HOTCO2: alternatief voor de WKK en ketel in de tuinbouw

Inschatting van de potentie van efficiëntere productie van warmte en CO2 met het HOTCO2 systeem in de tuinbouwsector

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In opdracht van Productschap Tuinbouw

Opzet van dit document

- Inleiding: wat en waarom
- Hoe hebben we het aangepakt?
- Resultaten
- Conclusies

Uitgevoerd door

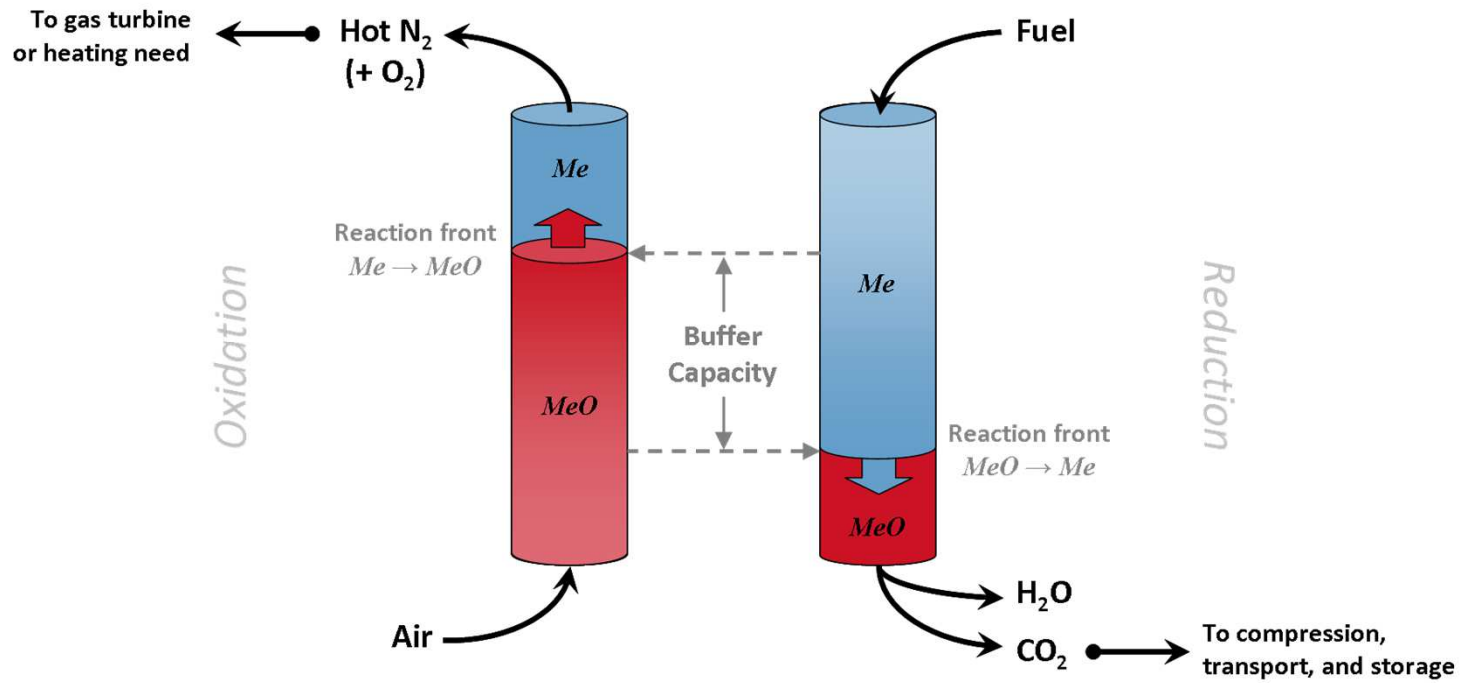
in opdracht van

Ministerie van ELI

Beschrijving HOTCO2

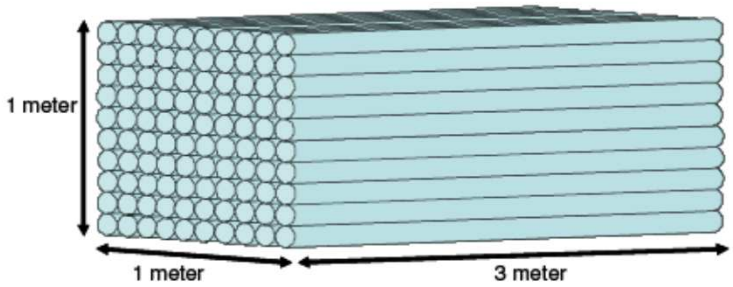
- HotCO2 is a new type of combustion system that would replace a ketel or WKK
- The air and fuel are separated so that two different streams are produced
  - One stream of hot depleted nitrogen (oxygen from the air is consumed)
  - One stream of CO2 + water from the fuel consumption
- CO2 and heat can be supplied separately and independently

Technology (Chemical Looping Combustion)



- Ability to go to elevated pressures
- Independent heat and CO_2 production
- No emissions of NO_x or ethylene
- Tailored operation
- Modular design allows for ease of scale up
- Still to investigate:
  - –Heat management
  - –Degradation of Me/MeO materials

Ontwerp van systeem



	Length (m)	Width, Height (m)	Material volume (m^3)	Heat production (MJ/hr)	CO_2 production (kg/hr)
Column	3	0.1, 0.1	0.024	0.22	0.56
Module	3	1, 1	2.4	22.9	56
Container	14	1.5, 2.6	38.4	350	896

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Aanpak voor analyse

- Voor vier verschillende teelten zijn de gem. jaarlijkse energie kosten per m^2 in kaart gebracht door gebruik van WKK en ketel of alleen ketel.
- Alle relevante aspecten zoals investeringskosten, elektriciteit in- en verkoop, gas inkoop, CO2 inkoop, etc. zijn daarbij meegenomen.
- Vervolgens zijn de kosten berekend op basis van een HOTCO2 systeem en vergeleken met een WKK en ketel of alleen ketel.

Case	Glasopp. (ha)	Warmte (MJ/m2)	Electriciteit (kWh/m2)	CO2 (kg/m2)
Tomaat	8	1250	7	60
Potplant	2	1213	9	14
Gerbera	2	947	85	50
Tomaat HNT	8	1055	7	59

HNT: Het Nieuwe Telen, sterk gereduceerde warmtevraag

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Detailed analysis

- HotCO2 can be used to give heat requirement or CO_2 need
  - When using CO_2 following, separate ketel or WKK is needed to supply extra heat
- Dosing of CO_2 with WKK and ketel systems
- Calculations with WKK and ketel only done with yearly average heat and CO_2 requirements

- Examples on next slides

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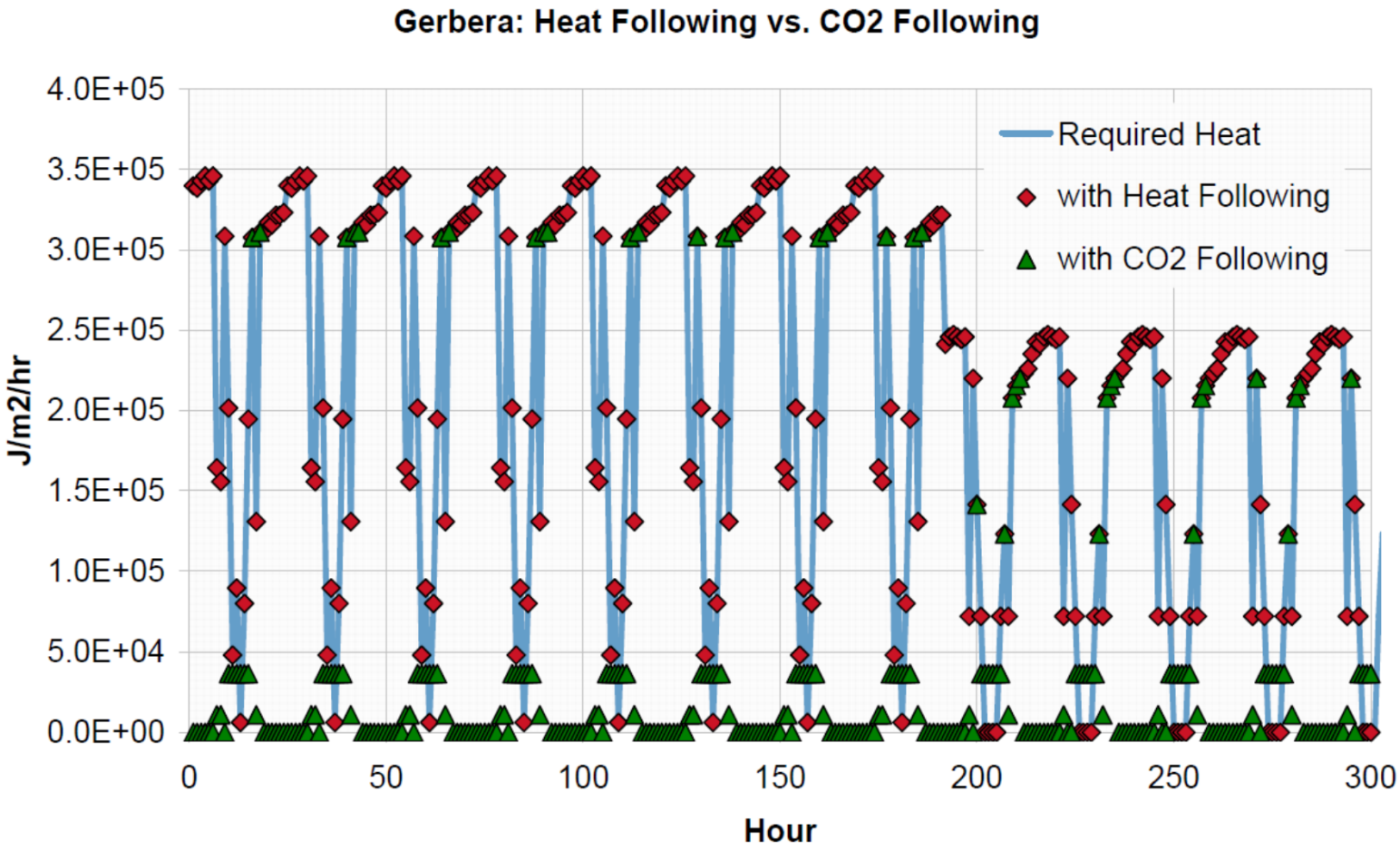
Heat vs. CO2 Following

