Lemna
Laboratoire d'Économie et de Management Nantes-Atlantique

Nantes Université

Multicriteria analysis for energy storage technology valuation: economic simulation of energy scenarios in islands grids

Antoine DEBILLE

Nantes University
antoine.debille@gmail.com

18th IAEE European Conference, July 25th 2023

Motivations

- Study the system benefits of storage integration to support variable renewables in islands grids
- Confront the impact of short term and long term storage in a high share renewable electricity system
- Investigate the use of multicriteria analysis for storage valuation

Case Study

Guadeloupe Islands

- 383,559 inhabitants
- 1,661 GWh of electricity consumption
- 244 MW power peak
- 564 MW of installed capacity
- Dry season / Wet season

Guadeloupe Island high voltage lines

Main objectives for energy transition:

- 10% reduction in finale energy consumption by 2023 through enhanced demand side management
- 261MW of renewable installed capacity by 2023
- Energy self-sufficiency by 2030

Case study: installed capacity hypothesis

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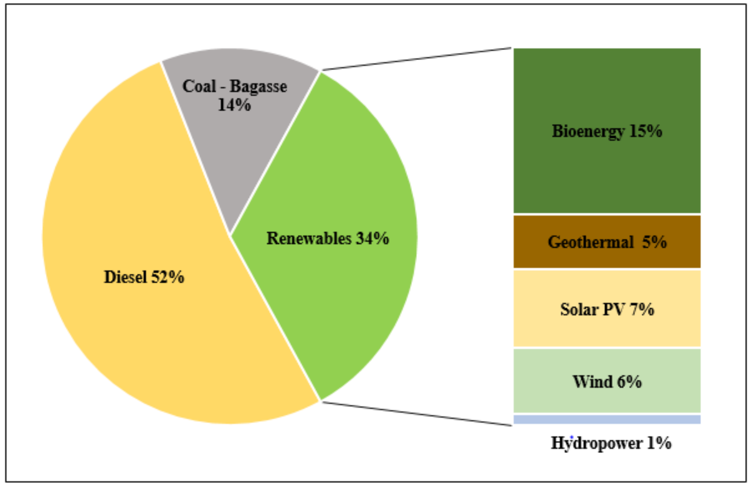
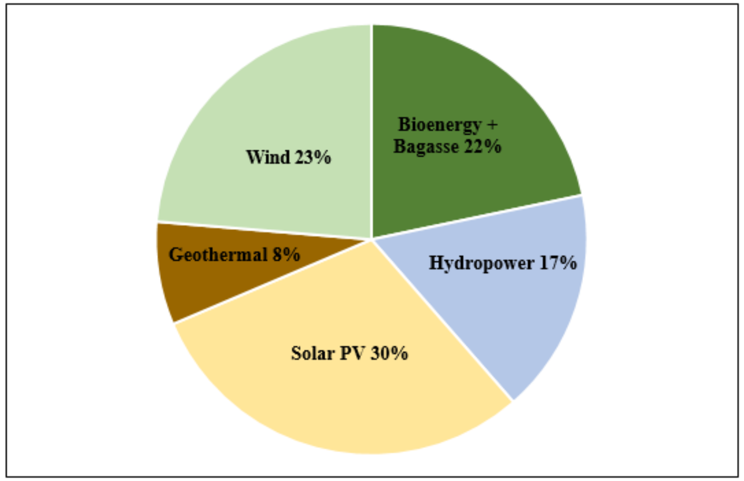
2021: electricity production and installed capacity



	Installed Capacity (MW)
Hydropower	11
Solar PV	86
Wind	42
Geothermal	14.7
Bioenergy	3.7
Diesel	318
Coal - Bagasse	93
Storage	5

- 70% of electricity production based on fossil fuel
- 129 MW of installed variable renewable
- 5 MW of battery storage dedicated to fast reserve

2030: electricity production and installed capacity forecast[1]



