An AIChE Technology Alliance

CCPS

Center for Chemical Process Safety

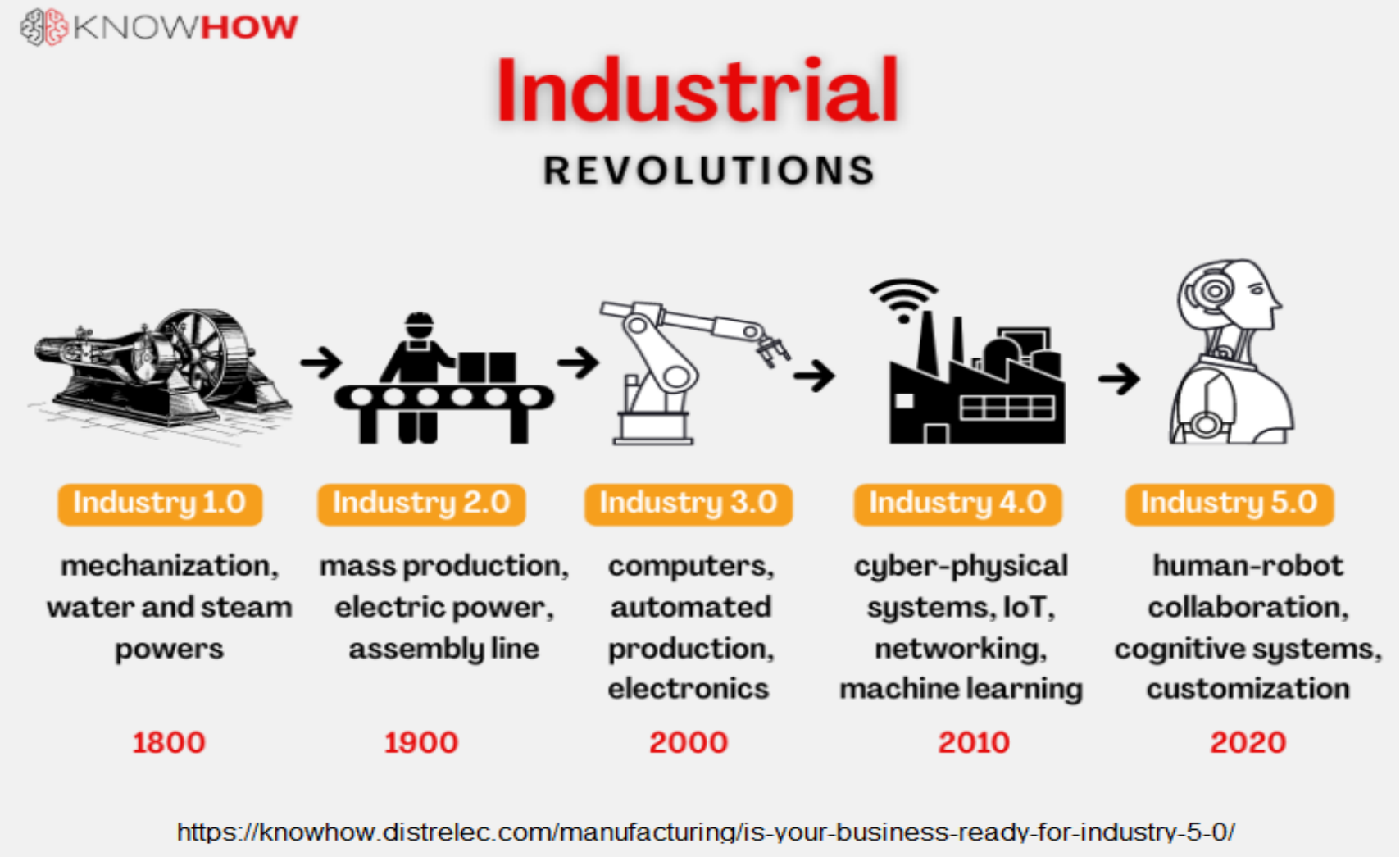
Safety Moment

How to make sense of your Data

(8 Sep 2022)

GOARC

Industrial Revolutions History (Industry 1.0 – 5.0)



International News Events (Jun 1-Jul 10, 2022)
Average = 1 major incident/ 2 days

June 1, 2022, Fire and explosions rip through **Omaha** chemical plant, prompting temporary evacuations

June 3, 2022, Schwechat oil refinery outside Vienna, **Austria** at 20% capacity after accident. 2 people were injured when a part at a crude oil distillation unit exploded at the refinery

June 3, 2022, Vadodara, **India** blaze at chemical plant after blast, 8 injured. A fire official said the blast was in a boiler of the chemical plant. Flames from the fire could be seen from the highway, around 10 km away.

June 5, 2022, BM Inland Container DHAKA, **Bangladesh** — A massive fire at a container depot killed at least 49 people, including 9 firefighters, and injured 100+ others, as efforts to extinguish the blaze continued into a 2nd night.

June 6, 2022, Fawley refinery in the **United Kingdom** fire in one of the units

June 11, 2022, Sinopec ethylene glycol processing unit in **Shanghai**. Huge fire leaving one person dead. Videos on social media of the scene showed raging fires and huge plumes of dark smoke rising from the Sinopec facility.

June 8, 2022, Freeport LNG fire in Quintana Island, **Texas**. "Completion of all necessary repairs after the fire and a returning to full plant operations is not expected until late 2022," the company said Tuesday in a statement. The explosion and fire shut down about 1/5 of the country's LNG export capacity and wasn't the first-time flames have bedeviled the Freeport LNG facility.

June 14, 2022, LyondellBasell **Houston** refinery shuts coker after fire. It was unclear whether the fire on the 57,000-bpd 737 coker would speed up plans for a permanent closure of the refinery, the sources said. The refinery can operate at a reduced production level with only one coker

June 14, 2022, Quasar energy plant, **Ohio**. Three people were injured after a chemical plant exploded.

June 16, 2022, Domino Sugar Refinery In **Baltimore** Turbine Fire

June 21, 2022, Oxy Vinyls - La Porte, **Texas** large chemical fire extinguished at La Porte plant

June 20, 2022, Valero fire at its 205,000-barrel-per-day Houston, **Texas**, refinery

July 3, 2022, Egypt: Firefighters responding to large blaze at a factory in El-Salam

July 3, 2022, Fire extinguished at **Norway's** Mongstad refinery

June 30, 2022, Petro Star refinery in Valdez, **Alaska**. A fiery explosion earlier this week led to the release of 5,000 gallons of fuel

July 7, 2022, Chemical Plant explosion in **Iran**. An explosion at a chemical factory in southern Iran injured scores of people

July 9, 2022, OneOk Natural Gas Plant In **Oklahoma**. The explosion caused a 1.74 magnitude earthquake. It's unclear what caused the explosion officials say This is still an active situation and a dangerous one

July 11, 2022, Armorock Polymer, Bolder City , **Nevada**. 6 Employees Injured After Explosion, Fire at a Nevada Plant

July 10, 2022, Allnex chemical plant explosion, **St. Louis**. Two people injured after a chemical plant exploded Sunday night in East St. Louis.

GOARC

Hydrocarbon Process Industry ESG Issues

- Eliminating industrial accidents will cut industrial greenhouse gases by 46%
  - Normal industrial processes make up 6% of all man-made greenhouse gases
  - Fugitive Emissions from incidents add almost the same amount (an additional 5.2%)
- Industrial Insurer Marsh McLennan reports that major industrial accidents have not improved in last 30 years
- Risks are not monitored using quantitative methods
- Current Operational risks are not monitored, prioritized and managed with a closed loop system
- Leading Indicators are not closely managed
- Current methods miss the dynamic nature of risk

* SOURCE: Climate Analysis Indicators Tool (World Resources Institute, 2017)

Case study: Plant Air System Failure

Executive Summary

On 3/26/2020, loss of Plant Air System (Unit 08 in Area 2) and failure of Emergency Air Supply control valve to actuate caused a Refinery shutdown.

Investigation Findings

- Welding rod found inside V-9 Depressure Valve on Air Dryer. Not the first time welding rods have been found in lines at Unit 008 Plant Air System.
- Employees left the air system (Unit 8) when told the FCCU and Boilers were shutting down.
- Preventive maintenance had never been performed on A and B Dryers, but the desiccant on A Dryer has been replaced.
- In the last 365 days to date (readings taken once per shift), 17 instances of critically high dew point on A Dryer (>50°) and 50 Caution (>20°). This was recorded by personnel on their [redacted] handheld device. On B Dryer, 3 Critical and 17 Caution readings.
- Preventive maintenance had never been performed on 08-PC-1016 the Emergency Air Supply control valve. It was sticking when they tried to manually stroke it.
- The Emergency Air Supply System had never been hooked up because the plant air and yard air subsystems had never been separated and isolated in Area 2.
- Preventive maintenance had never been done on Plant Air Emergency Shutdown valve XV-1016 that, in an air system failure, stops plant air flow so that all air flow goes to instrument air system. It was stuck in the open position.
- WO#409039 written 8/2/2017 to segregate instrument and plant air piping at FCCU not completed. MOC #2017-0885-013 for this WO was cancelled.

Timeline & Key Factors

Pre-Incident

- "A" Dryer was flooded due to high dew points and the V-9 Depressure Valve was open.
- Although an Employee switched to B Dryer, the air pressure was still dropping. The Employees left the air system to help stabilize FCCU and Boilers that were shutting down.
- The Emergency Air Supply control valve 08-PC-1016 failed to open.
- Plant Air Emergency Shutdown Valve XV-1016 stuck open and failed to close.
- Loss of the Refinery air supply caused a cascade affect shutting down the Boilers and all process units.

During Incident

- 5/26/2016, 8 initial operating procedures developed for Air System. No Emergency, Environmental, and Safety & Health procedures were written. The procedures have never been updated.
- 1/15/2017 the New Refinery Plant & Instrument Air System goes on line. But the Emergency Air Supply System was not hooked up and commissioned because the plant air and yard air subsystems had never been separated and isolated in Area 2.
- FCCU slide valves in Area 2 are actuated by plant air instead of instrument air .
- 8/2/2017 WO# 409039 was written to separate systems, but never completed. MOC for that WO was cancelled.
- At 3/26/2020 6:19 pm, low air pressure triggered the second, B compressor to start.

Post Incident

- When the Employees returned to the air system, one had to open the bypass -08-PC-1016 to get sufficient seal air pressure to start compressors and restore air pressure by ~7 pm.

OOT CAUSE ANALYSIS (RCA)

OOT CAUSE

Work Monitoring - Leadership System LTA (Interconnection of yard & plant air in Area 2 and non-commissioning of Emergency Air Supply system not reported to Management)

ONTRIBUTING CAUSE(S):

Work Monitoring – QA/QC LTA (Welding rods found in Plant Air System lines)
Knowledge and Skills – No or Inadequate Training (1. Operating Air Dryer with high dew points. 2.Leaving air system (Unit 8) to respond to FCCU and Boilers shutdown)

Recommended Actions to Prevent Reoccurrence

- Repair/PM Dryers – M. McAlister – WO#555768, WO#555774, WO#555171 – Planning/Scheduling – 5/15/2020
- Reconfigure and Repair PC-1016 – M. McAlister - WO#555773
- Develop, Review, and Train on Plant Air System Procedures – R. Small – 6/30/2020
- Complete WO#409039 to isolate Plant & Instrument at FCCU – Turnaround scheduled
- Write WO to connect Emergency Plant Air System reading from the compressors to DCS and commission on site – WO# 556468, WO# 558100, WO#558101
- Repair V-9 Valve – M. McAlister - WO#555399 – Completed

In the last 365 days to date (readings taken once per shift), 17 instances of critically high dew point on A Dryer (>50°) and 50 Caution (>20°). This was recorded by personnel on their [redacted] handheld device. On B Dryer, 3 Critical and 17 Caution readings.

Plant Air System Failure
Unplanned Shutdown
March 2020

- All process units shutdown
- Loss of production
- Increased risk from startup
- Repair costs

Plant Air System Failure

Operations: Dryer Dew Point too high

Maintenance: Uncompleted air system work orders

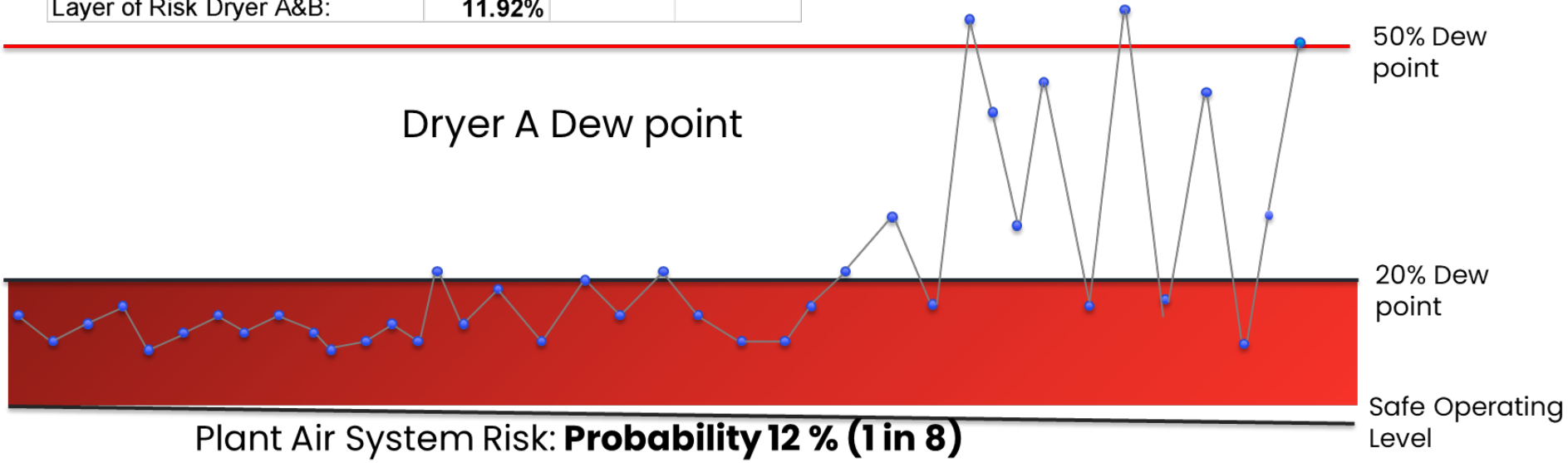
GOARC

Case study: Plant Air System Failure

	Alarms	Samples	% of Time		
Dryer A	17	730	2.33%	Dew Point >50%	
	50	730	6.85%	Dew Point >20%	
Total time % at Risk Dryer A:			**9.18%**		
Dryer B	3	730	0.41%	Dew Point >50%	
	17	730	2.33%	Dew Point >20%	
Total time % at Risk Dryer A:			**2.74%**		
Layer of Risk Dryer A&B:			**11.92%**		

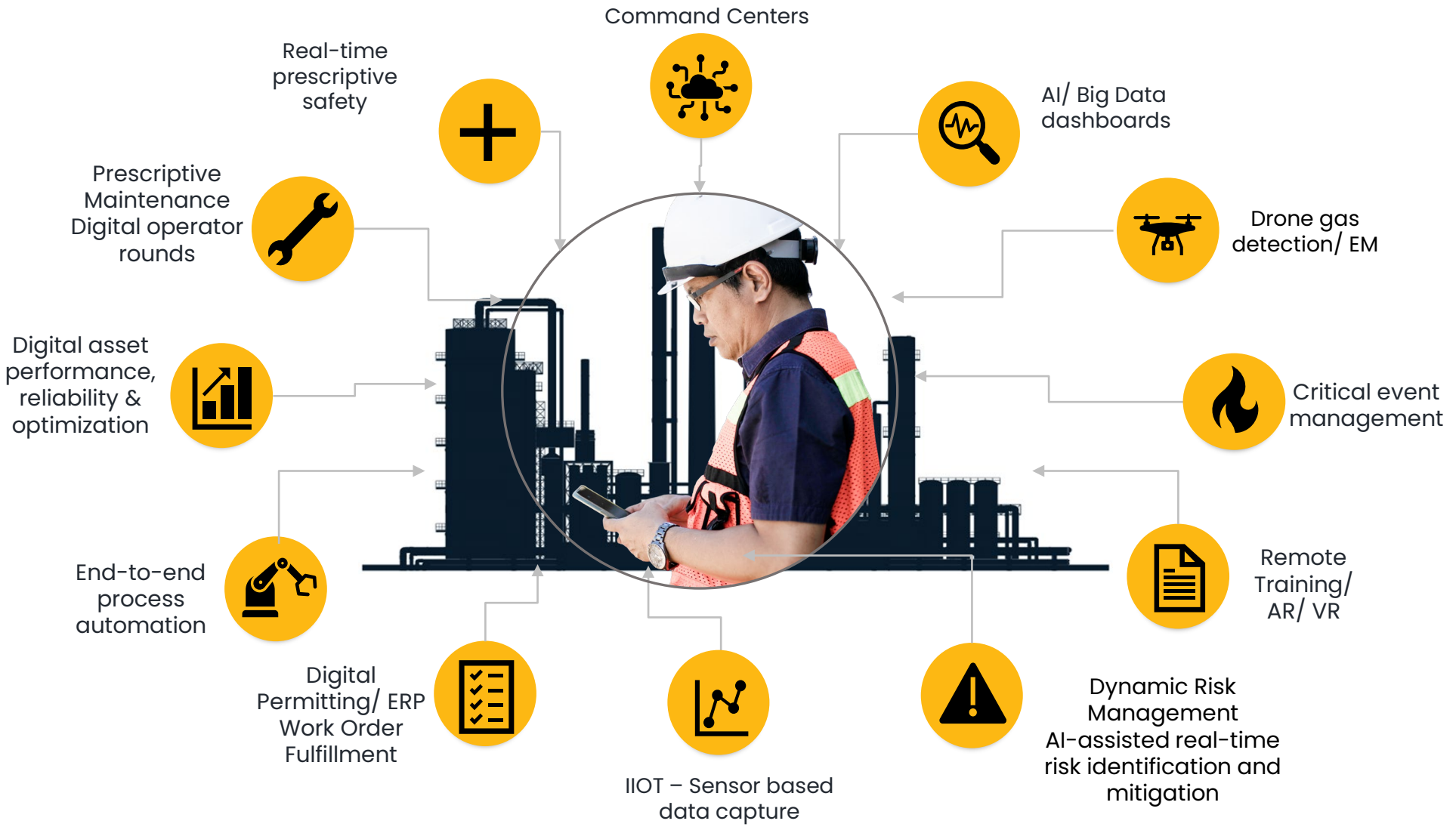
Permit to Work: Maintenance omission (welding rod left in air system unit)

Maintenance Management: Work Orders not completed - Emerg. air, separate instrument /plant air



Plant Air System Risk: **Probability 12 % (1 in 8)**

Today's Connected World



HOW CAN WE TRANSFORM THE WAY YOU DO WORK?

Christina Pitt, P.Eng.
Digital Transformation Director, Americas

(US) 832.370.5457
(CAN) 403.397.2748
Calgary | AB | Canada
christina.pitt@go-arc.com

GOARC

https://go-arc.com/knowledge-center/

GOARC


Chemical Institute of Canada | For Our Future
Institut de chimie du Canada | Pour notre avenir
PSMD
CCPS 2022-09-08
CSChE - PSMD
2022-09-08
RioTinto

CSChE – PSMD why? History

Bhopal, December 2 to 3 1984 water entered tank 610 causing a runaway reaction with MIC

From CSB's e-mail of Dec 2, 2014:

> An estimated 3,800 people died immediately, and tens of thousands were injured. Eventually thousands more died from toxic gas-related illnesses – the release eventually killed tens of thousands of people

PSMD

Chemical Institute of Canada | *For Our Future*
Institut de chimie du Canada | *Pour notre avenir*

RioTinto

Bhopal aftermath

- CCPS was created as a division of the American Institute of Chemical Engineering shortly after the disaster:

From Abstract of Process Safety Progress of the AIChE:

Leaders from the chemical industry asked AIChE to lead a collaborative effort to eliminate catastrophic process incidents by advancing state of the art technology and management practices, serving as the premier resource for information on process safety, supporting process safety in engineering, and promoting process safety as a key industry value. In the spring of 1985, CCPS was founded.

PSMD

Chemical Institute of Canada | *For Our Future*
Institut de chimie du Canada | *Pour notre avenir*

RioTinto

Bhopal aftermath in Canada

- In 1985, there was no interest in Canada to create a Canadian PSM initiative
- 1989, MIACC was created: Major Industrial Accident, this lead to the: Risk Assessment Guidelines for Municipalities and Industry
- CCPA had their own PSM initiatives, which lead to Responsible Care ®.