Heat requirement



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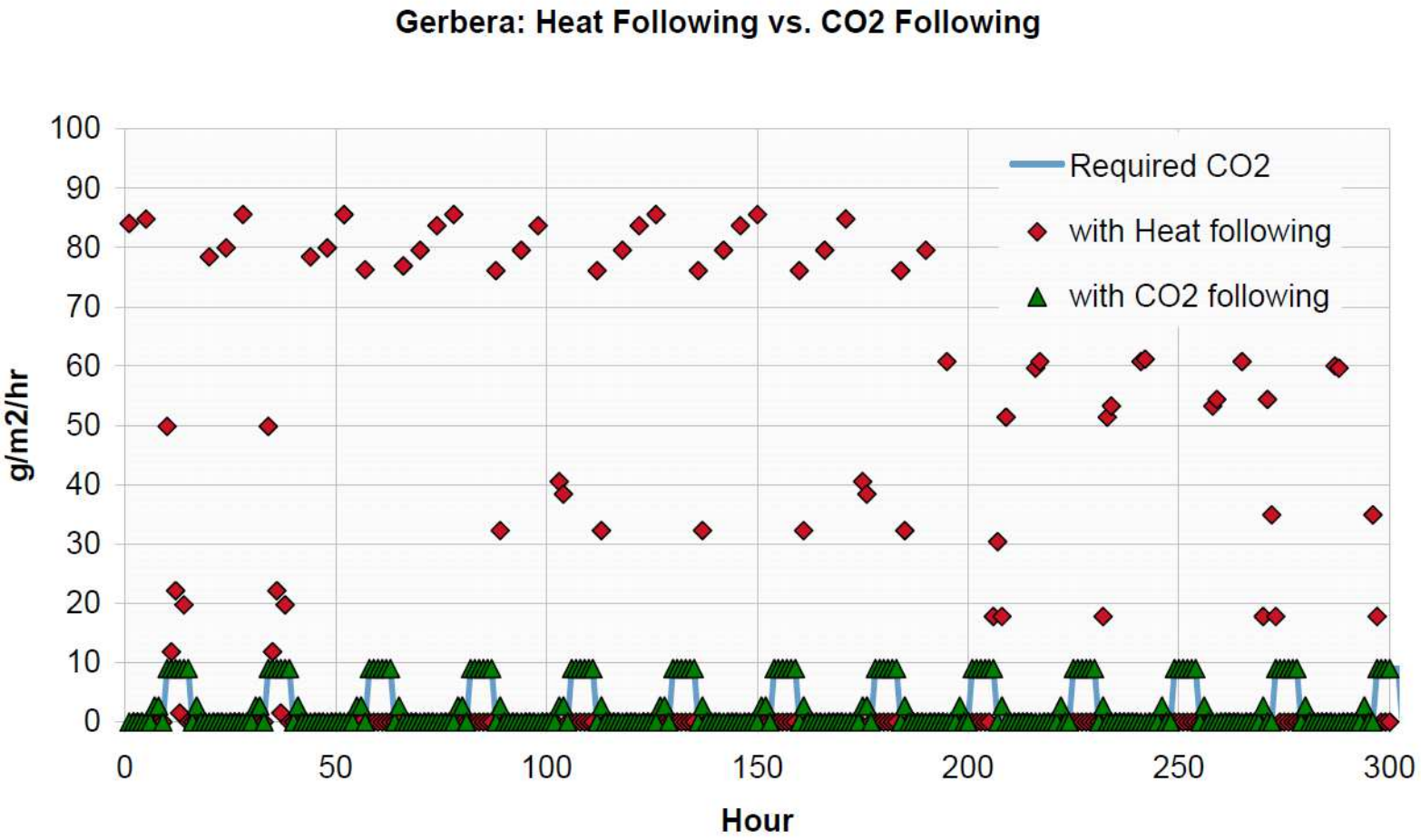
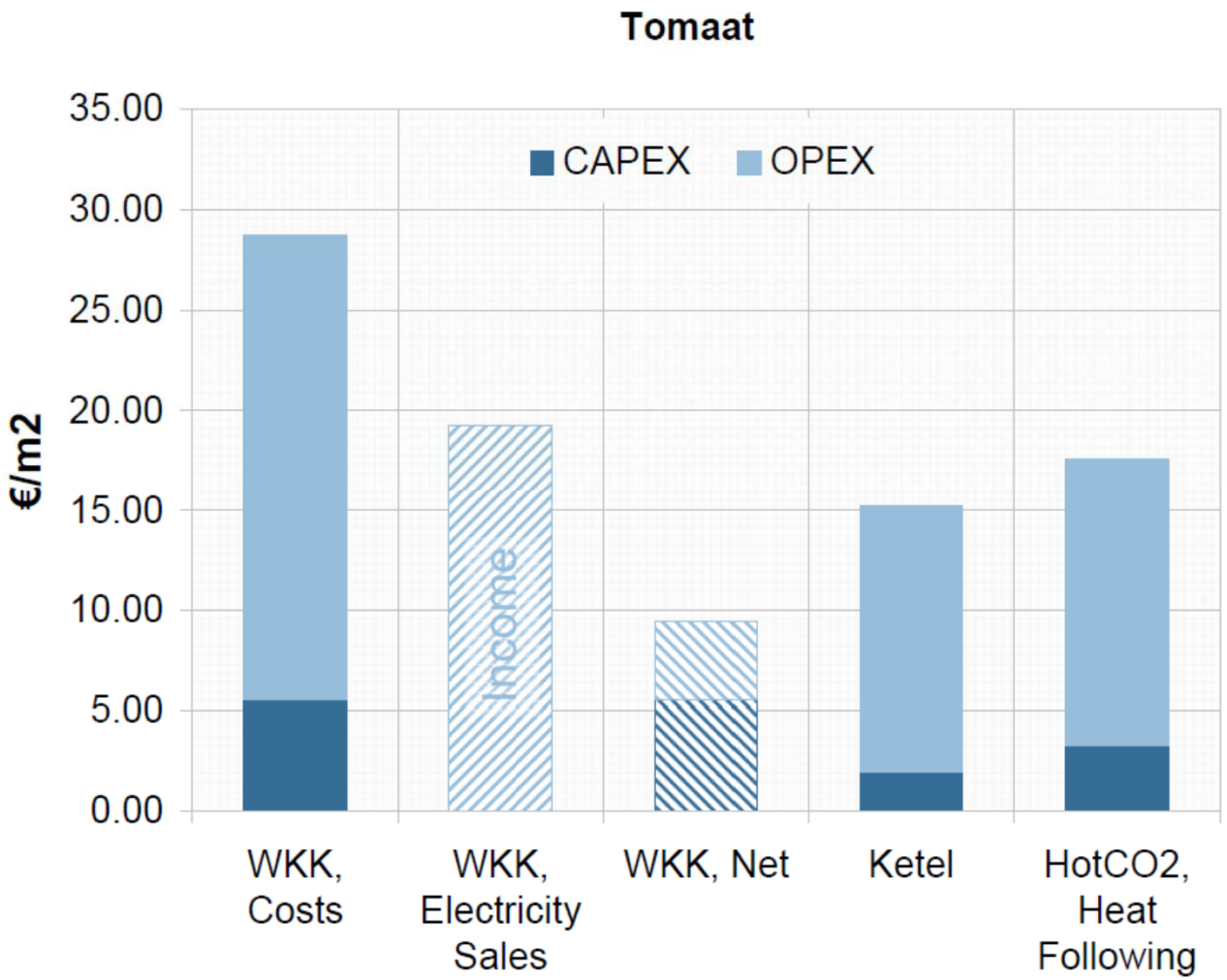
Heat vs. CO2 Following

CO_2 requirement

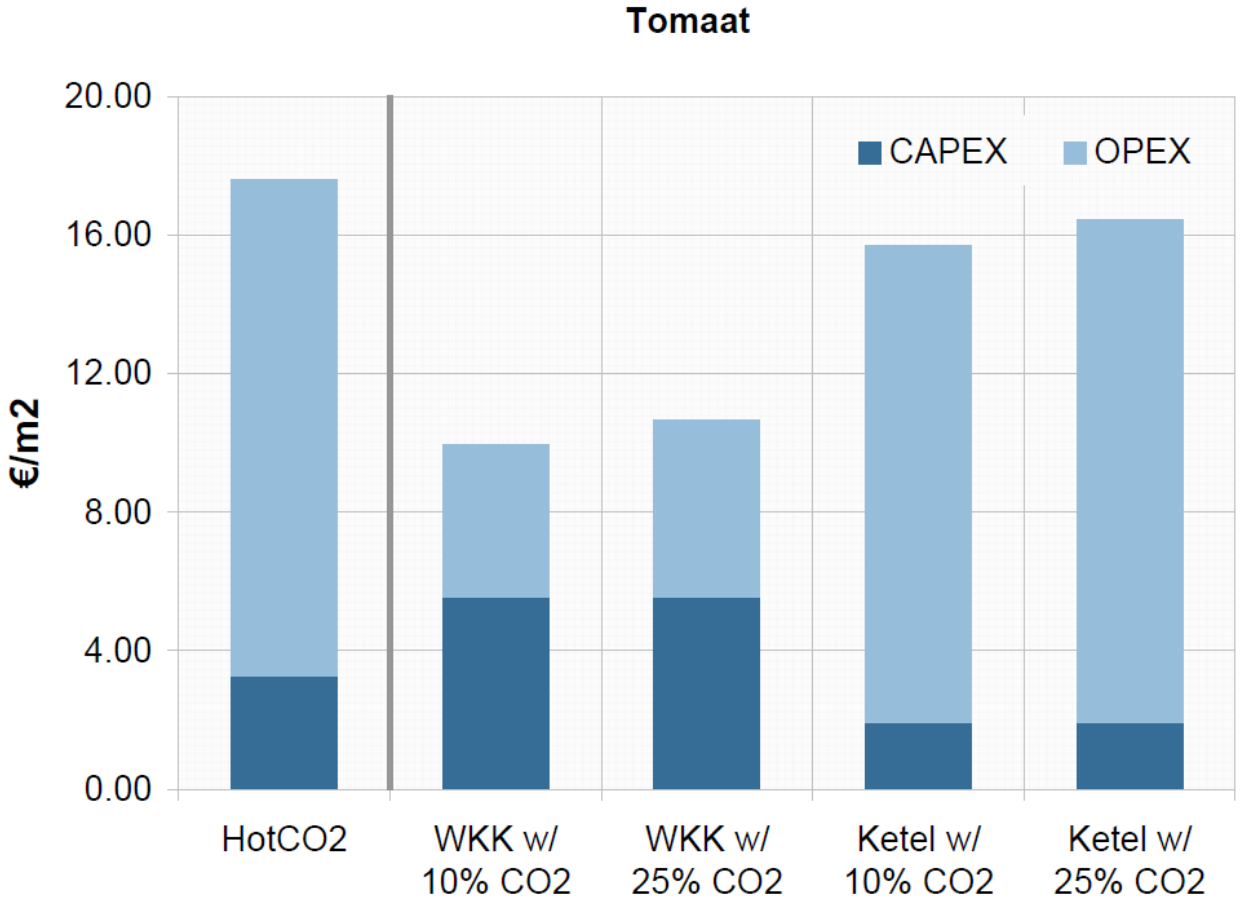


Results with HotCO2 Heat Following



- No electricity production considered with HotCO2, but should be possible with integration

