



Economic Assessment of Solar Heat for Industrial Process in Tunisia

Filip Schaffitzel





Content

1. Potential
2. Framework Conditions in Tunisia
3. Economics of Reference Case
4. Sensitivity Analysis
5. Effects of Policy Instruments
6. Annex



1. Potential

Theoretical Industrial Heat <250 °C	Technical Solar Heat	Source
376.61	n/a	Reiners, 2011
318.92	31.89	Amous, 2013

Economic Potential?



2. Framework Conditions in Tunisia

Energy Prices

Current Prices in EUR cents/KWh (incl. VAT)			Estimated Annual Increase	
Natural Gas	Fuel Oil	Electricity	2015-2021	2021-2035
1.63	2.28	8.19	10%	5%

Current Support mechanism (Prosol Industrie)

Grants 30% of investment costs,
capped at about 65 EUR/m²



3. Economics of Reference Case

Economic evaluation methods used:

- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Static Payback Period (SPP)

Assumptions:

Input Parameter	Unit	Value
Aperture area	m ²	1000
Lifetime	a	20
Real discounting factor	%	7
Inflation per year	%/a	4.4
Nominal discounting factor	%	11.7



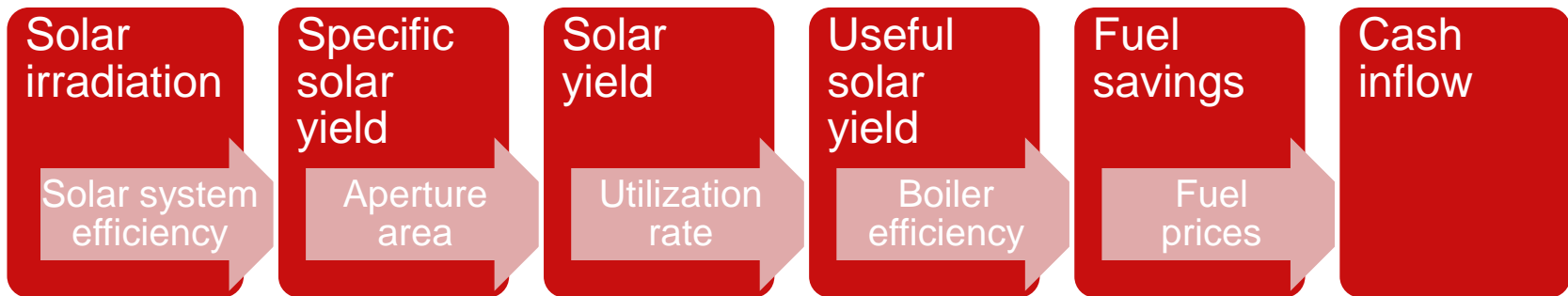
3. Economics of Reference Case Assumptions – Cash Outflows

Input Parameter	Unit	FPC	ETC	Concentrating
Specific total investment costs	EUR/m ²	400	500	550
Equity ratio	% of C _{inv}	30		
Interest rate	%	7		
Repayment period	a	5		
O&M costs	% of C _{inv}	1	1	1.5
Annual increase	%/a	0.5		
Electrical consumption	%	2	2	2.5



