AMMONIA ENERGY
ASSOCIATION

AMMONIA COMBUSTION EMISSIONS — PROJECT DEFINITION

Summary

The AEA intends to publish a whitepaper that will provide an accessible and authoritative introduction to the topic of ammonia combustion emissions in the context of a sustainable economy.

This public document will answer important and frequently asked questions regarding source emissions, and will provide context and illustration of technical material to support greater public understanding and acceptance of the use of ammonia as a fuel. It will contain an overview of ammonia combustion applications, a review of established emission limits across relevant markets and jurisdictions, and information about available and in-development ammonia combustion technologies, with useful data regarding emission levels and mitigation pathways. The whitepaper will be illustrated with industry case studies that demonstrate relevant technologies and applications. It will contain recommendations that can support the research agenda, policy development, and corporate planning. It will conclude with a robust literature review as a resource for further information.

Strategic objectives

This whitepaper fits into the Knowledge Stewardship pillar of the Ammonia Energy Association, as it fills a knowledge gap regarding ammonia combustion emissions and mitigation strategies. This allows AEA members to provide a substantiated answer to questions regarding ammonia (NH_3) and nitrogen oxide (NO_X and N_2O) emission levels, before and after emission mitigation.

Furthermore, this whitepaper supports the AEA's Collaboration pillar, as it will be a member-led process drawing input from AEA members via a dedicated working group, strengthening member networks and cooperation. The publication also allows the AEA to showcase the technologies and projects of its members.

Working Group establishment

The AEA is establishing an Ammonia Combustion Emissions Working Group, which will be responsible for directing the AEA staff and academic partners who will write this report. The Working Group will define the structure and content of the report, oversee the development of the report, and provide final approval of the report and the conclusions and positions it contains. Working Group participants may also wish to contribute text, images, and data, and may want to have a role in disseminating the finished report in public.

All AEA Members are entitled to participate in this working group and external experts will be invited to contribute as appropriate. The Working Group will disband upon completion of the report, estimated to be before the end of November 2022.

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Working Group schedule

All Working Group input can be provided through e-mail or via direct engagement with AEA staff, but the workplan is structured around four Working Group meetings, with the following proposed schedule:

- Meeting 1: **Kick-off and Project Definition**. Mid July.
  - Before attending the meeting, members are requested to fill in a questionnaire to:
    - state any content that they want to see included or emphasized
    - indicate their knowledge on specific technologies
    - propose case studies.
  - During the meeting, we aim to:
    - amend / approve this Project Definition
    - identify missing people/organizations who should be invited to participate
    - identify data requirements and sources
    - assign any specific tasks to working group participants.
- Meeting 2: **Data sets and initial conclusions**. Mid August.
  - After the first meeting, AEA staff will:
    - reach out to missing people/organizations
    - compile data and undertake initial analysis
    - draft an outline of conclusions supported by the data
    - develop a marketing and communication plan for the report launch
    - distribute these items to participants for written feedback.
  - During the meeting, we aim to:
    - identify any missing data
    - achieve consensus on the best presentation of data
    - achieve consensus on the outline of conclusions.
- Meeting 3: **First Draft**. Mid September.
  - Before the meeting, AEA staff will:
    - draft a first version of the whitepaper
    - distribute the manuscript to participants for written feedback.
  - During the meeting, we aim to:
    - discuss significant feedback
    - work to achieve consensus or identify issues requiring attention
    - identify any missing content (text, data, imagery).
- Meeting 4: **Final draft and launch plan**. Early October.
  - Before the meeting, AEA staff will:
    - draft a finished version of the whitepaper, including all data and images
    - distribute the manuscript to participants for written feedback.
  - During the meeting, we aim to:
    - discuss significant feedback
    - work to achieve consensus or identify issues requiring attention
    - approve release of the report, following final revisions, to the graphic designer
    - approve final details for marketing and communications activities.

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Project description

Significant interest exists for ammonia as zero carbon fuel and hydrogen carrier. However, there is also skepticism regarding associated ammonia and nitrogen oxide emissions. First of all, sources for such emissions should be clarified, e.g. does the emission come from the fuel itself, or is this a heat-driven process causing nitrogen oxide formation in air?