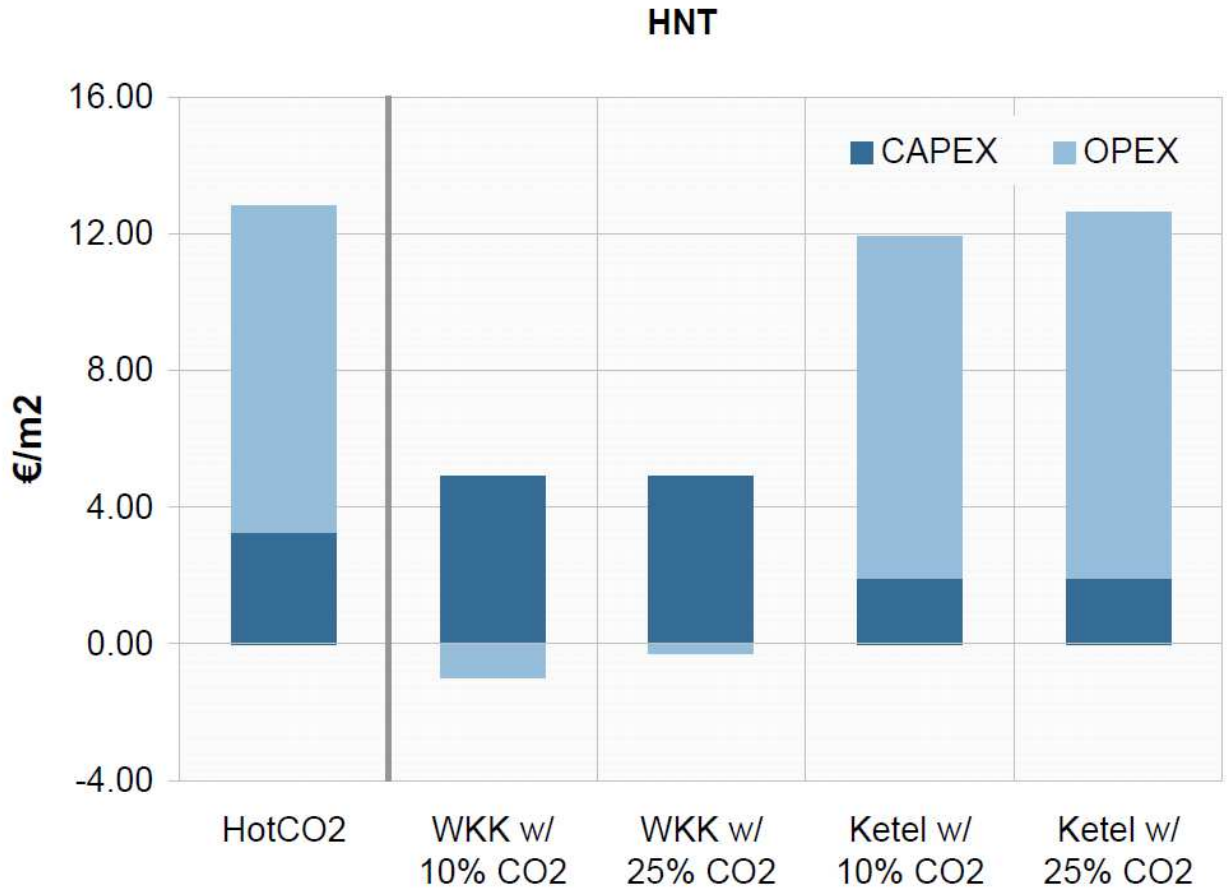
Results with heat following
Effect of CO_2 purchasing



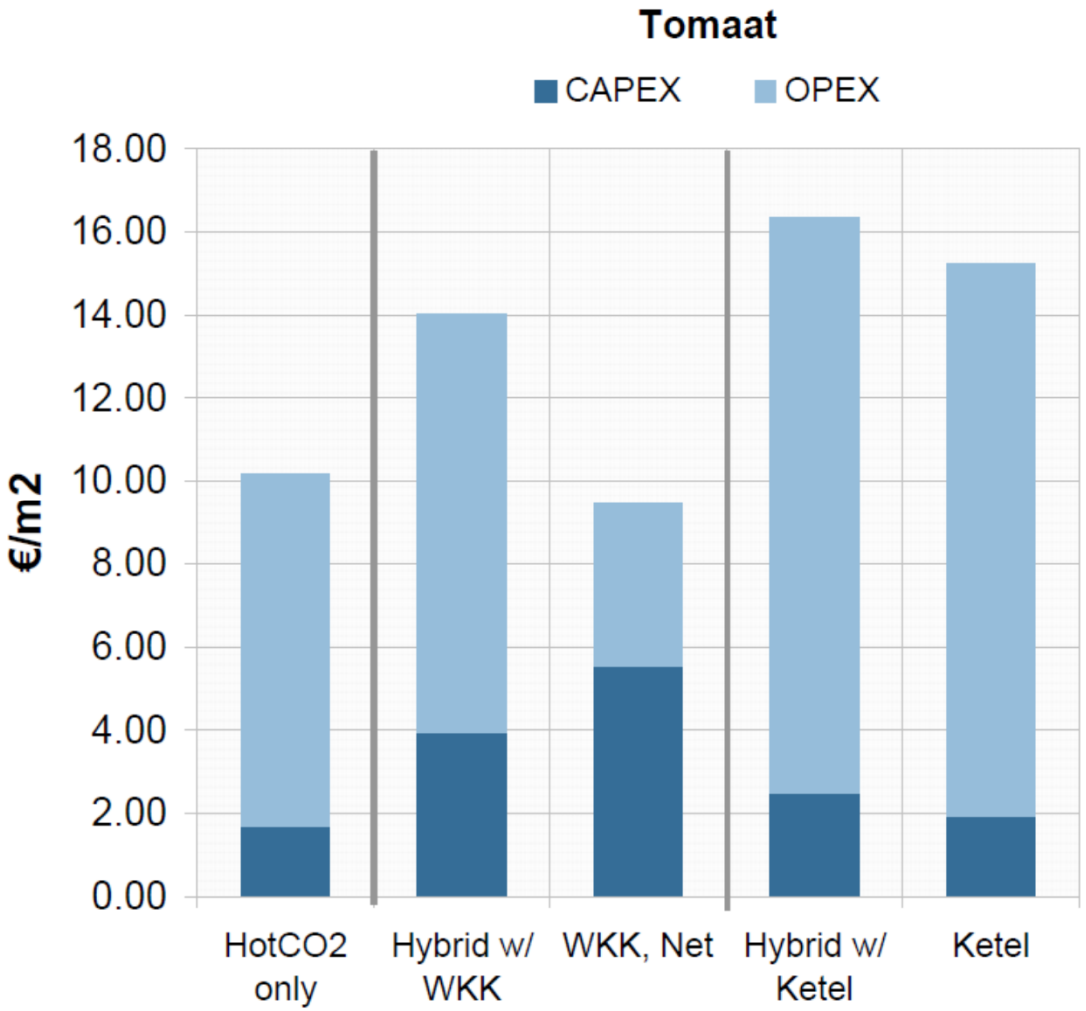
- If excess CO_2 is sold with HotCO2 system, income is 2.45 €/m^2 per year

Results with heat following

Effect of CO_2 purchasing



Results with CO_2 following



- HotCO2 system provides 88% of the CO2 required
- Hybrid system needed to fulfill heat requirement

Samenvatting en Conclusies

De Business Case

- Een **Business Case** berekening is uitgevoerd waarin HotCO2 wordt vergeleken met een WKK en een Ketel voor de gewassen Tomaat, Gerbera, Potplant en Tomaat HNT
- Studie is uitgevoerd in samenwerking met DLV
- De waarden voor de performance van HotCO2 zijn gebaseerd op meetdata verkregen uit de testopstelling bij TNO. Deze studie geeft stand van zaken voor de **huidige** technologieontwikkeling weer.

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Stand van zaken

		Investerings-kosten [€]*	Operationele kosten [€/jr]*
Ketel + warmtebuffer	1 ha	60.000	130.000
HotCO2	1 ha	60.000	140.000
WKK	1 ha	190.000	230.000 + (-190.000)

** Op basis van tomaat warmte en CO2 vraag*

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Conclusie

- Investering en operationele kosten voor HotCO2 zijn vergelijkbaar met die van een ketel inclusief warmtebuffer
- HotCO2 kan **nu** nog niet de strijd aan met een WKK. Electriciteits terugwinning is nog niet meegenomen in HotCO2

Voordelen van HotCO2

- HotCO2 produceert **zuivere CO_2**. Er is geen ethyleen productie en door de lage temperaturen (700- 800°C) is het onmogelijk om NO_x te vormen.
- Het HotCO2 systeem is **modulair** op te bouwen en te opereren.
- De buffercapaciteit van HotCO2 maakt het mogelijk om **piektijden** op te zoeken of te vermijden.
- Met HotCO2 is makkelijk de koppeling met **biogas** te maken.

