VR/AR Association White Paper

VR/AR in the Energy Sector

Authors & Contributors

Mr. Suhas P Bhagwat, Avroglide Consultants
Mr. David Moreno, Virtualware
Mr. Walter Davis, Aggreko
Ms. Sophia Moshasha, VRARA Washington DC Chapter
Mr. Ray Deatherage, GTI
Mr. Eduardo Neeter, FactualVR
Mr. Nick McKee, Cyan Stone Innovation
Mr. Tim Allen, Oberon Technologies, Inc.

www.thevrara.com

Sponsor

OBERON TECHNOLOGIES

Oberon Technologies is a leading provider of innovative interactive training solutions, leveraging virtual reality technologies coupled with state-of-the-art information delivery for environments where safety, security, or efficient cost of delivery is critical.

www.oberontech.com

Table of Contents

This white paper is broken into the following parts so you can skip to what is of interest to you:

1 Introduction

What does the Energy Sector comprise of and who are the stakeholders under VRARA Energy community?

The global energy mix is comprised of Oil, Gas (which also includes liquefied natural gas ie LNG), Coal, Nuclear, Renewable energy (such as Wind, Solar, Hydropower, Biomass, Geothermal, Ocean Waves etc), and Electricity sectors. During the mid 2010s fossil fuels (namely Coal, Oil and Gas) accounted for 82 percent of global primary energy. This percent number is targeted to decline, with large growth in the nuclear and renewable energy sectors (especially wind and solar energy) although the fossil fuels are expected to remain a primary source over the next 20 years. However, due to the current pandemic that hit the world early 2020, the projections are sure to undergo a change.

Energy is the lifeline of everything that happens in the world and this sector is one of the most important components of the Global Economy. The combined business that is conducted globally in the entire value chain of this sector is in multiples of Trillions of dollars and it engages several million personnel worldwide.

The Energy sector covers all the stakeholders in its entire value chain such as the Energy organizations (Oil & Gas production units, Refineries, Thermal Power Plants, Nuclear Power Plants, Wind Power Farms, Solar Power Plants, Power Transmission & Distribution Systems etc), Energy Technology / Process Licensors, Engineering organizations, EPC organizations, Manufacturers and Fabricators, Construction companies, Mining Companies (for Coal) as well as several service providers covering HSE, logistics, inspection and other services.

Therefore, as far as Energy as the VRARA Energy community is concerned, the Demand side of VR AR value chain covers all the VRARA members representing the stakeholder organizations in the Energy sector as above. The VR AR Supply side for VRARA Energy community on the other hand covers Digital Technology Creators, VR AR Hardware Manufacturers and VR AR Solutions providers & Content creators with experience in applications for the Energy Sector.

Just as for any industrial sector, the emerging technologies of VR and AR hold very significant potential to bring value to various business functions in the Energy Sector by way of enhanced efficiencies and effectiveness as well as increased safety. Various stakeholders in the Energy Sector have been taking serious note of this and therefore increased adoption of VR and AR in the sector has been evident over the recent years. It is expected that this will see a steep growth in the coming years.

The Ecosystem created by VRARA provides a common platform for all the stakeholders in the VR AR value chain of the Energy sector. The objective of this White Paper, therefore, is to bring out the essential features of VR AR technologies, highlight the relevance of the same to business functions in the Energy Sector and present an overview of applications and use cases of VR AR duly highlighting the benefits of the same for business processes.

2 Basic Elements and Features of VR and AR technologies and devices for VR and AR

It has been evident that Digital technologies have been playing a critical role in the rapid growth seen by various sectors of Industry, in their entire value chains covering all the business functions. Emergence of immersive technologies of VR and AR has particularly been revolutionizing the way business is conducted in a wide range of sectors of the economy such as Energy and Oil & Gas, Infrastructure projects, Manufacturing, Healthcare, Aviation, Education & Training, Tourism and so on. Within the Energy sector, the applications of VR and AR are seen to cover the complete range of the sector's value chain from Exploration & Production of energy resources to Engineering, Manufacturing, Construction, EPC Project Execution, Commissioning and Energy Facility Operations. In the process it also covers all the business functions namely Design & Engineering, Business Development & Marketing, Project Management, Training, Supply Chain Management, Inspection, Commissioning, Maintenance & Trouble-shooting, Plant operation, HSE, Quality Management and so on.

2.1 Basic Features of VR and AR and The Reality Spectrum

While for the sake of simplicity, it is common to make reference to two essential components of the immersive technologies as VR and AR, it will be useful to understand what is meant by three basic terms commonly used, namely Virtual Reality, Augmented Reality and Mixed Reality -

Virtual Reality

Virtual Reality (VR) is an immersive multimedia or computer-simulated environment that mimics physical presence in the imaginary world. VR also lets the user interact with that world. VR can artificially create sensory experiences, which can include sight, hearing, touch, movement.

Augmented Reality

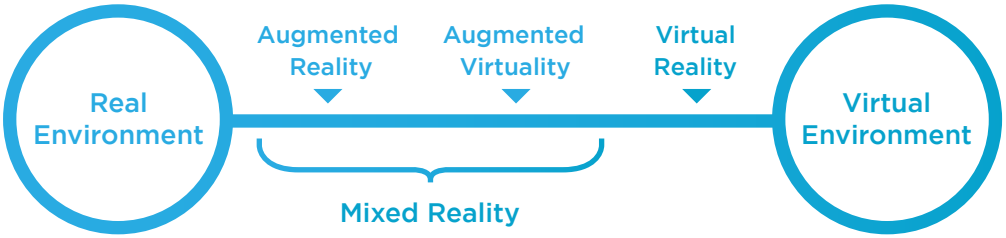
Augmented Reality (AR) provides a live view of the physical 'real world' where digital elements are overlaid or superimposed by computer-generated graphics, sound, haptics or GPS data. AR can also provide new ways to interact with digital information within a user's field of view - including voice control, head motion, hand gestures and touch.

