

Technical annexes

Comparative pathways for Saudi Arabia and the United Arab Emirates

Fiscal resilience, renewable power, industry and a differentiated just transition

Technical annex contents

A Analytical framework and baseline **3**

B Pathways and common assumptions **7**

C Fiscal accounting and supporting results **13**

D Power inputs and cost comparisons **18**

E Electrification parameters and results **23**

F Industrial methods and process options **27**

G Climate justice and safeguards **32**

H Data boundaries and evidence limits **35**

I Definitions, acronyms and units **37**

References **40**

A1 Analytical scope and case boundaries

These annexes document the assumptions, accounting boundaries and supporting tables behind the approved report. The findings charts remain in the main report.

Component	Coverage	Interpretation
Comparative baseline	Saudi Arabia and the UAE; source years retained	Country observations have different institutional and statistical boundaries
Fiscal pathways	A, B and C at 2030, 2040 and 2050; seven environments	126 country-pathway-horizon-environment comparisons
Power and electrification	Five generation/storage configurations; seven representative applications	New-build and application screens, rather than a national power-system optimisation
Industry	Six representative applications	Unit energy/feedstock costs and operational emissions, not complete plant economics
Climate justice	Responsibility, capacity, dependence and implementation; seven safeguards	Evidence requirements rather than certification of a just or Paris-aligned transition

All three pathways are tested under the same seven environments. The cases have no assigned probabilities. Results compare complete assumption packages; they do not isolate the causal effect of reducing production.

Historical conditions, scenario inputs and calculated outcomes are kept distinct. No national investment-return ranking, optimal extraction schedule, complete employment model or household-distribution model is established.

A2 Evidence classes and source treatment

Published observations and analyst-selected assumptions have different evidentiary status.

Evidence class	Meaning	Treatment
Published observation	A value reproduced or recalculated from an identified publication	Retain the source year, geography, unit and institutional coverage
Source-cited input	An input retained from a documented evidence series	Identify the publication; do not imply a fresh independent audit
Study assumption	A scenario index, engineering parameter, cost proxy or allowance	Label as illustrative; a citation does not turn it into an official forecast
Calculated result	An output of the stated accounting or screening assumptions	State the country, pathway, horizon, environment, valuation basis and output unit
Not assessed	Insufficient evidence to verify an outcome	Do not substitute zero, failure, success or a justice score

A complete case label is essential. Unless another comparison is explicitly stated, the power and application results reproduced here use Path A, 2030, Severe Downside and administered gas. Industrial A-to-C comparisons and separate process options are labelled individually.

Source publications support observations and methods. Production indices, growth assumptions, financing envelopes and support allowances are study inputs, not targets endorsed by those publications.

A3 Six hypotheses and evidence boundaries

The hypotheses organise comparative questions. The study does not perform statistical hypothesis tests.

Hypothesis	Question	Evidence boundary
H1 Fiscal resilience	Does new fossil-fuel expansion strengthen long-term public finances?	Annual fiscal comparisons do not establish project profitability or a complete debt-sustainability assessment
H2 Transition finance	Is expansion necessary or superior for financing transformation?	Existing receipts can finance change; alternative investment returns are not verified
H3 Renewable power	Can renewables and electrification improve costs and emissions?	Selected opportunities; no equal hourly reliability or national deployment forecast
H4 Complementarity	Can diversification, renewables and phase-down reinforce each other?	Joint assumptions are compared; causality is not independently demonstrated
H5 Industry	How do unit energy costs and operational emissions change?	Incomplete manufacturing costs, demand, investment and product-footprint evidence
H6 Differentiation	How do country circumstances affect implementation and support?	No fair-share national extraction date or verified justice outcome

A stronger annual fiscal balance does not independently establish higher national welfare, climate compatibility or adequate social protection. The same standard of evidence applies to all six hypotheses.

A4 Baseline indicators and comparison limits

Each indicator retains its own source period and denominator. Unlike series must not be forced to sum to a common total. [1, 2, 3, 4, 5, 6, 7, 8]

Indicator and period	Saudi Arabia	UAE
Hydrocarbon public revenue share, 2025	54.6%	44.0%
Hydrocarbon merchandise exports, KSA 2025 / UAE 2024	67.5%	26.2%
Non-oil merchandise exports, 2024	23.0%	73.9%
Fiscal balance, KSA 2025 / UAE 2024	–5.8% of GDP	+6.4% of GDP
Renewable installed-capacity share, 2025	12.2%	15.3%
Historical grid-average emissions, 2024	0.57 tCO_2/MWh	0.34 tCO_2/MWh
Aggregate inward FDI / GDP, source five-year average	1.6%	5.0%

The Saudi hydrocarbon and non-oil export shares refer to different years. UAE exports include re-exports; they are not a measure of domestic manufacturing value added. Aggregate inward FDI can include fossil-related activity and does not describe outward sovereign portfolios.

Installed capacity, electricity generation and historical grid emissions are different measures. The historical emissions factors reflect observed total generation mixes, not renewable-only supply or an endorsement of any technology.

Unreconciled non-oil GDP and extraction-share comparisons, proxy-based country scores and institutional rankings are not reproduced. The fiscal calculation uses its separate 2025 calibration.

