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Can Hydrogen be a Clean Fuel Source for Sustainable Road Freight Transport in South Africa?

Department of Industrial Engineering, Stellenbosch University

Ruan van Schalkwyk, Julia Lloyd, Dr Joubert van Eeden

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Hydrogen

Carbon-free energy carrier

3x **more** energy dense by **weight**

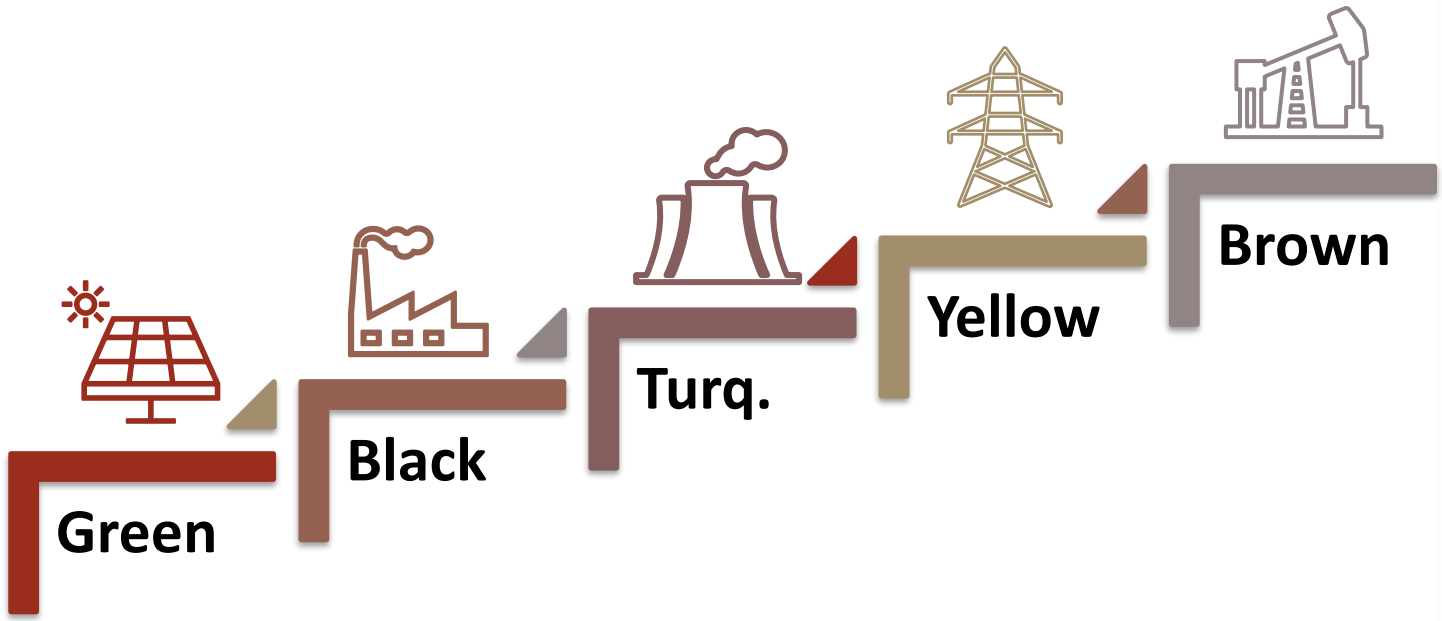
4x **less** energy dense by **volume**

Adequate density at **790 atm**

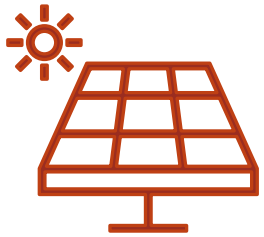
Liquifies at **-283°C** and **1 atm**

Utilises energy carriers as **feedstocks**

Types of hydrogen production



Overall efficiency



- **100** Renewable Electricity
- **61** Electrolysis
- **53** Compression and Distribution
- **32** Fuel Cell
- **27** Electric Motor

Energy loss from grid transmission

90% AC-DC rectifier efficiency

68% AEC electrolysis efficiency

13% energy loss from compression

60% fuel cell efficiency

90% DC-AC inverter efficiency

95% electric motor efficiency

27% overall efficiency

The future of hydrogen

Electrolysis:

