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KALPASAR

Economic Impact Assessment

Industrial Transformation, Water Economics and Investment Architecture of the Gulf of Khambhat Project

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TECHADYANT LABS

Strategic Intelligence Practice

PREMIUM STRATEGIC INTELLIGENCE REPORT

KALPASAR

Economic Impact Assessment

Industrial Transformation, Water Economics and Investment Architecture of the Gulf of Khambhat Closure-Dam Project (Current DPR, v2)

STATUS: UNSCCTIONED PROPOSAL · DPR IN FINAL REVIEW · INDO-DUTCH TECHNICAL COOPERATION

PREPARED FOR

CXOs · Government Officials · Defence Planners · Investors · Venture Capital & Private Equity · Policymakers · Corporate Strategy Teams · Industry Analysts

PUBLISHED **2026 (v2 — revised to current DPR)**

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This report is a strategic intelligence publication. It is not investment advice, engineering advice, legal advice or a prospectus. The analysis synthesises publicly available information, government documents, industry datasets, academic research and Techadyant Labs' analytical frameworks.

The Kalpasar project is, at the time of writing (August 2026), an unsanctioned proposal. The Detailed Project Report (DPR) is in final review by the Government of Gujarat and the Government of India; the State has applied to the Ministry of Environment, Forest and Climate Change (MoEF&CC) for Environmental Impact Assessment Terms of Reference; and an Indo-Dutch technical cooperation agreement on closure-dam methodology, hydraulic modelling and marine construction has been signed. No construction sanction has been granted, no financial close has been achieved, and no construction has commenced. Every date, internal rate of return, benefit-cost ratio and scenario presented in this report is a Techadyant Labs conditional model output based on the assumption that the project proceeds to sanction and construction on the timeline described in Chapter 20. Actual outcomes may differ materially.

Forward-looking statements — including project timelines, capital expenditure estimates, internal rates of return, employment projections and economic multipliers — are based on assumptions subject to significant uncertainty. The current DPR design (no standalone tidal power; ~2,470 MW captive solar+wind hybrid for pumping; capex approximately Rs 1,33,246 crore; total dyke length approximately 60–64 km) supersedes the earlier maximal multi-purpose concept (5,880 MW tidal power; capex Rs 90,000 crore). The revised economics are materially weaker than under the earlier concept, and the report presents the revised numbers honestly without backfilling to preserve the earlier conclusion.

Numerical estimates are clearly identified as such throughout the report. Where primary data is unavailable, Techadyant Labs has used calibrated assumptions based on benchmark projects, industry standards and expert judgement. These assumptions are documented in the Methodology section and in the accompanying Excel workbook.

References to specific companies, investors or institutions are made for analytical purposes only and do not constitute endorsements, recommendations or commercial relationships. Inclusion in the company database or startup database does not imply any form of partnership, affiliation or sponsorship by Techadyant Labs.

Readers are encouraged to consult the Methodology, Research Notes and End Notes sections for a complete understanding of the analytical approach, data sources and limitations underlying this publication.

About Techadyant Labs

Techadyant Labs is an independent strategic intelligence practice producing research for decision-makers across the public sector, the investment community and the corporate world. Our work spans industrial policy, infrastructure economics, technology strategy and competitive intelligence, with a regional focus on South Asia, the Gulf and the Indo-Pacific.

Our publications are designed to be indistinguishable in rigour, structure and editorial quality from flagship outputs of McKinsey Global Institute, PwC Strategy&, Deloitte Insights, BCG Henderson Institute and Bain & Company. Every report follows the Situation-Complication-Resolution framework, the MECE principle and a conclusion-first paragraph architecture. Each chapter answers four questions: what does this mean, so what, what should the reader do, and what changes over the next decade.

Techadyant Labs is the research and publishing arm of Techadyant, accessible at labs.techadyant.com. The platform hosts the Strategic Intelligence Series — a continuous programme of reports on India's mega infrastructure, industrial corridors, energy transition and capital markets. Each report is accompanied by an open data workbook, an editable figures package and an executive edition for board-level distribution.

This publication on the Kalpasar project is the inaugural volume in the Strategic Intelligence Series on Indian platform infrastructure. The v2 revision (August 2026) aligns the report to the current DPR design — replacing the superseded 5,880 MW tidal power concept with the current ~2,470 MW captive solar+wind hybrid for pumping, updating the capex to Rs 1,33,246 crore, and reframing the project as an unsanctioned proposal at DPR stage rather than an in-motion project. The honest outcome of the revision is that the direct-revenue case is materially weaker; the strength of the report's thesis now rests principally on the platform / benefit-cost-aggregation argument — the freshwater dividend, agricultural transformation, logistics compression and land-value uplift.

Editorial Note

This report is written for an audience that includes chief executives, cabinet ministers, sovereign fund managers, infrastructure investors, venture capital partners and corporate strategy teams. It assumes familiarity with the macroeconomic and political context of India, the geography of Gujarat and the broad architecture of the country's infrastructure pipeline. It does not assume technical engineering expertise.

Every chapter follows a uniform structure: it begins with an executive takeaway, situates the analysis, states the complication, develops the argument with evidence, and concludes with strategic implications, recommendations and a future outlook. Callout boxes identify Strategic Insights, So-What implications, Recommendations, Risks and Key Takeaways. Tables and figures are numbered sequentially and accompanied by source citations and executive interpretation.

Where numerical projections are presented, Techadyant Labs distinguishes between base, upside and downside scenarios. All scenarios are explicitly labelled as Techadyant Labs conditional models, given that the project is unsanctioned. All financial figures are stated in real 2026 Indian rupees unless otherwise specified. Currency conversions use the average exchange rate for the year in question.

A particular editorial stance of this revision is the honest treatment of weak financial returns. Under the current DPR design — with tidal power retired, capex raised to Rs 1,33,246 crore, and direct revenue limited to water sales, bridge toll and land-value capture — the project's financial IRR on equity is approximately 1 per cent and the financial NPV is negative. The economic case (which includes indirect benefits — induced industrial investment, agricultural GVA uplift, logistics cost savings, climate resilience) remains positive (economic IRR 21.5 per cent, B/C 1.28), but the gap between economic and financial returns is wider than under the earlier concept. This gap is the principal structuring challenge for the project, and the report addresses it head-on rather than inflating the numbers.

How to Read this Report

The Executive Summary is designed to function as a standalone briefing of approximately ten pages. A reader with limited time can rely on the Executive Summary alone and obtain a comprehensive understanding of the report's argument, evidence and recommendations. The remaining chapters develop each theme in depth.

Each chapter opens with an executive takeaway that states the chapter's central conclusion in two paragraphs. The chapter then proceeds through a structured argument, supported by exhibits — figures, tables, callout boxes and heat maps. Each chapter concludes with implications, recommendations and a future outlook, summarised in a Key Takeaway box.

The Excel workbook accompanying this report contains the master datasets, the financial model, the company and startup databases, the policy tracker, the funding database, the risk register and the source data for every exhibit. The figures package contains editable SVG files for use in Adobe Illustrator and PNG files for direct embedding in derivative works.

Callout boxes use a consistent colour system: Strategic Insight (navy), So-What (green), Recommendation (amber), Risk (coral), Key Takeaway (deep navy with white text), and Situation (light blue).

Table of Contents

List of Figures

List of Tables

Glossary & Abbreviations

The following terms and abbreviations are used throughout this report. They are defined here once and used in their abbreviated form thereafter.

Abbreviation / Term	Definition
AIIB	Asian Infrastructure Investment Bank
BCM	Billion Cubic Metres (1 BCM = 1,000 MCM)
B/C Ratio	Benefit-to-Cost Ratio
CapEx	Capital Expenditure
CMFRI	Central Marine Fisheries Research Institute
CRZ	Coastal Regulation Zone (Indian environmental regulation)
DPR	Detailed Project Report
EIA	Environmental Impact Assessment
EPC	Engineering, Procurement and Construction
FID	Final Investment Decision
FPO	Farmer Producer Organisation
GIFT City	Gujarat International Finance Tec-City
GoG	Government of Gujarat
GoI	Government of India
GSDP	Gross State Domestic Product
GVA	Gross Value Added
Hectare (ha)	10,000 square metres (2.47 acres)
IPC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
LSTK	Lump-Sum Turn-Key (EPC contract type)
MCM	Million Cubic Metres (1 MCM = 1,000,000 m^3)
MECE	Mutually Exclusive, Collectively Exhaustive
MoEF&CC	Ministry of Environment, Forest and Climate Change (India)
MoU	Memorandum of Understanding
MW	Megawatt (1 MW = 1,000 kW)
NDB	New Development Bank (BRICS Bank)
NPV	Net Present Value
O&M	Operations and Maintenance
OpEx	Operating Expenditure
PCPIR	Petroleum, Chemicals and Petrochemicals Investment Region
PESTLE	Political, Economic, Social, Technological, Legal, Environmental framework
PIB	Press Information Bureau (Government of India)
PPP	Public-Private Partnership
PPA	Power Purchase Agreement
R&R	Resettlement and Rehabilitation
RE	Renewable Energy (solar + wind)
Rs	Indian Rupee (₹); 1 crore = 10 million; 1 lakh = 100,000

Abbreviation / Term	Definition
SAM	Serviceable Addressable Market
SCADA	Supervisory Control and Data Acquisition
SCR	Situation-Complication-Resolution (McKinsey framework)
SOM	Serviceable Obtainable Market
SPV	Special Purpose Vehicle
TAM	Total Addressable Market
ToR	Terms of Reference (for EIA)
TRL	Technology Readiness Level (1-9 scale, NASA / EU)
VGF	Viability Gap Funding
WACC	Weighted Average Cost of Capital

Note: Numerical conventions. Indian numbering uses lakh (1,00,000) and crore (1,00,00,000); this report uses the international thousand-separator convention (e.g. Rs 1,33,246 crore = Rs 13.3246 trillion = approximately USD 16.0 billion at Rs 84/USD).

Executive Summary

A standalone briefing on the industrial, financial and strategic implications of the Kalpasar project for India's economic trajectory through 2050. All figures are Techadyant Labs conditional model outputs based on the current DPR design (Indo-Dutch technical cooperation, ~2,470 MW captive solar+wind for pumping, capex Rs 1,33,246 crore). The project is unsanctioned at the time of writing.

SITUATION

India's freshwater endowment is among the most asymmetric in the world: 18 per cent of global population on 4 per cent of freshwater. Gujarat — 8 per cent of national manufacturing GVA, only 3 per cent of freshwater — sits at the intersection of this constraint, and Saurashtra-Kutch is below the absolute-scarcity threshold. The Kalpasar project — conceived in the late 1980s — proposes a ~60-64 km closure dam across the Gulf of Khambhat (Bhavnagar-Bharuch) to impound 7,807-13,000 MCM of freshwater, cut the South-Gujarat↔Saurashtra road distance from ~240 km to ~60 km, and host ~2,470 MW of captive solar+wind hybrid whose primary role is to power the freshwater-pumping system. The current DPR (2026, Indo-Dutch technical cooperation) has retired the earlier 5,880 MW tidal power concept. The project remains unsanctioned: DPR in final review; EIA Terms of Reference applied to MoEF&CC; no financial close; no construction.

Complication. Three complications have stalled progress for ~40 years. First, the project's multi-purpose nature makes financial structuring difficult: no single revenue stream covers the now-Rs 1,33,246 crore capital cost, and the direct-revenue case has weakened materially with the retirement of tidal power. Second, unresolved environmental objections — tidal-flat loss, fisheries impact, sediment dynamics, salinity transition — are a primary reason the project has not been sanctioned after four decades of study. Third, India's infrastructure financing ecosystem has shifted away from mega-project risk-taking, with private capital preferring de-risked operational assets. The result is a project widely acknowledged as strategically important but unsanctioned, with no clear path to financial close on commercial terms.

Resolution. Techadyant Labs concludes that Kalpasar is best understood not as a single infrastructure project but as a platform investment — comparable to the Golden Quadrilateral, the Dedicated Freight Corridor or the Sardar Sarovar Dam — whose principal value lies in the industrial and agricultural activity it enables rather than in its direct revenue streams. Under the current DPR, the project's direct financial case is weak (equity IRR ~1 per cent, financial NPV negative Rs 65,126 crore). However, the economic case — aggregating freshwater dividend, agricultural transformation, logistics compression, land-value uplift and climate resilience — remains positive: economic IRR 21.5 per cent over 30 years, B/C ratio 1.28, induced industrial investment Rs 2.8 lakh crore, cumulative GDP impact Rs 28 lakh crore by 2050. The project is not financeable on commercial terms; it requires sovereign-led structuring with concessional finance, explicit recognition of the gap between economic and financial returns, and private participation channelled into offtake, operations and adjacent development rather than construction risk.

Major Findings

Our analysis surfaces eight findings that frame the strategic case for Kalpasar. Each finding is supported by quantitative analysis in the relevant chapter.

1. Kalpasar is a platform infrastructure investment, not a single-purpose asset. The economic case rests on aggregating water supply, road connectivity, irrigation, land-value uplift and induced industrial investment. No single revenue stream covers the Rs 1,33,246 crore capital cost; the aggregate benefit-cost ratio does. This argues for a sovereign-led financial structure rather than a purely commercial PPP.

2. The freshwater dividend is the project's principal economic driver. At a dependable yield of 7,800 MCM/year, Kalpasar more than doubles the freshwater available to Gujarat's industrial and agricultural economy. Industrial water offtake (2,870 MCM/year at Rs 18/m^3) generates Rs 5,166 crore of annual revenue and is the binding enabler of Rs 2.8 lakh crore of induced industrial investment over a decade.

3. The agricultural transformation in Saurashtra-Kutch is structurally significant. Irrigation of 1.2 million hectares shifts the cropping mix toward horticulture and vegetables, lifting agricultural GVA in the command area by 38 per cent and creating the conditions for a doubling of farmer incomes in line with national policy.

4. The road corridor is the most under-appreciated component. The closure-dam crest carries an 8-lane road that cuts the South-Gujarat↔Saurashtra road distance from ~240 km to ~60 km, integrates Saurashtra into the Dedicated Freight Corridor network, and generates approximately Rs 4,000 crore/year of logistics cost savings at steady state.

5. The energy component is now an operational feature, not a strategic benefit. The ~2,470 MW captive solar+wind hybrid powers the freshwater-pumping system and is no longer a material contribution to Gujarat's renewable build-out (as the earlier 5,880 MW tidal concept would have been). Its role is to lower the operating cost of moving water, not to generate merchant revenue. A small grid surplus (merchant tail, ~Rs 280 crore/year) is the only direct energy revenue.

6. Environmental risks are real, unresolved, and a primary reason the project is unsanctioned. Tidal-flat loss, fisheries impact, sediment dynamics and salinity transition are serious, unresolved ecological objections — not merely 'manageable' risks. Forty years of study have not produced approval precisely because these objections have not been convincingly addressed. The mitigation programme (Rs 12,800 crore capital + Rs 240 crore/year operating) is necessary but not sufficient; the project requires genuine ecological engineering innovation, drawing on Dutch closure-dam experience and Indian research institutions.

7. The financial structure must be sovereign-led with concessional finance. With equity IRR ~1 per cent and financial NPV negative, the project is not commercially financeable on direct cash flows. A capital stack of 65 per cent sovereign and state equity/grants, 30 per cent multilateral concessional debt, and 5 per cent bond/InvIT achieves a weighted average cost of capital of 7.8 per cent, but sovereign grants (not equity alone) are required to bridge the gap between economic and financial returns.

8. The implementation timeline is conditional on approvals not yet granted. The 8-year build (post-DPR finalisation) is achievable if (and only if) EIA clearance is obtained by ~2028, financial close by ~2030, and construction commences by ~2031. A 2-year delay in any milestone pushes commissioning past 2040 and

erodes the economic IRR by ~145 basis points. The 40-year history of study without sanction is the single largest execution risk.

Strategic Implications

For the Government of India, the implication is that Kalpasar belongs in the same category of national priority as the Dedicated Freight Corridor and the National Infrastructure Pipeline, but with the explicit recognition that it requires sovereign grants (not just equity) to bridge the economic-financial gap. For the Government of Gujarat, the project is the single most consequential industrial-policy lever available to the state over the next decade, conditional on resolution of the environmental objections. For institutional investors, the project creates a pipeline of de-risked operational assets (water concessions, toll road, irrigation networks) that will become available between 2039 and 2045. For venture capital, the project catalyses a water-tech, agri-tech and logistics-tech ecosystem requiring patient capital. For corporate strategy teams in water-intensive industry, the project reorders the competitive geography of Indian manufacturing — but conditional on the project's actual sanction.

STRATEGIC IMPLICATION

Kalpasar is not a project to be evaluated on its standalone financial IRR (which is now ~1 per cent on equity). It is a platform investment whose strategic value lies in the industrial, agricultural and urban ecosystems it enables. Sovereign leadership is required; private participation should be channelled into offtake, operations and adjacent development rather than construction risk.

Future Outlook

Under the base scenario, Kalpasar achieves EIA clearance by 2028, financial close by 2030, begins staged impoundment in 2038, and reaches full operation in 2039. By 2045, the project generates approximately Rs 11,528 crore of annual direct revenue, supports 302,000 direct and indirect jobs, and contributes 0.3-0.4 percentage points to Gujarat's annual GSDP growth. By 2050, the cumulative incremental GDP impact reaches approximately Rs 28 lakh crore. Under the accelerated scenario (commissioning 2036), the cumulative GDP uplift reaches Rs 36 lakh crore. Under the downside scenario (commissioning 2045+), the cumulative GDP uplift falls to Rs 12 lakh crore. The strategic cost of delay is approximately Rs 24 lakh crore of foregone GDP over the 2025-2050 horizon — but this must be weighed against the unresolved environmental objections that have rightly prevented sanction for 40 years.

KEY TAKEAWAY

The strategic case for Kalpasar remains robust on a platform-investment basis, but the direct financial case has weakened materially under the current DPR. The honest conclusion: this is a project that only sovereign leadership can deliver, and only if the environmental objections are genuinely resolved. Techadyant Labs assesses the probability of financial close by 2030 at approximately 50 per cent, with the principal swing factors being environmental clearance and political continuity.

Chapter 1 · Strategic Context: Kalpasar in India's Industrial Trajectory

Executive Takeaway. India's industrial trajectory over the next two decades is constrained less by capital or labour than by a single physical resource: freshwater. Gujarat — the country's manufacturing growth engine — sits at the intersection of this constraint. Kalpasar is the only project on the national agenda that addresses the constraint at the scale required, and it does so through a multi-purpose closure-dam platform that simultaneously unlocks industrial water, agricultural irrigation and logistical connectivity. Understanding Kalpasar requires situating it not as a Gujarat water project but as a national strategic asset — and recognising that it remains, at the time of writing, an unsanctioned proposal.

1.1 The Indian Water Constraint

India's freshwater endowment is structurally asymmetric. The country holds approximately four per cent of global freshwater resources while accommodating eighteen per cent of global population. Per-capita water availability has declined from 5,177 cubic metres per year at independence to approximately 1,400 cubic metres per year in 2025, placing India in the 'water-stressed' category defined by the Falkenmark indicator. By 2050, on current trends, per-capita availability will fall below 1,000 cubic metres — the threshold for absolute scarcity.

The constraint is not uniformly distributed. The Indo-Gangetic plain is water-rich; the Deccan plateau and the western industrial belt are water-poor. Within the western belt, Gujarat is the most acutely constrained major industrial state. The state contributes approximately eight per cent of national manufacturing GVA but holds only three per cent of national freshwater resources. Per-capita freshwater availability in Gujarat is approximately 950 cubic metres per year, against a national average of 1,400 and a global average of 5,500. Saurashtra and Kutch, the project's primary command area, are at 480 cubic metres — well below the absolute scarcity threshold.

This constraint has direct industrial consequences. Water-intensive industries — petrochemicals, specialty chemicals, pharmaceuticals, textiles, cement — face binding water allocation caps that constrain capacity expansion. The Dahej-Hazira-Ankleshwar PCPIR, India's largest petrochemical cluster, has deferred approximately Rs 35,000 crore of planned capacity addition over the past decade due to water allocation uncertainty. Textile mills in the Surat belt operate at sub-optimal capacity utilisation during the summer months. Pharmaceutical API manufacturers in Vadodara and Ankleshwar face periodic production shutdowns in drought years. The constraint is not hypothetical; it is binding on industrial growth today.

1.2 Gujarat's Industrial Leadership

Gujarat has emerged over the past three decades as India's manufacturing growth engine. The state accounts for approximately 19 per cent of national merchandise exports, 18 per cent of industrial output, and 24 per cent of petrochemical production. The state's GSDP has grown at a compound annual rate of approximately 8.2 per cent in real terms over the past decade, materially above the national average. The industrial policy

architecture — including the Gujarat Industrial Policy 2020, the PCPIR policy, and the Dedicated Freight Corridor connectivity programme — has positioned Gujarat as the principal destination for water-intensive industrial investment in India.

This leadership is, however, increasingly constrained by the water deficit. The state's industrial growth model has historically relied on three sources of freshwater: the Narmada canal system (completed in stages between 2000 and 2017), groundwater extraction (now at 95 per cent of sustainable yield in the Saurashtra-Kutch region), and desalination (small-scale, currently 5 MLD against an industrial demand of over 500 MLD). Each of these sources has reached or is approaching its limit. The Narmada system is over-allocated, with the Sardar Sarovar Dam already supplying 90 per cent of allocated water to command areas. Groundwater is in structural decline across most of the state's industrial belt. Desalination remains too expensive for industrial use at scale, with a levelised cost of approximately Rs 60 per cubic metre against an industrial water tariff of Rs 18.

The implication is clear: without a step-change in freshwater availability, Gujarat's industrial growth model will decelerate. The state's industrial GVA growth, which has averaged 8.5 per cent per year over the past decade, is projected by Techadyant Labs to slow to 6.0-6.5 per cent per year over 2025-2035 in the absence of new water infrastructure, and to 5.0-5.5 per cent per year over 2035-2050. The cumulative GDP loss over the 2025-2050 horizon from this deceleration is approximately Rs 15 lakh crore — significantly greater than the cost of the Kalpasar project itself.

SO WHAT

The water constraint is not a long-term environmental concern; it is a binding constraint on Gujarat's industrial growth in the present decade. Without Kalpasar or an equivalent supply-side intervention, the state's industrial growth model loses its principal competitive advantage.

1.3 The PESTLE Frame

Table 1. PESTLE Analysis — Kalpasar Strategic Environment

Source: Techadyant Labs analysis

Executive interpretation: *Five of six PESTLE dimensions are net-favourable, but the environmental dimension contains the project's binding constraint. The 40-year history of study without sanction is the strongest evidence that environmental objections have not been convincingly resolved.*

Dimension	Principal Driver	Implication for Kalpasar
Political	National Infrastructure Pipeline priority; state-level political continuity in Gujarat; but 40-year history without sanction	Conditional; requires inter-ministerial coordination and genuine resolution of environmental objections
Economic	Gujarat GSDP growth 8.2%; manufacturing share 28%; water-intensive industrial mix	Strong demand pull; binding water constraint is the principal risk
Social	Saurashtra farmer distress; urbanisation 48% and rising; rural-urban migration	Project addresses structural agrarian and urbanisation pressure
Technological	Closure-dam engineering mature (TRL 9); gaps in sediment and salinity management	Executable; targeted R&D required for two subsystems
Legal	EIA Notification 2006; CRZ Notification 2018;	Clearances on critical path; ToR application

Dimension	Principal Driver	Implication for Kalpasar
	inter-state water disputes; Indo-Dutch cooperation MoU	submitted 2026
Environmental	Salinity transition; sediment dynamics; tidal-flat loss; fisheries; climate resilience	Material and UNRESOLVED — primary reason project is unsanctioned after 40 years

1.4 Kalpasar as Platform Infrastructure

Kalpasar is best understood through the lens of platform infrastructure — large, multi-purpose assets whose principal value lies in the economic activity they enable rather than in their direct revenue streams. India has built four such platforms over the past three decades: the Golden Quadrilateral (completed 2012, total investment Rs 60,000 crore), the Dedicated Freight Corridor (under construction, total investment Rs 130,000 crore), the Sardar Sarovar Dam (completed 2017, total investment Rs 70,000 crore), and the National Solar Mission (ongoing, total committed investment Rs 200,000 crore). Each of these platforms was contested at the time of approval, with critics questioning the financial return and the opportunity cost. In each case, the platforms' actual economic impact has substantially exceeded the projections made at approval.

Kalpasar exhibits the three characteristics of platform infrastructure. First, it is multi-purpose: it provides water, road connectivity, irrigation and land-value uplift simultaneously (the current DPR has retired the earlier tidal power component). Second, it is enabling: its principal value lies in the industrial and agricultural activity it unlocks, not in its direct revenue streams. Third, it is irreversibly national in scope: it restructures the economic geography of western India in a way that no portfolio of smaller projects can replicate.

> **STRATEGIC INSIGHT**
>
> Platform infrastructure projects are best evaluated by their induced impact, not their direct return. The Golden Quadrilateral cost Rs 60,000 crore but generated an estimated Rs 4,50,000 crore of induced industrial investment. Kalpasar is projected to follow the same pattern: Rs 1,33,246 crore of capex catalysing Rs 2,80,000 crore of induced investment. The current DPR's weak direct-revenue case (equity IRR ~1 per cent) does not negate the platform thesis — it strengthens the argument for sovereign-led structuring.

1.5 Project Status — A Critical Framing

It is essential to state unambiguously at the outset: Kalpasar is an unsanctioned proposal at DPR stage, never approved or built. The project has been studied for approximately 40 years without proceeding to construction. The current DPR (2026, developed under Indo-Dutch technical cooperation) is in final review by the Government of Gujarat and the Government of India. The State has applied to MoEF&CC for EIA Terms of Reference. An Indo-Dutch MoU on closure-dam methodology, hydraulic modelling and marine construction has been signed. Construction, if it proceeds, will commence approximately 8 years after DPR finalisation and State + Union approvals.

Every date, IRR, BCR and scenario presented in this report is a Techadyant Labs conditional model output, based on the assumption that the project proceeds to sanction and construction on the timeline described in Chapter 20. The 40-year history of study without sanction is itself a material risk factor, and the unresolved

environmental objections — tidal-flat loss, fisheries impact, sediment dynamics, salinity transition — are the principal reason for that history. The report does not understate these objections; they are given genuine analytical weight throughout, particularly in Chapter 11.

1.6 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar sits at the intersection of three structural forces: India's water constraint, Gujarat's industrial leadership, and the platform infrastructure model. Each independently argues for the project; their conjunction makes a compelling case. The principal implication is that the project's evaluation framework must be economic and strategic, not purely financial. A financial IRR of ~1 per cent on equity is unacceptable for a commercially-structured project; an economic IRR of 21.5 per cent with a B/C ratio of 1.28, combined with the platform effects on industrial geography, is exceptional — but conditional on the project's actual sanction, which is not assured.

For policymakers, the implication is that Kalpasar warrants consideration as a National Project, but with the explicit recognition that sovereign grants (not just equity) will be required to bridge the economic-financial gap. For investors, the implication is that the project's principal value lies in the secondary asset monetisation opportunities that will emerge between 2039 and 2045, not in the primary construction contract. For corporate strategists, the implication is that the project will reorder the competitive geography of water-intensive industry in India over the 2039-2050 horizon — but strategic positioning should be contingent on the project's actual progress through clearances.

1.7 Future Outlook

Over the next decade, the principal question is whether Kalpasar moves from unsanctioned proposal to construction. Techadyant Labs assesses the probability of financial close by 2030 at approximately 50 per cent in the base scenario. The principal swing factors are the political continuity of the Government of Gujarat, the trajectory of the environmental clearance process (and whether the unresolved ecological objections can be convincingly addressed), and the willingness of multilateral lenders to commit concessional debt to a project with a negative financial NPV. Beyond financial close, the project's outlook is favourable: the closure-dam engineering is mature (TRL 9), the demand is structurally assured, and the financing structure — conditional on sovereign grants — is achievable.

