The AmmoniaDrive Research Project

de Vos, P.; Somers, L.M.T. ; Tinga, T. ; Foekema, E.M. ; van der Zwaan, B. ; Negenborn, R.R.

Publication date
2022

Document Version
Final published version

Published in
SWZ Maritime

Citation (APA)
de Vos, P., Somers, L. M. T., Tinga, T., Foekema, E. M., van der Zwaan, B., & Negenborn, R. R. (2022). The AmmoniaDrive Research Project. *SWZ Maritime*, *143*(7/8), 24-27.

THE AMMONIADRIVE RESEARCH PROJECT

Several news items and short movies have appeared online recently, announcing that the AmmoniaDrive Consortium was awarded a prestigious NWO Perspectief grant. But what is the AmmoniaDrive research project? How does it contribute to combatting shipping-induced climate change? Who are in the consortium and why? And finally, what research activities will take place?

AUTHORS: DR IR P. DE VOS, TU DELFT (CORRESPONDING AUTHOR, P.DEVOS@TUDELFT.NL); DR IR L.M.T. SOMERS, TU EINDHOVEN; PROF. DR IR T. TINGA, UNIVERSITY OF TWENTE; DR E.M. FOEKEMA, WAGENINGEN UNIVERSITY; PROF. DR B. VAN DER ZWAAN, UNIVERSITY OF AMSTERDAM; PROF. DR R.R. NEGENBORN, TU DELFT

At the NWO Teknowlogy festival on 31 May 2022, all seven new Perspectief research projects, amongst which AmmoniaDrive, were put in the spotlight as key research projects funded by NWO and the Ministry of Economic Affairs and Climate Policy. Nederland Maritiem Land published a news item about AmmoniaDrive winning a Perspectief grant, the Delft University of Technology (TU Delft) announced the winning of the grant on its website and the participating partners have shared the news through their intranet or social media. This article explains what the AmmoniaDrive research project actually entails.

The AmmoniaDrive Consortium

Before the "what", "why" and "how", let's first address the "who". The AmmoniaDrive Consortium consists of six Dutch universities, three Dutch applied research institutes and fifteen companies (see the table below). Building the AmmoniaDrive Consortium started in 2020 with the MIIP AmmoniaDrive and continued throughout the application and selection procedure of NWO Perspectief, in order to secure the grant and enable the AmmoniaDrive research actually taking place in the coming years.

NWO Perspectief – round 2020/2021

The aim of the funding instrument Perspectief is to make a contribution to the creation of economic opportunities within the societal challenges and key technologies of the Mission-driven Innovation Policy (see the NWO Perspectief website for more information,

Universities	TU Delft – 3ME: Maritime and Transport Technology department		
	University of Groningen: Energy Conversion division		
	Wageningen University & Research: Marine Animal Ecology subdivision		
	Eindhoven University of Technology: Power & Flow group		
	TU Delft – TPM: Safety and Security Science section		
	University of Amsterdam: Van 't Hoff Institute for Molecular Sciences		
	University of Twente: Department of Mechanics of Solids, Surfaces & Systems		
TO2 institutes	TNO: Powertrains Technology & Structural Dynamics expertise groups		
	Wageningen Marine Research		
	MARIN: Marine Power Systems		
Companies / other	Royal IHC	C-Job	Yara
	Bureau Veritas	Damen	Boskalis
	Progression-Industry	DNV	Wärtsilä
	DMO	Anthony Veder	SmartPort
	Circonica	Van Oord	Bijlboegfonds

The AmmoniaDrive Consortium.

www.nwo.nl/onderzoeksprogrammas/perspectief). NWO Domain Applied and Engineering Sciences organises an open Perspectief call for new programme ideas annually. A Perspectief round consists of three phases, which for round 2020/2021 meant the following:

I. Eighty programme-initiatives for applied, multidisciplinary research of a technical nature were handed in to NWO in Phase I.
II. 48 programme-design documents were handed in to NWO in Phase II. Fourteen were selected to progress to Phase III.
III. Seven consortia were awarded a Perspectief grant after further international peer review of Phase III, the detailed research proposal and presentation and defence before the selection committee at NWO.

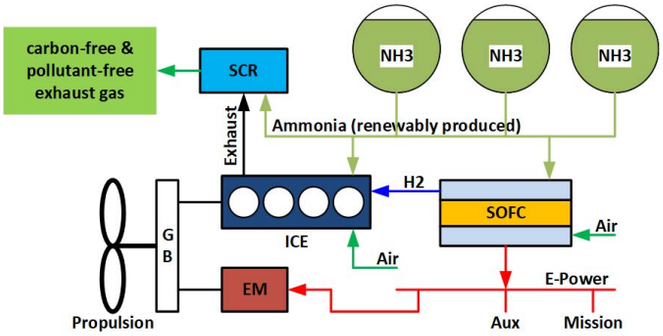
The AmmoniaDrive concept

To understand why the AmmoniaDrive research project received the grant, one needs to study the power plant concept that is depicted in the figure below. It is this power plant concept that is central to the AmmoniaDrive research project.