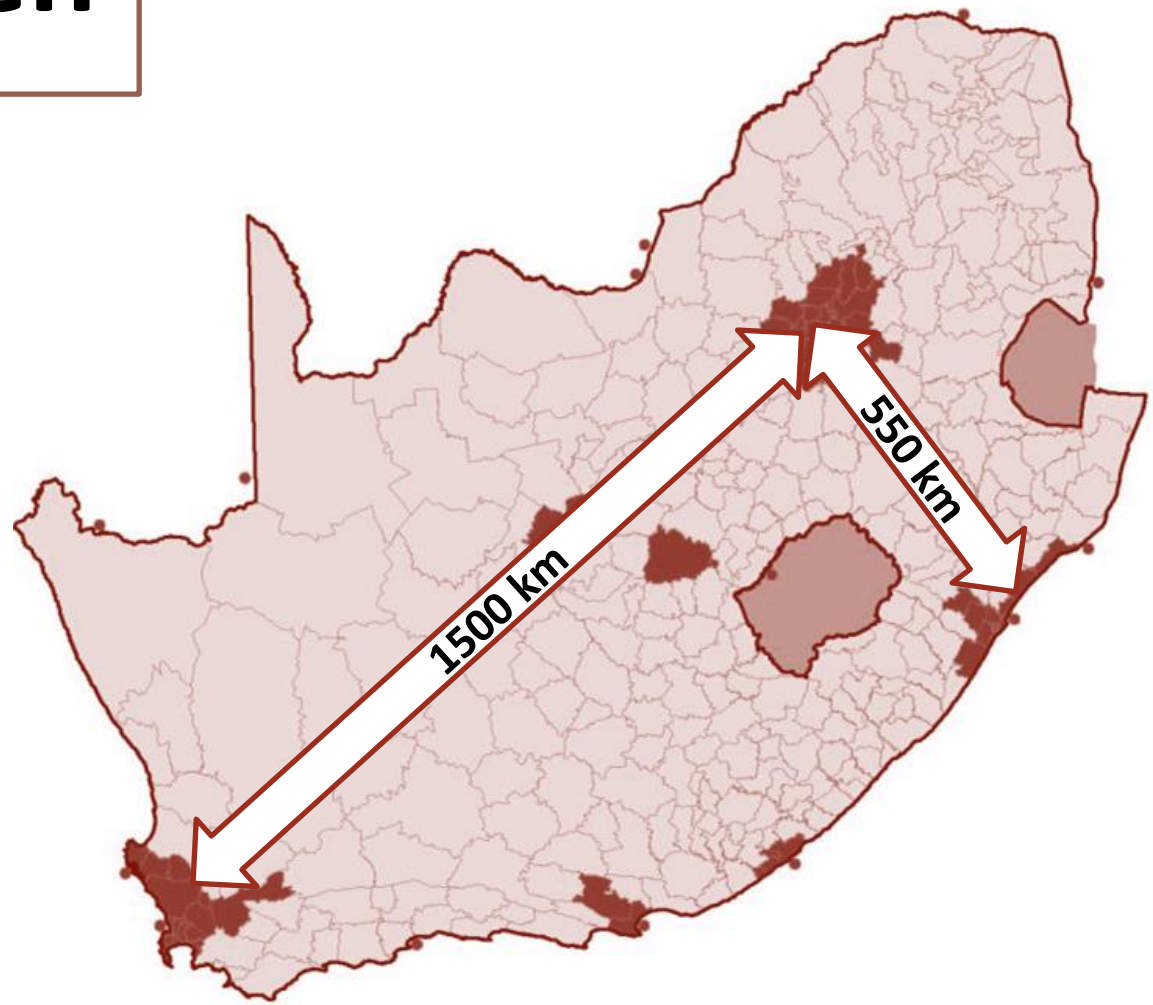
- AEC to **SOEC** (TRL 6) increases efficiency to **84%**
- Increasing **overall** efficiency to **34%** by 2045

Fuel Cell:

- Maximum **theoretical** efficiency of **90%**
- Potentially increasing **overall** efficiency to **41%**
- Combined **future overall** efficiency of **51%**

Distribution:

- **10-40%** energy **loss** to hydrogen transport
- Decreasing **future overall** efficiency to **30-46%**
- **Central** production facilities - **decreased** production cost, **increased** distribution cost
- **Distributed** production facilities – likely **increased** production cost, **decreased** distribution cost
- Freight HFCV have **1600 km** potential range