Mixed Reality

In simple terms, Mixed Reality (MR) is an enhanced version of Augmented Reality wherein the user can interact with the virtual objects which are superimposed on the real objects and can navigate in this mixed environment.

The three types of 'reality' can be represented on the so-called Reality – Virtuality Spectrum as depicted below –

Reality – Virtuality Spectrum



2.2 Devices for VR, AR and MR

While it is not the objective of this White Paper to discuss details of hardware items used for VR and AR applications, a very brief overview of the same is provided below.

VR Devices

As the name "Virtual" suggests, the Headsets used for Virtual Reality permit the view of only the "virtual" world while the real surroundings are completely blocked from the user's view. When the user wears the VR headset, he/she is taken to the midst of an entirely new and imaginary environment and surroundings with which he/ she can interact. While there are several suppliers of VR Headsets in the world, Oculus and HTC are some of the popular brands. Given below are snapshots of their relatively recent models –

Oculus Quest 2

HTC Vive Focus Plus

Both these models are standalone type, in the sense they do not need to be connected with a PC or a laptop since they have their own memory and software. There are other models such as Oculus Rift, HTC Vive which are the so called "tethered type" requiring to be connected to a PC.

AR & MR Devices

Among the popular brands of the devices for AR / MR are Microsoft "Hololens" developed by Microsoft, "HMT1" developed by a company called RealWear and "Blade" developed by Vuzix. (These are just a representative few; there are several more popular brands.) All these devices give the user a hands-free AR experience compared to Smartphones where users interact spatially using a 2D screen.

These devices are suitable for outdoor environment and can be worn along with hard hats or helmets.

These can be readily used at construction sites where the site-based personnel wearing these can collaborate with the experts based at design office or the project office of an organization.

RealWear HMT-1 (AR)

Microsoft Hololens (AR and MR)

Vuzix Blade (AR)

In many applications in the Energy sector, the AR devices may need to be certified for use in hazardous atmospheres such as those containing hydrocarbons, hydrogen and other inflammable materials. Special attention is therefore required to be paid to this aspect while selecting the hardware in case of such environment.

Relevance of VR and AR applications to Energy industry and their typical use cases are described further in the sections to follow.

3 Relevance of VR AR for Energy Sector

3.1 Underlying factors in Energy Sector

Following are some of the underlying reasons that VR and AR have the potential to play an important role in all the various business activities in the Energy Sector –

- The systems, equipment and machinery in the value chain of Energy often have extremely complex configurations based on concepts which are very involved and difficult to understand. The conventional methods of studying these concepts and configurations, flow schemes in complicated systems etc have often proved to be inadequate for training of personnel at broad scale. Immersive methodologies made available through VR and AR technologies have been gaining increasing acceptability by industry for the purpose of training.

- The immersive nature of the VR technology imparts a very good understanding of the environment to the user with very high level of knowledge retention in mind, and therefore this becomes an extremely effective tool for training, familiarization and orientation of personnel of an organization. This tool is demonstrated to be far more effective for these purposes as compared to conventional methodologies used by industry.
- This feature of VR also enables immersive presentation of complex systems such as nuclear, process and power plant sections, internal configuration of complex machinery such as compressors and turbines to the project teams or to client teams having interest in procuring such systems.
- VR enables realistic training of unexpected, hazardous, and dangerous scenarios in a safe yet fully immersive and realistic environment. VR allows nuclear and other energy providers to train staff without unnecessary exposure to radiation, toxic gases and chemicals, or high voltage which is often present in conventional training programs.
- The superimposition of the virtual on the real through the AR technology opens up huge number of possibilities in the way collaboration can be brought about between distantly located individuals or groups.
- The superimposition feature of the AR technology enables visualization-based work instructions and guides which obviate or substantially reduce the dependence of the in-experienced personnel on the conventional O&M manuals and / or the expert assistance and supervision.
- The lifecycle of energy sector assets exceeds the typical O&M human capital cycle. The use of AR as a historical repository for ongoing field maintenance allows for in situ superposition of past events and repair work details on an asset to the visibility of current field operations. This can greatly reduce the repair creep inherent to the long term capital intensive nature of assets in the energy sector.

3.2 Imperatives that make VR and AR useful for Energy Sector

While the Energy sector did experience initial hurdles in acceptance and implementation of VR and AR solutions, the situation is seen to be fast changing. The factors contributing to the relevance of these technologies in this sector include -

- Remote locations of the Energy facilities, often with difficulty accessibility.
- Risks and costs involved in creating (and re-creating) real situations for imparting training to personnel in wide ranging functions, especially those pertaining to hazardous environments.
- The need to urgently resolve issues at plant sites so as to avoid forced shutdown of plant operations, or for several other reasons.
- Difficulties involved in undertaking maintenance and troubleshooting of complex machineries or within areas that expose trainees to environmental hazards.
- Need to accurately simulate real-life dangers, in a realistic immersive environment so as to effectively train personnel and gauge visceral reactions, thereby decreasing actual injury occurrences or damage to equipment.
- Operational criticality of several packages and facilities in the sector from the point of view of catastrophic effect of their failure (such as explosion of Furnaces, Boilers, Reactors due to mal-operation, nuclear radiation and other reasons) – this calls for the operating personnel to be trained extremely effectively whereby they acquire complete understanding of the operational aspects and

the expertise to avoid such situations. This objective can be readily achieved through the immersive training based on VR based applications which can create simulated environment depicting a wide variety of situations.

- Involvement of multitude of stake-holders operating from distant locations and the need to have their participation at one location for purposes such as joint project reviews, inspection of critical machinery and others.
- Several others.....