B1 Three illustrative pathway packages

The neutral names describe relative pacing within the study. Neither transition pathway is certified as Paris-aligned, fair-share consistent or socially just.

Path	Production assumption	Other assumptions
A Hydrocarbon expansion	Additional capacity and production remain central to public and export income	Renewable deployment and economic diversification continue
B Managed illustrative transition	No new production expansion from 2026; gradual decline in the production-linked index	Stronger assumed renewable deployment, efficiency, alternative revenues and transition spending
C Faster illustrative transition	The same halt, followed by a steeper decline in the production-linked index	Faster assumed renewable deployment, efficiency and diversification; greater early transition and support allowances

The production-linked index represents combined oil-and-gas exposure for revenue calculations. It is not a separate physical extraction schedule for oil and gas. Domestic-use indices are additional illustrative inputs, not complete national energy balances.

The no-new-expansion condition is a design choice for B and C. The model does not independently derive national emissions budgets, a fair-share phase-out date or the production decline required for 1.5°C.

B2 Production-linked and domestic-use indices

All indices use 2025 = 1.00. Values below 1.00 represent reductions from that base before additional stress overlays.

Table B1 Production-linked revenue-volume indices

Country	Path	2030	2040	2050
Saudi Arabia	A	1.10	1.18	1.25
Saudi Arabia	B	0.96	0.80	0.60
Saudi Arabia	C	0.90	0.60	0.30
UAE	A	1.10	1.18	1.25
UAE	B	0.94	0.75	0.50
UAE	C	0.85	0.50	0.20

Table B2 Illustrative domestic fossil-use indices

Country	Path	2030	2040	2050
Saudi Arabia	A	1.03	1.08	1.10
Saudi Arabia	B	0.88	0.65	0.40
Saudi Arabia	C	0.75	0.40	0.15
UAE	A	1.02	1.06	1.08
UAE	B	0.85	0.60	0.35
UAE	C	0.70	0.35	0.10

By 2040, B reduces the production-linked index by 20% in Saudi Arabia and 25% in the UAE; C reduces it by 40% and 50%. These are scenario assumptions, not official forecasts or verified climate limits.

B3 Renewable generation and delivery assumptions

Renewable shares refer to total electricity generation. Nuclear generation is excluded from the renewable numerator.

Country	Path	2030	2040	2050
Saudi Arabia	A	25%	40%	50%
Saudi Arabia	B	40%	65%	80%
Saudi Arabia	C	55%	80%	95%
UAE	A	20%	35%	45%
UAE	B	30%	50%	65%
UAE	C	40%	65%	80%

Implementation mechanism

Achieved renewable share = target renewable share ÷ MAX(1, delivery-cost factor). The same simplified mechanism reduces realised electrification uptake and efficiency improvement.

For Saudi Path C in 2040, the 80% Reference share becomes about 59% under Implementation Stress, using the 1.35 delivery-cost factor. This is an analytical delivery assumption, not an engineering forecast.

The generation series begins at the first modelled horizon in 2030. A 2026 generation point is not inferred from installed-capacity observations. Generation assumptions do not prove that the grid, storage and equipment required for reliable delivery are available.

B4 Core 2030 fiscal and technology assumptions

These are pathway inputs before additional environment adjustments. They are not official forecasts or costed national programmes.

Variable	A	B	C
Oil-price index	0.98	0.98	0.98
Annual non-hydrocarbon revenue growth	3.5%	4.5%	5.5%
Annual core primary-expenditure growth	4.0%	3.5%	3.0%
GDP-growth sensitivity	3.0%	3.0%	3.0%
Sovereign borrowing rate	5.0%	5.0%	5.0%
Power-project WACC	7.0%	7.0%	7.0%
Renewable CAPEX index	0.82	0.82	0.82
Battery CAPEX index	0.75	0.75	0.75
Electrification opportunity uptake	40%	65%	90%
Annual efficiency improvement	1.0%	2.0%	3.0%
Additional worker/household support, GDP share	0.0%	0.3%	0.6%
Additional public transition investment, GDP share	0.0%	0.7%	1.5%

Inputs vary by horizon. Before stress, C's non-hydrocarbon revenue-growth assumptions are 5.0% in 2040 and 4.5% in 2050. Its support allowance is 0.4% and 0.25% of GDP, and its public transition-investment allowance is 1.0% and 0.6%.

Stronger revenue growth and different expenditure growth materially drive the later fiscal comparison. Production decline alone is not shown to cause those changes.

B5 Seven common comparative environments

Adjustments apply to the corresponding pathway inputs. Each environment combines several assumptions.