Model scenarios

Based on freight demand estimations imposed into the South African **TIMES** model

Hydrogen-fuelled **7.5-32 t** light, medium and heavy commercial vehicles

Scenario 1: Hydrogen replaces **5%** of freight truck diesel by **2030** and **25%** by **2045**

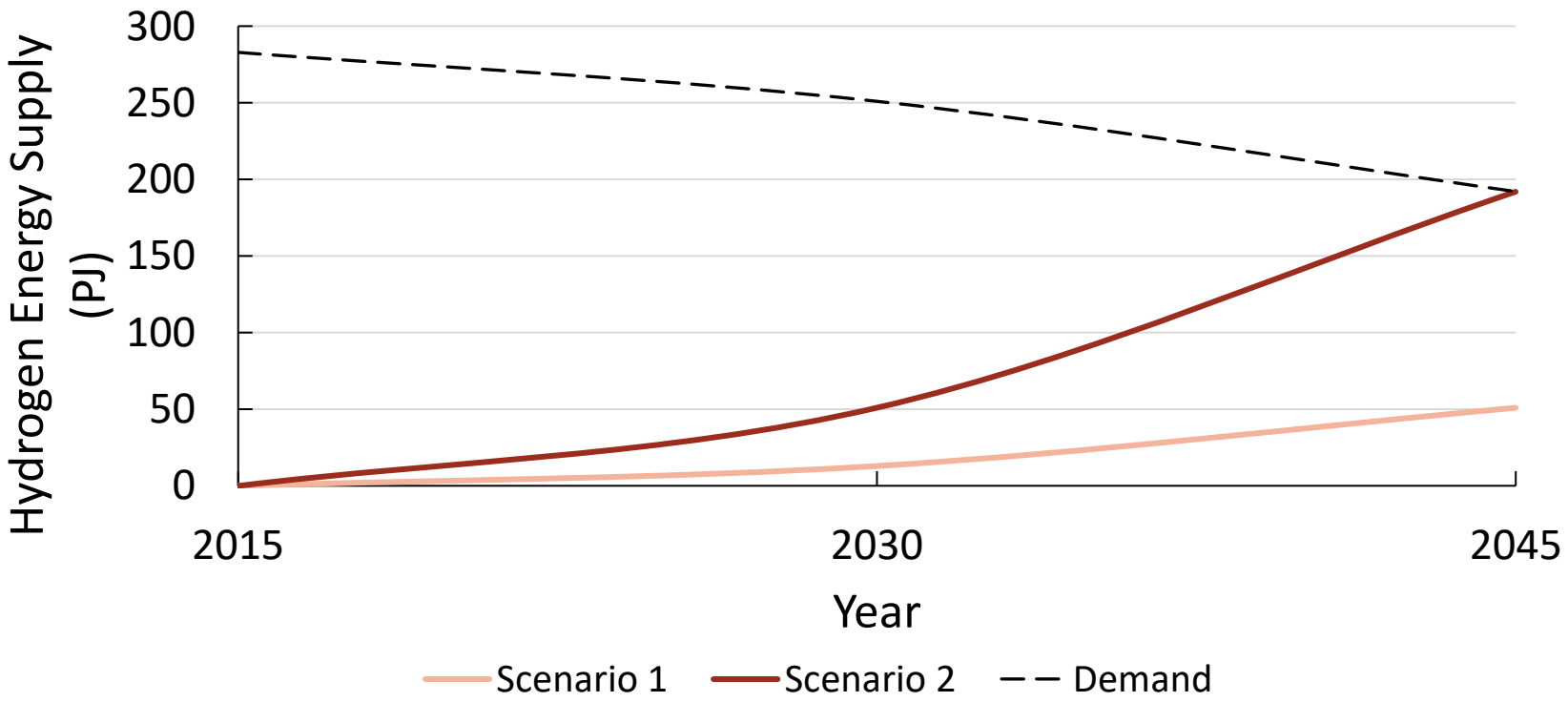
Scenario 2: Hydrogen replaces **20%** of freight truck diesel by **2030** and **100%** by **2045**

Freight truck energy demand

[Demand] FDM-estimated **7.44 billion litres** of freight truck diesel in **2019**