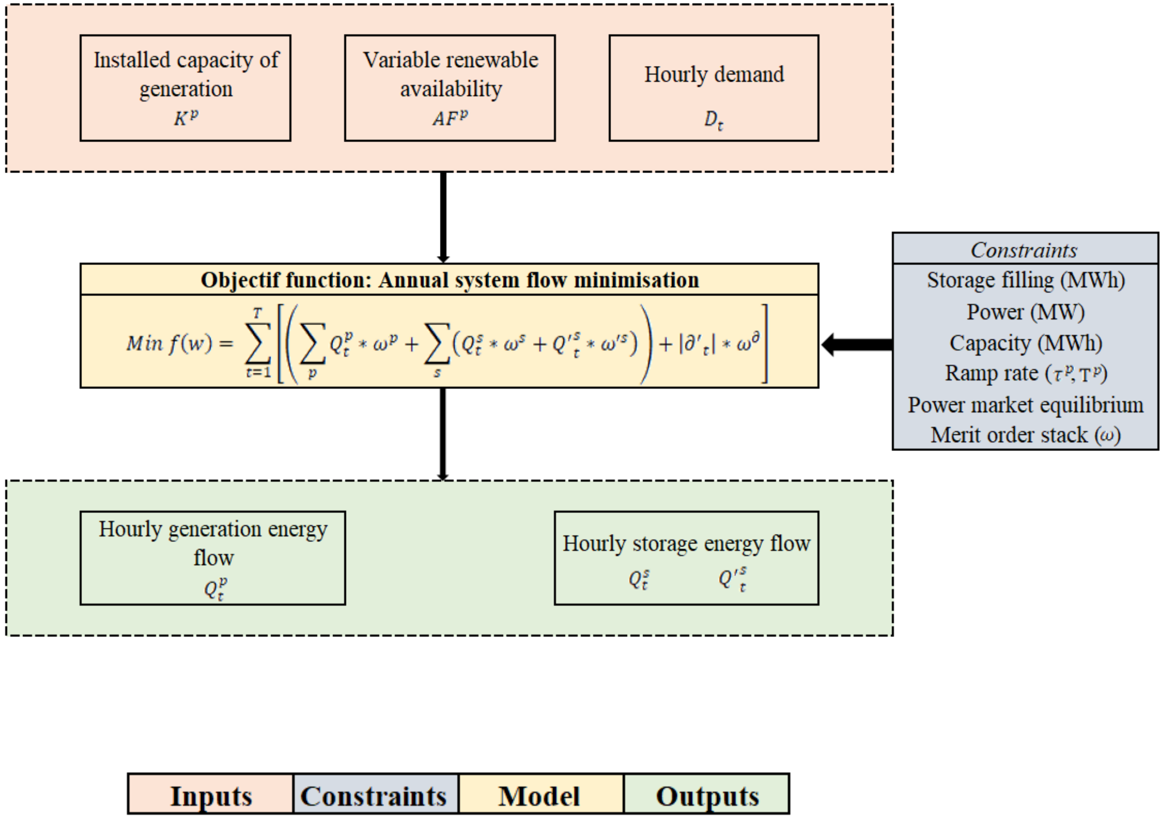
	Installed Capacity (MW)
Hydropower	79
Solar PV	344
Wind	140
Geothermal	22
Bioenergy	20
Diesel	211
Coal - Bagasse	94
Storage	253

- 100% renewable production
- 563 MW of installed variable renewable
- 253 MW of storage dedicated to support variable renewable generation and supply / demand imbalance

[1] ADEME, *Toward energy self-sufficiency in insular grid in 2030 – Final report for Guadeloupe*, 2019

