China Adipic Acid Production Protocol

Draft Version 1.0

March 6, 2023

The draft of the China Adipic Acid Production Protocol has been adapted from the US Adipic Acid Production Protocol V1.0 adopted in September 2020. For transparency, tracked changes are present to show changes for application to the jurisdiction and comments indicate areas of focus for the workgroup and technical review process. Stakeholders should submit a Statement of Interest to participate in protocol development and/or provide comments during the public comment period (to be announced at a later date). For questions, please contact rmooney@climateactionreserve.org.

Acknowledgements

Staff (alphabetical)

Holly Davison
Craig Ebert
Rachel Mooney

Workgroup

The list of workgroup members below comprises all individuals and organizations that have advised the Reserve in developing this protocol. Their participation in the Reserve process is based on their technical expertise and does not constitute endorsement of the final protocol. The Reserve makes all final technical decisions and approves final protocol content. Note that not all members were involved in every protocol revision process and affiliations may have changed. For more information, see section 4.2.1 and 4.3 of the Reserve Offset Program Manual.

[Insert Participant Names] **[Insert Organization]**

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William Flederbach
Lauren Mechak
Tip Stama
Jordan Shustack
Scott Subler
Jim Winch
Kayla Carey

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Abbreviations and Acronyms

AAPP	Adipic Acid Production Protocol
AAP	Adipic acid plant
AE	Abatement efficiency
AOR	Ammonia Oxidation Reactor
ASTM	American Society for Testing and Material Information
CARB	California Air Resources Board
CCER	China Certified Emission Reduction
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CEMS	Continuous emission monitoring system
CFR	Code of Federal Regulations
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COI	Conflict of interest
CRT	Climate Reserve Tonne
DAHS	Data acquisition and handling system
EPA	U.S. Environmental Protection Agency
ERU	Emissions Reduction Unit
ETS	Emissions Trading Scheme
FTIR	Fourier transform infrared spectroscopy
GHG	Greenhouse gas
GWP	Global warming potential
HC	Hydrocarbon
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization

KA	Cyclohexanone (K)/cyclohexanol (A)
kg	Kilogram
kt	Kilotonne (or metric kiloton)
lb	Pound
m	Meter
Mg	Megagram
MW	MegaWatt
MWh	MegaWatt-hour
NDIR	Non-dispersive infrared sensor
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxide; refers to NO and NO_2
NOV	Notice of violation
NOVA	Notice of verification activities
NSCR	Non-selective catalytic reduction
N_2O	Nitrous oxide
O_2	Oxygen
QA/QC	Quality assurance and quality control
RA	Relative Accuracy
RATA	Relative accuracy test audit
RP	Reporting period
SCR	Selective catalytic reduction
Reserve	Climate Action Reserve
SSR	Source, sink, and reservoir
t	Tonne (or metric ton)
TRU	Thermal reduction unit

1 Introduction

The Climate Action Reserve (Reserve) Adipic Acid Production Protocol (AAPP) provides guidance to account for, report, and verify greenhouse gas (GHG) emission reductions associated with the installation and use of a nitrous oxide (N_2O) emission control technology to reduce N_2O emissions as a byproduct of adipic acid production. This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification and verification of GHG emission reductions associated with an adipic acid project.[1]

The Reserve is the most trusted, efficient, and experienced offset registry for global carbon markets. A pioneer in carbon accounting, the Reserve promotes and fosters the reduction in GHG emissions through credible market-based policies and solutions. As a high-quality offset registry for voluntary carbon markets, it establishes rigorous standards and issues under those standards. The Reserve also supports the California Cap-and-Trade Program. The Reserve is an environmental non-profit organization headquartered in Los Angeles, California with satellite offices around the world. For more information, please visit www.climateactionreserve.org.

Project developers that initiate N_2O abatement projects at adipic acid plants (AAPs) ("adipic acid projects") use this document to quantify and register GHG reductions with the Reserve. The protocol provides eligibility rules, methods to calculate reductions, performance-monitoring instructions, and procedures for reporting project information to the Reserve. Additionally, all project reports receive independent verification by ISO-accredited and Reserve-approved verification bodies. Guidance for verification bodies to verify reductions is provided in the Reserve Verification Program Manual[2] and Section 0 of this protocol.

[1] See the WRI/WBCSD GHG Protocol for Project Accounting (Part I, Chapter 4) for a description of GHG reduction project accounting principles.
[2] Available at http://www.climateactionreserve.org/how/verification/verification-program-manual/.

2 The GHG Reduction Project

2.1 Background

Hexanedioic acid is a compound commonly known as adipic acid~~, is among the top 50 synthetic chemicals produced in the United States each year. Current~~. In 2015, annual global production ~~is~~was estimated at ~~2.5~~over 3 million metric tons~~[3]. ~~, with China and the United States (U.S.) representing the two largest sources of global production.[4] Although growth of adipic acid production has slowed in the U.S., production in China is projected to grow at 5.5%, faster than any other nation.

The largest use for adipic acid is in the manufacture of nylon 6,6 polyamide via its reaction with 1,6-hexamethylenediamine. Nylon 6,6 polymer, discovered by W. H. Carothers in the early 1930s, is now used in carpets, tire cord, safety air bags, apparel, upholstery, auto parts, and in hundreds of other applications that impact our lives in many ways. [5]

Most adipic acid produced in the world today is manufactured from cyclohexane feedstock in a two-stage process. First, cyclohexane is air-oxidized to form either cyclohexanol (A) or a cyclohexanone (K)/cyclohexanol (A) mixture (KA). In the second stage, KA is reacted with nitric acid (HNO3) to produce adipic acid, which is then purified by crystallization. The HNO_3 oxidization of KA, however, creates N_2O as an unavoidable byproduct that is emitted in the facility's off gas. Adipic acid and N_2O are created in proportional molar ratios (i.e., for every molecule of adipic acid produced, a molecule of N_2O is produced as a byproduct.). The process is represented by the chemical reaction[6] in Figure 2.1 below. Nitric oxide (NO) is also produced in the HNO_3 oxidation step and is generally absorbed from the reaction off-gases and re-converted to nitric acid for recycling.[7]

$$(CH_2)_5CO\ [cyclohexanone] + (CH_2)_5CHOH\ [cyclohexanol] + wHNO_3 \rightarrow HOOC(CH_2)_4COOH\ [adipic\ acid] + xN_2O + yH_2O$$

Figure 2.1. Chemical Reaction to Produce Adipic Acid

Adipic acid production facilities can operate one or more Adipic Acid Plants (AAPs), where a plant encompasses a single process unit, i.e., the equipment and process used to produce adipic acid. Emissions from each plant at a facility are managed independently; process units at the same facility can operate under different conditions and have different emission controls in place.

[4] 360 Research Reports, "Global Adipic Acid Sales Market – Industry Reports," October 28, 2020, https://www.360researchreports.com/global-adipic-acid-sales-market-16617960.
[5] The Human Metabolomics Database, "Metabocard for Adipic Acid (HMDB0000448)," accessed September 12, 2019, http://www.hmdb.ca/metabolites/HMDB0000448#references.
[6] United States Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016."
[7] Castellan, A., Bart, J. C. J., & Cavallaro, S. (1991). Industrial production and use of adipic acid. *Catalysis Today*, *9*(3), 237-254.

Adipic acid N_2O abatement technology is similar to the abatement technology at nitric acid facilities.[8] However, unlike nitric acid production, adipic acid production cannot tolerate the associated pressure change with secondary abatement (abatement in the burner/ammonia oxidation reactor (AOR) where the reaction occurs). As a result, abatement is limited to tertiary abatement, installing technology to scrub the facility's waste of gas downstream of the oxidation reactor.

Many adipic acid plants (AAPs) in Western industrialized countries are fitted with some N_2O abatement technology. The most appropriate type of control technology is also typically highly facility specific. Control technology falls into four types of systems, as described in Table 2.1 below. Figure 2.2 (below) portrays a typical process flowsheet for the catalytic decomposition of N_2O, one of the four approved abatement methods in this protocol. ~~Nevertheless, in 2018, U.S. AAPs were still responsible for a reported 10.3 million metric tons of carbon dioxide equivalent (tCO_2e) emissions,[9] a value that has increased each year from the year prior since 2015, while U.S. adipic acid production has risen gradually by roughly 10% since 1990 to approximately 830,000 metric tons.[10]~~

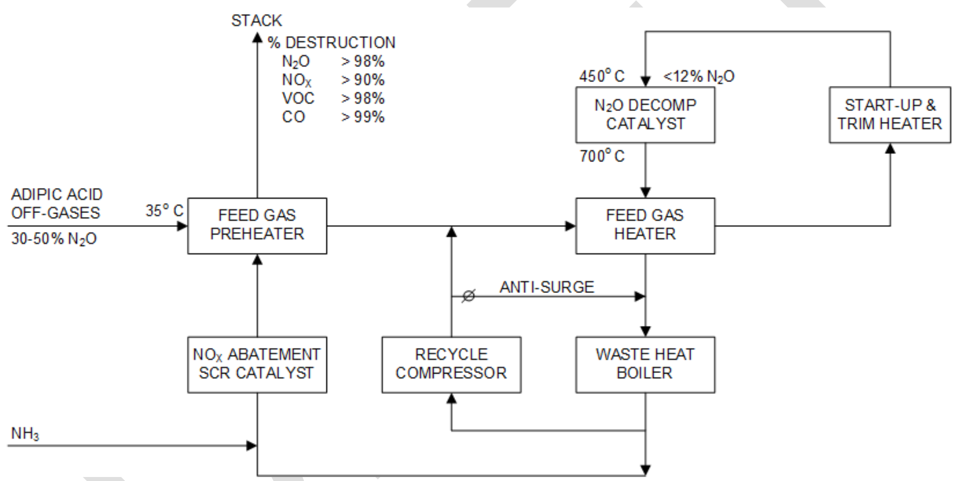

Figure 2.2. Typical Process Flowsheet for Catalytic Decomposition of N_2O

~~In the U.S., there is often a trade-off between N_2O abatement and the abatement of other potentially harmful pollutants, such as nitrogen oxide (NO_x). AAPs can send their off gas to an N_2O-specific control technology, such as a thermal reduction unit (TRU) (See Table 2.1), which reduces N_2O, but only has a limited capacity to reduce NO_x emissions. Alternatively, AAPs can~~

[8] Climate Action Reserve Nitric Acid Production Protocol Version 2.2, April 18, 2019. Available here: http://www.climateactionreserve.org/how/protocols/nitric-acid-production/

~~[9] U.S. Environmental Protection Agency (2019a). Greenhouse Gas Reporting Program (GHGRP) Facility Level Information on GHGs Tool (FLIGHT). Washington, D.C., October 3, 2019. Available at: https://ghgdata.epa.gov/ghgp/main.do#~~

~~[10] U.S. Environmental Protection Agency (2019b). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017. *EPA 430-R-19-001*. Washington, DC., April 11, 2019. Available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017~~

~~send their off gas to a NO_x-specific selective catalytic reduction (SCR) technology ("SCR de-NO_x unit"), which reduces NO_x emissions, but not N_2O emissions. Because N_2O emissions are not regulated, and NO_x emissions are regulated under the U.S. Clean Air Act (CAA) (Section 3.4.2), AAPs will only utilize their N_2O control technology, e.g., TRUs, when they're falling below their legal NO_x limits. In the absence of an offset system or a regulatory reason to reduce GHG emissions, facilities have no incentive to make a capital investment to adjust their operations to eliminate the NO_x/N_2O trade-off. With an incentive, an AAP could increase the abatement efficiency of existing N_2O control technology and/or install new N_2O control technology to abate the remaining N_2O emissions above current abatement levels.~~

Two facilities in China installed N_2O abatement equipment to participate in the Clean Development Mechanism (CDM) in 2007.[11,12] The projects certified over 1 billion Certified Emission Reductions (CERs) between 2008 and 2013, after which the projects ceased crediting. These CERs, however, faced controversy due to concerns of carbon leakage. Today, carbon market experts suggest that leakage can be mitigated through several measures, including a high baseline abatement level, which is employed by this protocol. Details around leakage and the history of CDM activity at China AAPs are discussed in detail in Appendix A.

Industrial N_2O emissions (including those from both adipic and nitric acid production processes) in China have increased fourfold between 2008 and 2018 to over 196 billion tonnes CO_2e.[13] Experts suggest incentivizing abatement could serve an important role in curtailing current N_2O emissions and preventing exponential growth in the emissions associated with the projected increase in adipic acid production. Voluntary investment in carbon credits represents a highly impactful mechanism to reduce large amounts of emissions in a region with few existing incentives and no anticipated regulatory requirements to abate.

2.2 Project Definition

For the purpose of this protocol, the adipic acid GHG reduction project is defined as 1) the installation and operation of a new, previously uninstalled N_2O abatement technology and/or 2) the enhancement of an existing control technology at a single AAP that results in the reduction of N_2O emissions that would otherwise have been vented to the atmosphere.

N_2O emissions can be abated by one of the four types of approved technologies listed in Table 2.1. Other control technologies that avoid N_2O emissions from the production of adipic acid not listed in Table 2.1 may also be permissible, pending review by and approval from the Reserve.

Table 2.1. Approved N_2O Control Technologies for Adipic Acid Projects

Abatement Type	Description	Example
Catalytic Destruction	Destroy N_2O using a catalyst – selective catalytic reduction (SCR) or non-selective catalytic reduction (NSCR)	Noble or precious metal catalysts
Thermal Destruction	Destroy N_2O using flame burners with pre-mixed CH_4 or natural gas	Thermal Reduction Units (TRUs)

[11] UNFCCC CDM, "Project: 1083 N2O Decomposition Project of Henan Shenma Nylon Chemical Co., Ltd - Crediting Period Renewal Reques," accessed August 2, 2022, https://cdm.unfccc.int/Projects/DB/DNV-CUK1176373789.59/view.
[12] UNFCCC CDM, "Project: 1238 N2O Decomposition Project of PetroChina Company Limited Liaoyang Petrochemical Company - Crediting Period Renewal Request," accessed August 2, 2022, https://cdm.unfccc.int/Projects/DB/DNV-CUK1184240745.87/view.
[13] Rui Feng and Xuekun Fang, "Devoting Attention to China's Burgeoning Industrial N2O Emissions," *Environmental Science & Technology* 56, no. 9 (May 3, 2022): 5299–5301, https://doi.org/10.1021/acs.est.1c06976.

Recycle to Nitric Acid	Recycle N_2O to create nitric acid by burning the gas at high temperatures with steam	Nitrogen recycling adiabatic reactor
Recycling / Utilization Technologies	Utilize N_2O as a reactant or input to produce other products	Using N_2O off gas as an oxidant to produce phenol from benzene

For the purpose of this protocol, an "enhancement" constitutes the implementation of a capital investment expenditure to improve the N_2O abatement efficiency of an existing control technology compared to historical N_2O abatement efficiency levels (See Section 3.4.1 and Section 5.1). Enhancements may range from improvements or changes to equipment in the AAP that augment control technology effects on emissions to full system retrofits but *must require* an upfront cost for implementation.

~~Projects may only be implemented at existing, relocated, or upgraded AAPs. The protocol does not apply to new AAPs constructed on or after September 30, 2020 with the exception of new AAPs for which a permit application for construction was submitted to the appropriate regulating authorities prior to September 30, 2020.~~

2.3 The Project Developer

The "project developer" is an entity that has an active account on the Reserve, submits a project for listing and registration with the Reserve, and is ultimately responsible for all project reporting and verification. Project developers may be owners of adipic acid facilities, entities that specialize in project development, or N_2O abatement technology suppliers. The project developer must have clear ownership of the project's GHG reductions. Ownership of the GHG reductions must be established by clear and explicit title, and the project developer must attest to such ownership by signing the Reserve's Attestation of Title form.[14] The project developer must be the entity with liability for the emissions of the AAP (i.e., the entity named on the facility's operating permit, unless the rights to the emissions reductions have been transferred to another entity.

[14] Attestation of Title form available at http://www.climateactionreserve.org/how/program/documents/.

3 Eligibility Rules

Projects that meet the definition of a GHG reduction project in Section 2.2 must fully satisfy the following eligibility rules in order to register with the Reserve.

Eligibility Rule I:	Location	→	*~~U.S. and its tribal lands and territories~~All locations in China except regions with ETS covering N_2O*
Eligibility Rule II:	Project Start Date	→	*No more than 12 months prior to project submission*
Eligibility Rule III:	Project Crediting Period	→	*Emission reductions may only be reported during the crediting period; the crediting period may be renewed one time*
Eligibility Rule IV:	Additionality	→	*Meet performance standard*
		→	*Exceed legal requirements*
Eligibility Rule V:	Regulatory Compliance	→	*Compliance with all applicable laws*

3.1 Location

Only projects located at AAPs in ~~the United States (U.S.) and on U.S. tribal lands~~China are eligible to register with the Reserve. Projects in the U.S. should use the U.S. Adipic Acid Production Protocol. Regions in China subject to the Emissions Trading Scheme (ETS) that cover N_2O abatement are excluded under this protocol.

3.2 Project Start Date

The project start date is defined as the date on which production first commences after the installation or enhancement, as well as associated initial start-up testing, of specific N_2O control technology, as defined in Section 2.2. For the purposes of this protocol, a project is eligible if N_2O control technology exists at the AAP prior to the project start date, but the installation of a new N_2O control technology or enhancement of the existing one results in additional N_2O abatement.

The initial start-up testing is defined as a period of time between the completion of the installation or enhancement of the abatement technology and the start of the initial reporting period. The start-up testing is limited to 9 months for the purpose of testing the successful implementation of the technology.

Commented [A1]: Review Language for start up testing

To be eligible, the project must be submitted to the Reserve no more than 12 months after the project start date.[15] Projects may always be submitted for listing by the Reserve prior to their start date. For projects that are transferring to the Reserve from other offset registries, start date guidance can be found in the Reserve Offset Program Manual.

[15] Projects are considered submitted when the project developer has fully completed and filed the appropriate Project Submittal Form, available at http://www.climateactionreserve.org/how/program/documents/.

3.3 Project Crediting Period

The crediting period for projects under this protocol is ten years. At the end of a project's first crediting period, project developers may apply for eligibility under a second crediting period. However, the Reserve will cease to issue Climate Reserve Tonnes (CRTs) for GHG reductions if at any point in the future, N_2O abatement becomes legally required, as defined by the terms of the legal requirement test (see Section 3.4.2). Thus, the Reserve will issue CRTs for GHG reductions quantified and verified according to this protocol for a maximum of two ten-year crediting periods after the project start date, or until the date the project activity is required by law, including under an emissions cap or other ETS.

The project crediting period begins at the project start date regardless of whether sufficient monitoring data are available to verify GHG reductions. Projects will be eligible to apply for a second crediting period, provided the project meets the eligibility requirements of the most current version of the protocol at the time of such application. If a project developer wishes to apply for eligibility under a second, ten-year crediting period, they must do so no sooner than six months before the end date of the initial crediting period and no later than the last day of the crediting period.

A project may be eligible for a second crediting period even if the project has failed to maintain continuous reporting up to the time of applying for a second crediting period, provided the project developer elects to take a zero-credit reporting period for any period for which continuous reporting was not maintained.[16] The second crediting period shall begin on the day following the end date of the initial crediting period.

