Feed-in Tariff Structure Development for the Kingdom of Bahrain for PV Electricity

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Presentation Outline:

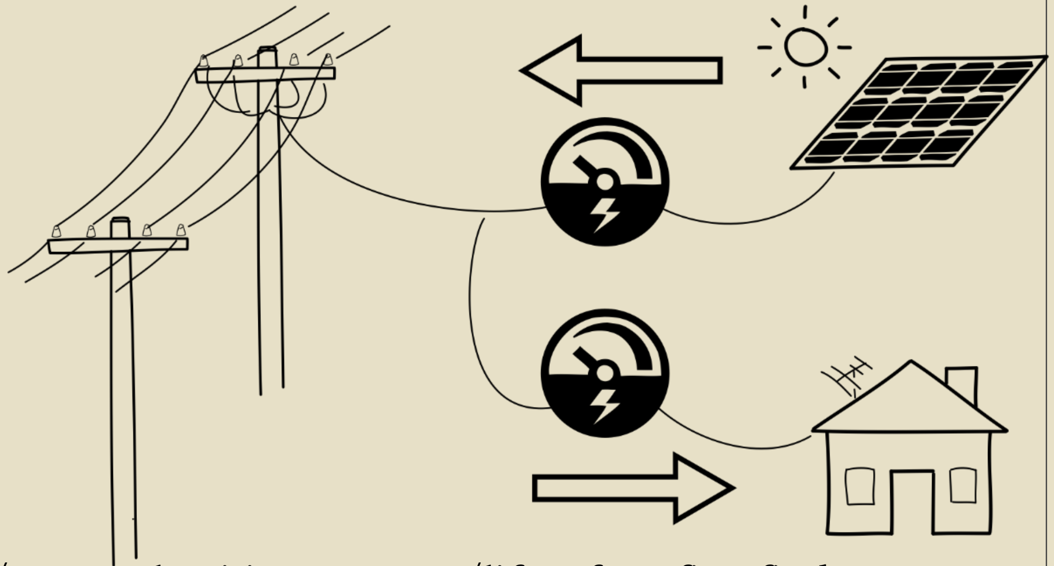
1. Introduction
2. Methodology of FIT Development
3. Results and Discussion
4. Conclusions

Introduction

- Grid-connected photovoltaic (PV) systems allow households to generate electrical power and feed it into the public grid.
- This PV-generated electricity is sold to the electric utilities under various subsidy schemes, among which are:
  - net metering
  - net purchase and sale
  - feed-in tariff (FIT).
- Currently, none of these schemes exists in the Kingdom of Bahrain.

Introduction

- **Feed-in tariff (FIT):**
  - Electric utility company is obligated to purchase all the PV-electricity generated by the household at a set price for a given number of years, usually the period of the PV panels warranty.
  - The FIT electric meter is placed directly after the PV system.
  - The household is paid for the PV-electricity generated, regardless to where/when it is consumed.



http://www.solarcitizens.org.au/life_after_fits_find_out_more

Introduction

- FIT scheme played a great role in promoting the use of renewable energy technologies, including PV, in different part of the world and is now well established worldwide
- In 2013, the cumulative number of jurisdictions (countries, states, or provinces) enacting feed-in policies reached 98 since it was first introduced in 1978 in the USA (REN21, 2014).
- In UK, the introduction of FIT scheme in April 2010 by the government encouraged the installation of 1.06 GW_p of PV capacity in two years, where the majority of these installations (88%) were domestic installations less than 4 kW_p (Cherrington et al., 2013)

Methodology of FIT Rate Development

1. Identify the PV module specifications
2. Estimate the required/suitable PV panel size
3. Calculate the corresponding cost of the PV system
4. Determine the local solar data
5. Calculate the PV-generated electrical energy
6. Estimating the cost of the PV-electricity
7. Estimate the feasible FIT rates

1. Identify the PV module specifications

- Crystalline Silicon Solar Cells
  - Polycrystalline Silicon
  - Monocrystalline Silicon

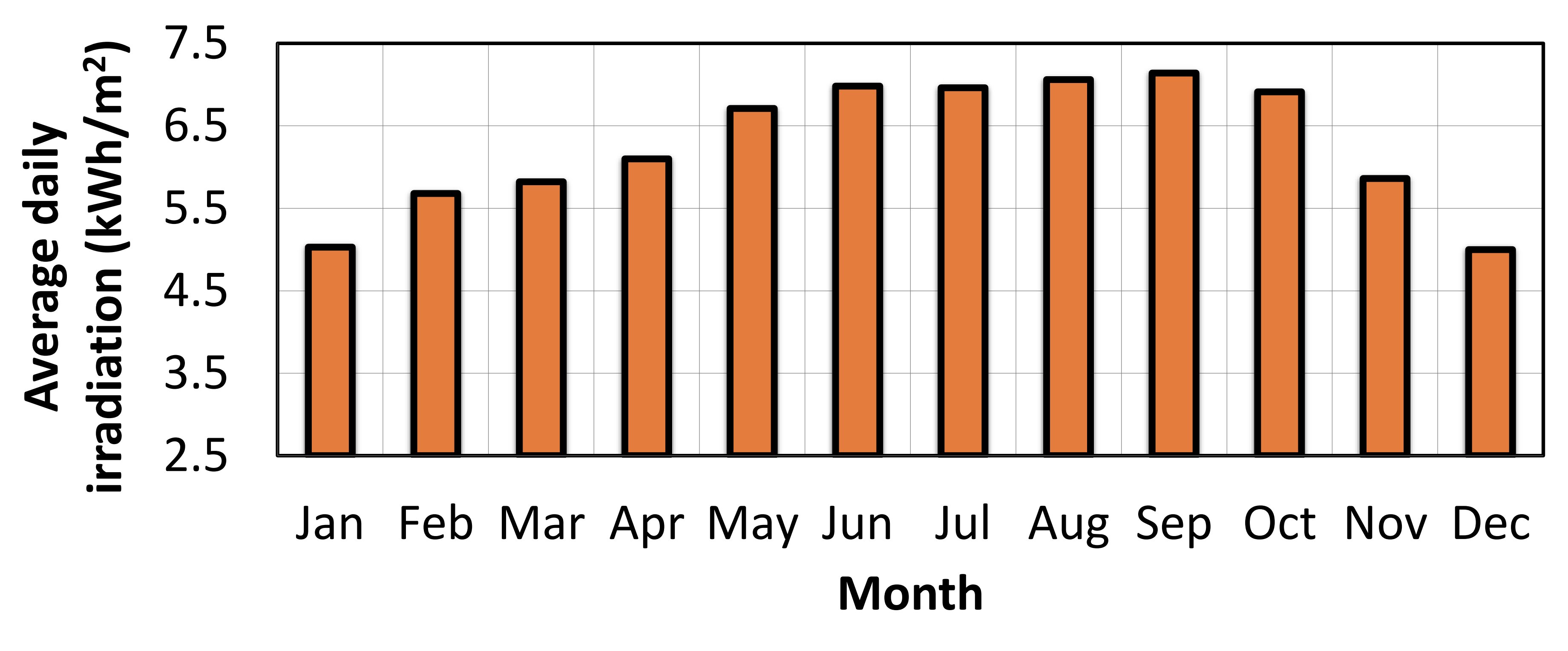
- Thin-Film Solar Cells
  - Amorphous silicon (a-Si)
  - Cadmium telluride (CdTe)
  - Copper indium gallium selenide (CIS/CIGS)
  - Organic photovoltaic cells (OPC)

Specifications of polycrystalline silicon PV module/system used in this study.		
PV module specifications:		
Rated power, W_p		200
Rated power density, W_p/m^2		138.5
Module efficiency		14%
Permissible operating temperature, °C		-40 to 85
Warranty, years		20
Grid-connected PV system		
Price, per W_p	BD 1.134/W_p=	$3.00
Combined losses		30%
Efficiency		9.8%
Annual performance degradation rate		0.5%
Inverter		
Percentage of system cost		20%
Warranty, years		10