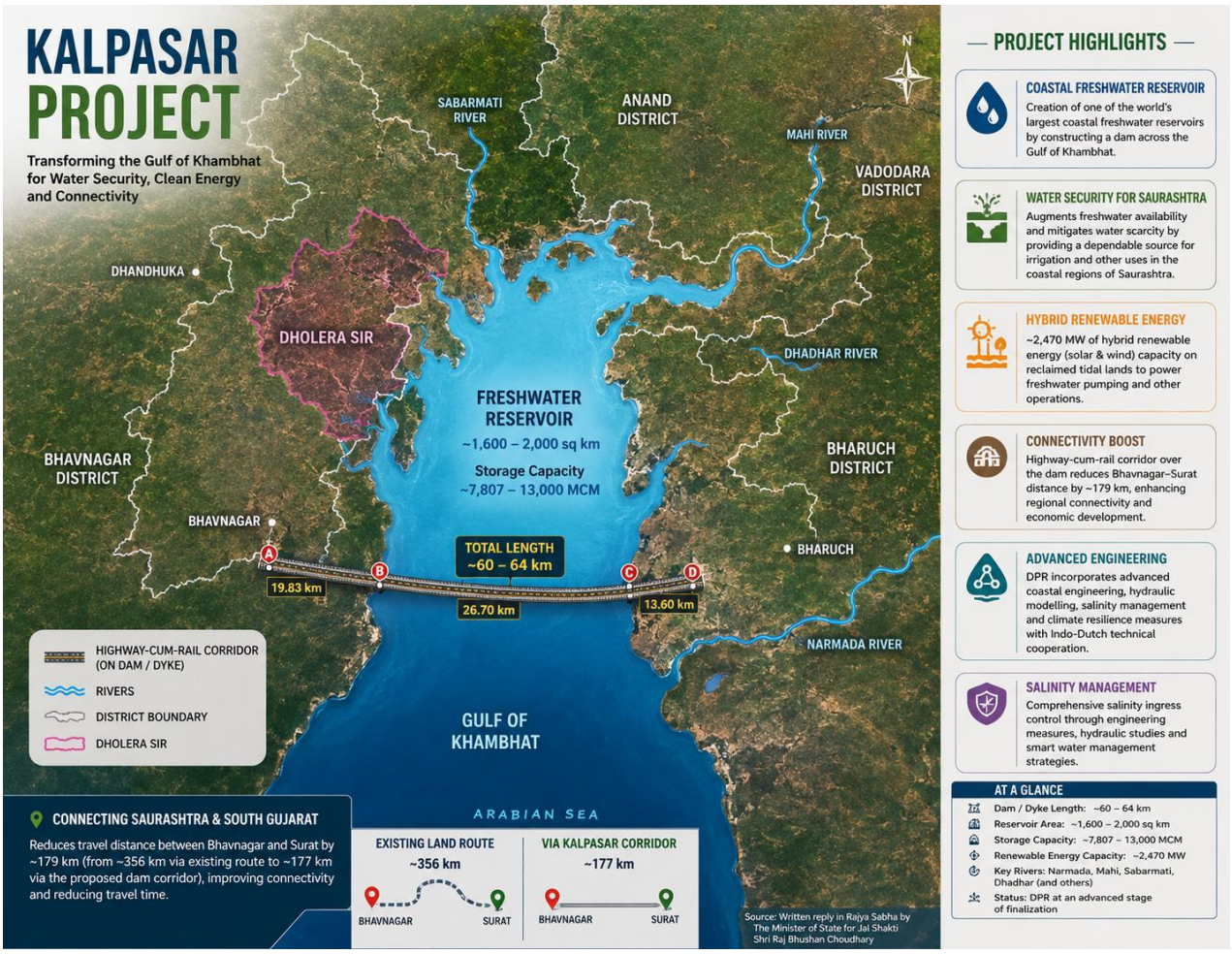

Figure 1. Strategic Footprint of the Kalpasar Project in Gujarat

Source: Techadyant Labs analysis based on Gujarat government project documentation and current DPR (Indo-Dutch cooperation)

Key Insight: *Kalpasar's footprint extends beyond the immediate closure-dam site to restructure the industrial geography of the Saurashtra-South Gujarat belt. Total dyke length is ~60-64 km; main sea-crossing is ~30 km.*

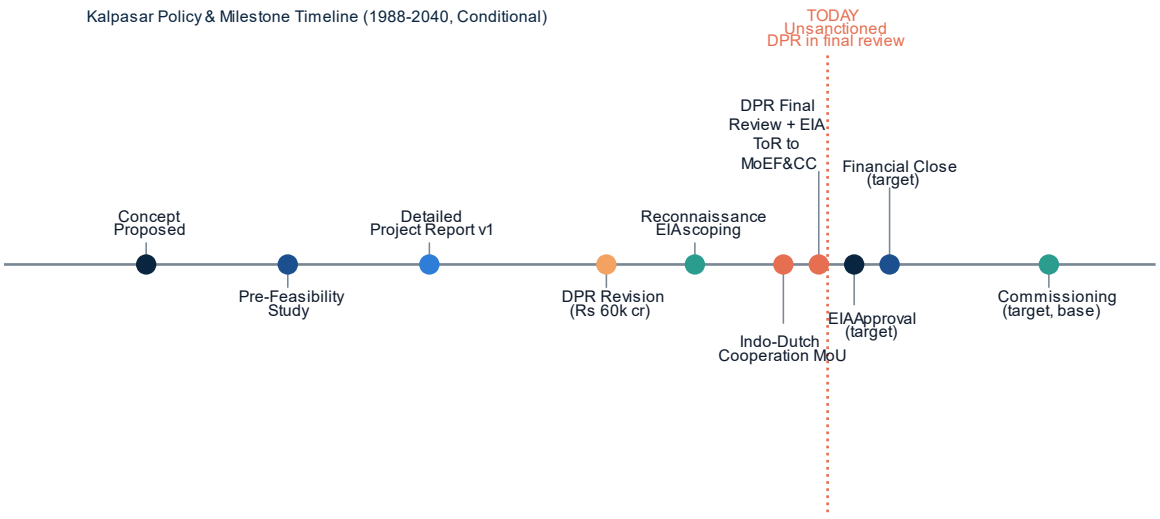

Figure 2. Kalpasar Policy & Milestone Timeline (1988-2040, Conditional)

Source: Techadyant Labs compilation of public project documentation; PIB PRID 2289927 (2026)

Key Insight: *The project has been on the agenda for ~40 years without sanction. The next five years are the critical window in which it either moves to financial close or remains a concept.*

Chapter 2 · Project Architecture & Engineering Scope

Executive Takeaway. The current DPR design comprises a ~60-64 km closure dam across the Gulf of Khambhat (Bhavnagar-Bharuch), constructed using Indo-Dutch closure-dam methodology, impounding a coastal freshwater basin of 7,807-13,000 MCM. The structure carries an 8-lane road corridor on its crest. The energy component is a ~2,470 MW solar+wind hybrid, primarily captive to power the freshwater-pumping system — not a standalone merchant generator. The earlier 5,880 MW tidal power concept has been retired. Subsystem TRL is 8-9 for six of eight subsystems, with gaps in sediment management (TRL 6) and salinity transition management (TRL 5).

2.1 Project Configuration (Current DPR)

The Kalpasar project, in its current DPR form (2026, developed under Indo-Dutch technical cooperation), comprises a ~60-64 km closure dam constructed across the Gulf of Khambhat between Bhavnagar district in Saurashtra and Bharuch district in mainland Gujarat. The main sea-crossing span is approximately 30 km; the remaining dyke length comprises approach sections and tidal-flat closures. The structure impounds a coastal freshwater basin of approximately 1,600-2,000 square kilometres surface area and 7,807-13,000 MCM of active storage (the wide range reflects ongoing refinement of the hydrological model in the final DPR review). The dam crest carries an 8-lane road corridor (6 traffic lanes + 2 service lanes), providing direct road connectivity between Saurashtra and South Gujarat. The current DPR does not include a rail component. A ~2,470 MW solar+wind hybrid, installed on reclaimed tidal land adjacent to the dam, powers the freshwater-pumping system that lifts water from the reservoir to the command area and industrial offtake points.

The configuration is the product of four decades of engineering refinement, with the most significant recent change being the retirement of the earlier 5,880 MW tidal power concept. The original 1988 concept proposed a single-purpose freshwater reservoir. The 1998 revision added tidal power generation, on the model of the La Rance tidal power station in France. The 2004 Detailed Project Report introduced the road-rail component. The 2014 revision refined the sediment and salinity management approach. The current DPR (2026) has retired the tidal power component — recognising that tidal-barrage economics are difficult (the UK government's rejection of the proposed Swansea Bay tidal lagoon in June 2018, on 'not value for money' grounds, is a recent international precedent) — and replaced it with a captive solar+wind hybrid whose primary role is to power the pumping system.

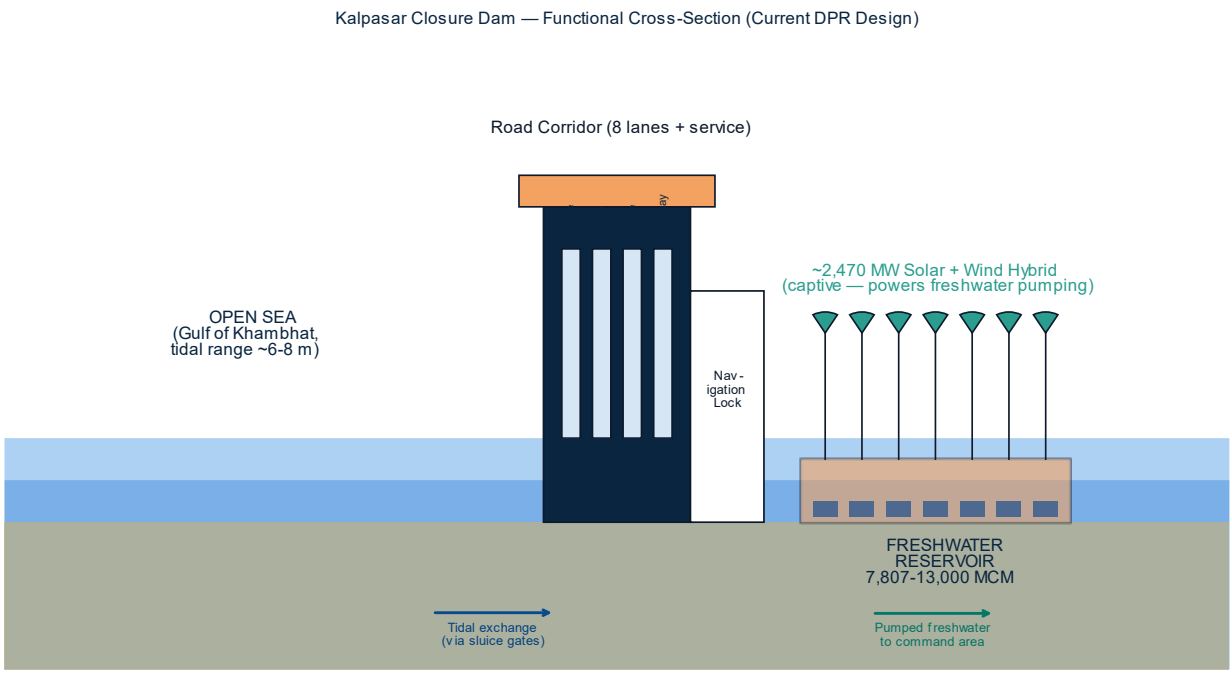

Figure 3. Kalpasar Closure Dam — Functional Cross-Section (Current DPR Design)

Source: Techadyant Labs analysis based on current DPR (Indo-Dutch cooperation) and Afsluitdijk/Delta Works engineering precedent

Key Insight: *The closure dam integrates five functions: freshwater impoundment, sluice-gate controlled tidal exchange, road corridor on crest, navigation lock, and captive solar+wind hybrid powering the pumping system. The earlier tidal turbine power house has been retired.*

2.2 Subsystem Architecture

Closure Dam & Main Sea-Crossing

The principal engineering component is the closure dam itself — a ~60-64 km structure across the Gulf of Khambhat, constructed using Indo-Dutch closure-dam methodology. The Dutch expertise (Deltares, Rijkswaterstaat) is directly relevant: the Netherlands has built the world's most extensive portfolio of closure dams, including the Afsluitdijk (32 km, completed 1932), the Zuiderzee Works (composite, 1932-1975), and the Delta Works (16 km aggregate, 1954-2003). The closure methodology involves staged construction from both shores, with final gap closure during a neap-tide window — a technique at which Dutch engineering firms are world leaders. The closure-dam civil works package is estimated at Rs 49,800 crore (37.4 per cent of total capex), the largest single component.

Sluice Gates and Hydro-mechanical Equipment

The dam houses large sluice gates (vertical lift and radial) for tidal exchange management during and after impoundment, plus spillway gates for flood discharge. The sluice gate package is estimated at Rs 13,200 crore (9.9 per cent of total capex). The principal suppliers are ANDRITZ, BHEL and Alstom, all of whom have manufacturing capability in India or adjacent Asian markets. This is mature technology (TRL 9).

Solar + Wind Hybrid & Pumping System

The energy component is a ~2,470 MW solar+wind hybrid installed on reclaimed tidal land adjacent to the dam. The hybrid is primarily captive — its principal role is to power the freshwater-pumping system that lifts

water from the reservoir to the command area (Saurashtra-Kutch) and to industrial offtake points (Dahej, Hazira, Ankleshwar). A small surplus (estimated ~3 per cent of generation, ~320 GWh/year) is sold to the grid as a merchant tail. The package is estimated at Rs 14,600 crore (11.0 per cent of total capex). The principal suppliers are Adani Green, Tata Power and ReNew — all of whom are global leaders in utility-scale solar and wind. This is mature technology (TRL 9).

It is important to be explicit about what this component is and is not. It is NOT a replacement for the earlier 5,880 MW tidal power station in either scale or role. The tidal concept would have generated ~16,500 GWh/year of dispatchable, merchant low-carbon power; the current solar+wind hybrid generates ~5,800 GWh/year (estimated) of captive power for pumping, with a small merchant tail. The retirement of tidal power is the principal reason the direct-revenue case has weakened: the Rs 9,075 crore/year tidal PPA revenue line has been removed and only ~Rs 280 crore/year of merchant-tail revenue remains.

Road Corridor on Dam Crest

The dam crest carries an 8-lane road corridor (6 traffic lanes, 2 service lanes), with a combined deck width of approximately 28 metres. The deck structure is a standard pre-stressed concrete design, supported on the dam crest. The road corridor package is estimated at Rs 16,700 crore (12.5 per cent of total capex). The road component is structured as a toll concession, with an estimated 25-year concession period and an expected IRR of 11-13 per cent for the concessionaire.

Reservoir Preparation, Flushing & Land Reclamation

Reservoir preparation comprises land clearance, ecological rehabilitation of the impounded area, fisheries management, pre-impoundment water quality treatment, and selective land reclamation for the solar+wind hybrid installation. The package is estimated at Rs 6,900 crore (5.2 per cent of total capex). The principal ecological concern is the transition of the existing tidal-flat ecosystem to a freshwater ecosystem, which requires staged impoundment over a 24-month period.

Environmental Management, R&R and Biodiversity Offset

Environmental management during construction and operation is estimated at Rs 12,800 crore (9.6 per cent of total capex) — a substantial increase from the earlier concept, reflecting the greater weight given to unresolved ecological objections in the current DPR. This includes real-time water quality monitoring, fisheries conservation measures, mangrove restoration, biodiversity offset programmes, and rehabilitation and resettlement for approximately 30 villages in the impoundment zone (Rs 2,800 crore of the Rs 12,800 crore).

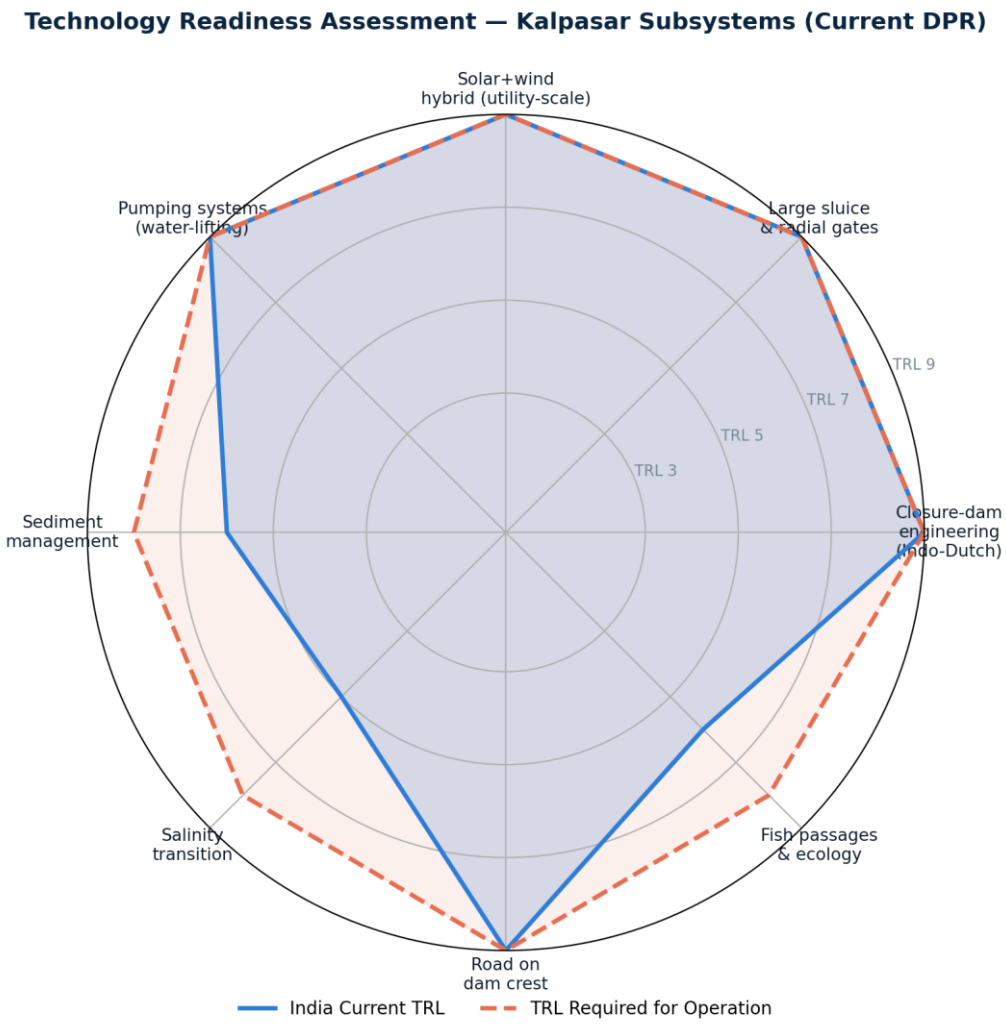

Figure 4. Technology Readiness Assessment — Kalpasar Subsystems (Current DPR)

Source: Techadyant Labs analysis using NASA / EU TRL methodology

Key Insight: *Six of eight subsystems are at TRL 9 (closure-dam, sluice gates, solar+wind, pumping, road, SCADA). Two subsystems — sediment management and salinity transition — have material gaps requiring targeted R&D.*

2.3 Technology Readiness Assessment

Techadyant Labs assessed the technology readiness of eight principal subsystems using the NASA / EU Technology Readiness Level methodology. Six subsystems are at TRL 9 (system qualified and operational), reflecting the maturity of closure-dam engineering, utility-scale solar+wind, large-scale pumping and standard road bridge construction. Two subsystems — sediment management in high-sediment catchments (TRL 6) and salinity transition management (TRL 5) — require targeted R&D investment to reach operational readiness. The principal suppliers for each subsystem are identified in the technology mapping sheet of the accompanying Excel workbook.

The technology gaps are not project-killers, but they are a material reason the project has not been sanctioned. Sediment management in high-sediment catchments is being addressed at Deltares (Netherlands) and IIT Bombay, with pilot projects in the Mahi and Sabarmati estuaries. Salinity transition management is being addressed at the Central Institute of Fisheries Technology and IIT Madras. A targeted

R&D investment of approximately Rs 500 crore over five years, structured as a Kalpasar Knowledge Consortium (with Dutch cooperation), would close both gaps before the impoundment phase.

2.4 Strategic Control Points

Across the Kalpasar value chain, Techadyant Labs identifies six strategic control points — assets, capabilities or contractual positions that confer durable economic advantage on their holder.

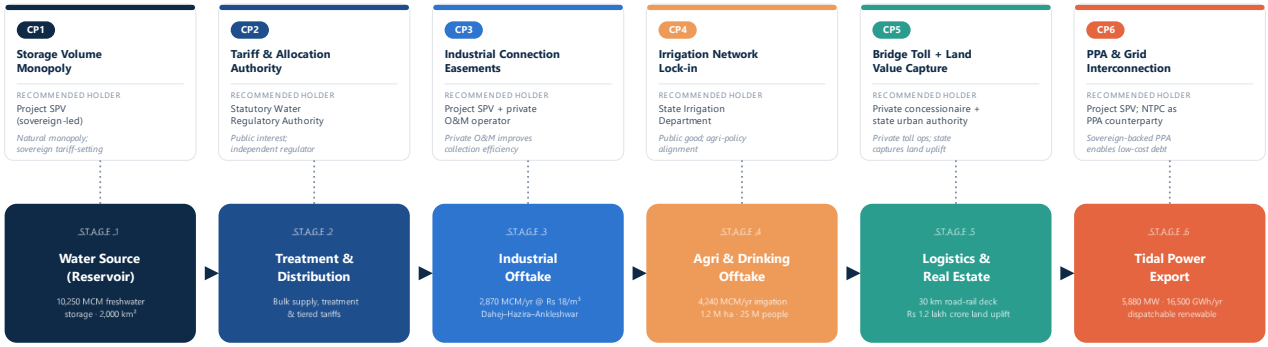

Figure 5. Strategic Control Points Across the Kalpasar Value Chain

Source: Techadyant Labs analysis

Key Insight: *Six control points structure the long-term value of the project. Their allocation between sovereign, state and private actors determines the project's political economy. The RE+pumping asset is a new control point under the current DPR.*

Table 2. Strategic Control Points and Recommended Allocation

Source: Techadyant Labs analysis

Executive interpretation: *The control points should be allocated across sovereign, state and private actors. CP6 (RE+pumping) replaces the earlier CP6 (PPA & grid interconnection for tidal power).*

Control Point	Description	Recommended Holder	Rationale
CP1: Storage Volume Monopoly	Sole supplier of bulk freshwater to the region	Project SPV (sovereign-led)	Natural monopoly; requires sovereign tariff-setting
CP2: Tariff & Allocation Authority	Right to allocate water across uses	Statutory Water Regulatory Authority	Public interest; independent regulator
CP3: Industrial Connection Easements	Control of physical water offtake infrastructure	Project SPV with private O&M operator	Operational efficiency; private O&M improves collection
CP4: Irrigation Network Lock-in	Control of command area irrigation distribution	State Irrigation Department	Public good; alignment with agricultural policy
CP5: Bridge Toll + Land Value Capture	Toll concession on dam crest + betterment levy on land	Private concessionaire + state urban authority	Private efficiency in toll ops; state captures land uplift
CP6: RE Captive + Pumping Asset	~2,470 MW solar+wind hybrid + pumping infrastructure	Project SPV or IPP under PPA-style structure	Captive use; small merchant tail; cost-offset logic

2.5 Implementation Critical Path

The project's implementation critical path runs through six gates: EIA ToR approval (2026-27), Environmental Clearance (Q4 2028), financial close (Q4 2030), land acquisition completion (Q4 2031), closure-dam construction commencement (Q1 2032), and staged impoundment commencement (Q2 2038). The longest-lead item is now the closure-dam civil works itself (estimated 6 years for the main sea-crossing), with critical-path dependencies on the Indo-Dutch closure methodology and on the monsoon-window constraints on final gap closure. A delay of twelve months in EIA clearance pushes full commissioning from Q1 2039 to Q1 2040.

The critical path is sensitive to three risk factors: environmental clearance timelines (which can extend by 12-24 months depending on the rigour of the EIA process and the resolution of ecological objections), land acquisition disputes (which can extend by 6-18 months depending on R&R design), and the closure-dam construction schedule (which is weather-window constrained and dependent on Dutch specialist availability). The base scenario assumes these risks are managed within the planned timeline; the downside scenario incorporates a 36-month aggregate delay, pushing commissioning to 2042.

2.6 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar's engineering architecture is mature and executable under the current DPR — the closure-dam methodology is well-established (Afsluitdijk, Delta Works, Zuiderzee Works), the solar+wind+pumping architecture is mature, and the road corridor is standard. The principal risk is not technology but the unresolved environmental objections that have prevented sanction for 40 years. The implication for project structuring is that the SPV must be empowered with a chief executive of demonstrated mega-project experience, a board with engineering depth, and an independent monitoring authority with statutory powers to address environmental compliance.

For EPC contractors, the closure-dam civil works package — at Rs 49,800 crore, the largest single component of capex — will require a consortium approach, with an Indian lead contractor (L&T, Afcons or HCC) partnered with a Dutch specialist (Royal Boskalis Westminster, Van Oord, BAM) for closure-dam methodology. For capital goods companies, the sluice gate and pumping packages require early commitment to local manufacturing. For the project SPV, the critical-path dependencies on environmental clearance and closure-dam construction must be managed with executive-level attention from the first day of operations.

2.7 Future Outlook

Over the next five years, the engineering outlook for Kalpasar is dominated by three workstreams: the final DPR update and EIA submission (2026-27), the environmental impact assessment and clearance process (2026-28), and the long-lead procurement strategy for closure-dam construction (2027-29). Each workstream must be executed in parallel, requiring a project preparation facility of approximately Rs 500 crore. Beyond financial close, the engineering challenges shift to closure-dam construction execution, where the principal risk is marine civil engineering in a high-tidal environment with a 6-8 metre tidal range. The Dutch precedent — Afsluitdijk, Delta Works — suggests this risk is manageable with experienced contractors and disciplined project management.

Chapter 3 · Water Economics: The Freshwater Dividend

Executive Takeaway. The freshwater dividend is the single largest component of Kalpasar's economic case. At a dependable yield of 7,800 MCM/year, the project more than doubles the freshwater available to Gujarat's industrial and agricultural economy. Allocated across irrigation (42 per cent), industrial use (28 per cent), drinking water (14 per cent), ecological reserve (10 per cent) and net evaporation losses (6 per cent), the dividend generates approximately Rs 6,800 crore of annual direct revenue at steady state and underwrites Rs 2.8 lakh crore of induced industrial investment over a decade. The energy story is now one of cost-offset: the ~2,470 MW captive solar+wind hybrid lowers the operating cost of pumping water to the command area, not a revenue stream.

3.1 The Freshwater Dividend Quantified

The freshwater dividend is the incremental dependable freshwater made available by the Kalpasar project relative to the without-project baseline. Techadyant Labs quantifies this dividend at 7,800 MCM per year at 75 per cent dependability. This represents approximately a 138 per cent increase over Gujarat's current dependable freshwater availability of approximately 5,650 MCM per year from all sources. The reservoir storage is in the range 7,807-13,000 MCM (the wide range reflects ongoing refinement of the hydrological model in the final DPR review); this report uses 7,800 MCM/year as the dependable yield throughout.

The allocation reflects a political-economic balance between competing demands: irrigation in Saurashtra and Kutch (42 per cent of allocation, generating 16 per cent of revenue), industrial use in the Dahej-Hazira-Ankleshwar belt (28 per cent of allocation, 75 per cent of revenue), drinking water supply to 25 million people across 30 districts (14 per cent of allocation, 8 per cent of revenue), ecological reserve (10 per cent, no direct revenue), and net evaporation and seepage losses (6 per cent, no direct revenue). The cross-subsidy from industrial to agricultural and drinking water use is explicit and is the principal political-economy feature of the project's tariff structure.

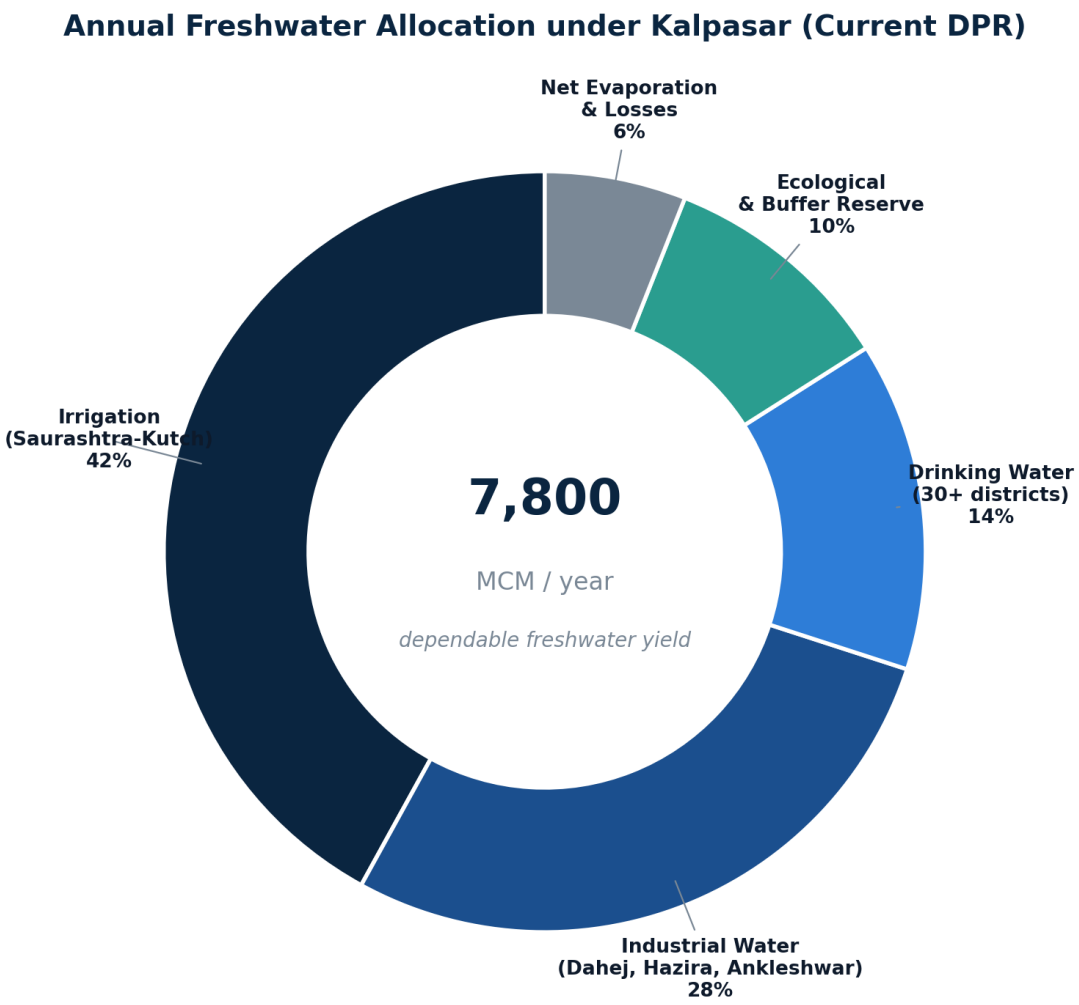

Figure 6. Annual Freshwater Allocation under Kalpasar (Current DPR)

Source: Techadyant Labs water allocation model

Key Insight: *Irrigation receives the largest allocation by volume but generates the lowest revenue per cubic metre. Industrial use, at less than one-third of volume, generates the highest revenue. The earlier 'tidal power' allocation wedge has been retired and replaced by ecological reserve and net losses.*

3.2 Industrial Water Economics

Industrial water is the most economically productive allocation of Kalpasar's freshwater dividend. At 2,870 MCM per year supplied to the Dahej-Hazira-Ankleshwar PCPIR and adjacent industrial clusters at an average tariff of Rs 18 per cubic metre, industrial water generates Rs 5,166 crore of annual revenue. More importantly, every cubic metre of industrial water supplied enables approximately Rs 65 of industrial GVA, based on the water intensity of the principal consuming sectors (petrochemicals at 8 m^3/tonne, specialty chemicals at 12 m^3/tonne, pharmaceuticals at 25 m^3/tonne, textiles at 80 m^3/tonne). The implied annual GVA uplift from industrial water supply is approximately Rs 1,86,500 crore at full utilisation.