PSMD

Chemical Institute of Canada | *For Our Future*
Institut de chimie du Canada | *Pour notre avenir*

RioTinto

CSChE - PSMD

In 1999, MIACC was disbanded, Gerry Phillips approached the board of directors of the CSChE (Paul Amyotte was the president), and the PSM subject Division was created (PSMD), first meeting in Halifax

PSMD

Chemical Institute of Canada | *For Our Future*
Institut de chimie du Canada | *Pour notre avenir*

RioTinto

PSMD Activities

- The PSMD is made up of volunteers, not companies
- Since it's inception the PSMD has published many documents;
  - The 4th edition of the Process Safety Management Guide served as the seed document for the CSA Z767 PSM Standard
  - The section 200 of the Canadian Environmental Protection Act was developed under CSChE
  - More recently, the PSMD has worked with the Canadian Energy Regulator for the Onshore Pipeline Regulations (OPR) discussion paper for the update of the regulations
- Currently working on:
  - Canadian Environmental / Ecological Risk Assessment Guideline
  - Canadian QRA Guideline with tolerability criteria

PSMD

Chemical Institute of Canada | *For Our Future*
Institut de chimie du Canada | *Pour notre avenir*

RioTinto

Risk Assessment white Paper

- *Focus: Acute hazards - fires, explosions, toxic gases*
- *Purpose:*
  - *Describe risk assessment types used in Canada*
  - *Describe when and how each risk assessment type should be used*
  - *Recommend risk evaluation criteria for each RA type*
- *Why:*
  - *Lack of a consistent pan-Canadian approach viz. risk assessment*
  - *Non-alignment among risk evaluation criteria*
  - *Documenting the basis – so that process safety engineers understand "why"*
- *Who: task force of subject RA specialists and regulators*
- *QRA Guideline will then be developed using White Paper as a seed document*

PSMD

Chemical Institute of Canada | *For Our Future*
Institut de chimie du Canada | *Pour notre avenir*

RioTinto

Risk Assessment – Current Situation

Risk assessment type	Type of risk estimated	Risk Evaluation	Known Users
QRA – aggregate risk: ALARP Principle	Individual specific individual risk (ISIR)	ISIR thresholds	British Columbia – LNG reg Ontario – Operating Engineers reg CSA: Z276, Z662
	Societal risk (SR)	FN Curves	British Columbia – LNG reg CSA: Z662
QRA – aggregate risk: Geographic risk	Location specific individual risk (LSIR)	Land use planning guidelines (MIACC)	Quebec – CRAIM Ontario – Propane
PHA	Single scenario	Risk matrix	Companies (e.g., HAZOPs) Worksafe BC

PSMD

Chemical Institute of Canada | *For Our Future*
Institut de chimie du Canada | *Pour notre avenir*

RioTinto

Risk Assessment – Some Known Issues

- Risk evaluation:
  - ISIR thresholds – solid basis already – describe the basis
    - Anchor point for all other criteria
  - FN curves: defend the basis for the emerging criteria (BC, Z276, Z662); slope of the curve (-1 or > -1)
  - Land use (MIACC) guidelines – greater clarity on the land uses for each category required
  - Risk matrix – will try to develop a single risk matrix linked SR thresholds for all to use
  - Public risk vs. worker risk
- Risk assessment
  - Incorrect use – e.g. Ontario uses LSIR land use guidelines for ISIR estimated risk
  - Risk assessment approach for public risk / major consequences
  - Justification of ALARP – qualitative vs. quantitative – when / why

PSMD

Chemical Institute of Canada | *For Our Future*
Institut de chimie du Canada | *Pour notre avenir*

RioTinto

PSMD

Presenter
Guy Brouillard
Chair CSChE – PSMD
Phone: (514) 258-2666
E-mail: guy.Brouillard@riotinto.com

PSMD

Chemical Institute of Canada | *For Our Future*
Institut de chimie du Canada | *Pour notre avenir*

RioTinto

CSA Z-767

Update, September 8, 2022

Adrian Pierorazio, Graeme Norval

Why a Canadian PSM Standard

- Canada has Federal and Provincial legislation on labour, safety and environment - this means 14 different regulatory regimes
- There can not be one “National” PSM regulation due to the constitution
  - India and Australia have similar legal issues
- A “National Standard” allows the various regulators to refer to one common standard, without requiring 14 different pieces of legislation - and that makes it easier for implementation, especially for firms with operations in multiple provinces

Background

- CSA Z-767 technical committee started work in February 2015
- The standard was issued in 2017 as a National Standard of Canada

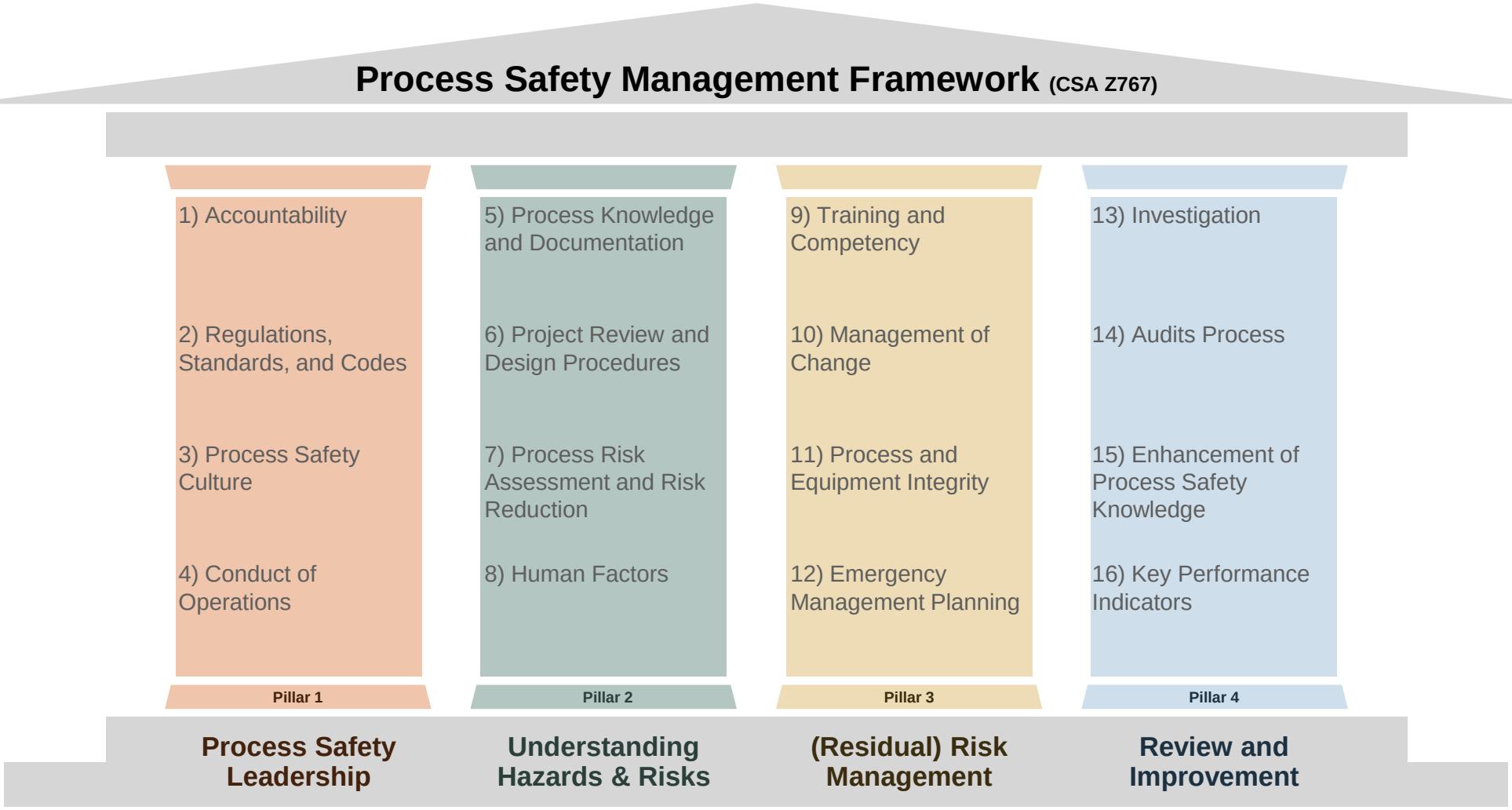
- The standard was re-affirmed in February 2022

Revisions

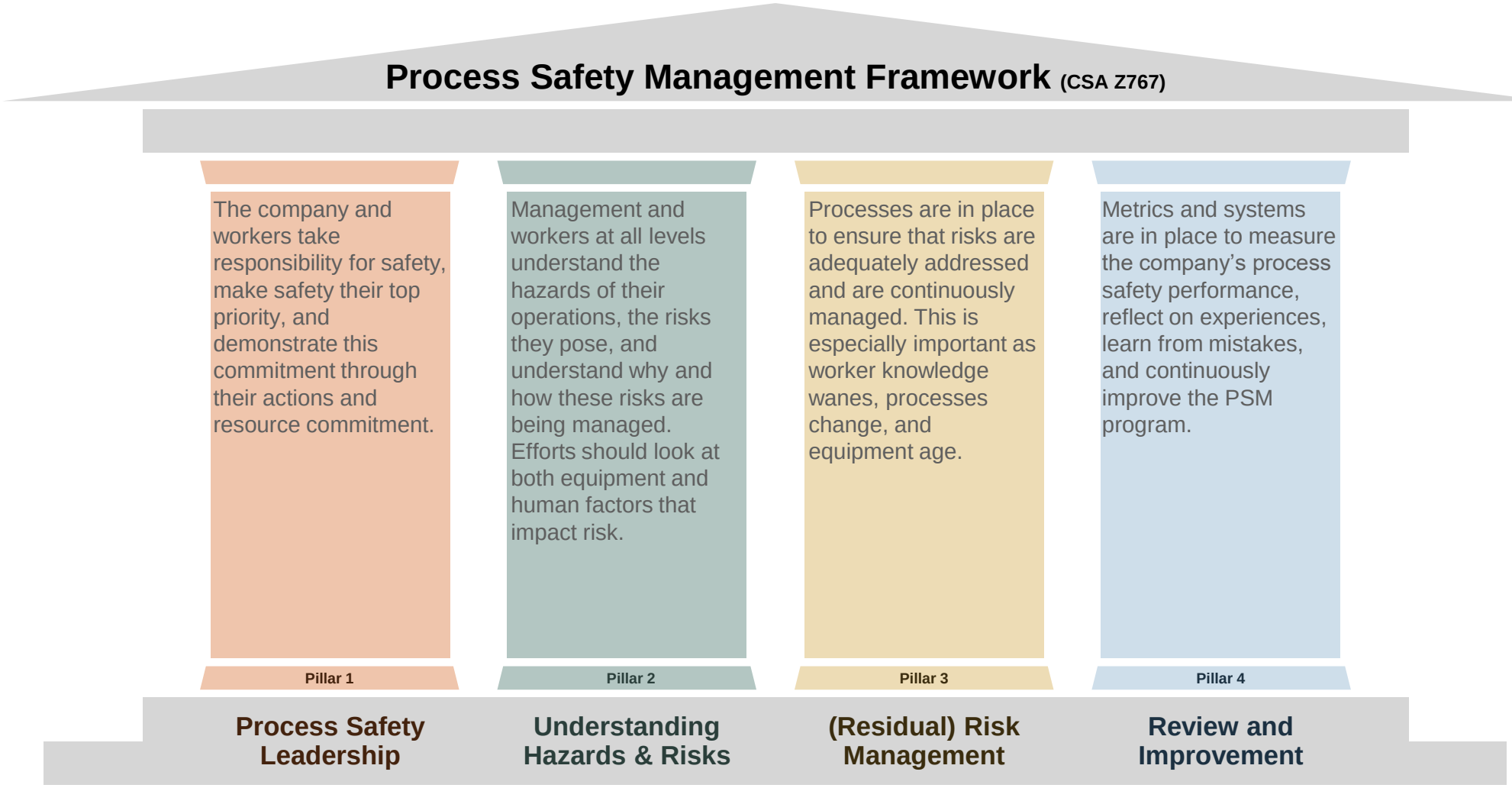
- The TC is working on revisions - essentially 3 types

- Simple - adding definitions, minor wording changes
- Simplifications - several clauses have similar requirements - reduce the requirements to one clause which makes auditing easier
- Complex Issues - How to better describe the scope and goals - this is slow work and requires much reflection

Process Safety Management Framework (CSA Z767)



Process Safety Management Framework (CSA Z767)



What Organizations are Covered?

- The UK, Europe and US have legislation that defines who must have PSM
- Organizations outside of the legislation also would benefit
  - Mining, chemical repackaging, municipalities, transportation

- How do we best explain this? Especially to people who are not tuned in to PSM.

Sayano-Shushenskaya dam (2009)

- Extended operation outside of the defined operating window, and in a region of elevated vibration
- blew turbines out of station
- 75 fatalities
- Loss of 6400 MWe production

Fernie, B.C.

- Ammonia refrigerant leak in a hockey arena/curling club
- Old equipment that had known leak issues, but had not been replaced
- 3 fatalities

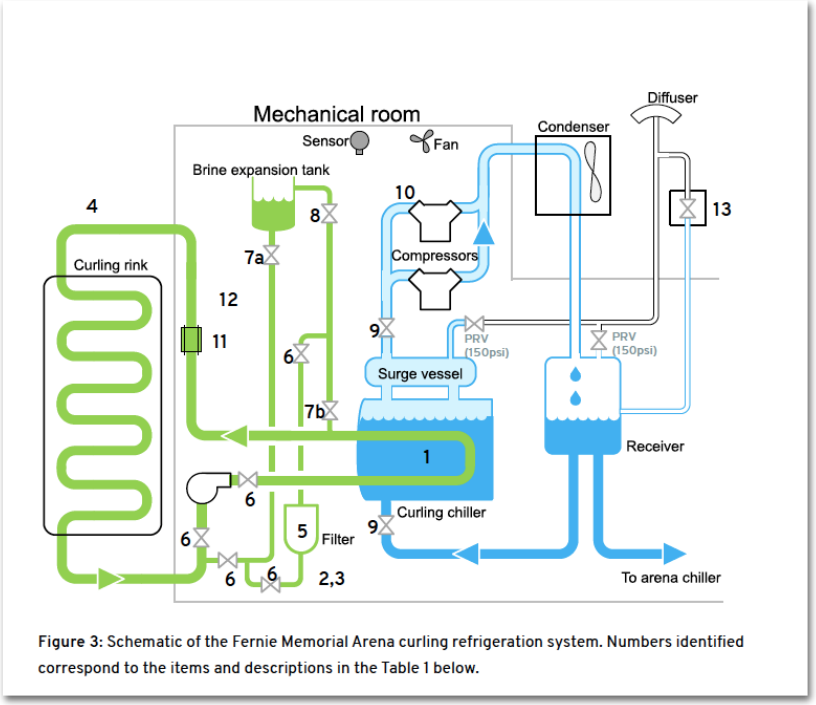


Figure 3: Schematic of the Fernie Memorial Arena curling refrigeration system. Numbers identified correspond to the items and descriptions in the Table 1 below.

Transportation

- Lac Megantic, 2013
- 47 fatalities
- Underinsured short-line railroad
- Unattended train on main line
- Insufficient handbrakes, coupled with loss of air pressure for brakes

Common Risk Matrix

- Risk matrices are a common communication tool (now in IT!)

- Smaller businesses usually have smaller consequence values
- But, the enterprise value is much lower as well

- Can one have a common risk matrix - and also communicate the maximum risk that an enterprise can accept, leading to where maximum attention is needed?

Our Request

- For those who have a PSM system
- Can you provide suggestions for improvements in the standard

- What are the clauses with which you have difficulty - perhaps with auditing, or perhaps with understand

- adrian.pierorazio@jensenhughes.com

AON

Overview and the Impact of Environmental, Social and Governance (ESG) on the Canadian Insurance Industry

September 8, 2022

Frank Verbeek

Environmental, social and governance (“ESG”) refers to non-financial risks and opportunities associated with a company or industry

Why Does ESG Matter?

Investors – Investors are increasingly active on ESG issues to address non-financial risks to mitigate volatility

Insurers – Understanding ESG risks leads to better underwriting and less risk of loss, protection of social license to operate & investment capital

Employees – Companies with strong ESG credentials decrease turnover and increase productivity

Social License to Operate – Making products and doing so in a way that resonates with consumers is increasingly important

Regulatory Bodies & Disclosure Regimes – An increasing number of regulatory bodies and disclosure regimes are pushing companies to embrace ESG

ESG – A Growing International Imperative

2,000+
Studies that show positive correlation between ESG and corporate performance

900+
Number of material ESG factors according to the Sustainability Accounting Standards Board

400
Out of 2,000 of the largest global companies have committed to Net Zero

85% of S&P 500 companies producing meaningful ESG disclosures and/or sustainability reports

650
Number of mandatory and voluntary ESG regulations/ disclosure regimes globally

175
CEOs committed to the CEO Action for Diversity and Inclusion

The need to address ESG grows daily, with companies taking action around the globe

AON

ESG & Insurers

ESG: What to Expect for Future Renewals

Properly showcase sophistication on ESG oversight, practices, and disclosures, a company must first know its exposure relative to:

- The constantly evolving legal & regulatory landscape;
- External stakeholder expectations;
- Competitive market practices & performance relative to peers

Aon's Energy ESG Performance Index

Leveraging data & analytics capabilities

Aon's ESG Performance Index

Primary Goals

- Gain a better understanding of each client's approach to the evolving ESG framework
- Support the underwriting process
- Access new or maintaining capital
- Consultation tool

Secondary Goals

- Track ESG progress over time (trending) - insurance policies responding based on ESG performance
- Connect to claims, risk factors, Nat Cat and other data sets through ORCA for deeper risk insights

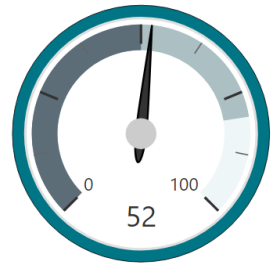
The Module

- Aligns SASB metrics with Energy Insurer considerations
- Condensed to 33 key metrics automatically populated by Aon
- Easily accessible through an online portal
- Data to be validated by clients prior to sharing with markets

ESG Performance Index

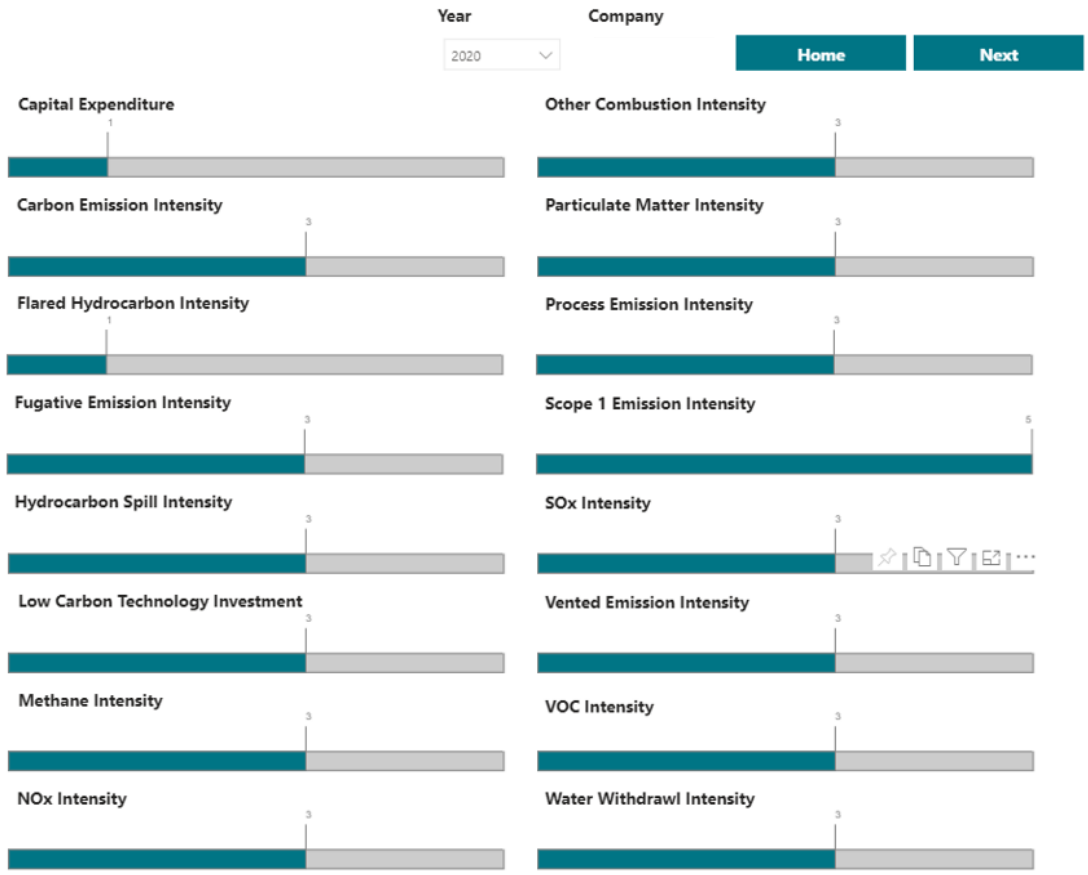
Year: 2019

Company

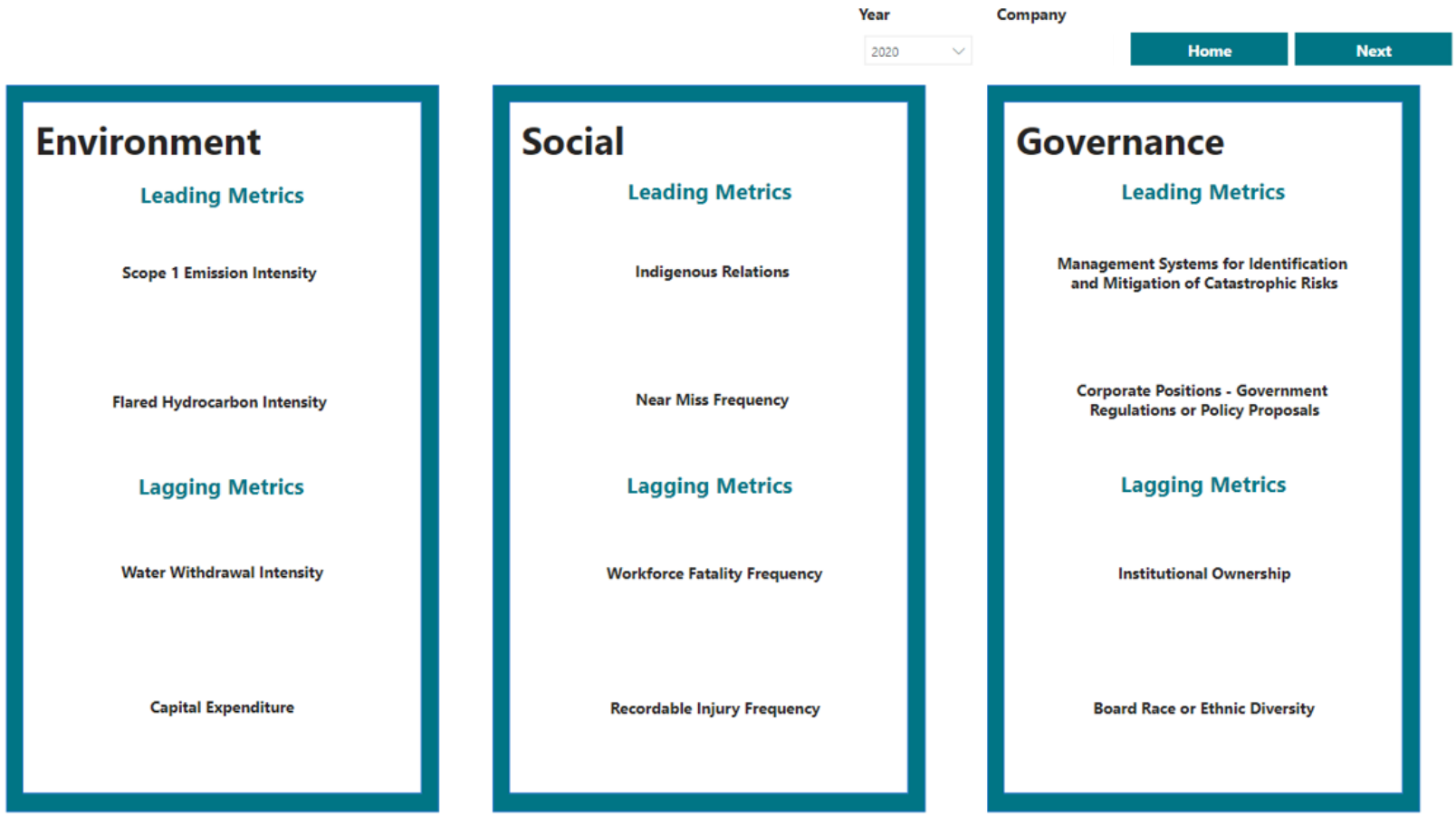
Environmental Profile		Social Profile		Governance Profile		Overall Performance
Emissions (35%)	49/100	Workforce (15%)	60/100	Corporate Behavior (3.5%)	40/100	
Environmental Opportunities (10%)	70/100	Social Responsibility (3%)	60/100	Corporate Governance (12%)	60/100	
Climate Management (5%)	100/100					
Water Management (10%)	20/100	Social Opportunities (2%)	50/100	Management (4.5%)	44/100	
E-Score (60%)	52/100	**S-Score (20%)**	59/100	**G-Score (20%)**	47/100	**ESG-Score** 52/100