Toekomstig onderzoek

Het vervolg van de TNO HotCO2 ontwikkeling zal zich richten op de volgende punten:

- Experimentele validatie van de koppeling van HotCO2 met **biogas.**
- Theoretische uitwerking van electriciteitswinnings mogelijkheden met HotCO2 in vergelijking met WKK. **Electriciteitswinning** met HotCO2 te realiseren.
- Optimalisatie van de huidige performance

Einde

- Questions?

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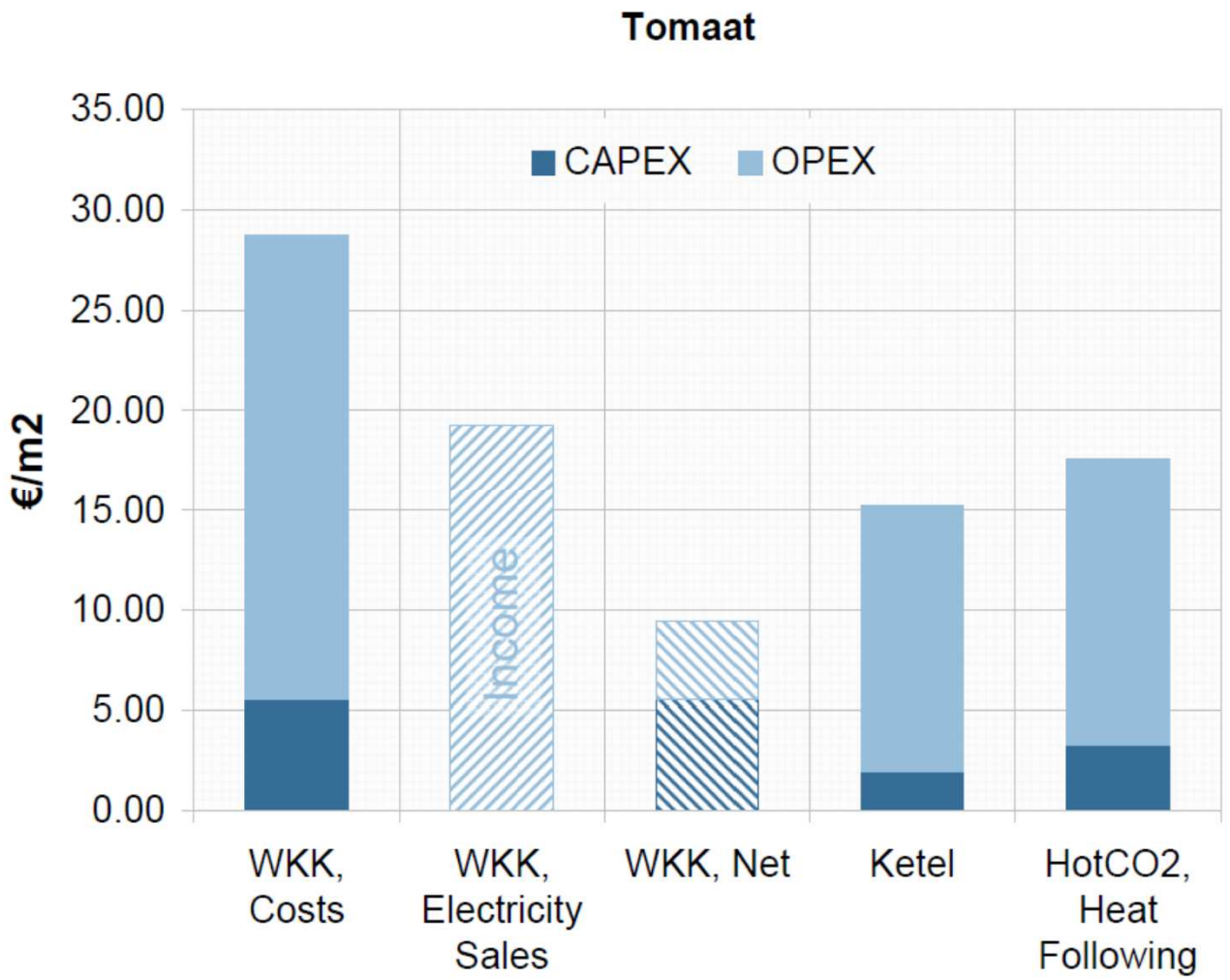
Complete set of results

Complete results: Heat Following



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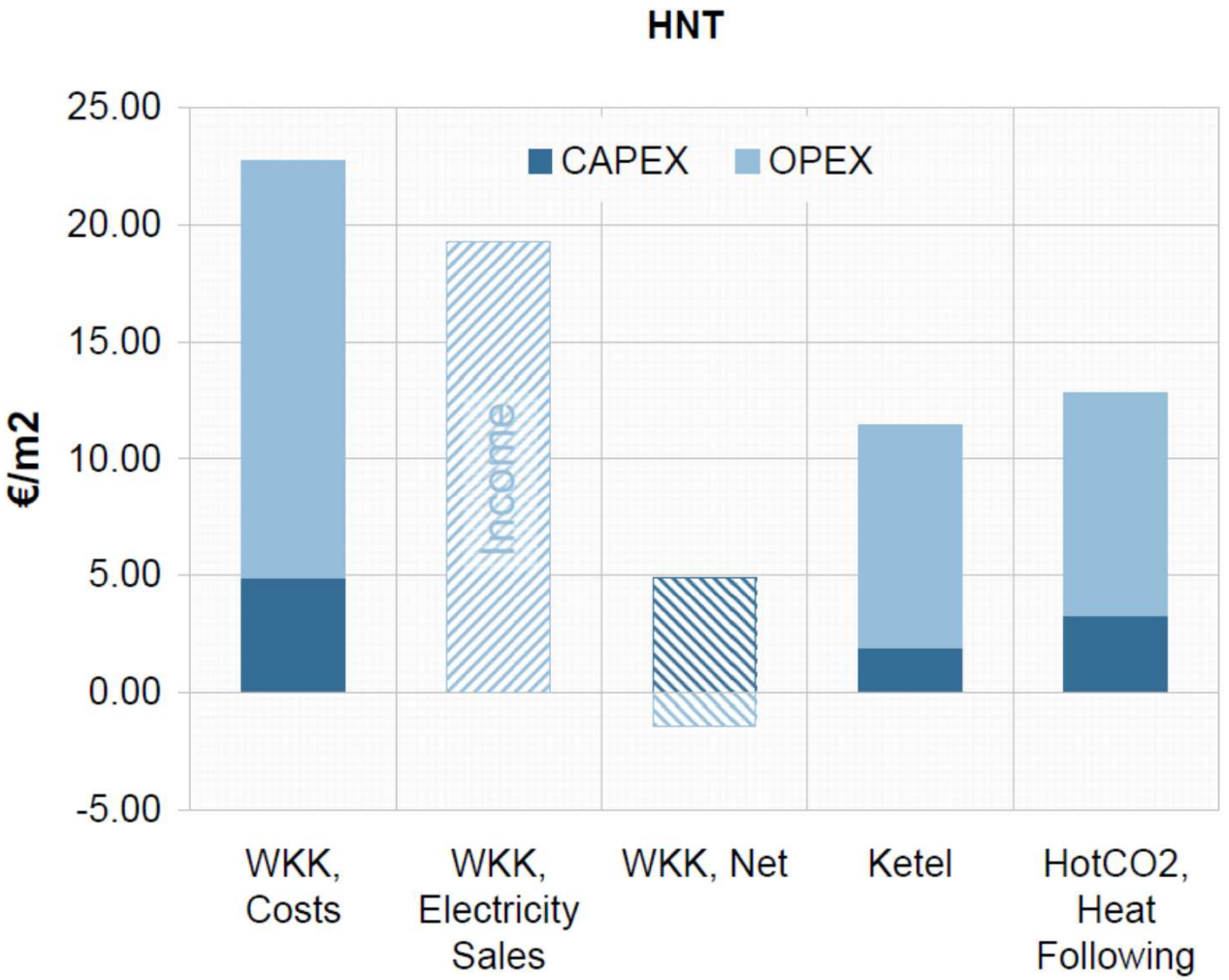
Complete results: Heat Following



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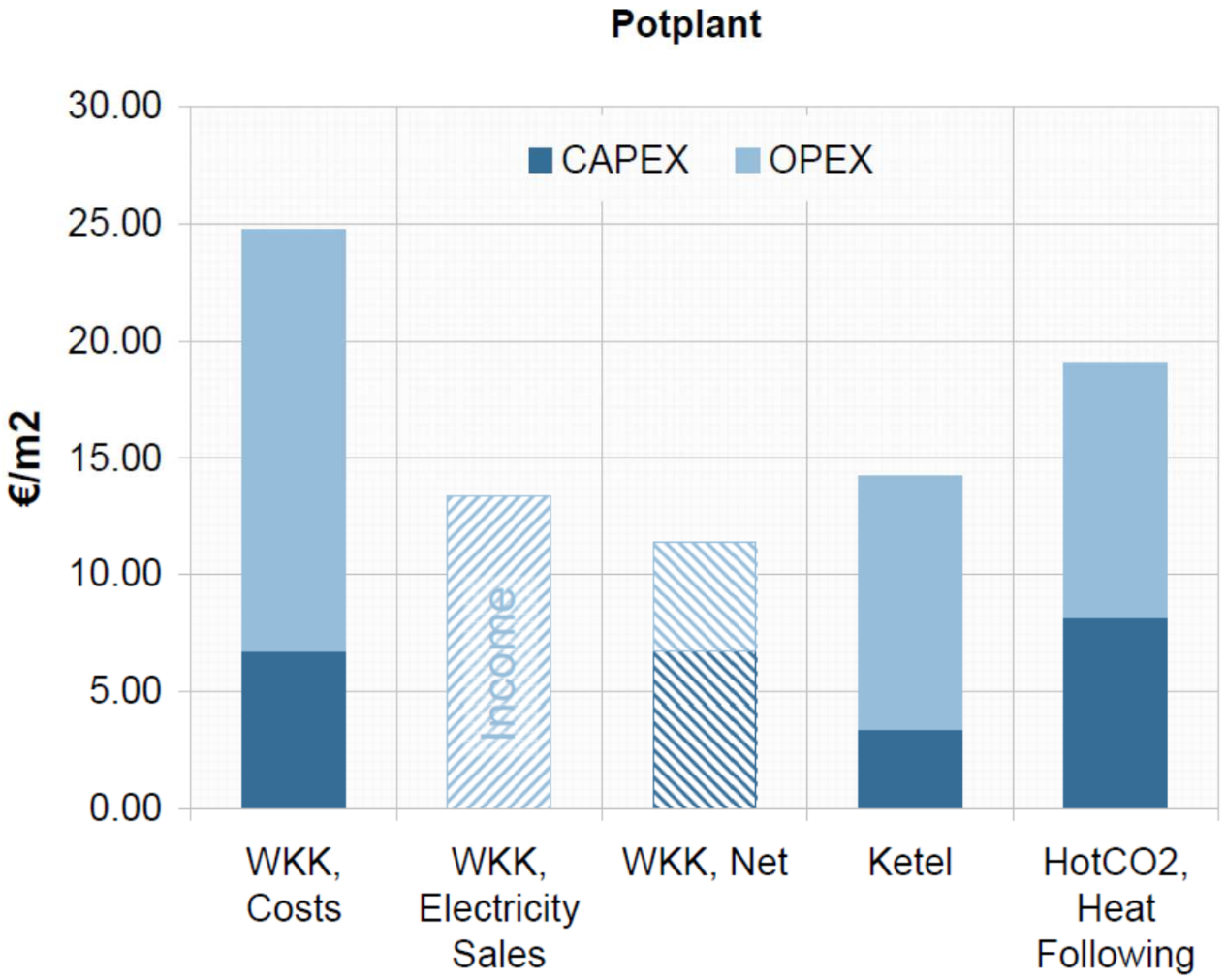