3.4 Additionality

The Reserve strives to register only projects that yield surplus GHG reductions that are additional to what would have occurred in the absence of a carbon offset market.

Projects must satisfy the following tests to be considered additional:

1. The performance standard test
2. The legal requirement test

3.4.1 The Performance Standard Test

In developing performance standards, the Reserve considers financial, economic, social, and technological drivers that may affect decisions to undertake a particular project activity. Standards are specified such that the large majority of projects that meet the standard are unlikely to have been implemented due to these other drivers. In other words, incentives created by the carbon market are likely to have played a critical role in decisions to implement projects that meet the performance standard.[17]

Projects pass the performance standard test by meeting a performance threshold, i.e., a standard of performance applicable to all adipic acid projects, established by this protocol. To assess additional performance, this protocol uses a technology-specific threshold: the

[16] See zero-credit reporting period guidance and requirements in the Reserve Offset Program Manual at http://www.climateactionreserve.org/how/program/program-manual/. See more information about reporting periods in Section 7.3 of this protocol.
[17] See "Additionality Determinations" in the Reserve Offset Program Manual.

installation and/or enhancement of an N_2O control system(s) at an AAP to improve and maintain improved levels of N_2O abatement efficiency better than business-as-usual levels (Section 5.1).

Both new installation and enhancement adipic acid projects face financial barriers to project implementation, with new investment costs estimated to range from roughly 10.6 million USD to 17.25 million USD and increased operating costs estimated to range from roughly 1.33 to 2.0 million USD per year.[18,19] Therefore, adipic acid projects automatically pass the performance standard test by either installing a new approved N_2O control technology not previously installed at the AAP and/or enhancing an existing one, as displayed in Table 2.1 and listed again below:

1. a catalytic destruction system;
2. a thermal destruction system;
3. a system that recycles captured N_2O into recovered nitric acid and avoids N_2O emissions upstream from the production of conventional nitric acid;
4. a system that recycles or utilizes captured N_2O as a reactant or production input and avoids direct N_2O emissions; or
5. another control technology that avoids N_2O emissions from the production of adipic acid, pending Reserve approval.

For new installations, both the installation of a technology completely new to the AAP and/or the installation of an additional technology (e.g., a second TRU) are eligible, so long as the technology was not installed and in operation at any point prior to the project start date, excluding a start-up period.

In the instance that a site has multiple AAPs at a single facility, start date and eligibility is assessed on a per-AAP basis. However, project developers that control multiple AAPs are subject to leakage requirements as described in Section 5.1.4 "Mitigating Leakage".

The performance standard test is applied as of the project start date and is evaluated at the project's initial verification. Once a project is registered, it does not need to be evaluated against the performance standard test of any future version of the protocol for the duration of its first crediting period. However, if the project chooses to upgrade to a newer version of the protocol, it must meet the performance standard test of that version of the protocol, applied as of the original project start date. Similarly, if a project developer wishes to apply for a second crediting period, the project must meet the eligibility requirements of the most current version of this protocol, including any updates to the performance standard test, applied as of the project start date.

3.4.2 The Legal Requirement Test

All projects are subject to a legal requirement test to ensure that the GHG reductions achieved by a project would not otherwise have occurred due to federal, provincial or local regulations, or other legally binding mandates. A project passes the legal requirement test when there are no laws, statutes, rules, regulations, ordinances, court orders, governmental agency actions, enforcement actions, environmental mitigation agreements, permitting conditions, permits or other legally binding mandates (e.g., cap-and-trade programs, emissions trading schemes) requiring the abatement of N_2O at the project site.

[18] Schneider et al., 2010. Industrial N_2O Projects Under the CDM: Adipic Acid – A Case of Carbon Leakage? Stockholm Environment Institute. October 9, 2010.
[19] All currencies were converted from EURs to 2010 U.S. Dollars (USD) with an annual average conversion factor of 1.33 https://www.x-rates.com/average/?from=EUR&to=USD&amount=1&year=2010.

To satisfy the legal requirement test, project developers must submit a signed Attestation of Voluntary Implementation form[20] prior to the commencement of verification activities each time the project is verified (see Section 0). In addition, the project's Monitoring Plan (Section 6) must include procedures that the project developer will follow to ascertain and demonstrate that the project at all times passes the legal requirement test.

As of the Effective Date of this protocol, the Reserve could identify no existing federal, provincial or local regulations that obligate AAPs to abate N_2O emissions in China. However, the following sections evaluate existing regulations that *could* regulate N_2O emissions from AAPs in the future. If an eligible project begins operation at a plant that later becomes subject to a regulation, ordinance, or permitting condition that calls for the abatement of N_2O, emission reductions may be reported to the Reserve up until the date that N_2O is legally required to be abated. Similarly, if the AAPs' N_2O emissions are included under an emissions cap (e.g., under a local, provincial, or federal cap-and-trade program), emission reductions may likewise be reported to the Reserve until the date that the emissions cap takes effect.

3.4.2.1 China Emissions Trading System

China's national Emissions Trading System (ETS), launched in 2021, currently covers the power sector only. By 2025, China plans to expand coverage to several other sectors including petrochemicals, chemicals, building materials, iron and steel, non-ferrous metals, paper, and domestic aviation.[21] Notably, coverage is limited to CO_2 emissions only – meaning other non-CO_2 gases including N_2O are not currently part of the coverage plan. This is consistent with China's Paris Agreement pledge, which also only covers CO_2.[22] AAPs in China are therefore expected to experience some compliance obligations associated with any CO_2 created at the facility, but the N_2O emissions in-scope for this Protocol will not be covered under the national ETS.

Alongside the development of the national ETS, there are eight regional carbon markets in China with variable rules and requirements. Only one municipality, Chongquing, covers N_2O emissions as part of their system. AAPs with N_2O emissions covered in this municipal ETS are not eligible for crediting. It is expected that the national ETS will supersede regional requirements in the future.

3.4.2.2 China Certified Emission Reduction Scheme (CCER)

China's Certified Emission Reduction Scheme (CCER), launched in 2015, is a carbon offset system hosted by China's Ministry of Ecology and Environment. CCERs can be used to meet up to 5% of a facility's compliance obligations under the national ETS, or in voluntary or semi-voluntary systems such as the International Civil Aviation Organization's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). However, in 2017 the CCER system halted project registration due to concerns around standardization and data collection, as well

[20] Attestation forms are available at http://www.climateactionreserve.org/how/program/documents/.
[21] International Energy Agency, "China's Emissions Trading Scheme," June 2020, 115.
[22] People's Republic of China, "China's Achievements, New Goals and New Measures for Nationally Determined Contributions," October 28, 2021, https://unfccc.int/sites/default/files/NDC/2022-06/China%E2%80%99s%20Achievements%2C%20New%20Goals%20and%20New%20Measures%20for%20Nationally%20Determined%20Contributions.pdf.

as fraudulent reporting.[23] Although some sources indicate the program was primed to re-launch in 2022, the actual timeline remains unknown.

The original CCER program permitted a wide range of project types to utilize CDM protocols and program design features. A re-launch of the CCER program is expected to limit eligible project types to renewable energy, forestry, and methane utilization. N_2O abatement from AAPs is not expected to be eligible. However, a voluntary CCER program that allows for N_2O abatement projects may not immediately preclude the ability of AAPs to generate CRTs unless jurisdictional guidance says otherwise.

3.5 Regulatory Compliance

As a final eligibility requirement, project developers must attest that project activities do not cause material violations of applicable laws (e.g., air, water quality, safety, etc.). To satisfy this requirement, project developers must submit a signed Attestation of Regulatory Compliance form[24] prior to the commencement of verification activities each time the project is verified. Project developers are also required to disclose in writing to the verifier any and all instances of legal violations – material or otherwise – caused by the project activities.

A violation should be considered to be "caused" by project activities if it can be reasonably argued that the violation would not have occurred in the absence of the project activities. If there is any question of causality, the project developer shall disclose the violation to the verifier.

If a verifier finds that project activities have caused a material violation, then CRTs will not be issued for GHG reductions that occurred during the period(s) when the violation occurred. Individual violations due to administrative or reporting issues, or due to "acts of nature," are not considered material and will not affect CRT crediting. However, recurrent administrative violations directly related to project activities may affect crediting. Verifiers must determine if recurrent violations rise to the level of materiality. If the verifier is unable to assess the materiality of the violation, then the verifier shall consult with the Reserve.

[23] Xu Nan, "Rebooting China's Carbon Credits: What Will 2022 Bring?," *China Dialogue* (blog), June 9, 2022, https://chinadialogue.net/en/climate/rebooting-chinas-carbon-credits-what-will-2022-bring/.
[24] Attestation forms are available at http://www.climateactionreserve.org/how/program/documents/.

4 The GHG Assessment Boundary

The GHG Assessment Boundary delineates the GHG sources, sinks, and reservoirs (SSRs) that must be assessed by project developers in order to determine the net change in emissions caused by an adipic acid project. As the project may include existing N_2O control technologies that are either replaced, expanded, or absorbed into new treatment regimes, most of the SSRs are evaluated in both the baseline and project scenarios.

Figure 4.1 illustrates all relevant GHG SSRs associated with adipic acid project activities and delineates the GHG Assessment Boundary.

Table 4.1 provides greater detail on each SSR and justification for the inclusion or exclusion of certain SSRs and gases from the GHG Assessment Boundary.

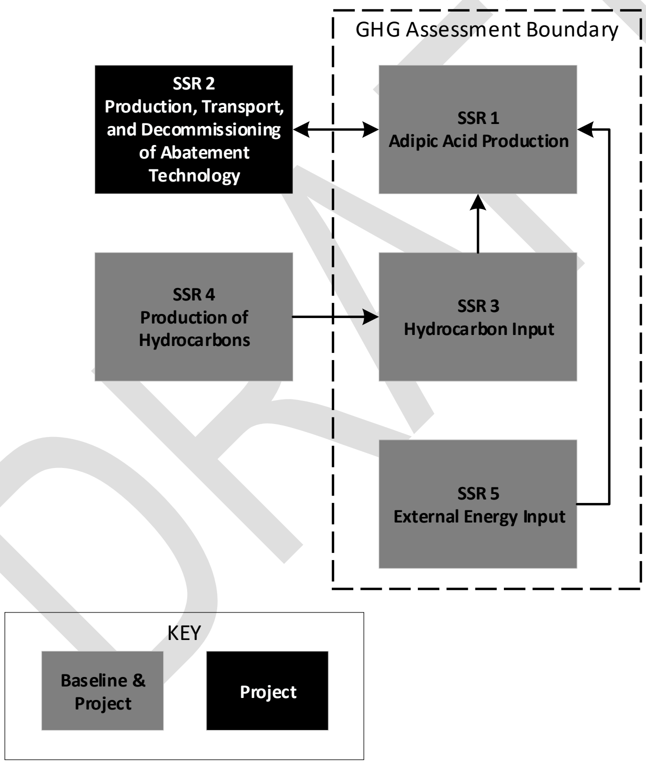

Figure 4.1. General illustration of the GHG Assessment Boundary

Table 4.1. Description of all Sources, Sinks, and Reservoirs

SSR	Source Description	Gas	Included (I) or Excluded (E)	Quantification Method	Baseline (B) or Project (P)	Justification/Explanation
1	Adipic acid production process unit (HNO3 oxidation of KA to/through stack)	CO_2	E	N/A	B, P	Excluded, as project activity is unlikely to impact emissions relative to baseline activity.
		CH_4	E	N/A	B, P	Excluded, as project activity is unlikely to impact emissions relative to baseline activity.
		N_2O	I	N_2O sampled before and after destruction	B, P	N_2O from production reaction is a primary effect and a major emission source.
2	Emissions from production, transport, and decommissioning of the N_2O abatement device	CO_2	E	N/A	P	Excluded as the upstream and downstream emissions related to the N_2O abatement device(s) are one-time emissions occurring off-site and outside the control of the AAP and are considered insignificant given the long project life.
		CH_4				
		N_2O				
3	Hydrocarbon used as reducing agent, for reheating the off gas, or for combustion fuel for thermal reduction units (*if applicable*)	CO_2	I	GHG emissions based on additional amounts of reducing agent or energy used during the project	B, P	If hydrocarbons are used as a reducing agent to enhance efficiency of the N_2O abatement system, additional GHG emissions from the project activity will occur.
		CH_4	I	GHG emissions based on additional amounts of reducing agent or energy used during the project		
		N_2O	E	N/A	B, P	Excluded as project activity only leads to CO_2 and/or CH_4 emissions.

SSR	Source Description	Gas	Included (I) or Excluded (E)	Quantification Method	Baseline (B) or Project (P)	Justification/Explanation
4	Emissions related to the production of hydrocarbon (*if applicable*)	CO_2	E	N/A	B, P	Excluded as GHG emissions related to the production of hydrocarbons used as reducing agent are one-time emissions occurring off-site and outside the control of the AAP and are considered insignificant given the long project life.
		CH_4				
		N_2O				
5	Emissions from increased external energy use (*if applicable*)	CO_2	I	GHG emissions based on additional amounts of energy used during the project	B, P	If any additional energy is used as a result of the project beyond what is required in the baseline (e.g., increased utilization of N_2O abatement technology), additional GHG emissions from the project activity will occur and may be significant.
		CH_4				
		N_2O				

5 Quantifying GHG Emission Reductions

GHG emission reductions from an adipic acid project are quantified by comparing actual project emissions to the calculated baseline emissions. Baseline emissions are an estimate of the GHG emissions from sources within the GHG Assessment Boundary (see Section 4) that would have occurred in the absence of the project. Project emissions are actual GHG emissions that occur at sources within the GHG Assessment Boundary. Project emissions must be subtracted from the baseline emissions to quantify the project's total net GHG emission reductions (Equation 5.1). GHG emission reductions must be quantified and verified on at least an annual basis. Project developers may choose to quantify and verify GHG emission reductions on a more frequent basis if they desire. The length of time over which GHG emission reductions are periodically quantified and reported is called the "reporting period." The length of time over which GHG reductions are verified is called a "verification period."[25]

Equation 5.1. Calculating GHG Emission Reductions

$$ER = BE - PE$$

Where,			Units
ER	=	Total emission reductions for the reporting period	tCO_2e
BE	=	Total baseline emissions for the reporting period, from all SSRs in the GHG Assessment Boundary, see Equation 5.2	tCO_2e
PE	=	Total project emissions for the reporting period, from all SSRs in the GHG Assessment Boundary, see Equation 5.55	tCO_2e

~~As of this writing, the Reserve relies on values for global warming potential (GWP) of non-CO_2 GHGs published in the IPCC Fourth Assessment Report: Climate Change 2007 (AR4).[26] The values relevant for this protocol are provided in Table 5.1 below, and are to be used for all nitric acid production projects unless and until the Reserve issues written guidance to the contrary.~~

~~**Table 5.1.** 100-year Global Warming Potential for Non-CO_2 GHGs~~

~~Non-CO_2 GHG~~	~~100-Year GWP (CO_2e)~~
~~Methane (CH_4)~~	~~25~~
~~Nitrous Oxide (N_2O)~~	~~298~~

[25] For more information on reporting and verification periods, see Section 7.3 of this protocol.
~~[26] Available here: https://ipcc.ch/publications_and_data/publications_and_data_reports.shtml.~~

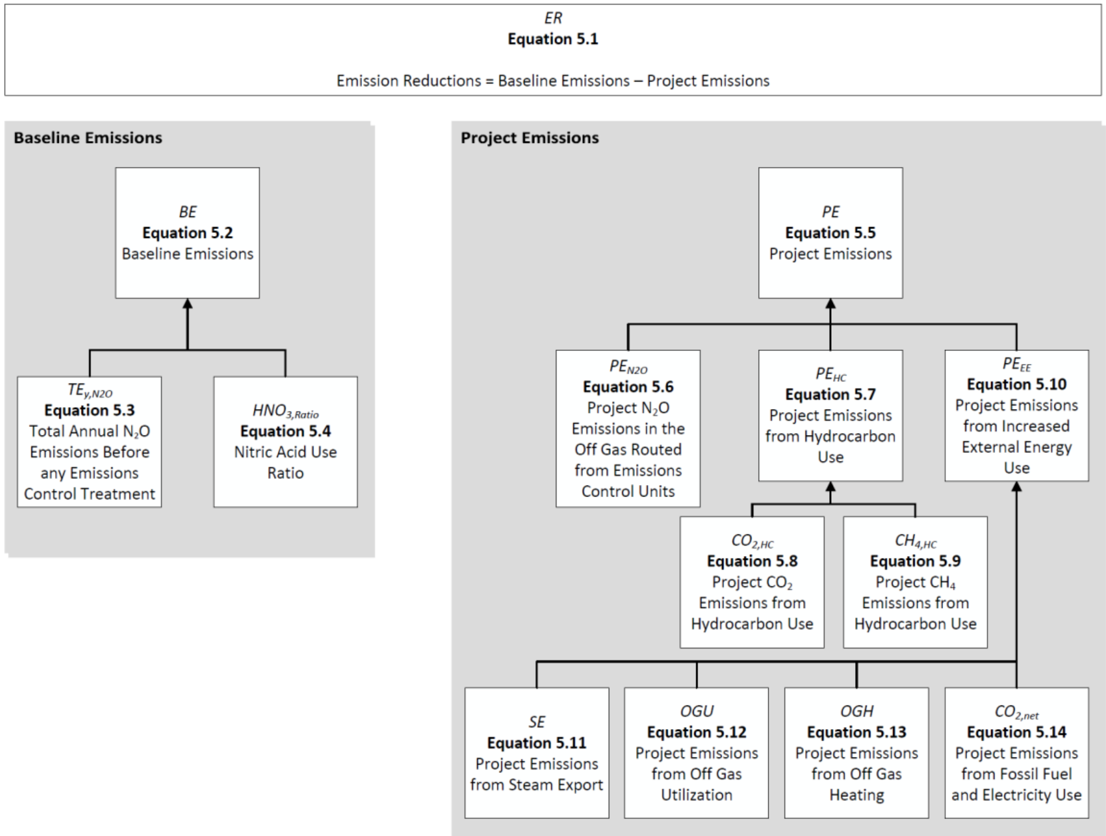

Figure 5.1. Organizational Chart of Equations for Adipic Acid Projects

5.1 Quantifying Baseline Emissions

Baseline emissions represent the GHG emissions within the GHG Assessment Boundary that would have occurred in the absence of the adipic acid project. Total baseline emissions for the reporting period are estimated by calculating and summing the emissions from all relevant baseline SSRs that are included in the GHG Assessment Boundary (as indicated in Figure 4.1 and Table 4.1). The calculation of baseline emissions in Equation 5.2 requires inputs related to adipic acid production, the project emissions prior to destruction in the reporting period, and nitric acid recovery ratios.