3. Economics of Reference Case

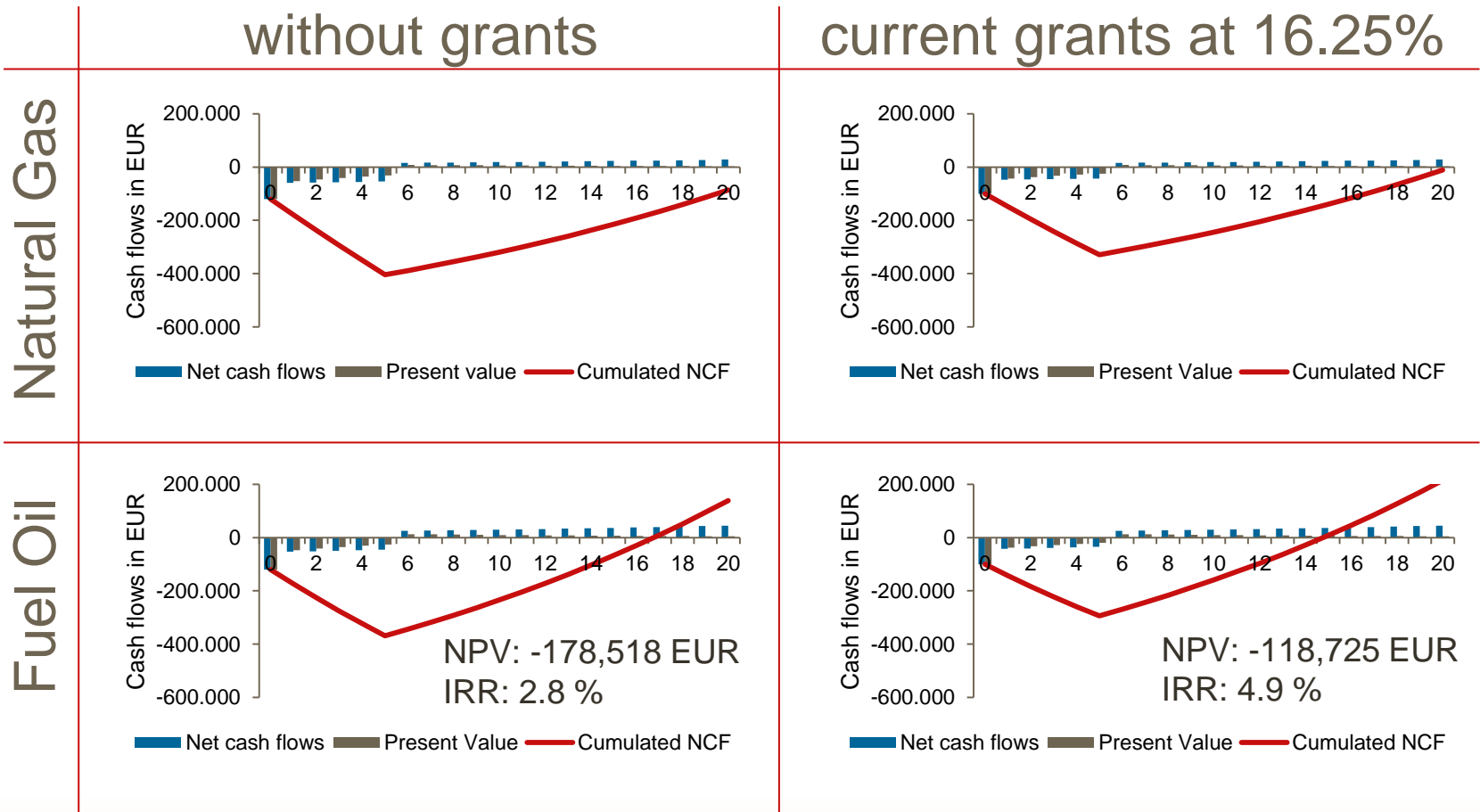
Assumptions – Cash Inflows



Input Parameter	Unit	FPC	ETC	Concentrating
Irradiation (G_{tilt} , DNI)	kWh/m ² /a	2050	2050	2000
System efficiency	% of G	45	40	40
Annual degradation	%/a	0.5		
Utilization rate	% of Q_{sol}	75	75	90
Boiler efficiency	%	85		

