



Delft University of Technology

## N2KWH

### from pollutant to power

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**Project timeline:** April 2016 – April 2020

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### INTRODUCTION TO RESEARCH

#### PROBLEM DESCRIPTION

Ammonia (NH<sub>3</sub>) is world's second most produced chemical and is a vital resource for protein production. NH<sub>3</sub> becomes present in residual (waste) water streams, for example after protein degradation by organisms, and is considered a pollutant for aqueous environments, because it potentially leads to algae blooming.

To this extend, NH<sub>3</sub> must be removed from residual water streams, before the water is discharged. Current methods applied in waste water treatment plants (WWTP), consume significant amount of energy: aeration (to facilitate (de-)nitrification) accounts for approximately 50-70% of the total energy usage of a WWTP<sup>2</sup>.

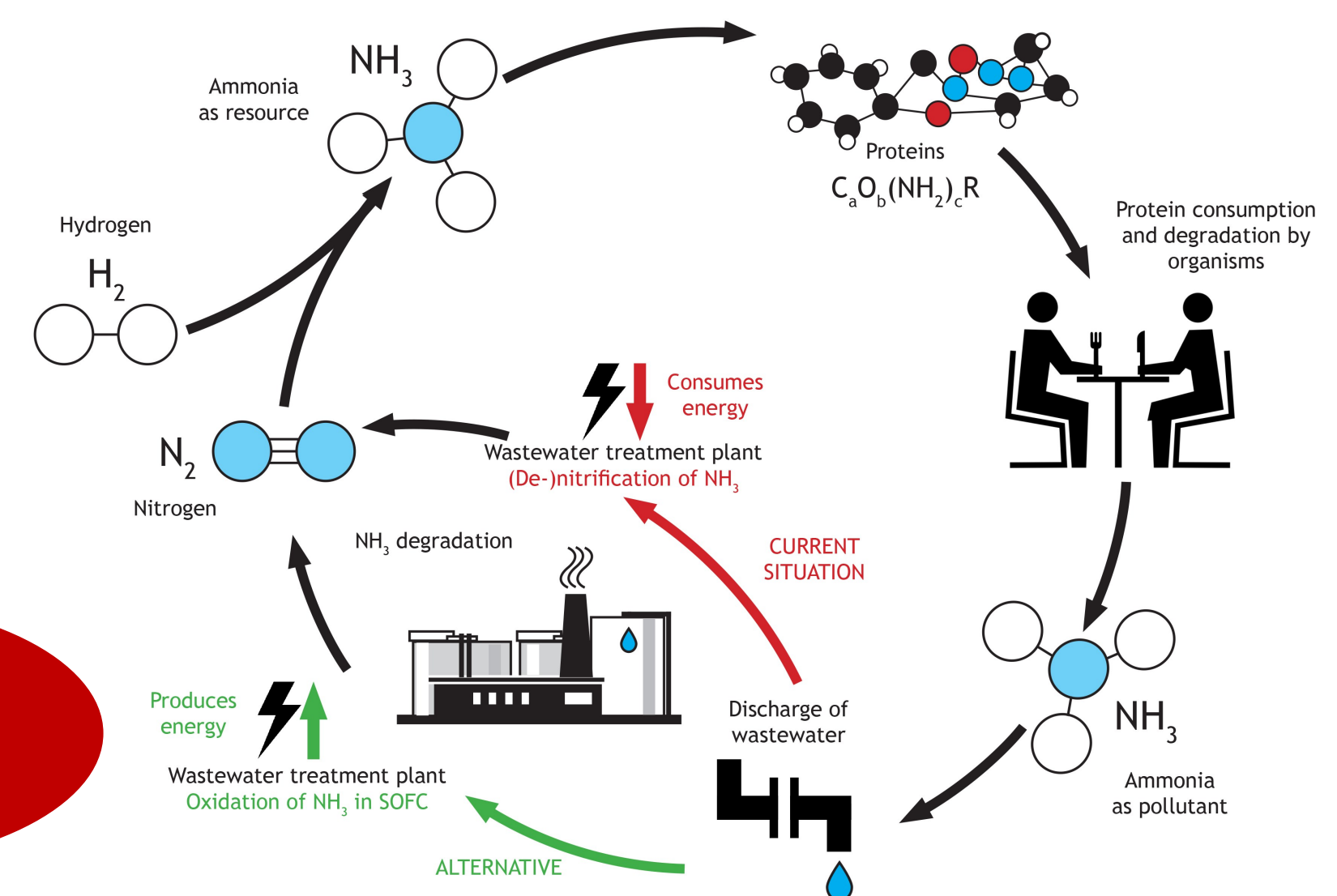
#### PARADIGM SHIFT

When the NH<sub>3</sub> can be recovered as fuel from residual water stream, energy can be produced in stead of used in order to remove NH<sub>3</sub>. This might lead to a paradigm shift:

from pollutant to power.

<sup>1</sup>Environmental Dynamics International (2011). *Aeration Efficiency Guide*

<sup>2</sup>Beck, M. B., & Speers, A. (2006). *2nd IWA Leading-Edge on Sustainability in Water-Limited Environments*: IWA Publishing.