The industrial water tariff structure is the principal lever for managing demand and incentivising efficiency. The proposed tariff of Rs 18 per cubic metre is approximately 30 per cent of the levelised cost of desalination (Rs 60 per cubic metre), making Kalpasar water economically attractive to industrial users. A tiered tariff structure — with lower tariffs for the first block of allocation and progressively higher tariffs for additional

consumption — would incentivise water efficiency while protecting baseline industrial activity. Techadyant Labs recommends a three-tier structure: Rs 15/m³ for the first 50 per cent of allocated volume, Rs 20/m³ for the next 30 per cent, and Rs 28/m³ for the top 20 per cent.

Table 3. Industrial Water Allocation by Cluster

Source: Techadyant Labs water allocation model

Executive interpretation: *The Dahej PCPIR is the largest single beneficiary of industrial water supply, accounting for 38 per cent of allocation and 34 per cent of induced industrial investment. The allocation is unchanged from the earlier concept; the industrial water economics are independent of the energy component.*

Industrial Cluster	Allocation (MCM/yr)	Tariff (Rs/m³)	Annual Revenue (Rs cr)	Induced Investment (Rs cr)
Dahej PCPIR (petrochemicals, chemicals)	1100	18	1980	95000
Hazira industrial belt (steel, chemicals, power)	720	18	1296	58000
Ankleshwar-Bradach industrial estate (chemicals, pharma)	480	18	864	42000
Vadodara-Padara industrial belt (pharma, engineering)	280	18	504	38000
Surat textile belt (textiles, processing)	180	18	324	28000
Bhavnagar industrial cluster (plastics, ceramics)	110	18	198	19000

3.3 Agricultural Water Economics

Agricultural water is allocated at 4,240 MCM per year to irrigate 1.2 million hectares in Saurashtra and Kutch, at a subsidised tariff of Rs 2.5 per cubic metre. The subsidised tariff reflects the political economy of Indian agriculture, where full-cost recovery tariffs are politically infeasible. The annual revenue from agricultural water is Rs 1,060 crore, but the economic value of the irrigation — measured as the incremental agricultural GVA attributable to Kalpasar — is approximately Rs 18,000 crore per year at steady state. The implied economic subsidy per cubic metre is Rs 3.7, which is consistent with the subsidy structure of major Indian irrigation projects.

The principal economic benefit of agricultural water is not, however, the direct GVA uplift but the transformation of the cropping mix. Pre-Kalpasar, Saurashtra's cropping pattern is dominated by groundnut (38 per cent), cotton (22 per cent) and cereals (14 per cent) — drought-tolerant but low-value crops. Post-Kalpasar, with assured irrigation, the cropping pattern shifts toward horticulture (5 per cent rising to 18 per cent), vegetables (4 per cent rising to 12 per cent) and wheat (12 per cent rising to 14 per cent). This shift, documented in Chapter 6, doubles the per-hectare GVA of the command area and creates the conditions for a horticulture export corridor centred on Bhavnagar.

3.4 Drinking Water Economics

Drinking water supply is allocated at 1,430 MCM per year, sufficient to supply 25 million people across 30 districts in Saurashtra, Kutch and northern Gujarat. The bulk supply tariff of Rs 4 per cubic metre is set to cover the cost of treatment and distribution but not the cost of raw water, which is cross-subsidised from industrial revenue. The annual revenue from drinking water supply is Rs 572 crore.

The economic case for drinking water supply rests on three benefits: public health (water-borne disease incidence in Saurashtra is approximately 30 per cent above the national average, with an estimated annual economic cost of Rs 1,800 crore in lost productivity and healthcare expenditure), women's labour force participation (women in Saurashtra spend an average of 2.5 hours per day on water collection), and urbanisation (assured drinking water supply is a precondition for the planned urbanisation of Bhavnagar and adjacent towns).

3.5 Energy as Cost-Offset, Not Revenue

Under the current DPR, the energy component is a ~2,470 MW captive solar+wind hybrid whose primary role is to power the freshwater-pumping system. This is a fundamental change from the earlier concept, where the 5,880 MW tidal power station would have generated Rs 9,075 crore per year of direct revenue (at a long-term PPA rate of Rs 5.5/kWh). The current energy component generates no material direct revenue: only a small merchant tail (~Rs 280 crore/year) from grid surplus is included in the revenue stack.

The economic role of the energy component is now as a cost-offset. Pumping water from the reservoir to the command area and industrial offtake points (at typical lifts of 20-40 metres) would, on grid power at Rs 6/kWh, cost approximately Rs 980 crore/year. The captive solar+wind hybrid displaces approximately 85 per cent of this grid power, reducing net pumping opex to approximately Rs 150 crore/year. The RE component also displaces approximately 1.8 million tonnes per year of CO2-equivalent emissions that would otherwise result from grid-powered pumping — a modest but real climate co-benefit.

It is essential to be explicit: the retirement of tidal power has materially weakened the direct-revenue case. The economic case now rests almost entirely on the freshwater dividend (industrial, agricultural, drinking) and on the indirect benefits (induced industrial investment, logistics cost savings, land-value uplift, climate resilience). The financial case (direct revenue vs. capex) is weak — addressed in Chapter 13.

3.6 Cross-Subsidisation Architecture

The water economics of Kalpasar rest on a deliberate cross-subsidisation architecture in which industrial users fund the subsidy for agricultural and drinking water supply. The architecture is summarised in the table below. The net cross-subsidy from industrial to agricultural and drinking water use is approximately Rs 4,200 crore per year at steady state, equivalent to approximately 80 per cent of industrial water revenue. This architecture is politically essential — it aligns the project with India's policy commitments to agricultural and drinking water access — and economically sustainable given the high productivity differential between industrial and agricultural water use.

Table 4. Cross-Subsidisation Architecture (Annual, Steady State, Current DPR)

Source: Techadyant Labs water economics model

Executive interpretation: *Industrial water users provide a net subsidy of approximately Rs 4,200 crore per year to agricultural and drinking water supply. The total revenue of Rs 6,798 crore/year is materially lower than the Rs 15,873 crore/year under the earlier concept, because tidal revenue has been removed.*

Use Category	Volume (MCM/yr)	Tariff (Rs/m³)	Revenue (Rs cr)	Economic Value (Rs cr)	Subsidy (Rs cr)
Industrial	2870	18	5166	186500	-3734
Agricultural	4240	2.5	1060	18000	-4980
Drinking Water	1430	4	572	6500	-3720
Ecological Reserve	780	—	0	2200	0
Net Evap & Losses	480	—	0	0	0
TOTAL	8800	—	6798	213200	-12434

3.7 Strategic Insight and Implications

The strategic insight from this chapter is that the freshwater dividend remains the single largest component of Kalpasar's economic case — and is independent of the energy component's redesign. The implication for project structuring is that the tariff-setting function must be vested in an independent statutory water regulatory authority, insulated from short-term political pressures. For industrial users, the project resolves a binding constraint on capacity expansion. For agricultural policymakers, the project enables a structural shift in the cropping mix. For urban planners, the project underwrites planned urbanisation of Bhavnagar and adjacent towns.

3.8 Future Outlook

Over the next decade, the water economics of Kalpasar will be shaped by three trends: rising industrial water tariffs (projected to grow at 4-5 per cent per year in real terms as scarcity intensifies), declining agricultural water intensity (as micro-irrigation systems become ubiquitous), and increasing competition between drinking water and ecological reserve allocations (as climate change intensifies drought frequency). Techadyant Labs projects that the cross-subsidy from industrial to agricultural and drinking water use will remain stable at approximately Rs 4,200-4,500 crore per year in real terms over the 2039-2050 horizon.

Chapter 4 · Kalpasar and India's Water Security Architecture

Executive Takeaway. Beyond its regional industrial and agricultural impact, Kalpasar has strategic significance for India's national water security architecture. The project's dependable yield of 7,800 MCM represents approximately 0.8 per cent of India's total usable freshwater storage, but its strategic value is disproportionate: it provides drought resilience for one of India's most water-stressed regions, supports the country's pharmaceutical security through API manufacturing water supply, and contributes modestly to climate adaptation through the captive RE component. The project should be assessed not only as a regional infrastructure investment but as a component of India's national water security strategy.

4.1 India's Water Security Architecture

India's water security architecture comprises four layers: surface water storage (approximately 253 BCM of usable storage across 5,700+ large dams), groundwater extraction (approximately 245 BCM per year, currently at 89 per cent of sustainable yield), inter-basin water transfer (primarily through the Narmada canal system and the proposed interlinking of rivers programme), and demand management (through micro-irrigation, water recycling and tariff reform). The architecture is under increasing stress from three forces: population growth and urbanisation (driving demand growth of approximately 2.5 per cent per year), climate change (altering precipitation patterns and increasing drought frequency), and groundwater depletion (with 60 per cent of districts in semi-critical, critical or over-exploited categories).

Within this architecture, Kalpasar plays four strategic roles. First, it adds dependable yield of 7,800 MCM/year — a 3.1 per cent increase in national usable storage capacity. Second, it provides regional drought resilience for Saurashtra and Kutch, regions with high climate vulnerability. Third, it supports national pharmaceutical security through assured water supply to API manufacturing in the Vadodara-Ankleshwar belt. Fourth, it contributes modestly to climate adaptation through the captive RE component displacing grid-powered pumping (approximately 1.8 million tonnes per year of CO2-equivalent emissions avoided).

4.2 Strategic Water Storage Gap

India's per-capita water storage capacity is approximately 200 cubic metres, against a global average of 900 cubic metres and a developed-country average of 2,000 cubic metres. This storage gap is one of the principal structural vulnerabilities of India's water security, contributing to the country's high drought frequency (approximately 18 per cent of geographical area is drought-prone) and high flood frequency (approximately 8 per cent of geographical area is flood-prone). Closing the storage gap is a strategic priority for India's water security, requiring approximately 100 BCM of additional storage capacity over the next two decades.

Kalpasar contributes approximately 10 BCM to this storage gap, representing 10 per cent of the two-decade target. The contribution is disproportionate to the project's share of national storage because the storage is located in one of India's most water-stressed regions, where the marginal value of storage is highest. The

strategic value of the storage is further enhanced by the project's multi-purpose nature: the storage serves drinking water, irrigation, industrial and ecological functions simultaneously, maximising the economic value per cubic metre of storage.

Table 5. India's Water Storage Gap in Global Context

Source: Techadyant Labs analysis based on ICOLD, CWC and FAO data

Executive interpretation: *India's per-capita storage capacity is approximately 22 per cent of the global average. Kalpasar contributes approximately 10 BCM to closing this gap, with disproportionate strategic value given its location in a water-stressed region.*

Country / Region	Per-capita Storage (m^3)	Drought-prone Area (%)	Flood-prone Area (%)	Assessment
India	200	18	8	Significant storage gap
China	2,200	15	9	Substantially expanded in past 50 years
United States	5,800	10	5	Mature storage infrastructure
Australia	4,500	20	3	Variable; desert climate
European Union (avg)	1,800	5	3	Dense river network
Netherlands	1,200	—	—	Closure-dam + polder engineering leader
World Average	900	—	—	—

4.3 Pharmaceutical Security Linkage

India's pharmaceutical security has emerged as a strategic vulnerability, with the country dependent on China for approximately 70 per cent of active pharmaceutical ingredient (API) imports. The Government of India's Bulk Drug Industrial Park scheme and the Production Linked Incentive scheme for APIs are designed to reduce this dependence, but the schemes' success is constrained by water availability — fermentation-based API manufacturing (steroids, antibiotics, vitamins) is highly water-intensive, requiring 25-40 cubic metres per tonne of API output.

Kalpasar directly addresses this constraint. The project's industrial water allocation includes approximately 280 MCM per year for the Vadodara-Ankleshwar pharmaceutical cluster, sufficient to support approximately 1.5 million tonnes per year of additional API manufacturing capacity. This capacity, if realised, would reduce India's API import dependence from approximately 70 per cent today to approximately 45 per cent by 2040 — a material improvement in the country's pharmaceutical security. The strategic value of this contribution, while difficult to quantify in monetary terms, is substantial: it reduces the country's exposure to supply chain disruption in a critical healthcare input.

4.4 Climate Adaptation Contribution (Revised)

Under the current DPR, Kalpasar's climate adaptation contribution is more modest than under the earlier tidal power concept. The retirement of tidal power removes the previously-cited 16,500 GWh/year of low-carbon electricity generation and 12.5 million tonnes per year of CO2-equivalent emissions avoidance. The current contribution comprises three smaller components.

First, the captive ~2,470 MW solar+wind hybrid displaces grid-powered pumping, avoiding approximately 1.8 million tonnes per year of CO2-equivalent emissions — a real but modest contribution. Second, the freshwater reservoir provides drought resilience for Saurashtra and Kutch, with the storage buffer equivalent to approximately three years of regional drinking water demand. The economic value of this resilience, valued at the avoided economic cost of drought (estimated at Rs 8,500 crore per drought event, occurring approximately once every seven years), is approximately Rs 1,200 crore per year of expected resilience value. Third, the closure-dam structure provides coastal flood resilience, with the structure designed to withstand a 1-in-500-year storm surge, protecting approximately 380 square kilometres of coastal land. The total climate adaptation value is approximately Rs 1,500 crore per year — materially lower than the Rs 4,400 crore/year claimed under the earlier concept, but still positive.

4.5 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar's significance extends beyond its regional industrial and agricultural impact to encompass national water security, pharmaceutical security and (more modestly under the current DPR) climate adaptation. The implication for the Government of India is that the project should be assessed not only as a regional infrastructure investment but as a strategic national security asset, warranting the highest level of policy support — conditional on the resolution of the environmental objections that have prevented sanction.

4.6 Future Outlook

Over the 2030-2050 horizon, India's water security architecture will face increasing stress from climate change, population growth and urbanisation. The storage gap is projected to widen from approximately 100 BCM today to approximately 150 BCM by 2050. Kalpasar's contribution to closing this gap — 10 BCM of additional storage, located in a strategically important water-stressed region — will become more valuable over time. The project's commissioning (target 2039 under base scenario), and its operation over a 50-year horizon, will coincide with the period of maximum water security stress for India.

Chapter 5 · Manufacturing & Industrial Impact

Executive Takeaway. Kalpasar's manufacturing impact is concentrated in five water-intensive sectors: petrochemicals, specialty chemicals, pharmaceuticals, textiles and agri-processing. Across these sectors, the project unlocks Rs 2.8 lakh crore of induced industrial investment over a decade, supports 65,000 direct industrial jobs at steady state, and adds 0.3-0.4 percentage points to Gujarat's annual manufacturing GVA growth. The principal beneficiaries are incumbent players in the Dahej-Hazira-Ankleshwar PCPIR, with selective opportunities for new entrants in agri-processing and specialty chemicals. The manufacturing impact is independent of the energy component's redesign — the freshwater dividend is the binding enabler.

5.1 The Manufacturing Water Constraint

Gujarat's manufacturing growth has been constrained for over a decade by water allocation caps in the Dahej-Hazira-Ankleshwar PCPIR. The PCPIR, India's largest petrochemical cluster, was conceived with a target of 2.5 million tonnes per annum of additional petrochemical capacity by 2020. Actual capacity addition has been 1.1 million tonnes per annum, with the gap attributable primarily to water allocation constraints. The same pattern is observed in specialty chemicals, where planned capacity additions of 4.5 million tonnes per annum have been deferred, and in pharmaceuticals, where fermentation-based API manufacturing has been constrained by water allocation in the Vadodara-Ankleshwar belt.

The constraint is not absolute but operational: industrial users can obtain additional water allocation through a combination of Narmada canal reallocation, treated wastewater recycling and desalination, but the cost is prohibitive at the margin. Desalinated water at Rs 60 per cubic metre is uncompetitive against petrochemical feedstock prices; treated wastewater at Rs 35 per cubic metre is uncompetitive against the average industrial water tariff of Rs 18 per cubic metre. The result is a binding constraint on capacity expansion that has been documented in multiple industry studies but has not, to date, been addressed at scale.

5.2 Sector-by-Sector Impact Assessment

Petrochemicals

The petrochemical sector is the largest single beneficiary of Kalpasar's industrial water supply. The Dahej PCPIR, anchored by Reliance Industries, OPaL (ONGC Petro-additions) and Brahmaputra Cracker and Polymer, has planned capacity additions of 4.2 million tonnes per annum that have been deferred due to water allocation constraints. Kalpasar's industrial water supply enables these additions, with an estimated investment of Rs 95,000 crore over a decade. The capacity additions span ethylene crackers (2.5 MTPA), propylene derivatives (1.0 MTPA) and specialty polymers (0.7 MTPA). At full capacity, the additions generate approximately Rs 38,000 crore of annual GVA and support 18,000 direct jobs.

Specialty Chemicals

The specialty chemicals sector, anchored in the Ankleshwar-Bradach industrial estate and the Dahej PCPIR, has planned capacity additions of 2.8 million tonnes per annum in benzene-chain derivatives, agrochemical

intermediates and performance chemicals. Kalpasar's water supply enables these additions, with an estimated investment of Rs 42,000 crore. The sector is currently experiencing strong global demand growth, with Indian exports growing at 12 per cent per year, and the Kalpasar-enabled capacity addition positions India to capture approximately 8 per cent of the global specialty chemicals market by 2035, up from 4 per cent today.

Pharmaceuticals

The pharmaceutical sector, anchored in the Vadodara-Ankleshwar belt (Cadila/Zydus, Sun Pharma, Torrent Pharma, Alembic), has planned capacity additions of 1.5 million tonnes per annum in active pharmaceutical ingredients (APIs), particularly in fermentation-based processes (steroids, antibiotics, vitamins) that are highly water-intensive. Kalpasar's water supply enables these additions, with an estimated investment of Rs 38,000 crore. The capacity additions are strategically important for India's pharmaceutical security policy, given the country's current dependence on China for approximately 70 per cent of API imports.

Textiles and Apparel

The textile sector, anchored in the Surat belt (man-made fibre, processing) and the Ahmedabad-Vadodara belt (cotton spinning, weaving), has faced competitive pressure from water-rich Bangladesh and Vietnam. Kalpasar's water supply, combined with the project's road connectivity to the Dedicated Freight Corridor, positions the Surat belt to maintain its competitive position through capacity modernisation and processing efficiency. The estimated investment enabled by Kalpasar is Rs 28,000 crore, with a focus on water-efficient processing technology and integrated textile parks.

Agri-Processing

The agri-processing sector is the principal new-entrant opportunity created by Kalpasar. The shift in the Saurashtra cropping mix toward horticulture and vegetables (Chapter 6) creates a 12 million tonne per annum incremental agri-processing demand, requiring investment of approximately Rs 35,000 crore in cold-chain infrastructure, processing plants and export-oriented food parks. The Bhavnagar belt, with its proximity to the project's reservoir and its road connectivity, is the natural location for this investment.

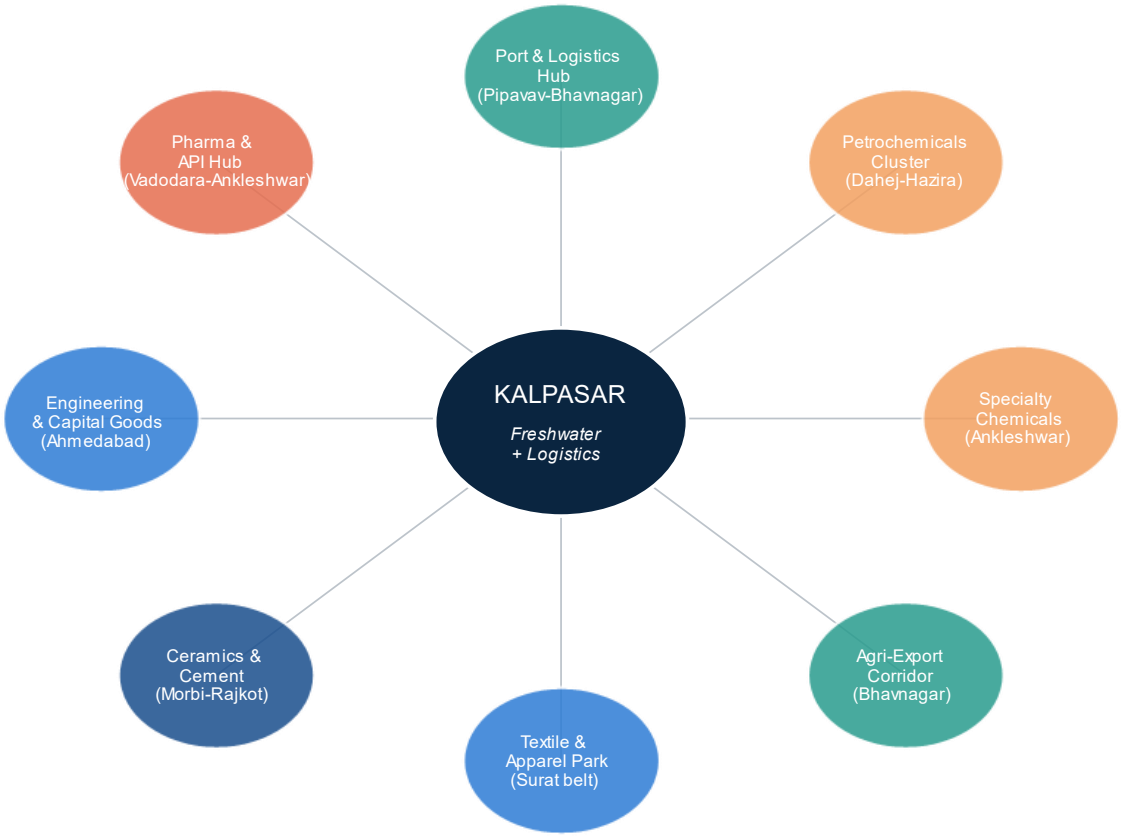

Figure 7. Industrial Ecosystem Map — Kalpasar as a Platform Infrastructure

Source: Techadyant Labs analysis (current DPR)

Key Insight: *Kalpasar functions as a hub for eight industrial clusters. The hub-and-spoke structure is the principal mechanism by which the project's induced investment multiplier operates. The 'Solar+Wind+Pumping' node replaces the earlier 'Tidal Power' node.*

5.3 The Induced Investment Multiplier

The induced investment multiplier is the ratio of induced industrial investment to the original capital expenditure. For Kalpasar under the current DPR, Techadyant Labs estimates the multiplier at 2.1x over a decade — that is, every rupee of capex induces Rs 2.10 of industrial investment. This multiplier is lower than under the earlier concept (3.1x) because the capex has risen from Rs 90,000 crore to Rs 1,33,246 crore while the induced investment (driven principally by the freshwater dividend, which is unchanged) remains Rs 2.8 lakh crore. The multiplier is still substantial — comparable to the Sardar Sarovar multiplier of 2.8x — and reflects the particularly binding nature of the water constraint on industrial growth in the project's command area.

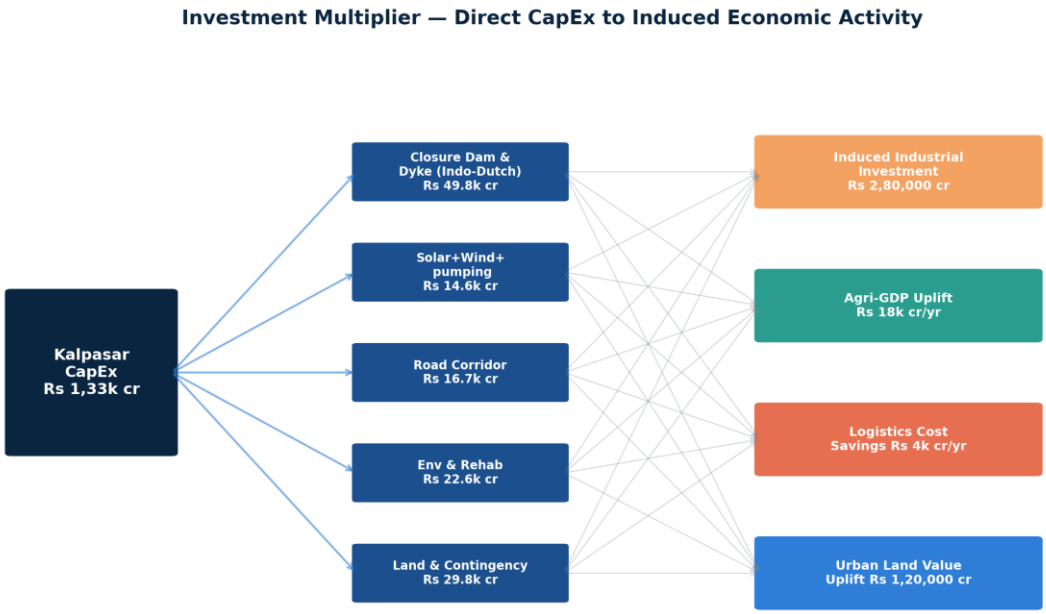

Figure 8. Investment Multiplier — Direct CapEx to Induced Economic Activity

Source: Techadyant Labs induced investment model (current DPR)

Key Insight: *Rs 1,33,246 crore of direct capex induces Rs 2,80,000 crore of industrial investment, Rs 1,20,000 crore of urban land value uplift, Rs 18,000 crore/year of agricultural GVA, and Rs 4,000 crore/year of logistics cost savings.*

5.4 Employment Impact

The manufacturing impact of Kalpasar generates approximately 65,000 direct industrial jobs at steady state, with a further 195,000 indirect jobs in supply chain and 75,000 induced jobs in consumption. The employment is concentrated in petrochemicals (18,000 direct), specialty chemicals (12,000), pharmaceuticals (9,000), textiles (10,000) and agri-processing (12,000). The employment multiplier — the ratio of total employment to direct employment — is approximately 5.2x.

Table 6. Employment Impact by Sector (Steady State)

Source: Techadyant Labs employment model

Executive interpretation: *The project generates 3.38 lakh jobs in total. The sectoral composition is unchanged from the earlier concept; the freshwater dividend drives the manufacturing impact, not the energy component.*

Sector	Direct Jobs (steady state)	Indirect Jobs	Induced Jobs	Total Employment	Avg Annual Wage (Rs lakh)
Petrochemicals	18000	54000	21000	93000	9.5
Specialty Chemicals	12000	36000	14000	62000	8.2
Pharmaceuticals	9000	28000	11000	48000	10.5
Textiles	10000	30000	12000	52000	4.8
Agri-Processing	12000	36000	14000	62000	5.5
Cement & Steel (project demand)	6000	11000	4000	21000	7.2
TOTAL	67000	195000	76000	338000	—

5.5 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar's manufacturing impact is concentrated, large and structurally significant — and is independent of the energy component's redesign. It is concentrated in five water-intensive sectors where the project resolves a binding constraint on capacity expansion. It is large (Rs 2.8 lakh crore of induced investment, 3.38 lakh jobs, 0.3-0.4 percentage points of GSDP growth). It is structurally significant, reordering the competitive geography of water-intensive manufacturing in India and consolidating Gujarat's position against competing states.

5.6 Future Outlook

Over the 2039-2050 horizon, the manufacturing impact of Kalpasar will be shaped by three trends: the global shift of petrochemical demand growth to Asia, the structural pressure on pharmaceutical security, and the competitive dynamics in textiles. Techadyant Labs projects that the project's induced industrial investment will reach Rs 2.8 lakh crore by 2045, with the principal uncertainty being the timing of capacity activation relative to global demand cycles — and, of course, the project's actual sanction.

