Bermuda Better Energy Plan

Internal distribution only

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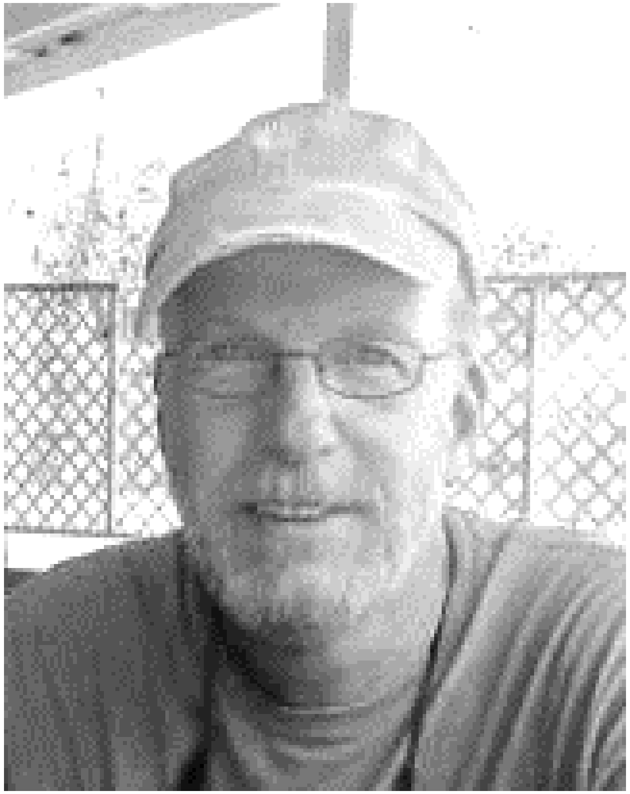

The Bermuda Better Energy Plan is dedicated to Barrett Lightbourn

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Bermuda's electricity planning process

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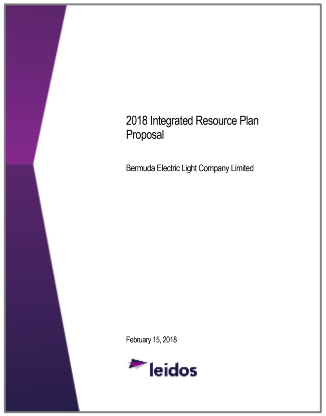
2018 Integrated Resource Plan
Proposal

Bermuda Electric Light Company Limited

February 15, 2018

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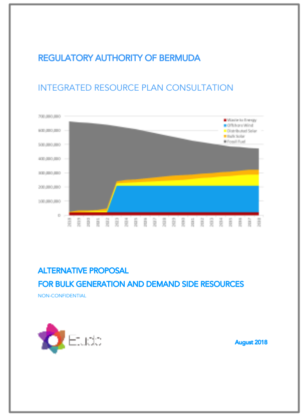
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INTEGRATED RESOURCE PLAN CONSULTATION

ALTERNATIVE PROPOSAL
FOR BULK GENERATION AND DEMAND SIDE RESOURCES
NON-CONFIDENTIAL

August 2018

?

Initial plan (BELCO) → Consultation → Alternative plans → Consultation → Final plan (BELCO)

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The two plans

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February 15, 2018

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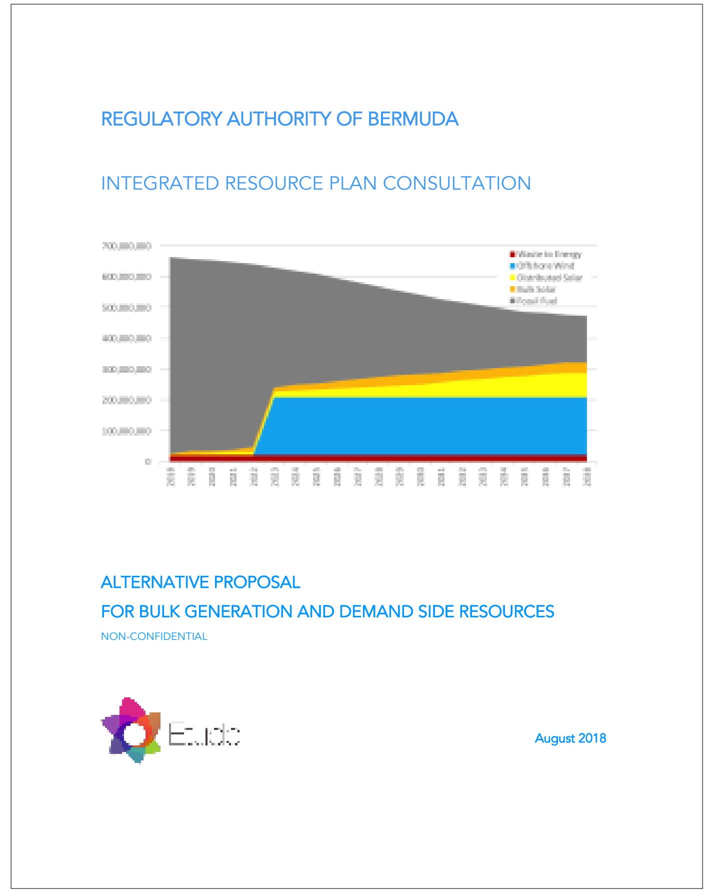
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A different energy future

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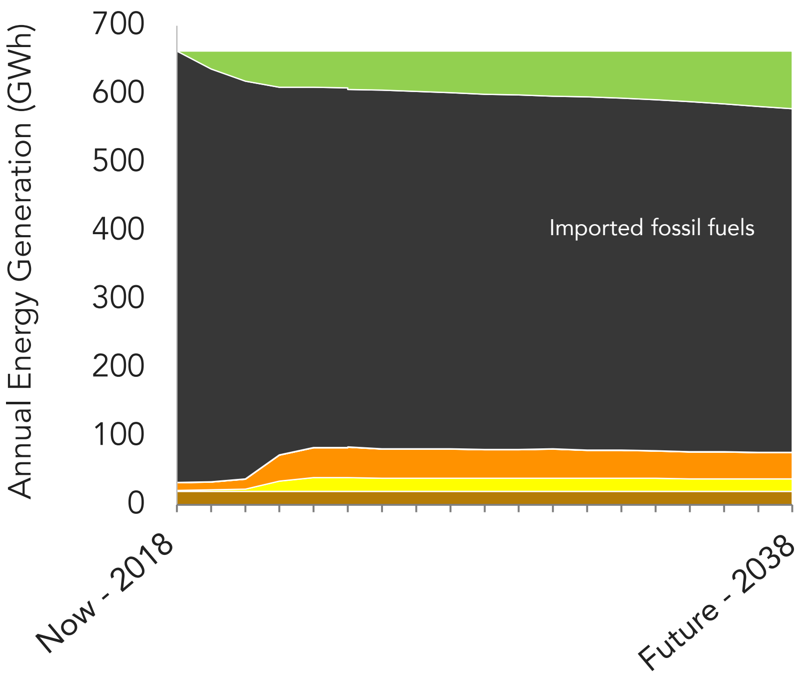

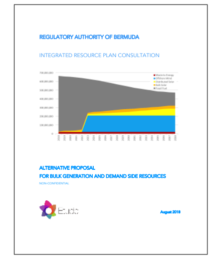

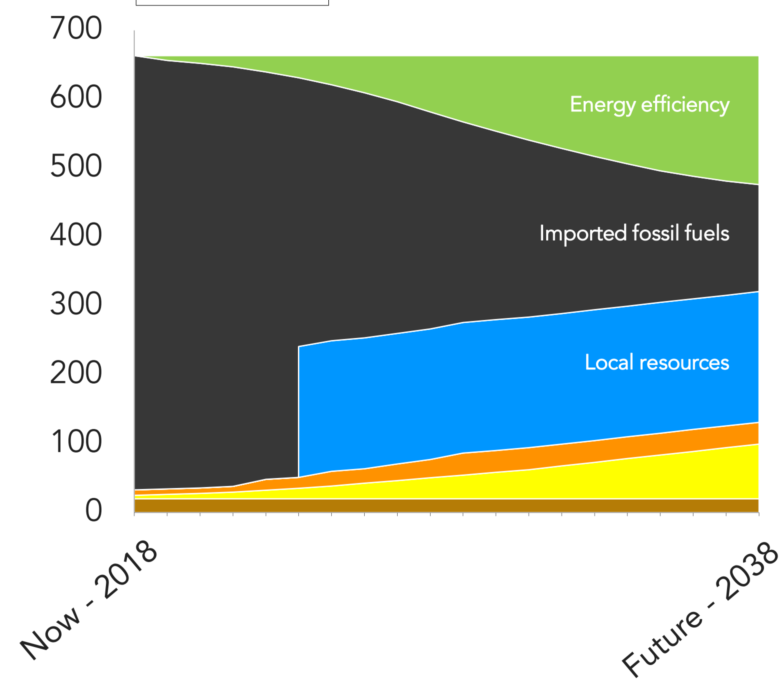

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Who is behind the BBEP?

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be solar

REGISTERED CHARITY No.704
Greenrock.org
Changing the Mindset

BERMUDA ENVIRONMENTAL SUSTAINABILITY TASKFORCE
BEST

BERMUDA
SOLAR
ENERGY
ASSOCIATION

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Who is behind the BBEP?

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Marion Conyngham
Carol Dixon
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Lalunahinsons
Thomas Honest
Jocelyn Jessica

Nick Hutchings
Jeff Kriendler
Jenny Kriendler
Natasher Tucker
Kathy Cervino
Olga Kriendler
Celine Fornaro
Francoise Plantade
David Joll
Bill Jewell
Glenda Resener
Dana Siberia
Glenn Clinton
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Martin Russell
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Renata Toman
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John Steele

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Emma Farge
Myles Orchard
Graham Frith

Natalia Linkova
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Yvette Davis
Claire Smith
Kathy Cervino
Luca Cervino
Matteo Cervino
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Jay Riihiluoma
Savanna Darby
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Low energy building certifier

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Leon Tatlock
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MSs in Energy and Buildings

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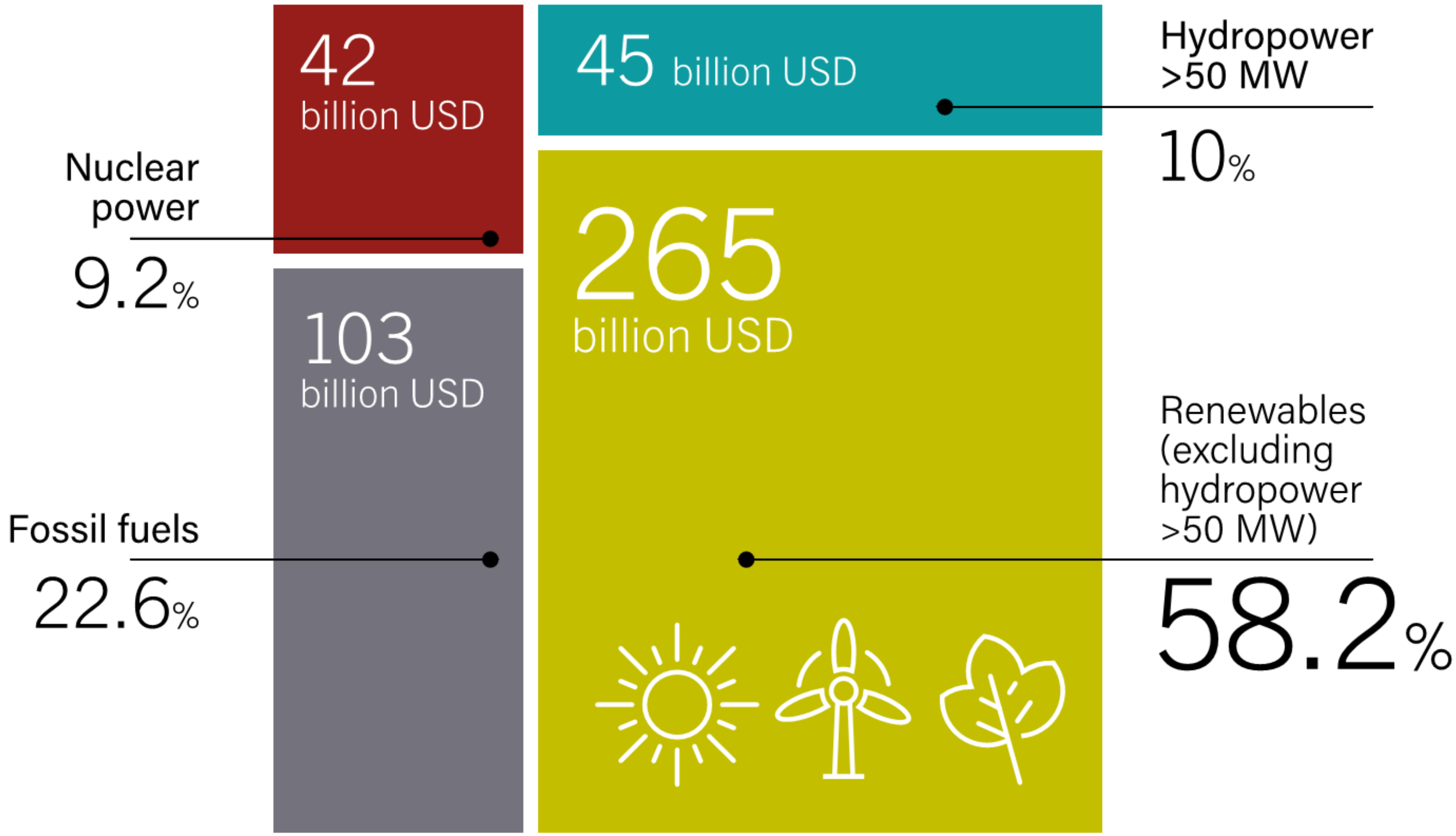
Why another plan?

