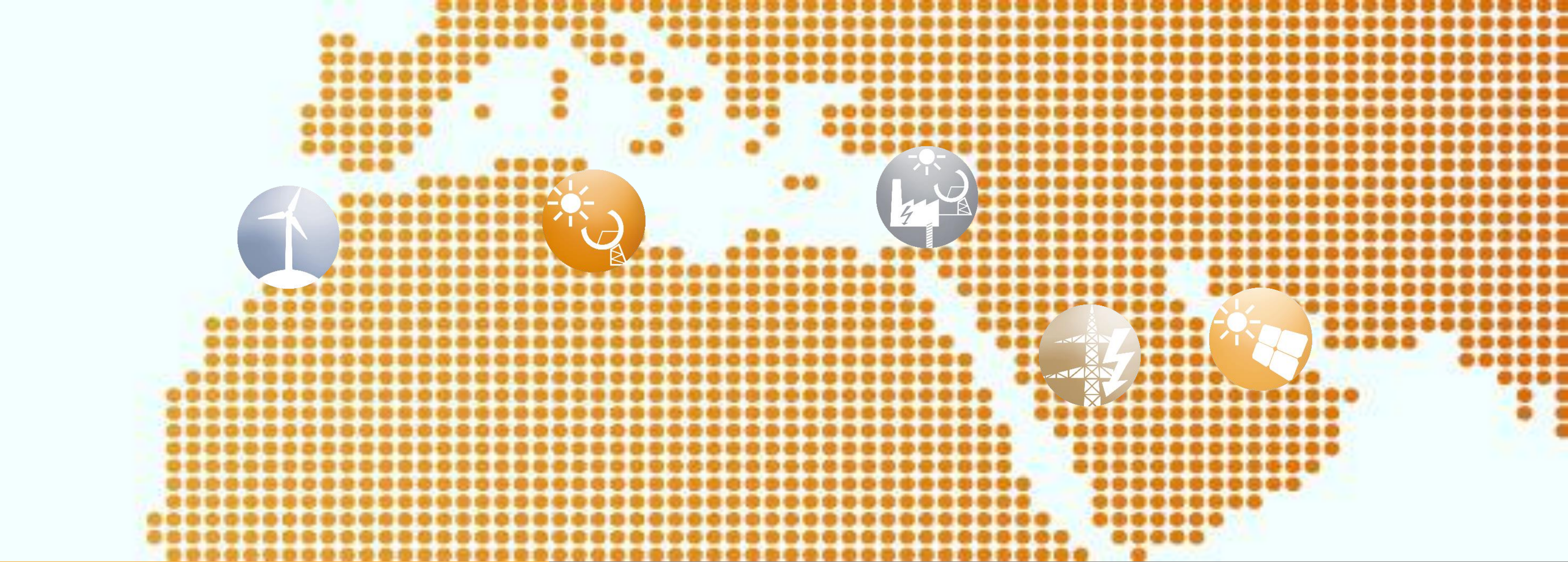

Trending! The SunBurn Test™

How to Integrate Climate Change Risks in Capital Budgeting for Solar PV Plants

Dii Desert Energy

Fadi Maalouf

CTO – Director IPP & EPC

29th Oct 2018

Disclaimer

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Outline

- SunBrun Test™: Where to Download the Technical Paper?
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- What is Capital Budgeting?
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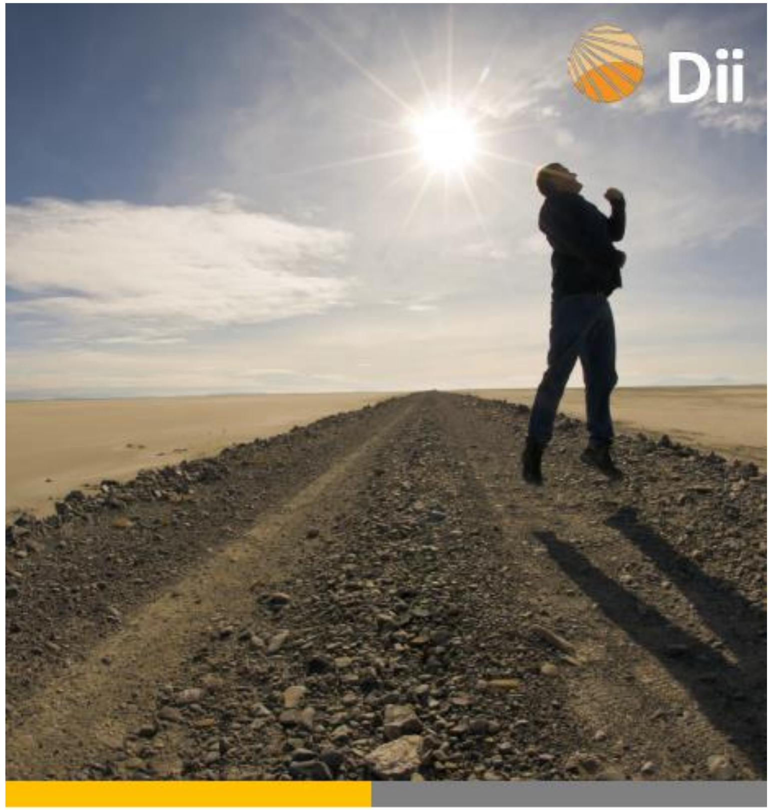
SunBurn Test™
Where to Download the Technical Paper?