2. & 3. Estimate the PV panel size & system cost

Specifications of the household roof & system cost		
Roof dimensions:		
Length, m		15
Width, m		12
Area, m^2		180
Area utilization percentage		25%
Total utilized system area, m^2		45
Gaps within the modules		20%
Area available for PV modules, m^2		36
Installable PV capacity		
within the available area, kW_p		5
No of modules		25
Total PV system cost	BD 5,670 =	$15,000

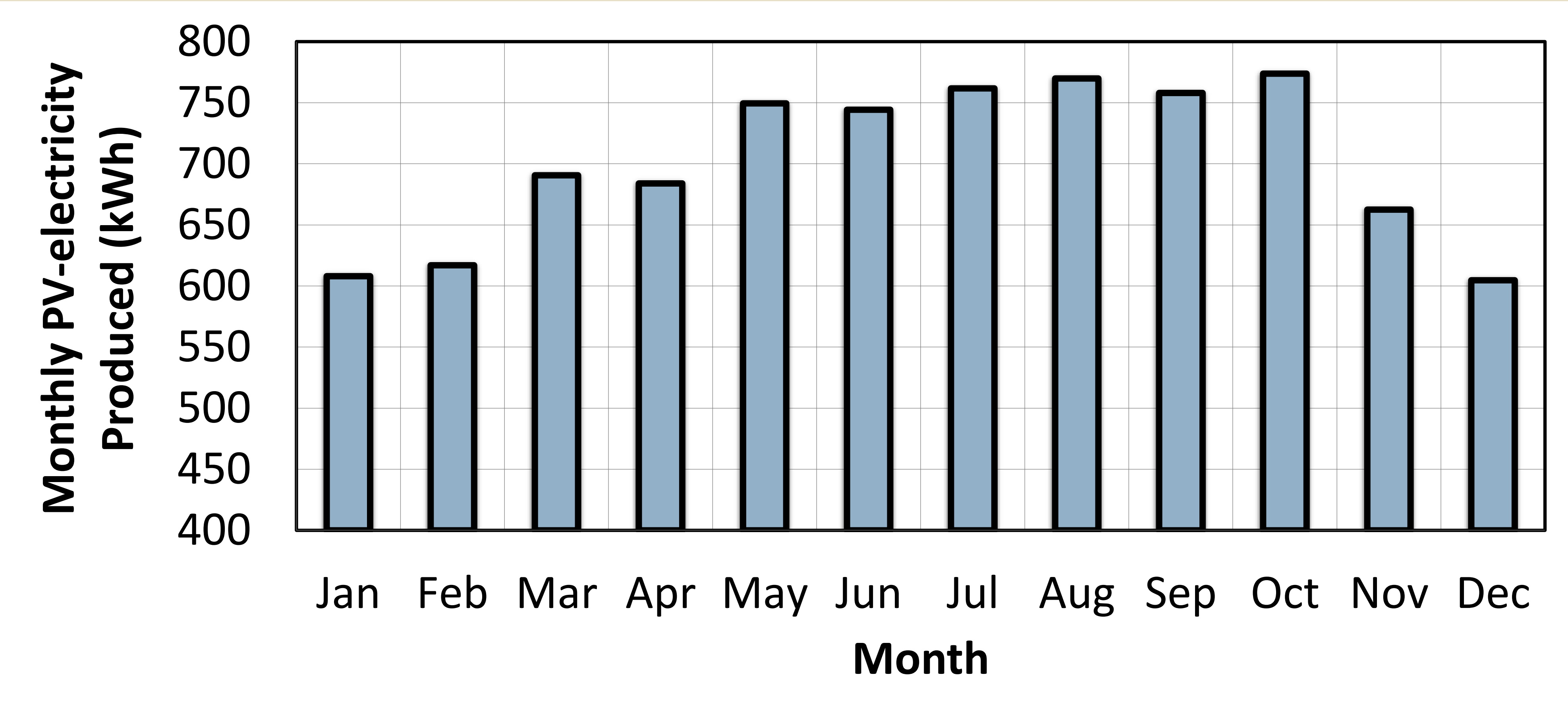
4. Determine the local solar data



The monthly average daily irradiation ($kWh/m^2 \cdot day$)

- At a fixed, optimized inclination (25°, facing south) and azimuth (–1°)
- From the Photovoltaic Geographical Information System (PVGIS) database (Manama)

5. Calculate the PV-electricity generated



6. & 7. Estimate the PV-electricity cost and suitable FIT rates

An example of the values of financial parameters needed for PV-electricity cost and FIT rate calculations.

PV system unit price (per W_p)	$3.00	BD 1.13
PV system capacity, kW_p	5.00	
Initial investment (PV system cost)	$15,000	BD 5,670
Capital rebate		
Percentage	15%	
Amount	$2,250	BD 851
Net initial investment	$12,750	BD 4,820
Investor down payment		
Percentage	10%	
Amount	$1,275	BD 481.95
Investor loan		
Percentage	90%	
Amount	$11,475	BD 4,338
Period, years	7	
Interest rate (APR)	4.15%	
Monthly installment	-$157.64	-BD 60
Discount rate (annual effective)	3.25%	
Project duration (PV system lifetime), years	20	
Operation & maintenance cost		
Annual percentage of initial investment	0.50%	
Monthly amount	$6.25	BD 2.36
Inverter replacement cost (in year 11)		
Percentage of initial investment	20%	
Amount	$3,000	BD 1,134

6. & 7. Estimate the PV-electricity cost and suitable FIT rates

The cash flow statement used for the calculation of the PV-electricity cost and the corresponding, feasible FIT rates.

Year	Month	Electricity produced, kWh	Received payment[a], $	Loan installment, $	O & M cost, $	Net cash flow, $	Cumulative cash flow, $
0			-1,275.00			-1,275	
1[b]	Jan	608.0	115.63	-157.64	-6.25	-48.27	-1,323.27
	Feb	616.9	117.33	-157.64	-6.25	-46.56	-1,369.83
	Mar	690.5	131.33	-157.64	-6.25	-32.57	-1,402.40
	Apr	683.9	130.06	-157.64	-6.25	-33.83	-1,436.23
	May	749.4	142.51	-157.64	-6.25	-21.38	-1,457.61
	Jun	744.2	141.53	-157.64	-6.25	-22.36	-1,479.98
	Jul	761.6	144.85	-157.64	-6.25	-19.05	-1,499.02
	Aug	769.9	146.42	-157.64	-6.25	-17.47	-1,516.49
	Sep	757.9	144.14	-157.64	-6.25	-19.75	-1,536.25
	Oct	773.8	147.15	-157.64	-6.25	-16.74	-1,552.99
	Nov	662.4	125.98	-157.64	-6.25	-37.92	-1,590.90
	Dec	604.6	114.98	-157.64	-6.25	-48.92	-1,639.82
≀				≀			≀
20[b]	Nov	602.2	114.53		-6.25	108.28	11,445.50
	Dec	549.6	104.53		-6.25	98.28	11,543.78

FIT rate[a], $/kWh *0.19*

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The cash flow statement used for the calculation of the PV-electricity cost and the corresponding, feasible FIT rates.

