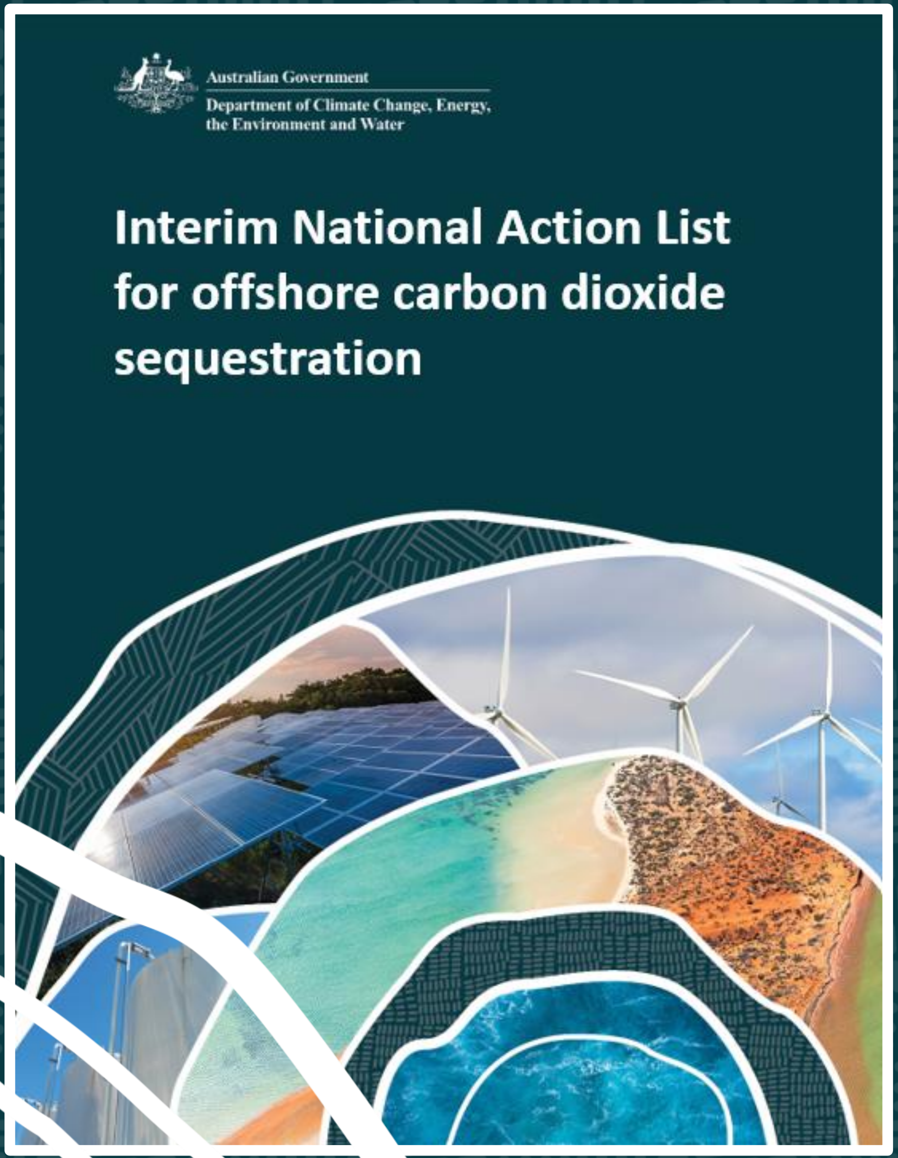


Australian Government

Department of Climate Change, Energy, the Environment and Water

Development of Australia’s National Action List for offshore CCS

London Protocol Science Day

18 April 2024

Presenters

Heather Agnew
Director, Sea Dumping
Department of Climate Change, Energy, the Environment and Water

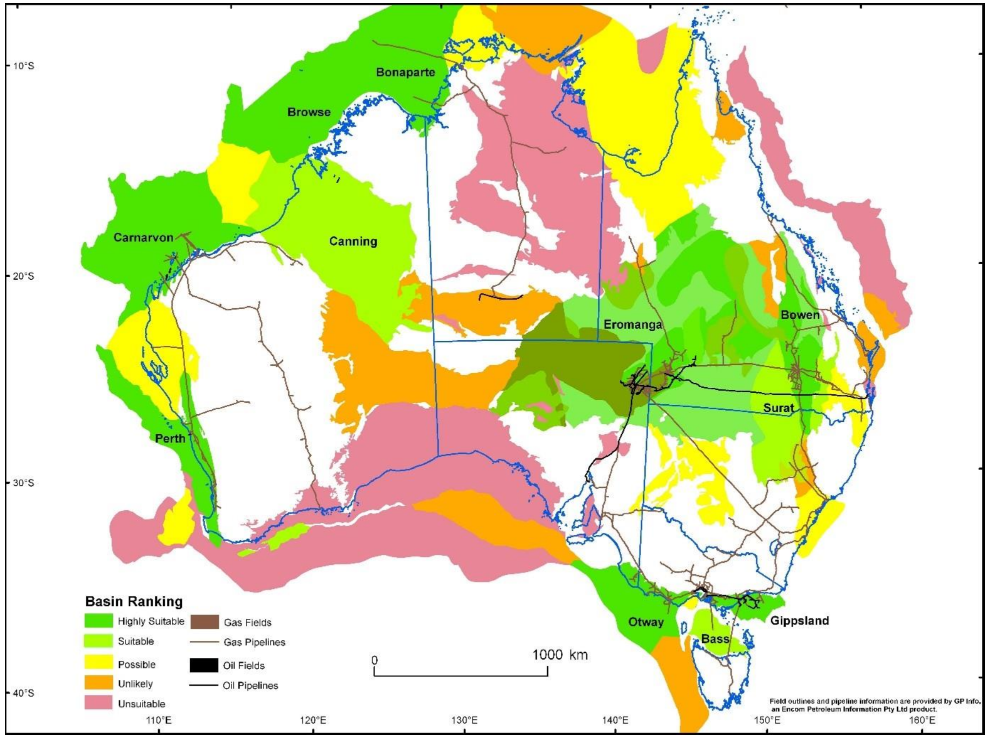
Dr Andrew Ross
Sr. Principal Research Scientist
Commonwealth Scientific and Industrial Research Organisation

Dr Linda Stalker
Sr. Principal Research Scientist
Commonwealth Scientific and Industrial Research Organisation