Environment	Principal adjustment or purpose
Reference	Pathway assumptions without additional stress multipliers
Moderate Downside	Oil-price index –20%; production-linked revenue-volume factor –5%; moderately weaker growth and financing conditions
Severe Downside	Oil-price index –40%; revenue-volume factor –15%; weaker growth, higher financing and delivery costs
High-Price Upside	Oil-price index +25%; revenue-volume factor +5% before pathway constraints; more favourable financing
Technology Acceleration	Renewable CAPEX –15%; battery CAPEX –25%; power WACC –1 percentage point; oil-price and revenue-volume factors –10%
Financing Stress	Sovereign borrowing rate +2 percentage points; power WACC +2.5 points; technology CAPEX +5%; weaker growth
Implementation Stress	Delivery-cost factor 1.35; technology CAPEX +15%; lower achieved deployment and efficiency; greater support and investment costs

Multipliers and rate changes have different meanings: adjusted oil-price index = pathway index × stress multiplier; adjusted borrowing rate = pathway rate + rate change.

Implementation Stress also reduces non-hydrocarbon revenue growth and raises core expenditure growth. Support costs rise by 25% and transition investment by 20%. The combined fiscal effect cannot be attributed to one driver.

None of these cases has a probability weight. They are not event-specific forecasts of the 2026 conflict.

B6 Horizon comparisons and causal limits

The model compares 2030, 2040 and 2050. It does not identify a precise year when transition costs end or fiscal rankings change.

Horizon	Annual fiscal comparison	Limit
2030	A has the strongest balance in all seven environments in both countries	Higher early receipts do not establish the best cumulative investment outcome
2040	C exceeds A in six of seven environments in each country; B exceeds A in three	High-Price Upside is the C-versus-A exception
2050	C exceeds A in all seven in both countries; B does so in seven Saudi and six UAE cases	Long-horizon growth, spending and financing assumptions accumulate; extreme ratios are stress indicators

Six out of seven is a count of tests, not an 86% probability or a forecast. B and C must not be combined into a single "managed transition outperforms" claim.

The study has not tested expansion with exactly the same diversification and expenditure settings as C. It cannot rule out every differently designed expansion-plus-diversification package.

An annual fiscal improvement does not establish overall national benefit or a risk-adjusted project return. A steeper production decline would need its own fiscal and delivery assumptions; the current ranking cannot be extrapolated to an untested trajectory.

C1 Fiscal accounting and interpretation

Annual flows and accumulated stocks answer different questions.

Measure	Accounting structure	Boundary
Hydrocarbon revenue	2025 hydrocarbon revenue × price index × production-linked volume index × fiscal-take factor	Combined oil-and-gas revenue exposure; not separate fuel production schedules
Annual fiscal balance	Total government revenue – primary expenditure – interest	A positive change can mean a smaller deficit rather than a surplus
Non-oil primary balance	Non-hydrocarbon revenue – primary expenditure	Scenario results divide by total GDP; published IMF ratios may use non-oil GDP
Net public financial position	Assumed financing assets – modelled public debt	Excludes many physical, human, resource and environmental assets and liabilities

Non-hydrocarbon revenue, core spending and GDP follow pathway- and environment-specific growth assumptions. Additional public transition investment and worker/household support are included in primary spending; they should not be added again.

Borrowing and asset drawdowns finance deficits under the stated allocation rules. Surpluses can repay debt and build assets. Interest depends on previous debt and the borrowing-rate assumption.

The horizon calculations are conditional accounting comparisons. They are not continuous annual debt-sustainability forecasts or complete extraction-project CAPEX and net-present-value appraisals.

C2 2025 calibration and historical observations

The fiscal scenario calibration is separate from the mixed-year comparative baseline. [1, 2, 9, 10]

Calibration input	Saudi Arabia	UAE
Nominal GDP, approximate US$bn	1,274	569
Hydrocarbon government revenue, US$bn	161.9	71.1
Non-hydrocarbon government revenue, approximate US$bn	135	90
Public debt / GDP	31.8%	34.5%
Fiscal balance / GDP	–5.8%	about +5.1%
Assumed financing-asset envelope, US$bn	950	1,200

GDP and revenue figures are rounded. The UAE GDP calibration is an estimate. The financing-asset envelopes are analyst-selected sensitivity inputs, not audited liquid sovereign wealth.

The comparative UAE baseline uses a 2024 general-government surplus of 6.4% of GDP and debt of 34.9%. These must not be substituted for its separate 2025 model calibration of approximately 5.1% and 34.5%.

Saudi fiscal observations principally cover central government; UAE fiscal observations cover general government. The difference in institutional coverage remains material when interpreting country comparisons.

C3 Annual balance comparisons by country and case

All balance levels in the first table are Reference-case results expressed as a percentage of GDP.

Horizon	Country	A	B	C
2030	Saudi Arabia	–8.0%	–9.3%	–10.0%
2030	UAE	+2.8%	+1.4%	+0.6%
2040	Saudi Arabia	–12.2%	–12.8%	–11.3%
2040	UAE	+1.0%	+0.4%	+2.0%

2040 C-minus-A differences in percentage points of GDP

Environment	Saudi Arabia	UAE
Severe Downside	+5.32	+5.12
High-Price Upside	–0.35	–0.27

Positive differences favour C; negative differences favour A. These are annual budget comparisons, not GDP-growth effects, cumulative savings or investment profits.

Both A and C still produce deficits in both countries in the Severe Downside test. A relative improvement therefore does not demonstrate fiscal sustainability. In Reference, B is below A in both countries in 2040, while C is above A.