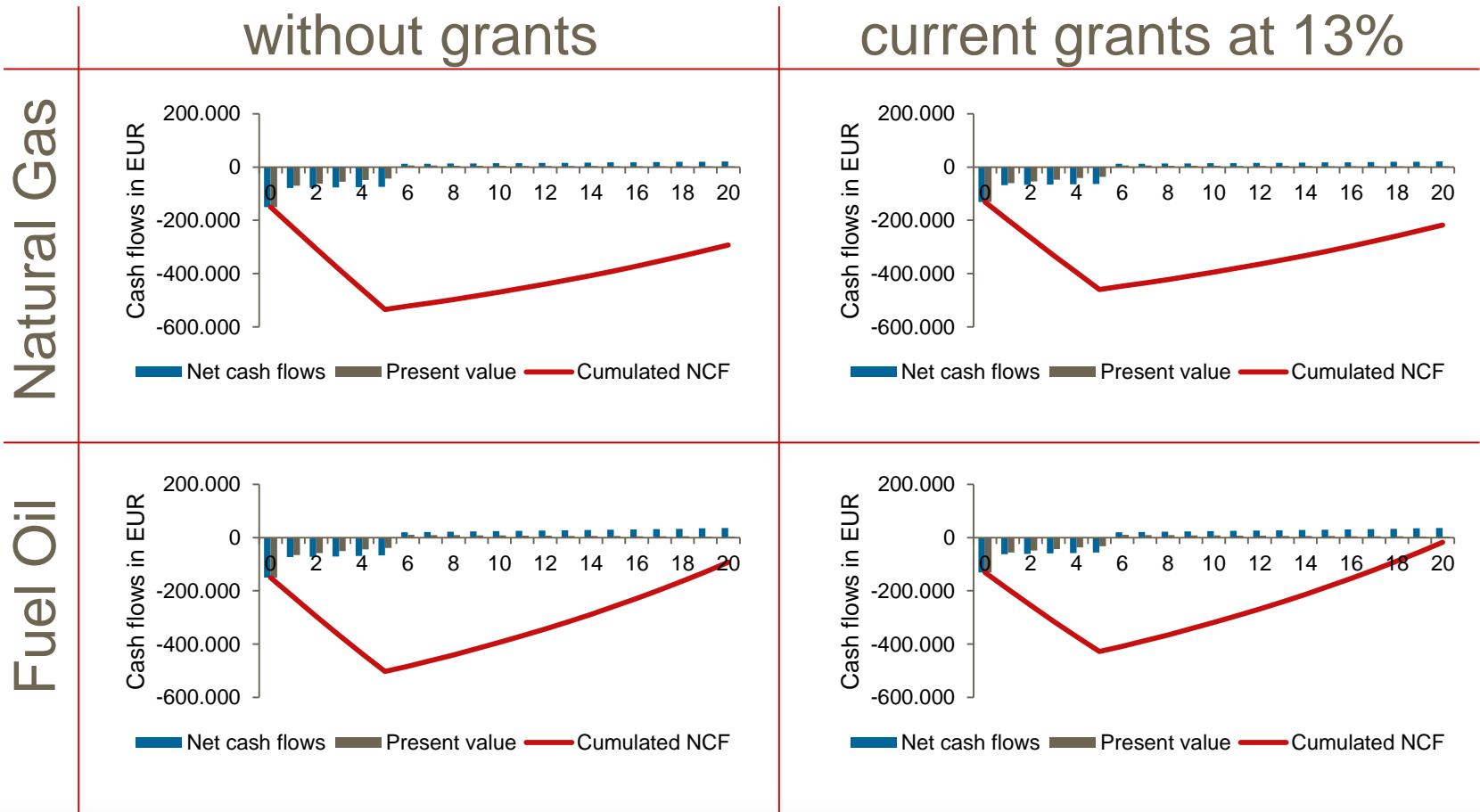


3. Economics of Reference Case Flat Plate Collectors



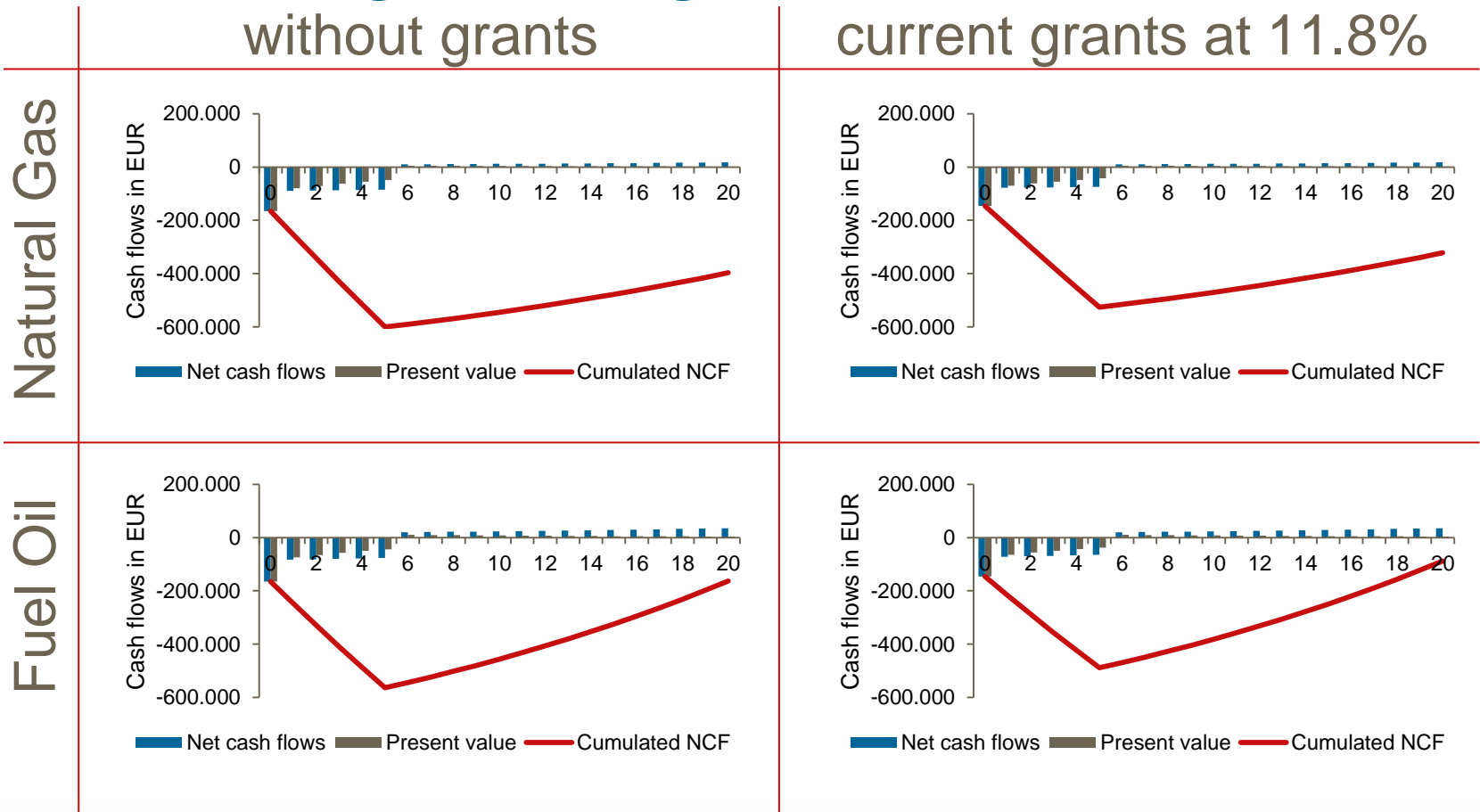


3. Economics of Reference Case Evacuated Tube Collectors



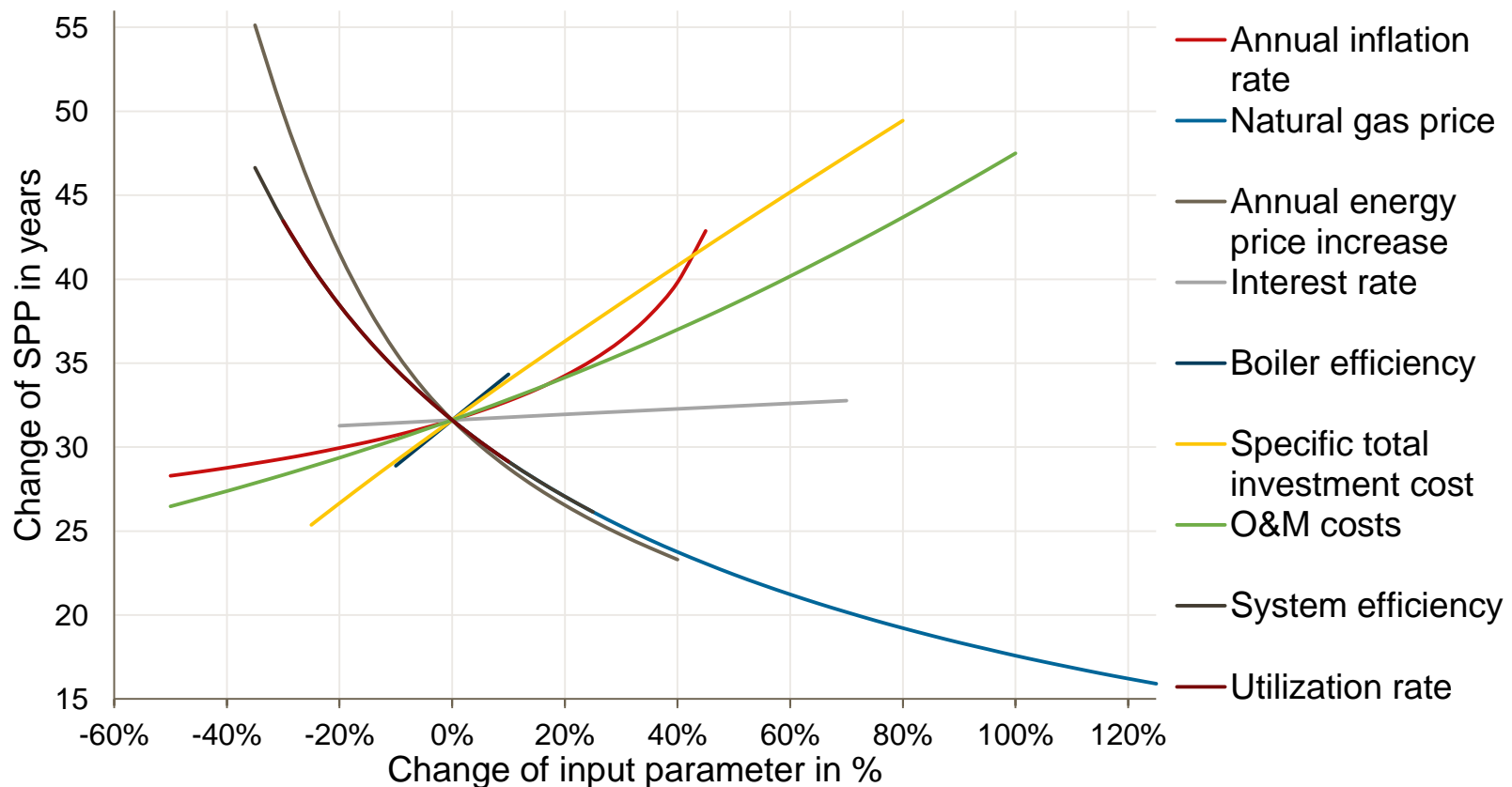


3. Economics of Reference Case Concentrating Technologies





4. Sensitivity Analysis Concentrating Technologies





5. Effects of Policy Instruments

Grants

Value	Unit	Replaced fuel	FPC		ETC		Concentrating	
			0%	50%	0%	50%	0%	50%
SPP	a	NG	22.8	14.3	30.8	20.2	36.4	24.1
		FO	16.7	10.1	22.4	14.0	24.2	15.2
Gross Public Costs	EUR/m ²	-	0	200	0	250	0	275
Public Savings	EUR/m ²	NG	52.81		46.94		54.96	
		FO	203.99		181.33		212.28	
Net Public Costs	EUR/m ²	NG	-52.81	147.19	-46.94	203.06	-54.96	220.04
		FO	-203.99	-3.99	-181.33	68.67	-212.28	62.72

- 50% grants lead to additional public costs, but still don't reach an economic level in most cases