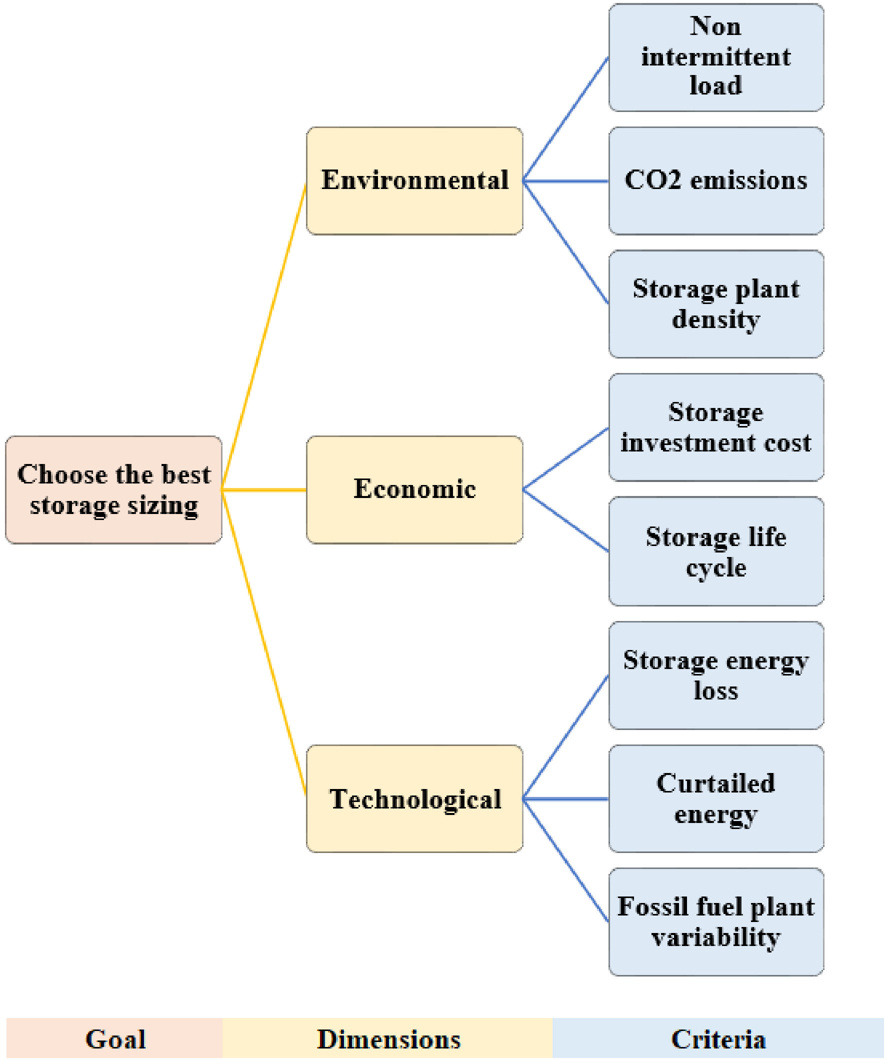
Methodology

Optimisation model



Methodology

Analytic Hierarchy Process



- Hierarchically structures a decision problem
- Helps comparing factors of decisions regardless of their measurement metric

Analytic hierarchy process scenarios

Prefered Dimensions	Environmental	Technological	Economics
Environmental	**64.0%**	20.6%	15.4%
Technological	12.2%	**64.8%**	23.0%
Economics	12.2%	23.0%	**64.8%**

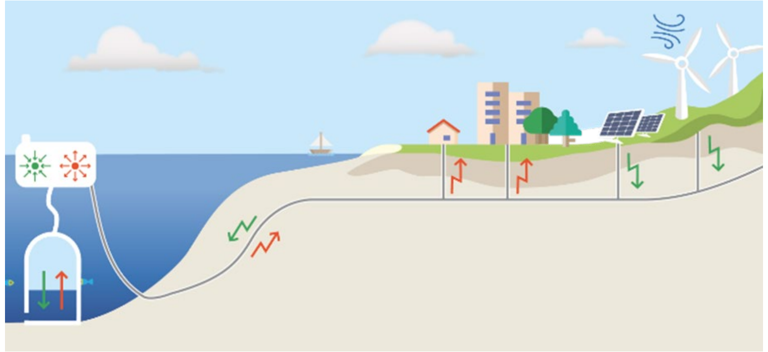
- Three AHP are done in a row, then aggregated

Storage hypothesis

Storage technologies

- Lithium-ion batteries for short term storage
  - 2.7 hours of discharge duration
  - 90% roundtrip efficiency / 10 years lifespan
  - Based on ADEME forecast[1]

- CAES for long-term storage
  - 6 hours of discharge duration
  - 70% roundtrip efficiency / 50 years lifespan
  - Offshore technology



Storage sizing scenarios

- 550 MWh of storage capacity
- 50 GWh maximum curtailed energy volume
- 7 repartition between Li-ion batteries and CAES

Storage sizing scenarios

Underwater I-CAES		Lithium-ion batteries		Overall storage	
Power (MW)	Capacity (MWh)	Power (MW)	Capacity (MWh)	Power (MW)	Capacity (MWh)
0	0	196	550	196	550
15	90	164	460	179	550
30	180	132	370	162	550
45	270	100	280	145	550
60	360	68	190	128	550
75	450	36	100	111	550
90	540	0	0	90	540

[1] ADEME, *Toward energy self-sufficiency in insular grid in 2030 – Final report for Guadeloupe*, 2019