C4 Signed contributions to the 2040 balance change

Reference case, C minus A. Values are annual US$ billion; a positive contribution improves the annual fiscal balance.

Contribution	Saudi Arabia	UAE
Hydrocarbon revenue loss	–107.7	–54.5
Higher non-hydrocarbon revenue	+70.2	+47.0
Lower primary expenditure	+54.9	+17.5
Higher interest expenditure	–0.3	–1.2
Net annual fiscal improvement	+17.1	+8.8

A reduction in primary expenditure is positive in this bridge because it improves the balance. A revenue loss or higher interest cost is negative. The rounded contributions reconcile to the net improvement.

The US$17.1 billion result concerns Saudi Arabia; the corresponding UAE result is US$8.8 billion. Neither is the 2030 comparison.

Stronger assumed alternative revenues and spending restraint offset lower hydrocarbon receipts within the package. This does not prove that production cuts cause diversification, or that similar fiscal reforms could not be combined with another production strategy.

C5 Debt, financing assets and net financial position

Reference assumptions. Annual balance gains must be read alongside previous borrowing and asset drawdowns.

2040 measure	Saudi A	Saudi C	UAE A	UAE C
Public debt / GDP	145.5%	127.1%	17.6%	20.3%
Remaining financing assets, US$bn	380	66	1,319	1,358

Net financial position as a percentage of GDP

Horizon	Saudi A	Saudi C	UAE A	UAE C
2025	+42.8	+42.8	+176.4	+176.4
2030	–3.3	–13.1	+166.0	+155.1
2040	–124.9	–123.5	+142.5	+144.5
2050	–308.8	–241.4	+116.6	+190.2

Net financial position = (assumed financing assets – modelled debt) ÷ GDP. It is not a measure of total national wealth. Negative values mean debt exceeds the assumed financing envelope.

C's stronger UAE annual balance in 2040 coexists with higher debt than A. Saudi C retains fewer assumed financing assets than A at that horizon. Earlier adjustment costs and financing choices remain in the stock.

The extreme 2050 ratios are mechanical stress indicators, not default forecasts. Resource reserves, infrastructure, human capital and many environmental liabilities are outside this financial measure.

D1 Power-cost accounting and service boundaries

The power module compares new-build options under common country, pathway, horizon, environment and gas-valuation assumptions. [11, 12, 13]

Cost component	Treatment
Generation LCOE	Capital and operating costs are spread over assumed lifetime electricity output
Capital recovery	$CRF = r(1 + r)^n \div [(1 + r)^n - 1]$, where r is WACC and n is asset life
Fuel valuation	Administered prices and alternative economic gas values are separate cases
System-service allowances	Stated grid, balancing, curtailment, residual-firming and integration allowances supplement generation costs
Application delivery	Electrification comparisons include annualised equipment and grid investment

Generation LCOE and system-adjusted cost are not delivered tariffs. An average firming allowance or bundled battery package does not prove identical hourly reliability, loss-of-load performance or system adequacy.

A lower new-build cost does not, by itself, establish that an existing gas plant should close. Network expansion, dispatch, storage duration, flexibility and the useful service required need a separate system assessment.

D2 Representative power-technology inputs

Starting CAPEX, capacity factors and asset lives are engineering and cost-screen assumptions, not measured national fleet averages or current tender prices.

Technology	Country	CAPEX US$/kW	Capacity factor	Life years
Solar PV	Saudi Arabia	700	31%	30
Solar PV	UAE	650	32%	30
Onshore wind	Saudi Arabia	1,100	42%	25
Onshore wind	UAE	1,200	35%	25
Solar PV + battery	Saudi Arabia	1,250	34%	25
Solar PV + battery	UAE	1,200	35%	25
Gas CCGT	Saudi Arabia	1,000	60%	30
Gas CCGT	UAE	950	62%	30
Gas OCGT	Saudi Arabia	700	15%	25
Gas OCGT	UAE	680	18%	25

CCGT means combined-cycle gas turbine; OCGT means open-cycle gas turbine. These configurations are compared as new builds.

The solar-plus-battery CAPEX is a bundled allowance. The configuration's capacity-factor parameter does not establish an optimised battery duration, hourly availability or a complete storage dispatch profile.

Horizon CAPEX indices, environment adjustments and financing assumptions are applied to the starting parameters. The selected 2030 Severe Downside screen uses power-project WACC of 8.5%.

D3 Gas valuations and opportunity-cost limits

Fixed analytical gas values are used to test sensitivity. They are not current transaction prices, live Dutch Title Transfer Facility (TTF) or Japan Korea Marker (JKM) quotations, or verified export netbacks.

Valuation basis	Saudi Arabia	UAE	Unit
Administered price	1.75	2.00	US$/MMBtu
Production cost	2.00	3.00	US$/MMBtu
Long-run marginal cost	4.50	5.50	US$/MMBtu
Export-parity proxy	6.00	7.00	US$/MMBtu

An actual export opportunity cost would use an accessible destination price less liquefaction or pipeline charges, transport, shipping, insurance and other delivery costs. The model does not establish that all domestically used gas could be exported.

The fixed export-parity proxies can understate the alternative value during high-price periods. They remain separate from administered domestic prices and should not be silently replaced by a spot quotation.