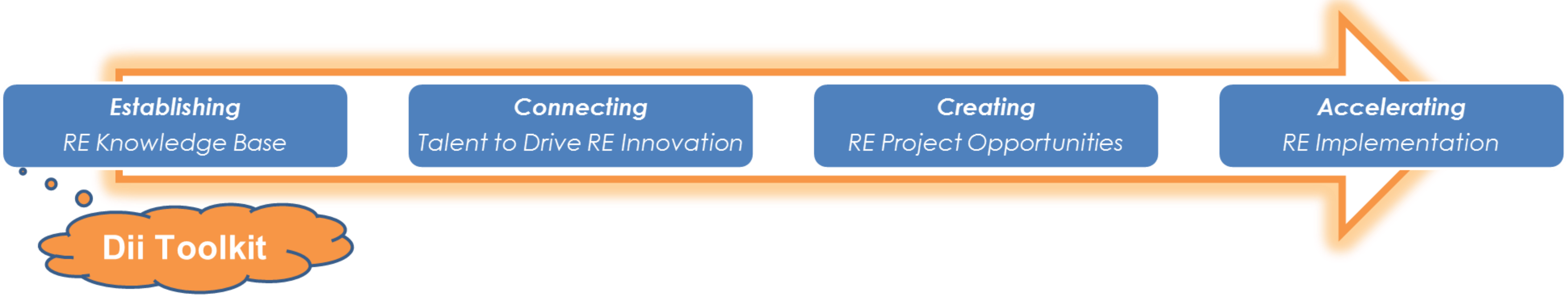
Trending! The SunBurn Test™

Integrating Climate Change in Capital Budgeting for Solar PV Plants

SlideShare.net/SolarUAE

Overview: Dii Toolkit Initiative

- **SunBurn Test™** technical paper is a publication under the Dii Toolkit Initiative
- The Dii Toolkit "Establishes RE Knowledge Base" thus enabling talent connection, opportunity creation, & therefore renewable energy implementation acceleration.
- Dii Toolkit Initiative sets a solid foundation for achieving the goal of energy independence via renewable energy, therefore accomplishing Objectives.



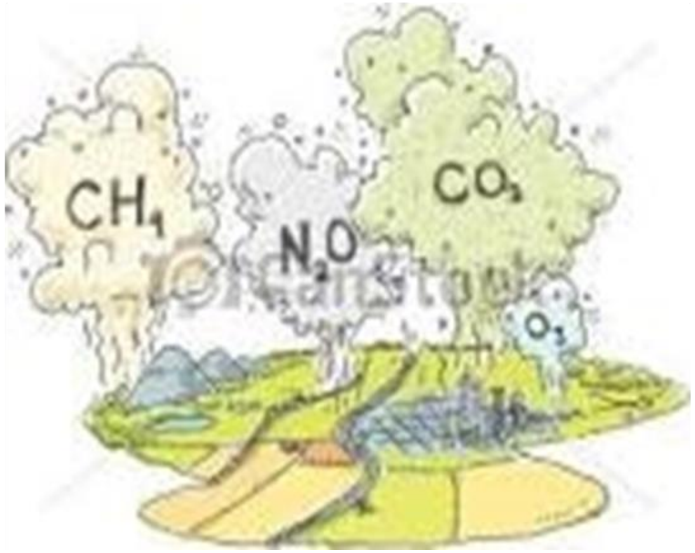
What is Climate Change?

The Basics

- Addressing the climate change impacts is a global mega trend.
- Climate change is addressed via mitigation, as well as adaptation to the “new normal”.
- Primary Cause: emissions of green house gases (GHG): carbon dioxide, nitrous oxide, methane, & others.
- Other gases and pollutants, like black carbon, lead to air pollution
- GHG result in global warming. The global average ambient temperature is rising from historical records.
- Global warming is resulting in:
  - Changing weather patterns and seasons, and extreme and adverse weather events
  - Increased frequency and severity of droughts, floods, hurricanes, heat waves, cold blizzards, etc.
  - Melting of arctic ice cover
  - Rising sea level