Used elec.  
energy<sup>2</sup>:  
3.1 kWh/kg-NH<sub>3</sub>

### NH<sub>3</sub> IN SOFC

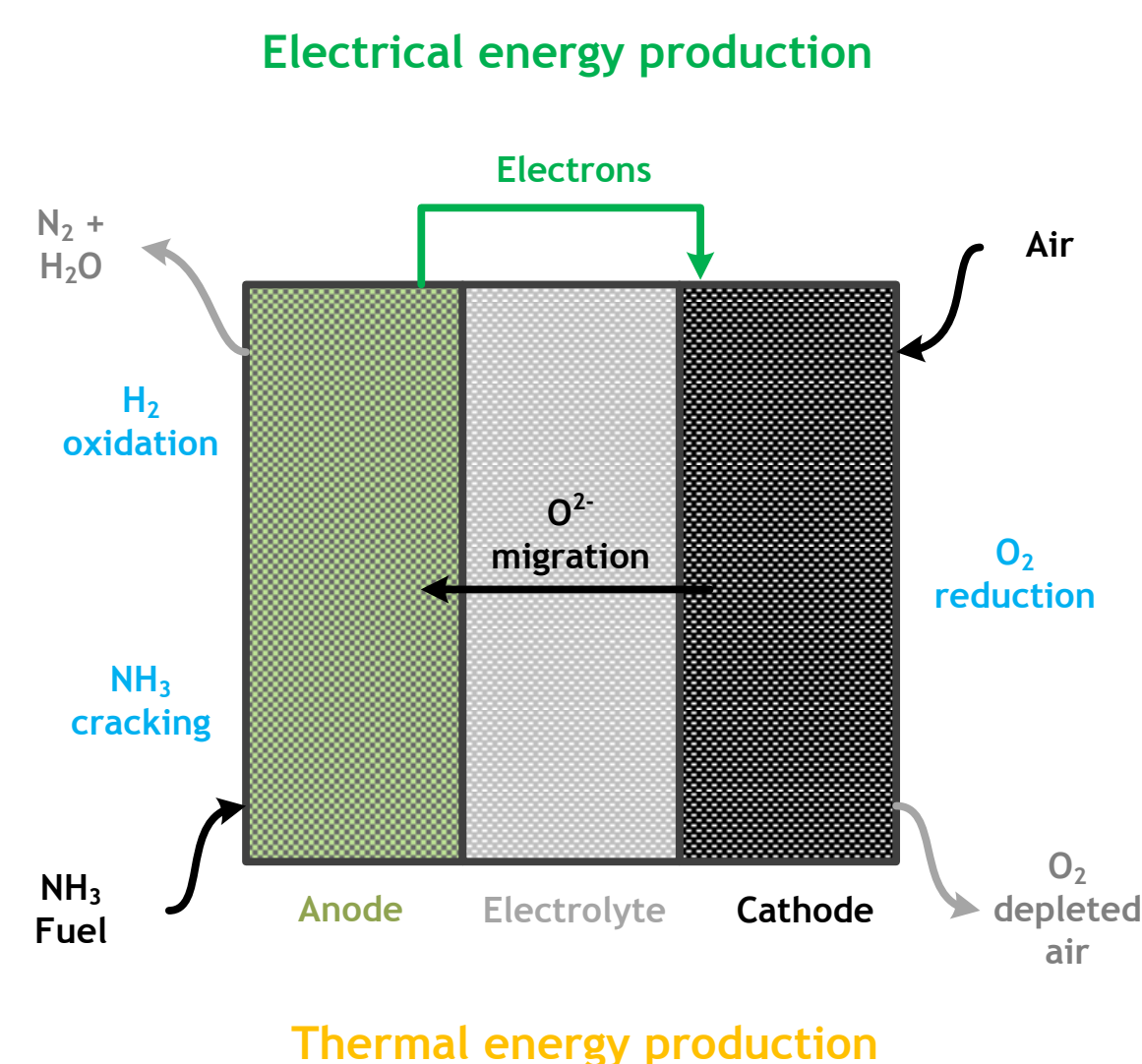
#### SOFC

A Solid Oxide Fuel Cell (SOFC) is a specific type of fuel, made of solid ceramic materials. In a SOFC, H<sub>2</sub> is oxidized by O<sub>2</sub>, resulting in a current of electrons, which can be utilized as electrical energy. Additionally, the residual released energy can partially be utilized as thermal energy.

The electrical efficiency of a SOFC is 50%, whereas the total energy efficiency can reach up to 85-90%, in case of thermal energy utilization<sup>3</sup>.

Because a SOFC operates at temperatures of T = 600 – 800 [°C], NH<sub>3</sub> can be cracked internally into H<sub>2</sub>, making it possible to use NH<sub>3</sub> directly as a fuel.

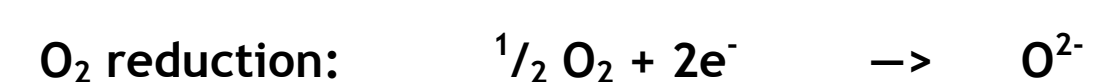
<sup>3</sup>Larminie, J., & Dicks, A. (2003). *Fuel Cell Systems Explained*. Southern Gate, Chichester: John Wiley & Sons Ltd.