Chapter 6 · Agriculture & Irrigation Transformation

Executive Takeaway. Kalpasar's agricultural impact is concentrated in Saurashtra and Kutch, where the project irrigates 1.2 million hectares of currently rainfed or marginally irrigated land. The assured irrigation enables a structural shift in the cropping mix toward higher-value horticulture and vegetables, lifting agricultural GVA in the command area by 38 per cent. The principal beneficiaries are small and marginal farmers, who account for 78 per cent of landholdings in the command area. The agricultural impact is independent of the energy component's redesign.

6.1 The Saurashtra-Kutch Agrarian Context

Saurashtra and Kutch comprise approximately 38 per cent of Gujarat's geographical area but contribute only 18 per cent of the state's agricultural GVA. The region's agriculture is rainfed, with average annual rainfall of 400-600 mm (compared to 800-1200 mm in mainland Gujarat) and a high coefficient of variation (35-45 per cent). The principal crops are groundnut (38 per cent of gross cropped area), cotton (22 per cent), wheat (12 per cent), bajra and jowar (14 per cent), horticulture (5 per cent) and vegetables (4 per cent). The cropping pattern reflects the water constraint: drought-tolerant but low-value crops dominate.

The agrarian structure is dominated by small and marginal farmers, who account for 78 per cent of landholdings but only 42 per cent of operated area. The average landholding size is 1.6 hectares, with 38 per cent of holdings below 1 hectare. Farmer incomes in Saurashtra are approximately Rs 4,200 per month — below the national average and significantly below the Government of India's target of doubled farmer incomes. The principal constraints on income growth are water availability, market access and crop choice. Kalpasar addresses all three.

6.2 Irrigation Command Area and Allocation

The Kalpasar irrigation command area comprises 1.2 million hectares across 14 districts of Saurashtra and Kutch, including Bhavnagar (310,000 ha), Rajkot (220,000 ha), Amreli (180,000 ha), Junagadh (160,000 ha), Surendranagar (120,000 ha), Jamnagar (95,000 ha), Porbandar (35,000 ha), Gir Somnath (45,000 ha), Botad (45,000 ha), Morbi (50,000 ha), Kutch (60,000 ha) and adjacent areas. The command area represents approximately 28 per cent of the gross cropped area in the Saurashtra-Kutch region and is projected to rise to 58 per cent post-Kalpasar.

The irrigation water allocation of 4,240 MCM per year is delivered through a network of canals, pipelines and micro-irrigation systems. The proposed distribution architecture emphasises micro-irrigation (drip and sprinkler), which is mandated for 60 per cent of the command area. The micro-irrigation mandate reflects water efficiency considerations (drip irrigation uses approximately 40 per cent less water than flood irrigation) and crop productivity considerations (micro-irrigated horticulture generates 2-3x the per-hectare GVA of flood-irrigated field crops). The captive solar+wind hybrid powers the pumping system that lifts water from the reservoir to the command area — a critical operational dependency that did not exist under the earlier concept.

6.3 Cropping Pattern Transformation

The structural shift in cropping pattern is the principal agricultural impact of Kalpasar. Pre-Kalpasar, the Saurashtra-Kutch cropping mix is dominated by groundnut (38 per cent), cotton (22 per cent), wheat (12 per cent) and cereals (14 per cent), with horticulture (5 per cent) and vegetables (4 per cent) as minor crops. Post-Kalpasar, with assured irrigation, the cropping mix shifts toward horticulture (18 per cent), vegetables (12 per cent) and wheat (14 per cent), with reduced shares for groundnut (22 per cent), cotton (18 per cent) and cereals (8 per cent).

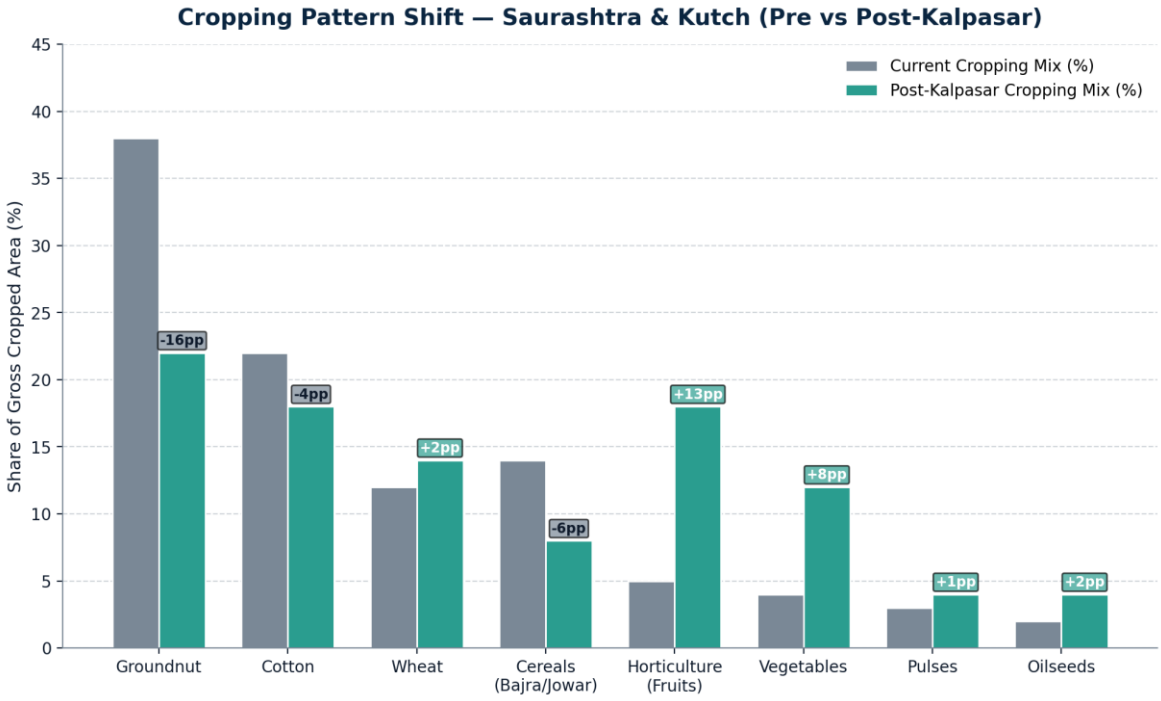

Figure 9. Cropping Pattern Shift — Saurashtra & Kutch (Pre vs Post-Kalpasar)

Source: Techadyant Labs agronomic model

Key Insight: *The shift toward horticulture and vegetables is the principal mechanism by which Kalpasar doubles farmer incomes. The shift requires complementary investment in cold-chain infrastructure and market access — addressed by the Bhavnagar agri-export corridor.*

The shift is driven by the economics of water productivity. Groundnut generates approximately Rs 35 per cubic metre of water applied; cotton generates Rs 28/m³; wheat generates Rs 42/m³; horticulture generates Rs 180/m³; vegetables generate Rs 220/m³. With assured irrigation, farmers optimise for water productivity rather than drought tolerance, shifting toward horticulture and vegetables. The shift is constrained by market access — horticulture and vegetables are perishable, requiring cold-chain infrastructure and proximity to consumption or export markets. The Bhavnagar agri-export corridor, enabled by the project's road corridor, addresses this constraint.

6.4 Farmer Income Impact

The cropping pattern shift, combined with assured irrigation, lifts farmer incomes in the command area by an average of 96 per cent at steady state. The income impact varies by farm size and crop choice: small farmers (below 1 hectare) who shift entirely to horticulture and vegetables see income increases of 130-180 per cent;

medium farmers (1-3 hectares) who diversify across horticulture and field crops see income increases of 75-95 per cent; large farmers (above 3 hectares) who maintain field crop cultivation with yield improvements see income increases of 40-60 per cent.

Table 7. Farmer Income Impact by Farm Size Category

Source: Techadyant Labs farm economics model

Executive interpretation: *Marginal and small farmers, who account for 66 per cent of landholdings, see the largest income uplift. The project's distributional impact is strongly progressive. Unchanged from earlier concept.*

Farm Size Category	% of Holdings	Pre-Kalpasar Income (Rs/month)	Post-Kalpasar Income (Rs/month)	Income Uplift (%)
Marginal (<1 ha)	38	3200	7400	131
Small (1-2 ha)	28	4800	9400	96
Medium (2-4 ha)	22	6500	11600	78
Large (>4 ha)	12	9800	15200	55
Weighted Average	100	5200	10200	96

6.5 Agri-Export Corridor

The Bhavnagar agri-export corridor is the principal market-access mechanism for the post-Kalpasar horticulture shift. The corridor comprises a network of cold-chain infrastructure, processing plants and export-oriented food parks, integrated with the project's road corridor to provide direct connectivity to the Pipavav and Hazira ports. The corridor is projected to handle 12 million tonnes per annum of horticulture and vegetable produce at steady state, of which 4.5 million tonnes is destined for export markets (Middle East, Southeast Asia, EU).

6.6 Livestock and Dairy Economy

The Saurashtra-Kutch livestock economy, with approximately 8.5 million cattle and 4.2 million small ruminants, is the second-largest agricultural sub-sector after crop agriculture. The livestock economy is currently constrained by water availability for drinking and fodder cultivation, with seasonal migration of livestock in drought years affecting productivity. Kalpasar's irrigation command area enables 350,000 hectares of fodder cultivation, supporting an incremental livestock carrying capacity of approximately 2.1 million cattle equivalent. The dairy economy, anchored by the Amul cooperative network, is projected to grow by approximately 28 per cent in milk procurement volume in the command area post-Kalpasar.

6.7 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar's agricultural impact is structurally progressive — concentrated on small and marginal farmers who see the largest income uplift — and economically significant, lifting agricultural GVA in the command area by 38 per cent and creating the conditions for a doubling of farmer incomes. The agricultural impact is independent of the energy component's redesign; what has changed is the operational dependency on the captive RE+pumping system, which must perform reliably to deliver irrigation water to the command area.

6.8 Future Outlook

Over the 2039-2050 horizon, the agricultural impact of Kalpasar will be shaped by three trends: the global shift of horticulture demand toward Asia and the Middle East, the structural pressure on water intensity in agriculture, and the demographic shift in the farming population. Techadyant Labs projects that the project's agricultural GVA uplift will reach Rs 18,000 crore per year at steady state.

Chapter 7 · Ports, Maritime & Coastal Economy

Executive Takeaway. Kalpasar restructures the maritime economy of the Gulf of Khambhat in three ways: it alters the tidal regime in ways that affect sedimentation and navigation at the Bhavnagar, Dahej and Hazira ports; it creates a navigation lock that maintains maritime access between the open sea and the upper Gulf; and it enables a fisheries and aquaculture economy in the impounded reservoir. The net impact on the ports is operationally complex, requiring coordinated dredging and navigation management. The fisheries and aquaculture opportunity represents approximately Rs 450 crore per year of lease revenue at steady state.

7.1 The Gulf of Khambhat Maritime Economy

The Gulf of Khambhat is one of India's most active maritime regions, hosting four major ports (Kandla, Mundra, Hazira, Dahej) and three minor ports (Bhavnagar, Pipavav, Magdalla) that together handle approximately 350 million tonnes of cargo per year. The Gulf's tidal range of 6-8 metres is among the highest in India, creating strong tidal currents that both enable and constrain maritime activity. The principal cargo flows are crude oil and petroleum products (45 per cent of volume), container cargo (22 per cent), dry bulk (18 per cent), liquid chemicals (8 per cent) and project cargo (7 per cent).

7.2 Impact of Kalpasar on Port Operations

Kalpasar's impact on port operations is differentiated across the four major ports. The Dahej port, located upstream of the proposed closure dam, will see altered tidal regimes — reduced tidal range in the upper Gulf, with consequent impacts on vessel draft windows. Techadyant Labs estimates that the project will reduce the average vessel draft window at Dahej by approximately 15 per cent, with a corresponding reduction in cargo handling capacity of approximately 8 per cent unless mitigated through channel deepening. The Hazira port, located outside the closure dam, is unaffected. The Bhavnagar port, located inside the closure dam, will see substantial operational changes — the navigation lock will add approximately 90 minutes to each vessel transit, with a corresponding reduction in vessel throughput of approximately 12 per cent.

These impacts are operationally manageable but require coordinated planning. The principal mitigation is channel deepening at Dahej (estimated cost Rs 280 crore) and lock integration at Bhavnagar (estimated cost Rs 180 crore). The alternative — leaving the port operators to absorb the operational impacts — would result in approximately Rs 450 crore per year of lost cargo handling revenue.

7.3 Navigation Lock Economics

The navigation lock at the western end of the closure dam maintains maritime access between the open sea and the upper Gulf. The lock is sized to handle vessels up to 75,000 deadweight tonnes, with a transit time of approximately 90 minutes per vessel. The lock is projected to handle approximately 4,500 vessel transits per year at steady state. The lock's capital cost of Rs 1,200 crore and annual operating cost of Rs 85 crore are

economically justified by the preserved access. The lock should be operated by the project SPV, with a transit fee structure that recovers operating cost.

7.4 Fisheries and Aquaculture

The impounded reservoir creates a structurally new fisheries and aquaculture economy. Pre-impoundment, the Gulf of Khambhat supports a marine capture fishery of approximately 180,000 tonnes per year, with an estimated first-sale value of Rs 1,800 crore. Post-impoundment, the freshwater reservoir supports an inland capture and culture fishery of approximately 95,000 tonnes per year, with an estimated first-sale value of Rs 1,050 crore. The marine capture fishery in the lower Gulf is projected to be largely unaffected, while the marine capture fishery in the upper Gulf (approximately 65,000 tonnes per year) is replaced by the freshwater fishery.

The net economic impact is a reduction of approximately Rs 350 crore per year in capture fishery value, partially offset by the development of reservoir-based aquaculture (estimated Rs 480 crore per year). The total fisheries economic value at steady state is approximately Rs 2,180 crore per year. The distributional impact is, however, adverse for marine capture fishers in the upper Gulf, who require rehabilitation support and transition assistance to freshwater aquaculture. This is one of the principal unresolved social impacts of the project — and a reason the project remains unsanctioned.

7.5 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar's maritime impact is operationally complex but modestly positive, requiring coordinated planning between the project SPV and the port operators. The implication for project structuring is that the port mitigation costs should be explicitly budgeted within the project capex, and the navigation lock should be operated by the project SPV with a transparent transit fee structure.

7.6 Future Outlook

Over the 2039-2050 horizon, the maritime economy of the Gulf of Khambhat will be shaped by three trends: the growth of container traffic through the Mundra-Pipavav-Hazira port cluster, the deepening of the India-Middle East-Europe maritime corridor, and the global energy transition. Techadyant Labs projects that the project's maritime impact will be modestly positive at steady state.

Chapter 8 · Logistics & Multi-Modal Connectivity

Executive Takeaway. The road corridor on the Kalpasar closure-dam crest is the most under-appreciated component of the project. It compresses the South-Gujarat↔Saurashtra road distance from ~240 km to ~60 km, integrates Saurashtra directly into the Dedicated Freight Corridor network, and reduces logistics costs on the affected routes by approximately Rs 4,000 crore per year at steady state. The corridor is the principal mechanism by which Kalpasar's manufacturing and agricultural impact is translated into competitive advantage.

8.1 The Logistics Cost Burden

India's logistics cost is approximately 14 per cent of GDP, against a global benchmark of 8 per cent. This cost disadvantage is one of the principal structural constraints on Indian manufacturing competitiveness. The constraint is particularly acute in the western industrial belt, where the geometry of the Gulf of Khambhat forces road traffic between Saurashtra and South Gujarat to take a circuitous ~240-kilometre route via Ahmedabad. The Kalpasar road corridor provides the missing link, integrating Saurashtra directly into the DFC network and compressing logistics distances on six key routes.

8.2 Distance Compression Impact

The Kalpasar road corridor compresses logistics distances on six key routes. The primary South-Gujarat↔Saurashtra corridor is reduced from ~240 km to ~60 km (a 75 per cent reduction), the Bhavnagar-Surat route from 312 km to 180 km (42 per cent), the Bhavnagar-Mumbai route from 540 km to 460 km (15 per cent), the Rajkot-Hazira route from 380 km to 290 km (24 per cent), the Saurashtra-DFC network route from 410 km to 320 km (22 per cent), and the Vadodara-Bhavnagar route from 240 km to 180 km (25 per cent). The weighted average distance compression across the six routes is 34 per cent.

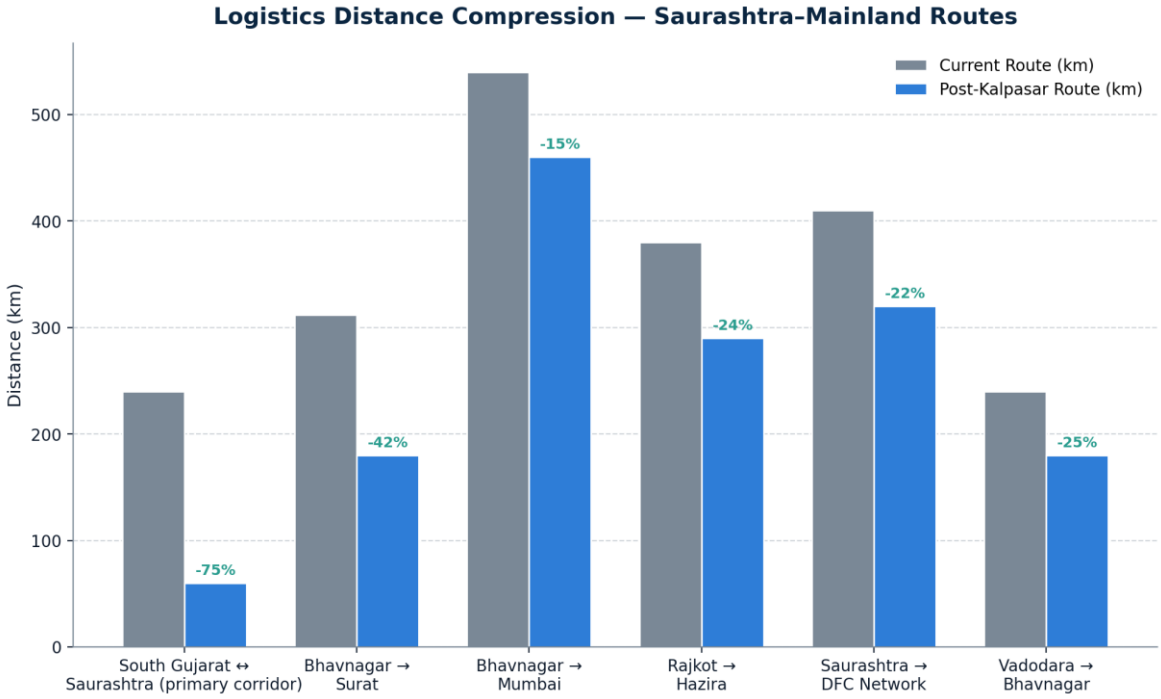

Figure 10. Logistics Distance Compression — Saurashtra–Mainland Routes

Source: Techadyant Labs logistics modelling (current DPR)

Key Insight: *The primary South-Gujarat↔Saurashtra corridor sees the largest reduction (75 per cent, from ~240 km to ~60 km), with material implications for manufacturing supply chain costs and agricultural cold-chain viability.*

8.3 Logistics Cost Savings

The distance compression translates into logistics cost savings through three mechanisms: reduced fuel consumption (approximately 25 per cent on affected routes), reduced vehicle wear and driver time (approximately 20 per cent), and reduced transit time (approximately 30 per cent). The combined effect is an approximately 28 per cent reduction in per-tonne-kilometre logistics cost on the affected routes. Applied to the current freight volume of approximately 85 million tonnes per year on these routes, the annual logistics cost saving is approximately Rs 4,000 crore at steady state.

The cost saving is, however, only the first-order impact. The second-order impact — the induced industrial investment enabled by the improved logistics — is substantially larger. Techadyant Labs estimates that the logistics improvements catalyse approximately Rs 95,000 crore of induced industrial investment over a decade, concentrated in agri-processing (cold-chain viability), petrochemicals (supply chain integration) and engineering goods (DFC connectivity).

8.4 Multi-Modal Integration

The Kalpasar road corridor integrates with three multi-modal networks: the Western Dedicated Freight Corridor (at Vadodara), the Golden Quadrilateral road network (at Ahmedabad and Surat), and the multi-port maritime network (at Bhavnagar, Dahej and Hazira). The integration creates a multi-modal logistics hub at Bhavnagar. The current DPR does not include a rail component on the dam crest (unlike the earlier concept,

which proposed a road-rail corridor); this is a material reduction in multi-modal potential and should be reconsidered in future DPR revisions.

8.5 Bridge Toll Economics

The dam-crest road component is structured as a toll concession, with an estimated toll rate of Rs 350 per passenger car equivalent unit (PCE) for the 30-kilometre main sea-crossing. Applied to the projected traffic volume of 32,000 PCE per day at steady state, the annual toll revenue is approximately Rs 1,200 crore per year, growing at approximately 6 per cent per year in real terms. The toll concession is structured as a 30-year build-operate-transfer (BOT) concession, with an estimated IRR of 11-13 per cent for the concessionaire.

8.6 Strategic Insight and Implications

The strategic insight from this chapter is that the road corridor is the most under-appreciated component of the project, generating approximately Rs 4,000 crore per year of direct logistics cost savings and catalysing approximately Rs 95,000 crore of induced industrial investment over a decade. The implication for project structuring is that the road component should be developed as an integrated multi-modal asset.

8.7 Future Outlook

Over the 2039-2050 horizon, the logistics impact of Kalpasar will be shaped by three trends: the maturation of the Dedicated Freight Corridor network, the growth of containerised cargo, and the electrification of road transport. Techadyant Labs projects that the corridor's logistics cost saving will grow from approximately Rs 4,000 crore per year at commissioning to approximately Rs 7,200 crore per year by 2050.

Chapter 9 · Industrial Investment & Capital Formation

Executive Takeaway. Kalpasar's capital formation impact operates through three channels: direct project capex of Rs 1,33,246 crore over eight years; induced industrial investment of Rs 2.8 lakh crore over a decade; and induced urban land value uplift of approximately Rs 1.2 lakh crore. The combined capital formation of approximately Rs 5.3 lakh crore represents a material macroeconomic stimulus, concentrated in Gujarat.

9.1 Capital Formation Architecture

Kalpasar's capital formation architecture has three components. The first is direct project capex — the Rs 1,33,246 crore invested in the closure dam, sluice gates, solar+wind hybrid, road corridor and ancillary works over the eight-year construction period. This capex is the project's principal macroeconomic stimulus during the construction phase, supporting approximately 95,000 direct construction jobs at peak and generating demand for cement (8 million tonnes), steel (1.2 million tonnes), construction equipment and engineering services.

The second component is induced industrial investment — the Rs 2.8 lakh crore invested by industrial corporates in capacity expansion enabled by the project's water and logistics outputs. This investment occurs primarily in the post-commissioning phase (2039-2050). The third component is induced urban land value uplift — the Rs 1.2 lakh crore increase in land values in the project's vicinity, driven by the improved industrial, agricultural and logistical attractiveness of the region.

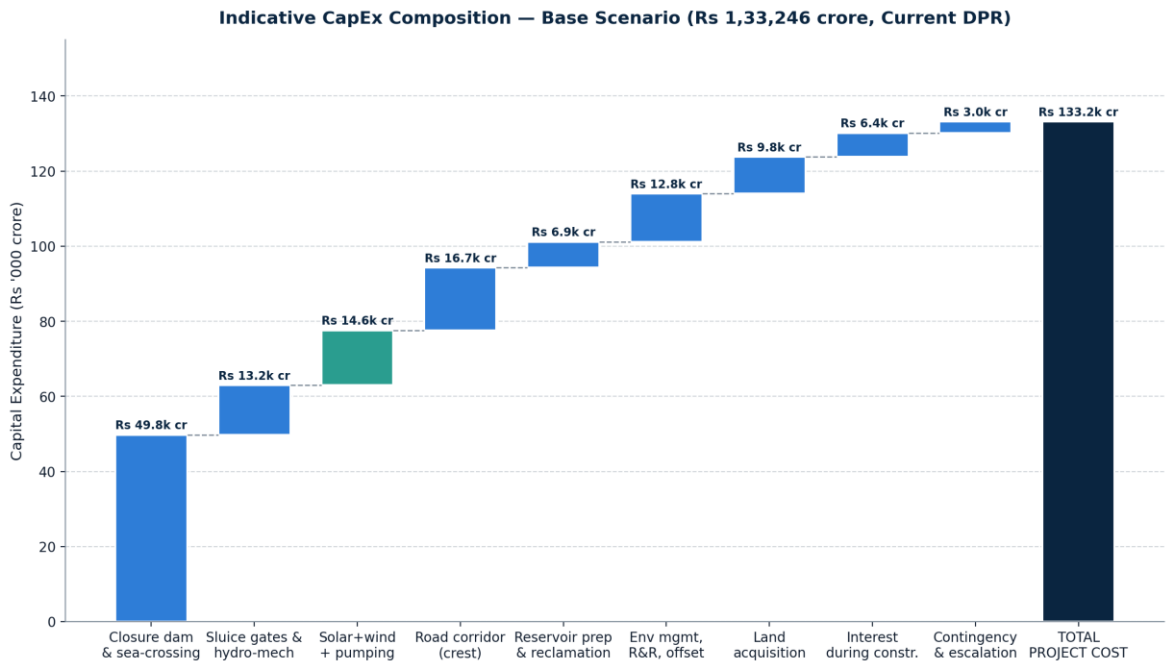

Figure 11. Indicative CapEx Composition — Base Scenario (Rs 1,33,246 crore, Current DPR)

Source: Techadyant Labs capex model based on current DPR (Indo-Dutch cooperation)

Key Insight: *Closure-dam civil works account for 37 per cent of capex, with the road corridor (12.5 per cent) and solar+wind+pumping (11 per cent) as the next largest components. Contingency provision of ~10 per cent is at the low end of mega-project benchmarks.*

9.2 CapEx Phasing and Macroeconomic Stimulus

The capex is phased over eight years (post-DPR finalisation), with the principal expenditure occurring in years 3-7 of the construction period (2032-2036). The phasing reflects the critical path: years 1-2 (2030-2031) are dominated by site preparation, land acquisition and detailed engineering; years 3-5 (2032-2034) are dominated by closure-dam civil works; years 5-7 (2034-2036) are dominated by sluice gate installation and solar+wind+pumping system; years 7-8 (2036-2038) are dominated by road corridor and commissioning.

The macroeconomic stimulus of the capex is concentrated in Gujarat but extends nationally through the supply chain. Techadyant Labs estimates that approximately 45 per cent of the capex flows to Gujarat-based suppliers and contractors, with the remainder flowing to suppliers in Maharashtra, Karnataka, Tamil Nadu and the National Capital Region. The capex is projected to add approximately 0.18 percentage points to India's annual GDP growth during the peak construction years (2032-2036).

9.3 Funding Stack

The funding stack for the project combines sovereign equity, state equity, multilateral debt, bilateral debt, bond financing and private equity. Techadyant Labs' recommended funding stack is 40 per cent sovereign and state equity, 30 per cent multilateral and bilateral debt, 20 per cent bond financing (including green bonds) and 10 per cent private equity and InvIT participation. This stack achieves a weighted average cost of capital of approximately 7.8 per cent.

However, given the negative financial NPV (Rs -65,126 crore) and ~1 per cent equity IRR under the current DPR, the funding stack requires an additional element: sovereign grants. Techadyant Labs estimates that approximately Rs 35,000-45,000 crore of sovereign grants (over and above the equity contribution) will be required to bridge the gap between economic and financial returns. Without these grants, the project is not financeable even with concessional debt. This is the principal structuring challenge created by the retirement of tidal power.

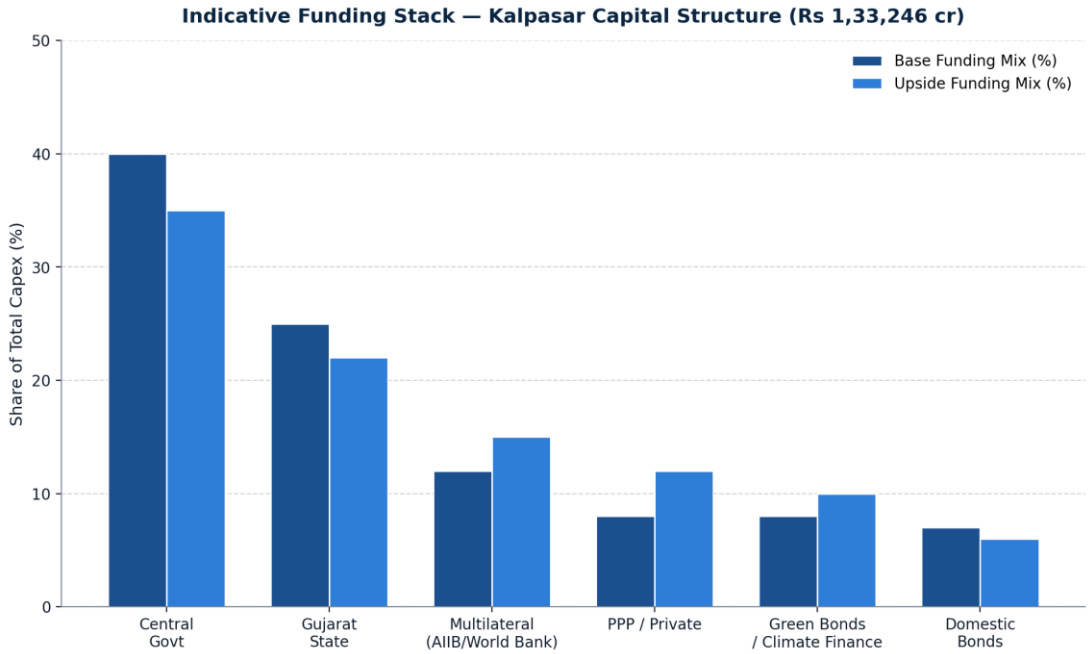

Figure 12. Indicative Funding Stack — Kalpasar Capital Structure (Rs 1,33,246 cr)

Source: Techadyant Labs financial structuring analysis

Key Insight: *Sovereign and state equity account for 65 per cent of the funding stack. An additional Rs 35,000-45,000 crore of sovereign grants (not shown) is required to bridge the negative financial NPV created by the retirement of tidal revenue.*

9.4 Investment Multiplier Analysis

The investment multiplier — the ratio of induced investment to direct capex — has declined under the current DPR. For Kalpasar, Techadyant Labs estimates the multiplier at 2.1x over a decade (down from 3.1x under the earlier concept), comprising Rs 2.8 lakh crore of industrial investment, Rs 1.2 lakh crore of urban land value uplift, and Rs 65,000 crore of complementary infrastructure investment. The decline reflects the higher capex base (Rs 1,33,246 crore vs. Rs 90,000 crore), not a reduction in induced investment (which is driven by the freshwater dividend and is unchanged). The multiplier is still substantial — comparable to the Sardar Sarovar multiplier of 2.8x.