Global Energy producing companies as well as other stakeholders such as Contracting organizations of global repute engaged in this industry are seen to be adopting these technologies in a very aggressive manner through deployment of a wide range of applications in various use cases and functions in their routine operations. However, others are seen to be at an early stage of this curve. It needs no emphasis that early adopters will have significant competitive advantages over those who are slow in this uptake.

4 Typical Applications of VR, AR and MR in Energy Sector

Over the recent years, several innovative applications based on VR, AR and MR have been evolved and deployed by various stakeholders in the Energy Value chain. A few examples of these use cases in various functions in Energy Value Chain are given below.

4.1 Engineering

a. Familiarization with Plant Facilities

This VR functionality is typically useful for providing orientation to operating personnel of a plant facility before they are deputed for their operational roles. This application can also be used for familiarizing project personnel working on a complex project as well as by the marketing teams for presenting the offering to prospective clients.

b. AR Books and AR based visualization of 3D Model emerging from the 2D Drawing

This is an AR based functionality in which the 3D Model of an object such as a Plant section, Machinery or equipment is superimposed on the 2D layout drawing. The virtual 3D model that appears on the 2D Drawing permits detailed review of the object from different angles, enabling a thorough review and understanding of the design covering aspects such as access, maintenance, clashing / mismatches between components, and so forth.

Augmented Reality based books also use similar concept wherein the visualization of 3D models from 2D images and drawings of various objects permits a better understanding of complex concepts such as functioning of rotating machinery, flow schemes in complex systems, visualization of phenomena occurring at micro-structure level and so on.

c. Study of Geological structures with VR Headsets

This feature can be a very useful tool for Geophysicists, Geologists, Drilling Engineers for the study of geological structures in minute detail and observing layers of oil, gas and minerals in the reserves. This can be useful for Oil & Gas exploration as well as mining applications.

d. Supplementation and enhancement of 3D models and 2D images with IR and Lidar imaging from ground and aerial vehicles (UAV specifically) and the processing of imagery into 3D point cloud mapping that can be tagged to geocoordinates.

This offers enhanced real-environment imaging from non-visual spectrum wavelengths to be superimposed on 3D models and real time visual images.

4.2 Marketing

a. Immersive Demonstration of Process System being offered

Oil companies have used VR applications to enhance customer engagement. In order to enrich the user experience and to bridge the gap between end-user and the Oil Company a VR based platform is used that depicts the process system configuration, flow schemes, equipment details, etc.

b. Demonstration of functioning of complex machines and systems

This is also a VR application where the immersive presentation can be made to the potential clients to explain the configuration, internal flow schemes and functioning of complex machines such as turbines, compressors as well as systems and packages in a process plant or a power generating project.

4.3 Plant Operations, Project Management, Supply Chain Management, Inspection

a. Remote collaboration through MR

This MR functionality enables immersive reviews by multiple number of participants such a review of project progress by multiple number of participants located at multiple remote locations, but appearing at the virtually visualized project location through their so-called “Avatars”. This permits participants to make a virtual walk through project site jointly as a team, looking at various aspects such as design, maintenance, accessibility and so on, permitting discussions among them within the project environment permitting meaningful decisions for further actions.

b. AR Enabled Warehouse Management

Operations in a large Warehouse can be tedious and an inexperienced operator can make mistakes or take excessive amount of time in locating and picking the right item for dispatch. AR based application for Warehouse operation provides the operator with the exact route to the desired item and also helps in identifying the right item through the inventory information available in the app. This application has proved to significantly enhance accuracy in warehouse operations while also reducing the time for pick-up and dispatch.

c. AR Enabled Inspection of machinery, structures

Inspection of complex machinery and structures in Energy Facilities under construction is a time consuming activity also prone to errors. The AR based application permits the Inspection Engineer to complete this activity with far greater accuracy and in a much shorter time. The AR application made available to the Inspector through the AR glasses provides a ready view of the exact specifications / drawings and images of the object to be superimposed onto the real object, permitting on-the spot identification of dimensional and other deviations. This also provides necessary alerts to the Inspection Engineer for further actions.

4.4 Manufacturing, Construction, Fabrication

a. Pre-authored Instructions for manufacturing activities

AR / MR based detailed instructions to carry out some critical manufacturing activities, in the form of visuals superimposed onto the work being done have proved to be of great benefit for ensuring error-free work, completed in shorter times. These instructions can be through tablets or head mounted AR Glasses, the latter holding the advantage of hands-free operation.

b. AR based remote assistance

This is one of the most commonly deployed AR solution in the manufacturing / construction / fabrication environment and also in plant operation. This application is also use-case agnostic and hence its deployment time is minimal. The typical use case involves collaboration between a technician at a remotely located project / construction site and the expert available at the design / project office. What the technician wearing the AR glasses sees, is seen by the expert who can provide necessary work instruction to the technician. These work instructions additionally supported by marked-up drawings, annotations etc, are seen by the technician on the virtual screen through the AR glasses.

c. MR based constructability studies

The MR enabled 3D view of the energy facilities under construction can be readily used by the project team members to undertake constructability study. This can enable decisions such as sequence of installation activities, the marching route for heavy duty cranes and the rigging schemes, piping installation activities etc. in complex projects with intricate pipe-work and other complexities.

4.5 VR Training

This is one of the most prominent applications of Virtual Reality for many reasons. While its immersive nature makes the VR based training very effective, this also permits creation of several simulated environments in the virtual form, thus obviating the need to create such environments in the real world or where the scenarios cannot be recreated in the real world safely, effectively, or economically. These virtual environments represent an advancement in VR training which permits the simultaneous training of numerous trainees with the active immersive involvement of the trainer. These environments also enable organizations to easily repeat or vary training experiences to prepare trainees for real-world situations. Examples of these environments and situations are described in several of the use cases in the following chapter.