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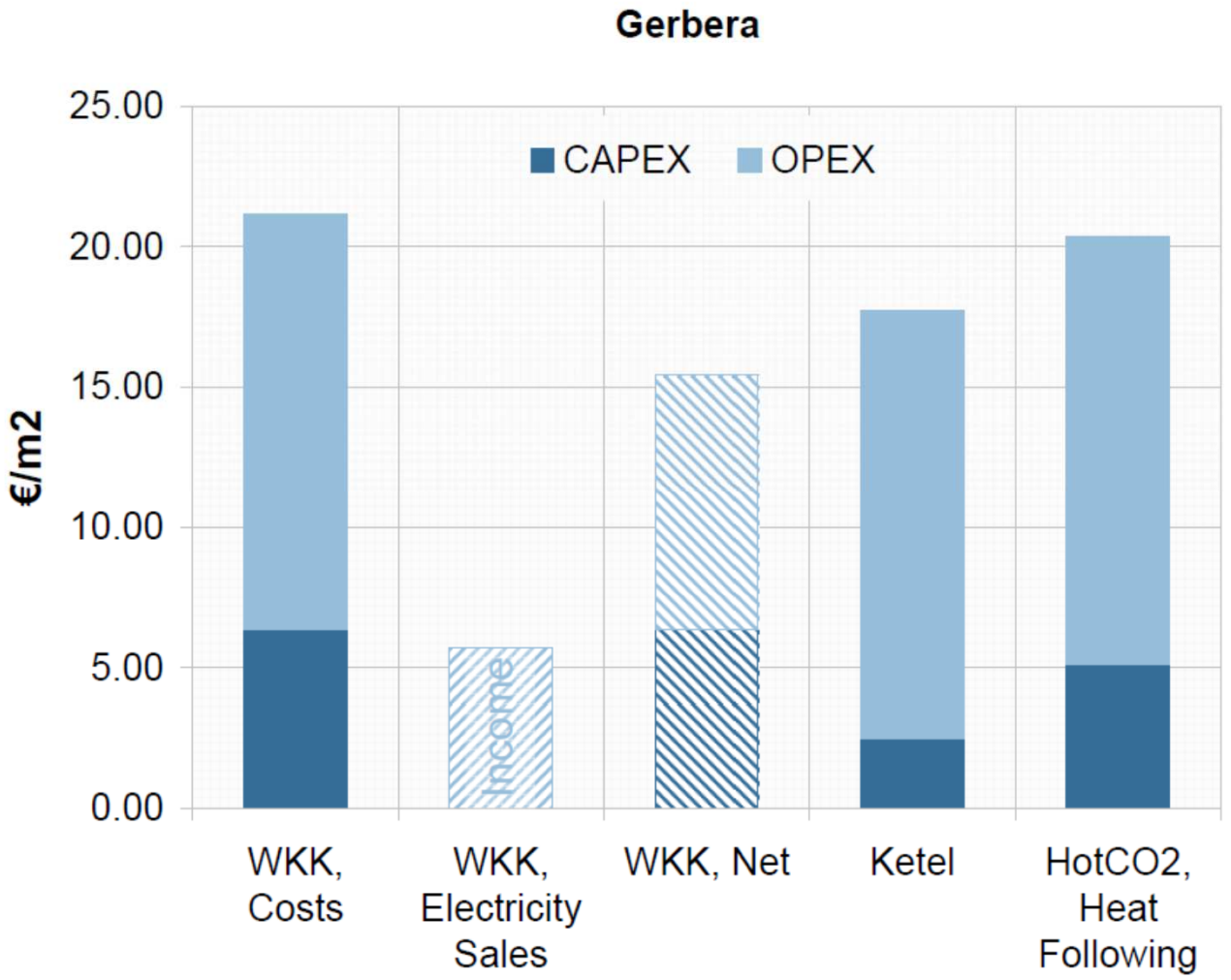
Complete results: Heat Following