The innovative AmmoniaDrive power plant concept uniquely combines solid oxide fuel cell (SOFC) and internal combustion engine (ICE) technology using renewably produced, i.e. "green", ammonia as fuel. Despite its toxicity, ammonia is considered by many as an effective hydrogen carrier and future fuel for sea-going vessels, mainly because of its promise of being a cost-effective, carbon-free and relatively energy-dense fuel. However, choosing ammonia as a sustainable shipping fuel does not yet solve the question of how it is used as a fuel, or in other words, how the energy stored in ammonia can be converted into useful (mechanical or electric) power on board of ships.

Engine manufacturers are currently developing diesel-ammonia dual-fuel marine ICEs as a solution to this question. The fuel cell community is at the same time advocating ammonia-fuelled fuel cells (FCs). By combining these two technologies, the AmmoniaDrive power plant has the potential to optimally use the strengths of both energy converters, SOFC and ICE, while utilising ammonia effectively as both hydrogen and energy carrier.

At the same time, the AmmoniaDrive power plant is expected to have a relatively small and thus acceptable impact on ship design; at least when compared to the impact hydrogen-based or battery power plants would have. AmmoniaDrive, therefore, is a single-fuel, high-efficiency power plant that could actually fit on board of ships and that has no pollutant emissions anywhere in the carbon-free energy chain (well-to-wake).



The AmmoniaDrive concept.

Organisation

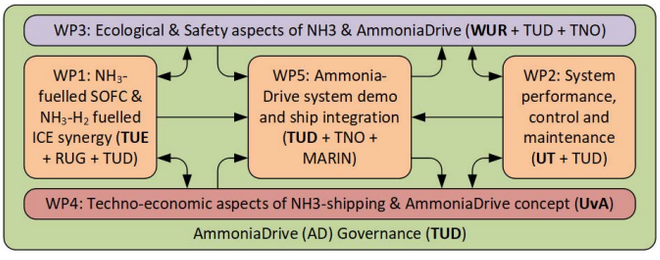
The AmmoniaDrive research programme consists of five Work Packages (WPs). The figure below provides an overview of the programme and the content of its WPs. Governance of the project lies with the Maritime & Transport Technology department of TU Delft, with Prof. Dr R.R. Negenborn as programme leader.

WP1 focuses on the experimental and numerical research into the main AmmoniaDrive system components: the SOFC and ICE. The function of the onboard SOFC-ICE power plant is to deliver useful power. WP1 aims to prove that the SOFC-ICE system can actually fulfill this function. WP1 leader is Dr Ir L.M.T. Somers of the Eindhoven University of Technology. Experimental and numerical research that will take place as part of WP1 addresses the performance of the ammonia-fuelled SOFC and ammonia-hydrogen fuelled ICE. Experiments to characterise combustion behaviour and engine performance will take place on different ICE facilities of research partners in the project.

AmmoniaDrive combines a solid oxide fuel cell with an internal combustion engine

WP2 focuses on the integrated system performance under various operating conditions using different automatic control and decision support strategies, while the anticipated sensor data is also applied for formulating dynamic maintenance strategies. WP2 leader is Prof. Dr Ir T. Tinga of the University of Twente, analytical and numerical research will be carried out under his and Prof. Dr Negenborn's supervision.

WP3 focuses on the very important ecological and safety aspects of AmmoniaDrive, including toxicity of NH_3. WP3 leader is Dr E. Foekema of Wageningen University & Research. Part of this WP is



AmmoniaDrive organisation.

the development of a safety framework based on experience in other sectors and fundamental safety sciences, while another part will experimentally study the ecological effects of an ammonia spill.
WP4 focuses on techno-economic aspects of NH_3 shipping in general and AmmoniaDrive ships in particular. WP4 leader is Prof. Dr B. van der Zwaan of University of Amsterdam. The AmmoniaDrive power plant is based on relatively immature technology and ammonia as a renewable, synthetic e-fuel. Both features contain a lot of uncertainty with regards to their economic viability. The researchers in WP4 will therefore try to find out, using learning curve analysis, what is needed to make the AmmoniaDrive power plant economically viable within a certain time frame.
Finally, WP5 integrates all information generated in the other WPs, aims to develop a (partly virtual) system demonstrator and researches a variety of ship integration aspects through post-doctoral research and (post-)MSc R&D activities at the companies of the consortium. WP5 leader is Dr Ir P. de Vos of TU Delft. Based on use case analyses, ship integration aspects will be researched for different ship types by developing concept and basic ship designs, thus quantifying the impact the AmmoniaDrive power plant will have on different ship types and developing novel design guidelines for naval architects.