Main optimisation results

- 100% renewable production is never reached in these scenarios (90% on average)
- Variable renewable represents two third of the annual production
- Volume of curtailed energy are higher when only one storage technology is installed
- CO2 emission are lower when only CAES is installed

CAES (MW)	0	15	30	45	60	75	90
Li-ion battery (MW)	196	164	132	100	68	36	0
Non intermittent load (GWh)	441	443	447	452	458	465	477
CO2 emissions (ktCO2/)	153	150	146	143	139	136	133
Storage plant density (t)	196	7 173	14 151	21 128	28 105	35 083	42 056
Energy loss due to efficiency (%)	10%	12%	14%	16%	19%	24%	30%
Curtailed energy (GWh)	44.79	41.5	39.69	38.7	38.6	40.23	47.53
Fossil fuel plant variability (%)	9%	8%	8%	8%	8%	9%	9%
Storage investment cost (M€)	313.6	320.9	328.2	335.5	342.8	350.1	351
Storage life cycle (% of consumed cycle)	7%	5%	4%	3%	2%	2%	1%

Synthesis of optimisation results

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Optimisation results

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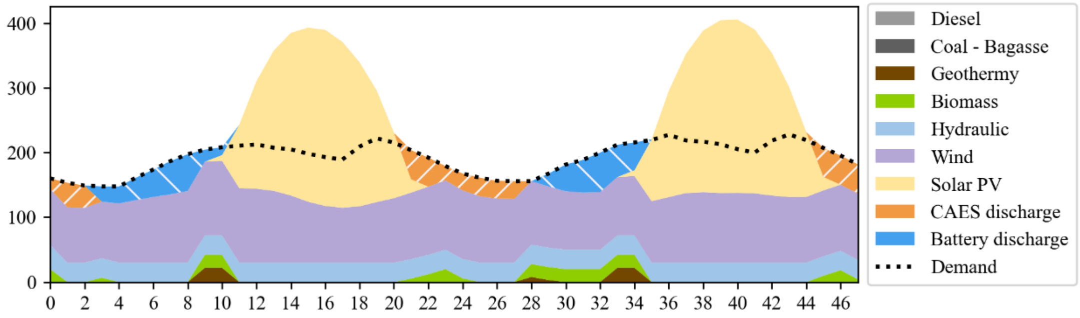
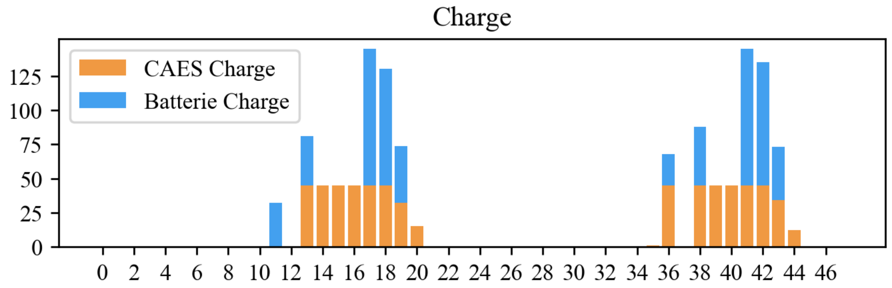
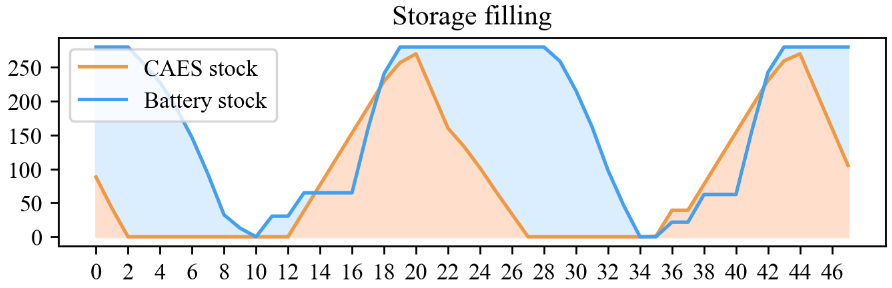
Dry season