What is Climate Change?
The Basics

Emissions → Global Warming → Climate Change

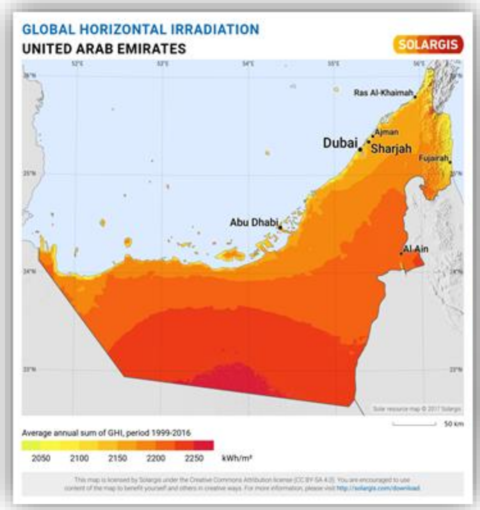


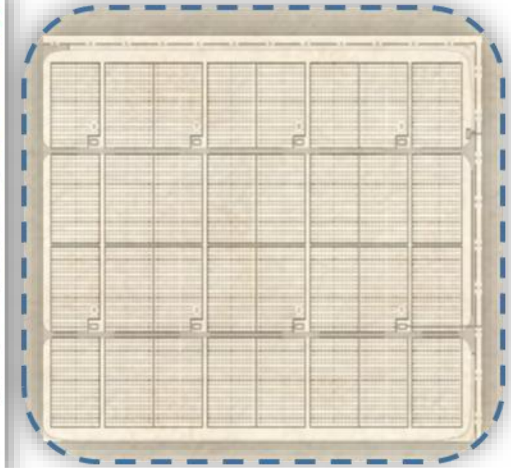
What is Capital Budgeting?
The Basics

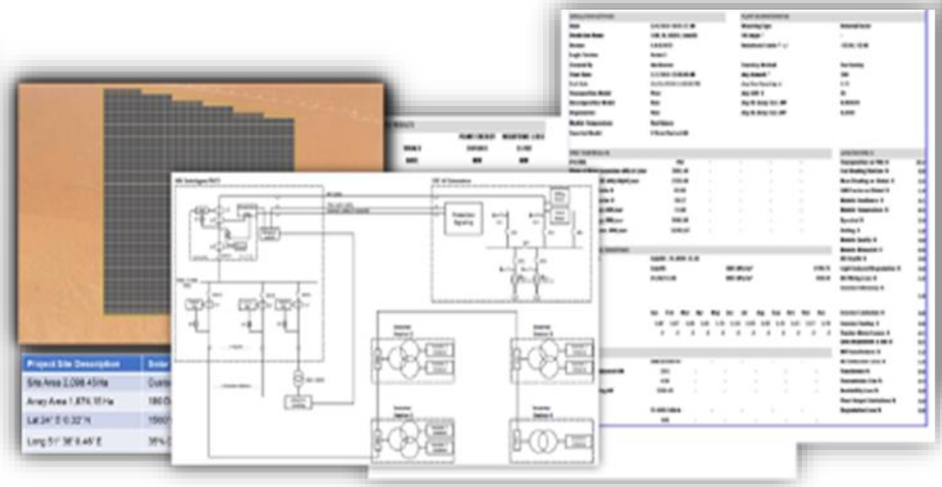
- Solar PV power plant financial feasibility is modelled based on its forecasted Levelized Cost of Electricity (LCOE).
- Such model is based on the principles of Capital Budgeting in Financial Management.
- The financial model uses various specific inputs, generates a cashflow waterfall, discounts it at an appropriate discount factor, and outputs the LCOE and other financial covenants such as Equity IRR, DSCR, PLCR, LLCR, and many others.
- Capital Budgeting for solar PV power plants is a two-step approach:
  - Technical Concept Development
  - Financial Model Development

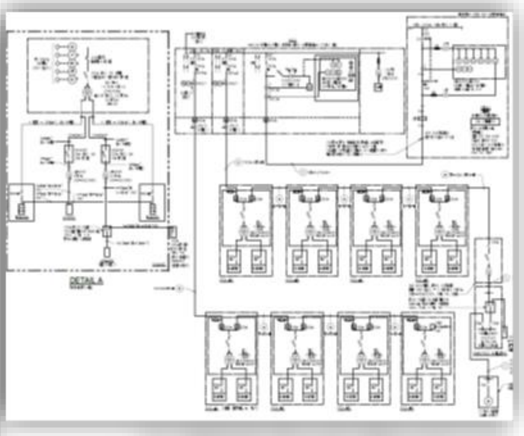
What is Capital Budgeting?
Technical Concept Development – Process Workflow

Solar Resource → Site Selection → Concept Design → Energy Yield → Interconnection Scheme