An economic gas valuation is not a recommendation to raise household tariffs. Distributional and affordability effects require their own assessment.

D4 Selected generation costs and gas thresholds

Path A, 2030, Severe Downside, administered gas. Costs are system-adjusted US$/MWh.

New-build option	Saudi Arabia	UAE
Solar PV	33.9	30.7
Onshore wind	45.5	55.9
Solar PV + battery	63.4	59.1
Gas CCGT	40.7	41.0
Gas OCGT	87.6	78.3

Gas value at cost parity with new CCGT, US$/MMBtu

Renewable configuration	Saudi Arabia	UAE
Solar PV	0.73	0.47
Onshore wind	2.48	4.23
Solar PV + battery	5.19	4.70

Above the named gas value, the renewable option has the lower screened unit cost, holding the case assumptions constant. Cost parity does not establish identical reliability or complete physical substitution.

Generation switching thresholds and industrial-procurement thresholds have different delivery boundaries. The 5.19 and 4.70 values refer specifically to this generation comparison.

D5 Financing and implementation sensitivities

The selected procurement-cost comparisons use Path A in 2030. Each environment combines technology, financing and delivery assumptions.

Environment	Power WACC	Saudi procurement US$/MWh	UAE procurement US$/MWh
Technology Acceleration	6.0%	48.0	44.7
Reference	7.0%	56.6	52.7
Financing Stress	9.5%	64.6	60.2

These are modelled electricity-procurement costs, not the standalone solar-plus-battery generation costs in the preceding generation comparison. The differences are not isolated causal estimates of WACC.

Technology Acceleration lowers renewable and battery CAPEX. Financing Stress increases both by 5%. Implementation Stress separately reduces achieved deployment and efficiency, while increasing selected costs and weakening revenue assumptions.

A general claim that either country is technologically behind, or entitled to a particular technology-transfer or climate-finance programme, cannot be inferred from these cost sensitivities.

E1 Electrification accounting and interpretation

The screen compares representative useful-energy services, not complete national sectors.

Element	Treatment
Useful service	Baseline and electric alternatives are compared using selected efficiency and service assumptions
Annual net economic benefit	Avoided baseline costs less electric-energy, equipment, operation and grid costs within the stated screen
Capital treatment	Application equipment and grid investment are annualised
Operational CO_2 reduction	Baseline operational emissions less the electric alternative's operational emissions
Scale and uptake	Illustrative application scales and pathway uptake settings determine the result

Positive annual net benefit means screened savings. Positive CO_2 reduction means lower operational emissions; a negative reduction means operational emissions increase.

The applications may overlap in energy demand or industrial boundaries. Their results must not be added into a national savings, deployment or emissions forecast.

The selected comparisons omit full upstream and life-cycle emissions, employment effects and complete commercial appraisal. An electric technology label alone does not establish a climate or cost benefit.

E2 Representative electrification parameters

These ratios describe selected service comparisons. They are not the efficiency of every existing facility or device.

Application	Current efficiency	Electric efficiency	Fuel value US$/GJ
Desalination	45%	85%	6
Passenger/commercial transport	25%	80%	8
Cooling and buildings	75%	100%	5
Low-/medium-temperature industrial heat	70%	95%	6
Oil and gas operations	40%	90%	5
Hydrogen and derivatives	65%	75%	6
Data centres	90%	100%	5

Application scales, capital costs and O&M inputs are illustrative. In the selected Path A, 2030, Severe Downside case, electricity-procurement emissions factors are approximately 0.313 tCO_2/MWh in Saudi Arabia and 0.333 in the UAE.

The cooling comparison is a generic direct-fuel-switching screen, not an assessment of efficient air-conditioning, passive cooling or building retrofit potential. The hydrogen service comparison is separate from the industrial hydrogen-product calculation.

E3 Selected electrification results

Path A, 2030, Severe Downside, administered gas. Values refer to the representative application scales and uptake assumptions.

Application	Saudi benefit US$m/year	UAE benefit US$m/year	Saudi CO_2 reduction Mt/year	UAE CO_2 reduction Mt/year
Desalination	–103.3	–63.5	+0.252	+0.115
Transport	+111.1	+87.4	+7.215	+4.511
Cooling/buildings	–380.3	–233.1	–0.346	–0.332
Industrial heat	–313.7	–200.3	–0.252	–0.251
Oil/gas operations	–132.5	–81.6	+0.631	+0.350
Hydrogen/derivatives	–525.7	–367.2	–0.754	–0.617
Data centres	–109.5	–70.8	–0.196	–0.157

Transport is the only application combining a positive annual net benefit with lower operational emissions in both countries in this selected screen. This is not a ranking of every possible national transport investment.

Equipment and grid investment are annualised. The results do not show that all electrification reduces costs or emissions. No weighted opportunity score or policy-priority ranking is used here.

E4 Application-specific evidence limits

A process, service boundary and electricity supply must be specified before generalising a result.

