Oil & Gas Producing Countries Options in a Zero-net Emissions World, with Focus on Qatar: A Multi-model Approach

June 7, 2023

Environmental Modeling & Assessment
https://doi.org/10.1007/s10666-023-09904-2

RESEARCH

GCC Countries Strategic Options in a Global Transition to Zero-Net Emissions

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Received: 3 May 2022 / Accepted: 16 May 2023

Abstract
Using a multi-level perspective approach combined with top-down macroeconomic models, we analyze the situation of the GCC countries in the perspective of a global transition to zero-net emissions before the end of the century. Based on these analyses, we propose strategic and political options for these oil and gas exporting countries. We show that it would be unwise for GCC member states to adopt an obstructionist strategy in international climate negotiations. On the contrary, these countries could be proactive in developing international emissions trading market and exploiting negative emissions obtained from CO_2 direct reduction technologies, in particular direct air capture with CO_2 sequestration, and thus contribute to a global net-zero-emissions regime in which clean fossil fuels are still used.

Keywords Net-Zero emissions · Multi-level perspective approach · Macroeconomic modeling · GCC countries · Carbon dioxide removal · Financial compensation · Energy policy

1 Introduction

How Gulf Cooperation Council (GCC) countries might lessen the negative effects of a reduction in hydrocarbon prices on their economies? This paper explores long-term policy options for a transition to sustainable energy systems in the GCC[1] countries. The role played by new technological developments involving renewable energy and negative emissions is analyzed using complementary qualitative and quantitative models.

The successive COPs[2] have encouraged a transition of the global energy system towards sustainability through deep decarbonisation and the active use of renewable energy sources. COP26, held in Glasgow UK in November 2021 reaffirmed the goal to *secure global zero-net emissions (ZNE) by mid-century and to keep 1.5°C within reach.* To deliver on these stretching targets, countries will need to accelerate the phase-out of coal, curtail deforestation, speed up the switch to electric vehicles and encourage massive investment in renewables.[3] This reaffirmation of the Paris agreement goals will not, however, convince everybody

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The Climate Change Conundrum

...a confusing and difficult problem...

Already in 2017 KAPSARK, a Saudi research centre on energy, has organised a workshop on the theme “Role of oil in the low carbon energy transition" [4]. Among key points put forth we can quote:

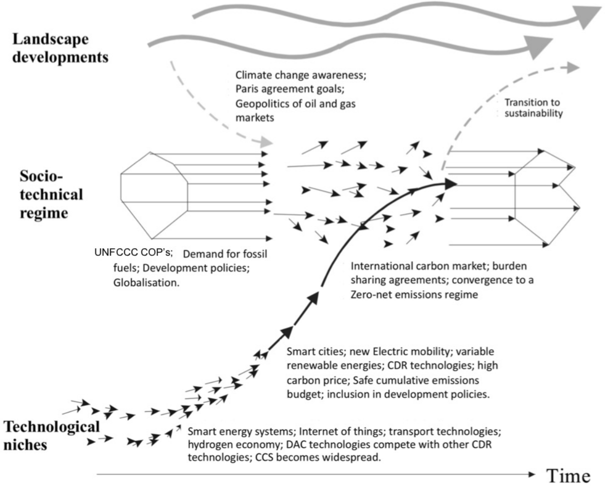
> *... Under a binding constraint, the energy transition would have an impact on demand for hydrocarbons, including oil, which would probably peak... Although Gulf Cooperation Council (GCC) oil producers are better placed to survive periods of greater price volatility that are expected as part of this transition than higher cost suppliers, they are still exposed to fiscal risks if they do not diversify from reliance on hydrocarbon revenues... The energy transition poses challenges for both companies and governments. Those institutions that assume that it is business as usual face a threat to their business models. For financial institutions, the uncertainty posed by this transition represents a major risk factor. ...*

For Oil and Gas Producing Countries (GCC Contries)

- The research project "*Modelling and Assessing the Transition to Low Carbon/Smart Economy in Gulf Countries", supported by QRNF.*, addressed this problem, by proposing a Multi-Level Perspective (MLP) approach to provide a qualitative assessment of the challenges for GCC countries and policy choices that could be taken to mitigate the societal cost of a transition to ZNE before the end of the century.
- This qualitative analysis is associated with quantitative scenario-building approaches that exploit top-down macroeconomic modeling to assess the welfare losses associated with different climate policies around the world.

https://matse-gcc.qu.edu.qa/

Multi Level Perspective framework to analyze transitions to ZNE (Geels [2])



Multi Level Perspective

Landscape developments concern the mounting awareness of climate change risks, the reaffirmation of Paris agreement goals, but also the evolution of oil and gas markets in a global geopolitics perspective. They are mainly dominated by the global climate change issue and the possible global drive toward ZNE worldwide.

Socio-technical regimes that develop in this landscape are negotiated at the UNFCCC COPs: (i) technological transformation of the world economy's energy systems needed to meet a ZNE target, (ii) continue to supply fossil fuels to developing and emerging countries, (iii) equitable sharing of costs and burdens between groups of nations, etc. (iv) T implementation of a global carbon pricing system, with an international market for tradable emission rights.