Clarification regarding emission levels from ammonia as fuel is required, preferably benchmarked against other fuels. Mitigation strategies, such as selective catalytic reduction (SCR) and ammonia oxidation (AMOX) catalysts are already industrially applied. In fact, ammonia is used to reduce nitrogen oxide emissions from carbon-containing fuels such as natural gas and coal. Emission levels before and after these emission mitigation levels should be identified, and put in the framework of existing legislation.

This whitepaper provides an overview of the above, in a format that allows policy makers to compare ammonia combustion emissions to emissions from other feedstocks.

The questions this report aims to answer include:

- What are the established acceptable emission levels in relevant markets and jurisdictions?
- How do emission levels from combustion of ammonia & ammonia blends currently compare to the established acceptable emission levels? How do they compare to the emissions of other fuels?
- How are technology developers working to reach acceptable emission levels in commercial products?
- What is the technology readiness level of ammonia and NOx emission mitigation technologies?
- How might regulations need to be adapted for ammonia combustion?
- What are the available and announced technologies of AEA members?

Proposed Charts and illustrations

- **Introduction:** Overview of ammonia applications with emphasis on its use as zero-carbon fuel.
- **Ammonia combustion overview:** Overview of various ammonia applications as a fuel.
- **Ammonia combustion overview:** Ammonia emission levels compared to other fuels in coal-fired power plants.
- **Ammonia combustion overview:** Ammonia emission levels compared to other fuels in combustion engines.
- **Ammonia combustion overview:** Ammonia emission levels compared to other fuels in gas turbines.
- **Ammonia combustion overview (case study):** Ammonia emission levels in Australia (ammonia feedstock), and in Japan when NH_3 is used as fuel.
- **Emission mitigation technologies:** Overview of emission mitigation technologies, typical applications, TRL, and downstream emission levels.

- **Case studies: emission mitigation (case study 1):** Show how emissions from cars have decreased through legislation and technology.
- **Case studies: emission mitigation (case study 2):** N_2O emission levels from EU nitric acid plants (2005-2020).

Proposed outline of the whitepaper

1. Executive summary

2. Background

- Ammonia as fuel and hydrogen vector, a carbon-free energy commodity
- Applications / markets: (1) ammonia as transportation fuel, (2) ammonia as stationary fuel, (3) ammonia as hydrogen carrier

3. Ammonia combustion & emissions mitigation

Ammonia combustion overview:

- Ammonia-fired boilers and furnaces incl. coal-fired power plants,
- Internal combustion engines incl. maritime engines,
- Stationary gas turbines & aerospace motors,
- Ammonia-fed fuel cells.
    - Emissions from combusting ammonia or ammonia blends (vs. other fuels) for these applications. (ppmv or g/kWh). Including and excluding emission mitigation technologies.

Case study: demonstrations of ammonia co-firing in coal-fired power plants in Japan. Global emission figures (GHG) & local nitrogen oxide emissions.

Emission mitigation technologies:

- Improved ammonia combustion
- Selective non-catalytic reduction (SNCR)
- Selective catalytic reduction (SCR)
- Ammonia oxidation catalysts,
- Emission detection systems.
    - Technology vendors (AEA members) for emission mitigation technologies

Legislation: Emission thresholds for transportation fuels & stationary power.

Technology readiness levels (TRL) of components and requirement for research. Parts will work, so test integrated systems, ramp up and ramp down.

4. Case studies: emission mitigation

- **Case study 1**: NO_X, CO_X, SO_X, and PM emission mitigation from transportation through legislation and technology.
- **Case study 2**: Nitrous oxide emission mitigation from European nitric acid production plants.

5. Conclusion, outlook, and recommendations

Conclude with main messages of the report:

- what are the available technologies and market applications?
- what are the opportunities for decarbonization & emission mitigation?
- where are the knowledge gaps?
- where should the R&D effort focus?
- what actions can industry take?
- what are the AEA's policy recommendations?

6. Further reading / References

A further reading section will be added.