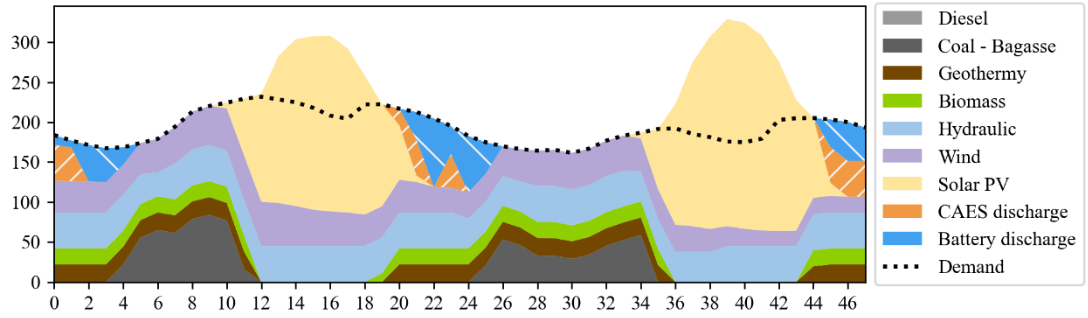


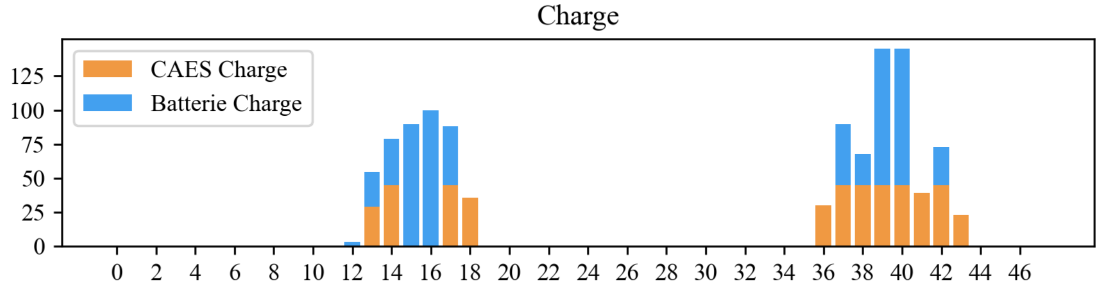


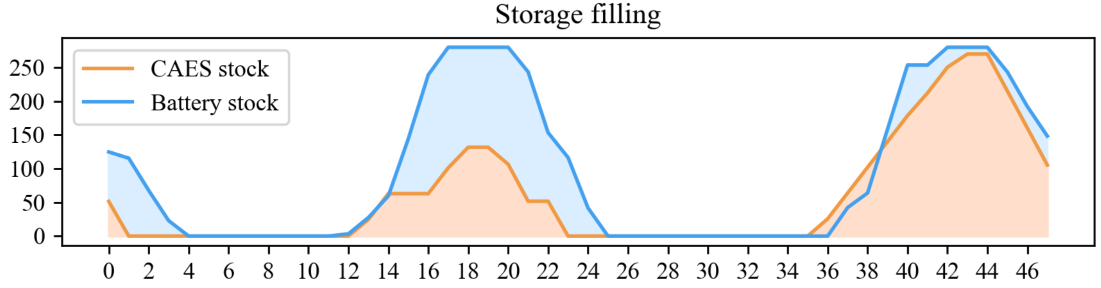
- The need for generation is during the evening and the night
- Combination of energy storage and programmable renewables is enough to satisfy the demand/supply equilibrium
- Discharge cycles of storage technologies are complementary
- Battery storage discharges more regularly than CAES, but for a less period of time

Optimisation results

Wet season







- Solar irradiation is lower than in the dry season
- Evening demand peak is higher than during the dry season
- Storage technologies need to overlap their cycles to respond to the demand peak
- Fossil fuel generation is needed to satisfy the supply/demand equilibrium

