Appendix:
Continuous monitoring of contaminant emissions from carbon sectors

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Rio Tinto's Areas of Interest (AoIs)

Rio Tinto is looking for solutions that enable continuous monitoring of gaseous and particulates emissions, taking into account the challenges of different facilities. Rio Tinto has identified four areas of focus that guide the development of a diverse range of innovative solutions.

Rio Tinto's four R&D Areas of Interest are:

- **Autonomous** and low maintenance requirement solutions that can operate independently, with minimal component replacement to improve resilience, longevity, and staff safety at facilities.
- **Resistant** solution being able to withstand the different operating conditions of the facilities
- **Versatile** contaminant measurement range
- **Sustainable** solutions with low energy use for increased supply chain resilience and minimal carbon footprint

The focus of this crowdsourcing campaign is to identify solutions that can continuously monitor gaseous and particulates emissions from our facilities.

The goal is to identify and implement solutions that can achieve:

- Reliable, robust, easy to use equipment with low maintenance requirements
- Versatile contaminant measurement range. The contaminants to be measured are, among others, TPM and $PM_{2.5}$, SO_2, NO_x, PAHs, CO, CO_2, HF
- Can withstand variations in the process as well as good resistance to corrosive and hot environments

Why is this important?

Operational Excellence opportunity

By taking the initiative to implement continuous gaseous and particulates emissions measurement, Rio Tinto is continuing its commitment to operational excellence and to be the best operator by going beyond what is currently required by local legislation in order to prepare for future changes. We are committed to the health and safety of our employees and their families as well as the communities surrounding our facilities. We know the challenges that climate change will pose in the coming decade and the first step in reducing our environmental footprint and the impact on the health of our workers and their families is to improve our understanding of our emissions so that we can target the technological improvements required in the future.

Market opportunity

In addition to the issues related to climate change, it is important to have a clear vision of the different atmospheric emissions to be able to reach Rio Tinto's environmental targets. The implementation of a continuous monitoring of emissions will allow us to improve our knowledge of atmospheric discharges and to implement the necessary actions to reduce them. In addition, with the acquisition of continuous data on certain contaminants, it will be possible to use this data to link them to process parameters and thus allow their optimization, which opens the way to improved production and greater value generation.

For example, it would be possible with continuous emissions monitoring to use this information as an additional data source in our regulation and control systems of operating conditions and thus increase the value production of our facilities

Key solution performance criteria

Solutions in this area should be able to achieve at least one of the following:

- Reliable, robust, easy to use equipment with low maintenance requirements
- Versatile contaminant measurement range. The contaminants to be measured are, among others, TPM and $PM_{2.5}$, SO_2, NO_x, PAHs, CO, CO_2, HF
- Can withstand variations in the process as well as good resistance to corrosive and hot environments

Technology Readiness Level (TRL) definitions

Technology Readiness Levels		Description	Supporting Information
1	Basic principles observed and reported	Scientific research begins translation to applied R&D. Paper studies of published peer reviewed papers.	Published research identifies the principles that underlie this technology.
2	Technology concept and/or application formulated	Invention begins, practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture.	Publications or other references that outline the application being considered and that provide analysis to support the concept.
3	Analytical and experimental critical function and/or characteristic proof of concept	Active R&D initiated (physical validation in laboratory)	Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions. Confirm technology concept has firm scientific underpinning. References to who, where, and when these tests and comparisons were performed.
4	Technology component validation in laboratory environment	Basic technological components are integrated to establish they will work together.	System concepts that have been considered and results from bench scale testing of the technology. References to who did this work and when. Details of how the bench scale technology and test results differ from the expected goals. For process technologies, the typical capacity of a bench-scale plant can be between 0.001 to 0.01% the one required for a commercial-size implementation.
5	Components/technology validation in relevant environment	Technology tested in a large bench scale laboratory environment using real world fluids, data or setpoints (more realistic simulation)	Results from testing technology are integrated with other supporting elements in a simulated operational environment. How does the “relevant environment” differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Were the technology components refined to match the expected system goals more nearly?
6	Prototype demonstration in a relevant environment	Prototype evaluation in a simulated laboratory operational environment	Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level? For process technologies, the typical capacity of a pilot plant can be between 0.01 to 1% the one required for a commercial-size implementation.