[S1] **155 PJ** of energy for freight trucks from **diesel** in 2045

[S2] **Hydrogen** meets **total** freight truck energy demand by 2045

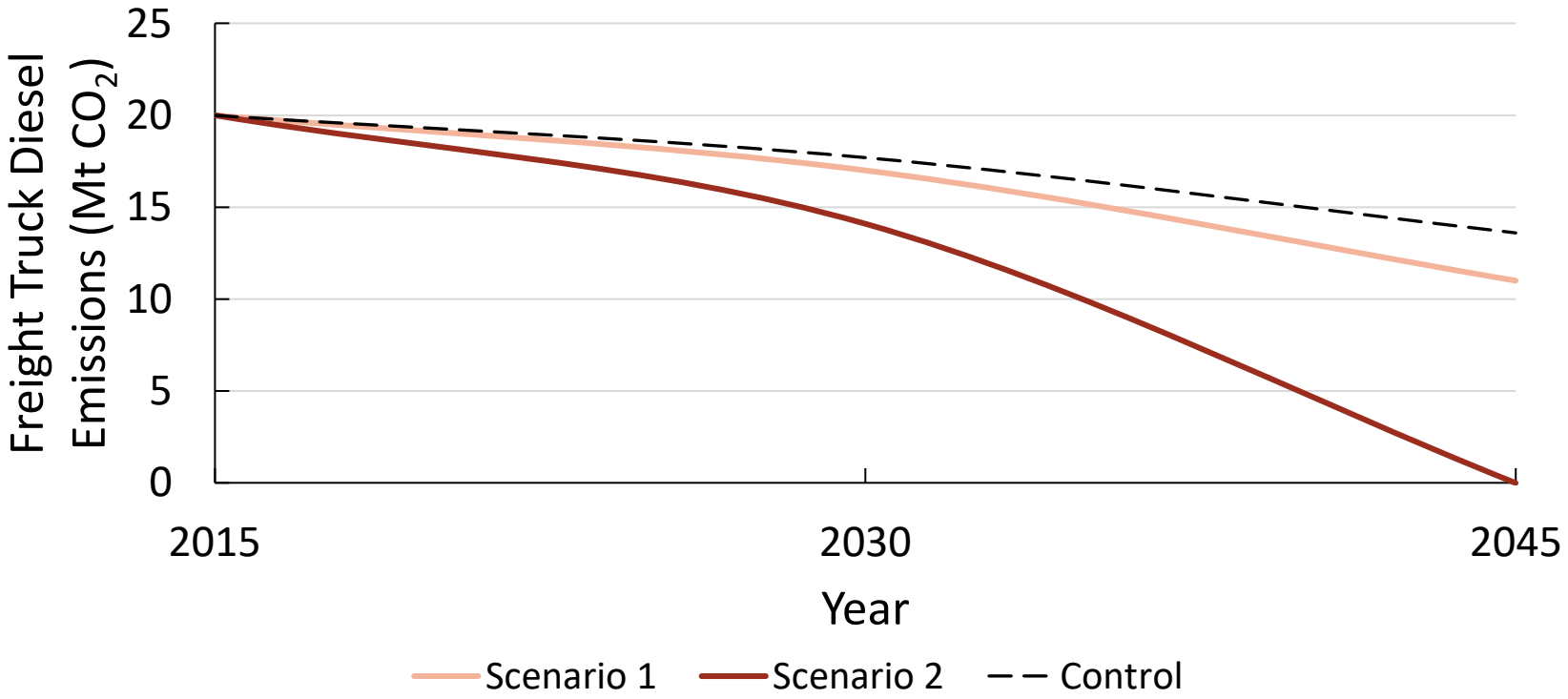


Impact on emissions

[Control] **No** road freight hydrogen technology **implementation**

[S1] **11 Mt** of carbon dioxide emissions from freight truck sector by 2045