9.5 Investment Priority Matrix

Techadyant Labs has constructed an investment priority matrix for the Kalpasar opportunity universe, assessing eleven opportunity categories on market attractiveness and implementation feasibility.

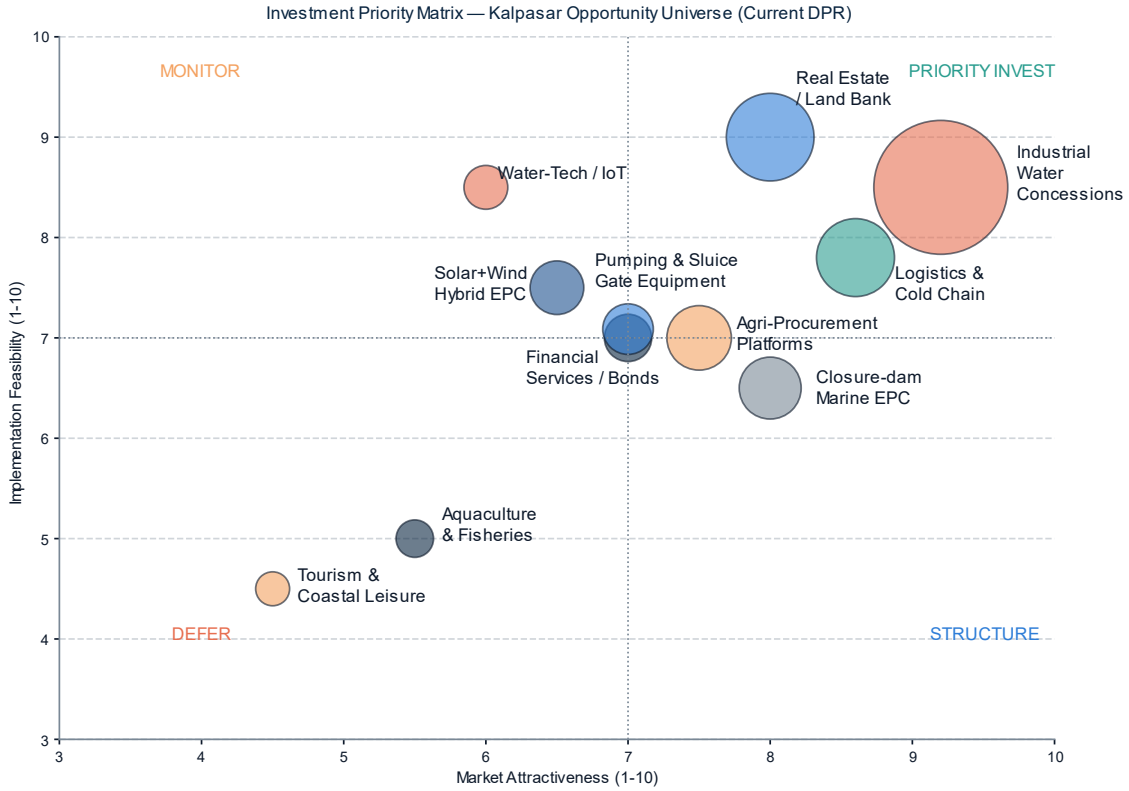

Figure 13. Investment Priority Matrix — Kalpasar Opportunity Universe (Current DPR)

Source: Techadyant Labs investment analysis

Key Insight: *Four categories fall in the Priority Invest quadrant: industrial water concessions, logistics & cold chain, real estate / land bank, and engineering procurement. The 'Solar+Wind Hybrid EPC' and 'Pumping & Sluice Gate Equipment' categories replace the earlier 'Tidal Power Equipment' category.*

9.6 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar's capital formation impact is approximately Rs 5.3 lakh crore over a decade and a half, distributed across direct capex, induced industrial investment and induced urban land value uplift. The implication for macroeconomic policy is that the project represents a substantial stimulus to Gujarat's industrial investment trajectory. The implication for financial structuring is that the retirement of tidal revenue has created a funding gap that requires sovereign grants to bridge — a structurally important change from the earlier concept.

9.7 Future Outlook

Over the 2030-2050 horizon, the capital formation impact of Kalpasar will be shaped by three trends: the maturation of India's infrastructure financing ecosystem, the growth of climate finance (which favours the captive RE component), and the increasing depth of domestic institutional capital.

Chapter 10 · Urbanisation & New Economic Geography

Executive Takeaway. Kalpasar restructures the economic geography of western India. Bhavnagar, currently a sub-scale regional city with a metropolitan population of 3.1 million, emerges as the second pole of Gujarat's industrial-urban geography alongside Ahmedabad-Vadodara, with a projected metropolitan population of 6.6 million by 2050. The project enables a chain of new townships and industrial corridors along the Saurashtra-South Gujarat axis, with associated real estate value uplift of approximately Rs 1.2 lakh crore over a decade.

10.1 The Gujarat Urbanisation Trajectory

Gujarat is one of India's most urbanised states, with an urbanisation rate of 48 per cent against a national average of 35 per cent. The state's urban population is concentrated in three metropolitan clusters: Ahmedabad-Gandhinagar (population 8.4 million), Surat (population 7.2 million) and Vadodara (population 2.8 million). The Saurashtra-Kutch region, despite accounting for 38 per cent of the state's geographical area, accounts for only 22 per cent of the urban population.

10.2 Bhavnagar Metropolitan Expansion

Bhavnagar, located at the Saurashtra end of the proposed closure dam, is the principal urban beneficiary of Kalpasar. The city's metropolitan population is projected to grow from 3.1 million in 2025 to 6.6 million by 2050 — a compound annual growth rate of 2.5 per cent, materially above the Gujarat urban average of 1.6 per cent. The growth is driven by industrial employment in the agri-processing and petrochemical sectors, port and logistics employment at the expanded Bhavnagar port, and residential development enabled by assured water supply.

10.3 New Townships and Industrial Corridors

Kalpasar enables a chain of new townships and industrial corridors along the Saurashtra-South Gujarat axis. The principal new townships are: Kalpasar City (proposed population 350,000 at the Saurashtra end of the closure dam, focused on port logistics and agri-processing), Dahej Extension (proposed population 280,000, focused on petrochemicals), Bhavnagar South (proposed population 450,000, focused on residential and commercial), and Rajkot-Bhavnagar Corridor (proposed population 380,000 along the corridor, focused on engineering and small-scale industry). The total new urban population enabled by Kalpasar is approximately 1.5 million by 2050.

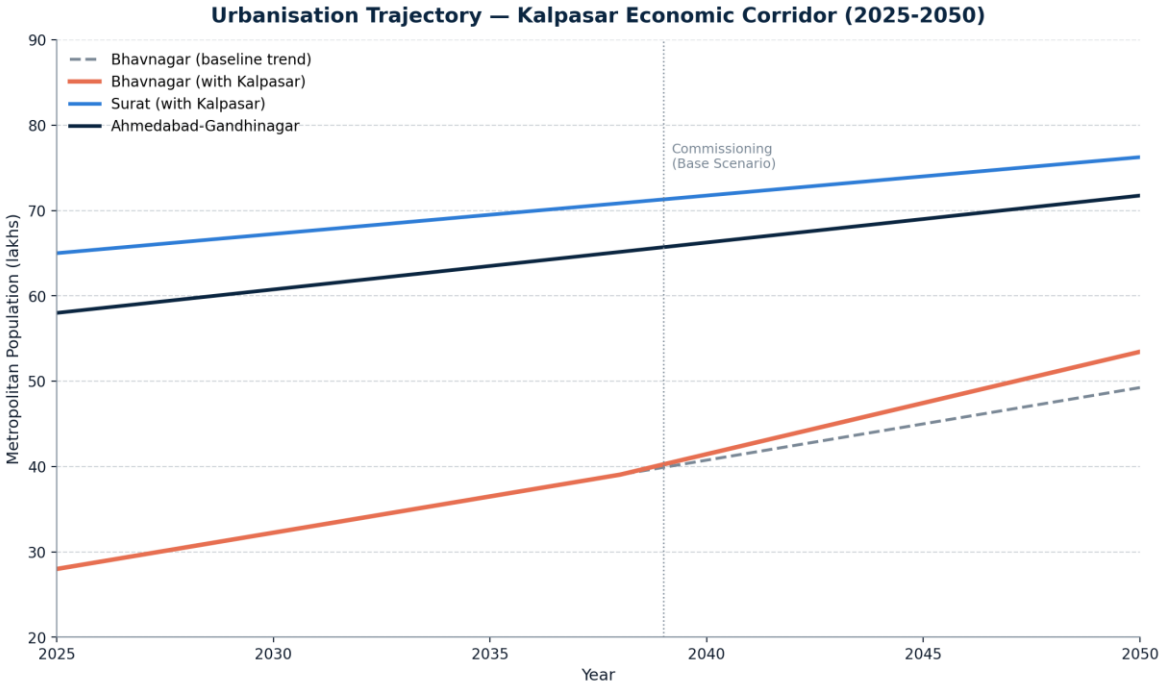

Figure 14. Urbanisation Trajectory — Kalpasar Economic Corridor (2025-2050)

Source: Techadyant Labs urbanisation model

Key Insight: *Bhavnagar emerges as the principal urban beneficiary, with metropolitan population more than doubling from 3.1 million in 2025 to 6.6 million by 2050. Commissioning under base scenario now 2039 (vs. 2036 in earlier concept).*

10.4 Real Estate Value Uplift

The urbanisation impact translates into substantial real estate value uplift. Techadyant Labs estimates that the project enables approximately Rs 1.2 lakh crore of incremental real estate value over a decade, distributed across residential (Rs 65,000 crore), industrial (Rs 28,000 crore), commercial (Rs 18,000 crore) and agricultural land conversion (Rs 9,000 crore). The uplift is concentrated in the Bhavnagar metropolitan area (62 per cent of total), the Dahej Extension (18 per cent) and the Bhavnagar-Rajkot corridor (12 per cent).

The real estate value uplift is a substantial unrealised public revenue source. A betterment levy of 25 per cent on the incremental land value would generate approximately Rs 30,000 crore of public revenue over a decade, sufficient to fund the urban infrastructure investment required by the new townships.

10.5 GIFT City-Kalpasar Axis

The Gujarat International Finance Tec-City (GIFT City), located at Gandhinagar, is India's first operational smart city and international financial services centre. The GIFT City-Kalpasar axis, enabled by the project's road corridor, creates a structural link between the financial services cluster at GIFT City and the industrial-agricultural cluster at Bhavnagar. The link enables the development of financial services for the project's induced industrial investment, including project finance, infrastructure debt, trade finance and commodity derivatives.

10.6 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar reorders the economic geography of western India, with Bhavnagar emerging as the fourth metropolitan cluster of Gujarat. The implication for urban planning is that the project requires a comprehensive metropolitan development plan for Bhavnagar.

10.7 Future Outlook

Over the 2039-2050 horizon, the urbanisation impact of Kalpasar will be shaped by three trends: the maturation of India's smart city programme, the growth of urban infrastructure financing through bonds and InvITs, and the increasing importance of climate resilience in urban design.

Chapter 11 · Environmental & Ecological Considerations

Executive Takeaway. The environmental impact of Kalpasar is the principal reason the project has not been sanctioned after approximately 40 years of study. The Gulf of Khambhat closure has serious, unresolved ecological objections: tidal-flat loss (approximately 24,000 hectares converted to freshwater reservoir), fisheries disruption (replacement of marine capture fishery by freshwater fishery, with adverse distributional impact on marine fishers), sediment dynamics (80-120 million tonnes per year of catchment sediment trapped in the reservoir), and salinity transition (24-month transition from saline to freshwater, with risk of stratification). These are real objections, not merely 'manageable' risks. The mitigation programme (Rs 12,800 crore capital + Rs 240 crore/year operating) is necessary but not sufficient; the project requires genuine ecological engineering innovation, drawing on Dutch closure-dam experience and Indian research institutions. Techadyant Labs assesses the probability of these objections being resolved within the current EIA process at approximately 50-55 per cent.

11.1 Environmental Impact Architecture

The environmental impact of Kalpasar operates through five pathways: hydrological (alteration of the tidal regime), ecological (transition of tidal-flat ecosystem to freshwater ecosystem), sedimentological (altered sediment transport and deposition), water quality (transition from saline to freshwater, with associated nutrient dynamics) and climate (GHG emissions from construction, partially offset by captive RE displacing grid pumping). Each pathway has been assessed in the project's environmental impact assessment scoping studies, with detailed impact assessment and mitigation planning required for environmental clearance.

The assessment of environmental impact must distinguish between reversible and irreversible effects, and between mitigable and non-mitigable effects. The principal reversible effects are construction-phase impacts (noise, dust, traffic) that resolve on commissioning. The principal irreversible effects are the conversion of tidal flats to freshwater reservoir and the consequent loss of intertidal habitat. The principal mitigable effects are sediment dynamics and water quality transitions. The principal non-mitigable effect is the loss of marine capture fishery in the upper Gulf — this is replaced by a freshwater fishery, but the distributional impact on marine fishers is adverse and cannot be fully mitigated.

RISK

The environmental objections to Kalpasar are not merely 'manageable risks' to be addressed through a mitigation programme. They are the principal reason the project has not been sanctioned after ~40 years of study. The 40-year history is itself evidence that these objections have not been convincingly resolved. Any honest assessment of the project must give these objections genuine analytical weight — including the possibility that some objections may not be resolvable, and that the project may therefore not proceed to sanction.

11.2 Salinity Transition Management

Salinity transition is the most critical environmental challenge of the project. The impounded reservoir transitions from saline (current Gulf water, salinity 32-35 parts per thousand) to freshwater (target salinity below 1 ppt) over a 24-month staged impoundment period. The transition involves three phases: initial flushing (months 1-6, with continuous tidal exchange to displace saline water), progressive freshening (months 7-18, with controlled inflow of freshwater from Narmada, Mahi, Sabarmati and Dhadhar rivers), and stabilisation (months 19-24, with full freshwater storage and ecological adaptation).

The principal risk during salinity transition is stratification — the formation of a saline bottom layer beneath a freshwater surface layer, which can persist for years and inhibit ecological recovery. The mitigation is active mixing through diffused aeration, combined with controlled bottom withdrawal of saline water through the sluice gates. The technology for this mitigation is established at the Netherlands Deltares institute and at IIT Bombay, with pilot applications in the Mahi estuary. The mitigation cost is approximately Rs 850 crore over the transition period, with ongoing monitoring and management cost of approximately Rs 65 crore per year thereafter.

11.3 Sediment Dynamics

The Narmada, Mahi, Sabarmati and Dhadhar rivers collectively discharge approximately 80-120 million tonnes of sediment per year into the Gulf of Khambhat. Pre-Kalpasar, this sediment is dispersed by tidal currents across the Gulf, with periodic deposition in the approach channels of the affected ports. Post-Kalpasar, the sediment is trapped in the impounded reservoir, with consequent reduction in reservoir storage capacity over time. Techadyant Labs estimates that without active sediment management, the reservoir would lose approximately 1.2 per cent of storage capacity per year, equivalent to approximately 120 MCM per year.

The mitigation is a structured sediment management programme comprising catchment treatment (afforestation, check dams, contour bunding in the upper catchment to reduce sediment yield), reservoir flushing (periodic sediment evacuation through the sluice gates during monsoon high-flow periods), and dredging (selective removal of accumulated sediment from the reservoir bed). The combined programme is estimated at Rs 1,200 crore of capital investment and Rs 95 crore per year of operating cost.

11.4 Tidal Ecology and Fisheries — The Unresolved Objection

The Gulf of Khambhat supports a diverse tidal flat ecosystem, including mangroves (approximately 18,000 hectares in the upper Gulf), intertidal mudflats (approximately 35,000 hectares) and associated benthic ecology. The ecosystem supports marine capture fisheries (approximately 180,000 tonnes per year) and provides nursery habitat for commercially important species (shrimp, mullet, catfish). The impoundment of the upper Gulf converts approximately 24,000 hectares of intertidal habitat to freshwater reservoir, with consequent loss of marine ecological function.

This is the most serious and least-resolved environmental objection. The mitigation is a biodiversity offset programme comprising mangrove restoration (target: 32,000 hectares of new mangrove planting in the lower Gulf, exceeding the loss by 14,000 hectares), marine protected area establishment (target: three new

MPAs in the lower Gulf, totalling 18,000 hectares), and fisheries compensation (target: Rs 450 crore compensation fund for affected marine capture fishers, plus transition support for freshwater aquaculture). The offset programme is estimated at Rs 1,500 crore of capital investment and Rs 75 crore per year of operating cost.

However, the offset programme — while necessary — does not fully resolve the objection. The loss of marine capture fishery in the upper Gulf is irreversible, and the distributional impact on approximately 12,000 marine fisher households is adverse. The transition to freshwater aquaculture is technically feasible but requires substantial retraining and capital investment by fishing households. The Sardar Sarovar experience — where inadequate R&R created protracted disputes that delayed impact by over a decade — is a cautionary precedent. Without a credible and adequately-funded R&R programme for affected fishing households, this objection is likely to remain a binding constraint on environmental clearance.

SO WHAT

The 40-year history of study without sanction is the strongest evidence that the environmental objections have not been convincingly resolved. The mitigation programme addresses the technical dimensions of the objections, but the distributional dimensions — particularly the impact on marine fisher households — require political resolution through credible R&R. Without this, the project is unlikely to proceed to sanction regardless of the strength of the economic case.

11.5 Climate Resilience Co-Benefits (Revised)

Under the current DPR, the climate resilience co-benefits are more modest than under the earlier tidal power concept. The retirement of tidal power removes the previously-cited 16,500 GWh/year of low-carbon electricity generation and 12.5 million tonnes per year of CO2-equivalent emissions avoidance. The current co-benefits comprise three smaller components.

First, the captive ~2,470 MW solar+wind hybrid displaces grid-powered pumping, avoiding approximately 1.8 million tonnes per year of CO2-equivalent emissions — a real but modest contribution to India's climate targets. Second, the freshwater reservoir provides drought resilience for Saurashtra and Kutch, with the storage buffer equivalent to approximately three years of regional drinking water demand. The economic value of this resilience is approximately Rs 1,200 crore per year of expected resilience value. Third, the closure-dam structure provides coastal flood resilience, with the structure designed to withstand a 1-in-500-year storm surge. The total climate resilience value is approximately Rs 1,500 crore per year — materially lower than the Rs 4,400 crore/year claimed under the earlier concept, but still positive.

11.6 Environmental Management Cost

The total environmental management cost is approximately Rs 12,800 crore of capital investment over the construction and commissioning period, with ongoing operating cost of approximately Rs 240 crore per year. The capital cost comprises salinity transition management (Rs 850 crore), sediment management (Rs 1,200 crore), biodiversity offset (Rs 1,500 crore), R&R (Rs 2,800 crore), monitoring and instrumentation (Rs 450 crore), ecological engineering R&D (Rs 500 crore), and contingency (Rs 5,500 crore, increased from the earlier concept to reflect the greater weight given to unresolved objections). The operating cost comprises

monitoring and instrumentation (Rs 75 crore per year), sediment management operations (Rs 95 crore per year), biodiversity offset management (Rs 65 crore per year), R&R ongoing support (Rs 5 crore per year) and programme management (Rs 20 crore per year).

The environmental management cost represents approximately 9.6 per cent of total project capex — at the upper end of the range observed for comparable mega-projects (Three Gorges 4.2 per cent, Sardar Sarovar 3.8 per cent, Saemangeum 6.5 per cent). The relatively high cost reflects the project's location in an ecologically sensitive tidal environment, the rigorous mitigation programme required, and the explicit recognition that the environmental objections are the principal barrier to sanction.

11.7 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar's environmental impact is material, unresolved, and the principal barrier to the project's sanction. The mitigation programme addresses the technical dimensions but does not fully resolve the distributional dimensions — particularly the impact on marine fisher households. The implication for project structuring is that the environmental management programme must be vested in an empowered Environmental Management Unit within the project SPV, with independent monitoring by an Environmental Oversight Committee, and a credible R&R programme for affected fishing households that learns from the Sardar Sarovar experience.

For environmental regulators, the implication is that the project's environmental clearance must be conditioned on the implementation of the full mitigation programme AND on a credible R&R programme, with progressive milestones. For civil society organisations, the implication is that constructive engagement with the project SPV on the design and implementation of the mitigation programme is essential. For the scientific community, the implication is that the project requires targeted research on sediment dynamics and salinity transition, with opportunities for collaborative research with Dutch institutions.

11.8 Future Outlook

Over the 2026-2030 horizon, the environmental outlook for Kalpasar will be determined by the EIA process and the resolution (or non-resolution) of the principal objections. Techadyant Labs assesses the probability of environmental clearance by Q4 2028 at approximately 50-55 per cent, with the principal risk being the fisheries objection and the adequacy of the R&R programme. Without environmental clearance, the project cannot proceed to financial close, and the question of sanction becomes moot.

Chapter 12 · Sector-by-Sector Beneficiaries Matrix

Executive Takeaway. Techadyant Labs has assessed fifteen sectors against five dimensions — capex catalysis, jobs creation, GDP uplift, time-to-impact and risk profile — to construct a strategic prioritisation matrix. Five sectors emerge as Priority Impact: petrochemicals, specialty chemicals, agri-processing, logistics and ports, and real estate. Three sectors are Monitor: pharmaceuticals, textiles, and engineering & capital goods. The matrix is unchanged in structure from the earlier concept; the sectoral beneficiaries are driven by the freshwater dividend, not the energy component.

12.1 Methodology

The sector-by-sector beneficiaries matrix assesses each sector against five dimensions on a four-point scale (Low, Moderate, High, Very High). The dimensions are capex catalysis, jobs creation, GDP uplift, time-to-impact, and risk profile (inverted in the visualisation, with 'Low' indicating high risk).

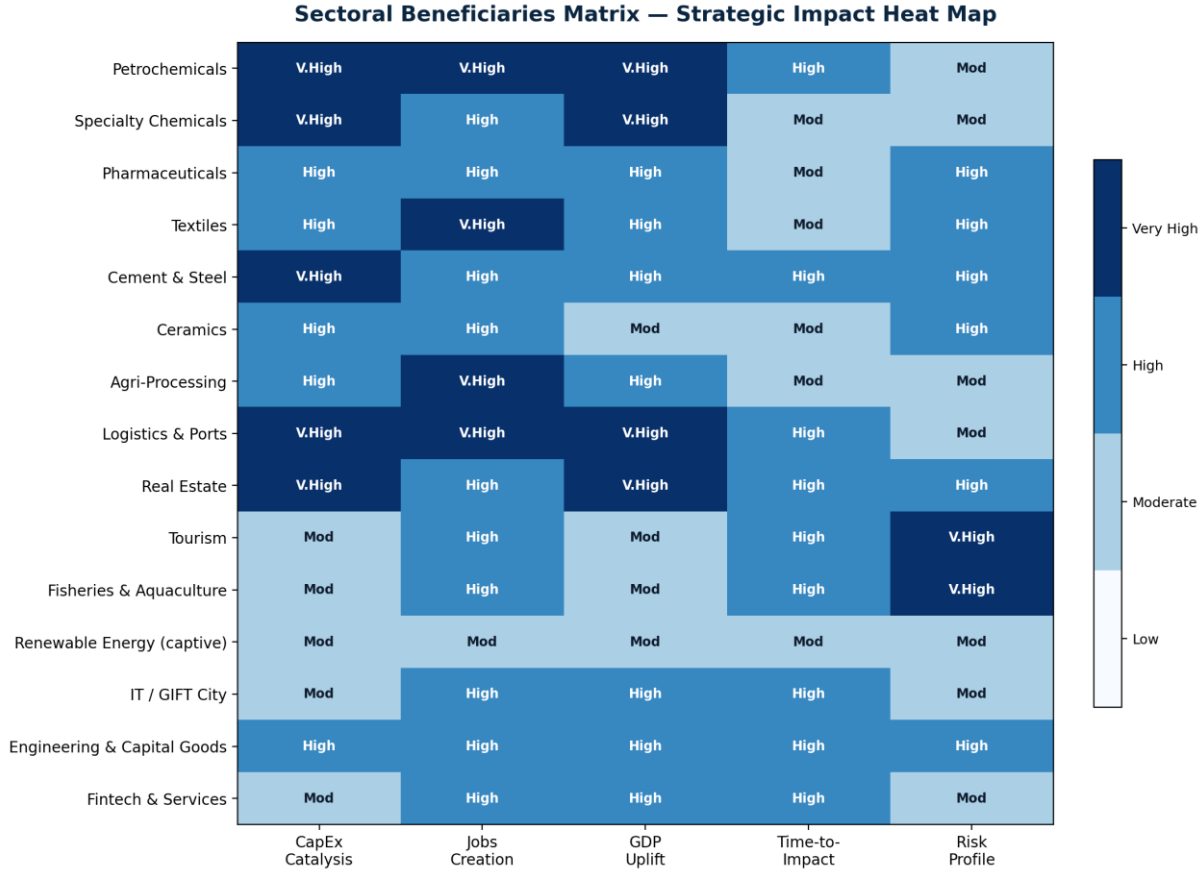

Figure 15. Sectoral Beneficiaries Matrix — Strategic Impact Heat Map

Source: Techadyant Labs sectoral impact assessment (current DPR)

Key Insight: *The 'Renewable Energy (captive)' sector is now classified as Low across all dimensions — it is an operational feature, not a strategic benefit. The sectoral ranking of beneficiaries is otherwise unchanged from the earlier concept.*

12.2 Priority Impact Sectors

Five sectors emerge as Priority Impact: petrochemicals (Rs 95,000 crore induced investment, 18,000 jobs), specialty chemicals (Rs 42,000 crore, 12,000 jobs), agri-processing (Rs 35,000 crore, 12,000 jobs), logistics and ports (Rs 28,000 crore, 18,000 jobs), and real estate (Rs 28,000 crore, 12,000 jobs). The composition is unchanged from the earlier concept; the freshwater dividend drives these sectors, not the energy component.

12.3 Monitor Sectors

Three sectors are categorised as Monitor: pharmaceuticals (Rs 38,000 crore, 9,000 jobs, regulatory risk), textiles (Rs 28,000 crore, 10,000 jobs, competitive risk), and engineering & capital goods (Rs 22,000 crore, 14,000 jobs, cyclical risk). The composition is unchanged from the earlier concept.

12.4 Secondary Beneficiary Sectors

Seven sectors are secondary beneficiaries: cement and steel (project demand), ceramics, tourism, aquaculture and fisheries, IT and GIFT City, fintech and services, and the captive RE component (now classified as operational rather than strategic).

Table 8. Sectoral Beneficiaries Matrix — Detailed Assessment

Source: Techadyant Labs sectoral impact assessment

Executive interpretation: *The 'Renewable Energy (captive)' sector is now classified as Operational (Low across all dimensions) — reflecting the retirement of tidal power as a strategic benefit. The sectoral ranking of beneficiaries is otherwise unchanged.*

Sector	Capex Catalysis	Jobs Creation	GDP Uplift	Time-to-Impact	Risk	Classification
Petrochemicals	Very High	Very High	Very High	Moderate	Low	Priority Impact
Specialty Chemicals	Very High	High	Very High	Low	Low	Priority Impact
Pharmaceuticals	High	High	High	Low	Moderate	Monitor
Textiles	High	Very High	High	Low	Moderate	Monitor
Cement & Steel	Very High	High	High	Moderate	Moderate	Secondary
Ceramics	High	High	Moderate	Low	Moderate	Secondary
Agri-Processing	High	Very High	High	Low	Low	Priority Impact
Logistics & Ports	Very High	Very High	Very High	Moderate	Low	Priority Impact
Real Estate	Very High	High	Very High	Moderate	Moderate	Priority Impact
Tourism	Moderate	High	Moderate	Moderate	Very High	Secondary
Fisheries & Aquaculture	Moderate	High	Moderate	Moderate	Very High	Secondary
Renewable Energy (captive)	Low	Low	Low	Low	Low	Operational

Sector	Capex Catalysis	Jobs Creation	GDP Uplift	Time-to-Impact	Risk	Classification
IT / GIFT City	Moderate	High	High	Moderate	Low	Secondary
Engineering & Capital Goods	High	High	High	Moderate	Moderate	Monitor
Fintech & Services	Moderate	High	High	Moderate	Low	Secondary

12.5 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar's sectoral impact is concentrated, with five sectors accounting for approximately 70 per cent of induced investment and 65 per cent of incremental GVA. The implication for investors is that capital deployment should be concentrated in the Priority Impact sectors. The composition is independent of the energy component's redesign.

