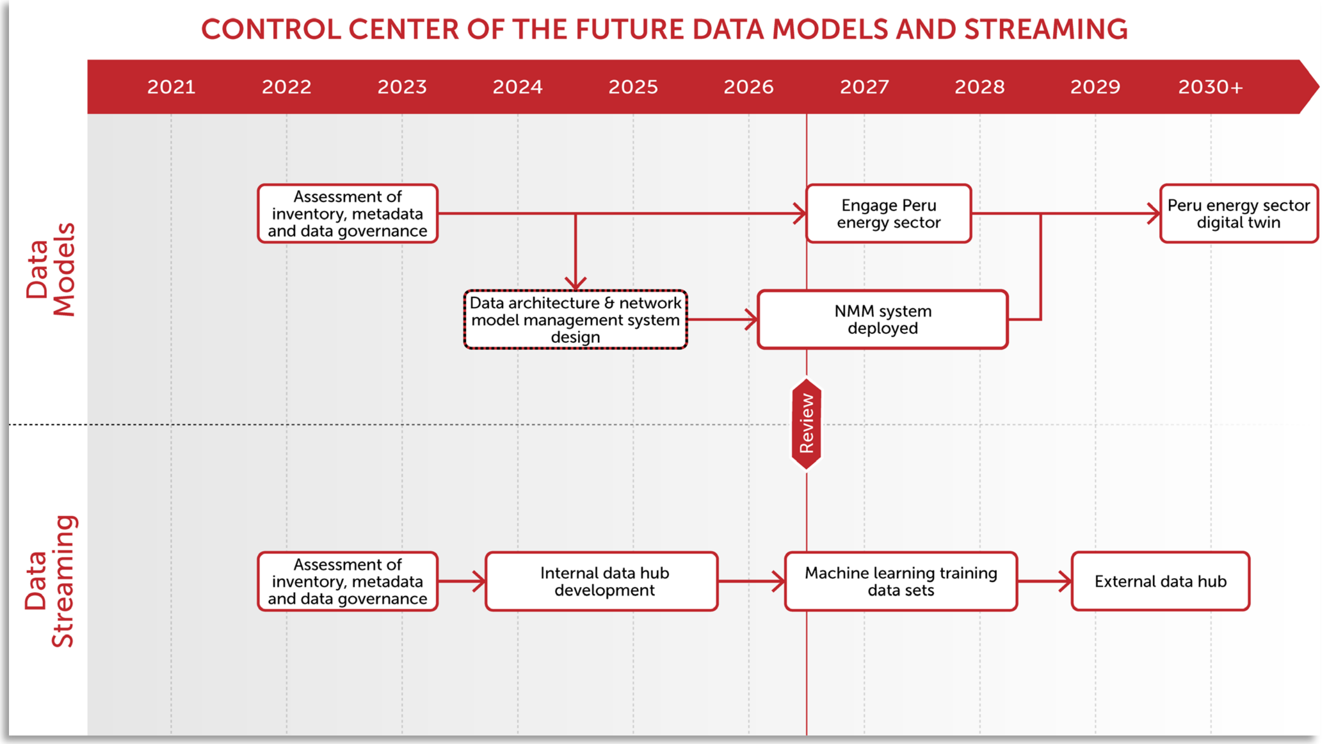


Figure 19. Road map and implementation plan for the Data pillar

3.5.9 Key Actions

- **Data Models**
  - **Assessment of inventory, metadata and governance,** inventory evaluation of all models in COES and mapping of all data flows (assessments on model data quality based on existing simulation system)
  - **Data architecture and network model management system design,** data architecture design, and network model management system completed
  - **Network Model Management (NMM) system deployed,** network model management system implemented for all applications
  - **Engage Peru energy sector,** participation of companies in the sector and other members of the electricity market in the NMM
  - **Perú energy sector digital twin,** high fidelity simulator model (digital twin) runs in parallel with the real control system and enables advanced checks to ensure that no changes affect the Peruvian electricity supply.
- **Data Streaming**

- **Assessment of inventory, metadata and governance,** evaluation of inventory and metadata for all data transferred in the control center and operations (data quality assessments)
- **Internal data hub development,** internal data center with all streaming data archived, structured for analytics, analytics, and machine learning
- **Machine learning training data sets:** control room tools that use AI/machine learning techniques as standards.
- **External data hub:** external data center for streaming data to companies and stakeholders.

3.6 Control Center Tools

The EMS/SCADA system is a key part of all control rooms around the world. EMS/SCADA are "monolithic" systems. COES have a Siemens Spectrum 7 system. EMS/SCADA vendors have their own product road map incorporating their own research and development. These are not available to the wider industry and community due to intellectual property restrictions. EMS/SCADA typically are in place for at least 5 years before they require an upgrade or replacement, which are major, resource-intensive information and communications technology projects.

For the CCOTF, the **EMS/SCADA** is required to be interoperable with all other CCOTF tools, operations planning support tools, and the YUPANA marketing management system. This should be primarily enabled through data exchange standards governed by the Common Information Model.

The **market management system in COES is YUPANA** and determines the cost of energy, unit commitment, and the dispatch in real time. It works in coordination with the PowerFactory tool to perform security constrained economic dispatch, to run N-1 security analysis on the preliminary dispatch and determine final dispatch. Dispatch instructions to generators are issued by the automatic generation control function, incorporated in the SCADA system. YUPANA will be the enduring solution for market systems in COES, but with some enhancements across the decade, to incorporate the changing network and regulatory requirements.

Associated with the market management system and the EMS are **the other control center tools** that may not be in EMS or YUPANA but are essential to operating the system. These could be software applications or platforms or even software as a service from external vendors. In general, they are linked via customized data connections to the data from the EMS or YUPANA. Control center tools can include voltage optimization, demand forecast, renewable forecast, wide area monitoring system, but also logging applications, workforce management, and asset monitoring. Some of these can be applications or modules within the EMS/SCADA system and do not necessarily have to be separate IT systems. The required control center tools for COES to carry out the processes and tasks should be derived from the functional and capability model which establishes the functions and processes for the CCOTF.

The **operations planning** (sometimes called operations engineering or operations support) teams in COES study the network at a longer time horizon than the real-time system operators, usually weeks or months out. For the most part, the engineers in these teams utilize a similar, smaller set of the tools used by the control center operators, who work in real time. The operations planning support tools should be interoperable with the control center tools and the EMS and YUPANA, utilizing a consistent model of the system under control and identical streaming system data; for example, outages should be studied with demand and renewable forecasts and market schedules that are as synchronized as possible to real-time operations.

3.6.1 Drivers for Change and CCOTF Vision

Having developed the architecture and data foundations, the control center tools should be developed to take advantage of the new architectures, data models, and streaming data enhancements.

Control centers are primarily made up of software applications and visualizations. The most important consideration is to make them useful and usable for the operators who monitor and control the system 24/7/365.

With the increase in demand, generation, and network expansion, the control center tools will need to expand to allow a greater extent of monitoring and control in operations.

Forecasting will need to be enhanced, and other software tools will need to accommodate an increase in demand and generation resources, while maintaining grid reliability and security.

New system phenomena will likely appear as the system expands, such as grid stability issues, oscillation, new congestion, voltage issues, and protection coordination. These will require an increase in real-time study and simulation capability for load flow, short circuit, and stability assessments.

These tools will have to be interoperable with one another via the architecture and data exchange standards.

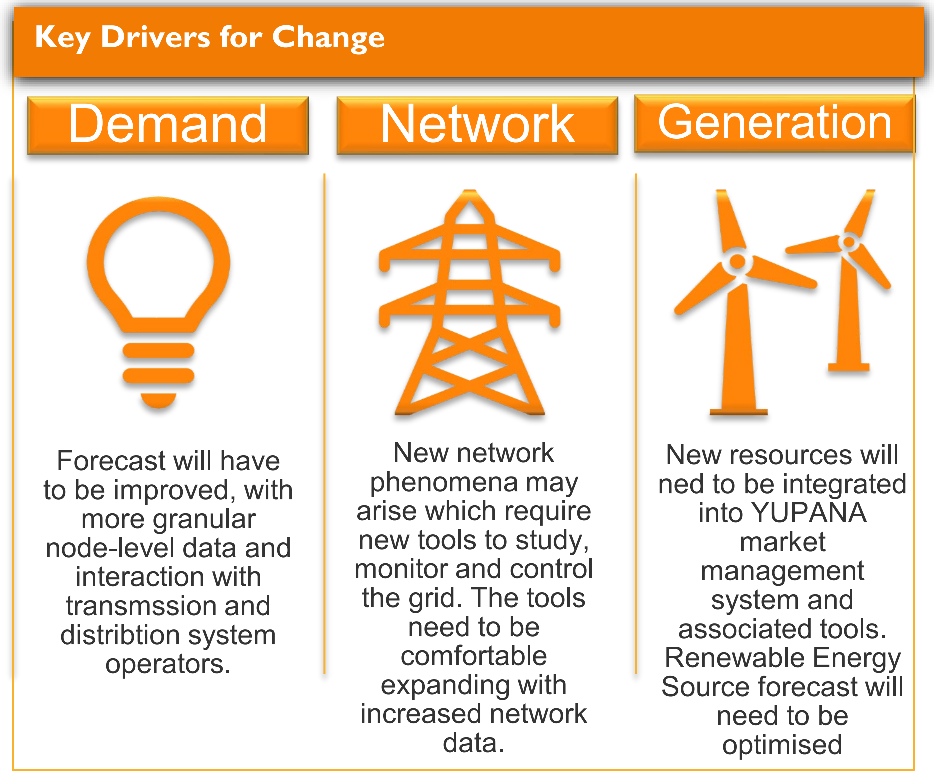


Figure 20. Key drivers for change for the Control Center Tools pillar

The vision is for developed control center tools, operations planning tools, EMS, and YUPANA to be integrated, interoperable, sharing data and models, and solving system issues in coordination with each other's processes.