Environmental Profile

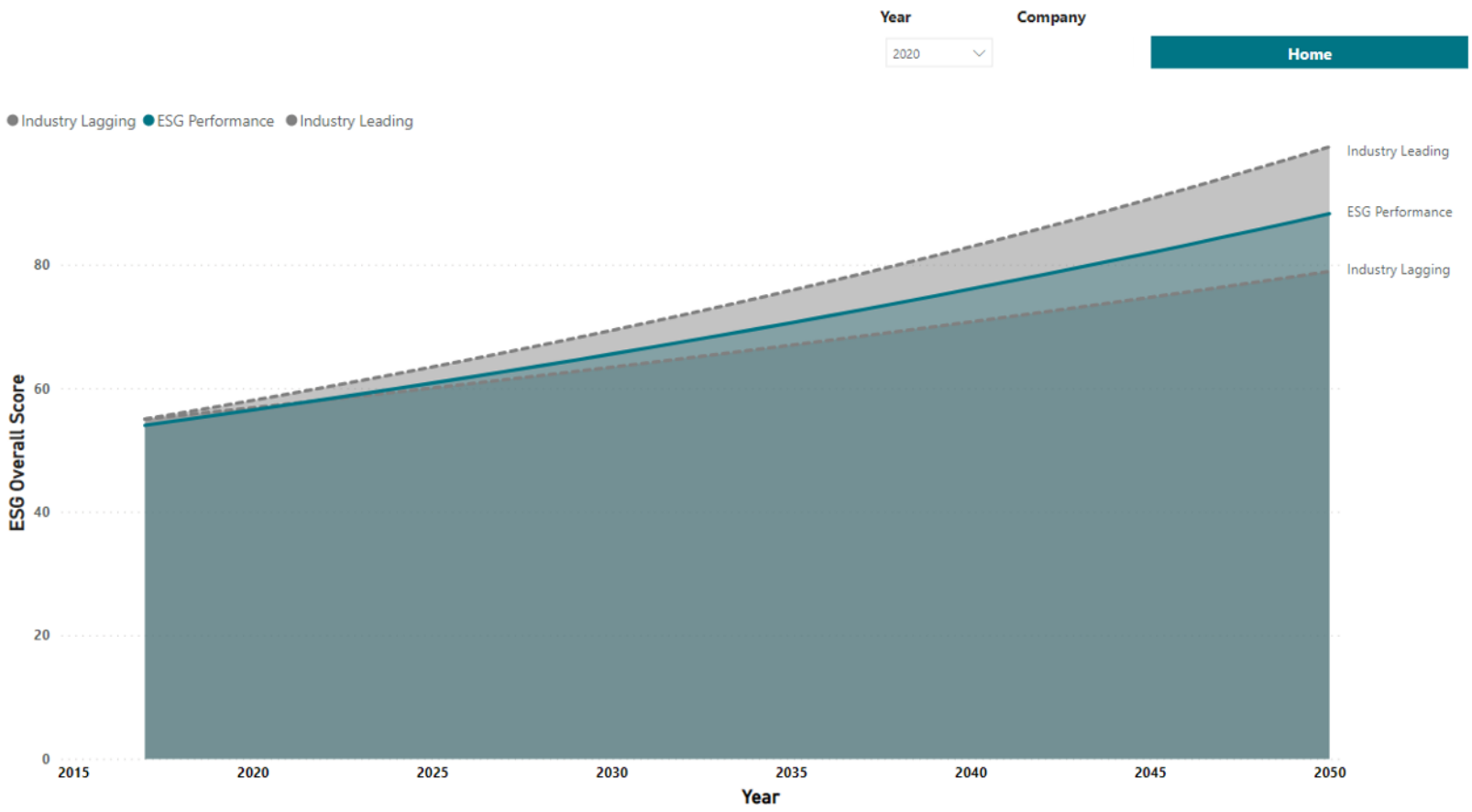
Metric Name	Environment Performance Score	Contribution to Environment Score
Capital Expenditure	1.67	8.33%
Carbon Emission Intensity	5.00	8.33%
Flared Hydrocarbon Intensity	0.67	3.33%
Fugitive Emission Intensity	2.00	3.33%
Hydrocarbon Spill Intensity	5.00	8.33%
Low Carbon Technology Investment	5.00	8.33%
Methane Intensity	5.00	8.33%
NOx Intensity	2.50	4.17%
Other Combustion Intensity	2.00	3.33%
Particulate Matter Intensity	2.50	4.17%
Process Emission Intensity	2.00	3.33%
Scope 1 Emission Intensity	8.33	8.33%
SOx Intensity	2.50	4.17%
Vented Emission Intensity	2.00	3.33%
VOC Intensity	2.50	4.17%
Water Withdrawal	10.00	16.67%
Total	**58.67**	**100.00%**



Leading and Lagging



ESG Forecasting



Thank You

Risktec Solutions

risk management and assessment for business
in partnership with Liverpool John Moores University

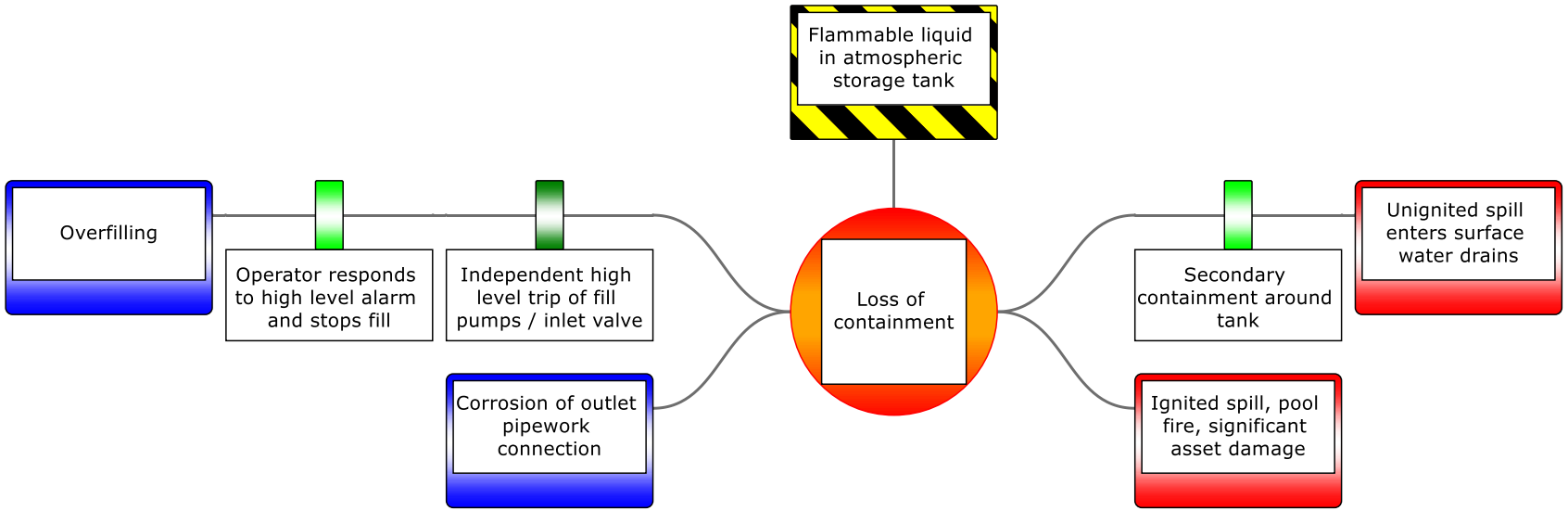
Application of Bowtie Analysis to Sub-Surface CO2 Disposal

7th Annual CCPS Canadian Regional Meeting

TÜVRheinland®
Risktec

Introduction to Bow Tie Analysis

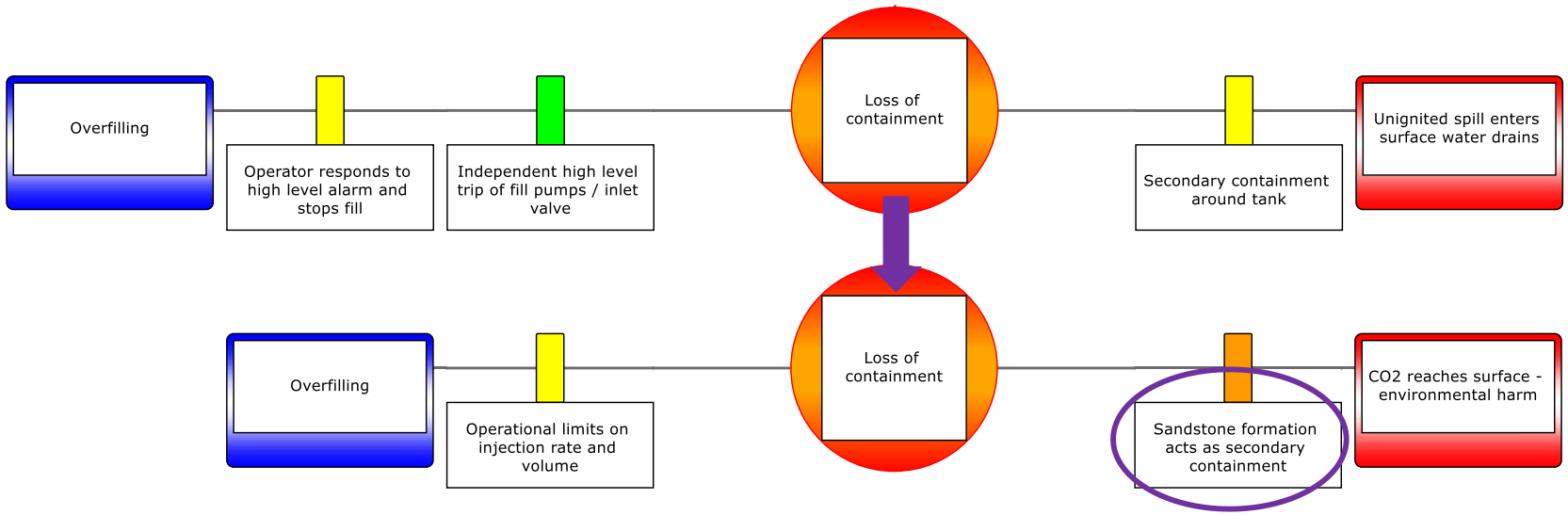
- Application of bowtie analysis within the oil and gas industry globally is mature
- Used to graphically represent how Major Accident Hazards are being managed
- How can we take this well-established approach and adapt it for sub-surface CO2 disposal?



TÜVRheinland®
Risktec

Challenge 1: Presence of Non-Engineered Barriers

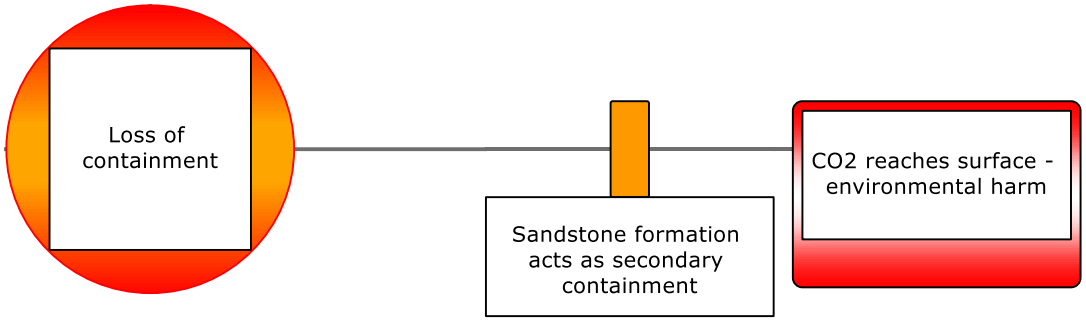
- Prevention and mitigation measures include natural geological formations or features which act as impermeable barriers or provide secondary containment
- Absence of conventional process industry-type reliability data for geological barriers means the analysis must adopt different ways of evaluating the barriers



TÜVRheinland®
Risktec

Challenge 1: Presence of Non-Engineered Barriers

Barrier Effectiveness

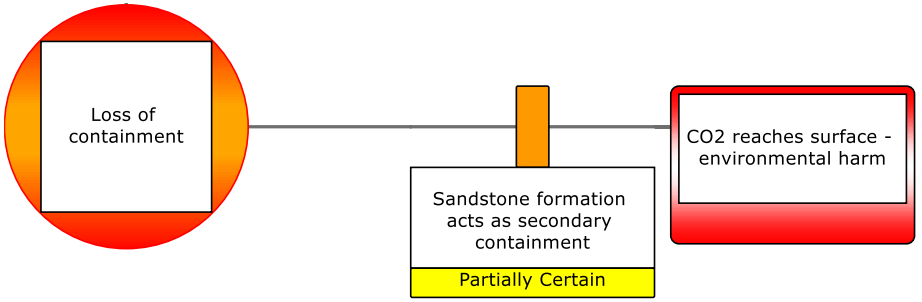


Fully effective	Geological controls with extremely low permeability and physical facts which cannot be overcome.
Effective	Geological controls with low permeability.
Partially effective	Geological controls which act as ‘buffers’ or ‘baffles’.
Ineffective	Geological layers which are highly permeable.

TÜVRheinland®
Risktec

Challenge 1: Presence of Non-Engineered Barriers

Barrier Certainty

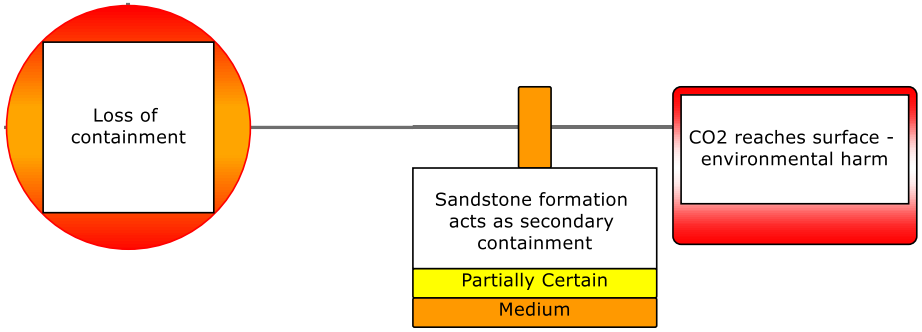


Fully effective	Reasonably certain	Barrier effectiveness rating is based on expert judgement and project-specific evidence, data or analysis
Effective Partially effective	Partially certain	Barrier effectiveness rating is based on expert judgement and may rely on relevant evidence, data or analysis from other projects / locations
Ineffective	Uncertain	Barrier effectiveness rating is based on expert judgement but there is currently no relevant evidence, data or analysis

TÜVRheinland®
Risktec

Challenge 1: Presence of Non-Engineered Barriers

Barrier Criticality

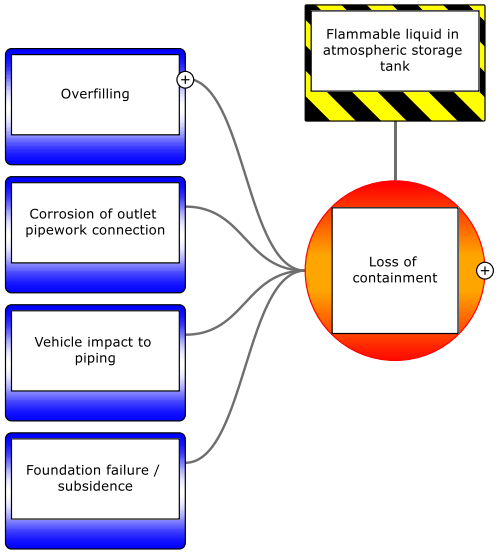


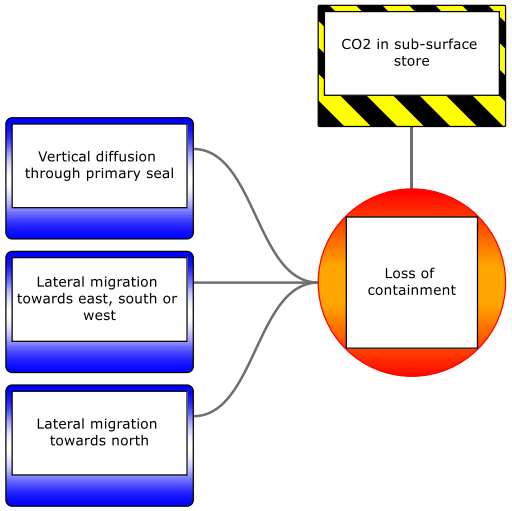
Fully effective	Reasonably certain	Very High Criticality	Crucial to the viability of the project. No or very few other effective barriers that can prevent the unwanted event, which has a very high likelihood or extensive consequences. Or barrier occurs on multiple bowtie branches.
Effective	Partially certain	High	If the barrier fails the likelihood of the unwanted event increases but there are alternative barrier(s) that can prevent the event. There are few other effective barriers on the bowtie branch.
Partially effective	Uncertain	Medium	Subject to a moderate amount of focus and attention in terms of analysis, ongoing monitoring and maintenance. There are alternative barrier(s) that can prevent the unwanted event.
Ineffective		Low	Subject to a limited amount of focus and attention in terms of analysis, ongoing monitoring and maintenance. There are several alternative barrier(s) that can prevent the unwanted event.

TÜVRheinland®
Risktec

Challenge 2: Defining Threats / Causes (Mechanism vs. Pathway)

- In traditional MAH applications, each causal branch considers a specific mechanism by which loss of containment can occur.
- Approach often requires amendment to ensure fit-for-purpose CO2 disposal diagrams (causal branches depicted for release pathways).

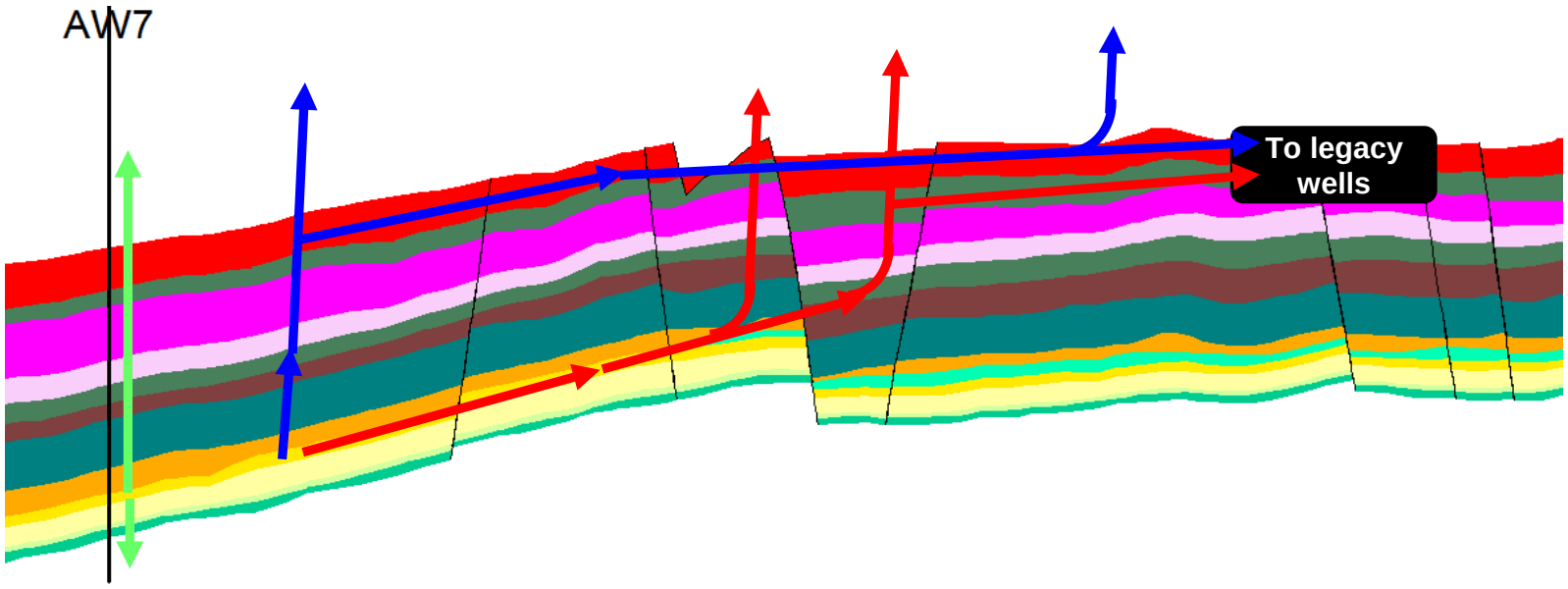




TÜVRheinland®
Risktec

Challenge 2: Defining Threats / Causes (Mechanism vs. Pathway)

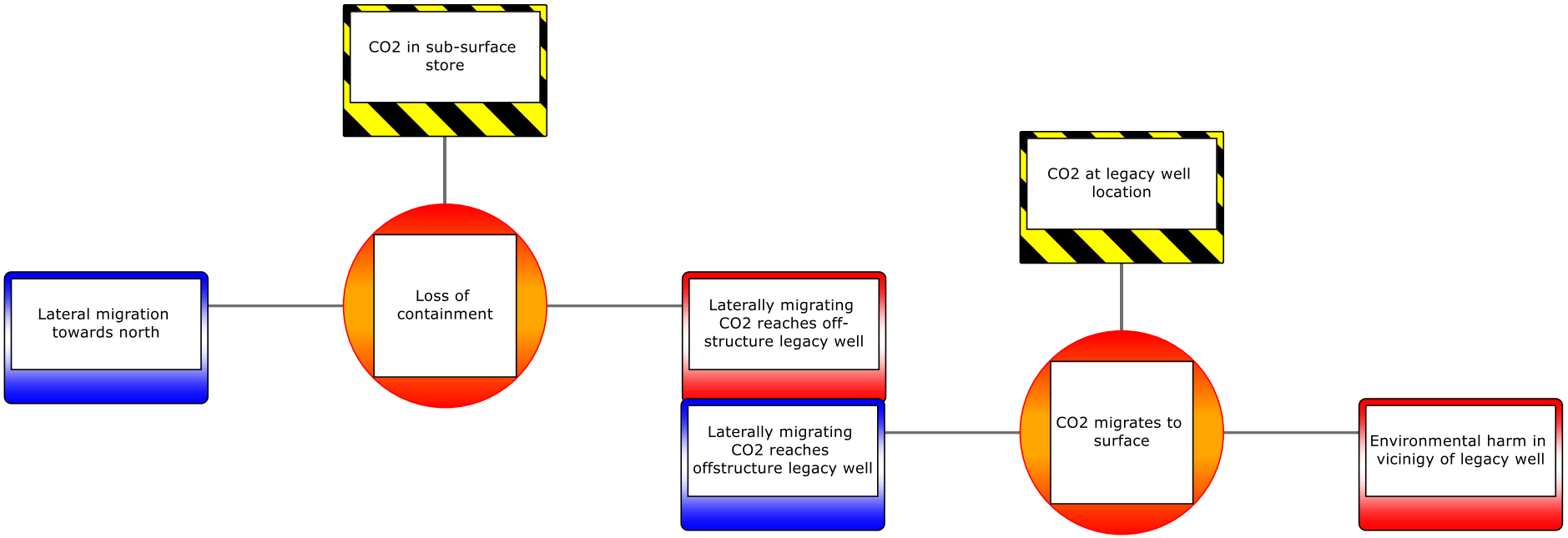
- Diagram highlights different leak paths taken by the CO2 injected into the reservoir



TÜVRheinland®
Risktec

Challenge 2: Defining Threats / Causes (Mechanism vs. Pathway)

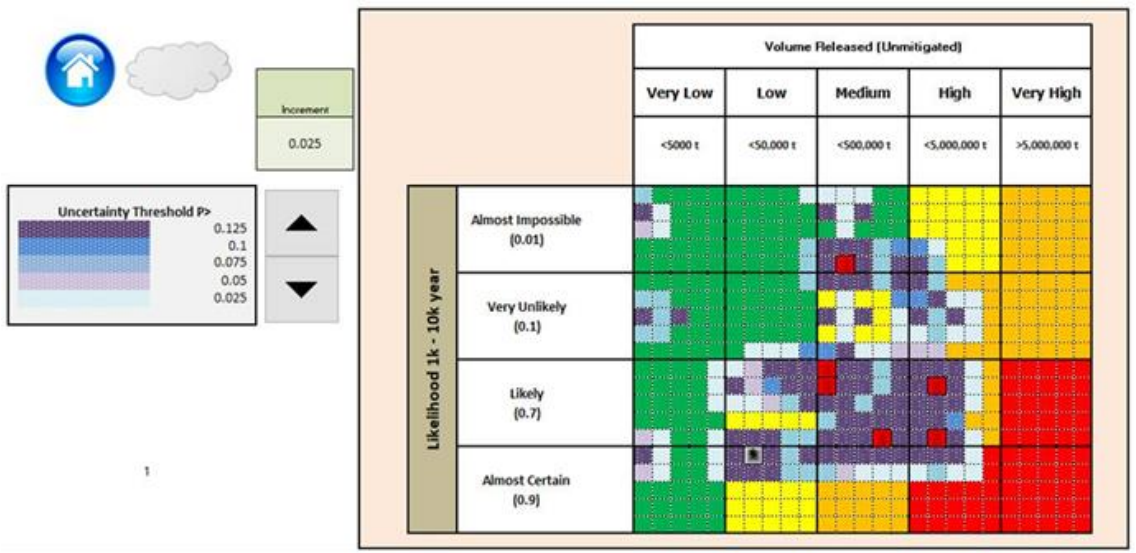
- Pathway approach allows for a network of interconnected bowtie diagrams which collectively form an overall bowtie model for the storage complex to be generated



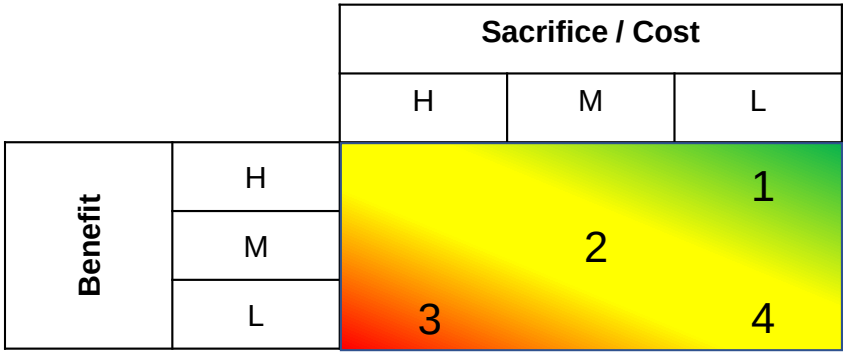
TÜVRheinland®
Risktec

Challenge 3: Is the risk tolerable?