Presentation outline

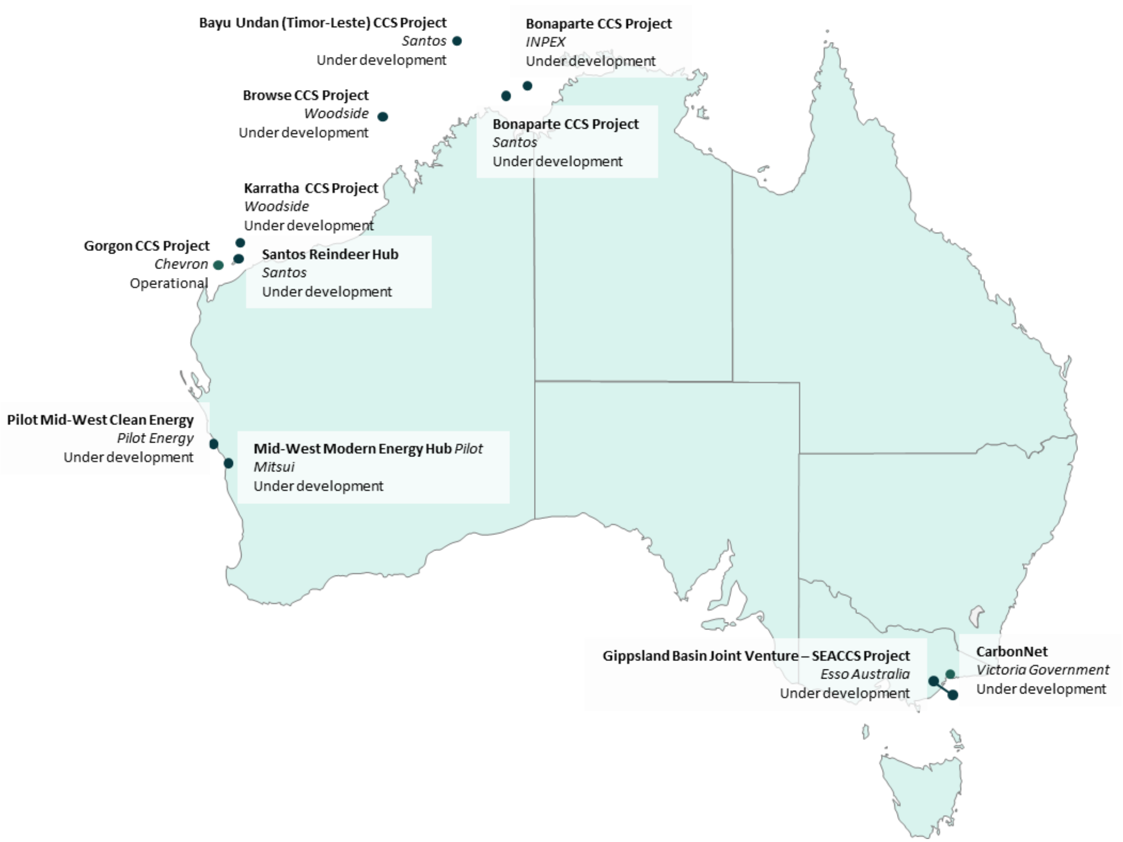
- Snapshot: CCS in Australia
- Australian context
- Australia's National Action List
- CSIRO – technical development of the National Action List
- Looking forward - National Action List

Snapshot: CCS in Australia



Australia's basins ranked for CO_2 storage potential (National Carbon Mapping and Infrastructure Plan, 2009, Figure 18)

Australia's operational CCS project and developing offshore CCS projects



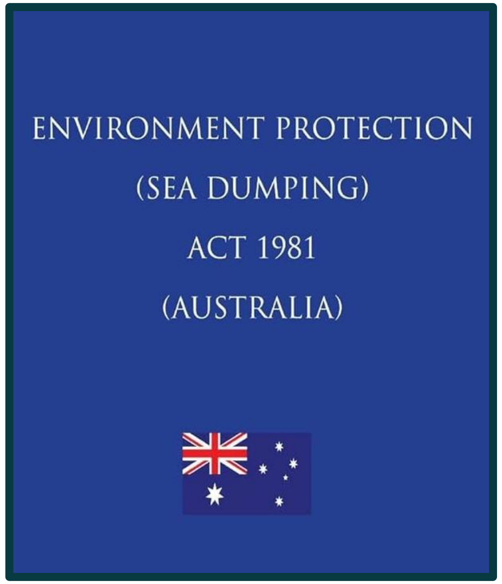
Australian context

International Agreements

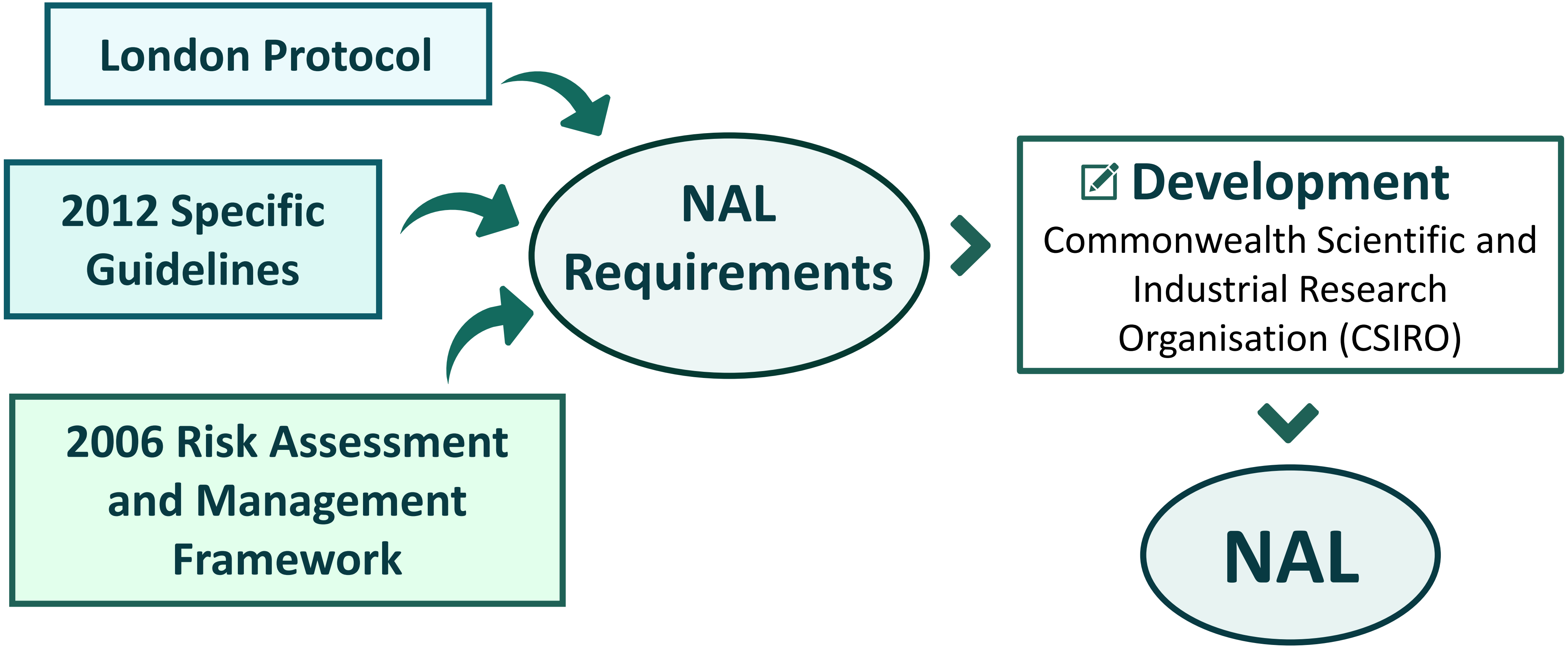
- The London Protocol

National Law

- *Environment Protection (Sea Dumping) Act 1981*
- *Environment Protection and Biodiversity Conservation Act 1999*
- *Offshore Petroleum and Greenhouse Gas Storage Act 2006*