VR training in Energy Sector can be broadly classified in three categories namely HSE Training, Facilities Location Training, and Training in specific operations within the Energy facilities.

Examples of HSE training –

- Fire Safety training
- Training for working at height
- Training for working in enclosed spaces
- Training in Electrical Safety
- Training for safety in special environments such as Offshore, Mines, Hazardous environments

Examples of Facility training –

- Locating components in situ
- Identifying appropriate entry and exit routes for safety
- Identifying shortest or safest paths to avoid environmental hazards
- Identifying proper transport routes for materials and equipment
- Identifying aide station locations
- Define temporary alternate routes needed during specific procedures
- Ingress and Egress planning
- Staging, storage, and logistics coordination

Examples of Training in Special Operations -

- Training in Fired Heater start-up, normal operation, abnormal operations, shut-down sequence etc
- Training for operation of construction machinery such as heavy-duty crawler mounted cranes
- Training in LNG unloading operations
- Training in operation of PSA units
- Training in operation of Steam and Gas Turbines
- Training in operations and inspections within a Nuclear Power plant

It is evident that there is no limit to what the subject of VR based training can cover. However, this needs development of specific training modules for the given application and this is a collaborative effort between the domain experts from the Energy industry and the content developers / solutions providers from the VR technology value chain. Certain HSE related VR based training modules such as working at height, working in enclosed spaces, could be standard and can be used by various stakeholders in the Industry.

4.6 Field Maintenance Applications

There are several use cases of VR and AR in field maintenance in a wide range of applications in the Energy sector. A few examples are –

- Geospatial identification of devices needing repair or probable root causes.
- Geospatial identification of energized or hazardous devices.
- Geospatial identification of past and future work orders.
- Non-spectral images from UAV, IR, radiation, or other sensors.
- Realtime information on quantitative measurements, impending weather, crew members, or enterprise alerts and updates.
- Instructions for accessing machinery and equipment as well as access to 3D cad models superpositions for in situ repair and assembly.
- Realtime image capture of work progress, documentations, and placement of future work orders (see an unexpected problem in the field while addressing a separate concern).
- Alert of potential risks (settings could be custom tailored for enterprise level competency roles). This could be at height, energized parts, rotating parts, etc.

5 Sample Use Cases for Energy Value Chain

This section presents details of VR and AR applications deployed by industry in specific use cases, along with the benefits realised.

5.1 Workforce training through VR Rooms

Use Case Title	To revolutionize workforce training in operations of Nuclear Facilities through Virtual Reality Immersive Rooms (VIROO)
User Organization	General Electric Hitachi Nuclear Energy
Application Developer	Virtualware

Use Case Description :

Objective: To train the workforce so as to help implementation of significant savings opportunities in the most efficient manner. The specific process identified is fuel movement operations, a complex and highly skilled activity requiring high expertise and training, as well as outstanding coordination between the different parties involved during the fuel movement process.

New Practice vis-à-vis Current practice: The current practice for workforce training is a physical process of training professionals on the Fuel Movement (FM) Simulator. This physical process is replaced by Virtual Reality Immersive Rooms (VIROO).
The objective of FM simulator is to improve capabilities of professionals through intensive training and contribute to the reduction of both costs and risks. The FM VR simulator replicates the complex process permitting multiple users collaborating in 1:1 scale VR nuclear environment. The simulator replicates the process with tactile and haptic feedback. A physical replica of the refuelling mast is connected directly to the virtual environment, so users carry out virtual fuel movement operations as if they were doing so in reality.

Functionalities :

- Replication of all functions of FM Simulator into Virtual Environment.
- Continuous presence of training session manager console with the ability to introduce unplanned failures to challenge the trainees to improve their capability.
- Provide reply to standard problems faced by trainees during the fuel movement.
- Ability to reproduce different refuel floor configurations along with a live view station to let the audience and the instructor monitor and supervise the training in real time.
- These functionalities are incorporated on VIROO Platform which manages the equipment and streamlines the workflow to generate and launch the VR content. This software allows the immersive room to be managed centrally thanks to the following functionalities, any organisations to generate VR content.

Hardware:

VIROO is powered by the powerful Virtual Reality equipment:

- Virtualware's patented tracking technology with no limitations in terms of space and users.
- Z by HP's VR solutions: HP Reverb 2, VR backpacks and workstation.

VIROO" based training for Fuel Movement Simulator

POC Details:

Proof of Concept is planned to be done on the new generation of simulators to be released by GE Hitachi in alliance with Virtualware for the Boiling Water Reactor technology, Pressurized Water Reactor also covering Decommissioning and Dismantlement.

Parameters to be monitored:

These will include trainees' performance, detecting fuel moving challenges in advance to instruct nuclear operators on human performance errors. For this purpose, the so called "Red button" concept will be introduced, that will open a set of new options to challenge the operators during the training. This reinforces their skills to react to day-to-day disturbances such as changes in the water flow into the vessel producing misalignments, potential bridge malfunctions, or failures.

Improvements observed and benefits realized:

Due to the strong regulatory controls, Nuclear training suppliers normally are limited to traditional OEM companies and a small number of enterprises with nuclear pedigree. On this backdrop, the subject application addresses and avoids following issues which under normal procedures lead to increased costs of this training:

- Necessity of complex mockups which are expensive to be maintained
- Physical mockups integrity limits the scope of training (efficiency vs contingency)
- Training necessities are very specific, sometimes linked to specific site conditions
- Mockups are not deployable and consequently training has associated high T&L expenses

This initiative improves the capabilities of professionals through intensive training and contribute to the reduction of both costs and risks. In addition, these systems will help Nuclear customers to have just-in-time bespoke training solutions on site that will contribute to the reduction of operational costs associated with training and quality issues.