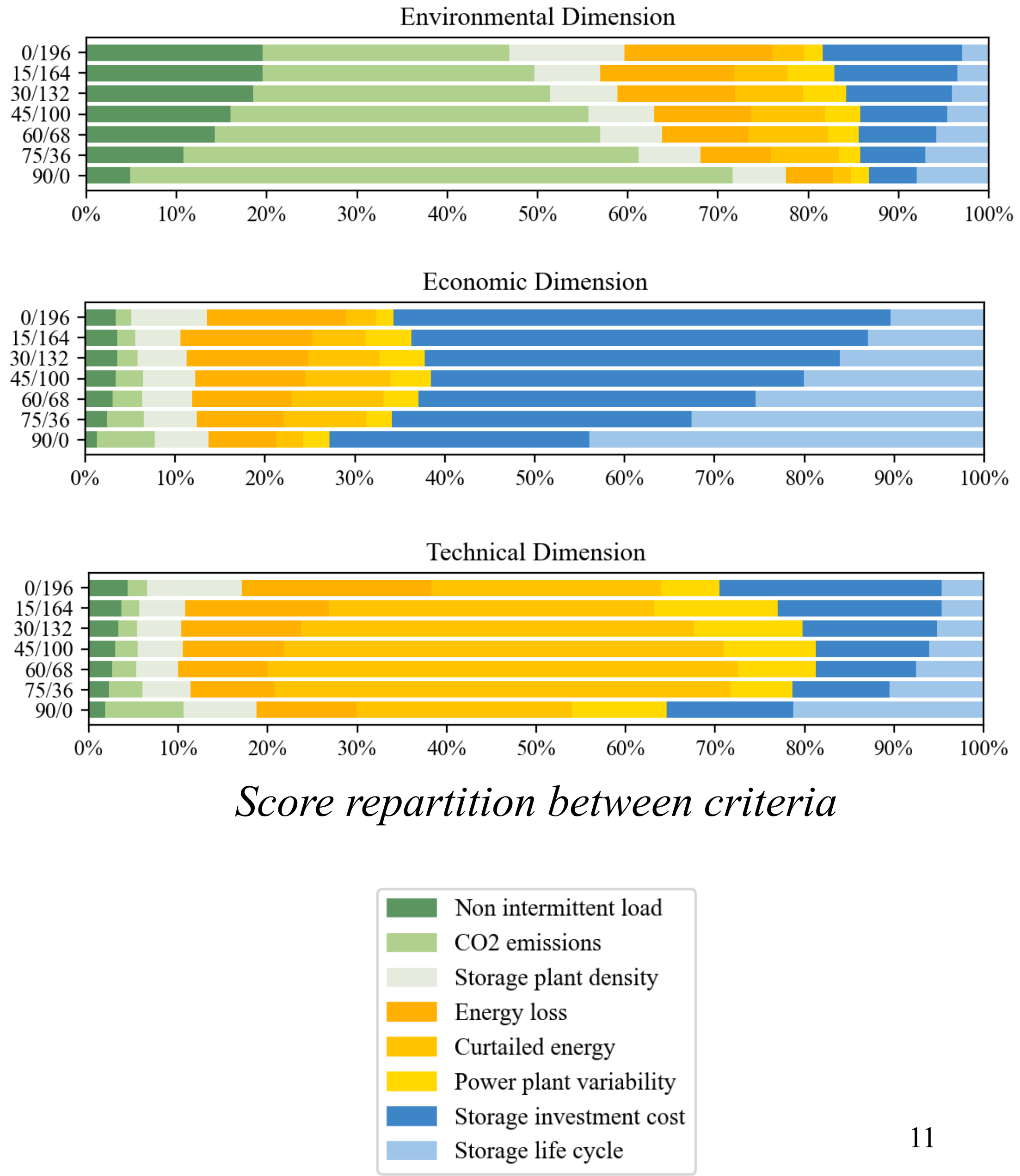
Analytic hierarchy process results

Aggregated scores

Sizing scenarios	Environnemental	Technological	Economics	Total
0/196	0.153	0.142	0.180	0.475
15/164	0.144	0.160	0.163	0.467
30/132	0.140	0.163	0.149	0.452
45/100	0.143	0.162	0.139	0.444
60/68	0.133	0.153	0.129	0.415
75/36	0.133	0.133	0.121	0.386
90/0	0.155	0.087	0.119	0.361

- Short term storage is preferred in general
- The technological put forth a combination of energy storage technology
- Investment cost is an important criteria

- Following Guadeloupe guidelines, the second scenario (15/164) would be a better fit to benefit both renewable penetration and grid reliability



Score repartition between criteria

Concluding Statements

- A combination of both long term and short term storage is preferred to support variable renewable penetration

- Curtailed energy savings requires large storage capacity along high power supply

- Storage integration will not be sufficient to reach a 100% renewable mix because of the difference between peak load and renewable availability

- Aggregation of several AHP allow better identification of key drivers for the selection of a suitable mix

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