National Action List (NAL) requirements



Australia’s National Action List

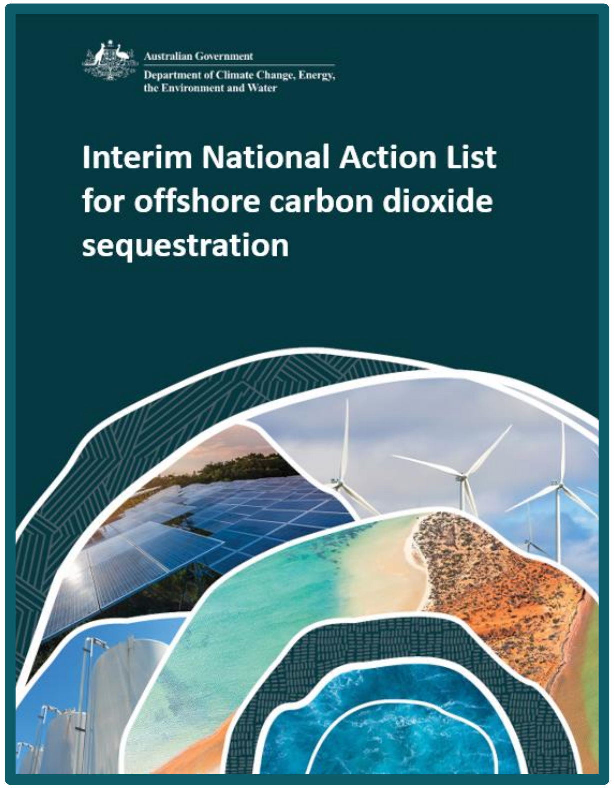
Interim NAL for CCS

- sets out a list of specified substances for which the waste would need to be screened
- sets an upper-limit threshold for each substance
- is available on our department’s website www.dcceew.gov.au

NAL for CCS

- may specify a lower-level substance concentration, below which there is little concern
- consider more types of capture scenarios

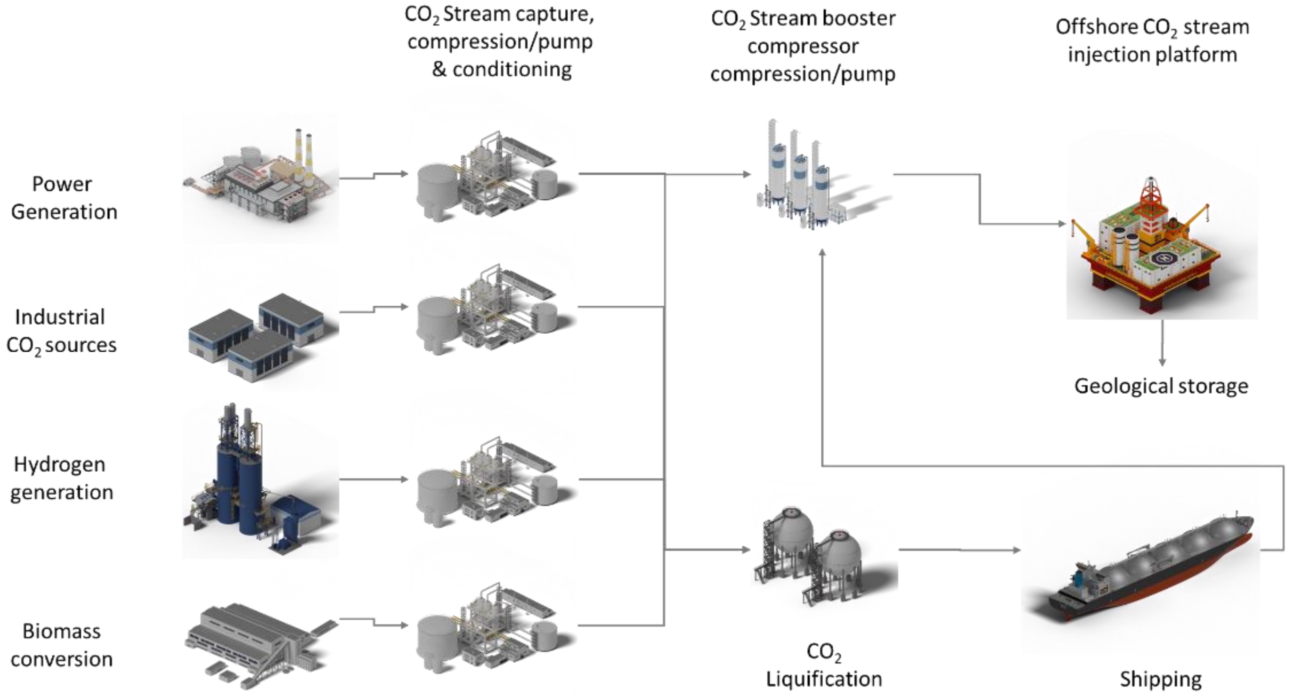
Department website



Cover – Interim National Action List for offshore carbon dioxide sequestration

Carbon Capture and Storage Value Chain

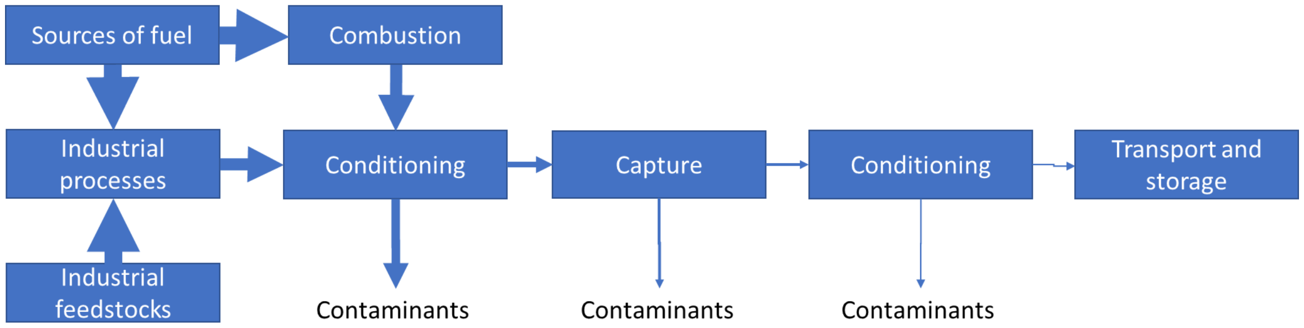
Traditional CCS concept



Current concepts

Defining upper-limits for the Interim NAL

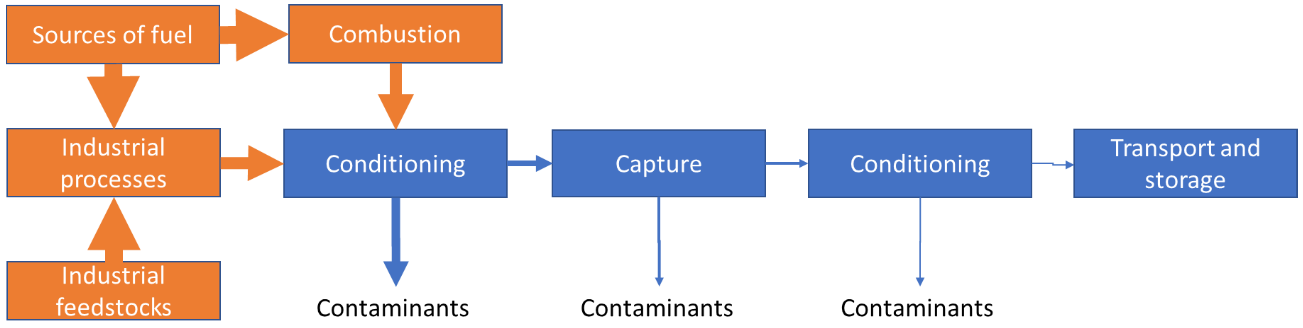
- Tracking CO_2 and Incidental Associated Substances through the value chain
- Benchmarking against ISO transport standards and CCS project CO_2 specifications
- Comparison with Human Health Short Term Exposure Limits (STELs)
- Measurement
- Interim NAL construction