Most new generators are renewable



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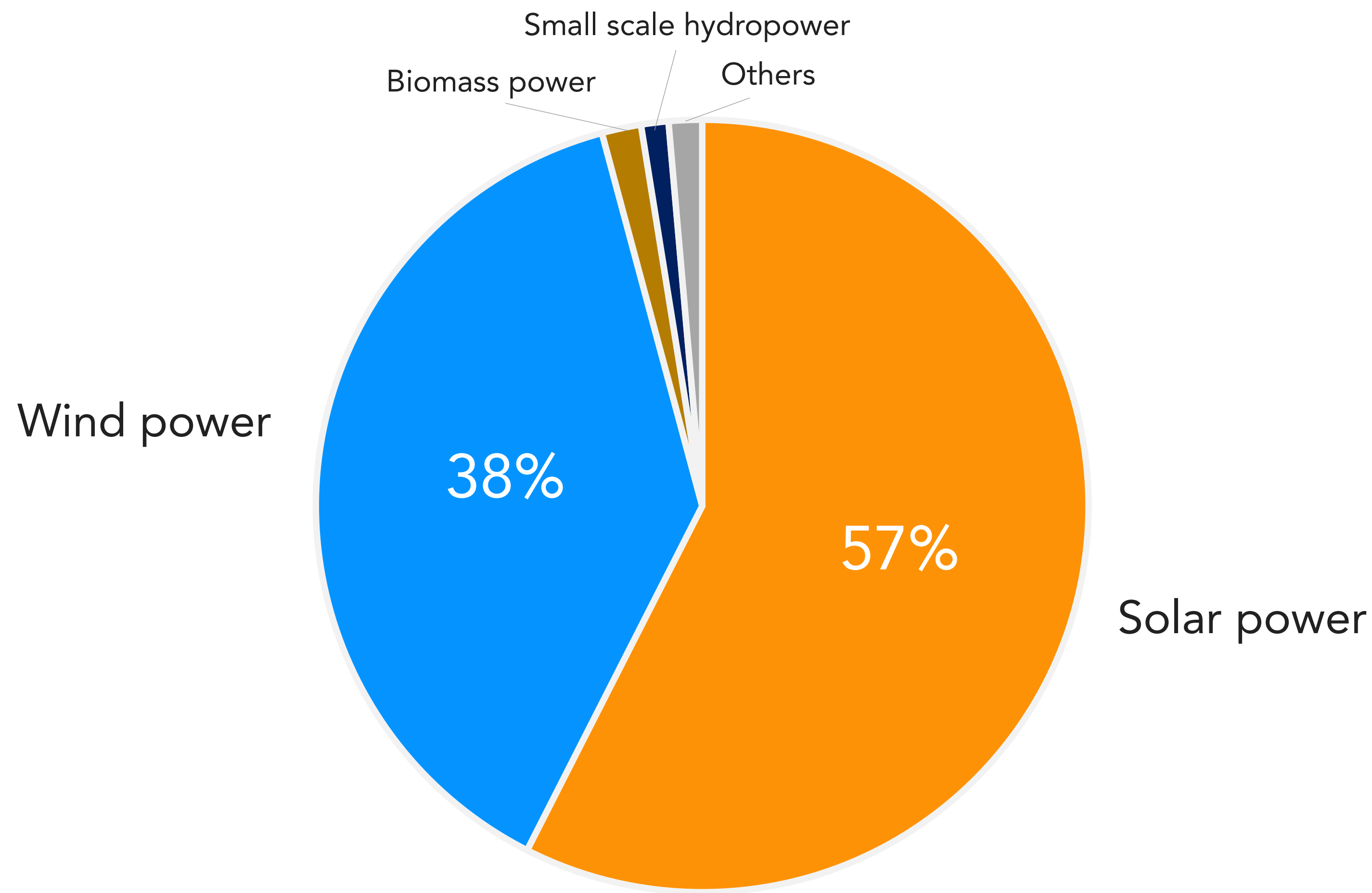
Solar and wind dominate the market



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And they keep on growing

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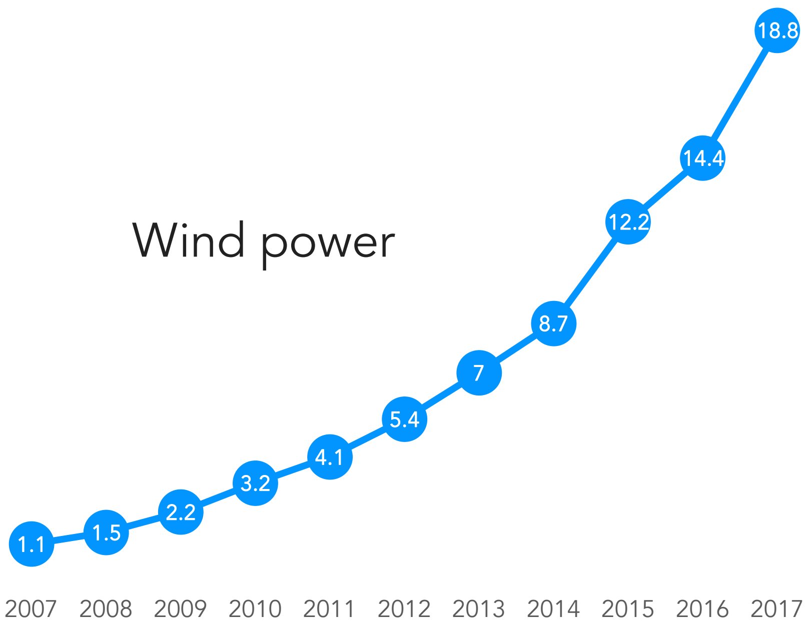

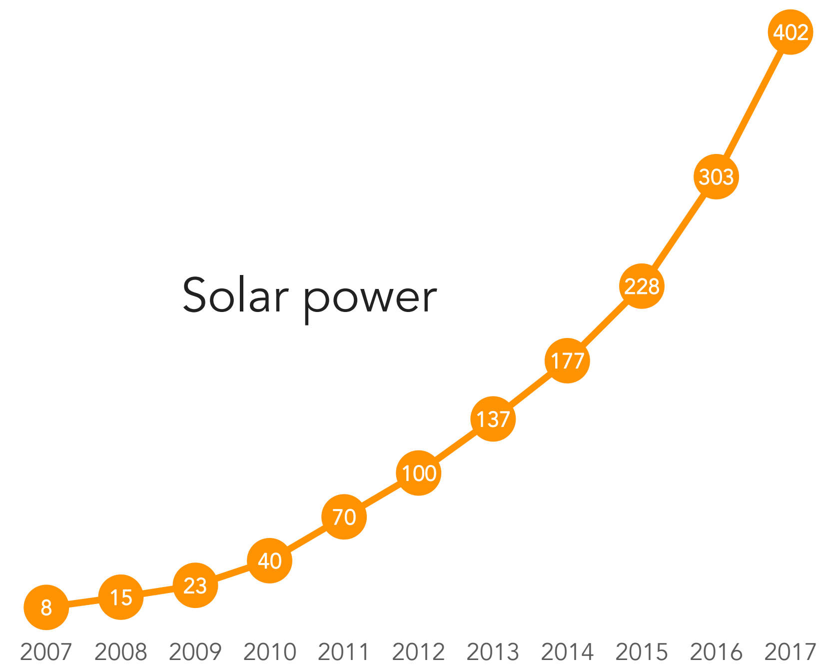

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Countries with more than 20% renewables

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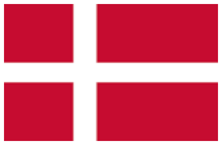
Denmark


Germany


Ireland


United Kingdom


Spain


Uruguay


Portugal


Honduras


Greece

85 countries, states or provinces are targeting more than 50% renewable electricity

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Islands are using renewable electricity

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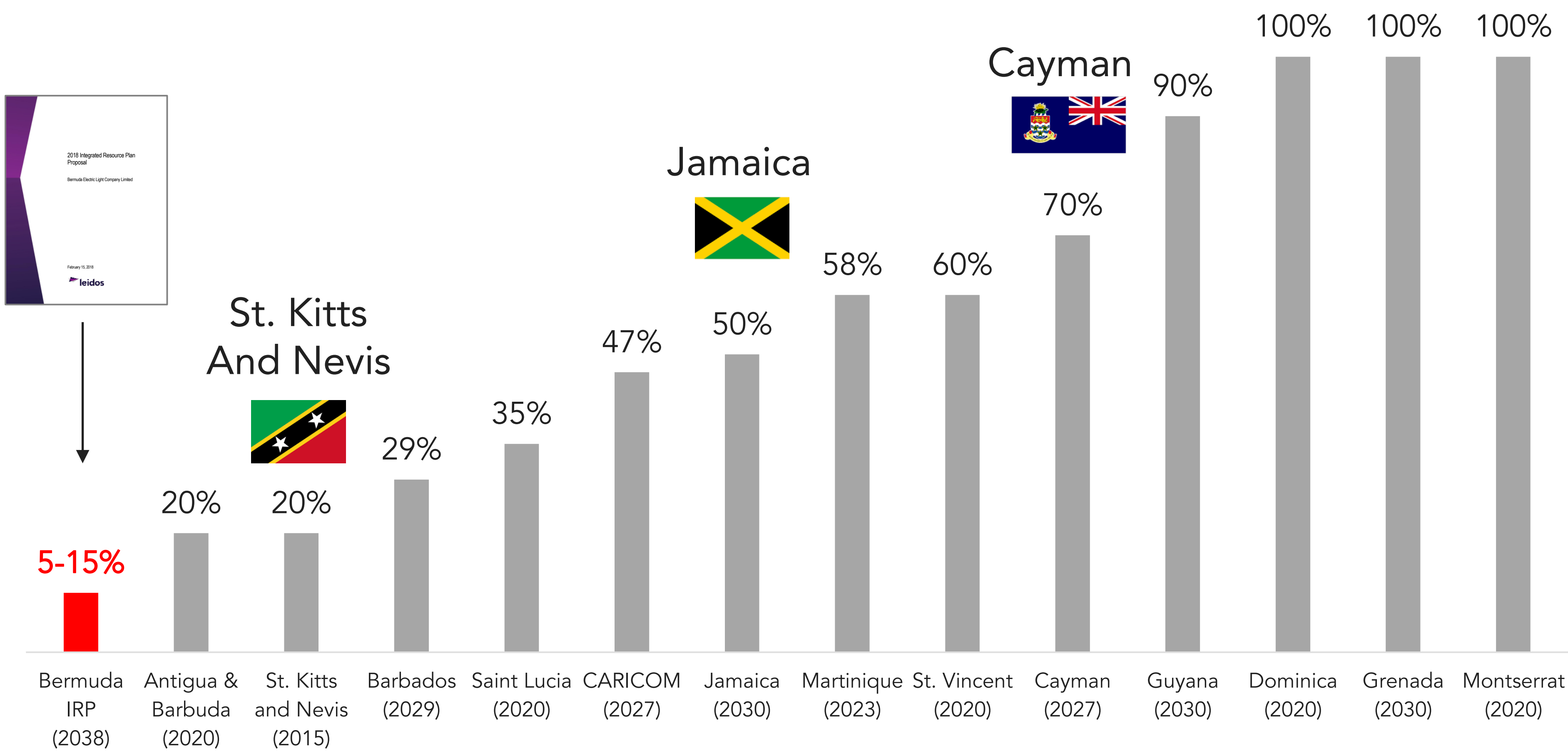