Year	Month	Electricity produced, kWh	Received payment[a], $	Loan installment, $	O & M cost, $	Net cash flow, $	Cumulative cash flow, $
10	Aug	736.0	139.96		-6.25	133.71	-87.50
	Sep	724.5	137.78		-6.25	131.53	44.04
	Oct	739.6	140.66		-6.25	134.41	178.45
	Nov	633.2	120.42		-6.25	114.17	292.62
	Dec	577.9	109.90		-6.25	103.65	396.27
11	Jan	578.3	109.97		-3,006.3	-2,896.3	-2,500.01
	Feb	586.8	111.59		-6.25	105.34	-2,394.66
≀				≀			≀
≀				≀			≀
20[b]	Nov	602.2	114.53		-6.25	108.28	11,445.50
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PV-electricity cost[c] or FIT rate[a], $/kWh	*0.19*
NPV (based on *d* = 3.25%), $	*2,365.11*
IRR	*13.0%*
PBP, years	*9.7*

FIT = $0.19/kWh (72 fils/kWh)
vs.
Cost = $0.14/kWh (53 fils/kWh)

[a] The shown numbers reflect the calculation of a FIT rate that leads to a 13% IRR for a case where the PV system was purchased at a price of $3/W$_p$ through a 7-year loan with 10% down payment including a 15% capital rebate.

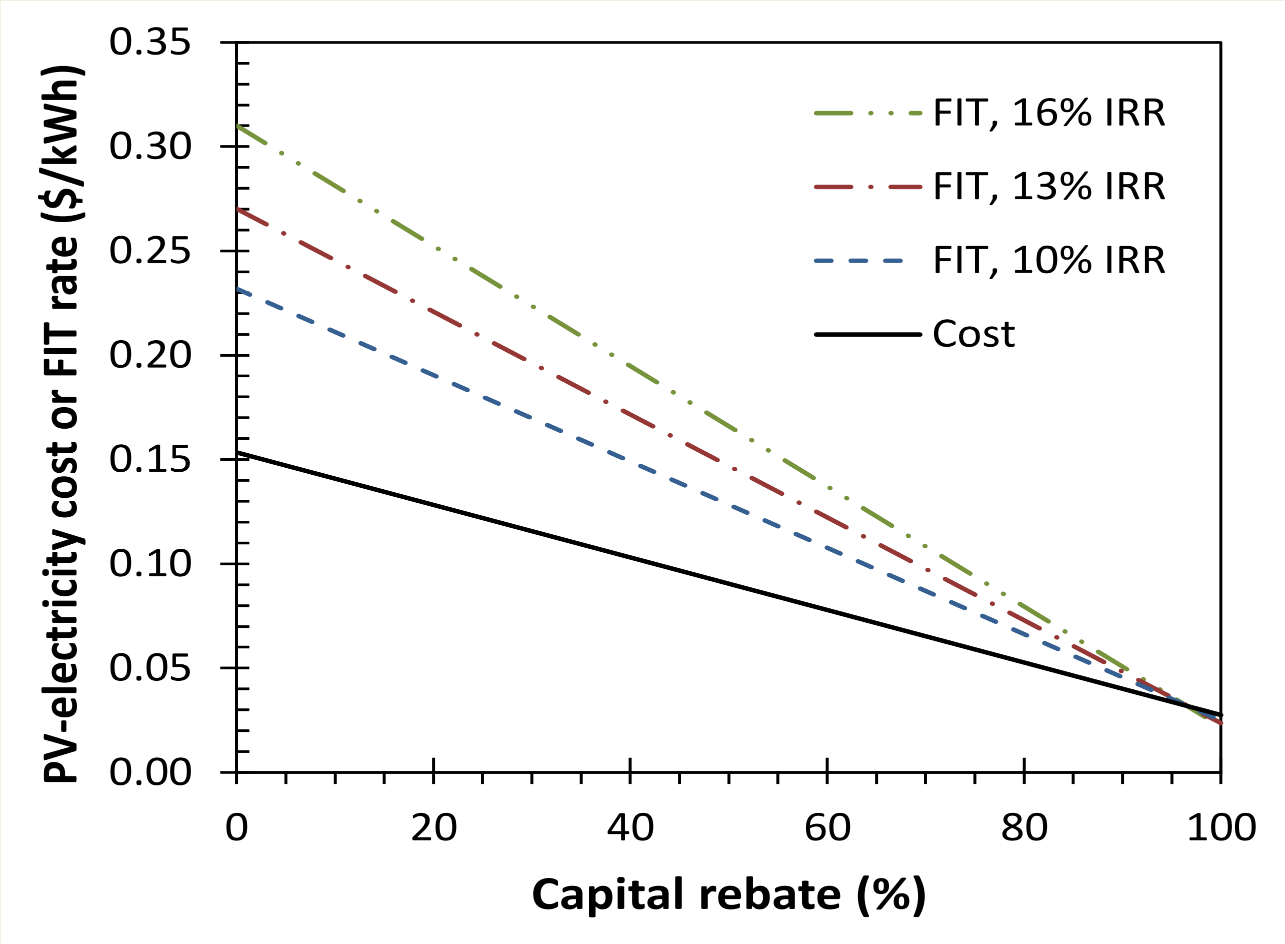
[b] The estimated annual electricity produced from the 5 kWp installation was 8,423.2 kWh for year 1 compared to 7,658.0 kWh for year 20 where 0.5% annual degradation rate was considered.

[c] The same table was used to calculate the PV-electricity cost ($0.14/kWh) where NPV = 0.

Results & Discussion

1. Scenario 1: Cost and FIT calculations with capital rebate and without loan
2. Scenario 2: Cost and FIT calculations with capital rebate and loan
3. Scenario 3: Cost and FIT calculations without capital rebate and with loan
4. The effect of the PV system price on the FIT rates and IRR
5. Payback period determination
6. Reduction in natural gas consumption and emissions
7. Government contribution towards the FIT cost
8. FIT cost pooling
9. Contribution of PV-electricity towards the growth of the peak load and energy demand.
10. Benefits to the local job market

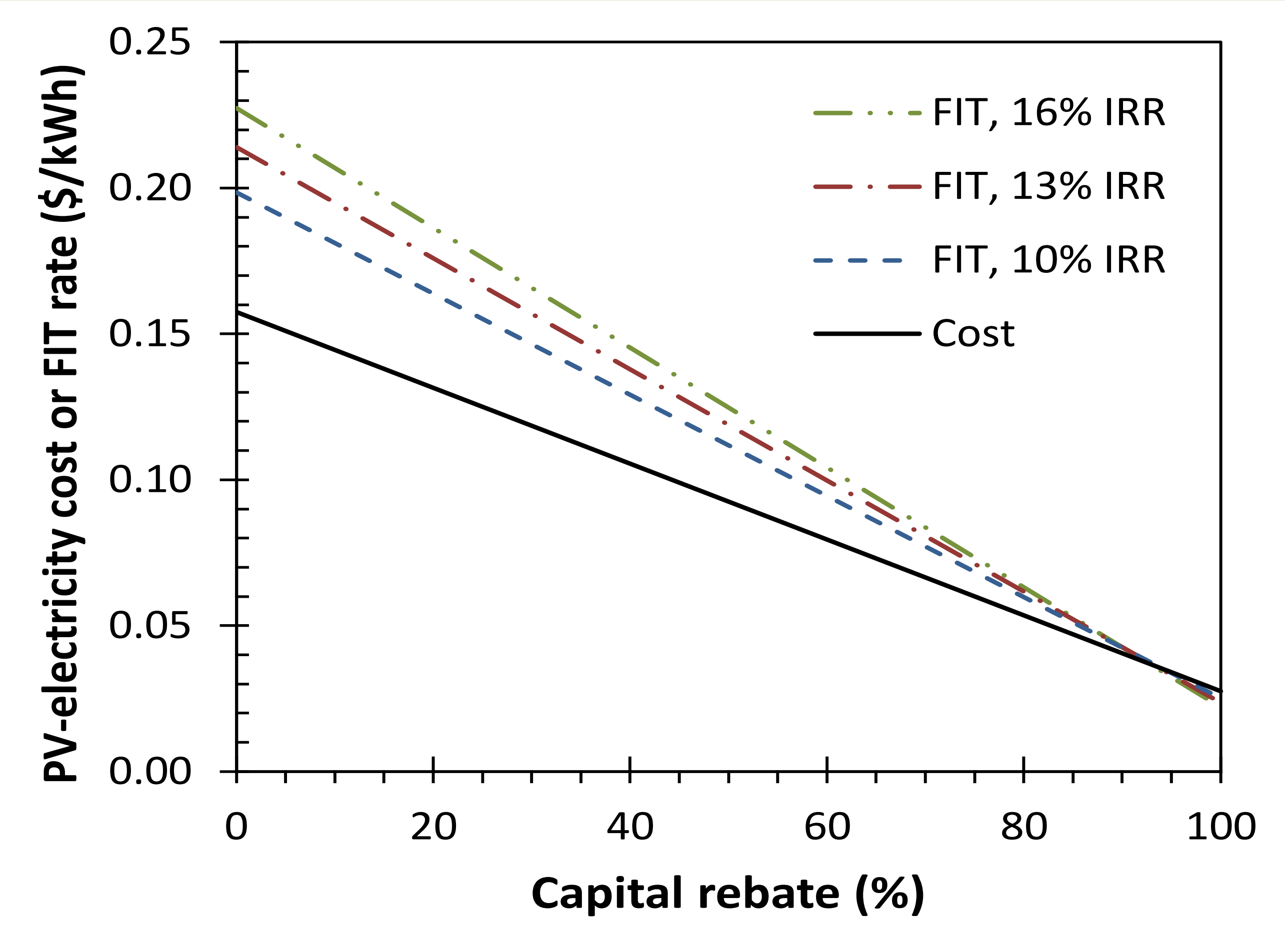
Scenario 1: Cost & FIT calculations with capital rebate & without loan