Technological niches regroup the development of smart energy systems, exploiting the Internet of Things (IOT) in Smart Grids (SG) that are delivering electricity to Smart Cities (SC), the development of an hydrogen economy and also the development of operational large scale negative emission technologies, like DAC coupled CCS.

Multi Level Perspective

LANDSCAPE	Paris agreement goals	What is meant by ZNE	GCC polity & conflicts	New social contract sustainable	coalitions of the willing diplomacy	A future for clean fossil fuels	
MESO Level	Drive toward renewables	Smart cities developmt.	Efficient energy markets	Participation in internat. carbon mkt.	CDR/DAC developt. R&D	H2 economy R&D	
MICRO Level	Efficiency in buildings	Smart grids	Demand response	Electric mobility	CCS in industry	DAC technology	H2 (green)

Figure: Topics in MLP

Modelling scenarios for socio-technical regimes

- To explore possible socio-technical regimes for GCC countries under a transition to ZNE, we developed scenarios using two top-down macroeconomic models.
  - The first model is based on an optimal economic growth paradigm,
  - The second model is a game-theoretic approach to the burden-sharing issue, with focus on the economic impact on the GCC countries.
- In these macro models, some key elements of an MLP are retained at the landscape or technology niche level, but the socio-technical regimes that emerge are dictated by pure cost-benefit or cost-effectiveness considerations.
- At the landscape level, we represent the advent of active global climate policy by: (i) the definition of a remaining safe emissions budget (SEB), which should not be exceeded for the entire future, as suggested in [9, 1]; and (ii) the creation of an international emissions trading system, where different groups of countries will trade on their respective shares of the SEB.
- At the technological niche level, we represent two important innovations: (a) the progress in efficiency and cost of renewable energy technologies; and (b) the penetration of direct air capture technologies that generate negative emissions. DAC is an emergent technology that has been described and analysed in [7, 6]; and more recently, in [3] and [5].

Compact OR model-1

- We regroup the world countries in three “coalitions" j called BRIC (Brazil, Russia, India and China), OECD (Organisation for Economic Co-operation and Development) and ROW (Rest of the world), respectively. They represent groups of nations in similar states of development. In each group, we represent an economy where a general economic good is produced with three inputs: labour L_0, capital K_0 and energy E_0.
- The energy input E_0, or useful energy, can be obtained from two kinds of inputs: fossil enf_0 and renewable enr_0. The fossil energy input enf_0 is obtained from two factors, respectively the fossil fuel power plants K_1 and the fossil primary energy enp_1. The renewable input enr_0 is produced by zero-emission plants, represented by the capital K_2.
- CO_2 emissions are associated with the fossil energy primary source enp_1. Negative emissions v can be produced by CDR/DAC technologies using three production factors, labor L_3, capital K_3 and useful energy E_3. The energy mix, fossil vs. renewable, is supposed to be common to energy input for the general productive economy E_0 and the DAC/CDR sector E_3.

The dynamic model has:

- A time set $t \in \{0, 1, \ldots, T\}$, where each period corresponds to a number of years Ny. In this application, we take ten-year periods ($Ny = 10$). Period 0 is centred on the year 2020, Period $T = 12$ is centred on 2120.
- Five state variables, which are the capital stocks $K_i(t, j)$; $i = 0, 1, 2, 3,$ and the remaining emission budget $b(t, j)$, for coalition j at period t;
- Five control variables, which are the annual investment levels $I_i(t, j)$; $i = 0, 1, 2, 3,$ and the annual supply $\omega(t, j)$ of emission permits by coalition j at each period t.

Compact OR model-2

- The performance criterion $\Phi = \sum_j \phi(j)$, where for each coalition j the expression $\phi(j)$ represents the discounted sum of utility derived from consumption for the population.

$$\phi(j) = \sum_{t=0}^{T-1} \beta(t) PV \cdot L(t,j) \log(C(t,j)/L(t,j)), \quad j = \mathrm{BRIC}, \mathrm{OECD}, \mathrm{ROW}, \tag{1}$$

where $PV = \sum_{s=1}^{Ny} (1+r)^{(1-s)}$ is the present value factor and $\beta(t) = 1/(1+r)^{Ny \cdot t}$ the periodic discount factor, with $r = 3\%$, at each time t. $L(t,j)$ refers to the population of coalition j at time t. The expression $\log(C(t,j)/L(t,j))$ represents the utility derived from per-capita consumption; $C(t,j)$ is the consumption level by coalition j at period t, given by

$$C(t,j) = Y(t,j) - \sum_{i=0,1,2,3} I_i(t,j) - \pi(t,j) enp_1(t,j), \tag{2}$$

where $Y(t,j)$ is the quantity of output and $\pi(t,j)$ is the price of primary fossil energy.

- To compare different scenarios we also use another welfare criterion $W(j)$ for each coalition j. It corresponds to the discounted sum of per-capita consumption, net of the revenue from permit trading, over the whole horizon 2020-2160. For coalition j, we have

$$W(j) = \sum_{t=0}^{T-1} \beta(t) PV \, \frac{C(t,j) + p(t)(\omega(t,j) - emf(t,j))}{L(t,j)}, \tag{3}$$

where $\omega(t,j)$ is the supply of permits by coalition j and $p(t)$ is the permit price on carbon market, at period t.

