



Use of ammonia as energy carrier in compact thermochemical heat/cold storage units for residential buildings

Introduction

In the MiniStor technology, ammonia is used as working fluid and chemical energy carrier that interacts with the TCM material. Ammonia's inherent toxicity has forced restrictive standards for its use in HVAC systems since the very earliest refrigeration systems. Systems using ammonia are generally placed outdoors. The final placement of the system, either indoors or outdoors, potentially restricts the market sector for which it is directed. With the proposed enclosures and systems which are being used in commercial applications for mobile refrigeration systems, new standards can be set for ammonia containers, valves and tubing that are safer and more reliable. Ammonia regulations are based on the European Standard regulating the load limits in refrigeration systems: EN 378: 2016. This standard specifies that if the refrigeration system (the absorption loop in the case of the MiniStor system) has a double indirect system configuration, there is no load limit, since the ammonia will be stored in a different room, and not directly connected to any inhabited space. However, the room where the TCM is placed must comply with requirements of EN 378: 2016 - Part 3. It is

very likely that most of EU Member States have legislated certain load limits based on the EN 378:2016. Regional or even local regulations may impose more restrictive requirements that in some cases could bring some interdictions to installing the TCM in certain places. These potential interdictions could be a barrier for the placement of TCM at the time to commercialize the MiniStor product in certain locations. The existing regulations for ammonia at European level cover emissions limits, workplace safety, transportation, environmental protection, and industrial risk management. Companies handling ammonia must strictly comply with these regulations to operate legally and sustainably. Legislation in France and at the European level aims to guarantee worker safety, environmental protection, and public health, considering the industrial needs. The operators of systems using ammonia are required to adhere to strict standards, take necessary measures to prevent accidents and minimize the operational risks. Authorities monitor and update such regulations to ensure the safe use of ammonia.

- Ammonia is a toxic gas that is used as refrigerant interacting with the TCM in the MiniStor unit.
- Ammonia regulations are based on the European Standard EN 378: 2016, which regulates the load limits in refrigeration systems.
- Regional or even local regulations may bring some interdictions to installing the TCM in certain places, such as indoor environments.
- Potential interdictions could be a barrier for the placement of TCM at the time to commercialize the MiniStor product in certain locations.

Benefits of using ammonia

- 🏠 Ammonia is an environmentally friendly substance which (unlike other refrigerants) does not contribute to the depletion of the Earth's ozone layer and has a negligible global warming potential, whose synthesis and decomposition chemical reactions involve significant enthalpy changes (~30 MJ/kg), enabling compact energy storage in buildings, where minimizing storage volume is crucial.
- 🏠 Ammonia's decomposition and synthesis through a reversible endothermic/exothermic reaction enables cyclical absorption and release of heat without significant degradation over many cycles, typically ammonia-based thermochemical energy storage systems show no loss of performances in 20+ years.
- 🏠 Maintenance of ammonia-based thermochemical energy storage systems is manageable because ammonia is contained in sealed closed loop circuits, minimising the need of interventions, e.g. for ammonia refills. Furthermore, sensors and automated controls reduce the need for manual inspection.
- 🏠 Ammonia salts used in thermochemical energy storage are recyclable as they absorb and release ammonia over many cycles without being consumed. Graphite used in thermochemical energy storage systems as thermal conductivity enhancer and/or structural/porous matrix for salt impregnation is also highly recyclable as it does not react with ammonia or salts, and it may be used for decades.
- 🏠 Thermochemical heat storage systems using ammonia like the Ministor system are technically performant and are likely to become a commercial products as they have a COP well higher than the average, produce no noise during operation, and are based on a mature and reliable technology.
- 🏠 Ammonia is one of the most widely produced chemicals, that is used primarily for fertilizers. Therefore, ammonia has a well-established global supply chain. However, the use of ammonia salts in thermochemical energy storage is still an emerging application which is not fully developed at scale yet.

