Green Hydrogen Microgrids for Remote Areas: Design, Assessment, and Feasibility

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Introduction

Why Green Hydrogen for Remote Areas?

14% of the global population lacks electricity access

Integrate green hydrogen as storage
Solar excess as H_2
Reconvert when needed

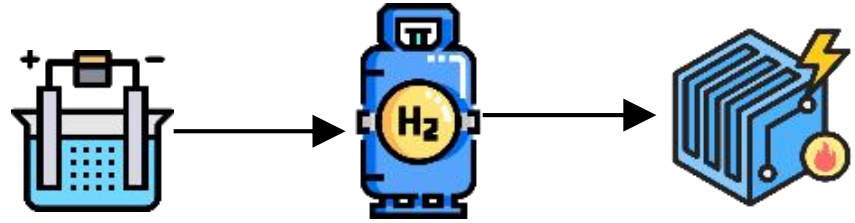
Traditional

Diesel generators
High O&M costs
High CO_2 emissions
High pollution

Modern

Microgrids with RES
Decentralized solutions
Variable nature

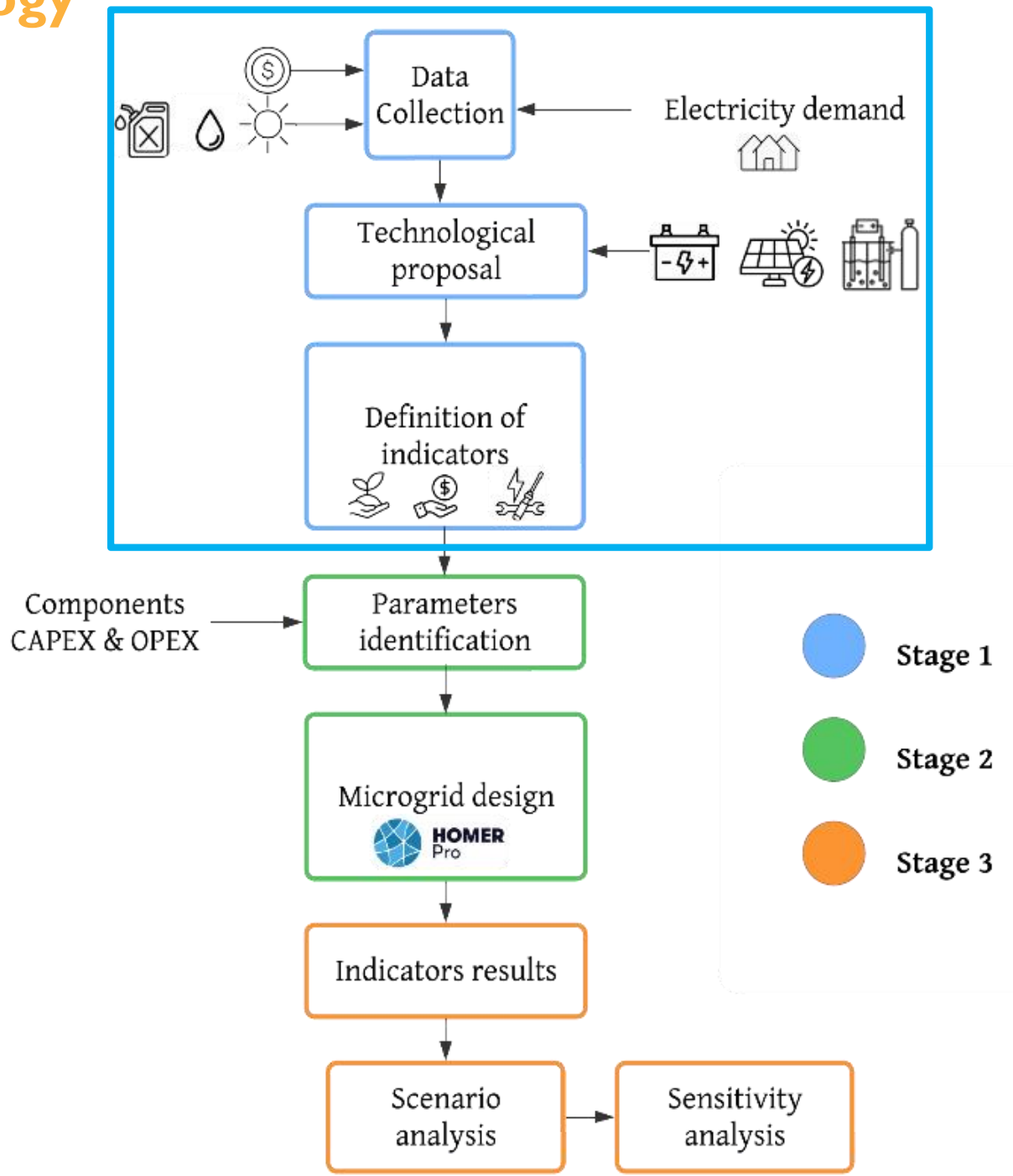
→ Storage become critical



Power-to-Hydrogen-to-Power (P2H2P)