PV-electricity cost and FIT rates as a function of capital rebate percentage for scenario 1 where the PV system is purchased in cash.

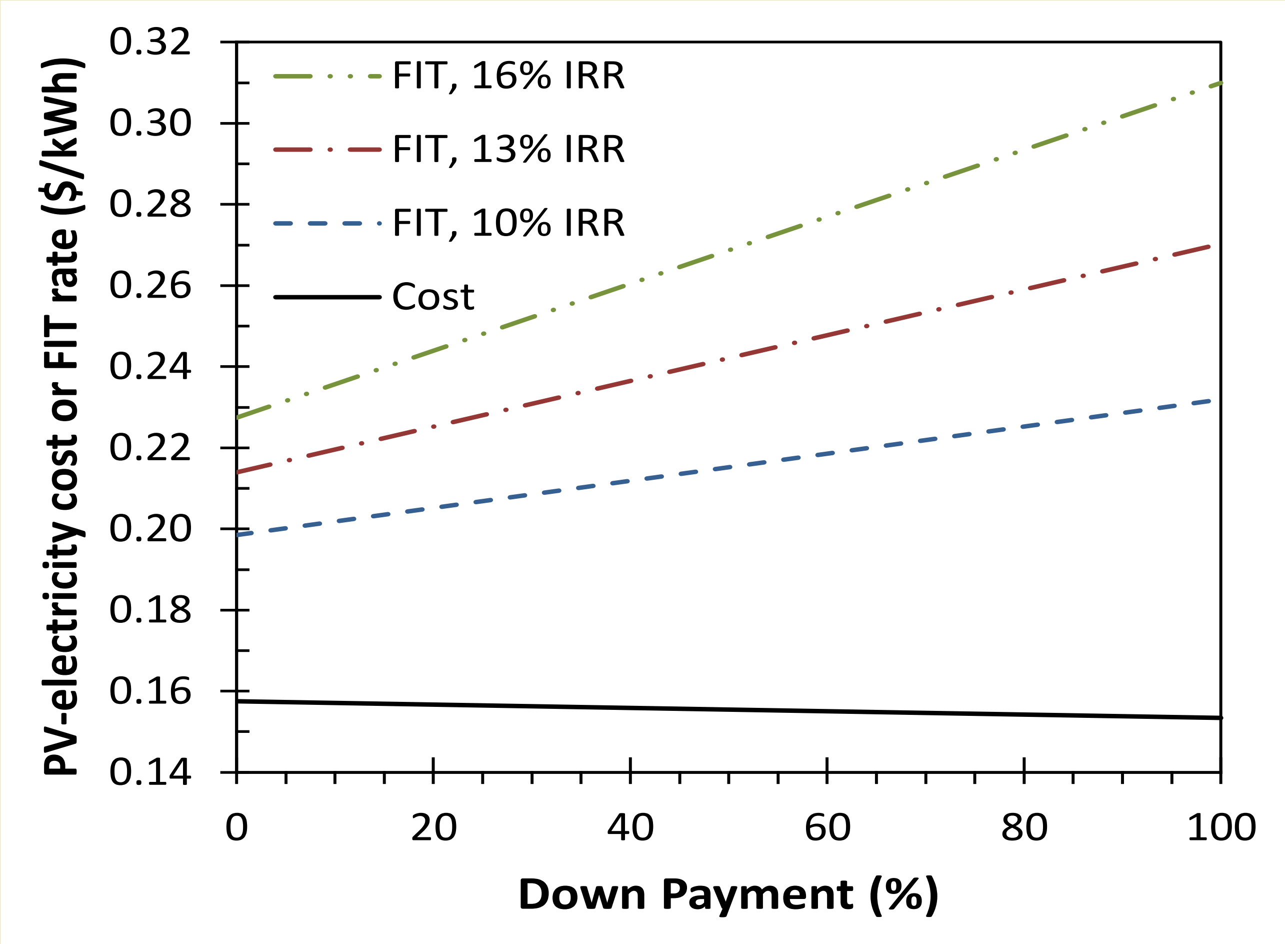
Scenario 2: Cost and FIT calculations with capital rebate and loan

Higher COE & lower FIT compared to no-loan case.