Equation 5.2. Baseline Emissions

$$BE = \cancel{[(TE_{RP,N_2O} \times (1 - AE_{BL})) + (HNO_{3\,Ratio} \times AA_{RP} \times 0.0025)]}[(TE_{RP,N_2O} \times 0.1) + (HNO_{3\,Ratio} \times AA_{RP} \times 0.0025)] \times GWP_{N_2O} \times (1 - ld)$$

Where,			Units
BE	=	Baseline emissions during the reporting period	tCO_2e
$TE_{RP,N2O}$	=	Measured total N_2O emissions in off gas during the reporting period before any emissions control treatment (e.g., abatement), see Equation 5.3	tN_2O
~~AE_{BL}~~	~~=~~	~~Baseline N_2O abatement efficiency; either static ($AE_{BL,S}$) or dynamic ($AE_{BL,D}$), see Equation 5.3 or Section 5.1.2~~	~~%~~
HNO_{3Ratio}	=	Ratio of HNO_3 to AA, see Equation 5.4.	$tHNO_3/tAA$
AA_{RP}	=	Measured adipic acid production in the project reporting period	tAA
0.0025	=	IPCC emission factor for N_2O emissions per HNO_3 production	$tN_2O/tHNO_3$
GWP_{N2O}	=	Global warming potential of N_2O[27]	tCO_2e/tN_2O
ld	=	The proportion of adipic acid production in the reporting period assessed as being due to leakage into the project facility	

5.1.1 Total N_2O Emissions without Abatement

Error! Reference source not found. is used to determine the total N_2O emissions directly measured in the off gas during the current reporting period ($TE_{RP,N2O}$ in Equation 5.2~~) and during each year, BLy, of the baseline look-back period ($TE_{BLy,N2O}$ in Equation 5.3) to determine the total amount of N_2O produced before any N_2O emissions are destroyed.~~). The Project Developer must account for any off gas flowing to the N_2O emission control units (e.g., thermal reduction unit, adiabatic reactor, absorption media, or other N2O abatement device) as well as any off-gas flow that is unabated (e.g., selective catalytic reduction unit or other non-N2O abating device), inclusive of any bypassed and direct venting of N_2O emissions.

Direct measurement results can be distorted before and after periods of downtime or malfunction of the monitoring system. To eliminate such extremes and to ensure that data during the baseline period are representative of standard operating conditions, the following statistical valuation is to be applied to the data series of N_2O concentration ($N_2O_{y,conc,cu}$ and

[27] Refer to section 2.6.1 of the Reserve Offset Program Manual and relevant policy memos for the most recent GWP value.

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$N_2O_{y,conc,ncu}$) and gas volume flow in the off gas ($F_{y,cu}$ and $F_{y,ncu}$) when calculating the baseline. Operating hours are not adjusted.

1. Calculate the sample means (x);
2. Calculate the sample standard deviations;
3. Calculate the 95% confidence intervals (equal to 1.96 times the standard deviations);
4. Eliminate all data that lie outside the 95% confidence intervals; and
5. Calculate the new sample means from the remaining values (volume flow rate in the off gas ($F_{y,cu}$ and $F_{y,ncu}$), and N_2O concentration in the off gas ($N_2O_{y,conc,cu}$ and $N_2O_{y,conc,ncu}$))

Note that 'operating hours' are defined to include any period of time where there is any production of adipic acid and/or N_2O. Any periods where there is production of either, would need to remain in the dataset.

Equation 5.3. Total Annual N_2O Emissions Before any Emissions Control Treatment

$$TE_{y,N_2O} = \sum_{cu}(F_{y,cu} \times N_2O_{y,conc,cu} \times OH_{y,cu}) + \sum_{ncu}(F_{y,ncu} \times N_2O_{y,conc,ncu} \times OH_{y,ncu})$$

Where,			Units
$TE_{y,N2O}$	=	Measured total N_2O emissions in off gas during the current reporting period *RP* ~~or the year *BLy* of the baseline look-back period before any emissions control treatment (e.g., destruction)~~	tN_2O
$F_{y,cu}$	=	Volume flow rate in the off gas during the ~~current~~ reporting period *RP* ~~or the year *BLy* of the baseline look-back period~~ to the N_2O control unit, *cu*	m^3/hour
$F_{y,ncu}$	=	Volume flow rate in the off gas during the ~~current~~ reporting period *RP* ~~or the year *BLy* of the baseline look-back period~~ to the non-N_2O control unit, *ncu*	m^3/hour
$N_2O_{y,conc,cu}$	=	N_2O concentration in the off gas during the ~~current~~ reporting period *RP* ~~or the year *BLy* of the baseline look-back period~~ to the N_2O control unit, *cu*	tN_2O/m^3
$N_2O_{y,conc,ncu}$	=	N_2O concentration in the off gas during the ~~current~~ reporting period *RP* ~~or the year *BLy* of the baseline look-back period~~ to the non-N_2O control unit, *ncu*	tN_2O/m^3
$OH_{y,cu}$	=	Operating hours in the ~~current~~ reporting period *RP* ~~or~~by the ~~year *BLy* of the baseline look-back period by~~ N_2O control unit, *cu*	hours
$OH_{y,ncu}$	=	Operating hours in the ~~current~~ reporting period *RP* ~~or~~by the ~~year *BLy* of the baseline look-back period by~~ non-N_2O control unit, *ncu*	hours
cu	=	Each installed N_2O emissions control unit (e.g., thermal reduction unit, adiabatic reactor, absorption media, or other N_2O abatement device)	
ncu	=	Each installed non-N_2O emissions control unit (e.g., selective catalytic reduction unit or other non-N_2O abating device), inclusive of any bypassed and direct venting of N_2O emissions	

~~Next, to determine the amount of N_2O that is destroyed in the given year, *BLy*, in the static baseline look-back period, Equation 5.5 measures the amount of off gas directed to each control unit and multiplies it by the efficiency of the respective N_2O control unit. $N_2O_{y,conc,cu}$ and $F_{y,cu}$ following the elimination of outliers must be used, as described above for Equation 5.4.~~

~~**Equation 5.5**. Annual Abated Baseline N₂O Emissions~~

$$\cancel{RE_{BLy,N_2O} = \sum_{cu} (F_{BLy,cu} \times N_2O_{BLy,conc,cu} \times OH_{BLy,cu}) \times E_{cu}}$$

~~*Where,*~~			~~Units~~
$\cancel{RE_{BLy,N2O}}$	=	~~Total N_2O reduced and destroyed by the N_2O emission control unit in year *BLy* of the baseline look-back period~~	~~tN_2O~~
$\cancel{F_{BLy,cu}}$	=	~~Volume flow rate in the off gas flowing into the N_2O control unit during year *BLy* of the baseline look-back period~~	~~m^3/hour~~
$\cancel{N_2O_{BLy,conc,cu}}$	=	~~N_2O concentration in the off gas flowing into the N_2O control unit during year *BLy* of the baseline look-back period~~	~~tN_2O/m^3~~
$\cancel{OH_{BLy,cu}}$	=	~~Operating hours in year *BLy* of the baseline look-back period of the N_2O control unit~~	~~hours~~
$\cancel{E_{cu}}$	=	~~N_2O destruction efficiency, expressed as a fraction of total N_2O destroyed, of the N_2O emissions control unit~~	
~~*cu*~~	=	~~Each installed N_2O emissions control unit (e.g., thermal reduction unit, adiabatic reactor, absorption media, or other N_2O abatement device)~~	

~~5.1.2 Dynamic Baseline Approach~~

~~To follow the dynamic baseline approach, project developers *must* submit data for review and approval by the Reserve before a dynamic baseline N_2O AE can be employed in the calculation of emission reductions. Once the dynamic AE regression has been developed and approved by the Reserve, it will be fixed for the duration or remainder of the initial crediting period. If a project developer wishes to apply for a second crediting period, the project must meet the baseline requirements of the most current version of this protocol, applied as of the project start date~~

~~This protocol utilizes a baseline look-back period defined as *at least* the five most recent calendar years of operation prior to the project start date. Due to significant structural changes in the U.S. adipic acid production industry, it is not appropriate to use data prior to 2015. Therefore, if a project was to start in 2020, the project must use a 5-year historical baseline look-back period, starting in 2015. If a project was to start in 2021, the project must use a 6-year historical baseline look-back period, starting in 2015, etc.~~

~~To set the dynamic baseline, the project developer must establish quarterly AE values using all available measurements of N_2O abatement and adipic acid production during the given quarter, in order to establish an AAP-specific N_2O abatement and adipic acid production trend (e.g., lower levels of N_2O abatement with greater levels of adipic acid production).~~

~~Equation 5.4 and Equation 5.5 must be used to calculate *Total Quarterly Baseline N_2O Emissions Before any Emissions Control Treatment* and *Quarterly Abated Baseline N_2O Emissions,* respectively, but in the case of the dynamic baseline each will be calculated for every quarter of the historical baseline period (instead of the annual calculations used for the static approach). Just as in calculations for the static baseline, extreme values must be removed according to the guidance preceding Equation 5.4.~~

~~The quarterly baseline AE represents the percent of the AAP's N_2O emissions that are destroyed by the N_2O emission control unit measured daily during each quarter within the historical baseline look-back period. Each quarterly baseline AE must be calculated using the full amount of N_2O produced (following the elimination of extreme values as set out in Section~~

~~5.1.1 above, using the guidance preceding Equation 5.4) during each quarter of the dynamic baseline look-back period prior to any destruction (using Equation 5.4 above, and substituting each quarter of data for years in that equation) and the amount of N_2O reduced and/or destroyed in the given period of time of the dynamic baseline look back period (using Equation 5.5 above, and substituting each quarter of data for years in that equation).[28]~~

~~The Reserve will be looking for a regression with an adjusted R-squared value of at least 0.8, but encourages project developers to reach out during the development of such regressions to ensure that the dynamic baseline will be acceptable.~~

~~In order for the baseline to be dynamically tied to the amount of actual N_2O emissions created by an AAP in a project reporting period, the AAP-specific baseline abatement efficiency ($AE_{BL,D}$), derived from the Reserve-approved regression) must be multiplied by total N_2O emissions in a given reporting period prior to any abatement (TE_{N2O} using Equation 5.4 above, substituting reporting period data for the annual data used in that equation). However, the correct AE_{BL} value to use in the calculation of baseline emissions (Equation 5.2) is dependent on the results of a Reserve-approved regression analysis using the following:[29]~~

- ~~Maximum and minimum periodic baseline N_2O abatement efficiencies ($AE_{t,MAX}$[30] and $AE_{t,MIN}$, respectively) over the dynamic baseline look-back period;~~
- ~~Maximum and minimum periodic baseline amounts of adipic production ($AA_{t,MAX}$ and $AA_{t,MIN}$, respectively) over the dynamic baseline look-back period; and~~
- ~~The amount of adipic acid produced in a project reporting period (AA_{RP})~~

~~The project developer must calculate the AE for each quarter, *t*, of the dynamic baseline look-back period and identify the periodic maximum abatement efficiency ($AE_{t,MAX}$) and periodic minimum abatement efficiency ($AE_{t,MIN}$) obtained over the dynamic baseline look-back period. The project developer must also identify the maximum amount of adipic acid ($AA_{t,MAX}$) and minimum amount of adipic acid ($AA_{t,MIN}$) produced during any given quarter within the dynamic baseline look-back period, which may or may not be from the same quarter, *t*, (e.g., day) as the maximum and minimum abatement efficiencies; i.e., baseline N_2O abatement efficiency levels are decoupled from baseline adipic acid production values. There are also a few other important conditions that apply, as listed below:~~

- ~~Each quarterly AE value is always lower bound by $AE_{t,MIN}$~~
- ~~Each quarterly $AE_{t,MAX}$ must be equal > 90%~~

~~The $AE_{t,MIN}$, as calculated during the baseline look-back period shall be fixed as the minimum of the dynamic AE for the duration of the project. In no instances shall the dynamic baseline utilize an AE below $AE_{t,MIN}$, even If production increases to a level such that the dynamic baseline correlation line would be extrapolated below $AE_{t,MIN}$, thus ensuring AE values are more conservative.~~

~~[28] Direct measurements of the N_2O concentration in the off gas and the flow rate (*F*) of the off gas shall be made using a continuous emission monitoring system (CEMS); see Section 6 for complete information.~~

~~[29] This protocol assumes that the NO_x/N_2O abatement trade-off faced by U.S. AAPs would continue in the absence of the project, and thus the inverse general trend of decreasing N_2O abatement with increasing adipic acid production would also continue in the absence of the project (Section 2.1).~~

~~[30] This protocol assumes that each AAP is *capable* of achieving their $AE_{t,MAX}$ in any given period of time, but is not always able to do so due to financial constraints, the NO_x/N_2O abatement trade-off (Section 2.1), and/or other constraints that make it impracticable to fully utilize the existing technology and achieve $AE_{t,MAX}$ day after day.~~

Among projects there may be variability in the output units of the various N_2O CEMS configured for reporting. The flow rate monitoring system may provide output in terms of unit mass per unit time (i.e., lb/hr) or in terms of unit volume per unit time (i.e., m^3/hr). The N_2O concentration monitoring system will likely provide output in terms of percent by volume, mole percent, or parts per million. Gas flow meters that are not thermal mass flow meters should be compensated for actual temperature and pressure, and volume flow rates must be adjusted to standard temperature and pressure (as defined in this Protocol).

Alternatively, in order to minimize errors that could occur during unit conversions via the ideal gas law, project developers may utilize project data in the units' output directly by the N_2O and flow rate CEMS for completing calculations in Equation 5.3 and **Error! Reference source not found.** – so long as the necessary temperature and pressure compensation has been made for flow parameters and that the final N_2O mass emissions generated, emitted, and reduced are presented in metric tonnes. See Table 6.2 for more information.

Note above that the non-N_2O emissions control unit includes bypassing of the N_2O control unit or venting directly to the atmosphere. Control unit bypass and venting situations are expected to be brief if at all. Given the elevated baseline abatement efficiency built into this protocol, projects are incentivized to ensure that the N_2O control unit is always operational to minimize or eliminate instances of control unit bypass or venting.

Commented [A2]: Assess methodology for instances of venting/bypass and threshold for alternative method.

Given the low likelihood and brief duration of bypass or venting situations anticipated, it may be unnecessary to purchase, install, and rigorously calibrate N_2O and flow CEMS situated along all bypass or vent streams. In the instance that CEMS are not installed along all paths of potential off-gas release, project developers may develop and seek Reserve approval for an alternative method for calculating the amount of N_2O released into the atmosphere through vent stacks and/or process lines bypassing the N_2O control unit. Alternative methods should incorporate data from process instrumentation, i.e., control valve position(s), process line pressure transmitters, or thermocouples to definitively indicate the beginning and end dates and times of venting situations.

Any alternative method must meet the following criteria:

- May only be used to account for non-N_2O control unit parameters;
- May only be used to account for rare events that represent less than **[percentage TBD]**% of total emissions in a reporting period; and
- Methods must be conservative in nature and utilize actual flow, N_2O concentration, and/or adipic acid production data from the project.

An example of an appropriate alternative method would be to utilize conservative missing data substitution procedures programmed into the project's Data Acquisition and Handling System (DAHS) for substituting N_2O concentration and flow rate data to estimate N_2O released during periods of bypass or venting. Here, quality assured N_2O concentration and flow rate data representing conditions at the inlet to the control unit collected prior to the instance of venting/bypass would be used to determine a conservative volume of N_2O released uncontrolled.

5.1.2 Baseline Abatement Efficiency in China

Abatement of N_2O emissions in Chinese AAPs is currently not common practice. To determine an appropriate lookback percentage of the emissions abated, the Reserve evaluated the potential for unintended secondary effects (i.e., carbon leakage). Two main drivers of carbon leakage are:

1. protocol baseline N2O abatement emission level at 0% (i.e., no abatement); and
2. the value of certified emission reductions (CERs) created through abatement technology exceeded the value of the adipic acid itself, creating perverse incentives.

This protocol utilizes a static 90% Abatement Efficiency in the baseline for all AAPs in China to protect against leakage incentives. Refer to Appendix B for the full evaluation of leakage potential.

Commented [A3]: How we will address situations where a 90% baseline abatement efficiency is not met?

5.1.3 Baseline Nitric Acid Recovery Ratio

Error! Reference source not found. shows the calculation to quantify the impact of lower "virgin" nitric acid (HNO_3) use as a function of N_2O conversion to NO, which is then converted to HNO_3 in the downstream process. This occurs when recycling technologies that convert a portion of the N_2O in the exhaust to beneficial byproducts rather than simply oxidizing the N_2O to nitrogen (N_2) and oxygen (O_2) (conventional technology). The calculation establishes a ratio of HNO_3 to adipic acid as an average of the annual ratio of HNO_3 to adipic acid over the baseline 5 year look-back period. This ratio is then compared to the ratio of HNO_3 to adipic acid in the reporting period (RP).

Equation 5.4. Nitric Acid Use Ratio

$$\boldsymbol{HNO_{3_{Ratio}} = avg\left(\frac{HNO_{3_y}}{AA_y}\right) - \frac{HNO_{3_{RP}}}{AA_{RP}}}$$

Where,			Units
$HNO_{3,Ratio}$	=	Ratio of nitric acid (HNO_3) to adipic acid	$tHNO_3/tAA$
HNO_{3y}	=	Annual tonnes of HNO_3 used as an input for adipic acid production in a given year during the baseline look-back period (5 years)	t
AA_y	=	Annual tonnes adipic acid in a given year during the baseline look-back period (5 years)	t
$HNO_{3,RP}$	=	HNO_3 used as an input for adipic acid production in project reporting period	t
AA_{RP}	=	Measured adipic acid production in the project reporting period	t

5.1.4 Mitigating Leakage

Commented [A4]: Continue to evaluate leakage and ways to mitigate potential leakage and gaming the system. Specifically, 1) is 90% baseline sufficient; 2) what's the impact if the price for CRTs increases; 3) should a production cap be included for a project to avoid the potential to increase production simply to produce more carbon credits?

Secondary effects, i.e., leakage, may occur if an AAP with a Reserve adipic acid project begins to produce more adipic acid than it otherwise would because the value of the carbon offset creates an incentive to shift production to the respective AAP and/or to maintain and/or increase production at levels above market conditions. The most acute leakage risk may be if a given entity has multiple AAPs within their corporate group, and was able to shift production between facilities, to facilitate higher production at any given facility that was able to generate carbon offsets for emission reductions associated with N_2O abatement. For AAPs that are not a part of a corporate group controlling multiple AAPs, there may still be a threat of leakage if the single project AAP was to increase production to a statistically significant volume (or keep production at a volume above what market conditions would otherwise justify), due to a competitive advantage afforded to it in the form of carbon revenues. If leakage were to occur, a portion of the CRTs would not be representative of real GHG emission reductions.

For any AAP that is part of a corporate group that controls multiple AAP, anywhere in the world, the project must assess average annual factory loading of the project AAP (that is the percentage of facility-specific total production capacity that is being used) during the baseline look-back period, relative to the AAP factory loading during each reporting period. In any given reporting period, if factory loading decreases at other AAPs controlled by the group, whilst simultaneously increasing at the project AAP (or remaining steady at the project AAP, while decreasing elsewhere) by a statistically significant amount, leakage would have occurred.