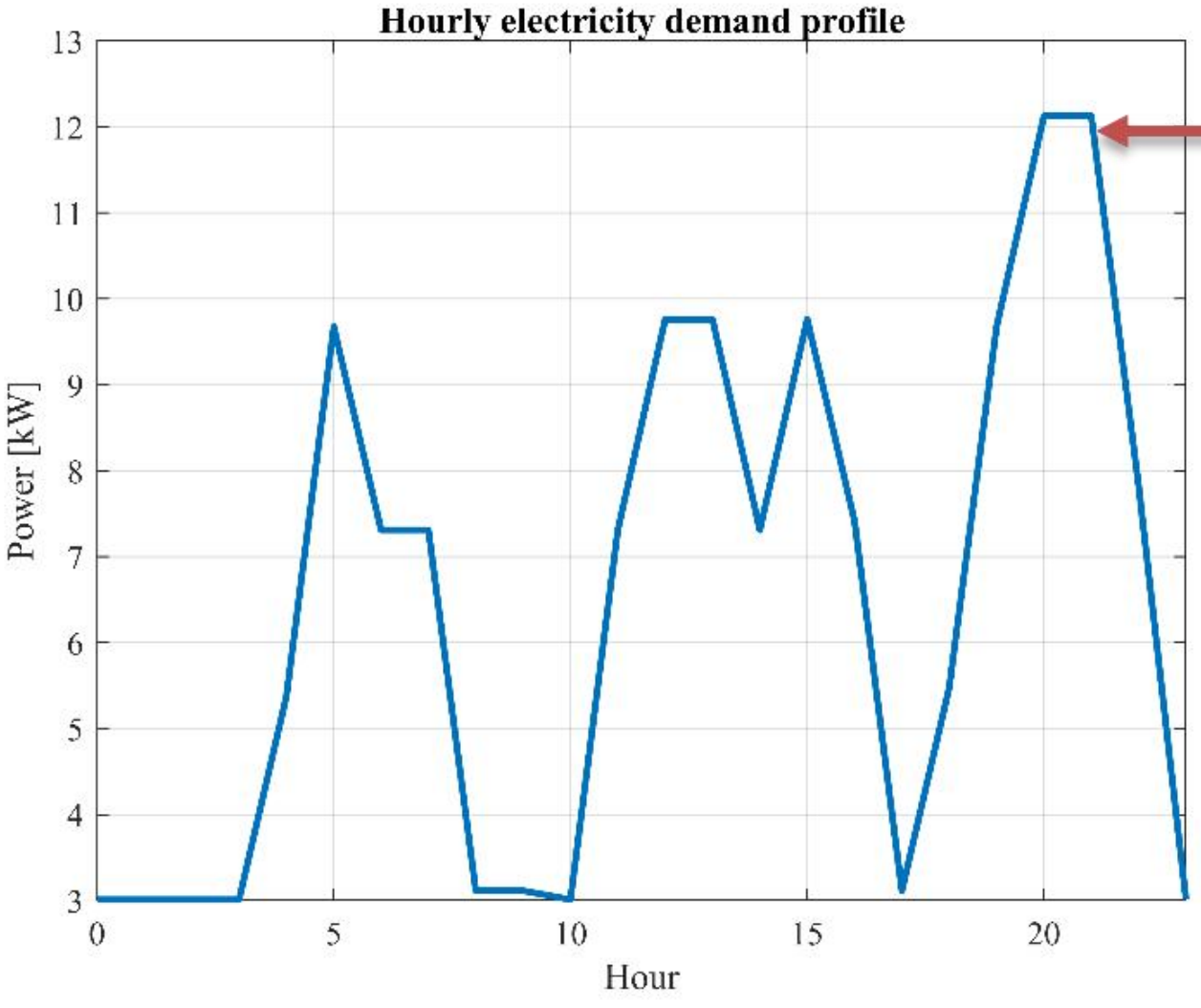
This work proposes a comprehensive methodological framework for the design and evaluation of green hydrogen powered isolated microgids

Methodology



Stage 1: Data Collection

43 households

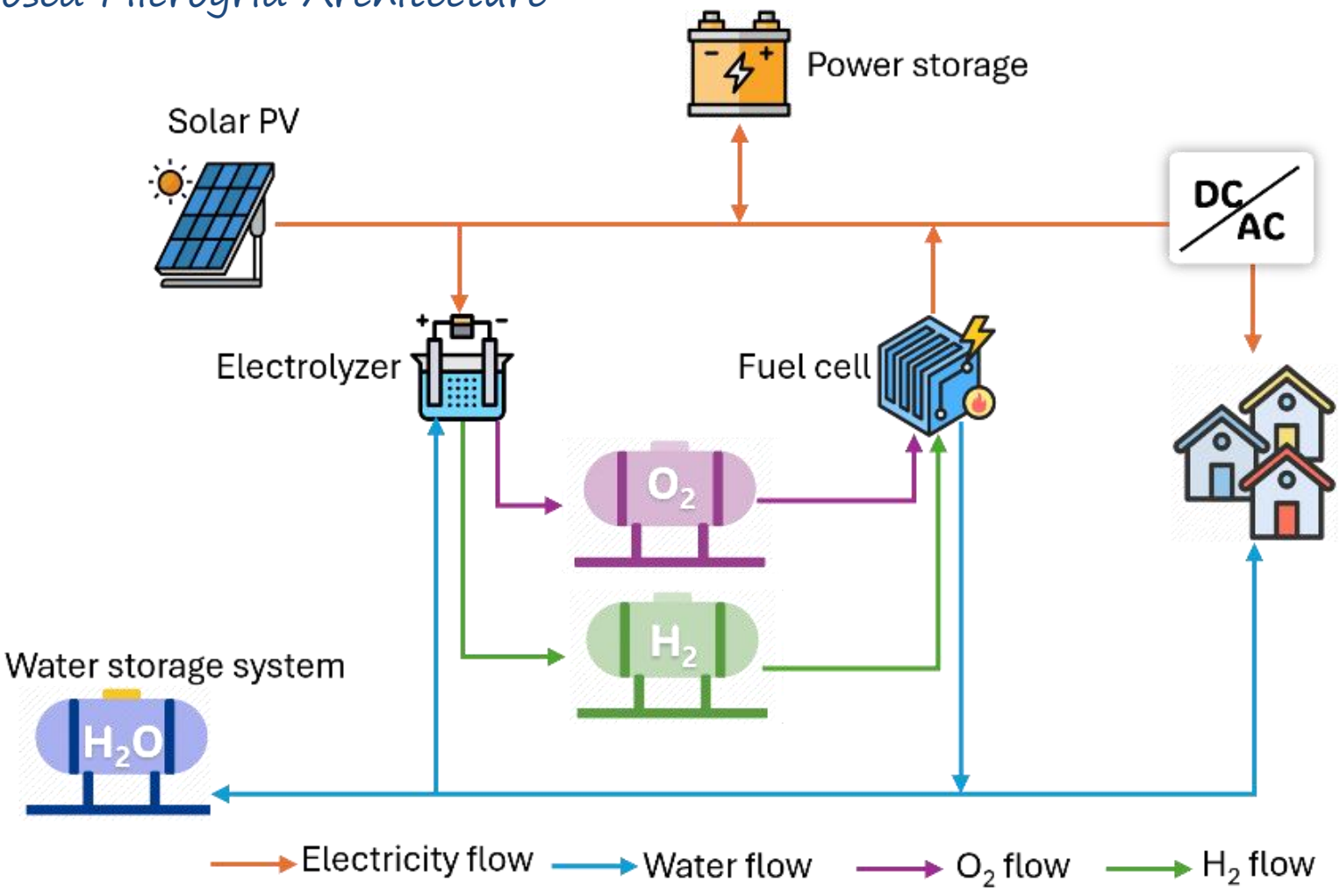


12.1 kW

Resources availability

Stage 1: Technological Proposal

Proposed Microgrid Architecture



Stage 1: Definition of Indicators

CAPEX: amount associated with the investment required for the system (kUSD).