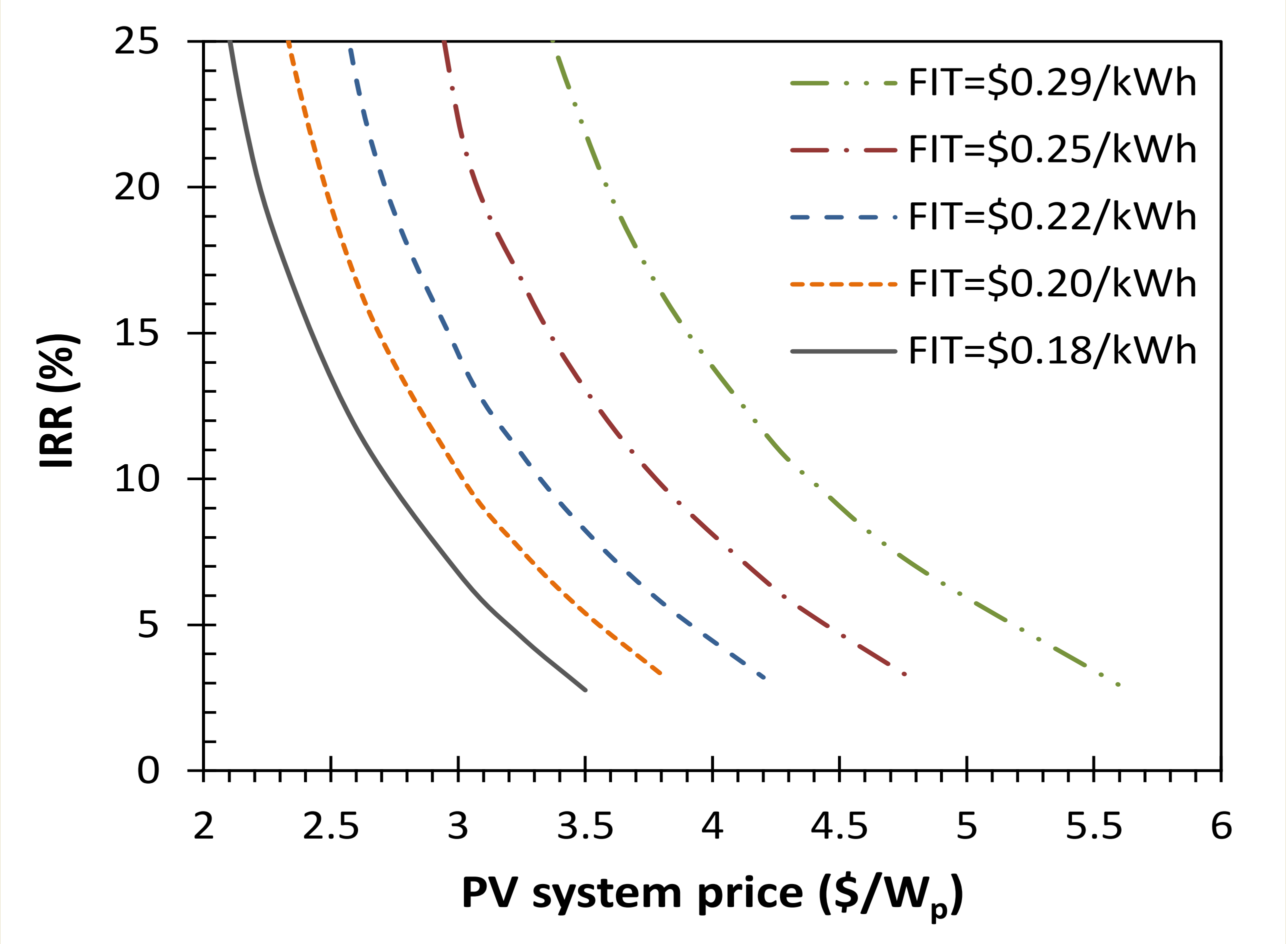
PV-electricity cost and FIT rates as a function of capital rebate percentage for scenario 2 where the PV system is purchased with a 7-year loan without any down payment.

Scenario 3: Cost & FIT calculations without capital rebate & with loan



PV-electricity cost and FIT rates as a function of the down payment percentage in a 7-year loan arrangement in the absence of capital rebate, scenario 3.

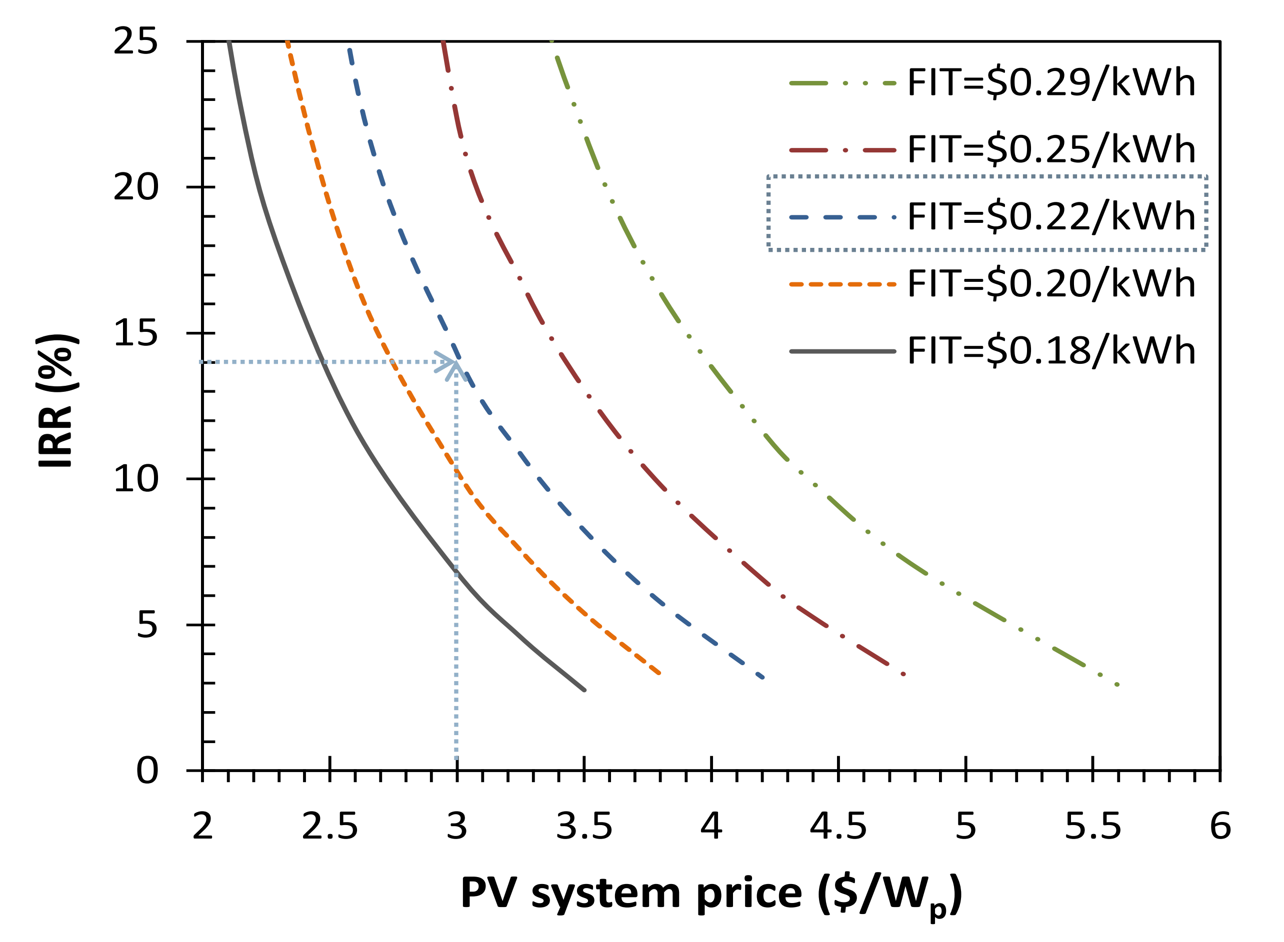
The effect of the PV system price on the FIT rates and IRR



The effect of the price of the grid-connected PV system on the IRR value for different FIT rates (no capital rebate, 7-year loan, 0% down payment).