If the project facility is not part of a corporate group that controls more than one AAP facility, then the project may seek Reserve approval for demonstrating the threat of leakage is minimal by using alternative means. An alternative assessment may be undertaken using data that is no more than 5 years old, and the Reserve may also accept an alternative assessment based on data spanning less than the full baseline look-back period, where data for the full baseline look-back period is lacking. Projects should reach out to the Reserve for guidance as soon as possible when seeking to develop a suitable methodology for a leakage assessment for any given reporting period. Projects utilizing this option must demonstrate, using publicly available market data and a reasonable explanation, that any increase in market share is not attributable to carbon offset revenue. Acceptance of an alternative leakage assessment in a given reporting period does not necessitate such method being accepted in any other future reporting period. Reserve staff will determine if reasonably satisfied the materials provided demonstrate a lack of statistically significant changes in production relative to production elsewhere, such that the threat of leakage is material or not. If the project is unable to demonstrate to the Reserve's satisfaction that leakage has not occurred in a given reporting period, then leakage will be assumed to have occurred, and the project must mitigate such leakage.

~~Where the project facility is not part of a corporate group that controls more than one AAP facility, and the project is unable to secure Reserve approval for an alternative method for demonstrating no leakage has occurred, then adipic acid production must not exceed the AAP's CAA Title V permitted production levels as at the project start date.~~
Although all AAPs are required to provide the aforementioned evidence to mitigate leakage, it should be noted that the mandated 90% baseline abatement efficiency will also mitigate the potential for secondary effects.

5.2 Quantifying Project Emissions

Project emissions are actual GHG emissions that occur within the GHG Assessment Boundary as a result of the project activity. Project emissions must be quantified every reporting period on an *ex-post* basis.

Equation 5.5. Project Emissions

$$PE = PE_{N_2O} + PE_{HC} + PE_{EE}$$

Where,

			Units
PE	=	Total project emissions during the reporting period	tCO_2e
PE_{N2O}	=	Measured N_2O emissions in the off gas from project N_2O control units during the reporting period (Equation 5.6.)	tCO_2e
PE_{HC}	=	GHG emissions from the use of hydrocarbons as a reducing agent or to reheat off gas during the reporting period (Equation 5.7)	tCO_2e

PE_{EE}	=	GHG emissions from external energy used to reheat the off gas during the reporting period (**Error! Reference source not found.**0)	tCO_2e

5.2.1 Calculating Project N_2O Emissions in the Off Gas

N_2O abatement is not 100% efficient. Therefore, N_2O emissions that are not destroyed by abatement technology are measured and included as project emissions, using Equation 5.6. below. In the calculation of N_2O emissions during the reporting period projects must remove extreme values following the guidance as set out in Section 5.1.1. Similarly, project developers may utilize alternative units when quantifying flow and concentration in Equation 5.3.

Equation 5.6. Project N_2O Emissions in the Off Gas Routed from Emissions Control Units

$$PE_{N_2O} = \left[\sum_{cu}(F_{RP,cu} \times N_2O_{RP,conc,cu} \times OH_{RP,cu}) + \sum_{ncu}(F_{RP,ncu} \times N_2O_{RP,conc,ncu} \times OH_{RP,ncu})\right] \times GWP_{N_2O}$$

Where,			Units
PE_{N2O}	=	Measured N_2O emissions in the off gas from project control units during the reporting period	tCO_2e
$F_{RP,cu}$	=	Volume flow rate in the off gas during the reporting period from the N_2O control unit	m^3/hour
$F_{RP,ncu}$	=	Volume flow rate in the off gas during the reporting period from the non-N_2O control unit	m^3/hour
$N_2O_{RP,conc,cu}$	=	N_2O concentration in the off gas during the reporting period from the N_2O control unit	tN_2O/m^3
$N_2O_{RP,conc,ncu}$	=	N_2O concentration in the off gas during the reporting period from non-N_2O control unit	tN_2O/m^3
$OH_{RP,cu}$	=	Operating hours in reporting period by N_2O control unit	hours
$OH_{RP,ncu}$	=	Operating hours in reporting period by non-N_2O control unit	hours
GWP_{N2O}	=	Global warming potential of N_2O	tCO_2e/tN_2O
cu	=	Each installed N_2O emissions control unit (e.g., thermal reduction unit, adiabatic reactor, absorption media, or other N_2O abatement device)	
ncu	=	Each installed non-N_2O emissions control unit (e.g., selective catalytic reduction unit or other non-N_2O abating device), inclusive of any ~~bypassed and direct venting of~~ N_2O emissions directly vented to the atmosphere	

5.2.2 Calculating Project Emissions from Hydrocarbon Use

Hydrocarbons can be used as a reducing agent, to reheat off gas to enhance the N_2O reduction efficiency or simply as a combustion source for thermal treatment, which leads to CO_2 and CH_4 emissions. The project emissions related to hydrocarbon input to the project shall be calculated. In cases where hydrocarbon use for N_2O control technology that predates the project exists, the difference in baseline and project scenario hydrocarbon use shall be calculated. If the project developer demonstrates that the implementation of project activities produces the same amount of emissions as baseline N_2O control technology hydrocarbon usage or reduces emissions from hydrocarbon use compared to baseline N_2O control technology hydrocarbon usage, project developers may assert zero project emissions from hydrocarbon use.

Equation 5.7. Project Emissions from Hydrocarbon Use

$$PE_{HC} = CO_{2_{HC}} + CH_{4_{HC}}$$

Where,			Units
PE_{HC}	=	Net GHG emissions from the use of hydrocarbons as a reducing agent or to reheat off gas during the reporting period	tCO_2e
CO_{2HC}	=	Net GHG emissions as CO_2 from hydrocarbon use during the reporting period (Equation 5.8)	tCO_2e
CH_{4HC}	=	Net GHG emissions as CH_4 from hydrocarbon use during the reporting period (**Error! Reference source not found.**)	tCO_2e

Hydrocarbons (organic compounds made up of carbon and hydrogen) are used primarily as a combustible fuel source (e.g., natural gas, which is mostly methane, propane, and butane). When hydrocarbons are combusted, they produce heat, steam, and CO_2. For calculation of the GHG emissions related to hydrocarbons, this protocol assumes all hydrocarbons other than CH_4 are completely converted to CO_2 (Equation 5.8) and all CH_4 in the fuel or reducing agent is emitted directly as CH_4 to the atmosphere and is not converted to CO_2 (**Error! Reference source not found.**). In Equation 5.8, the hydrocarbon CO_2 emission factor (EF_{HC}) is given by the molecular weight of the hydrocarbon and CO_2 and the chemical reaction when hydrocarbons are converted.[31]

Equation 5.8. Project Carbon Dioxide Emissions from Hydrocarbon Use

$$CO_{2_{HC}} = \sum_{cu,p} (\rho_{HC} \times Q_{HC,RP} \times EF_{HC,RP}) - \sum_{cu,b} (\rho_{HC} \times Q_{HC,avg} \times EF_{HC,avg})$$

Where,			Units
CO_{2HC}	=	Net GHG emissions as CO_2 from converted hydrocarbon during the reporting period	tCO_2e
ρ_{HC}	=	Hydrocarbon density	t/m^3
$Q_{HC,avg}$	=	Historical average annual quantity of hydrocarbon, with two or more molecules of carbon (i.e., not methane), during the baseline look-back period (5 years)	m^3
$Q_{HC,RP}$	=	Quantity of hydrocarbon, with two or more molecules of carbon (i.e., not methane), input during the reporting period	m^3
$EF_{HC,avg}$	=	Historical average annual carbon emission factor of hydrocarbon, with two or more molecules of carbon, from use during the baseline look-back period (5 years)	tCO_2e/tHC
$EF_{HC,RP}$	=	Carbon emission factor of hydrocarbon use during the reporting period	tCO_2e/tHC
cu	=	Each installed N_2O emissions control unit (e.g., thermal reduction unit, adiabatic reactor, absorption media, or other N_2O abatement device)	

[31] For example, where CH_4 is used as hydrocarbon, each converted tonne of CH_4 results in 44/16 tonnes of CO_2, thus the hydrocarbon emission factor is 2.75.

Equation 5.9. Project Methane Emissions from Hydrocarbon Use

$$CH_{4_{HC}} = \sum_{cu} \rho_{CH_4} \times (Q_{CH_{4,RP}} - Q_{CH_{4,avg}}) \times GWP_{CH_4}$$

Where,			Units
CH_{4HC}	=	Net GHG emissions as CH_4 from unconverted hydrocarbon (methane) during the reporting period	tCO_2e
ρ_{CH4}	=	Methane density	t/m^3
$Q_{CH4,RP}$	=	Quantity of methane used during the reporting period	m^3
$Q_{CH4,avg}$	=	Historical average annual quantity of methane used during the baseline look-back period (5 years)	m^3
GWP_{CH4}	=	Global warming potential of CH_4	tCO_2e/tCH_4
cu	=	Each installed N_2O emissions control unit (e.g., thermal reduction unit, adiabatic reactor, absorption media, or other N_2O abatement device)	

5.2.3 Calculating Project Emissions from Increased External Energy Use

If an external energy source is used in greater amounts compared to baseline usage (e.g., from adjusting off gas temperatures at the inlet of the N_2O, increasing the utilization rate of the N_2O abatement technology, the use of the newly installed technology and/or enhancement, etc.), and the additional energy is not recovered before the off gas is released to the atmosphere, then GHG emissions from the energy used shall be calculated and included as project emissions.

Equation 5.10. Project Emissions from Increased External Energy Use

$$PE_{EE} = SE + OGU + OGH + CO_{2,net}$$

Where,			Units
PE_{EE}	=	Project emissions from external energy during the reporting period. If result is <0, use a value of 0	tCO_2e
SE	=	Emissions from net change in steam export during the reporting period (Equation 5.11)	tCO_2e
OGU	=	Emissions from net change in off gas utilization during the reporting period (**Error! Reference source not found.**)	tCO_2e
OGH	=	Emissions from net change in off gas heating during the reporting period (**Error! Reference source not found.**)	tCO_2e
$CO_{2,net}$	=	Net increase in CO_2 emissions from increased fossil fuel and/or electricity use due to project activity (**Error! Reference source not found.**)	tCO_2

In practice, project developers shall account for the emissions from the operation of any new N_2O abatement technology or enhancement of an existing one for the purpose of implementing the project. Project developers may use **Error! Reference source not found.** to **Error! Reference source not found.** below to calculate the net increase in GHG emissions for any *applicable* external energy source (i.e., steam, off gas, fossil fuel, or electricity), or if they can demonstrate during verification that project GHG emissions are estimated to be equal to or less than 5% of the total baseline emissions from these sources, then the project developer may estimate baseline and project GHG emissions from these sources. If an estimation method is used, verifiers shall confirm based on professional judgment that project GHG emissions are equal to or less than 5% of the total baseline emissions based on documentation and the estimation methodology provided by the project developer. If emissions cannot be confirmed to be below 5%, then **Error! Reference source not found.** to **Error! Reference source not found.** shall be used as necessary. Regardless of the method used, all estimates or calculations of GHG emissions within the GHG Assessment Boundary must be verified and included in emission reduction calculations.[32]

If calculations or estimates indicate that the project results in a net decrease in GHG emissions from external energy use, then for quantification purposes the increase in these emissions must be specified as zero for PE_{EE}.

Equation 5.11. Project Emissions from Steam Export

$$\boldsymbol{SE} = \left[\frac{(\boldsymbol{ST_{avg}} - \boldsymbol{ST_{RP}}) \times \boldsymbol{OH_{RP}}}{\boldsymbol{\eta_{ST}}}\right] \times \boldsymbol{EF_{ST}}$$

Where,

			Units
SE	=	Emissions from net change in steam export during the reporting period	tCO_2e
ST_{avg}	=	Average annual steam export during the baseline look-back period (5 years)	MW
ST_{RP}	=	Project steam export during the reporting period	MW
OH_{RP}	=	Operating hours in reporting period	hours
η_{ST}	=	Efficiency of steam generation	fraction
EF_{ST}	=	Fuel emission factor for steam generation	tCO_2e / MWh

Equation 5.12. Project Emissions from Off Gas Utilization

$$\boldsymbol{OGU} = \left[\frac{(\boldsymbol{EE_{avg}} - \boldsymbol{EE_{RP}}) \times \boldsymbol{OH_{RP}}}{\boldsymbol{\eta_r}}\right] \times \boldsymbol{EF_r}$$

Where,

			Units
OGU	=	Emissions from net change in off gas utilization during the reporting period	tCO_2e
EE_{avg}	=	Average annual energy export from off gas utilization during the baseline look-back period (5 years)	MW
EE_{RP}	=	Project energy export from off gas utilization during the reporting period	MW
OH_{RP}	=	Operating hours in reporting period	hours
η_r	=	Efficiency of replaced technology	fraction
EF_r	=	Fuel emission factor for replaced technology	tCO_2e / MWh

Equation 5.13. Project Emissions from Off Gas Heating

$$\boldsymbol{OGH} = \left[\frac{\boldsymbol{EI_{OGH}}}{\boldsymbol{\eta_{OGH}}}\right] \times \boldsymbol{EF_{OGH}}$$

Where,

			Units
OGH	=	Emissions from net change in off gas heating during the reporting period	tCO_2e

[32] This is consistent with guidance in WRI's GHG Protocol regarding the treatment of significant secondary effects.

EI_{OGH}	=	Energy input for additional off gas heating during the reporting period compared to the average annual amount of off gas heating	MWh
η_{OGH}	=	Efficiency of additional off gas heating	fraction
EF_{OGH}	=	Emission factor for additional off gas heating	tCO_2e / MW

Error! Reference source not found. below calculates the net increase in carbon dioxide emissions resulting from the project activity. The quantities of electricity and fossil fuel consumed must be taken from operational records such as utility bills.

Equation 5.14. Project Emissions from Fossil Fuel and Electricity Use

$$CO_{2,net} = PE_{CO_2,EL,FF} - BE_{CO_2,EL,FF}$$

Where, Units

$CO_{2,net}$	=	Net increase in CO_2 emissions from increased fossil fuel and/or electricity use due to project activity	tCO_2
$BE_{CO2,EL,FF}$	=	Average baseline CO_2 emissions from fossil fuel and/or electricity use from operation of N_2O abatement technology during the baseline look-back (5 years - see equation below)	tCO_2
$PE_{CO2,EL,FF}$	=	Total project CO_2 emissions from fossil fuel and/or electricity use from operation of N_2O abatement technology during the reporting period (see equation below)	tCO_2

All CO_2 emissions associated with fossil fuel and/or electricity consumption from operation of N_2O abatement technology are calculated using the equation:

$$CO_{2,EL,FF} = (QE_{avg} \times EF_{CO_2,E}) + [(QF_{avg} \times EF_{CO_2,F}) \times 0.001]$$

Where, Units

$CO_{2,EL,FF}$	=	CO_2 emissions from fossil fuel and/or electricity consumption from operation of N_2O abatement technology	tCO_2
QE_{avg}	=	Quantity of grid-connected electricity consumed from operation of N_2O abatement technology; average amount during each year, *BLy*, of the baseline look-back period or annual amount during the reporting period	MWh
$EF_{CO2,E}$	=	CO_2 emission factor for electricity used[33]	tCO_2/MWh
QF_{avg}	=	Quantity of fossil fuel consumed from operation of N_2O abatement technology; average amount during each year, *BLy*, of the baseline look-back period or annual amount during the reporting period	MMBtu or gallons
$EF_{CO2,F}$	=	Fuel-specific emission factor *f* from **Error! Reference source not found.**	kg CO_2/MMBtu or kg CO_2/gallon
0.001	=	Conversion factor from kg to metric tons	

[33] ~~Refer to the version of the U.S. EPA eGRID most closely corresponding to the time period during which the electricity was used. Projects shall use the annual total output emission rates for the subregion where the project is located, not the annual non-baseload output emission rates. The eGRID tables are available from the U.S. EPA website: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid~~ Refer to the most recent Ministry of Ecology and Environment (MEE) Baseline Emission Factor of China's Regional Power Grids for Emission Reduction Projects, which can be found here. Project Developer shall use for the average of OM and BM for the appropriate Regional Power Grid(s).

6 Project Monitoring

The Reserve requires a Monitoring Plan to be established for all monitoring and reporting activities associated with the project. The Monitoring Plan will serve as the basis for verifiers to confirm that the monitoring and reporting requirements in this section and Section 7 have been and will continue to be met, and that consistent, rigorous monitoring and record keeping is ongoing at the project site. The Monitoring Plan must cover all aspects of monitoring and reporting contained in this protocol and must specify how data for all relevant parameters in Table 6.2 will be collected and recorded.

At a minimum, the Monitoring Plan shall include the frequency of data acquisition; a record keeping plan (see Section 7.2 for minimum record keeping requirements); the frequency of quality assurance/quality control (QA/QC) activities; the role of individuals performing each specific monitoring activity; and a detailed project diagram. The Monitoring Plan must include QA/QC provisions to ensure that data acquisition and meter calibration are carried out consistently and with precision.

Finally, the Monitoring Plan must include procedures that the project developer will follow to ascertain and demonstrate that the project at all times passes the legal requirement test (Section 3.4.2).

To ensure that all aspects of monitoring and reporting are met, the project developer shall follow the relevant guidance in this section as well as the relevant sections of the ~~United States Code of Federal Regulations Title 40 (40 CFR) Part 75~~Professional Standard of the People's Republic of China, HJ 75-2017, Specifications for Continuous Emissions Monitoring of SO_2, NO_x, and Particulate Matter in the Flue Gas Emitted from Stationary Sources – as indicated in protocol Sections 6.1 - 6.3. HJ 75-2017 provides guidance on the standards of performance for continuous emission monitoring systems (CEMS) for NO_X emission measurements, which is also applicable to N_2O emission testing at AAPs.

Commented [A5]: Review HJ 75 with workgroup to determine the applicability of the standard and how it compares to the US Code of Federal Regulations

Direct measurements of the N_2O concentration in the off gas and the flow rate of the off gas shall be made using a continuous emission monitoring system (CEMS). CEMS is the most accurate monitoring method because N_2O emissions are measured continuously from a specific source.[34] Elements of a CEMS include a platform and sample probe within the stack to withdraw a sample of the off gas, an analyzer to measure the concentration of the N_2O (typically a non-dispersive infrared sensor (NDIR) or Fourier transform infrared (FTIR) spectrometer) in the off gas, and a flow meter within the stack to measure the flow rate of the off gas. The emissions are calculated from the concentration of N_2O in the off gas and the flow rate of the off gas. A CEMS continuously withdraws and analyzes a sample of the gas and continuously measures the N_2O concentration and flow rate of the gas.[35] HJ 75-2017 Section 4: Composition and Function Requirements on CEMS for Stationary Sources – discusses components and capabilities required for CEMS.

These parts outline the minimum requirements for the installation, evaluation, monitoring, and record keeping for CEMS (see Section 7.2 of this protocol for Reserve minimum record keeping requirements).

[34] This method is consistent with Approach 1 from the World Business Council for Sustainable Development and the "A" rated approach from the U.S. Department of Energy.

[35] U.S. EPA Technical Support Document for the Adipic Acid Production Sector: Proposed Rule for Mandatory Reporting of Greenhouse Gases, Office of Air and Radiation, January 22, 2009.

Project developers are responsible for monitoring the performance of the project and ensuring that the operation of all N_2O control system and other project-related equipment is consistent with the manufacturer's recommendations for each component of the system.