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CARICOM – Caribbean Sustainable Energy Roadmap (and others)

Fossil fuel costs are volatile = risk

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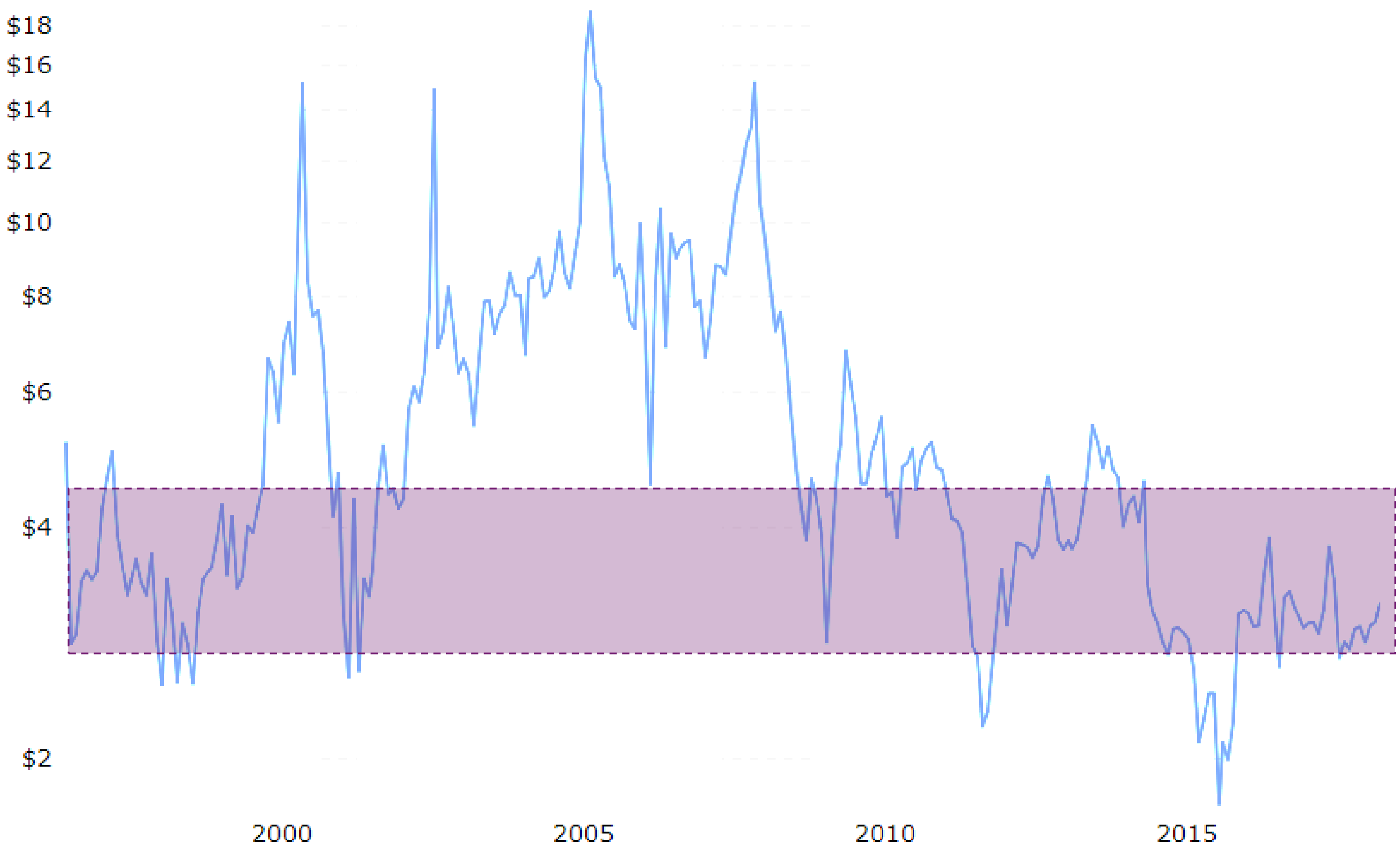

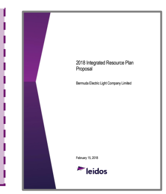

© Macro trends – Natural gas price historical chart

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How our plan was developed

The Electricity Act – Key requirements

BERMUDA

ELECTRICITY ACT 2016

Purposes of this Act

6 The purposes of this Act include the following, namely, to seek—

(a) to ensure the adequacy, safety, sustainability and reliability of electricity supply in Bermuda so that Bermuda continues to be well positioned to compete in the international business and global tourism markets;

(b) to encourage electricity conservation and the efficient use of electricity;

(c) to promote the use of cleaner energy sources and technologies, including alternative energy sources and renewable energy sources;

(d) to provide sectoral participants and end-users with non-discriminatory interconnection to transmission and distribution systems;

(e) to protect the interests of end-users with respect to prices and affordability, and the adequacy, reliability and quality of electricity service;

(f) to promote economic efficiency and sustainability in the generation, transmission, distribution and sale of electricity.

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The four key scenarios


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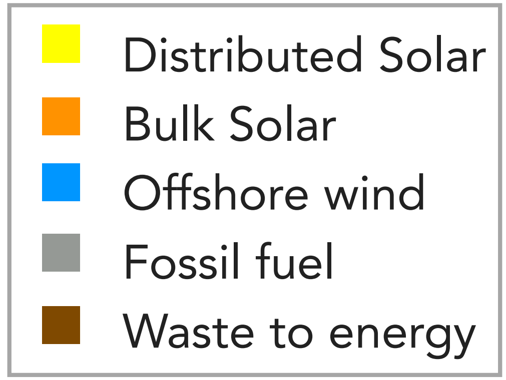
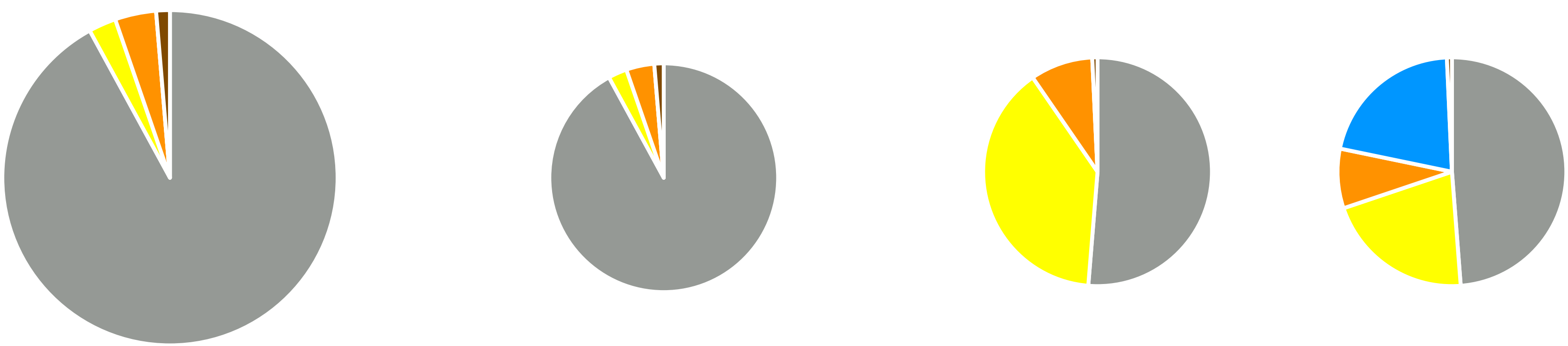
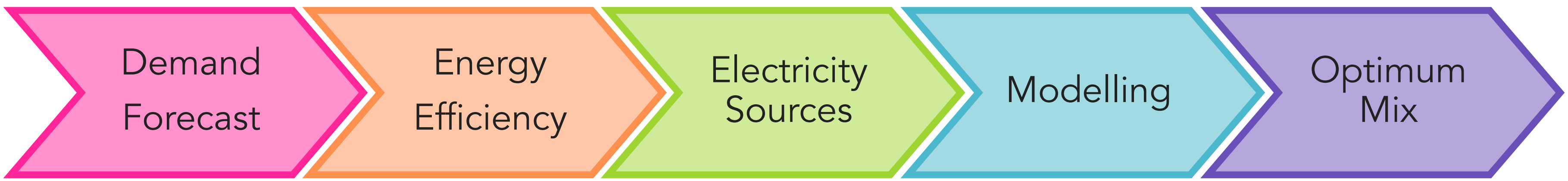


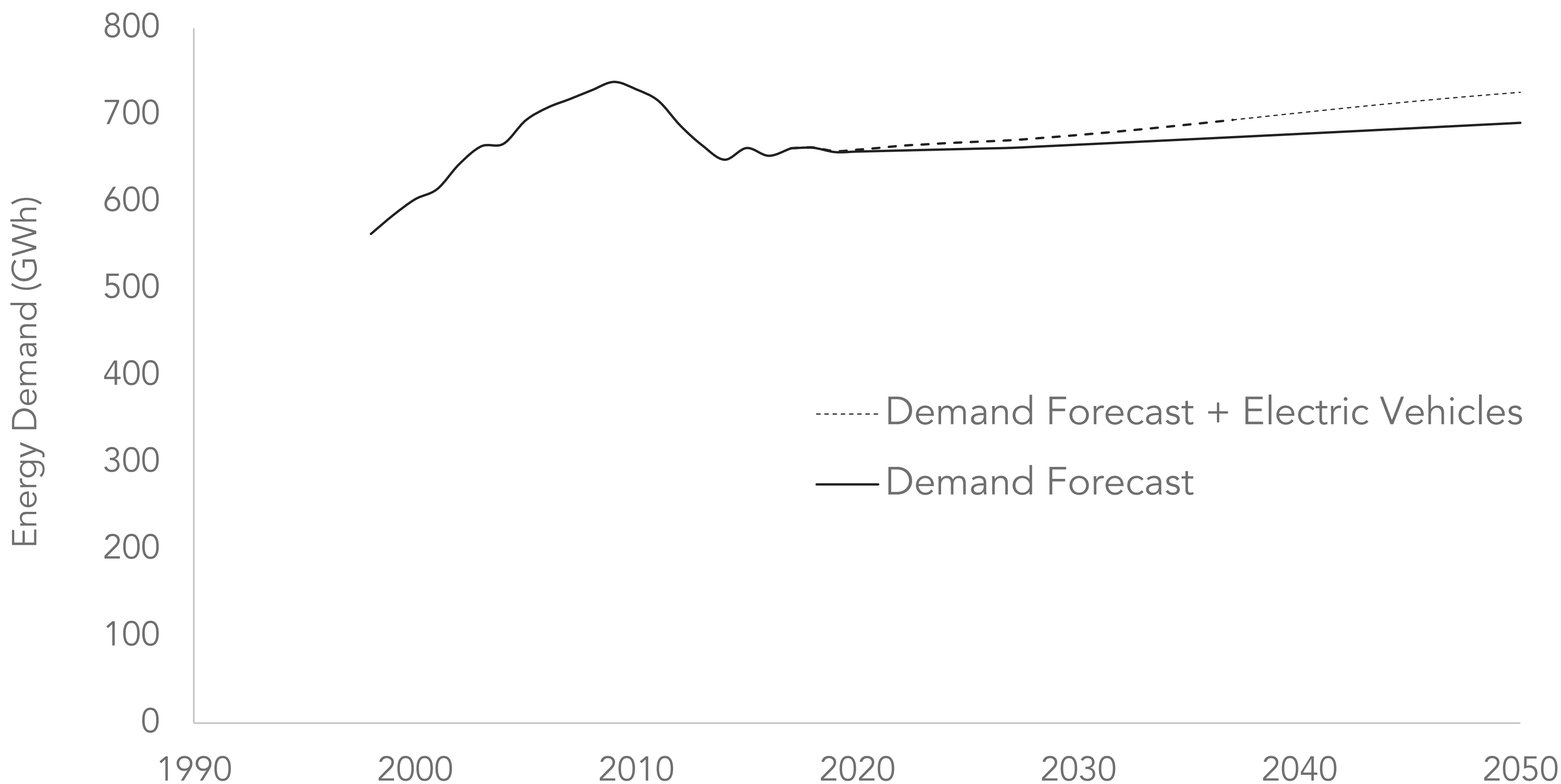


Baseline | Energy efficiency | High solar | Optimum renewable

How did we develop the plan?