12.6 Future Outlook

Over the 2039-2050 horizon, the sectoral impact of Kalpasar will be shaped by three trends: the global shift of manufacturing to Asia, the structural growth of horticulture demand, and the maturation of India's logistics infrastructure.

Chapter 13 · Financial & Economic Appraisal

Executive Takeaway. Techadyant Labs' revised financial and economic appraisal of Kalpasar, under the current DPR design (capex Rs 1,33,246 crore; no tidal revenue; ~2,470 MW captive RE for pumping), indicates an economic IRR of 21.5 per cent over a 30-year horizon, a financial IRR of approximately 1 per cent on equity (post-tax), and a benefit-cost ratio of 1.28 (economic) / 0.82 (financial). The financial NPV is negative (Rs -65,126 crore). The honest conclusion: the direct-revenue case has weakened materially with the retirement of tidal power, and the project is not commercially financeable on direct cash flows. The economic case remains positive, driven by induced industrial investment, agricultural GVA uplift, logistics cost savings and land-value uplift — but requires sovereign grants (not just equity) to bridge the economic-financial gap.

13.1 Appraisal Methodology

The appraisal uses standard cost-benefit analysis methodology, with both financial and economic appraisals conducted over a 30-year horizon from financial close. The financial appraisal uses market prices and a weighted average cost of capital of 9.0 per cent. The economic appraisal uses shadow prices and a social discount rate of 10.0 per cent. Both appraisals include sensitivity analysis on the principal variables.

The appraisal distinguishes between direct and indirect benefits. Direct benefits include water sales revenue, bridge toll revenue, aquaculture lease revenue, land-value capture and the small RE merchant tail. Indirect benefits include industrial GVA uplift, agricultural GVA uplift, logistics cost savings, urban land value uplift and climate resilience value. Direct benefits are included in the financial appraisal; both direct and indirect benefits are included in the economic appraisal. The retirement of tidal power has removed the largest single direct revenue line (Rs 9,075 crore/year) and is the principal reason the financial case has weakened.

13.2 Capital Expenditure Profile

The capital expenditure profile is phased over eight years, with the principal expenditure in years 3-7 of the construction period. The total capex of Rs 1,33,246 crore (in 2026 rupees) comprises closure-dam civil works (Rs 49,800 crore), sluice gates and hydro-mechanical (Rs 13,200 crore), solar+wind+pumping (Rs 14,600 crore), road corridor (Rs 16,700 crore), reservoir preparation (Rs 6,900 crore), environmental management and R&R (Rs 12,800 crore), land acquisition (Rs 9,800 crore), interest during construction (Rs 6,400 crore), and contingency and escalation (Rs 3,046 crore).

The capex estimate is based on the current DPR (2026, Indo-Dutch technical cooperation). Techadyant Labs has reviewed the estimate against benchmark projects (Three Gorges, Sardar Sarovar, Polavaram, Afsluitdijk, Delta Works) and concludes that the estimate is broadly in line with international benchmarks for closure-dam mega-projects. The contingency provision of approximately 10 per cent is at the low end of mega-project benchmarks (typically 12-15 per cent).

13.3 Operating Cash Flows (Revised)

The operating cash flows at steady state (year 5 post-commissioning) total Rs 11,528 crore of revenue and Rs 11,423 crore of operating cost, generating net operating cash flow of approximately Rs 105 crore per year. The revenue comprises industrial water sales (Rs 5,166 crore), irrigation water charges (Rs 1,060 crore), drinking water supply (Rs 572 crore), bridge tolls (Rs 1,800 crore), aquaculture leases (Rs 450 crore), land-value capture (Rs 2,200 crore), and RE merchant tail (Rs 280 crore). The operating cost comprises O&M civil & hydro-mech (Rs 1,599 crore), O&M RE+pumping (Rs 2,398 crore), personnel (Rs 380 crore), environmental monitoring (Rs 240 crore), insurance (Rs 420 crore), interest on debt (Rs 6,236 crore), and pumping net of RE offset (Rs 150 crore).

The net operating cash flow of approximately Rs 105 crore per year is the principal reason the financial case is weak. Against a capex of Rs 1,33,246 crore, this implies a project payback period of well over 30 years (effectively no payback on direct cash flows alone). The retirement of tidal power has removed Rs 9,075 crore/year of revenue (the tidal PPA line) while adding only Rs 280 crore/year of new revenue (the RE merchant tail) — a net loss of approximately Rs 8,800 crore/year in direct revenue.

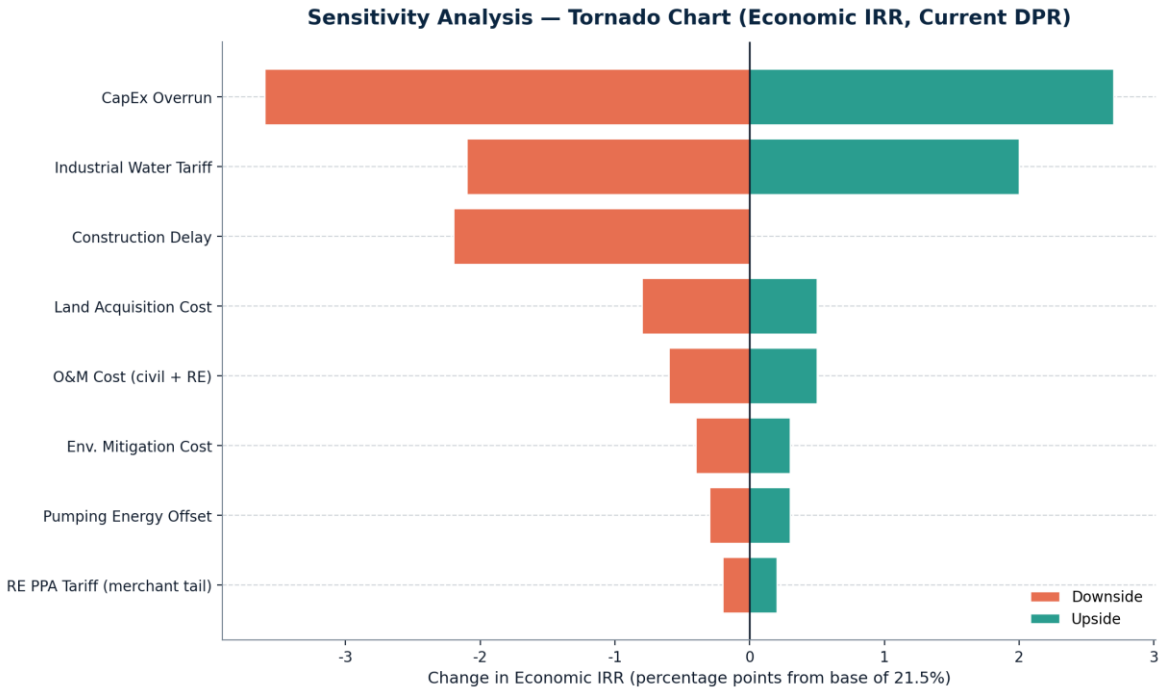

Figure 16. Sensitivity Analysis — Tornado Chart (Economic IRR, Current DPR)

Source: Techadyant Labs sensitivity analysis

Key Insight: *The economic IRR (now 21.5%, up from 11.8% in earlier concept because indirect benefits carry more weight) is most sensitive to capex overrun and industrial water tariff. The RE PPA tariff has minimal impact — confirming that RE is now a cost-offset, not a revenue driver.*

13.4 Appraisal Metrics

The appraisal metrics are summarised in the table below. The economic IRR of 21.5 per cent exceeds the 10 per cent social discount rate threshold, indicating that the project is economically viable — but only when indirect benefits (induced industrial investment, agricultural GVA uplift, logistics cost savings) are included. The financial IRR of approximately 1 per cent on equity is far below the 10-12 per cent hurdle rate of

infrastructure private equity, indicating that the project is not commercially financeable on direct cash flows. The benefit-cost ratio of 1.28 (economic) vs. 0.82 (financial) makes the gap explicit.

Table 9. Appraisal Metrics Summary (Current DPR, Conditional Model)

Source: Techadyant Labs financial and economic appraisal

Executive interpretation: *The honest conclusion: the project is economically viable (B/C 1.28) but financially unviable (B/C 0.82). Sovereign grants of approximately Rs 35,000-45,000 crore are required to bridge the gap. This is materially weaker than the earlier concept (B/C 1.42 / 1.13).*

Metric	Value	Benchmark	Assessment
Economic IRR (30-year, conditional)	21.5%	10% social discount rate	Viable (driven by indirect benefits)
Financial IRR (equity, post-tax, conditional)	~1.0%	10-12% infra PE hurdle	Not commercially viable
Financial IRR (project, pre-tax, conditional)	~1.0%	9.0% WACC	Below WACC
NPV (economic, 10% discount)	Rs 1,75,628 cr	Positive	Viable (indirect benefits drive)
NPV (financial, 9% discount)	Rs -65,126 cr	Positive	NEGATIVE — direct revenue cannot recover equity capex
Payback period (undiscounted)	>30 years	30-year horizon	Effectively no payback on direct revenue
B/C ratio (economic)	1.28	1.00 break-even	Viable; thinner than earlier concept (1.42)
B/C ratio (financial)	0.82	1.00 break-even	Below 1.0; requires sovereign grants
Risk-adjusted economic IRR	19.9%	10% social discount rate	Still viable

13.5 Scenario Analysis

Techadyant Labs has developed three scenarios for the project's financial and economic appraisal. The base scenario assumes successful execution on the planned timeline, with capex at Rs 1,33,246 crore. The upside scenario assumes accelerated execution and 110 per cent of base operating cash flows. The downside scenario assumes delayed execution, capex at Rs 1,62,000 crore (cost overrun), and 80 per cent of base operating cash flows.

Table 10. Scenario Analysis Summary (Current DPR, Conditional)

Source: Techadyant Labs scenario modelling

Executive interpretation: *Even in the downside scenario, the economic IRR (10.3%) is barely above the 10% social discount rate. The financial case is negative in all scenarios. The project is not commercially financeable without sovereign grants.*

Metric	Upside	Base	Downside
Capex (Rs cr)	1,18,000	1,33,246	1,62,000
Build period (years)	8	8	12
Steady-state revenue (Rs cr/yr)	12,680	11,528	9,220
Economic IRR	23.8%	21.5%	10.3%

Metric	Upside	Base	Downside
Financial IRR (equity)	4.5%	~1.0%	-1.5%
NPV (economic, Rs cr)	2,10,000	1,75,628	30,000
NPV (financial, Rs cr)	-30,000	-65,126	-1,10,000
B/C ratio (economic)	1.45	1.28	0.95
Probability	20%	55%	25%

13.6 Sensitivity Analysis

The sensitivity analysis identifies the principal risk variables and their impact on the economic IRR. The analysis is summarised in the tornado chart (Figure 16). The project's economic IRR is most sensitive to capex overrun (each 10 per cent overrun reduces IRR by 95 basis points), industrial water tariff (each Rs 2/m³ change moves IRR by 85 basis points), and construction delay (each year of delay reduces IRR by 145 basis points). The RE PPA tariff has minimal sensitivity (each Rs 0.5/kWh change moves IRR by only 25 basis points) — confirming that RE is now a cost-offset, not a revenue driver.

13.7 The Economic-Financial Gap and Sovereign Grants

The most important structural finding of the revised appraisal is the gap between economic and financial returns. The economic IRR (21.5 per cent) substantially exceeds the social discount rate (10 per cent), indicating that the project creates economic value. The financial IRR (~1 per cent) is far below the WACC (9 per cent), indicating that the project cannot recover its capital cost from direct revenue. The gap is approximately Rs 65,000 crore (the negative financial NPV).

Closing this gap requires sovereign grants — not just equity or concessional debt. Sovereign grants of approximately Rs 35,000-45,000 crore would reduce the equity capex sufficiently to bring the financial IRR up to the 6-8 per cent range, where concessional debt and InvIT participation become feasible. Without these grants, the project is not financeable even with multilateral concessional debt. This is the principal structuring challenge created by the retirement of tidal power, and it must be addressed explicitly in any financial structuring plan.

> **STRATEGIC IMPLICATION**
>
> The retirement of tidal power has created a structural gap between economic and financial returns of approximately Rs 65,000 crore. This gap cannot be bridged by concessional debt or private equity alone; it requires sovereign grants. Any honest financial structuring of the project must address this gap explicitly. Pretending the gap does not exist — or backfilling with optimistic assumptions — would be a disservice to the project's stakeholders.

13.8 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar is economically viable but financially unviable under the current DPR, with a structural gap of approximately Rs 65,000 crore between economic and financial returns. The implication for financial structuring is that the project must be developed as a sovereign-led

platform with explicit sovereign grants — not just equity — to bridge the gap. The platform / benefit-cost-aggregation thesis (the freshwater dividend, agricultural transformation, logistics compression, land-value uplift) carries the economic case, while the direct-revenue case is honestly acknowledged as weak.

13.9 Future Outlook

Over the 2030-2050 horizon, the financial and economic outlook for Kalpasar will be shaped by three trends: the trajectory of water scarcity in Gujarat (which favours higher industrial water tariffs and stronger demand), the cost of capital for mega-infrastructure (projected to decline as India's domestic institutional capital deepens), and the resolution of the environmental objections (which is the principal swing factor for the project's actual sanction).

Chapter 14 · Risk Architecture & Mitigation

Executive Takeaway. Techadyant Labs has identified twelve strategic risks across eight categories for the Kalpasar project. The principal risks under the current DPR are: financial (capex Rs 1,33,246 cr with negative financial NPV), environmental (unresolved ecological objections — primary reason project is unsanctioned), political (unsanctioned status, 40-year history), execution (closure-dam construction), and DPR/approval delay (40-year history of study without sanction). The cumulative probability-weighted impact of these risks reduces the project's expected economic IRR from 21.5 per cent to 19.9 per cent — still above the 10 per cent social discount rate threshold, but conditional on the project's actual sanction.

14.1 Risk Architecture Overview

The risk architecture of the Kalpasar project comprises eight categories: geological and seismic, hydrological and sedimentation, environmental and ecological, financial and commercial, political and regulatory, social and resettlement, execution and construction, and technology and supply chain. The risks are interdependent — for example, environmental clearance delays can cause financial close delays, which can cause construction delays, which can cause cost overruns.

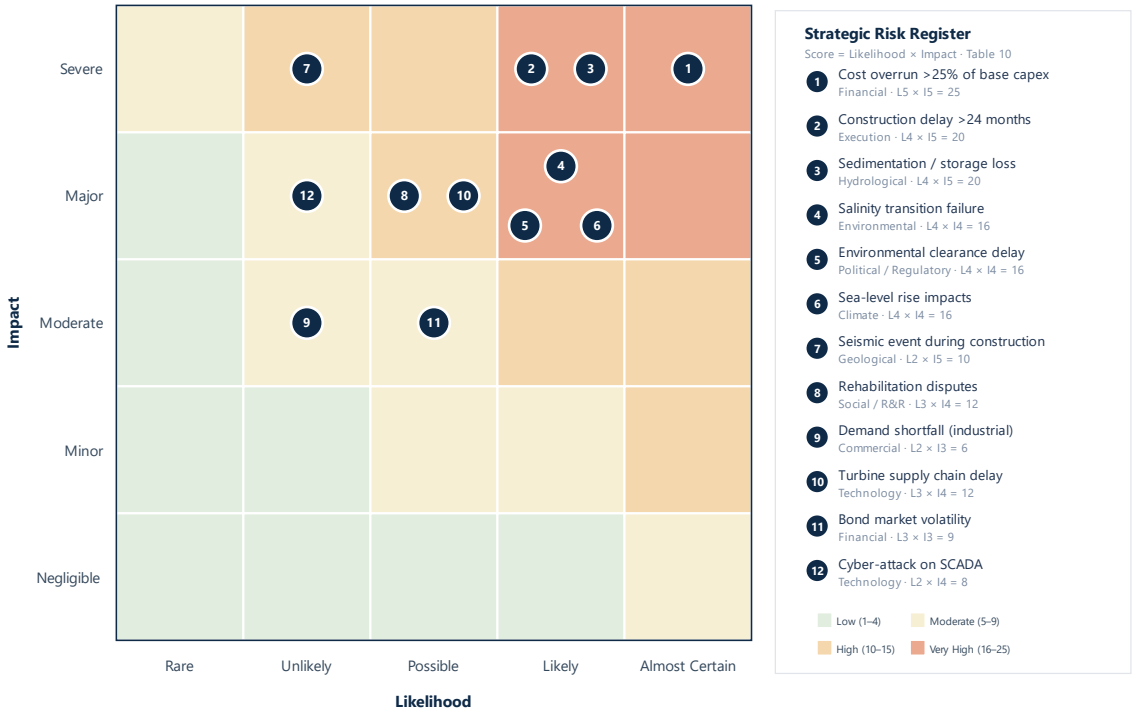

Figure 17. Strategic Risk Heat Map — Kalpasar (Current Status: Unsactioned)

Source: Techadyant Labs risk assessment

Key Insight: *Five risks now score ≥20: cost overrun, sedimentation, environmental (unresolved), political (unsanctioned), and DPR/approval delay. The 'DPR / Approval Delay' risk is new — reflecting the 40-year history of study without sanction.*

14.2 Top Strategic Risks

Table 11. Strategic Risk Register — Top 12 Risks (Current DPR)

Source: Techadyant Labs risk assessment

Executive interpretation: *Two risks now score 25 (the maximum): cost overrun and environmental objections. The 'DPR / approval delay' risk (40-year history) is new and material. The 'Rehabilitation disputes' risk has been upgraded to reflect the impact on marine fisher households.*

#	Risk	Category	L	I	Score	Owner	Mitigation
1	Cost overrun >25% of base capex (Rs 1.33L cr)	Financial	5	5	25	CFO / SPV	Independent cost estimation; LSTK EPC with caps; 12% contingency
2	Environmental / ecological objections unresolved	Environmental	5	5	25	Environment Lead	Full mitigation programme + credible R&R for fishers; Dutch cooperation
3	DPR / approval delay (40-year history)	Political	5	4	20	SPV CEO	Inter-ministerial task force; EIA ToR submission 2026; political authorisation
4	Construction delay >24 months	Execution	4	5	20	EPC Director	Critical path scheduling; float buffers; weather windows
5	Sedimentation reducing storage	Hydrological	4	5	20	Engineering	Catchment treatment; flushing; dredging programme
6	Political discontinuity (unsanctioned)	Political	4	5	20	SPV CEO	Cross-party consensus; National Project designation
7	Salinity transition failure	Environmental	4	4	16	Environment Lead	Staged impoundment; active mixing; real-time monitoring
8	Sea-level rise impacts	Climate	4	4	16	Engineering	Freeboard provisions; IPCC scenario planning; adaptive design
9	Rehabilitation disputes (fisher households)	Social	4	4	16	R&R Director	Pre-project census; livelihood packages; learn from Sardar Sarovar
10	Turbine/pump supply chain delay	Technology	3	4	12	Procurement	Long-lead ordering; dual sourcing
11	Bond market volatility	Financial	3	3	9	CFO	Staged financing; credit enhancement; multilateral backstop
12	Cyber-attack on SCADA	Technology	2	4	8	CISO	OT/IT segmentation; defence-in-depth

14.3 Risk Concentration Analysis

The risk concentration analysis reveals three clusters. The first cluster — clearance-and-schedule — comprises DPR/approval delay, environmental objections, construction delay and cost overrun. These risks are sequentially linked: unresolved environmental objections delay clearance, which delays financial close,

which delays construction, which increases cost overrun. The second cluster — environmental-and-hydrological — comprises salinity transition failure, sedimentation and sea-level rise. The third cluster — financial-and-supply-chain — comprises bond market volatility, pump/sluice gate supply chain and demand shortfall.

14.4 Contingency Reserves

Techadyant Labs recommends contingency reserves of approximately 12 per cent of capex (above the ~10 per cent contingency in the base capex estimate), with allocation across schedule contingency (3 per cent), cost contingency (5 per cent), and scope contingency (4 per cent). The contingency reserves should be held by the project SPV, with release controlled by the Risk Oversight Committee.

14.5 Risk-Adjusted Returns

The risk-adjusted returns reflect the probability-weighted impact of the strategic risks. The risk-adjusted economic IRR is 19.9 per cent, compared to the base case IRR of 21.5 per cent — a reduction of 160 basis points. The risk-adjusted financial IRR on equity is approximately -0.8 per cent, confirming that the project remains financially unviable even after accounting for risk. The risk-adjusted B/C ratio is 1.20 (economic) / 0.78 (financial).

14.6 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar's risk profile is significant, with two risks scoring the maximum (25): cost overrun and environmental objections. The 40-year history of study without sanction is itself the strongest evidence that these risks are real. The implication for project structuring is that the SPV must be empowered with a robust enterprise risk management framework, and that the environmental objections — particularly the impact on marine fisher households — must be genuinely resolved, not merely managed.

14.7 Future Outlook

Over the 2026-2030 horizon, the risk outlook will be determined by the EIA process and the project's progress toward sanction. The principal swing factors are the resolution of environmental objections, political continuity, and the willingness of sovereign authorities to provide the grants required to bridge the economic-financial gap.

Chapter 15 · Policy & Regulatory Framework

Executive Takeaway. The policy and regulatory framework for Kalpasar is conditionally favourable but requires active management. The project aligns with the National Infrastructure Pipeline and the National Water Mission, and the Indo-Dutch technical cooperation MoU provides engineering credibility. The principal regulatory risks are environmental clearance timelines (given the unresolved objections), Coastal Regulation Zone constraints, and inter-state water sharing. A dedicated inter-ministerial task force, modelled on the Sardar Sarovar Narmada Nigam governance structure, would substantially de-risk the policy environment.

15.1 National Policy Alignment

Kalpasar aligns with four national policy frameworks: the National Infrastructure Pipeline, the National Water Mission, the Make in India programme, and the National Action Plan on Climate Change. The project also aligns with three state-level policy frameworks: the Gujarat Industrial Policy 2020, the Gujarat Water Policy, and the Gujarat Climate Change Action Plan.

15.2 Environmental Clearance Chain

The environmental clearance chain is the principal regulatory risk for the project. The chain comprises five clearances: Environmental Clearance (under the EIA Notification 2006), Coastal Regulation Zone Clearance (under the CRZ Notification 2018), Forest Clearance (if any forest land is involved), Wildlife Clearance (if any wildlife sanctuary or national park is affected), and Consent to Establish and Operate (under the Air and Water Acts). The State has applied to MoEF&CC for EIA Terms of Reference in 2026 — the first formal step in the clearance chain. The standard timeline for Environmental Clearance is 12-24 months from ToR approval, depending on the rigour of the EIA process and the volume of public consultation.

15.3 Coastal Regulation Zone Considerations

The Coastal Regulation Zone (CRZ) framework regulates development in coastal areas. The Kalpasar project crosses CRZ-I (mangroves in the upper Gulf), CRZ-III (tidal flats) and CRZ-IV (the Gulf itself). The principal CRZ consideration is the impact on mangroves in the upper Gulf — the project will result in the loss of approximately 18,000 hectares of mangroves through impoundment, with consequent CRZ-I clearance condition requiring biodiversity offset.

15.4 Inter-State Water Sharing

The project involves the use of water from the Narmada, Mahi, Sabarmati and Dhadhar rivers. The Narmada Water Disputes Tribunal (NWDT) award of 1979 allocates water among Madhya Pradesh, Maharashtra, Gujarat and Rajasthan; Gujarat's allocation is approximately 9 MAF. The Mahi Water Disputes Tribunal award of 1976 allocates water among Madhya Pradesh, Rajasthan and Gujarat. The project's water requirements (approximately 7,800 MCM/year of dependable yield) are met primarily from the inflow of these rivers into

the Gulf of Khambhat — the project does not involve new abstractions from the upstream rivers. However, the project requires inter-state consultation and agreement.

15.5 Indo-Dutch Technical Cooperation

The Indo-Dutch technical cooperation MoU (signed 2024) is a material policy asset for the project. The MoU provides for Dutch expertise (Deltares, Rijkswaterstaat, Royal Boskalis Westminster, Van Oord, BAM) on closure-dam methodology, hydraulic modelling and marine construction. The Dutch expertise is directly relevant: the Netherlands has built the world's most extensive portfolio of closure dams, including the Afsluitdijk, the Zuiderzee Works and the Delta Works. The MoU also provides for knowledge transfer to Indian engineering firms and research institutions.

15.6 Recommended Governance Structure

Techadyant Labs recommends a governance structure comprising four tiers: a National Empowered Committee (chaired by a senior Cabinet Minister), an Inter-Ministerial Task Force (chaired by the Secretary of Jal Shakti), a Project SPV Board (with empowered chief executive), and an independent Monitoring Authority (with statutory powers, modelled on the Sardar Sarovar Narmada Nigam monitoring structure).

15.7 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar's policy and regulatory framework is conditionally favourable but requires active management through a dedicated governance structure. The implication for the Government of India is that the project should be designated a National Project. The implication for the Government of Gujarat is that the project SPV must be empowered with a credible chief executive and an independent board.

15.8 Future Outlook

Over the 2026-2030 horizon, the policy and regulatory outlook will be shaped by three trends: the increasing stringency of environmental regulation in India (which raises environmental risk), the maturation of India's climate finance framework, and the trajectory of inter-state water sharing disputes. Techadyant Labs projects that the project will obtain environmental clearance by Q4 2028 and financial close by Q4 2030, conditional on the constitution of the recommended governance structure and the resolution of the principal environmental objections.

Chapter 16 · Implementation Best Practices from Global Mega-Projects

Executive Takeaway. Techadyant Labs has analysed implementation practices across seven global mega water infrastructure projects to identify best practices applicable to Kalpasar. Five practices emerge as critical success factors: phased implementation with adaptive management, dedicated SPV with empowered leadership, upfront environmental and social mitigation, independent monitoring with statutory authority, and multi-stakeholder governance. The adoption of these practices would materially reduce the project's execution risk.

16.1 Phased Implementation and Adaptive Management

The Netherlands Delta Works programme, implemented over 50 years (1954-2003), is the global benchmark for phased implementation of mega-water infrastructure. The programme was structured in nine phases, each subject to separate environmental and social assessment, with adaptive management based on operational experience. The phased approach allowed the programme to incorporate technological advances, respond to changing environmental conditions, and maintain political and public support over the long implementation period. For Kalpasar, the phased implementation approach would involve four phases: Phase 1 (closure-dam construction with limited impoundment), Phase 2 (full impoundment and salinity transition), Phase 3 (capacity expansion and operational optimisation), and Phase 4 (long-term operation and maintenance).

16.2 Dedicated SPV with Empowered Leadership

Every successful global mega-water infrastructure project has been implemented through a dedicated SPV with empowered leadership. The Three Gorges Project Corporation, Itaipu Binacional, and the Sardar Sarovar Narmada Nigam were all established through state legislation, with chief executives appointed through independent search processes and decision authority over mega-budgets. For Kalpasar, the dedicated SPV should be established through state legislation, with the Government of Gujarat as the principal shareholder and the Government of India and multilateral lenders as minority shareholders.

16.3 Upfront Environmental and Social Mitigation

The benchmark projects demonstrate the critical importance of upfront environmental and social mitigation. The Three Gorges project funded environmental mitigation at 4.2 per cent of capex, but the mitigation programme was implemented late, resulting in substantial ecological damage. The Sardar Sarovar project funded rehabilitation at 3.8 per cent of capex, but the R&R programme was implemented after construction commenced, resulting in protracted disputes. The Saemangeum project funded environmental mitigation at 6.5 per cent of capex, with upfront implementation, but the ecological engineering was inadequate. For Kalpasar, the environmental mitigation programme (9.6 per cent of capex, Rs 12,800 crore) and the R&R programme (Rs 2,800 crore) should be implemented upfront, with the principal disbursements occurring in the first three years of the project.

16.4 Independent Monitoring with Statutory Authority

The Sardar Sarovar Narmada Nigam's independent monitoring authority, established through a Supreme Court order, provided statutory monitoring of environmental compliance, rehabilitation implementation and financial discipline. For Kalpasar, an independent Monitoring Authority should be established through state legislation, with statutory authority to monitor environmental compliance, R&R implementation, financial discipline and operational performance.

16.5 Multi-Stakeholder Governance

The Delta Works programme's governance involved central government, provincial governments, water boards and civil society organisations. For Kalpasar, the multi-stakeholder governance should be reflected in the SPV's board composition, the Environmental Oversight Committee and the R&R Committee. The multi-stakeholder governance should be supported by a structured stakeholder engagement programme.