Tracking Incidental Associated Substances

Combustion and industrial processes CO_2 streams

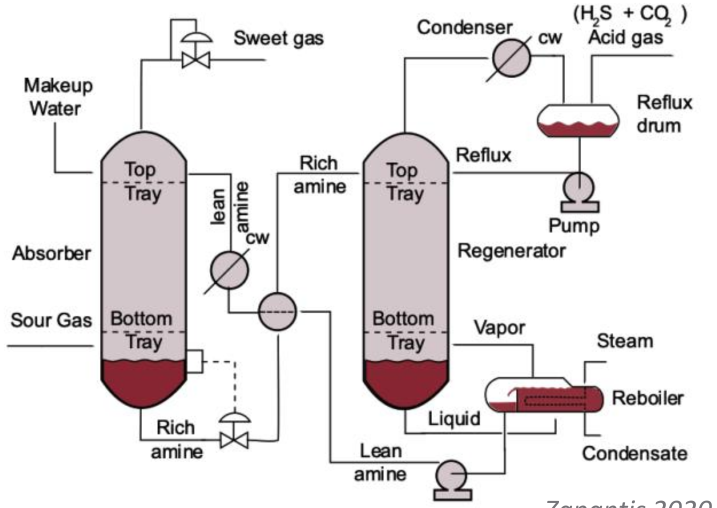
- Australian energy and industry focus
- **Combustion**
  - Coal, gas biomass and waste
- **Industrial processes**
  - Cement/lime
  - Metal smelters
  - Chemicals
  - Ammonia and fertiliser production



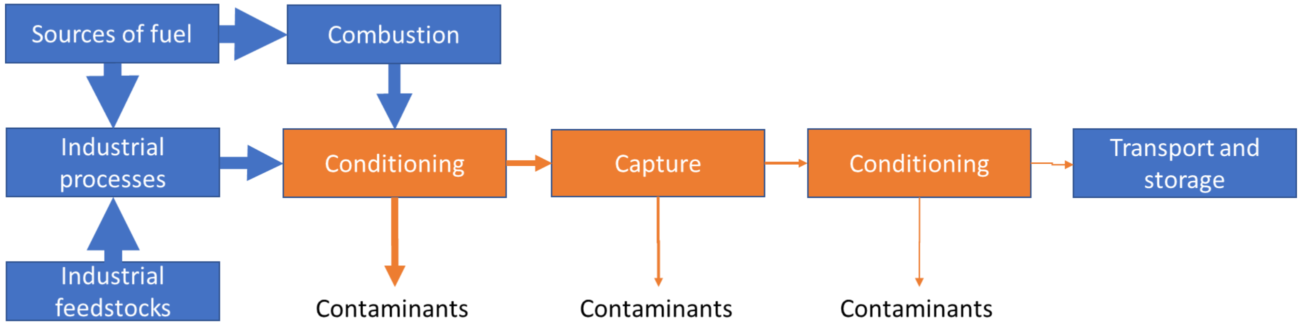
Tracking Incidental Associated Substances

CO_2 capture and conditioning

- **Preconditioning**
  - Removal of compounds such as NO_X SO_X Hg
- **Amine-based CO_2 capture**
- **Postconditioning**
  - Dehydration, amine removal



Zapantis 2020



Incidental Associated Substances are removed during capture and conditioning

Tracking Incidental Associated Substances

Collated CO_2 contaminants from industrial sectors flue gas and CO_2 product streams

Concentrations of impurities in dried CO_2

- Concentrations of Incidental Associated Substances in dried CO_2 (post capture and purification)
- Ranges of Incidental Associated Substance concentrations in CO_2 streams

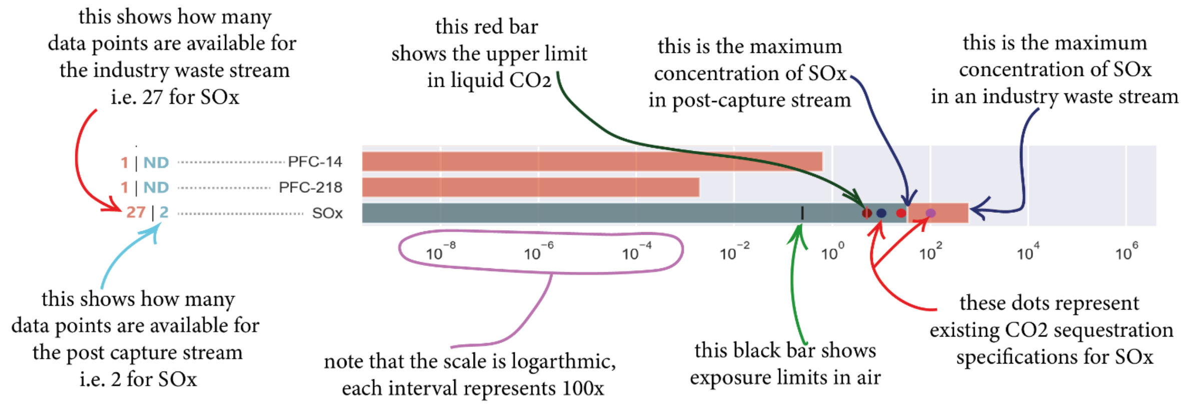
Constituent	Concentrations from combustion of thermal coal (%)	Concentrations from combustion of gas (%)
Carbon Dioxide (CO_2)	98.84 – 99.97	98.78 – 99.97
Carbon Monoxide (CO)	0.001 – 0.04 (10 – 400 ppm)	<DL - 0.0050 (<DL - 50 ppm)
Nitrogen (N_2)	0.01 – 0.9 (100 – 9,000 ppm)	0.01 – 0.9 (100 – 9,000 ppm)
Argon (Ar)	0.01 – 0.15 (100 – 1,500 ppm)	0.01 – 0.15 (100 – 1,500 ppm)
Oxygen (O_2)	0.01 – 0.03 (100 – 300 ppm)	0.01 – 0.03 (100 – 300 ppm)
Sulphur Dioxide (SO_2)	0.001 – 0.01 (10 – 100 ppm)	0.001 – 0.01 (10 – 100 ppm)
Nitrogen Oxides (NO_x)	<DL – 0.01 (<DL – 100 ppm)	<DL - 0.01 (<DL - 100 ppm)
Hydrogen (H_2)	<DL – 0.002 (<DL – 20 ppm)	<DL – 0.01 (<DL – 100 ppm)
Hydrogen Sulphide (H_2S)	<DL – 0.01 (<DL – 100 ppm)	<DL – 0.01 (<DL – 100 ppm)
Water (H_2O)	0.001 – 0.06 (10 – 600 ppm)	0.001 – 0.06 (10 – 600 ppm)
Methane (CH_4)	<DL – 0.01 (<DL – 100 ppm)	<DL – 0.01 (<DL – 100 ppm)
Ammonia (NH_3)	<DL – 0.005 (<DL – 50 ppm)	<DL – 0.005 (<DL – 50 ppm)
Methanol (CH_3OH)	<DL – 0.02 (<DL – 200 ppm)	<DL – 0.02 (<DL – 200 ppm)