6.1 Initial Monitoring Requirements

Both newly installed CEMS for the adipic acid project and projects utilizing a CEMS that was initially installed for a purpose other than the monitoring of an adipic acid project (e.g., to monitor NO_X abatement) must meet all initial monitoring requirements specified in this section. If any of the required tests listed below were not conducted or the requirements were not met at the time of initial installation and certification, the project developer must conduct the tests and ensure that the requirements are met prior to the project start date. Project developers must include the CEMS installation and initial performance testing and technical acceptance report to the Monitoring Plan for ease of review by the verification body and the verification body must ensure adherence to the requirements, as summarized in the remainder of Section 6.1.

6.1.1 System Installation and Certification

The project developer shall follow the requirements for CEMS installation and technical acceptance detailed in ~~40 CFR Appendix A to Part~~HJ 75~~ – Specifications~~-2017 Section 7: Requirements on Installation of CEMS for Stationary Sources, HJ 75-2017 Section 8: Performance Testing for the Technical Indexes of CEMS, HJ 75-2017 Section 9: Technical Acceptance of CEMS, and HJ 75-2017 Annex A: Performance Testing Methods for Key Technical Indexes of CEMS. Collectively, these sections outline the monitoring system diagnostic testing routines, technical performance acceptance criteria, and performance testing procedures required for CEMS for stationary sources. CEMS must be installed and operational before conducting performance tests on the system. To achieve operational status, the project developer must show that the CEMS also meets manufacturer requirements or recommendations for installation, operation, and calibration.

The following initial certification requirements are summarized from ~~40 CFR Appendix A to Part~~HJ 75~~:~~-2017 section ~~3~~8: Performance ~~Specifications~~Testing for the Technical Indexes of CEMS, section ~~4 Data Acquisition~~9: Technical Acceptance of CEMS, and ~~Handling Systems, and section 6 Certification Tests and Procedures.~~Annex A: Performance Testing Methods for Key Technical Indexes of CEMS for Stationary Sources. Please refer to ~~those~~these sections of the HJ 75-2017 standard for complete installation and certification requirements.

- ~~7-day calibration error test to~~ Zero drift and span drift checks of CEMS for gaseous pollutants (N_2O) to evaluate the accuracy and stability of a gas analyzer's ~~or flow monitor's~~ calibration over a period of unit operation (section 9.3.~~1~~3.3, 9.3.7, and ~~6.3~~section A.2.2 of ~~40 CFR Appendix A to Part~~HJ 75~~; protocol Section 6.1.2).~~-2017 Annex A).
- ~~Linearity~~ Indication Error test to check ~~to determine~~ whether the ~~response of the~~ N_2O concentration monitor response is linear across its range by challenging the N_2O CEMS with three different levels of calibration gas concentrations (section 9.3.~~2 and 6~~3.2~~-~~, 9.3.7, and A.4.1 of ~~40 CFR Appendix A to Part~~HJ 75-2017 Annex A; protocol Section 6.1.2).
- ~~Relative~~ System Response Time test to ensure that the monitoring system is sufficiently responsive to changes in gas concentration (section 9.3.3.2, 9.3.7, and A.4.2 of HJ 75-2017 Annex A).

- Performance Testing of Technical Indexes of Accuracy ~~Test Audit (RATA)~~and Precision of CEMS for Gaseous Pollutants (N_2O) and CMS for Flue Gas Parameter to determine the accuracy of the system by comparing N_2O ~~emissions~~concentration, flow velocity, flue gas temperature and humidity data recorded by the CEMS to data collected concurrently with an emission reference ~~test method. All RATA of CEMS must be conducted by a testing body conforming to the requirements of ASTM D7036-04 (section 3.3 and 6~~method (sections 9.3.3.4, 9.3.4, 9.3.8, and sections A.5, A.6, A.7, A.8, A.9, and A.10 of ~~40 CFR Appendix A to Part~~HJ 75-2017 Annex A; protocol Section 6.1.3).~~[36]~~
- ~~Bias test~~Verification of CEMS for Gaseous Pollutants and CMS for Flow Velocity to ensure that the monitoring system is not biased ~~low~~ with respect to the reference method, based on ~~RATA~~ reference method testing results (section 9.3.4~~8~~ and ~~6~~sections A.5, A.6, A.7, and A.10 of ~~40 CFR Appendix A to Part~~HJ 75-2017 Annex A; protocol Section 6.1.3).
- ~~Cycle time test to ensure that the monitoring system is capable of completing at least one cycle of sampling, analyzing, and~~ Networking Acceptance Procedures to ensure that data ~~recording every 15 minutes (section 3.5 and 6.4 of 40 CFR Appendix A to Part 75).[37]~~
- ~~Automated~~ transmission procedures and network stability of the data acquisition and handling system (DAHS) ~~verification to ensure~~are sufficient and that all emission calculations are performed correctly and that the missing data substitution methods are applied properly (section 9.4 of ~~40 CFR Appendix A to Part~~HJ 75-2017).

6.1.2 Calibration

The initial ~~certification calibration~~technical index testing and acceptance procedures from ~~40 CFR Appendix~~HJ 75-2017 Annex A ~~to Part 75~~ for NO_x and flow velocity monitors shall be followed for CEMS measuring N_2O emissions and flow under this protocol. Calibration test procedures are outlined in ~~sections 6.3.1~~ section A2.2 and ~~6.3.2~~A4.1 of ~~40 CFR Appendix A to Part~~HJ 75~~.~~-2017 Annex A. The performance specifications for ~~the 7-day calibration~~zero and span drift checks and indication error ~~test and linearity check~~checks are described in ~~sections 3.1 and 3.2~~section 9.3.7 of ~~40 CFR Appendix A to Part~~HJ 75-2017.

6.1.3 Accuracy Testing

The initial ~~certification~~N_2O CEMS and flow CMS relative accuracy testing and ~~RATA~~acceptance procedures from HJ 75-2017 sections 9.3.3.4, 9.3.~~3~~4, and A.5, A.6, and A.7~~, and 6.5~~ of ~~40 CFR Appendix A to Part 75~~Annex A shall be followed for CEMS measuring N_2O emissions and flow in adipic acid projects. The guidance for NO_X CEMS shall be used for N_2O emission monitoring where the CEMS relative accuracy (RA) shall not exceed ~~10%~~the applicable threshold presented in Table 2 or Table A.3 of HJ 75-2017 at any operating level at which ~~a RATA~~an accuracy test utilizing a reference method is performed.

Because there is not a standard reference test method for N_2O CEMS at this time, ~~a RATA~~accuracy testing for the verification of an FTIR or NDIR installation for N_2O analysis may use any standard method released by the State or profession for performance testing of NOx concentration CEMS under HY 75-2017. ~~of the following:~~

~~[36] 40 CFR Part 75, Appendix A, section 6.1.2(a).~~
~~[37] 40 CFR Part 60, 60.13(e)(2).~~

- ~~U.S. EPA test method 320[38] for the measurement of vapor phase organic and inorganic emissions by extractive FTIR spectroscopy[39]~~
- ~~ASTM D6348-03 method for the determination of gaseous compound by extractive direct interface FTIR spectroscopy[40]~~
- ~~ISO/DIS 21258 stationary source emissions determination of the mass concentration of N_2O reference method for NDIR[41]~~

~~Other NDIR methods used in AM0034 or AM0028, or performance specification-based reference method such as EPA method 7E[42]~~

6.1.3.1 Sampling

For all ~~RATA~~N_2O CEMS accuracy acceptance testing, a minimum of nine test runs ~~have to~~/ data pairs must be conducted / collected for a period of at least ~~21~~5-15 minutes for each run. ~~More~~For CMS for Flow Velocity, at least 5 valid test runs ~~may~~/ data pairs must be ~~completed with the option to exclude up to three test runs from the audit. However, all data~~ conducted / collected for a period of at least 5 minutes. All data recorded must be reported, including ~~the rejected data.[43]~~data pairs that are rounded off. Accuracy acceptance testing procedures should be carried out continuously for three days. For details on ~~RATA~~accuracy testing sampling, see the ~~relative~~ accuracy ~~test~~performance testing procedures and performance specifications in sections 9.3.3.4 through 9.3.4 of HJ 75-2017 and ~~6~~A.5 through A.10 of ~~40 CFR Appendix~~Annex A to ~~Part~~HJ 75-2017.

6.2 Ongoing Monitoring and QA/QC Requirements

The quality assurance and quality control (QA/QC) provisions required for this protocol shall be included in the Monitoring Plan and consistent in stringency, data reporting, and documentation with the CEMS QA/QC program described in ~~Appendix B of 40 CFR to Part 75 – Quality Assurance and Quality Control Procedures (see Section 7 of this protocol for further record-keeping requirements). Per Appendix B of 40 CFR to Part 75~~HJ 75-2017 Section 10: Daily Operation and Management Requirements for CEMS; Section 11: Quality Assurance Requirements for Daily Operation of CEMS, and Section 12: Data Review and Processing for CEMS. In line with the general requirements of HJ 75-2017 Section 10, AAPs must develop and implement a QA/QC program for the CEMS that at a minimum, includes a written plan that describes in detail (or that refers to separate documents containing) complete, step-by-step procedures and operations for the following:

- Procedures for ~~preventative~~routine inspection and maintenance of the monitoring system
- Record keeping and reporting procedures
- Testing, maintenance, and repair activity records for CEMS or any component of CEMS
- Calibration drift and indication error ~~test and linearity~~ check procedures
- Calibration and ~~linearity~~indication adjustment procedures
- ~~RATA~~Accuracy testing and acceptance procedures, such as sampling and analysis methods

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[38] ~~EPA Air Emission Measurement Center (EMC), Method 320 - Vapor Phase Organic and Inorganic Emissions by Extractive FTIR~~
[39] ~~40 CFR Part 63, Appendix A; 40 CFR Part 98.54 – Subpart E. Adipic Acid Production.~~
[40] ~~40 CFR Part 60, 60.17(a)(82); 40 CFR Part 98.54 – Subpart E. Adipic Acid Production.~~
[41] ~~ISO 21258:2010, Stationary source emissions -- Determination of the mass concentration of dinitrogen monoxide (N_2O) -- Reference method: Non-dispersive infrared method.~~
[42] ~~EPA Air Emission Measurement Center (EMC), Method 7E - Nitrogen Oxide - Instrumental Analyzer~~
[43] ~~40 CFR Part 60, Appendix B, section 8.4.4~~

Project developers shall include the AAP's written plan for its ~~CEMS'~~CEMS ongoing QA/QC program, and any referenced supporting documentation, as required to be developed and implemented per ~~Appendix B of 40 CFR to Part 75~~HJ 75-2017 Sections 10 through 12, to the project Monitoring Plan for ease of review by the verification body. The verification body shall review the written QA/QC plan and ensure successful implementation of all CEMS QA/QC requirements as summarized in the remainder of Section 6.2.

6.2.1 Frequency of Testing

The schedule for the frequency of testing required for CEMS is prescribed in ~~section 2, Appendix B~~HJ 75-2017 Section 11: Quality Assurance Requirements for Daily Operation of ~~40 CFR Part 75.~~CEMS for Stationary Sources, while Annex G presents CEMS QA/QC recordkeeping guidance. For CEMS that were installed and certified for NO_X abatement prior to implementation of the ~~adipic acid~~N_2O abatement project, the daily, quarterly, and semi-~~annual, and~~ annual assessments detailed below only need to be performed, documented, and verified as of the project start date, not as of the date when the CEMS originally completed certification testing for NO_X abatement. For CEMS that were installed specifically for ~~adipic acid~~N_2O abatement project implementation, assessments must be performed, documented, and verified as of the date that the CEMS was certified. At a minimum, the following schedule, as summarized in Table 6.1, must be followed for tests relevant to N_2O analysis using CEMS:

Daily (operating days only) assessments to quality-assure the hourly data recorded by the CEMS as of the date when CEMS completes ~~certification~~technical acceptance testing:

- ~~Calibration error test~~Zero and span calibration for N_2O analyzer (~~section 6.3.1~~Section 11.2 (a) and A.2.2 of ~~40 CFR Appendix A to Part~~HJ 75-2017)
- ~~Calibration~~Zero calibration and absolute error ~~test~~check for flow meter (~~section 6.3~~Section 11.2 (f) of ~~40 CFR Appendix A to Part~~HJ 75-2017)
- Calibration adjustments for N_2O analyzer and flow meter (~~section 2.1.3~~Section 11.6.2 of ~~40 CFR Appendix B to Part~~HJ 75-2017)
- CEMS Data ~~validation (section 2~~Review (Section 12.1~~.4~~ of ~~40 CFR Appendix B to Part~~HJ 75-2017)
- ~~Quality assurance (section 2.1.5~~Data Processing (Section 12.2 of ~~40 CFR Appendix B to Part~~HJ 75-2017)
- Data recording ~~(section 2.1.6~~and statement (Section 12.3 of ~~40 CFR Appendix B to Part~~HJ 75-2017)

HJ 75-2017 requires that routine inspections of CEMS components occur at a weekly frequency. Weekly assessments are required as a component of the CEMS routine inspection plan. Routine inspection requirements are described in Section 10.2 and covered in detail in Table G.1 of Annex G of HJ 75-2017. Annex G specifies that the condition of the following monitoring system component checks should be performed and remarked upon at least once every 7 days:

- N_2O CEMS (Table G.1 – Annex G of HJ 75-2017):
    - Probe and pipeline heating temperature inspection
    - Sampling system flow
    - Reverse purging filter and valve inspection
    - Manual reverse purging inspection
    - Sampling pump flow
    - Refrigerator temperature
    - Drainage system and pipeline condensate water inspection

- Air filter
- Standard gas validity and cylinder pressure inspection
- Flue gas analyzer state inspection
- Measurement data inspection
- Flow Velocity CMS (Table G.1 – Annex G of HJ 75-2017):
  - Velocity, flow, and flue pressure measurement data
- Other flue gas monitoring parameters (Table G.1 – Annex G of HJ 75-2017):
  - Oxygen content measurement data
  - Temperature measurement data
  - Humidity measurement data
- Data transmission unit – DAHS – (Table G.1 – Annex G of HJ 75-2017):
  - Communication line connection
  - Transmission equipment power supply

Monthly monitoring system inspections are required as a part of HJ 75-2017 Section 11 and Annex G. The following checks are required at least once each 30 days:

- N_2O CEMS (Table G.1 – Annex G of HJ 75-2017):
  - Sampling pipeline air tightness inspection
  - Sampling probe, pump, and filter cleaning
- Flow Velocity CMS (Table G.1 – Annex G of HJ 75-2017):
  - Reverse purging device inspection
  - Measuring sensor inspection

Quarterly assessments apply as of the calendar quarter following the calendar quarter in which the CEMS is provisionally certified:

- ~~Linearity check in quarters for which there is no RATA (section 6.2 of 40 CFR Appendix A to Part 75)~~
- ~~Leak check for CEMS utilizing differential pressure (DP) flow meters (section 2.2.2 of 40 CFR Appendix B to Part 75)~~
- ~~Data validation (section 2.2.3 of 40 CFR Appendix B to Part 75)~~
- ~~Linearity and leak check grace period (section 2.2.4 of 40 CFR Appendix B to Part 75)~~

- Total system calibration for extractive N_2O CEMS (Section 11.2 (e) of HJ 75-2017):
  - Zero and span calibration drift test
  - Indication error test
  - System response time test
- Flow Velocity CMS (Annex G Table G.1):
  - Probe inspection

Semiannual[44] ~~and annual~~ assessments apply as of the calendar quarter following the calendar quarter in which the CEMS is provisionally certified:

- ~~RATA (sections 6.5 – section 6.5.2.2 of 40 CFR Appendix A to Part 75; sections 2.3.1.3 – 2.3.1.4 of 40 CFR Appendix B to Part 75). If the RA is less than 7.5%, annual RATAs can be performed, if the RA is equal to or greater than 7.5% and less than or equal to 10%, the RATAs can be performed semi-annually~~
- ~~Data validation (section 2.3.2 of 40 CFR Appendix B to Part 75)~~

[44] "Semiannual" means once every ~~two successive operating quarters~~180 days.

- ~~RATA grace period (section 2.3.3 of 40 CFR Appendix B to Part 75)~~
- ~~Bias adjustment factor applied if a monitor fails the bias test (section 2.3.4 of 40 CFR Appendix B to Part 75; section 7.6 of 40 CFR Appendix A to Part 75)~~

- Periodic accuracy checkout/verification of CEMS for gaseous pollutants and CMS for flow velocity (Sections 11.4 and Annex G Table G.5 of HJ 75-2017).
  - Velocity field coefficient or correlation correction in case CMS fails to meet verification requirements
  - Accommodation coefficient as necessary where the CEMS fails to meet the requirements of the technical index for accuracy and to adjust for bias

Table 6.1. Quality Assurance Test Frequency Requirements

Test	Frequency		
	Daily[45]	Quarterly[46]	Semiannual ~~or Annual[47]~~
Zero and Span Calibration ~~Error Test~~Check (N_2O~~, flow~~ CEMS)	X		
~~Interference Check (flow)~~Zero Calibration Check and Absolute Error Check (Flow CMS)	X		
Total System Calibration (N_2O CEMS)		X	
Probe Inspection (Flow~~-to-Load Ratio~~ CMS)		X	
~~Leak Check (DP flow monitors)~~		~~X~~	
~~Linearity Check~~		~~X~~	
~~RATA (N_2O, flow)[48]~~Accuracy Checkout/verification (N_2O and Flow)			X

If a daily zero calibration ~~error tests reveal~~drift test reveals accuracy outside of a +/- 5% threshold for the N_2O analyzer or +/- ~~6~~8% threshold for the flow meter,~~[49]~~ the instrument is out-of-control and corrective actions such as calibration~~ by the ~~, commissioning, or replacement of equipment shall be taken according to instrument manufacturer ~~or a certified service provider is required~~instructions and relevant requirements of the HJ 75-2017 standard. The out-of-control index for the ~~N_2O analyzer or flow meter accordingly. For the interval between the last successful~~daily span calibration ~~error test and the calibration error~~drift test ~~that revealed~~for N_2O analyzers is accuracy outside ~~+/- 5%~~of 10.0%, while the absolute error of a CMS for flow velocity must not exceed 1.8 m/s. If an instrument is found to be out-of-control – due to a failed

[45] "Daily" means operating days only.

[46] "Quarterly" means once every ~~operating quarter~~90 days.

~~[47] "Annual" means once every four operating quarters.~~

~~[48] Conduct RATA annually rather than semiannually if monitor meets accuracy requirements to qualify for less frequent testing.~~

~~[49] 40 CFR Appendix B to Part 75, Section 2.1.4.~~

calibration or otherwise – the out-of-control period and the out-of-control parameter must be recorded and shall be substituted or ~~+/- 6% threshold, respectively, conservativeness will determine what flow meter data are used~~"rounded off" according to the procedures in ~~emission reduction calculations.~~HJ 75-2017 Section 12.2.3. The verification body shall confirm that any adjustments to the metered values result in the most conservative quantification of emission reductions. Any adjustments shall be made for the entire period from the last successful calibration error test until such time that the meter is properly calibrated and re-installed.