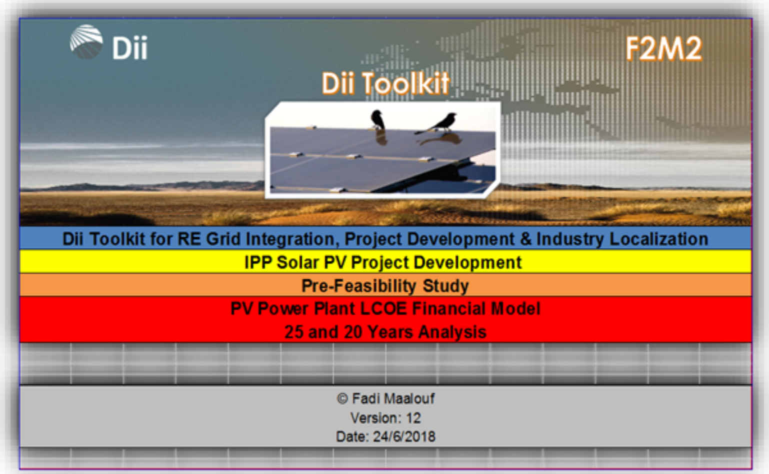


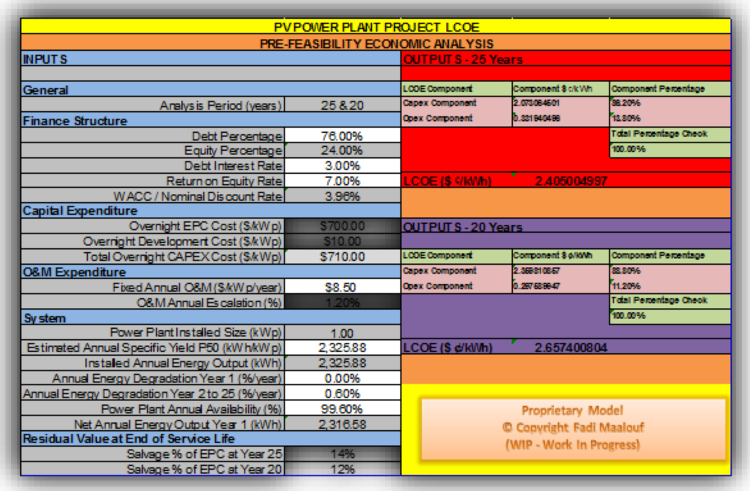




What is Capital Budgeting?
Financial Model Development – Process Workflow

Financial Model → Inputs/Output Summary → Sensitivity & Scenario Analysis





PV POWER PLANT PROJECT LCOE
PRE-FEASIBILITY ECONOMIC ANALYSIS

INPUTS	
General	
Analysis Period (years)	25 & 20
Finance Structure	
Debt Percentage	76.00%
Equity Percentage	24.00%
Debt Interest Rate	3.00%
Return on Equity Rate	7.00%
WACC / Nominal Discount Rate	3.96%
Capital Expenditure	
Overnight EPC Cost ($/kWp)	$700.00
Overnight Development Cost ($/kWp)	$10.00
Total Overnight CAPEX Cost ($/kWp)	$710.00
O&M Expenditure	
Fixed Annual O&M ($/kWp/year)	$8.50
O&M Annual Escalation (%)	1.20%
System	
Power Plant Installed Size (kWp)	1.00
Estimated Annual Specific Yield P50 (kWh/kWp)	2,325.88
Installed Annual Energy Output (kWh)	2,325.88
Annual Energy Degradation Year 1 (%/year)	0.00%
Annual Energy Degradation Year 2 to 25 (%/year)	0.60%
Power Plant Annual Availability (%)	99.60%
Net Annual Energy Output Year 1 (kWh)	2,316.58
Residual Value at End of Service Life	
Salvage % of EPC at Year 25	14%
Salvage % of EPC at Year 20	12%

OUTPUTS - 25 Years

LCOE Component	Component $ c/kWh	Component Percentage
Capex Component	2.073084501	86.20%
Opex Component	0.331940496	13.80%
		Total Percentage Check
		100.00%
LCOE ($ ¢/kWh)	2.405004997	

OUTPUTS - 20 Years

LCOE Component	Component $ ¢/kWh	Component Percentage
Capex Component	2.359810857	88.80%
Opex Component	0.297589947	11.20%
		Total Percentage Check
		100.00%
LCOE ($ ¢/kWh)	2.657400804	