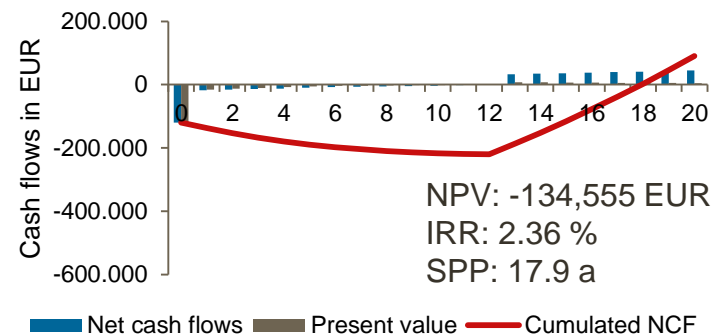
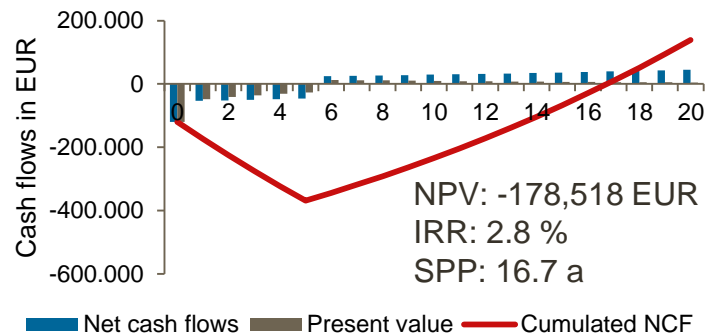


5. Effects of Policy Instruments

Soft Loans

- Interest rate: 7.0%
 - Grace period: 0 years
 - Repayment period: 5 years
-
- Interest rate: 5.5%
 - Grace period: 3 years
 - Repayment period: 12 years
- Little impact on PBP
- PBP can even be prolonged

Case: Flat plate collector, Fuel oil, no grants





5. Effects of Policy Instruments

Bonus Model

Value	Unit	FPC	ETC	Conc	FPC	ETC	Conc	FPC	ETC	Conc
NG Bonus	EUR/kWh	0			0.015			0.04		
SPP	a	22.8	30.8	36.4	15.4	21.7	25.5	9.2	13.2	15.3
Net Public Costs	EUR/m ²	-52.81	-46.94	-54.96	58.24	51.77	60.61	243.33	216.29	253.22
FO Bonus	EUR/kWh	0			0.035			0.05		
NPV	EUR	-178,518	-307,434	-357,846	59,829	-95,570	-151,150	161,977	-4,772	-62,566
IRR	%	2.80%	-1.70%	-2.83%	14.80%	7.66%	5.82%	20.41%	11.50%	9.27%
SPP	a	16.7	22.4	24.2	8.6	12.1	13.5	7.0	9.9	11.0
Net Public Costs	EUR/m ²	-203.99	-181.33	-212.28	55.13	49.00	57.37	166.18	147.72	172.94

- Bonus payments of 4 ct/kWh can be economic in some cases, but lead to high public costs



6. Annex



Gas Price

TARIFS DU GAZ NATUREL EN MOYENNE PRESSION à compter du 1^{er} Mai 2014 (HORS TAXES)

TARIF MOYENNE PRESSION	DEBIT SOUSCRIT (th/h)	REDEVANCE (**)		PRIX D'ENERGIE (*-) (mill/th)
		D'ABONNEMENT (DT/ab-mois)	DE DEBIT (mill/th-h-mois)	
MP1	1 000 à 4 000	20	200	37,6
MP2	6 000 à 30 000	20	325	37,1
MP Cimentier (Ciment gris)	1 000 à 30 000	20	325	58,0

(*-) La TVA est à appliquer au taux de 18% sur les redevances et les prix d'énergie hors taxes.