6.2.2 Data Management

Data management procedures are an important component of a comprehensive QA/QC plan. As such, data management procedures ~~are described throughout 40 CFR Appendix B to Part 75 and~~for a project should include the following items.[50], at minimum:

- Check for temporal consistency in production data and emission estimates. If outliers exist, an explanation could be required as to changes in the facility operations or other factors. A monitoring error may have occurred, if differences between annual data cannot be explained by changes in activity levels, changes concerning fuels or input material, or changes concerning the emitting process.
- Determine the reasonableness of the emission estimate by comparing it to previous year's estimates.
- Maintain data documentation, including comprehensive documentation of data received through personal communication.
- Check that changes in data or methodology are documented.

Projects should consider including a narrative in their Monitoring Report describing any statistically significant data inconsistencies, and be prepared to answer questions from verifiers, and Reserve staff regarding the same.

6.3 Missing Data Substitution

For periods when the N_2O CEMS is missing data, the project developer shall follow the missing data substitution procedures for NO_X CEMS found in section ~~75.33~~12 of ~~40 CFR Part~~HJ 75-2017. In summary, missing data from the operation of the CEMS may be replaced with substitute data to determine the N_2O emissions during the period for which CEMS data are missing. The owner or operator of the CEMS can substitute for missing N_2O ~~concentration~~emissions data using the procedures specified in ~~section 75.33.~~[51]Table 5 and Table 6 of sections 12.2.3 and 12.2.4, respectively.

For each hour of missing data, the project developer shall calculate substitute data for the N_2O ~~concentration~~mass emission rate based on up to the previous 2,160 quality-assured monitor operating hours for the CEMS. The data substitution procedures depend on the percentile of available monitoring data from the system and the length of the missing data period. If there are no prior quality-assured data or minimal available data (the minimum percent is specified in section ~~75.33~~12.1.3), the owner or operator must substitute the minimum potential N_2O ~~concentration~~emission rate for missing data in the baseline and the maximum potential N_2O ~~concentration~~emission rate for missing data in the project, per the following:

[50] ~~The data management items are gathered from section 7.3 of the U.S. EPA Technical Support Document for the Adipic Acid Production Sector: Proposed Rule for Mandatory Reporting of Greenhouse Gases, Office of Air and Radiation, January 22, 2009.~~
[51] ~~40 CFR Part 75, 75.33, Standard missing data procedures for SO₂, NOx, Hg, and flow rate.~~

- Minimum – Baseline:
  - N_2O monitoring at the inlet of the control technology
- Maximum – Project:
  - N_2O monitoring at the outlet of the control technology

If the developer has received approval from the Reserve to utilize a simplified approach to quantifying N_2O emissions due to venting that utilizes data substitution methods, the venting assumption should always substitute the maximum N_2O emission rate recorded over the applicable lookback period.

6.4 Monitoring Parameters

Prescribed monitoring parameters necessary to calculate baseline and project emissions are provided in Table 6.2.

Table 6.2. Adipic Acid Project Monitoring Parameters

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
General Project Parameters						
	Regulations	Project developer attestation of compliance with regulatory requirements relating to the composting project		n/a	Each verification	Information used to: 1) To demonstrate ability to meet the legal requirement test – where regulation would require the abatement of N_2O or the installation of certain NO_X emission control technology that will impact N_2O emissions at an AAP. 2) To demonstrate compliance with associated environmental rules, e.g., criteria pollutant emission standards, health and safety, etc.
Equation 5.1	ER	Emission reductions for the reporting period	tCO_2e	c	Per reporting period	
Equation 5.2; Equation 5.4.	AA_{RP}	Measured adipic acid production during the reporting period	t	m	Measured daily, totaled for the reporting period	
Equation 5.2; Equation 5.6.6	GWP_{N2O}	Global warming potential of N_2O	tCO_2e / tN_2O	r	Per reporting period	
Equation 5.2	ld	The proportion of adipic acid production in the reporting period assessed as being due to leakage into the project facility	%	c	Per reporting period	Leakage deduction calculated using one of the methods prescribed in Section 5.1.4, and applied each reporting period (where relevant).

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.33; 6; Equation 5.6.	*cu*	Each installed N_2O emissions control unit (e.g., thermal reduction unit, adiabatic reactor, absorption media, or other N_2O abatement device)	All applicable units	o	Each verification	
Equation 5.33; Equation 5.6.6	*ncu*	Each installed non- N_2O emissions control unit (e.g., selective catalytic reduction unit or other non- N_2O abating device), inclusive of any bypassed and direct venting of N_2O emissions	All applicable units	o	Each verification	
Error! Reference source not found.9	GWP_{CH4}	Global warming potential of CH_4	tCO_2e / tCH_4	r	Per reporting period	
Error! Reference source not found.4	$EF_{CO2,E}$	Carbon dioxide (CO_2) emission factor for electricity used	MWh	r	Each verification	Refer to the version of the U.S. EPA eGRID most closely corresponding to the time period during which the electricity was used. Projects shall use the annual total output emission rates for the subregion where the project is located, not the annual non-baseload output emission rates. The eGRID tables are available from the U.S. EPA website: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
Error! Reference source not found.4	$EF_{CO2,F}$	Fuel-specific emission factor f from **Error! Reference source not found.**	MMBtu or gallons	r	Each verification	**Error! Reference source not found.**
Baseline Calculation Parameters						
Equation 5.1; Equation 5.2	*BE*	Baseline emissions for the reporting period	tCO_2e	c	Each reporting period	Emissions that would have occurred in the absence of the project activity.
Equation 5.2; **Error! Reference source not found.**	$TE_{y,N2O}$/ $TE_{RP,N2O}$	Measured total N_2O emissions in off gas during year *y* of the reporting period (*RP*) before any emissions control treatment (e.g., destruction)	tN_2O	c	Once	
~~Equation 5.2~~	$\cancel{AE_{BL}}$	~~Baseline~~ $\cancel{N_2O}$ ~~abatement efficiency – either static,~~ $\cancel{AE_{BL,S}}$~~, or dynamic,~~ $\cancel{AE_{BL,D}}$	~~%~~	~~c~~	~~Each reporting period~~	
Equation 5.2; Equation 5.4.4	HNO_{3Ratio}	Ratio of nitric acid (HNO_3) to adipic acid	$tHNO_3$ / tAA	c	Per reporting period	
~~Equation 5.3~~	$\cancel{AE_{BL,S}}$	~~Static average baseline~~ $\cancel{N_2O}$ ~~abatement efficiency~~	~~%~~	~~c~~	~~Once~~	
~~Equation 5.3~~	$\cancel{AE_{BLy}}$	~~Abatement efficiency rate in year *y* of the baseline look-back period~~	~~%~~	~~c~~	~~Once~~	
~~Equation 5.3~~	$\cancel{z}$	~~Total number of annual~~ $\cancel{N_2O}$ ~~abatement efficiency rates included in calculation~~	~~years~~	~~c~~	~~Once~~	~~*z* will always be >= 5 years.~~

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
~~Equation 5.3; Equation 5.5~~	~~$RE_{BLy,N2O}$~~	~~Measured N_2O reduced and/or destroyed by the N_2O emission control unit in year *y* of the baseline look-back period~~	~~tN_2O~~	~~c~~	~~Once~~	
Equation 5.33;	$F_{y,cu}$	Volume flow rate in the off gas during year *y* of the reporting period (*RP*) to the N_2O control unit, *cu*. Developer may also use mass flow or other units as reported by the equipment so long as final calculations are in the appropriate format.	m^3 / hour or as reported by unit	m, o	Measured continuously and ~~recorded at least~~rolled into hourly ~~or totalized for year *y* in the baseline look-back period~~averages	Note that this measurement is taken in the off gas prior to entering any control equipment.
Equation 5.33;	$N_2O_{y,conc,cu}$	N_2O concentration in the off gas during year *y* of the reporting period (*RP*) to the N_2O control unit, *cu* Developer may also use other units as reported by the equipment so long as final calculations are in the appropriate format.	tN_2O / m^3 or as reported by unit	m, o	Measured continuously and ~~recorded at least~~rolled into hourly ~~or totalized for year *y* in the baseline look-back period~~averages	Data collected using a gas analyzer and processed using appropriate software programs. The analyzer will be calibrated according to manufacturer specification and recognized industry standards. Note this measurement is taken in the off gas prior to entering any control equipment.
Equation 5.33;	$OH_{y,cu}$	Operating hours in year *y* of the reporting period (*RP*) by N_2O control unit, *cu*	hours	m, o	Totaled once for each year *y* in the baseline look-back period	

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.33	$F_{y,ncu}$	Volume flow rate in the off gas during year *y* of the reporting period (*RP*) to the non-N_2O control unit, *ncu*	m^3 / hour	m, o	Measured continuously and ~~recorded at least~~rolled into hourly ~~or totalized for year y in the baseline look-back period~~averages	Note this measurement is taken in the off gas prior to entering any non-control equipment.
Equation 5.33	$N_2O_{y,conc,ncu}$	N_2O concentration in the off gas during year *y* of the reporting period (*RP*) to the N_2O control unit, *ncu*	tN_2O / m^3	m, o	Measured continuously and ~~recorded at least~~rolled into hourly ~~or totalized for year y in the baseline look-back period~~averages	Data collected using a gas analyzer and processed using appropriate software programs. The analyzer will be calibrated according to manufacturer specification and recognized industry standards. Note this measurement is taken in the off gas prior to entering any non-control equipment.
Equation 5.33	$OH_{y,ncu}$	Operating hours in year *y* of the reporting period (*RP*) ~~or the baseline look-back period (BL)~~ by N_2O control unit, *ncu*	hours	m, o	Totaled once for each year *y* in the baseline look-back period	
~~Equation 5.5~~	~~E_{cu}~~	~~N_2O destruction efficiency, expressed as a fraction of total N_2O destroyed, of the N_2O emissions control unit, cu~~		~~o~~	~~Once~~	
Equation 5.4.4	HNO_{3y}	Tonnes HNO_3 produced in year *y* of the baseline look-back period (5 years)	$tHNO_3$	o	Once	
Equation 5.4.	AA_y	Annual tonnes adipic acid in year *y* of the baseline look-back period (5 years)	t adipic acid	o	Once	

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.4.4	HNO_{3RP}	Measured HNO_3 production in reporting period	$tHNO_3$	m	Daily, totaled for the reporting period	
Error! Reference source not found.4	$BE_{CO2,EL,FF}$	Average baseline CO_2 emissions from fossil fuel and/or electricity use from operation of N_2O abatement technology during the baseline look-back period	tCO_2	c	Once	
Error! Reference source not found.4	QE_{avg}	Average quantity of grid-connected electricity consumed from operation of N_2O abatement technology during the baseline look-back period or annual amount during the reporting period	MWh	o	Once	
Error! Reference source not found.4	QF_{avg}	Average quantity of fossil fuel consumed from operation of N_2O abatement technology during the baseline look-back period or annual amount during the reporting period	MMBtu or gallons	o	Once	
Project Calculation Parameters						
Equation 5.1; Equation 5.55	PE	Project emissions during the reporting period	tCO_2e	c	Per reporting period	Emissions resulting from project activities.

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.55; Equation 5.6.6	PE_{N2O}	Measured N_2O emissions in the off gas to project N_2O control units during the reporting period	tCO_2e	c	Per reporting period	
Equation 5.55; Equation 5.77	PE_{HC}	GHG emissions from use of hydrocarbons as a reducing agent or to reheat off gas during the reporting period	tCO_2e	c	Per reporting period	
Equation 5.55; **Error! Reference source not found.**10	PE_{EE}	GHG emissions from external energy used to reheat the off gas during the reporting period	tCO_2e	c	Per reporting period	
Equation 5.6.6	$F_{RP,cu}$	Volume flow rate in the off gas during the reporting period to the N_2O control unit Developer may also use mass flow or other units as reported by the equipment so long as final calculations are in the appropriate format.	m^3 / hour	m	Every one minute of the reporting period; rolled into hourly averages	Note this measurement is taken in the off gas prior to entering any control equipment.

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.6.6	$N_2O_{RP,conc,cu}$	N_2O concentration in the off gas during the reporting period to the N_2O control unit Developer may also use mass flow or other units as reported by the equipment so long as final calculations are in the appropriate format.	tN_2O / m^3	m	Every one minute of the reporting period; rolled into hourly averages	Data collected using a gas analyzer and processed using appropriate software programs. The analyzer will be calibrated according to manufacturer specification and recognized industry standards. Note this measurement is taken in the off gas prior to entering any control equipment.
Equation 5.6.6	$OH_{RP,cu}$	Operating hours in reporting period by N_2O control unit	hours	o	Totaled once for the reporting period	
Equation 5.6.6	$F_{RP,ncu}$	Volume flow rate in the off gas during the reporting period to the non-N_2O control unit Developer may also use mass flow or other units as reported by the equipment so long as final calculations are in the appropriate format.	m^3 / hour	m	Every one minute of the reporting period	Note this measurement is taken in the off gas prior to entering any non-control equipment.

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.6.6	$N_2O_{RP,conc,ncu}$	N_2O concentration in the off gas during the reporting period to the non- N_2O control unit Developer may also use mass flow or other units as reported by the equipment so long as final calculations are in the appropriate format.	tN_2O / m^3	m	Every one minute of the reporting period	Data collected using a gas analyzer and processed using appropriate software programs. The analyzer will be calibrated according to manufacturer specification and recognized industry standards. Note this measurement is taken in the off gas prior to entering any non-control equipment.
Equation 5.6.6	$OH_{RP,ncu}$	Operating hours in reporting period by non- N_2O control unit	hours	o	Totaled once for the reporting period	
Equation 5.77; Equation 5.88	CO_{2HC}	Net GHG emissions as CO_2 from hydrocarbon use during the reporting period	tCO_2e	c	Per reporting period	
Equation 5.77; **Error! Reference source not found.**9	CH_{4HC}	Net GHG emissions as CH_4 from hydrocarbon use during the reporting period	tCO_2e	c	Per reporting period	
Equation 5.88	ρ_{HC}	Hydrocarbon density	t / m^3	m	Per reporting period	
Equation 5.88	$Q_{HC,RP}$	Quantity of hydrocarbon, with two or more molecules of carbon (i.e., not methane, input during the reporting period)	m^3	o	Daily during the reporting period	

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.88	$EF_{HC,RP}$	GHG emissions as CH_4 from hydrocarbon use during the reporting period	tCO_2e / tHC	c	Per reporting period	Given by the molecular weight of the hydrocarbon and CO_2 and the chemical reaction when hydrocarbons are converted.
Equation 5.88	$Q_{HC,avg}$	Historical average annual quantity of hydrocarbon, with two or more molecules of carbon, during the baseline look-back period (5 years)	m^3	o	Once	
Equation 5.88	$EF_{HC,avg}$	Historical average annual GHG emissions as CH_4 from hydrocarbon use during the baseline look-back period (5 years)	tCO_2e / tHC	c	Once	Given by the molecular weight of the hydrocarbon and CO_2 and the chemical reaction when hydrocarbons are converted.
Error! Reference source not found.9	ρ_{CH4}	Methane density	t / m^3	m	Per reporting period	
Error! Reference source not found.9	$Q_{CH4,RP}$	Quantity of methane used during the reporting period	m^3	o	Daily per reporting period	
Error! Reference source not found.9	$Q_{CH4,avg}$	Historical average annual quantity of methane used during the period predating the project (5 years)	m^3	o	Once	
Error! Reference source not found.10; **Error! Reference source not found.**1	*SE*	Emissions from net change in steam export during the reporting period	tCO_2e	c	Per reporting period	

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
Error! Reference source not found.10; **Error! Reference source not found.**2	*OGU*	Emissions from net change in off gas utilization during the reporting period	tCO_2e	c	Per reporting period	
Error! Reference source not found.10; **Error! Reference source not found.**3	*OGH*	Emissions from net change in off gas heating during the reporting period	tCO_2e	c	Per reporting period	
Error! Reference source not found.10; **Error! Reference source not found.**4	$CO_{2,net}$	Net increase in CO_2 emissions from increased fossil fuel and/or electricity use due to project activity. If result is <0, use a value of 0	tCO_2	c	Per reporting period	
Error! Reference source not found.1	ST_{avg}	Baseline steam export during a reporting period	MW	c	Once	
Error! Reference source not found.1	ST_{RP}	Project steam export during the reporting period	MW	c	Once	
Error! Reference source not found.1; **Error! Reference source not found.**2	OH_{RP}	Operating hours in reporting period	hours	o	Totaled once for the reporting period	
Error! Reference source not found.1	η_{ST}	Efficiency of steam generation	fraction	c	Once	Manufacturer supplied information.
Error! Reference source not found.1	EF_{ST}	Fuel emission factor for steam generation	tCO_2e / MWh	r	Per reporting period	From fuel supplier certificate or default value.

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
Error! Reference source not found.	EE_{avg}	Baseline energy export from off gas utilization during a reporting period	MW	c	Once	
Error! Reference source not found.2	EE_{RP}	Project energy export from off gas utilization during the reporting period	MW	c	Once	
Error! Reference source not found.	η_r	Efficiency of replaced technology	fraction	c	Once	Manufacturer supplied information.
Error! Reference source not found.	EF_r	Fuel emission factor for replaced technology	tCO_2e / MWh	r	Per reporting period	From fuel supplier certificate or default value.
Error! Reference source not found.	EI_{OGH}	Energy input for additional off gas heating during the reporting period	MWh	m or c	Monthly	
Error! Reference source not found.	η_{OGH}	Efficiency of additional off gas heating	fraction	c or r	Once	Manufacturer supplied information.
Error! Reference source not found.	EF_{OGH}	Emission factor for additional off gas heating	tCO_2e / MW	r	Once	From fuel supplier certificate or default value.
Error! Reference source not found.	$PE_{CO2,EL,FF}$	CO_2 emissions from fossil fuel and/or electricity use from operation of N_2O abatement technology during the reporting period	tCO_2	c	Per reporting period	

7 Reporting Parameters

This section provides requirements and guidance on reporting rules and procedures. A priority of the Reserve is to facilitate consistent and transparent information disclosure among project developers. Project developers must submit verified emission reduction reports to the Reserve for every reporting period. To respect proprietary information, a number of project documents will not be publicly available, and will be identified as such in Section 7.1.

7.1 Project Submittal Documentation

Project developers must provide the following documentation to the Reserve in order to list an adipic acid project:

- Project Submittal form
- Project diagram
- Signed Attestation of Title form
- Signed Attestation of Voluntary Implementation form
- Signed Attestation of Regulatory Compliance form
- Verification Report
- Verification Statement

Project developers must provide the following documentation each reporting period in order for the Reserve to issue CRTs for quantified GHG reductions:

- Verification Report
- Verification Statement
- Project diagram (if changed from previous reporting period)
- Signed Attestation of Title form
- Signed Attestation of Voluntary Implementation form
- Signed Attestation of Regulatory Compliance form

At a minimum, the above project documentation (except for the project diagram) will be available to the public via the Reserve's online registry. Further disclosure and other documentation may be made available on a voluntary basis through the Reserve. Project submittal forms can be found at http://www.climateactionreserve.org/how/program/documents/.

7.2 Record Keeping

For purposes of independent verification and historical documentation, project developers are required to keep all information outlined in this protocol for a period of 10 years after the information is generated or 7 years after the last verification. This information will not be publicly available but may be requested by the verifier or the Reserve.