[S2] **Carbon-zero** freight truck sector by 2045



Renewable energy requirements

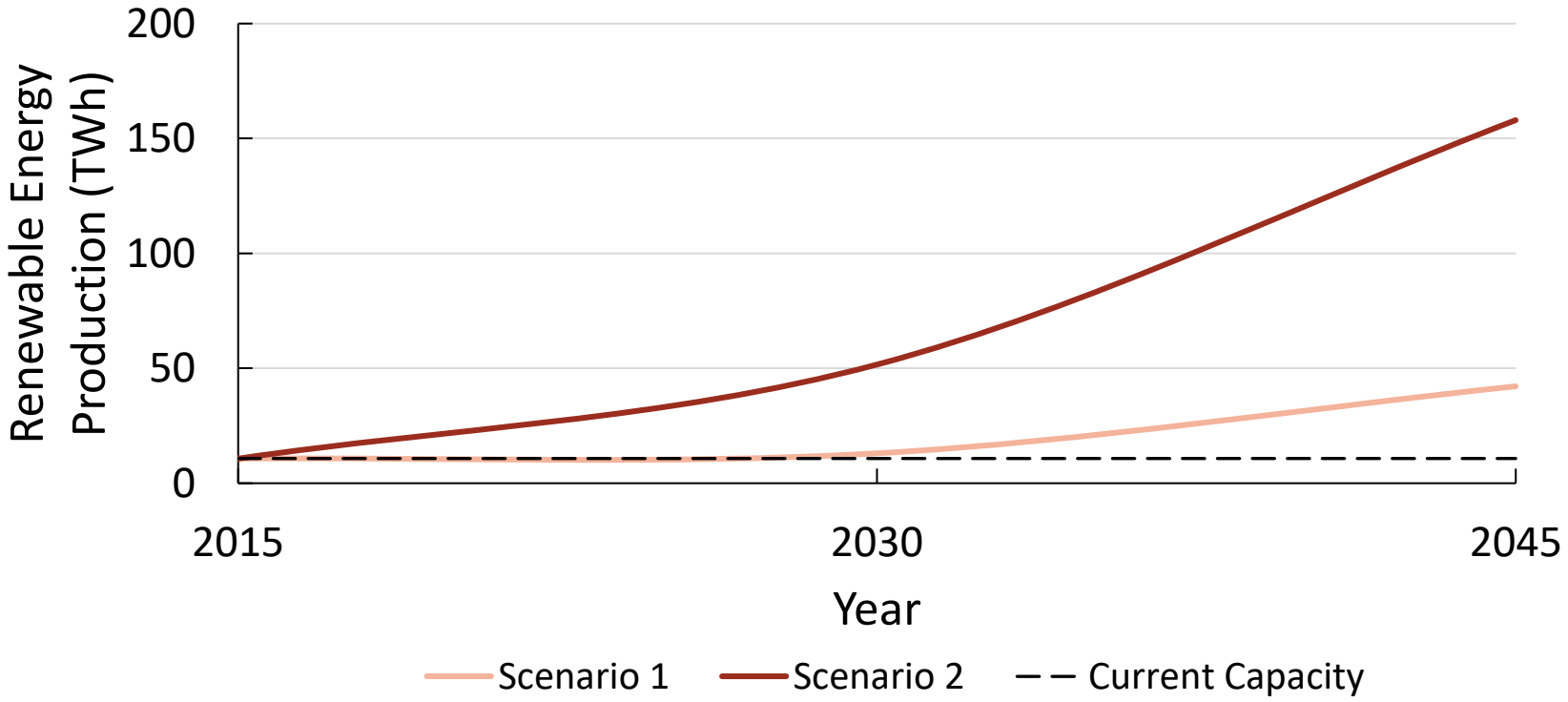
1:1 ratio of onshore wind energy to solar PV energy production

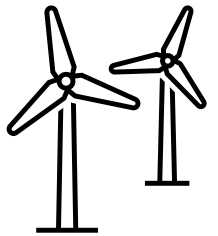
[S1] **3x** and [S2] **12x** current wind energy capacity increase by 2045