There is also a need to move to more automated systems for certain very algorithmic processes, such as reporting and logging, outage scheduling, and demand forecasting. As an example, machine learning-based artificial neural networks are well-suited to demand forecasting and basic automation scripts can take data from various operational databases and automatically create reports, without need for operator intervention.

3.6.2 Operational Requirements for Control Center Tools in the CCOTF

Operators will require tools to be easy to use and interpret, stable, reliable, and resilient. They should be accurate and regularly validated. Tools should be aligned to processes which are defined in the functional and capability models, defined above so that they can expand and adapt as required.

Ideally, all the tools should coordinate with one another seamlessly. So the YUPANA system should easily operate with the EMS system and vice versa. Manual processing (such as data entry) should be eliminated, in as much as that is possible.

The output results or data visualization should be consolidated in a single dashboard to optimize situational awareness (described in further detail below in the Human Factors and Decision Support pillar).

COES have demonstrably high capability in tool development for the control center, including visualization development and coding with Python. This approach allows flexibility, efficiency, and reduced costs. If choosing to continue in-house development of certain tools for the CCOTF, the importance of security, quality control, and upgrade cycles cannot be understated. At present, COES are implementing processes related to Python application developments, incorporating its execution with management methodology and coding practices.

The tool development and deployment should take advantage of high-performance computing and cloud computing where possible, given the depth and quantity of data available. New machine learning applications can be applied to certain tools toward the second part of decade.

The 13 control center tools (not including EMS or YUPANA) are detailed in **Table 1**. This table documents the current toolkit, inputs, outputs, and idealized future state. It also identifies priority for the development of the tool, when considering the evolving system of the future.

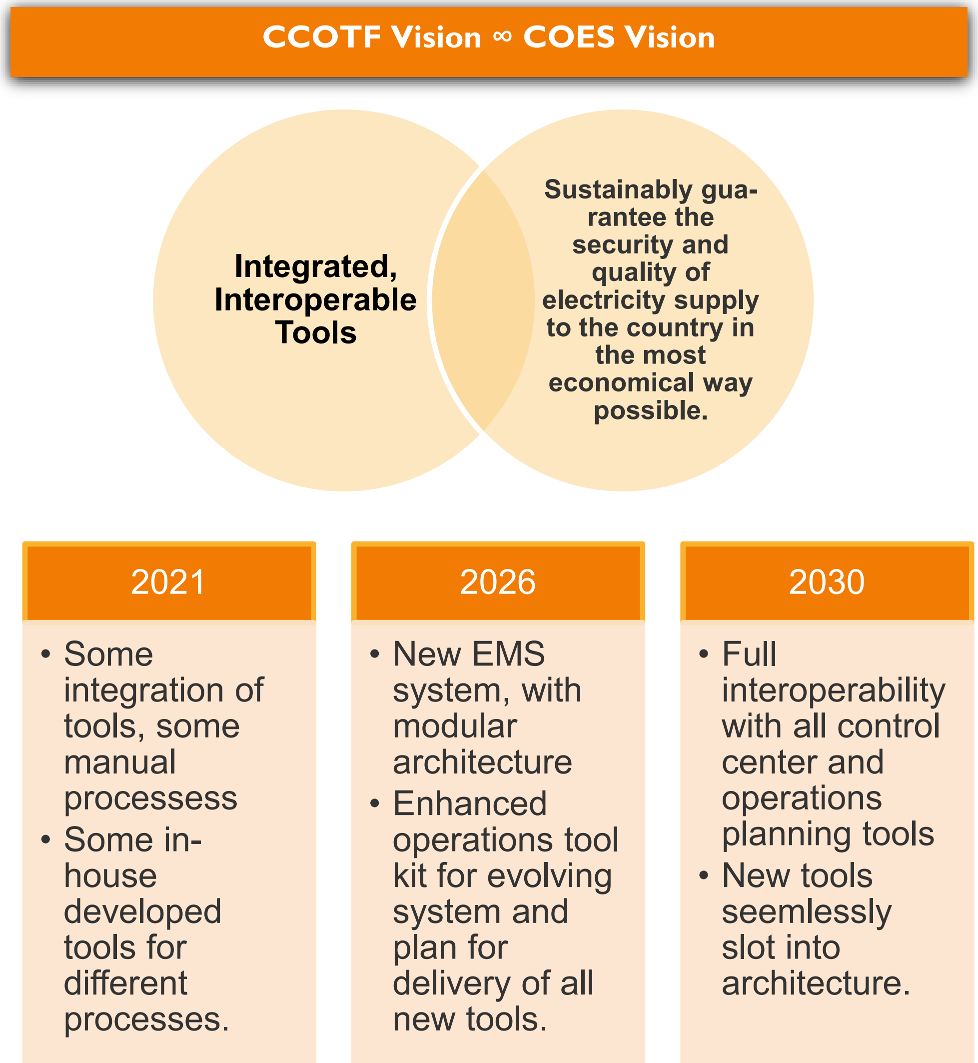


Figure 21. Operational requirements for CCOTF Control Center Tools pillar to 2030

3.6.3 Value of Developing Control Center Tools Pillar

Developing and enhancing the EMS, YUPANA, and control center tools for operation and the control center should lead to a reduction in errors, even as the system expands drastically.

It should increase reliability, reduce the risk of major system disturbances by having advanced forecast and study capability and in the event the disturbances occur, it should provide adequate systems to restore service as quickly as possible.

3.6.4 Risks to Developing and Enhancing Data Capability

The risks associated with the development and enhancement of the control center tools capability are shown in Figure 22. The most important risk to be considered and addressed is in system integrity. If the operational and control center tools are not developed adequately for the rapidly expanding system of the future, there will be an increased risk to electricity system reliability.

Much of the documented expansion of control center tool capability relates to having the ability to scale for new system challenges that are unseen today but are likely to emerge.

Risk	Impact	Likelihood	Rating
Major System disturbances	High	Medium	High
Maintaining multiple IT systems	High	High	Medium
Operator Errors	Medium	Low	Medium
Cybersecurity for Control Center Tols	High	Medium	High

Figure 22. Risk register for developing and enhancing the control center tools

3.6.5 Road Map for Control Center Tools for the CCOTF

Table 1. List of 13 Control Center Tools for the CCOTF

Control Room or Operations Planning Tool	Current State	Inputs	Outputs	Ideal Future State	Priority
Congestion Management Tool **(RT & OP)**	YUPANA, PowerFactory TNA	State estimation solution, market data, forecasts, distribution system operator data, device setpoints	Visually presents a solution for congestion on TX & DX system. Visualisation of congestion and suggested mitigations automatic control.	Automated Optimal Power Flow and control solution with network and redispatch for real time and look-ahead that mitigates congestion on Tx and Dx system based on cost, with probability.	High
Voltage Control Reactive Power Optimisation Tool **(OP, RT)**	PowerFactory, TNA optimal power flow	State estimation solution, market data, demand forecast RES forecasts, device setpoints	Voltage setpoints for all buses on the network for real time and look ahead. Visualisations and ability to issue commands.	An automated control tool for optimized and look-ahead voltage setpoint tool based on forecast trajectories, cost of dispatch.	Medium
Alarm Root Cause Analysis / Disturbance Investigation Tool (RT)	Grafana Dashboard	SCADA alarm data, asset health data, previous disturbances and logs, weather data, etc.	Visually presents concise message indicating root cause of disturbance with mitigation.	Umbrella tool for all data that instantly identifies alarm and disturbance root cause and directs operator's attention to issues and solutions. Likely to use machine learning.	Low
Dynamic Security Assessment and Power Quality (Including Voltage, Frequency,	Organon, WAProtector	State estimation solution, dynamic model of the system, forecasts, Wide Area Management System.	Visually identifies stability, oscillations and security in real time and look ahead. Studies transients for switching and	Interoperable with all tools running look-ahead stability assessment with suggested mitigation. Integrates with dashboard. Automated switching transient studies. Potential for	Medium

Control Room or Operations Planning Tool	Current State	Inputs	Outputs	Ideal Future State	Priority
Inertia, Transient, Small Signal Stability) **(RT&OP)**		EMT model of system	monitors power quality,	automated control actions. Link to system strength evaluation tool. Link to training simulator.	
System Strength Evaluation Tool	TNA	State estimation solution, outage plan, market data, forecast data, RT simulator	A visual assessment of the current system strength relative to grid limits. Some suggested control actions.	Online tool to monitor system strength in real time and look-ahead based on forecast data, potential for automatic control. Link to Dynamic Stability Assessment protection tool.	Medium
Protection, Short Circuit, and SPS Coordination Tool (OP)	PowerFactory	State estimation solution, protection grid model, outage data, forecast data, market schedules, Special Protection Scheme device status	A visual assessment determining if the protection on the system is coordinated in real time, for the outages ahead and for a look-ahead horizon.	Interoperable with EMS, dashboard, and asset health tool. Feeds Organon for transient stability analysis and is coordinated with system strength tool and congestion management tool.	Low
Black-start and Restoration Enhancements, Including RES (RT)	None	State estimation model, protection model, outage data, market schedules.	Tool to guide the process of both black-start resource start optimisation, including RES and restoration pathways	Online tool that works in the case of a blackout or major system restoration to guide operator through the process.	Medium
Demand Forecasting (RT)	In-House Tool	Archive demand data, weather data, node level, distribution system operator data	Forecast of system demand with confidence ranges to feed into all CC tools.	Continuous tracking of forecast accuracy, continuous improvement in forecast with	High