System information the project developer must retain includes:

- All data inputs for the calculation of the project emission reductions, including all required sampled data
- Copies of all solid waste, air, water, and land use permits, Notices of Violations (NOVs), and any administrative or legal consent orders dating back at least five years prior to the project start date, and for each subsequent year of project operation

- Executed Attestation of Title, Attestation of Regulatory Compliance, and Attestation of Voluntary Implementation forms
- Plant design information (nameplate capacity and operating parameters per manufacturer's operating manual) and diagrams/drawings of the AAP
- Diagram schemes showing the type of and detailed components of the N_2O control system and where it is or where it will be installed
- Automated extractive gas analyzer or monitor information (model number, serial number, calibration procedures)
- Gas volume flow meter information (model number, serial number, calibration procedures)
- Plans or diagram schemes showing the selection of data measuring points upstream and/or downstream to the N_2O control system
- Calibration results for all meters
- Information relevant to the N_2O abatement catalysts (composition, operation, and installation)
- The total production of adipic acid, number of operating hours, and control unit utilization rate per reporting period
- Onsite fossil fuel use records
- Onsite grid electricity use records
- Results of CO_2e annual reduction calculations
- Initial and annual verification records and results
- All maintenance records relevant to the N_2O control system and monitoring equipment

Calibrated gas analyzer information that the project developer must retain includes:

- Date, time, and location of N_2O measurement
- N_2O measurement instrument type and serial number
- Date, time, and results of instrument calibration
- Corrective measures taken if instrument does not meet performance specifications

7.3 Reporting Period and Verification Cycle

A reporting period is the length of time which GHG emission reductions from project activities are quantified. Project developers must report GHG reductions resulting from project activities during each reporting period. Although projects must be verified each reporting period at a minimum, the Reserve will accept verified emission reduction reports on a sub-annual basis, should the project developer choose to have a sub-annual reporting period and verification schedule (e.g., monthly, quarterly, or semi-annually). One site visit is required ~~each reporting period~~for every 24 months of data at a minimum.

Reporting periods must be contiguous; there must be no time gaps in reporting during the crediting period of a project once the initial reporting period has commenced. For periods where no adipic acid is being produced, all requisite data must still be recorded, and full datasets made available to verifiers upon request.

A verification cycle is the length of time which GHG emission reductions from project activities are verified. To meet the reporting period verification deadline, the project developer must have the required verification documentation (see Section 7.1) submitted within 12 months of the end of each reporting period. ~~A~~Two reporting ~~period~~periods may ~~exceed 12 months, and only in such circumstances can more than 12 months of emission reductions~~ be verified in once cycle, for a maximum of 24 months of project data.

8 Verification Guidance

This section provides verification bodies with guidance on verifying GHG emission reductions associated with the project activity. This verification guidance supplements the Reserve's Verification Program Manual and describes verification activities in the context of reducing GHG emissions through adipic acid projects at AAPs.

Verification bodies trained to verify adipic acid projects must be familiar with the following documents:

- Reserve Offset Program Manual
- Reserve Verification Program Manual
- Reserve China Adipic Acid Production Protocol (this document)

The Reserve Offset Program Manual, Verification Program Manual, and protocols are designed to be compatible with each other and are available on the Reserve's website at http://www.climateactionreserve.org.

ISO-accredited verification bodies trained by the Reserve for this project type are eligible to verify China adipic acid project reports. Information about verification body accreditation and Reserve project verification training can be found in Section 3.4.1 of the Reserve Verification Program Manual

8.1 Verification of Multiple Projects at a Single Adipic Acid Production Facility

Because the protocol allows for multiple projects at a single adipic acid production facility, project developers have the option to hire a single verification body to verify multiple projects under a joint project verification. This may provide economies of scale for the project verifications and improve the efficiency of the verification process. Joint project verification is only available as an option for a single project developer; joint project verification cannot be applied to multiple projects registered by different project developers at the same facility.

Under joint project verification, each project, as defined by the protocol, must be registered separately in the Reserve system, and requires its own verification process and Verification Statement (i.e., each project is assessed by the verification body separately as if it were the only project at the facility). However, all projects may be verified together by a single site visit to the facility. Furthermore, a single Verification Report may be filed with the Reserve that summarizes the findings from multiple project verifications.

If during joint project verification, the verification activities of one project are delaying the registration of another project, the project developer can choose to forego joint project verification. There are no additional administrative requirements for the project developer or the verification body if joint project verification is terminated.

~~8.1~~8.2 Standard of Verification

The Reserve's standard of verification for adipic acid projects is the Adipic Acid Production Protocol (this document), the Reserve Offset Program Manual, and the Verification Program Manual. To verify an adipic acid project report, verification bodies apply the guidance in the Verification Program Manual and this section of the protocol to the standards described in

Sections 2 through 7 of this protocol. Sections 2 through 7 provide eligibility rules, methods to calculate emission reductions, performance monitoring instructions and requirements, and procedures for reporting project information to the Reserve.

~~8.2~~8.3 Monitoring Plan

The Monitoring Plan serves as the basis for verification bodies to confirm that the monitoring and reporting requirements in Section 6 and Section 7 have been met, and that consistent, rigorous monitoring and record keeping is ongoing at the project site. Verification bodies shall confirm that the Monitoring Plan covers all aspects of monitoring and reporting contained in this protocol and specifies how data for all relevant parameters in Table 6.2 are collected and recorded.

~~8.3~~8.4 Verifying Project Eligibility

Verification bodies must affirm an adipic acid project's eligibility according to the rules described in this protocol. The table below outlines the eligibility criteria for adipic acid projects. This table does not present all criteria for determining eligibility comprehensively; verification bodies must also look to Section 3 and the verification items list in Table 8.1.

Table 8.1. Summary of Eligibility Criteria for an Adipic Acid Project

Eligibility Rule	Eligibility Criteria	Frequency of Rule Application
Start Date	Projects must be submitted for listing within 12 months of the project start date	Once during first verification
Location	~~United States and U.S. territories and tribal areas~~China	Once during first verification
Performance Standard	▪ For new installations, the installation of a previously uninstalled N_2O control technology at an AAP ▪ For enhancements, the increased utilization of the existing N_2O control technology compared historical utilization	Every verification
Legal Requirement Test	Signed Attestation of Voluntary Implementation form and monitoring procedures for ascertaining and demonstrating that the project passes the legal requirement test	Every verification
Regulatory Compliance Test	Signed Attestation of Regulatory Compliance form and disclosure of all non-compliance events to verifier; project must be in material compliance with all applicable laws	Every verification

~~8.4~~8.5 Core Verification Activities

The Adipic Acid Production Protocol provides explicit requirements and guidance for quantifying the GHG reductions associated with reducing N_2O emissions at adipic acid plants. The Verification Program Manual describes the core verification activities that shall be performed by verification bodies for all project verifications. They are summarized below in the context of an adipic acid project, but verification bodies must also follow the general guidance in the Verification Program Manual.

Verification is a risk assessment and data sampling effort designed to ensure that the risk of reporting error is assessed and addressed through appropriate sampling, testing, and review. The three core verification activities are:

1. Identifying emission sources, sinks, and reservoirs (SSRs)
2. Reviewing GHG management systems and estimation methodologies

3. Verifying emission reduction estimates

Identifying emission sources, sinks, and reservoirs
The verification body reviews for completeness the sources, sinks, and reservoirs identified for a project.

Reviewing GHG management systems and estimation methodologies
The verification body reviews and assesses the appropriateness of the methodologies and management systems that the adipic acid project operator uses to gather data on plant operations and N_2O emissions and to calculate baseline and project emissions.

Verifying emission reduction estimates
The verification body further investigates areas that have the greatest potential for material misstatements and then confirms whether or not material misstatements have occurred. This involves site visits to the project facility to ensure the systems on the ground correspond to and are consistent with data provided to the verification body. In addition, the verification body recalculates a representative sample of the performance or emissions data for comparison with data reported by the project developer in order to double-check the calculations of GHG emission reductions.

~~8.5~~8.6 Adipic Acid Production Verification Items

The following tables provide lists of items that a verification body needs to address while verifying an adipic acid project. The tables include references to the section in the protocol where requirements are further specified. The table also identifies items for which a verification body is expected to apply professional judgment during the verification process. Verification bodies are expected to use their professional judgment to confirm that protocol requirements have been met in instances where the protocol does not provide (sufficiently) prescriptive guidance. For more information on the Reserve's verification process and professional judgment, please see the Verification Program Manual.

Note: These tables shall not be viewed as a comprehensive list or plan for verification activities, but rather guidance on areas specific to adipic acid projects that must be addressed during verification.

~~8.5.1~~8.6.1 Project Eligibility and CRT Issuance

Table 8.2 lists the criteria for reasonable assurance with respect to eligibility and CRT issuance for adipic acid projects. These requirements determine if a project is eligible to register with the Reserve and/or have CRTs issued for the reporting period. If any requirement is not met, either the project may be determined ineligible or the GHG reductions from the reporting period (or subset of the reporting period) may be ineligible for issuance of CRTs, as specified in Sections 2, 3, and 6.

Table 8.2. Eligibility Verification Items

Protocol Section	Eligibility Qualification Item	Apply Professional Judgment?
2.2	Verify that the project meets the definition of an adipic acid project	No
2.2	Verify whether the AAP is existing, upgraded, relocated, or restarted	No
2.3	Verify ownership of the reductions by reviewing the Attestation of Title	No
3.1	Verify that the project only consists of activities at a single AAP operating within ~~the U.S. or its territories~~China	No
3.2	Verify project start date	No
3.3	Verify that project is within its 10-year crediting period	No
3.4.1	Verify that the project meets the technology-specific threshold for the performance standard test	No
3.4.2	Confirm execution of the Attestation of Voluntary Implementation form to demonstrate eligibility under the Legal Requirement Test	No
3.4.2	Confirm that ~~neither the Title V nor PSD permit for~~ the AAP ~~includes language requiring installation of~~is not subject to any requirements to install N_2O control technology	Yes
3.4.2; 6	Verify that the Monitoring Plan contains procedures for ascertaining and demonstrating that the project passes the Legal Requirement Test at all times	Yes
3.5	Verify that the project activities comply with applicable laws by reviewing any instances of non-compliance provided by the project developer and performing a risk-based assessment to confirm the statements made by the project developer in the Attestation of Regulatory Compliance form	Yes
6	Verify that the project has documented and implemented a Monitoring Plan	No
6	Verify that monitoring meets the requirements of the protocol. If it does not, verify that a variance has been approved for monitoring variations	No
6.1	Verify that installation and initial certification of the N_2O CEMS were completed according to manufacturer specifications and the requirements of this protocol	No
6.1.2; 6.2	Verify that the calibration test procedures were properly followed, including the calibration error test and linearity check	No
6.1.3; 6.2	Verify that the relative accuracy test audits were completed according to the required procedure and schedule	No
6.2	Verify that the QA/QC activities meet the protocol's QA/QC requirements	No
6.3	If used, verify that data substitution methodology was properly applied	No
	If any variances were granted, verify that variance requirements were met and properly applied	Yes

~~8.5.2~~8.6.2 Quantification

Table 8.3 lists the items that verification bodies shall include in their risk assessment and recalculation of the project's GHG emission reductions. These quantification items inform any determination as to whether there are material and/or immaterial misstatements in the project's GHG emission reduction calculations. If there are material misstatements, the calculations must be revised before CRTs are issued.

Table 8.3. Quantification Verification Items

Protocol Section	Qualification Item	Apply Professional Judgment?
4	Verify that SSRs included in the GHG Assessment Boundary correspond to those required by the protocol and those represented in the project diagram for the reporting period	No
4	Verify that all SSRs in the GHG Assessment Boundary are accounted for	No
5.1	Verify that the baseline emissions are properly aggregated	No
~~5.1~~	~~Verify that the correct value for AE_{BL} is used in the calculation of baseline emissions~~	~~No~~
~~5.1~~	~~Verify that the project developer received Reserve approval for using the dynamic baseline approach, if applicable~~	~~No~~
~~5.1.1~~	~~Verify that the project developer correctly calculated and applied $AE_{BL,S}$, *if applicable*~~	~~No~~
~~5.1.2~~	~~Verify that the project developer correctly calculated and applied $AE_{BL,D}$, *if applicable*~~	~~No~~
5.1.3	Verify that the project developer correctly calculated the nitric acid recovery ratio	No
5.2	Verify that the project emissions were calculated according to the protocol with the appropriate data	No
5.2.1	Verify that the project developer correctly accounted for N_2O emissions at the inlet and/or outlet of the control system for the project, as applicable	No
0	Verify that the project developer correctly quantified hydrocarbon use for the project, *if applicable*	No
5.2.3	Verify that the project developer correctly quantified external energy inputs or was correct in not estimating this source due to capture and use of the additional energy within the system, *if applicable*	Yes
5.2.3	Verify that the project developer correctly monitored, quantified, and aggregated electricity use, *if applicable*	Yes
5.2.3	Verify that the project developer correctly monitored, quantified, and aggregated fossil fuel use, *if applicable*	Yes
5.2.3	Verify that the project developer applied the correct emission factors for fossil fuel combustion and grid-delivered electricity, *if applicable*	No
5	If default emission factors are not used, verify that project-specific emission factors are based on official source-tested emissions data or are from an accredited source test service provider	No
5	Verify that the appropriate calculations were performed by the project developer and quantification and equation processes were followed	No

~~8.5.3~~8.6.3 Risk Assessment

Verification bodies will review the following items in Table 8.4 to guide and prioritize their assessment of data used in determining eligibility and quantifying GHG emission reductions.

Note that regulatory requirements are extensive, particularly with respect to system installation, certification, calibration, accuracy testing and sampling, as are manufacturer recommendations for the same. Whilst a verifier should not ignore any instances they observe where such requirements have not been met (for instance where equipment is being operated in a manner inconsistent with manufacturer recommendations), these requirements should be taken as an input into verification risk analysis, and verifiers should use their professional judgement to determine to what extent they feel the project-specific risk justifies them inspecting compliance with specific requirements. A verifier may determine that a sampling-based approach is appropriate in certain circumstances.

Table 8.4. Risk Assessment Verification Items

Protocol Section	Item that Informs Risk Assessment	Apply Professional Judgment
6	Verify that the project Monitoring Plan is sufficiently rigorous to support the requirements of the protocol and proper operation of the project	Yes
6	Verify that appropriate monitoring equipment is in place to meet the requirements of the protocol.	Yes
6	Verify that the individual or team responsible for managing and reporting project activities are qualified to perform this function	Yes
6	Verify that appropriate training was provided to personnel assigned to GHG reporting duties	Yes
6	Verify that all contractors are qualified for managing and reporting GHG emissions if relied upon by the project developer. Verify that there is internal oversight to assure the quality of the contractor's work	Yes
6, 7.2	Verify that all required records have been retained by the project developer	No

~~8.5.4~~8.6.4 Completing Verification

The Verification Program Manual provides detailed information and instructions for verification bodies to finalize the verification process. It describes completing a Verification Report, preparing a Verification Statement, submitting the necessary documents to the Reserve, and notifying the Reserve of the project's verified status.

9 Glossary of Terms

Accredited verifier	A verification firm approved by the Climate Action Reserve to provide verification services for project developers.
Additionality	Project activities that are above and beyond “business as usual” operation, exceed the baseline characterization, and are not mandated by regulation.
Carbon dioxide (CO_2)	The most common of the six primary greenhouse gases, consisting of a single carbon atom and two oxygen atoms.
CO_2 equivalent (CO_2e)	The quantity of a given GHG multiplied by its total global warming potential. This is the standard unit for comparing the degree of warming which can be caused by different GHGs.
Direct emissions	GHG emissions from sources that are owned or controlled by the reporting entity.
Effective Date	The date of adoption of this protocol by the Reserve board: September 30, 2020.
Emission factor (EF)	A unique value for determining an amount of a GHG emitted for a given quantity of activity data (e.g., metric tons of carbon dioxide emitted per barrel of fossil fuel burned).
Fossil fuel	A fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.
Greenhouse gas (GHG)	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), or perfluorocarbons (PFCs).
GHG reservoir	A physical unit or component of the biosphere, geosphere, or hydrosphere with the capability to store or accumulate a GHG that has been removed from the atmosphere by a GHG sink or a GHG captured from a GHG source.
GHG sink	A physical unit or process that removes GHG from the atmosphere.
GHG source	A physical unit or process that releases GHG into the atmosphere.
Global Warming Potential (GWP)	The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one unit of a given GHG compared to one unit of CO_2.
Indirect emissions	Reductions in GHG emissions that occur at a location other than where the reduction activity is implemented, and/or at sources not owned or controlled by project participants.
Metric ton (t, tonne)	A common international measurement for the quantity of GHG emissions, equivalent to about 2204.6 pounds or 1.1 short tons.

Methane (CH_4)	A potent GHG with a GWP of 25, consisting of a single carbon atom and four hydrogen atoms.
MMBtu	One million British thermal units.
Mobile combustion	Emissions from the transportation of employees, materials, products, and waste resulting from the combustion of fuels in company owned or controlled mobile combustion sources (e.g., cars, trucks, tractors, dozers, etc.).
Nitrous oxide (N_2O)	A potent GHG with a GWP of 298, consisting of two nitrogen atoms and one oxygen atom.
Off gas	All gases (e.g., NO_x and N_2O) produced during and post adipic acid production that are emitted to the atmosphere; also referred to as "tail gas."
Project baseline	A "business as usual" GHG emission assessment against which GHG emission reductions from a specific GHG reduction activity are measured.
Project developer	An entity that undertakes a GHG project, as identified in Section 2.2 of this protocol.
Verification	The process used to ensure that a given participant's GHG emissions or emission reductions have met the minimum quality standard and complied with the Reserve's procedures and protocols for calculating and reporting GHG emissions and emission reductions.
Verification body	A Reserve-approved firm that is able to render a verification opinion and provide verification services for operators subject to reporting under this protocol.

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Appendix A Development of the Performance Standard

A.1 Emission Controls at Adipic Acid Plants

A.1.1 Existing Controls

Installation of N_2O abatement technology is common in most Western industrialized countries. However, in China, abatement has been limited except for two locations that installed equipment for crediting under the CDM.

The two CDM crediting projects, located in the Henan and Liaoning Provinces of China, were operational between 2007 and 2013 reducing over 1 billion tonnes of emissions during that timespan.[52] Both projects applied for second crediting periods in 2013 but failed to certify any further CERs. Although the exact reason for a lack of further issuance is unknown, it is likely that the stoppage was a result of controversy associated with concerns over leakage as well as a drop in CER pricing when such credits were no longer eligible for compliance under the European Union's Emissions Trading System.[53]

China does not regularly track or publish data on N_2O emission abatement at individual AAPs. A 2020 study, however, examined that the average emissions intensity of adipic acid projects in China was approximately 0.300 tN_2O/tAA in 2015, an increase from 0.206 tN_2O/tAA in 2010.[54] The more recent intensity value is equivalent to the IPCC's unabated emissions factor of 0.3 tN_2O/tAA, indicating that there was little to no N_2O abatement in China in 2015.[55] The author of the study notes that the change in emissions intensity over time is likely attributed to abatement that occurred in the short term for CERs, and that enrolled AAPs have ceased abating. This indicates that income from CERs were a necessary incentive for AAPs to abate N_2O emissions.