Risks of using ammonia

Risks of using ammonia (NH₃) in the TCM unit to meet the operational requirements of the MiniStor system must be carefully assessed. The aim of such risk assessment is to provide a comprehensive analysis of the potential health, environmental and explosion risks that may result from the use of NH₃. Adequate measures must be implemented to reduce health risk such as discomfort and eye irritation, or more severe respiratory and eye symptoms, e.g., implementing ventilation and gas detection systems to safeguard the well-being of people who could come in contact with ammonia. Other risks that must be assessed include environmental risks, flammability and explosive risk, risk of materials corrosion. Effective safety measures to mitigate the risks associated with the use of ammonia include integrated monitoring systems, risk detection and mitigation technologies, emergency response plans, strict access control, comprehensive training and compliance with regulatory standards.

Conclusion

Barriers, opportunities and recommendations

Policy barriers and opportunities for TCM system application

- 🏠 Safety concerns and regulations may limit the diffusion of the Ministor system to some specific applications and use cases ^{1,2,3}.
- 🏠 Ammonia is listed in Annex I of the Seveso-III Directive (2012/18/EU), a European Union regulation aimed at preventing and controlling accidents involving hazardous substances⁴, as it poses an actual risk when it is used in high-volume industrial uses. However, Seveso-III compliance is disproportionate for low-risk applications such as thermochemical energy storage in residential buildings.
 - The Seveso-III directive defines application-specific quantitative limits (thresholds) for ammonia, which differentiate the safety requirements for a specific site depending on whether the site handles or holds amounts of equal to or above these thresholds, without considering whether the application of ammonia is low-risk (e.g. use of ammonia in small, sealed and monitored parts of a thermochemical energy storage system) or high-risk (e.g. tons of ammonia stored in an open tank of a fertiliser plant).
- 🏠 Transport and installation permits for ammonia-based systems are unnecessarily complicated, especially for small and low-risk systems, which could benefit of simplified and accelerated applications for permits without compromising the safety and regulatory compliance.

Policy recommendations

- 🏠 **Incentivise** the use of highly efficient and environmentally friendly refrigerants such as ammonia (R-717) by means of subsidies or tax breaks.
- 🏠 **Incentivise** the installation of thermochemical heat storage systems using ammonia which use a photovoltaic thermal (PVT) system and enable to increase RES-generated heat of the PVT, achieving a COP greater than one (the Ministor system achieves a COP of 1.8).
- 🏠 **Develop** a new technical standard for ammonia-based system design and containment specific for the residential sector, which lacks the infrastructure available in industry to handle risks due to ammonia's toxicity and mild flammability. Key requirements for the design of safe systems in residential buildings are: 1. Place the compressor and ammonia-containing parts in a separate sealed shed outside the main building, while a secondary refrigerant (such as water or glycol) is circulated into the living space. 2. Install leakages detection and ventilation systems.

- 🏠 **Develop** guidelines for the design of ammonia detection systems comprising installation of gas sensors in plant rooms and their connection to emergency ventilation fans, automatic shut-off valves and alarm systems.
- 🏠 **Develop** a comprehensive training programme for technicians of refrigeration and energy storage systems containing ammonia, tailored to residential applications. Such programme should cover aspects related to safety and risk management, system installation and commissioning, ordinary maintenance, diagnosing of common faults and repairs, compliance with technical standards and regulations, system decommissioning with ammonia recovery and disposal.
- 🏠 **Update** the Seveso-III directive introducing an exemption from the application of the directive for low risk applications, such as thermochemical energy storage in residential buildings.
- 🏠 **Allow** pre-certification of ammonia-based system designs using modular components (such as thermochemical energy storage systems for residential buildings), aimed at a faster transport and installation permit approval, especially for low complexity systems containing low amounts of ammonia.

References

- 1 Ministor D2.3: Analysis of relevant legislation and standards for system operation (Identification of barriers and opportunities for system application through examination of standards and regulations.)
- 2 Ministor D2.5 : Safety and maintenance report (Specification of safety requirements for system operation.)
- 3 Ministor D4.6 : Safety assessment for NH₃ handling in the system (detailing of a safe operation plan for handling ammonia in the system)
- 4 Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances. <https://eur-lex.europa.eu/eli/dir/2012/18/oj/eng>

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