Modeling carbon market equilibrium

The constraints describing the international carbon market are given below. The strategic variable, for each coalition j, is the annual quantity of emission rights $\omega(t, j)$ they supply to the market at period t. On the carbon market the total supply of permits must be greater or equal to total emissions. The firms, in each coalition, will set their emission at a level where carbon price equals the marginal productivity of emissions (or marginal abatement cost). These two sets of conditions determine the market equilibrium:

- Emissions from primary fossil energy (for coalition j at period t)

$$em(t, j) = Coeff(j) \times enf_1(t, j), \tag{4}$$

  where the emission rate is evaluated at $Coeff(j) = 0.004$ $GtCO_2$ per EJ of fossil energy source.

- Total supply of permits is greater or equal to total emissions (at period t)

$$\sum_j \omega(t, j) - \sum_j em(t, j) \geq 0. \tag{5}$$

- Efficiency (at period t)

$$p(t) = \frac{\partial Y(t, j)}{\partial em(t, j)} \tag{6}$$

$$= \frac{\partial Y(t, j)}{\partial E_0(t, j)} \frac{\partial E_0(t, j)}{\partial enp_1(t, j)} \frac{\partial enp_1(t, j)}{\partial em(t, j)}. \tag{7}$$

Economic Growth with 1170 Gt CO_2 SCEB

Table: SCEB shares and sequestration bounds

Budget shares $\theta(\cdot)$			DAC-CCS Bounds (Gt CO_2/Y)		
BRIC	OECD	ROW	BRIC	OECD	ROW
0.4	0.1	0.5	8	5	10

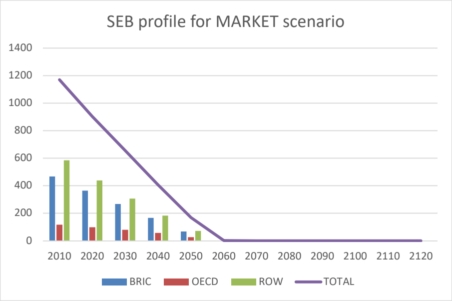


Figure: Budget Profiles (Gt of CO_2)

CDR/DAC Penetration

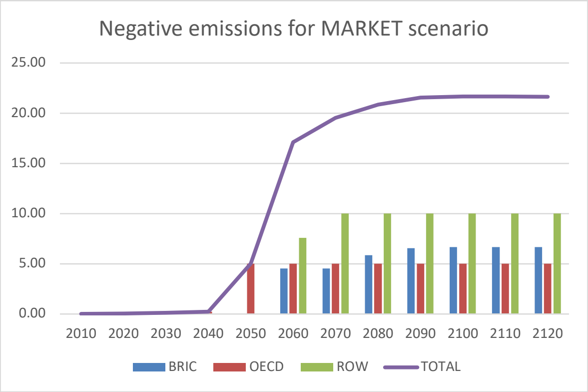
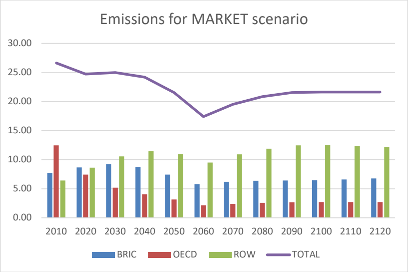


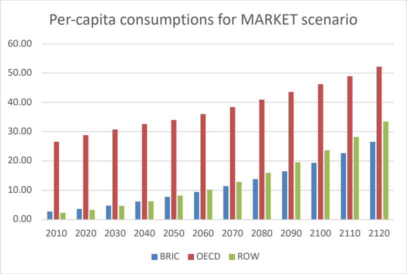
Figure: DAC activity (in Gt CO_2 /Year)

Market Scenario

Table: DAC/MARKET scenario: Emissions (in Gt CO_2 /Year) and consumption (in \$1000/Year)



	BRIC	OECD	ROW	TOTAL
2014	7.75	12.47	6.40	26.63
2120	6.69	2.67	12.08	21.44



	BRIC	OECD	ROW
2014	2.94	24.54	2.97
2120	26.53	53.54	33.26

Market Scenario

Table: MARKET scenario: Carbon price and permits trading

Price ($)		Trading (per-capita)			Negative emissions (Gt CO_2)		
Year	BRIC	BRIC	OECD	ROW	BRIC	OECD	ROW
2014	241	0.20	-2.03	0.66	0.00	0.00	0.00
2070	761	-0.40	1.44	-0.12	4.52	5.00	10.00
2120	828	-0.07	1.43	-0.26	6.44	5.00	10.00

Table: MARKET scenario: K_1/L versus $K2/L$

K_1/L

Year	BRIC	OECD	ROW
2014	1.56	3.82	0.89
2120	8.11	10.87	9.82

K_2/L

Year	BRIC	OECD	ROW
2014	2.17	7.90	2.32
2120	39.81	60.88	67.18

Welfare Loss

Table: Welfare criteria (in $1000)