Demand Forecast



© BELCO + Adjustment for electric vehicles

Improving energy efficiency

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Example for residential sector

Appliances and equipment
Improvement in products

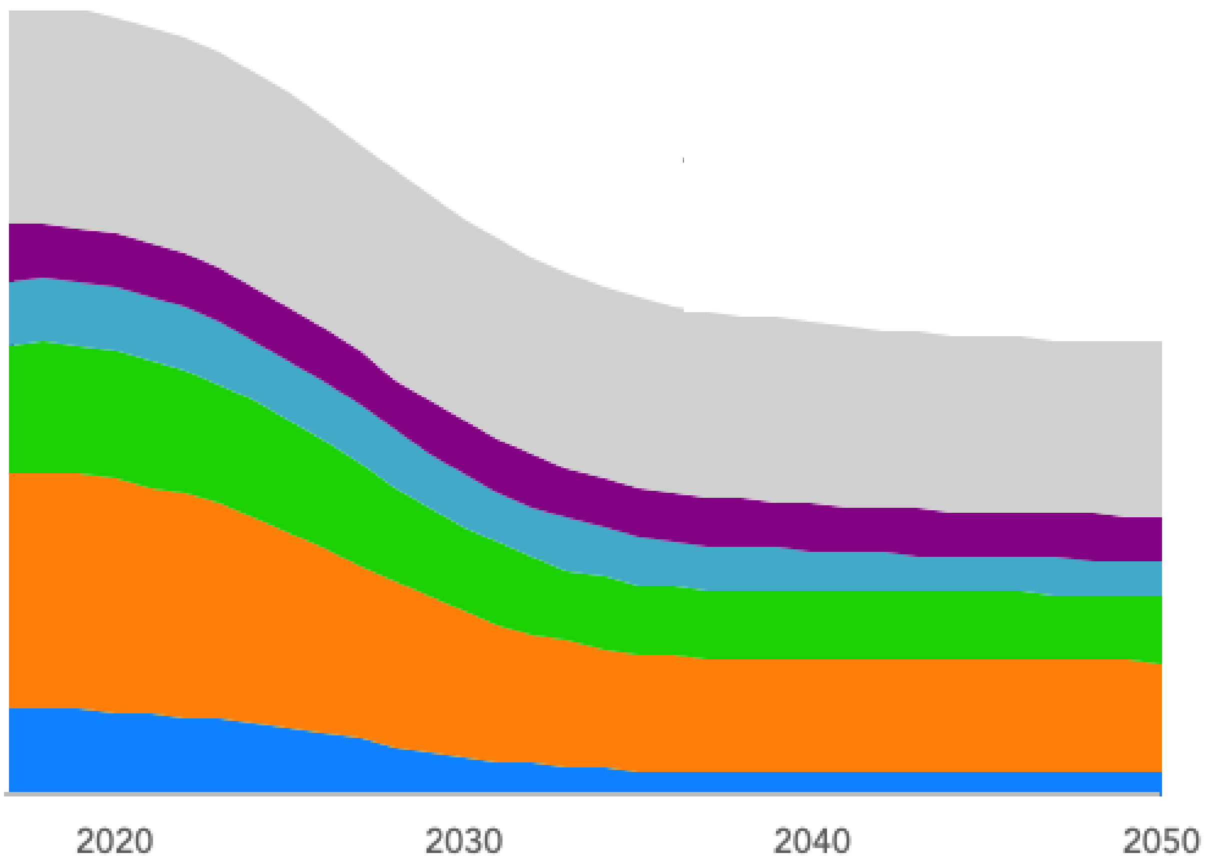
Pumps and fans
More efficient motors

Refrigeration
Better fridges and freezers

Water heating
Solar hot water or water heat pumps

Building fabric
Better roofs and walls
Better windows

Cooling
More efficient split units



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Demand Forecast + Energy Efficiency

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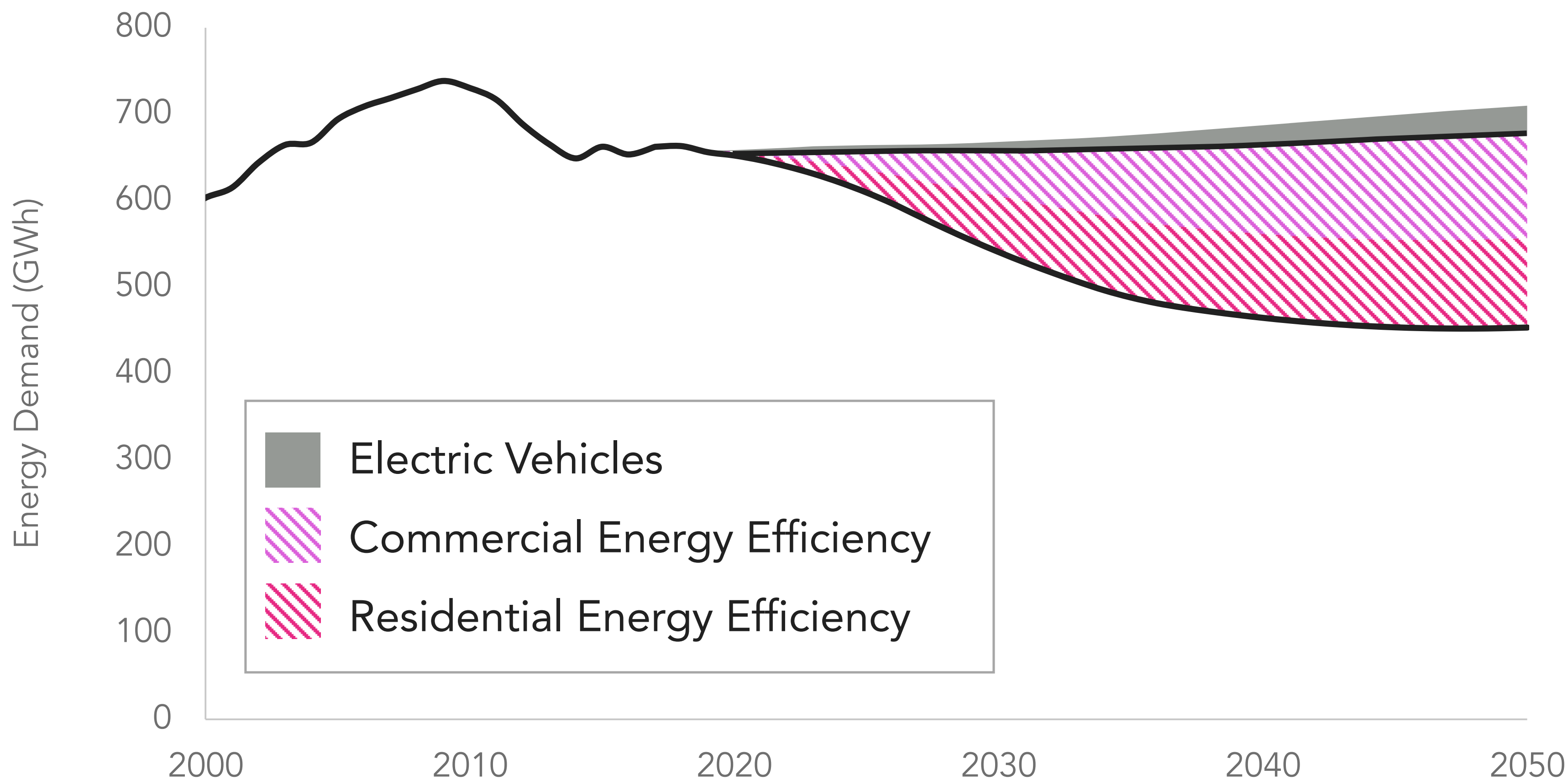

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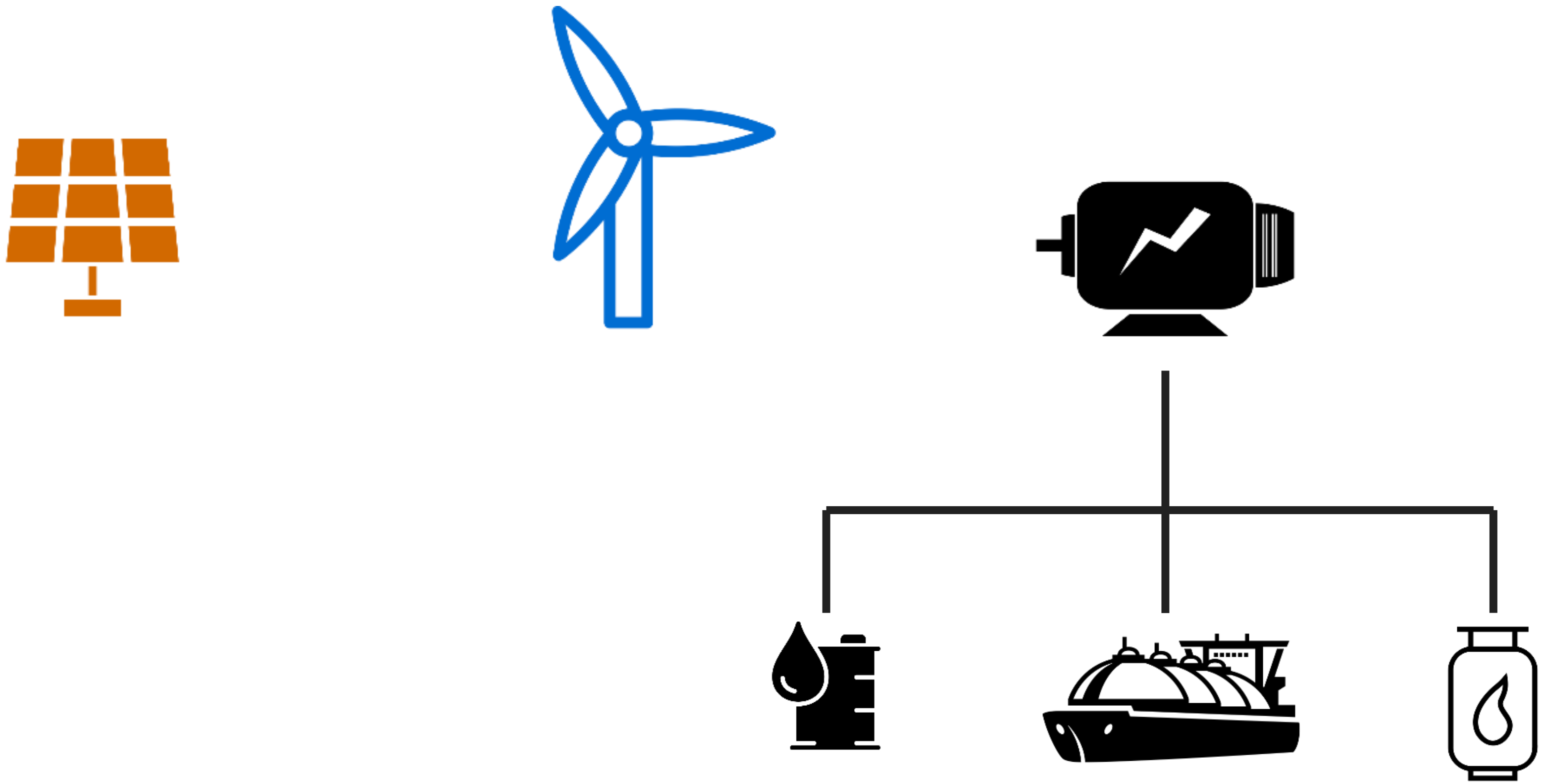
Key generation resources



Solar

- ✓ Excellent solar resource
- ✓ 8% building footprint = 60MW
- ✓ Utility scale = 24MW
- ✓ Lifespan: 25-30 years
- ✓ Reliable, mature technology

Solar: Why not more?