Proprietary Model
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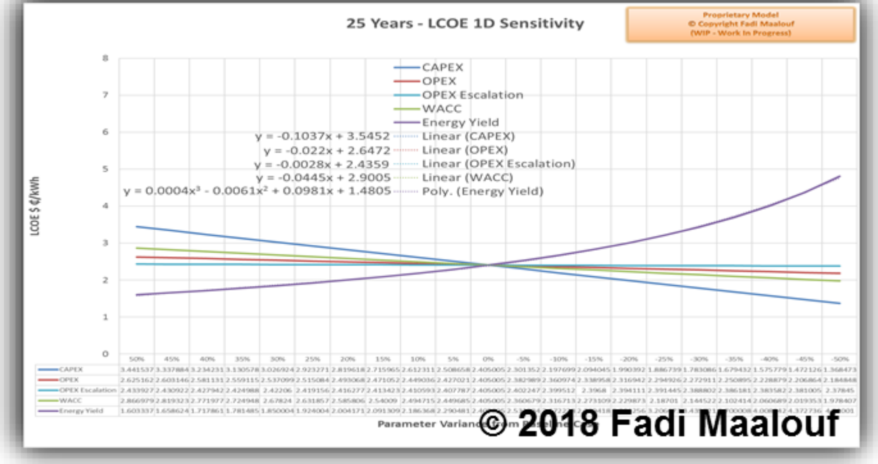
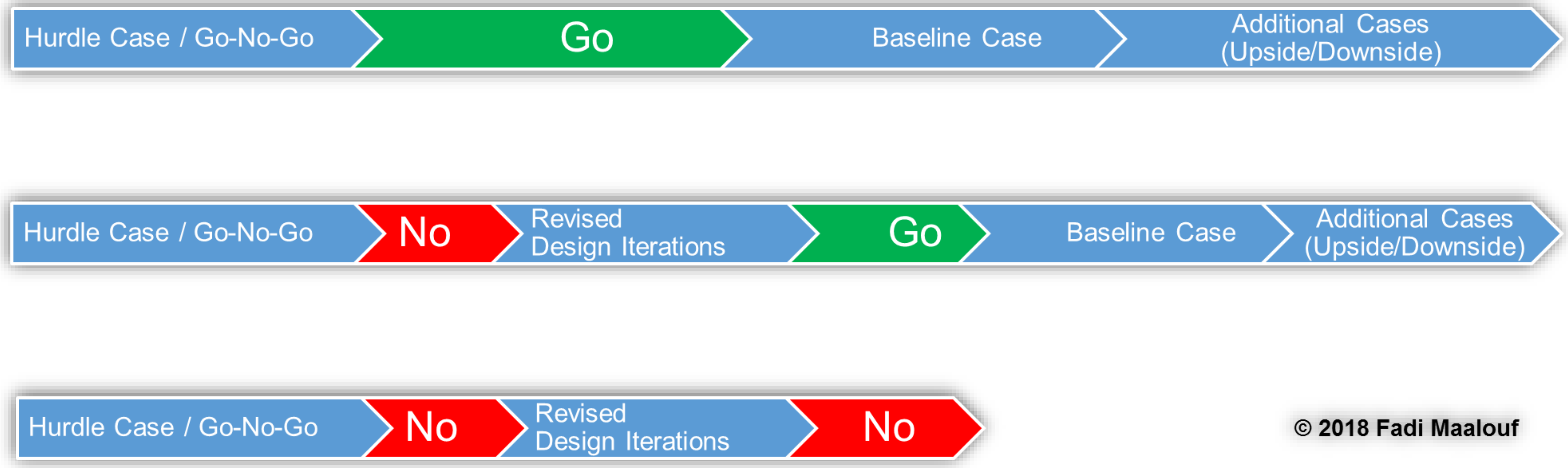
(WIP - Work In Progress)



What is Capital Budgeting?
Financial Model Development – Process Workflow



Baseline Case Financial Model
Inputs/Outputs Summary

PV POWER PLANT PROJECT LCOE	
PRE-FEASIBILITY ECONOMIC ANALYSIS	
INPUTS	
General	
Analysis Period (years)	25 & 20
Finance Structure	
Debt Percentage	76.00%
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OUTPUTS - 25 Years