Welfare	MARKET	OPT	BAU	GREEN
BRIC	231	231	254	220
OECD	1094	1087	1156	1029
ROW	248	248	262	238
Welfare Loss	**MARKET**	**OPT**	**BAU**	**GREEN**
BRIC	9%	9%	0%	13%
OECD	5%	6%	0%	11%
ROW	6%	5%	0%	9%

Fair budget sharing model

$j \in \{1, \dots, m\}$	index of coalition;
$t \in \{1, \dots, T\}$	time periods;
$\delta(t)$	duration of time period t;
B	global safety emission budget over the time horizon $[0, T]$;
θ_j	share of the global emission budget allocated to coalition j;
$b_j = \theta_j B$	cumulative emission budget for coalition j at period 0;
$b_j(t)$	remaining emission budget for coalition j at end of period t;
$v_j(t)$	K-T multiplier for global budget constraint of coalition j at period t;
$\omega_j(t)$	supply of emission permits at period t by coalition j;
$\Omega(t)$	total supply of emission permits at period t;
$v_j(t)$	negative emission activity (CDR) by coalition j at period t;
$v_j(0)$	negative emission activity (CDR) by coalition j at period 0;
$\kappa_j(v_j(t), t)$	cost of CDR for coalition j at period t;
$q_j(t)$	abatement level by coalition j at period t;
$\epsilon_j(t)$	BaU emission level by coalition j at period t;
$e_j(t)$	emission level by coalition j at period t;
$e_j(0)$	emission level by coalition j at period 0;
$\varpi_j(q_j(t), t)$	Abatement cost for coalition j at time t;
$\mathbf{e}(t)$	vector of all m emission levels at period t;
$\pi_j(\mathbf{e}(t), t)$	Net abatement cost (including changes in the terms of trade) for coalition j at time t;
$\gamma_j(\sum_{k=1}^{m} q_k(t), t)$	gains from the changes in terms of trade for coalition j at time t;
β_j	discount factor for coalition j equals 3%;

Fair budget sharing model-2

- This equation relates the abatement and emission levels relative to BaU

$$e_j(t) = \epsilon_j(t) - q_j(t) \tag{8}$$

- Let $b_j(\tau)$ denote the remaining emission budget, for region j at the end of period τ, $\tau = 0, \ldots, T-1$. We approximate the integral of net emissions up to period τ, using the trapezoidal method. The part of the emissions budget remaining at period τ is thus defined as

$$0 \leq b_j - (\frac{1}{2} \sum_{t=0}^{\tau-1} \delta(t+1)(\omega_j(t) + \omega_j(t+1) - v_j(t) - v_j(t+1))),$$
$$j = 1, \ldots, m, \quad \tau = 0, \ldots, T-1. \tag{9}$$

- By imposing non negative remaining budgets, we eliminate the possibility for each “player" to perform short-selling of the future DAC activities.
  This expression can also be rewritten

$$b_j - (\frac{1}{2}\delta(1)(\omega_j(0) - v_j(0)) + \frac{1}{2} \sum_{t=1}^{\tau-1} (\delta(t) + \delta(t+1))(\omega_j(t) - v_j(t))$$
$$+ \frac{1}{2}\delta(\tau)(\omega_j(\tau) - v_j(\tau))) \geq 0, \quad j = 1, \ldots, m, \quad \tau = 0, \ldots, T-1. \tag{10}$$

Fair budget sharing model-3

- *Emissions trading.* An international carbon market determines a price and emissions levels.

$$p(t) = \frac{\partial}{\partial q_j(\cdot)} \varpi_j(q_j(t), t) = -\frac{\partial}{\partial e_j(\cdot)} \varpi_j(\epsilon_j(t) - e_j(t), t) \tag{11}$$

$$\Omega(t) = \sum_{k=1}^{m} e_k(t); \quad j = 1, \ldots m. \tag{12}$$

The price and emission levels are thus functions of the total permit supply $\Omega(t)$, thus denoted $\tilde{\mathbf{e}}(\Omega(t), t)$ and $\tilde{p}(\Omega(t), t)$, respectively.

- The derivatives w.r.t. Ω of price and emission levels are given by

$$\tilde{p}'(\Omega, t) = \frac{1}{\sum_{j=1}^{m} \frac{1}{\frac{\partial^2 \varpi_j(q_j, t)}{\partial q_j^2}}} \tag{13}$$

$$\tilde{e}_j'(\Omega, t) = \frac{1}{\sum_{k=1}^{m} \frac{\frac{\partial^2 \varpi_j(q_j, t)}{\partial q_j,^2}}{\frac{\partial^2 \varpi_j(q_k, t)}{\partial q_k^2}}} \tag{14}$$

respectively. Since $\Omega(t) = \sum_{j=1}^{m} \omega_j(t)$ the derivatives w.r.t. $\omega_j(t)$ are the same as the derivatives w.r.t. $\Omega(t)$.