AUGMENTATION DU DEBIT SOUSCRIT :

En cas d'augmentation du débit souscrit (avec ou sans changement de tarif), le coût de renforcement est calculé sur le débit supplémentaire

ABREVIATIONS :

mill = millime tunisien , DT = Dinar tunisien , ab = abonnement , th = thermie , h = heure

TVA = taxe sur la valeur ajoutée

Pressure	Consumption				Price				Conversions		
	th/month	th/h			Tariff in mill/th	Tariff in mill/kWh	Average in mill/kWh	Average in EUR cents/kWh			Average in EUR cents/kWh (incl. VAT)
Medium		1000	to	4000	37.6	32.34	32.12	1.385	1.634	th/kWh	0.86005065
		6000	to	30000	37.1	31.91				mill/EUR cent	23.2
High*		10000	to	30000	32.0					VAT	18%
	<	20000000		<	30000	35.0					
	>	20000000		<	30000	47.5					

*only 23 industries obtain high pressure NG: those are power plants and heavy industries, not relevant for SHIP



Energy Subsidies and Public Savings

t		Mean cost price (increase by 1 %/a)		Industrial retail price (excl. VAT) (increase 2015-21: 10%, then 5%)		Total subsidies (mean cost-retail price)		Fuel Savings			Discounted specific public savings, NG			
		EUR cents/kWh		EUR cents/kWh		EUR cents/kWh		kWh/1000m ²			EUR/m ²			
		NG	FO	NG	FO	NG	FO	FPC	ETC	Conc	FPC	ETC	Conc	
	2012		6.45		2.15									
	2013		6.51											
0	2014	3.10	6.58	1.38	2.28	1.72	4.30							
1	2015	3.13	6.65	1.52	2.51	1.61	4.14	813,971	723,529	847,059	12.09	10.75	12.58	
2	2016	3.16	6.71	1.67	2.76	1.49	3.95	809,901	719,912	842,824	10.25	9.11	10.67	
3	2017	3.19	6.78	1.84	3.03	1.36	3.74	805,851	716,312	838,609	8.54	7.60	8.89	
4	2018	3.23	6.85	2.02	3.34	1.21	3.51	801,822	712,731	834,416	6.95	6.18	7.24	
5	2019	3.26	6.92	2.22	3.67	1.04	3.24	797,813	709,167	830,244	5.48	4.87	5.70	
6	2020	3.29	6.98	2.44	4.04	0.85	2.95	793,824	705,621	826,093	4.10	3.64	4.27	
7	2021	3.32	7.05	2.57	4.24	0.76	2.81	789,855	702,093	821,963	3.36	2.99	3.50	
8	2022	3.36	7.12	2.70	4.45	0.66	2.67	785,905	698,583	817,853	2.69	2.39	2.80	
9	2023	3.39	7.20	2.83	4.68	0.56	2.52	781,976	695,090	813,764	2.09	1.86	2.17	
10	2024	3.42	7.27	2.97	4.91	0.45	2.36	778,066	691,614	809,695	1.55	1.38	1.61	
11	2025	3.46	7.34	3.12	5.16	0.34	2.19	774,176	688,156	805,646	1.06	0.94	1.10	
12	2026	3.49	7.41	3.28	5.41	0.22	2.00	770,305	684,715	801,618	0.62	0.55	0.65	
13	2027	3.53	7.49	3.44	5.68	0.09	1.80	766,453	681,292	797,610	0.23	0.21	0.24	
14	2028	3.56	7.56	3.61	5.97	-0.05	1.60	762,621	677,885	793,622	-0.12	-0.10	-0.12	
15	2029	3.60	7.64	3.79	6.27	-0.19	1.37	758,808	674,496	789,654	-0.43	-0.38	-0.45	
16	2030	3.63	7.72	3.98	6.58	-0.35	1.14	755,014	671,123	785,705	-0.70	-0.62	-0.73	
17	2031	3.67	7.79	4.18	6.91	-0.51	0.88	751,239	667,768	781,777	-0.95	-0.84	-0.98	
18	2032	3.71	7.87	4.39	7.25	-0.68	0.62	747,483	664,429	777,868	-1.16	-1.03	-1.21	
19	2033	3.75	7.95	4.61	7.62	-0.86	0.33	743,745	661,107	773,979	-1.35	-1.20	-1.40	
20	2034	3.78	8.03	4.84	8.00	-1.06	0.03	740,026	657,801	770,109	-1.51	-1.34	-1.57	
											52.81	46.94	54.96	