Scale-up and wider deployment planned:

The solution addresses the ability to be located in strategic hubs around the world interconnected for remote collaboration especially with the threat of restricted travel and social distancing in pandemic situations. The fuel movement VR simulator is part of a new generation of simulators that GE Hitachi in alliance with Virtualware will release for operation during the coming years, not only for the Boiling Water Reactor technology but Pressurized Water Reactor and Decommissioning and Dismantlement as well.

Other applications where similar solution can be deployed:

Virtual Reality Immersive Room concept (VIROO) is also transforming education, giving educational institutions the best tools to help teachers guide their students towards more consistent and complete learning to succeed in the real world.

- For teachers: to bring out the best in the students
- For students: to be ready to face the challenges as they embark upon their career
- For educational Institutions: to create the future world´s best leaders.

Reference Links :
https://youtu.be/8xJ_qK0nbW0
https://youtu.be/DAaL7hc-75w
https://www.virtualwareco.com/news/the-vr-center-university-retono-unveiled/

5.2 Immersive Employee Development, Training & Certification

Use Case Title	Self-paced Equipment / Product Training
User Organization	Aggreko
Application Developer	Scope AR

Use Case Description:

Training on Aggreko products has traditionally been delivered in-person and face to face. The objective for this use case was to make learning more readily available through AR functionality, which eliminates the need for employee travel or for products and equipment to have to be physically present and available while still providing the same “life size” spatial product learning experience.

Functionalities:

- User Management & Single Sign On
- Experience & Audience Grouping & Assigning
- Codeless Authoring & Publishing Tool
- Spatial Positioning
- Visual user guidance & orientation for real world movements
- 3D Animations & Interactions
- In experience multiple choice challenges
- Full scale experience (products used up to 20’ x 8’ x 8’6”)
- Step tracking for individual activities in experience
- Available both online (connected to internet) or offline
- Available in Holographic view (without real equipment) or locked onto the actual equipment in the real-world

Hardware used:

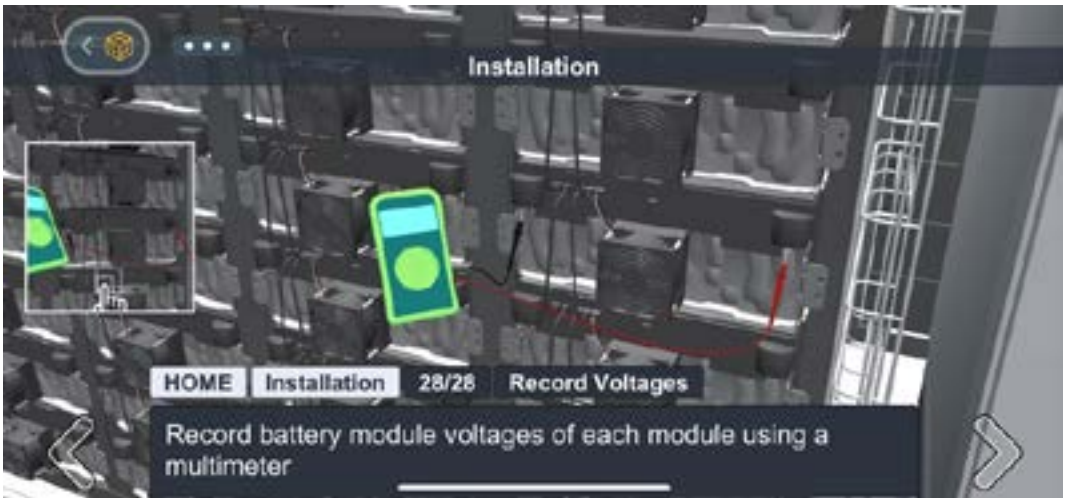
- Mobile Phones (iOS, Android)
- Tablets (iOS, Android)

Details of PoC:

- **Parameters monitored:** Employee Completions, Time Spent and Access
- **Improvement observed:** reduced time to competency, reduced time to access to equipment and knowledge, increased employee engagement.
- **Benefits realised:** Reduction in Travel and Equipment Downtime.

Phase of Deployment: Currently scaling with multiple experiences for multiple products already available and others in the pipeline.

Self Paced Learning using ScopeAR Worklink on Aggreko Y.Cube Energy Storage System



Self Paced Learning using ScopeAR Worklink on Aggreko Y.Cube Energy Storage System

5.3 Virtual Classroom Training Activity on Components

Use Case Title	Virtual Classroom Training
User Organization	Aggreko
Application Developer	Scope AR

Use Case Description:

Due to the impacts of COVID on training delivery it was necessary to adapt the learning to be delivered in a virtual format. Aggreko used Microsoft Teams for the activities that included presentation, whiteboarding, & Q&A, covering much of the knowledge but left the sessions lacking a spatial understanding of products and components that were being taught. By using Augmented Reality Aggreko have been able to offer

Holographic experiences of parts and components to compliment the virtual sessions being delivered. Now the employees have a digitally enabled practical activity to help them learn about the components using a digital version of the actual part and components.