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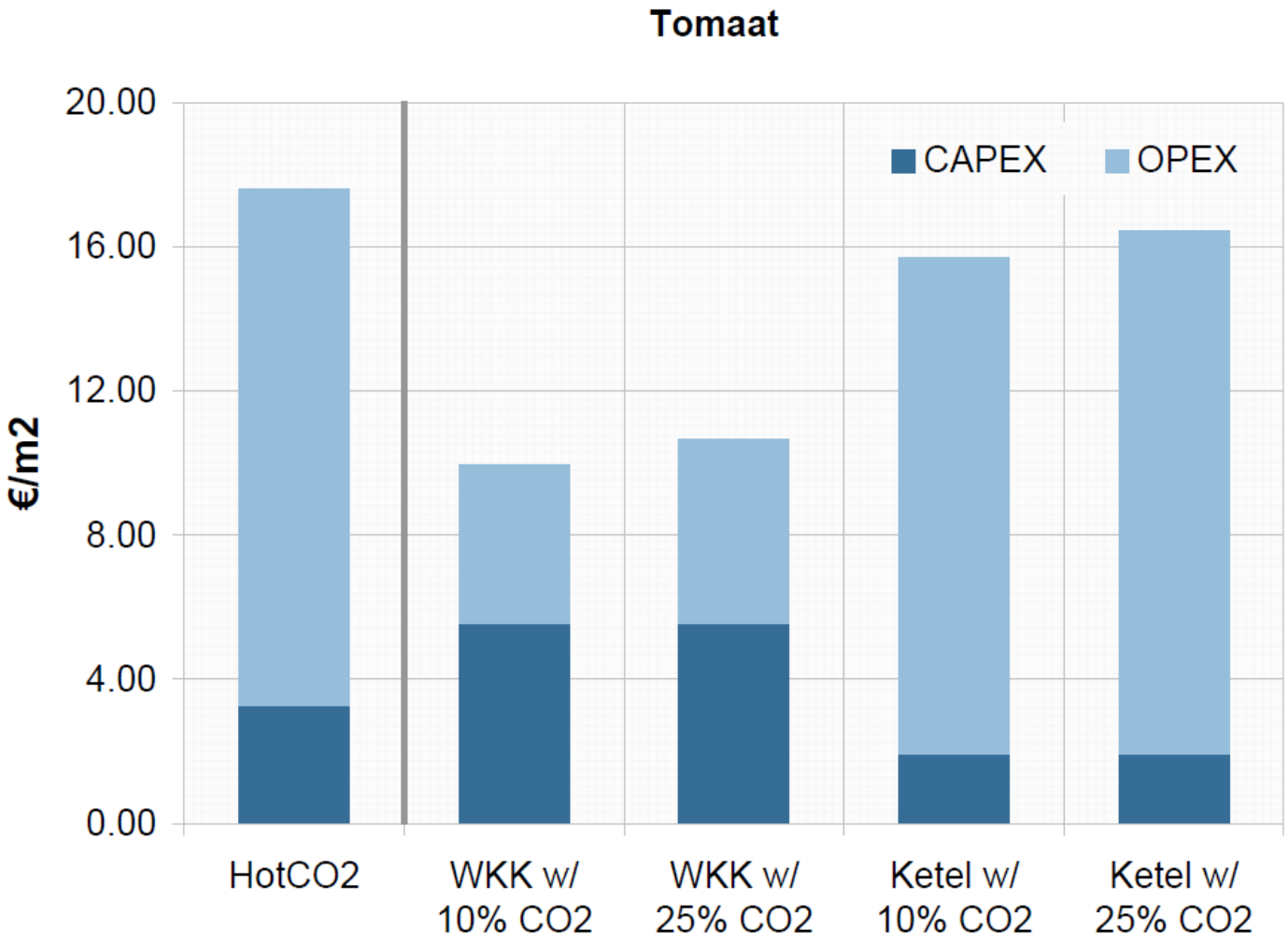
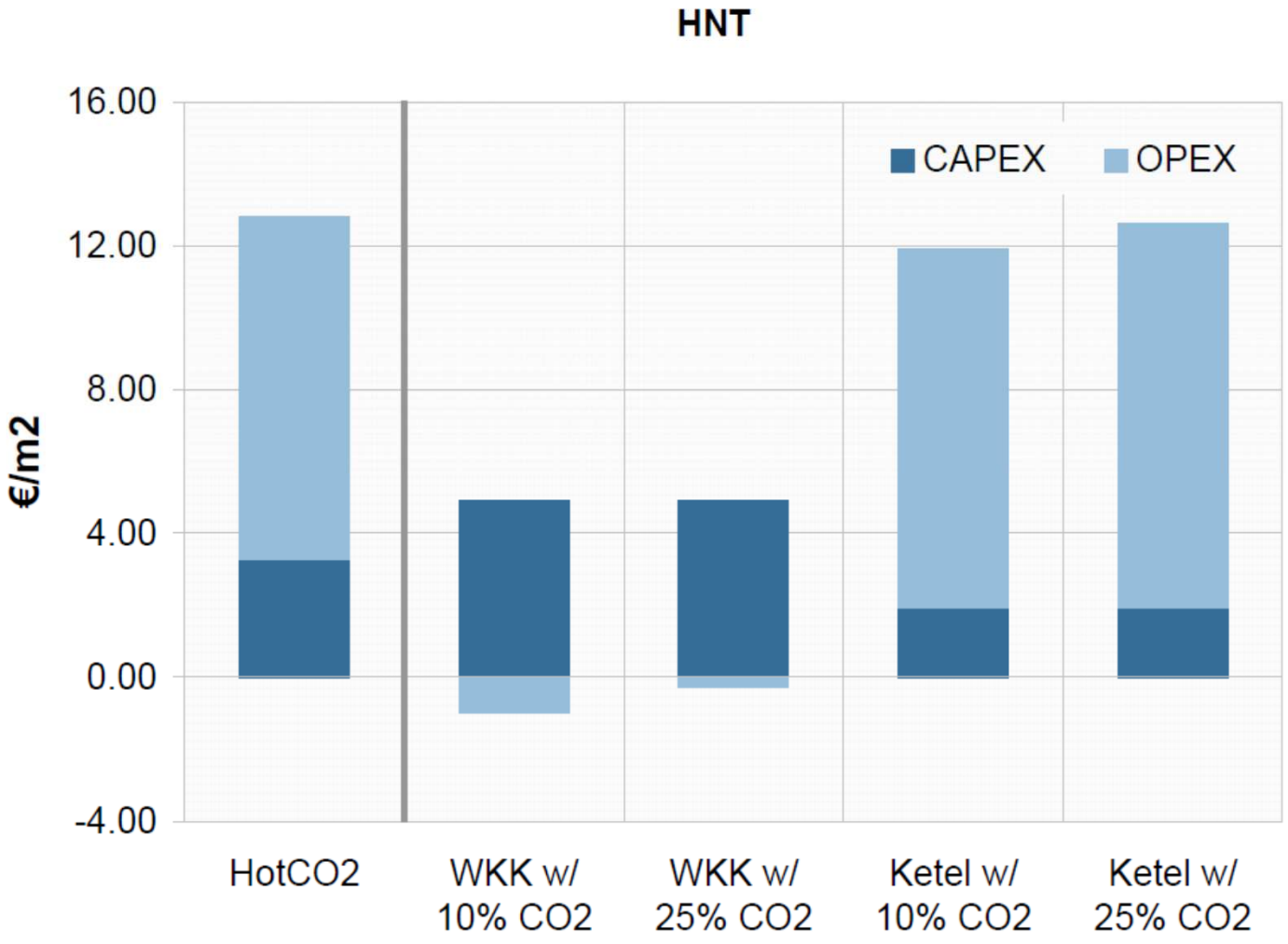
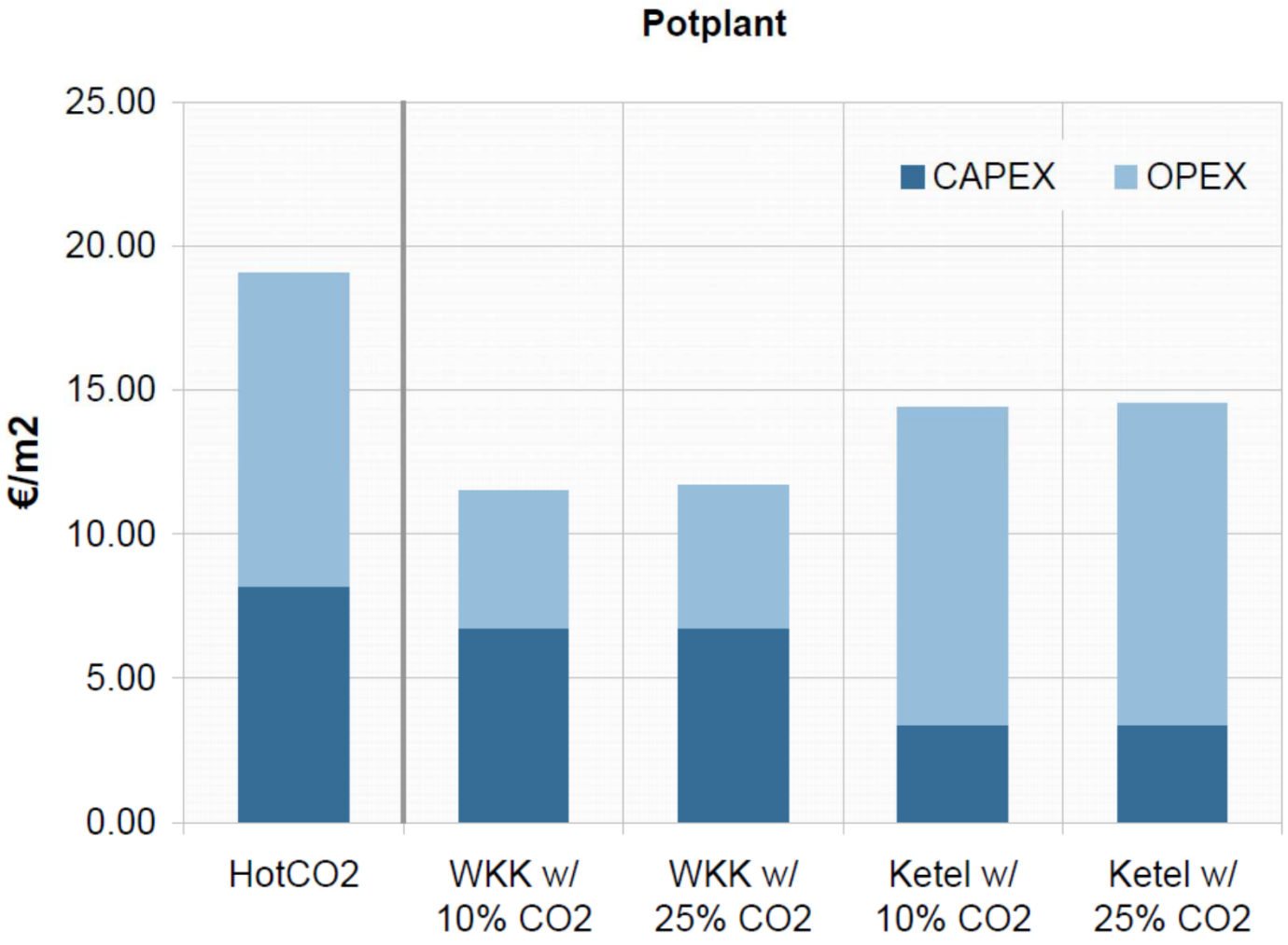
Complete results: CO_2 purchasing