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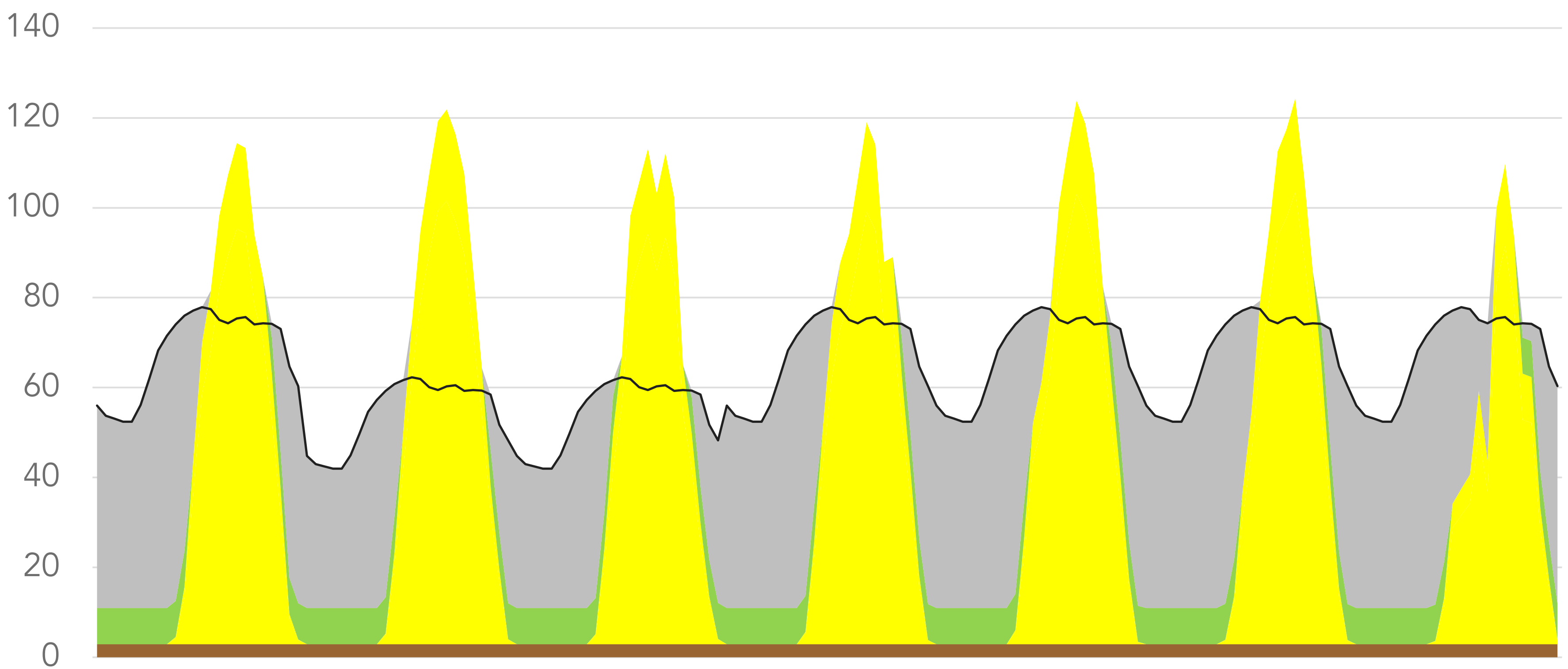
This is what would happen with 140MW (vs 84MW)



© Etude – Solar July 01-07

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Offshore wind turbines

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- ✓ Excellent wind resource

  (BELCO, UCSB and Etude analyses)
- ✓ Power: 6-12MW each
- ✓ Lifespan: 25-30 years
- ✓ Max wind: 156 mph
- ✓ Reliable, mature technology

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Offshore wind

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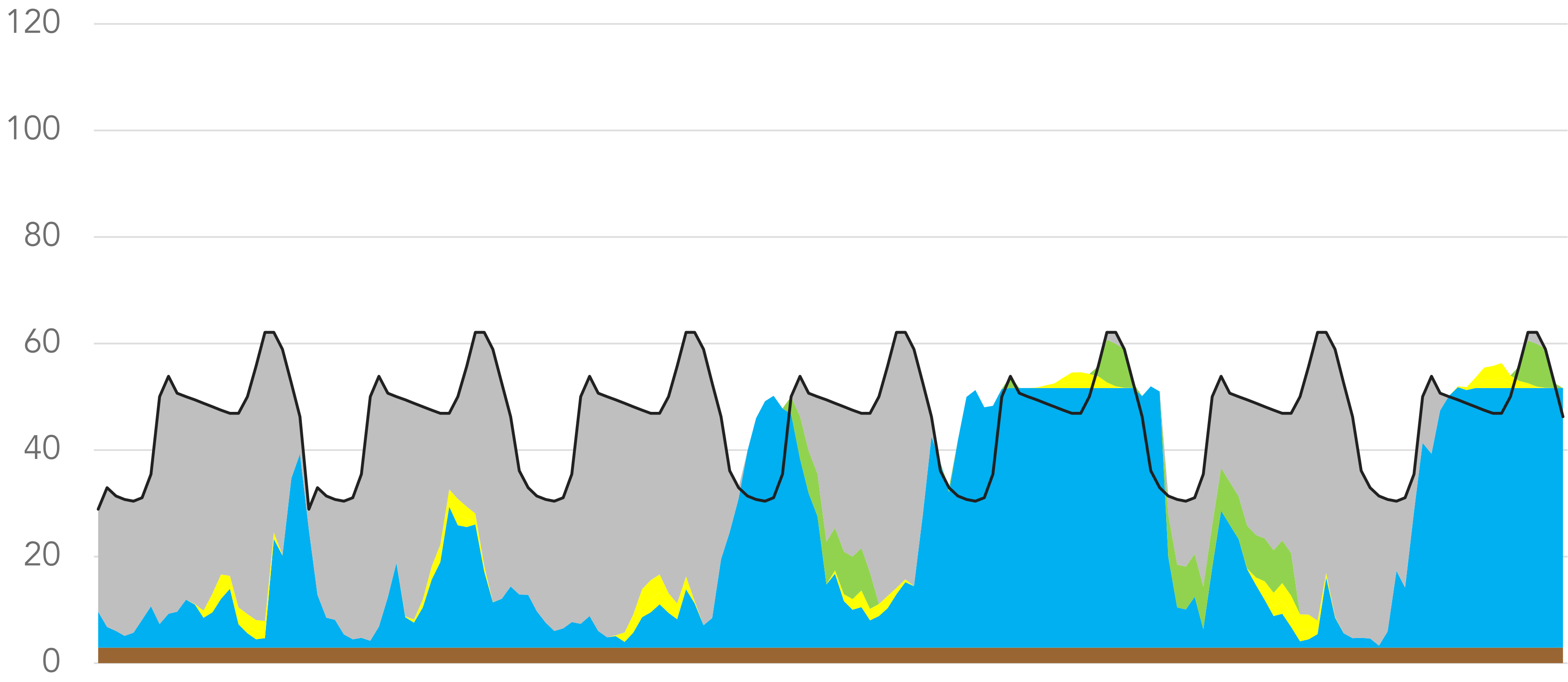
Assuming 10 x 6MW wind turbines



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Fossil fuels

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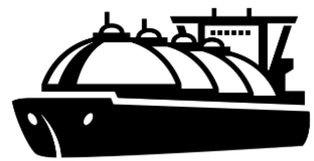
Fuel Oil

- ✓ Flexible generation
- ✓ Existing technology
- ✘ Air pollution
- ✘ Expensive
- ✘ Volatile costs
- ✘ Carbon emissions

LNG



- ✓ Flexible generation
- ✓ Cleaner burning
- ✘ LNG terminal
- ✘ LNG ship
- ✘ Volatile costs
- ✘ Carbon emissions
- ✘ Fracking

LPG

- ✓ Flexible generation
- ✓ Cleaner burning
- ✓ Flexible supply
- ✘ Volatile costs
- ✘ Carbon emissions

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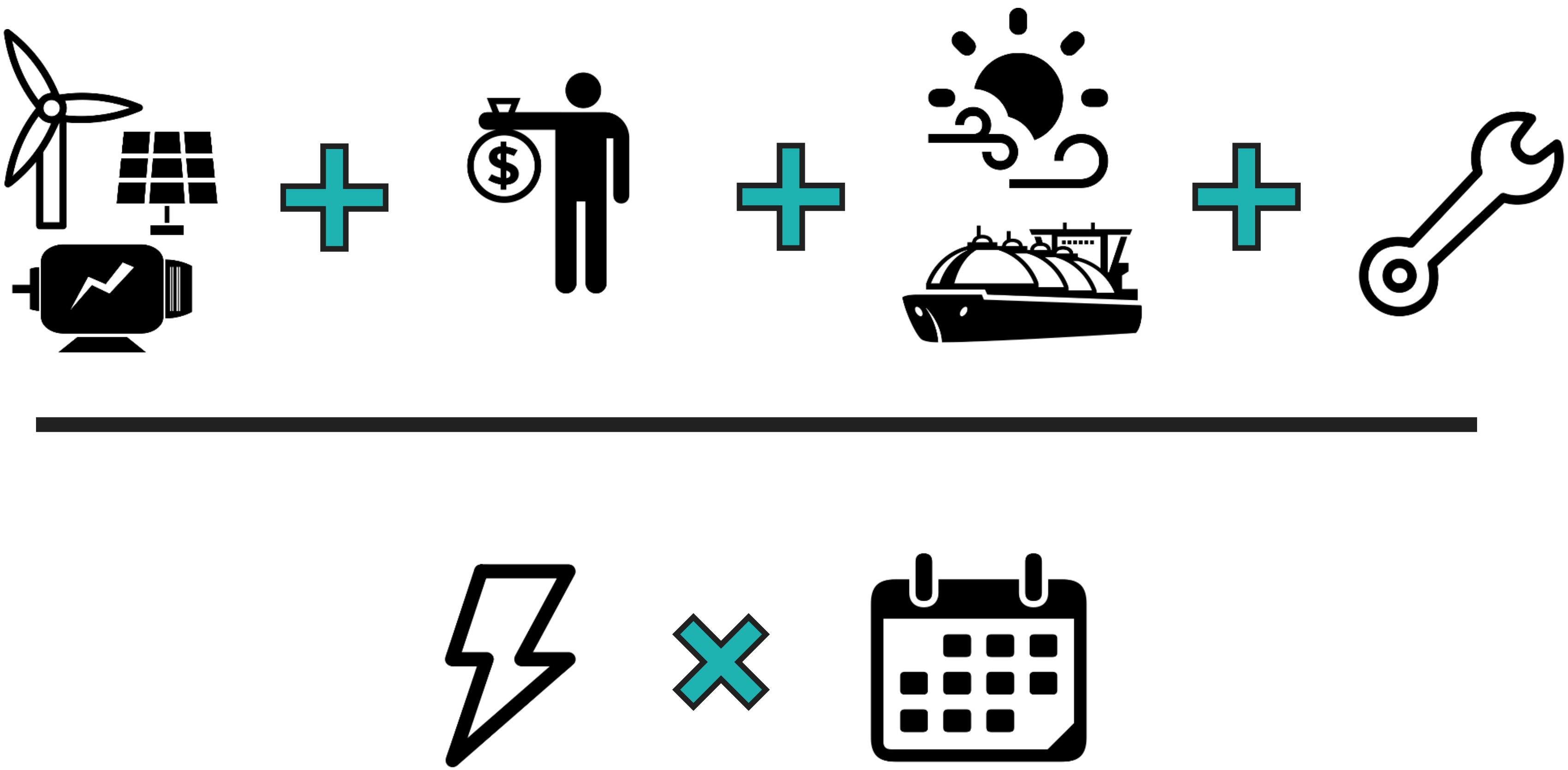
Calculating future electricity costs



Assumptions for cost calculations

Offshore Wind

- Capital Cost
- WACC
- Lifetime
- O&M Costs
- Capacity Factor (annual energy gener…
- Losses

Solar Photovoltaics

- Capital Cost
- WACC
- Lifetime
- O&M Costs
- Capacity Factor (annual energy generation)
- Degradation

Fuel Oil

- Capital Cost
- WACC
- Lifetime
- O&M Costs
- Capacity Factor (annual energy gener…
- Total Fuel Cost: Consisting of:
- 1. Commodity Price
- 2. Through-put
- 3. Freight and supply
- 7. UNESCO Tax
- 6. Customs Duty
- Efficiency