Functionalities:

- User Management & Single Sign On
- Experience & Audience Grouping & Assigning
- Codeless Authoring & Publishing Tool
- Spatial Positioning
- 3D Animations & Interactions
- Step tracking for individual activities in experience
- Available in Holographic view

Hardware used:

- Mobile Phones (iOS, Android)
- Tablets (iOS, Android)

Alternator parts and components activity used during Aggreko Alternator & Schematics virtual course using ScopeAR Worklink

5.4 Equipment/Product Training Practical Assessment

Use Case Title	Equipment / Product Training Practical Assessment
User Organization	Aggreko
Application Developer	Scope AR

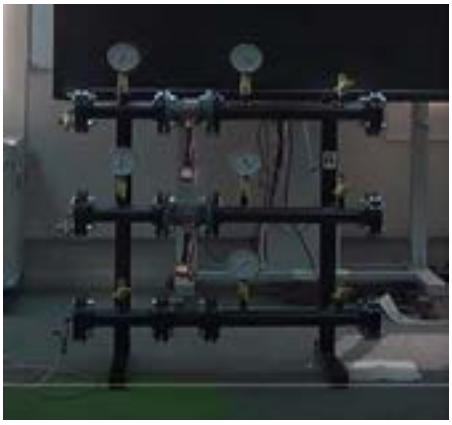
Use Case Description:

Due to the impacts of COVID on certification program deliveries Aggreko has partnered with SGAS & LOGIC UK to virtualize entry level Gas Safety Program. While this enabled moving instruction and assessments online it still left needed Practical Assessment to be conducted with a trained instructor/ assessor. By using Augmented Reality Aggreko created a life size holographic duplicate of the Gas Rig

assembly including piping, flanges, gauges and relevant pressures under specific conditions. Using this multiple scenarios could be created with different faults/failures for each scenario that would need to be identified within the experience. This experience is also enabled by Remote “LIVE” session where the student and instructor can communicate over VoIP and the instructor can has a “See what i see” view of what the student is doing. This allows the instructor to also ask questions during this practical exercise just like it was done pre-COVID.

Functionalities:

- User Management & Single Sign On
- Experience & Audience Grouping & Assigning
- Codeless Authoring & Publishing Tool
- Spatial Positioning
- Live Streamed Session (Experience, Video & Audio)
- Instructor/Assessor in Experience Interactions
- 3D Animations & Interactions
- Step tracking for individual activities in experience
- Available in Holographic view



Physical Aggreko Gas Rig for practical assessment shown at learning centre in Dubai, UAE

Aggreko holographic Gas Rig using ScopeAR Worklink shown from students view during practical assessment

Hardware used:

- Mobile Phones (iOS, Android)
- Tablets (iOS, Android)
- Laptop/Desktop (Windows)

Details of PoC:

- Parameters monitored: Employee Completions, Time Spent and Access
- Improvement observed: reduced time to certification, Reduced the time for employees access to customer sites/locations.
- Benefits realised: Reduction in Travel

Phase of Deployment: Deployed for Gas Safety Programs and planning further programs for inclusion.

5.5 VR Based Training of Heavy Duty Crane Operators

Use Case Title	VR based training of Operators of Heavy Duty Cranes
User Organization	American Fuel & Petrochemical Manufacturers, Houston, TX ExxonMobil, Baytown, TX
Application Developer	Brightline Interactive, Washington DC

Use Case Description:

Conventionally, training of operators of heavy construction plant and machinery such as heavy duty cranes is a gradual and long drawn process starting with exposure of trainees to basic principles and design / configuration details of the construction equipment using operations manuals and drawings, which is then followed by demonstration of the operation by experienced personnel before trainees are involved in operation of the machines. In most cases trainees are also required to be certified by some authorised agencies before being deployed on jobs.

Construction safety is an important consideration and therefore it is required to be specifically incorporated in the contents of the conventional training programs for operation of construction plant & machinery.

VR based training of operators of construction plant and machinery has proved to be effective due to the immersive nature of training, permitting trainees to get real like experience and high level of knowledge retention. This method is also cost effective since it does not involve expensive physical assets and can be repeated a number of times without major extra cost, also permitting purposeful mistakes by trainees which impresses upon them the implications of these mistakes.

The objective of VR based training of heavy-duty crane operators is to provide complete understanding of design/ configuration / control and safety aspects of the machine and impart operations training through an immersive virtual experience. This permits trainees to develop necessary proficiency in operating this critical machine without supervision, so that the trainee can start performing this operation independently on the actual job within a short period of time.

Functionalities:

The application has following functionalities –

- Explanation of crane configuration, various components such as boom, crane operator cabin and controls, slings / hook, drive mechanism
- Specifications such as lifting capacity, boom radius, boom angle / Crane Make / Model
- Description of operational controls
- Safety precautions and procedures
- Rigging plan, Lifting and installation operations, controlling the swing and other critical aspects
- Crane dismantling details and transportation

VR Based Training for Crane Operators

Improvements observed & Benefits realized:

- Conversion of a long drawn training process requiring 30 days activity based on a 120 page manual into a crisp 30 minute VR based activity for the trainees
- Significant increase in trainees' comprehension of crane operations
- Enhanced awareness of consequences of dangerous / hazardous situations and the means to avoid / mitigate the same

5.6 VR Based Training for the Natural Gas Distribution Industry

Use Case Title	VR Based Training for the Natural Gas Distribution Industry
User Organization	Gas Technology Institute (GTI) and miscellaneous gas distribution companies throughout the U.S.
Application Developer	PixoVR, Royal Oak MI

Use Case Description:

Pipeline operators are required to train and qualify personnel who perform Covered Tasks on a pipeline. Traditional training and qualification methods included on the job training for several years followed by a multi-day classroom session and then hands-on in a lab environment to complete the qualification process. This process is no longer effective due to the increased number of retirements and new employees entering the workforce at all levels of the organization. Therefore, VR training technology is now being adopted by the industry to give new employees an opportunity to experience years of work activities in a fraction of the time. In addition, this technology delivers consistent training to each trainee. Lastly, now pipeline operators have a way to deliver effective and engaging training to personnel across several states instead of requiring travel by trainees or instructors to complete required training.

Pipeline safety is monitored and enforced by federal and state agencies; therefore, it is required to be specifically incorporated in the contents of the conventional pipeline operator training programs for performing Covered Tasks on natural gas pipelines.