Fair budget sharing model-4

- *Periodic net cost.* The periodic net cost to coalition j includes the abatement cost plus the cost of buying permits on the market (negative if selling) and is given by

$$\psi_j(t) = [\pi_j(\tilde{\mathbf{e}}(\Omega(t), t) + \kappa_j(v_j(t), t) - \tilde{p}(\Omega(t), t)(\omega_j(t) - e_j(\Omega(t), t))], \tag{15}$$

where

$$\pi_j(\mathbf{e}(t), t) = \varpi_j(q_j(t), t) - \gamma_j(\sum_k p_k(t), t). \tag{16}$$

- *Payoffs.* The payoff for coalition j is defined by the integral of the discounted periodic costs

$$J_j(\cdot) = \frac{1}{2}\delta(1)\psi_j(0) + \frac{1}{2}\sum_{t=1}^{T-1}\beta_j^t(\delta(t) + \delta(t+1))\psi_j(t) + \frac{1}{2}\beta_j^T\delta(T)\psi_j(T),$$

$$j = 1, \ldots, m. \tag{17}$$

$$J_j(\cdot) = \sum_{t=0}^{T-1}\beta_j^t\,[\pi_j(\tilde{\mathbf{e}}(\Omega(t), t) + \kappa_j(v_j(t), t) - \tilde{p}(\Omega(t), t)(\omega_j(t) - e_j(\Omega(t), t))] \tag{18}$$

Fair budget sharing model-5

- *Nash equilibrium conditions* We write now the first order conditions for a Nash equilibrium solution. The existence of a solution is implied by the convexity of the cost functions. Denoting $\nu_j(t)$ the K-T multiplier of the emission budget constraint (10) for coalition j, we may write the Lagrangian for each player j as given by

$$\mathcal{L}_j(\cdot) = \frac{1}{2}(\delta(1)\psi_j(0) + \beta_j^T \delta(T)(\psi_j(T)) + \frac{1}{2}\sum_{t=0}^{T-1} \beta_j^t(\delta(t) + \delta(t+1))(\psi_j(t)+$$

$$\nu_j(t)(b_j - \frac{1}{2}\sum_{s=0}^{t-1} \delta(s+1)(\omega_j(s) + \omega_j(s+1) - v_j(s) - v_j(s+1)))$$

$$j = 1, \ldots, m. \qquad (19)$$

- *Complementarity conditions for* $\omega_j(t)$

$$0 \leq \beta_j^t \frac{\partial}{\partial \omega_j(t)}[\pi_j(\tilde{\mathbf{e}}(\Omega(t), t) - \tilde{p}(\Omega(t), t)(\omega_j(t) - e_j(\Omega(t), t))] + \nu_j \qquad (20)$$

$$0 \leq \omega_j(t) \qquad (21)$$

$$0 = \omega_j(t)\left\{\beta_j^t \frac{\partial}{\partial \omega_j(t)}[\pi_j(\tilde{\mathbf{e}}(\Omega(t), t) - \tilde{p}(\Omega(t), t)(\omega_j(t) - e_j(\Omega(t), t))] + \nu_j\right\}. \quad t = 1 \ldots T \qquad (22)$$

Fair budget sharing model-6

- *Complementarity conditions for $v_j(t)$*

$$
\begin{aligned}
0 &\leq \beta_j^t \frac{\partial}{\partial v_j(t)} \kappa_j(v_j(t), t) - \nu_j && (23)\\
0 &\leq v_j(t) && (24)\\
0 &= v_j(t) \left\{ \beta_j^t \frac{\partial}{\partial v_j(t)} \kappa_j(v_j(t), t) - \nu_j \right\}. && (25)
\end{aligned}
$$

- *Complementarity conditions for $\nu_j(t)$*

$$
\begin{aligned}
0 &\leq b_j - \frac{1}{2} \sum_{s=0}^{t-1} \delta(s+1)(\omega_j(s) + \omega_j(s+1) - v_j(s) - v_j(s+1)) && (26)\\
0 &\leq \nu_j(t) && (27)\\
0 &= \nu_j(t) \left\{ b_j - \frac{1}{2} \sum_{s=0}^{t-1} \delta(s+1)(\omega_j(s) + \omega_j(s+1) - v_j(s) - v_j(s+1)) \right\} &&\\
&\quad , j = 1, \ldots, m. && (28)
\end{aligned}
$$

Table 2 CO_2 price and welfare cost in the period 2018–2100 assuming a safety budget of 1170 Gt CO_2 and a 3% discount factor

DAC & BECCS	Without	With
Discounted CO_2 price (ref. 2030) in $\$_{2010}$	775	480
Discounted World cost in % of discounted GDP	3.8%	2.8%

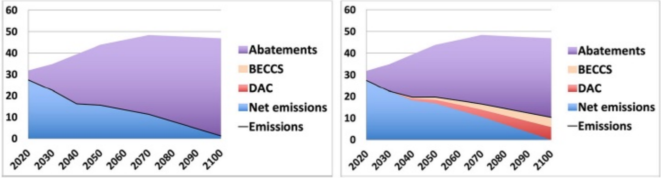


Fig. 2 Net emissions, DAC, BECCS, and abatement profiles without (left) and with (right) DAC/BECCS (in Gt CO_2)

Rawlsian Rule

Table: Burden-sharing and welfare cost with Rawlsian rule in percentage difference from the reference scenario.