Application	What the selected result does not establish
Transport	Whole-sector savings, national vehicle uptake or equal economics for every vehicle application
Desalination	That reverse osmosis is generally less economic than thermal desalination; plant scale, starting assets, water quality and supply integration matter
Cooling/buildings	That efficiency, thermal storage or passive cooling is unattractive
Industrial heat	One switching cost or pace for every temperature, utilisation rate and connection requirement
Retained oil/gas operations	A case for more fossil-fuel production or expansion from lower operating emissions
Hydrogen/derivatives	Complete production costs, certified renewable hydrogen or a verified offtake market
Data centres	That direct fuel switching is the same intervention as improving power usage effectiveness

Renewable procurement, equipment efficiency, network connections and reliable service delivery must be considered together. Lower generation LCOE does not automatically become a lower end-user cost.

F1 Industrial equations and conversion factors

The industrial boundary covers energy/feedstock costs and modelled direct and purchased-electricity emissions. [14, 15]

Energy cost per unit = electricity intensity × electricity-procurement cost + gas/feedstock intensity × gas value per GJ.

Operational emissions per unit = gas intensity × gas emissions factor + other direct process emissions + electricity intensity × electricity-procurement emissions factor.

Parameter	Value	Unit
Natural gas combustion	0.0561	tCO_2/GJ, NCV
Gas/diesel combustion	0.0741	tCO_2/GJ, NCV
Energy conversion	1.055056	GJ/MMBtu
Energy conversion	0.277778	TWh/PJ
Annual hours convention	8,760	hours/year
Energy conversion	1,000	kWh/MWh

Outputs use tonnes of product, except data-centre services, which use MWh of IT load. The calculation is not a complete life-cycle assessment or verified product carbon footprint.

Gas prices in US$/MMBtu must be converted to US$/GJ before multiplication by GJ per unit. Manufacturing CAPEX, most non-energy production costs and market demand remain outside the energy-cost measure.

F2 Representative industrial process inputs

These are selected process parameters rather than measured national industry averages. [16, 17, 18, 19, 20, 21, 22]

Application / output unit	Electricity MWh/unit	Gas/feedstock GJ/unit	Other direct emissions tCO_2e/unit
Primary aluminium / tonne	14.0	0	1.600
NG-DRI/EAF steel / tonne crude steel	0.7	10.0	0.200
Gas-based ammonia / tonne	0.0	28.0	0.000
Electrolytic hydrogen / tonne	55.0	0	0.000
Data-centre service / MWh IT load	1.4	0	0.000
Blended cement / tonne	0.1	2.556	0.37275

Gas-based ammonia has no material purchased-electricity input in its reference process. Changing electricity procurement therefore leaves that particular process unchanged.

Aluminium results do not establish a full product footprint, including upstream inputs and relevant process gases. Electrolytic hydrogen is not automatically renewable hydrogen or a verified low-emissions product.

Process intensities are illustrative inputs. The cited literature provides technical context; it does not certify these assumptions as national averages.

F3 Selected Path A industrial results

2030, Severe Downside, administered gas. Costs are energy/feedstock costs, not total manufacturing costs.

Application	Saudi cost US$/unit	UAE cost US$/unit	Saudi emissions tCO_2e/unit	UAE emissions tCO_2e/unit
Aluminium	637.2	610.9	5.98	6.26
NG-DRI/EAF steel	45.8	46.5	0.980	0.994
Gas-based ammonia	39.0	44.6	1.571	1.571
Electrolytic hydrogen	2,503	2,400	17.19	18.32
Data-centre IT service	63.7	61.1	0.438	0.466
Blended cement	8.11	8.43	0.547	0.549

The output unit is a tonne of the named product, except data-centre IT service, which uses MWh of IT load. Values with different units must not be summed or directly ranked across products.

In the selected A-to-C comparison, the five electricity-using applications have lower operational emissions but higher energy costs. Gas-based ammonia is unchanged. This is distinct from a separate process-technology option.

Electricity-procurement costs used in industry have their own delivery boundary. They must not be replaced by standalone PV LCOE or the historical grid-average emissions factor.

F4 Separate industrial process-option assumptions

These options compare a changed process with its Path A reference. They are not relabelled A-to-C procurement results.

Option	Selected assumption or comparison
Aluminium	Illustrative renewable-electricity procurement for smelting; incomplete upstream and process-gas footprint
Steel	Hydrogen-based direct reduction; illustrative hydrogen requirement of 0.055 tonnes per tonne of crude steel
Ammonia	Electrolytic hydrogen; approximately 0.1765 tonnes hydrogen and 0.6 MWh auxiliary electricity per tonne ammonia
Hydrogen	Renewable procurement for electrolysis, with selected electrolyser assumptions held constant
Data centres	Power usage effectiveness improves from 1.4 to 1.2
Cement	Clinker-to-cement ratio falls from 0.71 to 0.57

Additional parameter	Assumption
PEM uninstalled electrolyser CAPEX	US$1,000/kW
Electrolyser installation factor	1.30 × uninstalled cost
Illustrative water price	US$1.00/m³
Cement kiln thermal energy	3.6 GJ/tonne clinker
Clinker process emissions	0.525 tCO_2/tonne clinker
Industrial financing spread	2 percentage points above power WACC

Hydrogen-based steel and ammonia can increase operational emissions when the electricity used for hydrogen is carbon-intensive. The screens do not establish full retrofit costs, market demand, certification or project bankability.