- Absence of traditional numerical risk values and acceptability criteria results in challenges associated with proving that the risk of unwanted CO2 release from storage is adequately managed.



Candidate Risk Reduction measure		Recommendation
1	Fibre optic monitoring in injection well annulus	Recommended
2	Additional seismic monitoring	Consider further
3	Deep set monitoring for presence of CO_2 within cement	Not recommended
4	Injection of tracers in CO_2	Consider further



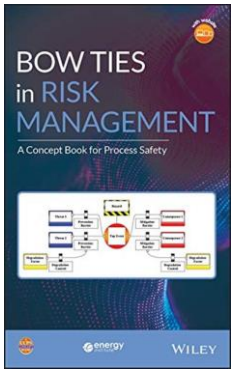
TÜVRheinland®
Risktec

Conclusions

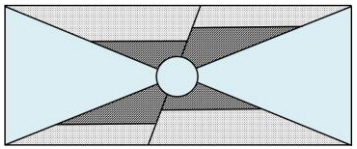
1. Bowties provide an easily understood representation of how risks are managed – ‘standard’ approach can be adapted for CO2 subsurface storage although there are challenges
2. Applicable at all stages of project – updated as more information becomes available and uncertainty improves
3. Dependent on the quality of facilitation and personnel involved - all disciplines need to provide input

Further Information

- Bow Ties in Risk Management: A Concept Book for Process Safety
  https://www.aiche.org/ccps/resources/publications/books/bow-ties-risk-management-concept-book-process-safety



- D E T E C T – Integrated CO2 Leakage Risk Assessment
  https://www.risktec.tuv.com/our-industries/clean-energy/detect-project



Accelerating CCS Technologies

- Subsurface Evaluation of CCS and Unconventional Risks SECURe | Subsurface Evaluation of CCS and Unconventional Risks | (https://www.securegeoenergy.eu)

SECURe
Subsurface Evaluation of CCS and Unconventional Risks

TÜVRheinland®
Risktec

Thank you for your attention

James Sneddon
Clean Energy Team Lead - Americas
James.sneddon@risktec.tuv.com
risktec.tuv.com

TÜVRheinland®
Risktec

CCPS Update
Calgary Regional Meeting
September 8, 2022

Michele Horwitz
CCPS Membership Manger
michh@aiche.org
646-495-1371

About CCPS

- Not for profit organization supported by Corporate Members globally
- It is part of the American Institute of Chemical Engineers [AIChE]
- It was started on 23 March 1985, in response to the Bhopal Union Carbide tragedy, which lead to a collaborative effort to eliminate catastrophic process safety incidents.
- Our headquarters are in New York City, offices in Mumbai, Frankfurt and Houston (representing Latin America Region)

Vision

An AIChE Technology Alliance
CCPS
Center for Chemical Process Safety

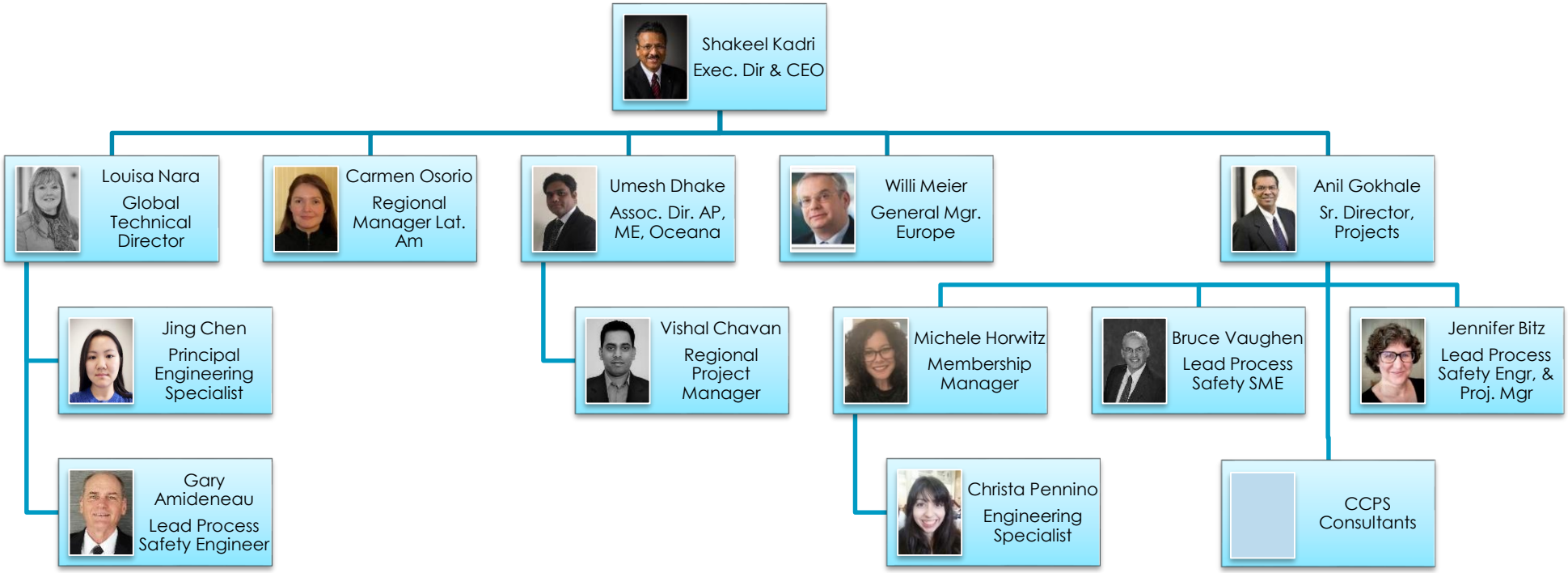
A World without Process Safety Incidents

Mission

CCPS is committed to achieve a world without Process Safety incidents by:

- **Serving** as a premier worldwide resource for Process Safety knowledge and understanding
- **Advancing** Process Safety culture, technical concepts and management practices
- **Enhancing** individual & organizational Process Safety competency
- **Fostering** collaboration within and across organizations, at all levels
- **Promoting** Process Safety as a key societal value and foundation for responsible, sustainable operation

CCPS Staff


Shakeel Kadri
Exec. Dir & CEO
Louisa Nara
Global Technical Director
Carmen Osorio
Regional Manager Lat. Am
Umesh Dhake
Assoc. Dir. AP, ME, Oceana
Willi Meier
General Mgr. Europe
Anil Gokhale
Sr. Director, Projects
Jing Chen
Principal Engineering Specialist
Vishal Chavan
Regional Project Manager
Michele Horwitz
Membership Manager
Bruce Vaughen
Lead Process Safety SME
Jennifer Bitz
Lead Process Safety Engr, & Proj. Mgr
Gary Amideneau
Lead Process Safety Engineer
Christa Pennino
Engineering Specialist
CCPS Consultants

CCPS CANADIAN MEMBERS

40 Organizations in Attendance (15 Mbr Comp)

An AIChE Technology Alliance
CCPS
Center for Chemical Process Safety

- ABS Engineering
- ACM Facility Safety
- AON Energy Risk Engineering (M)
- ARC Resources Limited
- Avantor (M)
- BakerRisk (M)
- Cailin Energy Corp.
- Canadian Natural Resources Ltd. (M)
- Cenovus (M)
- ClearSky Risk Management, Inc.
- CNOOC International
- ConocoPhillips
- DNV (M)
- Dow Chemical Canada ULC (M)
- Factory Mutual Insurance Co.
- GOARC (M)
- INEOS Canada Partnership Ltd.
- Inter Pipeline (M)
- IQ Trucking Consultants Inc.
- Jensen Hughes (M)
- KDS Process Safety
- Kent PLC
- Keyera
- LIVE Electrical & Controls Ltd.
- LUPATECH Canada
- MAADEN WAAD ALSHAM PHOSPHATE Co.
- Mann Enterprise
- Marsh
- Memorial Univ. of Newfoundland
- NOVA Chemical Corp. (M)
- Orano
- Paramount Resources
- Parkland Refining (BC) Ltd. (M)
- PETRONAS CANADA (M)
- Rio Tinto (M)
- Risktec Solutions, Inc.
- Strathcona
- Suncor Energy
- TC Energy (M)
- University of Alberta

2022 New Members

data as of September 2022

25 New Members

United States

8 US Members

- Aggreko
- Avantor
- BYK
- Ergon
- Gopher Resource
- Process Safety Core Consulting LLC
- Thermo Fisher Scientific
- Wacker

2022 New Members

25 New Members

data as of September 2022

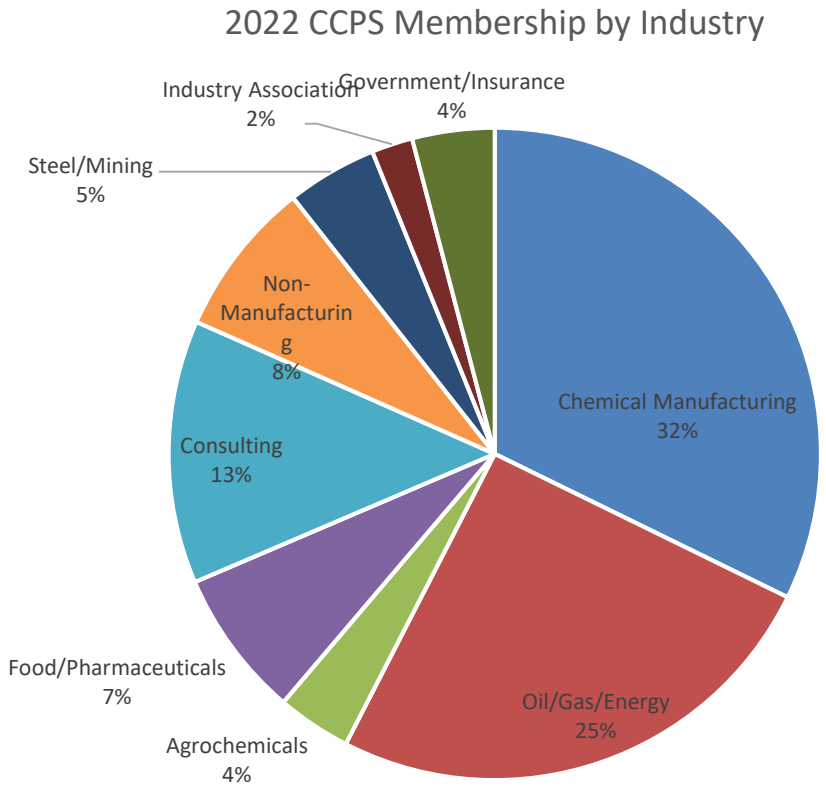
Non-US (17 Members)

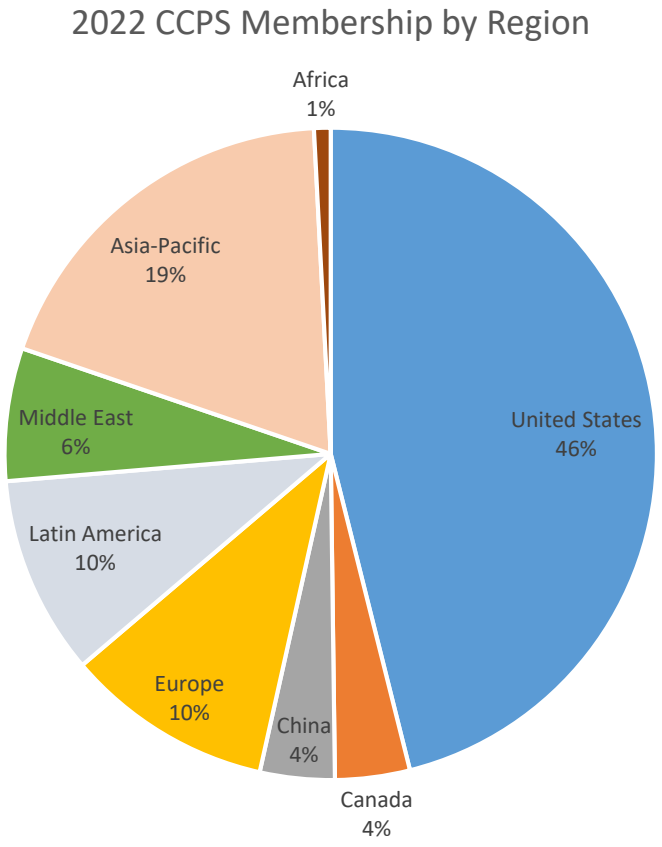
- Aarti Industries Limited (India)
- Asian Paints, Ltd (India)
- BHP Mining (Chile)
- Ecopetrol (Colombia)
- Engineers India Limited (India)
- Fatima Fertilizer Company Ltd. (Pakistan)
- Finolex Industries, Ltd. (India)
- Gerdau Aços Longos S.A. (Brazil)

Non-US

- Gramercy Trade Industries Private Limited (India)
- Heritage Petroleum Co. Ltd (Trinidad & Tobago)
- HPCL –Mittal Energy Ltd. (India)
- PrefChem PENGERANG REFINING Co. (Malaysia)
- PROAIM (China)
- Shaanxi Beiyuan Chemical Industry Group Co., Ltd (China)
- Showa Yokkaichi Seikiyu Co., Ltd (Japan)
- Transpetro (Brazil)
- Uniphos Colombia Plant Ltd. (Colombia)

CCPS Membership by Industry and Region [2022]





244 Member Companies (September 2022)

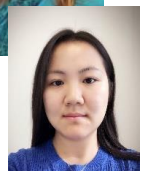
An AIChE Technology Alliance

CCPS Center for Chemical Process Safety

Global News

Membership

- +25 members in 2022, 244 total members to-date, 46%US-54% Int'l Mbers
- 95% of the budgeted 2022 membership dues received
- Handles all North American Recruitment & worldwide retention
- Executes details for Canadian and US TSC Meetings



Technical

- 2023 Project Planning effort underway
- Global TSC Web Conference 9/22/2022
- 19th GCPS Call for abstracts is now open

Projects

- 3 Books and several Monographs published (2022)
- Various Credentialing Offerings for Students, Young Professionals and Experts
- 25+ Ongoing projects, programs and initiatives
- PSIE Software Refresh in Progress

Global / Regional Engagement

SPRING22 +18TH GCPS
A Joint AIChE and CCPS Meeting

2022 GLOBAL CONFERENCE ON PROCESS SAFETY & BIG DATA
CCPS EPSC

4th CCPS MIDDLE EAST PROCESS SAFETY CONFERENCE
27-28 September 2022
Sheraton Dammam, Saudi Arabia

9TH CCPS LATIN AMERICAN CONFERENCE ON PROCESS SAFETY

Annual Global TSC Meeting in Houston
November 2-3. 2022

CCPS Canada Regional
Calgary
September 8, 2022

CCPS China Regional
Virtual

CCPS Africa Regional
Virtual – Oct 4, 2022

CCPS South East Asia Member Meeting, Pattaya, Thailand
November 29, 2022

CCPS India Regional
Virtual

Active Responsible Collaborations

Organization	Collaborating activity
Energy Institute [EI]	Bow Tie Guideline Book + Human Performance
Society of Petroleum Engineers [SPE]	Process Safety for Upstream concept book completed
European Process Safety Center [EPSC]	7th Edition Global Conference of PS + Big Data Conference planned
EPSC	RAST / CHEF Virtual & in-person workshops are very popular
Shenyang Research Inst. of Chem. Ind. Co., Ltd. (SYRICI)	Guidelines for fine chemicals process safety in China
Singapore Chemical Industry Council [SCIC]	Global Summit [2025]
American Chemistry Council [ACC]	Formal Engagement at Membership level + Leadership Workshop
Instituto Brasileiro DePetroleo – IBP	Joint execution of 2020 CCPS Latin America Conference
Instituto Brasilerio Mineracao (IBRAM)	Collaborating at Latin America Process Safety Conference [2022]
Jordanian Engineers Association [JEA]	MOU signed, JEA also became a CCPS member
Egyptian Ministry of Petroleum	MOU being processed, major collaborative plan in the works
Chemical Safety Board [CSB]	Collaborative support on mutually important process safety programs

CCPS Membership Benefits

CCPS Holds Meetings to Get Key Stakeholders Inputs and Sharing

- Technical Steering Committee Meetings (5 annually)
  - –One dinner and in-person meeting following Global Congress on Process Safety
  - –3 meetings via web conference February, June, September annually
  - - TSC Meeting in Houston area each November
- Global Regional meetings – outside USA (1-3 annually per region)
- Project committee meetings (as needed)
  - –Typical project meets monthly by web conference for 1-3 hrs.

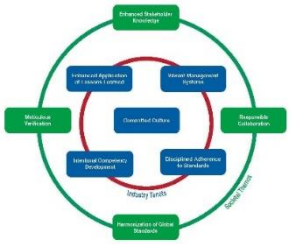
Value of TSC meetings: Member sharing and interaction leads to an open exchange of ideas and lessons learned

Networking

Leading Process Safety Since 1985

An AIChE Technology Alliance
CCPS Center for Chemical Process Safety

VISION 20/20
Five Company Tenets and Four Societal Themes

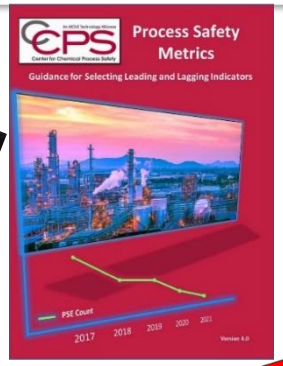


CCPS CERTIFIED

CCPSf
CCPS PROCESS SAFETY FUNDAMENTALS CERTIFICATE

Books and Publications

Industry-wide Tools, Programs

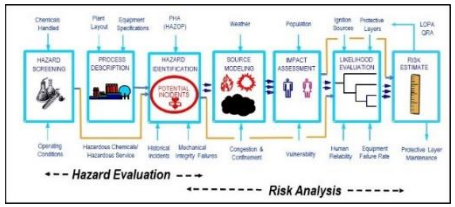


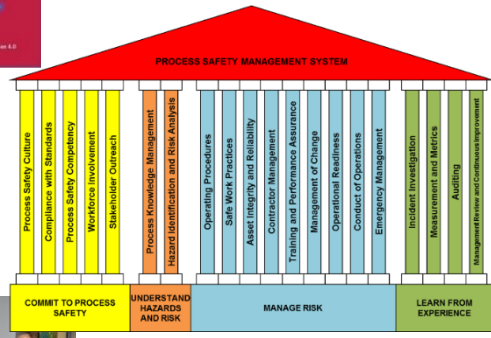
PSID
PROCESS SAFETY INCIDENT DATABASE
From the Center for Chemical Process Safety

SAChE
Safety+Chemical Engineering Education

Sharing Best Practices

Process Safety Beacon 20 YEARS ANNIVERSARY





TSC/Regional

Conducting Global Conferences and Training

Educating Educators

Pharma, Food and Fine Chemicals Subcommittee

2022 workshops

- Dust hazards
- Chemical Reactivity

Open System Chemical Operations

- Presented on March 1st by Frank Renshaw PhD, CIH, CSP, CCPSC, and CCPS Instructor & Consultant.

Hierarchy of requirements e.g. standards, regulations, internal procedures

- Presented on May 10th by Peter Lodal - PE, CCPSC

NFPA Combustible Dust - Consensus Standards & Development of NFPA 660

- Presented on July 20th by Chris Aiken, Cargill, Senior Director Process Safety

Additional Workshops

- November 1 Face to Face – Houston

Interested in Forming a

Minerals, Mining & Metals Subcommittee?