The effect of the PV system price on the FIT rates and IRR

Fig used by the legislator



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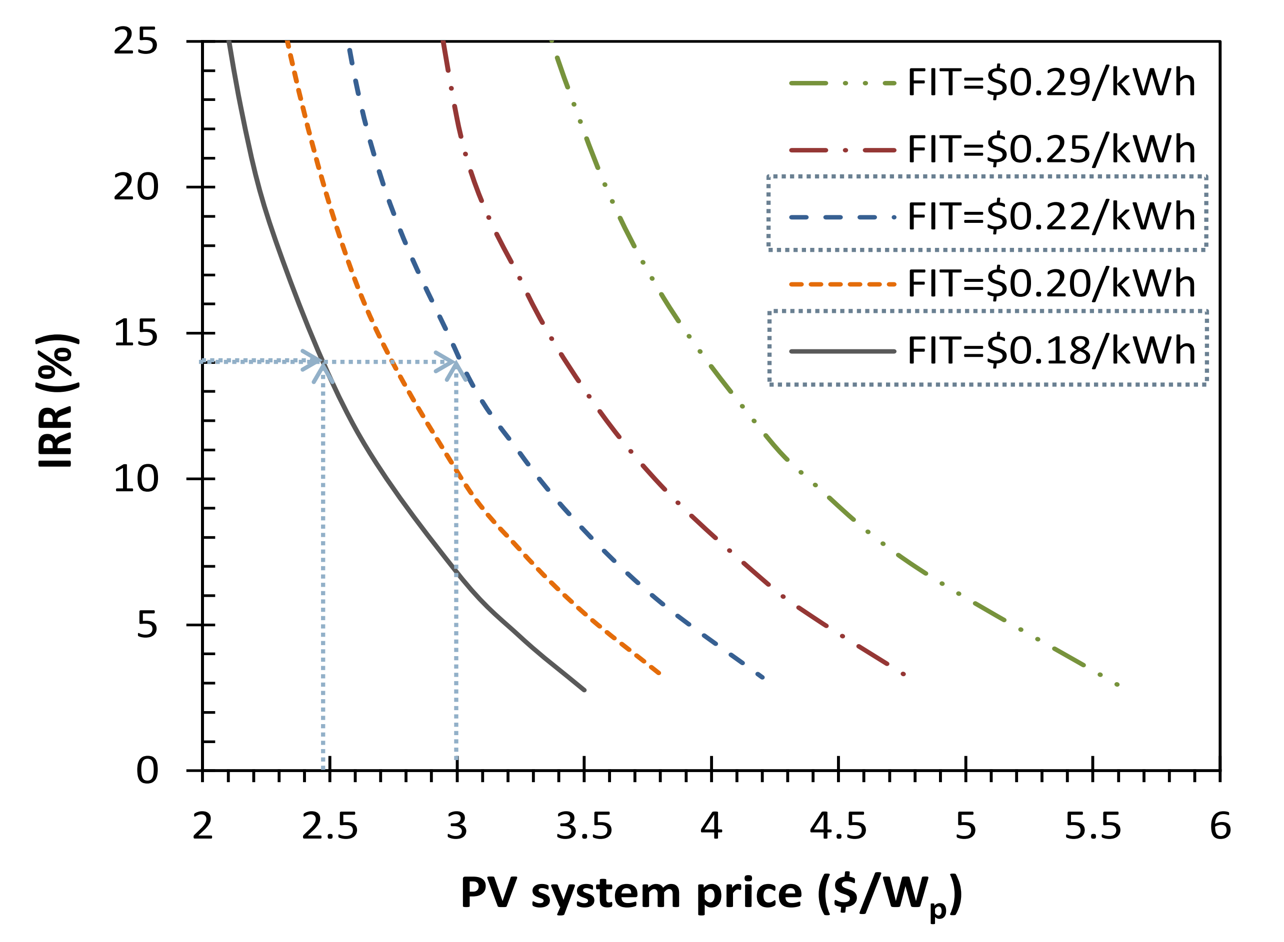

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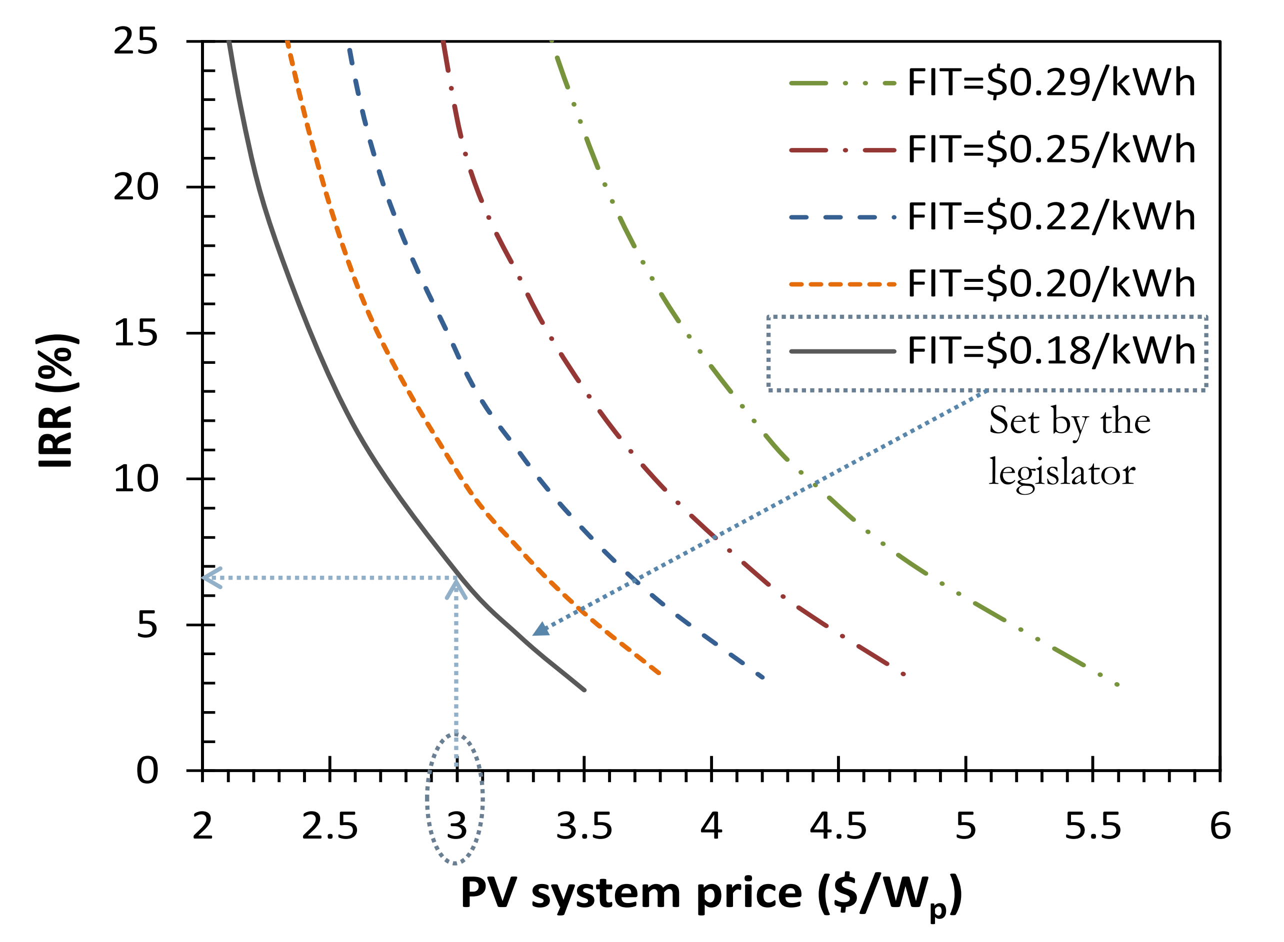
Fig used by the investor