There are no known reasons for an AAP in China to install N_2O abatement equipment today except for revenue from carbon credits. As discussed earlier, the China ETS is not expected to cover N_2O emissions, nor are N_2O emissions included in China's international decarbonization commitments. A performance standard test that credits emissions above 0% in China may therefore be appropriate. However, due to concerns of leakage (see Appendix B), the Reserve will conservatively only credit for abatement efficiency of greater than 90%. Additionally, AAPs must meet a technology standard by installing eligible abatement equipment as described in the following section.

A.1.2 Potential Controls and Eligible Project Activities

Adipic acid N_2O abatement technology is similar to the abatement technology at nitric acid facilities. In the Reserve's Nitric Acid Protocol, abatement can either be secondary (abatement

[52] UNFCCC CDM, "Project: 1238 N2O Decomposition Project of PetroChina Company Limited Liaoyang Petrochemical Company - Crediting Period Renewal Request"; UNFCCC CDM, "Project: 1083 N2O Decomposition Project of Henan Shenma Nylon Chemical Co., Ltd - Crediting Period Renewal Reques."

[53] "Commission Regulation (EU) No 550/2011 of 7 June 2011 on Determining, Pursuant to Directive 2003/87/EC of the European Parliament and of the Council, Certain Restrictions Applicable to the Use of International Credits from Projects Involving Industrial Gases," 149 OJ L § (2011), https://eur-lex.europa.eu/eli/reg/2011/550/oj.

[54] Qing Tong et al., "Scenario Analysis on Abating Industrial Process Greenhouse Gas Emissions from Adipic Acid Production in China," *Petroleum Science* 17, no. 4 (August 1, 2020): 1171–79, https://doi.org/10.1007/s12182-020-00450-0.

[55] "EFDB - Main Page," accessed September 2, 2021, https://www.ipcc-nggip.iges.or.jp/EFDB/main.php.

in the burner/ammonia oxidation reactor (AOR) where the reaction occurs) or tertiary (abatement of the waste off gas downstream of the AOR). However, unlike nitric acid production, adipic acid production cannot tolerate the associated pressure change with secondary abatement. As a result, abatement is limited to installing technology to scrub the facility's off-gas. Control technology falls into four types of systems, outlined in Table A.1.

Table A.1. Review of Potential Control Technologies at Adipic Acid Plants[56]

Abatement Type	Description	Example Equipment
Catalytic Destruction	Destroy N_2O using a catalyst – selective catalytic reduction (SCR) or non-selective catalytic reduction (NSCR)	Noble or precious metal catalysts
Thermal Destruction	Destroy N_2O using flame burners with pre-mixed CH_4 or natural gas	Thermal Reduction Units (TRUs)
Recycle to Nitric Acid	Recycle N_2O to create nitric acid by burning the gas at high temperatures with steam	Nitrogen recycling adiabatic reactor
Recycling / Utilization Technologies	Utilize N_2O as a reactant or input to produce other products	Using N_2O off gas as an oxidant to produce phenol from benzene

~~Existing facilities can reduce their emissions beyond a business-as-usual level in two ways. First, they could utilize their existing emissions control technology at a higher rate, or they could install new emissions abatement control technology. Increasing the use of existing abatement technology is particularly pertinent to U.S. AAPs; all plants were early movers in installing abatement technology. However, there are often barriers (financial or otherwise) that make it impracticable to fully utilize the existing technology to abate N_2O.~~

~~For example, if a facility has TRU, there can be a trade-off between N_2O abatement and abating other potentially harmful pollutants such as NO_x.[57] Facilities can send their off gas to the TRU, which reduces N_2O[58] but has only a limited capacity to reduce NO_x emissions, or send their off gas to a NO_x-specific SCR ("SCR de-NO_x unit"), which reduces NO_x emissions but not N_2O emissions. The SCR de-NO_x unit also creates some GHG emissions due to the ammonia used during operation. Because N_2O is not regulated and NO_x emissions are regulated under the Clean Air Act, facilities will only utilize their TRUs when they are falling below their legal NO_x limits. In the absence of an offset system or a regulatory reason to reduce GHG emissions, facilities have no incentive to make a capital investment to adjust their operations to eliminate the NO_x/N_2O trade-off. With an incentive, a facility could in practice increase TRU utilization by finding a pathway to reduce NO_x.~~

56 IEA Greenhouse Gas R&D Programme, "Abatement of Other Greenhouse Gases - Nitrous Oxide," September 2000, https://ieaghg.org/docs/General_Docs/Reports/PH3-29%20nitrous%20oxide.pdf. IEA Greenhouse Gas R&D Programme, "Abatement of Other Greenhouse Gases - Nitrous Oxide," September 2000, https://ieaghg.org/docs/General_Docs/Reports/PH3-29%20nitrous%20oxide.pdf.

Appendix B Evaluation of Leakage Potential

Commented [A6]: Continue to evaluate leakage and ways to mitigate potential leakage and gaming the system. Specifically, 1) is 90% baseline sufficient; 2) potential rise in price for CRTs; 3) do we set production cap like the US Version?

Unintended secondary effects, i.e., carbon leakage, may occur if an adipic acid plant (AAP) begins to over-produce their product because the value of carbon offsets creates a perverse incentive ("product gaming"). If leakage occurs, a portion of the offsets would not represent real emission reductions nor be additional, and the activity could shift production away from other AAPs worldwide. This occurred in early Clean Development Mechanism (CDM)[59] adipic acid projects. According to the Stockholm Environmental Institute (SEI),[60] there were two primary carbon leakage drivers:

1. The protocol set the baseline N_2O abatement emissions level at 0% (i.e., no abatement); *– and –*
2. The value of the certified emission reductions (CERs)[61] created through abatement technology exceeded the value of the adipic acid itself, creating perverse incentives.

To provide an example of the economic incentives that created secondary effects in early CDM projects, SEI compared the financials of early CDM projects with later Joint Implementation (JI) projects.[62] According to SEI, JI projects had baseline historical abatement levels around 90%.[63] By only crediting the incremental emissions beyond individual facility's abatement levels, the economic incentives for JI projects remained attractive but did not appear to create the same highly skewed incentive structure as CDM projects (Table B.1).

[59] The Clean Development Mechanism (CDM) allows a country with an emission reduction/limitation commitment under the Kyoto Protocol to implement an emission reduction project in developing countries.
[60] Schneider, Lambert, Michael Lazarus, and Anja Kollmus. 2010. Industrial N_2O Projects Under the CDM: Adipic Acid – A Case of Carbon Leakage? Stockholm Environment Institute. October 9, 2010.
[61] CDM projects can earn saleable certified emission reduction (CER) credits, each equal to 1 tCO_2e, which can be counted towards meeting Kyoto targets.
[62] Joint Implementation (JI) is a mechanism that allows a developed country with an emission reduction/limitation commitment under the Kyoto Protocol to earn emission reduction units (ERUs) from an emission reduction or emission removal project in another developed country. JI offers countries a flexible and cost-efficient means of fulfilling a part of their Kyoto commitments, while the host country benefits from foreign investment and technology transfer.
[63] Schneider et al., 2010.

Table B.1. Reference Cases for the Costs and Economic Incentives for CDM and JI Projects[64]

	Unit	CDM	JI
Technology	-	Single catalytic/thermal decomposition	Redundant catalytic/thermal decomposition[65]
Adipic Acid Production	Kiloton/year	150	150
Revenues from CERs or ERUs			
Baseline emission factor	kg N_2O/t adipic acid	270	30
Project emission factor	kg N_2O/t adipic acid	4	0
Other emissions	tCO_2/t adipic acid	0.1	0.1
CERs or ERUs	CERs or ERUs/t adipic acid	82.4	9.2
Price for CERs or ERUs	USD	$23.63	$23.63
Revenues from CERs or ERUs	USD/t adipic acid	$1,947.17	$218.17
CDM / JI Transaction Costs	USD/CER or ERU	$1.04	$0.69
Abatement Costs			
Investment Costs	Million USD	$14.55	$23.63
Operational Costs	Million USD/year	$1.82	$2.73
Technical Lifetime	Years	20	20
Required Return on Investment	-	15%	15%
Net Profits from CDM or JI	USD/t adipic acid	$1,834.44	$167.26

All currencies were converted from EURs to 2010 U.S. Dollars (USD) with an annual average conversion factor of 1.33[66] and then converted to 2022 USD with a conversion factor or 1.37[67]

SEI's evaluation demonstrated a considerable difference in profit between CDM projects and JI projects ($1,834 per metric ton adipic acid versus $167 per metric ton adipic acid), largely due to differences in baseline setting.

In general, the Reserve believes there is low risk for this scenario to occur in projects with the China Adipic Acid Production Protocol for the following reasons:

1. This Protocol requires a static 90% Abatement Efficiency in the baseline for all AAPs in China. (Section 5.1). As a result, China-based projects would not achieve the same volume of credits as projects created under the CDM on a per-unit adipic acid produced basis, which had a baseline N_2O abatement emissions level of 0%; and

2. The historical average and most up-to-date (as of the time of this publication) average value of voluntary carbon offsets in Asia are lower than the historical CDM CER level

[64] Adapted from Table 6 in Schneider et al., 2010.
[65] "Redundant" refers to the installation of a second, additional catalytic or thermal decomposition unit at an AAP.
[66] https://www.x-rates.com/average/?from=EUR&to=USD&amount=1&year=2010
[67] https://www.bls.gov/data/inflation_calculator.htm

when product gaming occurred (average of $3.64 2022 USD/tCO$_2$e in Asia[68] compared to over $23.63 2022 USD/tCO$_2$e[69]). Figure B.1 below displays the historical average voluntary carbon credit prices for globally-located projects, China/Asia-based projects, and global industrial N_2O projects, as well as the average price for CERs and ERUs (Table B.1) at the time of CDM project leakage. All data were retrieved from *State of the Voluntary Carbon Market* reports from 2007 – 2021, as published by Ecosystem Marketplace, A Forest Trends Initiative.[70] In addition to showing that Chinese averages have stayed well under the 2010 CER value, Figure B.1 also shows that the value for credits from industrial N_2O projects has either stayed at the same or below the global and Chinese averages.

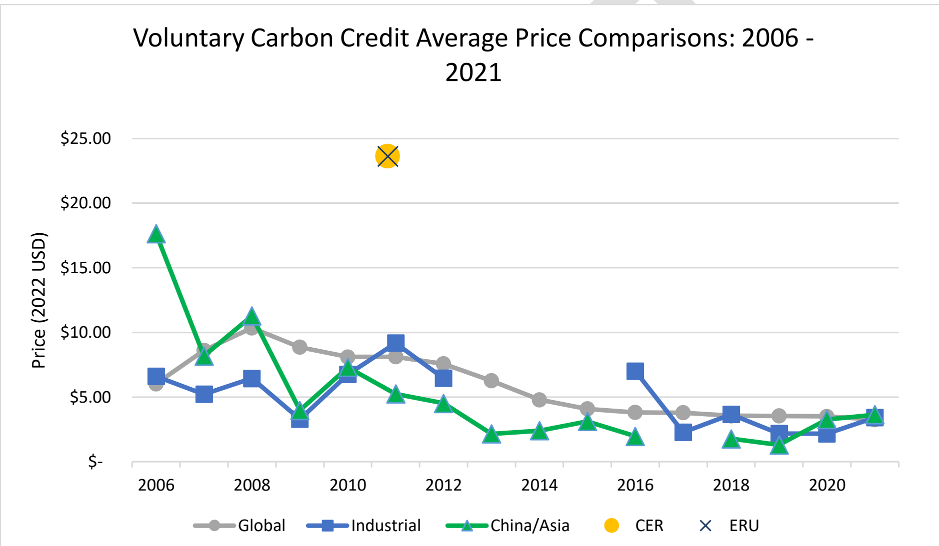

Figure B.1. Voluntary Carbon Credit Average Price Comparisons in 2022 USD

[68] ~~Kelley Hamrick and Melissa Gallant, "Voluntary Carbon Market Insights: 2018 Outlook and First-Quarter Trends" (Ecosystem Marketplace, August 2018), https://www.forest-trends.org/wp-content/uploads/2018/09/VCM-Q1-Report_Full-Version-2.pdf.~~ Donofrio et al., "Markets in Motion State of the Voluntary Carbon Markets 2021 Installment 1" (Ecosystem Marketplace, September 2021), https://www.ecosystemmarketplace.com/publications/state-of-the-voluntary-carbon-markets-2021/

[69] Schneider, Lazarus, and Kollmuss, "Industrial N_2O Projects Under the CDM: Adipic Acid - A Case of Carbon Leakage?"

[70] Note, data collected and presented, as well as project categorizations, in each State of the Voluntary Carbon Market report are not consistent from year to year. Specifically, Industrial N_2O projects represent data categorized as "Geological Sequestration and Industrial Gas" in 2006 and 2009, "Industrial Gas" in 2007 and 2008, "N_2O" in 2010 through 2012, "Gases" in 2016, and "Chemical Processes / Industrial Manufacturing" in 2017 and 2018. No average price data were available on this project type for 2013 through 2015. Also, the U.S. average price values from 2006 through 2010 are specifically for the U.S., while 2011 and 2012, and 2014 through 2018, are inclusive of all projects in North America. No regional data for the U.S. or North America were available in 2013.

The above graph shows the voluntary carbon credit average price comparisons in 2022 USD among global averages (all project types), global industrial N_2O projects, projects located in China/Asia (all project types), and the average CER and ERU price at the time of international leakage (i.e., 2010).

Furthermore, at the time of this publication the most recent average value for domestic adipic acid is just over $1,500 per tonne adipic acid in China in July 2022.[71]

Although an offset project may be financially attractive in China, the above factors all indicate that the project alone should not bring an AAP high enough value to justify increasing production exclusively for the carbon offset value; should adipic acid production increase beyond business-as-usual rates, it's likely to be for the value of adipic acid itself. Even if China-based voluntary credits rise in value to a level comparable to early CDM CER levels, the Reserve believes that the decrease in credit issuance with a tighter baseline requirement would still protect against leakage incentives.

[71] Adipic acid price analysis data was obtained over July 2022 from Echemi at the following address: https://www.echemi.com/productsInformation/pd20150901270-adipic-acid.html.

Appendix C Emission Factor Tables

Table C.1. CO_2 Emission Factors for Fossil Fuel Use[72]

Fuel Type	Heat Content	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Coal and Coke	**MMBtu / Short ton**	**kg CO_2 / MMBtu**	**kg CO_2 / Short ton**
Anthracite Coal	25.09	103.62	2,602
Bituminous Coal	24.93	93.46	2,325
Sub-bituminous Coal	17.25	97.17	1,676
Lignite	14.21	97.72	1,389
Mixed (Commercial Sector)	21.39	94.27	2,016
Mixed (Electric Power Sector)	19.73	95.52	1,885
Mixed (Industrial Cooking)	26.28	93.90	2,468
Mixed (Industrial Sector)	22.35	94.67	2,116
Coal Coke	24.80	113.67	2,819
Other Fuels - Solid	**MMBtu / Short ton**	**kg CO_2 / MMBtu**	**kg CO_2 / Short ton**
Municipal Waste	9.95	90.70	902
Petroleum Coke (Solid)	30.00	102.41	3,072
Plastics	38.00	75.00	2,850
Tires	28.00	85.97	2,407
Biomass Fuels - Solid	**MMBtu / Short ton**	**kg CO_2 / MMBtu**	**kg CO_2 / Short ton**
Agricultural Byproducts	8.25	118.17	975
Peat	8.00	111.84	895
Solid Byproducts	10.39	105.51	1,096
Wood and Wood Residuals	17.48	93.80	1,640
Natural Gas	**MMBtu / scf**	**kg CO_2 / MMBtu**	**kg CO_2 / scf**
Natural Gas	0.001026	53.06	0.05444
Other Fuels - Gaseous	**MMBtu / scf**	**kg CO_2 / MMBtu**	**kg CO_2 / scf**
Blast Furnace Gas	0.000092	274.32	0.02524
Coke Oven Gas	0.000599	46.85	0.02806
Fuel Gas	0.001388	59.00	0.08189
Propane Gas	0.002516	61.46	0.15463

[72] EPA Center for Corporate Climate Leadership. "Emission Factors for Greenhouse Gas Inventories, Table 1. Stationary Combustion." 9 March 2018. Available at: https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf.

Fuel Type	Heat Content	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Biomass Fuels - Gaseous	**MMBtu / scf**	**kg CO_2 / MMBtu**	**kg CO_2 / scf**
Landfill Gas	0.000485	52.07	0.025254
Other Biomass Gases	0.000655	52.07	0.034106
Petroleum Products	**MMBtu / gallon**	**kg CO_2 / MMBtu**	**kg CO_2 / gallon**
Asphalt and Road Oil	0.158	75.36	11.91
Aviation Gasoline	0.120	69.25	8.31
Butane	0.103	64.77	6.67
Butylene	0.105	68.72	7.22
Crude Oil	0.138	74.54	10.29
Distillate Fuel Oil No. 1 (diesel)	0.139	73.25	10.18
Distillate Fuel Oil No. 2 (diesel)	0.138	73.96	10.21
Distillate Fuel Oil No. 4 (diesel)	0.146	75.04	10.96
Ethane	0.068	59.60	4.05
Ethylene	0.058	65.96	3.83
Heavy Gas Oils	0.148	74.92	11.09
Isobutane	0.099	64.94	6.43
Isobutylene	0.103	68.86	7.09
Kerosene	0.135	75.20	10.15
Kerosene-Type Jet Fuel	0.135	72.22	9.75
Liquified Petroleum Gases (LPG)	0.092	61.71	5.68
Lubricants	0.144	74.27	10.69
Motor Gasoline	0.125	70.22	8.78
Naptha (<401 deg F)	0.125	68.02	8.50
Natural Gasoline	0.110	66.88	7.36
Other Oil (>401 deg F)	0.139	76.22	10.59
Pentane Plus	0.110	70.02	7.70
Petrochemical Feedstocks	0.125	71.02	8.88
Petroleum Coke	0.143	102.41	14.64
Propane	0.091	62.87	5.72
Propylene	0.091	67.77	6.17
Residual Fuel Oil No. 5	0.140	72.93	10.21
Residual Fuel Oil No. 6	0.150	75.10	11.27
Special Naphtha	0.125	72.34	9.04

Fuel Type	Heat Content	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Unfinished Oils	0.139	74.54	10.36
Used Oil	0.138	74.00	10.21
Biomass Fuels - Liquid	**MMBtu / gallon**	**kg CO_2 / MMBtu**	**kg CO_2 / gallon**
Biodiesel (100%)	0.128	73.84	9.45
Ethanol (100%)	0.084	68.44	5.75
Rendered Animal Fat	0.125	71.06	8.88
Vegetable Oil	0.120	81.55	9.79
Biomass Fuels - Kraft Pulping Liquor, by Wood Furnish	**MMBtu / gallon**	**kg CO_2 / MMBtu**	**kg CO_2 / gallon**
North American Softwood	-	94.40	-
North American Hardwood	-	93.70	-
Bagasse	-	95.50	-
Bamboo	-	93.70	-
Straw	-	95.10	-