	Budget share	Welfare cost[a]	Components of welfare cost[a]				
			Abatement	DAC	BECCS	GTT	Emissions trading[b]
USA	9.07%	2.84%	1.78%	0.17%	0.32%	-0.02%	0.58%
EUR	4.31%	2.84%	0.82%	0.33%	0.24%	-0.41%	1.87%
CHI	19.93%	2.84%	3.72%	0.20%	0.15%	-0.63%	-0.61%
IND	6.53%	2.84%	3.49%	0.29%	0.57%	-1.33%	-0.18%
RUS	7.01%	2.84%	3.16%	6.22%	1.29%	1.89%	-9.70%
GCC	8.81%	2.84%	3.30%	5.38%	0.02%	5.55%	-11.39%
OEE	15.57%	2.84%	1.68%	0.19%	0.14%	0.99%	-0.16%
ASI	9.45%	2.84%	1.45%	0.28%	0.23%	-0.69%	1.56%
LAT	3.00%	2.84%	1.83%	1.56%	1.22%	0.11%	-1.88%
ROW	16.31%	2.84%	2.53%	0.27%	0.19%	0.32%	-0.47%
World	100.00%	2.84%	2.04%	0.54%	0.29%	0.00%	0.00%

[a] Discounted welfare cost in % of discounted GDP

[b] Negative (positive) values are for net sellers (buyers)

Table 3 Budget shares and welfare losses for two allocation rules

	Grandfathering allocation in %	Welfare cost[a]	Per capita allocation in %	Welfare cost[a]
USA	16.6%	1.3%	4.0%	4.0%
EUR	11.2%	1.4%	4.3%	2.8%
CHI	27.2%	1.2%	15.1%	4.0%
IND	6.3%	3.0%	17.2%	−4.5%
RUS	4.5%	6.9%	1.5%	11.4%
GCC	2.9%	11.0%	0.9%	13.8%
OEE	8.8%	4.7%	11.6%	3.9%
ASI	11.8%	2.4%	17.5%	1.4%
LAT	3.0%	2.9%	4.5%	1.1%
ROW	7.7%	6.4%	23.3%	−0.1%
World	100.0%	2.8%	100.0%	2.8%

[a]Discounted welfare cost in % of discounted GDP

Welfare loss and CO_2 price

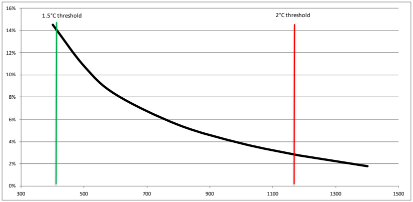


Figure: Discounted global welfare cost in % of discounted GDP with respect to carbon budget in Gt CO_2

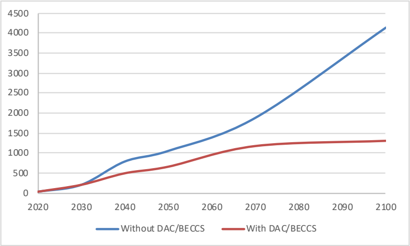


Figure: CO2 prices

Clues provided by the macroeconomic scenarios

- The technical progress of renewable energies will make them dominant in the energy landscape, even in the absence of a strict climate policy; however, this will not make it possible to achieve the goal of climate stabilisation before the end of the century.
- Making a full transition to renewables in order to stabilise the temperature change at 2°C would generate a large welfare cost, in terms of lost consumption, in particular for emerging and developing countries.
- The availability of DAC technology at scale can mitigate the welfare losses and stranded asset costs of a global climate policy consistent with a 2°C target.
- The Gulf countries appear to have a comparative advantage in deploying DAC activities due to their easy access to natural gas as a primary energy source and depleted oil and gas reservoirs as storage facilities.
- An effective international carbon market will be an essential part of the DAC development strategy. It would allow the sale and purchase of negative emissions to offset remaining GHG emissions in different parts of the world.

Clues provided by a bottom-up model ETEM-Qatar

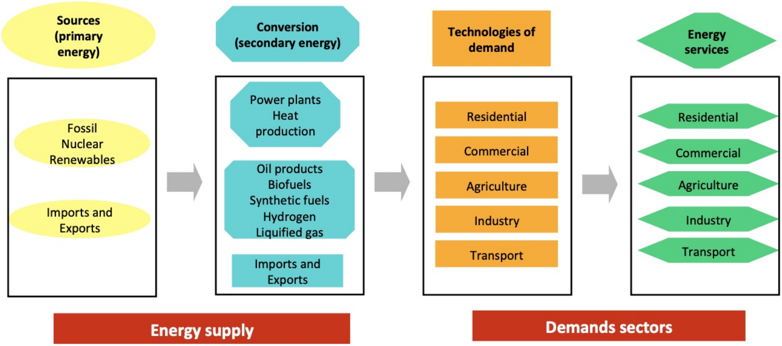
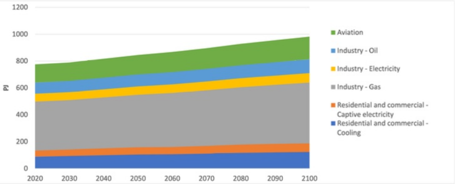
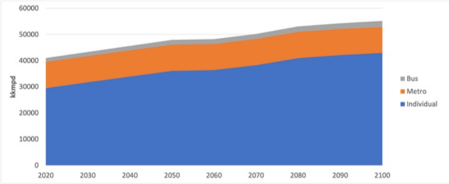