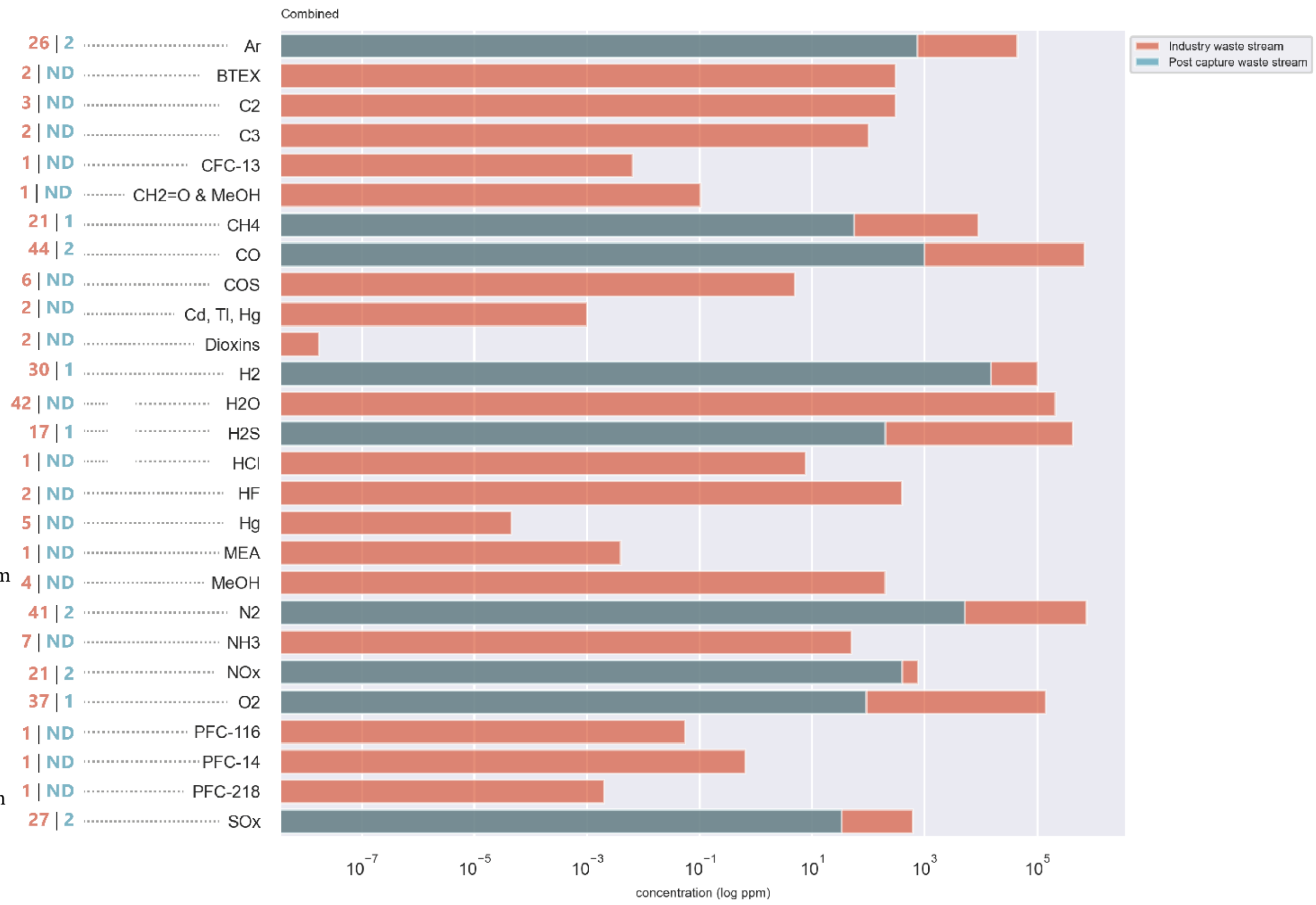
Sourced from Wang et al., 2011a; Metz et al., 2005

DL indicates 'lower than detection limit' of analytical method used for determination, this does not however mean that the compounds are not present.

Composition from industries pre- and post-capture

- Concentration ranges of Incidental Associated Substances in CO_2 streams pre- and post-capture
- Collated for the range of industrial and combustion CO_2 sources





Benchmarking against CO_2 specifications

- ISO 27913
- CCS projects
    - Sleipner
    - Hynet
    - Weyburn
    - Acorn and related Scottish cluster projects
    - Northern Territory low emission hub
    - Northern Lights
    - Porthos Project
    - DeepC Store