OPEX: amount linked to the annual maintenance and operation of the system (USD/year).

LCOE: levelized cost of a unit of energy (USD/kWh).

LCOH: levelized cost of a unit of hydrogen

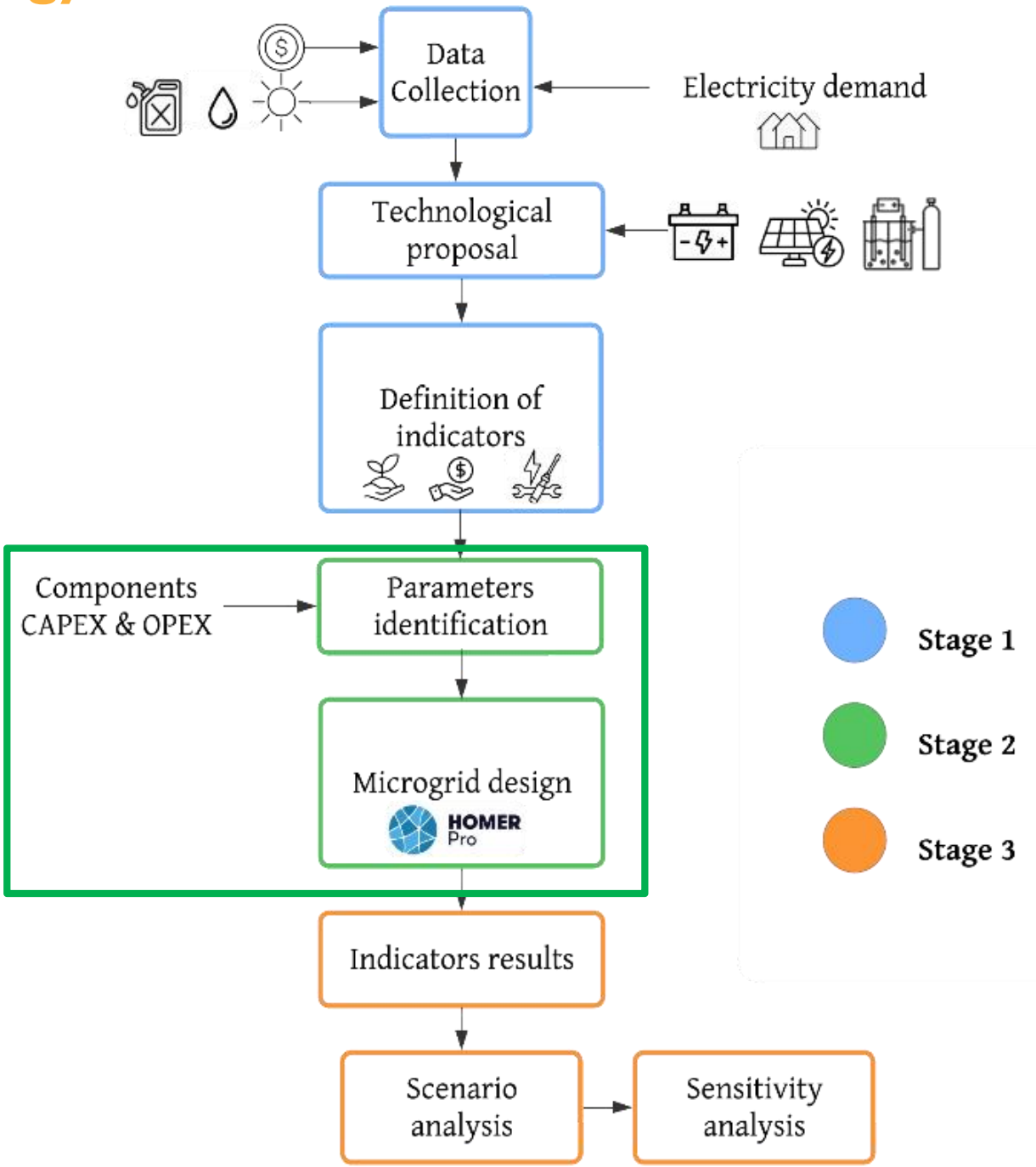
CO_2 Emissions: emissions of the system in terms of energy production ($kgCo_2$/year).

Renewable energy penetration: share of total energy demand met by renewable sources (%).

Electricity excess: additional energy produced that can be not utilized (%).

Unserved load: energy not provided (%).

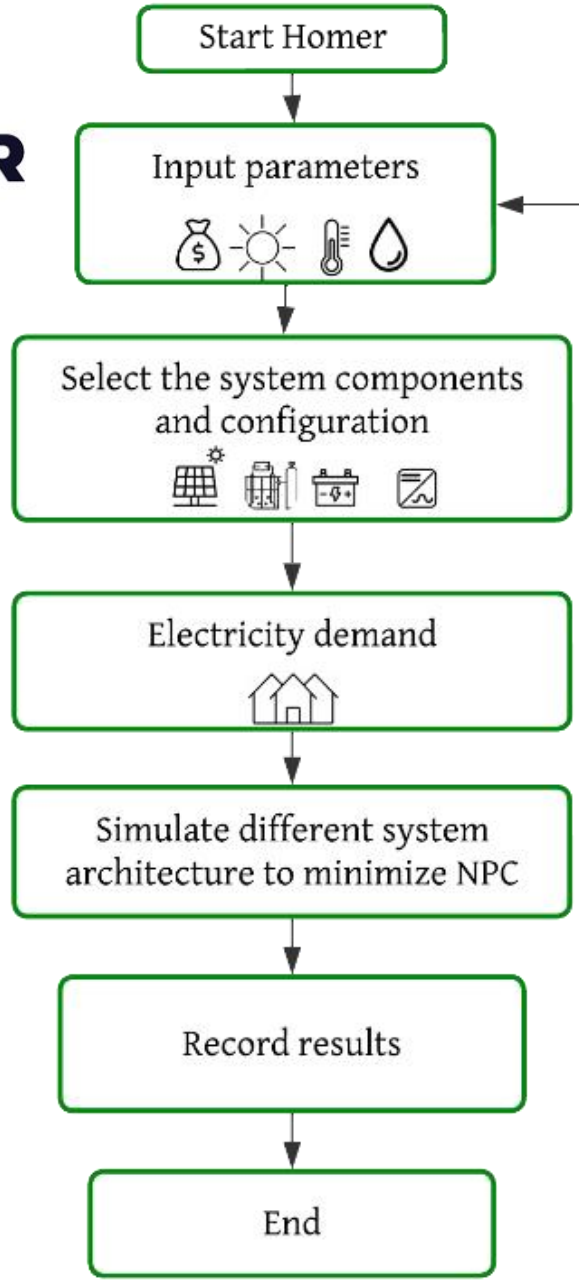
Methodology



Stage 2: Microgrid Design

Parameters Identification and Energy Solution Design

HOMER Pro



Constrains & Reliability
Lifetime: 25 years

- ✓ Maximum annual electricity excess: 10%
- ✓ Maximum unserved load: 5%
- ✓ Green hydrogen as the main energy storage mechanism.