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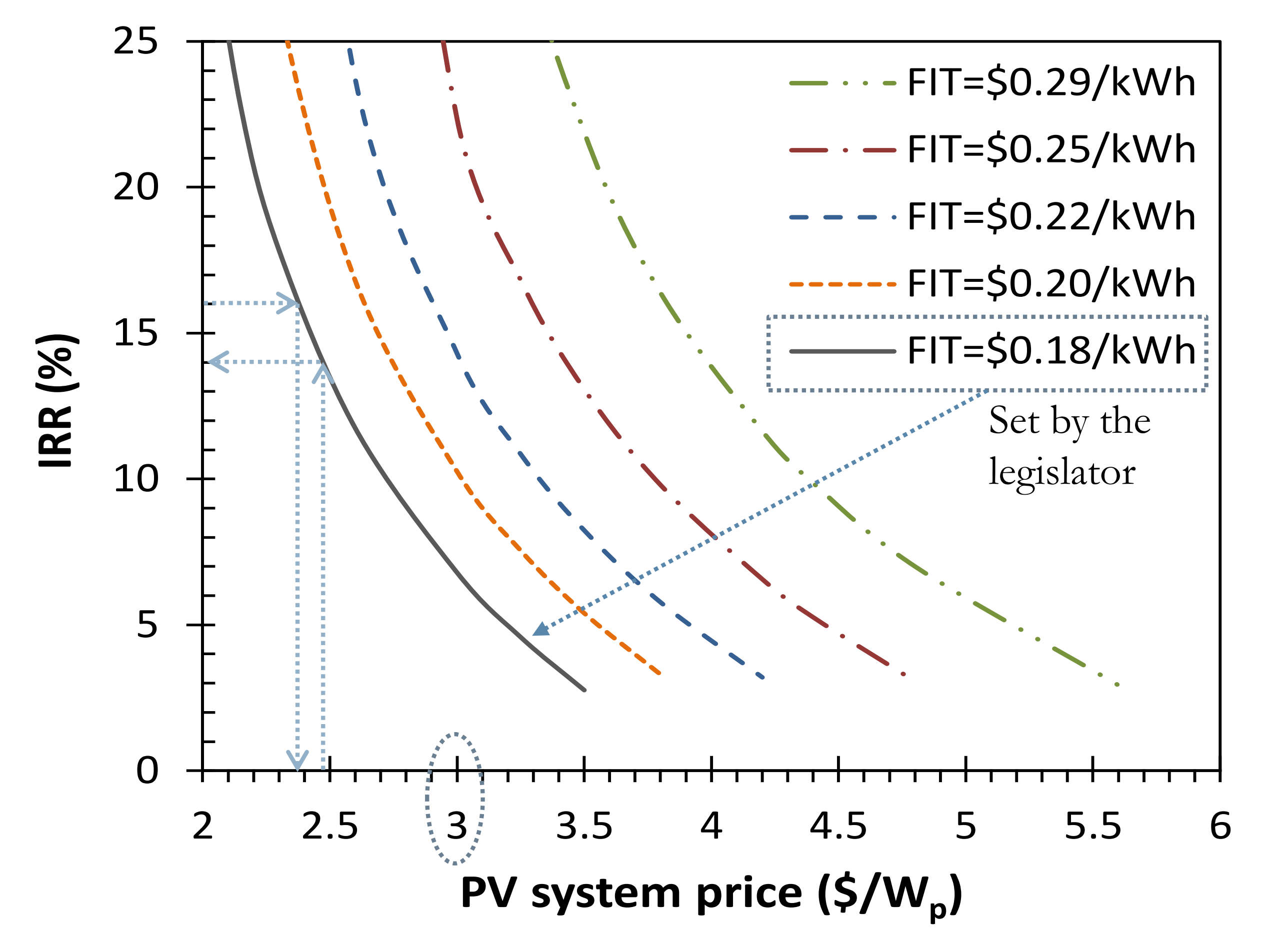
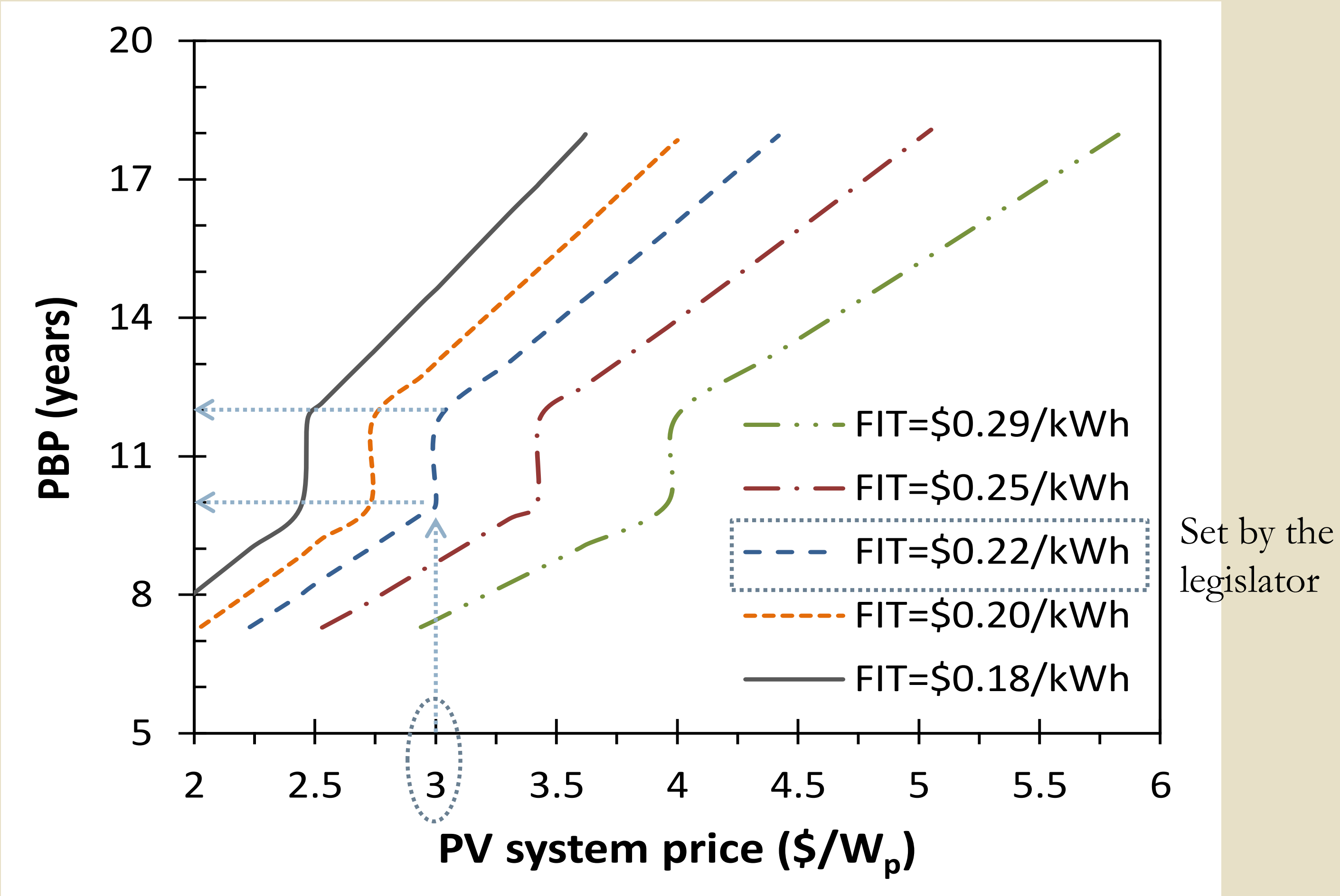


The effect of the price of the grid-connected PV system on the IRR value for different FIT rates (no capital rebate, 7-year loan, 0% down payment).

Payback period determination



The effect of the price of the grid-connected PV system on the payback period for different FIT rates (no capital rebate, 7-year loan, 0% down payment).

Go to Conclusions

Continue through Calculations of other Benefits

Reduction in natural gas consumption and emissions

The parameters and factors used to estimate the spared natural gas and the avoided emissions as a result of generating PV-electricity.

Parameter/factor	Units	Value
NG heat content, LHV[a]	Btu/scf	1,000
NG-fired power plant heat rate[b]	Btu/kWh	10,354
NG amount used to generate 1 kWh electricity	scf/kWh	10.354
PV-electricity generated per household	kWh/household	8,423
Avoided NG burned per household	scf/household (MMBtu/household)	87,212 (87.212)
IPCC[c] emission factors[d]:		
CO_2	lb/MMBtu (g/kWh)	130.5 (612.8)
CH_4	g/MMBtu (mg/kWh)	1.06 (10.92)
N_2O	g/MMBtu (mg/kWh)	0.106 (1.09)
NO_x	g/MMBtu (mg/kWh)	158.3 (1,638.6)
CO	g/MMBtu (mg/kWh)	21.1 (218.5)
NMVOC	g/MMBtu (mg/kWh)	5.28 (54.6)
SO_2[e]	mg/MMBtu (mg/Wh)	0.038 (0.398)

[a] IEA, International Energy Agency, 2012. Natural Gas Information. International Energy Agency, France.