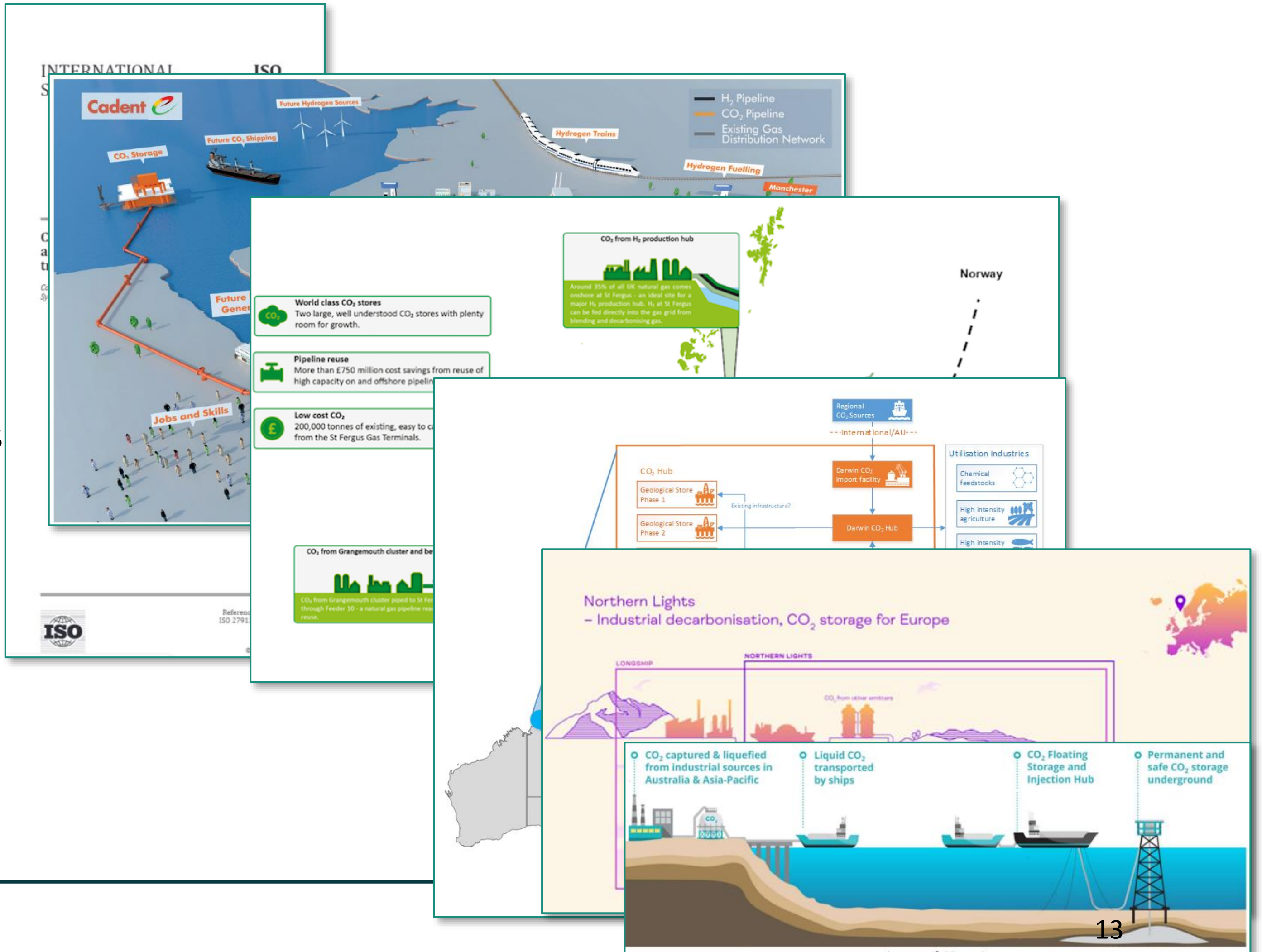
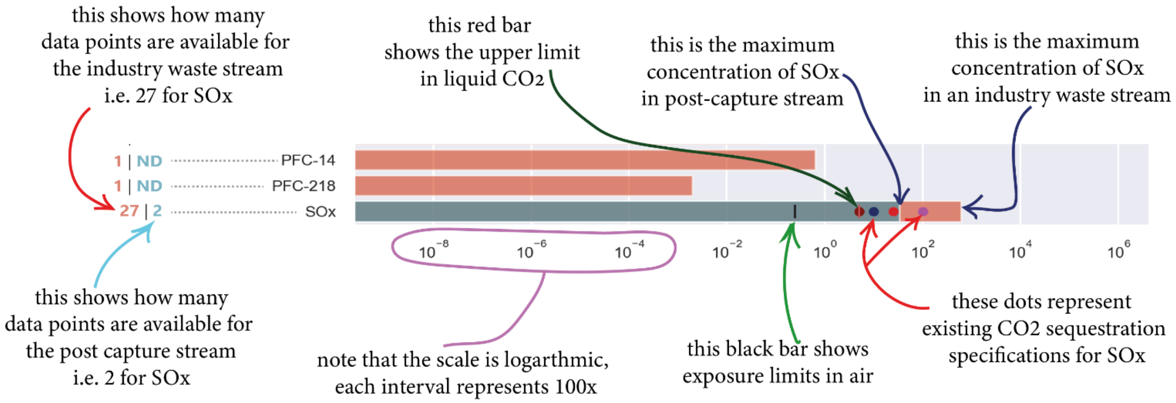
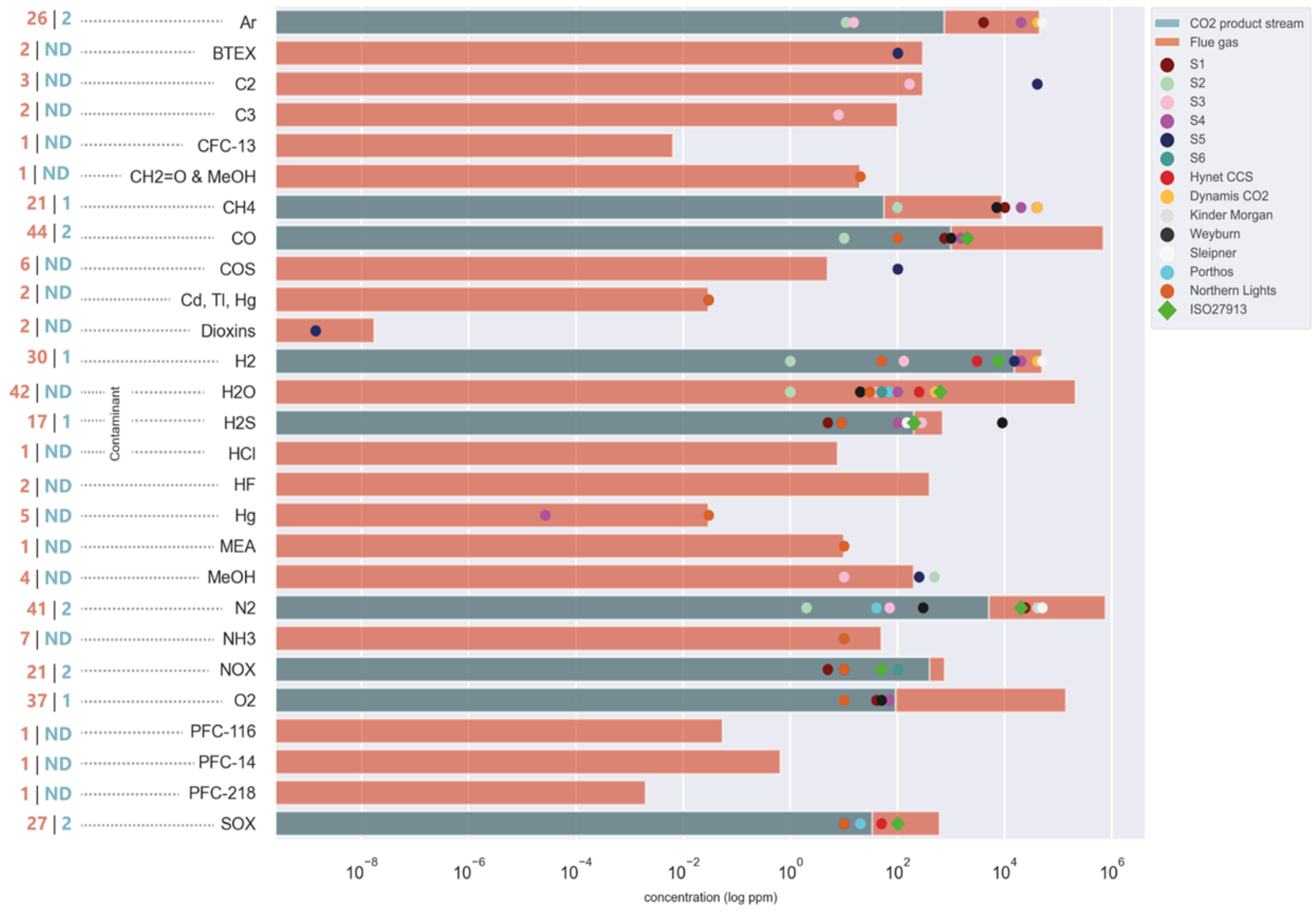


Image of CStore1

Capture and CO_2 specifications comparison

- Comparison of CO_2 stream pre and post capture with CO_2 specifications
- Shows many specifications are in line with expected post capture composition
- However there are exceptions