[S1] **5x** and [S2] **19x** current solar PV energy capacity increase by 2045

[S1] **1720 km²** and [S2] **6440 km²** of onshore wind farm area by 2045

[S1] **290 km²** and [S2] **1090 km²** of solar PV farm area by 2045





Production infrastructure costs

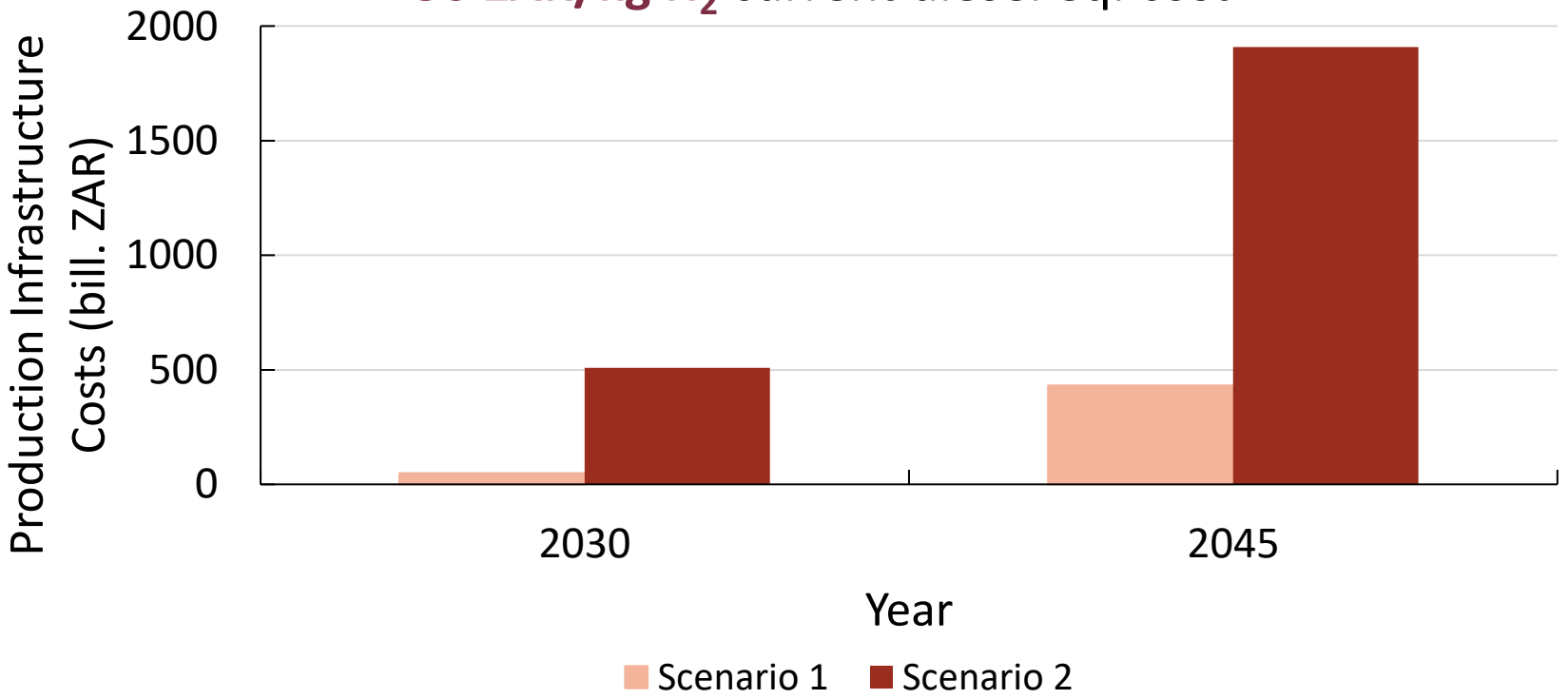
349 ZAR/kg H_2 renewable energy production infrastructure cost