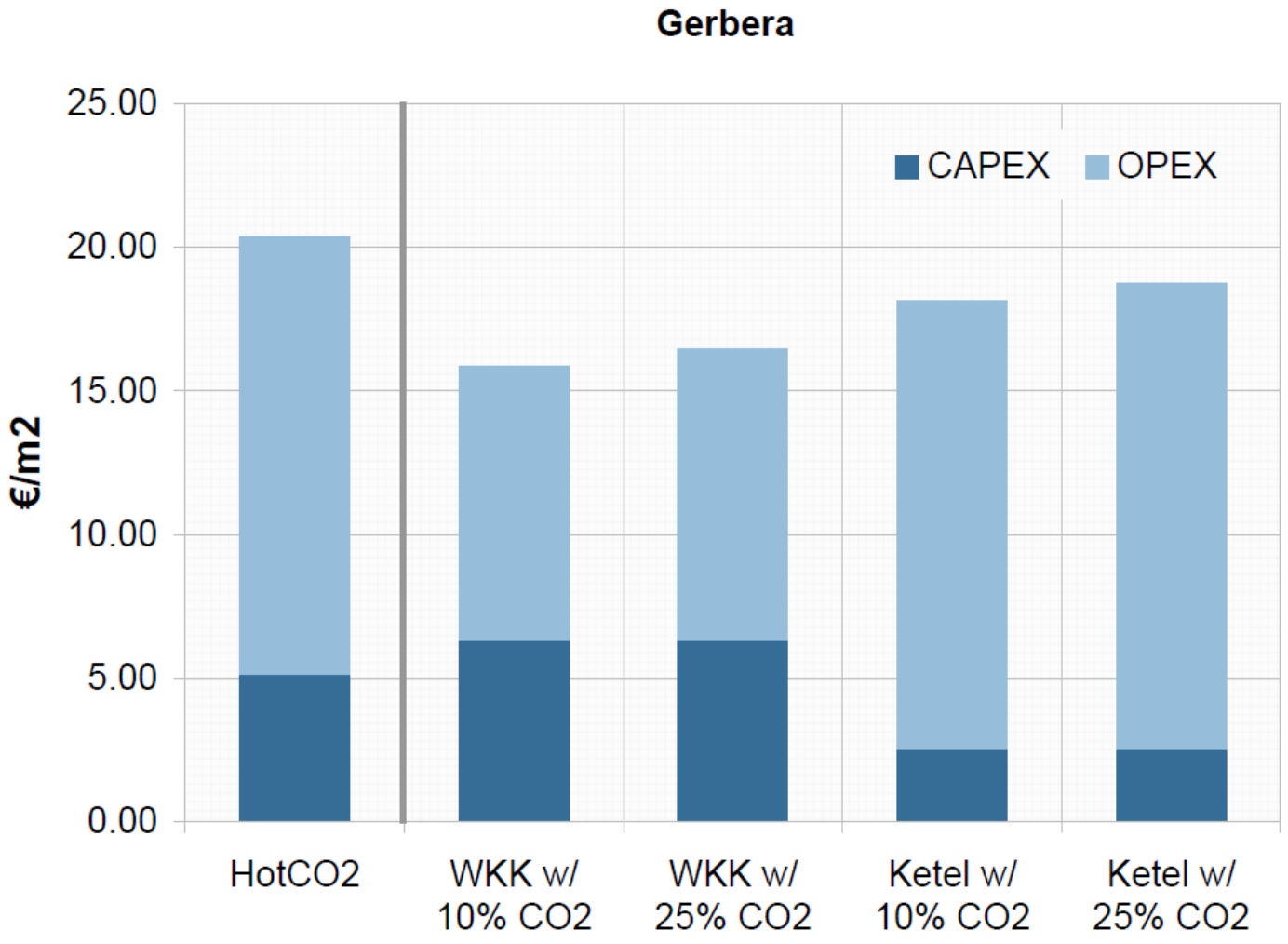
Complete results: CO_2 purchasing



Complete results: CO_2 purchasing



Complete results: CO_2 purchasing



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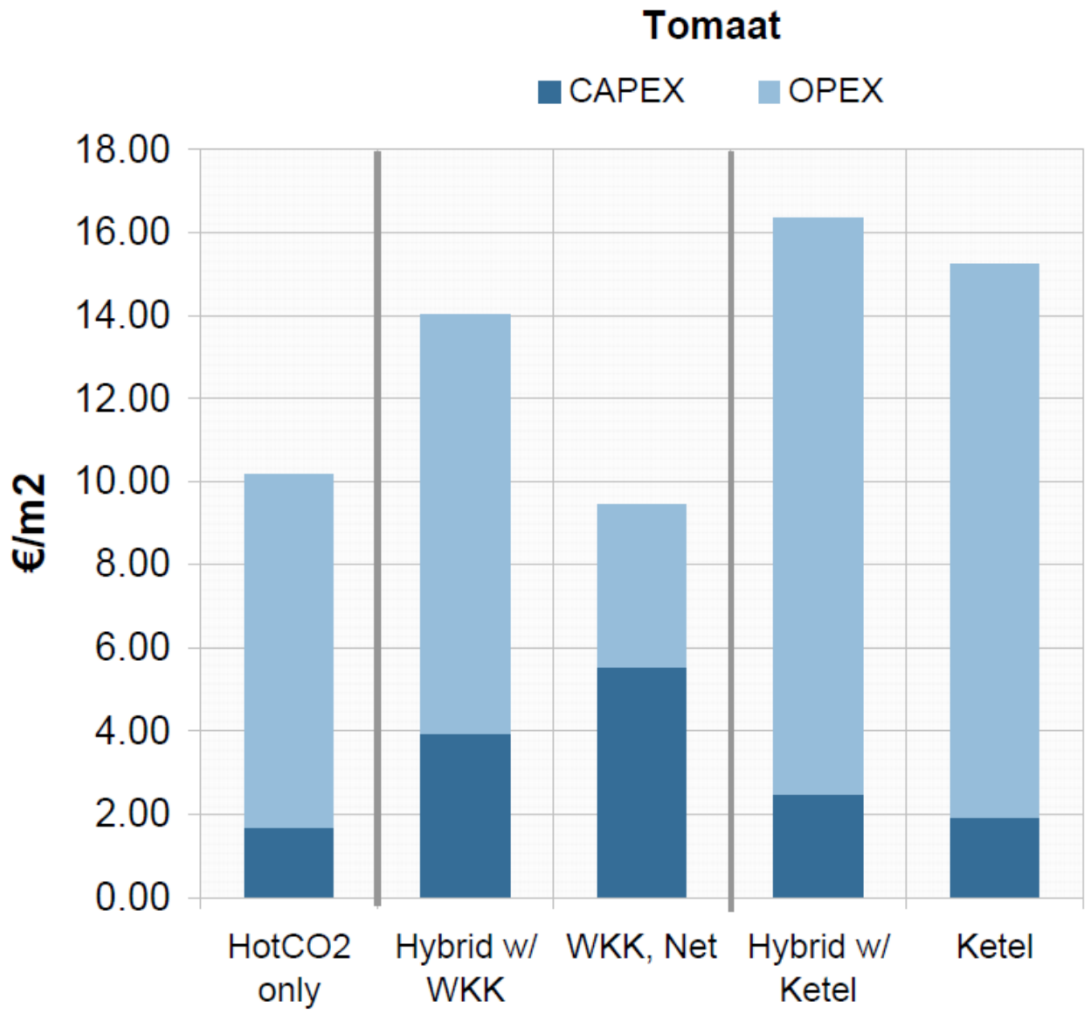
Complete results: CO_2 following



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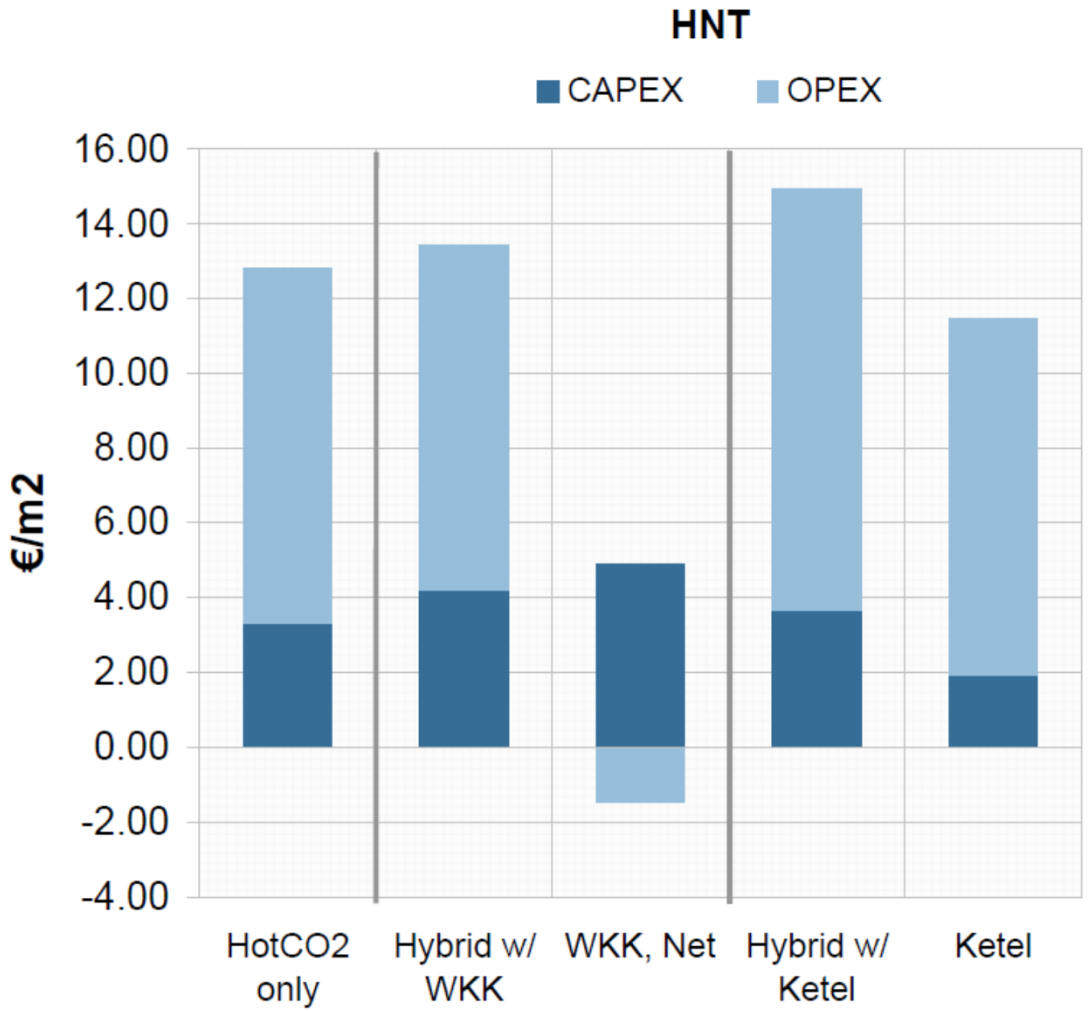

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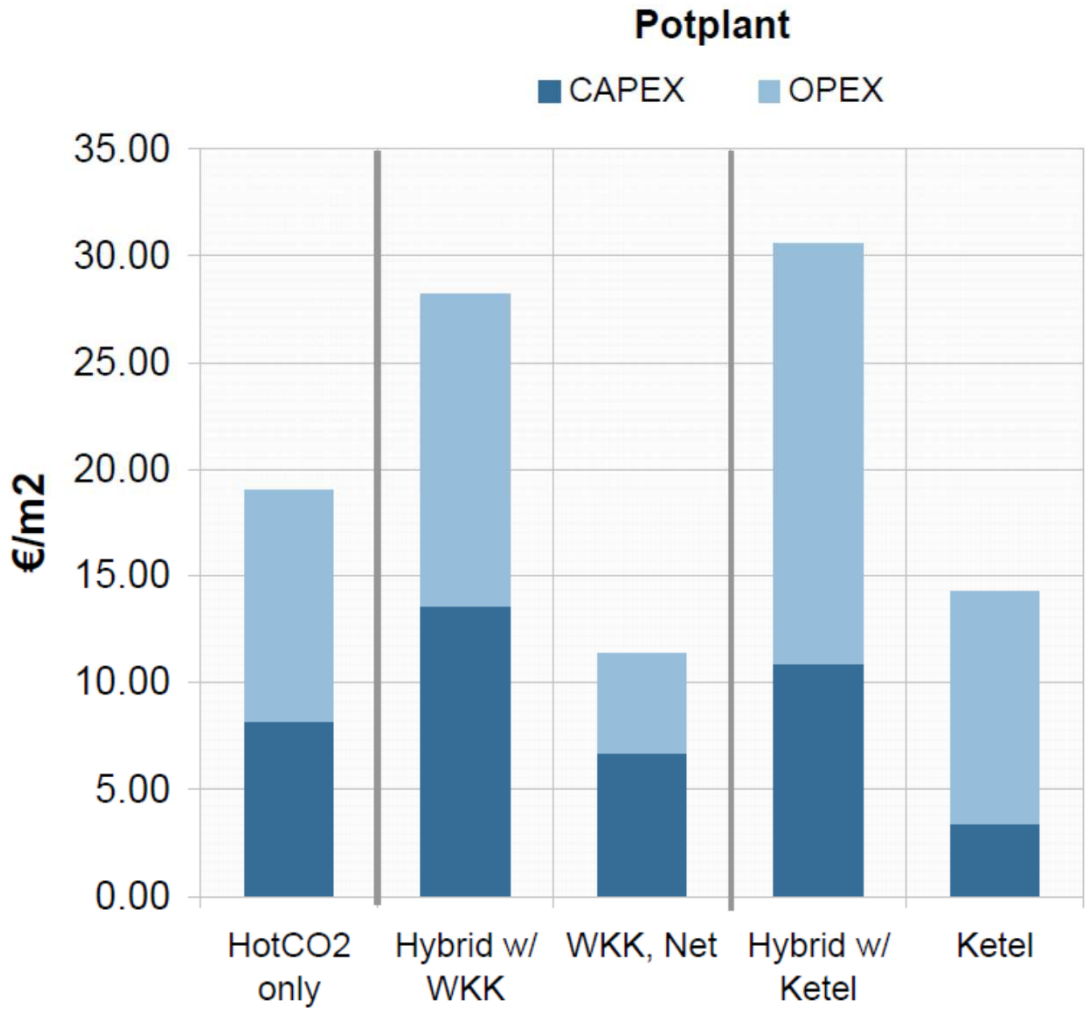