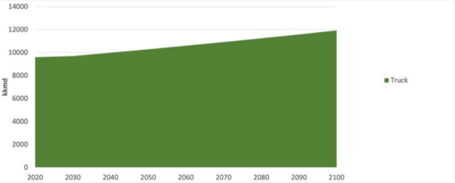
Figure: Reference energy system for ETEM



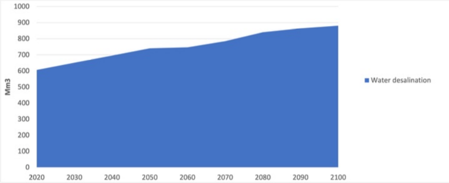
(a) Demand in PJ



(b) Demand in Kkmpd

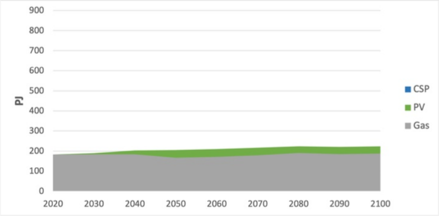


(c) Demand in Kkmd

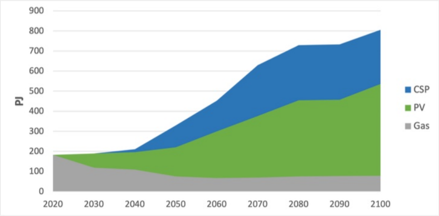


(d) Demand in Mm^3

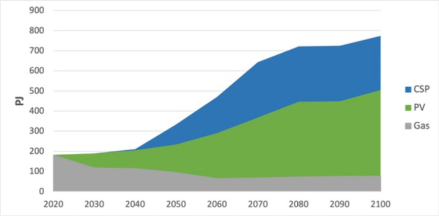
Figure: Evolution of demands on 2020-2100.



(a) Reference

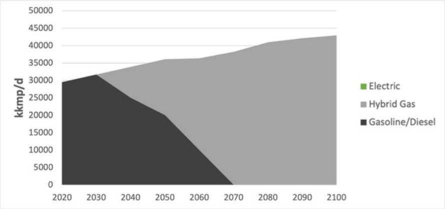


(b) ZNE

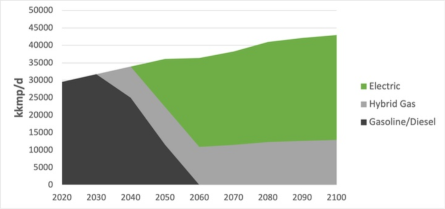


(c) ZNE_{ICM}

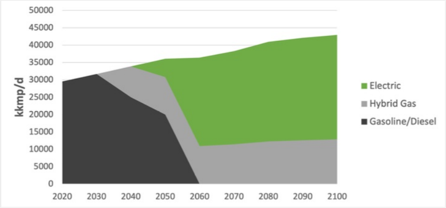
Figure: Electricity production by source



(a) BAU scenario

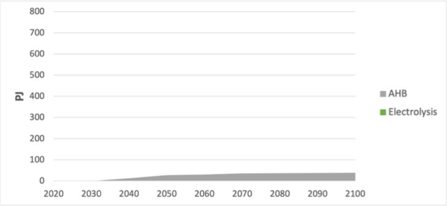


(b) ZNE

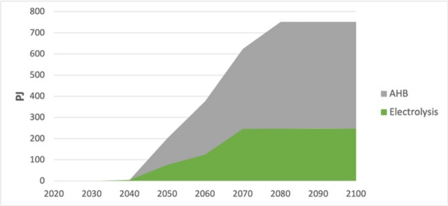


(c) ZNE_{ICM}

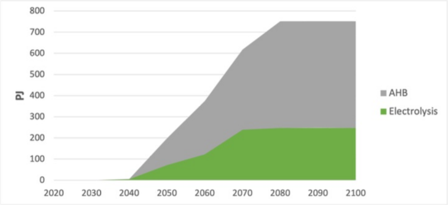
Figure: Usage technology for private transport



(a) BAU scenario

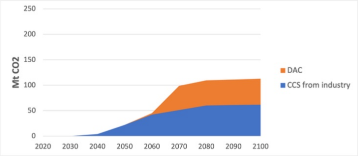


(b) ZNE

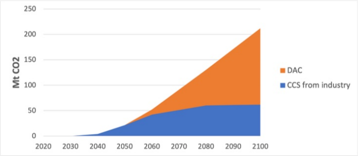


(c) ZNE_{ICM}

Figure: Hydrogen production by source.



(a) ZNE



(b) ZNE_{ICM}

Figure: CO_2 storage

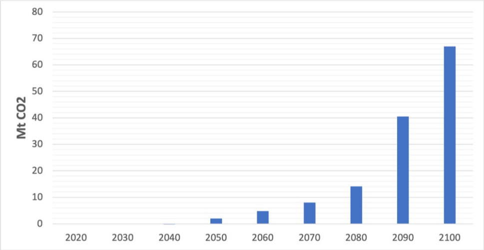
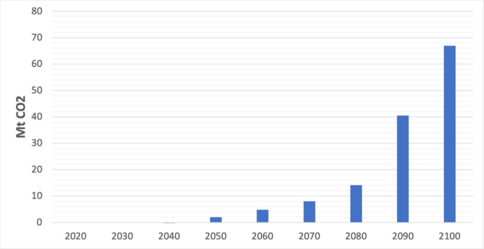


Figure: Permit sales in the ZNE_{ICM} global scenario

So, which climate strategy for GCC states?