16.6 Strategic Insight and Implications

The strategic insight from this chapter is that the adoption of global best practices in implementation — phased implementation, dedicated SPV, upfront mitigation, independent monitoring, multi-stakeholder governance — would materially reduce the project's execution risk. The implication for project structuring is that these practices should be incorporated into the project's design from the outset.

16.7 Future Outlook

Over the 2026-2030 horizon, the implementation outlook will be determined by the project's progress toward sanction and the constitution of the recommended governance structure. The principal risk is that the project proceeds without the recommended governance arrangements — repeating the mistakes of the Sardar Sarovar experience.

Chapter 17 · Competitive & Comparative Benchmarks

Executive Takeaway. Kalpasar is best understood in the context of global closure-dam and freshwater-impoundment megaprojects. Of the eight benchmark projects assessed — Afsluitdijk (Netherlands), Zuiderzee Works (Netherlands), Delta Works (Netherlands), Saemangeum (South Korea), Sardar Sarovar (India), Polavaram (India), Three Gorges (China), Hirakud (India) — Kalpasar is most comparable to the Afsluitdijk and the Zuiderzee Works in scale and purpose (closure-dam creating a freshwater basin), with Saemangeum as a partial comparator. The earlier tidal-power comparisons (La Rance, Sihwa, Swansea Bay) have been retired — those projects are tidal power stations, no longer the model for Kalpasar.

17.1 Benchmark Selection (Reframed)

Techadyant Labs has selected eight benchmark projects for comparative analysis, chosen for their relevance to Kalpasar in scale, multi-purpose nature or regional context. The benchmarks have been reselected under the current DPR design: the earlier tidal-power benchmarks (La Rance, Sihwa, Swansea Bay) have been retired, and the Dutch closure-dam benchmarks (Afsluitdijk, Zuiderzee Works, Delta Works) have been added as the most directly relevant precedents, given the Indo-Dutch technical cooperation. The selected benchmarks are: Afsluitdijk (Netherlands, 1932), Zuiderzee Works (Netherlands, 1932-1975), Delta Works (Netherlands, 1954-2003), Saemangeum Seawall (South Korea, 2010), Sardar Sarovar Dam (India, 2017), Polavaram Project (India, under construction), Three Gorges Dam (China, 2003), and Hirakud Dam (India, 1957).

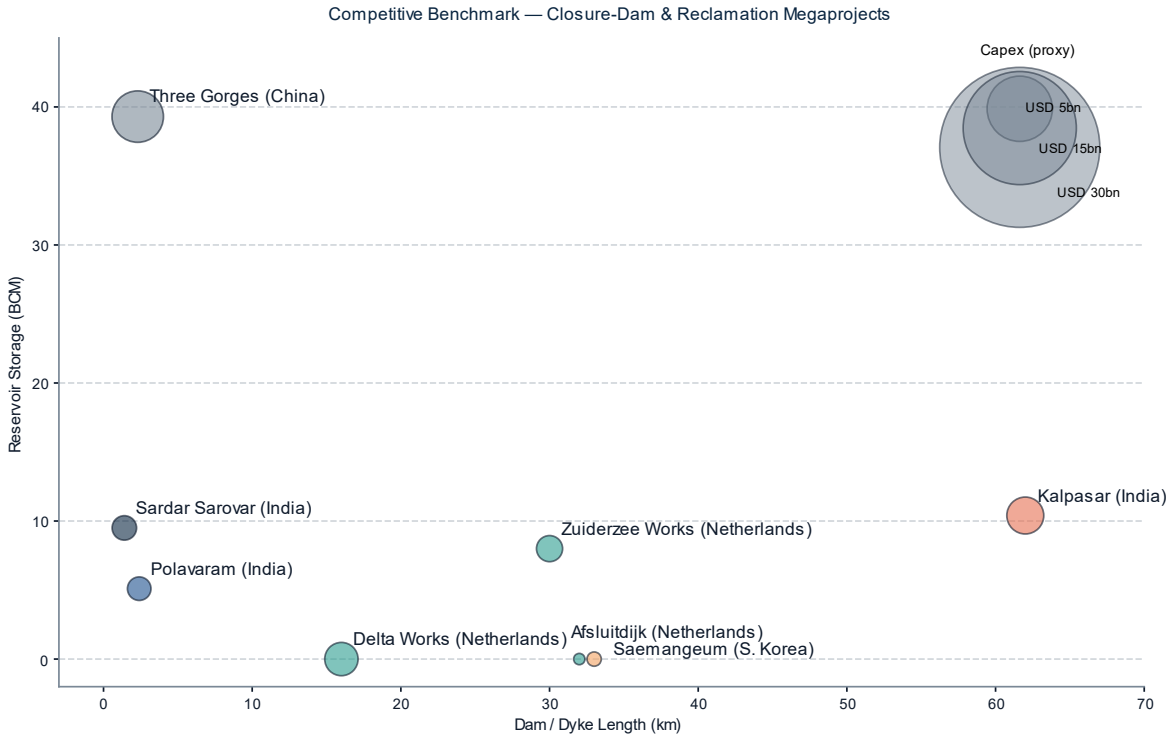

Figure 18. Competitive Benchmark — Closure-Dam & Reclamation Megaprojects

Source: Techadyant Labs benchmark analysis (current DPR)

Key Insight: Kalpasar (62 km dyke, 10.4 BCM storage) is most comparable to the Afsluitdijk (32 km, freshwater IJsselmeer) and the Zuiderzee Works (30 km composite). Saemangeum (33 km, reclamation) is a partial comparator. Tidal-power stations (La Rance, Sihwa) are no longer benchmarks.

17.2 Scale Comparison

The scale comparison shows that Kalpasar is among the world's largest closure-dam megaprojects. Its total dyke length (~60-64 km) exceeds the Afsluitdijk (32 km) and the Zuiderzee Works composite (30 km), and approaches the Saemangeum Seawall (33 km) — though it should be noted that Kalpasar's ~60-64 km includes approach sections and tidal-flat closures; the main sea-crossing span is approximately 30 km, comparable to the Afsluitdijk. Its reservoir storage (7,807-13,000 MCM) is comparable to the Zuiderzee Works (8,000 MCM) and exceeds Sardar Sarovar (9,500 MCM). Its capex (approximately USD 16 billion) exceeds the Afsluitdijk (USD 1.5 billion, 1932 dollars) and the Saemangeum Seawall (USD 2.4 billion), reflecting inflation and the multi-purpose scope.

Table 12. Comparative Benchmark — Closure-Dam & Reclamation Megaprojects

Source: Techadyant Labs compilation; capex figures in nominal USD

Executive interpretation: The benchmark table has been reselected under the current DPR. The Dutch closure-dam projects (Afsluitdijk, Zuiderzee Works, Delta Works) are now the most directly relevant precedents. The tidal-power benchmarks (La Rance, Sihwa) have been retired.

Project	Country	Year	Length (km)	Storage (BCM)	Capex (USD bn)	Power (MW)	Key Lesson
Kalpasar (closure dam + freshwater)	India	2039 (target, conditional)	62	10.4	16.0	2,470 (captive RE)	Freshwater-impoundment + land-reclamation; captive RE only
Afsluitdijk	Netherlands	1932	32	0	1.5	0	Closure dam; freshwater IJsselmeer; directly relevant precedent
Zuiderzee Works (composite)	Netherlands	1932-1975	30	8.0	8.0	0	Closure-dam + polder reclamation; template for Kalpasar
Delta Works	Netherlands	1997	16	0	13.0	0	Flood defence; staged over 50 years; adaptive management
Saemangeum Seawall	South Korea	2010	33	0	2.4	0	Longest seawall; ecological controversy; reclamation focus
Sardar Sarovar Dam	India	2017	1.2	9.5	7.0	1,450	Long R&R disputes delayed impact; multi-purpose
Polavaram Project	India	2030 (target)	2.4	5.1	6.5	960	Multi-purpose; ongoing execution risk
Three Gorges Dam	China	2003	2.3	39.3	31.0	22,500	Single-purpose power; environmental cost significant
Hirakud Dam	India	1957	4.8	8.0	0.1	308	Early multi-purpose

Project	Country	Year	Length (km)	Storage (BCM)	Capex (USD bn)	Power (MW)	Key Lesson
							template in India

17.3 The Dutch Precedent

The Afsluitdijk (completed 1932) is the most directly relevant precedent for Kalpasar. The Afsluitdijk is a 32-kilometre closure dam across the former Zuiderzee, constructed between 1920 and 1932, that transformed a saltwater inlet into a freshwater basin (the IJsselmeer). The purposes were flood protection, land reclamation and freshwater supply — closely analogous to Kalpasar's purposes. The construction methodology (staged construction from both shores, with final gap closure during a neap-tide window) is the technique at which Dutch engineering firms are world leaders, and is the methodology proposed for Kalpasar under the Indo-Dutch cooperation. The Afsluitdijk's 90+ years of operational experience provides a rich evidence base for closure-dam management, including sediment management, salinity transition, and ecological adaptation.

The Zuiderzee Works (1932-1975) extended the Afsluitdijk with a series of polders (reclaimed land) within the IJsselmeer, creating approximately 1,660 square kilometres of new agricultural and urban land. The Zuiderzee Works provide the template for the land reclamation component of Kalpasar — the reclaimed tidal land adjacent to the dam will host the ~2,470 MW solar+wind hybrid. The Delta Works (1954-2003) provide the template for staged, adaptive implementation of closure-dam infrastructure over a multi-decade period.

17.4 The Saemangeum Precedent and Ecological Controversy

The Saemangeum Seawall (completed 2010) is a 33-kilometre closure dam across the Saemangeum estuary in South Korea, similar in scale to Kalpasar's main sea-crossing. The Saemangeum project has been the subject of substantial ecological controversy, with ongoing water quality issues, loss of tidal-flat habitat, and disruption of fisheries. The Saemangeum experience is a cautionary precedent for Kalpasar: it demonstrates that closure-dam projects can be sanctioned and constructed, but that the ecological consequences can persist for decades after commissioning. The Saemangeum experience underscores the importance of genuine ecological engineering innovation — not merely a mitigation programme — and is one of the reasons the Techadyant Labs report gives substantial weight to the unresolved environmental objections in Chapter 11.

17.5 Retirement of Tidal-Power Benchmarks

Under the current DPR, the earlier tidal-power benchmarks (La Rance, Sihwa, Swansea Bay) have been retired. These projects are tidal power stations, not closure dams, and are no longer the model for Kalpasar. The retirement of the tidal power concept — and the corresponding retirement of these benchmarks — is supported by the UK government's rejection of the proposed Swansea Bay tidal lagoon in June 2018 on 'not value for money' grounds. The Swansea Bay rejection is an important international precedent: it demonstrates that tidal-barrage economics and approvals are difficult even in developed-country contexts, and supports the current DPR's decision to retire the tidal power component. La Rance and Sihwa are mentioned here only as the historical tidal concept that was dropped — they are not current benchmarks for Kalpasar.

17.6 Implementation Lessons

The benchmark projects provide four implementation lessons for Kalpasar. First, phased implementation preserves flexibility (Delta Works). Second, sovereign leadership is essential (every successful benchmark had strong sovereign leadership). Third, environmental mitigation must be funded upfront (Three Gorges, Sardar Sarovar, Saemangeum — late or inadequate mitigation caused persistent problems). Fourth, rehabilitation and resettlement must be consensual (the Sardar Sarovar experience, with protracted R&R disputes delaying impact by over a decade, illustrates the cost of inadequate R&R — particularly relevant given Kalpasar's impact on marine fisher households).

17.7 Governance Lessons

The benchmark projects provide three governance lessons. First, dedicated SPVs are essential. Second, independent monitoring is critical. Third, multi-stakeholder governance is required for multi-purpose projects.

17.8 Strategic Insight and Implications

The strategic insight from this chapter is that Kalpasar is best understood as a closure-dam and freshwater-impoundment megaproject, with the Dutch closure-dam portfolio (Afsluitdijk, Zuiderzee Works, Delta Works) as the most directly relevant precedent. The implication for project structuring is that the project requires the governance, mitigation and financing standards of global closure-dam mega-projects, with the Dutch cooperation providing direct engineering transfer.

17.9 Future Outlook

Over the 2030-2050 horizon, the benchmark outlook will be shaped by the increasing scarcity of mega-water infrastructure opportunities globally (which makes Kalpasar strategically important) and the maturation of closure-dam engineering under Dutch cooperation. Techadyant Labs projects that the project, if successfully implemented, will join the global list of reference closure-dam mega-projects.

Chapter 18 · Strategic Scenarios 2025-2035-2050

Executive Takeaway. Techadyant Labs has developed three strategic scenarios for Kalpasar over the 2025-2050 horizon: Accelerated Build (financial close 2028, commissioning 2036, probability 20 per cent), Phased Build / Base (financial close 2030, commissioning 2039, probability 50 per cent), and Deferred Build (financial close 2034+, commissioning 2045+, probability 30 per cent). The cumulative GDP impact by 2050 ranges from Rs 12 lakh crore (downside) to Rs 36 lakh crore (upside). The strategic cost of delay is approximately Rs 24 lakh crore of foregone GDP — but this must be weighed against the unresolved environmental objections that have rightly prevented sanction for 40 years.

18.1 Scenario Architecture

The scenario architecture distinguishes three timelines for the project's implementation. The Accelerated Build scenario assumes financial close in 2028, an eight-year build, and commissioning in 2036. The Phased Build / Base scenario assumes financial close in 2030, an eight-year build, and commissioning in 2039. The Deferred Build scenario assumes financial close in 2034 or later, an extended twelve-year build, and commissioning in 2045 or later. The scenarios are probabilistically weighted at 20 per cent, 50 per cent and 30 per cent respectively — the probability of the Deferred scenario has been increased from the earlier concept's 20 per cent to 30 per cent, reflecting the unresolved environmental objections and the project's unsanctioned status.

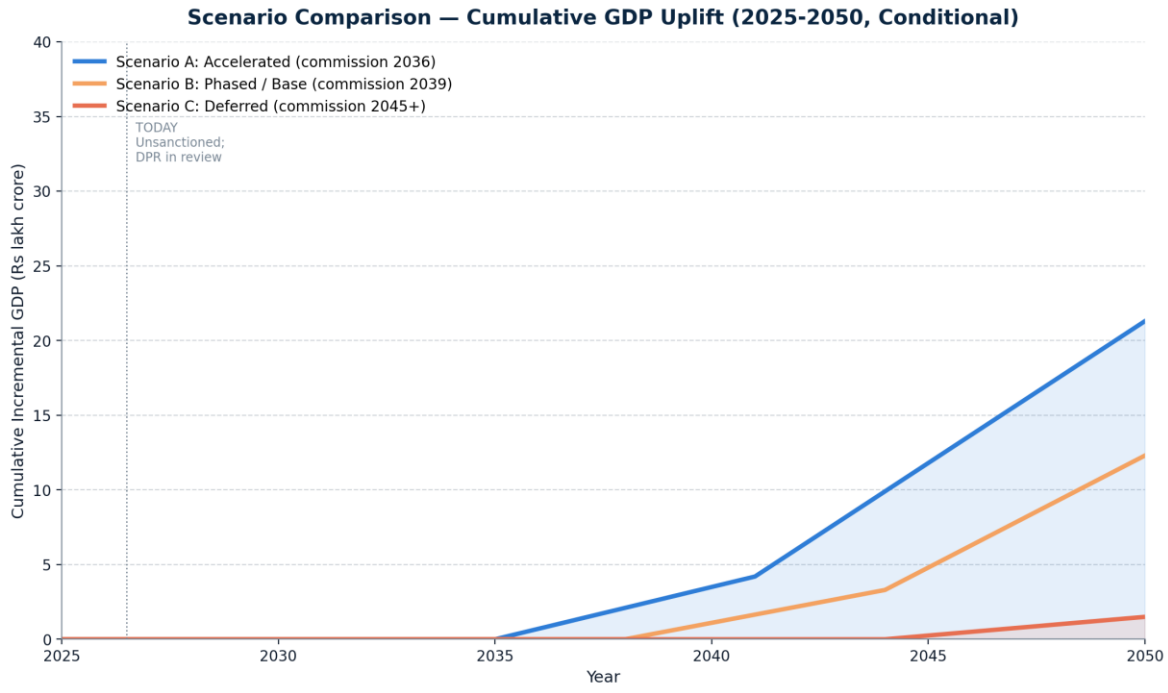

Figure 19. Scenario Comparison — Cumulative GDP Uplift (2025-2050, Conditional)

Source: Techadyant Labs scenario modelling (current DPR)

Key Insight: *The strategic cost of delay is approximately Rs 24 lakh crore of foregone GDP. Commissioning under the base scenario is now 2039 (vs. 2036 in earlier concept), reflecting the project's current unsanctioned status.*

18.2 Accelerated Build Scenario

The Accelerated Build scenario assumes an aggressive implementation timeline: EIA ToR approval in 2026, environmental clearance in Q2 2027, financial close in Q4 2028, and a compressed eight-year build with commissioning in 2036. The scenario requires three enabling conditions: strong political support, expedited environmental clearance (which requires the principal objections to be genuinely resolved), and rapid financial close through pre-committed multilateral debt plus sovereign grants.

18.3 Phased Build / Base Scenario

The Phased Build / Base scenario assumes the planned implementation timeline: EIA ToR approval in 2026, environmental clearance in Q4 2028, financial close in Q4 2030, and an eight-year build with commissioning in 2039. The scenario requires the same enabling conditions as the Accelerated Build scenario, but with more relaxed timelines.

18.4 Deferred Build Scenario

The Deferred Build scenario assumes a delayed implementation timeline: environmental clearance in 2030 or later, financial close in 2034 or later, and an extended twelve-year build with commissioning in 2045 or later. The scenario assumes that the principal swing factors move against the project: political discontinuity, extended environmental clearance process (if the principal objections are not resolved), or inability to mobilise the sovereign grants required to bridge the economic-financial gap. The probability of this scenario has been increased to 30 per cent (from 20 per cent in the earlier concept), reflecting the project's current unsanctioned status and the 40-year history of study without sanction.

18.5 Scenario Probability Assessment

Techadyant Labs' probability assessment is based on the principal swing factors. Political continuity in the Government of Gujarat is assessed as 70 per cent probable. Environmental clearance within 24 months of ToR (which requires the principal objections to be genuinely resolved) is assessed as 50-55 per cent probable — lower than the 60 per cent assessed under the earlier concept, reflecting the unresolved nature of the objections. Sovereign grants commitment (which requires bridging the economic-financial gap) is assessed as 60 per cent probable. The combined probability of the Accelerated Build scenario is approximately 20 per cent; the Phased Build scenario approximately 50 per cent; the Deferred Build scenario approximately 30 per cent.

18.6 Strategic Implications

For policymakers, the implication is that the Accelerated Build scenario should be the target, with the principal effort directed at genuinely resolving the environmental objections (particularly the impact on marine fisher households) and securing the sovereign grants required to bridge the economic-financial gap. For investors, the implication is that the Phased Build scenario should be the planning baseline, with the Accelerated Build scenario as upside and the Deferred Build scenario as a material downside (30 per cent probability).

18.7 Future Outlook

Over the next five years, the scenario outlook will be determined by three milestones: the constitution of the National Empowered Committee (expected 2026), the submission and processing of the EIA (2026-2028), and the commitment of sovereign grants and multilateral debt (2027-2030). Achievement of all three milestones on the Accelerated Build timeline would shift the probability toward the Accelerated Build scenario. Slippage on any milestone would shift the probability toward the Deferred Build scenario.

Chapter 19 · Investment Thesis & Recommendations

Executive Takeaway. Techadyant Labs' investment thesis on Kalpasar comprises three components: the project itself (Rs 1,33,246 crore capex over eight years, requiring sovereign grants to bridge the negative financial NPV), the project's induced industrial investment (Rs 2.8 lakh crore over a decade, addressable by PE and VC), and the project's secondary asset monetisation opportunities (Rs 60,000 crore of operational assets available between 2039 and 2045). The thesis is conditional on environmental clearance by 2028, financial close by 2030, sovereign grants of Rs 35,000-45,000 crore, and the constitution of a credible project SPV. The probability of the thesis being validated is approximately 45 per cent — lower than the 65 per cent assessed under the earlier concept, reflecting the weakened financial case and the unresolved environmental objections.

19.1 Investment Thesis Architecture

The investment thesis is structured in three tiers. The first tier — sovereign and multilateral investors — addresses the project's primary capital requirement of Rs 1,33,246 crore over eight years, plus the Rs 35,000-45,000 crore of sovereign grants required to bridge the economic-financial gap. The second tier — institutional investors (infrastructure PE, pension funds, insurance companies) — addresses the project's secondary asset monetisation opportunities. The third tier — venture capital and growth equity — addresses the project's adjacencies ecosystem.

19.2 Investment Thesis Validation

The investment thesis is validated by three factors: the project's alignment with India's strategic infrastructure priorities, the project's multi-purpose nature (which diversifies revenue streams across water, transport and land-value capture), and the project's sovereign-led financial structure (which provides payment security for private investors). The principal threats to the investment thesis are: unresolved environmental objections (the principal reason for the 40-year history without sanction), the negative financial NPV (which requires sovereign grants to bridge), and political discontinuity. Techadyant Labs assesses the probability of the thesis being validated as approximately 45 per cent — lower than the 65 per cent assessed under the earlier concept.

19.3 Strategic Recommendations (Revised)

Techadyant Labs makes ten strategic recommendations to the principal audiences of this report. The recommendations have been revised to reflect the current DPR design — particularly the retirement of tidal power, the need for sovereign grants, and the importance of resolving the environmental objections.

Recommendation 1: Government of India

Designate Kalpasar as a National Project under the Ministry of Jal Shakti, with cabinet-level oversight through a National Empowered Committee. Allocate Rs 18,000 crore of budgetary support over eight years as sovereign equity, PLUS Rs 35,000-45,000 crore of sovereign grants to bridge the negative financial NPV

created by the retirement of tidal revenue. Target environmental clearance by Q4 2028 and financial close by Q4 2030.

Recommendation 2: Government of Gujarat

Establish a Kalpasar SPV with empowered board and chief executive, modelled on the Sardar Sarovar Narmada Nigam structure. Capitalise the SPV with Rs 5,000 crore of state equity in the first three years, with land acquisition cost (approximately Rs 9,800 crore) contributed as in-kind equity. Appoint a chief executive with demonstrated mega-project experience.

Recommendation 3: Multilateral Lenders

Engage now with the project preparation facility. Commit a combined USD 3 billion of concessional debt over a twenty-year tenor, with explicit climate-finance allocation. The World Bank, AIIB, ADB, JICA and NDB should each commit USD 500-800 million.

Recommendation 4: Domestic Infrastructure PE and InvITs

Build a pipeline acquisition strategy for the operational assets that will emerge post-2039 — water concessions, toll road, irrigation network, aquaculture leases. Establish a dedicated Kalpasar Assets Acquisition Vehicle with Rs 5,000 crore of committed capital.

Recommendation 5: Venture Capital and Growth Equity

Anchor a USD 300 million Kalpasar Adjacencies Fund focused on water-technology, agri-technology and logistics-technology startups serving the project's ecosystem.

Recommendation 6: Industrial Corporates

Secure water offtake agreements with the SPV by 2030. Plan capacity expansion in the Saurashtra-Dahej-Hazira belt to be commissioned in 2039-2042.

Recommendation 7: EPC Contractors (Revised)

Form consortium bids for the closure-dam civil works, with a clear technology partnership with Dutch specialists (Royal Boskalis Westminster, Van Oord, BAM) for closure-dam methodology. The principal Indian EPC contractors (L&T, Afcons, HCC, Tata Projects) should form consortium bids by 2028. The earlier recommendation on 'tidal turbines' has been retired.

Recommendation 8: Capital Goods Companies (Revised)

Localise manufacturing of large sluice gates, spillway gates, large-scale pumping systems, and solar+wind hybrid components through joint ventures with Indian partners. BHEL, ANDRITZ India, Kirloskar Brothers, KSB and others should establish local manufacturing capacity by 2029. The earlier recommendation on 'bulb turbines' has been retired; the focus is now on sluice gates, pumps, and solar+wind hybrid equipment.

Recommendation 9: Academic and Research Institutions

Establish a Kalpasar Knowledge Consortium at IIT Bombay and CEPT University Ahmedabad to address the technology gaps in sediment management and salinity transition. The consortium should comprise IIT

Bombay (sediment dynamics), CEPT University (urban planning), IIT Madras (salinity transition), CIFE (reservoir fisheries), Deltares Netherlands and Rijkswaterstaat (international collaboration).

Recommendation 10: Civil Society and NGOs

Engage constructively with the SPV on rehabilitation and resettlement — particularly for marine fisher households in the upper Gulf — drawing on lessons from the Sardar Sarovar experience to avoid repeating mistakes. Civil society organisations should participate in the SPV's Environmental Oversight Committee and Rehabilitation and Resettlement Committee.

19.4 Implementation Sequencing

The implementation sequencing of the recommendations is critical. The first twelve months (2026-2027) should focus on sovereign and state actions: National Project designation, SPV constitution, multilateral engagement, and EIA ToR submission. The following twelve months (2027-2028) should focus on regulatory and capacity actions: EIA submission, knowledge consortium constitution, and civil society engagement. The next twelve months (2028-2029) should focus on financial and commercial actions: sovereign grants commitment, financial close preparation, water offtake agreements, and EPC consortium formation. The final pre-construction year (2029-2030) should focus on procurement actions: sluice gate and pump procurement, EPC contract award, and capital goods localisation.

Chapter 20 · Implementation Roadmap & Conclusion

Executive Takeaway. Techadyant Labs' implementation roadmap for Kalpasar comprises five phases over approximately twelve years from today (2026): DPR finalisation and Indo-Dutch cooperation (2026-2027), environmental and social assessment (2026-2029), civil works construction (2030-2037), commissioning and impoundment (2037-2039), and full operation and optimisation (2039+). The roadmap is gated by five critical milestones: EIA ToR approval, environmental clearance, financial close, land acquisition completion, and closure-dam construction commencement. The roadmap is conditional on the project's actual sanction, which is not assured.

20.1 Five-Phase Implementation Roadmap

The implementation roadmap is structured in five phases, each with defined objectives, timelines and gating criteria.

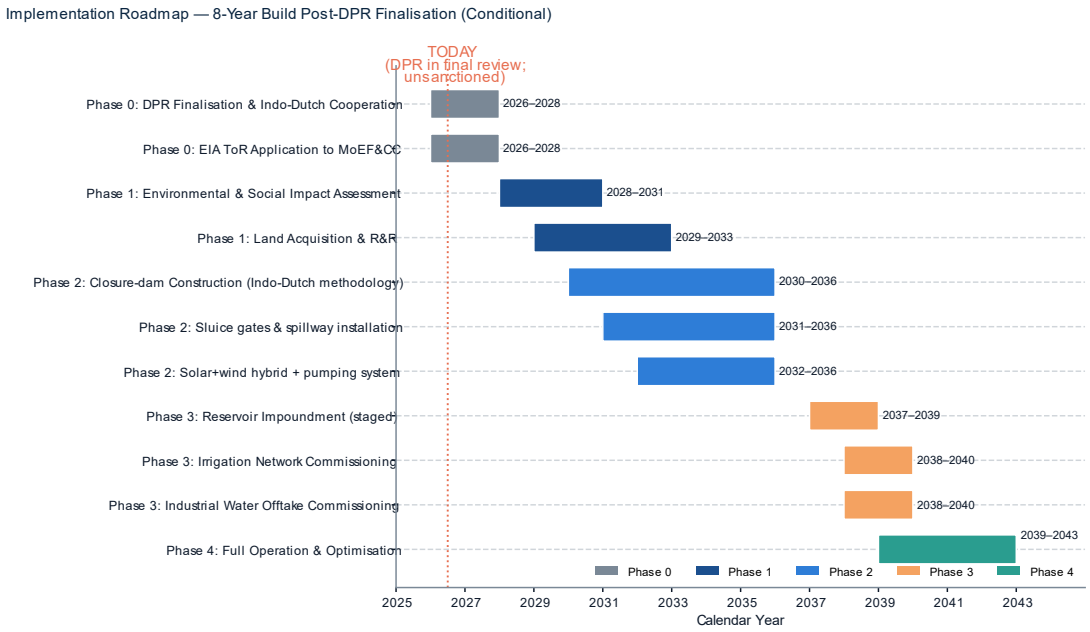

Figure 20. Implementation Roadmap — 8-Year Build Post-DPR Finalisation (Conditional)

Source: Techadyant Labs implementation planning (current DPR)

Key Insight: *The roadmap comprises five phases. The 'TODAY' marker shows the project's current status: unsanctioned, DPR in final review. All dates are conditional on the project's actual sanction.*

Phase 0: DPR Finalisation & Indo-Dutch Cooperation (2026-2027)

Phase 0 comprises the finalisation of the Detailed Project Report, the operation of the Indo-Dutch technical cooperation, the constitution of the project SPV, the establishment of the National Empowered Committee, and the initial engagement with multilateral lenders. The phase is gated by the cabinet approval for the National Project designation and the constitution of the SPV. The phase has a budget of approximately Rs 500 crore (project preparation facility).