Stage 2: Microgrid Design

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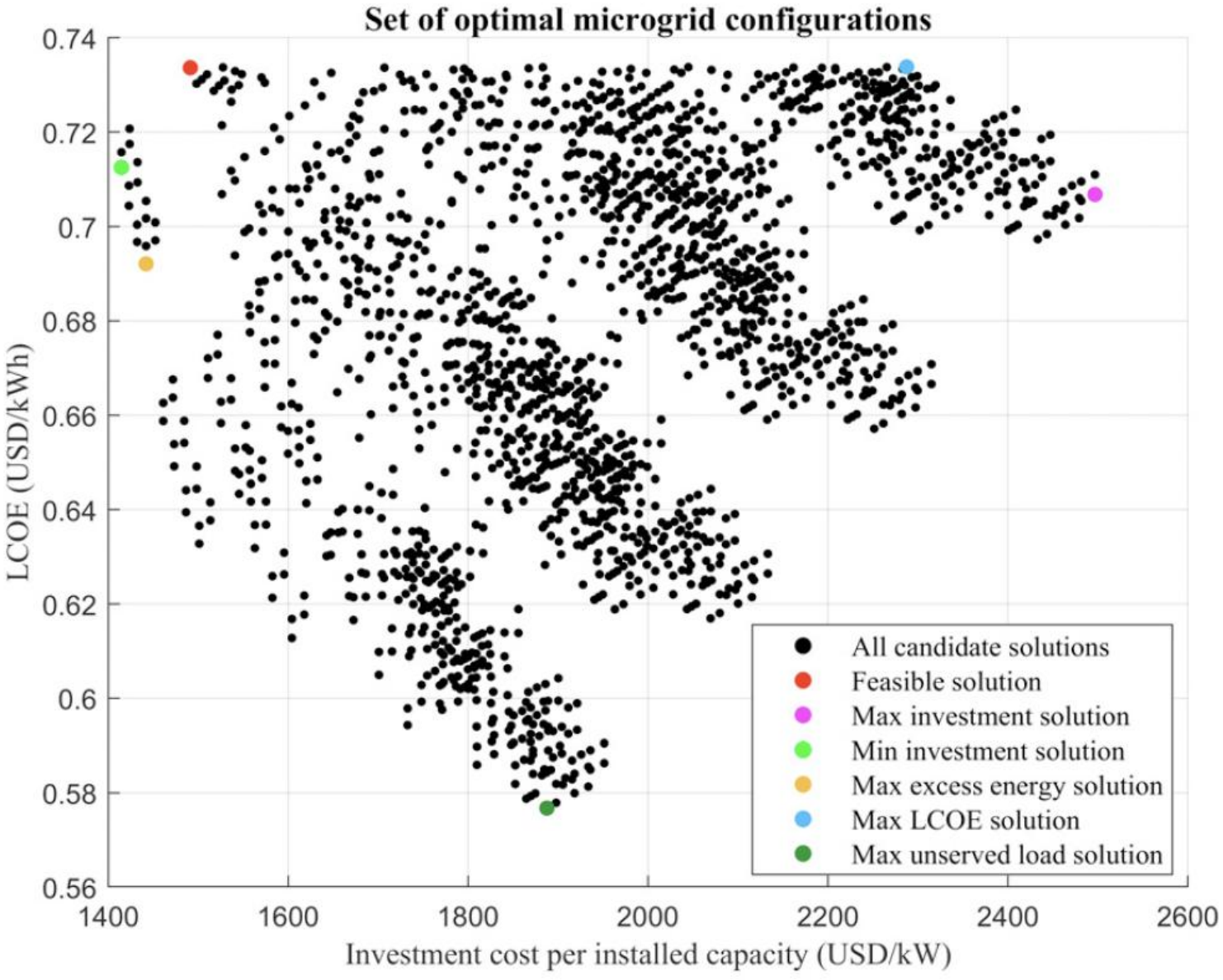
MG design feasible solutions



Stage 2: Microgrid Design

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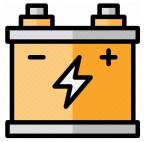
Components Size