Many technical and non-technical challenges need to be addressed before AmmoniaDrive is applied on ships

Researchers

From the short introduction to the AmmoniaDrive research project above, it is clear that many technical and non-technical challenges still need to be addressed before AmmoniaDrive power plants will actually be installed on board of ships. The central problem statement in the AmmoniaDrive research project, as mentioned in the research proposal, therefore is: it is unknown how the proposed AmmoniaDrive SOFC-ICE power plant performs on key performance indicators like emissions, system efficiency, safety, environmental impact, cost effectiveness, etc., either on board of ships or in other heavy-duty applications. This leads to the main objective of the project: the objective of the AmmoniaDrive research is to raise the Technology Readiness Level (TRL) and Societal Readiness Level (SRL) of the AmmoniaDrive power plant concept from 1-2 to 4-5.
The AmmoniaDrive Consortium will aim to achieve this with nine PhD researchers and a Post-Doctoral researcher. The table below lists the researchers, their research topic and affiliations (i.e. supervising universities).
Next to the researchers mentioned in the table, the intention is to have a large number of graduation students researching for example ship integration aspects of the AmmoniaDrive concept in collaboration with the companies that are part of the consortium.

Timeline, vision and societal impact

The proposed start date of the AmmoniaDrive research programme is in the first quarter of 2023 with a duration of five years. During the research, the consortium aims to assess the feasibility of the AmmoniaDrive power plant for future ships and hence critically reflect on the vision and societal impact of the AmmoniaDrive research project. With AmmoniaDrive, we could be moving towards a future envisioned as follows:
It is 2050. The mainstream media announce that the 1000th AmmoniaDrive ship has begun its maiden voyage. This important milestone is celebrated by the AmmoniaDrive initiators. The ship was designed in the Netherlands, like most of the AmmoniaDrive ships before it, and built at a shipyard in Africa. Now it has arrived at the North Sea-based "Clean Energy" island, where green ammonia is produced from air and water. Renewable electric power from nearby offshore wind turbines and solar panels is used to obtain nitrogen and hydrogen from air and water. Here, the ship will bunker locally produced green ammonia, after which it will sail to the next port of call for

PhD	Research topic	Supervisor
1	NH_3-fuelled SOFC (NH_3 internal decomposition + AOG composition)	University of Groningen +TU Delft
2	NH_3-AOG combustion properties of different NH_3-AOG compositions	University of Groningen + Eindhoven University of Technology
3	NH_3+AOG-fuelled ICE #1 (ICE experiments & 0D/1D ICE models)	TU Delft-3ME (Mechanical, Maritime and Materials Engineering)
4	NH_3+AOG-fuelled ICE #2 (ICE CFD models)	Eindhoven University of Technology
5	AmmoniaDrive maintenance strategies (failure behaviour, availability)	University of Twente
6	AmmoniaDrive system performance and control (multilevel control)	TU Delft-3ME
7	NH_3-shipping & AmmoniaDrive safety aspects (in- & outboard safety)	TU Delft-TPM (Technology, Policy and Management)
8	NH_3-shipping ecological aspects (impact + mitigation of NH_3 spills)	Wageningen University & Research
9	AmmoniaDrive techno-economic analysis (cost and financial features)	University of Amsterdam
PD1	Transient load characterisation (power demand dynamics)	TU Delft + MARIN

AmmoniaDrive researchers.

loading its first cargo. While the ship is refuelling, a number of specialists from different Dutch firms, all with their own specialty with regards to AmmoniaDrive power plants, enter the ship to visually check the engine room. No irregularities are expected, as the data from the different sensors on board were already transmitted automatically to the AmmoniaDrive Systems and Control Centre in Amsterdam during the voyage to the Netherlands and no signs of issues or malfunctions were reported. Still, the visit provides additional certainty that everything is indeed as it should be and shipowners around the world have frequently expressed their appreciation of the care, quality and innovativeness of the Dutch maritime community exemplified by these visits.

ACKNOWLEDGEMENT

This research is supported by the Perspectief project "AmmoniaDrive" (project 14267/P20-18) of the Netherlands Organization for Scientific Research (NWO), domain Applied and Engineering Sciences (TTW).

This vision demonstrates how the AmmoniaDrive research can be the start of new economic activities for the Dutch maritime industry. The societal impact of AmmoniaDrive is therefore defined as: in a world where ammonia is embraced as a safe and affordable fuel for ships and other applications with no greenhouse gas or other harmful emissions, (engineering) professionals and society in general know the AmmoniaDrive power plant to be the best technical solution for powering ships, as well as other heavy-duty applications, such as island/emergency generators. Shortly, the consortium hypothesises that the combined SOFC-ICE AmmoniaDrive power plant is ammonia as a marine fuel "done right" and will undertake the necessary research to test this hypothesis.

Conclusion

This article has introduced the AmmoniaDrive research project, which will start shortly and run for the coming five years. The application and selection process to secure the funds for the project was challenging, but the AmmoniaDrive Consortium is proud to share the news that they succeeded in obtaining an NWO Perspectief grant. We look forward to sharing more exciting news and insights coming from the AmmoniaDrive research.