100 ZAR/kg H_2 hydrogen production infrastructure cost

419 ZAR/kg H_2 total hydrogen production infrastructure cost

50 ZAR/kg H_2 CSIR-estimated future hydrogen cost

50 ZAR/kg H_2 current diesel eq. cost

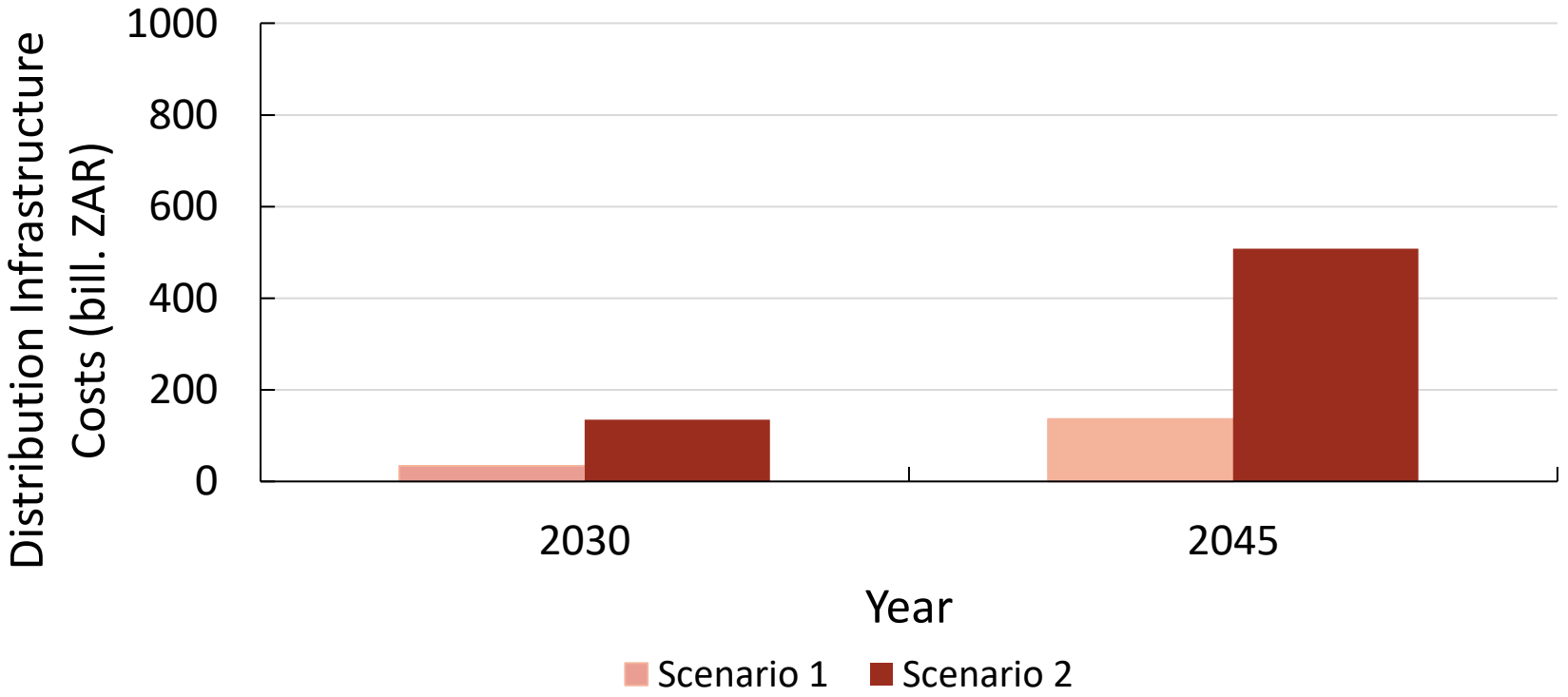


Distribution infrastructure costs

[S1] **0.8 Mt** and [S2] **3.1 Mt** of hydrogen to be transported by 2045

166 ZAR/kg H_2 hydrogen distribution infrastructure cost

4 ZAR/kg H_2 current diesel eq. distribution infrastructure cost



Conclusions and recommendations

Conclusions

- **Overall** efficiency increase from **27%** to **34%** by 2045, and potentially **51%** thereafter
- **7530 km^2** of renewable energy farm area for **carbon-zero** freight truck sector by 2045
- Future **hydrogen** cost roughly **equal** current **diesel** eq. cost
- **40x** current diesel eq. **distribution** infrastructure cost
- Using **stored** electricity for vehicle **propulsion**, where feasible, would be a **better** energy use

Recommendations

- Prioritise **SOEC** commercial availability
- Improve hydrogen **fuel cell** efficiency
- Compare **central** versus **distributed** production facilities
- Determine **placement** of facilities on **major** corridors
- Assess hydrogen **storage** mediums for **surplus** renewable electricity
- Curtail distribution energy loss with **LOHC** implementation

References

1. **Ahjum, F., Merven, B., Stone, A. & Caetano, T. 2018.** Road transport vehicles in South Africa towards 2050: Factors influencing technology choice and implications for fuel supply. *Journal of Energy in Southern Africa. 29(3):33–50.*
2. **Ayodele, T.R. & Munda, J.L. 2019.** The potential role of green hydrogen production in the South Africa energy mix. *Journal of Renewable and Sustainable Energy.* 11(4):44301.
3. **Bossel, U. 2006.** Does a hydrogen economy make sense? *Proceedings of the IEEE.* 94(10):1826–1836.
4. **Calitz, J.R. & Wright, J.G. 2021.** [Online], Available: http://hdl.handle.net/10204/11865.
5. **Roos, T. & Wright, J. 2021.** Powerfuels and Green Hydrogen.

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