F5 Clinker substitution and data-centre efficiency

Selected 2030 Severe Downside / administered-gas process options, compared with the Path A reference process.

Item	Reference	Option	Screened implication
Clinker per tonne cement	0.71	0.57	Lower thermal energy and clinker process emissions
Saudi cement operational emissions	Reference process	Option versus reference	About 18.6% lower
UAE cement operational emissions	Reference process	Option versus reference	About 18.5% lower
Cement energy-cost reduction	Reference process	Saudi / UAE	About US$0.70 / US$0.80 per tonne
Data-centre PUE	1.4	1.2	14.3% less electricity per unit of IT service

Cement thermal input = clinker ratio × 3.6 GJ per tonne clinker. Clinker process CO_2 = clinker ratio × 0.525 tCO_2 per tonne clinker. Lower clinker content addresses emissions beyond purchased electricity.

The cement result excludes substitute-material availability and cost, grinding/blending changes, product performance, certification and implementation CAPEX. The 0.57 ratio is not a validated target for every plant.

PUE = total facility electricity ÷ IT electricity. At unchanged IT service and procurement, the reduction is 1 – 1.2/1.4 = 14.3%. It does not imply lower service demand or a 14.3% reduction in total facility expenditure.

G1 Responsibility, capacity and dependence evidence

These dimensions inform interpretation but do not produce a numerical justice ranking or national phase-out date. [23, 24, 25, 26]

Measure	Saudi Arabia	UAE	Boundary
Cumulative fossil/industrial CO_2 through 2024	19.0 $GtCO_2$	5.82 $GtCO_2$	Territorial fossil and industrial CO_2
Annual CO_2 per person, 2024	20.38 t	20.13 t	Same territorial fossil/industrial scope
2025 calibration GDP, approximate US$bn	1,274	569	UAE value is an estimate
Assumed financing assets, US$bn	950	1,200	Sensitivity envelope, not audited liquid wealth

Cumulative emissions and annual emissions per person answer different questions. Neither includes all greenhouse gases, exported-fuel combustion or an independently justified national fair share. A two-country comparison cannot establish a global ranking.

Dependence must be assessed through the specific fiscal, export, employment, production or consumption channel. Institutional capacity and financial resources do not verify worker rights, affordability, participation or environmental protection.

G2 Seven safeguards and their evidence requirements

All seven outcomes remain unassessed in both countries. This means insufficient evidence, not seven findings of failure. [27, 28, 29]

Safeguard	Evidence required
Climate alignment	Complete national greenhouse-gas pathways, cumulative budgets and a justified fair-share framework
Workers and livelihoods	Affected occupations, rights, income protection, retraining and redeployment, including migrant, contract and indirect workers
Household affordability	Income-group energy/water expenditure, essential-service access, compensation design and coverage
Participation and remedies	Meaningful participation, access to information and effective grievance arrangements
Environmental integrity	Environmental and biodiversity assessment, responsible supply chains, protection and remediation
Costed and funded support	Eligible populations, programme costs, funding, coverage and delivery verification
Differentiated cooperation	Transparent responsibility, capability, technology cooperation and international-support considerations

Economic scores and stronger fiscal balances cannot substitute for these requirements. The framework follows equity, Common but Differentiated Responsibilities and Respective Capabilities (CBDR-RC), and just-transition principles; it does not certify that the illustrative pathways meet them.

G3 Support allowances and climate-alignment limits

Budget allowances in B and C are illustrative inputs, not verified protection programmes. [30, 31]

2030 Reference allowance, each country	B	C
Additional worker and household support / GDP	0.3%	0.6%
Additional public transition investment / GDP	0.7%	1.5%

The study does not estimate all affected populations, income losses, programme coverage or distributional effects. Adequacy must be established with costed worker and household programmes, including relevant indirect, migrant and contract workers.

Programme costing requires eligible populations, unit costs, duration, administration and verified delivery. Requirements must be reconciled with support already included in fiscal expenditure to avoid double-counting; an unverified administrative percentage is not an adequacy test.

Neither pathway has been assessed against nationally determined contributions (NDCs). The no-new-expansion condition and national circumstances guide interpretation. They do not turn the combined production-linked revenue index into a fuel-specific extraction schedule, national carbon budget or verified fair-share pathway.

External extraction-equity frameworks have different baselines and fuel boundaries. They cannot certify B or C by direct percentage comparison. A steeper fair-share pathway needs new fiscal calculations, full emissions accounting and explicit protection costs.

H1 Data years and statistical boundaries

A data vintage is part of the finding, not a detail that can be removed from a comparison.