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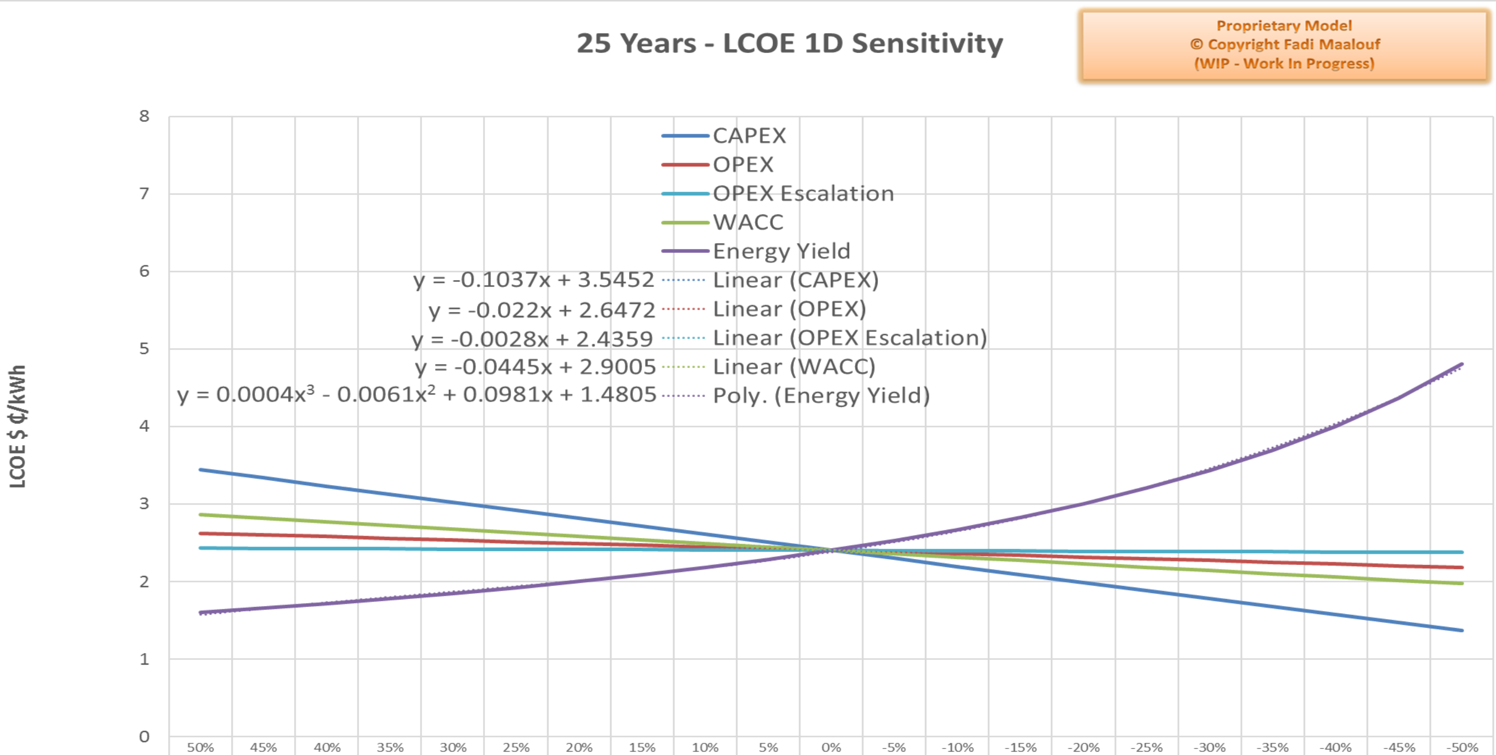
Capex Component	2.073064501	86.20%
Opex Component	0.331940496	13.80%
		Total Percentage Check
		100.00%
LCOE ($ ¢/kWh)	**2.405004997**	

OUTPUTS - 20 Years

LCOE Component	Component $ ¢/kWh	Component Percentage
Capex Component	2.359810857	88.80%
Opex Component	0.297589947	11.20%
		Total Percentage Check
		100.00%
LCOE ($ ¢/kWh)	**2.657400804**	

Baseline Case Financial Model

Sensitivity Analysis



	50%	45%	40%	35%	30%	25%	20%	15%	10%	5%	0%
CAPEX	3.441537	3.337884	3.234231	3.130578	3.026924	2.923271	2.819618	2.715965	2.612311	2.508658	2.405005
OPEX	2.625162	2.603146	2.581131	2.559115	2.537099	2.515084	2.493068	2.471052	2.449036	2.427021	2.405005
OPEX Escalation	2.433927	2.430922	2.427942	2.424988	2.42206	2.419156	2.416277	2.413423	2.410593	2.407787	2.405005
WACC	2.866979	2.819323	2.771977	2.724948	2.67824	2.631857	2.585806	2.54009	2.494715	2.449685	2.405005
Energy Yield	1.603337	1.658624	1.717861	1.781485	1.850004	1.924004	2.004171	2.091309	2.186368	2.290481	2.405005

	-5%	-10%	-15%	-20%	-25%	-30%	-35%	-40%	-45%	-50%
CAPEX	2.301352	2.197699	2.094045	1.990392	1.886739	1.783086	1.679432	1.575779	1.472126	1.368473
OPEX	2.382989	2.360974	2.338958	2.316942	2.294926	2.272911	2.250895	2.228879	2.206864	2.184848
OPEX Escalation	2.402247	2.399512	2.3968	2.394111	2.391445	2.388802	2.386181	2.383582	2.381005	2.37845
WACC	2.360679	2.316713	2.273109	2.229873	2.18701	2.144522	2.102414	2.060689	2.019353	1.978407
Energy Yield	2.531584	2.672228	2.829418	3.006256	3.206673	3.435721	3.700008	4.008342	4.372736	4.81001