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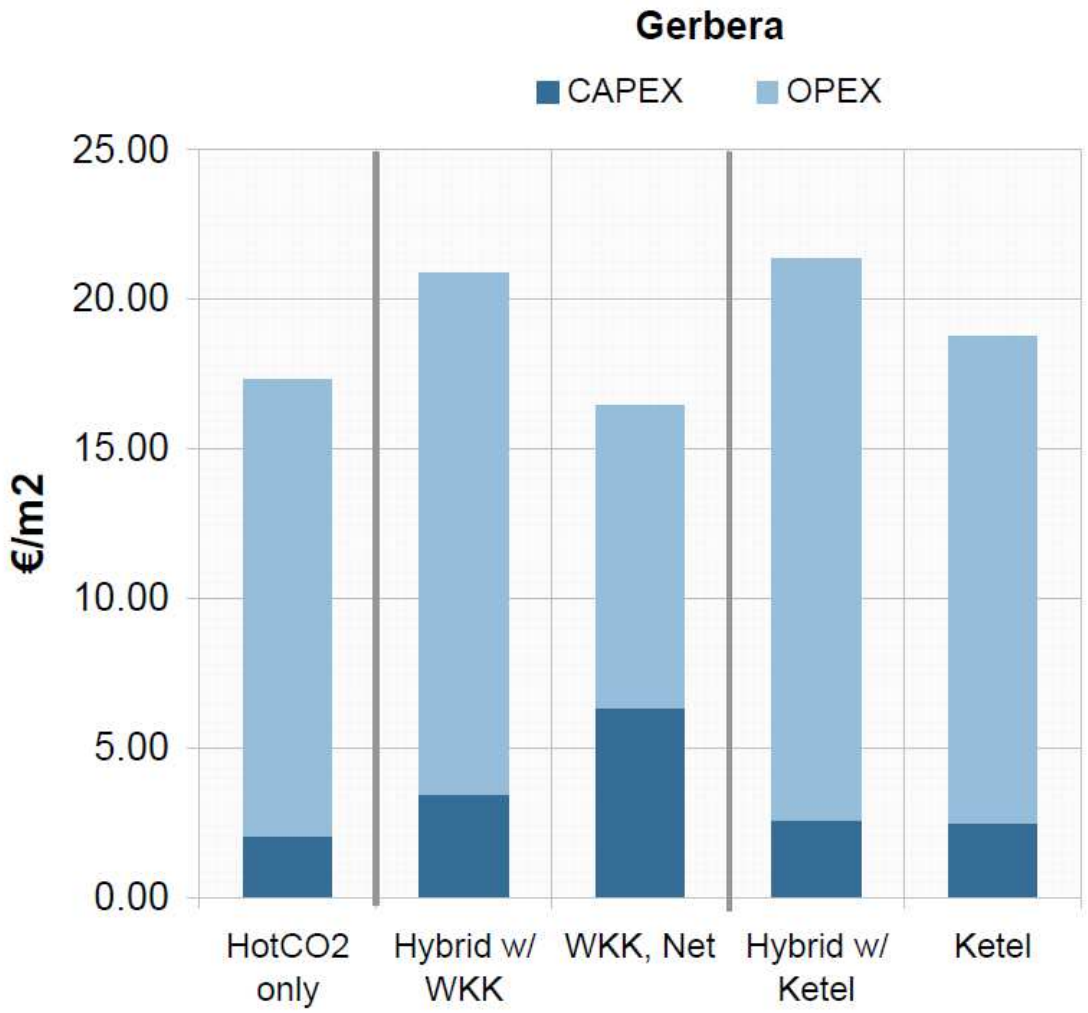
Complete results: CO_2 following



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Tomaat

Heat following			
Hours with NG required to supply heat needed		1774	
Percent of time that NG is required		20.25%	
Size of buffered required for operation (days)		3	> min time for each step = 1 hour
Maximum O2 taken up in bed (mol; mol O2=mol CO2)		875294.3624	
Reactor design size (m2)		**61.98**	
> based on max flow rates and max superficial velocity			
Reactor design length (m)		1.61	
Total gas usage per y	**(m3)**	**4,099,881**	
	(m3/m2)	**51.25**	> in calcs w/ daily average = 39.5
CO2 following			
Hours with NG required to supply heat needed		3239	
Percent of time that NG is required		37%	
Size of buffered required for operation (days)		2	> min time for each step = 1 hour
Maximum O2 taken up in bed (mol; mol O2=mol CO2)		583529.5749	
Reactor design size (m2)		**9.73**	
> based on max flow rates and max superficial velocity			
Reactor design length (m)		6.82	
Total gas usage per y	**(m3)**	**2,356,720**	
	(m3/m2)	**29.46**	
> value from previous calculations w/o following = 3,013,193 m3/yr			
Percent of CO2 required that is produced		**88%**	
Extra heat that would be required	**(MJ/m2/yr)**	**635.66**	
	(m3 gas/m2/yr)	**20.05**	
	Total gas required	**49.51**	
Percentage of heat required by other system		40.5%	

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HNT

Heat following			
Hours with NG required to supply heat needed		1712	
Percent of time that NG is required		19.54%	
Size of buffered required for operation (days)		3	> min time for each step = 1 hour
Maximum O2 taken up in bed (mol; mol O2=mol CO2)		875294.3624	
Reactor design size (m2)		**61.98**	
> based on max flow rates and max superficial velocity			
Reactor design length (m)		1.61	
Total gas usage per year	**(m3)**	**2,899,944**	
	(m3/m2)	**36.25**	> in calcs w/ daily average = 33.3

CO2 following			
Hours with NG required to supply heat needed		3190	
Percent of time that NG is required		36%	
Size of buffered required for operation (days)		2	> min time for each step = 1 hour
Maximum O2 taken up in bed (mol; mol O2=mol CO2)		583529.5749	
Reactor design size (m2)		**9.73**	
> based on max flow rates and max superficial velocity			
Reactor design length (m)		6.82	
Total gas usage per year	**(m3)**	**2,314,561**	> value from previous calculations w/o following = 2,550,236 m3/yr
	(m3/m2)	**28.93**	
Percent of CO2 required that is produced		**86%**	
Extra heat that would be required	**(MJ/m2/yr)**	**208.50**	
	(m3 gas/m2/yr)	**6.58**	
	Total gas required	**35.51**	
Percentage of heat required by other system		18.5%	

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Gerbera

Heat following			
Hours with NG required to supply heat needed		1327	
Percent of time that NG is required		15.15%	
Size of buffered required for operation (days)		2	> min time for each step = 1 hour
Maximum O2 taken up in bed (mol; mol O2=mol CO2)		125754.919	
Reactor design size (m2)		**9.21**	
> based on max flow rates and max superficial velocity			
Reactor design length (m)		1.55	
Total gas usage per year	**(m3)**	**649,374**	
	(m3/m2)	**32.47**	> in calcs w/ daily average = 29.9

CO2 following			
Hours with NG required to supply heat needed		3483	
Percent of time that NG is required		40%	
Size of buffered required for operation (days)		2	> min time for each step = 1 hour
Maximum O2 taken up in bed (mol; mol O2=mol CO2)		125754.919	
Reactor design size (m2)		**2.04**	
> based on max flow rates and max superficial velocity			
Reactor design length (m)		7.00	
Total gas usage per year	**(m3)**	**497,342**	> value from previous calculations w/o following = 564,973 m3/yr
	(m3/m2)	**24.87**	
Percent of CO2 required that is produced		**86%**	
Extra heat that would be required	**(MJ/m2/yr)**	**218.83**	
	(m3 gas/m2/yr)	**6.90**	
	Total gas required	**31.77**	
Percentage of heat required by other system		21.7%	

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Potplant

Heat following			
Hours with NG required to supply heat needed		1464	
Percent of time that NG is required		16.71%	
Size of buffered required for operation (days)		10	> min time for each step = 1 hour
Maximum O2 taken up in bed (mol; mol O2=mol CO2)		177218.891	
Reactor design size (m2)		**13.98**	
> based on max flow rates and max superficial velocity			
Reactor design length (m)		1.44	
Total gas usage per year	**(m3)**	**830,783**	
	(m3/m2)	**41.54**	> in calcs w/ daily average = 38.3
CO2 following			
Hours with NG required to supply heat needed		3344	
Percent of time that NG is required		38%	
Size of buffered required for operation (days)		1	> min time for each step = 1 hour
Maximum O2 taken up in bed (mol; mol O2=mol CO2)		17721.8891	
Reactor design size (m2)		**0.57**	
> based on max flow rates and max superficial velocity			
Reactor design length (m)		3.51	
Total gas usage per year	**(m3)**	**149,995**	> value from previous calculations w/o following = 736,315 m3/yr
	(m3/m2)	**7.50**	
Percent of CO2 required that is produced		**92%**	
Extra heat that would be required	**(MJ/m2/yr)**	**991.60**	
	(m3 gas/m2/yr)	**31.28**	
	Total gas required	**38.78**	
Percentage of heat required by other system		80.7%	