Liquified Natural Gas

	TD&R licensee IRP	Etude Low Case	Etude High Case
Capital Cost	Not specifically stated. Assumed to be $2,737	$2,737 Based on TD&R licenses's IRP Appendix II.D4	
WACC	8% Based on TD&R licenses's IRP		
Lifetime	30 years Based on TD&R licenses's IRP		
O&M Costs	36.16 per kw fixed 6.30 per MWh variable Based on TD&R licenses's IRP for new engines in North Power Station		
Capacity Factor (annual energy generation)	Not specifically stated. Assumed to be 65.7%	65.7% Based on dispatch modelling for Etude baseline scenario	25% Based on initial dispatch modelling for Etude optimum renewables scenario.
Total Fuel Cost: Consisting of:	$17.56 / mmBtu	$17.65 / mmBtu	$20.24 / mmBtu
1. Commodity Price	$4.37 / mmBtu Based on EIA AEO 2017: High Oil Case or LNG High Resource Case for 2022	$3.97 / mmBtu Based on EIA AEO 2018: Low Oil Case for 2022	$5.84 / mmBtu Based on EIA AEO 2018: Low Oil & Gas Resource & Technology for 2022
2. Liquifaction	$6.22 / mmBtu Includes 'margin'. + $0.37 Listed as 'commodity adder'	$3.00 / mmBtu Based on Oxford Institute for Energy Studies[49]	$3.50 / mmBtu Based on Wartsila[50] and McKinsey
3. Shipping		$1.85 / mmBtu Based on Wartsila paper on LNG for small tropical locations	$0.60 / mmBtu Based on Oxford Institute for Energy Studies. Conservative figure as this scenario assumes Bermuda invests $75M in its own ship.
4. Terminal Capital Costs	$1.93 / mmBtu Based on $117M facility CAPEX	$2.30 / mmBtu Based on $117M facility CAPEX from TD&R licensee's IRP. Accounts for reduced energy demand in Etude energy efficiency scenario	$3.77 / mmBtu Based on $117M facility CAPEX from TD&R licensee's IRP and $75M ship from Castalia study[51]. Accounts for reduced energy demand in Etude energy efficiency scenario
5. Terminal OPEX	$0.55 / mmBtu	$1.05 / mmBtu	$1.57 / mmBtu
7. UNESCO Tax	$0.11 / mmBtu Based on TD&R licensee's IRP		
6. Customs Duty	$5.37 / mmBtu Normalised to maintain government revenue neutrality. Based on TD&R licensee's IRP.		
Efficiency	34% Based on TD&R licenses's IRP		

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Cost comparison

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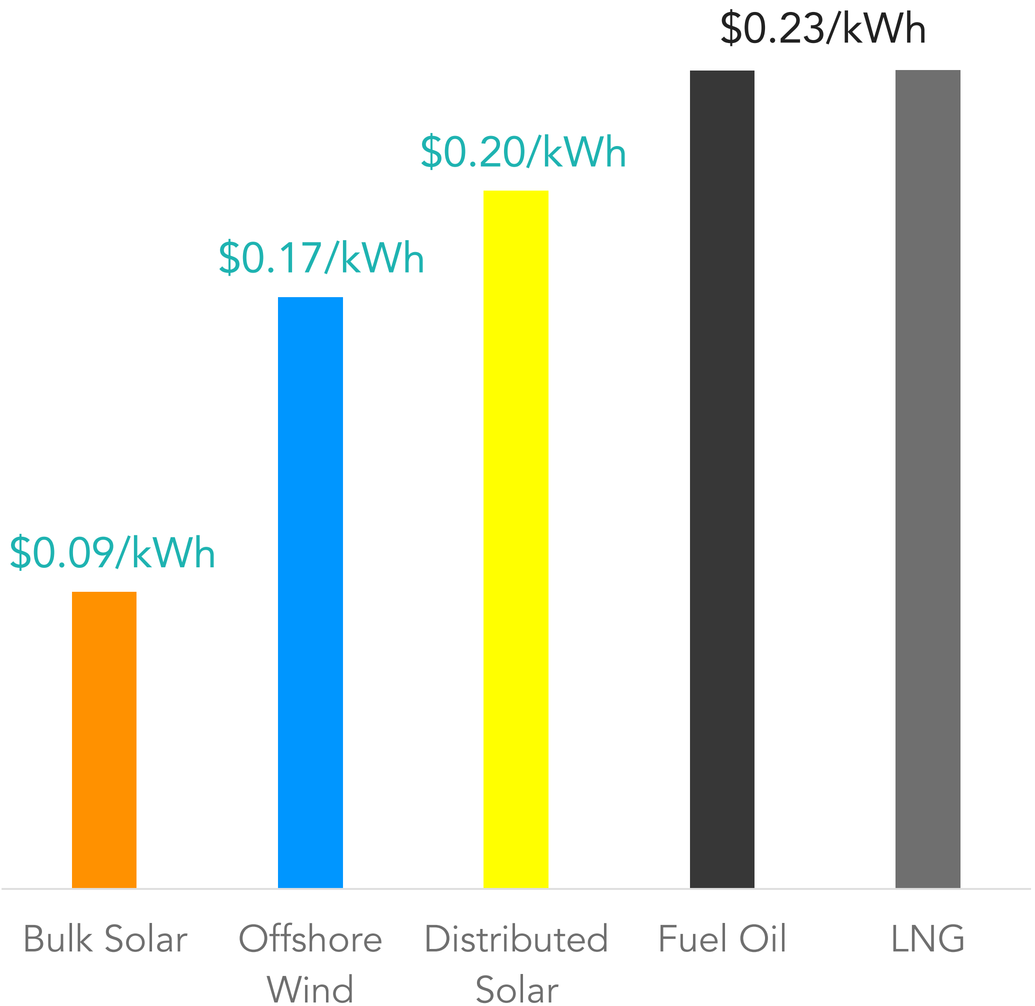

© Etude – Levelized Energy Cost Calculation Results

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How did we assess environmental impact?

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nature energy

ARTICLES

https://doi.org/10.1038/s41560-017-0032-9

Understanding future emissions from low-carbon power systems by integration of life-cycle assessment and integrated energy modelling

Michaja Pehl[1*], Anders Arvesen[2], Florian Humpenöder[1], Alexander Popp[1], Edgar G. Hertwich[3] and Gunnar Luderer[1*]

Both fossil-fuel and non-fossil-fuel power technologies induce life-cycle greenhouse gas emissions, mainly due to their embodied energy requirements for construction and operation, and upstream CH_4 emissions. Here, we integrate prospective life-cycle assessment with global integrated energy–economy–land-use–climate modelling to explore life-cycle emissions of future low-carbon power supply systems and implications for technology choice. Future per-unit life-cycle emissions differ substantially across technologies. For a climate protection scenario, we project life-cycle emissions from fossil fuel carbon capture and sequestration plants of 78–110 $gCO_2eq\ kWh^{-1}$, compared with 3.5–12 $gCO_2eq\ kWh^{-1}$ for nuclear, wind and solar power for 2050. Life-cycle emissions from hydropower and bioenergy are substantial (~100 $gCO_2eq\ kWh^{-1}$), but highly uncertain. We find that cumulative emissions attributable to upscaling low-carbon power other than hydropower are small compared with direct sectoral fossil fuel emissions and the total carbon budget. Fully considering life-cycle greenhouse gas emissions has only modest effects on the scale and structure of power production in cost-optimal mitigation scenarios.

The Paris Agreement of COP21 confirmed the goal of limiting global temperature increase well below 2 °C and acknowledged the need to achieve net greenhouse gas neutrality during the second half of the century[1]. Previous research based on integrated energy–economy–climate models has shown that achieving these targets cost-effectively requires a rapid, almost full-scale decarbonization of the electricity system by mid-century[2,3]. In electricity production, ample low-carbon alternatives are available[4] and electricity is a potential substitute for fossil-based fuels in all economic sectors, which leads to final energy electricity shares of 25–45% in stringent mitigation scenarios[2].

The life-cycle assessment (LCA) literature illustrates that all energy transformation technologies are associated with upstream energy demands and corresponding indirect (that is, not caused by fuel-burning on site) greenhouse gas (GHG) emissions[4–7]. Concerns have been voiced that these can impair the emission reduction potential of low-carbon technologies[6,8,9]. However, LCA studies of electricity mostly focus on impacts on a per-kilowatt-hour basis in static settings, typically neglecting technology improvements in electricity generation technologies, as well as the effects of concurrent decarbonization measures in other sectors of the energy system and the economy[6,10,11].

Integrated energy–economy–climate modelling approaches estimate cost-optimal long-term strategies to meet the emissions constraints implied by climate targets[3]. Whereas direct combustion emissions as well as CH_4 from fossil fuel extraction and indirect land-use change emissions are accounted for by many state-of-the-art modelling systems, other indirect emissions, in particular those related to energy required for the construction of power plants and the production and transportation of fuels and other inputs (defined here as embodied energy use, EEU), are not considered in the optimization. We investigate to what extent this omission leads to incomplete internalization of externalities.

A previous study by Hertwich et al.[5] used prospective LCA to compare similar scenarios in terms of environmental impacts, but relied on exogenous scenarios for technology deployment, and focused on non-climate environmental impacts to assess co-benefits and trade-offs of climate change mitigation. Daly et al.[9] and Scott et al.[12] investigated the influence of national climate policy on domestic and non-domestic indirect GHG emissions and found them to have a large potential for carbon leakage, as the ratio of emissions caused domestically and overseas shifts to the latter due to imports of goods and services. However, their analysis considered only the United Kingdom, based carbon intensities on aggregate input–output relationships rather than process detail, and did not account for policy-induced non-domestic emission reductions in the context of coordinated international climate change mitigation efforts. Portugal-Pereira et al.[13] included LCA emission coefficients in an integrated assessment model (IAM) and studied the effect of taxing indirect emissions on the electricity mix. However, they considered only the Brazilian electricity system and used static LCA coefficients.

In this study, we present consistent and detailed modelling of EEU and indirect GHG emissions for global scenarios of future electricity systems. By linking an IAM with EEU coefficients from a prospective LCA model, we can provide a holistic and detailed perspective on future life-cycle greenhouse gas emissions of low-carbon technologies and power systems in the context of a universal climate change mitigation regime, thus closing an important research gap[14–16] by quantifying these emissions and their effect on the choice of low-carbon technologies in mitigation scenarios. This study combines results from the REMIND model[17,18], which details energy use and

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http://dx.doi.org/10.1016/j.wasman.2016.02.010
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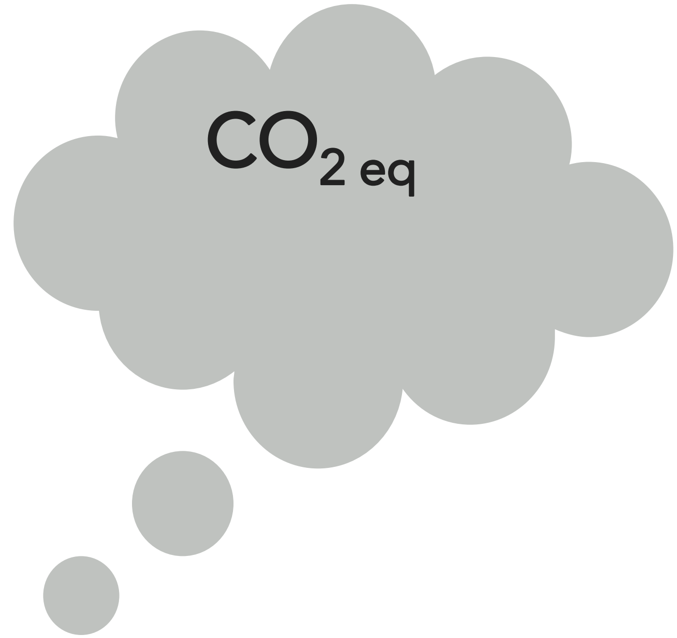

NO_x SO_x particulates…

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Environmental comparison

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Waste to energy	Oil	Liquefied natural gas	Solar	Offshore wind
1000 gCO_{2eq}/kWh	900 gCO_{2eq}/kWh	600 gCO_{2eq}/kWh	35 gCO_{2eq}/kWh	8 gCO_{2eq}/kWh

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Modelling

Integrating intermittent energy

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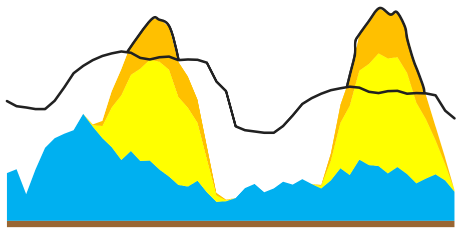
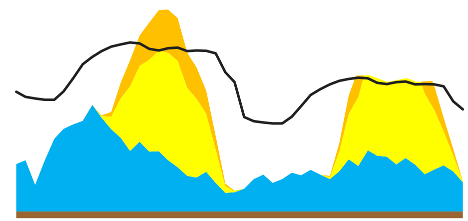
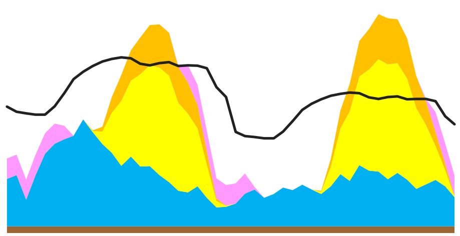