Control Room or Operations Planning Tool	Current State	Inputs	Outputs	Ideal Future State	Priority
				improved customer data and methodologies	
Renewable Energy Forecasting (RT)	None	Weather data, generator availability and location	Forecast of RES with confidence ranges to feed into all CC tools.	Continuous tracking of forecast accuracy, continuous improvement in forecast algorithms for increased RES penetrations.	High
Balancing, Dispatch, and Load Frequency Control	Automatic generation control in EMS SCADA. Currently, the rotating reserve allocation is co-optimized with the hydrothermal dispatch, and the system is prepared for connection with all the SEIN generators.	Market data, generator status, frequency	Continuous dispatch instructions to all market participants based on market output	Interaction with VPP (virtual power plants) and market participants on distribution system operators as required.	Low
Reserve, Ramping, Flexibility Tool (RT)	In-House Tool	Market data, generator statuses, demand	Assessment of the ramping requirement and capability of system	Integrated with YUPANA, dashboard, congestion management and organon. Automated detection and redispatch for flexibility.	Medium
Outage Management, Reporting, and Workforce Management	Separate In-House Tools	Outage data, state estimation solutions, market schedules, archive system data, field data	Study results and schedule of outages with switching plans. Integrated reporting	Automated study of near-term and long-term outages with various realistic market, generation scenarios. Interoperable tool.	Medium

Control Room or Operations Planning Tool	Current State	Inputs	Outputs	Ideal Future State	Priority
			app with a tool to manage workforce.	Automated logging of field workforce personnel and automated reporting of system issues, link to dashboard.	
Environmental (Fire and Weather) Forecasting	None	Weather and fire data from publicly available resources	As assessment of weather by location, integrated with system and market data where possible	All weather data is integrated into all control center tools with forecast confidence ranges. Congestion management, protection coordination, and stability tools.	High

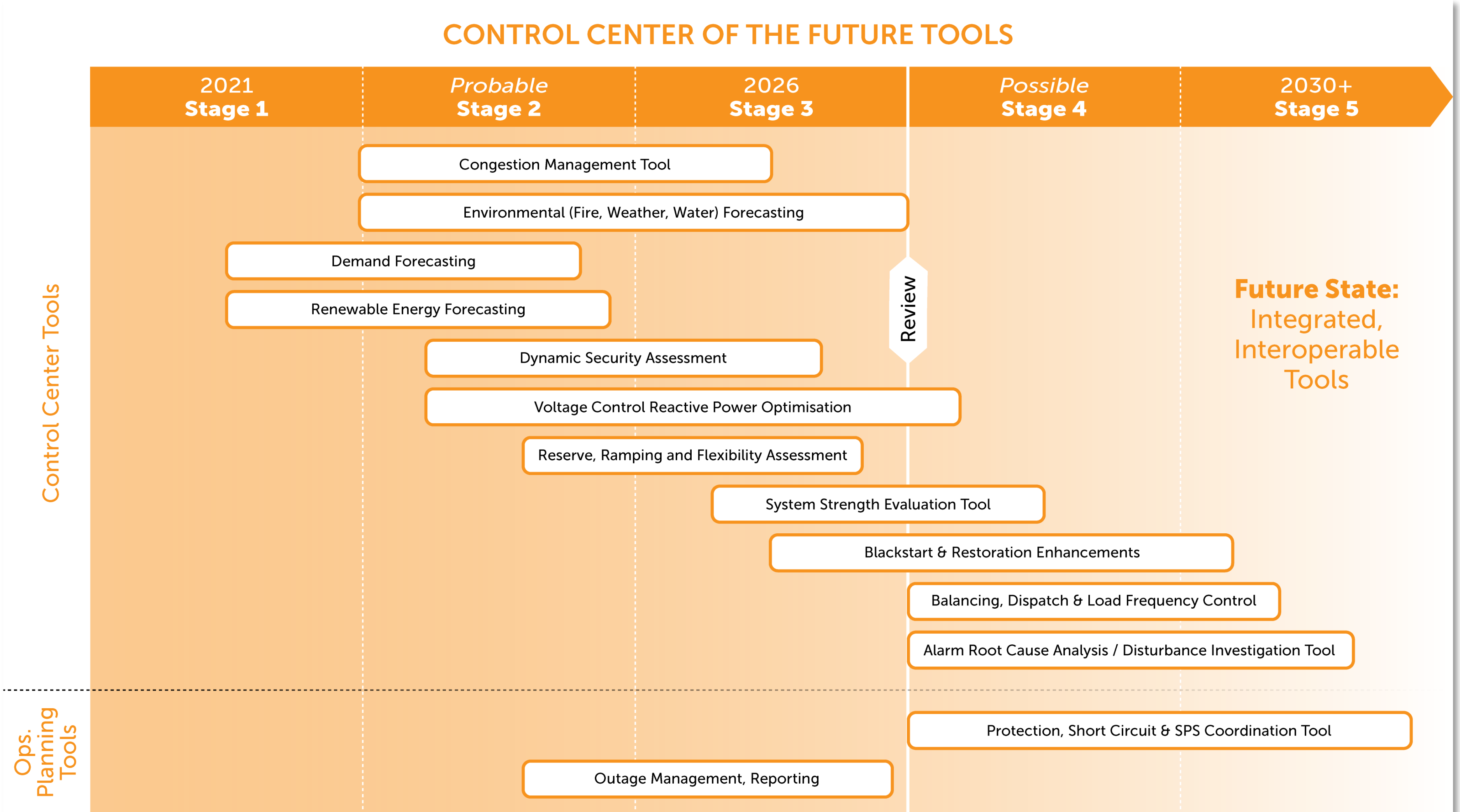


Figure 23. Road map for the development of the control center and operations planning tools for the CCOTF based on the indicative priority

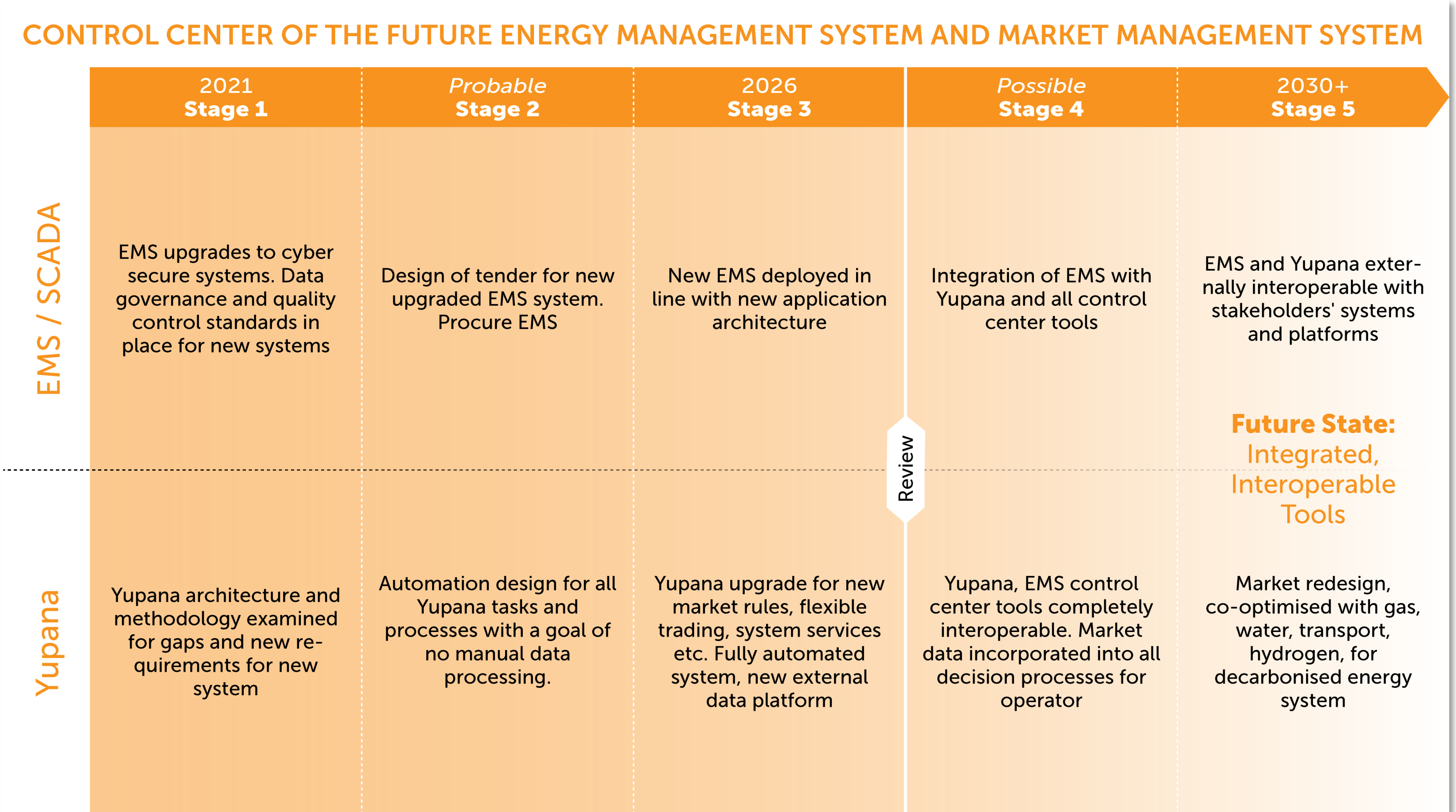


Figure 24. Road map for the development of the EMS and YUPANA tools for the CCOTF

3.6.6 How to Deliver the Road Map: Implementation Plan

The projects to be delivered as part of the control center tools, EMS, and YUPANA will be extensive and be very resource-intensive and complex.