VR based training of pipeline operator personnel has proved to be effective due to the immersive nature of training, permitting trainees to get real like experience and high level of knowledge retention. In addition, the technology offers the ability to create thousands of randomizations so no two training experiences are the same. Lastly, the technology allows pipeline operators to train up to 16 individuals remotely across several regions and states. This capability allows for increased on-demand training and qualifications and reduces the travel expense for attending training at one office location.

The objective of VR based training for pipeline operators and its field employees is to provide complete understanding on how to perform Covered Tasks safely and also to be able to recognize and react to Abnormal Operating Conditions (AOC's) that may occur when performing a task. This permits trainees to develop the necessary proficiency in performing Covered Tasks without supervision, so that the trainee can start performing work activities independently on the actual pipeline within a short period of time.

Functionalities:

The application has following functionalities –

- There are five learning objectives that the trainee is scored on - 1) Elimination of Ignition Sources 2) Leak Investigation 3) Evacuation and Ventilation 4) Communication 5) Identifying Changing Conditions.
- Ability to train up to 16 people in the VR environment.
- Ability to create specific training scenarios or just complete random scenarios generated by the system.
- Trainees are required to select the appropriate personal protective equipment (PPE) and interactive tools to complete the necessary emergency work.
- Trainees are required to communicate effectively with other first responders and company personnel (e.g., Dispatch, Supervisor, etc.).
- Trainees are required to perform leak investigation in the immediate area of the hazardous situation based on scenario presented.
- Trainees are required to evacuate and ventilate pedestrians and structures as required based on the scenario presented.
- Trainees are required to identify changing conditions (e.g., elevated gas readings, ignited gas, etc.) throughout the training event.
- Trainees have the ability to go into "review mode" upon completion of the training scenario which allows the trainee to see what they completed correctly and incorrectly.

VR Based Training for Natural Gas Emergency Responders

Improvements observed & Benefits realized:

- Ability to train on hazardous work activities in a safe environment.
- Trainees are able to experience years of real-life work scenarios in a matter of hours.
- Ability to deliver effective and engaging training remotely with up to 16 trainees across several offices, regions, and states in a virtual environment.
- Ability to train and qualify personnel remotely without the need for travel by trainers and trainees.
- Reduced classroom time due to being able to train on and learn complex procedures in VR. This eliminates the time required to disassemble and reassemble training props.
- Increased learner retention of VR training content.
- Reduced labor time for instructors setting up training props, creating training scenarios, and disassembling training props at the completion of training.
- Increased on-demand training opportunities with the use of VR training technology.
- Reduced instructor contact time with trainees due to learners performing most training in VR environments solo.

5.7 MR Based Remote Assistance in Sub-Stations Operations

Use Case Title	MR remote training and assistance in Sub Stations operations
User Organization	Large Electric Utility in the North East USA
Application Developer	FactualVR

Use Case Description:

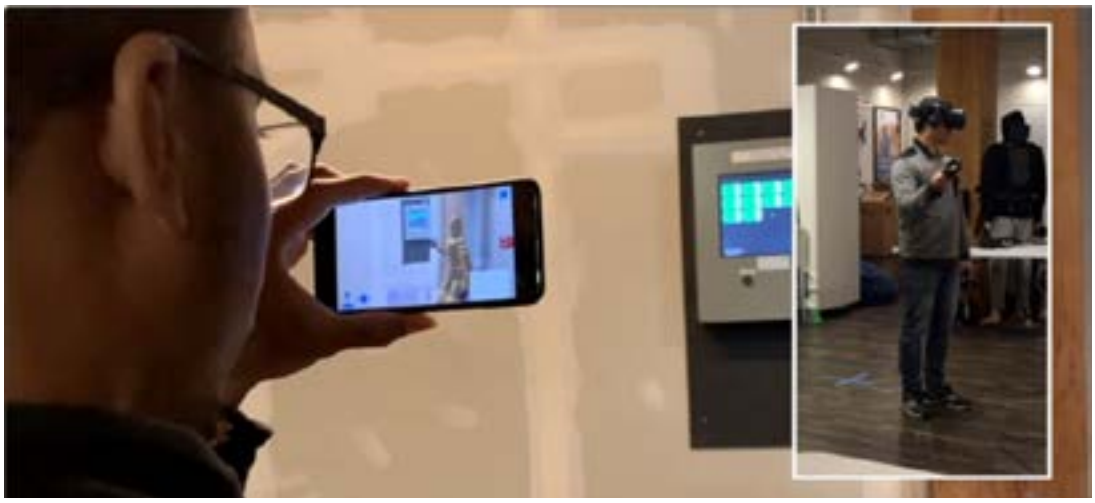
One of the key challenges FactualVR is looking to address is the electric utility workforce that is rapidly retiring and the significant loss of institutional knowledge which has created a vulnerability in the United States electric grid, especially during widespread power outages.
To mitigate this challenging problem, FactualVR is developing the HyperTunnel® platform under a U.S. Department of Energy Phase II SBIR award for Advanced Grid Technologies which leverages a limited number of experienced electric utility field personnel to train and/or supervise a larger workforce using a mixed reality remote collaboration system.

HyperTunnel® unique value proposition is enabling field technicians to summon an expert or supervisor for side-by-side guidance and oversight through a shared immersive digital twin, by “teleporting” the expert as a real-time avatar to mimic operations on a shared virtual workspace. This grants the supervisor the ability to observe and understand the actions performed, as well as provide real-time demonstrations to field technicians.