Parameter Variance from Baseline Case

SunBurn Test™: Climate Change Risks Register

SunBurn Test™ Scenario Analysis Model		
Climate Change Risk Register (Extract)		
S.N.	**Qualitative**	**Quantitative**
1	Year 1 Air pollution (PM2.5/10, smog/haze) Not accounted for or fully accounted for in historical P50 TMY weather file and P50 forecasted energy yield report	Decreased solar irradiance, decreased annual energy yield, whilst noting that different PV module technologies get impacted differently according to their light spectrum range
2	Forward looking: Year 2 onwards till plant end of life (PPA term). Continuous percentage increase YoY in air pollution	Continuous percentage decrease YoY in solar irradiance, continuous percentage decrease YoY in annual energy yield
3	Year 1 Higher annual average ambient temperature than forecasted in historical P50 TMY weather file (global warming due to GHG, frequent heat wave events) and hence impacting P50 forecasted energy yield report	Decreased annual energy yield, decrease is proportional to solar module power temperature coefficient
4	Forward looking: Year 2 onwards till plant end of life (PPA term). Continuous percentage increase YoY in annual average ambient temperature, net 2 °C increase in the next 30 years (straight line, slope +0.0666 °C / year)	Continuous percentage decrease YoY in annual energy yield, decrease is proportional to solar module power temperature coefficient
5	Year 1 Extreme weather events Increased frequency of sand storms and/or muddy rain and/or acid rain	Increase in solar modules cleaning frequency (dry and wet), Increase in OPEX Cost (parts & labor & water consumption rate as well as water unit cost rate due to scarcity)

SunBurn Test™ Scenario Analysis Model		
Climate Change Risk Register (Extract)		
S.N.	**Qualitative**	**Quantitative**
6	Forward looking: Year 2 onwards till plant end of life (PPA term). Consistent extreme and harsh weather events	Accelerated solar module power degradation, higher percentage rate per annum, Decreased energy yield
7	Extreme weather events that result in increased frequency of preventive and corrective maintenance events	Increase in OPEX Cost due to increase MTBF (parts & labor costs)
8	Extreme weather events that result in equipment being out-of-operating-range (high wind speed events for tracking systems, ambient temperature Tmax & Tmin, etc.), and hence plant on temporary curtailment or shutdown	Decrease in power plant annual availability percentage
9	Adverse weather events that result in increased frequency of preventive and corrective maintenance events (hurricanes, floods, landslides, wild fires, etc.) requiring partial or complete power plant shutdown events	Decrease in power plant annual availability percentage
10	Consistent adverse weather events YoY that result in insurance claims (hurricanes, floods)	Increase in OPEX Cost due to increase in insurance costs
11	Catastrophic climate change phenomenon (rising sea levels) that necessitate remedial measures	Increase in CAPEX and OPEX Costs due to protection and fortification measures
12	New & emerging risks attributable to climate change	Ongoing proactive analysis

SunBurn Test™: Risk Management Methodology

- Gross Risk Value = GRV = Risk Value x Probability of Occurrence = RV x PO
- Net Risk Value = NRV = Gross Risk Value x Post-Mitigation Correction Factor = GRV x PMCF
- **NRV = RV x PO x PMCF**
- **PO = 0% to 100%**
- **PMCF = 0 to 1**

- PMCF examples as follows:
  - PMCF = 0 is for fully mitigated Gross Risk and hence no residual risk remains (no Net Risk Value)
  - PMCF = 1 is for fully unmitigated Gross Risk and hence remaining residual risk (NRV) equals GRV
  - PMCF = 0.7 is for 30% mitigated Gross and hence 70% residual risk remains (NRV)
  - PMCF = 0.25 is for 75% mitigated Gross Risk and hence 25% residual risk remains (NRV)

SunBurn Test™: Theory and Practice
Mini Case Hypothetical Scenario

- Risk A Description: Air pollution resulting in 4% decrease in annual energy yield
- Risk B Description: Year 2 onwards till plant end of life (PPA term), continuous percentage increase YoY in annual average ambient temperature, net 2.5 °C increase in the next 30 years (straight line, slope +0.0833 °C / year) which result in annual energy yield decrease of 0.0375%
- Risk C Description: Extreme weather events causing increased frequency of preventive and corrective maintenance events which result in additional annual OPEX of 25%
- Risk D Description: Adverse weather events causing increased frequency of preventive and corrective maintenance events and/or plant-out of-operating-range requiring partial power plant shutdown events, hence plant's overall annual availability baseline value is reduced by 2%
- Risk E Description: Year 2 onwards till plant end of life (PPA term), consistent extreme and harsh weather events causing accelerated solar module power degradation, annual degradation rate increases by 20%

Climate Change Risks Impacts on Baseline Case

Mini Case Hypothetical Scenario

The SunBurn Test™ - Stress Test Scenario Analysis Model Climate Change Risks	
Air Pollution - Decrease in Energy Yield	4%
Probability of Occurrence x Post-Mitigation Correction Factor	75%
Ambient Temperature Increase - Decrease Energy Yield Annually, Yr2+	0.0375%
Probability of Occurrence x Post-Mitigation Correction Factor	100%
Extreme Weather Events - Increase OPEX	25%
Probability of Occurrence x Post-Mitigation Correction Factor	50%
Adverse Weather Events - Decrease Annual Availability	2%
Probability of Occurrence x Post-Mitigation Correction Factor	50%
Extreme & Harsh Weather - Increase Annual Module Degradation, Yr2+	20%
Probability of Occurrence x Post-Mitigation Correction Factor	75%
25 Years LCOE Increase from Baseline Case	7.852%
20 Years LCOE Increase from Baseline Case	7.321%