They will primarily be focused and led from the control center Operations Directorate with extensive input from the IT Directorate.

Development of the tools should be strongly linked with the developments of the architectures, and data systems improvement projects.

In Figure 25, the development of the control center and operations planning tools are shown as a continuous process across the decade. These are described in Figure 23 and Table 1.

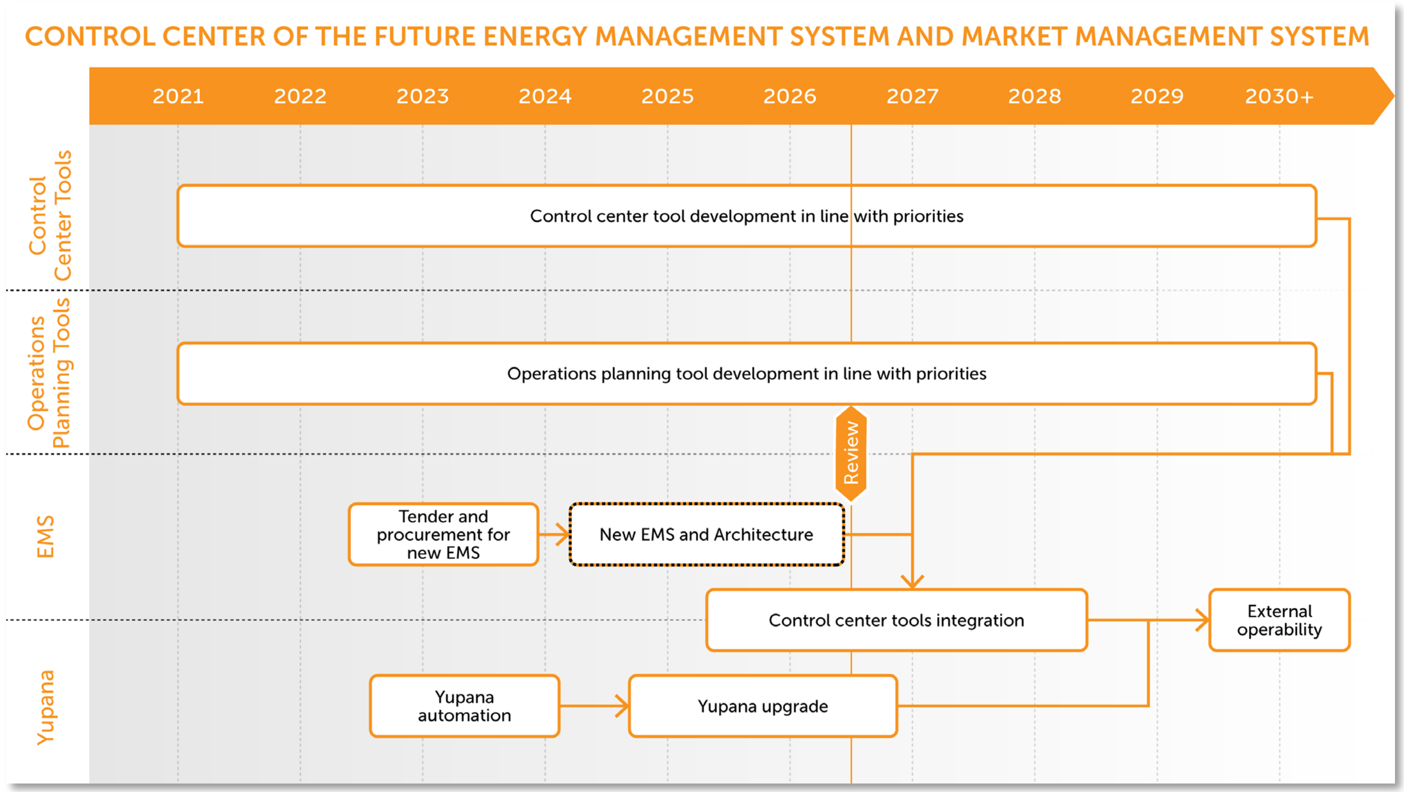
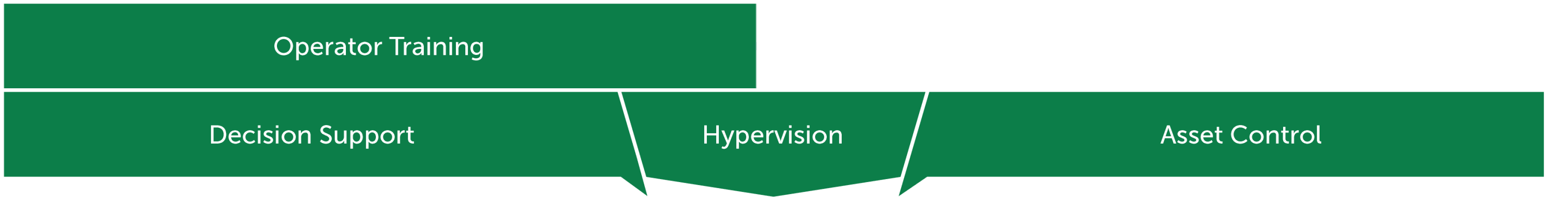


Figure 25. Road map and implementation plan for the Control Center Tools pillar

3.6.7 Key Actions

- **Control Center Tools**
    - **Control center tool development in line with priorities,** this activity that must be carried out throughout the decade until 2030 at least. Contains tools related to real-time operation and operations planning, and it must be in accordance with the processes and priorities of the control center, as well as with the IT architecture. Indicative priority for control center tool development is shown in Figure 23.
- **Operations Planning Tools**
    - **Operations planning tool development in line with priorities,** this activity must be carried out throughout the decade, until 2030 at least. It contains only planning tools which have an orientation of being an input to the operation and do not have a version applicable to the control center. Indicative priority for control center tool development is shown in Figure 23.
- **EMS**
    - **Tender and procurement for new EMS,** development of terms of reference for the tender and acquisition of a new EMS
    - **New EMS and Architecture,** new EMS implemented in line with the new application architecture.
    - **Control center tools integration,** interoperability, and integration of the new EMS system with the new applications of the control center
    - **External operability,** interoperability of the new EMS system and other applications with the platforms of external companies.
- **YUPANA**
    - **YUPANA automation,** this activity seeks to automate YUPANA, eliminating manual processes. It must be accompanied by the design of an architecture that supports this automation.
    - **YUPANA upgrade,** updating of the YUPANA software, according to the priorities and processes of the control center, as well as possible new rules in the electricity market.

3.7 Human Factors and Decision Support



3.7.1 Drivers for Change and CCOTF Vision

This multifaceted pillar is intended to encompass the control of power system elements from the future control center. This builds on the fact that much of the modern power system is automatically controlled such as generation, demand, and reclosing on overhead lines and special protection schemes. This trend is expected to continue in the future, to the point that all elements of the power system will be automatically controlled, with operators likely to only intervene when the automation is disrupted, or for major system events and emergencies.

Operators require streamlined, optimized interfaces of the software applications they interact with, and information should be presented in the clearest, most unambiguous, and most actionable format. Display design should be standardized and follow best practice guidelines. Because the control center hosts vast quantities of streaming analog and alarm data from multiple tools, presenting this in a clear, concise manner to improve situational awareness is a key focus of the CCOTF road map.

The idealized vision for the CCOTF for this pillar is to have fully automated control of all network assets and generation resources, and, if possible, demand response (via distribution system operators). Operators will intervene as required, when and if automation breaks or in the event of an emergency. Operators will generally plan the system based on forecasts and intervene when automation does not operate correctly.