127 kW

100 kW

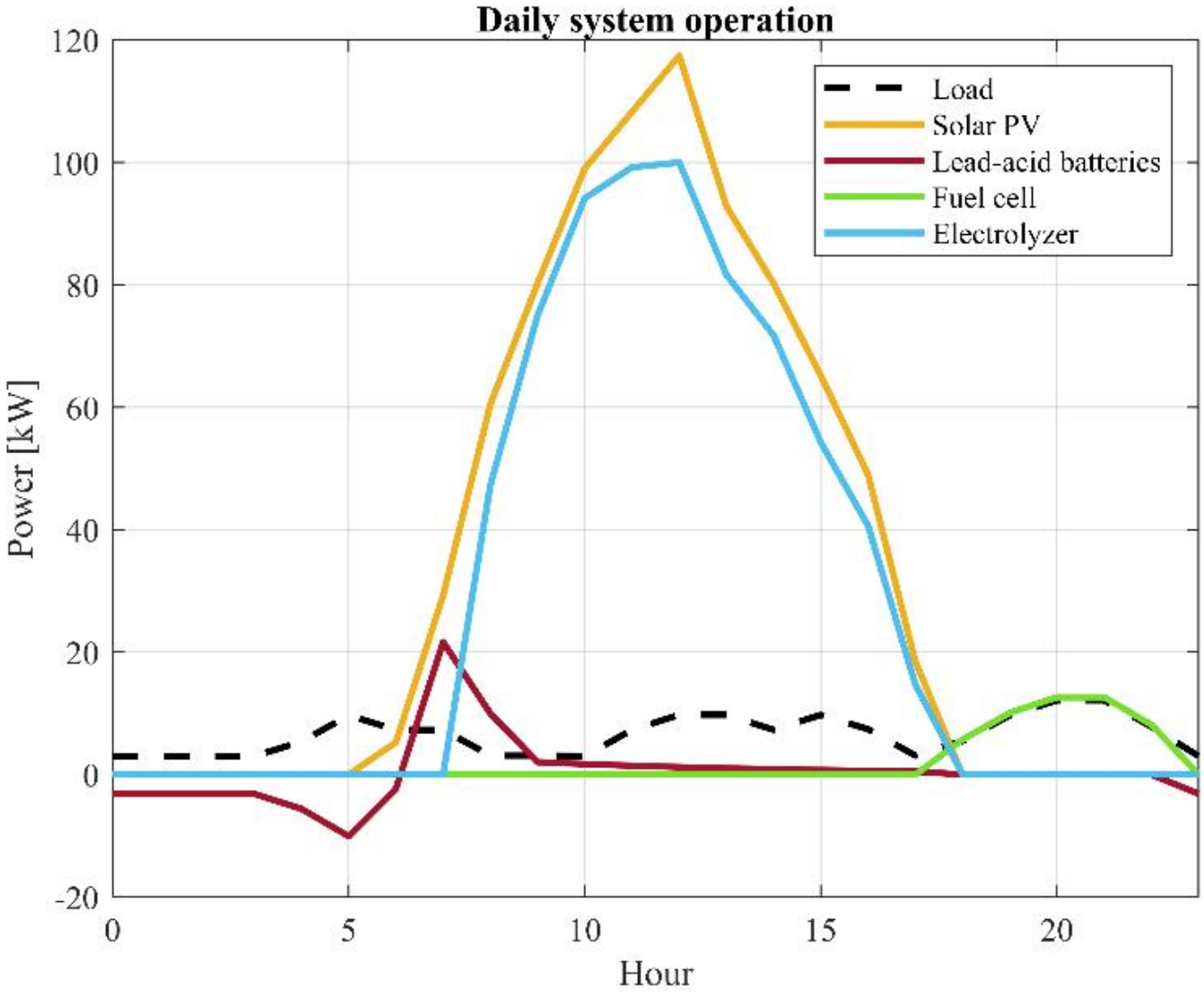


207 kWh

20 kW

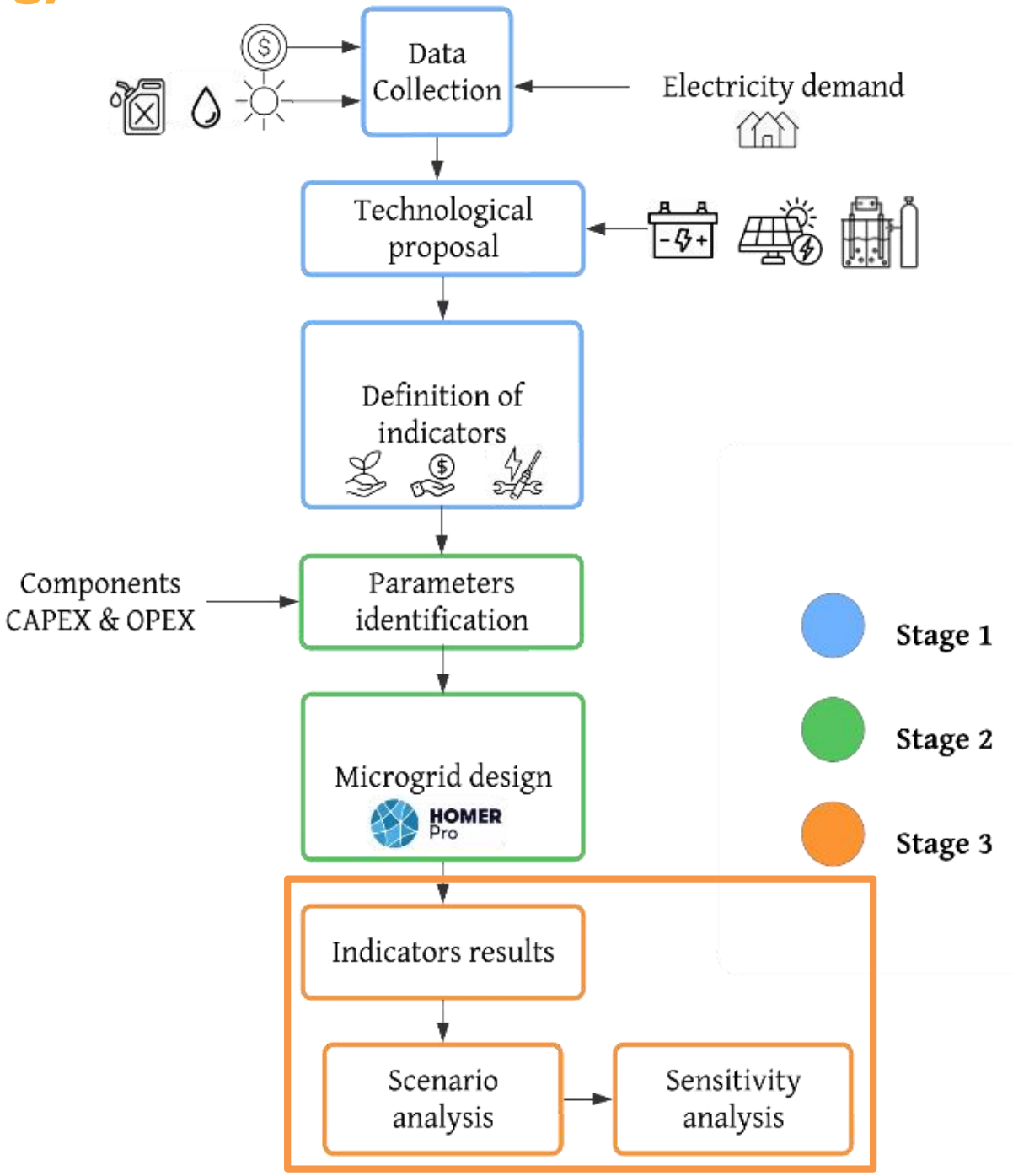
50 kg

Daily Microgrid Operation



Annual production: 223,019 kWh

Methodology

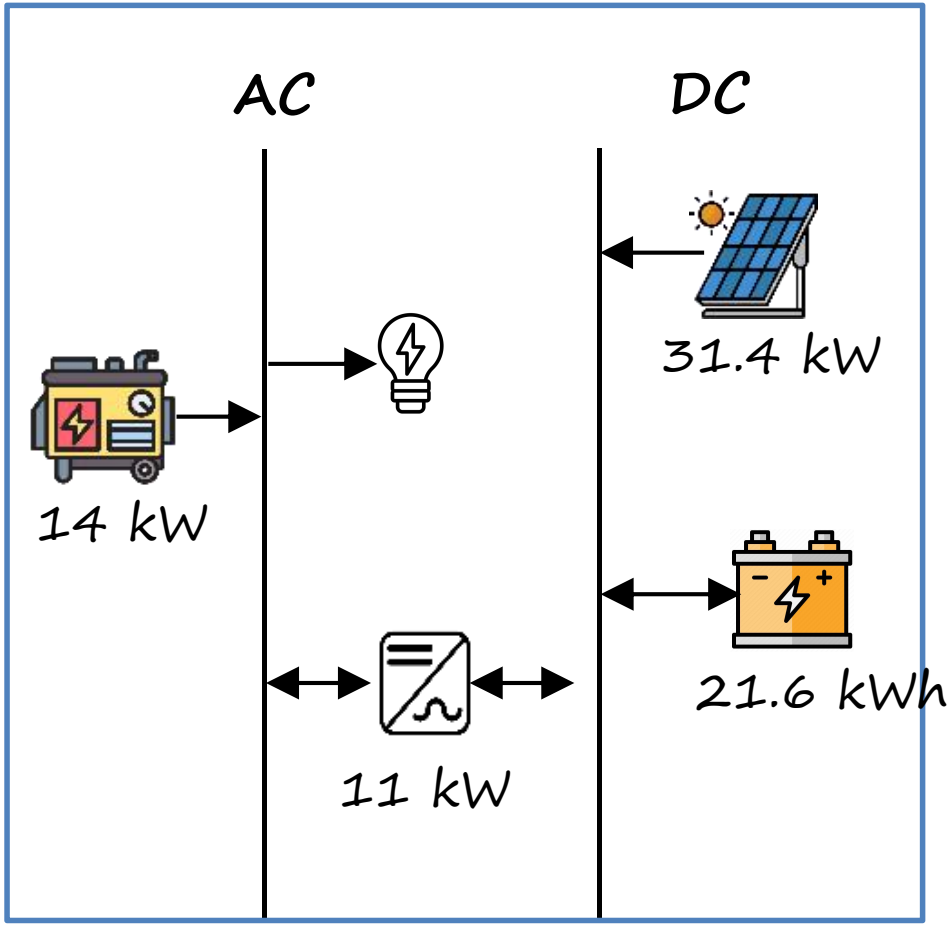


Stage 3: Indicators results

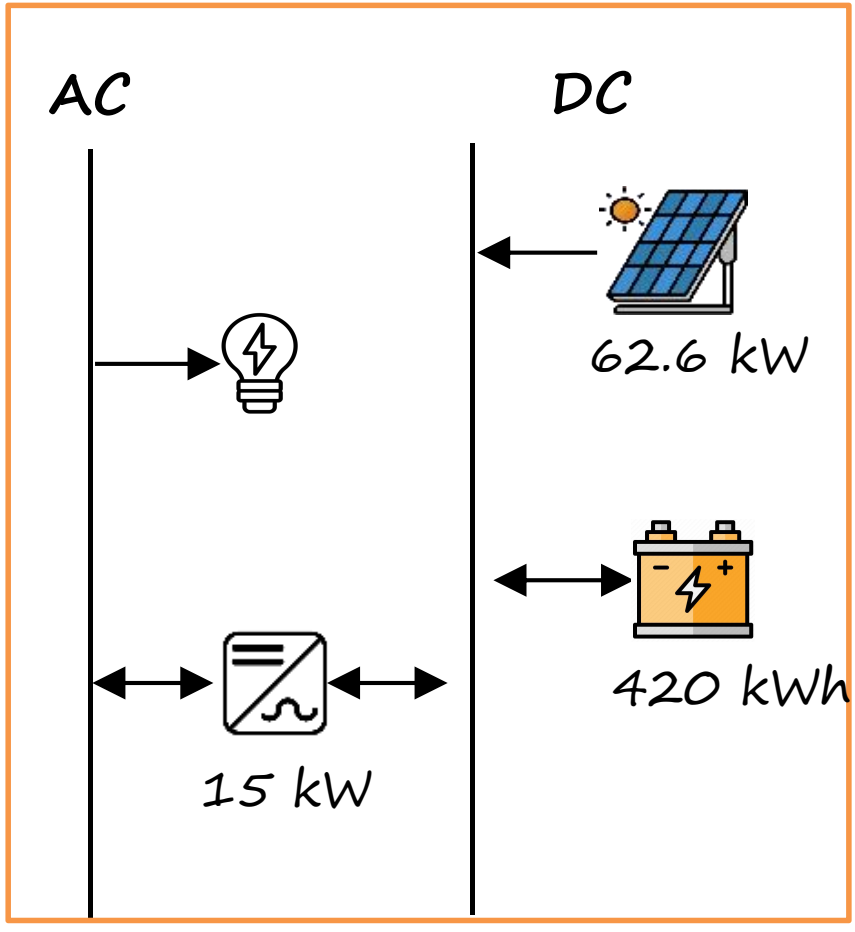
	Indicator	Value	Unit
	CAPEX	367.9	kUSD
	OPEX	810.6	USD/year
	LCOE	0.734	USD/kWh
	LCOH	12	USD/kg
	CO_2 Emissions	0	$kgCO_2$/year
	Renewable energy penetration	100	%
	Excess electricity	0.1	%
	Unserved load	0	%

Stage 3: Scenario Analysis

Alternative Microgrids



Microgrid A



Microgrid B

Stage 3: Scenario Analysis

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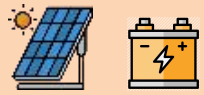
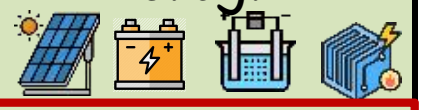
Microgrids Indicators Results

Indicator	Microgrid A 	Microgrid B 	Proposed H_2 microgrid 
CAPEX (kUSD)	40	154	367.9
OPEX (USD/year)	8087.4	47.6	810.6
LCOE (USD/kWh)	0.226	0.380	0.734
CO_2Emissions ($kgCO_2$/year)	31,898	0	0
Renewable energy penetration (%)	39.6	100	100
Excess electricity (%)	31.8	33.7	0.1
Unserved load (%)	0	0.03	0

Microgrid A shows the lowest CAPEX but highest OPEX.
Microgrid B has the lowest OPEX.