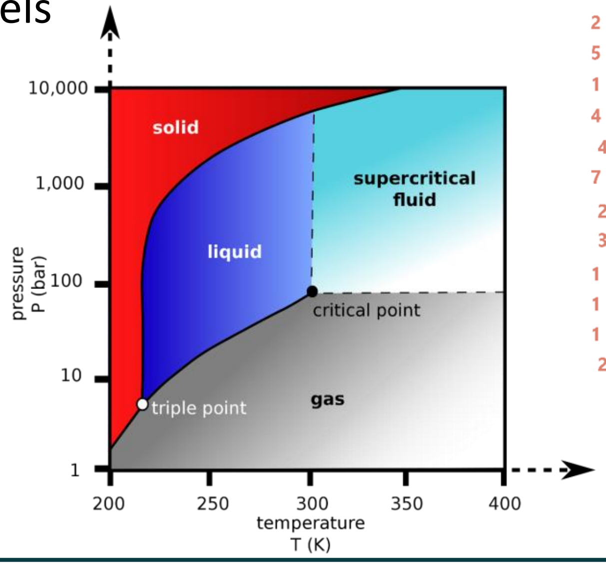


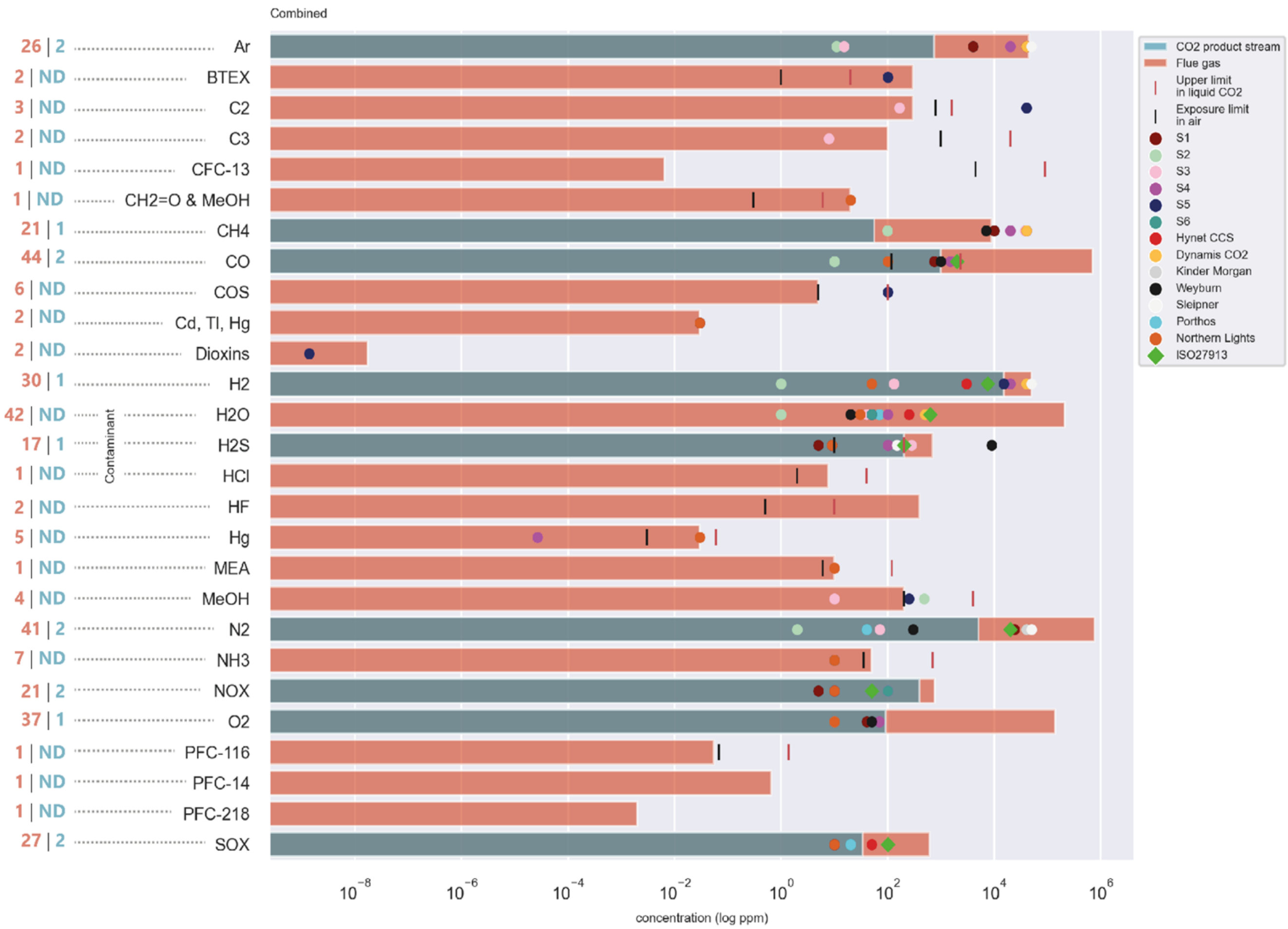
Short Term Exposure Limits (STELs)

Assessing the risk of CO_2 stream contaminants

- Contaminant toxicity
- Pathway to harm
- Risks to workers
- Risks to the environment
- Use of screening levels

Considerations of CO_2 phase





Measurement

https://www.sulzer.com/en/

Review of CO_2 stream monitoring approaches

- Inline measurement methods
- Offline measurement methods
  - Mobile methods and instruments
  - Laboratory based techniques

Further method development required

Contaminant	Online Methods and Instrumentation				Mobile Methods and Instrumentation				Laboratory Based Techniques			
	Instrument Type	Supplier	Lower Limit	Method	Instrument Type	Supplier	Lower Limit	Method	Instrument Type	Supplier	Lower Limit	Method
Mercury	Online subsampling; UV absorbance / UV Fluorescence	Various	0.1 $\mu g/m^3$	Relevant Standard: ISO 6978-2:2003 (Detection in Natural Gas Streams)	Portable Mercury Analyser	Ion - MVI	0.1 ug/m^3	USEPA OTM-31: Guide for Developing a Multi-Metals, Fence-Line Monitoring Plan for Fugitive Emissions Using X-Ray Based Monitors	Ultraviolet Atomic Fluorescence (UV AF), ultraviolet atomic absorption (UV AA), X-ray Fluorescence (XRF)	Various	0.1µg/dscm (dry standard cubic metre)	USEPA Method 30B
	Multi-Metal CEMS	SCI SailBri Cooper Inc - Xact 640	0.09 ng/m^3	USEPA Method IO 3.3: Determination of Metals in Ambient PM Using XRF					Atomic Absoprtion Sepctrophotometry (AAS)	Various	Dependent on spectrophotomer	USEPA Method 102
									Cold Vapour Atomic Absorption Spectroscopy (CVAAS)	Various	0.56 $\mu g/m^3$ estimated, instrument dependent	USEPA Method 29
Arsenic (Arsine)	Multi-Metal CEMS	SCI SailBri Cooper Inc - Xact 640	0.06 ng/m^3	USEPA Method IO 3.3: Determination of Metals in Ambient PM Using XRF	Portable Gas Detector	Oldham - BM25	1 ppm	USEPA Method 29: Metals Emissions from Stationary Sources	AAS		10 ug/ml	USEPA Method 108 Particulate and Gaseous Arsenic Emissions
Cadmium	Multi-Metal CEMS	SCI SailBri Cooper Inc - Xact 640	1.2 ug/m^3	USEPA Method IO 3.3: Determination of Metals in Ambient PM Using XRF	Continuous Particulate Monitor + X-Ray Fluorescence	Horiba - PX-375 analyser	11.3 ng/m^3	USEPA Method IO 3.3: Determination of Metals in Ambient PM Using XRF	AAS		0.5 ug/m^3	USEPA Method 29
	Multi-Metal CEMS	ELS - AeroLead 3000	0.05 ug/m^3	USEPA Method IO 3.3: Determination of Metals in Ambient PM Using XRF	Multi-Metal CEMS	SCI SailBri Cooper Inc - Xact 625i	52 ng/m^3	USEPA Method IO 3.3: Determination of Metals in Ambient PM Using XRF				EN 14385
	Atmospheric Heavy Metals Analyser	FPI - AMMS-100	0.5 ug/m^3	USEPA Method IO 3.3: Determination of Metals in Ambient PM Using XRF					ICP-MS			OSHA Method 1006
									ICP-OES			OSHA Method ID125G
									Electrochemical Trace Metal Analyser	CI Scientific - Ionix		