Issue	Treatment in the approved comparison
Fiscal institutions	Saudi central-government and UAE general-government observations retain their coverage
UAE starting figures	2024 baseline: +6.4% fiscal balance and 34.9% debt/GDP; 2025 scenario: about +5.1% and 34.5%
Trade shares	Different years and re-exports prevent a forced complementary export total or domestic-value-added interpretation
GDP activity shares	Unreconciled non-oil GDP and extraction-share rankings are omitted
Electricity indicators	Capacity, generation, historical grid emissions and future contracted procurement are distinct
Financial capacity	The assumed financing envelope is distinct from total sovereign assets and usable budget liquidity
Overseas investment	A foreign fossil asset retains its underlying fossil-market exposure; aggregate inward FDI does not identify non-fossil diversification

The 2024-25 starting point does not fully represent all 2026 conflict, reconstruction, shipping, insurance or overseas-portfolio effects. The seven environments are comparative sensitivities, not a complete reconstruction of those events.

H2 Limits of the evidence and use of the results

Claim	What the study establishes
Expansion is always necessary	Not established: a transition package can improve later annual balances in the conditions tested
Production decline causes fiscal gains	Not established: revenue, expenditure, financing and delivery assumptions change jointly
A better 2040 balance means higher overall welfare	Not established: accumulated stocks, full investment returns, employment and distribution require additional evidence
Lower LCOE means equivalent power service	Not established: hourly reliability, networks and full system adequacy are not optimised
Electrification always reduces costs/emissions	Not established: the result varies by service, electricity supply, scale and investment assumptions
Lower industrial emissions prove competitiveness	Not established: full plant costs, product quality, demand and footprints are incomplete
B or C is a verified just 1.5°C pathway	Not established: national emissions budgets, equity choices and safeguards need separate assessment

No multi-criteria policy ranking, national implementation roadmap, carbon-market recommendation or net carbon-border liability is inferred from these screens. Nuclear generation, carbon capture and offsets are not proposed as transition solutions.

Project decisions require complete investment, engineering, environmental and distributional assessment. These requirements preserve the meaning of the conditional fiscal and representative technology results.

I1 Key analytical terms

Term	Meaning
Baseline	Source-cited starting conditions, each retaining its own period and statistical boundary
Pathway	A complete package of production, revenue, spending and energy assumptions
Environment	A common combination of market, financing or delivery conditions applied to each pathway
Production-linked index	Combined oil-and-gas exposure used in revenue calculations, with 2025 as the base
Annual fiscal balance	Government revenue less primary and interest expenditure in the stated year
Primary expenditure	Government expenditure excluding interest
Non-oil primary balance	Non-hydrocarbon revenue less primary expenditure; denominator must be stated
Fiscal diversification	Development of durable public revenue beyond hydrocarbon receipts
Financing-asset envelope	Assumed assets available for simplified financing mechanics
Net financial position	Assumed financing assets less modelled public debt
LCOE	Generation costs spread over lifetime electricity output
System-adjusted cost	Generation cost plus the stated system-service allowances
Operational emissions	Modelled direct and purchased-electricity emissions within the process boundary
PUE	Total data-centre facility electricity divided by IT electricity
Not assessed	Insufficient evidence to verify the outcome; neither zero nor an automatic failure

I2 Acronyms

Acronym	Meaning
CAPEX	Capital expenditure
CBDR-RC	Common but Differentiated Responsibilities and Respective Capabilities
CCGT	Combined-cycle gas turbine
CO_2 / CO_2e	Carbon dioxide / carbon dioxide equivalent
CRF	Capital recovery factor
DRI / EAF	Direct-reduced iron / electric-arc furnace
EF	Emissions factor
FDI	Foreign direct investment
GDP / GHG	Gross domestic product / greenhouse gas
IEA / IRENA	International Energy Agency / International Renewable Energy Agency
ILO / IMF / IPCC	International Labour Organization / International Monetary Fund / Intergovernmental Panel on Climate Change
IT	Information technology
KSA / UAE	Kingdom of Saudi Arabia / United Arab Emirates
LCA / LCOE	Life-cycle assessment / levelised cost of electricity
NCV / NDC	Net calorific value / nationally determined contribution
NPV / O&M	Net present value / operation and maintenance
OCGT	Open-cycle gas turbine
PEM / PV / PUE	Proton exchange membrane / photovoltaic / power usage effectiveness
RE	Renewable energy
WACC	Weighted average cost of capital

I3 Units and comparison conventions

Unit	Meaning
US$m / US$bn	Million / billion United States dollars
kW / MW / GW	Kilowatt / megawatt / gigawatt of capacity
kWh / MWh / TWh	Kilowatt-hour / megawatt-hour / terawatt-hour of energy
GJ / PJ	Gigajoule / petajoule
MMBtu	Million British thermal units
toe / boe	Tonne of oil equivalent / barrel of oil equivalent
tCO_2 / tCO_2e	Tonne carbon dioxide / tonne carbon dioxide equivalent
$MtCO_2$ / $GtCO_2$	Million / billion tonnes carbon dioxide
US$/MWh / US$/MMBtu	Cost per unit electricity / gas energy
% of GDP	A flow or stock expressed relative to the stated GDP measure
Percentage points	Difference between two percentage values
Index, 2025 = 1.00	Relative scenario input; not a physical-volume unit

A fiscal balance changing from –10% to –8% of GDP improves by two percentage points, not two percent. Monetary values are nominal US dollars unless another basis is stated.

Annual fiscal flows, accumulated debt/assets, per-unit industrial costs and representative application totals must not be combined as though they describe the same national outcome.

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