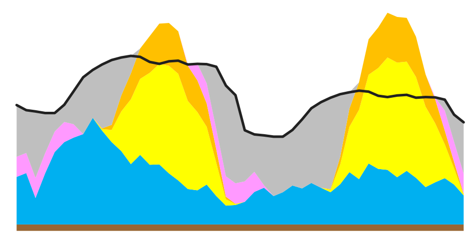
Demand response



Curtailment



Battery storage



Fossil fuel

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Putting it all together

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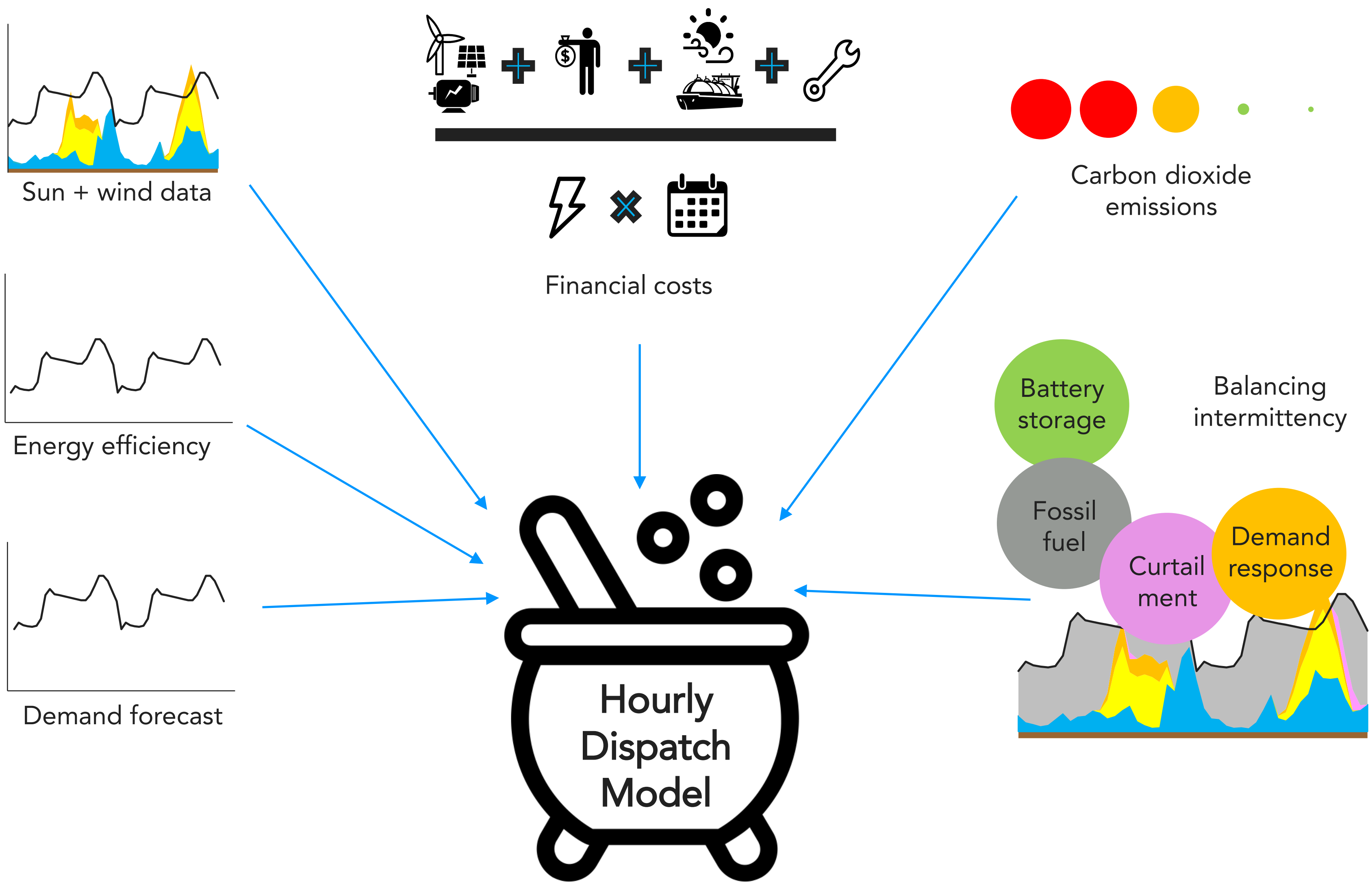

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How it will work together - January

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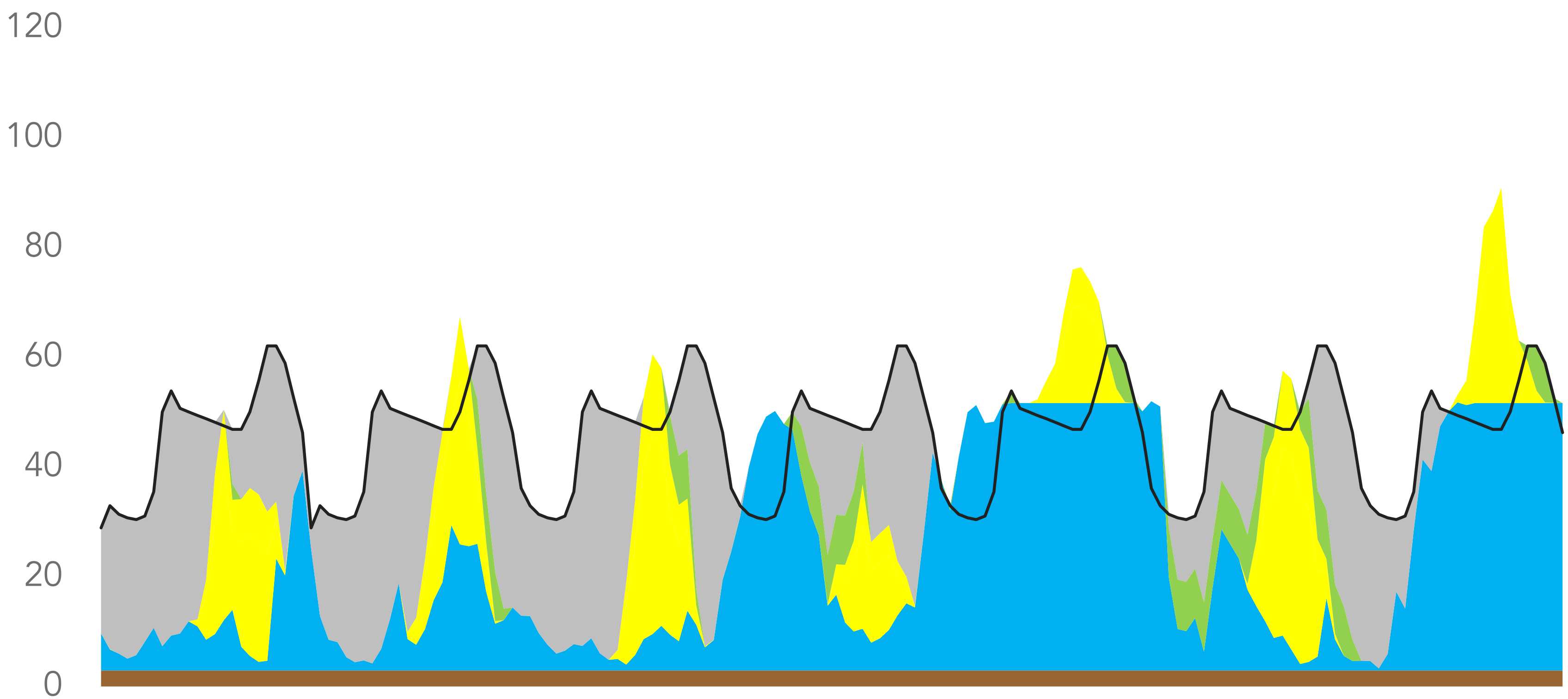

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How it will work together - July

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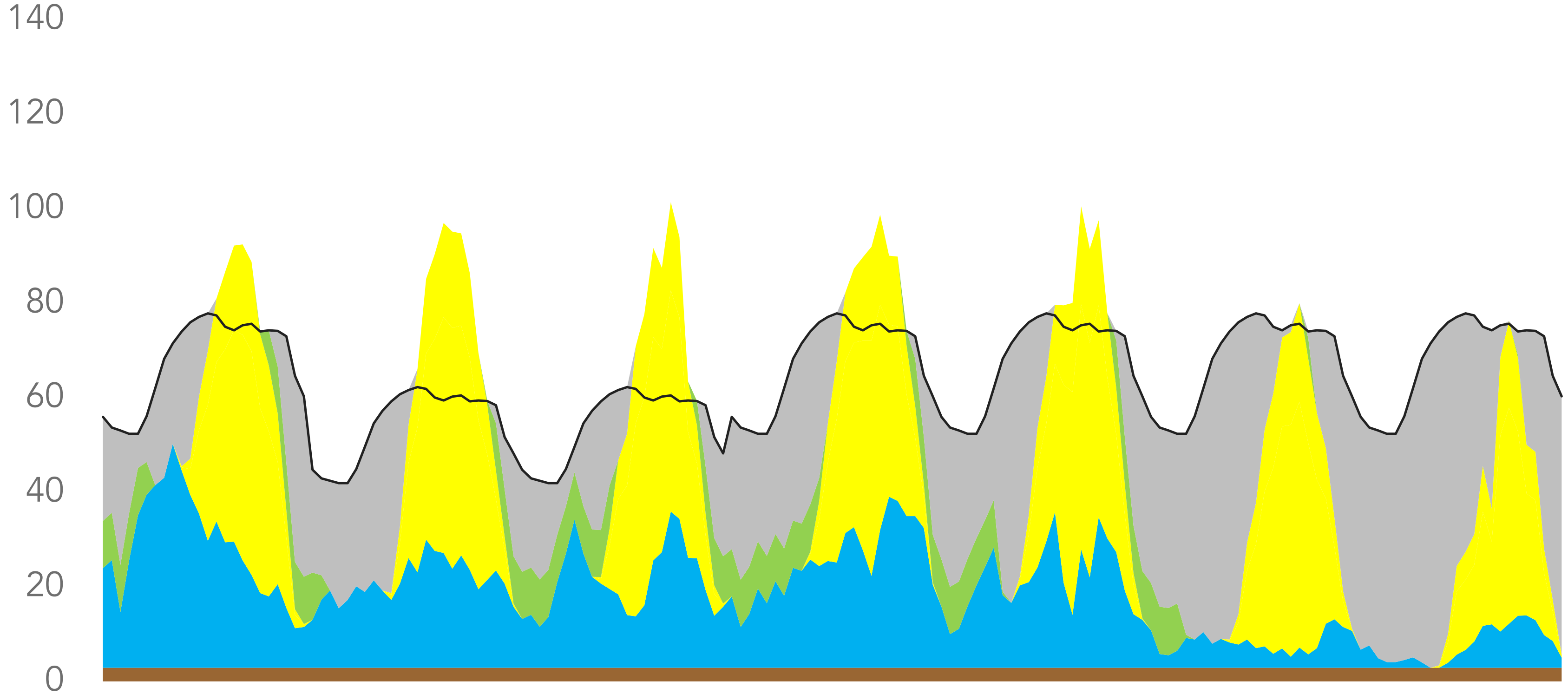