- If so, what key topics of interest would you most be interested in exploring?
- Would you be interested in joining and actively contributing?
- If so, please reach out to Michele Horwitz (me) at Michh@aiche.org with your replies to the above

Education and Training

- Classroom and eLearning Content
  - LOPA
  - HAZOP Studies and other PHA Techniques for Process Safety and Risk Management
- In Person Training & Continuing Education
  - Risk Based Process Safety
  - Incident Investigation
  - Human Factors for Safety & Improved Performance
- Boot Camps – Taught by 30+ Year Veterans
  - Presented virtual or at company site, related to company goals and objectives
- Free eLearning Courses for New Member Companies
- Free Sponsored Webinars for member companies >75
- Free CCPS course opportunities for newly launched CCPS courses
- Member Discounts on Conference or Education Training

Executive Leadership

Process Safety Leadership – Workshop Overview

Who Should Attend

Designed for top-level executives, this workshop will address the needs of:

- **Corporate executive leadership teams**
- **Business leadership teams**
- **Regional leadership teams**

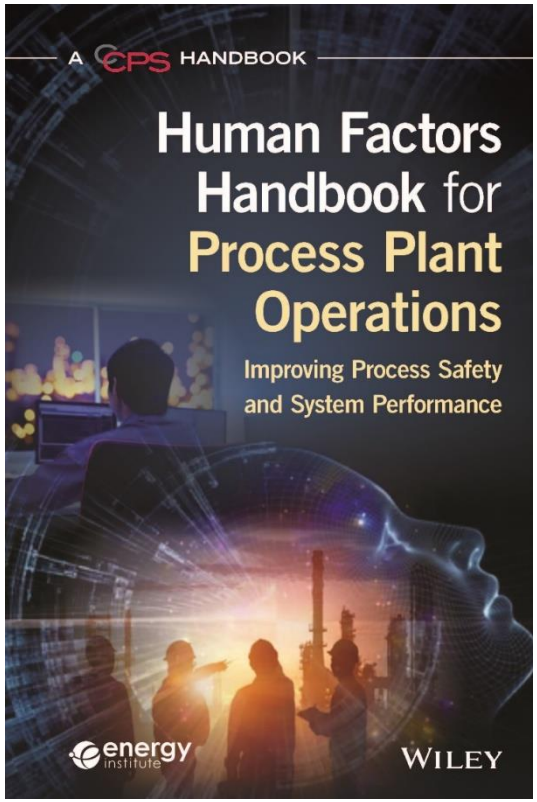
Key Learnings

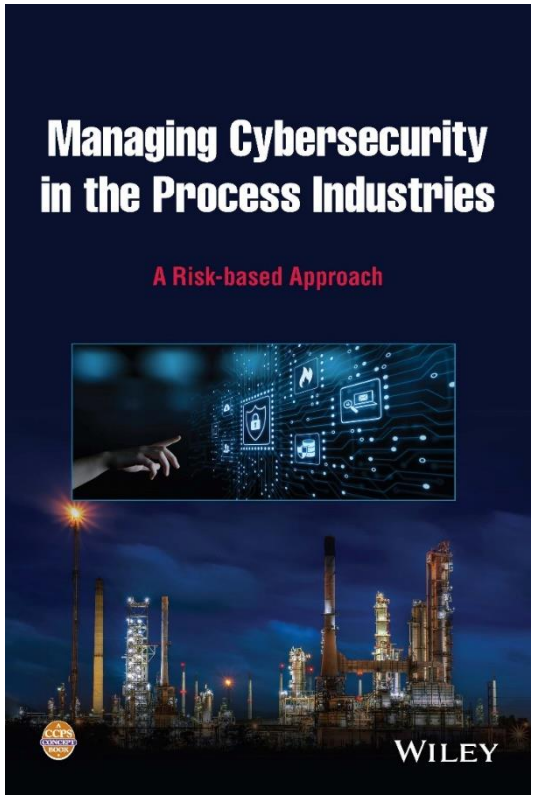
In this interactive session, you'll learn how to:

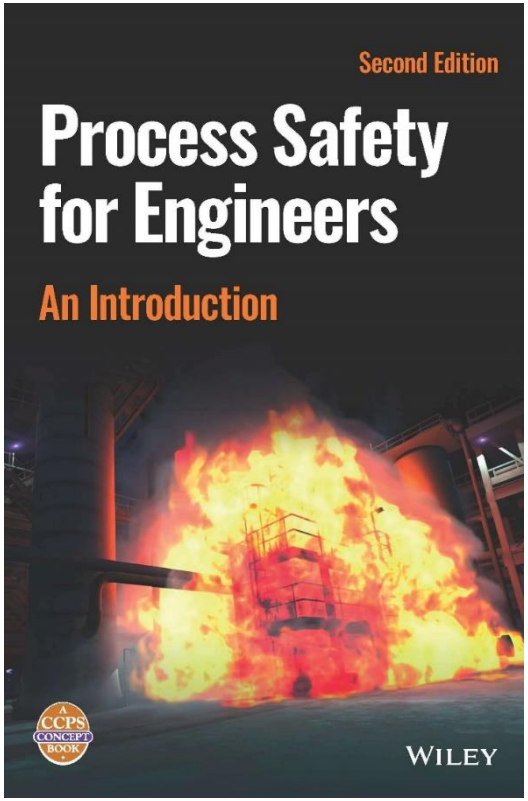
- **Establish a process safety vision and roadmap**
- **Make a business case for process safety**
- **Understand why process safety isn't just safety**
- **Hone your process safety communication and visibility skills**
- **Define process safety accountabilities and responsibilities at the senior level**
- **Align personal commitment, courage and conviction to process safety**
- **Drive your culture with your leadership**
- **Establish the corporate safety imperative**

New Books 2021- Free to member companies

An AIChE Technology Alliance
CCPS
Center for Chemical Process Safety



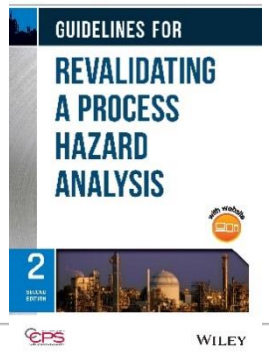


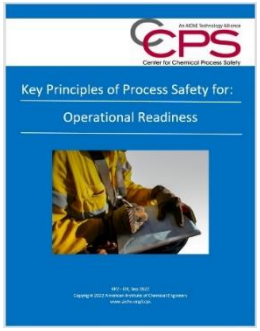


Members get 35% discount on previously published book title from CCPS/AIChE

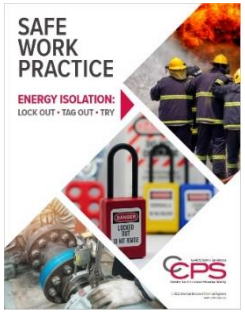
Ongoing Projects

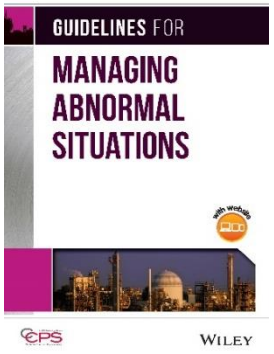
- Book of Beacons — *Ongoing*
- G/L for Process Safety in Pilot Plants & Laboratories — *Completion Q4*
- G/L for PHA Revalidation & Update 2nd Ed. — *Publication Q4*
- G/L for Managing Abnormal Situations — *Publication Q4*
- G/L for Process Knowledge Management — *Publication Q1 - 2023*
- G/L for Chemical Reactivity Evaluation — *Publication Q3 - 2023*
- *Golden Rules of Process Safety (MOC Published)* — *Ongoing New Topic Development*
- *Safe Work Practices, Energy Isolation coming soon* — *Ongoing New Topic Development*



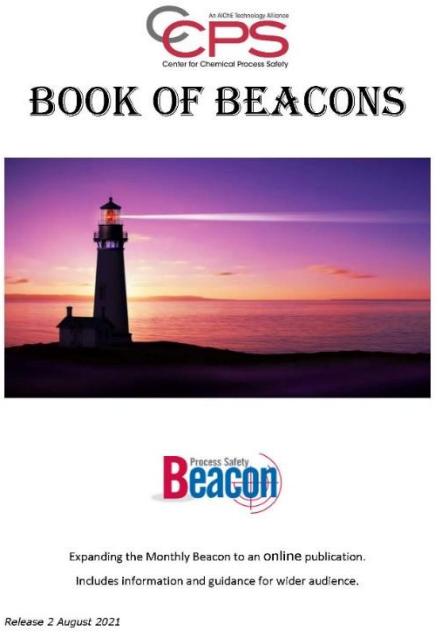


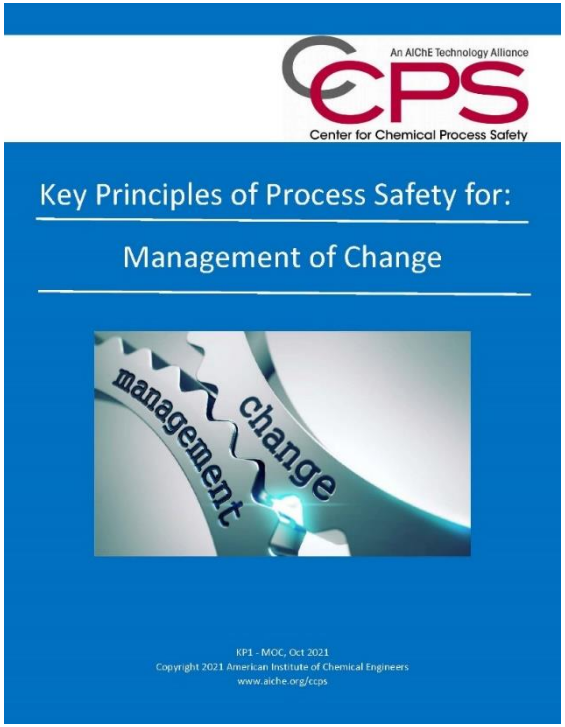
Details: https://www.aiche.org/ccps/projects





Online Publications (more on web)





2020 Incident Monograph

Key Principles / Golden Rules

Book of Beacons 4th Release

Process Safety Beacon

http://www.aiche.org/CCPS/Publications/Beacon/index.aspx

Messages for Manufacturing Personnel

Sponsored by CCPS Supporters

Containment Dikes and Pads

June 2010

Most people recognize that containment dikes around storage tanks, and sloped containment pads for pumps, process buildings and structures, truck and rail car unloading areas, and other potential spill locations have an important environmental protection function – preventing contamination of soil and surface water. But, do you know that they often also have important safety functions? Some examples include:

- limiting the spread of a fire and preventing exposure of other equipment if a flammable material spills and is ignited
- preventing contact of incompatible reactive materials in case of leak or spill
- limiting the spread of spilled corrosive material and preventing contact with equipment which could be damaged by contact with the corrosive material

In 2001, the US Chemical Safety and Hazard Investigation Board (CSB) investigated a fire that destroyed a petroleum blending facility in Texas. Poor dike design and maintenance resulted in burning liquid spreading the fire from tank to tank, eventually engulfing the whole plant.

←Spill containment dikes for chemical storage tanks

A sloped containment pad directs any spills from a truck unloading facility to a chemical sewer trench →

What can you do?

- Periodically include containment dikes around storage tanks, sloped containment areas, and drainage trenches as part of your routine plant safety inspections. Look for physical damage, spilled material, accumulation of rain water in dikes, or blocked drainage. Look for debris, equipment, or anything which restricts flow of a spill.
- Make sure that your plant procedures include pumping out or draining rain water from containment dikes – if a dike is partly filled with rain water, it may not be able to contain a large spill.
- If you have any kind of valves or other piping to remove rain water from a containment dike, make sure these are closed or otherwise blocked when not being used.
- If you do any maintenance or construction work on a storage dike which results in damage to the integrity of the dike, make sure the damage is repaired before the job is finished.

The arrow shows a hole in a containment dike. More damage can be seen at the base and the top of the dike wall. Other examples of damage include cracks in dike walls or floors, holes where pipes have been installed passing through dike walls, and anything else which would allow spilled material to flow out of the dike area.

Inspect and maintain your containment dikes and pads!

The Beacon is usually available in Afrikaans, Arabic, Chinese, Danish, Dutch, English, French, German, Greek, Gujarati, Hebrew, Hindi, Hungarian, Indonesian, Italian, Japanese, Korean, Malay, Marathi, Norwegian, Persian, Polish, Portuguese, Russian, Spanish, Swedish, Tamil, Thai, Telugu, Turkish, Urdu, and Vietnamese.

Process Safety Beacon

- More than a million readers
- 31 languages
- Delivered monthly
- Just celebrated 20th anniversary of publishing
- Used as a safety training tool

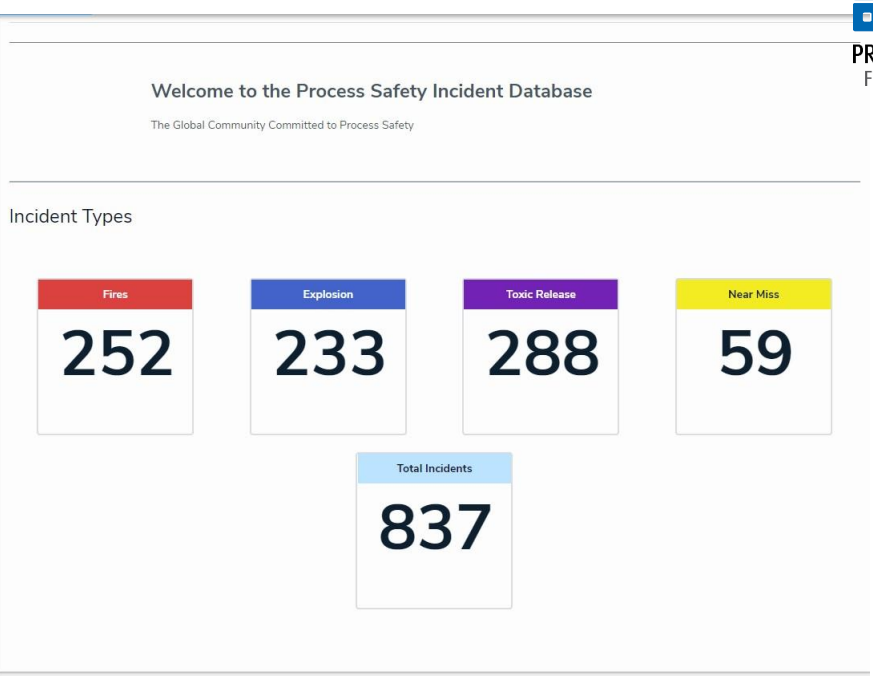
Compare & Contrast

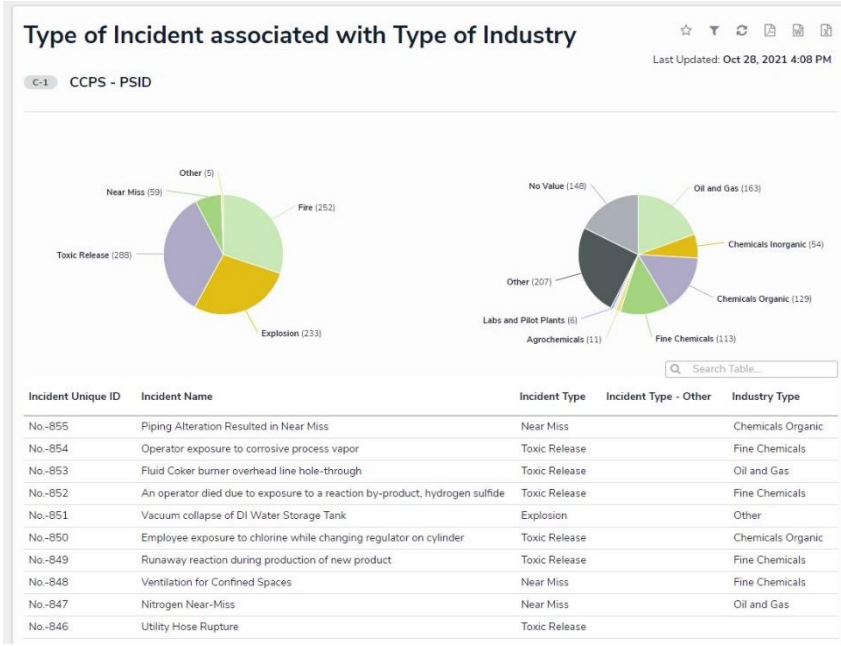
CCPSf	CCPSC
Certificate granted following completion of courses. Content for the courses included in cost.	Certification granted following application approval and passing an exam that tests knowledge, skills, and competency.
No degree or experience required. Students and Early Career Professionals encouraged.	Requires STEM degree and at least 5 years professional experience (or 10 years with no degree) and three professional references.
Completion of 24 SAChE courses (different than a degree-granting program). Good preparation for CCPSC. PS Basics, Intro to Hazards, Understanding Risk, Practical Applications for Managing Risk, RBPS Pillars	Competency as measured against a defensible set of standards (CCPS RBPS Elements), by application and exam.
Usually listed on a resume detailing education.	Credentials to be listed after one's name: CCPSC
Demonstrates understanding of course content at the end of each course.	Has on-going requirements in order to maintain; including PDH and renewal fees.
More information and cost: https://www.aiche.org/ccpsf	More information and cost: https://www.aiche.org/ccpsc

An AIChE Technology Alliance
CCPS
Center for Chemical Process Safety

Signup at ccps_psid@aiche.org

PSID
PROCESS SAFETY INCIDENT DATABASE
From the Center for Chemical Process Safety

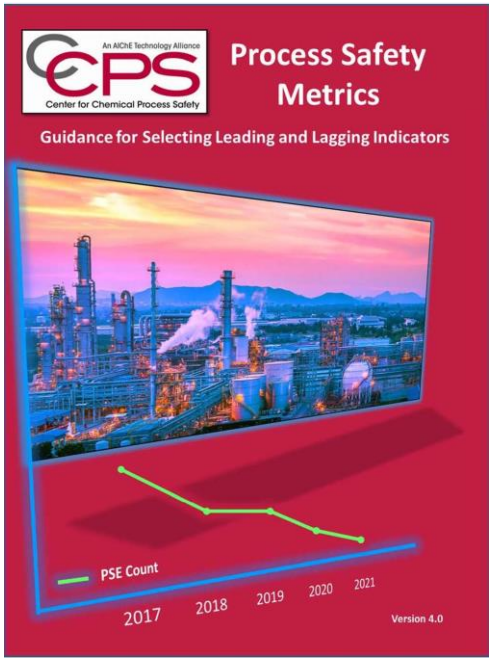




Incident Unique ID	Incident Name	Incident Type	Incident Type - Other	Industry Type
No.-855	Piping Alteration Resulted in Near Miss	Near Miss		Chemicals Organic
No.-854	Operator exposure to corrosive process vapor	Toxic Release		Fine Chemicals
No.-853	Fluid Coker burner overhead line hole-through	Toxic Release		Oil and Gas
No.-852	An operator died due to exposure to a reaction by-product, hydrogen sulfide	Toxic Release		Fine Chemicals
No.-851	Vacuum collapse of DI Water Storage Tank	Explosion		Other
No.-850	Employee exposure to chlorine while changing regulator on cylinder	Toxic Release		Chemicals Organic
No.-849	Runaway reaction during production of new product	Toxic Release		Fine Chemicals
No.-848	Ventilation for Confined Spaces	Near Miss		Fine Chemicals
No.-847	Nitrogen Near-Miss	Near Miss		Oil and Gas
No.-846	Utility Hose Rupture	Toxic Release		

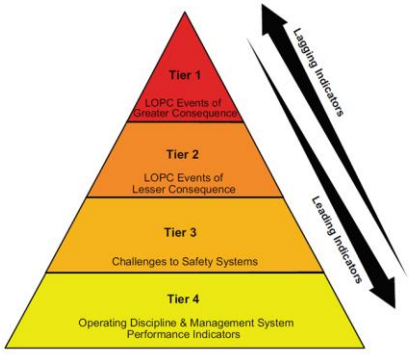
Process Safety Metrics

- API 754 3rd Edition – released Aug 2021
- CCPS issued a revised metrics document that is harmonized with the API-754 3rd edition
- *CCPS had representation on the API-754 revision committee*
- CCPS is updating PSIE software tool



4th Edition

https://www.aiche.org/ccps/process-safety-metrics



CHEF Virtual Workshop

An AIChE Technology Alliance
CCPS
Center for Chemical Process Safety

- 10 Recorded sessions
- Duration: 2-hours/session
- Delivered by Ken First &
- Dr. Bruce Vaughen

CHEF Workshops

Workshop Content

What are the Hazards?
- Flammability Hazards
- Toxicity Hazards
- Reactivity Hazards
- Other Hazards

What can go Wrong?
- Inherently Safety Design
- Hazard Evaluation Techniques
- Hazard and Operability Study (HAZOP)
- Development of Incident Scenarios

How Bad could it be?
- Source Models
- Vapor Dispersions
- Explosions
- Impact Assessment

How Often might it Happen?
- Frequency Evaluation
- Overview of Risk Analysis

Is the Risk Tolerable?
- Scenarios, Enabling Conditions and Conditional Modifiers
- Procedures and Human Error
- Preventive Safeguards/Protection Layers
- Mitigating Safeguards/Protection Layers

Application and Case Studies

RAST Workshop

An AIChE Technology Alliance
CCPS
Center for Chemical Process Safety

Hands on workshop with several exercises & case studies

RAST Workshops

Workshop Content

Getting Started
- Opening the tool
- Example Case study
- Data Input
- Reports

Chemical Data
- Data used
- Adding new Chemicals
- Create a chemical mixture

Reactivity Data & Evaluation
- Reactivity Screening
- Data Input
- Reactivity Evaluation
- Process Upsets

Additional Input & Reports
- List of Reports & Inputs

Scenario Development
- Loss of Containment events
- Scenario Creation in RAST
- Initiating events
- Incident types & Outcomes
- Screening criteria
- Screening Library
- User defined scenarios

Risk Analysis & LOPA
- Consequence Modeling
- Likelihood / Frequency
- Risk Matrix
- Scenario selection for analysis
- LOPA

Case Studies
- Class exercise(s)

LOPA Tool

CCPS Database	Utilization in 2020	Importance of the CCPS Tool
LOPA Tool	Provide access to LOPA to your company employees.	• This is a benefit for employees of CCPS member companies. Full access requires login. • Guidelines for Initiating Events and Independent Layers of Protection build on LOPA by: • Providing additional examples of initiating events (IE) and independent protection layers (IPLs) • Provides more guidance for determining the value of each prospective initiating event frequency (IEF and IPL probability of failure on demand (PFD) • Proving more information on the overall management systems as well as other considerations specific to a particular IE or IPL, which are needed to support the use of the values. https://www.aiche.org/ccps/resources/tools/lopa

More CCPS Member Benefits…

- Involvement and participation on Technical Projects, Books, Tools, Monographs
- Voting on new projects to enhance process safety initiatives worldwide
- Free postings in the Professional Services Directory for all CCPS Service Comp's.