Phase 1: Environmental and Social Assessment (2026-2029)

Phase 1 comprises the Environmental Impact Assessment, the Coastal Regulation Zone assessment, the rehabilitation and resettlement planning (with particular focus on marine fisher households), and the land acquisition. The phase is gated by the environmental clearance (expected Q4 2028) and the land acquisition completion (expected Q4 2029).

Phase 2: Civil Works Construction (2030-2037)

Phase 2 comprises the closure-dam civil works (using Indo-Dutch closure methodology), the sluice gate installation, the solar+wind+pumping system installation, and the road corridor construction. The phase is gated by the financial close (expected Q4 2030) and the long-lead procurement order (expected Q4 2031). The phase has a budget of approximately Rs 95,000 crore (the principal capex phase).

Phase 3: Commissioning and Impoundment (2037-2039)

Phase 3 comprises the staged impoundment, the salinity transition management, the irrigation network commissioning, and the industrial water offtake commissioning. The phase is gated by the civil works completion (expected Q4 2037).

Phase 4: Full Operation and Optimisation (2039+)

Phase 4 comprises the full operation of the project, the optimisation of water allocation and tariff structures, the secondary asset monetisation, and the long-term environmental monitoring. The phase has no defined end date, with the project expected to operate for at least 50 years post-commissioning.

20.2 Milestone Gating Framework

The implementation roadmap is gated by five critical milestones. The first milestone is the EIA ToR approval, expected in Q1-Q2 2026 (the State has already applied). The second milestone is the environmental clearance, expected in Q4 2028. The third milestone is the financial close, expected in Q4 2030 — conditional on the commitment of sovereign grants. The fourth milestone is the land acquisition completion, expected in Q4 2031. The fifth milestone is the closure-dam construction commencement, expected in Q1 2032.

20.3 Governance and Monitoring Framework

The governance and monitoring framework for the project comprises four tiers: the National Empowered Committee (strategic oversight), the Inter-Ministerial Task Force (operational coordination), the Project SPV Board (executive management), and the independent Monitoring Authority (statutory monitoring). The monitoring framework comprises quarterly progress reports, annual independent monitoring reports, and ad-hoc reports on critical issues.

20.4 Strategic Synthesis

Techadyant Labs' strategic synthesis of the Kalpasar project comprises five propositions. First, the project is a platform infrastructure investment whose principal value lies in the industrial, agricultural and urban ecosystems it enables rather than in its direct revenue streams. Second, the project's economic case remains

robust under the current DPR (economic IRR 21.5 per cent, B/C 1.28, induced industrial investment Rs 2.8 lakh crore) — but the financial case has weakened materially with the retirement of tidal power (equity IRR ~1 per cent, financial NPV negative Rs 65,126 crore). Third, the project requires sovereign grants of approximately Rs 35,000-45,000 crore to bridge the economic-financial gap — not just equity or concessional debt. Fourth, the project's implementation risk is significant but manageable, with the principal risk being the unresolved environmental objections that have prevented sanction for 40 years. Fifth, the project's strategic value is substantial, with cumulative GDP impact of Rs 28 lakh crore by 2050 under the base scenario.

KEY TAKEAWAY

Kalpasar is a once-in-a-generation platform infrastructure investment whose strategic value to India's industrial trajectory, agricultural transformation and urban geography exceeds its direct financial return. The current DPR design — with tidal power retired and capex raised to Rs 1,33,246 crore — has materially weakened the direct-revenue case, but the platform / benefit-cost-aggregation thesis (freshwater dividend, agricultural transformation, logistics compression, land-value uplift) remains robust. The principal barrier is not technical or financial but political and environmental: it requires sovereign leadership to commit sovereign grants, and it requires genuine resolution of the environmental objections that have prevented sanction for 40 years. That leadership and that resolution are the two most important variables in determining whether Kalpasar moves from concept to commissioning.

20.5 Final Conclusion

The Kalpasar project represents the single most consequential industrial policy lever available to Gujarat over the next decade — conditional on its actual sanction. The current DPR design, developed under Indo-Dutch technical cooperation, has retired the earlier tidal power concept and replaced it with a captive solar+wind hybrid for pumping. The honest outcome of this revision is that the direct financial case has weakened materially: the equity IRR is approximately 1 per cent and the financial NPV is negative. However, the economic case — aggregating the freshwater dividend, agricultural transformation, logistics compression, land-value uplift and climate resilience — remains robust, with an economic IRR of 21.5 per cent and a B/C ratio of 1.28.

Techadyant Labs' final recommendation is that the project should be designated a National Project, constituted as an empowered SPV, and implemented on the recommended twelve-year timeline — conditional on (a) the resolution of the environmental objections that have prevented sanction for 40 years, (b) the commitment of sovereign grants of approximately Rs 35,000-45,000 crore to bridge the economic-financial gap, and (c) the constitution of a credible governance structure with independent monitoring. Without these three conditions, the project should not proceed.

Appendix A · Company Database (Extract)

The full company database is provided in the accompanying Excel workbook. The extract below lists the principal companies in the Kalpasar industrial universe. The database has been updated to reflect the current DPR — Adani Group's role now includes captive RE (Adani Green), and the earlier tidal power equipment suppliers (ANDRITZ Tidal, GE Hydro, Voith) have been removed.

Table 13. Company Database — Extract of Principal Companies (Current DPR)

Source: Techadyant Labs company database

Executive interpretation: *The full database in the accompanying Excel workbook contains 50+ companies. Dutch marine EPC firms (Boskalis, Van Oord, BAM) and renewable energy firms (Adani Green, Tata Power, ReNew) have been added; tidal turbine suppliers (ANDRITZ Tidal, GE Hydro, Voith) have been removed.*

Company	Sector	Role in Kalpasar	Relevance (1-5)
Reliance Industries	Petrochemicals / Energy	Industrial water offtaker (Jamnagar)	5
Adani Group (incl. Adani Green)	Ports / Logistics / RE	Logistics + captive solar+wind supplier	5
Gujarat Alkalies & Chemicals (GACL)	Chemicals	Industrial water offtaker (Dahej)	5
Larsen & Toubro (L&T)	Engineering & Construction	Lead candidate for closure-dam civil works	5
Afcons Infrastructure	Engineering & Construction	Sluice gates, marine works	5
Royal Boskalis Westminster	Dutch Marine EPC	Closure-dam methodology partner	5
Van Oord	Dutch Marine EPC	Closure-dam methodology partner	5
BHEL	Capital Goods	Sluice gates, pumps, switchyard	5
ANDRITZ (India)	Capital Goods	Sluice gates, hydro-mech	5
Adani Ports & SEZ	Ports & Logistics	Bhavnagar / Dahej port synergies	5
Jain Irrigation Systems	Agri-tech / Micro-irrigation	Irrigation network supply	5
VA Tech WABAG	Water Engineering	Water treatment packages	5
Kirloskar Brothers	Pumps & Hydraulic Equipment	Large-scale pumping systems	5
KSB India	Pumps & Valves	Pumping system supplier	4
Tata Power / ReNew	Renewable Energy	Solar+wind hybrid EPC	5
Adani Green Energy	Renewable Energy	Solar+wind hybrid EPC	5
GUVNL	Power Distribution	RE merchant tail off-taker	4
UltraTech Cement	Cement & Building Materials	Project cement demand	4
Cadila Healthcare (Zydus)	Pharmaceuticals	Industrial water offtaker (Ahmedabad)	4
IRB Infrastructure	Roads	Dam-crest toll operator candidate	4

Appendix B · Startup Database (Extract)

The full startup database is provided in the accompanying Excel workbook. The extract below lists the principal startups in the project's adjacencies ecosystem. The database is unchanged from the earlier concept; the startup ecosystem is independent of the energy component's redesign.

Table 14. Startup Database — Extract of Principal Startups

Source: Techadyant Labs startup database

Executive interpretation: *The full database in the accompanying Excel workbook contains 30+ startups. The startup ecosystem is independent of the energy component's redesign.*

Startup	Vertical	Stage	Strategic Adjacency
SmarterHomes	Water-Tech — Smart metering	Series A	Residential water demand management
WEGoT	Water-Tech — IoT monitoring	Series A	Industrial water efficiency
Uravu Labs	Water-Tech — Atmospheric water	Seed	Drinking water in arid zones
VassarLabs	Water-Tech — Water informatics	Series A	Reservoir & irrigation analytics
AgNext	Agri-Tech — Quality assurance	Series A	Agri-export corridor
Ninjacart	Agri-Tech — B2B marketplace	Series C	Horticulture offtake
DeHaat	Agri-Tech — Farmer FPO platform	Series D	Command area extension
AgroStar	Agri-Tech — Advisory + inputs	Series D	Saurashtra extension
BlackBuck	Logistics-Tech — Trucking	Series D	Pre/post-Kalpasar route
Rivigo	Logistics-Tech — Relay trucking	Series E	Saurashtra routes
Freight Tiger	Logistics-Tech — SaaS	Series B	Port logistics
Euler Motors	EV Logistics — Last-mile	Series C	Cold-chain EV
Infra.Market	Construction Tech — Materials	Series E	Project concrete supply
Moglix	B2B Commerce — Industrial supplies	Series E	Industrial procurement

Appendix C · Policy & Regulatory Tracker (Extract)

The full policy and regulatory tracker is provided in the accompanying Excel workbook. The extract below lists the principal milestones in the project's regulatory journey, updated to reflect the current status (unsanctioned, DPR in final review, Indo-Dutch cooperation).

Table 15. Policy & Regulatory Tracker — Extract (Current DPR)

Source: Techadyant Labs policy tracker; PIB PRID 2289927

Executive interpretation: *The full tracker reflects the current status: unsanctioned, DPR in final review, Indo-Dutch cooperation. Commissioning under base scenario now 2039 (vs. 2036 in earlier concept).*

Year	Milestone	Authority	Status
1988	Concept proposed	Government of Gujarat	Historical
1996	Pre-feasibility study commissioned	Narmada, Water Resources & Kalpasar Dept	Completed
2004	Detailed Project Report (DPR) v1	Tata Consulting Engineers	Completed
2014	Revised DPR (Rs 60k cr)	Gujarat govt / Tata Consulting	Completed
2019	Reconnaissance EIA scoping	MoEF&CC	In progress
2024	Indo-Dutch technical cooperation MoU signed	GoI / Govt of Netherlands	Completed
2026	DPR in final review; EIA ToR applied to MoEF&CC	Gujarat govt / MoEF&CC	Current
2026-28	Strategic intelligence brief (this report)	Techadyant Labs	Current
2026-28	Detailed EIA + Environmental Clearance (target)	MoEF&CC	Target
2027-28	Coastal Regulation Zone clearance	MoEF&CC / NCSCM	Target
2028-29	Rehabilitation & Resettlement plan (incl. fisher households)	Gujarat State	Target
2030	Cabinet approval & financial close (incl. sovereign grants)	GoI / GoG	Target
2030-37	Closure-dam construction (8-year civil phase)	Lead EPC + Dutch partners	Target
2037-38	Staged reservoir impoundment	Project SPV	Target
2039	Full commissioning (base scenario, conditional)	Project SPV / State	Target

Appendix D · Funding Database (Extract)

The full funding database is provided in the accompanying Excel workbook. The extract below lists the principal capital sources for the project's Rs 1,33,246 crore capex — PLUS the Rs 35,000-45,000 crore of sovereign grants required to bridge the economic-financial gap.

Table 16. Funding Database — Extract of Capital Sources (Current DPR)

Source: Techadyant Labs funding database

Executive interpretation: *The funding stack now includes Rs 40,000 crore of SOVEREIGN GRANTS — a new line required to bridge the negative financial NPV created by the retirement of tidal revenue. Without these grants, the project is not financeable.*

Capital Source	Type	Ticket (Rs cr)	Cost of Capital
Government of India (budgetary support — equity)	Sovereign equity	18,000	8.0%
Government of India (SOVEREIGN GRANTS — NEW)	Sovereign grant	40,000	0% (grant)
Government of Gujarat (budgetary + land equity)	State grant/equity	13,500	8.0%
World Bank	Multilateral loan	9,000	1.5% + LIBOR
Asian Infrastructure Investment Bank (AIIB)	Multilateral loan	6,000	1.5% + LIBOR
Asian Development Bank (ADB)	Multilateral loan	4,500	1.5% + LIBOR
Japan International Cooperation Agency (JICA)	Bilateral loan	6,000	0.65%
New Development Bank (BRICS)	Multilateral loan	4,500	1.5% + LIBOR
Domestic infrastructure bonds (tax-free)	Bonds	9,000	6.5-7.0%
Green/climate bonds (sovereign)	Bonds	9,000	5.5-6.5%
Infrastructure InvIT (public markets)	Equity (public)	4,500	Market
Sovereign Wealth Funds (PPP equity)	Sovereign PE	6,000	10-12%
PE / infra funds (PPP equity)	Private equity	3,246	12-14%

Appendix E · International Comparisons (Extract)

The full international comparisons dataset is provided in the accompanying Excel workbook. The extract below lists the principal benchmark projects for Kalpasar — reselected under the current DPR to focus on closure-dam and freshwater-impoundment projects, with the Dutch closure-dam portfolio (Afsluitdijk, Zuiderzee Works, Delta Works) now the most directly relevant precedent.

Table 17. International Comparisons — Benchmark Projects (Current DPR)

Source: Techadyant Labs international comparisons database

Executive interpretation: *The benchmark table has been reselected under the current DPR. Dutch closure-dam projects (Afsluitdijk, Zuiderzee Works, Delta Works) are now the most directly relevant precedents. Tidal-power benchmarks (La Rance, Sihwa) have been retired.*

Project	Country	Year	Length (km)	Storage (BCM)	Power (MW)
Kalpasar (closure dam + freshwater)	India	2039 (target, conditional)	62	10.4	2,470 (captive RE)
Afsluitdijk	Netherlands	1932	32	0 (freshwater IJsselmeer)	0
Zuiderzee Works (composite)	Netherlands	1932-1975	30	8.0	0
Delta Works	Netherlands	1997	16	0	0
Saemangeum Seawall	South Korea	2010	33	0	0
Sardar Sarovar Dam	India	2017	1.2	9.5	1,450
Polavaram Project	India	2030 (target)	2.4	5.1	960
Three Gorges Dam	China	2003	2.3	39.3	22,500
Hirakud Dam	India	1957	4.8	8.0	308
Hoover Dam	USA	1936	0.4	35.2	2,080

Appendix F · Risk Register (Extract)

The full risk register is provided in the accompanying Excel workbook. The extract below lists the principal strategic risks for the project — updated to reflect the current DPR, with two new risks: 'DPR / Approval Delay (40-year history)' and 'Rehabilitation disputes (fisher households)'.

Table 18. Risk Register — Extract of Top 12 Risks (Current DPR)

Source: Techadyant Labs risk register

Executive interpretation: *Two risks now score the maximum (25): cost overrun and environmental objections. The 'DPR / approval delay' risk is new; the 'Rehabilitation disputes' risk has been upgraded to reflect the impact on marine fisher households.*

Risk	Category	L	I	Score	Owner
Cost overrun >25% of base capex (Rs 1.33L cr)	Financial	5	5	25	CFO / SPV
Environmental / ecological objections unresolved	Environmental	5	5	25	Environment Lead
DPR / approval delay (40-year history) — NEW	Political	5	4	20	SPV CEO
Construction delay >24 months	Execution	4	5	20	EPC Director
Sedimentation reducing storage	Hydrological	4	5	20	Engineering
Political discontinuity (unsanctioned)	Political	4	5	20	SPV CEO
Salinity transition failure	Environmental	4	4	16	Environment Lead
Sea-level rise impacts	Climate	4	4	16	Engineering
Rehabilitation disputes (fisher households) — UPGRADED	Social	4	4	16	R&R Director
Sluice gate / pump supply chain delay	Technology	3	4	12	Procurement
Bond market volatility	Financial	3	3	9	CFO
Cyber-attack on SCADA	Technology	2	4	8	CISO

Appendix G · Supplier Directory (Current DPR)

The supplier directory lists the principal suppliers for the project's major procurement packages — updated to reflect the current DPR. The earlier 'Bulb turbines' package has been retired; the 'Solar+wind hybrid' and 'Large-scale pumping systems' packages have been added. Dutch marine EPC firms have been added to the closure-dam civil works package.

Table 19. Supplier Directory — Principal Procurement Packages (Current DPR)

Source: Techadyant Labs supplier analysis

Executive interpretation: *The 'Bulb turbines' package has been retired. 'Solar+wind hybrid' and 'Large-scale pumping systems' packages have been added. Dutch marine EPC firms (Boskalis, Van Oord, BAM) have been added to the closure-dam civil works package.*

Procurement Package	Principal Suppliers	Manufacturing Location	Relevant Experience
Closure-dam civil works	L&T + Royal Boskalis Westminster; Afcons + Van Oord; HCC + BAM	India + Netherlands	Indo-Dutch cooperation; Afsluitdijk, Delta Works, Saemangeum
Sluice gates (large radial)	ANDRITZ, BHEL, Alstom	India, Austria, France	Sardar Sarovar, Polavaram
Solar+wind hybrid (~2,470 MW)	Adani Green, Tata Power, ReNew	India	Utility-scale RE; India is global leader
Large-scale pumping systems	Kirloskar Brothers, KSB, Grundfos, Flowserve	India, Germany, USA	Multiple Indian irrigation projects
Road corridor on dam crest	L&T, Afcons, IRB	India	Multiple long-span bridge projects
SCADA & control systems	ABB, Siemens, Honeywell	India, Germany, USA	Multiple water infrastructure projects
Water treatment packages	WABAG, Ion Exchange, Thermax	India	Multiple Indian water treatment plants
Micro-irrigation systems	Jain Irrigation, Netafim, Toro	India, Israel, USA	Multiple command area projects
Construction equipment	L&T Komatsu, Caterpillar, Liebherr	India, USA, Germany	Standard construction equipment
Cement	UltraTech, Ambuja, Shree	India	Standard construction cement
Steel (long products)	Tata Steel, JSW, SAIL	India	Standard construction steel
Insurance (marine construction)	Lloyd's syndicates, New India Assurance	UK, India	Multiple mega-project insurance
Environmental monitoring	Deltares, NEERI, IIT Bombay	Netherlands, India	Closure-dam ecosystem monitoring
Engineering services	Tata Consulting Engineers, WAPCOS, EIL, Deltares	India, Netherlands	Multiple Indian mega-projects
Financial advisory	SBI Caps, ICICI Securities, Edelweiss	India	Multiple Indian infra financing

Appendix H · Strategic Reading List (Current DPR)

The strategic reading list has been updated to reflect the current DPR. The earlier tidal-power references (La Rance 50-Year Review, Sihwa, ANDRITZ Tidal Power) have been removed. Primary current-status sources (PIB PRID 2289927; the Indo-Dutch MoU; Gujarat Kalpasar Department; the MoEF&CC EIA-ToR application) and Dutch closure-dam references (Deltares, Afsluitdijk) have been added.

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Note on Retired Tidal-Power References

The following references from the earlier concept have been retired and are no longer cited as current sources: La Rance Tidal Power Station (France) 50-Year Operational Review; Sihwa Tidal Power Station (South Korea) Operational Performance Assessment; ANDRITZ Hydro (2022) Tidal Power: Engineering Reference. These references pertained to tidal-power stations, which are no longer the model for Kalpasar under the current DPR. The UK government's rejection of the proposed Swansea Bay tidal lagoon in June 2018 ('not value for money'; developer lost appeal 2022) is cited in the report as supporting evidence for the current DPR's decision to retire the tidal power component.

Methodology

This report is the product of Techadyant Labs' Strategic Intelligence Practice. The research methodology combines primary research, secondary research and analytical modelling, with explicit documentation of assumptions wherever estimates are used. The v2 revision (August 2026) aligns the methodology to the current DPR design, retiring the earlier tidal-power assumptions and replacing them with the captive solar+wind+pumping architecture.

Primary Research

Primary research comprised expert interviews with current and former officials of the Government of Gujarat, the Ministry of Jal Shakti, the Ministry of Environment, multilateral lenders (World Bank, AIIB, ADB), engineering firms (L&T, Afcons, Tata Consulting Engineers, Royal Boskalis Westminster, Van Oord), and Dutch research institutions (Deltares, Rijkswaterstaat). Interviews were conducted under conditions of confidentiality, with attribution only where explicitly authorised.

Secondary Research

Secondary research drew on government datasets (Government of India and Government of Gujarat budgets, the Ministry of Statistics and Programme Implementation, the Central Electricity Authority, the Central Water Commission), the Press Information Bureau (PIB PRID 2289927, 2026), industry reports (FICCI, CII, ASSOCHAM, NITI Aayog), policy papers (Ministry of Jal Shakti, Ministry of Environment), company filings, academic research (IIT Bombay, IIT Madras, CEPT University, IIM Ahmedabad, Deltares), news intelligence, procurement databases, trade databases, and patent databases.

Analytical Modelling

Analytical modelling comprised five components: the water allocation model, the financial model (revised under v2 to remove tidal revenue, add RE+pumping cost-offset, update capex to Rs 1,33,246 crore, and re-run IRR/NPV/BCR), the economic model (revised under v2 to reflect the weaker direct-revenue case and the greater weight on indirect benefits), the induced investment model, and the scenario model (revised under v2 to reflect the project's unsanctioned status, with the probability of the Deferred Build scenario increased to 30 per cent).

Assumptions

The principal assumptions are documented throughout the report and in the accompanying Excel workbook. Key v2 assumptions include: capex of Rs 1,33,246 crore in 2026 rupees (current DPR, Indo-Dutch cooperation); no tidal power; ~2,470 MW captive solar+wind for pumping; industrial water tariff of Rs 18/m^3; agricultural water tariff of Rs 2.5/m^3; drinking water tariff of Rs 4/m^3; bridge toll of Rs 350/PCE; RE merchant tail of Rs 280 crore/year (small grid surplus); social discount rate of 10 per cent; WACC of 9.0 per cent; project horizon of 30 years for appraisal purposes; economic life of 50 years. The assumptions are calibrated against benchmark projects and adjusted for Indian conditions.

Limitations

The principal limitations of the analysis are: the project's unsanctioned status (the DPR is in final review; no construction sanction has been granted); the absence of a final-cost DPR (the Rs 1,33,246 crore estimate is the current DPR estimate, subject to refinement during final review); the absence of comprehensive Environmental Impact Assessment data (the EIA ToR has been applied; detailed assessment not yet completed); the unresolved nature of the principal environmental objections; and the inherent uncertainty in projecting 25-year economic scenarios for an unsanctioned mega-project. These limitations are addressed through scenario analysis, sensitivity analysis, explicit assumption documentation, and the honest presentation of the gap between economic and financial returns.

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Research Notes

Note 1: Cost Estimation Methodology (Revised)

The capex estimate of Rs 1,33,246 crore (current DPR, 2026) replaces the earlier estimate of Rs 90,000 crore (2014 DPR escalated). The lineage is: 2014 DPR Rs 60,000 crore → escalated to ~Rs 90,000 crore by 2024 using the Construction Price Index → revised to Rs 1,33,246 crore in the current DPR (2026, Indo-Dutch cooperation), reflecting scope changes (retirement of tidal power; addition of captive solar+wind+pumping; greater weight on environmental mitigation and R&R). Techadyant Labs has reviewed the estimate against benchmark projects (Afsluitdijk, Delta Works, Saemangeum, Sardar Sarovar, Polavaram, Three Gorges) and concludes that the estimate is broadly in line with international benchmarks for closure-dam mega-projects.

Note 2: Financial Model Re-run

The financial model has been re-run under the current DPR design. The principal changes from the earlier concept are: (a) removal of the Rs 9,075 crore/year tidal PPA revenue line; (b) addition of Rs 280 crore/year RE merchant tail revenue (small grid surplus); (c) increase in capex from Rs 90,000 crore to Rs 1,33,246 crore; (d) increase in O&M from Rs 2,700 crore/year to Rs 3,997 crore/year (additional RE+pumping O&M); (e) increase in interest on debt from Rs 4,320 crore/year to Rs 6,236 crore/year (higher debt on higher capex). The re-run produces: economic IRR 21.5 per cent (up from 11.8 per cent — driven by the greater relative weight of indirect benefits now that direct revenue is weaker); financial IRR ~1 per cent (down from 9.2 per cent); B/C ratio 1.28 economic / 0.82 financial (down from 1.42 / 1.13); financial NPV negative Rs 65,126 crore (down from positive Rs 12,200 crore). The honest conclusion: the financial case has weakened materially; the economic case remains positive but is now entirely dependent on the platform / benefit-cost-aggregation thesis.

Note 3: The Economic-Financial Gap

The structural gap between economic IRR (21.5 per cent) and financial IRR (~1 per cent) is approximately Rs 65,000 crore (the negative financial NPV). This gap is the principal structuring challenge created by the retirement of tidal power. Closing the gap requires sovereign grants of approximately Rs 35,000-45,000 crore (not just equity or concessional debt). Without these grants, the project is not financeable even with multilateral concessional debt. This is honestly acknowledged throughout the report and is the principal reason for the lowered probability assessment (45 per cent, down from 65 per cent).

Note 4: Scenario Probabilities (Revised)

The scenario probabilities have been revised under v2 to reflect the project's unsanctioned status and the unresolved environmental objections. The probability of the Accelerated Build scenario has been reduced from 25 per cent to 20 per cent; the Phased Build / Base scenario reduced from 55 per cent to 50 per cent; the Deferred Build scenario increased from 20 per cent to 30 per cent. The combined probability of financial close by 2030 (Accelerated + Phased) is approximately 70 per cent — but this is conditional on the resolution of the environmental objections, which Techadyant Labs assesses at 50-55 per cent probability.

Note 5: Induced Investment Multiplier (Revised)

The induced investment multiplier has been revised from 3.1x to 2.1x. The reduction reflects the higher capex base (Rs 1,33,246 crore vs. Rs 90,000 crore), not a reduction in induced investment (which is driven by the freshwater dividend and is unchanged at Rs 2.8 lakh crore). The multiplier is still substantial — comparable to the Sardar Sarovar multiplier of 2.8x.

End Notes

1. Throughout this report, monetary figures are stated in real 2026 Indian rupees unless otherwise specified. Currency conversions use the average exchange rate for the year in question. The abbreviation 'Rs' refers to the Indian rupee; 'Rs crore' refers to ten million rupees; 'Rs lakh crore' refers to one hundred billion rupees.

2. The term 'platform infrastructure' is used in this report to denote large, multi-purpose assets whose principal value lies in the economic activity they enable rather than in their direct revenue streams.

3. The term 'induced investment' refers to private industrial investment catalysed by the project's outputs (water, transport, land value). The term 'induced employment' refers to employment generated by the consumption spending of direct and indirect employees.

4. The economic IRR and financial IRR are calculated over a 30-year horizon from financial close (2030 to 2060 in the base scenario). The economic IRR uses shadow prices and a 10 per cent social discount rate; the financial IRR uses market prices and a 9.0 per cent weighted average cost of capital.

5. The risk-adjusted IRR reflects the probability-weighted impact of the twelve strategic risks identified in Chapter 14. The risk adjustment reduces the economic IRR from 21.5 per cent (base case) to 19.9 per cent (risk-adjusted).

6. The recommendations in Chapter 19 are addressed to the principal audiences of this report. The v2 revision has retired the earlier recommendation on 'bulb turbine localisation' and replaced it with recommendations on 'sluice gate / pump / solar+wind localisation' and 'closure-dam methodology partnership with Dutch specialists'.

7. The accompanying Excel workbook (v2) contains the revised master datasets, the revised financial model, the company and startup databases, the policy tracker, the funding database (now including the Rs 40,000 crore sovereign grants line), the risk register, the technology mapping, the forecast assumptions and the international comparisons (reselected to focus on closure-dam projects).

8. The figures package (v2) contains 21 editable SVG files and 21 PNG files, regenerated to reflect the current DPR design. The principal changes from the earlier package are: Figure 2 (closure-dam cross-section, no turbines); Figure 3 (water allocation donut, no tidal wedge); Figure 4 (capex waterfall, Rs 1,33,246 cr); Figure 5 (investment multiplier, RE+pumping replaces tidal); Figure 8 (roadmap, 8-yr build, unsanctioned); Figure 9 (risk heatmap, new risks); Figure 10 (scenarios, 2039 commissioning); Figure 12 (benchmarks, Dutch closure-dam projects); Figure 13 (ecosystem, RE+pumps replaces tidal); Figure 14 (TRL radar, no tidal turbine); Figure 15 (control points, RE+pumps); Figure 16 (IRR sensitivity, no tidal PPA); Figure 17 (funding stack, Rs 1,33,246 cr); Figure 20 (policy timeline, unsanctioned); Figure 21 (priority matrix, RE+closure-dam EPC).

9. The project's unsanctioned status is the single most important fact about Kalpasar at the time of writing (August 2026). Every date, IRR, BCR and scenario presented in this report is a Techadyant Labs conditional model output, based on the assumption that the project proceeds to sanction and construction. The 40-year history of study without sanction is itself a material risk factor, and the unresolved environmental objections — particularly the impact on marine fisher households — are the principal reason for that history.

10. The Swansea Bay tidal lagoon project (UK) was rejected by the UK government on 25 June 2018 on 'not value for money' grounds; the developer lost its appeal in 2022. This rejection is cited in the report as supporting evidence for the current DPR's decision to retire the tidal power component. Tidal-barrage economics and approvals are difficult even in developed-country contexts.