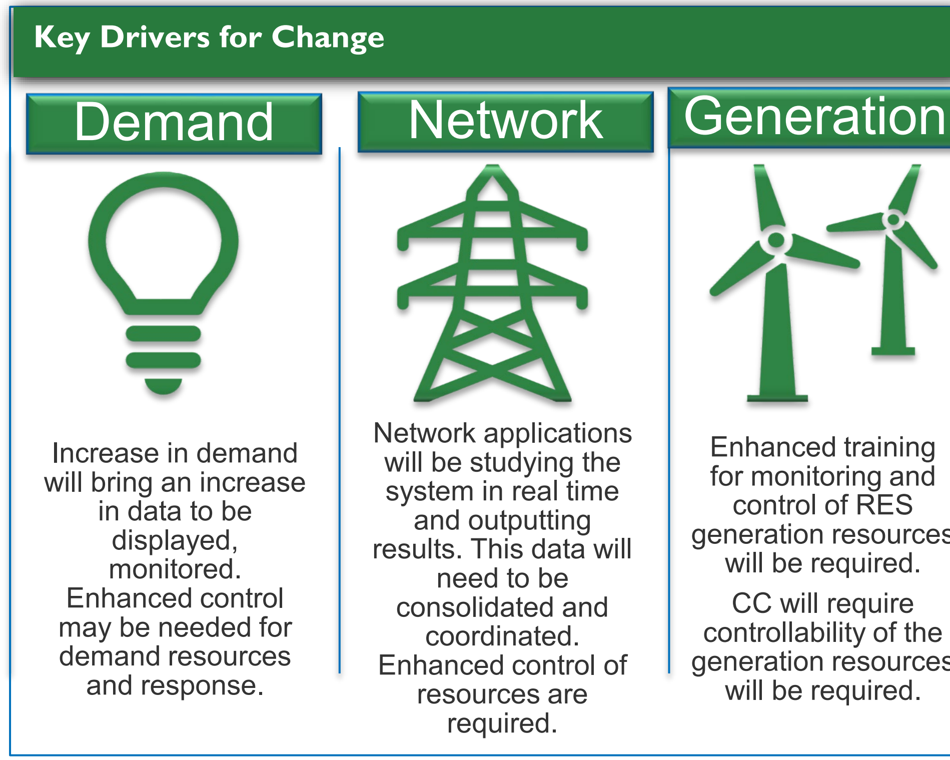
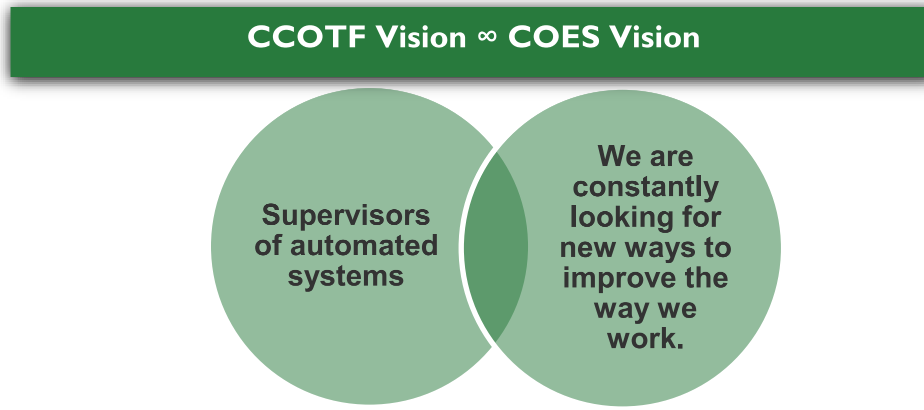


Figure 26. Key drivers for change for the Human Factors and Decision Support pillar

Operators are fully trained with certification and regular updates on all control center tools and on intervention scenarios. Operators are comfortable assessing risk and maintain situational awareness to avoid out-of-the-loop effect. Out-of-the-loop effect is a common risk in aviation when pilots use auto pilot and they develop a degraded ability to intervene when autopilot malfunctions.

To enable this vision, the concept of Hypervision is introduced. Hypervision is a concept that streamlines the data from all the control center tools into one user interface, presenting clear, concise actions for the operator to monitor and drill into direct manual control, if necessary. It was deveoped by RTE in France.[5]

COES have begun development of this concept with a dashboard for situational awareness based on Grafana environment and PI System architecture, which will be the first step in this road map to continued development.



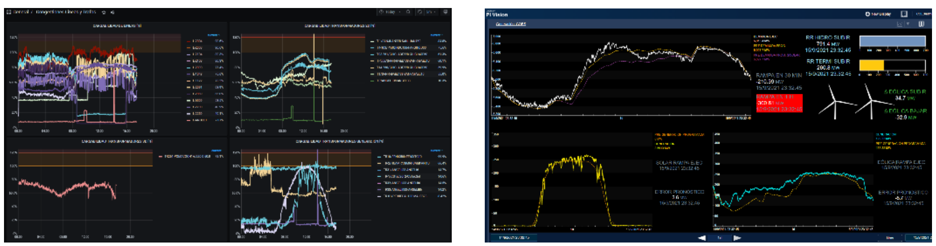


Figure 27. Existing COES situational awareness dashboard

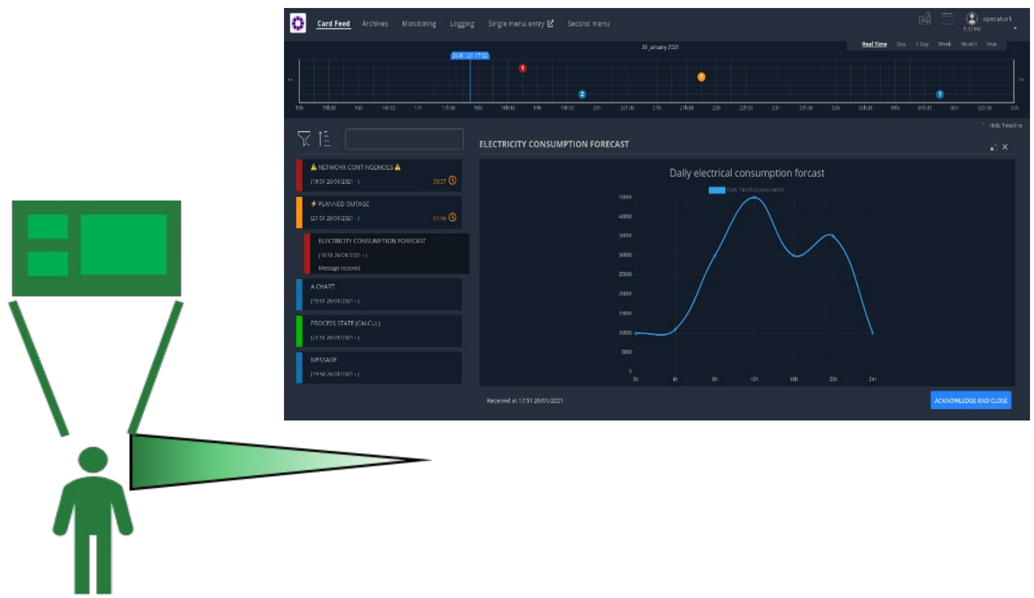


Figure 28. Hypervision concept as deveoped by RTE in France

[5] Source: https://www.lfenergy.org/projects/operatorfabric/

3.7.2 Operational Requirements for Human Factors and Decision Support in the CCOTF

Based on the range of new and upgraded control center and operations planning tools that will be required in the CCOTF and the massively increased data quantities, the associated human factors will have to be a major consideration for the CCOTF.

The operators in the control center will require:

- Streamlined data from all control center tools to a single Hypervision interface
- Enhanced decision support to identify issues ahead of time, display the root cause
- Enhanced decision support to identify mitigation actions for system issues in as quickly a fashion as possible.
- Automatic control of all devices and resources with manual backup for operator intervention as required if automation breaks
- Training that is tailored for the tools and automated operations paradigm.

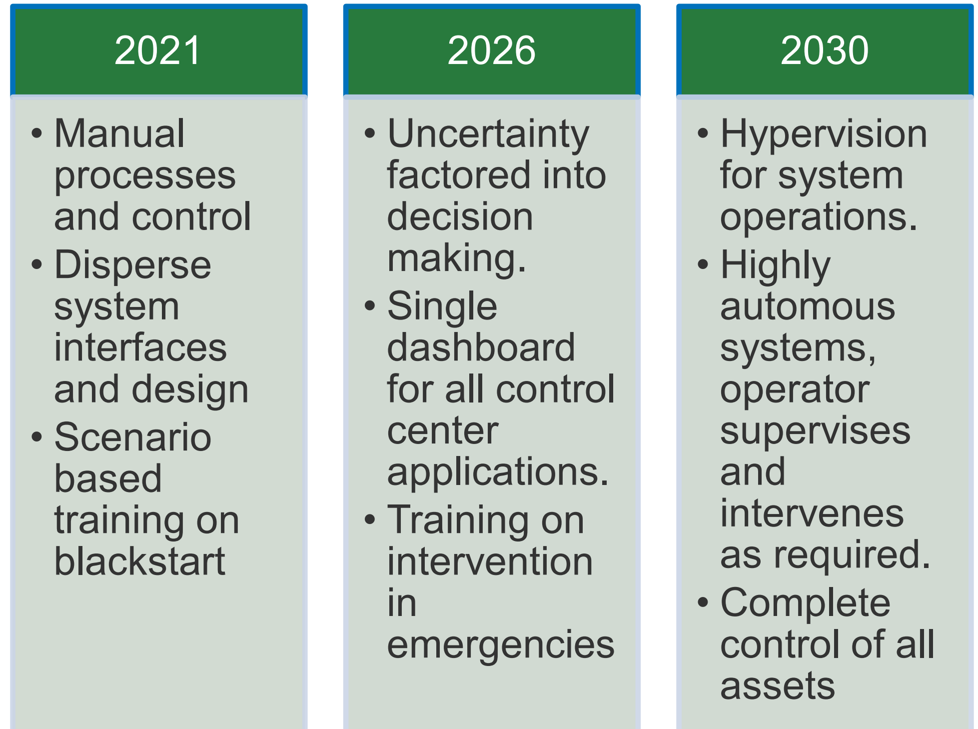


Figure 29. Operational requirements for CCOTF Human Factors and Decision Support pillar to 2030

3.7.3 Value of Developing and Enhancing Operator Human Factors and Decision Support

The Human Factors and Decision Support pillar for operators in the CCOTF will be a key enabler to reliability but will also be valuable to COES and the Peruvian state. Improved situational awareness should lead to fewer errors on the system and ensure that outages are restored as soon as possible. This will be complemented by tailored training in the ORC (discussed in the section below).