System Costs

Plant (Country)	Process (Temp. in °C)	Col- lector	Specific system costs in EUR/m ²	Aperture area in m ²	Year	PP (incl. subsidy)	Source
Benetton Textiles (TUN)	Dyeing (60)	FPC	345	869	2014	n.a.	Frein et al. (2014, p. 1162)
Göss Brewery (AUT)	Brewing (80)	FPC	815	1375	2013	10 (50%)	Mauthner et al. (2013)
LEITL Con-crete (AUT)	Drying (45)	FPC	1,045	287	2010	n.a.	SO-PRO (2010b)
Montesano Meat (ESP)	Washing (40-45)	FPC	763	229	2011	7 (33%)	SO-PRO (2014)
Merl Food (DEU)	Washing (60)	FPC	575	517	2010	9 (30%)	SO-PRO (2010a)
Steinbach Metal (DEU)	Preheating (60-80)	ETC	600	400	2008	7 (50%)	ESV (2011)
Hustert Gal-vanik (DEU)	Heating Baths (80)	ETC	724	221	2011	(30%)	SO-PRO (2014) ESV (2011)
El Nasr Pharma (EGY)	Steam (175)	PTC	1025	1900	2003	n.a.	Cottret (2011)
Emmy Dairy (CHE)	Steam (140- 180)	PTC	957	627	2012	10 (50%)	Minder (2014)
Crema Dairy (CHE)	Superheated water (125- 170)	PTC	1205	581	2013	10 (50%)	Minder (2014)



Solar Irradiation

GHI in kWh/m ² /a			DNI in kWh/m ² /a			Source
North	Center	Average	North	Center	Average	
1743	1891	1817	1853	2040	1947	Solar Med Atlas
1719	1820	1770	1814	1888	1851	SoDa, 2005
1856	2047	1952	2113	2311	2212	PVGIS (optimal inclination angle: 31°)
(2112)	(2332)	(2222)				
-	-	-	1800	2250	2025	Trieb et al.
1716	-	-	-	-	-	El Ouderni et al.
1759	1919	1839	1895	2122	2009	Total Average (Irradiation at optimal angle)
(1988)	(2168)	(2078)				



Detailed Economics

	Unit	FPC			ETC			Concentrating		
Grant rate	%	0	16.25	50	0	13	50	0	11.8	50

Natural Gas Replacement

NPV	EUR	- 249,571	- 189,777	- 65,591	- 370,592	- 310,799	- 140,617	- 431,787	- 372,086	- 178,815
IRR	%	-1.99%	-0.28%	5.45%	-6.34%	-5.19%	-0.13%	-8.50%	-7.53%	-2.75%
SPP	a	22.8	20.4	14.3	30.8	28.5	20.2	36.4	33.9	24.1

Fuel Oil Replacement

NPV	EUR	- 178,518	- 118,725	5,462	- 307,434	- 247,641	- 77,460	- 357,846	- 298,145	- 104,875
IRR	%	2.80%	4.87%	12.19%	-1.70%	-0.35%	5.83%	-2.83%	-1.66%	4.32%
SPP	a	16.7	14.8	10.1	22.4	20.5	14.0	24.2	22.3	15.2



Sensitivity Analysis - Ranges

Input parameter	Unit	Minimum		Reference	Maximum	
		absolute	relative	absolute	absolute	relative
Annual inflation	%/a	2	45%	4.4	6.5	148%
Natural gas price	EUR/kWh	-	-	0.0163	0.037	227%
Annual energy price increase	%/a	1	14%	7	10	143%
Interest rate	%	5.5	79%	7	12	171%
Boiler efficiency	%	75	88%	85	95	112%
Specific Total Investment Costs	EUR/m ²	400	73%	550	1000	182%
O&M	% of C _{inv}	0.75	50%	1.5	3	200%
System efficiency	% of G	25	63%	40	50	125%
Utilization rate	% of Q _{sol}	60	67%	90	100	111%