Functionalities:

- Scanning a remote work site -- Leverages input from 3D scanners, cameras and other sensors available through the AR devices at the remote worksite
- Creating a Digital Twin at HQ – Captured data is used to reproduce an immersive digital twin of the worksite at a central office location

- Matching and Enhancing the Shared Scenes – Remote worksites and immersive digital twins are synched and enhanced by Computer Vision and Artificial Intelligence
- Annotating and Demonstrating -- Users can interact simulated components, provide guidance and demonstrate actions in the shared virtual space



Remote collaboration between Field Technician and Expert using HyperTunnel®

Multi-user training and simulation of substation operation using HyperTunnel®

Key benefits:

- Economic – Cost savings from eliminating traveling time and reduced operational risk from avoiding co-location requirements
- Commercial – Reduce down-time by leveraging scarce supervisors or experts across multiple remote worksites
- Technical – Improved quality and efficiency of repairs and upgrades
- Societal -- Faster response during major outages

Hardware used:

- Mobile Phones / Tablets (iOS, Android)
- Microsoft HoloLens
- HTC Vive Pro

Reference Links:
https://youtu.be/Qsq9lkck6c0
https://factualvr.com/demos/

5.8 Nuclear Pump Room Training Maximizes Efficiency

Use Case Title	Nuclear Pump Room Training Maximizes Efficiency
User Organization	Exelon Corporation
Application Developer	Oberon Technologies. Inc.

Use Case Description:

Exelon employees periodically perform maintenance and repairs throughout the Exelon nuclear plants around the country. The protocols and activities employees must perform in Exelon plants are specific, and performing them in the proper sequence is critical. When employees are preforming these operations within the plant they may be exposed to radiation, so training is paramount to making sure employees work at maximum efficiency.

To train employees, Exelon developed a series of simulations and created model equipment so employees could practice in a safe environment the actions they would need to perform quickly in the pump room within their plant. The pump room, however, is a large, complex environment that is difficult to replicate. Exelon leaders recognized that the various training simulations covering different aspects of the pump room, which were being taught at different times and in separate locations, were not translating in the minds of trainees in an integrated, sequential way. Exelon needed a more realistic way for trainees to practice being in the pump room and progressing through the full sequence of actions while moving around the space.

Oberon's VR development team understood that any successful Virtual Reality training exercise for Exelon would have to recreate the vast and complex pump room with a high degree of accuracy. The virtual environment would need to bring together simulations of all the protocols employees would need to follow, the tasks they would need to perform, the equipment they would need to interact with, and the

VR-based Training for Nuclear Plant Pump Room and Pumps

potential hazards they could encounter in the environment. First, Oberon worked with photographs and measurements provided by Exelon to create a true-to-life virtual environment for training. Within the VR experience Trainees can now practice a number of different activities and training functions. As an example, they are able to follow critical lockout/tagout protocols in the virtual pump room, and then move on to dismantling and reassembling the pump in the correct order. Exelon now uses their VR environment in 13 dedicated training rooms. This state-of-the-art training is resulting in significant cost savings to the client by maximizing the efficiency of pump room repairs, and reduced radiation exposure for employees.

Functionalities:

- Replication of complex pump room and equipment in true-to-life virtual environment
- Train in hazardous environment without any risk or radiation exposure
- Full scale experience of representative nuclear facility and exact pump replications
- Follow critical lockout/tagout protocols
- Dismantle and reassemble pumps in proper sequence
- Enable spatial awareness and positioning
- Conduct specific, random, or rare scenarios
- Simulate defects which would be difficult to reproduce in real-world scenarios
- Randomize issues with pumps and repair procedures required to address the issue
- Create hazardous scenarios without risk to personnel (e.g. fire, explosion, accidental pressure release, falling equipment, etc.)
- Trainees are prompted to select appropriate personal protective equipment (PPE) and tools necessary to complete the tasks

Hardware used:

- Custom-built X64 Workstation (Windows)
- HTC Vive, Valve Index HMD and controllers

Improvements & Benefits:

- **Safety** – eliminated radiation exposure to employee during training and reduced radiation exposure during repair through efficiency improvements
- **Experience/Proficiency** – trainees can practice different activities as often as needed and experience real-life work scenarios that would otherwise take years in a matter of hours
- **Knowledge Retention** - Highly immersive VR learning environments, like Exelon's, typically lead to subject matter retention rates of up to 80%, compared to around 20% for traditional training. The enhanced retention translates to improved locational awareness and area knowledge that allows operators, mechanics, technicians, and engineers to work more efficiently, and most importantly, safer.
- **On-demand Training** – ability to perform infrequent operations as often as is necessary to develop proficiency in the plant without risk to personnel. As well as, the ability to introduce alternate or rarely occurring scenarios within the same environment.

- **Reduced Training Time** – for both trainees and instructors. VR Environments provide a more efficient method to complete complex procedures and environments without extensive setup time or need for physical simulators
- **Cost Savings** - The company estimates that shaving off even single digit millirems (radiation exposure) per employee per year, through improved situational awareness, and reduced time on repairs, could lead to millions of dollars a year in savings.

Other applications where similar solution can be deployed:

- Exelon continues to be committed to providing additional Virtual Reality training experiences for its employees and partners. Future applications in development include the creation of Complete exact plant replications for location awareness, hazard recognition, foreign material exclusion, in situ component identification, and various other training scenarios. Training courses to include Line-of-Fire, Seismic Walkdown, Fuel Moves, and Active Shooter and other threat scenarios.

Reference Links:
https://oberontech.com/wp-content/uploads/2020/07/Exelon_CaseStudy_OBERON.pdf
https://oberontech.com/solutions/vr-training/

6 Concluding Remarks

It is evident that there are several use cases of VR and AR suitable for various business functions in the entire value chain of Energy Industry. With deployment of these solutions in appropriate manner, stakeholders in Energy Industry have realised immense benefits.

At the same time, it is also seen that the level of adoption of VR and AR in Energy sector is still on a low scale. It is however clear that the early adopters of these immersive technologies will hold the competitive edge over those which are yet to come on board.