Stage 3: Scenario Analysis

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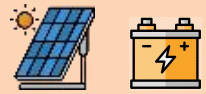
Microgrids Indicators Results

Indicator	Microgrid A 	Microgrid B 	Proposed H_2 microgrid 
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Microgrid A shows the highest CO_2 emissions due to its low renewable energy penetration.

Stage 3: Scenario Analysis

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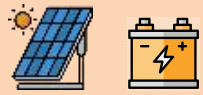
Microgrids Indicators Results

Indicator	Microgrid A 	Microgrid B 	Proposed H_2 microgrid 
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Unserved load (%)	0	0.03	0

The proposed H_2 -based microgrid is the only configuration that completely avoids excess electricity.

Stage 3: Scenario Analysis

Long-term Scenarios (Year 2050)

Component	Investment cost		
	Scenario 1	Scenario 2	Reference Scenario
PEM Electrolyzer	250 USD/kW	250 USD/kW	1200 USD/kW
Fuel cell	900 USD/kW	900 USD/kW	3000 USD/kW
Solar PV	857 USD/kW	600 USD/kW	857 USD/kW
Batteries (255 Ah)	702.6 USD/unit	654.8 USD/unit	702.6 USD/unit

Costs reduction

International Renewable Energy Agency (IRENA). (2020). *Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5°C Climate Goal.* Abu Dhabi.

Stage 3: Scenario Analysis

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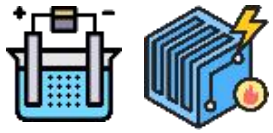

70% 70%

International Renewable Energy Agency (IRENA). (2020). *Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5°C Climate Goal*. Abu Dhabi.

Stage 3: Sensitivity Analysis

Long-term Scenarios (Year 2050)

Component	Investment cost		
	Scenario 1	Scenario 2	Reference Scenario
PEM Electrolyzer	250 USD/kW	250 USD/kW	1200 USD/kW
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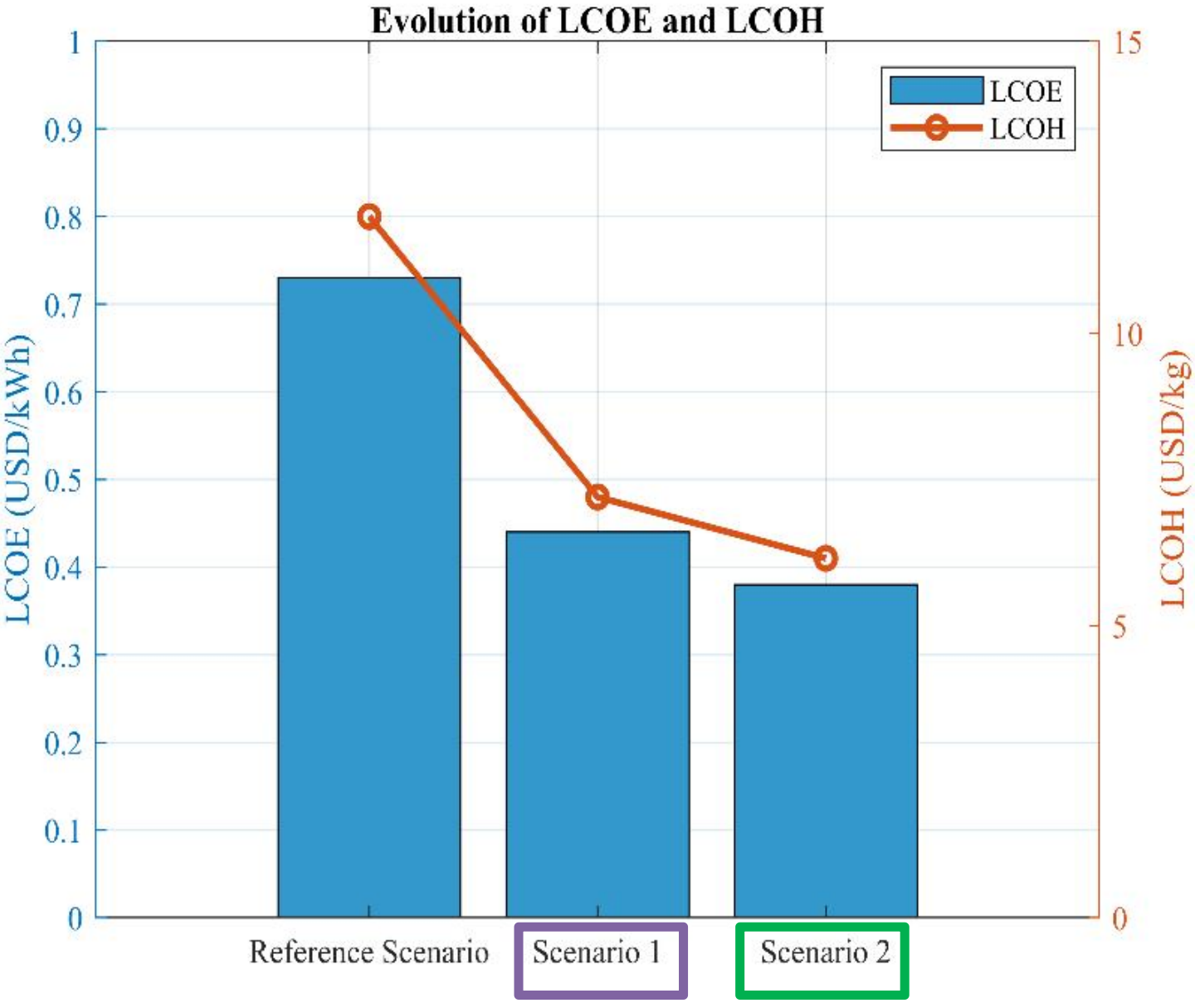
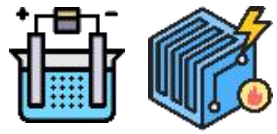
Stage 3: Sensitivity Analysis

LCOE and LCOH Results



Scenario 1



Scenario 2

Conclusions

- Technical feasibility achieved.
- Strong environmental performance.
- Economic challenge remains.
- Comparative analyses validate value.
- Sensitivity analysis shows future potential.
- **Future work**: evaluate water use, explore application in urban settings and analyze system under different reliability conditions.