System issues will be proactively identified and categorized ahead of time, reducing the need for operator action.

Enhanced system control, from the control centers to all resources will ensure supply is restored as quickly as possible and power is optimally transmitted around the grid, in as economical manner as possible.

3.7.4 Risks to Enhancing Operator Human Factors and Decision Support

The risks associated with the development and enhancement of the human factors are shown in Figure 30.

The most important risk to be considered is around reduced situational awareness or data overload and lack of training.

A well-designed Hypervision interface and training schemes will be the primary mitigation features and will help to clarify cause and optimize the future control center.

Risk	Impact	Liklihood	Rating
Reduced situational awareness	High	High	High
Suboptimal training	High	Medium	High
Sow restoration of electricity supply	Medium	Low	Medium

Figure 30. Risk register for developing and enhancing the functional capability model

3.7.5 Road Map for Human Factors and Decision Support for CCOTF

CONTROL CENTER OF THE FUTURE HUMAN FACTORS & DECISION SUPPORT

	2021 **Stage 1**	*Probable* **Stage 2**	2026 **Stage 3**	*Possible* **Stage 4**	2030+ **Stage 5**
Training	Rationalize training documentation and procedures	Digitize training procedures and methodologies. Training program on all CC tools	Enhanced simulator for EMS with improved dynamic response	Integration of all CCOTF tools into Operations readiness center	Multi-domain scenario training across energy sector
Hypervision	Initial Grafana dashboard for some KPIs	Development of a HMI visualisation philosophy for EMS and all CC tools. Enhanced dashboard	Standardised control room display visual coding , All CC tools in dashboard	Development of Hypervision interface	Seamless switching between manual, automatic control for all tools
Decision Support	Digitization of all procedures, work orders and work instructions.	Training in uncertainty, risk, probability and out-of-the loop interventions for all control processes	Root cause identified for system issues in all tools	Mitigation actions for system issues in all tools	
Asset Contorls	Modelling of SPS and Reclosing in all tools	Full observability of all transmission, generation and demand	Full controllability and reclosing of all transmission, generation and demand	Initial controllability from some control center tools	Full controllability from all CC tools

Review

Future State: Supervisors of Automated Systems

Figure 31. Road map for the Human Factors and Decision Support pillar of the CCOTF framework

3.7.6 How to Deliver the Road Map: Implementation Plan

The projects to be delivered as part of the Human Factors and Decision Support pillar will be primarily focused and led from the operations and control center personnel with support from the groups responsible for control center tool developments. This is especially important in relation to the development of Hypervision.

The development of the ORC as part of the Buildings, Facility, and Hardware pillar will work together with the training aspect, as control center tools and the training simulator will be integrated seamlessly into the ORC.

The most important and resource-intensive stages of the project are for root cause and mitigation aspects of system issues and related activity on Hypervision development. Root cause detection algorithms are included as part of the control center tool kit, and Hypervision should be developed in line with the development of the control center tools. These developments are expected to take a long time before they are operational.

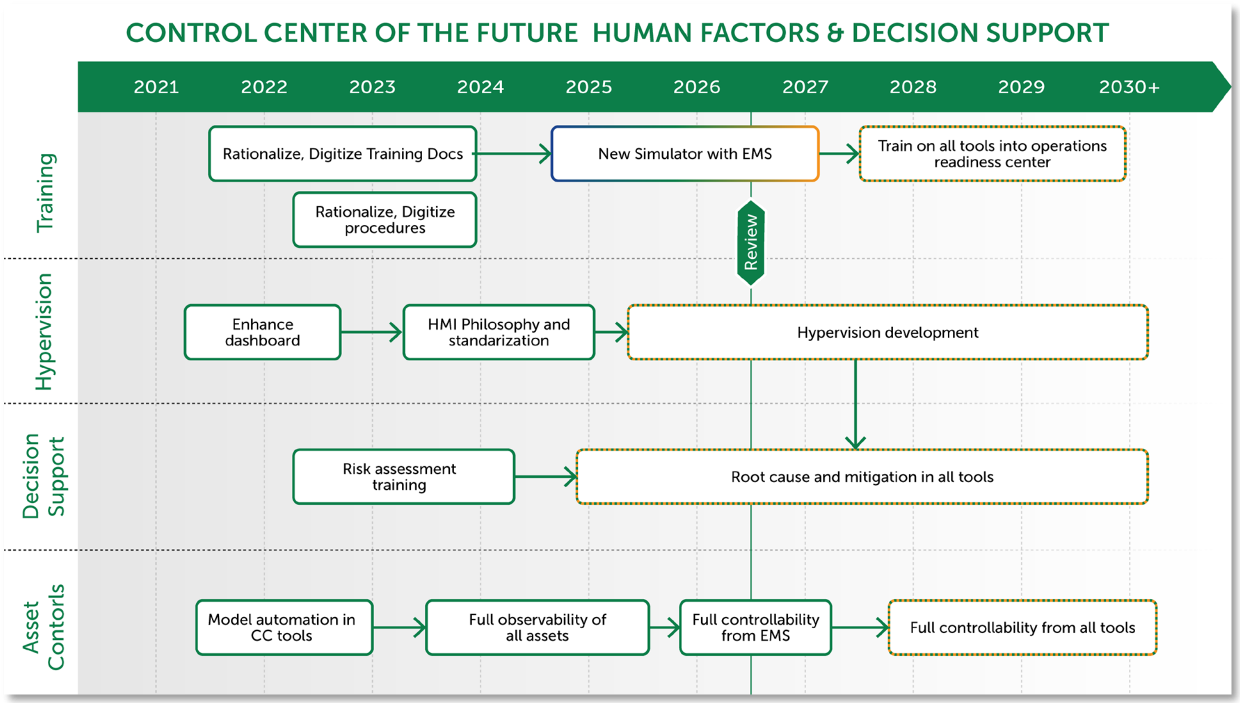


Figure 32. Implementation plan for Human Factors and Decision Support pillar

3.7.7 Key Actions

- **Training**
  - **Rationalize, Digitize Training Docs**, the main objective of this activity is to document the training processes, based on a vision of sustainable knowledge management over time.
  - **New Simulator with EMS**, the main objective of this activity is to enrich the training scenarios with casuistry obtained from the EMS
  - **Train on all tools into ORC**, with the aim of providing comprehensive training to operators.
- **Hypervision**
  - **Enhance dashboard,** the main objective of this activity is to continue the development of key performance indicator-oriented dashboards in the control center.
  - **HMI Philosophy and standardization,** this activity is oriented so that COES can define the standards to be used to define the design, implementation, operation, and maintenance of the HMI interfaces.

- **Hypervision development,** this activity is oriented towards the development of Hypervision, which is aimed at the construction of dashboards with a volume of summarized and processed data, which can include geographic data and based on key performance indicator trends, in order to provide a comprehensive understanding of the power system and its associated processes.

- **Decision Support**
  - **Risk assessment training,** this activity involves providing risk assessment guidance to the control center tools, with the objective of providing support for real-time decisions based on this concept.
  - **Root cause and mitigation in all tools,** this activity implies providing guidance to identify the origin of adverse conditions, in each application of the control center whenever possible.
- **Asset Control**
  - **Model automation in CC tools,** oriented to a constant update of the control center models, automatically.
  - **Full observability of all assets,** oriented so that the tools of the control center have a wide observability of the elements of the power system that are managed.
  - **Full controllability from EMS,** oriented so that the elements of the power system can be totally controlled from the EMS/SCADA system of the national operator.
  - **Full controllability from all tools,** oriented so that the elements of the power system can be fully controlled from the tools of the national operator.

3.8 Building Facility and Hardware

3.8.1 Drivers for Change and CCOTF Vision

To deliver on the vision and ambition for CCOTF, the output of the control center tools requires a simulator environment for the testing tools and to facilitate training of operators. At present COES—like most control centers—has an operator training simulator for operators, but this is used primarily for training operators on specific tasks such as black start and is generally underutilized for normal business as usual, despite significant investment.

In the CCOTF, all software applications should have a simulator environment with a pristine model of the system (a digital twin). The operator training simulator facility should be upgraded to become an **ORC** for:

- User acceptance testing of software tools
- Training with operator's predeployment of new tools (e.g., EMS)
- Testing new user interface designs
- Testing new hardware devices and innovations
- Providing its core function of training and testing operators
- Real-time study simulator environment for control center tools
- Potential backup control center facility in the event of an emergency

It is probable that none of the ambitions of the CCOTF road map are achievable without an effective simulator environment to test new tools and technology and train the operators of the future.