In [8] Jim Krane analysed the possible climate strategies for oil and gas production countries, taking the case of KSA as a motivating example. He focused on three types of nearer-term climate strategies that he titled “Dig in," “Join in" and “Throw in."

- By “Digging in" states assume GHG accords like Paris agreement remain aspirational rather than binding, and act to insulate the hydrocarbon sector against the aims of such accords;
- By “Joinning in," states engage in pursuing economically rational domestic energy policies that provide benefits in reducing GHG emissions;
- In “Throw in" strategy producer governments concede that climate change is inevitable and argue that damage caused by anthropogenic GHG emissions is preferable to costly GHG mitigation in line with Paris goals [8].



Mt CO2
80
70
60
50
40
30
20
10
0
2020
2030
2040
2050
2060
2070
2080
2090
2100

Scenario based analysis

- The climate change issue is now recognised everywhere and there is no future for GCC member states in adopting an obstructionist strategy;
- The options offered by CCS, DAC and Hydrogen economy contribute to foster a mix of the “Dig in" and “Join in" types of strategy. On one side one will work at preserving the economic value of fossil fuels, while on the other side one will decarbonise entirely the local economy and exploit the opportunities offered by the international carbon markets.
- CCS and CDR technologies are essential to achieving the ZNE regime globally and also locally. In the scenarios studied in our research, the cumulative emissions budget was not allowed to be exceeded. Therefore, there was no incentive to adopt a “Throw in" strategy.
- GCC countries could be more proactive in the coming negotiations, and aim at defining a governance based on equalizing the relative welfare losses among groups or coalitions of countries.
- GCC countries could develop their programs of clean fossil fuels, in particular CCS and Hydrogen extraction.
- GCC countries must prepare to the change in oil and gas demand patterns caused by the advent of electric mobility and smart energy systems.
- All of these transitional policies will require an effort to diversify the economies of GCC member states and to change their polity and social contracts.

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An oligopoly game of CDR strategy deployment in a steady-state net-zero emission climate regime

Alain Haurie

Climatic Change (2021) 165: 64
https://doi.org/10.1007/s10584-021-03058-4

Economic assessment of the development of CO_2 direct reduction technologies in long-term climate strategies of the Gulf countries

Frédéric Babonneau[1,3] · Ahmed Badran[2] · Maroua Benlahrech[2] · Alain Haurie[3,4] · Maxime Schenckery[5] · Marc Vielle[6]

Received: 26 June 2020 / Accepted: 9 March 2021 / Published online: 25 April 2021

Abstract
This paper proposes an assessment of long-term climate strategies for oil- and gas-producing countries—in particular, the Gulf Cooperation Council (GCC) member states—as regards the Paris Agreement goal of limiting the increase of surface air temperature to 2°C by the end of the twenty-first century. The study evaluates the possible role of carbon dioxide removal (CDR) technologies under an international emissions trading market as a way to mitigate welfare losses. To model the strategic context, one assumes that a global cumulative emissions budget will have been allocated among different coalitions of countries—the GCC being one of them—and the existence of an international emissions trading market. A meta-game model is proposed in which deployment of CDR technologies as well as supply of emission rights are strategic variables and the payoffs are obtained from simulations of a general equilibrium model. The results of the simulations indicate that oil and gas producing countries and especially the GCC countries face a significant welfare loss risk, due to "unburnable oil" if a worldwide climate regime as recommended by the Paris Agreement is put in place. The development of CDR technologies, in particular direct air capture (DAC) alleviates somewhat this risk and offers these countries a new opportunity for exploiting their gas reserves and the carbon storage capacity offered by depleted oil and gas reservoirs.

Keywords GCC countries · Climate negotiations · Carbon dioxide removal · Financial compensation · Negative emissions · CDR technologies

Published: 22 October 2020

An Oligopoly Game of CDR Strategy Deployment in a Steady-State Net-Zero Emission Climate Regime

Frédéric Babonneau, Olivier Bahn, Alain Haurie & Marc Vielle

Environmental Modeling & Assessment **26**, 969–984 (2021) | Cite this article

Abstract

In this paper, we propose a simple oligopoly game model to represent the interactions between coalitions of countries in deploying carbon dioxide removal (CDR) strategies in a steady-state net-zero emission climate regime that could take place by the end of the twenty-first century. The emission quotas and CDR activities obtained in the solution of this steady-state model could then be used as a target for end-of-period conditions in a dynamic integrated assessment analysis studying the transition to 2100. More precisely, we analyze a steady-state situation where m coalitions exist and behave as m players in a game of supplying emission rights on an international emission trading system. The quotas supplied by a coalition must correspond to the amount of CO_2 captured through CDR activities in the corresponding world region. We use an extension of the computable general equilibrium model GEMINI-E3 to calibrate the payoff functions and compute an equilibrium solution in the noncooperative game.

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