Thank you!

Andrea Cusva-García, Guillermo Jiménez-Estévez, Nicanor Quijano. Green hydrogen microgrids for remote areas: design, assessment, and feasibility. IFAC-PapersOnLine,Volume 59, Issue 9,2025, Pages 79-84,ISSN 2405-8963, https://doi.org/10.1016/j.ifacol.2025.08.116.

* Integrated Energy Systems: An Overview from a Multi-layer Architecture. David Erazo-Caicedo, Nicanor Quijano, Carlos Ocampo-Martinez, Guillermo Jiménez-Estévez. Pages 21-51

* Productive Solar Energy Solutions for Communities: The Ayllu Solar Project. Rodrigo Palma-Behnke, Guillermo Jiménez-Estévez, Marcia Montedonico. Pages 133-147

* Integrated Multi-energy Systems Analysis for a Colombian Cocoa Plantation. Andrea Cusva-García, Guillermo Jiménez-Estévez, Rocío Sierra-Ramírez, Nicanor Quijano. Pages 151-178

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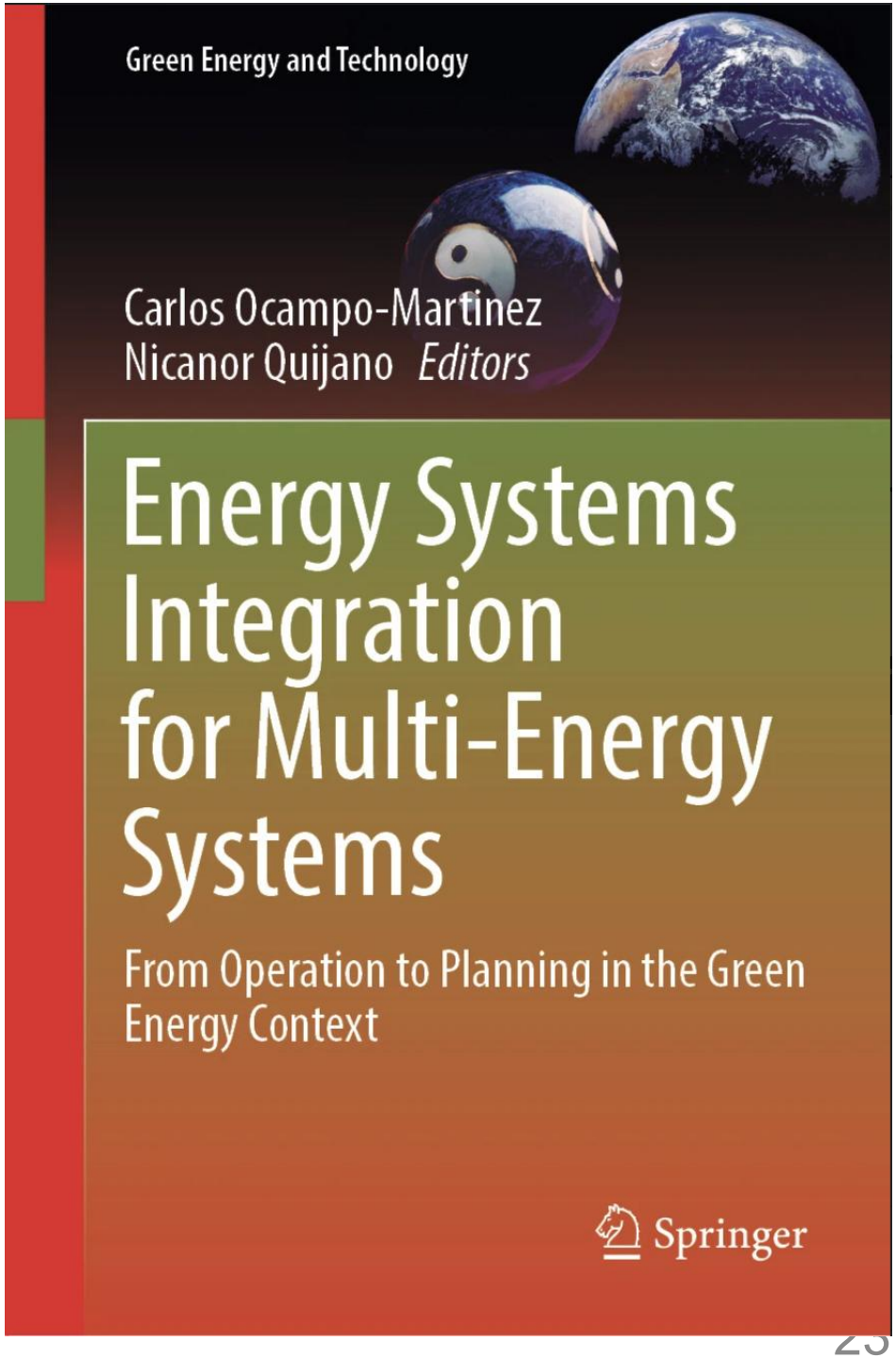

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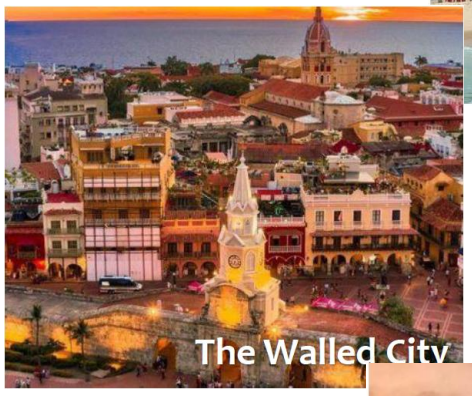
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Stage 2: Microgrid Design

Desing: parameters identification and progressive energy solution design

Parameter	Value	Unit
Solar PV investment cost	857	USD/kW
Solar PV operating cost	0.34	USD/kW/year
Biomass thermal investment cost	3697	USD/kW
Biomass thermal maintenance cost	0.0105	USD/h
Lead-acid batteries investment cost	702.6	USD/unit
DC/AC inverter investment cost	300	USD/kW/year
DC/AC inverter maintenance cost	10	USD/year
Diesel generator investment cost	300	USD/kW
Diesel generator operating cost	0.0102	USD/h
Electrical grid tariff	0.147	USD/kWh
Grid sell back rate	0.052	USD/kWh