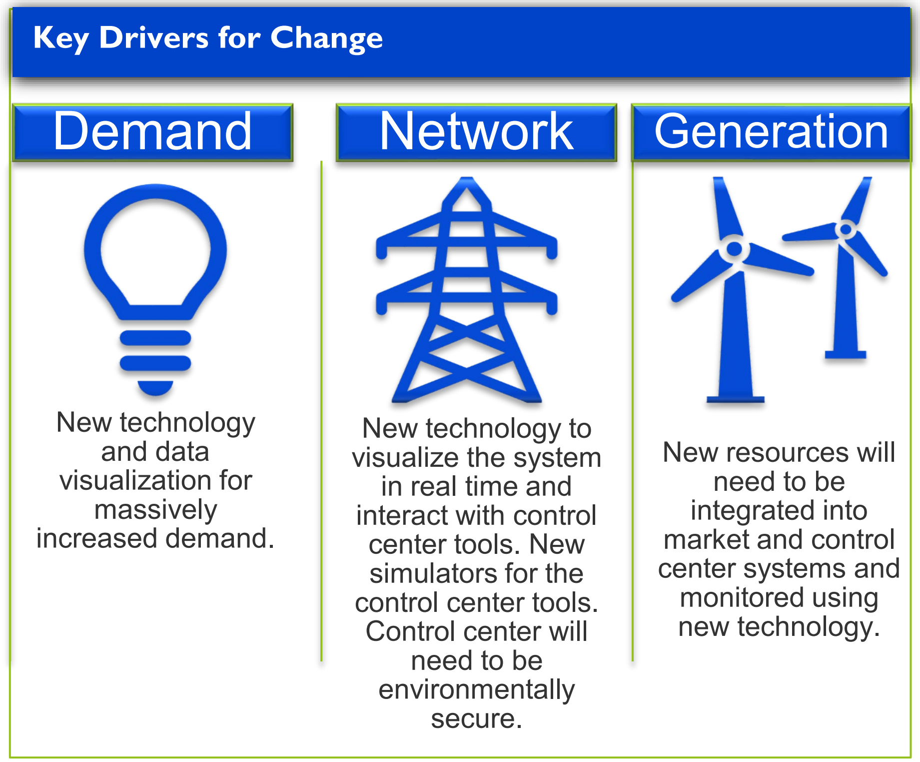


Figure 33. Key drivers for change for the Building Facilities Hardware pillar

The control rooms of the future should feature upgrades to the physically secure cyberfacilities that are already in place today. The facilities should be resilient to pandemics and major events, with lessons learned in facility design from the COVID-19 pandemic. Control rooms that operate on the same transmission footprint or have similar functions should have video-enabled interactive systems.

Currently, the equipment in the COES control center is ergonomic and has been designed to achieve maximum operator comfort, thinking about their health, safety, and well-being 24/7/365. There are adjustable tables, screens, videowalls, mouse, keyboard, height-adjustable screens, among other peripherals under the same comfort criteria.

It is recommended that new ergonomic approaches should be tested in the ORC before deployment in the real-time control room. It is recommended that for the CCOTF, updates are made based on the ISO 11064 standard for control rooms.

3.8.2 Operational Requirements for Building Facilities and Hardware

To ensure seamless, interoperable integration for the range of new control center and operations planning tools, the ORC should be used extensively. The control center buildings should be cyber/physically secure to the highest standard, ensuring there is no risk to operators or the system. The ORC should be a close replica of the control center space, with equivalent IT infrastructure and capability. It should have simulator or test environments for all software tools.

The desk consoles should be arranged ergonomically, to maximize operator health and safety and comfort. Control center visual technology and hardware innovations should be introduced, where there is a use case, and tested extensively in the ORC. Hardware should be introduced to improve operator situational awareness and improve monitoring and control to complement the other pillars in the CCOTF framework.

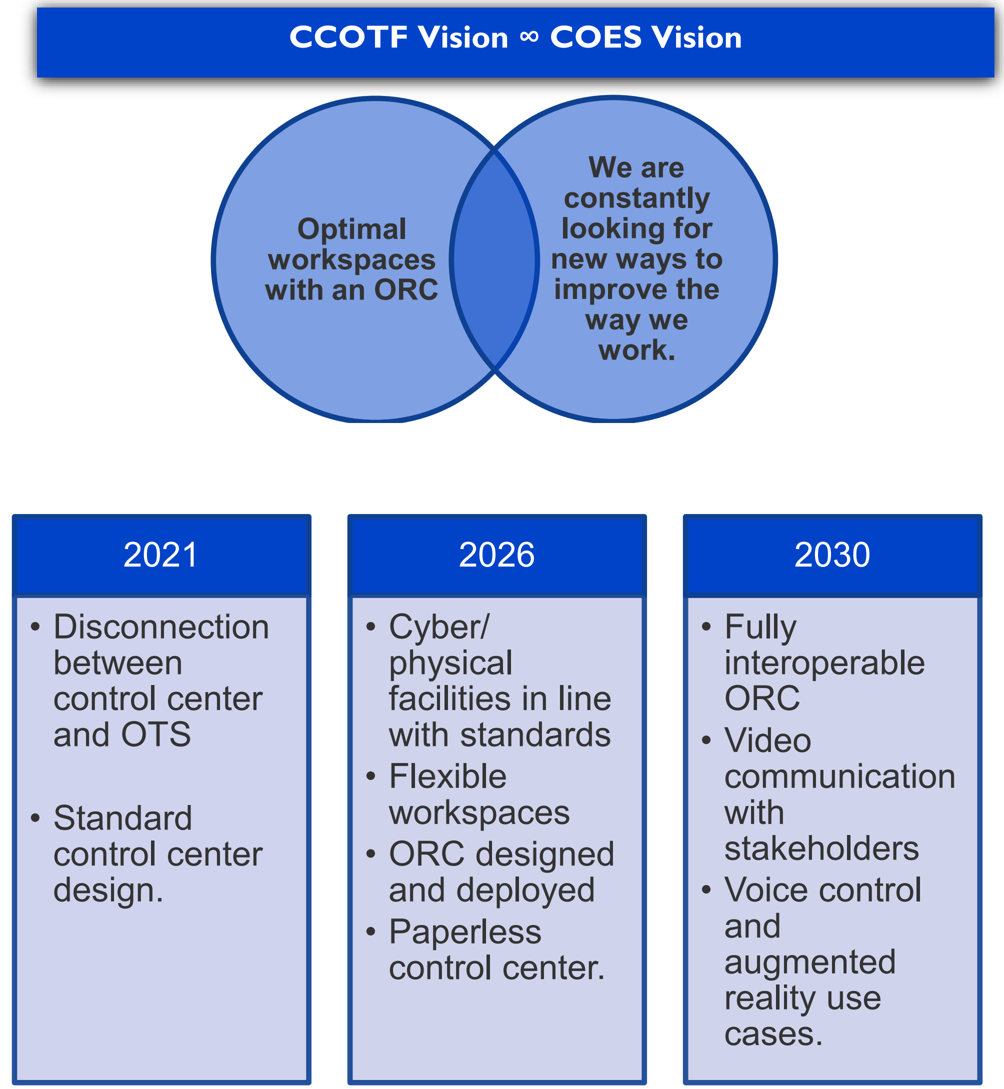


Figure 34. Operational requirements for CCOTF Building Facilities Hardware pillar to 2030

3.8.3 Value of Developing and Enhancing a Functional Model and Architecture Foundations

Developing control center physical facilities and hardware will allow the operators to have the most ergonomically efficient workspaces. This will ensure their health and safety is adequately catered for as they carry out the stressful task of monitoring and controlling the system. Employing valuable new techniques to digitize paper-based documents in the control center and utilize voice control will prove valuable in terms of operator efficiency, monitoring, and reporting. This should also improve situational awareness, with consequent reliability improvements.

By developing an effective simulator environment with the new ORC, new innovations that will be required in the CCOTF can be trialed and tested with operators before they are deployed in real time. This will eliminate wasted resources and ensure software is fit for purpose before it hits real time. There will also be a need to enhance the real-time study capability of the control center tools, the ORC will be the most optimal environment for this. New hardware is expensive, to procure and maintain, so having a test facility for new hardware will ensure capital is allocated as efficiently as possible.

3.8.4 Risks to Developing and Enhancing the Buildings, Facilities and Hardware of the CCOTF

The risks associated with the development and enhancement of the buildings, facilities and hardware are shown in Figure 35. The most important risk to be considered and addressed is that of cybersecurity breaches and operator health and safety.

Well-designed buildings, facilities and hardware should complement the control center tools, decision support, data, and architecture design for the CCOTF.