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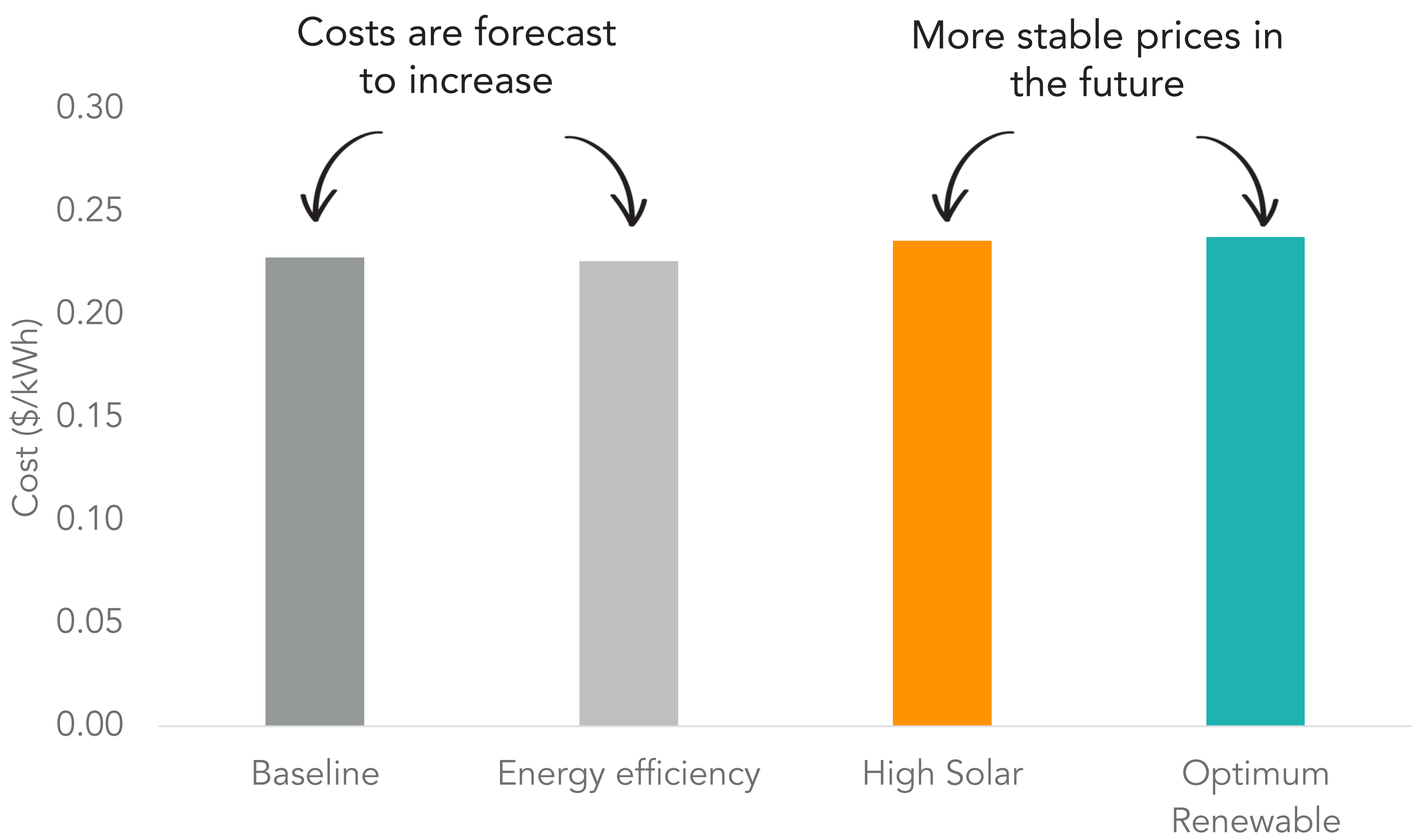
Results

Minimising cost risks (LCOE in 2022)



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Large reduction in carbon emissions

Current	Baseline	Energy efficiency	High Solar	Optimum Renewable
886 gCO_2/kWh	610 gCO_2/kWh	610 gCO_2/kWh	420 gCO_2/kWh	341 gCO_2/kWh

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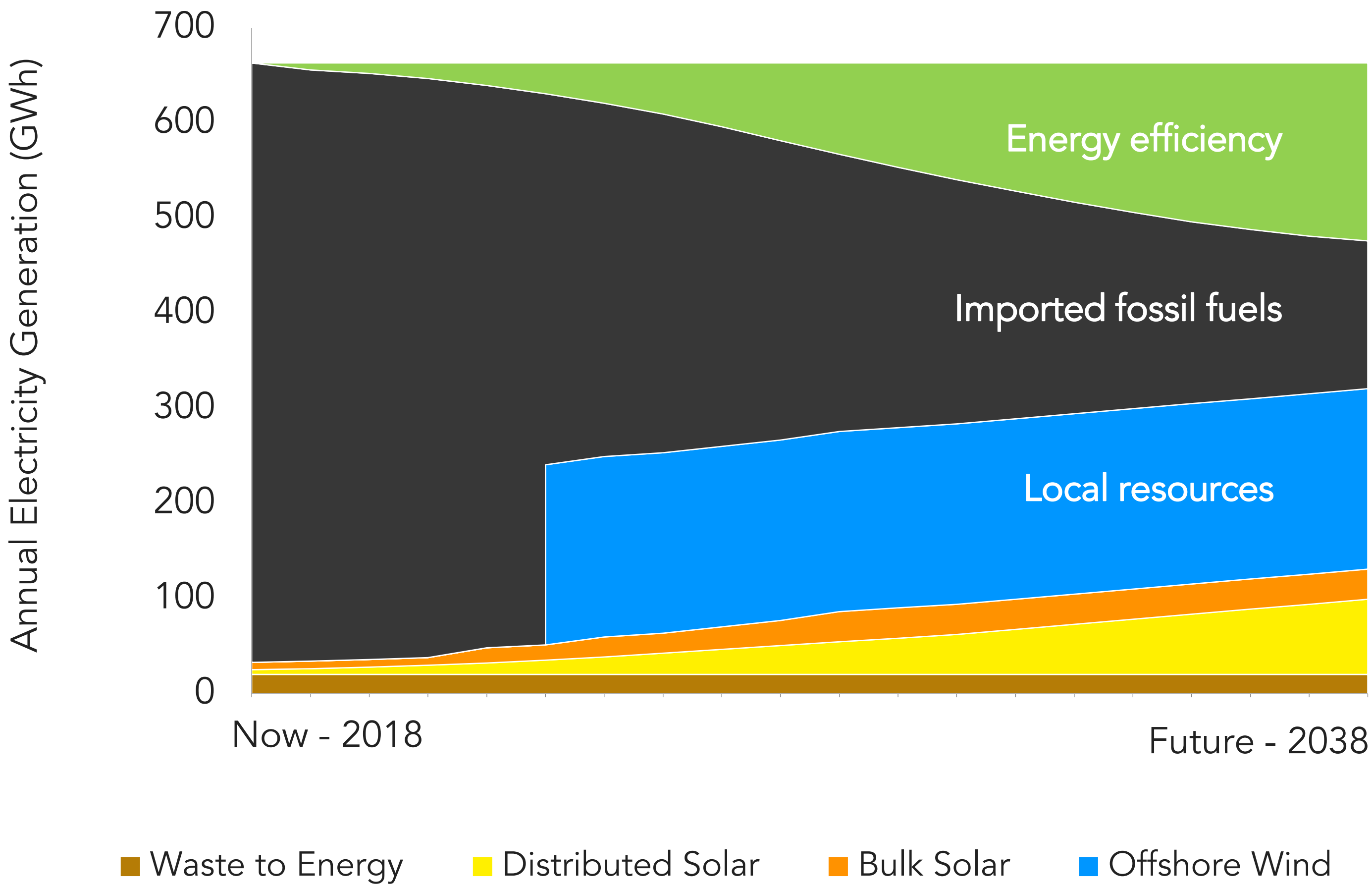
Our recommendation

Bermuda Better Energy Plan

The plan

Bermuda
Better Energy
Plan



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Compliance with Electricity Act

The table below summarises how this alternative proposal complies with the requirements of the Electricity Act and the Guidelines.

No.	Requirement	Check
1	Demonstration of how its inclusion would result in an electricity supply that is more consistent with the purposes of the Electricity Act and Ministerial directions	✓
2	Demonstration of the technology's commercial operation in another jurisdiction	✓
3	Data on capital, operating and fuel costs	✓
4	Assumptions on future macroeconomic performance and government policy	✓
5	Technical and operating characteristics and availability	✓ *
6	Price for input fuels and other related commodities as well as import infrastructure	✓
7	Costs related to network infrastructure upgrades (if required)	
8	Sensitivity analysis	✓

* Although assumptions are not thoroughly justified or referenced.

Headlines

- 64% of our electricity can come from renewables
- Renewable energy costs less than fossil fuels
- Bermuda can source its energy locally
- We can take action against climate change
- We can create jobs in local energy
- Our energy supply can be more resilient
- It would be better in terms of national security

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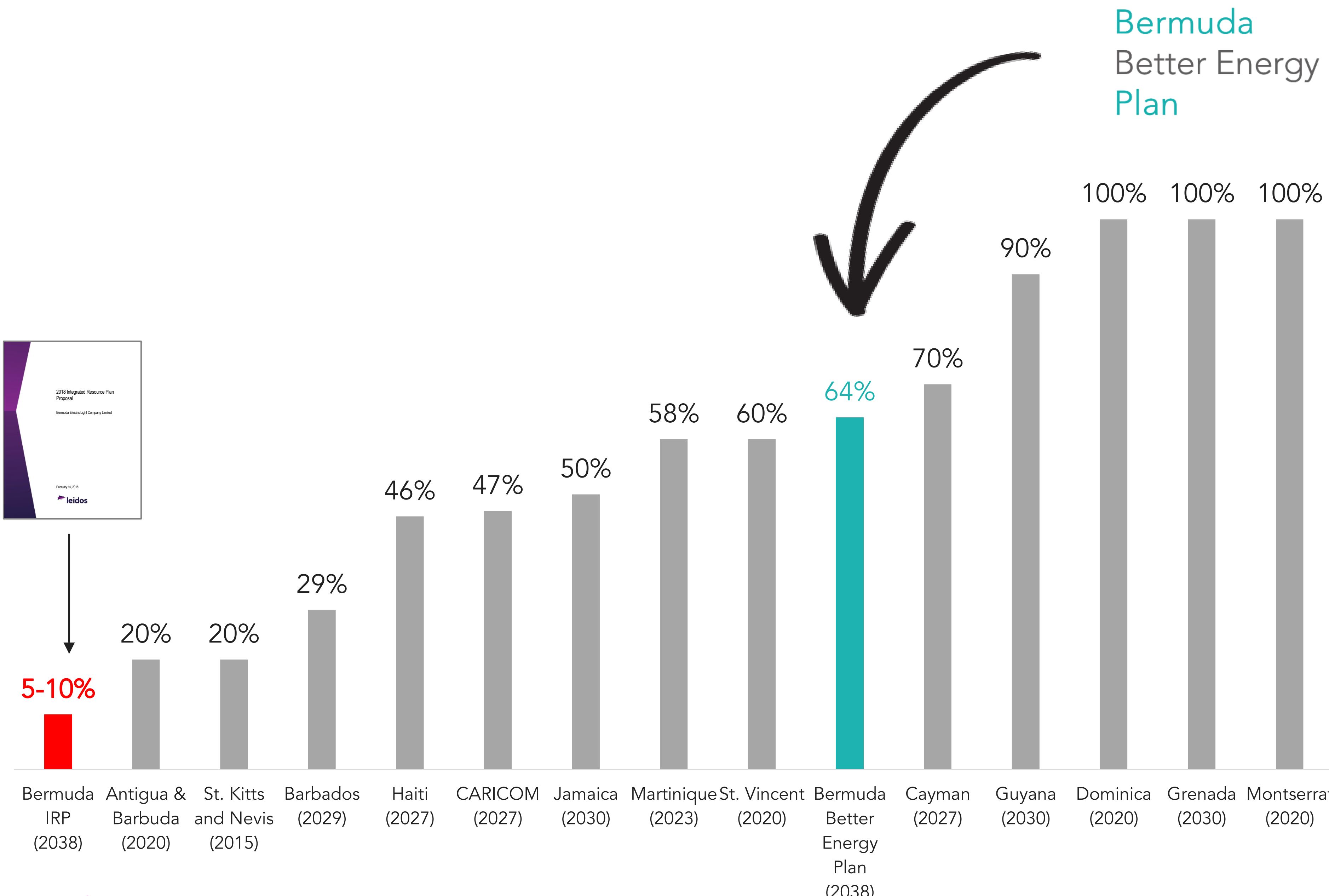

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CARICOM – Caribbean Sustainable Energy Roadmap (and others)

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INDIEGOGO

Bermuda Better Energy Plan

Support our plan to help Bermuda generate most of its electricity from renewable...

ENVIRONMENT

$9,253 USD raised 54%

16 days left

Thank you for your donation

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THANK YOU

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