Participation

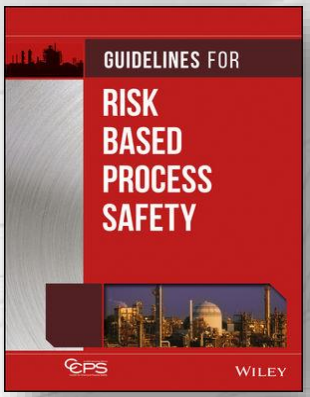
An AIChE Technology Alliance

CCPS

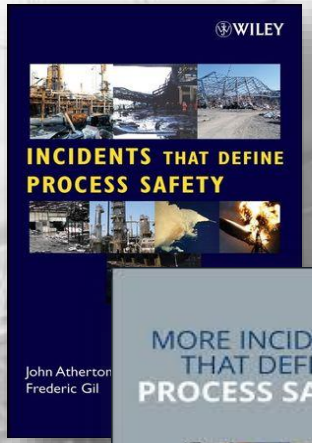
Center for Chemical Process Safety

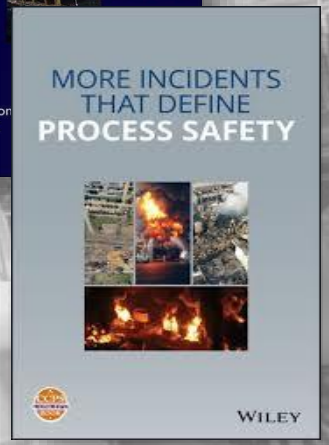
FOUNDATIONS OF
RISK BASED PROCESS SAFETY

"The Basics for the PROCESS SAFETY EXCELLENCE JOURNEY"



Calgary AB
October 24-27, 2022
4 day interactive workshop





An AIChE Technology Alliance

CPS

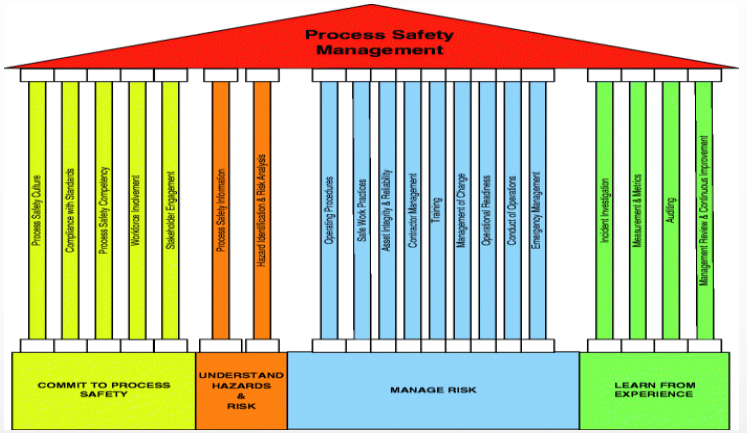
Center for Chemical Process Safety

Format and Logistics

- Presentations and interactive discussion
- Techniques and methodologies
- Accident case studies
- Videos
- Team breakout exercises
- Quizzes

Workshop Scope

- Process Safety
  - Background and purpose
  - Process safety vs Occupational Safety
- Accident Theory
- Loss of containment/leaks and spills
- Process hazards/fire/explosion/toxicity
- Engineering safeguards
- Risk Management/ risk acceptance/RA techniques
- RBPS elements – detailed analysis and discussion



Who should attend?

- Personnel with direct process safety responsibilities
- Chemical / mechanical engineers
  - Operational
  - Technical support
  - Design/project responsibilities
- Plant managers
- Senior process operators / foremen / supervisors
- Other safety personnel (including training)

Suggest 2 attendees from each organization

FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA

7th Annual CCPS Canadian Regional Meeting

Regulatory scan for market entry of small-scale modular energy generation using hydrogen fuel cells

FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA

Sama Manzoor, Doctoral Student

Department of Chemical and Materials Engineering,
Faculty of Engineering, University of Alberta

samamanz@ualberta.ca

Jéssica Haupt de Castro, Masters Student

Department of Chemical and Materials Engineering,
Faculty of Engineering, University of Alberta

hauptdec@ualberta.ca

Anusha Priya, Masters Student

Department of Chemical and Materials Engineering,
Faculty of Engineering, University of Alberta

apriya1@ualberta.ca

Presentation Overview

Introduction

United States Federal Regulations

California State Regulations

Canadian Regulations

Next Steps

Introduction

General overview of which regulations apply to Hydrogen in various North American jurisdictions

- Hydrogen specifically listed
- Discussing flammable/hazardous gases generally, which should cover hydrogen
- Another material (i.e., natural gas) that would need to be modified to include hydrogen

US Federal Regulations

Code Development Organizations

ICC INTERNATIONAL CODE COUNCIL®

NFPA®

Standard Development Organizations

CGA Compressed Gas Association
The Standard For Safety Since 1913

ASME
SETTING THE STANDARD

Regulatory Bodies

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

OSHA® Occupational Safety and Health Administration

PHMSA Pipeline and Hazardous Materials Safety Administration

California State Regulations

California Department of Forestry and Fire Protection (CAL FIRE)

The Office of the State Fire Marshal (OSFM)

California Fire Code

California Residential Code

Canadian Federal Regulations

CSA GROUP

BNQ Bureau de normalisation du Québec

Natural Resources Canada

CHFCA Clean. Efficient. Energy.

SCC CCN

FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA

Canadian Provincial Regulations

Ontario	Alberta	British Columbia

TECHNICAL STANDARDS & SAFETY AUTHORITY
TSSA

ABSA the pressure equipment safety authority

TECHNICAL SAFETY BC

Safety Codes Council

Next Steps

- Review the regulatory gaps and overlaps within a specific geographical area, considering the various Authorities Having Jurisdiction
- Consider whether the regulatory framework from one jurisdiction (like California) might be adopted in other jurisdictions (like Texas or Alberta) and how this would govern design and siting decisions
- Narrow down the regulatory review to more specific design and operational questions which apply to our Hydrogen product
- Other market entry considerations (economic incentives, infrastructure requirements, etc.)
- CSA Approval processes

7th Annual CCPS Canadian Regional Meeting

Addressing the problem of marginally explosible dusts

Albert Addo

Ph.D. Candidate
Process Engineering & Applied Science,
Dalhousie University, Halifax, NS,
Canada

DALHOUSIE UNIVERSITY
Inspiring Minds

Presentation outline

- Introduction
- Problem statement
- Research objectives
- Experimental work
- Results and discussions
- Conclusions

Introduction – dust explosions

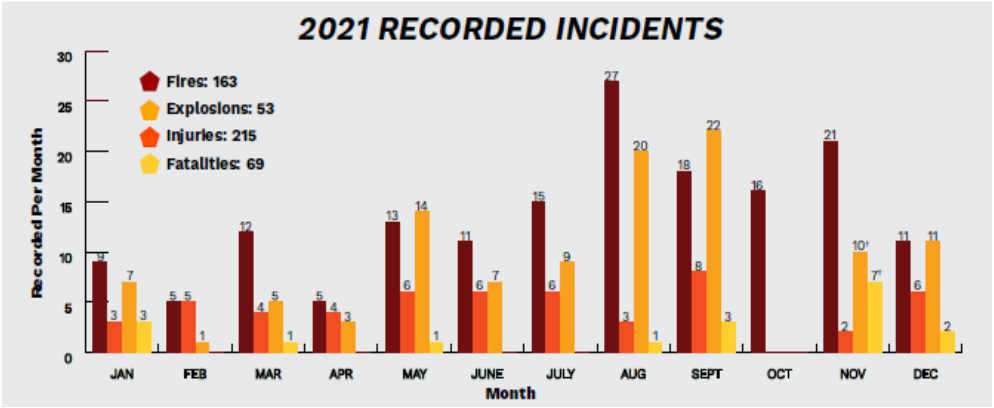
- A dust explosion can occur when finely divided solid material is suspended in air and in the presence of a sufficiently energetic ignition source
- Five factors come together cause a dust explosion

Dust explosion pentagon

- Dust explosions may cause fatalities, injuries, business interruptions, property and environmental damages

Effect of a dust explosion in a foundry (February 1999, Massachusetts).

Fine plastic dust explosion and fire that ripped through a pharmaceutical plant (North Carolina, 2003).

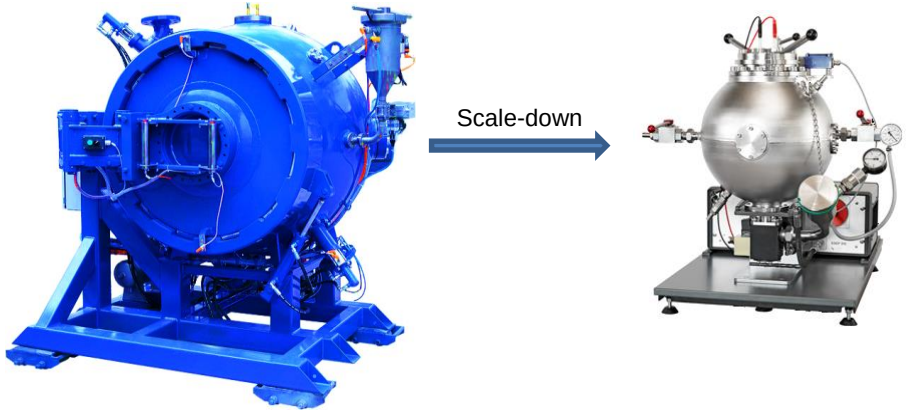


2021 recorded incidents (Cloney, 2022)

Yuan, Z.; Khakzad, N.; Khan, F.; Amyotte, P. Process Safety Environment, 98, 2015
www.osha.gov
Cloney, C. (2022). “2021 Combustible Dust Incident Report - Version #1” DustEx

Introduction – marginally explosible dusts

- Dust hazard identification is a vital step in the dust explosion risk assessment process
  - explosible or non-explosible
- Two of the explosion test apparatus used are the 20-L and 1-m^3 chambers



1-m^3 explosion chamber

Siwek 20-L explosion chamber

- 1-m^3 chamber is the preferred choice of vessel
- over time, industry has accepted the 20-L sphere as the test standard

- Due to:
  - cost (testing expensive pharmaceutical dusts), handles 50 times less material
  - ability to give data that correlates with 1-m^3 data
  - testing hazardous and toxic materials
- However, some recent studies have shown that
  - data does not always corelate in both vessels especially for low-K_{St} dusts
- Some studies have referred to these dusts as "marginally explosible dusts (MEDs)
  - characterized by deflagration index (K_{St}) values < 45 bar·m/s in the 20-L chamber with 10-kJ ignition energy

Problem statement

- Recent interest in overdriving has resulted in “hard rules” in industry that suggest that:
  - if K_{St} < 45 bar·m/s in the 20-L chamber, non-explosible at larger scale (Proust et al., 2007; ASTM E1226. 2018)
  - if K_{St} > 45 bar·m/s, and P_{max} > 5 bar, then not overdriven

- Lack of understanding with reference to scaling low-K_{St} values from the 20-L explosion chamber for design of safety strategies

- Different opinions whether to refer to these dusts as “low-reactivity” or “marginally explosible”
  - difficulties in the design of dust explosion safety measures as a result of the ambiguity

Proust, C., Accorsi, A. & Dupont, L. (2007). Measuring the violence of dust explosions with the “20-L sphere” and with the standard “ISO 1-m^3 vessel”. Systematic comparison and analysis of the discrepancies. *Journal of Loss Prevention in the Process Industries*, 20, 599-606
ASTM E1226-12a. Standard test method for explosibility of dust clouds. ASTM International, West Conshohocken, PA, United States, 2018.

Research objectives

- The study focuses on low-K_{St} dusts in the 20-L chamber. These are suspicious and raise the questions;
  - whether these low-K_{St} dusts actually pose an explosion risk on the industrial scale?
    - ✓ Severity of explosion
    - ✓ Likelihood of explosion
  - what physics and chemistry account for the peculiar behavior exhibited in these two chambers (20-L and 1-m^3)?
  - whether the claim that MEDs have low ignition sensitivity is accurate?
  - what level of protection is required for facilities that handle these dusts (i.e. “basis of safety”)?
    - ✓ has a direct influence on cost
- Answers to these questions will provide guidance to industry on how to handle these dusts
- To answer these questions, two strategies have been deployed namely,
  - experimental approach (which is the focus of the current presentation)
  - probabilistic modeling approach using Bayesian Networks (work in progress)

Experimental approach

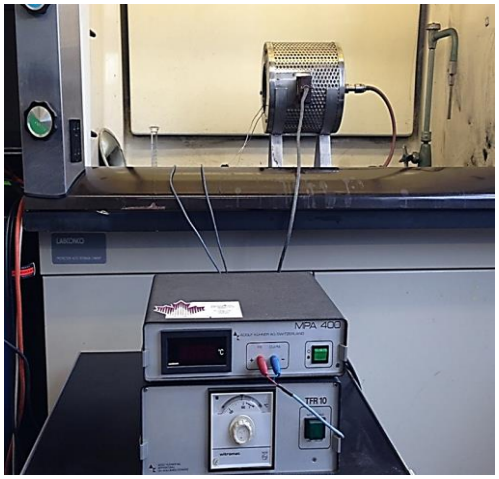
- Materials selected due to the low-K_{St} values as reported in NFPA 652
  - carbon black
  - oat grain flour
  - urea
  - zinc

- Material characterization
  - particle size distribution
  - moisture content
  - bulk density
  - proximate analyses
  - ultimate analyses
  - polydispersity
  - TGA/DTG
  - FTIR

- Explosion severity parameters tested using 20-L (with 10-, 5-, 2.5-, 1-, and 0.5-kJ ignition energies) and 1-m^3 chambers (with 10-kJ ignition energy)
  - maximum explosion pressure (P_{max})
  - deflagration index (K_{St})

- Explosion likelihood parameters
  - minimum explosible concentration (MEC) using 20-L and 1-m^3 chambers

MIKE-3 apparatus for testing minimum ignition energy (MIE)

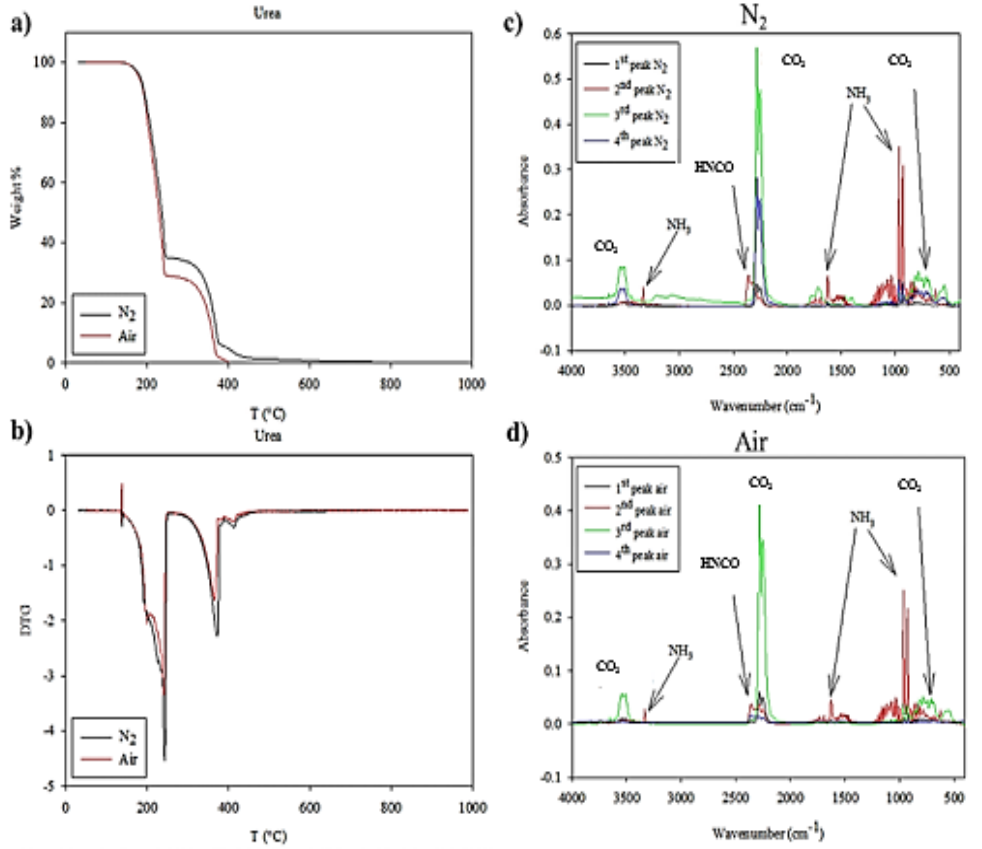


BAM oven for testing minimum ignition temperature (MIT)

Some results to demonstrate the behaviour of marginal explosibility

Explosion Severity (P_{max} and K_{St}) of urea and zinc dusts

Material	Ignition Energy (kJ)	20 L 60 ms		1 m³ 600 ms	
		P_{max} bar(g)	K_{St} (bar·m/s)	P_{max} bar(g)	K_{St} (bar·m/s)
Urea	10.0	3.0	7	0	0
	5.0	0.0	0.0	–	–
	2.5	0.0	0.0	–	–
	1.0	0.0	0.0	–	–
	0.5	0.0	0.0	–	–
Zinc	10.0	6.2	57	6.0	129
	5.0	6.7	45	–	–
	2.5	6.4	43	–	–
	1.0	6.2	41	–	–
	0.5	5.5	40	–	–



(a) Weight % and (b) DTG curves as a function of temperature (°C) in nitrogen (black line) and air (red line) flow of urea. FTIR on gaseous species in (c) nitrogen and (d) air flow

Thermochemistry of carbon black and zinc

Typical combustion reaction for:

- carbon black: $C(s) + {}^{1}/_{2}O_2(g) \longrightarrow CO$
  $C(s) + O_2(g) \longrightarrow CO_2$
  - surface burning, fuel and oxidant react in different physical phases (i.e., solid/gas) (Heterogeneous combustion)

- Zinc: $Zn(s) + {}^{1}/_{2}O_2(g) \longrightarrow ZnO(s)$;
  - no hydrocarbon bonds in Zn to break, surface burning (Heterogeneous combustion)

- Differently from zinc, the interaction between carbon black particles and oxygen is faster and active at low temperature.

Conclusions

The disagreements related to marginally explosible dusts can be addressed by:

- choosing the right test chamber for measuring the explosibility of marginally explosible dusts
- identifying the dominant combustion modes (homogeneous or heterogeneous) of materials
- performing a detailed thermal analyses which provide very important information about the explosibility of a dust, in addition to the usual physical and chemical characteristics (e.g., PSD, proximate and ultimate analysis)

THANK YOU

Questions?

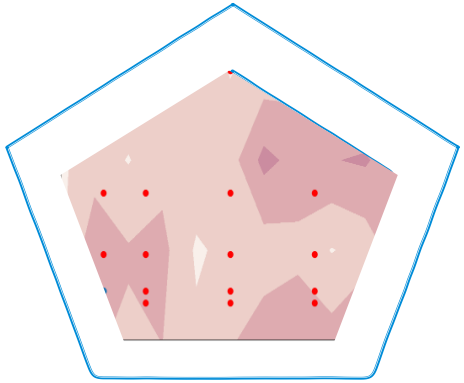
Albert Addo
Ph.D. Candidate

Process Engineering & Applied Science,
Dalhousie University, Halifax, NS,
Canada.

al246147@dal.ca

DALHOUSIE UNIVERSITY
Inspiring Minds

Data-Driven Approach to Dust Explosion Risk Reduction

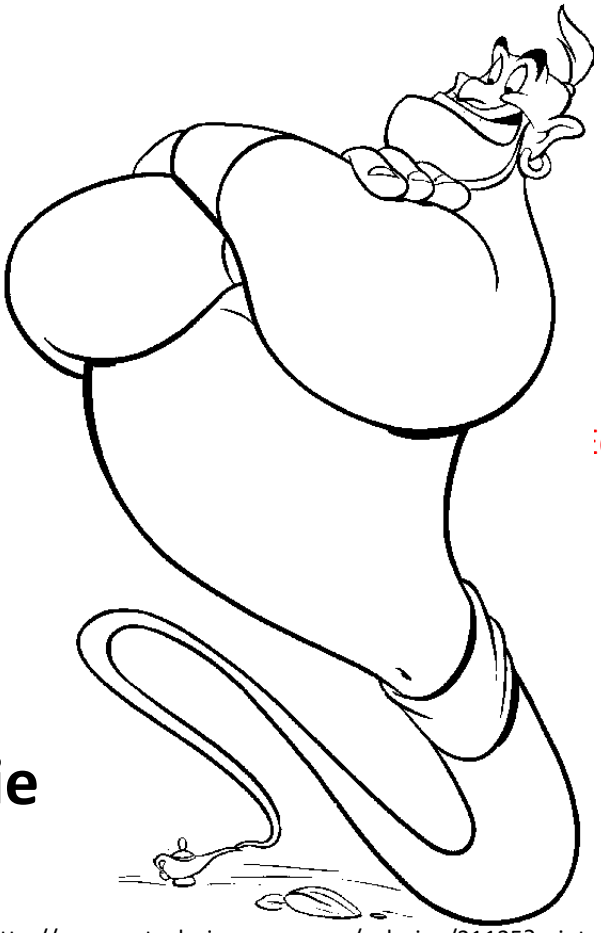


Mohammad Alauddin

PDF
Dust Explosion Lab
Process Engineering & Applied Science,
Dalhousie University, Halifax, NS, Canada

Data-Driven Approach to Dust Explosion Risk Reduction

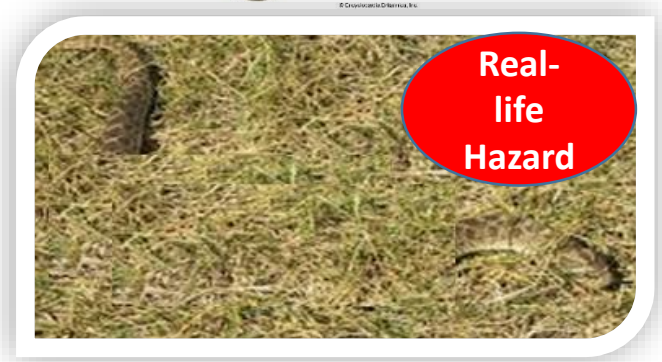
The beauty of data vi :d

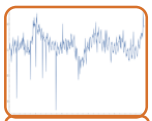


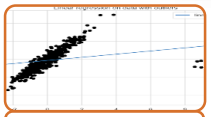
http://www.getcoloringpages.com/coloring/31125?print

Aladin's Genie

Data-related challenges of modeling of process safety systems




Noise


Outliers

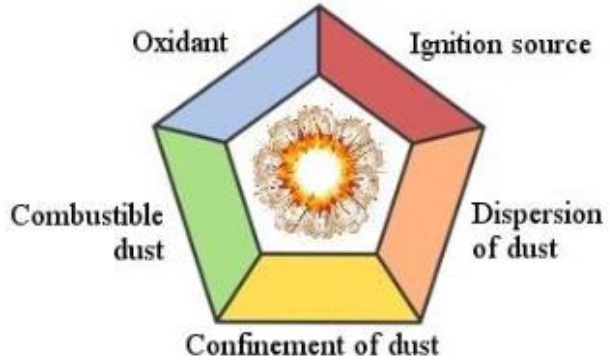

Dynamic


Imbalance


Integrated


Uncertainty

Data-Driven Approach to Dust Explosion Risk Reduction



https://www.sciendo.com/article/10.1515/rput-2015-0006

Explosion Severity

- P_{max}
- K_{St}

Explosion likelihood parameters

- minimum ignition energy (MIE)
- minimum explosible concentration (MEC)
- minimum ignition temperature (MIT)