[b] EIA, U.S. Energy Information Administration, 2015. How much coal, natural gas, or petroleum is used to generate a kWh of electricity? http://www.eia.gov/tools/faqs/faq.cfm?id=667&t=6.

[c] IPCC, Intergovernmental Panel on Climate Change, 1996. The Greenhouse Gas Inventory Workbook/Reference Manual, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC, France.

[d] Natural gas combustion default (uncontrolled) emission factors for energy industries.

[e] Estimated for NG with 600 ppmv H_2S (not from the IPCC reference).

Reduction in natural gas consumption and emissions

- The estimated annually spared natural gas per household (87,212 scf) is worth \$337 (BD 127) or \$67.4 (BD 25.5) per kW_p PV installed (based on natural gas market price of \$3.86/MMBtu).

- That is 18% of the total annual FIT received by a household, which is \$1,851 (BD 700) per household (based on FIT of \$0.22/kWh = 83 fils/kWh).

Reduction in natural gas consumption and emissions

- The annual amount of avoided emissions per PV-installed household were estimated to be:
  - 5.16 tons of CO_2
  - 13.8 kg of No_x
  - 1.84 kg of CO
  - 0.46 kg of non-methane VOC
  - 92 g of CH_4
  - 9.2 g of N_2O
  - 3.35 mg of SO_2.
- If 1000 household installs PV systems/year, the yearly increment in the avoided CO_2 emission will be 5.16 Gg.
- But that is only 0.0324% of the 2000 CO_2 emission in the energy sector in Bahrain.

Government contribution towards the FIT cost

- Electricity generation costs the government of Bahrain $0.074/kWh (28 fils/kWh).
- In reference to the lowest residential electricity tariff which is $0.008/kWh (3 fils/kWh), the maximum government subsidy is calculated to be $0.066/kWh (28 – 3 = 25 fils/kWh).
- Compared to an FIT rate of $0.22/kWh (83 fils/kWh), the calculated government subsidy constitutes 30% of the FIT rate.
- In other words, the government can redirect the electricity subsidy from the conventional to the environment-friendly electricity production technologies by paying 30% of the FIT rate without any extra financial burden.
- Note: the subsidy on the electricity tariff is being reduced gradually until it is completely removed by 2019 for households with more than one account.

FIT cost pooling

- For each PV installed household, the total received compensation was estimated to be $1,851 (BD 700) per year.
- The total number of electricity customers in Bahrain was 365,000 in 2014 (EWA, 2015).
- The total number of residential houses was 84,000 in 2010 (CIO, 2010).
- If the $1,851 (BD 700) is shared, the monthly contribution would be $0.000423 per customer or $0.00184 per house for each PV-installed household.
- In other words, if 1000 households enroll in the FIT scheme annually, the annual average increment in the monthly bill would be $0.423 (160 fils) per customer or $1.836 (BD 0.694) per house.

FIT cost pooling

- In other words, if 1000 households enroll in the FIT scheme annually, the annual average increment in the monthly bill would be $0.423 (160 fils) per customer or $1.836 (BD 0.694) per house.
- Based on the daily average electricity consumption per capita in Bahrain in 2014 (31 kWh/capita·day) (EWA, 2015), a five-member household in Bahrain consumes 4,650 kWh per month, which costs $63.1 (BD 24) per month.
- Therefore, the annual increment in the electricity bill represents 2.91% for the households.

Contribution of PV-electricity towards the growth of the peak load and energy demand

- The electricity demand in Bahrain experiences an afternoon daily peak load that spans between 13:00 to 16:00.
- A peak load of 3,613 MW was forecasted for 2015 (Qamber, 2012) with an estimated average yearly growth rate of 6% for the years 2000-2011 (Al-Hamad et al., 2013).
- The average global irradiance in Bahrain at around 15:00 during the month of August is ~663 W/m^2 (PVGIS, 2015).
- This irradiance results into PV-electricity generation of 2.34 kW per household or 0.47 kW per kWp installed.
- To meet only 5% of the estimated annual growth in the peak load from 2015 to 2016 (an increase of 217 MW), 4,630 households should install grid-connected PV systems during that year with a total capacity of 23 MWp.

Contribution of PV-electricity towards the growth of the peak load and energy demand

- The proposed 23 MWp installation in Bahrain will also provide 39 GWh of electricity annually, which covers 5% of the average annual increase in the electricity consumption in Bahrain (780 GWh) (Burashid, 2012) & (EWA, 2015).
- This estimated installation capacity (4,630 houses, 23 MWp, or 17.3 Wp/capita):
  - is considered to be high where it represents 5.5% of the residential houses in Bahrain
  - requires an estimated total area of 0.167 km^2 of PV panels

Benefits to the local job market

- For the jobs that could be created by the PV market in Bahrain, two cases were considered:

Case	Created Jobs	
	construction /installation	operation/ maintenance
1000 PV system installations per year, with a total capacity of 5 MWp (1000 X 5 kWp)	170	15
23 MWp installing capacity per year	800	60

Benefits to the local job market

- Moreover, the implementation of such projects will raise renewable energy awareness, and thus, could open a new market for other sustainable projects, such as the use of solar energy for thermal applications (e.g. water heating)

Conclusions

- In this study, an economical model was structured for the estimation of feasible FIT rates for PV-electricity generated by a grid-connected PV system for the Kingdom of Bahrain.
- The developed spreadsheets and figures can be used by the legislator to determine the cost of PV-electricity and the corresponding appropriate FIT rate.
- It can also be used by the investing household to determine the resulting IRR and PBP.
- The established model and spreadsheets can be used for different economic scenarios, PV system scales, and geographical locations by employing the applicable parameters.

Conclusions

- In the scenario where the PV system is purchased through a 7-year loan without a down payment, the ratio between the PV-electricity cost and PV system price was estimated to be 0.0525 \$/kWh per \$/W_p (20 fils/kWh per \$/W_p).
- In the same scenario with a presumed PV system price of \$3/W_p, the estimated FIT rates were \$0.20–\$0.23 (75–86 fils) per kWh for IRR of 10%–16%, compared to the resulting \$0.16 (60 fils) per kWh PV-electricity cost.
- Due to the highly subsidized electricity tariff in Bahrain [≥0.8 cent (3 fils) per kWh], these FIT rates are 5 to 30 times more than the residential electricity tariff.

Conclusions

- The government can redirect the electricity subsidy from the conventional to the environment-friendly electricity production technologies by paying almost 30% of the FIT rate without any extra financial burden.
- Therefore, the FIT cost was suggested to be shared by both the government (30%) & the electricity customers (70%).
- In case the FIT cost was shared by electricity customers only:
  If 1000 households enroll in the FIT scheme annually, the annual average increment in the monthly bill would be $0.42 (160 fils) per customer or $1.84 (694 fils) per house.
- For the households, this annual increment ($1.836) in the monthly electricity bill represents 3% of the electricity bill amount.

Conclusions

- Furthermore, this study highlighted the associated benefits of the introduction of FIT scheme and, thereafter, the installation of PV systems for electricity generation.
- These benefits include the following (on annual basis per 1000 households with 5 kW_p installed PV system):
  - production of 8.4 GWh of renewable electricity
  - generation of up to 2.3 MW of power around the afternoon peak hour
  - sparing 87 MMscf of natural gas (worth of ~ $0.34 million, 18% of the annual FIT received)
  - avoiding 5.2 Gg of CO_2 emission (0.0324% of the 2000 CO_2 emission in the energy sector)
  - creation of ~15 O&M jobs (Plus the initial 170 C&I jobs created).

Q & A

Thank You!

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Feed-in tariff structure development for photovoltaic electricity and the associated benefits for the Kingdom of Bahrain

Shaker Haji [a], Amal Durazi[a] and Yaser Al-Alawi[b]