Interim NAL

- CO_2 Streams for storage to comprise >95% CO_2
- STELs with safety factor included used to define upper limits of Incidental Associated Substances
- Incidental Associated Substances without STELs are included that relate to:
  - Infrastructure integrity
  - Subsurface reactivity
  - Efficiency

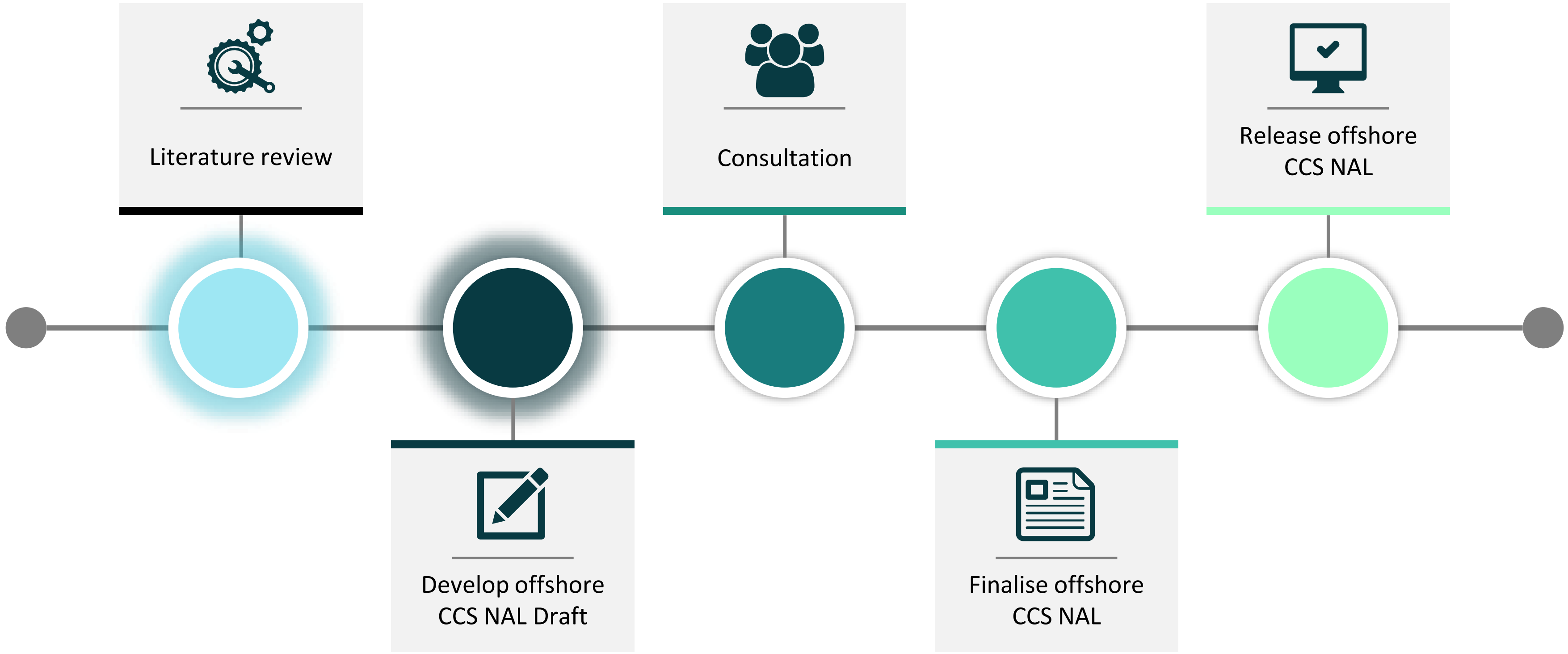
Adjustments will occur where required for offshore CCS NAL release

Interim NAL

Contaminant	Upper Limit	Rationale for Limit
CO (carbon monoxide)	2,000 ppm	• Health and safety aspects • Engineering with respect to mitigation of stress cracking of steels due to carbide formation
COS (carbonyl sulphide)	100 ppm	• Health and safety aspects
H_2S (hydrogen sulphide)	200 ppm	• Health and safety aspects • Engineering with respect to mitigation of stress cracking of steels due to hydride formation
HCl (hydrogen chloride)	40 ppm	• Health and safety aspects • Engineering with respect to mitigating metal corrosion • Environmental with concerns about dissolution of carbonate minerals, especially in sub-surface rock formations or well-bore cements due to acidic nature of HCl in water (forms hydrochloric acid)
HF (hydrogen fluoride)	10 ppm	• Health and safety aspects • Engineering with respect to mitigating metal corrosion • Environmental with concerns about dissolution of carbonate or silicate-rich minerals, especially in sub-surface rock formations or well-bore cements due to acidic nature of HF in water (forms hydrofluoric acid)
CH_3OH (methanol)	4,000 ppm	• Health and safety aspects
NH_3 (ammonia)	700 ppm	• Health and safety aspects • Engineering with respect to mitigation of stress cracking of steels due to hydride formation and corrosion of copper-based alloys
NO_x (nitrogen oxides)	4 ppm	• Health and safety aspects • Engineering with respect to mitigating metal corrosion • Environmental with concerns about dissolution of carbonate minerals, especially in sub-surface rock formations or well-bore cements due to acidic nature of NO_x in water (forms nitrous and nitric acids) • Microbiological with respect to any nitrites and nitrates (formed by the acid reaction) acting as electron acceptors in the anaerobic sub-surface formations with multi-step reductions to nitrous oxide (N_2O, small amounts) and nitrogen (N_2, main product) • Chemical with respect to possible reaction with other contaminant species to form new compounds

Excerpt of interim NAL

Looking forward – National Action List



Australian Government

Department of Climate Change, Energy, the Environment and Water

CSIRO

Contact us

Heather Agnew
Director, Sea Dumping
heather.agnew@dcceew.gov.au

Dr Andrew Ross
Senior Principal Research Scientist
andrew.ross@csiro.au

Dr Linda Stalker
Senior Principal Research Scientist
linda.stalker@csiro.au

Interim National Action List

Department website