Risk	Impact	Liklihood	Rating
Cyber Security Breaches	High	Medium	High
Operator Healt and Safety	Medium	Medium	Medium
Hardware detiroration	Medium	Low	Medium
Untested CC Tools	High	Low	High

Figure 35. Risk register for developing and enhancing the buildings, facilities, and hardware

3.8.5 Road Map for Buildings Facilities and Hardware for CCOTF

CONTROL CENTER OF THE FUTURE BUILDINGS, FACILITIES & HARDWARE

	2021 **Stage 1**	*Probable* **Stage 2**	2026 **Stage 3**	*Possible* **Stage 4**	2030+ **Stage 5**
Building, Facility Design	Redundant back up facilities and data centres	Building and facilities completely pandemic resilient. Agile flexible spaces for lodging, meetings etc. Cyber physical standards development	Deployment of shared workspaces, video links between facilities. Cyber physical security enforcement.	Seamless integration on operations readiness centre. Common user experience in all environments	Deployment of shared workspaces video to all Peru energy sector stakeholders
Operations Readiness Centre	Current OTS. Development of simulator test environments for all CR tools.	Physical and IT architecture design for ORC, as seamless integration with existing facilities and ICT	Build and commission ORC. ORC used for training. Enhanced simulator with dynamics & protection integrations	ORC for user acceptance tests sandbox for new CC tools & visualisations.	Fully interoperable ORC with all CCOTF facilities and tools
Hardware Ergonomics	Ergonomically optimal sit-stand desks.	Level 1,2,3,4 display screens. Single desk user interface (keyboard/mouse) into dual IT environments	Paperless control center. Interactive video systems. Single telecoms interface, with automated call handling	Voice control interactivity with applications and equipment. Hardware innovations tested in ORC	Augmented reality use cases for visualisation

Review (between Stage 3 and Stage 4)

Future State: Optimal Workspaces with an Operations Readiness Center

Figure 36. Road map for the Building Facilities and Hardware pillar of the CCOTF

3.8.6 How to Deliver the Road Map and Implementation Plan

The projects to be delivered as part of the Buildings Facility and Hardware pillar will be primarily focused and led from the infrastructure and facility teams and directorates with support from the operations, training, and control center teams. There will be a heavy dependency on the IT subject matter experts also when designing and commissioning the ORC.

In the later part of the decade, assuming COES have industry-leading governance, practices, and technology, it is recommended to begin innovations on technology such as voice control and activation and augmented reality. It is anticipated that these technologies will be commercially widespread and economically viable, and they have very good applications in control center operations.

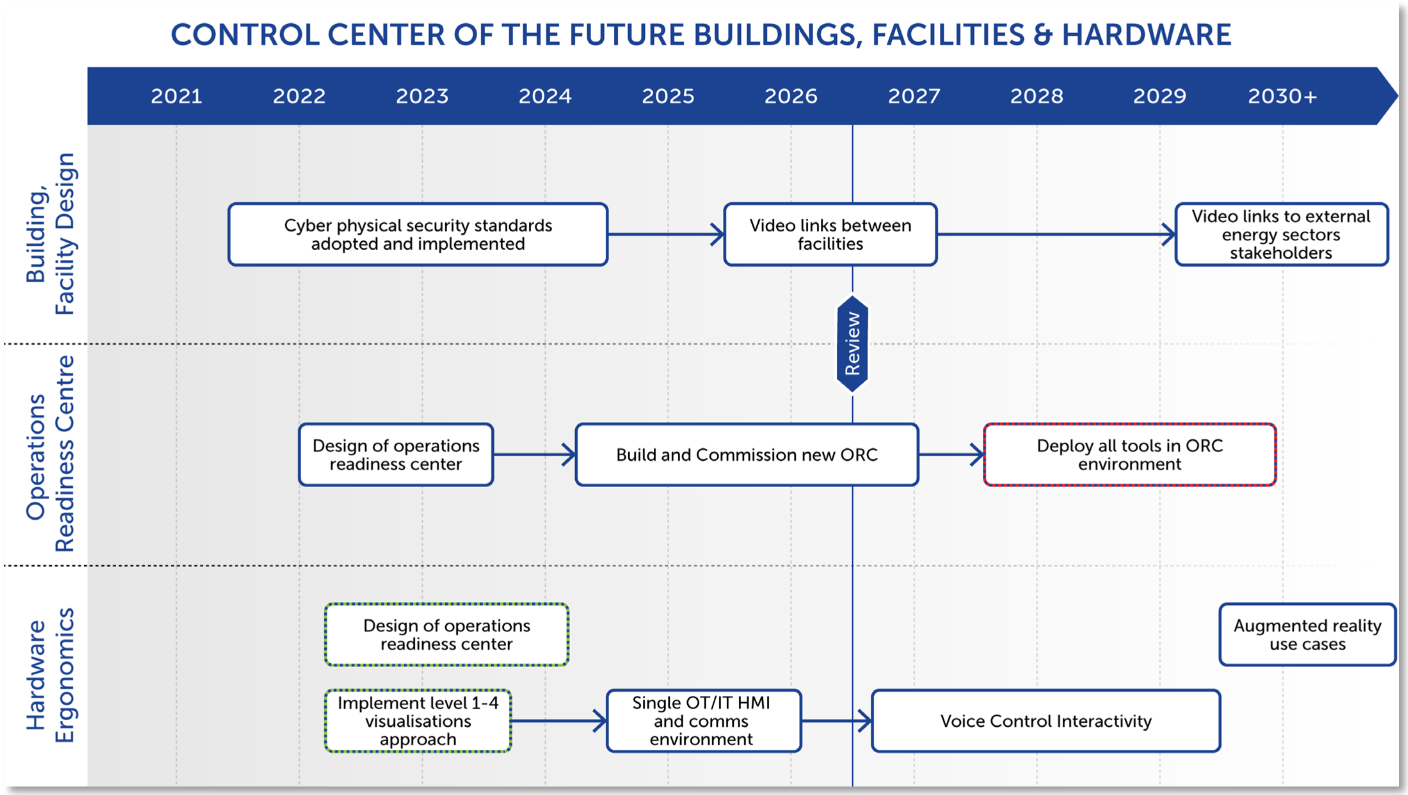


Figure 37. Implementation plan for the Building Facilities and Hardware pillar of the CCOTF

3.8.7 Key Actions

- **Building Facility Design**
  - **Cyber/physical security standards adopted and implemented:**
    - Ensuring there is resilience to cyberattacks and physical attacks on the building and associated data centers and premises.
  - **Video links between facilities**
    - For control centers that frequently communicate (e.g., COES control center with transmission or distribution owner operators), a video link is an optimal way to communicate and share the same visualization of the system under control. This is achievable but rarely implemented in present-day control rooms.
  - **Video links to external energy sectors stakeholders**
    - If there are market participants or other stakeholders that require discussion on real-time or market system outcomes, they can be accommodated through this process also.
- **ORC**
  - **Design of ORC**
    - The construction of an advanced simulator or ORC may need a detailed design to upgrade current facilities or to build a new one if the current facility is inadequate. This includes desks, IT/OT equipment, screens, etc.
  - **Build and commission new ORC**
    - Following detailed design, there may be a long process to build and commission the new ORC.
  - **Deploy all tools in ORC environment**
    - Moving the simulator test environment of all control center tools to the new ORC will take time and resources. The new ORC will not just be an EMS/operator training simulator and will include versions of all OT/IT tools that will be deployed in the control room.
- **Hardware and Ergonomics**
  - **Digitize procedures paper-free environment**
    - Make all paper procedures digital by scanning or inputting into a document file system for easy access.
  - **Implement Level 1–4 visualizations approach**
    - Level 1 is an overall view of the system. Level 2 is a function-level view with key performance indicators (like Hypervision), usually a screen between desk monitors and the large videowall displays. Level 3 are desk monitors for control. Level 4 are displays that are diagnostic for IT and OT tools such as EMS.
  - **Single Operations Technology OT/ Information Technology IT Human Machine Interface (HMI) and comms environment**

- Having one keyboard and mouse controlling both IT and OT environments with combined displays. The IT and OT systems are in separate application environments, but the windows can be combined and visible on a single screen.

- **Voice Control Interactivity**
  - Voice control or the OT and IT tools in the control center, for example call and response for system parameters such as voltage and frequency and voice search function for details and information within technical procedures and digitized documents.
- **Augmented reality use cases**
  - Some early-stage research is being developed into the use cases for augmented reality, mixed reality, and virtual reality in control centers. These can include training and data and image enhancement, among others.

4 Summary

The vision for the CCOTF outlined in this report is aimed to position COES at the forefront of innovation in control center and operational capability. It is an ambitious plan to 2030 and beyond, and it aims to ground the development of operational technology and the control center in the context of rapidly increasing generation, demand, and network growth in the coming decade.

The road map is structured in five key areas: architecture, data, control center tools, human factors, and buildings and hardware, with 11 key pillars of innovation within each area. Part of the framework included developing a potential pathway to 2030 and beyond, while recognizing the uncertainty in projected growth forecasts. Developments to Stage 3 (approximately 2025) are considered probable, while developments to 2030 are considered possible. It is recommended to review the road maps and plan, given new information after Stage 3 or in 2025.

5 Recommendations

The recommendations are developed extensively within each pillar road map and implementation plan. The following comprise a list of potential first steps to the delivery of the CCOTF vision:

- Establish teams of expertise to consider the road map using the structure of the road map (i.e., architecture, data, tools, human factors, and building and hardware). Each team should examine the implementation plans and adjust if necessary.
- Devise the capital and human resources required to deliver the road map in 5-year cycles. The road map should be reviewed in 2026 to assess the Peru system and progress of the road map.
- Engage with external experts such as vendors, research institutes, and laboratories, through all available channels on available technology, standards, and approaches to solving issues related to the control center.
- Assess and complete the 2021 and 2022 aspects of the road map. These mostly involve the assessment and inventory of current states and repositories, which may not require extensive design and investment. These are essential building blocks for later innovations.
- Based on the road map and the resource requirements, develop a detailed implementation plan for the delivery of the CCOTF vision.