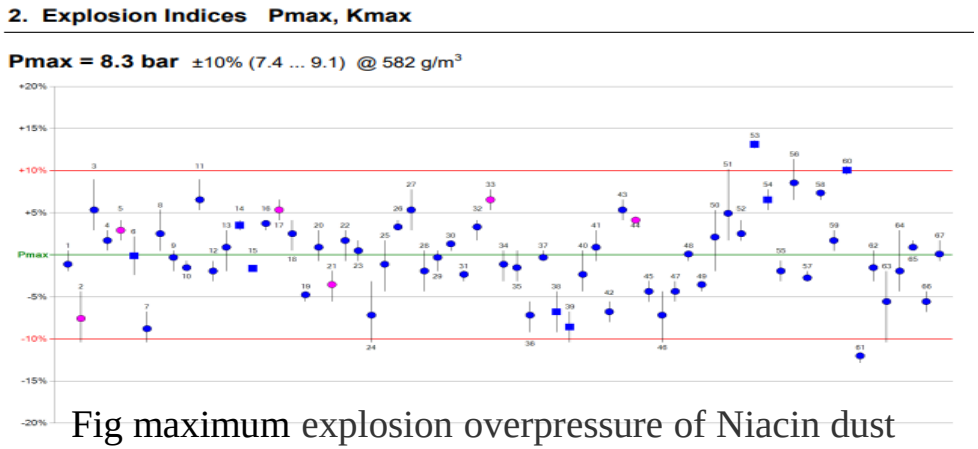


Fig maximum explosion overpressure of Niacin dust
(taken from the CaRo21; Calibration-Round-Robin 21 Final Report)

Particle size

Moisture

Dispersibility and mixing patterns

Change in the chemical composition of the samples

Equipment malfunctioning and human errors

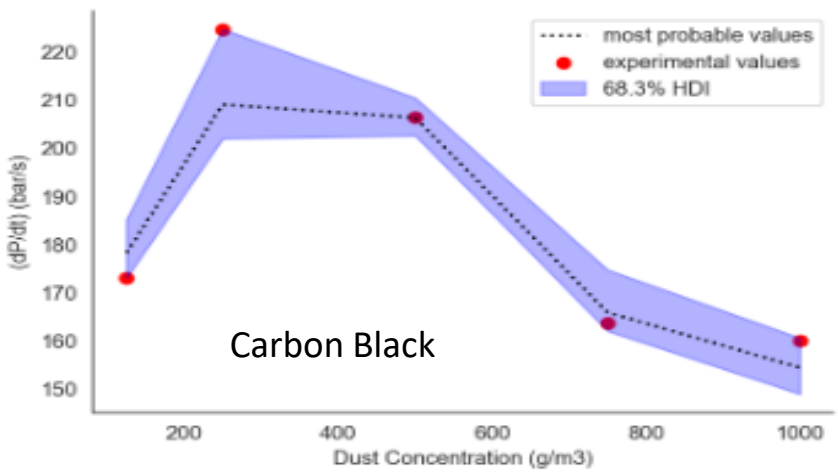
Data-Driven Approach to Dust Explosion Risk Reduction

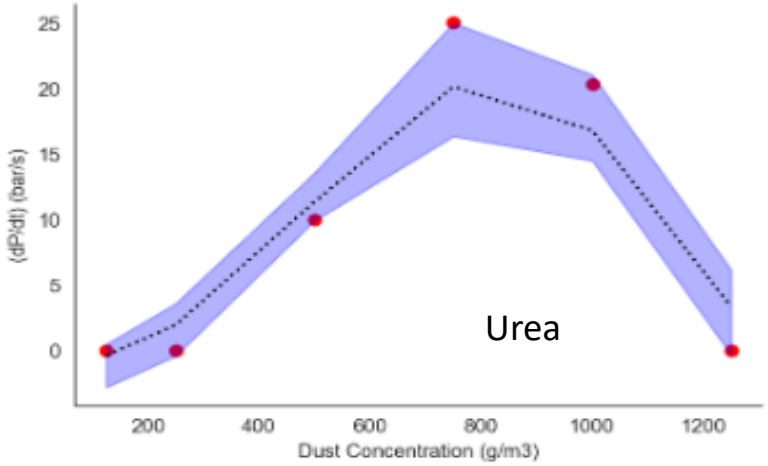
Part A: Probabilistic Modeling of Dust Explosion Parameters

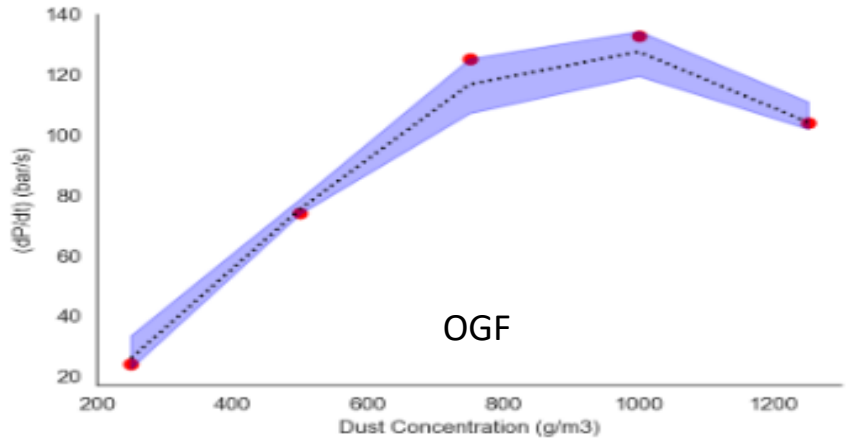
Part B: Determination of explosibility and nonexplosibility conditions

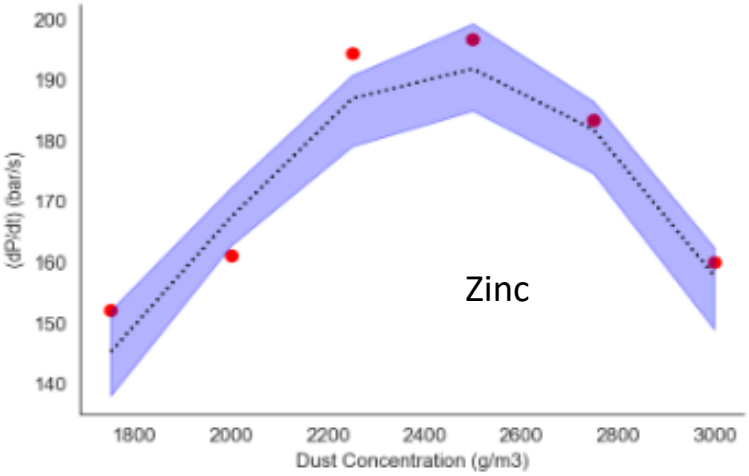
Part C: Handling source variabilities using Hierarchical Modeling

Part A: Probabilistic Modeling of Dust Explosion Parameters









Part B: Determination of explosibility and nonexplosibility conditions

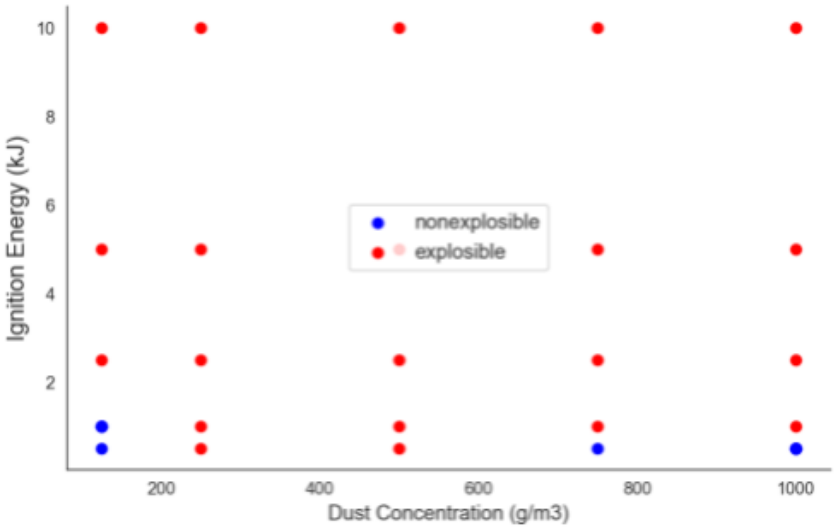
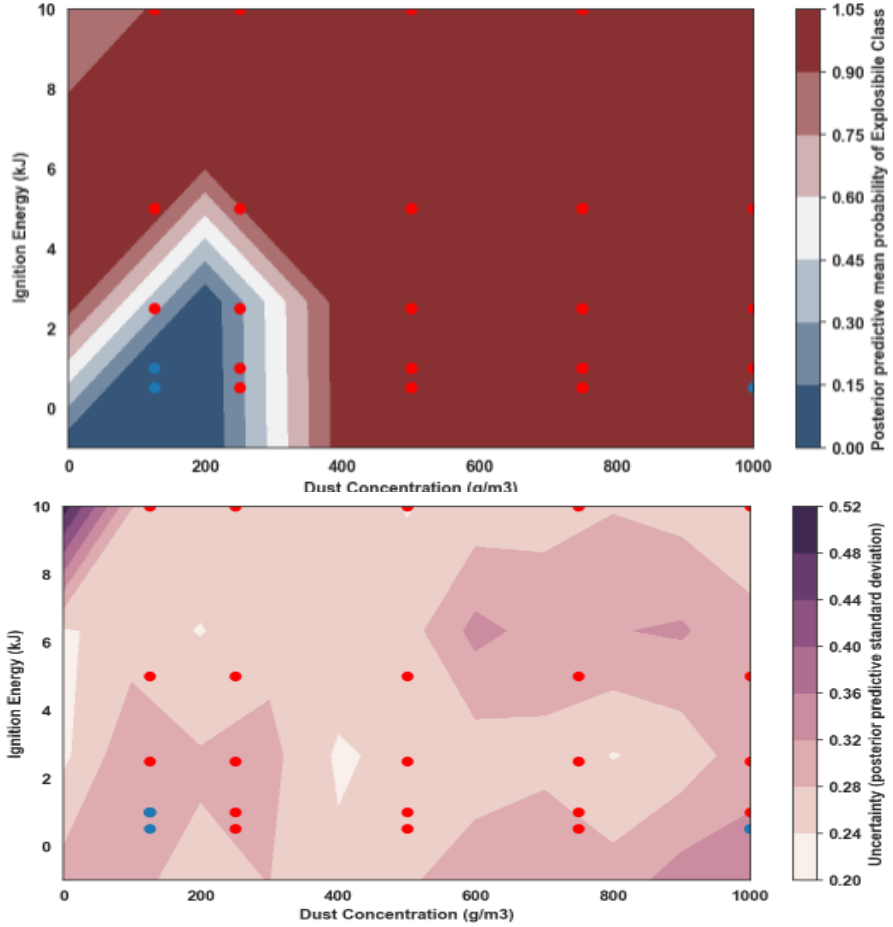
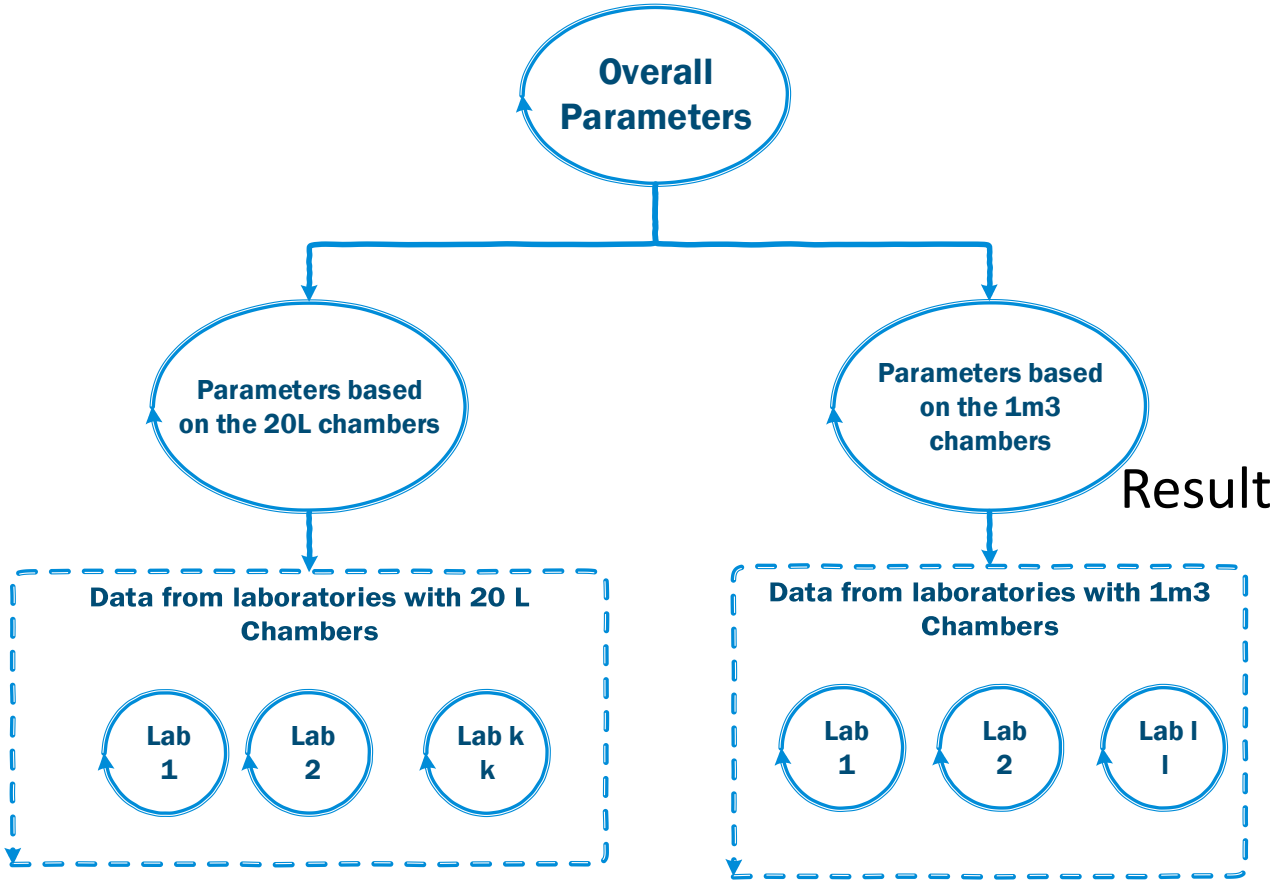


Fig : Effect of Ignition energy and dust concentration on the explosibility of dust

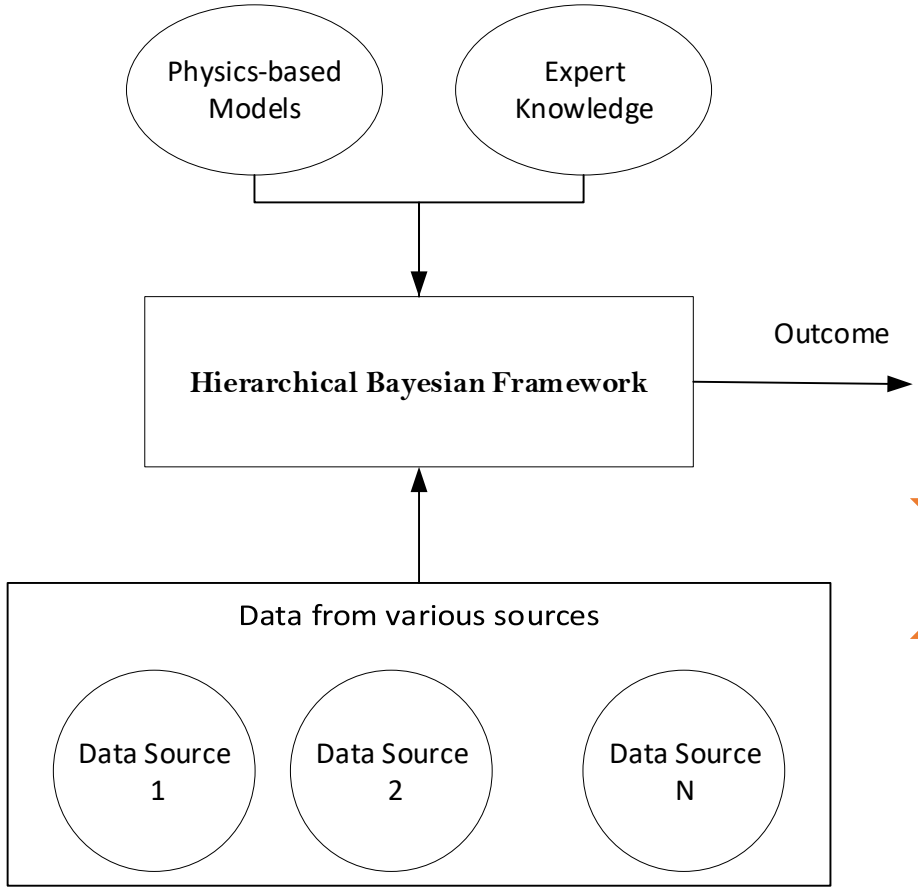


C: Handling variabilities using Bayesian Hierarchical Modeling



Results in process…

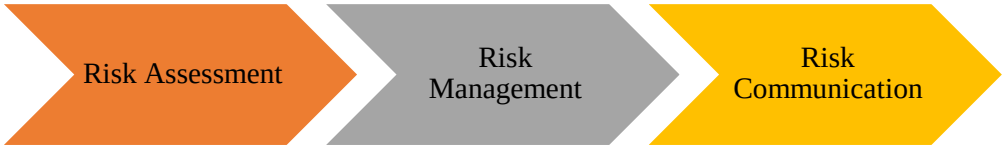
Information fusion using semi-mechanistic Hierarchical Modeling



Risk is the effect of uncertainty on objectives

(International Organization for Standardization, ISO, 31000)

Risk analysis comprises-



identification
characterization
evaluation

actions taken to undertake, accept, and mitigate

exchange of information to a better understanding of the risk

Conclusion

- Overview of **data-related problems** in data-driven modelling
- **Probabilistic modeling** of **dust explosion parameters**
- Probabilistic determination of **explosibility conditions**
- **Information fusion** for **handling uncertainties of distinct sources**

Acknowledgement

Advisor	Funding Agencies
Dr. Paul Amyotte	• Natural Sciences and Engineering Research Council • WorkSafeBC

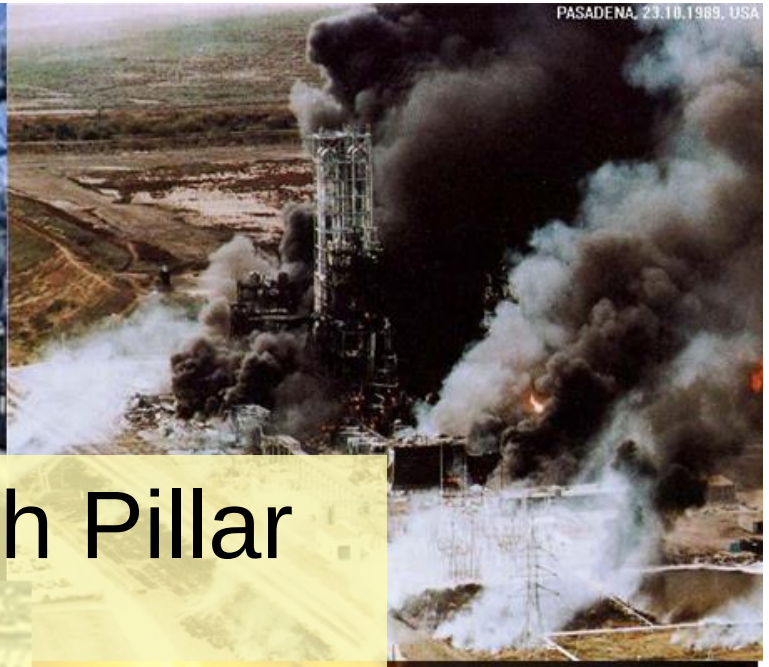
Thank You !