With applied Climate Risks:
25 Years LCOE increased by 7.85%

PV POWER PLANT PROJECT LCOE PRE-FEASIBILITY ECONOMIC ANALYSIS	
INPUTS	
General	
Analysis Period (years)	25 & 20
Finance Structure	
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Annual Energy Degradation Year 2 to 25 (%/year)	0.60%
Power Plant Annual Availability (%)	99.60%
Net Annual Energy Output Year 1 (kWh)	2,224.52
Residual Value at End of Service Life	
Salvage % of EPC at Year 25	14%
Salvage % of EPC at Year 20	12%

OUTPUTS - 25 Years

LCOE Component	Component $ ¢/kWh	Component Percentage
Capex Component	2.185821159	84.27%
Opex Component	0.408028097	15.73%
		Total Percentage Check
		100.00%

LCOE ($ ¢/kWh) 2.593849256

OUTPUTS - 20 Years

LCOE Component	Component $ ¢/kWh	Component Percentage
Capex Component	2.482820234	87.06%
Opex Component	0.369127085	12.94%
		Total Percentage Check
		100.00%

LCOE ($ ¢/kWh) 2.851947319

Proprietary Model
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(WIP - Work In Progress)

Climate Change Risks Impacts on Baseline Case
Mini Case Hypothetical Scenario

The SunBurn Test™ - Stress Test Scenario Analysis Model Climate Change Risks	
Air Pollution - Decrease in Energy Yield	4%
Probability of Occurrence x Post-Mitigation Correction Factor	75%
Ambient Temperature Increase - Decrease Energy Yield Annually, Yr2+	0.0375%
Probability of Occurrence x Post-Mitigation Correction Factor	100%
Extreme Weather Events - Increase OPEX	25%
Probability of Occurrence x Post-Mitigation Correction Factor	50%
Adverse Weather Events - Decrease Annual Availability	2%
Probability of Occurrence x Post-Mitigation Correction Factor	50%
Extreme & Harsh Weather - Increase Annual Module Degradation, Yr2+	20%
Probability of Occurrence x Post-Mitigation Correction Factor	75%
25 Years LCOE Increase from Baseline Case	0.037%
20 Years LCOE Increase from Baseline Case	0.506%

With applied Climate Risks & fixed LCOE to Baseline Return on Equity dropped from 7.00% to 3.61%, a 48.42% decrease.

PV POWER PLANT PROJECT LCOE

PRE-FEASIBILITY ECONOMIC ANALYSIS

INPUTS	
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Debt Percentage	76.00%
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Residual Value at End of Service Life	
Salvage % of EPC at Year 25	14%
Salvage % of EPC at Year 20	12%

OUTPUTS - 25 Years

LCOE Component	Component $ ¢/kWh	Component Percentage
Capex Component	2.007320222	83.43%
Opex Component	0.398570164	16.57%
		Total Percentage Check
		100.00%

LCOE ($ ¢/kWh) 2.405890386

OUTPUTS - 20 Years

LCOE Component	Component $ ¢/kWh	Component Percentage
Capex Component	2.311299393	86.54%
Opex Component	0.359549309	13.46%
		Total Percentage Check
		100.00%

LCOE ($ ¢/kWh) 2.670848702

SunBurn Test™ (SBT™): Takeaways

1. Climate change is a reality. It presents both risks and opportunities, which can be generally categorized as current short-term impacts and forward-looking long-term impacts.

2. A global mega trend is evolving where corporations will be required to report climate change related impacts in their financial reporting and disclosure. Hence corporations are integrating climate related impacts in their corporate strategies.

3. In the context of Independent Power Producers and solar PV power plants, understanding and accounting for climate change related impacts is paramount.

4. SBT™ is stress test technique in which a scenario analysis is applied to health-check the financial feasibility of a solar PV power plant. The stress parameters are derived from climate change related risks.

SunBurn Test™ (SBT™): Takeaways

5. SBT™ is a process that utilizes:
    1. Location specific climate change risks from credible scientific research where historical measured data is modelled to create forward looking climate projections.
    2. Risk Management approach to qualify and quantify climate change related risks.
    3. Resultant risks values form a scenario and are used to stress test a project baseline case financial feasibility model.
    4. The goal is to determine whether the stressed project remains financially viable. For solar PV power plant, the focus is equity IRR, DSCR, amongst other covenants.
    5. Care of not falling in the trap of GIGO: Garbage In » Garbage Out. Modelling parameters must neither be artificially low nor doomsday high!
6. A hypothetical stress test with a few selected risks was run. It indicated significant impact on a solar PV power plant project profitability, especially in very competitively priced LCOE's with single digit IRR's.
7. SBT™ is a useful technique. It may help prevent a nasty sun burn!

Thank You

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