Technology Readiness Levels		Description	Supporting Information
7	Prototype demonstration in an operational environment	Whole system prototype evaluation in actual operational environment (on a water, wastewater or network site)	Results from testing a prototype system in an operational environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
8	Actual technology completed and qualified through test and demonstration	Final phase of technology development; validation of technical performance and compliance with design specifications (Initial commercial trials)	Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before finalizing the design? For process technologies, the typical capacity of a demonstration plant can be between 1% to 10% the one required for a commercial-size implementation.
9	Actual technology proven through successful operations	Actual commercial application of the technology in its final form and under real world conditions (Commercial trials).	Operational commissioning reports.

Target use cases

These emission data are for information purposes only to give an indication of concentration measurement range requirements and operating conditions. They are not necessarily representative of Rio Tinto facilities emissions data.

Green coke calciner

Cold outlet

Contaminant	Concentration (mg/Rm^3)
SO_2	[0 - 10]
NO_x	[0-10]
TPM	[0 - 250]
CO (ppmv D.B.)	[0 - 50]
CO_2 (% v/v D.B.)	[0 – 2]
Operating conditions	**Value**
Temperature (°C)	[75 – 115]
Flow (m^3/h)	[15 000 – 35 000]
Humidity (% v/v W.B.)	[40 – 70]
Speed (m/s)	[2 – 30]
Static pressure (in. H2O)	[-0.5 – 0]

Hot outlet

Contaminant	Concentration (mg/Rm^3)
SO_2	[0 - 5000]
NO_x	[0 - 500]
TPM	[0 - 300]
CO (ppmv D.B.)	[0 - 50]
CO_2 (% v/v D.B.)	[0 – 10]
Operating conditions	**Value**
Temperature (°C)	[800 – 1250]
Flow (m^3/h)	[150 000 – 750 000]
Humidity (% v/v W.B.)	[0 – 15]
Speed (m/s)	[10 – 30]
Static pressure (in. H2O)	[-0.5 – 0]

- Without energy recuperation

Contaminant	Concentration (mg/Rm^3)
SO_2 (ppmv D.B.)	[0 - 2000]
NO_x	[0 - 500]
TPM	[0 - 100]
CO (ppmv D.B.)	[0 - 50]
CO_2 (% v/v D.B.)	[0 – 10]
Operating conditions	**Value**
Temperature (°C)	[170 - 210]
Flow (m^3/h)	[150 000 – 300 000]
Humidity (% v/v W.B.)	[0 – 25]
Speed (m/s)	[5 – 20]
Static pressure (in. H2O)	[-0.5 – 0]

- With energy recuperation

Anode baking furnace

Contaminant (mg/Rm^3)	Before treatment	After treatment
SO_2	[0 - 2000]	
Total fluorides	[0 - 500]	[0 - 10]
Gaseous fluorides	[0 - 500]	[0 - 5]
NO_x	[0-500]	
TPM	[0 - 500]	[0 - 20]
PAHs	[0 - 5]	[0 - 10]
CO (ppmv D.B.)	[0 - 1000]	
CO_2 (% v/v D.B.)	[0 5]	
Operating conditions	**Value**	
Temperature (°C)	[60 – 120]	
Flow (m^3/h)	[50 000 – 300 000]	
Humidity (% v/v W.B.)	[0 – 15]	
Speed (m/s)	[5 – 40]	
Static pressure (in. H2O)	[-0.5 – 0]	

Paste plant

Contaminant	Concentration (mg/Rm^3)
TPM	[0 - 50]
PAHs	[0 - 15]
Operating conditions	**Value**
Temperature (°C)	[15 – 75]
Flow (m^3/h)	[15 000 – 75 000]
Humidity (% v/v W.B.)	[0 – 5]
Speed (m/s)	[5 – 30]
Static pressure (in. H2O)	[-1 – 0]