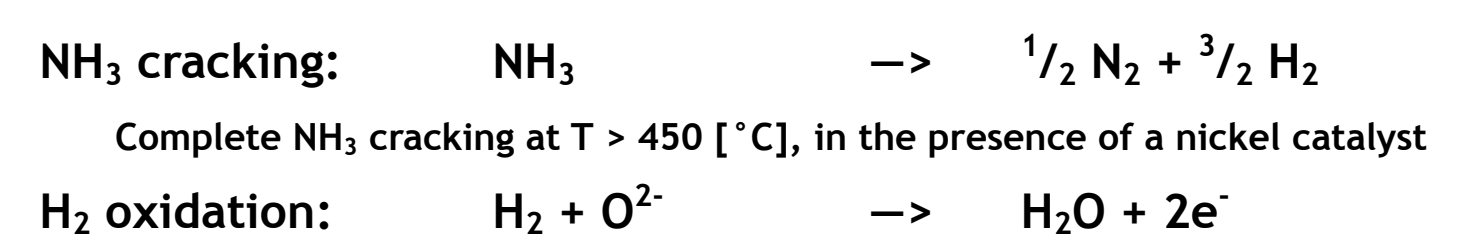
#### NH<sub>3</sub> AS FUEL

Available elec.  
energy:  
3.7 kWh/kg-NH<sub>3</sub>

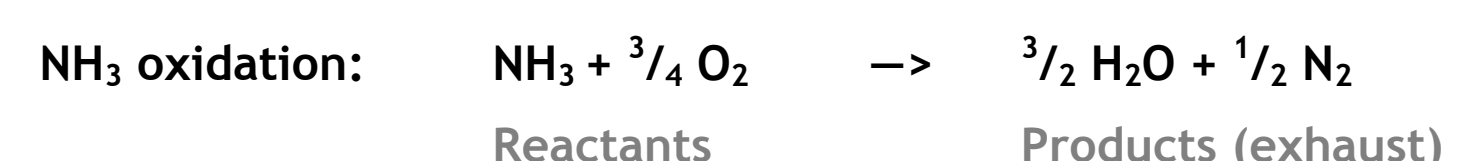
##### Cathode reaction



##### Anode reactions

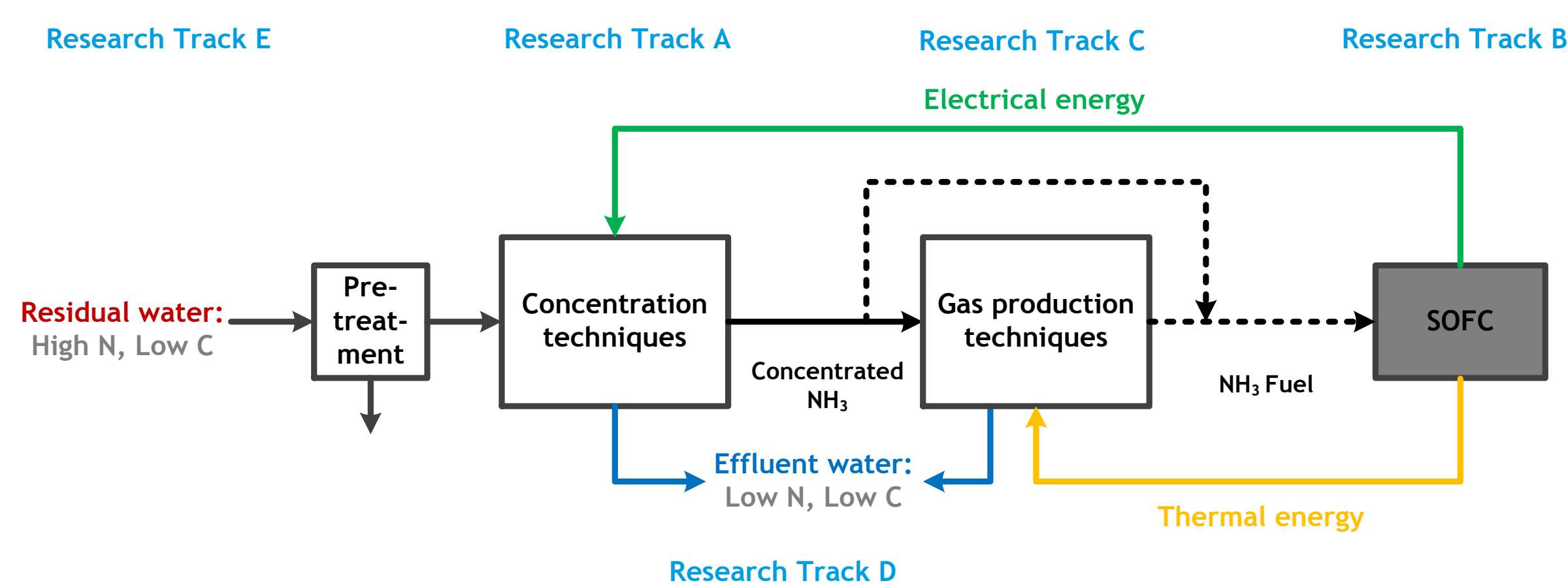


##### Overall reaction



### N2KWH RESEARCH

#### RESEARCH PLAN



#### RESEARCH STEPS

- Research Track A:** Selection of most suitable technique to concentrate NH<sub>3</sub>
- Research Track B:** Evaluation of SOFC performance on the produced NH<sub>3</sub> fuel
- Research Track C:** Selection of most suitable technique produce gaseous NH<sub>3</sub>
- Research Track D:** Development of a mass and energy balance tool, in order to evaluate various scenarios
- Research Track E:** Implementation of the system and determine the required pre-treatment for various residual water streams

#### RESEARCH OBJECTIVE

Development of an energy producing system to remove NH<sub>3</sub> from high N, low C residual (waste) water streams using a SOFC: the energy that is required to produce the fuel should be lower than the energy produced from the fuel.