For feedback comments, and suggestions please contact at: mdalauddin@dal.ca

David and Joan Lynch
School Of Engineering Safety and Risk Management

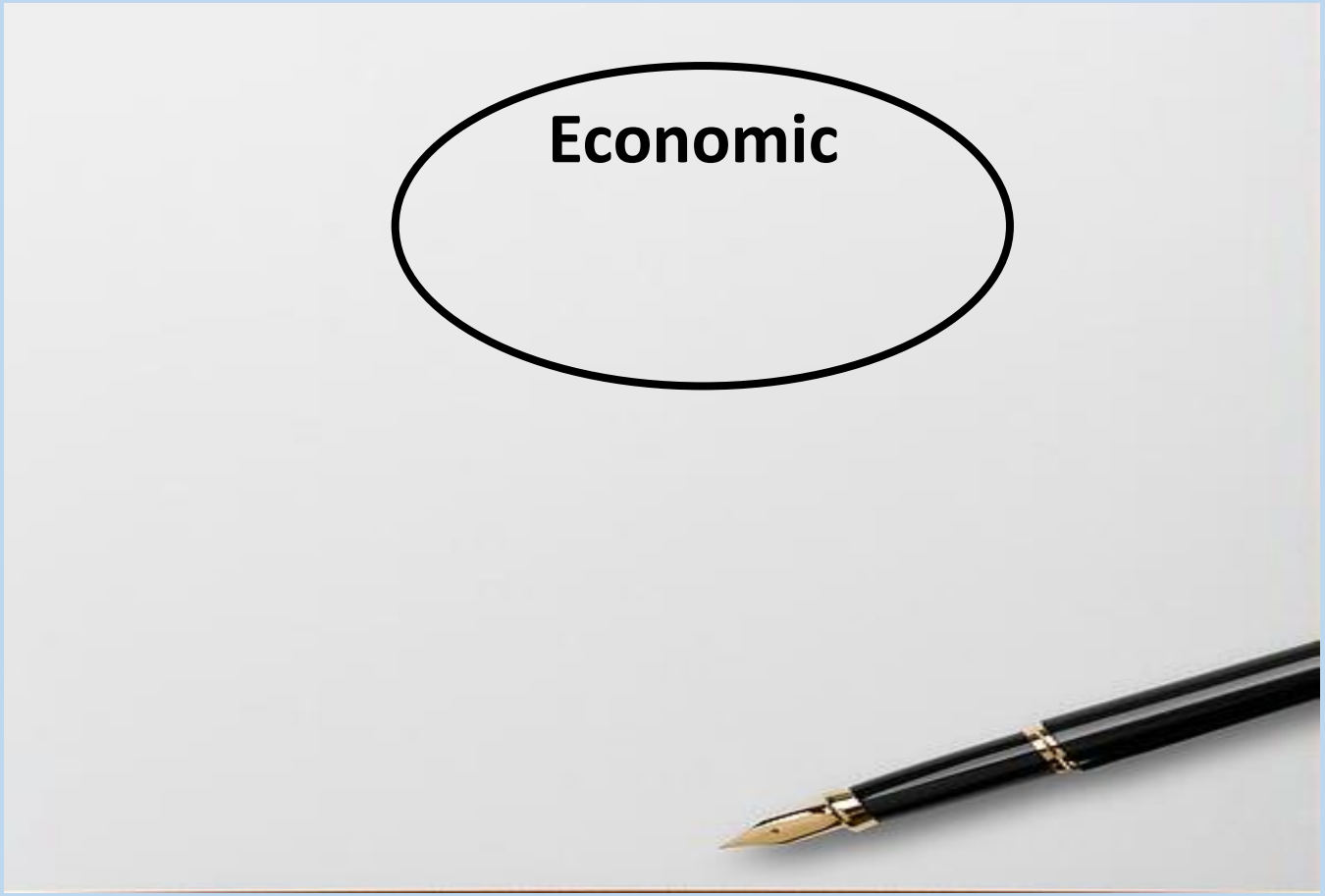
FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA

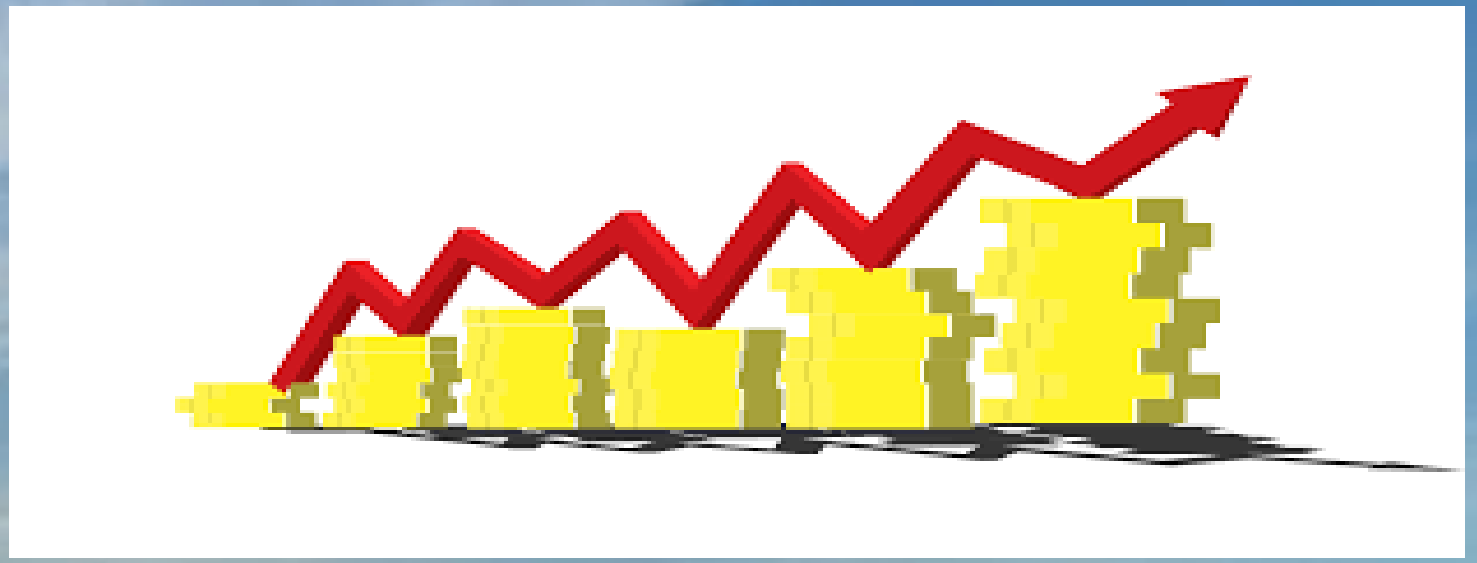





Risk Management is the Fourth Pillar of Sustainability

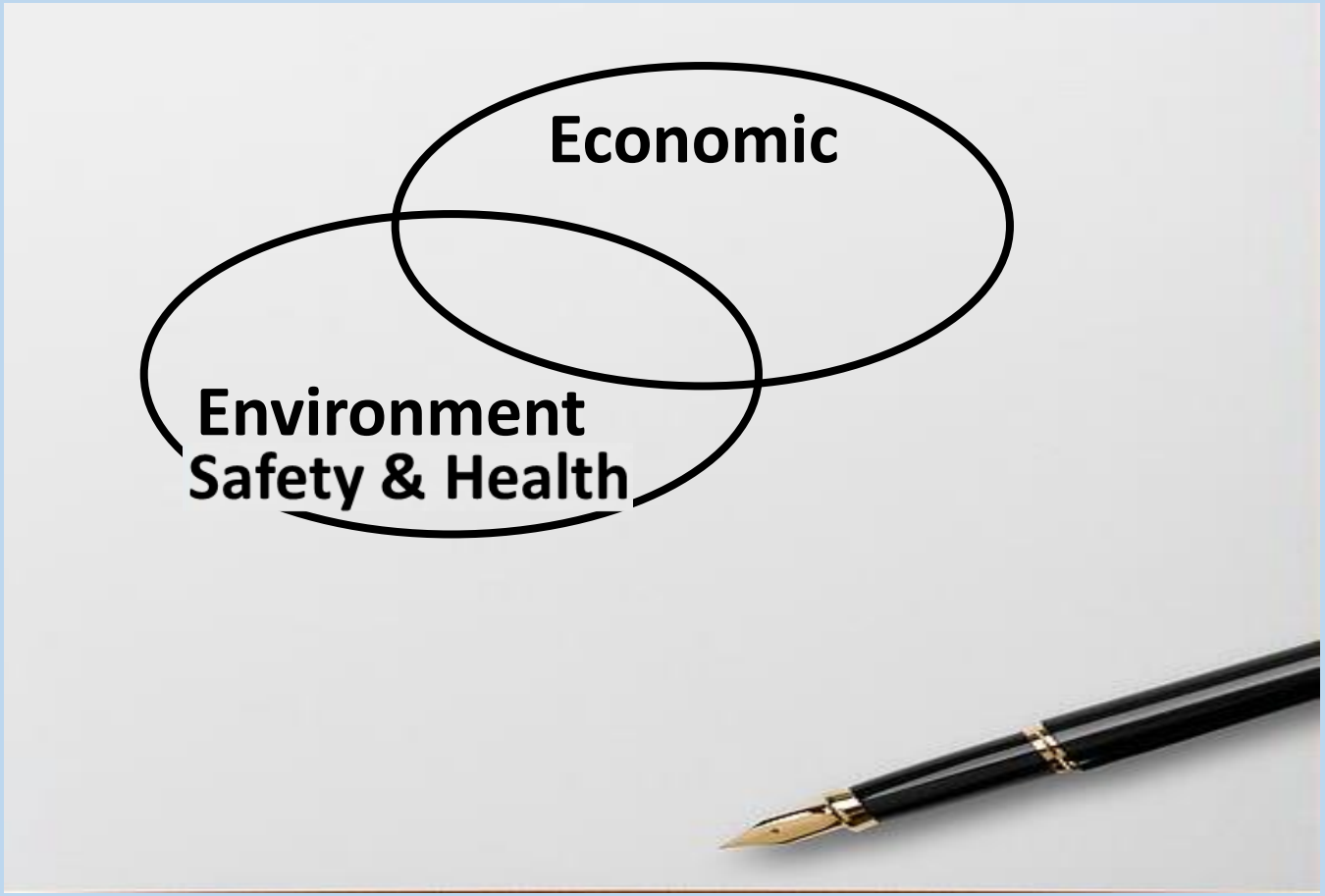
The Sustainability Journey….





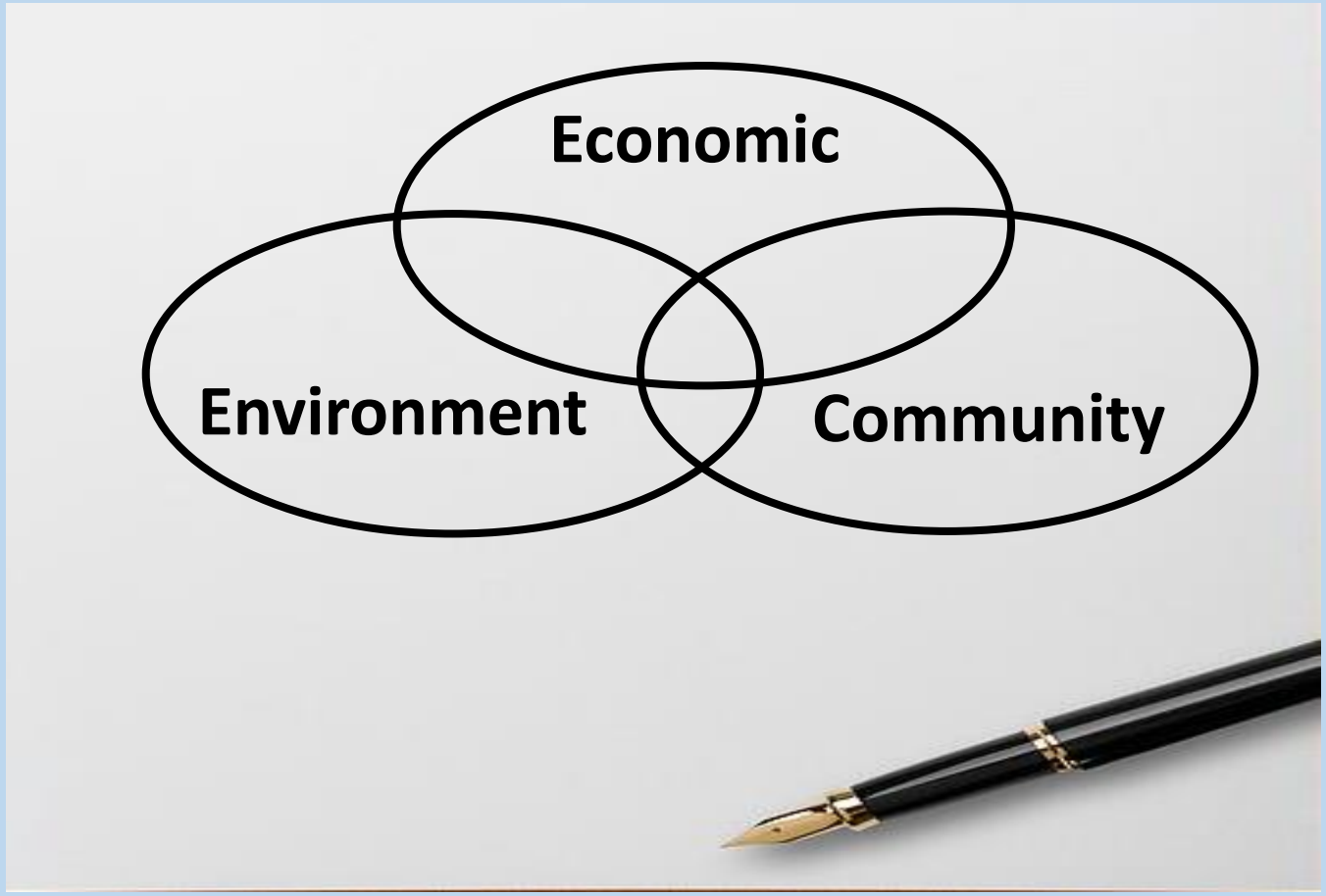
ECONOMIC

The Sustainability Journey….



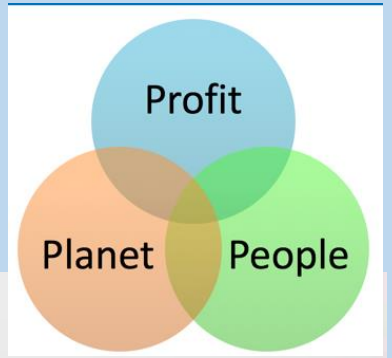
ENVIRONMENT

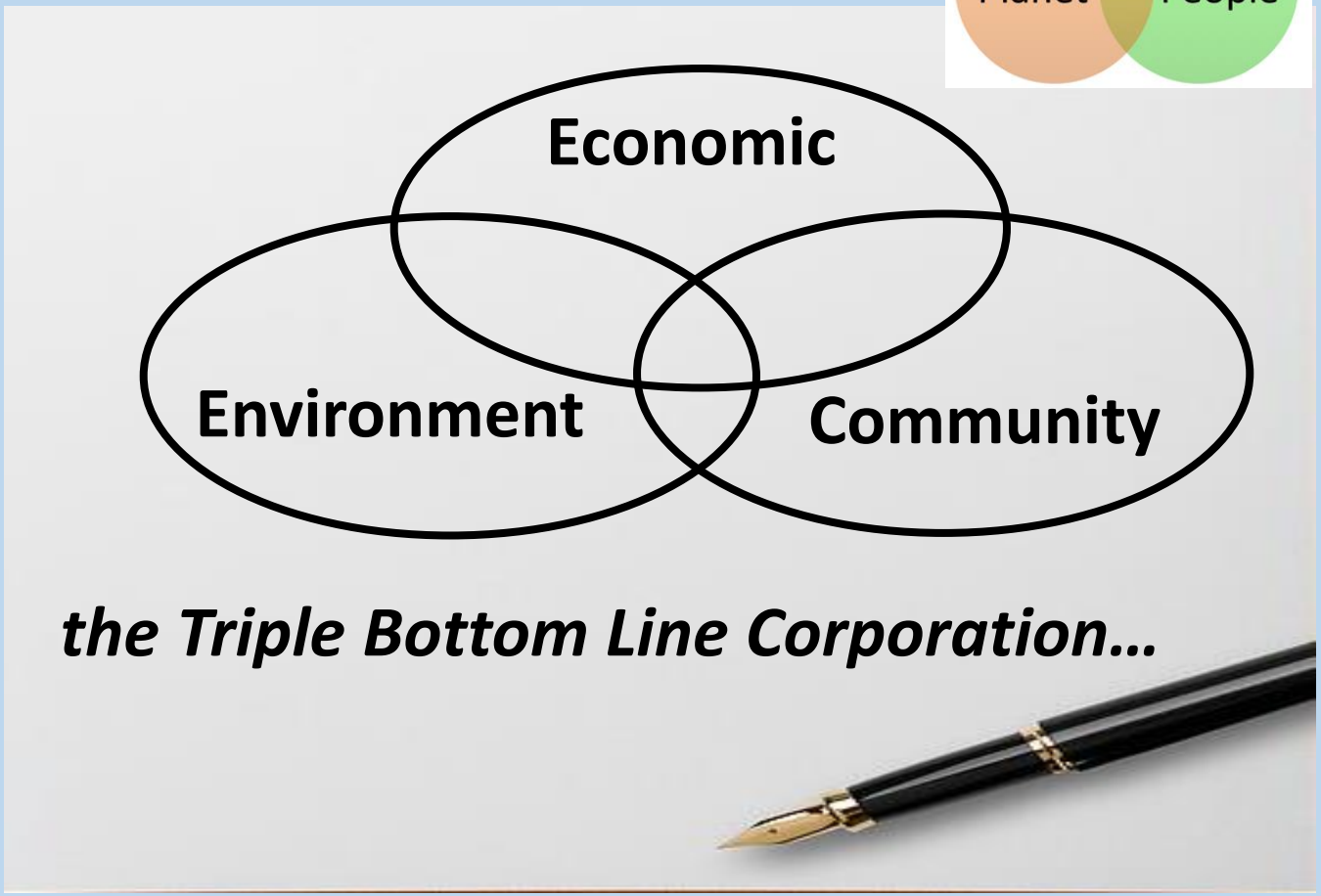
The Sustainability Journey….



COMMUNITY

The Sustainability Journey….

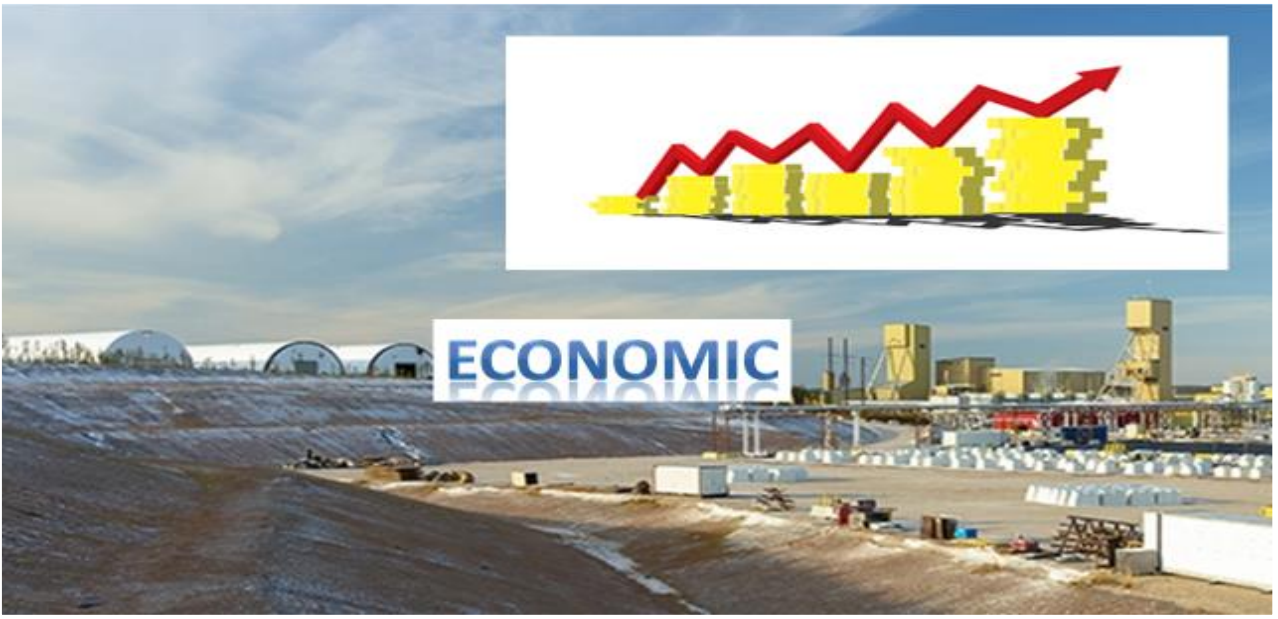





IDENTIFY
ANALYZE
RISK
MANAGEMENT
CONTROL
ACTION
MONITOR

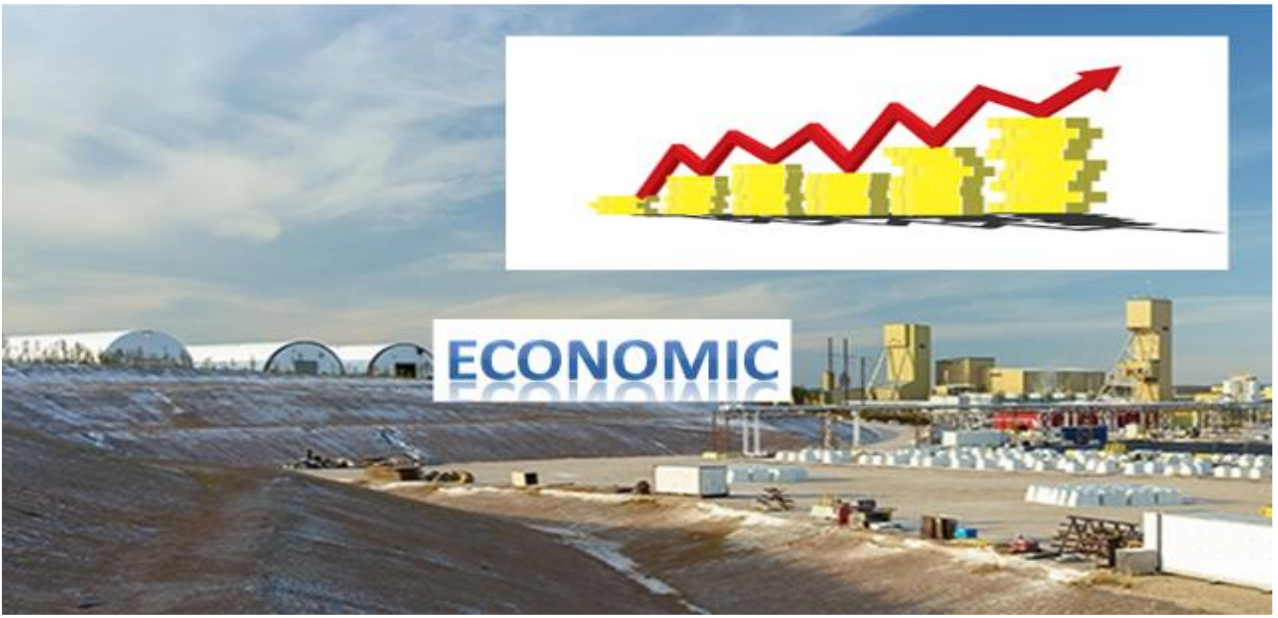
David and Joan Lynch
School Of Engineering Safety and Risk Management

FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA

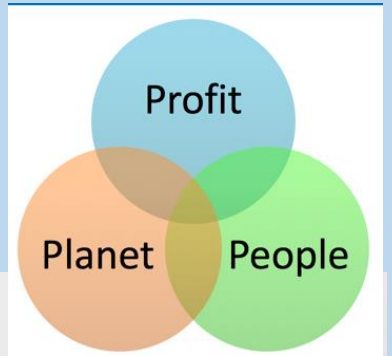


David and Joan Lynch
School Of Engineering Safety and Risk Management

FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA



The Sustainability Journey….



ESG

- **Greater Transparency**
- **Greater Efforts**
- **Greater Good**

ESG (WEF)

- **People**
- **Planet**
- **Prosperity**
- **Principles of Governance**

Accountability
Informing RISK

THE CANADIAN ENERGY SECTOR IS A **LEADER IN ESG GLOBALLY.**

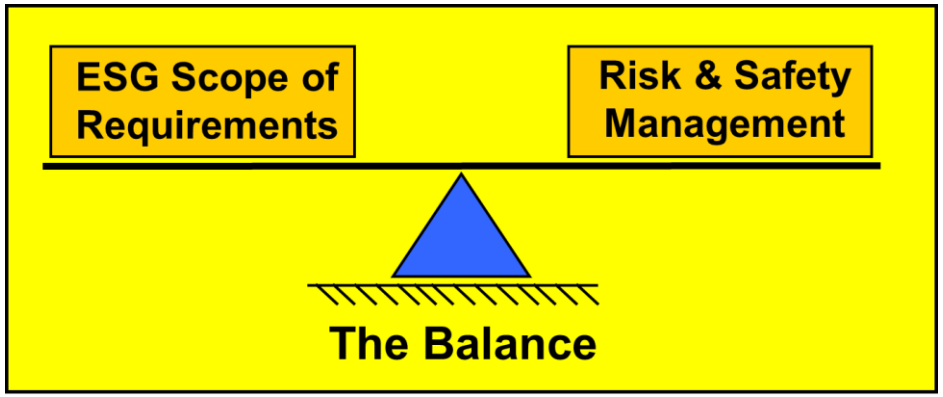
It's no surprise to us to read the conclusion from a study prepared by Worley Parsons Canada "that Canada's Environmental Assessment processes are among the best in the world."[14]

Many of our corporations are being viewed as "best in the world" for their ESG performance.

Accountability
Informing RISK

Excerpt from Canada's Energy Leadership Opportunity – Marc Van Wielingen

The Sustainability Journey….Keeping Our Focus



David and Joan Lynch
School Of Engineering Safety and Risk Management

FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA

Innovating Sustainability with Risk Management

David and Joan Lynch
School Of Engineering Safety and Risk Management

FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA

Innovating Sustainability with Risk Management

David and Joan Lynch
School Of Engineering Safety and Risk Management

FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA

Innovating Sustainability….

Risk Management is the Fourth Pillar of Sustainability